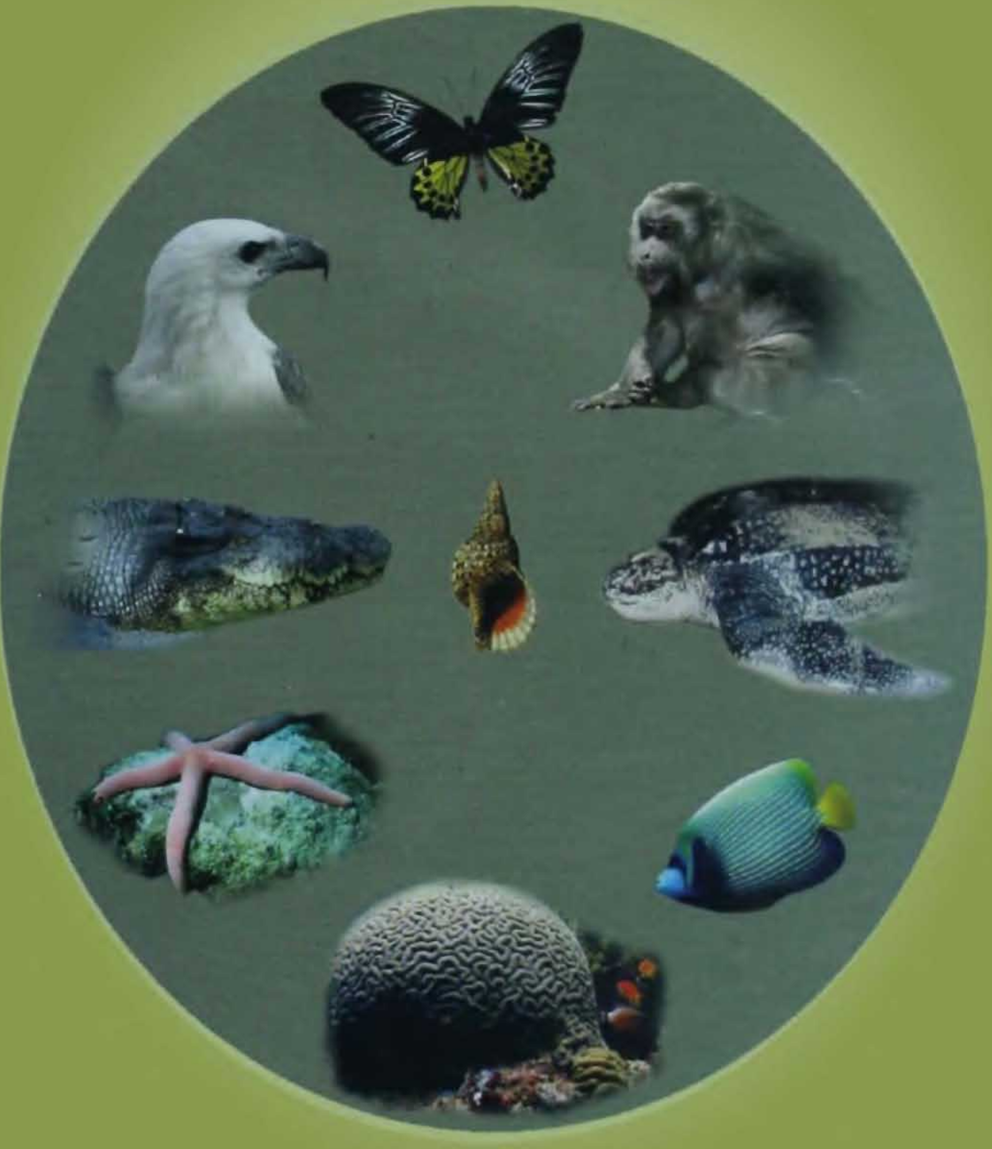
Recent Trends in Biodiversity *of* Andaman and Nicobar Islands

Ramakrishna
C. Raghunathan
C. Sivaperuman



ZOOLOGICAL SURVEY OF INDIA

Recent Trends in Biodiversity of Andaman and Nicobar Islands

RAMAKRISHNA
Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata 700 053
C. RAGHUNATHAN
C. SIVAPERUMAN
Zoological Survey of India, Andaman and Nicobar Regional Centre, Haddo, Port Blair 744 102
Andaman and Nicobar Islands

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PREFACE

The Andaman and Nicobar Islands is known for rich biodiversity resources. There are 345 islands, which can be distinguished geographically into two groups, with land area extending up to 8,249 km^2 and a coastline stretch of 1,962 km; the Andaman Islands constitute 6408 km^2 and the Nicobars 1841 km^2. The Andaman Islands are the extension of the submerged Arakan Yoma Mountain range of Myanmar and the Nicobars are the continuation of the Mentawai Islands to the south and southeast of Sumatra. These islands are the summits of a submarine mountain range lying on the great tectonic suture zone extending from the eastern Himalayas along the Mayanmar border to the Arakan and finally Sumatra and Lesser Sundas. The northern most part of these islands is isolated from cape Negrais in Southern Mayanmar by the North Preparis channel and the southern most part is also separated from the Acheen Head of Western Sumatra by the Great channel. There are two more deep channels – (i) *the ten degree channel* which isolates Andaman islands from Nicobar islands and (ii) *the Sombero channel* which isolates Great Nicobar from Nicobars and the Nancowries group.

The topography of the Andaman and Nicobar Islands is hilly and undulating, the elevation in the Andamans is from 0 to 732 m, Saddle Peak being the highest in North Andaman Island. In the Nicobars the elevation rises from 0 to 568 m, Mt Thuillier being the highest peak on Great Nicobar Islands. The average annual rainfall exceeds 3000mm, but the northern islands show greater seasonal climatic variation that the southern islands. The habitats represented in the islands include bays, mangroves, moist deciduous forests and evergreen forests. The Andaman Islands support one of the most extensive mangrove ecosystems. Flora and fauna in Andaman bears close biogeographical affinities with Myanmar and Thailand while Nicobar has affinities with Indonesia and South-East Asia.

The regions encompass a very high degree of endemicity in all taxa, especially in plants, reptiles, fishes and corals. The only primate, the Long-tailed Macaque (*Macaca fascicularis umbrasa*) occurs in the southern group of the Nicobar Islands. Four aboriginal tribes namely, Andamanese, Jarwas, Onges and Sentinelese inhabit the Andaman Islands group and Nicobaris and Shompens inhabit the Nicobar group. The economy of these islands is mainly based on agriculture and fishing. Paddy is the main food crop and is mostly cultivated in the Andaman group of islands, whereas coconut and areca nut are the main cash crops of the Nicobar group of islands.

The Andaman and Nicobar characterized by distribution of biodiversity in a contrasting interface of terrestrial and marine habitats. 19.65% area of Andaman and Nicobar Islands is under protected area comprising 9 National Parks (Mahatma Gahndi Marine, Middle button, Mount Harriet, North Button, Rani Jhansi Marine, Saddle Peak, South Button, Camphell Bay and Galathea), 96 Wildlife Sanctuaries and one Biosphere Reserve.

This book is a result of detailed observation by reputed scientist working on the flora and fauna of the Andaman and Nicobar Islands, the floral groups ranging from sea weed to evergreen trees and the faunal groups ranging from zooplankton to marine mammals (Dugong). There are 47 chapters, and each effort has been made by an expert or professional in their field. The book offer novel information on biodiversity of Andaman and Nicobar Islands. We sincerely hope that his book will provide the much needed information on the flora and fauna of this Island.

Ramakrishna
C. Raghunathan
C. Sivaperuman

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CONTENTS

CONTRIBUTORS

Abdul Nazar, A.K., Ocean Science and Technology for Islands, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Government of India, Narayanapuram, Pallikaranai, Chennai 600100, Tamil Nadu, India.

Ajmal Khan, S., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608 502

Anrose, A., Fishery Survey of India, Port Blair

Arumugam, M., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai

Balasubramanian, T., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai

Chakrabarty, T., Botanical Survey of India, Western Circle, 7 Koregaon Road, Pune 411 001, Maharashra

Choudhury, B.C., Wildlife Institute of India, Dehra Dun, Uttarakhand

Davidar, P., Department of Ecology and Environmental Science, Pondicherry University, Pondicherry-605014 India, E-mail : pdavidar@yahoo.com

Devy, M.S., Ashoka Trust for Research in Ecology and the Environment, Hebbal, Bangalore- 560024, India

Dharani, G. Ocean Science and Technology for Islands, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Govt. of India, Narayanapuram, Pallikaranai Chennai 600100, Tamil Nadu, India.

Dhivya, P., Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair 744 102, Andaman and Nicobar Islands

Dilipan, E., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai- 608 502, Tamilandu, India

Diwakar, P.G., Botanical Survey of India, Western Circle, 7 Koregaon Road, Pune 411 00, Maharashra

Dutt, C.B.S., Indian Space Research Organization, Department of Space, Anthariksh Bhavan, Bangalore, 560 094 India, Email : dutt_cbs@isro.org

Elrika D'souza, Reef Watch Marine Conservation, Priyanka Building, 50 St. Paul's Road, Bandra (W), Mumbai 400050, Email : elrikad@gmail.com

Ezhilarasi, N, Salim Ali Center for Ornithology and Natural History, Anaikatty PO, Coimbatore, Tamil Nadu, India. E-mail: ezhilarasinatarajan@gmail.com

Ganesh, T., Ashoka Trust for Research in Ecology and the Environment, Hebbal, Bangalore- 560024, India

Govindaraj, K., Fishery Survey of India, Port Blair

Padalia, H., Regional Remote Sensing Service Centre (RRSSC), Indian Space Research Organisation, Dehra Dun-248001, Email: hiten_pa@yahoo.co.in

Harikrishnan, S., Wildlife Institute of India, Dehra Dun, Uttarakhand

Islam, M.Z., Research and Field Monitoring Manager (Reintroduction Programs), National Wildlife Research Center, Taif., Saudi Arabia, Email: mzafarul.islam@gmail.com

Jayakumar, V., Division of Field Crops, Central Agricultural Research Institute, Port Blair 744101, Andaman & Nicobar Islands, Email : jkpath@rediffmail.com

Kailash Chandra, Central Regional Station, Zoological Survey of India, Jabalpur 482002

Kala, N., Department of Environment and Forests, Andaman and Nicobar Islands

Kannan, L., Thiruvalluvar University, Fort Campus, Vellore 632 004, Email: kannanlk69@yahoo.com

Kar, A.B., Fishery Survey of India, Port Blair

Karthikeyan Vasudevan, Wildlife Institute of India, Dehra Dun, Uttarakhand, E-mail: karthik@wii.gov.in

Kathiroli, S., Ocean Science and Technology for Islands, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Government of India, Narayanapuram, Pallikaranai, Chennai 600100

Khatri, T.C., J N Government College, Port Blair-744104, Andaman and Nicobar Islands, India, E-mail: tikamtulsi@rediffmail.com

Kirubagaran, R., Ocean Science and Technology for Islands, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Government of India, Narayanapuram, Pallikaranai, Chennai 600100, Tamil Nadu, India

Lakra, G.S., Botanical Survey of India, Andaman and Nicobar Circle, Port Blair 744 012,

Magesh Peter, D. Andaman and Nicobar Centre for Ocean Science and Technology National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Govt. of India, Dollygunj, Port Blair – 744103, Andaman and Nicobar Islands, India

Mathur, V.B., Wildlife Institute of India, Chandrabani, Dehra Dun-248001, Email. vbm@wii.gov.in.

Mewa Singh, Department of Psychology, Mysore University, Mysore.

Mishra, J.K., Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair 744 103, Andaman and Nicobar Islands, India, E-mail: jayant64@yahoo.com

Mohan, P.M., Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair 744 102, Andaman and Nicobar Islands Email : pmmtu@yahoo.com; pmmpu@rediffmail.com

Nagabhatla, N., Global Research Division, International Water Management Institute, Colombo, Sri Lanka, Email : N.Nagabhatla@CGIAR.ORG

Nagarajan, B., Institute of Forest Genetics and Tree Breeding, Coimbatore, 641 002

Nobi, E.P., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai- 608 502, Tamilandu, India

Oswin D. Stanley, Eco Balance Consultancy, 6 B, Umiya Park Scoiety, Subhanpura 390 023. Vadodara, Gujarat, India, Email: oswinbaby@rediffmail.com

Paul Pandian, P. Fishery Survey of India, Port Blair

Padma Bohra, Desert Regional Station, Zoological Survey of India, Pali Road, Jhalamand 342 005, Jodhpur, Rajasthan

Pai, I.K, Department of Zoology, Goa University, Goa

Palanisamy, M., Botanical Survey of India, Southern Circle, TNAU Campus, Coimbatore- 641 003

Palavai , V., Department of Ecology and Environmental Science, Pondicherry University, Pondicherry 605014

Patro, S., Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair 744 103

Pattnayak, S.K., Fishery Survey of India, Port Blair

Pereira, M.L, Department of Biology, Aveiro University, Aveiro, Portugal

Prasad, P.R., Lab for Spatial Informatics, International Institute of Information Technology, Gachibowli, Hyderabad-500 032, India, Email : rcprasad@iiit.ac.in;

Raffi, S.M., Centre of Advanced Study in Marine Biology, Annamalai University Parangipettai 608 502. Tamil Nadu

Raghunathan, C., Zoological Survey of India, Andaman and Nicobar Regional Station, Haddo, Port Blair-744 102, Andaman and Nicobar Islands, Email: kscraghu@rediffmail.com

Raghuraman, R., Zoological Survey of India, Andaman and Nicobar Regional Centre,Port Blair– 744 102, Andaman and Nicobar Islands, Port Blair-744 102, Andaman and Nicobar Islands

Rahmani, A.R., Bombay Natural History Society, Hornbill House, Shaheed Bhagat Singh Road, Mumbai-400001, India

Rajalakshmi, S., Division of Field Crops, Central Agricultural Research Institute, Port Blair 744101, Andaman & Nicobar Islands

Rajan, P.T., Andaman Nicobar Regional Centre, Zoological Survey of India, Haddo, Port Blair-744102

Rajshekhar, C., Department of Palaeobiolog, Agharkar Research Institute, G.G. Agarkar Road, Pune 411 004, E-mail : c_rajshekhar@yahoo.co.in

Ramakrishna, Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata 700 053

Rauf Ali, Foundation for Ecological Research, Advocacy and Learning (FERAL) P.B. 28, Pondicherry 605 001, Email : rauf@feralindia.org

Raveendran, E.K., Directorate of Fisheries, Andaman and Nicobar Islands, Port Blair 744 101

Reddy, C.S., Forestry and Ecology Division, National Remote Sensing Agency, Balanagar, Hyderabad 500 037, India, Email : csreddy_nrsa@rediffmail.com

Rema Devi, K., Marine Biological Station, Zoological Survey of India, 130, Santhome High Road, Chenni-600 028

Revathi, P., Centre of Advanced Study in Marine Biology, Annamalai University Parangipettai 608 502, Tamil Nadu

Sampath Kumar, V., Botanical Survey ot India, Southern Circle, TNAU Campus, Lawley Road (P.O.), Coimbatore 641 003, Tamil Nadu, E-mail: vskumar10@rediffmail.com

Santhanakumar, J., Andaman and Nicobar Centre for Ocean Science and Technology, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Govt. of India, Dollygunj, Port Blair–744103, Andaman and Nicobar Islands, E-mail sanpraus2003@yahoo.co.uk

Shanmugam, A., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502.

Sharief, M.U., Botanical Survey of India, National Orchidarium and Experimental Garden, Yercaud 636 602, Salem, Tamil Nadu, E-mail : shariefbsi@yahoo.co.in

Sinha, M.K., Fishery Survey of India, Port Blair

Sivakumar, K., Centre of Advanced Study in Marine Biology, Annamalai University Parangipettai 608 502

Sivakumar, K., Wildlife Institute of India, P.O. Box. No. 18, Chandrabani Dehra Dun–248 001, Uttarakhand

Sivaperuman, C., Zoological Survey of India, Andaman and Nicobar Regional Centre, Haddo, Port Blair-744 102, Andaman and Nicobar Islands, E-mail : c_sivaperuman@yahoo.co.in

Soumasundaram, S.T., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, Tamil Nadu

Sreeraj C. R., Zoological Survey of India, Andaman and Nicobar Regional Centre, Port Blair– 744 102, Andaman and Nicobar Islands, Port Blair-744 102, Andaman and Nicobar Islands

Sumathi, R., Foundation for Revitalisation of Local Health Traditions, Bangalore

Sunita Reddy, Centre of Social Medicine and Community Health, School of Social Sciences, Jawaharlal Nehru University, New Delhi, India 110 067; E-mail: sunitareddy@mail.jnu.ac.in

Swarnakumar, N.S., Centre of Advanced Study in Marine Biology, Annamalai University Parangipettai-608 502

Terdalkar, S., Department of Zoology, Goa University Goa, India

Thangaradjou, T., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608 502, Email: umaradjou@gmail.com

Thomas J. Kariathil, Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, Tamil Nadu

Titus Immanuel, Zoological Survey of India, Andaman and Nicobar Regional Centre,Port Blair-744 102, Andaman and Nicobar Islands, Port Blair-744 102, Andaman and Nicobar Islands

Tripta Khatri, J N Government College, Port Blair-744104, Andaman and Nicobar Islands

Umapathy, G., Laboratory for the Conservation of Endangered Species (LaCONES) Centre for Cellular and Molecular Biology, Annexe-1, Attapur Ring Road, Hyderabad 500 048, E-mail: ksivakumar@wii.gov.in

Vardhan Patankar, Reef Watch Marine Conservation, Priyanka Building, 50 St. Paul's Road, Bandra (W), Mumbai-400050, E-mail : elrikad@gmail.com

Venkatesan, R., Ocean Science and Technology for Islands, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Govt. of India, Narayanapuram, Pallikaranai, Chennai-600100, Tamil Nadu, India

Venkatraman, C., Zoological Survey of India, Marine Biological Station, Chennai-600 028

Verma, S.K., Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair 744 103, India, E-mail : jayant64@yahoo.com

Vijaya Baskara Sethupathi, G., Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, Tamil Nadu

Vijayan, L., Salim Ali Center for Ornithology and Natural History, Anaikatty - PO, Coimbatore, Tamil Nadu, India, E-mail : ezhilarasinatarajan@gmail.com

Vinithkumar, N.V., Andaman and Nicobar Centre for Ocean Science and Technology, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Government of India, Dollygunj, Port Blair – 744103, Andaman and Nicobar Islands, India

Vinod Maina, Botanical Survey of India, Southern Circle, TNAU Campus, Lawley Road (P.O.), Coimbatore-641 003, Tamil Nadu

Vinoth S. Raviendran, Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502

Yoganand, K., Ashoka Trust for Research in Ecology and the Environment, Hebbal, Bangalore-560024, India

Chapter 01

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 1-42, 2010

BIODIVERSITY OF ANDAMAN AND NICOBAR ISLANDS– AN OVERVIEW

RAMAKRISHNA, C. RAGHUNATHAN* and C. SIVAPERUMAN*

Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata-700 053

INTRODUCTION

Biodiversity comprised the whole life on earth. It denotes the nature's variety and is regarded at three different levels, *viz*. Species, Genetic and Ecosystem. The word 'biodiversity' is a contraction of *biological diversity*. Diversity is a concept which refers to the range of variation or differences among some set of entities; *biological diversity* thus refers to variety within the living world. The term 'biodiversity' is indeed commonly used to describe the *number*, *variety* and *variability* of living organisms. This very broad usage, embracing many different parameters, is essentially a synonym of 'Life on Earth'

Biodiversity definition

Biodiversity represents the variety and abundance of life expressed at the genetic, population, species and ecosystem levels, cultivated and natural, terrestrial and marine. Biodiversity provides the goods and services essential for the survival of human beings and other species on the earth. Thus biodiversity may be roughly defined as the total number of species in a particular area. Conservation of biodiversity is therefore important to ensure sustainable human development. A bacterium, the domestic cow, rice, the resplendent tiger are all part of biodiversity. Biodiversity knows no limits, and no distinction between wild and domesticated, microbial and terrestrial. In short biodiversity is the diversity among all living forms in this universe'

Biodiversity is not distributed evenly or uniformly across the globe. Certain countries, lying wholly or partly within the tropics are characterized by high species richness and a high number of endemic species. These countries are known as megadiverse countries. There are seventeen countries are rich in biological diversity, the are Bolivia, Brazil, China, Colombia, Costa Rica, Democratic Republic of Congo, Ecuador, India, Indonesia, Kenya, Madagascar, Malaysia, Mexico, Peru, Philippines, South Africa, and Venezuela (Arora and Ahuja, 2006).

Species diversity

Perhaps because the living world is most widely considered in terms of species, biodiversity is very commonly used as a synonym of *species diversity*, in particular of 'species richness' which is the number of species in a site or habitat. Discussion of global biodiversity is typically presented in terms of global numbers of species in different taxonomic groups. An estimated 1.7 million species have been described to date; estimates for the total number of species existing on earth at present vary from five million to nearly 100 million. A conservative working estimate suggests there might be around 12.5 million. In terms of species number alone, life on earth appears to consist essentially of insects and microorganisms.

The species level is generally regarded as the most natural one at which to consider whole-organism diversity. Species are also the primary focus of evolutionary mechanisms, and the origination and extinction of species are the

**Zoological Survey of India, Andaman and Nicobar Regional Centre, Haddo, Port Blair-744 102*

principal agents in governing biological diversity in most senses in which the latter can be defined. On the other hand species cannot be recognized and enumerated by systematists with total precision, and the concept of what a species is differs considerably between groups of organisms.

Further, a straightforward count of the number of species only provides a partial indication of biological diversity, for implicit within the term is the concept of degree or extent of variation; that is, organisms which differ widely from each other in some respect by definition contribute more to overall diversity than those which are very similar.

The more different a species is from any other species (as indicated, for example, by an isolated position within the taxonomic hierarchy), then the greater its contribution to any overall measure of global biological diversity.

Developing this argument, a site with many different higher taxa present can be said to possess more *taxonomic diversity* than another with fewer higher taxa but many more species. Marine habitats frequently have more different phyla but fewer species than terrestrial habitats; i.e. higher taxonomic diversity but lower species diversity. Measures under development endeavour to incorporate quantification of the evolutionary uniqueness of species.

The ecological importance of a species can have a direct effect on community structure, and thus on overall biological diversity. For example, a species of tropical rain forest tree which supports an endemic invertebrate fauna of a hundred species evidently makes a greater contribution to the maintenance of global biological diversity than a European alpine plant which may have no other species wholly dependent on it.

Genetic diversity

This represents the heritable variation within and between populations of organisms. Ultimately, this resides in variations in the sequence of the four base-pairs which, as components of nucleic acids, constitute the genetic code.

New genetic variation arises in individuals by gene and chromosome mutations, and in organisms with sexual reproduction can be spread through the population by recombination. It has been estimated that in humans and fruit flies alike, the number of possible combinations of different forms of each gene sequence exceeds the number of atoms in the universe. Other kinds of genetic diversity can be identified at all levels of organization, including the amount of DNA per cell, and chromosome structure and number.

This pool of genetic variation present within an interbreeding population is acted upon by selection. Differential survival results in changes of the frequency of genes within this pool, and this are equivalent to population evolution. The significance of genetic variation is thus clear: it enables both natural evolutionary change and artificial selective breeding to occur.

Only a small fraction (often less than 1per cent) of the genetic material of higher organisms is outwardly expressed in the form and function of the organism, the purpose of the remaining DNA and the significance of any variation within it is unclear.

Ecosystem diversity

The quantitative assessment of diversity at the ecosystem, habitat or community level remains problematic. Whilst it is possible to define what is in principle meant by genetic and species diversity, and to produce various measures thereof, there is no unique definition and classification of ecosystems at the global level, and it is thus difficult in practice to assess ecosystem diversity other than on a local or regional basis and then only largely in terms of vegetation. Ecosystems further differ from genes and species in that they explicitly include abiotic components, being partly determined by soil parent material and climate.

Ecosystem diversity is often evaluated through measures of the diversity of the component species. This may involve assessment of the relative abundance of different species as well as consideration of the types of species. In the first instance, the more equally abundant different species are, then in general the more diverse that area or habitat is considered to be. In the second instance, weight is given to the numbers of species in different size classes, at different trophic levels, or in different taxonomic groups. Thus a hypothetical ecosystem which consisted only of several species of plants, would be less diverse than one with the same number of species but which included animal herbivores and predators. As different weightings can be given to these different factors when estimating the diversity of particular areas, there is no one authoritative index for measuring diversity. This obviously has important implications for the ranking of different areas.

Biodiversity of India

India is one of the 17 "megadiverse" countries and is composed of a diversity of ecological habitats like forests, grasslands, wetlands, coastal and marine ecosystems, and desert ecosystems. India lies between 8°04′ and 37°06′ N latitude and 68°07′ and 97°25′ E longitude with total geographical area of 329 million ha. From the biological diversity point, India is regarded as a mega diversity country. Out of the total estimated species of the world, about 8.4 million species are from India.

India is very rich in terms of biological diversity due to its diversified habitat and climatic conditions. India harbours as much as 7 per cent of the total animal species of the world, though India land mass are about 2 per cent (Table 1). India is known to have nearly 91,364 species, of which insect alone 61,171. The inventories of reptiles, amphibian, fish, birds and mammals are fairly complete. More than 5150 species of plants, 16214 species of insects, 44 species of mammals, 42 species of birds, 162 species of reptiles, 121 species of amphibians and 435 species of species of fishes are endemic in India (Ravindranath *et al.*, 2006).

These living species are not uniformly distributed but are seen in those areas where their species specific ecological requirements are satisfactorily fulfilled. Even in India, biodiversity is very high in the Eastern Himalayas and the Western Ghats. These two regions are recognised as hot spots rich in biodiversity. Unfortunately, these areas are also under constant threat of destruction.

About 7000 endemic species are found in India; they do not occur anywhere else in the world. Of these, the Himalayas and the Khasi Hills in Meghalaya account for about 3000 species, and the Deccan Peninsula for about 2000 species. The area of maximum diversity in India is the north-eastern region, which happens to be also the most threatened. The second major area of genetic diversity is the lower region of the Western Ghats around the Nilgiris.

Around 600 species of vascular plants are facing the threat of extinction; the fate of the animal world is not much different either. About 150 species of animals are on the verge of extinction, which include 81 mammals, 47 birds, 15 other animals including 3 species of amphibians and butterflies and moths and beetles of different kinds.

Table 1. Described faunal groups in India

Taxonomic group	World	India	Percentage in India
PROTISTA (Protozoa)	**31250**	**2577**	**8.24**
ANIMALIA			
Mesozoa	71	10	14.08
Porifera	4562	500	10.70
Cnidaria	9916	842	8.49
Ctenophora	100	12	12.00
Platyhelminthes	17500	1622	9.22
Nemertinea	600	–	–
Rotifera	2500	330	13.20
Gastrotricha	3000	100	3.33
Kinorhyncha	100	10	10.00
Nematoda	30011	2862	9.53
Nematomorpha	250	–	–

Table 1. *Contd.*

Taxonomic group	World	India	Percentage in India
Acanthocephala	800	229	28.62
Sipuncula	145	35	24.14
Mollusca	66535	5072	7.62
Echiura	127	43	33.86
Annelida	12700	840	6.61
Onychophora	100	1	1.00
Arthropoda	**999422**	**71263**	**7.13**
Crustacea	35536	2936	8.26
Insecta	867365	61171	7.05
Arachnida	73440	5818	7.90
Pycnogonida	600	17	2.83
Pauropoda	360	–	–
Chilopoda	3000	100	3.33
Diplopoda	7500	162	2.16
Symphyla	120	4	3.33
Merostomata	4	2	50.00
Phoronida	11	3	27.27
Bryozoa (Ectoprocta)	4000	200	5.00
Entoprocta	60	10	16.66
Brachiopoda	300	3	1.00
Pogonophora	80	–	–
Priapulida	8	–	–
Pentastomida	70	–	–
Chaetognatha	111	30	27.02
Tardigrada	514	30	5.83
Echinodermata	6223	765	12.29
Hemichordata	120	12	10.00
Chordata	**48463**	**5016**	**10.35**
Protochordata	2106	119	5.65
Pisces	21723	2546	11.72
Amphibia	5162	262	5.07
Reptilia	5817	460	7.91
Aves	9026	1232	13.66
Mammalia	4629	397	8.58
Total (Animalia)	**1196902**	**88787**	**7.42**
Grand Total (Protista + Animalia)	**1228152**	**91364**	**7.44**

(*Source* : Ramakrishna, 2009)

Marine Biodiversity

Among coastal wetlands, the estuaries, mangroves, coral reefs and coastal lagoons are biodiversity rich areas, whereas the other brackish habitats have only a few specialized species. It is generally commented that there are less species in estuaries compared to the adjacent seas and in-flowing rivers. However, as far as the Indian estuaries are concerned, the statement is only partly true. There are fewer species in the estuaries than in the adjacent seas, but the upper riverine ecosystem does not harbour as many species as its estuary. It has been observed that as the distance increases from the sea, the number of species decreases. Salinity becomes an important regulating factor.

The marine ecosystem has a varying profile. The coastline encompasses almost all types of intertidal habitat, from hyper saline and brackish lagoons, estuaries, and coastal marsh and mudflats, to sandy and rocky shores. The sub tidal habitats are equally diverse. Each local habitat reflects prevailing environmental factors and is further characterized by its biota. Thus, the marine fauna itself demonstrates gradients of change throughout the Indian coasts.

Out of the total 32 animal phyla, 15 are represented by the taxa in the marine ecosystem (Table 2). They may constitute either migratory or resident species. The former includes pelagic crustaceans, coelenterates, cephalopods, fishes, reptiles, birds and mammals. Amphibians are generally absent in estuaries. The benthic macro fauna comprises resident species of polychaetes, bivalves, gastropods, sipunculas and mud-burrowing fishes. Among invertebrates, the sponges, phoronids and echinoderms generally do not prefer an estuarine ecosystem. In the Indian estuaries, species diversity seems to be maximum in the molluscs. About 245 species belonging to 76 genera under 54 families have been catalogued. Other important taxa, polychaeta are represented by about 167 species belonging to 97 genera under 38 families. Maximum diversity has been reported in the much-studied Hoogly-Matiah estuary (West Bengal). Macro organisms and meiofauna of Indian estuaries are not properly investigated. Estuarine mud may contain rich variety of bacteria, flagellates, ciliates, nematodes, ostracods, harpacticoid copepods, rotifers, gastrotriches, arachnids and tardigrades.

Free swimmers or nekton are important components of marine biodiversity and constitute important fisheries of the world. The dominant taxa in the nekton are fish, others being crustaceans, molluscs, reptiles and mammals. Out of the total 22,000 finfish species, about 4,000 species occur in the Indian Ocean of which 1,800 species are reported in the Indian Seas. A majority of the nektonic species is found in the coastal waters. It is estimated that 40 species of sharks and 250 species of bony species represented the oceanic fishes.

Among reptiles, sea snakes and turtles are important and represented worldwide by 50 and 7 species, respectively. These are generally oceanic forms but a majority of them visit the shore at some part of their life. About 26 species of sea snakes belonging to one family, Hydrophiidae, and five species of sea turtles were reported from seas around India. Oceanic islands seem to harbour more reptiles in their marine environment. All the sea snakes and four species of turtles in their marine environment are known from islands of Andaman and Nicobar. Nesting sites of an amphibious snake were reported from the shores of North Andaman Islands. Turtles visit the shore during breeding time to lay their eggs. The shore visit of these turtles, especially the olive ridley is a spectacular sight on the sandy beach at Gahirmatha near Bitarkanika in Orissa. The Andaman and Nicobar Islands have the best nesting beaches for the leatherback, the hawksbill and the green turtle in addition to the olive ridley (Baskar, 1993).

The seashore offers a variable feeding and breeding ground for a number of birds. It is difficult to define precisely the avian component of marine biodiversity. There are some special species, which are exclusively dependent on the marine ecosystem, while a few are generalists without much dependence on it. From the available data it has been inferred that 12 families, 38 genera and 145 species occur in the coastal ecosystem.

Marine mammals belong to three orders, Sirenia, Cetacea and Carnivora. About 120 occur in world seas and of these 30 are reported from seas around India. The sea cow occurs in near shore waters.

Table 2. Marine fauna and flora of India

Sl. No.	Group	Number of species	Sl. No.	Group	Number of species
Flora			24.	Chaetognatha	3030
1.	Diatoms	200	25.	Tardigrada	10
2.	Dinoflagellates	90	26.	Copepoda	1925
3.	Algae	724	27.	Ostocoda	120
4.	Rhodophyta	434	28.	Branchiura	5
5.	Phaeophyta	191	29.	Cirripedes	104
6.	Xanthophyta	3	30.	Mysidacea	75
7.	Chlorophyta	216	31.	Cumacea	30
8.	Sea grass	14	32.	Tanidacea	1
9.	Mangroves	39	33.	Isopoda	33
Fauna			34.	Amphipoda	139
10.	Protozoa	532	35.	Euphasacea	23
11.	Foraminifera	500	36.	Stomatopoda	121
12.	Tintinids	32	37.	Macrura	55
13.	Porifera	486	38.	Brachyura	705
14.	Cnidaria	842	39.	Anomura	162
15.	Hydrozoa	212	40.	Mollusca	3370
16.	Scyphozoa	25	41.	Bryzoans	200
17.	Cubozoa	5	42.	Echinodermata	765
18.	Anthozoa	600	43.	Hemichordata	12
19.	Ctenophora	12	44.	Prochordata	119
20.	Achianeellida	20	45.	Fishes	2546
21.	Polychaeta	250	46.	Reptiles	35
22.	Sipuncula	35	47.	Mammals	25
23.	Echiura	3333			

(*Source* : Venkataraman, and Wafer 2005)

ANDAMAN AND NICOBAR ISLANDS

The far southeastern region of the Bay of Bengal presents some tropical evergreen sprinkles of lands in the form small and large island rising from the deep blue waters of sea interrupting the view of the infinite Indian Ocean. The archipelago comprises 572 islands known as the Andaman and Nicobar Islands extending over 800 km (Fig. 1). These islands were once a part of the Asian mainland but got detached some 100 million years ago during the Upper Mesozoic Period due to geological upheaval. The existing groups of islands constitute the physiographic continuation of the mountainous ranges of Naga and Lushai Hills and Arakan Yoma of Burma through Cape Negrais to the Andaman and Nicobar Islands and southeast of Sumatra (Achin Head). The chains of these islands are in fact the camel backs of the submerged mountain ranges projecting above the sea level running north to south between 6045'N and 13030' N latitudes and 90020'E and 93056'E longitudes. As per 1981 census the total landmass of these islands is 8249 km^2 approximately.

The Andaman and Nicobar Islands are geologically young. These islands probably had their origin in the Tertiary period, which started

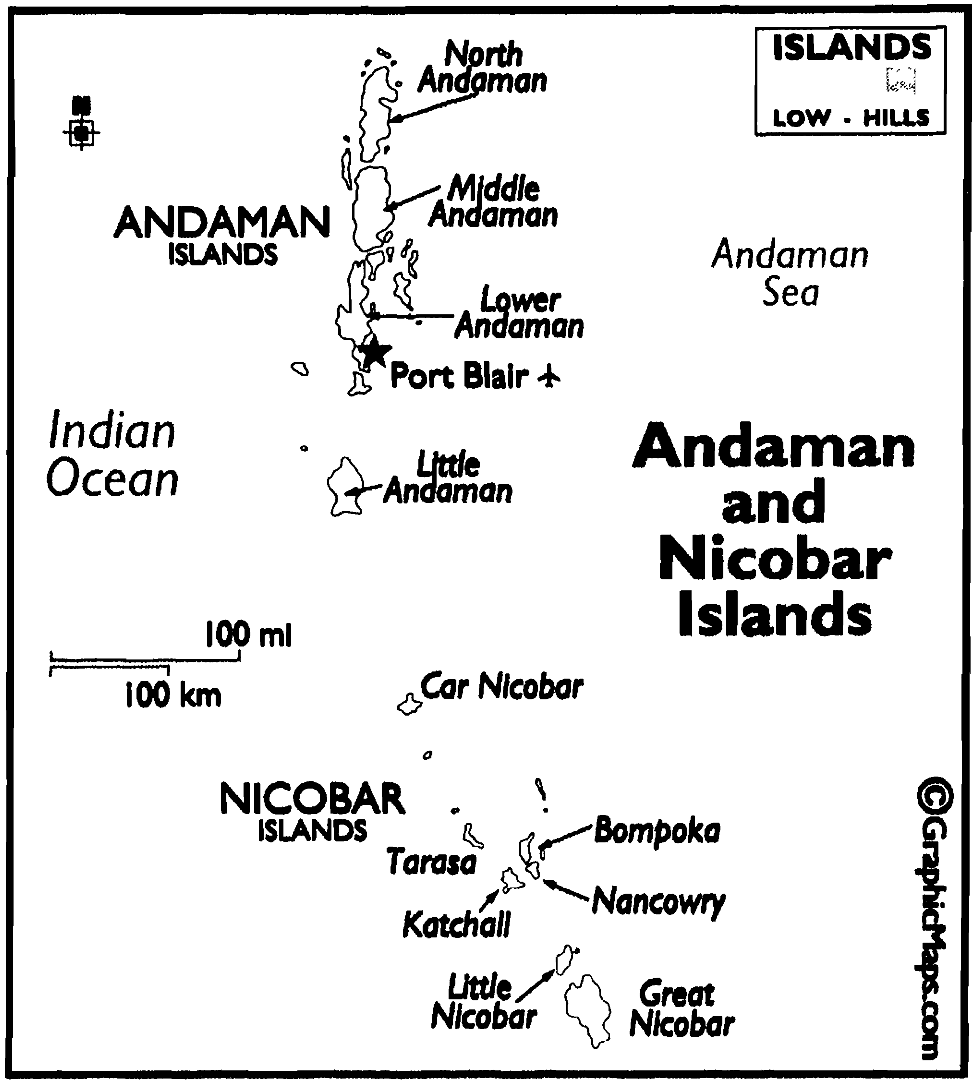

Fig. 1. Map showing Andaman and Nicobar Islands

about 63 million years ago and ended about 1 million years ago when Quaternary period started. For centuries, the islands remained cut off from the mainstream of history. Except for a few passing references by the foreign travellers, nothing was known of these islands. It was believed in the past that the inhabitants were cannibals and hence these islands were avoided. The first real contact with the Indian mainland was established with the founding of a settlement in September, 1789 at Port Cornwallis, now known as Port Blair.

The Andaman and Nicobar Archipelago can be broadly divided into two groups of islands, namely, the Andamans and the Nicobars. The two groups are separated by the Ten-degree Channel which is about 150 km wide 400 fathoms deep.

The Andaman group consists of 324 islands of which only 20 are inhabited. The main part of the group is collectively known as the Great Andamans comprising five closely adjoining islands, Baratang and Rutland Islands. All these are separated by narrow channels. The Great Andaman group covers a land area of 6408 km^2. This island is 48 km long and 27 km wide and its land area is about 960 km^2.

The Nicobar group comprises 24 islands of which 13 are inhabited and others are of less significance. The distance between the northernmost point of Car Nicobar and Pygmalian Point presently called as Indira Point (the southern-most tip of Great Nicobar) is 310 km. The Pygmalion Point is in fact the southernmost boundary of India and is about 144 km from Achin Head of Sumatra. Of all the island of Nicobar group, Great Nicobar is the largest having an area of nearly 1045.1 km^2 with a length of 55 km between Murray Point in the north and Pygmalion Point in the south. Other islands of the group worth mentioning are Car Nicobar, Choura, Tillanchong, Teressa, Bompoka, Camorta, Trinket, Nancowry, Katchal, Pulomilo, Kondul and Little Nicobar. Most of these islands are fertile and support evergreen vegetations, especially the clusters of coconut palms that bear green fans waving high above the slim bare trunks against the blue sky. Car Nicobar is the Headquarter of the Nicobar group of islands. It is a coral island and has a shape more or less that of Australia with a land area of 126.9 km^2.

GEOLOGICAL HISTORY

The Andaman and Nicobar groups of islands belong to a geosynclinals basin. The sediments of this region have gradually changed their characters, according to tectonic movements, to which they have been subjected to from time to time; as such the rocks are highly folded.

The six distinct geological formations consisting of various groups of rocks, from these islands were reported. These formations include "Older Sedimentaries", Ophiolite Suite (with basic and ultrabasic intrusive), Mithakhari Group, Andaman Flysch, Archipelago 'series' and the Rutland Shell-Limestone. They represent a period of sedimentation, from Cretaceous (about 100 million years) to Sub-Recent (less than 10,000 years). The surface deposits of gravel beds and raised soil covers, on the other hand, are of very late origin, i.e., Recent to Sub-Recent (i.e., less than 10,000 years).

In general, it is believed, that the mountain ridges of the island were formed at the expanse of a narrow but deep oceanic furrow during Late Mesozoic Period (100 million years).

The older sediments of Mesozoic formed the basement for younger deposits. The history of later deposition is that of an inconsistent basin i.e. associated with movement, volcanism and deposition, side by side with igneous intrusions. Over the older sediments, at the deeper part of the sea bottoms, there was rich accumulation of siliceous tests of radiolarians, possibly and deposition of sediments of late Cretaceous to Oligocene (consisting of group of rocks of Mithakhari Group, Andaman Flysch, Archipelago 'Series').

During Oligocene, the islands faced a tremendous earth movement resulting in mountain ridges, although well within the sea. Some of the ridges were suited for the growth of corals and also had the rising tendency for developing the reef islands. As such, formation of Rut islands (West Coral Reef, Middle Coral Reef, Chaura Coral Reef, Sambero Channel Coral Reef, and Car Nicobar Coral Reef) in this region is attributed to these and also to the deposition of limestone.

The present configuration was, however, achieved by these islands only about 26 million years ago. Two of the islands, Narcondam and barren Islands are of volcanic origin. The former is an apparently extinct volcano, while the latter is still active.

Zoogeography

Zoogeographically, Andaman and Nicobar Islands occupy a unique position. These are close to the "Indo-Malayan region," which is considered to be a "faunistic centre'from which other sub-divisons of the Indo-west Pacific Region recruited their fauna (Ekman, 1953). Although a certain degree of endemicity is known among a few groups of terrestrial animals, the endemism among marine animals is not known, since our knowledge on many groups is far from satisfactory. Some of the typical Indo-West Pacific groups of shore animals are found in these islands. Gaint clams (Tridacnidae) among mollluscs and fishes such as sea moths (Pegasidae), whitings (Silliginidac), rabbit fishes (Siganidae) and plesiopids (Plesiopidae) which are restricted to the Indo-West Pacific region are found in these Islands. Out of 50 species of sea snakes from the Indo-Pacific region 26 are reported from the waters off these islands. Dugong, a marine mammal which is endemic to Indo-West Pacific is recorded off these Islands. There are many more such marine animals which are typical of Indo-West Pacific and occur in these islands. Although the Islands have a great diversity of marine fauna many groups are yet to be worked out in detail.

Soil

The soil cover is more or less thin varying between two and five metres in the hilly tracts. The alluvial soil is found on top of the ridges and diluvial soil covers the blocks of the ridges and valleys. Thick alluvial soil (30 to 50 metres) is formed along river courses. Coastal flats are admixture of sand, silty clay and diluvial material together with fine fragments of coral lime. The soil, in general, is mild to moderately acidic with appreciably high humus on top.

Climate

These islands are tropical, that is, warm, moist and equable. The proximity of the sea and the abundant rainfall prevent extremes of heat. The mountainous parts of the southern islands get about 300 cm of rain annually whereas the islands of north get lesser rainfall. Winter is practically unknown; the period from December to February is comparatively cool due to the effect of northeast monsoon. The warm weather extends from March to April when there is the least precipitation. In the May southwest monsoon breaks over the area and continues till October end.

The variation of temperature over the islands is small (23°-31°C). The range of the mean temperature in the year is about two degrees. Due to high humidity (over 80 per cent) the weather remains oppressive. Expect for three dry months (December- February) sky remains overcast with clouds. Thunderstorms occur most frequently in the hot season. During the southwest monsoon season winds are moderate but with its retreat typhoons affect the area. Some of these develop into full fledged cyclonic storms, lashing the coasts accompanied by the heavy rain and strong gusty winds dreading the lives of the sea-farer.

Andaman Sea

Andaman Sea is partially isolated portion of the northeastern Indian Ocean which lies enclosed between the coast of Burma, Thailand and Malaysia on the east and the chain of Andaman and Nicobar Islands and Sumatra Islands of Indonesia on the west (Fig.2). It occupies an area of 6.02×105 km^2 and has a volume of 6.6×105 km2 with an average depth of 1096m and a maximum depth of 4360m. Andaman Sea contains a relatively extensive basin, a north-south arc of volcanic island and seamounts including the Barren and Narcondam Islands in this sea, delineates this basin from 2 smaller basins on the north and south (Wyrtki, 1961; Rodolfo, 1966; Curray and Moore, 1974). It is connected to the Bay of Bengal by numerous channels which are broadly, interruptions in the ridge that lies on the western boundary. Among them the Preparis Channel, divided into north and south portions by the islands with a depth of 200m; the Ten Degree Channel, between the Andaman and Nicobar groups of Islands with a depth of about 800m and the Great Channel, between Great Nicobar Island and Sumatra. This Sea is also connected with the South China Sea through the Strait of Malacca. Strong tidal currents occur in this strait which has a depth of 30m and a width of 35km at its narrows part (Rodolfo, 1966).

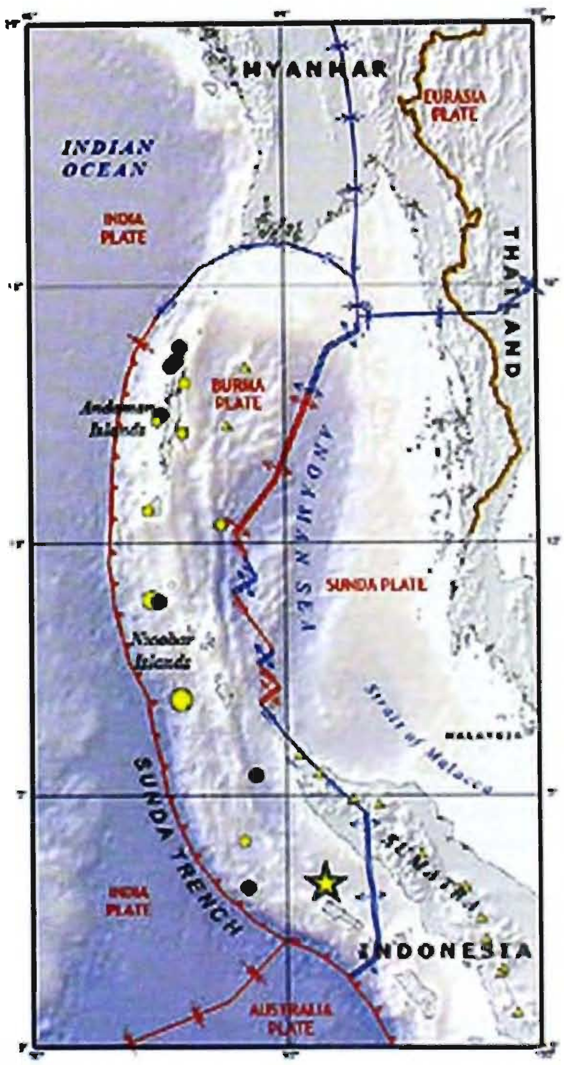

Fig. 2. Andaman Sea showing geographical boundary

Topography

This Island territory from its highest peak to the deepest depth possesses a unique and sensitive ecosystem. It possesses different geological, topographic, oceanographical features. Being a volcanic island it is endowed with a shallow continental shelf of about 35000 km^2. The shelf topography of the islands is highly irregular. The upper surface of the shelf is marked by frequent rises supporting coral reefs and depressions known as passages and straits. The archipelago of geographical area (8249) km² is surrounded by the coral reefs; rocky areas, mangrove swamps. A deep oceanic trench above 1000 fathoms deep runs between the Nicobar and Sumatra and extends upto Norcondam Island. The continental shelf which runs upto 100 fathoms depth is very narrow, only 2 25 miles in width, broader on the western side and becomes very deep there after the deepest known depth is 4198m east of car Nicobar Island. The shores are rocky with fringing coral reefs with a few sandy beaches. The sea bed too is rocky with coral growths. Muddy grounds are limited and are found only in protected bays and creeks. The Little Andaman and Nicobar Islands except Great Nicobar lying on the south are flat, sandy islands, probably of most recent origin, formed by coral formations. The sea water is less saline on the east coast than in the west which for this reason has more coral reefs. Ocean currents sweep the sea floor and upwell on the east coast thus bringing rich nutrients and it makes the water more potential.

Barren and Narcondam Islands

The Barren Island is part of the Andaman group of islands situated at 12°16′40″ N and 93°51′30″ E in the Andaman Sea and about 135 km northeast of the Union Territory's Capital, Port Blair. The island is almost circular in shape with total surface area of about 10 km². The Barren Island is the only active volcano in South Asia although volcano activity was reported from Narcondam Island also, which is located at 13°26′ N and 95°15′ E and about 120 km away from Barren Island in the Northeast direction (Fig. 3). Both these islands stand in the midst of a volcanic belt on the edge of the Indian and Myanmarese tectonic plates. There are other extinct sea and land volcanoes reported in and around these regions.

The first recorded eruption of the Volcano in the Barren Island date back to 1787. Since then, eruptions were recorded for more than half-a-dozen times *viz.*, 1789, 1795, 1803-04, 1852, 1991, 1994-95, 2000 and 2005-06. Almost after one and

Barren Island

Volcanic eruption of Barren Island

Arial view of Barren Island

Narcondam Island

Fig. 3 Valconic islands of Andaman

half century of dormancy, the eruption in 1991 has lasted for nearly six months and caused considerable damage to the flora as well as fauna of this island. The Lava paths are seen towards the northern part of main caldera. As its name itself indicates the island is uninhabited, but various species of insects, reptiles, birds and mammals have been reported (Rao *et al.*, 1990). Nevertheless, feral goats (*Capra hircus* L.) and rats (*Rattus* spp.) are quite large in number and the rodents really become a menace in the night. The drinking water source for the goats are fresh water springs found in the Southeastern part of the island and they survive not by drinking saline sea water as speculated earlier.

History of investigation

Oceanographic researches in the Andaman Sea date back to 1896 when Francis Day, a well known army officer and fishery biologist, visited Andaman and Nicobar Islands and recorded the occurrence of 136 species of fishes in the Andaman waters. This investigation gained further impetus with the inclusion of a few Surgeon Naturalists in the Marine Survey of India, who conducted pioneering investigations on some aspects of physics, chemistry, biology and geology of the Andaman Sea from the survey vessel *Investigator* during 1875-1925. The first record of these marine surveys was published in 1902 by A. Alcock, a *Naturalist* in Indian Seas. Subsequently, the most outstanding and comprehensive study of the Andaman Sea was carried out from 1913 to 1925 by the Former Director of Zoological Survey of India, Surgeon Major R. B. Seymour Sewell and results were published in the *Memoirs of the Asiatic Society of Bengal* (Vol. IX, Nos.1-8, 1925-1935). Since then several international expeditions were conducted by many research ships, viz. *Challenger, Valdivia, Siboga, Galatea* and *Vitiaz* to Andaman as it attracted with rich marine wealth. Apart from that during the course of International Indian Ocean Expedition, the oceanographic surveys were undertaken by the research vessels *NS Kistna, RV Cerano* and *RV Anton Bruun* in this sea during 1970s. The National Institute of Oceanography has undertaken 2 cruises during 1970 and 3 cruises during 1980 by *R.V. Gaveshani* and studied the physical and wave characteristics, hydrography, nutrients, trace metals, primary productivity, distribution of phytoplankton, zooplankton, benthic meiofauna and macro fauna, microbes and bioaccumulation of heavy metals in some fishes. The findings of these surveys have been published in the special issue of *Indian Journal of Marine Sciences*, Vol.10 (3), 1981. Recently, National Institute of Ocean Technology, Ministry of Earth Sciences, Government of India is undertaking surveys in Andaman Sea to explore its productivity besides studying hydrobiological features.

Scientific significance

The entire Andaman Sea is of considerable interest to marine scientists. This is the region where the complex air-sea interaction phenomenon released enormous energy for the genesis of the tropical cyclone which hits the east coast of India and north and northeastern coast of Bay of Bengal almost every year. Furthermore, the Andaman and Nicobar group of Islands even more interesting with the yearly cycle of northeast and southwest monsoonal wind system reversing the atmospheric circulation and the surface currents of Bay of Bengal and Andaman Sea from December to April and June to October with intervening transitional periods. All the islands of this archipelago have; in general, steep slopes on all sides and hence oceanic conditions prevail even in near shore regions. The Andaman Sea is influenced by large quantities of freshwater runoff from the perennial rivers of Burma, Thailand and Malaysia and it largely influences on the topmost layers. The discovery of large deposits of natural gas in the sea-bed off south Andaman, this area has become of special significance.

Hydrography

The sea surface temperature of Andaman Sea varied from 27 to 28.5°C with an increasing trend from north to south. Noticeable difference in the temperature of the waters below 1500m is decreased from 5°C to 3°C. The sea surface salinities ranged from 31.20 to 32.6ppt and it increased from north to south on the western side and south to north on the eastern side (Rama Raju *et al.*, 1981). The thermocline has a moderately developed gradient in this sea and extends to a maximum depth of 125m where the temperature is of the order of 15-16°C (Murty *et al.*, 1981). In the Andaman Sea the wave characteristics like zero crossing period and significant wave height vary from 6 to 12 sec and 0.6 to 1.4m around Andaman and Nicobar Islands while along the equatorial transect they are respectively 7 to 9 sec and 0.8 to 1.8m (Gouveia *et al.*, 1981). The different water masses identified on the basis of distribution of temperature, salinity and sigma-t are Persian Gulf water in the depth range 200-500m and a mixture of Persian Gulf and Red Sea waters in the depth range 500-900m. At depths 1500m and below the water are warmer on the western side. Water masses on the eastern and western margins of Andaman and Nicobar Islands have similar hydrographic features up to a depth of 1500m (Sen Gupta *et al.*, 1981). The content of trace metals *viz.* Cu, Cd, Zn, Pb, Fe, Mn, Co and Ni in seawater is very low concentrations in both dissolved and particulate fractions. Dissolved Pb was higher at depths of 0-100m while levels of particulate Pb were higher at depths exceeding 100m (Sanzgiry and Braganca, 1981). The mean dissolved petroleum hydrocarbons, measured at 0 and 10m depth of water column ranging from 28 to 83μg/L (Topgi *et al.*, 1981).

Biological Diversity of Andaman & Nicobar Islands

The Union Territory of Andaman and Nicobar Islands are considered as *Paradise of Biological Diversity,* About 6540 species of Fauna, of which 834 species are endemic, while about 2500 species of Flora reported, of which 261 species are endemic. Among them 63.7 per cent of Biota belongs to Marine habitat. It is known that 32 out of 33 animal phyla found in these islands exist in sea. The details of the fauna reported from Andaman and Nicobar Islands are presented in table 3.

Table 3. Faunal diversity of Andaman and Nicobar Islands

Sl. No.	Faunal group	World	India	A & N Islands	per cent in India	Endemic	per cent of Endemic
1.	Sponges	5100	519	112	21.58	5	7.14
2.	Corals	700	235	235	100		
3.	Earthworms	4000	585	21	3.58	7	33.33
4.	Leeches	500	59	10	16.90		
5.	Polychaetes	8000	428	186	42.90		
6.	Arachnids	120	21	14	66.60		
7.	Gastrotricha	2500	88	32	36.60	6	18.75
8.	Chinorincha	100	10	4	40.00	2	50.00
9.	Crustaceans	24375	2970	607	20.40	56	9.22
10.	Spiders & Scorpions	35810	1352	94	6.90	28	45.16
11.	Centipede	3000	100	17	17		
12.	Millipedes	7500	162	5	3		
13.	Insects	867391	59353	2256	4.4	485	21.5
14.	Land molluscs	15000	950	110	11.5	75	68.18
15.	Freshwater molluscs	8765	284	51	17.9	12	23.52
16.	Marine molluscs	56235	32751	1422	4.34	2	0.2
17.	Siphonculates	202	38	25	65.7		
18.	Echninoderms	6226	765	430	43.9	2	0.59
19.	Fishes	21723	2546	1283	46.5		
20.	Amphibians	550	219	23	8.21	3	16.66
21.	Reptiles	5817	456	104	19.73	23	25.55
22.	Aves	9026	1232	284	23.05	105	36.97
23.	Mammals	4629	390	62	15.38	33	55.00

(*Source* : ZSI)

Productivity

Andaman Sea is oligotrophic in nature with low primary (273 $mgC/m^2/day$) and secondary productivity (288.8 $mgC/m^2/day$). The production of large quantities of detritus therefore appears to supplement the nutritional inadequacy of these waters. Exracellular production by phytoplankton varies from 0 to 1.2 $mgC/m^3/hr$ at different depths representing a loss of 0 to 85% photosynthate. The phytoplankton population varied from 1400 to 4900 cells/litre and it is mostly constituted by *Navicula* sp. *Peridinium* sp. and *Trichodesmium thiebautii*. Dinoflagellates formed an important constituent of phytoplankton in the Andaman Sea (Bhattathiri and Devassy, 1981). The average zooplankton biomass is 5.6 $ml/100m^3$ and copepods form the dominant groups followed by chaetognaths and tunicates. The higher biomass distribution of zooplankton is above thermocline i.e. above 20m depth (Madhupratap *et al.*, 1981a). Among the copepod species, *Undinula vulgaris, Euchaeta marina, Eucalanus monachus, Eucalanus mucronatus, Corycaeus* sp. and *Oncea* sp. are commonly found above the thermocline layer (Madhupratap *et al.*, 1981b). The macrobenthic fauna in the depth range 11-2150m comprised of 22 faunal taxa. Of these polychaetes were the most dominant group and contributed 76.8 per cent. The distribution of macrobenthic fauna was substrate specific with maximum (410 m^{-2}) in clayey deposits and minimum (266 m^{-2}) in coralline sand areas. The mean standing stock is relatively very low in this sea as it has $6gm^{-2}$. The biomass of infauna is considerably lower than those of the epifauna or onfauna and the production decreased rapidly with increasing depth (Parulekar and Ansari, 1981). The meiofauna of this sea ranged between 68 and $438/10cm^2$ with a biomass range of 3.57 and $32.8mg/10cm^2$). Meiofaunal components were maximum in sandy sediments which contained little silt and clay. The fauna diminished in coarse coralline sand and clayey sediments (Ansari and Parulekar, 1981). The bacterial population in the sediments of Andaman Sea widely fluctuated from 2.1 × 103 to 3.7 × 106. Ratio of gram positive to gram negative bacteria is 1 : 15.4.

Forest ecosystem

India possesses a distinct identity, not only because of its geography, history and culture but also because of the great diversity of its natural ecosystems. The panorama of Indian forests ranges from evergreen tropical rain forests in the Andaman and Nicobar Islands, the Western Ghats, and the north-eastern states, to dry alpine scrub high in the Himalaya to the north. Between the two extremes, the country has semi-evergreen rain forests, deciduous monsoon forests, thorn forests, subtropical pine forests in the lower montane zone and temperate montane forests.

One of the most important tropical forests classifications was developed for Greater India (Champion, 1936) and later republished for present-day India (Champion and Seth, 1968). This approach has proved to have wide application outside India. In it 16 major forests types are recognized, subdivided into 221 minor types. The estimated forest area in Andaman and Nicobar Islands is 6,629 km^2 which is equivalent to 80.96 per cent of total landmass area. The Andaman and Nicobar Islands have tropical evergreen rain forests and tropical semi-evergreen rainforests as well as tropical monsoon moist monsoon forests. This tropical evergreen rain forest is only slightly less grand in stature and rich in species than on the mainland. The dominant species is *Dipterocarpus grandiflorus* in hilly areas, while *Dipterocarpus kerrii* is dominant on some islands in the southern parts of the archipelago. The monsoon forests of the Andamans are dominated by *Pterocarpus dalbergioides* and *Terminalia* spp.

Mangroves

India with a long coastline of about 7516.6 km, including the island territories has a mangrove cover of about 6,749 km^2, the fourth largest mangrove area in the world (Naskar & Mandal, 1999). These mangrove habitats (69°E-89.5°E longitude and 7°N-23°N latitude) comprise three distinct zones: East coast habitats having a coast line of about 2700 km, facing Bay of Bengal, West coast habitats with a coast line of about 3000 km, facing Arabian sea, and Island Territories of Andaman & Nicobar and Laccadives with about 1816.6 km coastline. The long coastlines and their mangrove vegetation have immense role in protecting coastal biodiversity. A total of 966 km^2 area of mangrove vegetation occurs in Andaman and Nicobar Islands (i.e. 20% of the total mangrove area of the Indian territory). In Andaman district, the area under mangroves is

929 km²; while in Nicobar district mangroves occupy only 37 km². Area wise, Andaman and Nicobar Islands are second in the country after West Bengal, but as far as density and growth are concerned, mangroves of these islands are the best in the country. Mangroves occurring in these islands are mostly fringing the creeks, backwater and muddy shores. Along the creeks, the width ranges from 0.5 to 1 km. This salt-tolerant community is found on rocky shores exposed to tidal action and sometimes is also found growing in tidal mudflat. Luxuriant mangroves are seen in Shoal Bay (South Andaman), Yerrata (Middle Andaman), Austin Creek, Kalighat Creek and Cadell Bay (North Andaman).

In India, a total of 82 mangrove species, distributed in 52 genera and 36 families, has been recorded by different workers. Andaman & Nicobar Islands harbour 61 species distributed in 39 genera and 30 families, including two new species, *R. lamarkii* and *R. stylosa*, and has the maximum species of the genus *Rhizophora* (four species). Lakshadweep Atoll has 8 species distributed in 5 genera and 3 families.

The mangrove flora of Andaman and Nicobar Islands have been studied by Chengappa (1944), Banerji (1954, 1958), Sahany (1957) and of late by Mall *et al.* (1985) and Vasudeva Rao (1986). Mall *et al.*(*op.cit.*) have listed 26 exclusive mangrove species and 10 non-exclusive mangrove species. But perusal of literature including the work of Vasudeva Rao (*op. cit.*), consultation with the Botanical Survey of India, Port Blair Circle and personal observation in different mangrove areas of these islands reveal the presence of 37 species of mangroves and their associated vegetation.

The mangroves of the Bay Islands are noteworthy for their gregariousness and nearly uniform degree of dominance by the fewer number of species unlike on the mainland (Krishnamurty, 1985). Two categories of mangroves, namely, core mangroves and associated and peripheral vegetation are also recognized. Among the Andaman mangroves, *Rhizophora mucronata* and *R. apiculata* are most dominant and grow on the outer seaward fringe of the swamp. Sometimes open mudflats, and rocky and coral reef flats are occupied by *Sonneratia alba*, *S. apetala* and *Avicennia marina* In the tidal creeks *Bruguiera gymnorhiza* and *B. parviflora* are abundant, of which tallest trees grow as high as 25 metres. In the tidal swamps, *Avicennia officinalis, Ceriops tagal, Kandelia candel, Xylocarpus granatum, X. moluccensis, Lumnitzera racemosa, L. littorea, Excoecaria agallocha* and *Aegiceras corniculatum* are found to grow. *Acanthus ilicifolius* forms dense prickly undergrowth generally near the creek. *Heritiera littoralis, Scyphiphora hydrophyllacea, Brownlowia lanceolata* and *Cynometra ramiflora* grow towards the landward fringe. Sometimes fern, *Acrostichum* spp and palms, *Nypa fruticans* and *Phoenix paludosa* are quite common in this zone. In the supra-littoral zone of the disturbed mangrove forests *Acanthus ilicifolius* and *Acrostichum aureum* are sometimes very frequent as in Sippighat area, South Andaman.

In both Andaman and Nicobar islands, members of the family Rhizophoraceae are pioneers in mangrove formation and the guardian of the soil builders. These forests along with their peculiar root system develop gregariously fringing the coasts or at the mouth of the creeks. Once *Rhizophora* colony becomes established other species grow gradually behind them. Mention may be made here that *Rhizophora* and its allied species have become rare or tended to be disappeared in other parts of India except in Cauvery delta and in the Andaman islands due to strong biotic pressure. The status of mangroves categorized from Andaman and Nicobar Islands as recorded by Botanical Survey of India is as follows (BSI, 1983).

List of mangrove plant species in Andaman & Nicobar Islands

Name	Life form	Status	Occurrence
ARECACEAE			
1. *Nypa fruticans* (Van.) Wurmb.	Tree	C	Landward
2. *Phoenix paludosa* Roxb.	Tree	C	Landward

Name		Life form	Status	Occurrence
	AVICENNIACEAE			
3.	*Avicennia marina* (Forsk.) Vierh.	Tree	C	Seaward
4.	*A. officinalis* L.	Tree	C	Seaward
	COMBRETACEAE			
5.	*Lumnitzera littorea* (Jack.) Voigt	Tree	R	Landward
6.	*L. racemosa* Willd.	Tree	R	Landward
	RHIZOPHORACEAE			
7.	*Bruguiera gymnorhiza* (L.) Lamk.	Tree	C,V	Seaward
8.	*B. parviflora* (Roxb.) Wt. & Arn. Ex Griff.	Tree	C,V	Landward
9.	*Ceriops decandra* (Griff) Ding Hou	Tree	R	Backwater
10.	*C. tagal* (Perr.) Robin.	Tree	R	Backwater
11.	*Kandelia candal* (L) Druce	Shrub	C	Landward
12.	*Rhizophora apiculata* Bl.	Tree	A	Seaward
13.	*R. mucronata* Lamk.	Tree	A	Seaward
14.	*R. stylosa* Griff	Tree	R,V	Seaward
	SONNERATIACEAE			
15.	*Sonneratia alba* J. Sm.	Tree	C	Seaward
16.	*S. caseolaris* (L) Engl. (*S. acida* L. f.)	Tree	C	Seaward
	SEMI MANGROVE SPECIES			
	EUPHORBIACEAE			
17.	*Excoecaria agallocha* L.	Tree	C	Landward
	MELIACEAE			
18.	*Xylocarpus moluccensis* (lamk.) Roem.	Tree	T	Seaward, Landward
19.	*X. granatum* Koen	Tree	T	Seaward, Landward, Creeks
	MYRSINACEAE			
20.	*Aegiceras corniculatum* (L) Blanco	Tree	R	Backwater
	PLUMBAGINACEAE			
21.	*Aegieceras rotundifolia* Roxb.	Shrub	R	Middle
	PTERIDACEAE			
22.	*Acrostichum aureum* L.	Herb/Fern	A	Landward
23.	*Acrostichum specisum* Wild	Fern	C	Landward
	RUBIACEAE			
24.	*Scyphiphora hydrophyllacea* Gaertn.	Shrub	C	Middle
	STERCULIACEAE			
25.	*Heritiera littoralis* Dryand. Ex. Ait.	Tree	C	Landward

Name	Life form	Status	Occurrence
ASSOCIATE MANGROVE SPECIES			
ACANTHACEAE			
26. *Acanthus ilicifolius* L.	Herb	C	Landward
27. *A. volubilis* Wall	Herb	C	Landward
APOCYNACEAE			
28. *Cerbera manghas* (L.)	Tree	C,T	By the side of Creeks
ASCLEPIADACEAE			
29. *Finlaysonia obovata* Wall	Shrub	–	Landward
30. *Sarcolobas carinatus* Wall	Scandent shrub	C	Landward
31. *S. globosus* Wall	Scandent shrub	C	Landward
ASTERACEAE			
32. *Pluchea indica* Less	Under shrub	C	Landward
BIGNONIACEAE			
33. *Dolichandrone spathacea* (L.f.)K. Sch.	Tree	C	Landward
CAESALPINIACEAE			
34. *Caesalipinia bonduc* (L) Roxb. emend. Dandy Exell	Climbing shrub	C	Landward
35. *Cynometra iripa* Kosterm.	Tree	C	Landward
36. *Intsia bijuga* (Coleb.) O.K	Tree	C	Landward
CELASTRACEAE			
37. *Salacia chinensis* L.	Scandent shrub	C	Landward
CYPERACEAE			
38. *Fimbristylis ferruginea* (L) Vahl	Herb	C	Landward
FABACEAE			
39. *Derris trifoliate* Lour.	Climber	C	Landward
40. *Mucuna gigantean* (Wild.) Dc.	Climber	C	Landward
LECYTHIDACEAE			
41. *Barringtonia racemosa* (L) Spreng.	Tree	C	Landward
MALVACEAE			
42. *Hibiscus tiliaceus* L.	Tree	C	Landward
43. *Thespesia populnea* Correa	Tree	C	Landward
MELIACEAE			
44. *Aglaia cucullata* Roxb.	Tree	C	Landward
PANDANACEAE			
45. *Pandanus oboratissimus* L.f.	Tree	C	Landward
TILIACEAE			
46. *Brownlowia tersa* (L.) Gaertn.	Shrub	R	Landward
VERNENACEAE			
47. *Clerodendrum inermae* (L.) Gaertn.	Shrub	C	Along mangroves

A : Abundant C : Common R : Rare T : Threatened

The mangrove vegetation of these islands constitutes 9.4 per cent of the land area or 10.85 per cent of the total forest area. Mangroves occurring in these islands are mostly fringing the creeks, backwater and muddy shores. Along the creeks the width ranges from 0.5 km to 1 km. Mangroves do occur on rock shores subjected to tidal action and regular deposits of mud. Mangroves in Andaman are represented by 35 species and other common associated flora represents 62 species (Tables 4 and 5).

Table 4. Mangrove Flora of Andaman

Sl. No	Mangroves of Andaman	Family
1.	*Acanthus ebracteatus*	Acanthaceae
2.	*Acanthus ilicifolius*	Acanthaceae
3.	*Acanthus volubilis*	Acanthaceae
4.	*Acrostichum aureum*	Pteridaceae
5.	*Aegialitis rotundifolia*	Plumbaginaceae
6.	*Aegiceras corniculatum*	Myrsinaceae
7.	*Avicennia alba*	Verbenaceae/Avicenniaceae
8.	*Avicennia marina*	Verbenaceae/Avicenniaceae
9.	*Avicennia officinalis*	Verbenaceae/Avicenniaceae
10.	*Bruguiera cylindrica*	Rhizophoraceae
11.	*Bruguiera gymnorrhiza*	Rhizophoraceae
12.	*Bruguiera parviflora*	Rhizophoraceae
13.	*Bruguiera .sexangula*	Rhizophoraceae
14.	*Ceriops decandra*	Rhizophoraceae
15.	*Ceriops tagal*	Rhizophoraceae
16.	*Excoecaria agallocha*	Euphorbiaceae
17.	*Heritiera littoralis*	Sterculiaceae
18.	*Kandelia candel*	Rhizophoraceae
19.	*Kandelia rheedii*	Rhizophoraceae
20.	*Lumnitzera littorea*	Combretaceae
21.	*Lumnitzera racimosa*	Combretaceae
22.	*Nypa fruiticans*	Palmaceae
23.	*Phoenix paludosa*	Arecaceae
24.	*Rhizophora apiculata*	Rhizophoraceae
25.	*Rhizophora lamarckii*	Rhizophoraceae
26.	*Rhizophora mucronata*	Rhizophoraceae
27.	*Rhizophora stylosa*	Rhizophoraceae
28.	*Scyphiphora hydrophyllacea*	Rubiaceae
29.	*Sonneratia alba*	Lythraceae
30.	*Sonneratia apetala*	Lythraceae
31.	*Sonneratia caseolaris*	Lythraceae
32.	*Sonneratia griffithii*	Lythraceae
33.	*Xylocarpus granatum*	Meliaceae
34.	*Xylocarpus mekongensis (=X-gangeticus)*	Meliaceae
35.	*Xylocarpus moluccensis*	Meliaceae

Table 5. Other Mangrove Associated Coastal Flora in Andaman

Other Mangrove Associated Coastal Flora in Andaman			
Sl. No.		**Sl. No.**	
1.	*Adenanthera pavonina*	32.	*Hernandia peltata*
2.	*Aglaia cucullata*	33.	*Hibiscus tiliaceus*
3.	*Aisandra butyracea*	34.	*Indigofera glandulosa*
4.	*Ardisia solanacea*	35.	*Indigofera zollingeriana*
5.	*Atalantia monophylla*	36.	*Ipomoea pes-caprae*
6.	*Barringtonia asiatica*	37.	*Ischaemum muticum*
7.	*Barringtonia racemosa*	38.	*Manilkara littoralis*
8.	*Boswellia serrata*	39.	*Messerschmidia argentea*
9.	*Brownlowia lanceolata*	40.	*Mimusops species*
10.	*Calophyllum innophyllum*	41.	*Morinda citrifolia*
11.	*Centotheca lappacea*	42.	*Mucuna gigantean*
12.	*Cerbera manghas*	43.	*Ochrosia oppositifolia*
13.	*Chydenanthus excelsus*	44.	*Olax imbricata*
14.	*Clerodendrum inerme*	45.	*Ophiorrhiza mungos*
15.	*Cocos nucifera (introduced between the years 1789 and 1796)*	46.	*Pandanus andamanensis*
16.	*Cycas rumphii*	47.	*Pandanus leram*
17.	*Cynometra iripa*	48.	*Pandanus odoratissimus*
18.	*Cynometra ramiflora*	49.	*Pandanus tectorius*
19.	*Cyperus kyllinga*	50.	*Pemphis acidula*
20.	*Dalbergia spinosa*	51.	*Pongamia pinnata*
21.	*Dendrolobium umbellatum*	52.	*Scaevola plumierii*
22.	*Derris heterophylla*	53.	*Scaevola sericea*
23.	*Derris trifoliata*	54.	*Scaevola taccada*
24.	*Ehretia acuminate*	55.	*Sophora tomentosa*
25.	*Euphorbia nerifolia*	56.	*Sporobolus virginicus*
26.	*Ficus altissimai*	57.	*Syzigium samarangense*
27.	*Finlaysonia obovata*	58.	*Tabernaemontana crispa*
28.	*Fimbrisstylis littoralis*	59.	*Thespesia populnea*
29.	*Glochidion calocarpum*	60.	*Triphasia trifolia*
30.	*Glycosmis mauritiana*	61.	*Vitex diversifolia*
31.	*Guettarda speciosaI*	62.	*Vitex trifoliata L.*

According to the latest estimate of the Forest Survey of India, the total area under mangrove vegetation in India is 4827 km^2. Out of this, 966 km^2 area of mangrove vegetation occurs in Andaman and Nicobar Islands (i.e. 20 per cent of the total mangrove area of the Indian territory), (Fig. 4). In Andaman district, the area under mangroves is 929 km^2; while in Nicobar district mangroves occupy only 37 km^2. This salt-tolerant community is found on rocky shores exposed to tidal action and sometimes is also found growing in tidal mudflat. Luxuriant mangroves are seen in

Shoal Bay (South Andaman), Yerrata (Middle Andaman), Austin Creek, Kalighat Creek and Cadell Bay (North Andaman).

Impact of tsunami on mangroves

The earthquake (9.0 Richter scale) which struck Andaman and Nicobar Islands on 26 December 2004 and the consequent tsunami have caused considerable change on the mangrove stands of Andamans. The tidal waves that swamped the mangrove stands have affected the giant fern *Acrostichum aureum* and the aquatic sedge *Fimbrisstylis littoralis*. The true mangroves, viz. *Rhizophora* spp, *Bruguiera* spp, *Avicennia* spp, *Sonneratia* spp, etc. have also got affected in various degrees based on their physiological response to the continuous inundation/exposure under the changed scenario. In South Andaman, in particular localities 30–80 per cent of mangrove stands got affected. In Middle Andaman the impact is negligible, whereas in the North Andaman due to the elevation of land, the sea water is not reaching some of the mangrove stands. Some visible impact has also been felt in the habitat of various fin fishes and shell fishes.

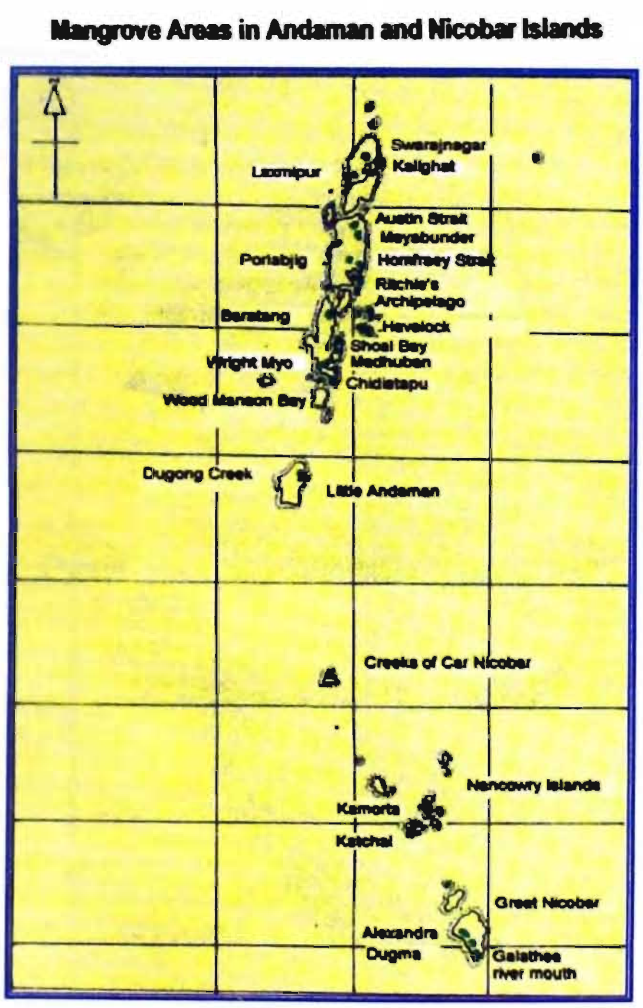

Fig. 4 Map showing the magrove area in A&N Islands

Coral reefs

Coral reefs represent some of the most biologically diverse ecosystem on the earth providing critical habitats to approximately 25% of marine organisms. It offers many values to human society and to the health of the biosphere. Reef protects the shoreline and supports faunal and floral components, recycling nutrients, providing food and shelter and nursery habitat for many other species. Coral reef supports most of the coastal fishery in tropics upon which a large number of people depend of their supply of animal protein. It is estimated that the world production potential in terms of fish catch has been 5-25 tons per sq km of the reef per year. Coral reef fisheries has also been estimated to yield at least 10 per cent of the world's fish catches and 25 per cent of the fish catches in developing countries (Munro, 1996; Roberts *et al*., 1998)

Coral reefs of complex ecosystem threatened globally with a variety of natural and anthropogenic factors. Coral reef throughout the tropics suffered extreme mortality during 1998 due to warming of surface seawater, El-Nino. Over 10 per cent of the world's coral reefs have been lost to disease, coral bleaching and pollution and more than 58 per cent of the reefs are considered 'under threat' due to human activities (Bryant *et al*., 1998). However, an assessment of the status of coral reefs carried out in 2004 showed that the majority of reefs were severely over-fished and most high-organisms were missing; and it also indicated that 20 per cent of worldwide coral reefs have been destroyed, while 24 per cent are in imminent danger and a further 26 per cent are under long term danger of collapse (Wilkinson, 2004).

The Andaman and Nicobar Islands are surrounded by fringing reef on their eastern side, and the barrier reef on their western side between 10°26'N and 13°40'E for a distance of about 360 km. These islands offers a varied and complex animal life of which the colourful coral reefs constitute the most fragile and interesting faunal element as elsewhere in the Indo-Pacific Reefs. Majority of these coral reefs are of fringing type occurring close to the shore which covers an area of 948.8 sq km (Fig. 5). A total of 364 species of corals belongs to 65 genera and 18 families have been reported from these islands. The coral reef associated fauna and flora from these islands includes; 750 species of fishes, 1422 species of molluscs, 430 species of echinoderms, 112 species of sponges, 111 species of soft corals, 89 species of nudibranchs, 411 species of crustaceans and 64 species of algae.

The studies on taxonomy of Indian coral reef started in India as early as 1847 by Rink in Nicobar Islands. Alcock (1893) published an account of some ahermatypic corals from the seas around India. Later Alcock (1902) described 25 species of deep sea Madreporaria dredged by Royal Indian Marine Survey Ship *Investigator* from depth of more than hundred fathoms, around Andaman Islands. Sewell (1922, 1925) reported on ecology and formation of coral reefs of these islands. Reef ecology and structure in various reef areas of these islands have been studied by several authors (Reddiah, 1977; Pillai, 1983; Mahadevan and Easterson, 1983; Wood, 1989; Arthur, 1996; Soundararajan, 1997; Venkataraman and Rajan, 1998; Jeyabaskaran, 1999; Kulkarni *et al.*, 2001; Turner *et al.*, 2001).

The listing of coral species began since Matthai (1924), who listed coral species from the Andamans based on collections in the Indian Museum in Calcutta. Pillai (1983b) listed 135 coral species from this region. Turner *et al.* (2001) lists 197 species within 58 genera. The latest Status Report (Wilkinson, 2002) sources that 203 hard coral species occur in these islands. The faunal studies other than corals have also been carried out at different reef locations of the Andaman and Nicobar Island. More than 1200 fish species have recorded around Andamans and Nicobars (Rajasuriya *et al.*, 2002)

Quantification of reef areas has been carried out by Space Application Centre (MWRD 2000) using Landsat TM, IRS LISS II and SPOT satellite imagery. The reef area calculated by this study comprised 795.7 km2 in Andaman Islands, 30.81 km2 in Great Nicobar, 15.53 km2 in North Reef, 27.15 km2 in Rani Jansi Marine National Park, 6.78 km2 in Cinque and 58.29 km2 in Little Andaman. In-depth information on coral reef ecology and community structure are limited to few studies on some specific reef sites only: The percentage cover of live corals has been estimated for the islands of the Mahatma Gandhi Marine National Park (Dorairaj and Soundararjan, 1997;

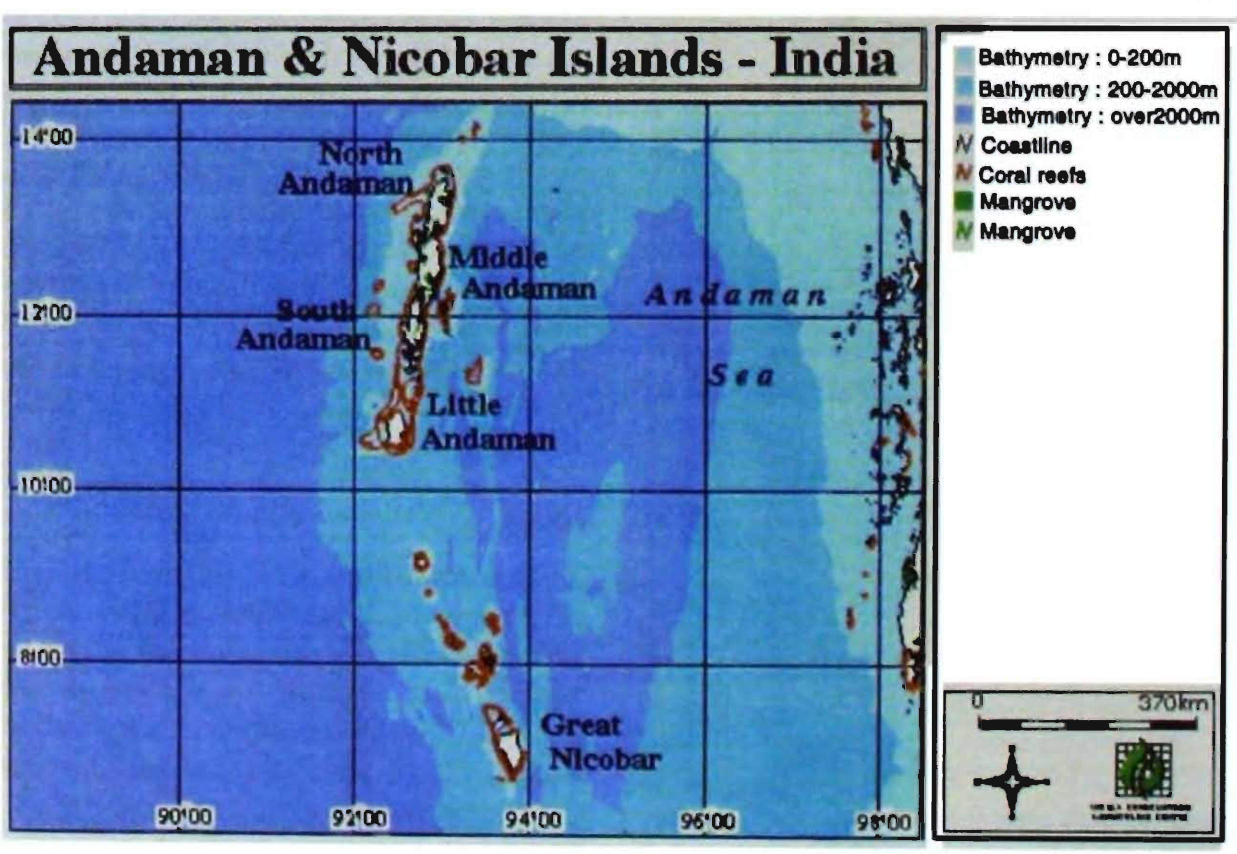

Fig. 5. Distribution of coral reefs and mangroves of Andaman Nicobar Islands

Arthur, 1996; Kulkarni, 2001) and North Reef, Cinque Island, Twin Islands reef, West Rutland Island, Tarmugli Island, Flat Island, South Button, Outram Island, Henry Lawrence, Minerva ledges, and Neil Island (Turner *et al.*, 2001). These studies also listed species wise distribution for these reef areas. In addition, Kulkarni *et al.* (2001) addressed several ecological parameters in their study, which include sedimentation, terrestrial zone influence and other anthropogenic factors.

Coral associated faunal diversity

1. *Fishes*

Fish constitutes one of the most important marine food resources of these Islands. Fishes serve as an indicator species for the health and phase shifting nature of the coral reef. The major indicator fishes are butterfly fishes and parrot fishes. Authentic information on the fish fauna of this region is essential for planning of proper fisheries developmental programs and sustainable utilization of suitable fish resources for economic growth. Talwar (1990) prepared a comprehensive list of fishes with 724 species known to inhabit the freshwater, mangroves and marine ecosystems of these Islands, followed by a supplementary list by Kamala Devi (1991) containing 71 species of fishes.

Extensive taxonomic studies made in the recent years resulted in the additional record of more than 300 fish species. The checklist of fishes from these Islands by Rao (2009) cited 1371 species under 586 genera belonging to 175 families. The surveys conducted by ZSI during the year 2009 resulted with the addition of more than 70 species of reef fishes.

2. *Molluscs*

The phylum Mollusca is very large consisting of thousands of species commonly known as shells. The number of species of molluscs recorded from various parts of the world varies from 80,000 to 1, 50,000 (Venkataraman *et al.*, 2003). In India 5070 species of mollusca have been recorded from freshwater (183 species); land (1487 species) as well as from marine habitats (3370 species). Andaman and Nicobar Islands have a rich molluscan diversity, which Include more than 1000 species from the marine region. Gulf of Mannar and Lakshadweep have 428 and 424 species respectively. 3,370 species of marine molluscs have been reported from India that includes those occurring in coral reef ecosystem as well as other areas. The molluscan diversity studies of Andaman and Nicobar Islands were started in the late 19th century. The literature available shows that the earliest molluscan (Shells) study was on a collection of marine shells made by Smith in 1878.

Subba Rao and Dey (2000) catalogued 1282 species of marine molluscs from these Islands (Table 6). They occur in different habitats such as mangroves, coral reefs, rocky coasts, sandy beaches, sea grass beds and also at greater depths in the sea.

Table 6. Diversity of Molluscs in Andaman and Niocbar Islands

Class	Families	Genera	Species
Polyplacophora	4	7	12
Gastropoda	76	196	880
Cephalopoda	11	18	33
Bivalivia	53	150	350
Scaphopoda	1	1	7
Total	145	372	1282

3. *Echinoderms*

Among the various animal groups, members of the phylum echinodermata are most conspicuous. They have two unique features which are not found in any other group of animals. The first one is the presence of water vascular system and other is presence of tentacle like structures called tube feet. The former helps in locomotion of the animal and the latter in food gathering. They have no heart, brain and eyes. Although they are the most highly evolved among the invertebrates, yet they show primitive characters like radial symmetry, regeneration and asexual reproduction. It is known that more than 6000 species of echinoderms are living in various area of the world. In Indian seas, 649 species are reported so far. Bell (1887) for the first time listed the echinoderms from the Andaman Islands. Earlier there were only stray reports of occurrence of individual species of these Islands. From this time onwards many workers reported echinoderms from these Islands and added several species to the echinoderm fauna. James (1983) while dealing with sea cucumber and sea urchin resources of the Andaman and Nicobar Islands gave a list of echinoderms known from these Islands.

In addition, there have been several revisionary works effecting changes in the nomenclature and status of several taxa. Sastry (2005) attempted to compile all the available published literature on echinoderms of Andaman and Nicobar Islands as well as the materials in the National Zoological Collection of Zoological Survey of India at Kolkata and Port Blair. It is resulted with a total of 425 species of echinoderms from these Islands (Table 7).

4. ***Porifera***

The sponges are found from shallow water to the depth of the ocean. Most sponges need a hard surface for attachment, but some can live on soft sediments. Few species are able to bore in rocks and shells. Sponges are common on rocky reefs, shipwrecks and coral reefs in a wide range of temperature and depths. They inhabit a wide variety of marine and freshwater systems and are found throughout tropical, temperate and polar region. Of the approximately 15,000 sponge species, most occur in marine environments, only about 1 per cent of the species inhabits freshwater. The largest population occurs where there are strong tidal currents, which bring extra food. In Indian seas 451 species of sponges belonging to 3 classes, 17 orders, 65 families and 169 genera has been reported.

Tikader, *et al.* (1986) given a comprehensive account of sea shore fauna of Andaman and Nicobar Islands. This list comprises of sponges belonging to 1 species of Calcarea, 16 species of Hexatinellidae and 63 species of Demospongiae. The recent work by Pattanayak (2006) describes 75 species, 48 genera, 35 families from the Andaman and Nicobar Islands. These include 4 new species records, 18 new locality records and 15 species endemic to the Andaman and Nicobar Islands. The work by Pattanayak (2009) reported 20 species of Hexatinellida and 122 species of Demospongiae from the National Zoological Collection India, in the Zoological Survey of India, Kolkata; which includes specimens from Andaman also.

5. ***Crustaceans***

Crustacean diversity of Andaman and Nicobar Islands is well studied during 20th century by many researchers. Coral reefs inhabit several commonly important crustacean fauna. Heller (1865) revealed 14 species of hermit crabs from Nicobar Islands. Alcock (1905) further revealed 14 species and 5 new varieties/species of hermit crabs. Reddy and Ramakrishna (1972) found the occurrence of 20 species followed by Tikader *et.al.* (1986) reported 37 species lead to a total of 40 species of hermit crabs from Andaman and Nicobar Islands.

Species composition of brachyuran crabs of A&N Islands has been consolidated as 220 species through the reports of Kathirvel (1983), and Tikader *et al.* (1986). A total of 162 species of prawn found in coral reef environment of these Islands are published by Silas *et al.* (1983) and Tikader *et al.* (1986). Apart from that 6 species of lobsters occurred in these Islands (Shanmugham and Kathirvel, 1983)

Ajmal Khan (2002) compiled the list on crustacean fauna from these Islands and it depicts 837 species of crustaceans (Table 8).

Table 7. Diversity of Echinoderms in Andaman and Niocbar Islands

Class	No. of Species Andaman	No. of species Nicobar	No. of species A & N Islands	Total
Crinoidea	35	7	8	50
Asteroidea	78	7	19	104
Ophiuroidea	70	9	24	103
Echinoidea	56	4	20	80
Holothuroidea	56	4	28	88
Total	295	31	99	425

Table 8. Diversity of Crustaceans in Andaman and Niocbar Islands

Group	Family	Species
Prawns	18	161
Lobsters	1	6
Brachyuran crab	23	544
Hermit crabs	2	40
Stomatopods	5	39
Other crustaceans	16	47
Total	65	837

6. *Polychaeta*

The polychaetes from Andamans available in the Indian Museum collections were described by Fauvel (1953) and incorporated in the Fauna of India Series by the same author in which he describes 90 species from these Islands. Subsequently many studies have been conducted in Andaman and Nicobar Islands for the exploration of this faunal group. Recently Rajasekaran and Fernando (2009) identified 30 more species under 23 genera and 8 families. All of them were new record to this archipelago and 15 species new to Indian waters. The work also includes an up to date list of polychaetes so far recorded from Andaman and Nicobar Islands in which 191 species belongs to 107 genera and 29 families were recorded.

7. *Tunicates*

This group remains as one of the least studied coral reef fauna of India. Although tunicates are very commonly seen in the coral reef ecosystem, the taxonomical works on the group is rather nil in Andaman and Nicobar Islands. Pelagic tunicates from Andaman and Nicobar Islands have been studies by Dhandapani (1996), but we could not find any literature for reef associated tunicates. As per the observations of ZSI, *Didemnum molle* and *Herdmania pallida* is very common in the reefs of Andaman and Nicobar Islands. *Clavinella moluccensis* is common in the reefs of South Andaman Island.

8. *Flat worms*

One of the diverse groups which has wide distribution in the coral reefs worldwide. The polyclad worms associated with the coral reefs are not yet explored from Andaman and Nicobar Islands. Preservation of organism is almost impossible for this group, and may be the reason for lack of studies by the earlier workers who were depending on the specimens most of the work. Digitalization makes a possible scope for the detailed study of this group from the coral reefs. *Acanthozoon* species was observed many a times from the reefs of South Andaman region. More or less 10 species were observed during the surveys of ZSI in the whole archipelago.

9. *Reptiles*

About 26 species of sea snakes belonging to the family Hydrophiidae and five species of sea turtles have been reported from seas around India. All the sea snakes and four species of turtles out of 5 species reported worldwide in the marine environment are known from islands of Andaman and Nicobar. Sea turtle nesting beaches at South Andaman, Little Andaman and the Nicobar Islands have almost vanished. These losses may reduce nesting by leatherback, green, hawksbill and Olive Ridley turtles.

10. *Mammals*

Marine mammals belong to three orders Cetacea, Carnivora and Sirenia. A little over 120 species are estimated to occur worldwide and of these 40 are reported from Indian Ocean and 25 species of marine mammals belonging to the order Cetacea and Sirenia are reported from Indian waters. However, a majority of these are oceanic forms and occasionally a few individuals may get stranded on the shore. Sea cow, *Dugong dugong* occurs in near shore waters of Gulf of Mannar, Gulf of Kachchh and Andaman and Nicobar Islands. Dolphins and some of the whales that live or breed in tropical waters, such as humpbacks, are occasionally seen near shore areas. The Government of India has so far listed three species of cetaceans (Irrawady dolphin, Ganges River dolphin and sperm whale) and the dugong in Schedule I of Wildlife Act 1972 (Amended in 1991).

Dolphins are very common in Andaman and Nicobar Islands. Off Port Blair they are seen in large groups. They are also seen very commonly in Ritchie's archipelago, Little Andaman, Car Nicobar etc. Dugongs are seen very often in Neil Island (Ritchie's Archipelago) and Teressa Islands of Nicobar.

Avifauna

The Andaman and Nicobar Islands are unique in their avifauna. The isolation of these islands from the mainland has been responsible for high degree of endemism. Scientific studies on the birds of Andaman and Nicobar Islands commenced with listing the avifauna man and Nicobar Islands by Blyth (1845, 1846, 1863 and 1866) followed Beavan (1867), Hume (1873, 1874a, 1874b, 1876). Later, Bombay Natural History Society, conducted many avifaunal survey in the Andaman and Nicobar Islands (Abduali, 1964, 1965, 1967, 1979, and 1981). Zoological Survey of India also carried out several surveys (Das, 1971; Mukherjee and Dasgupta, 1975; Dasgupta, 1976; Saha and Dasgupta, 1980; Mukherjee, 1981; Chandra and Rajan, 1996). Recently various researchers have been studied the population of ecology of particular species *e.g.* Nicobar Magapode (Sankaran, 1995), Andaman Teal (Vijayan, 1996), Edible-Nest Swiftlets (Sankaran, 2001), Narcondam Hornbill (Yahya and Zarri, 2003). Birds were classified as migratory or resident species based on Ali and Ripley (1983). The Common and scientific names are after Manakadan and Pittie (2001).

Out of 1340 species of birds recorded from Indian s)bcontinent, 21% are found in Andaman and Nicobar Islands. A total of 284 species of birds were recorded from Andaman and Nicobar Islands, belonging 56 families under 17 orders. Of which, 160 species were residents, 59 were trans-continental migrants, 64 were local migrants and one species is a straggler.

Highest number of insectivores (105) followed by omnivores (47), aquatic feeders (40), carnivores (37), granivores (30), frugivores (20) and nectar-frugivores (5) were recorded so far (Table 9). Out of the 284 species of birds found in Andaman and Nicobar Islands, 22 species namely, *Pelecanus philippensis, Accipiter butleri, Falco naumanni, Megapodius nicobariensis, Aceros narcondami,*

Table 9. Status of birds recorded from Andaman & Nicobar Islands

Sl. No.	Order	Status			Feeding guilds						
		R	M	Total	A	I	G	N/F	C	F	O
1.	**Procellariiformes**	02		02	02						
2.	**Pelecaniformes**	06		06	06					-	
3.	**Ciconiiformes**	15		15	15						
4.	**Anseriformes**	06	01	07	07						
5.	**Falconiformes**	21	07	28					28		
6.	**Galliformes**	05	0	05		05					
7.	**Gruiformes**	11	0	11			11				
8.	**Charadriiformes**	16	29	45						-	45
9.	**Columbiformes**	16		16			16				
10.	**Psittaciformes**	06		06						06	-
11.	**Cuculiformes**	11		11					-	11	-
12.	**Strigiformes**	08	01	09					09		
13.	**Caprimulgiformes**	02		02		02				-	
14.	**Apodiformes**	05	01	06		06					
15.	**Coraciiformes**	15		15	10	04					01
16.	**Piciformes**	03		03		03					
17.	**Passeriformes**	70	27	97		85	03	05		03	01
	Total	218	66	284	40	105	30	05	37	20	47

R = Resident, M = Migrants, A = Aquatic feeders, I = Insectivores, C = Carnivores, G = Granivores, F = Frugivores, N/F = Nectar-frugivores, O = Omnivores

Hypsipetes nicobariensis, Rallina canningi, Otus alius, Spilornis elgini, Spilornis minimus, Gallinago media, Esacus magnirostris, Columba palumboides, Macropygia rufipennis, Caloenas nicobarica, Psittacula longicauda, Psittacula caniceps, Otus balli, Ninox affinis, Dryocopus hodgei, Dicrurus andamanensis, Dendrocitta bayleyi were listed in the threatened birds of the world.

Endemic species

Endemism of Indian Biodiversity is significant. About 4,900 species of flowering plants or 33per cent of the recorded flora are endemic to the country. As per the records of BSI, these are distributed over 141 genera belonging to 47 families. They are concentrated in the floristically rich areas of North-East India, the Western Ghats, North-West Himalaya and the Andaman & Nicobar Islands. In India 220 species of pteridophyte, 4950 species of angiosperm, 878 species of molluscs, 16214 species of insects, 110 species of amphibians, 214 species of reptiles, 69 species of birds and 39 species of mammals are endemic. Among them, in Andaman and Nicobar Islands, 261 species of flora, 5 species of sponges, 7 species of earthworms, 6 species of gastroticha, 2 species of chinirincha, 56 species of crustaceans 28 species of spiders and scorpions, 485 species of insects, 75 species of land molluscs, 12 species of freshwater molluscs, 2 species of marine molluscs, 2 species of echinoderms, 3 species of amphibians, 23 species of reptiles, 30 species of birds and 33 species of mammals are endemic to these islands.

Protected Areas

The notified forest area of Andaman and Nicobar Islands is 7171 km², out of which 105 protected areas have been declared. They are 96

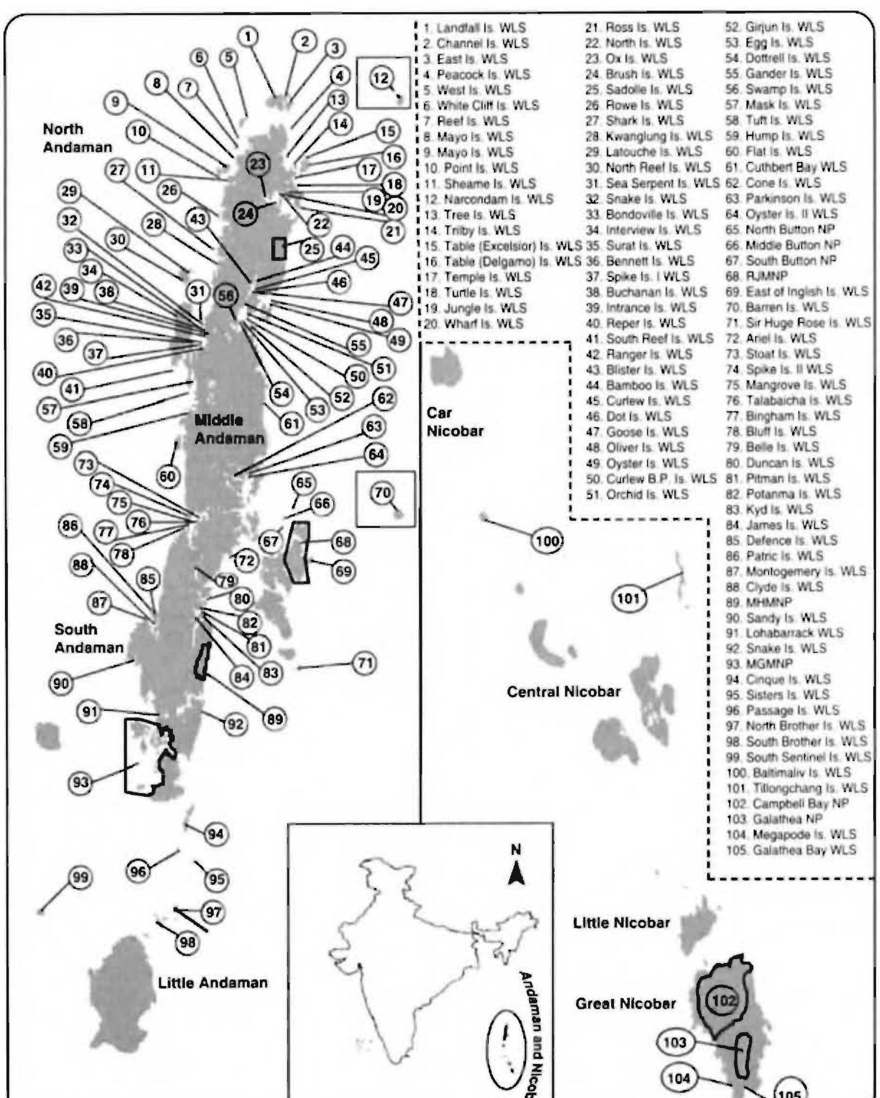

Fig. 6. Protected Areas of Andaman and Nicobar Islands

sanctuaries, 9 national parks and 1 biosphere reserve (Fig. 6). Among four marine national parks notified in India, Mahatma Gandhi Marine National Park and Rani Jhansi Marine National Park are located in Andaman Islands.

Mahatma Gandhi Marine National Park

Under the Wildlife (Protection) Act of 1972 the Mahatma Gandhi Marine National Park(MGMNP) of Andaman and Nicobar Islands was notified on 24th May 1983 for the protection of marine life including corals and nesting sea turtles. The Park is located on the south western coast of South Andaman in the Bay of Bengal includes vast stretch of marine ecosystem, tropical rain forests and mangroves (Fig. 7). The MGMNP comprises of 15 labyrinth group of islands viz. Jolly Buoy, Malay, Pluto, Red Skin, Boat, Snob, Chester, Grub, Hobday, Alexandra, Tarmugli, Twins, Belle, Rifleman and western part of Rutland. Out of 281.5 km^2 area of this Park, approximately 61.5 km^2 has a total land area which includes 59.77 km^2 of the land area of 15 islands mentioned above and 1.73 km^2 of rocky outcrops. The main feature of this Park is the occurrence of corals and other associated fauna. The species reported from these islands through earlier surveys of ZSI are mammals – 13 species, birds – 83 species, reptiles-19 species, fishes-282 species, butterflies-15 species, echinoderms-60 species, crustacean-31 species, corals-122 species and mollusca-57 species.

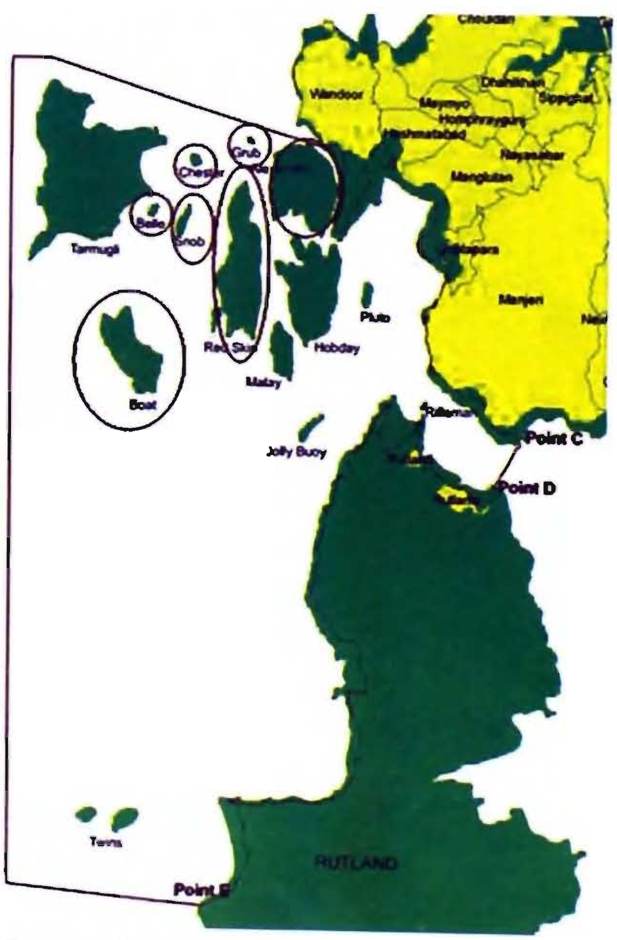

Fig. 7 Mahatama Gandhi Marine Naitonal Park

Rani Jhansi Marine National Park

Rani Jhansi Marine National Park is located in Ritchie's Archipelago (Fig. 8). Notified as a national park in 1996, the park comprises of a group of islands namely John Lawrence Island, Henry Lawrence Island and Outram Island. Total area is about 256 sq km. The important wildlife includes the terrestrial moist forests, mangroves, coral reefs, marine life, crocodile, dugong and birds. However the dtailed study on the biotic components of the national park has yet to be intensified.

Saddle Peak National Park

The Saddle Peak forests has been declared as a National Park in Diglipur forest division of North Andaman and lies between 13°15′ to 13°41′ N latitudes and 92°37′ to 93°7′ E longitudes (Fig. 9). This National Park is characterized as humid tropical evergreen forests. The North Andaman is a major group of Islands and known for rich species diversity. It is the highest peak of these Islands possessing several endemic species. The Saddle Peak National Park in the North Andaman is also part of the proposed North Andaman Biosphere Reserve. 20 species of mammals, 96 species of birds, 26 species of reptiles, 16 species of fishes, 19 species of molluscs, 7 species of annelids and 227 species of insects were reported from this park by ZSI.

North, Middle and South Button Islands Sanctuary

The North Button Island, Middle Button Island and South Button Island were designated (vide notification No. CF/HQ/12(G)/2/162 dated 13th November 1979) as National Parks based on preliminary observations and assessments. The three sanctuaries of North-, Middle- and South Button Island located at northern end of the Ritchie's Archipelago of Andaman group. The sandy beaches of North and Middle Button Islands are ideal for turtle nesting. The area of North Button Island is about 0.44 km^2 while Middle and

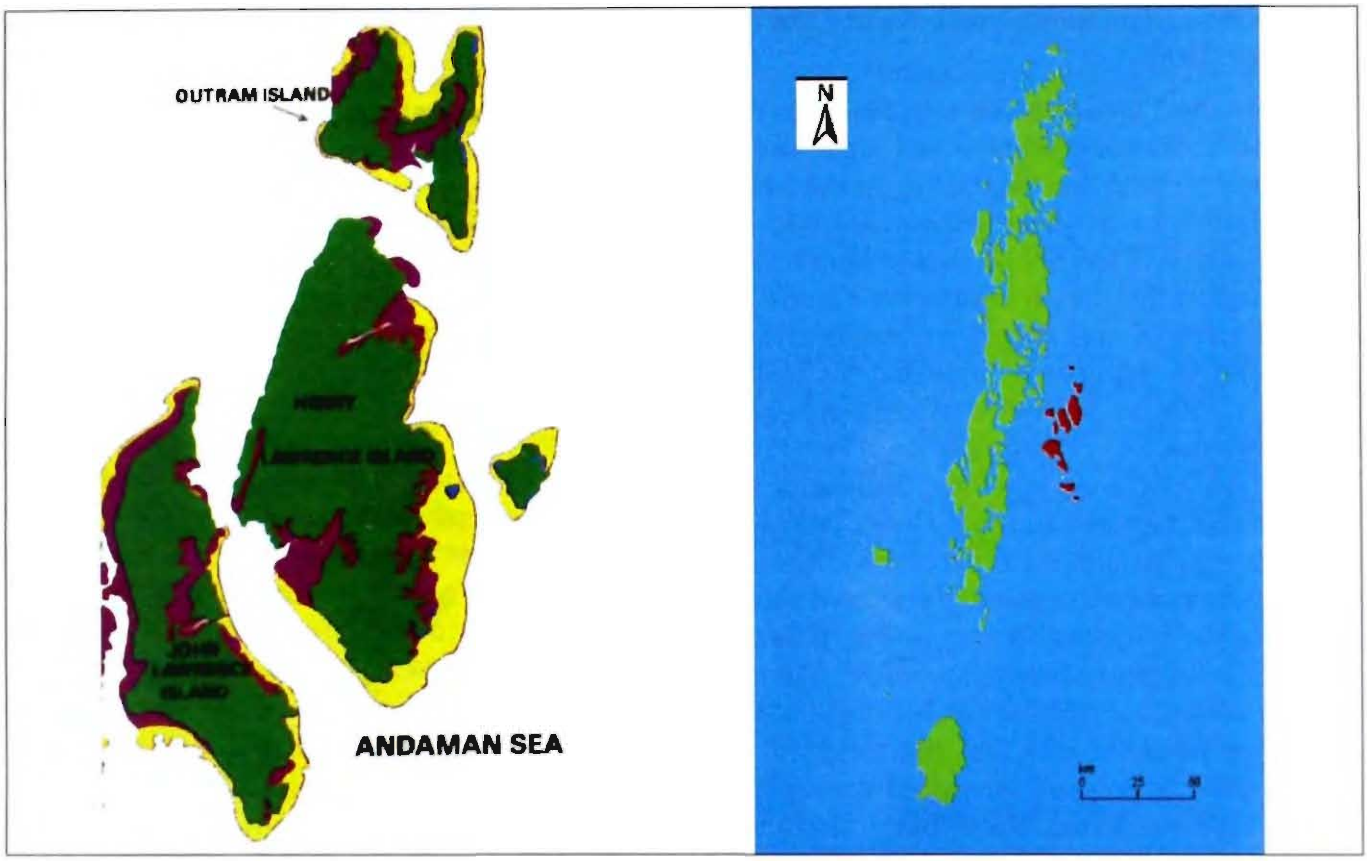

Fig.8 Rani Jhansi Marine National Park

Fig. 9 Map locating Saddle Peak National Park

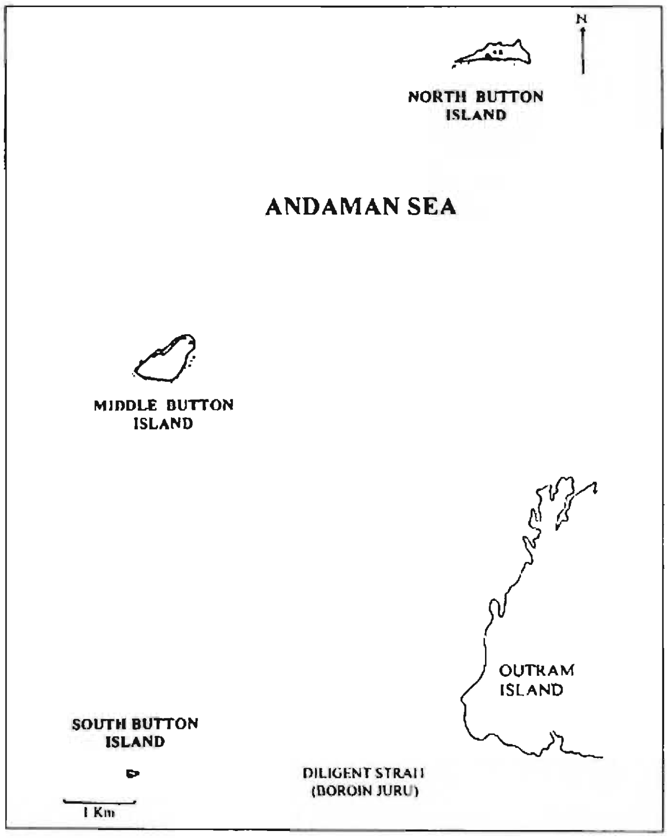

Fig. 10 Map showing North, Middle and South Botton Islands Sancturay

South Button Islands are about 0.64 km^2 and 0.03 km^2 respectively.

Due to small area and hilly terrain for the most part, the forest component is not significant in the sanctuary. The thin vegetation on the islands is a mixture of tropical semi-evergreen and deciduous type. There are patches of littoral forest and mangrove vegetation around the islands. The central part of the forest of the islands is dominated by *Manikara littoralis, Terminalia bialata, T.catappa, T.procera, Planchonia valida, Dipterocarpus* spp., *Thespesia populnea,Prema integrifolia, Guttarda speciosa, Manisuris* spp. *Begonia* spp.,*Dendrobium* spp.,*Derris indica* and *Sterculia* spp. The littoral forest of the Middle and North Button Islands consists of scattered patches of *Hibiscus liliaceus, Baringtonia asiatica, Ipomoea pescaprae, Thuarea involuta, Panicum repens, Cassytha filiformes, Scaevola seicea, Pandanus furcatus* etc. The vegetation of the littoral forest is not well developed due to spray from heavy wave action. North Button Island has comparatively rich vegetation of evergreen rain forest with deciduous trees.

The mangrove belts are narrow and patchy. *Rhizophora* is the common mangrove plant of the South Button Island while *Rhizonphora* and *Bruguiera parviflora* are common on North and Middle Button Islands. In the interstitial spaces of the boulders all around the South Button Island, the littoral forest consists of a few patches of the mangrove plant *Rhizophora apiculata*.

The fauna of the islands of the National parks is diverse. A total of 887 species of fauna including marine and terrestrial components are recorded from the button islands during the surveys made by ZSI. These include several groups which are summarized in table 10. Water Monitor, Leathereback and Olive Ridley Turtles, Andaman Wild Pig and Spotted Deer are some of the endangered animals of these islands. South Button Islands has congenial habits for edible swiftlet nests.

Table 10. Summary of Fauna of the Button Island National parks.

	Group	No. of species
Porifera		13
Cnidaria- Anthozoa	Hexacorallia (Hard corals)	50
	Octocorallia (Soft Corals)	13
Mollusca	Polyplacophora	2
	Gastropoda	82
	Bivalvia	16
	Cephalopoda	1
Annelida	Polychaeta	14
Arthropoda	Crustacea	68
	Insecta	63
Echinodermata	Asteroidea	4
	Ophiuroidea	7
	Echinoidea	3
	Holothuroidea	16
Chordata	Chondritchtheyes	23
	Osteichthyes	459
	Reptilia	7
	Aves	40
	Mammalia	6
	Total	887

The diversity and density of the marine faunal components are higher than the terrestrial components so far known. Birds and insects are the major terrestrial components. Birds of 40 species are encountered on the islands. Of the 63 species of insects, lepidopterans are the most dominant with 35 species followed by bugs (6 species) and bees and wasps (5 species). Due to presence of extensive coral reefs around the islands, the marine environment supports a rich fauna of more than 750 species. Of these the fishes are the dominant group with about 482 species followed by mollusks (101 species), crustaceans (68 species) and echinoderms (30 species). Among the echinoderms, Holothuroidea are represented by a maximum of 16 species, the rest belong to Asteroidea, Ophuroidea and Echinoidea. Crinoids are also present but could not be identified since they were very much damaged during collection from coral colonies crevices.

The rocky shores of the islands experience heavy wave action. The extensive sandy and rocky intertidal habits support the common species of worms, molluscs including spiny chitons, limpets and neritids and the brachyuran crabs. On the other hand, the extensive fringing coral reefs around the islands form an important habit for a large number of associated faunal components. The fishes, worms, echinoderms and molluscs, however, constitute the major groups of animals occurring in association with reef ecosystem.

As elsewhere, the most common and abundant reef building corals around these islands consist of the species of *Pocillopora, Stylophora, Montipora, Gonipora, Acropora etc.* There occur also a few patches of *Porites, Psammocora, Favites, Goniastrea, Fungia, Galaxia, Lobophyllia etc.* The *Acropora aspera* and *A. robusta* are the most dominant species spreading over hundreds of square meters like a thick forest and cover about 60% of the reef area, up to 2m down the reef slope. The Middle Button Island has extensive patches of corals from shallow to 10-13m with about 70 per cent of live coral cover.

Next to branching corals *Acropora,* the boulder forms *Porites lutea* and *P.lobata* dominate growing to a large size. Large patches of Soft corals are represented by species of *Lobophytum, Sarcophyton, Sinularia* and *Cladiella.* Large sized sea anemones abound among the coral heads. Feathersworms and Christmas tree worms of Polychaeta, boring crabs and oysters inhabit crevices and holes in the boulder corals particularly *Porites lutea.* Large sized giant clams *Tridocna maxima* are found on reef and deep sandy bottom. The Common dolphins *Delphis,* are found in the sea off the islands. Among the decapods, the xanthids are quite conspicuous in their density, while *Palunirus versicolor* is the common lobster found in large numbers under coral blocks and rock. Of the molluscan fauna species of gastropods like limpets, *Trochus, Turbo, Nerita, Lambis* and *Cyprea* and bivalves like rock oysters, pearl oysters, winged oysters and clams are very common. The polyplacophoran spiny chitons also form an important component while the octopuses are seen frequently.

Only a few echinoderms species were reported in these islands. Among them ophiuroid *Ophiocoma*, the echinoid *Diadema* and some representatives of holothurians are very common in Button Islands. Diversity of crinoids was also reported in more numbers as coral inhabitants. Considerable number of the crown-of-thorn starfish *Acanthaster planci* is distributed in North Button Island. The most commonly occurred echinoderms in these islands are holothurians, *Actinopyga echinites, Bohadschia marmorata, Bohadschia argus* and *Holothuria atra, Holothuria scabra*; ophiuroids *Ophiocoma erinaceus, Ophiocoma brevipes* and *Ophiocoma pussila*; echinoids *Diadema setosum, Diadema savignyi* and *Echinothrix calamaris*.

Among the vertebrates, the fish forms the major dominant element around the reefs of the islands. The most common among them are damsels, butterflyfishes, cardinalfishes, angelfishes, groupers, snappers, ceasionids, labrids, barracudas, balistids and puffers. Large sharks were seen moving off the reefs. The sea anemones host the colourful symbiotic clownfishes *Amphiprion peridarian. A. clarkia, A. fraenatus* and *A. ephippium*. The hawk fishes *Cirrhitus pinnulatus* and *Paracirrhites forestry,* leather jackets *Oxymonacanthus longirostris* are found fairly in large numbers among *Acropora* thickets. Amphibious sea snakes of the genus *Laticauda* are common in the waters.

The marine environment of Middle and North Button Islands is almost similar and the sandy, rocky and reef ecosystems support a large number of faunal components. The sandy beaches of Middle and North Button islands offer an ideal habitat for nesting of sea turtles like Leatherbacks and Olive Ridleys. These two species are regular visitors to the beaches for nesting.

Because of huge steep boulders and suddenly sloping shoreline, the South Button Island has a very limited intertidal region. Large plate corals, nephthid soft corals and gorgonians grow on the vertical rock surfaces. Due to severe wave action mostly digitate type corals such as *Acropora digitifera, A. gemmifera, Pocillopora damicornis, P. verrucosa,* plate type forms such as *Acropora cytherea, A. hyacinthus, A. nasuta, A. clathrata,* boulder forms like *Porites* sp., *Montipora digitata, Acanthastrea* sp., Symphyllia sp., *Favia favus, F. stelligera, Goniastrea* sp. and encrusting forms like *Pavona venosa, Montastrea* sp. are present. The heavy wave action restricts the fauna to sessile and strongly clinging forms as limpets, chitons and oysters and a large number of crevice dwelling forms such as the crabs, *Grapsus, Portunus* and *Thalamita* spp. Species of *Nerita, Trochus, Turbo, Lambis, Giant clams, oysters* are also found among the coral heads. The echinoderm fauna is poorly represented. Only one species of *Holothuria* and *Stichopus chloonotus* was found in rock pools and *Holothuria atra* on sandy patches. Echinoids belonging to the species *Diadema setosum* were found in holes and crevices of coral rocks. The submerged rock walls of the island and wide rock crevices are with a variety of coral formations, Sea stars, *Linckia laevigata* and *Asterina sarasini* and sea snake *Laticauda colubrinus* are common around coral blocks. Fish are the most dominant component of the reef area of which Labrids, Scarids, Chaetodontids, Pomacentrids, Acanthurids are more in number.

The main threat to three National Parks is from poachers as in the case of other localities of these islands. The wealth of these islands includes luxuriant coral beds with commercially important species like shells, sea cucumbers, fish and nesting turtles particularly at the Middle and North Button Islands due to remoteness. During 1996 the islands were having rich populations of holothurians and molluscs. But the recent investigations during 2003 and 2004 clearly indicated deterioration of the reef ecosystem and decline of reef associated fauna, particularly echinoderms and molluscs. Because of remoteness, lack of surveillance and inaccessibility, poaching for holothurians and shells possibly could not be controlled resulting in the depletion of their populations. More vigilance and surveillance of these National Parks is the need of the hour for conservation of their faunal wealth. In general, the scattered nature and small area with added shortage of resources and personnel are the limiting factors for posting of guards for surveillance of the Protected Areas. The three Button Island National Parks are no exception (Rao and Sastry, 2007).

Mount Harriet National Park

Mount Harriet national park is lies between 10°43′57″N latitudes and 92°43′41″ to 92°47′11″E longitudes. The area of park is about 46.62 km^2 and there is also a proposal to extend the area by another 1700 hectares to include the adjacent hill ranges on Southern part and to conserve the marine ecosystem along the eastern coast (Fig. 11). The park possesses various hill ranges, which generally lie in the north and south direction as islands. From these, numerous spurs and ridges branch out in east and west directions. The hills are steeper on the east than on west. The principal peaks are Mt. Koyob (459m, the highest peak of N.P), Mt. Hext. (425m), Mt. Harriett (422m), Mt. Godridge (376m) and Mt. Carpenter (346m). The park is covered with different types of thick green vegetation. The beaches on eastern coast are generally rocky with a few sandy patches. The park also possesses a few fresh water streams, arising from the hill ranges and draining into the east coast. The Chief Commissioner; Andaman and Nicobar islands declare his intension to constitute the Mount Harriett national Park under sub-section (1) of section 35 of Wildlife (Protection) Act 1972 (No. 53 of 1972) and was notified vide Notification No. 161/CF/HQ/12(6) 2 on Wednesday, dated 13th November 1979.

Flora

The major forest types from Mt. Harriett National Park include Giant Evergreen Forest, Andaman Tropical Evergreen Forest, Andaman Semi Evergreen Forest, Andaman Moist Deciduous Forest and Littoral Forest.

Giant Evergreen Forest

This is the most luxuriant type of forest met with and is the climate climax wheresite conditions are optimum for the tree growth. The top canopy formed by the giant trees is almost entirely

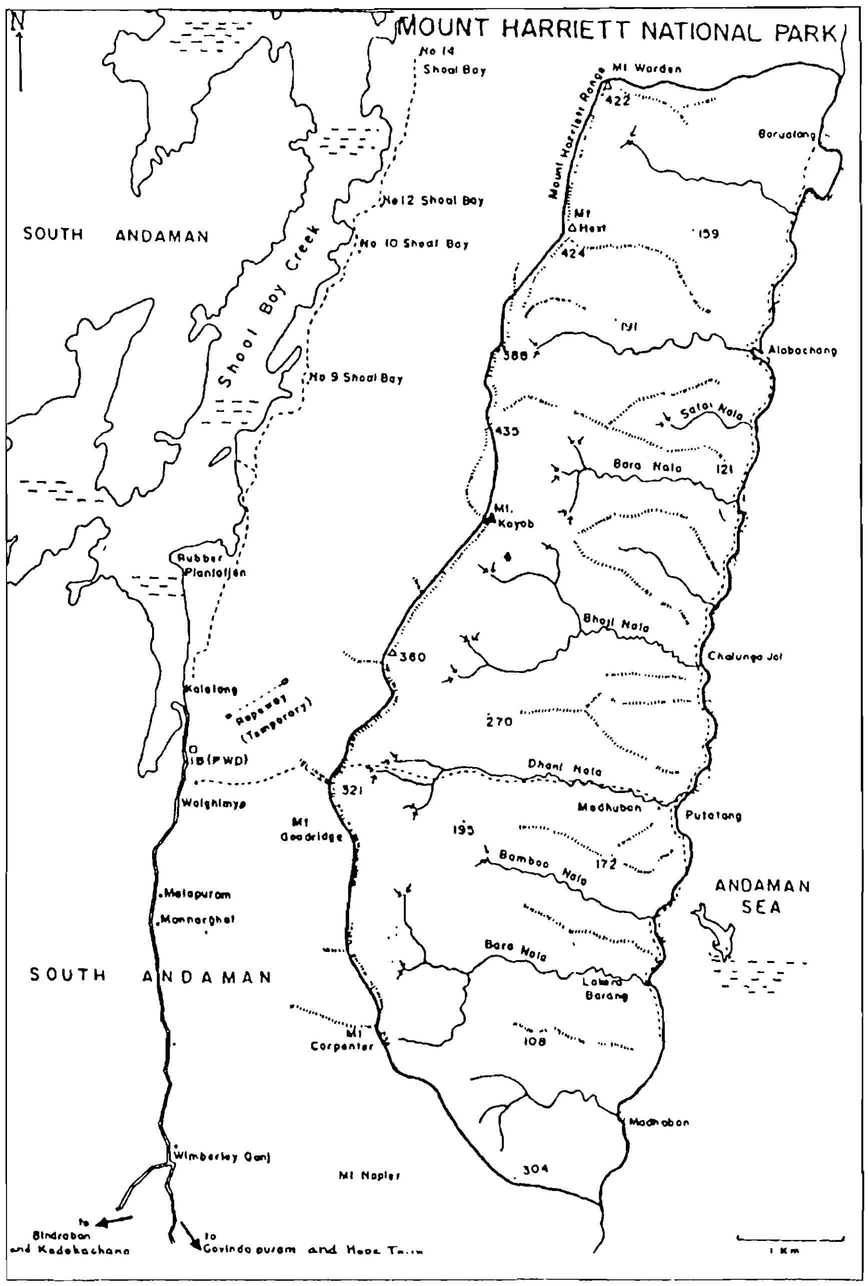

Fig. 11. Mount Harriet National Park

evergreen. This type is intimately mixed with the semi-evergreen forest.The important trees are *Artocarpus chaplasha, Dipterocarpus gracilis. Calophyllum soulattri* etc. Other species like *Amoora wallichii, Messua ferra* and climber *Dinochloa andamanica* are also present.

Andaman Tropical Evergreen Forest

This is not so luxuriant as Giant Evergreen Forest, but with similar species in composition and less species in the top canopy and deciduous elements being rather more frequent. The type is mostly disturbed on caps of hill ranges and slopes. The important spp. are *Dipterocarpus* spp., *Artocarpus chaplasha, Planchonia andamanica, Dinochloa andamanica* and *Calamus palustris* etc. *Diptetocarpus grandiflorus* is a characteristic member of evergreen forest.

Andaman Semi- Evergreen Forest

The luxuriant type of forest includes both deciduous and evergreen species oftenly mixed but in-group with the abundance of climbers. This type is known to be dense and most economical forest in Andaman. The major species are *Dipterocarpus* sp., *terminalia bialata, Terminalia procera, Albizzia lebbek, Artocarpus chaplasha* and *pterocarpus dalbergeoides* etc. This type of forest is mostly present in main valleys.

Andaman Moist Deciduous Forest

The Forest mostly dominated by the decidous species having more than 40m or more height, of which many with large girth and having buttressed. Beneath these trees a rather definite second story of numerous species including some evergreen mixed with deciduous and some patches of shrubs and climbers. The dominant trees are *Teerminalia procera, T. bialata, Pterocarpus dalbergiodes, Canarium euphyllum, Albizzia lebbek, Lannea coromandelica, Diosphyros marmorata and Baambusa* sp. etc.

Littoral Forest

The type is also known as Beach or Dune Forest. The forest type is found all around the coast and mostly near the fair width of sandy beaches. The characteristic species is the *Manilkara littoralis*, which often forms an almost pure fringe on sandy beaches and dunes along the sea face. The scattered smaller evergreen trees occur with fewer deciduous trees and numerous shrubs and grasses also occur. The other important trees of the are *Terminalia catappa, Calophyllum soulattri, Pongamia pinnata* etc. The littoral forest is also lined sometimes with *Scavela frutescens* and *Hibiscus tiliaceus* with a fringe of *Calubrina asiatica*.

Fauna

Mount Harriett National Park is one of the few pristine areas within the Andaman Archipelago, where, almost all the major groups of animal's characteristics of tropical rain forests are well represented.The composition of terrestrial fauna of National Park shows greater similarities with that of Myanmar and Indo-China. Some species are restricted only to Andamans and sometimes even to certain islands, while some are common to both the groups of islands. Hitherto, 529 species are known from Mount Harriett National Park, of which 149 are endemic to species/subspecies level. The highest endemicity has been recorded in case of butterflies, which is more than 66 per cent followed by the birds (50 per cent). These two groups have been extensively studied in these islands.

Invertebrates

Annelida has seven species of earthworms are of which two species, *Amynthas osmastoni* and *Mataphire Harriettensis* are endemic to Andaman. Arachnida : Two species of scorpions i.e. *Isometrus (Raddyannus) europaenus* and *Hormurus australasiae*.Myriapoda: Five species of Centepeds belonging to Family Scolopendridae are known. Among them *Otostigmus (Otostigmus) rugulosu* is endemic to Andaman Islands. 348 species of insects under 12 orders including 71 endemic species also been noticed. The land mollusc are six species, of these four species viz. *Pleuropoma scrupla, Logochilus, Quickia graveleyi andamanensis* and *Macro chlamyschoinix* are endemic to Andamans.

Vertebrates

16 speceis of fishes belonging mainly to eels, cat fishes, gobies, sleepers and snakehead fishes; 8 species of amphibians of which three species Andaman bull frog *Kaloula baleata ghoshy*, Andaman paddy field frog *Limnonectes andamanensis* and Darwin's frog *Rana melanosticus* are endemic to Andaman. 31 species of reptiles were recorded form the park area. The saltwater crocodile *Crocodyluys porosus*, green sea turtle *Chelonia mydas*, Hawksbill sea turtle *Eretmochelys imbricate*, Olive ridley sea turtle *Lepidochelys olivacea* are visit the sandy beaches from October to February. The important species of lizards are Spotted Gecko *Gehyra mutilata*, Andaman Giant Gecko *Gekko verreauxi*, Andaman's bent-toed Gecko *Cyrtodactylus rubidus*, Andaman Day Gecko *Phelsuma andamanense*, Bay Island Forest Lizard *Coryphophylax subcristatus* and Flat-tailed Gecko *Cosymbotus platyurus* while the endemic snakes represented from the area are Andaman cat snake *Boiga andamanensis*, Andaman Keelback water snake *Xenochrophis melanzostus*, Andaman Cobra *Naja sagittifera*, Andaman Krait *Bungarus andamanensis*, Island wolf snake *Lycodon capucinus* have also been recorded. In addition Andaman water monitor lizard *Varanus salvator andamanensis* is also found in various places of the park. 88 species of birds belongs to 68 genera and 32 families were observed. Of these 46 species are endemic to Andaman and 10 are endemic to both the group of Islands. However, the Andaman wood-pigeon *Columba palumboides*, Andaman Crow-Pheasant *Centropus andamanensis*, Small Andaman Drongo *Dicrurus andamanensis* Andaman Tree-Pie *Dendrocitta bayleyi* and Little Bunting Emberiza usilla are endemic to species level. Total of 12 species of mammals are known

from this park of which 9 are endemic to Andaman. Among them, Andaman wild pig *Sus scrofa andamensis* and Andaman masked palm civet *Paguma larvat tytleri* are commonly found.

Great Nicobar Biosphere Reserve (GNBR)

The GNBR of Andaman and Nicobar Islands is one of the 17 Biosphere Reserves created under the Man and Biosphere Reserve Programme of Ministry of Environment and Forests, Government of India. It is situated in Great Nicobar Island which is about 60°N of the equator and is only about 145 km from Sumatra Island of Indonesia (Fig. 12). The GNBR encompasses two National Parks, the Galathea National Park (185 km² area) which represents Galathea river basin composed of low-lying hills not exceeding 250m and the Campbell Bay National Park (520 km2 area) with the high mountain ranges reaching to a height of 670m. The extremely high endemism and extraordinary diversity at the species and community levels make the Campbell Bay National Park one of the hottest hotspots in the world (Babu, 2002).

The vertebrate fauna recorded so far includes 14 species of mammals, 71 species birds, 26 species of reptiles and 10 species of amphibians and 113 species of fishes; Invertebrates are represented by 7 species of annelids, 417 species of insects

Fig. 12. Great Nicobar Biosphere Reserve

including 73 species of butterflies and 132 moths. A large number of lower vertebrates and invertebrate fauna remain unexplored. The systematics (diversity of species and the interrelations between species which determines its survival rate over time) of the known species has also not been studied. WWF recognises Lowland forests of Nicobar Islands as one of the global centres of plant diversity, which requires understanding the faunal diversity from this island and biosphere reserve *per se*.

Floral diversity of GNBR

- 650 species of Angiosperms, Ferns and Gymnosperms are reported
- 13.11% of plant species is endemic to GNBR
- 14 taxa are categorized as rare and endangered flora to GNBR

Faunal Diversity of GNBR

Over 2050 species of fauna are reported. Important endemic species are given below (Table 11) :

1. Nicobar Megapode–*Megapodius nicobariensis*
2. Edible-nest Swiftlet–*Aerodramus fuciphagus*
3. Nicobar Tree Shrew–*Tupaia nicobarica*
4. Long-tailed Macaque–*Macaca fascicularis*
5. Saltwater Crocodile–*Crocodylus porosus*
6. Giant Leatherback Sea Turtle–*Dermochelys coriacea*
7. Reticulated Python–*Python reticulatus*
8. Coconut Crab–*Birgus latro*

Biodiversity Hotspots in India

Certain tropical forest areas rich in diverse endemic species, on the verge of destruction are called 'Hot Spots' The conservation of these areas is indispensable for the survival of mankind. About 18 'Hot Spots' (of tropical forests) are identified around the world. Among them two are in India one in the Western Ghats and the other in the eastern Himalayan region. Apart from that part of Sunda Land Hotspot is also been located in Nicobar Islands of India.

These 'Hot Spots' together have about 5330 endemic species including flowering plants,

Table 11. Endemic fauna of Great Nicobar Biosphere Reserve

Group	Total No. of Species	No. of Endemic Species	% of Endemism
Mammals	14	12	85.7
Aves	71	35	49.3
Reptiles	26	7	26.9
Amphibians	10	4	40.0
Pisces	113		
Annelids	7		
Insects	418	100	23.9

mammals, reptiles, amphibians and butterflies. In India, forest area is fast depleting and wildlife is fast disappearing. Much of the wild life once widely distributed is now confined to certain pockets. Many innovative schemes and projects have been launched to salvage the Indian wild life from extinction. The Project Tiger was started in 1973. As tiger stands at the apex of the biological pyramid, ensuring its survival implies conservation of the entire biota. Subsequently the Crocodile Project (1975) and the Project Elephant (1991) were implemented. Now, efforts are being made to establish elephant corridors, linking the various forest areas so as to ensure continuity of forest habitats. The Man and Biosphere Programme was formulated in 1986. Eco-development programmes are currently designed to involve people living in and around the protected areas, in conservation efforts with a view to improving their living conditions and thereby reducing their dependence on forest resources.

Threats to biodiversity

The biodiversity in India's forests, grasslands, wetlands and mountains, deserts and marine ecosystem takes many pressures. One of the major causes of biological diversity in India has been the depletion of vegetative cover in order to expand agriculture. Since most of the biodiversity rich forests also contain the maximum mineral wealth, and are also the best sites for water impoundment, mining and development projects in such areas have often led to destruction of habitats. Poaching and illegal trade of wildlife products too have adversely affected biological diversity.

Loss of biodiversity

The loss of biological diversity may take many forms but at its most fundamental and irreversible, it involves the extinction of species. Over geological time, all species have a finite span of existence. Species extinction is therefore a natural process which occurs without the intervention of man. However, it is beyond question that extinctions caused directly or indirectly by man are occurring at a rate which far exceeds any reasonable estimates of background extinction rates, and which, to the extent that it is correlated with habitat perturbation, must be increasing. Unfortunately, quantifying rates of species extinction, both at present and historically, is difficult and predicting future rates with precision is impossible.

Documenting definite species extinctions is only realistic under a relatively limited set of circumstances, where a described species is readily visible and has a well-defined range which can be surveyed repeatedly. Unsurprisingly, most documented extinctions are of species that are easy to record (e.g. land snails, birds) and inhabit sites which can be relatively easily inventoried (e.g. oceanic islands). The large number of extinct species on oceanic islands is not solely an artifact of recording, because island species are generally more prone to extinction as a result of human actions.

Loss of biodiversity in the form of crop varieties and livestock breeds is of near zero significance in terms of overall global diversity, but genetic erosion in these populations is of particular human concern in so far as it has implications for food supply and the sustainability of locally-adapted agricultural practices. For domesticated populations, loss of wild relatives of crop or timber plants is of special concern for the same reason. These genetic resources may not only underlie the productivity of local agricultural systems but also, when incorporated in breeding programmes, provide the foundation of traits (disease resistance, nutritional value, hardiness, etc.) of global importance in intensive systems and which will assume even greater importance in the context of future climate change. Erosion of diversity in crop gene pools is difficult to demonstrate quantitatively, but tends to be indirectly assessed in terms of the increasing proportion of world cropland planted to high yielding, but genetically uniform, varieties.

Causes for loss of biological diversity

Species may be exterminated by man through a series of effects and agencies. These may be divided into two broad categories: direct (hunting, collection and persecution), and indirect (habitat destruction and modification). Over hunting is perhaps the most obvious direct cause of extinction in animals, as it has affected several large and well-known species. In terms of overall loss of biodiversity, however, it is undoubtedly far less important than the indirect causes of habitat modification and loss. Nevertheless, as it self-evidently selectively affects species which are or have been considered a harvestable resource, it has important implications for the management of natural resources.

Genetic diversity, as represented by genetic differences between discrete populations within wild species, is liable to reduction as a result of the same factors affecting species. The genetic diversity represented by populations of crop plants or livestock is liable to reduction as a result of mass production; the desired economies of scale demand high levels of uniformity.

Virtually any form of sustained human activity results in some modification of the natural environment. This modification will affect the relative abundance of species and in extreme cases may lead to extinction. This may result from the habitat being made unsuitable for the species (for example, clear-felling of forests or severe pollution of rivers), or through the habitat becoming fragmented. The latter has the effect of dividing previously contiguous populations of species into small sub-populations. If these are sufficiently small, then chance processes lead to raised probabilities of extinction within a relatively short time.

Conservation of Biodiversity

The conserve of biological diversity at all levels is fundamentally the maintenance of viable populations of species or identifiable populations. This can be carried out either on site or off site. Some integrated management programmes have begun to link these basically dissimilar approaches.

In situ conservation

The maintenance of a significant proportion of the world's biological diversity at present only appears feasible by maintaining organisms in their wild state and within their existing range. This is generally preferable to other courses of action because it allows for continuing adaptation of wild populations by natural evolutionary processes and, in principle, for current utilisation practices to continue, although these often require enhanced management.

Ex situ conservation

Viable populations of many organisms can be maintained in cultivation or in captivity. Plants may also be maintained in seed banks and germplasm collections; similar techniques are under development for animals (storage of embryos, eggs and sperm) but are more problematic. In any event, *ex situ* conservation is clearly only feasible at present for a small percentage of organisms. It is extremely costly in the case of most animals, and while it would in principle be possible to conserve a very large proportion of higher plants ex situ, this would still amount to a small percentage of the world's organisms. It often involves a loss of genetic diversity through founder effects and the high probability of inbreeding.

Conventions or Agreements on Biodiversity

CBD : The objective of the Convention on Biological Diversity (CBD) are the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising out of the use of genetic resources.The Convention on Biological Diversity (CBD), which came into force on December 29, 1993, recognizing the sovereign right of each individual nation over its biodiversity in the areas of protection, management, conservation and utilization and the emergence of the new world order on trade and intellectual property rights

(IPR) serious attention is being given to inventorying, documentation and conservation of the biological resources.

The main objectives of the Convention are

1. Conservation of biological diversity
2. Sustainable use of its components, and
3. Fair and equitable sharing of the benefits arising out of the utilization of the genetic resources by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies and by appropriate funding.

India is a Party to the Convention on Biological Diversity (1992). Recognizing the sovereign rights of States to use their own biological resources, the Convention expects the parties to facilitate access to genetic resources by other Parties subject to national legislation and on mutually agreed upon terms (Article 3 and 15 of CBD). Article 8(j) of the Convention on Biological Diversity recognizes contributions of local and indigenous communities to the conservation and sustainable utilization of biological resources through traditional knowledge, practices and innovations and provides for equitable sharing of benefits with such people arising from the utilization of their knowledge, practices and innovations.

CARTAGENA PROTOCOL ON BIO SAFETY : The Cartagena Protocol promotes bio safety by establishing practical rules and procedures for the safe transfer, handing and use of GMOs, with a specific focus on regulating movements of these organisms across borders, from one country to another. The Protocol features two separate sets of procedures, one for GMOs that are to be intentionally introduced into the environment and one for GMOs that are to be used directly as food or feed for processing.

CITES : The convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Through its three appendices, the Convention accords varying degrees of protection to more than 30,000 plants and animals species.

CMS : The Convention on the Conservation of Migratory Species of Wild Animals (CMS, or the Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range. Parties to the CMS work together to conserve migratory species and their habitat by providing strict protection for the most endangered migratory species, by concluding regional multilateral agreements for the conservation and management of particular species or categories of species, and by undertaking cooperative research and conservation activities.

RAMSAR : The Ramsar Convention is an international treaty for the conservation and sustainable utilization of wetlands: i.e. to stem the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value.

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an inter governmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 158 Contracting Parties to the Convention, with 1822 wetland sites, totaling 168 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance. India joined in the Ramsar Convention in 1982 and 25 wetlands (6,77,131 ha) are designated as Ramsar sites in India

UNFCC : The UN Framework Convention on Climate Change (UNFCC) set an overall frame work for intergovernmental efforts to tackle the challenge posed by climate change. Its recognizes that the climate system is a shared resource who stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. Under the convention governments: gather and share information on greenhouse gas emissions, national policies and best practices; launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries and cooperate in preparing for adaptation to the impacts of climate changes.

UNCCD : The UN Convention to Combat Desertification (UNCCD) aims to promote effective action through innovation local programmes and supportive international partnerships. The treaty acknowledges that the struggle to protect dry lands will be along one there will be no quick fix. This is because the causes of desertification are many and complex, ranging form international trade patterns to unsustainable land management practices. Real and difficult changes will have to be made at both the international and the local level.

LEGISLATION ON BIODIVERSITY

About forty legislations related to biodiversity starting from 1871 to 1987. Biological diversity is not a new concept. The convention on biological diversity reaffirms the sovereign rights of the nation over their bio-diversity and each nation must take appropriate steps towards inventorying, monitoring and conserving bio-diversity as a part of the integrated development planning. Various components of bio-diversity may fall within the jurisdiction of the States or the Central Government or the list of concurrent subjects.

There are specific Central and State enactments relevant to the environment. The most intimately connected to biodiversity are the Wildlife (Protection) Act 1972, Forest Act 1927, Forest Conservation Act 1980 and Biological Diversity Act 2002. Particular mention should be made of enactments relating to water and air pollution and the all embracing Environmental Protection Act 1986. Official agencies have used these laws to good effect to conserve large stretches bio-diversity rich areas though neither of these provides for public involvement in their enforcement and so often dis-empowers local communities.

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Chapter 02

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 43-54, 2010

SEASCAPE – HYDROGRAPHY, CHEMICAL AND GEOLOGICAL ASPECTS OF THE GREAT NICOBAR ISLAND

VINOTH S. RAVIENDRAN, LINOY LIBINI, T. THANGARADJOU*, K. SIVAKUMAR, L. KANNAN and S. AJMAL KHAN**
Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai–608 502
E-mail : umaradjou@gmail.com

INTRODUCTION

Physico-chemical parameters of water and sediments play a key role in the respiration, calcification, photosynthesis, and growth etc. of the organisms in any aquatic ecosystem. These parameters also influence the diversity and density of varied groups of both adult and larval forms of the ecosystems. In this sense, all such features are of great importance in any marine ecosystem, where a dynamic trophic food-chain functions. Diverse habitats including the open sea, estuaries, mangroves, rocky coasts, sandy beaches and muddy intertidal areas, coral reefs and other marine areas display various physico-chemical features, which will determine the efficiency and dynamism of that particular ecosystem.

The study of sediments represents a useful tool for determining the actual state of the environmental condition and for understanding the origin and mechanism of the same. It is well recognized that the primary productivity in shallow marine environment depends on nutrient economy which is known to be governed by the sediment nutrients. Marine seafloor sediments and adjoining marsh surfaces serve as reservoirs of trace metals. A significant portion of heavy metals in many marine environs is derived from domestic and industrial wastes. The flux of trace metals in these parts of marine systems depends on a number of processes, including adsorption-desorption reaction, flocculation and sedimentation. Bottom sediments, because of their larger concentration of heavy metals, exert strong control on the biogeochemical cycling of the elements.

Oil and other petroleum hydrocarbons are introduced into the marine environment through various anthropogenic activities such as shipping, spillage during fuel filling, fishing with mechanized boats and lubricating oil fractions or related sources. Similarly, several man made organo-chlorine compounds used as pesticides for agricultural activities, have become ubiquitous environmental contaminants. Considerable concern about their presence is essential even at extremely low levels. Further, pesticides are known for their persistence in seawater, bio-concentration and bio-magnification that tend to cause direct or long-term harmful effects.

The Andaman sea, especially the marine environment of the Great Nicobar Island is suspected to be exposed to these man-made hazards. Even the very low concentrations of these compounds in ocean water can lead to a fraught situation. Studies on the concentration and

*Corresponding author
**Thiruvalluvar University, Fort Campus, Vellore–632 004; E-mail : kannanlk69@yahoo.com

distribution patterns of such compounds in seawater are therefore urgently needed to understand the environmental response of these anthropogenic contaminants. Such information is not available for this region so far and they have not been treated concisely and comprehensively in earlier studies. Thus, the foregoing account of the studies relating to hydrography and geochemical aspects in the Andaman and Nicobar groups of islands indicates that there is a gap in our knowledge about these aspects in the coastal waters of the Great Nicobar Islands. Hence, the present study.

MATERIALS AND METHODS

Various environmental parameters such as temperature, transparency, salinity, pH, dissolved oxygen etc. were recorded from 33 stations located along the entire coast of the Great Nicobar Island. Air, surface water and sediment temperatures were measured with a mercury thermometer with ±0.02°C accuracy. Transparency was recorded using a Secchi disc. With the use of refractometer (Erma, Japan), salinity was measured. pH of water was measured by a calibrated pH pen (pH Scan 1 Tester–Eutech Instruments, Singapore) and sediment pH was measured by soil pH Tester (Model DM–13, Takemura Electric Works Ltd., Tokyo, Japan). Water samples were collected for dissolved oxygen estimation by using BOD bottles. The dissolved oxygen was immediately fixed and brought to the laboratory and analysed using the modified Winkler's method (Strickland and Parsons, 1972). Water nutrients viz. silicate, phosphate, nitrate and nitrite were analyzed by using the methods of Strickland and Parsons (1972). Estimation of total nitrogen in the water samples was performed, following the method of Koroleff (1970).

After taking sediment samples by using Peterson grab, they were transferred to clean polythene bags, then air-dried and used for the analysis of sediment composition and organic carbon. The textural analysis of the sediments was carried out by the combined method of sieving and pipette analysis after taking known quantity of sample by coning and quartering method. Dry sieving was done using Ro-Tap sieve shaker for 15 minutes (Folk, 1966). Fine particles were separated by pipette method, as proposed by Krumbein and Pettijohn (1938). The organic carbon content in the sediment samples was determined by using the standard method of Wakeel and Riley (1956).

For the study of trace metals, known quantities of sediment samples were taken and were oven dried at 110°C for 24 hours and ground with the help of a mortar and pestle. The samples were digested with concentrated perchloric acid and nitric acid (1 : 3) based on the standard procedures of Topping (1973) and Watling (1981). The supernatant was analyzed in the Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS). The amount of oil (petroleum hydrocarbon) present in the sea water was calculated using the method given in APHA (1971). The pesticide residue in the seawater was analysed by using the standard method of Grasshoff *et al.* (1999).

RESULTS

Hydrography

The summarized results of various physico-chemical parameters are given in Tables 1, 2, 3 and 4.

Air temperature

The three year collections in the Great Nicobar Island revealed that, in the east coast, the minimum air temperature (25°C) was recorded at Dillon nallah during 2003 and the maximum (35°C) was recorded at Chingan Basthi in 2003. The range of surface water temperature at this coast was between 24 and 32°C recording the minimum at Pigeon Island during 2003 and the maximum was recorded at Lakhshmi Nagar in 2001. Sediment temperature ranged between 23°C at Pigeon Island during 2003 and 31°C at Laful Bay and Lakshmi nagar in 2001.

In the west coast, the air temperature ranged between 27 and 33°C. The minimum was recorded at Pilokunji during 2002 and the maximum was noticed at Koshindon and Kopenheat during 2002 and 2003 respectively. The surface water temperature ranged from a minimum of 25°C at Megapod Island, Dagmar, Casuarina Bay, Pilokunji and Kiched nallah during 2003 to a maximum of 31°C at Alexandria Bay and Dagmar in 2002. The sediment temperature ranged between 24 and 29°C registering the minimum at Casuarina Bay and Pilobet and the maximum at Pilobhabi in 2002.

Table 1. Physico-chemical parameters recorded in the east coast of the Great Nicobar Island

Parameter	2001		2002		2003	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
Air Temperature (°C)	26 (St.15)	32 (St.1,5,7 10,11)	26 (St.13)	32 (St.17)	25 (St.5)	35 (St.17)
Surface water Temperature (°C)	26 (St.4)	32 (St.11)	26 (St.13,9)	29 (St.5,6,7,8, 10, 11,12,33)	24 (St.33)	31 (St.17)
Sediment Temperature (°C)	26 (St.13)	31 (St.8,11)	25 (St.13)	28 (St.5,7,11,12)	23 (St.33)	30 (St.3,17)
Transparency (m)	2.32 (St.13)	22.93 (St.12)	2.25 (St.14)	16 (St.15)	2.4 (St.15)	17 (St.12)
Salinity (‰)	24 (St.13)	37 (St.15)	36 (St.13)	31 (St.15)	21 (St.15)	40 (St.6)
Water pH	7.4 (St.10)	8.1 (St.1,3,6, 7,8,12)	7.1 (St.10)	7.6 (St.3,6,7,8, 12,14,33)	7.2 (St.10,13, 14,15)	7.6 (St.5,33)
Sediment pH	6.6 (St.2,13, 14,15)	8 (St.8)	6.8 (St.14)	7.7 (St.1)	7.5 (St.1,3)	7.0 (St.15)
Dissolved oxygen (ml l^{-1})	2.7 (St.1)	8 (St.9)	2.98 (St. 11)	5.46 (St. 10)	3.4 (St.6)	8.6 (St.12)
Silicate (µM)			27.48 (St.15)	39.96 (St.2)	28.25 (St.15)	37.42 (St.2)
Phosphate (µM)			6.225 (St.9)	13.05 (St.10)	6.208 (St.9)	8.364 (St.11)
Nitrate (µM)			7.13 (St.33)	14.59 (St.10)	7.21 (St.4)	10.32 (St.9)
Nitrite (µM)			0.0215 (St.2)	1.591 (St.15)	0.021 (St.2)	0.079 (St.33)
Total nitrogen (µM)			7.063 (St.6)	15.02 (St.10)	7.264 (St.5)	10.421 (St.9)
TOC (mgC/g)			6.105 (St.4)	8.824 (St.15)	6.124 (St.3)	8.39 (St.15)

Table 2. Physico-chemical parameters recorded in the west coast of the Great Nicobar Island.

Parameter	2002		2003	
	Min	Max	Min	Max
Air Temperature (°C)	33 (St.22)	27 (St.27)	28 (St.25, 29,29)	33 (St.23)
Surface water Temperature (°C)	31 (St.24,25)	26 (St.27)	25 (St.20,25, 26,27,29)	27 (St.18,22, 23)
Sediment Temperature (°C)	25 (St.10,26)	29 (St.21)	24 (St.26,28)	27 (St.24)
Transparency (m)	4.6 (St.26)	18 (St.18)	3.5 (St.24)	16 (St.20)
Salinity (‰)	35 (St.27)	33 (St.18,19, 24,29)	33 (St.22)	37 (St.20)
Water pH	7 (St.24)	7.7 (St.18,19)	7.3 (St.24)	7.6 (St.20,26)
Sediment pH	6.9 (St.23)	7.6 (St.18)	7.1 (St.24)	7.5 (St.20)
Dissolved oxygen (ml l^{-1})	2.7 (St. 20)	5.52 (St.27)	2.7 (St.20)	4.82 (St.29)
Silicate (μM)	28.32 (St. 26)	32.76 (St. 29)	28.73 (St. 22)	33.25 (St. 20)
Phosphate (μM)	6.821 (St. 27)	14.25 (St. 21)	6.328 (St. 28)	12.35 (St. 21)
Nitrate (μM)	3.66 (St. 29)	14.49 (St. 26)	7.12 (St. 26)	8.64 (St. 22)
Nitrite (μM)	0.0215 (St.20)	0.43 (St. 28)	0.135 (St. 22)	0.032 (St. 21)
Total nitrogen (μM)	3.725 (St. 29)	14.572 (St. 26)	7.293 (St. 26)	8.925 (St. 22)
TOC (mgC/g)	0.926 (St. 29)	7.256 (St. 21)	3.241 (St. 28)	8.521 (St. 24)

Table 3. Physico-chemical parameters recorded at Indira Point (south coast) of the Great Nicobar Island.

Parameter	2001	2002	2003
Air Temperature (°C)	29	30	34
Surface water Temperature (°C)	30	29	30
Sediment Temperature (°C)	30.0	29	29
Transparency (m)	17.0	10.5	16
Salinity (‰)	37.0	35	32
Water pH	7.8	7.5	7.5
Sediment pH	7.2	7.5	7.4
Dissolved oxygen (ml l^{-1})		2.7	4.5
Silicate (μM)		29.88	29.35
Phosphate (μM)		6.68	6.321
Nitrate (μM)		14.93	7.22
Nitrite (μM)		0.082	0.093
Total nitrogen (μM)		15.012	7.358
TOC (mgC/g)		7.023	7.523

Table 4. Physico-chemical parameters recorded in the north coast of the Great Nicobar Island.

Parameter	2002	
	Min	Max
Air Temperature (°C)	29 (St.30)	31 (St.31,32)
Surface water Temperature (°C)	26 (St.32)	29 (St.31)
Sediment Temperature (°C)	25 (St.30,32)	27 (St.31)
Transparency (m)	9 (St.30)	12 (St.31,32)
Salinity (‰)	35 (St.31)	34 (St.30,32)
Water pH	7.5 (St.30)	7.6 (St.31,32)
Sediment pH	7.4 (St.30)	7.5 (St.31,32)
Dissolved oxygen (ml l^{-1})	4.0 (St. 32)	4.2 (St. 30)
Silicate (μM)	32.91 (St.31)	32.78 (St.30)
Phosphate (μM)	7.28 (St.32)	6.6 (St.30)
Nitrate (μM)	6.46 (St.32)	8.66 (St.30)
Nitrite (μM)	0.021 (St.32)	0.068 (St.31)
Total nitrogen (μM)	6.482 (St.32)	8.708 (St.30)
TOC (mgC/g)	0 (St.30,31)	6.134 (St.32)

In the north coast, a minimum of 29°C of air temperature was recorded at Safeath Bhalu and the maximum of 31°C was recorded at Pryce Channel and Trinket Champlong Bay. The surface water temperature varied between 26°C at Trinket Champlong Bay to 29°C at Pryce Channel. The minimum sediment temperature recorded was 25°C at Safeath Bhalu and Trinket Champlong Bay and the maximum was 27°C at Pryce Channel. In the south coast at Indira Point, the minimum air temperature (29°C) was recorded during 2001 and the maximum (34°C), during 2003, while the surface water temperature ranged between 29°C (during 2002) and 30°C (during 2001 and 2003). The sediment temperature recorded the minimum (29°C) during 2002 and 2003 and the maximum (30°C) during 2001.

Transparency

In the east coast, the maximum transparency (22.93 m) was observed at Sastri nagar in 2001and the minimum (2.25 m) was observed at Galathea river mouth during 2002. The range of transparency in the west coast was between 3.5 and 18 m registering the minimum at Alexandira Bay during 2003 and the maximum at Inhengloi during 2002. In the north coast, the transparency ranged between 9 m at Safeath Bhalu and 12m at Pryce Channel and Trinket champlong Bay during 2002. Indira Point in the south coast recorded a transparency range between 10.5 and 17m during 2002 and 2001 respectively.

Salinity

In the east coast, salinity ranged between 21 and 40‰ registering the minimum at Galathea estuary and the maximum at Dubey nallah both during 2003. In the west coast, salinity ranged from a minimum of 33‰ during 2002 and 2003 at Inhengloi (shore), Inhengloi (open sea), Koshindon, Alexandria Bay and Kiched nallah, to a maximum of 37‰ at Megapod Island during 2003. The north coast had a minimum salinity of 34‰ at Safeath Bhalu and Trinket Champlong Bay and the maximum of 35‰ was recorded at Pryce Channel. Indira Point in the south coast had a salinity range between 32 (2003) and 37‰ (2001).

Hydrogen-ion concentration (pH)

In the east coast, minimum pH (7.1) in water was recorded at Vijay nagar during 2002 and the maximum of 8.1 was recorded at Dongi nallah, Sippy nallah, Dubey nallah, Swarup nallah, Laful Bay and Sastri Nagar in 2001. The sediment pH in the coast was minimum (6.6) at Magar nallah, Galathea Bay, Galathea river mouth and Galathea estuary during 2001, whereas the maximum (8.0) was recorded at Laful Bay during 2001. In the west coast, pH of the water ranged between 7 at Alexandria Bay (2001) and 7.7 at Inhengloi (shore) and Inhengloi (open sea) (2002). The sediment pH had a range between 6.9 at Kopenheat and 7.6 at Indira Point (2002).

In the north coast, pH of the water was minimum (7.5) at Safeath Bhalu and maximum (7.6) at Pryce Channel and Trinket Champlong Bay. The sediment pH ranged between 7.4 and 7.5 with the minimum at Safeath Bhalu and the maximum at Pryce Channel and Trinket Champlong Bay. In the south coast, water pH ranged between 7.5 (2002, 2003) and 7.8 (2001), whereas the pH of the sediments was between 7.2 (2001) and 7.5 (2002).

Dissolved oxygen

In the east coast, dissolved oxygen ranged between a minimum of 2.7 ml l^{-1} (2001) at Dongi nallah and a maximum of 8.6 ml l^{-1} at Sastri nagar during 2003. In the west coast, the dissolved oxygen was minimum (2.7 ml l^{-1}) at Megapod Island during 2003 and the maximum (4.82 ml l^{-1}) was recorded at Kiched nallah during 2003. In the north coast, minimum (4.0 ml l^{-1}) dissolved oxygen content was recorded at Trinket Champlong Bay during 2002 and the maximum (4.2 ml l^{-1}) was recorded at Safeath Bhalu during 2003. In the south coast, dissolved oxygen content ranged between 2.7 ml l^{-1} during 2002 and 4.5 ml l^{-1} during 2003.

Nutrients

East coast : Concentration of silicate ranged between 27.48 µM at Galathea estuary and 39.96 µM at Magar nallah whereas the phosphate concentration varied between 6.208 and 13.05 µM at Campbell Bay and Vijay nagar respectively. Nitrate concentration ranged from a minimum of 7.13 µM at Pigeon Island to a maximum of 14.59 µM at Vijay nagar. Nitrite was minimum (0.021 µM) at Magar nallah and maximum (1.591 µM) at Galathea estuary. The range of total nitrogen was between 7.063 µMat Dubey nallah and 15.02 µM at Vijay nagar. TOC was minimum at Prem nallah with 6.105 mgC/g and maximum at Galathea estuary with 8.824 mgC/g. All the minimum and maximum values were recorded during 2002.

West coast : In the west coast, the amount of silicate present in the water was higher (33.25 µM) at Megapod Island during 2003 and lower (28.32 µM) at Casuarina Bay during 2002. Phosphate concentration ranged from 6.32 µM at Pilobet during 2003 to 14.25 µMat Pilobhabi during 2002. The amount of nitrate detected in the water column was minimum (3.66 µM) at Kiched nallah during 2002 and maximum (14.49 µM) at Casuarina Bay during 2002. The concentration of nitrite varied between 0.0215 µM in 2002 at Megapod Island and 0.43 µM in 2002, at Pilobet. Total nitrogen ranged from a minimum of 3.275 µM at Kiched nallah during 2002 to a maximum of 14.572 µM at Casuarina Bay during 2002. The range of total organic carbon (TOC) in this coast was between 0.926 mgC/g at Kiched nallah, during 2002 and 8.521 mgC/g at Alexandria Bay during 2002.

North coast : In the north coast, minimum concentration of silicate (32.78 µM) was recorded at Safeath Bhalu and the maximum (32.98 µM) was recorded at Pryce Channel. In the case of phosphate, Safeath Bhalu recorded the minimum (6.6 µM) while Trinket Champlong Bay recorded the maximum (7.28 µM). Nitrate concentration varied between 6.46 µM at Trinket Champlong Bay and 8.86 µM at Safeath Bhalu. Nitrite concentration recorded a minimum of 0.0215 µM at Trinket Champlong Bay and a maximum of 0.068 µM at Pryce Channel. Total nitrogen content varied from 6.482 µM at Trinket Champlong Bay to 8.708 µM at Safeath Bhalu. TOC content was detectable at Safeath Bhalu and Pryce Channel and the maximum (6.134 mgC/g) was noticed at Trinket Champlong Bay.

South coast : Silicate concentration at this station ranged between 29.35 and 29.88 µM during 2003 and 2002 respectively. Phosphate content varied between 6.32 µM (2003) and 6.68 µM (2002). Nitrate content ranged from a minimum of 7.22 µM during 2003 to a maximum of 14.93 µM during 2002. Nitrite concentration ranged from 0.082 (2002) to 0.093 µM (2003). The minimum value for total nitrogen was 7.358 µM during 2003 at this station while the maximum was 15.012 µM during 2002. The minimum total organic carbon content at this station was 7.023 mgC/g (2002) and the maximum was 7.52 mgC/g (2003).

Heavy metals (Table 5)

East coast : In the east coast, Zinc concentration in water ranged between a minimum of 0.313 μg l^{-1} at Swarup nallah to a maximum of 2.24 μg l^{-1} at Galathea estuary. The Zinc concentration in the sediments had a range between 0.337 μg g^{-1} at Galathea estuary and 1.47 μg g^{-1} at Lakshmi nagar. Lead concentration both in water and sediments were below the detectable limit. Cadmium concentration in the water ranged between 0.011 μg l^{-1} at Laful Bay and 0.025 μg l^{-1} at Lakshmi nagar and Sastri nagar and cadmium concentration in the sediments was below the detectable level. Nickel concentration in the water samples was below detectable level. In the sediments, it ranged between 0.039 μg g^{-1} at Dubey nallah and 0.427 μg g^{-1} at Campbell Bay. Iron content in the water sample was minimum (0.075 μg l^{-1}) at Galathea Bay and maximum (0.748 μg l^{-1}) at Dubey nallah. In the case of sediment samples, the minimum (18.6 μg g^{-1}) content was recorded at Dongi nallah and the maximum (291 μg g^{-1}) content was recorded at Campbell Bay. Concentration of chromium in the water samples was below detectable limit while in sediments, it ranged between 0.124 μg g^{-1} at Galathea river mouth and 2.19 μg g^{-1} at Lakshmi nagar.

In the water samples, manganese content was minimum (0.077 μg l^{-1}) at Sippy nallah and maximum (1.39 μg l^{-1}) at Dongi nallah. In the sediment samples, minimum (1.39 μg g^{-1}) was recorded at Dubey nallah and the maximum (5.18 μg g^{-1}) was recorded at Swarup nallah. Concentration of copper in the water column recorded a minimum of 0.016 μg l^{-1} at Laful Bay and a maximum of 0.164 μg l^{-1}, at Vijay nagar. In sediments, concentration of copper ranged from a minimum of 0.034 μg g^{-1} at Laful Bay to a maximum of 0.209 μg g^{-1} at Campbell Bay. In the case of water samples, the minimum (0.084 μg l^{-1}) concentration of aluminium was recorded at

Table 5. Concentrations of heavy metals recorded from the east and south coasts of the Great Nicobar Island.

Heavy metal (μg/ml in water and μg/g in sediments)		East Coast		South Coast (Indira Point)
		Min	Max	
Zinc (Zn)	Sediments	0.337 (St.14)	1.47 (St.11)	0.285
	Water	0.313 (St.7)	2.24 (St.15)	0.535
Lead (Pb)	Sediments	BDL	BDL	BDL
	Water	BDL	BDL	BDL
Cadmium (Cd)	Sediments	BDL	BDL	BDL
	Water	0.011 (St.8)	0.025 (St.11,12)	0.02
Nickel (Ni)	Sediments	0.039 (St.6)	0.427 (St. 9)	0.074
	Water	BDL	BDL	BDL
Iron (Fe)	Sediments	18.6 (St.1)	291 (St.9)	22.9
	Water	0.075 (St.14)	0.748 (St.6)	0.287
Cromium (Cr)	Sediments	0.124 (St.14)	2.19 (St.11)	0.364
	Water	BDL	BDL	BDL
Manganese (Mn)	Sediments	1.39 (St.6)	5.18 (St.7)	1.85
	Water	0.77 (St.3)	1.39 (St.1)	0.641
Copper (Cu)	Sediments	0.034 (St.8)	0.208 (St.9)	0.068
	Water	0.016 (St.8)	0.164 (St.10)	0.046
Aluminium (Al)	Sediments	8.27 (St.1)	317 (St.9)	10.3
	Water	0.084 (St.15)	0.557 (St.10)	BDL

Galathea estuary and the maximum (0.557 μg l^{-1}) was recorded at Vijay nagar. Concentration of aluminium in the sediments ranged between a minimum of 8.27 μg g^{-1} at Dongi nallah to a maximum of 317 μg g^{-1} at Campbell Bay.

South coast : Different metals recorded different concentrations. In water, 0.535 μg l^{-1} of zinc, 0.02 μg l^{-1} of cadmium, 0.287 μg l^{-1} of iron, 0.641 μg l^{-1} of manganese and 0.046 μg l^{-1} of copper were recorded. Metal *viz.* nickel, chromium and aluminium were below detectable limit. In the case of sediments, 0.285 μg g^{-1} of zinc, 0.074 μg g^{-1} of nickel, 22.9 μg g^{-1} of iron, 0.364 μg g^{-1} of chromium, 1.85 μg g^{-1} of manganese, 0.068 μg g^{-1} of Copper and 10.3 μg g^{-1} of aluminium were recorded. Cadmium was below detectable limit in the sediments. Lead concentration was below detectable limit both in water and the sediment samples.

East coast : In the east coast, composition of sand was maximum at Sippy nallah with 97.29% of sand particles and Galathea estuary was less sandy with just 10.68 per cent of sand in the total composition. Silt composition in the east coast ranged between a minimum of 1.96-84.59 per cent. The minimum was recorded at Sippy nallah and the maximum, at Galathea estuary.

Clay type of substratum was totally absent at stations such as Dongi nallah, Sippy nallah, Swarup nallah, Laful Bay, Campbell Bay, Lakshmi nagar, Sastri nagar and Galathea Bay. All along the coast, clay composition was maximum at Galathea estuary recording 11.89 per cent of the total composition and a minimum of 1.13 per cent was recorded at Chingen basthi.

West coast : In the west coast, substratum was totally sandy with 100 per cent of sand in the total composition at Kopenheat. Minimum sand composition of 3.857 per cent was recorded at Alexandria Bay. Silt was totally absent in stations such as Pilobhabi and Kopenheat and it was maximum at Alexandria Bay with 94.34 per cent of the total composition and minimum of 1.03 per cent at Pilobhabi. Stations such as Pilobhabi, Kopenheat and Pilobet exhibited the total absence of clay type of substratum and the substratum had 22.99 per cent clay particles at Alexandria Bay.

North coast : In the North, only Trinket Champlong Bay was surveyed for the estimation of soil composition. The nature of the substratum was silty rather than sandy or clayey. Out of the total composition, 67.41 per cent was silt, 27.69 per cent was sand and 4.23 per cent was clay.

South coast : In the south coast, i.e. Indira Point, sand composition ranged between 92.47-94.52 per cent. Silt ranged between 3.34-6.62 per cent. Clay composition ranged between 0-2.13 per cent.

Table 6. Soil texture of the east and west coast stations of the Great Nicobar Island

Soil texture	2001		2002		2003	
	Min	Max	Min	Max	Min	Max
East coast						
Sand (%)			13.94 (St.14)	97.29 (St.3)	10.68 (St.15)	96.34 (St.3)
Silt (%)			81.25 (St.14)	1.96 (St.3)	2.05 (St.3)	84.59 (St.15)
Clay (%)			11.89 (St.15)	0 (St.1,3,7,8,9,11,12,13)	1.13 (St.17)	9.43 (St.13)
West coast						
Sand (%)			3.857 (St.24)	100.0 (St.23)	5.62 (St.24)	98.52 (St.21)
Silt (%)			94.34 (St.24)	0 (St.21,23)	1.03 (St.21)	74.06 (St.29)
Clay (%)			2.84 (St.18)	0 (St.21,23,28)	0.45 (St.21)	22.99 (St.24)

Table 7. Soil texture of the north and south coast stations of the Great Nicobar Island.

Soil texture %	2002	2003
North coast		
Sand (%)	27.69 (St.32)	
Silt (%)	67.41 (St.32)	
Clay (%)	4.23 (St. 32)	
South coast		
Sand (%)	92.47	94.52
Silt (%)	6.62	3.34
Clay (%)	0	2.13

DISCUSSION

Coastal area of the Great Nicobar Island is perhaps one of the least explored areas in the Indian Ocean region. In general, various physical-chemical parameters recorded during the present study for a period of three years were within the optimum range of a typical tropical marine environment, and fell within the range recorded in other Indian coast. Present results also indicated that the temperature was fluctuating well within the optimum temperature range (18-36°C) suggested for coral reef areas by Charless Birkeland (1997).

Flexibility and fluctuations in the temperatures of the coastal waters recorded during the present study might be due to the fluctuations in the wind speed, tidal amplitude and depths prevailing along the entire coast of the island. It has been previously reported that the tidal amplitude of the Andaman sea is 2.5 m (Doriraj and Soundararajan, 1997) and the wind speed under ordinary conditions is 3-4 m/sec and during cyclonic periods, it is 7 m/sec. Such fluctuations would affect air as well as the surface water temperatures and eventually the sediment temperature.

Rangarajan and Marichamy (1972) have reported 29.5 to 32.81‰ salinity from the Andaman Sea. During the present study, salinity varied between 21 and 40‰ registering the lower value at the Galathea estuary and it is quite obvious that estuaries have lower salinities mainly due to the freshwater inflow and the Galathea river is the only perennial river in the entire Andaman and Nicobar Islands. The higher salinity recorded at Dubey nallah could be attributed to the geomorphology of this station which forms a shallow basin at the landward side with comparatively lesser scope for continuous water circulation. Moreover, almost all the nallahs of the Great Nicobar Island are discharging fresh water only during rainy days. This could be one of the reasons for the higher salinity in addition to the higher evaporation rate at this shallow, less circulated region. In general, though the east coast showed wide fluctuations in salinity values, there was not much variation in the salinity of different other stations.

All along the coast, water pH varied between 7 and 8.1. The lower range of hydrogen-ion concentration was recorded at Alexandria Bay in the west coast which could be due to the inflow of copious amount of freshwater from the Alexandria river. Higher pH was observed at stations such as Dongi nallah, Sippy nallah, Dubey nallah, Swarup nallah, Laful Bay and Sastri Nagar in the east coast which exhibited higher salinities. This is in good agreement with the findings of Balasubramanian (2003) who obtained positive correlation between water pH and salinity in the Gulf of Mannar and negative correlation with rainfall and opined that the increase in salinity would increase the alkaline condition of the water.

In the present study, sediment pH ranged between 6.6 and 8.0 along the entire Great Nicobar coast. In general, water and sediment pH was lower at stations, characterized by rich humus content and on the other hand, higher pH was noticed at stations with reef assemblage, having higher concentrations of $CaCo_3$, and in the open sea. During the present investigation, transparency ranged between 2.4 m at Galathea estuary (mangrove environment) and 22.93 m at Sastri Nagar. The poor transparency at Galathea estuary could be due to the large input of organic and suspended matter through the river from the catchment areas and the clayey nature of the bottom. On the other hand, these two factors might have favoured the luxuriant growth of mangroves at this station. Reason for the higher transparency noticed at Sastri Nagar could be due to the long stretches of fringing coral, with lower organic matter content. In general, most stations of the west, east, north and south coasts estuarine stations such as Galathea estuary in the east coast and Alexandria (river) Bay in the west coast and the stations with higher wave action such as

Trinket in the north coast exhibited lower range of transparency and the stations with fringing reefs such as Sastri Nagar in the east coast and Indira Point in the south coast were found to have higher transparency.

Sea water in the Great Nicobar Island was mostly found to be saturated with oxygen. However, lower values of dissolved oxygen were also observed in stations such as Megapod Island (2.7 ml l^{-1}) in the west coast. Even much lower level of dissolved oxygen (0.2 ml l^{-1}) has been observed by Gupta *et al.* (1981), in the Andaman sea. In general, lower values of dissolved oxygen were recorded at stations exhibiting higher values of surface water temperature and salinity (which would affect the dissolution of oxygen). Stations like Campbell Bay, Sastri Nagar, Indira Point and Kiched nallah have recorded higher DO values and this could be due to the combined contribution of the phytoplankton, zooxanthellae of live corals, seaweeds and seagrasses, through photosynthetic release.

In the present study, nutrients were found in a wide range of concentrations. Battathri and Devassay (1981) reported a southward flow of water from the Bay of Bengal to Andaman sea through the channels around and between Andaman and Nicobar islands. Battathri and Devassay (1981) reported a southward flow across the 10° N' channel and the flow increased further due to the western currents. Maslennikov (1973) has stated the occurrence of cyclonic and anti cyclonic cells in the Andaman Sea of 100 to 200 km size, causing upwelling and sinking (Ramesh Babu and Shastry, 1976). All these might be responsible for the wide fluctuation in the concentrations of nutrients recorded in the coastal waters of the Great Nicobar Island, during the present study. However, nitrate and sediment total organic carbon contents were higher in the Galathea estuary in the east coast. This might be due to the imput of higher organic matter content through the Galathea river. Lower nutrient concentrations were recorded at stations viz. Sippy nallah and Laful Bay along the east coast and Koshindon and Kopenheat along the west coast. This could be attributed to the presence of fringing reef assemblages which tend to be oligotrophic in nature.

During the present investigation, generally, most of the heavy metals were found to be in lower concentrations both in water and sediments of all the east coast stations. Further, in the east and south coasts, lead was below the detectable limit in have been as well as sediments. But metals such as nickel and chromium were found only in sediments whereas in water, they were below the detectable limit. Similar observations have been made by Sanzgiry and Braganca (1981) in the Andaman Sea with respect to both dissolved and particle fractions of metals in water at various depth zones. From the first year results, it was understood that there was only very less heavy metal and pesticide pollution in the island coast and there was no source for large scale input of heavy metals and pesticides in to the coastal environment of the Great Nicobar Island. Considering these, the other coasts of the island were not studied for heavy metals and pesticides during the subsequent years.

Analysis for oil (petroleum hydrocarbon) concentration in water at various stations (Table 3.6) has revealed that comparatively higher amount of oil is present in the Campbell Bay than the other stations. This is mainly because of oil spillage due to harbour and shipping activities along with the operations of mechanized fishing boats at Campbell Bay. However, concentration of oil in the Great Nicobar coast is very less when compared to that of the world oceans i.e. 0-1000 $\mu g\ l^{-1}$ (Farrington and Meyer, 1975) because of comparatively lesser shipping activities and heavy tidal action in the former. Topgi *et al.* (1981) have observed the concentration of petroleum hydrocarbons in the range of 73 ± 1.3 and 61 ± 1.4 $\mu g\ l^{-1}$ at 0 and 10 m respectively, in the oil tanker route across the Bay of Bengal. Results obtained in the present study (maximum28 µg/ml) reveal that the concentration of oil is very low in the coastal waters of the Great Nicobar Island and it is lower than that reported by Topgi *et al.* (1981).

Soil all along the coast had different textures. It was sandy, silty and also had coral rubbles at some stations. In the east coast, Dongi nallah, Sippy nallah and Vijay nagar were found to be more sandy. In the west coast, Pilobhabi, Casuarina Bay, Pilokunji, Megapod Island, Dagmar and Kopenheat were found to be with more sand fractions. Silt fractions were predominant in the east coast at Galathea estuary, Galathea river mouth and Dubey nallah and in the west coast, at Kiched nallah. Clay fractions were very less or almost absent in most of the stations. However, along the east coast, Galathea Bay, Campbell Bay and Magar nallah and in the west coast, Alexandria river mouth and Inhengloi showed clay composition in the sediments. This is mainly because of the higher amount of terrigenous material transport form the catchment areas along with the deposition of seagrass humus especially at Inhengloi. In the north, Trinket Champlong Bay exhibited silty substratum. In the south, Indira Point had a substratum made of dead corals and it was also sandy at some places.

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Chapter 03

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 55-76, 2010

MICROBIAL RESOURCES OF THE GREAT NICOBAR ISLAND

N.S. SWARNAKUMAR, K. SIVAKUMAR*, T. THANGARADJOU, L. KANNAN and S. AJMAL KHAN**

Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608 502

INTRODUCTION

Marine environment is the largest habitat on the earth. Many distinct marine ecosystems and their microbial assemblages have been identified and studied, ranging from ice swept pol seas to deep-sea hydrothermal vents. Abundance and biomass of bacteria are central parameters of the ecosystems and are very essential to understand the role of heterotrophic bacteria in the marine environment. The environment of the mangroves, estuaries, coral reefs, and brackish waters is the cosmos for the total heterotrophic bacterial community. Therefore, many microbiological studies have been carried out in these environs to understand the 'health' of the ecosystems.

Since two to three decades, microbial (water quality) analyses have found a key place in the marine pollution monitoring. Microbial pollution is mainly caused by human enteric pathogens such as the species of *Vibrio*, *Salmonella*, *Shigella*, *Klebsiella* and *Pseudomonas* and also *Escherichia coli* and *Streptococcus feacalis*. These pathogens enter into the marine environment due to river run off, sewage disposal, agricultural run off, industrial effluent discharges, recreational uses and processing of sea foods on the shore. Further, studies on the spatial and temporal distribution of the total and faecal coliforms as well as the pathogenic bacteria in water, sediments and organisms contribute to identify the overall sanitary status of the water bodies.

MATERIALS AND METHODS

Water sample : For bacteriological assessment, surface water samples were collected in 100 ml sterile screw capped bottles. Enough air space was left in the bottles to allow thorough mixing. Precautionary measures were taken to avoid contamination through handling.

Sediment sample : Sediment samples were collected by employing an alcohol rinsed and air-dried small Peterson's grab. The central portion of the collected sediments was aseptically transferred into sterile polyethylene bags using sterile spatula.

All samples were brought to the laboratory in portable icebox as soon as possible after collection and bacteriological analyses were done in the field laboratory at Campbell Bay immediately after arrival and with necessary dilution.

THB population was enumerated by adopting the spread plate method using ZoBell's Marine Agar medium (2216 e, Hi-Media, Mumbai).

TCBS agar used for the selective isolation and culture of *Vibrio* spp. Populations of total enteric pathogens were enumerated by adopting the spread plate method using Xylose Lysine

* E-mail : umaradjou@gmail.com

**Thiruvalluvar University, Fort Campus, Vellore 632 004, E-mail : kannanlk69@yahoo.com

Deoxycholate Agar (XLD Agar) for the isolation of enteric pathogens especially *Salmonella, Shigella and Klebsiella* species). Macconkey agar used for the detection, isolation and enumeration of *E. coli*. M-*Enterococcus* agar is used as a selective medium for membrane filtration procedure or as a direct plating medium for the isolation and enumeration of *S. faecalis*. Cetrimide Agar was used as the selective medium for the isolation of *Pseudomonas aeruginosa*.

IMVC (Indole, Methylred, Voges Proskauer, Citrate test), H_2S production test, Cytochrome oxidase test, ONPG test, Motility of bacteria, Gram staining and Fermentation of carbohydrates (Acid and gas production) tests were carried out by following the methods of Simidu and Aiso (1962).

RESULTS

Generic composition of total heterotrophic bacteria (THB)

From the 220 strains isolated from water and sediments of 29 stations, 123 strains were selected randomly; sub cultured and identified up to generic level. Diagnostic tests were used for the identification of pathogenic bacteria (Table 1). A total of 10 genera viz. *Pseudomonas, Vibrio, Streptococcus, Esherichia, Klebsiella, Flavobacterium, Bacillus, Shigella, Corynebacterium* and *Salmonella* were recorded. Of the 10 genera, *Pseudomonas* contributed more (25.0 per cent) followed by *Vibrio*, (18.50 per cent), *Streptococcus* (15.50 per cent) (Fig. 1).

Among the 10 genera recorded, *Vibrio, Pseudomonas, Shigella, Escherchia, Flavobacterium, Streptococcus* and *Salmonella* belong to the gram-negative group, and the remaining two genera (*Corynebacterium* and *Bacillus*) belong to the gram-positive group. Thus, presence of gram-negative genera was more than the gram-positive genera.

Distribution of Total Heterotrophic Bacteria

East Coast (Figs. 2 and 3) : During the first year (2001), along the east coast region, THB population density in the water samples ranged from 13 (Lakshmi nagar) to 2922 × 10^2 CFUml^{-1} (Galathea estuary). In the second year (2002), THB population density was minimum (2 × 10^2 CFUml^{-1}) at Magar nallah and maximum (906 × 10^2 CFUml^{-1}) at Campbell Bay. It was lower (1.5 × 10^2 CFUml^{-1}) at Laful Bay and higher (600 × 10^2 CFUml^{-1}) at Galathea estuary in the third year (2003).

Along the east coast region, in the sediment samples, THB population density ranged from 0.82 × 10^5 CFUg^{-1} (Galathea river mouth) to 2116.8 × 10^5 CFUg^{-1} (Galathea estuary) in the year 2001. In the year 2002, it ranged from 2 × 10^5 CFUg^{-1} (Laful Bay) to 1032 × 10^5 CFUg^{-1} (Galathea estuary) while in 2003, the minimum (1 × 10^5 CFU g^{-1}) THB population density was recorded at Laful Bay and the maximum (1547 × 10^5 CFUg^{-1}), at Galathea estuary.

West Coast (Figs. 4 and 5) : THB population densities in the water and sediment samples of the 2 stations in the west coast region were enumerated only during second and third years (2002 and 2003).

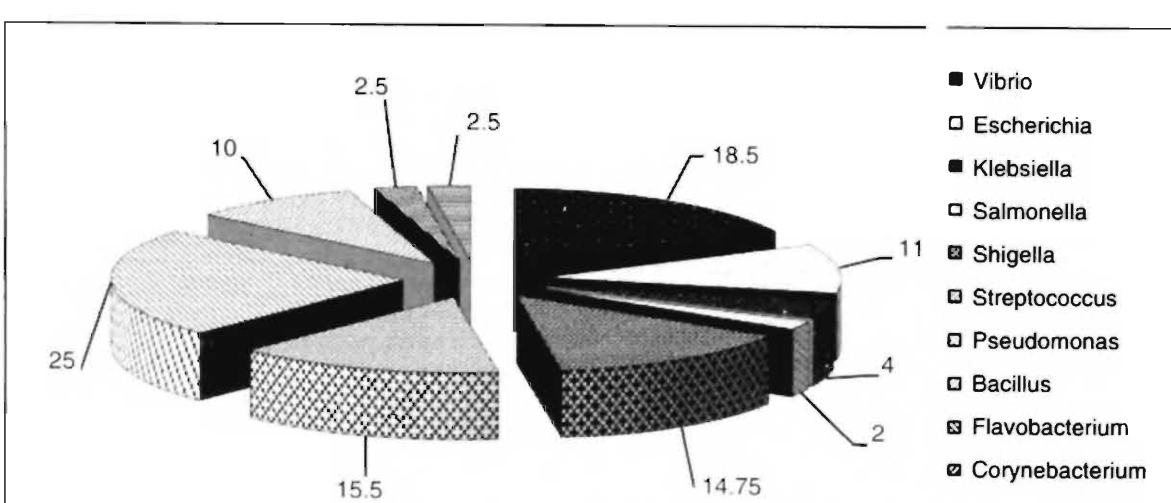

Fig. 1. Percentage contribution of bacterial genera recorded from the Great Nicobar Island.

Table 1. Response to diagnostic tests of the pathogenic bacteria isolated from the Great Nicobar Islands

Sl. No.	Tests	*Vibrio cholerae*	*V. parahaemolyticus*	*Salmonella spp.*	*Esherchia coli*	*Klebsiella pneumonia*	*Shigella dysenteriae*	*Streptococcus faecalis*	*Pseudomonas aeruginosa*
1	Hydrogen sulphide	+		+		+		+	
2	Urea hydrolyzed		+			+	+	+	+
3	Indole	+	+	+	+		(+) or (-)		
4	Methyl red (37?C??	+			+	+	+		
5	Voges-Proskauer (37?C??	(+) or (-)							
6	Citrate (Simmson's)	+	(+) or (-)	(+) or (-)		(+) or (-)			+
7	Growth in KCN	(+) or (-)	+						(+) or (-)
8	Catalase	(+) or (-)	+		+	+			+
9	Cytochrome oxidase	+	+				(+) or (-)	(+) or (-)	+
10	Growth in peptone water		+	+	+				+
11	I. Without NaCl II. With 3% NaCl III. With 8% NaCl	+	+						+
12	Growth at 42	+	+	+	(+) or (-)		(+) or (-)	(+) or (-)	
13	Motility	+	+	(+) or (-)	(+) or (-)		(+) or (-)	(+) or (-)	
14	Gelatin hydolysis	+	(+) or (-)	+	(+) or (-)		(+) or (-)	(+) or (-)	
15	Lysine decarboxylase	+	(+) or (-)	+		(+) or (-)			(+) or (-)
16	Sodium molanate		+	(+) or (-)	+		+	+	(+) or (-)
17	Nitrate reduction	+	+	+	+	+	+		+
18	Glucose acid, gas Acid form		(+) or (-)	+		(+) or (-)	+	+	(+) or (-)
19	Adonitol	+	(+) or (-)	+	+			+	(+) or (-)
20	Arabinose	+		+	(+) or (-)	(+) or (-)		+	(+) or (-)
21	Dulcitol	+			(+) or (-)			+	+
22	Inositol	+		+			(+) or (-)	+	
23	Lactose	(+) or (-)	+		+	(+) or (-)	(+) or (-)	+	
24	Maltose		(+) or (-)	+	+		(+) or (-)	+	
25	Monnitol	(+) or (-)	(+) or (-)	+	+		(+) or (-)	+	(+) or (-)
26	Salicin	(+) or (-)	(+) or (-)	(+) or (-)	(+) or (-)				(+) or (-)
27	Sorbitol	(+) or (-)	(+) or (-)	+	+			+	
28	Sucrose			+	(+) or (-)		(+) or(-)	+	
29	Trehalose	(+) or (-)	+	+	+	+	+		
30	Xylose	+	+		(+) or (-)	+	(+) or (-)		
31	Sodium mucate	+			+	+	(+) or (-)		+
32	Gram's reation								

(-) Denotes 100% response; (-) No reaction; (+) or (-) denotes 50 % of strains showing positive reaction and the other 50%, negative reaction.

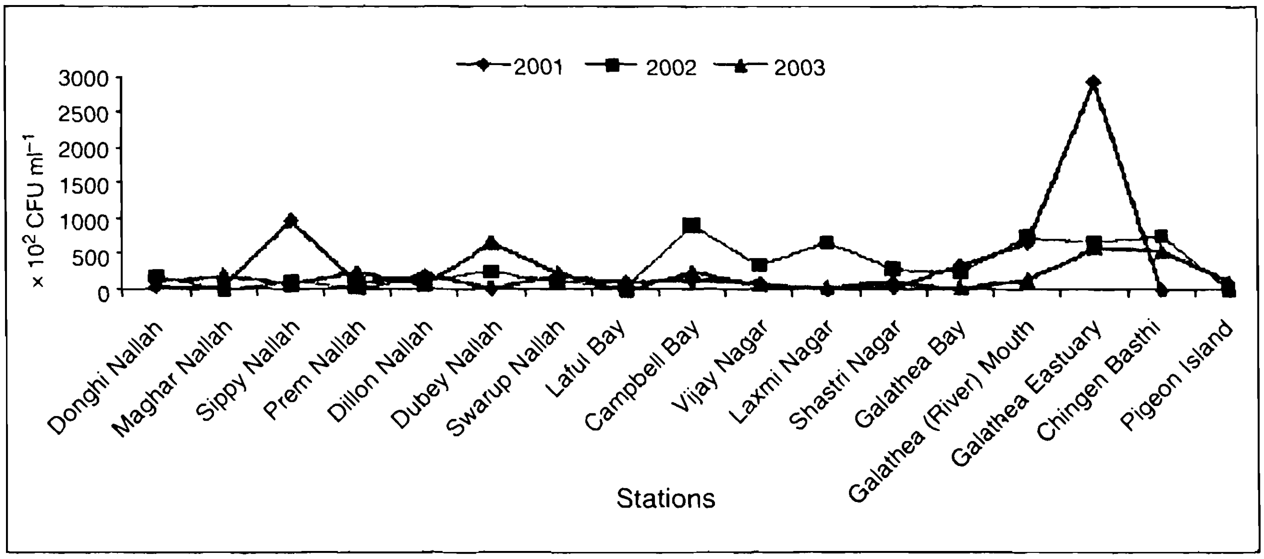

Fig. 2. Population density of THB in water recorded from the eastcoast of the Great Nicobar Island

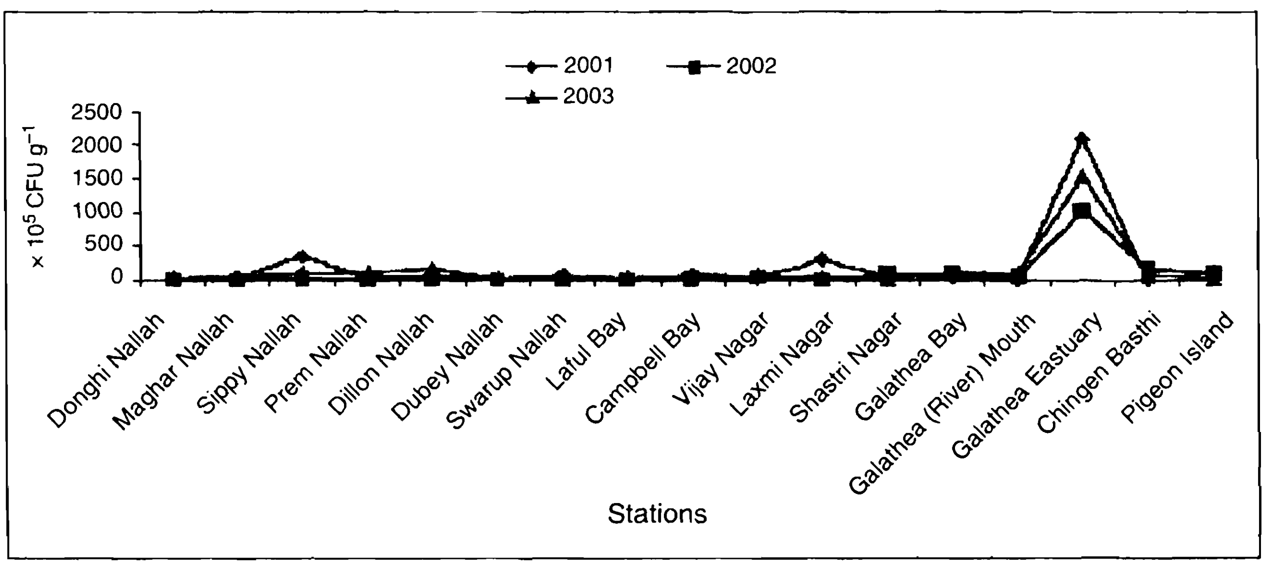

Fig. 3. Population density of THB in sediments recorded from the east coast of the Great Nicobar island.

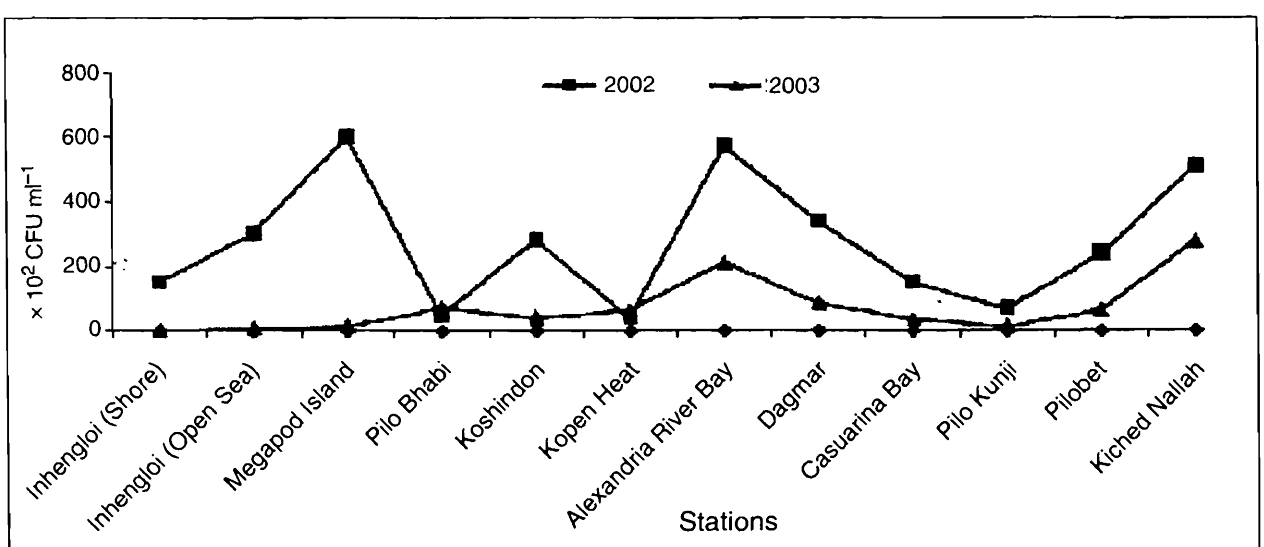

Fig. 4. Population density of THB in water recorded from the west coast of the Great Nicobar Island.

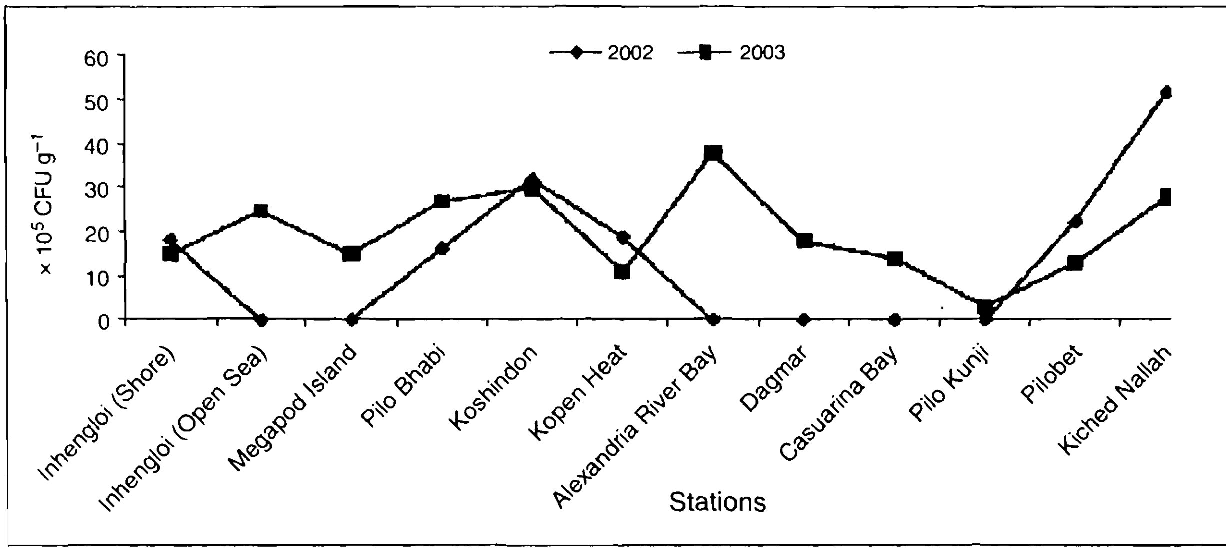

Fig. 5. Population density of THB in sediments recorded from the west coast of the Great Nicobar Island.

During 2002, THB population density in the water samples was lower (41 × 10^2 $CFUml^{-1}$) at Kopenheat and higher (600 × 10^2 $CFUml^{-1}$) at Megapod Island. During the 2003, the occurrence of THB population density in the water samples ranged from 2 × 10^2 $CFUml^{-1}$ at Inhengloi (shore) to 280 × 10^2 $CFUml^{-1}$ at Kiched nallah.

In the sediment samples, THB population density ranged from 16.2 × 10^5 CFU g^{-1} at Pilobhabi to 52.0 × 10^5 CFU g^{-1} at Kiched nallah in 2002. In 2003, the minimum (3 × 10^5 $CFUg^{-1}$) was observed at Pilokunji and the maximum (38 × 10^5 $CFUg^{-1}$) at Alexandria Bay.

South Coast (Figs. 6 and 7) : Indira Point is the only station covered in the southern coastal region in all the three years for the bacteriological studies. In water, the THB population density was 525 × 10^2 $CFUml^{-1}$ in 2001. It was 420 × 10^2 $CFUml^{-1}$ and 300 × 10^2 CFU ml^{-1} in 2002 and 2003 respectively. In the sediments, THB population density was 0.82 × 10^5 $CFUg^{-1}$ in 2001, while the density was 21.6 × 10^5 $CFUg^{-1}$ in 2002 and 58 × 10^5 $CFUg^{-1}$ in 2003.

North Coast (Figs. 6 and 7) : In the north coast, three stations were covered during the year 2002. THB population density in the water was lower (52 × 10^2CFU ml^{-1}) at Pryce Channel and higher (400 × 10^2 CFU ml^{-1}) at Safeath Bhalu. In the sediment sample, the THB population density recorded was 0.7 × 10^5 $CFUg^{-1}$ during the year 2002 at Trinket Champlong Bay.

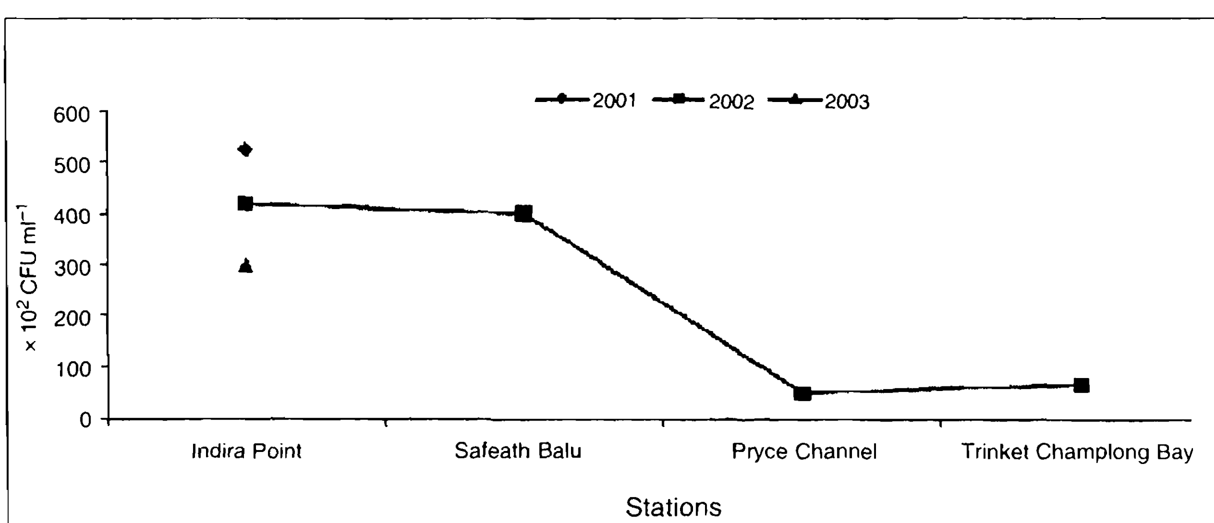

Fig. 6. Population density of THB in water recorded from the south and north coasts of the Great Nicobar island

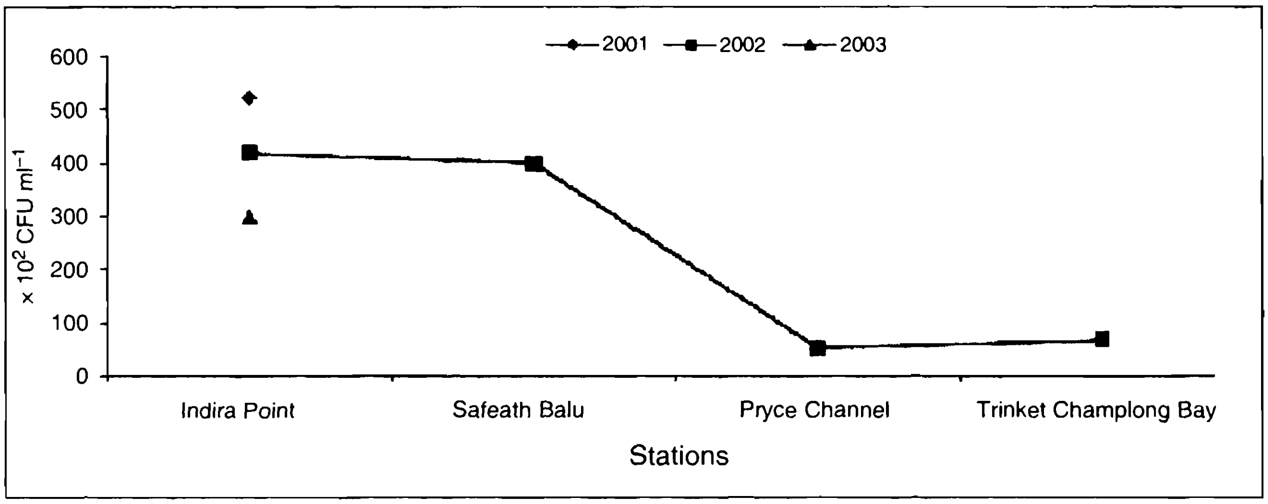

Fig. 7. Population density of THB in sediments recorded from the south and north coasts of the Great Nicobar Island

Distribution of pathogenic bacteria

East coast (Figs. 8 and 9) : Water samples were collected from seventeen stations along the east coast and the population density of both the *Vibrio cholerae* and *V. parahaemolyticus* was recoded. In 2002, density of *V. cholerae* was lower (1×10^2 $CFUml^{-1}$) at Laful Bay and higher (320×10^2 $CFUml^{-1}$) at Galathea river mouth. Density of another pathogenic bacterium, *V. parahaemolyticus* was also lower (0.04×10^2 $CFUml^{-1}$) at Laful Bay and higher ($280 \times 10^2 CFUml^{-1}$) at Galathea river mouth.

In sediment samples, *V. cholarae* population density was minimum ($0.2 \times 10^5 CFUg^{-1}$) at Pigeon Island and maximum (3.2×10^5 $CFUg^{-1}$) at Vijay nagar and *V. parahaemolyticus* bacterial population density was lower ($0.1 \times 10^5 CFUg^{-1}$) at Magar nallah and higher (2.8×10^5 $CFUg^{-1}$) at Galathea Bay during the year 2002.

In 2003, population density of *V. cholerae* in water was lower (1.2×10^2 $CFUml^{-1}$) at Campbell Bay and higher (260×10^2 $CFUml^{-1}$) at Galathea river mouth. Population density of *V. parahaemolyticus* was lower (1×10^2 $CFUml^{-1}$) at Dubey nallah and higher (30×10^2 $CFUml^{-1}$) at Galathea estuary in the water samples.

In the sediment sample, *V. cholerae* population density was minimum ($0.04 \times 10^5 CFUg^{-1}$) at Dubey nallah and maximum (20×10^5 $CFUg^{-1}$) at Magar nallah. Population density of *V.parahaemolyticus* was lower (0.36×10^5 $CFUg^{-1}$) at Galathea Bay and higher (2.5×10^5 $CFUg^{-1}$) at Galathea river mouth, during 2003.

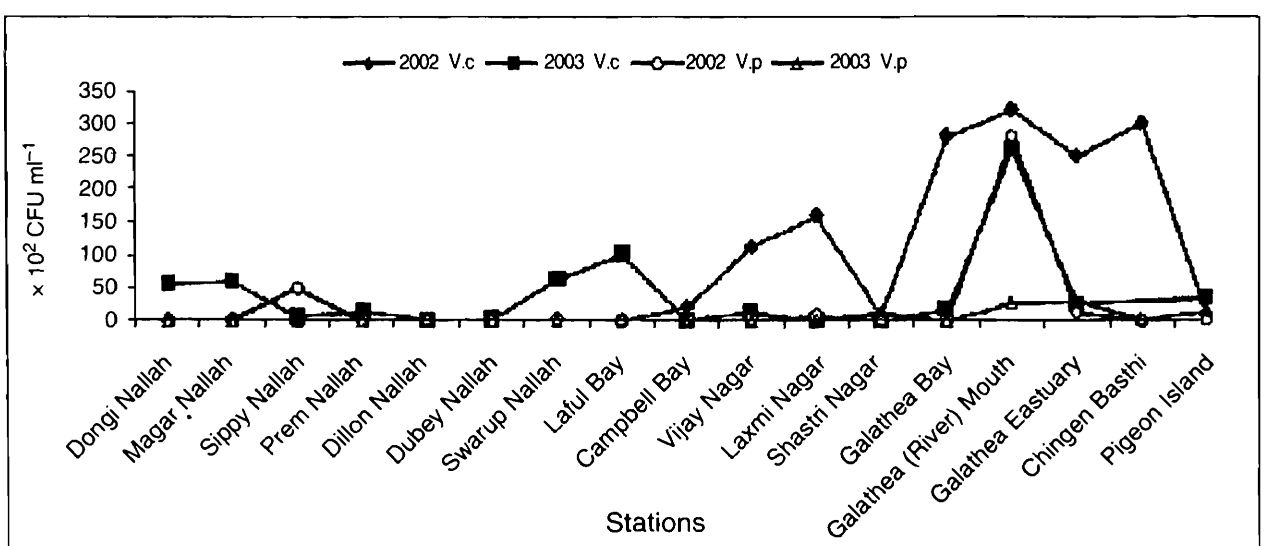

Fig. 8. Population density of *V. cholerae* and *V. parahaemolyticus* in the water recorded from the east coast of the Great Nicobar Island

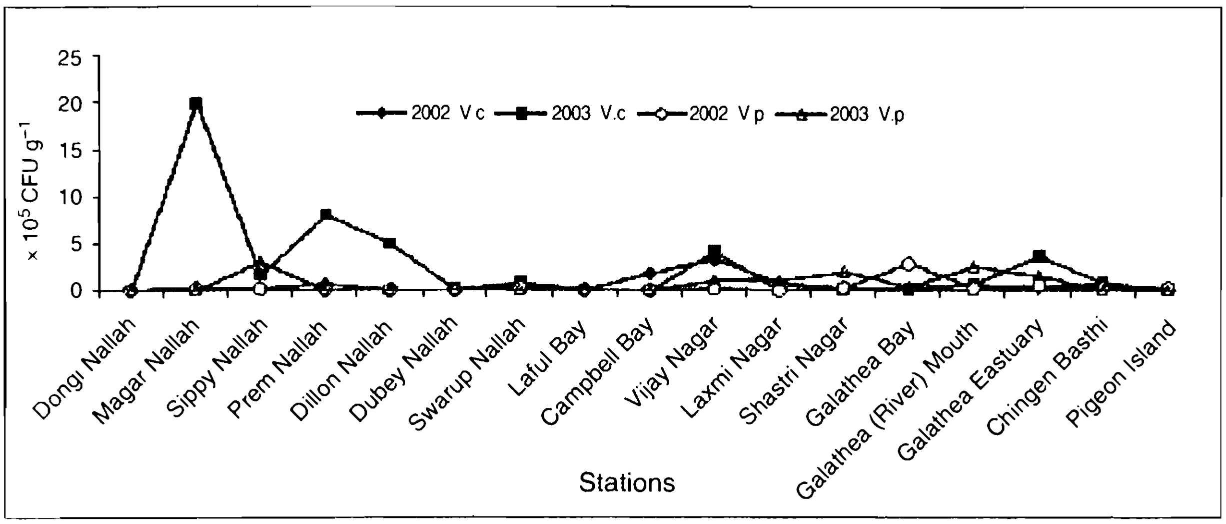

Fig. 9. Population density of *V. cholerae* and *V. parahaemolyticus* in sediments recorded from the east coast of the Great Nicobar Island

West Coast (Figs. 10 and 11) : In the year 2002, population density of the pathogenic *V. cholerae* in the water ranged from 1 × 10^2 $CFUml^{-1}$ (Inhengloi open sea) to 250 × 10^2 $CFUml^{-1}$ (Kiched nallah). Population density of *V. parahaemolyticus* was found to be lower (1 × 10^2 $CFUml^{-1}$) at Inhengloi (open sea) and higher (60 × 10^2 $CFUml^{-1}$) at Inhengloi (shore).

In the sediment samples, both *V. cholerae* and *V. parahaemolyticus* densities were lower (0.3 × 10^5 $CFUg^{-1}$ and 0.1 × 10^5 $CFUg^{-1}$ respectively) in Kopenheat and the former was higher (3.2 × 10^5 $CFUg^{-1}$) at Inhengloi (shore) and the latter was higher (13.2 × 10^5 $CFUg^{-1}$) at Pilobet.

In the year 2003, population density of *V. cholerae* in the water samples ranged from 5 (Pilobet) to 167 × 10^2 $CFUml^{-1}$ (Kiched nallah). In the case of *V. parahaemolyticus*, population density was lower (1 × 10^2 $CFUml^{-1}$) at Kopenheat and higher (23 × 10^2 $CFUml^{-1}$) at Inhengloi (shore).

In the sediment samples, *V. cholerae* density was lower (0.2 × 10^5 $CFUg^{-1}$) at Megapod Island and higher (1.2 × 10^5 $CFUg^{-1}$) at Pilobet and *V. parahaemolyticus* density was lower (1 × 10^5 $CFUg^{-1}$) at Megapod Island and higher (15 × 10^5 $CFUg^{-1}$) at Pilobet.

South Coast (Figs. 12 and 13) : In 2002, at Indira Point, population density of *V. cholerae* and *V. parahaemolyticus* was 14 × 10^2 CFU ml^{-1} and 4 × 10^2 CFU ml^{-1} in the water sample respectively. In sediment samples, it was 0.7 × 10^5 $CFUg^{-1}$ and 0.01 × 10^5 $CFUg^{-1}$ respectively.

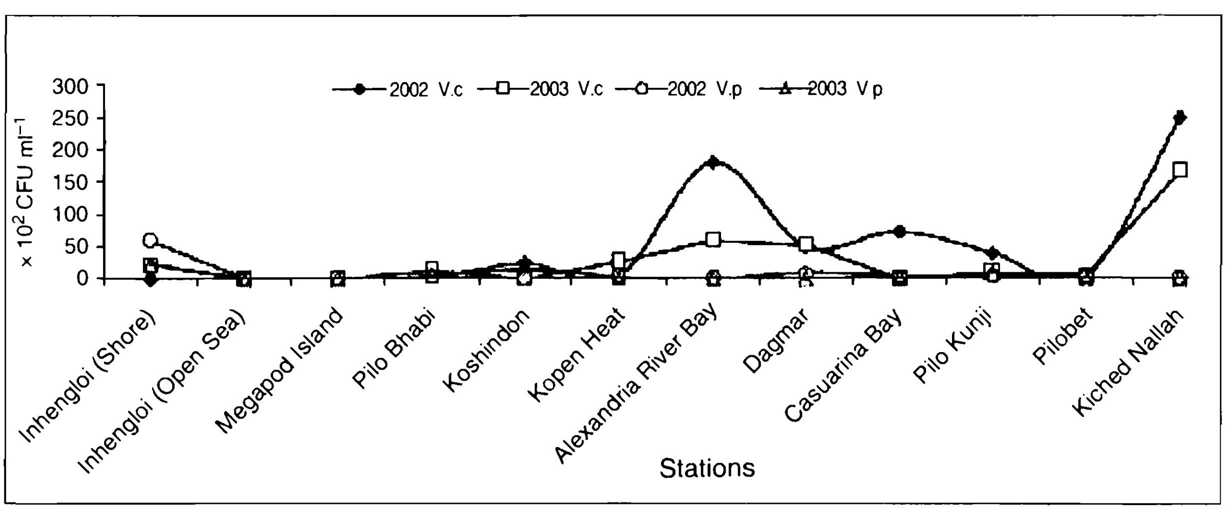

Fig. 10. Population density of *V. cholerae* and *V. parahaemolyticus* in water recorded from the west coast of the Great Nicobar Island

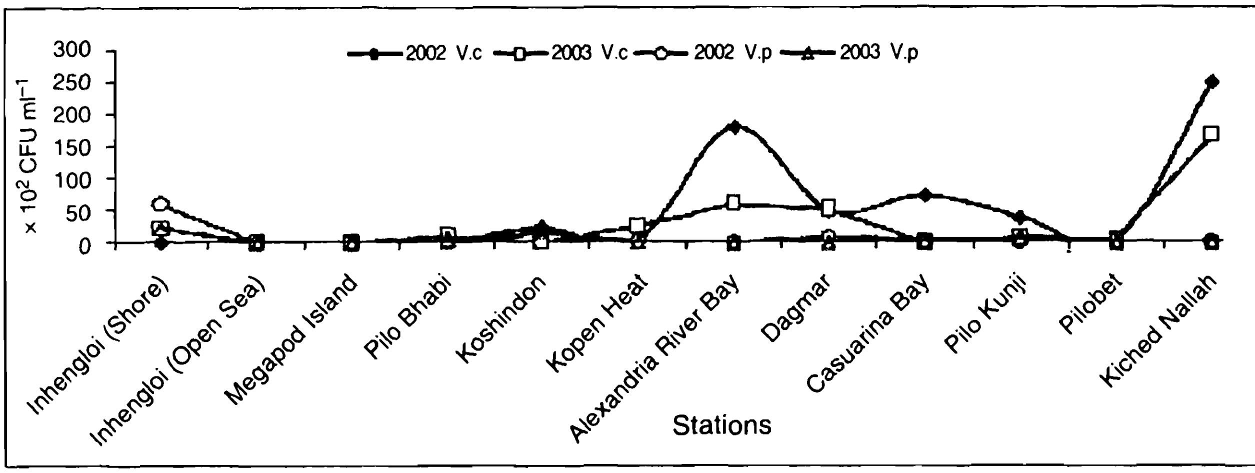

Fig. 11. Population density of *V. cholerae* and *V. parahaemolyticus* in sediments recorded from the west coast of the Great Nicobar Island

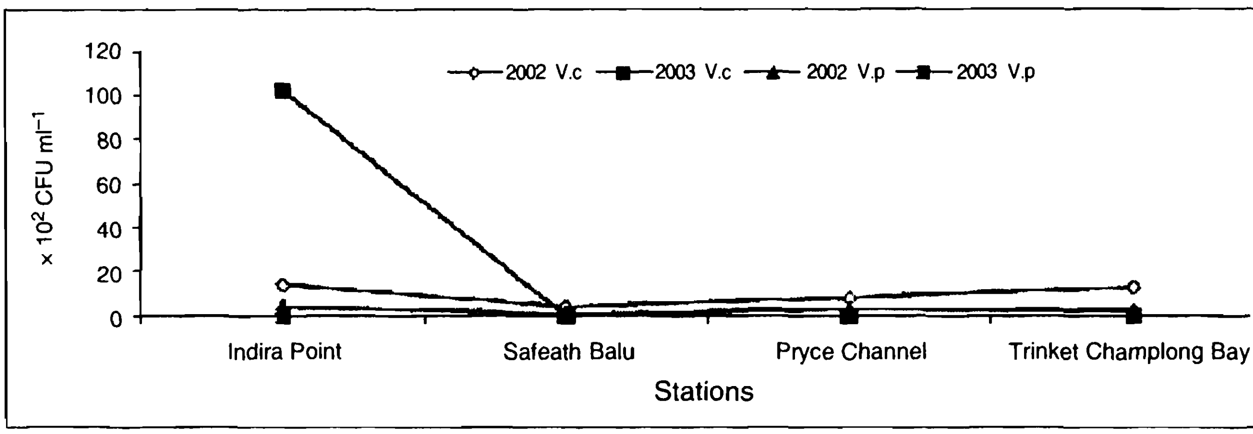

Fig. 12. Population density of *V.cholerae* and *V.parahaemolyticus* in water recorded from the south and north coasts of the Great Nicobar Island

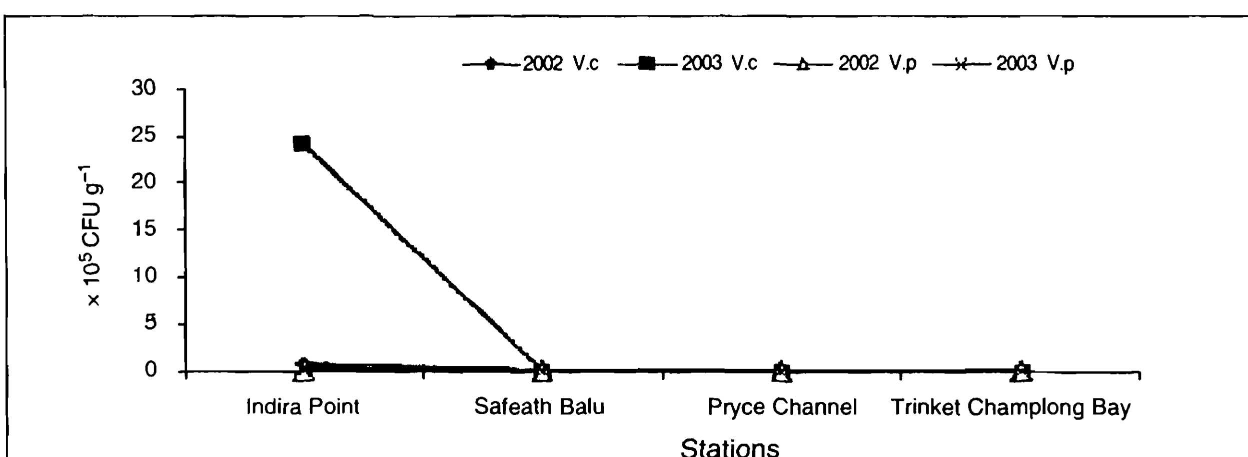

Fig. 13. Population density of *V. cholerae* and *V. parahaemolyticus* in sediments recorded from the south and north coasts of the Great Nicobar Island

In 2003, population density of *V. cholerae* was 102×10^2 CFU ml^{-1} in the water sample and in the sediment samples, it was 24×10^5 $CFUg^{-1}$. *V. parahaemolyticus* was observed only in the sediment samples and its density was 0.13×10^5 $CFUg^{-1}$.

North Coast (Figs. 12 and 13) : Population density of the pathogenic bacterium *V. cholerae* in water was found to be lower (4×10^2 CFU ml^{-1}) in Safeath bhalu and higher (13×10^2 CFU ml^{-1}) in Trinket Champlong Bay. Population density of *V. parahaemolyticus* was lower (1×10^2 CFU ml^{-1})

in Safeath bhalu and higher (3×10^2 CFU ml^{-1}) in Pryce Channel during the year 2002. These were absent in the sediment samples collected from the Trinket Champlong Bay, from where only the sediment sample could be collected for the north coast.

Both in 2002 and 2003, among all the stations surveyed, population density of *Salmonella* spp. could be recorded only in the east and south coast stations. In 2002, it was recorded from Sippy nallah with a density of 1×10^2 CFU ml^{-1}. In 2003, it was observed in water (18×10^2 CFU ml^{-1}) and sediment (11×10^5 CFU g^{-1}) samples of Galathea estuary (east coast) and in the water sample (1×10^2 CFU ml^{-1}) of Indira Point (south coast).

East coast (Figs. 14 and 15) : In the water samples, population density of the *Shigella* spp. ranged from 1.98×10^2 CFUml^{-1} (Galathea river mouth) to 88×10^2 CFU ml^{-1} (Chingen basthi) in 2002, while in the sediment sample, *Shigella* spp. density ranged from 0.1×10^5 CFU g^{-1} (Magar nallah) to 3.7×10^5 CFU g^{-1} (Vijay nagar). In 2003, population density of *S. dysenteriae* ranged from 1×10^2 CFU ml^{-1} (Galathea Bay) to 88×10^2 CFUml^{-1} (Galathea river mouth) in water and in sediments, it ranged from 0.1×10^5 CFU g^{-1} (Dillon nallah) to 3.5×10^5 CFU g^{-1} (Galathea estuary).

In the water samples, another enteric pathogen *Klebsiella* spp. population density was lower (1×10^2 CFU ml^{-1}) at Magar nallah and higher (128×10^2 CFU ml^{-1}) at Galathea Bay during 2002. In 2003, population density of *K. pneumoniae* was lower (1×10^2 CFU ml^{-1}) in Vijay nagar and higher (67×10^2 CFU ml^{-1}) in Galathea river mouth.

In the sediments samples, population density of *Klebsiella* spp. was lower (0.1×10^5 CFU g^{-1}) at Prem nallah and higher (12.0×10^5 CFU g^{-1}) at Sastri Nagar in 2002. Population density of *K.*

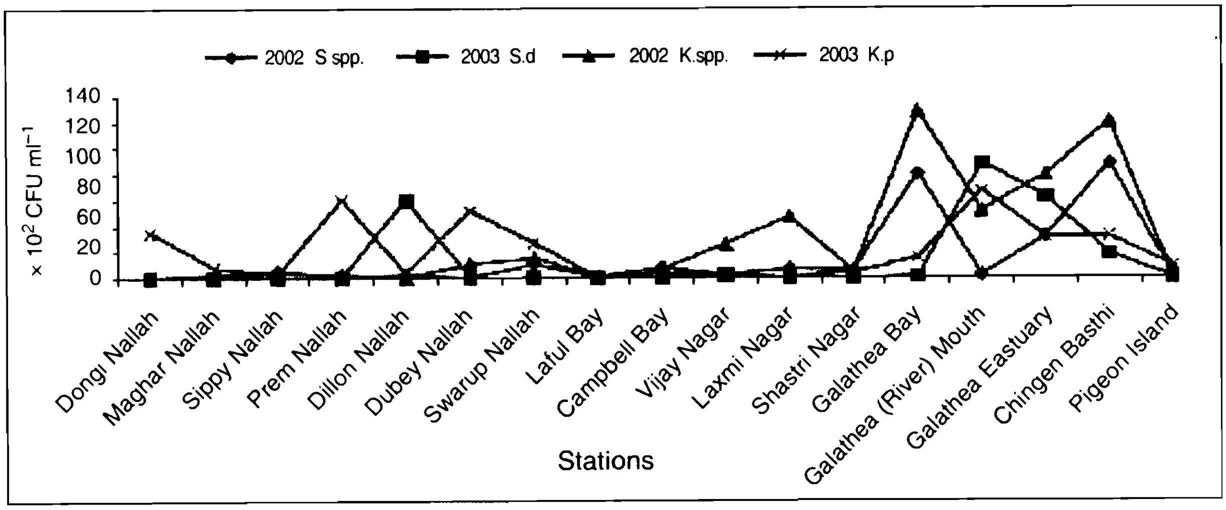

Fig. 14. Population density of *Shigella* and *Klebsiella* in water recorded from the east coast of the Great Nicobar Island

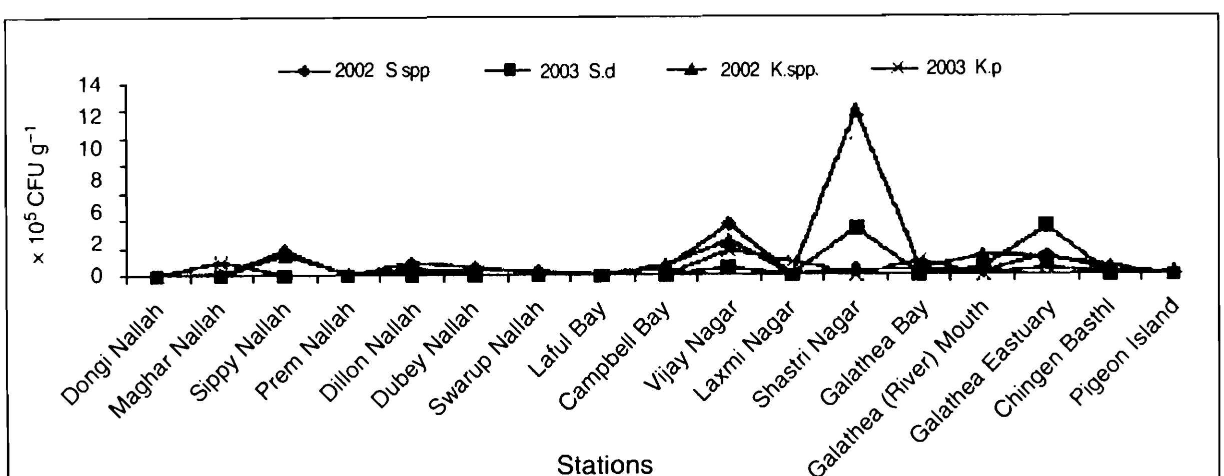

Fig. 15. Population density of *Shigella* and *Klebsiella* in sediments recorded from the east coast of the Great Nicobar Island.

pneumoniae was lower (0.01 × 10^5 CFU g^{-1}) at Galathea river mouth and higher (1.8 × 10^5 CFU g^{-1}) at Vijay nagar during 2003.

West Coast (Figs. 16 and 17) : Population density of *Shigella* spp. ranged from 1 × 10^2 CFU ml^{-1} (Pilokunji) to 98 × 10^2 CFU ml^{-1} (Kiched nallah) in the water sample of the west coast region during 2002. In the year 2003, population density of *S. dysenteriae* ranged from 1 × 10^2 CFU ml^{-1} (Kopenheat) to 43 × 10^2 CFU ml^{-1} (Kiched nallah).

In the sediments samples, *Shigella* spp. population density ranged from 0.3 × 10^5 CFU g^{-1} at Pilobhabi to (2.5 × 10^5CFU g^{-1}) at Inhengloi (shore) in 2002. In the year 2003, the density of *S. dysenteriae* ranged from 0.1 × 10^5 CFU g^{-1} (Megapod Island) to 1.1 × 10^5CFU g^{-1} (Kiched nallah).

In the water sample, population density of *Klebsiella* spp. was found to be lower (12 × 10^2 CFU ml^{-1}) at Pilobhabi and higher (80 × 10^2 CFU ml^{-1}) at Kiched nallah during 2002. Population density of *K. prteumoniae* was lower (15 × 10^2 CFU ml^{-1}) at Dagmar and higher (80 × 10^2 CFU ml^{-1}) at Kiched nallah during 2003.

In the sediment samples, population density of *Klebsiella* spp. was found to be lower (0.6 × 10^5 CFU g^{-1}) at Inhengloi (shore) and higher (1.5 × 10^5CFU g^{-1}) at Kopenheat during the year 2002. Population density of *K. pneumoniae* was lower (0.3 × 10^5 CFU g^{-1}) at Pilobhabi and higher (1.7 × 10^5 CFU g^{-1}) at Kiched nallah during 2003.

South Coast (Figs. 18 and 19) : At Indira Point, population density of *Shigella* spp. was 142 × 10^2 CFU ml^{-1} and 0.8 × 10^5 CFU g^{-1} in water and

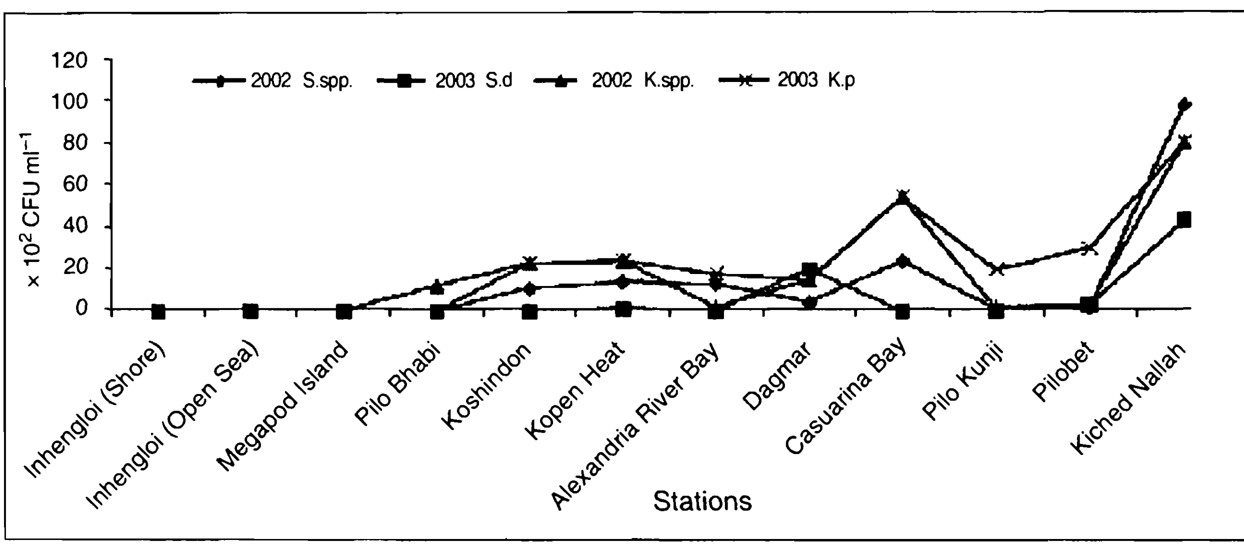

Fig. 16. Population density of *Shigella* and *Klebsiella* in water recorded from the west coast of the Great Nicobar island

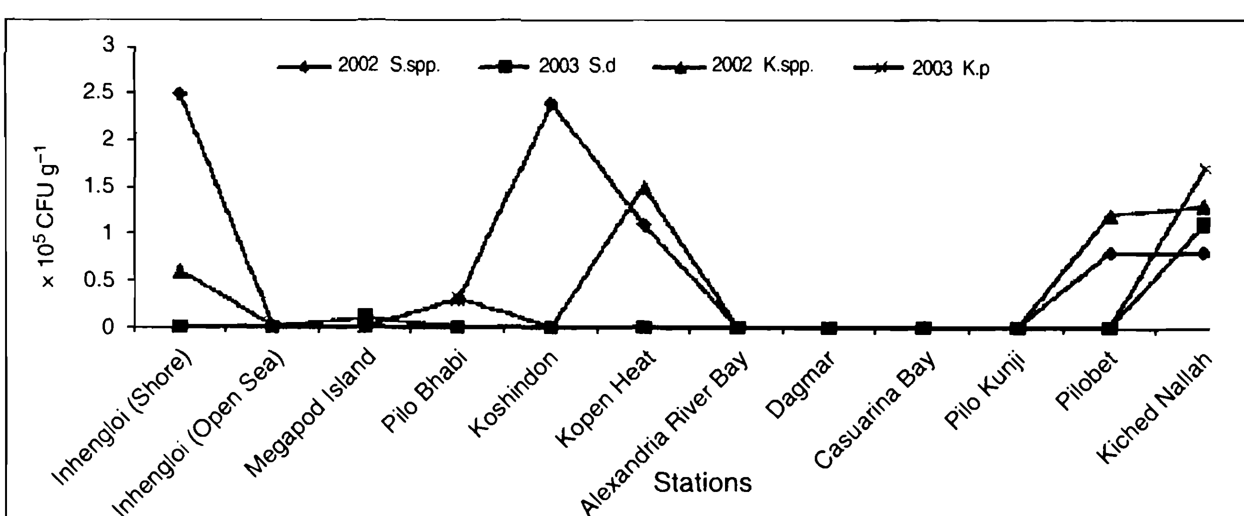

Fig. 17. Population density of *Shigella* and *Klebsiella* in sediments recorded from the west coast of the Great Nicobar island

sediment samples respectively in 2002. During the year 2003, it was observed only in the water sample (47 × 10^2 CFU ml^{-1}).

Population density of *Klebsiella* spp. was 80 × 10^2 CFU ml^{-1} in 2002 while in 2003, the population density of *K. pneumoniae* was recorded as 27 × 10^2 CFU ml^{-1} in water sample. In the case of sediment sample, it was observed as 1.3 x 10^5 CFU g^{-1} and 1.0 × 10^5 CFU g^{-1} in 2002 and 2003, respectively.

North Coast (Figs. 18 and 19) : In the water samples, population density of *Shigella* spp. was found to be lower (10 × 10^2 CFUml^{-1}) in Pryce Channel and higher (13 × 10^2 CFUml^{-1}) in Safeath Bhalu during 2002. Population density of *Klebsiella* spp. was found to be lower (3 × 10^2 CFUml^{-1}) in Pryce Channel and higher (116 × 10^2 CFUml^{-1}) in Safeath bhalu during 2002. In the sediment samples, both *Shigella* spp. and *Klebsiella* spp. were not observed.

East Coast (Figs. 20 and 21) : In water, population density of *E. coli* was lower (0.5 × 10^2 CFU ml^{-1}) at Laful Bay and higher (88 × 10^2 CFU ml^{-1}) at Galathea (river) mouth. In sediments, population density of *E. coli* was minimum (0.01 × 10^5 CFU g^{-1}) in Laful Bay and maximum (1.5 × 10^5CFU g^{-1} in Campbell Bay, during 2003.

West Coast (Figs. 22 and 23) : In the west coast, population density of *E. coli* ranged from 1 × 10^2 CFU ml^{-1} at Inhengloi (shore) to 69 × 10^2 CFU ml^{-1}at Kiched nallah in the water samples. In sediments, it ranged from 0.2 × 10^5 CFU g^{-1} (Alexandria (river) Bay) to 12. × 10^5 CFU g^{-1} (Kopenheat) during 2003.

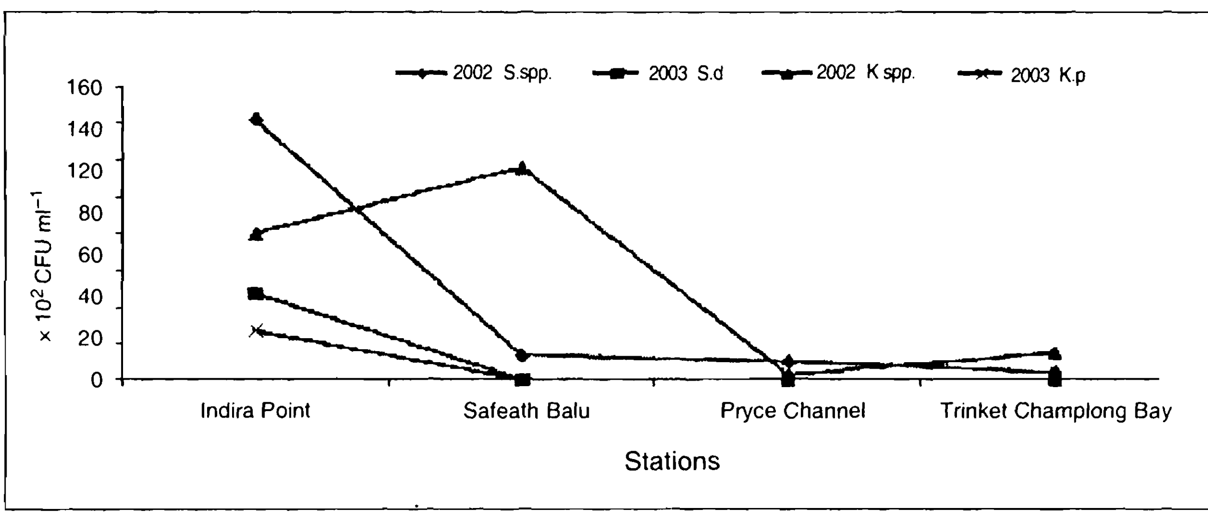

Fig. 18. Population density of *Shigella* and *Klebsiella* in water recorded from the south and north coasts of the Great Nicobar Island

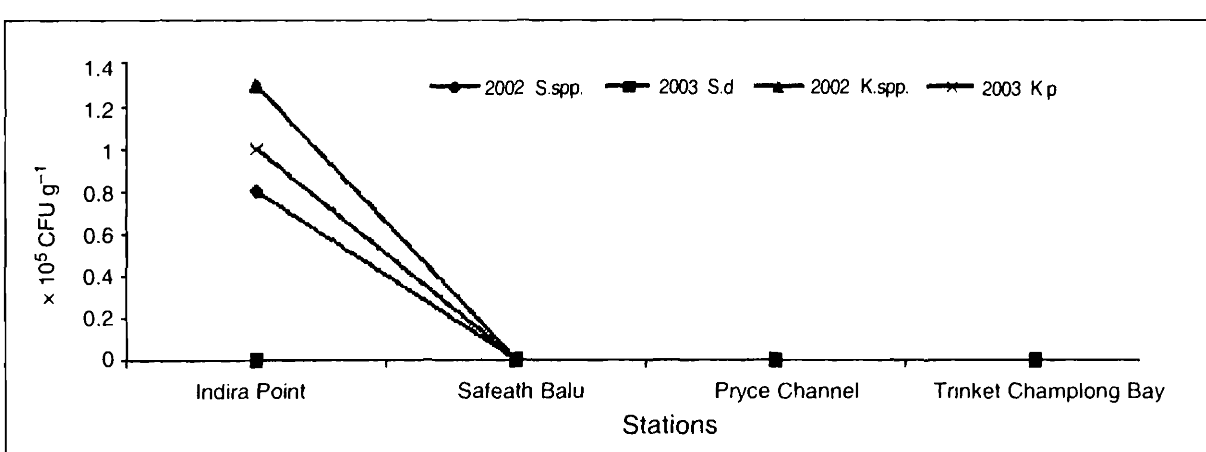

Fig. 19. Population density of *Shigella* and *Klebsiella* in sediments recorded from the south and north coasts of the Great Nicobar Island

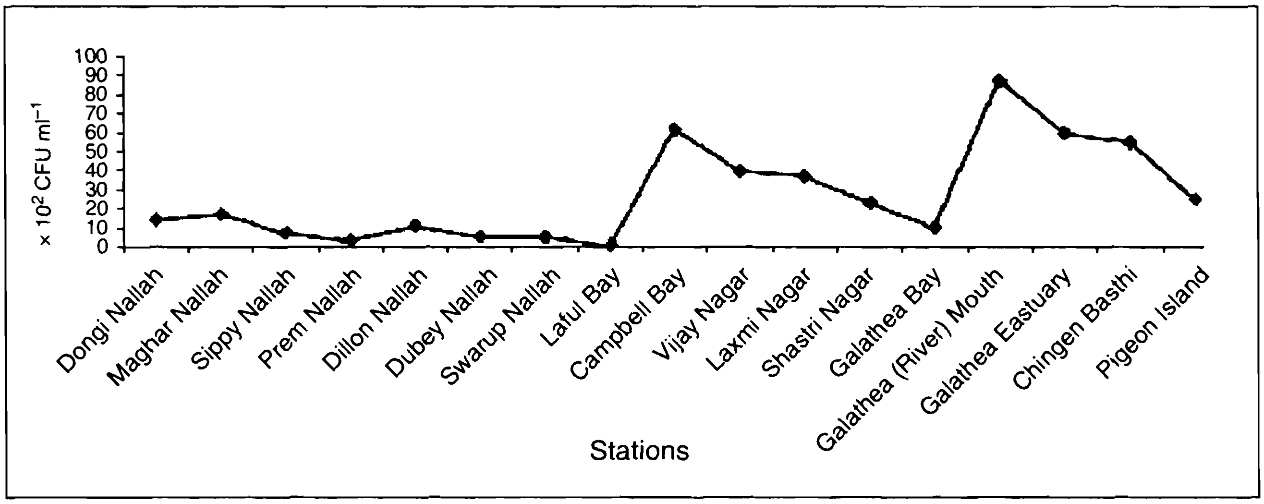

Fig. 20. Population density of *E.coli* recorded in water from the east coast of the Great Nicobar Island during 2003

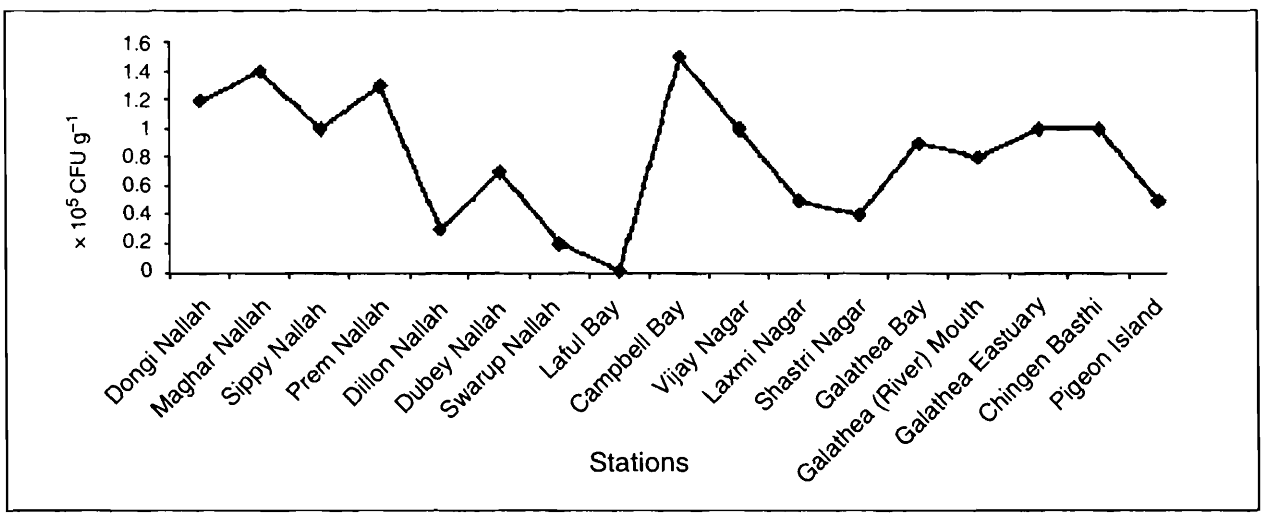

Fig. 21. Population density of *E.coli* recorded in sediments from the east coast of the Great Nicobar Island during 2003

South Coast (Figs. 22 and 23) : At Indira Point, population density of *E. coli* was 40 x 10^2 CFU ml^{-1} in water and 0.4 x 10^5 CFU g^{-1} in sediments during 2003.

East Coast (Figs. 24 and 25) : In the water samples, population density of *S. faecalis* was found to be lower (2 CFU ml^{-1}) at Galathea estuary and higher (80 CFU ml^{-1}) at Galathea Bay during 2002. In 2003, this bacterial population density was lower (3 CFU ml^{-1}) in Sippy nallah and higher (70 CFU ml^{-1}) in Campbell Bay.

The lowest population density (2 x 10^2 CFU g^{-1}) was observed at Dubey nallah and the highest population density (160 x 10^2 CFU g^{-1}) was found at Galathea Bay in the sediment samples during 2002. In 2003, the lower population density (1x 10^2 CFU g^{-1}) was recorded at Dubey nallah and the higher density (67 x 10^2 CFU g^{-1}) was recorded at Dongi nallah.

West coast (Figs. 26 and 27) : In the water samples, population density of *S. faecalis* ranged from 1 CFU ml^{-1} (Megapod Island) to 19 CFU ml^{-1} (Kiched nallah) in 2002 while in 2003, it was minimum (1 CFU ml^{-1}) at Koshindon and maximum (15 CFU ml^{-1}) at Kiched nallah.

In the sediments, it was found to be lower (16 x 10^2 CFUg^{-1}) in Pilobhabi and higher (59 x 10^2 CFUg^{-1}) in Koshindon in 2002. In 2003, it could not be observed from the sediment samples.

South Coast (Figs. 28 and 29) : Population density of *S. faecalis* in the water sample of Indira Point was 6 CFU ml^{-1} and 40 CFU ml^{-1} during 2002 and 2003 respectively.

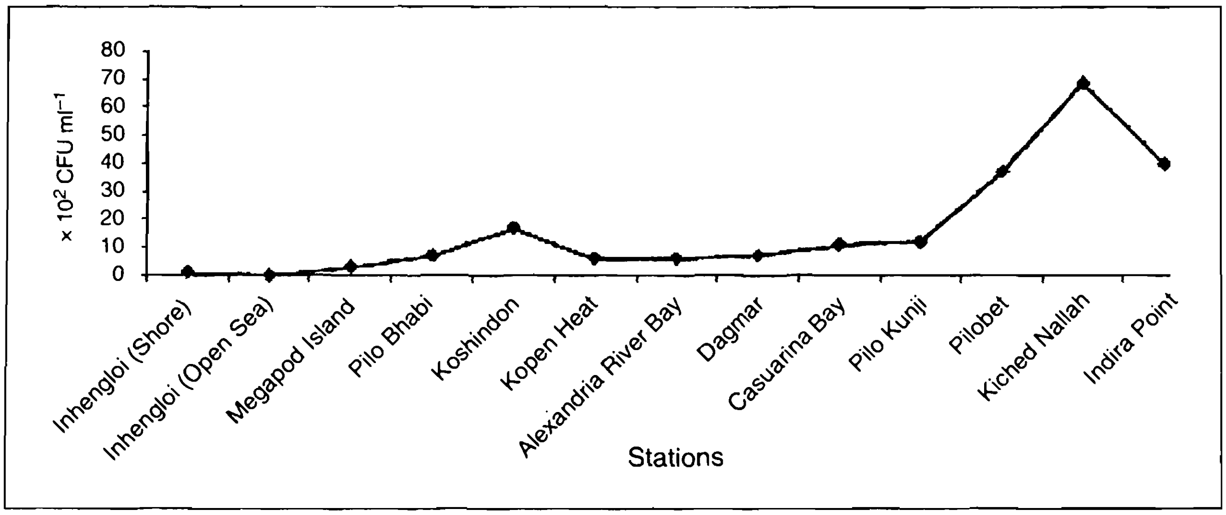

Fig. 22. Population density of *E.coli* recorded in water from the west and south coasts of the Great Nicobar Island during 2003

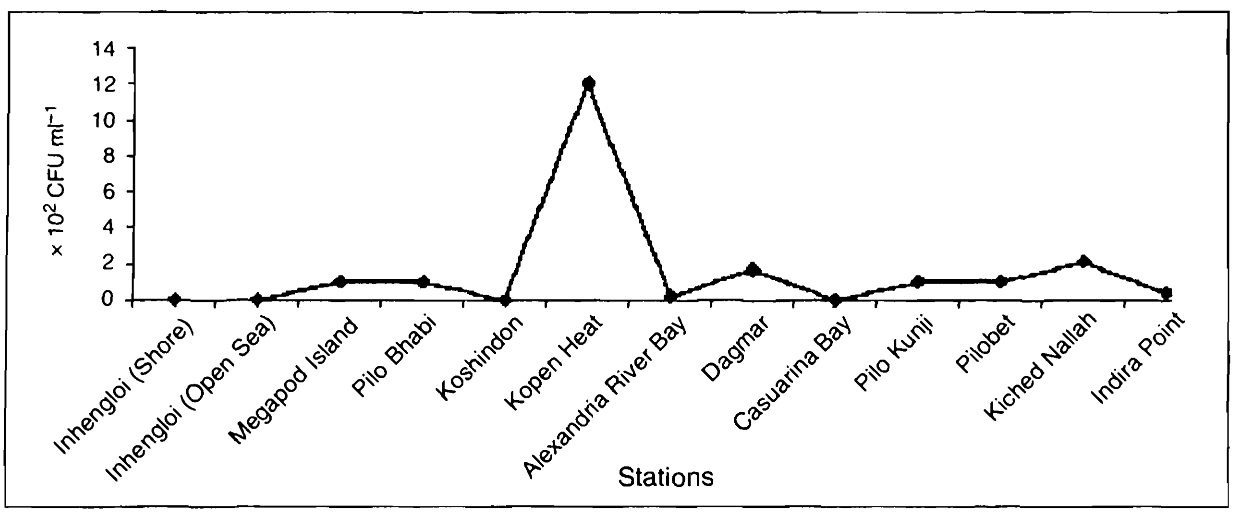

Fig. 23. Population density of *E.coli* recorded in sediments from the west and south coasts of the Great Nicobar Island during 2003

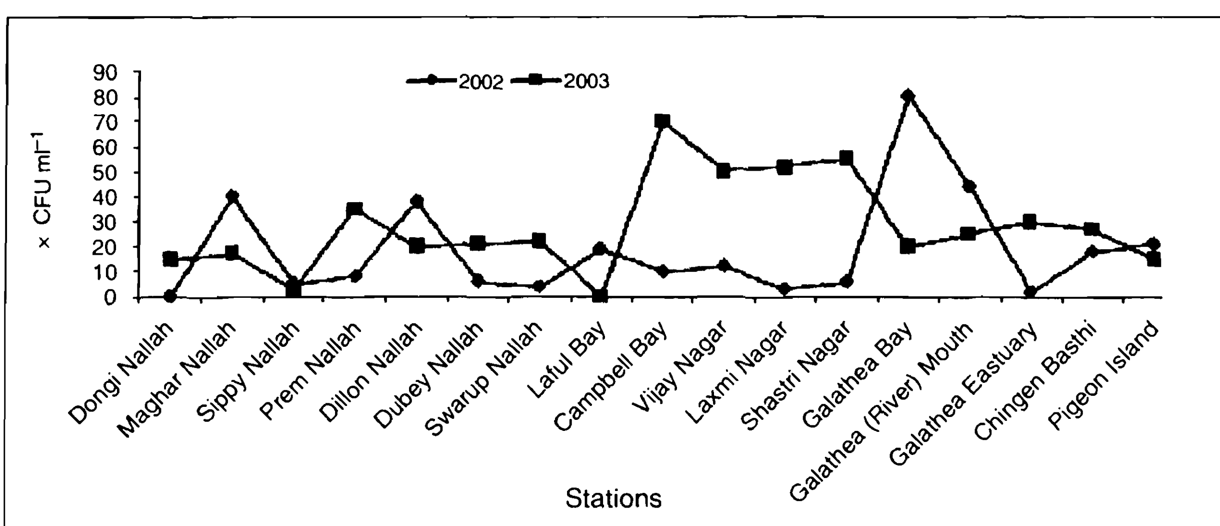

Fig. 24. Population density of *Streptococcus faecalis* in water recorded from the east coast of the Great Nicobar Island

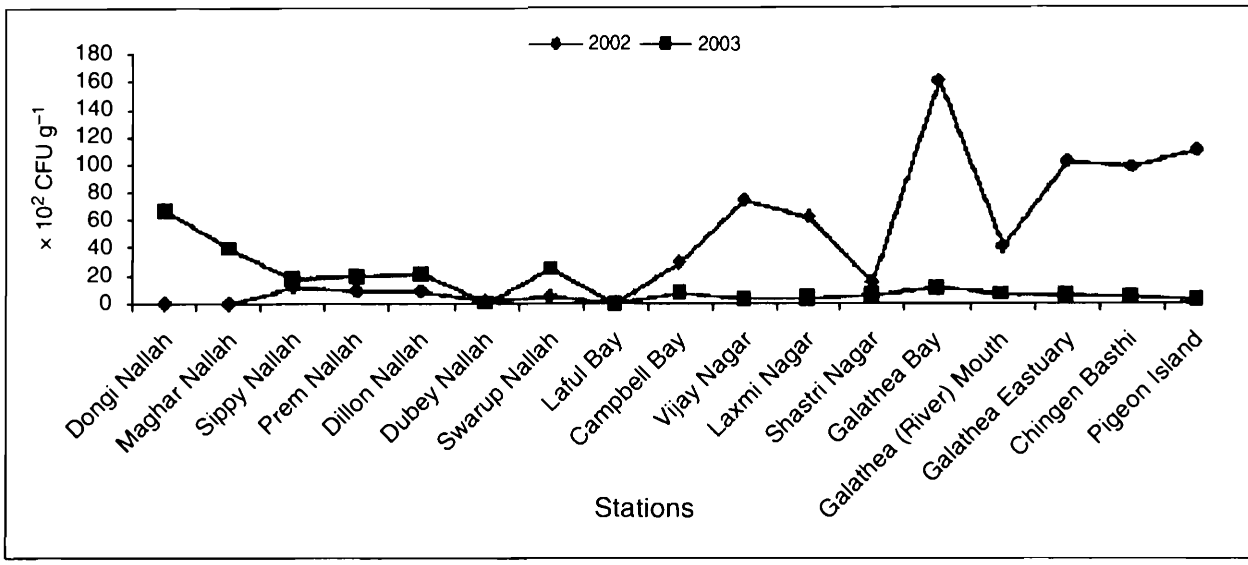

Fig. 25. Population density of *Streptococcus faecalis* in sediments recorded from the east coast of the Great Nicobar Island

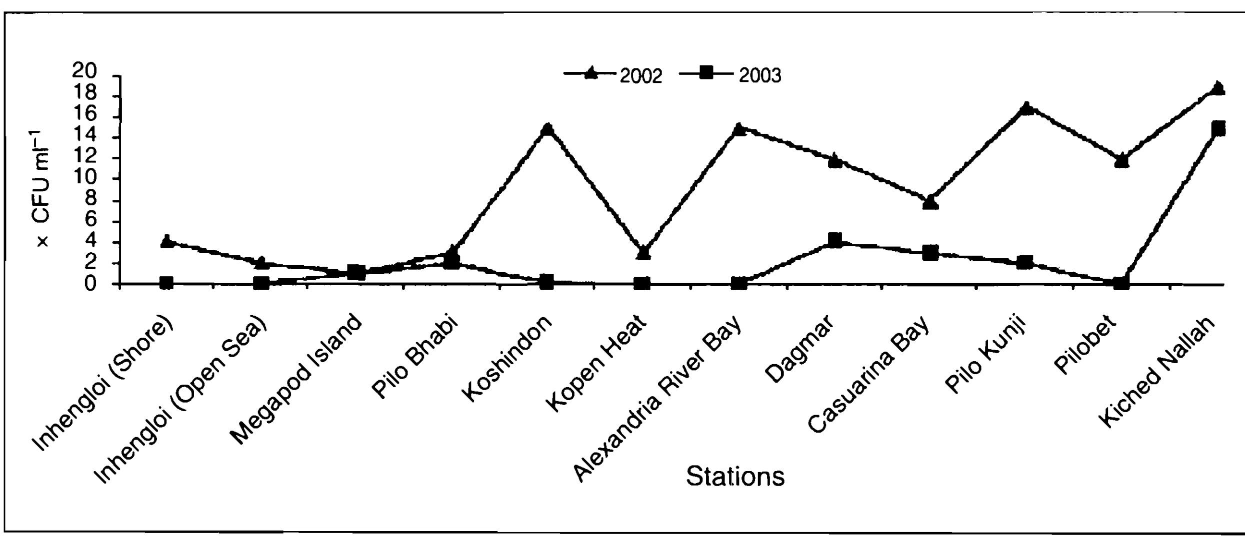

Fig. 26. Population density of *Streptococcus faecalis* in water recorded from the west coast of the Great Nicobar Island

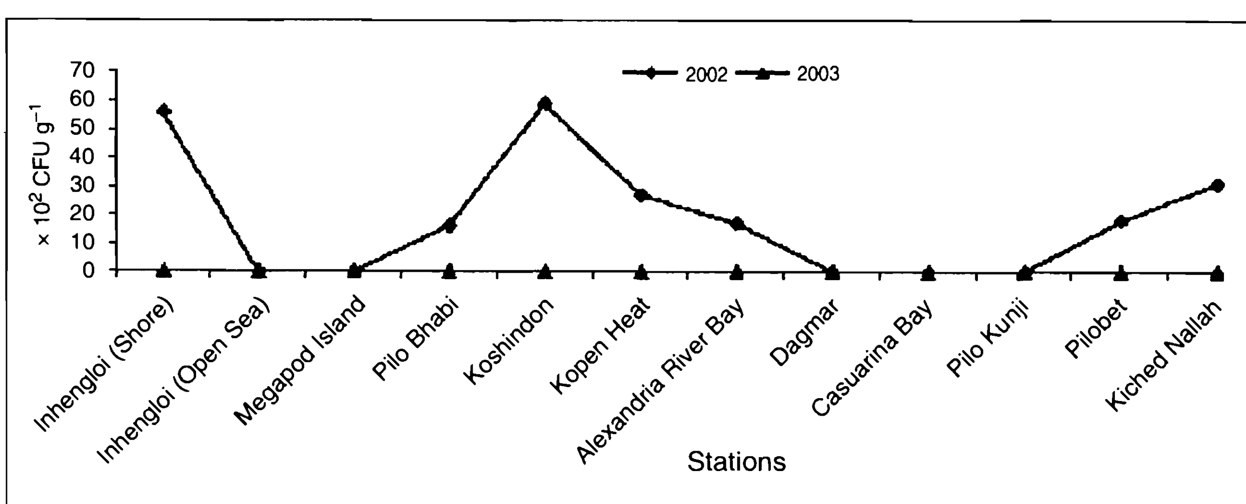

Fig. 27. Population density of *Streptococcus faecalis* in sediments recorded from the west coast of the Great Nicobar Island

In the sediment samples, population density of *S. faecalis* was recorded as 31 × 10^2 CFU g^{-1} in 2002 and it was 44 × 10^2 CFU g^{-1} in 2003.

North Coast (Figs. 28 and 29) : Population density of *S. faecalis* was recoded in the north coast region only during 2002. Population density of *S. faecalis* in the water sample was lower (13 CFU ml^{-1}) in Pryce Channel and higher (23 CFU ml^{-1}) in Safeath Bhalu. Sediment sample could be collected only from the Trinket Champlong Bay in the north coast and the population density of *S.faecalis* was 3 × 10^2 CFU g^{-1} at this station.

East Coast (Figs. 30 and 31) : In the water samples, population density of *Pseudomonas aeruginosa* was found to be lower (5.5 CFU ml^{-1}) in Dillon nallah and higher (139 CFU ml^{-1}) in the Galathea river mouth during 2002. In the year 2003, density of *P. aeruginosa* was lower (1 CFU ml^{-1}) in Magar nallah and higher (44 CFU ml^{-1}) in Galathea estuary.

In 2002, in the sediment samples, minimum population density of 7 × 10^2 CFU g^{-1} was found at Swarup nallah and the maximum population density of 500 × 10^5 CFU g^{-1} was noticed at Galathea estuary. In 2003, the minimum population density of 1x 10^2 CFU g^{-1} was recorded at Dubey nallah and the maximum (67 × 10^2 CFU g^{-1}) was recorded at Galathea river mouth.

West Coast (Figs. 32 and 33) : Minimum population density (15 CFU ml^{-1}) was observed at Casuarina Bay and the maximum (131 CFU ml^{-1}) was observed at Inhengloi (shore) in the water samples during 2002. In the year 2003, minimum population density of *P. aeruginosa* was observed (1 CFU ml^{-1}) at Pilokunji and the maximum density (45 CFU ml^{-1}), at Alexandria (river) Bay.

During 2002, minimum population density of *P. aeruginosa* (8 × 10^2 CFU g^{-1}) was observed at Pilobet and the maximum density (38 × 10^2 CFU g^{-1}) was observed at Inhengloi (shore) in the

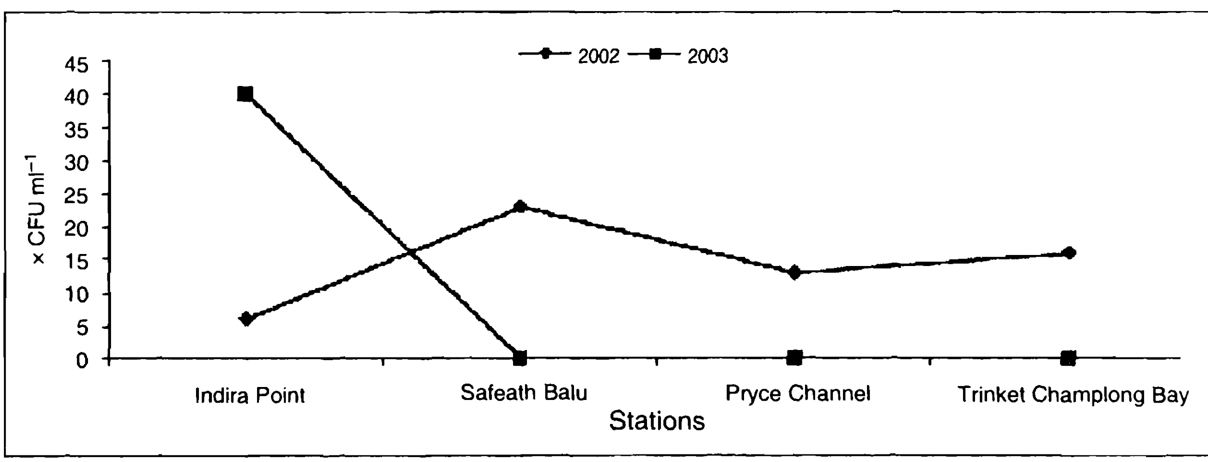

Fig. 28. Population density of *Streptococcus faecalis* in water recorded from the south and north coasts of the Great Nicobar Island

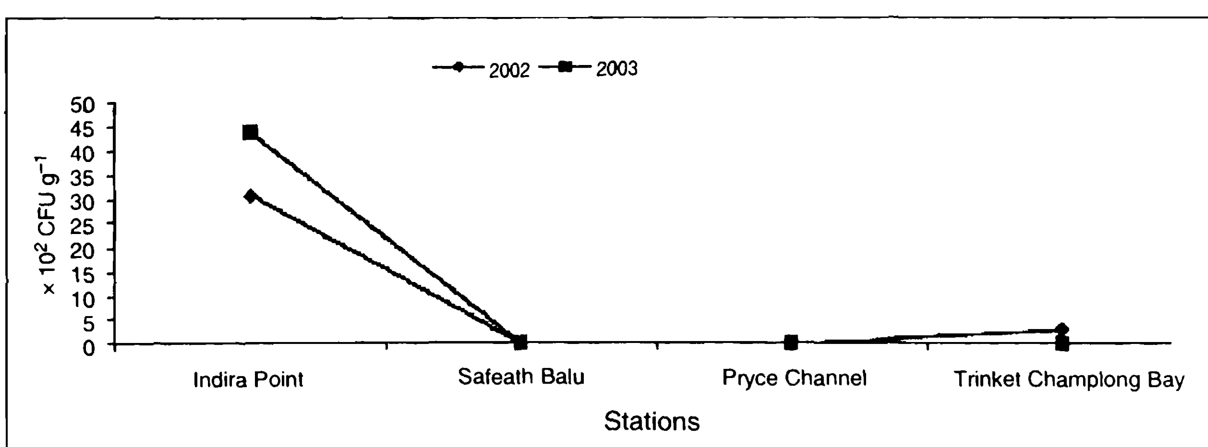

Fig. 29. Population density of *Streptococcus faecalis* in sediments recorded from the south and north coasts of the Great Nicobar Island

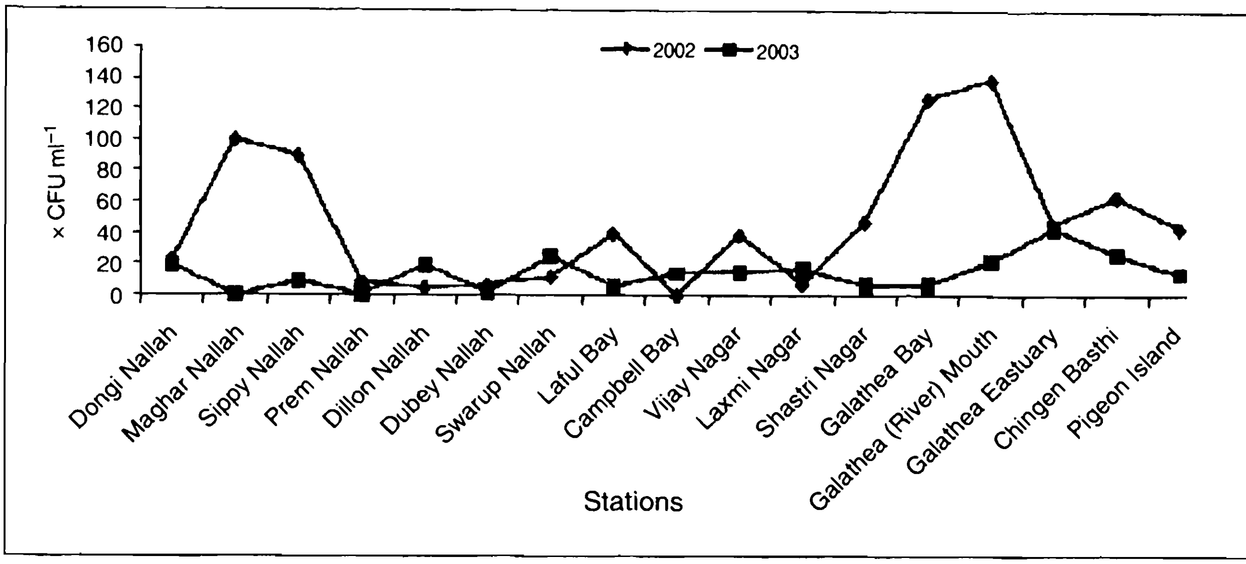

Fig. 30. Population density of *Pseudomonas aeruginosa* in water recorded from the east coast of the Great Nicobar Island

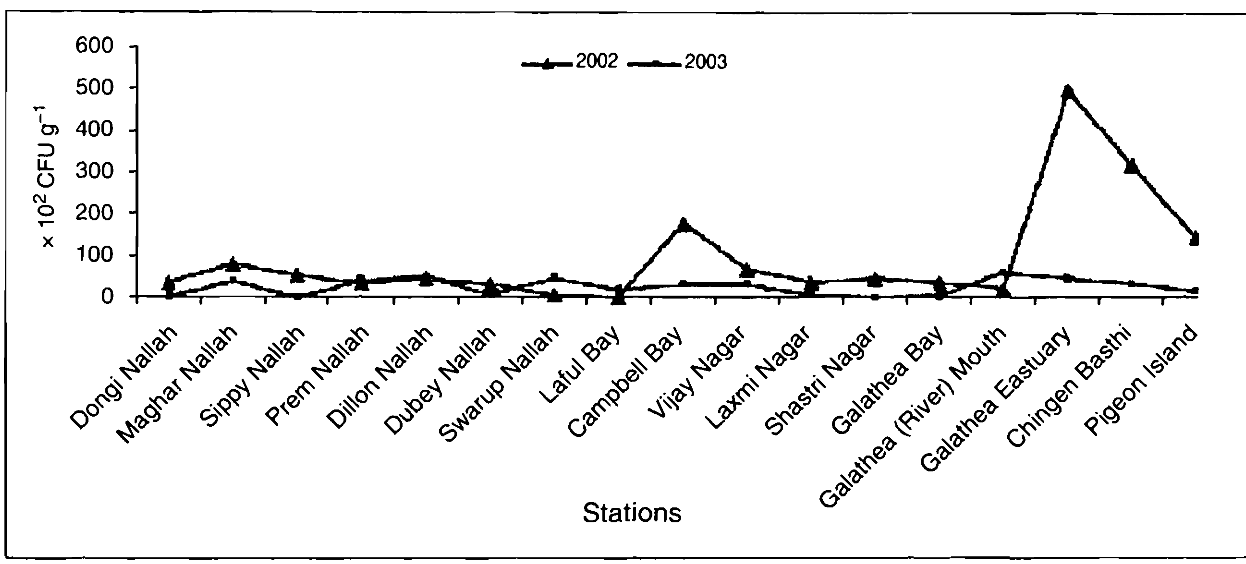

Fig. 31. Population density of *Pseudomonas aeruginosa* in sediments recorded from the east coast of the Great Nicobar Island

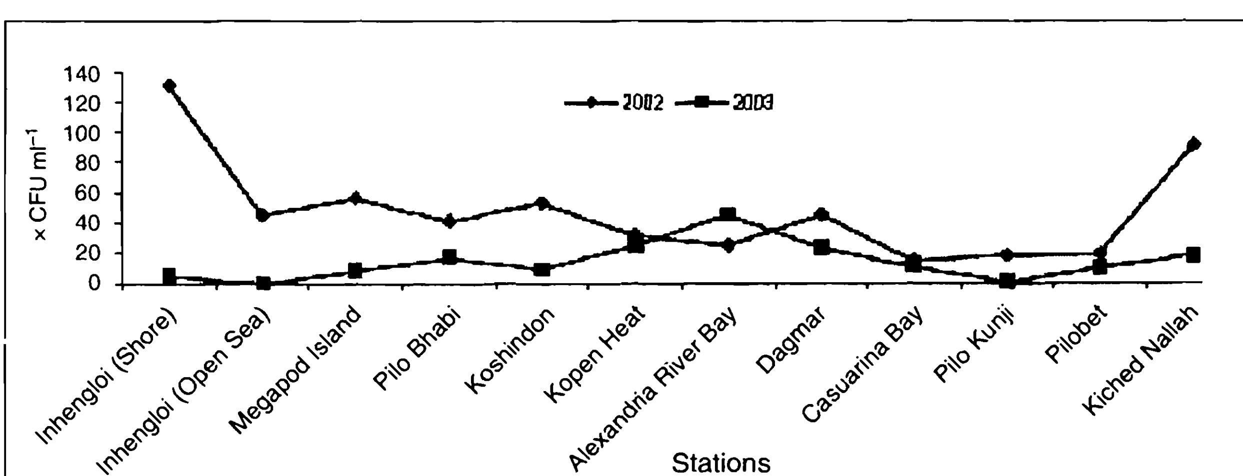

Fig. 32. Population density of *Pseudomonas aeruginosa* in water recorded from the west coast of the Great Nicobar Island

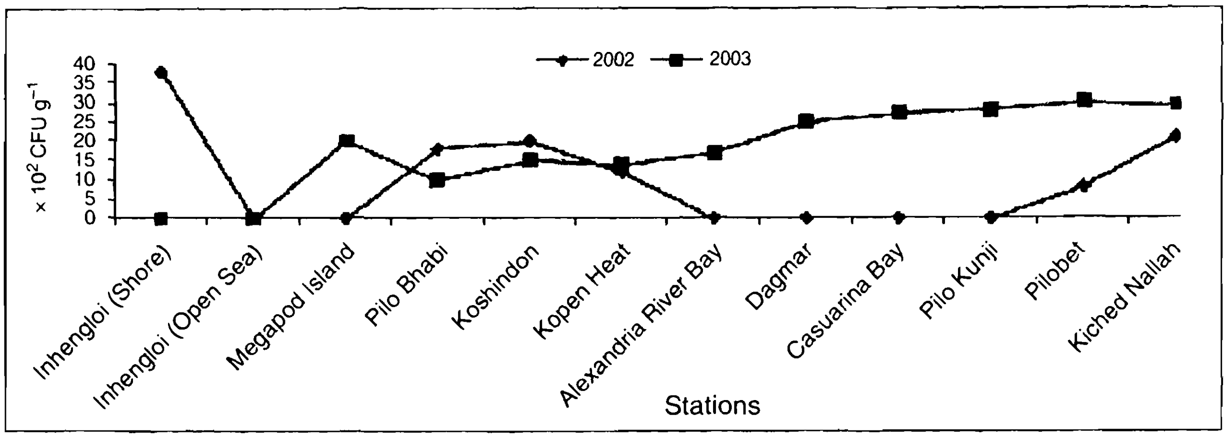

Fig. 33. Population density of *Pseudomonas aeruginosa* in sediments recorded from the west coast of the Great Nicobar Island

sediments samples. In 2003, it was lower (10×10^2 CFU g^{-1}) at Pilobhabi and higher (30×10^2 CFU g^{-1}) at Kiched nallah.

South Coast (Figs. 34 and 35) : Population density of *P. aeruginosa* in water at Indira Point was 20 CFU ml^{-1} both in 2002 and 2003. In the sediment sample, density of *P. aeruginosa* was maximum (140×10^2 CFU g^{-1}) and minimum (20×10^2 CFU g^{-1}) during 2002 and 2003 respectively.

North coast (Figs. 34 and 35) : In the water sample, population density of *P. aeruginosa* was lower (31 CFU ml^{-1}) in Pryce Channel and higher (52 CFU ml^{-1}) in Safeath Bhalu in 2002. In the sediment sample, population density was 11×10^2 CFU g^{-1} at Trinket Champlong Bay.

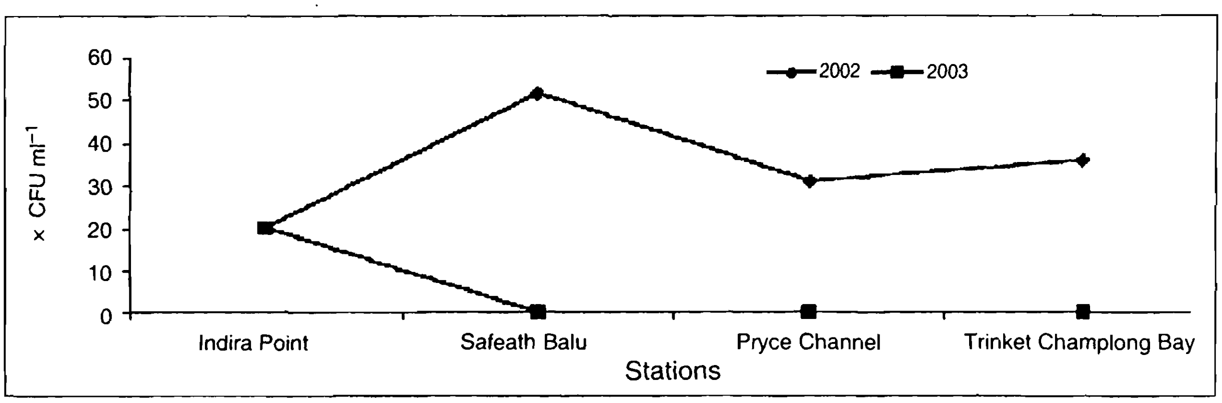

Fig. 34. Population density of *Pseudomonas aeruginosa* in water recorded from the south and north coasts of the Great Nicobar Island

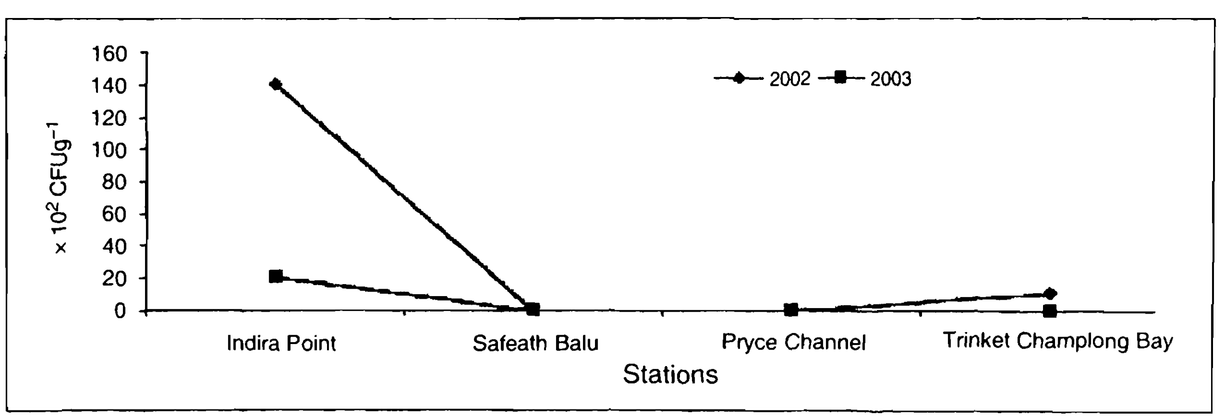

Fig. 35. Population density of *Pseudomonas aeruginosa* in sediments recorded from the south and north coasts of the Great Nicobar Island

DISCUSSION

Studies on the microorganisms of the Andaman and Nicobar Islands are very scanty, particularly bacterial flora of the Great Nicobar Island have not been studied so far. In the present study, some useful information on the bacterial resources of the Great Nicobar Island has been collected, which would pave way to understand the microbial resources of this region and help manage it and to exploit these resources for human prosperity in future. Population density of Total Heterotrophic Bacteria (THB) in water was lower (13×10^2 CUF ml^{-1}) at Lakshmi nagar and higher (2922×10^2 CUF ml^{-1}) at Galathea estuary and in the sediment sample, it ranged from 0.82×10^5 CUF g^1 at Indira Point to 2116.8×10^5 CUF g^{-1} at Galathea estuary during the first year (2001).

In the second year (2002) both the THB and pathogenic bacterial flora have been studied from the east, west, south and north coasts regions (33 stations). The THB population density in water was lower (30×10^2 CUF ml^{-1}) at Magar nallah and higher (906×10^2CUF ml^{-1}) at Campbell Bay. In the sediment sample, the THB population density was lower (2×10^5 CUF g^{-1}) at Laful Bay and higher (1032×10^{-5} CUF g^{-1}) at Galathea estuary. In the third year (2003), THB population density was lower (1.5×10^2 CFU ml^{-1}) at Laful Bay and higher (670×10^2 CFU ml^{-1}) at Dubey nallah. In the sediment samples, it was lower (1×10^5 CUF g^{-1}) at Laful Bay and higher (1547×10^5 CFUg^{-1}) at Galathea estuary.

Present investigation on the population density of THB in the water and sediment samples of the Great Nicobar coast has revealed that the east coast of the island embraces more bacterial population density than the other coasts. It could be due to the existence of comparatively greater anthropogenic pressure and diverse marine habitats viz. nallahs, dead and live coral habitats, mangroves and estuaries along the east coast region than the other coasts of the island.

Further, distribution of THB was more in the sediment samples than in water and more number of bacterial genera (*Pseudomonas, Vibrio, Streptococcus, Esherichia, Klebsiella, Flavobacterium, Bacillus, Shigella, Corynebacterim* and *Salmonella*) were recorded from the sediments of the Galathea estuary. This could be attributed to the fertility of the sediments in the estuarine environment, as the sediment nutrients and the particulate organic carbon could promote the growth of THB in the sediments. This would support the findings of Yanagita *et al.* (1971), Martin Abraham (1981) and Sathiamurthy (1992) who have stated that there would be increased availability of nutrients due to fresh water inflow, along with the higher density of bacterial population. The present findings are also in conformity with that of Ravi Kumar (1995) who has stated that mangrove sediments harbour larger bacterial populations than the water column.

The lower bacterial population density (1×10^5 CUF g^{-1}) observed in the sandy shore of the Laful Bay could be ascribed to the fact that the organic matter content in the sand (to promote the growth of THB) would be less as compared to that of clay (Pomeroy *et al.*, 1965; Ayyakkannu and Chandramohan, 1970).

Presence of enteric bacteria in the marine environment and seafood raises considerable alarm because of the dangers that these pathogenic members pose to human (Natarajan and Ramesh, 1987). During the second and third year (2002 and 2003) periods, pathogenic bacterial flora were collected and studied from 29 stations, covering the east, west, south and north coasts of the Great Nicobar Island. The pathogenic bacterial (*Vibrio, Escherichia coli, Salmonella, Shigella, Klebsiella, Pseudomonas* and also *Streptococcus feacalis*) population densities were as follows.

Population densities of the pathogenic bacteria viz. *Vibrio cholerae* and *V.parahaemolyticus* in water were lower (1×10^2 CFU ml^{-1} and 0.04×10^2 CFU ml^{-1} at Laful Bay and higher (320×10^2 CFU ml^{-1} and 60×10^2 CFU ml^{-1}) at Galathea river mouth and Inhengloi (shore), during 2002. In the sediment sample, these bacterial population densities were minimum (0.2×10^5 CFU g^{-1} and 0.1×10^5 CFU g^{-1}) at Pigeon Island and Magar nallah and were maximum (3.2×10^5 CFU $g^{-1}$and 13.2×10^5 CFU g^{-1}) at Vijay nagar and Pilobet respectively during 2002.

In 2003, in the water samples, population densities of the *Vibrio* spp. were lower (1.2×10^2 CFU ml^{-1} and 1×10^2 CFU ml^{-1}) at the Campbell Bay and Dubey nallah and were higher (260×10^2 CFU ml^{-1} and 30×10^2 CFU ml^{-1}) in the Galathea river mouth and Galathea estuary. In sediments, the population density of *V. cholerae* ranged from 0.04 × 10^5 CFU g^{-1} to 80 × 10^5 CFU g^{-1} at Dubey nallah and Prem nallah respectively. Population of *V. parahaemolyticus* density was recorded lower 0.13 × 10^5 CFU g^{-1} at Indira Point and higher (15 × 10^5 CFU g^{-1}) at Pilobet.

In 2002 and 2003, among all the stations surveyed in the Great Nicobar Island, population density of *Salmonella* spp. could be recorded only in the east and south coasts. In 2002, it was recorded only from Sippy nallah and its density was 1 × 10^2 CFU ml^{-1}. In 2003, it was observed in water (18 × 10^2 CFU ml^{-1}) and sediments (11 × 10^5 CFU g^{-1}) in Galathea estuary (east coast). It could be recorded only in water sample (1 × 10^2 CFU ml^{-1}) at Indira Point (south coast). In 2002, in the water sample, population density of *Shigella* spp. was lower (1 × 10^2 CFU ml^{-1}) at Pilokunji and higher (142 × 10^2 CFU ml^{-1}) at Indira Point. In the sediments, it was minimum (0.1 × 10^5 CFU g^{-1}) at Megapode Island and Magar nallah and maximum (3.7 × 10^5CFU g^{-1}) at Vijay nagar during 2002.

In 2003, in water, *S. dysenteriae* population density was minimum (1 × 10^2 CFU ml^{-1}) at Galathea Bay and maximum (88 x10^2 CFU ml^{-1}) at Galathea river mouth. In sediments, it ranged from 0.1 × 10^5 CFU g^{-1} at Megapod Island to 3.5 × 10^5 CFU g^{-1} at Prem nallah and Galathea estuary during 2003. In 2002, in water sample, population density of one of the enteric pathogens *Klebsiella* spp. was lower (1 × 10^2 CFU ml^{-1}) at Magar nallah and higher (128 × 10^2 CFU ml^{-1}) at Galathea Bay. In sediments, it was minimum (0.1 × 10^5 CFU g^{-1}) at Prem nallah and the maximum (12 × 10^5 CFU g^{-1}) at Sastri Nagar during 2002.

Population density of *K. pneumoniae* in water was lower (1 × 10^2 CFU ml^{-1}) at Vijay nagar and higher (67 × 10^2 CFU ml^{-1}) at Galathea river mouth. In sediments, it was lower (0.01 × 10^5CFU g^{-1}) at Galathea river mouth and higher at Vijay nagar during 2003. *E. coli* population density was recorded only in 2003. In water, it was lower (0.5 × 10^2 CFU ml^{-1}) at Laful Bay and higher (88 × 10^2 CFU ml^{-1}) at Galathea river mouth. In sediments, it was minimum (0.01 × 10^5CFU g^{-1}) at Laful Bay and maximum (12 × 10^5 CFU g^{-1}) at Kopenheat. In 2002, population density *S. faecalis* was lower (1 CFU ml^{-1}) in water at Megapod Island and higher (80 CFU ml^{-1}) at Galathea Bay. In sediments, it was minimum (2 × 10^2 CFU g^{-1}) at Dubey nallah and maximum (160 × 10^2 CFU g^{-1}) at Galathea Bay.

In 2003, population density *S. faecalis* was lower (1 CFU ml^{-1}) in water at Koshindon and higher (70 CFU ml^{-1}) at Campbell Bay. In sediments, it was lower (1 × 10^2 CFU g^{-1}) at Dubey nallah and higher (67 × 10^2 CFU g^{-1}) at Dongi nallah. In 2002, population density of *Pseudomonas areuginosa* was found be lower (5.5 CFU ml^{-1}) in Dillon nallah and higher (139 CFU ml^{-1}) in Galathea river mouth. In sediments, it was minimum (7 × 10^2 CFU g^{-1}) at Swarup nallah and maximum (140 × 10^2CFU g^{-1}) at Indira Point. In 2003, in water, it was lower (1 CFU ml^{-1}) at Magar nallah and higher (45 CFU ml^{-1}) at Alexandria (river) Bay. In sediments, it was minimum (1 × 10^2 CFU g^{-1}) at Dubey nallah and maximum (67 × 10^2 CFU g^{-1}) at Galathea river mouth.

Investigations on the distribution of the pathogenic bacteria in the Great Nicobar coastal waters have revealed the presence of *Pseudomonas* sp., *Vibrio* spp., *Streptococcus* sp., *Salmonella* spp., *Escherchia coli*, and species of *Shigella* and *Klebsiella*. Among these pathogenic forms, *Pseudomonas* sp. was dominant (25 per cent) followed by *Vibrio* spp. (18.5 per cent) and *Streptococcus* sp. (15.5 per cent). Predominance of *Pseudomonas* among the other groups in the marine environment is being reported from all parts of the world. Higher *Pseudomonas* population density recorded from the dead coral reef environment (Indira Point) in the present study lends support to the findings of Kannapiran (1997) who has reported similar feature from the dead coral sediments of the Gulf of Mannar.

Vibrio spp. formed the second dominant group in the Great Nicobar Island coast which reflects on the quality of the marine environment here. *Vibrio* spp. have been reported from many parts of the world. Kasthuri Venkateswaran *et al.* (1981) reported that incidence of Vibrios (19.7 per cent) pathogenic to humans in the Japanese waters posed threat to the local inhabitants. Presence of higher population density of *V. cholerae* was recorded in the present study in the dead coral reef environment (Indira Point) than the live coral reef environment (Galathea Bay). This could have been mainly because of the presence of higher organic content in the dead coral reef environment to support these bacteria. *Vibrio* sp. were also isolated from the Galathea estuary (mangrove environment) of the Great Nicobar. Likewise, Martin Abraham (1981) reported the occurrence of *Vibrio* spp. in the mangrove environment of Pitchavaram, south east coast of India.

Another pathogenic bacterium *Streptococcus faecalis* was isolated during the present study period from the Indira Point, where dead coral are abundant. The present study has also revealed the occurrence of higher population density of *S. faecalis* in Galathea Bay (80 CFU ml^{-1}) and mangrove dominated Galathea estuary (40 CFU ml^{-1}). Likewise, Matonkar (1986) have reported *S.faecalis* from the mangrove swamps of Goa.

In the present study, presence of the enteric pathogens viz. *Escherchia coil, Klebsiella pneumoniae, Shigella dysenteriae,* and *Salmonella* spp. has been noticed in the different coastal locations of the Great Nicobar Island. More interestingly, Galathea estuary (mangrove environment) has recorded higher population density of all these bacteria. Further, higher population densities of these bacteria were noticed in the sediment samples, than in water samples, as was earlier reported by of Abhay Kumar and Dube (1991). This kind of trend has been reported by many investigators (Kaneko, 1973; Ayyamperumal, 1992; Velammal, 1993). The pathogens though allochthonous to the estuarine region, could have established themselves very well in that environment, especially in the sediments where the organically rich clayey sediment fractions, ideal for their survival, are copious.

At Laful Bay and Inhengloi, *E.coli* population density was lower and other pathogenic forms viz. *K. pneumoniae S. dysenteriae,* and *Salmonella* spp. were not at all present. This could be due to the fact that the sandy substrate prevailing here could not hold the pathogens because of continuous dislodgement of bacteria (Grimes, 1980).

Further, the present study has revealed that the pathogenic bacterial diversity and density were more along the east coast stations than the west and north coasts. This could be correlated to the anthropogenic activities which are more along the east coast including the Campbell Bay.

Ecological niches of selected groups of bacteria

The Great Nicobar Island is bestowed with live coral reefs, dead coral reefs, Nallahs (estuary), mangroves, sandy shore and rocky coasts. The present survey on THB and pathogenic bacteria has revealed the presence of higher densities of bacterial populations in the mangrove environment (Galathea estuary) and it could be mainly because of the presence of higher amount of mangrove litter and large-scale input of organic matter into this environment through the Galathea river, from its catchment area (tropical rain forest).

Studies on the distribution of the pathogenic bacteria in the Great Nicobar coastal waters have revealed the presence of *Pseudomonas* sp. (25 per cent), *Vibrio* spp. (18.5 per cent), *Streptococcus* spp. (15.5 per cent), *Escherchia coli, Salmonella* spp. and species of *Shigella* and *Klebsiella*. Higher population densities of *Pseudomonas* and *Vibrio* spp. have been recorded from the dead coral reef environment (Indira Point), where inorganic and organic materials, suitable for the growth of these bacteria, are more.

Mangrove environment (Galathea estuary) was found to support good growth of the enteric pathogens *viz. Escherchia coli, Klebsiella pneumoniae, Shigella dysenteriae* and *Salmonella* spp. than the other coastal locations of the Great Nicobar Island. It is worth mentioning here that the estuarine environment is unique for microbes because of the constantly changing environmental parameters that create a wide diversity of ecological niches (Atlas, 1998). Further, the range of saline concentrations creates three types of niches *viz.* fresh water, brackish water, and saline water. Each such niche is occupied by organisms that are adapted to those conditions prevailing here. This form of ecological partitioning would reduce exploitative competition and enhance the growth of different types of microbial communities (Campbell, 1993).

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Chapter 04

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 77-87, 2010

LATE QUATERNARY FAUNAL (PROTOZOA) DIVERSITY OF SOUTH ANDAMAN SEDIMENTS, ANDAMAN SEA, BAY OF BENGAL

C. RAJSHEKHAR*
Department of Palaeobiology, Agharkar Research Institute, G.G. Agarkar Road, Pune 411 004

INTRODUCTION

Foraminifera are single cellular organisms (protozoa) capable of highlighting the faunal diversity and the depositional of environment (Haslett, 2002). They have hard shell called test invariably made up of $CaCO_3$. Preservation of the soft parts of the animal in the sediments are extremely rare but the test gets preserved and are used for various paleoenvironmental analyses. The preserved parts and skeleton is termed as fossil. Fossils are extremely useful as their presence in the sediments highlight various environmental factors such as salinity, temperature, bathymetry, climatic conditions, pollution, oceanic condition, ecology, evolution, substrate etc. The foraminifera are purely marine in habitat. However, there are a few called Thecomoebians occur near the boundary of fresh and marine waters. Foraminifera depending upon their chemical composition broadly occur in three groups *viz.*, calcareous, porcellaneous and agglutinated. These groups have their own characteristics and they on the basis of the morphological characters are further established in to several families, genera and species.

As mentioned above, there are various environments such as oceans, seas, bays, gulfs, estuaries, lagoons, shores etc. and each one has its own characteristic foraminiferal assemblages. To examine critically the environments under which a particular sediment is deposited, paleozoologists and micropaleontologists essentially consider the modern distribution of foraminifera. It is an established fact that the foraminiferal fauna around 6000 years B.P. has almost identical distribution that closely matches with the present day distribution pattern (Haslett, 2002) therefore, sediments bearing the above age have immense potential to reveal the depositional history more meaningfully.

The knowledge of the fauna of the immediate past has immense impact on the modern distribution and its comprehensive study. This information is not only useful in knowing the faunal diversity but also significant from the evolution view point. Hence the study presented here on the fauna of the sediments of the South Andaman coast is significant as it would highlight the environment that existed between the present and the 6000 years B.P. during which the beach sedimentaries of South Andaman were formed. Further, it would help in reconstructing the ecological conditions existed around this period in and around South Andaman coast.

The aim of the present communication is to study the faunal diversity from such sediments from the South Andaman Coast and pinpoint their

*E-mail : c_rajshekhar@yahoo.co.in

precise environment of deposition using foraminifera as principal tool and comment upon the overall diversity of fauna since Miocene (23 million years) of the Andaman-Nicobar archipelago. The Andaman archipelago forms a part of the tectonic ridge between 6° N and 14° N (location map, Fig. 1) extending from Arakan-Yoma in the north to Java-Sumatra in the south. Tectonically, the Andaman-Nicobar islands are the part of the subduction zone involving Indian and Australian plates.

The movement of these plates have caused the great Tsunami (26th Dec. 2004) in this region. In addition, the islands are also experience frequent earthquakes due to their link with tectonically active zones. In fact, within Andaman-Nicobar chain of islands there occur two major arcs viz., non-volcanic arc and volcanic arc (Rodolfo, 1969; Srinivasan, 1986). The latter has two volcanoes – the Narcondam and Barren island. In Recent times the Barren island has exhibited several erruptions. The non-volcanic arc contains many mud volcanoes. The Andaman-Nicobar islands were the center of attraction for Geological Survey of India and also for Oil and Natural Gas Corporation. As a result, several contributions have been made to the geology of these islands and notable among them are Rink (1847), Hochstetter (1866), Oldham (1885), Gee (1927), Tipper (1911), Karunakaran *et al.* (1964) and Eremenko and Sastri (1981). As mentioned above, these islands were attracted many geologists as these have a continuous sedimentary sequence ranging from Cretaceous to Recent. Srinivasan and his co-workers (Srinivasan, 1968, 77, 78a,b, 79, 84, 86a, 86b, 87, 88; Srinivasan and Azmi, 1976a,b,c,d; Srinivasan and Rajshekhar, 1980, 1981; Sharma, 1970; Srivastava, 1970; Azmi, 1976; Singh, 1979; Rajshekhar, 1979; Dave, 1982; Sharma and Srinivasan, 2007) have presented a very comprehensive account on the Geology and Micropaleontology of the Neogene sedimentary sequence. These sedimentary sequences are mainly represented by chalk, limestone (carbonates) and mudstone and these lithologies can be encountered as land based sections across the Andaman-Nicobar islands. Thus it is observed that geological as well as the micropaleontological knowledge of the Late Quaternary sediments have not been paid any attention despite their significance in coastal evolution and management. Recently the author (2002, 2003a,b, 2007a,b) has taken up a

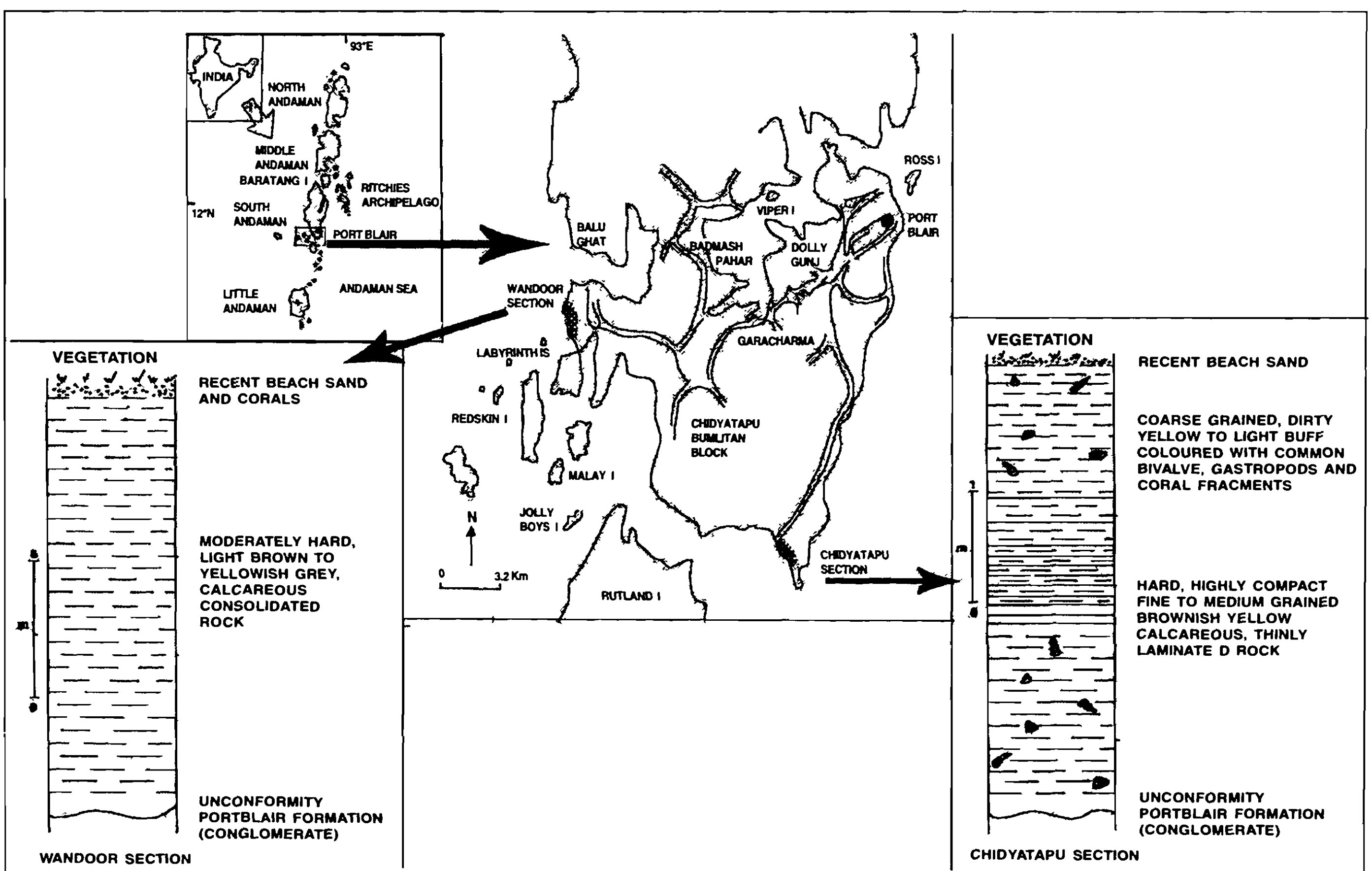

Fig. 1. Location Map

comprehensive work on these sediments and the results are incorporated in the study presented here. In addition, an attempt is made here for the first time to study the modern foraminiferal distribution from the Andaman coast and highlight the distributional pattern from the mangrove ecosystem.

MATERIALS AND METHODS

The sediments were collected from the various localities of Andaman regions. The beach rocks, sand and clays from mangroves were collected during several field tours taken to these islands. The material collected during the most recent tours to South Andaman, Ritchie's Archipelago and Baratang Island in February 2008 is used for the analyses. The samples were wet seived using 70, 140 and 300 mesh sizes followed by drying the processed samples in oven. Foraminiferal slides were prepared by hand picking method under the steroscopic binocular zoom microscope. Selected samples were sent to ^{14}C dating to BSIP, Lucknow. Live foraminiferal material collected from different parts of the South Andaman using most commonly used methods (75 ml of formal dehyd. + 1 gm of Rose Bengal AR and topped to 1 lit with sea water) (Nigam, personal communication). The foraminiferal specimens were photographed using Cambridge Model S120 SEM at ARI.

Geology

Geologically the Andaman sedimentary basin has a very massive thickness of sedimentary sequence consisting of the older and younger sediments. For the sake of convenience the older one is termed here as Pre-Archipelago and the younger one as Archipelago Group of sediments. The classification of these sediments are mandetory basically for correlations and for understanding the basin especially for its faunal turnover. The stratigraphic classifications proposed so far are given in Table 1 for ready reference.

As mentioned earlier, the Archipelago Group of sediments contain a thick sequence of mudstone and carbonate rocks ranging from Miocene to Recent. The latter encompasses the sediments of marginal marine environments including shore and coastal sediments. Coasts form the integral part of the transitional zone involving oceanic conditions on one side and the terrestrial set up on the other side and therefore, their study acquires special significance as they hold the useful and important clues pertaining to environment and faunal diversity (Mackay *et al.*, 2005). Thus the coastal sediments of South Andaman in particular and Andaman archipelago in general have immense potential to unravel the environmental history and faunal diversity of the immediate recent past. Taking this into consideration, Holocene epoch is the most significant to study as it represents youngest most chapter of the earth's geological history encompassing the sedimentary history, human evolution and climateic fluctuations of the last 10,000 years (Mackay *et al.*, 2005). An attempt is made here for the first time to present an account on the fauna of the Andaman coast. Beach sedimentaries of the south Andaman Coast consist of beach sand, beach rock, sands from raised beaches and clays of the creeks and swamps. These sediments are the life line of the coasts as they support a large population for its livelihood, industry and also for defence establishments. Study of these marine sedimentaries would not only highlight the environmental related aspects but also help in coastal planning and its management. These regions are vulnerable to high energy sea waves, sea level variations, storms, flash floods and Tsunami (Hussain *et al.*, 2006; Rajshekhar, 2007). Thus, these above mentioned events are important to identify and can be achieved using fossil foraminifera (protozoa) as chief criteria.

Evolution of Andaman and Nicobar Islands

- The Andaman and Nicobar archipelago forms the part of the subduction zone and a complex junction of Indian and Australian plates.
- Geologically the archipelago represents a continuous sedimentary sequence ranging from Cretaceous to Recent and they have significant record of microfossils such as foraminifera, radiolaria, diatoms, calc. algae, nanoplankton, ostracoda, silicoflagellates and pteropods.
- From the diversity view point nannoplankton, radiolaria and foraminifera are significant.
- The Island Arc System can be divided into two arcs viz., the volcanic arc conisting of Narcondam and Barren volcanoes and the non-

volcanic arc includes the rest of the Andaman-Nicobar archipelago.

- The Andaman-Nicobar archipelago was uplifted as Andaman-Nicobar Ridge – Late Eocene – Oligocene.

Major tectonic features: Sharma and Srinivasan (2007).

		Age
Diastrophism	Late Pliocene	3.42 ma
Origin of Andaman Sea	Late Miocene	10.2 ma
Spreading of Rifts and Transform faults	Middle Miocene	16.2 ma
Upliftment of Main Ridge & Unconformity	Late Oligocene	24.3 ma
Deposition of Biogenic sediments	Subsidence	
Origin of Fore arc Basin	Subduction Process	

RESULTS AND DISCUSSION

As mentioned earlier beach rock, beach sand, raised beaches and clays are the major constituents of the Late Quaternary deposits of South Andaman.

Beach Rocks : These rocks occur all along the coastal tract of Andaman-Nicobar archipelago (Reddiah *et al.*, 1974, Srinivasan and Azmi 1976a & b, Karunakaran *et al.*, 1964, Rajshekhar and Reddy, 2002). The occurrence of these rocks indicate former strandline (Bowen, 1988; Bruckner, 1989; Pirazzoli, 1991; Kennett, 1982) and hence studied extensively. In India, these rocks are common all along the coastal tract of Penninsular India (East Coast: Ahmed, 1972; Vaidyanadhan and Raju, 2000; Banerjee, 2000; West Coast: Guzder, 1980; Gupta, 1977, Wagale, 1989; Sukhtankar, 2004).

The thickness of these rocks ranges from few centimeter to few meters and the ^{14}C dates suggest their age in general ranges between 700 years B.P. and 6000 years B.P. Recently the author has taken up a systematic study of these rocks from the South Andaman coast and analysed its faunal contents. The beach rocks are common in South Andaman region especially good exposures can be seen at Wandoor, Chidyatapu, Grub I and Jolly Buoy regions. These beach rock exposures are considered under Chidyatapu Member (Table 1). Stratigraphically, Chidyatapu Member has been incorporated into the Neill West Coast Formation of Neill Island (Rajshekhar 2007a). The Chidyatapu Member is the youngestmost lithologic unit of this formation.

In addition to the South Andaman coasts (Plate 1, fig. C), the beach rocks are also common on the west coast of Neill Island. The Neill west coast section has been designated as the type section of Chidyatapu Member (Rajshekhar, 2007). The Neill West Coast Formation consists of rocks encompassing an environmental history ranging in age from Pliocene to Recent. The lithologic variation and locations are given in Fig. 2.

Fauna : The beach rocks have commonly yielded marine organisms such as foraminifera. The foraminiferal tests are very common in such rocks. The faunal analyses reveal the presence of–

Smaller Foraminifera	Larger Foraminifera
Ammonia sp. *beccarii*	*Amphistegina lessonii*
Elphidium crispum	*Amphistegina radiata*
Elphidium advenum	*Amphisorus* sp., *A. hemiprichii*
Elphidium craticulatum	*Sorites orbicularis*
Quinquelocilina sp.	*Borelis schlumbergeri*
Siphogenerina costata	*Cymbaloporetta bradyi*
Calcarina splingeri	*Peneroplis pertusus*

Frerichs (1967) has worked out the modern distribution of benthic foraminifera from Andaman. Out of the above listed foraminiferal species in Andaman Sea the bathymetric distribution of *Ammonia beccarii* ranges from 26 m to 400 m. *Elphidium craticulatum* ranges from 122-210 m; *Elphidium crispum* ranges from 77-225 m, *Quinqueloculina seminulum* ranges from 15-300 m. The foraminiferal fauna consists of both the smaller as well as the larger ones. The larger group are associated with coral reef environment.

The larger foraminifera requires light and Oligotrophic environment (Reiss and Hottinger, 1984); temp: 16-18°C (during winter) and depth: within the ranges of euphotic zone (Langer and Hottinger, 2000). Langer and Hottinger (2000) have studied the modern distribution of several taxa belonging to larger foraminiferal group. Accordingly,

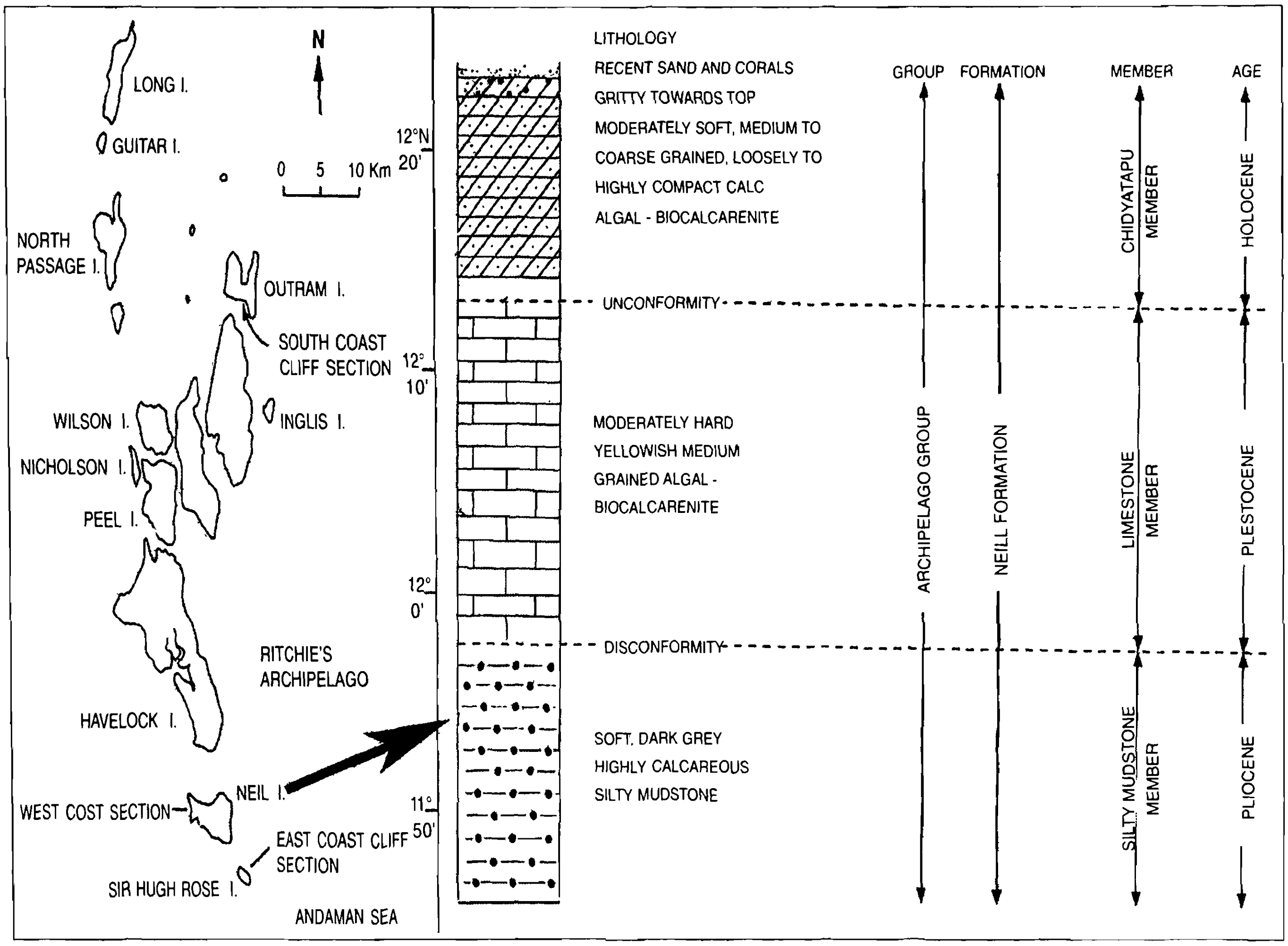

Fig. 2. Location lithocolumn and stratigraphy of Neill West Coast Formation Niell Island and Ritchie's Archipelage.

Sorites orbicularis – circumtropical cosmopolitan sp.,

Habitat : Epiphyte – Upper half of the Upper Photic zone

Temp.: 14°C to 34°C

Borelis sp. – circumtropical cosmopolitan sp.,

Indo-Pacific distribution : Red Sea to East Africa,

West to Exmouth (Western Australian site 42)

Pitcairn Island – South Pacific

Temp. : 24°C to 34°C

Borelis sp. has not been encountered in the Indian waters.

Amphistegina spp. : Langer and Hottinger (2000) have observd that the species of *Amphistegina* have widest latitudinal extensions. In Indian Ocean waters it occurs from 25°S (Mozambique) to the Red Sea, east to shores of Indonesia and Shark Bay, Australia.

Temp. : 14°C to 34°C

Modern Bathymetric range of *Amphistegina cossonii* : 5 m to 100 m.

Peneroplis pertusus : 0 m to 45 m

Sorites orbicularis : 5 m to 65 m

Beach Sand : South Andaman : The beaches of falls under prograding group. Prograding coasts are characterised by sediment deposition in such a way that there is a shift of shoreline towards seaward (Einsele, 1992). The sands of South Andaman (Plate 1, Fig. A), particularly that of Chidyatapu and Wandoor consist of both the organic as well as inorganic constituents. The organic constitutents consists of foraminifera, algae, molluscs and skeletal parts of corals. The molluscs are dominantly represented by bivalves and gastropods. Among Algae, *Helemida* fragments are common. The foraminiferal constituents consist of species of *Ammonia, Elphidium, Amphistegina, Calcarina, Sorites and Cymbaloporetta.*

The foraminiferal composition in general closely matches with that of beach rock foraminiferal composition. The diagenesis and the lithification of the beach sand gave rise to the origin of beach rocks and therefore, there is a close relation in faunal composition between the two. The sand is of marine origin and therefore the beach rocks which represent former strand lines are very useful in studying the sea level variation. The faunal diversity in Wandoor Sand is more as compared to that of Chidyatapu Beach Sand.

Raised Beaches: Besides the beach sand there occurs another sand which belongs to raised beaches. Raised beaches are formed due to tectonic activity which has resulted the upliftment of beaches. In South Andaman Island, the raised beaches are common along the Wandoor Coast (Plate 1, fig. D). The raised beach on the west coast of Wandoor is uplifted about 0.5 m and is of recent origin. The sand sample of the raised beach has sent to Birbal Sahni Instt. of Paleobotany for dating. The estimated carbon isotope age is 1100±80 yrs. B.P. Therefore, geologically the raised beach is of most recent origin. The general faunal composition of the raised beach sand closely matches with the modern beach sand and beach rocks. In general it is observed that there is no major diferences in faunal composition between the three i.e. beach sand, sand from raised beaches and beach rocks.

Havelock Island Beach Sand: The beach sand from the east coast of Havelock Island has very well preserved foraminiferal fauna. The foraminiferal fauna is dominantly represented by larger foraminifera that was encountered in South Andaman Island and dominantly of coralline affinity. Varietally the fauna is rich as compared to the fauna of all other localities. In addition to the benthic foraminifera, planktonic foraminifera also occur. Generally, planktonic foraminifera is not expected in the shore fauna as they are surface dwellers and occur considerably far away from the shore. The occurrence of planktonic foraminifera in the beach sand indicates that the reworking of Middle Miocene sediments. It may be mentioned here that the rocks in and around Jetty and Havelock island characterised by silty mudstone of Ongeian stage assignable to Middle Miocene age. The presence of species of *Globigerinoides* in sand may indicate reworking of silty mudstone. It may be pointed out that the sand analysed here is that of Pre-Tsunami episode. Therefore, the presence of planktic foraminifera may not be necessarily of Tsunami origin.

Dating of Sediments: The beach rock samples and the shell material from raised beaches have been dated using the isotopic methodology at BSIP, Lucknow. The dates are summarised below giving the details of measured and calibrated ages :

Batch No.	Sample No.	Sediment	Measured Yrs. B.P.	Calibrated Yrs. B.P.
BS 1630	No.C/99 (Chidyatapu)	Beach Rock Chidyatapu	3760 ± 150	4410-3900
BS 1631	No.NS/99 (Wandoor)	Shells Sand Wandoor	1100 ± 80	1070-930
BS 1634	No.4/0/D/99 (Wandoor)	Beach Rock Wandoor	1580 ± 80	1540-1350
BS 2799	No.S-3625	Beach Rock	1760 ± 100	1681
BS 2797	. No.S-3623	Neill Isalnd Beach Rock	5680 ± 120	6475
BS 2789	No.S-3624	Wandoor Beach Rock	1550 ± 110	

Considering the calibrated ages of the Holocene sediments, it is revealed that the beach rock of Neill Island is the oldest one and the beach rock of Wandoor is the youngest one.

As mentioned earlier since the occurrence of beach rocks are related to strand lines the age differences mentioned above clearly indicate in variations in sea levels. It would be interesting to note that the climate during which these sediments are formed was not uniform but shows distinct variations of dry and humid conditions.

Oxygen isotopic studies of the Speleothems from the tropical India reveal the following interesting features (Ramesh, 2000) :

1200-400 years B.P.	High rainfall
3000-2900 years B.P.	Reduced rainfall
3350-3200 years B.P.	Humid climate
3400-3000 years B.P.	Enhanced rainfall
3700-3350 years B.P.	Arid climate

Besides these studies, an exhaustive account of pre-history civilization and agriculture, Radhakrishna (1998) outlined the following climatic events within the Holocene epoch.

2000 years B.P.	Intensive aridity, great famine and end of Indus Civilization
3000 years B.P.	Tectonic disturbance shifting of Yamuna to join Ganga and Sutlej to join Indus
4000 years B.P.	End of wet climate commencement of aridity
5000 years B.P.	Stimulating environment foundation laid for stable agriculture
6000 years B.P.	Lakes with higher water levels
7000 years B.P.	Wet spell Break through in Himalayan Drainage

A critical analysis of the faunal diversity reveals that there is a drastic decrease in number of foraminiferal families in the younger formations being high in Miocene and Pliocene sediments to minimum in Holocene epoch. This indicates the decrease in foraminiferal diversity in comparatively younger sediments. It may be mentioned here that the fauna discussed here belong to benthic category. Since this group of foraminifera are controlled by depth, the shallow waters would show less number of taxa as compared to the deep ones and hence the low diversity in the younger sediments such as beach sedimentaries of South Andaman Island.

However, taking into consideration the number of foraminiferal taxa in the present day oceans it is observed that there is an increase in foraminiferal diversity. An analyses of the reported foraminiferal fauna from the beach sedimentaries such as beach sand, raised beach and beach rocks, it is observed that there is no major difference in faunal contents and they are more or less the same. It implies that there is no change in faunal turnover and the diversity since 6000 years. B.P.

The reported foraminifera has affinity to the coral reef and hence it suggests that the present day living foraminifera associated with coral reefs that are thriving in shallow depths are not very far from the present day coast especially at Wandoor and Havelock coasts. *Calcarina spengleri* characterises shallow water tropical species especially from coral reef flats (Lobegeier 2002). Further the localities such as Chidyatapu, Wandoor, the coast near Havelock Jetty falls under sheltered environment and hence the fauna of these regions belongs to very low energy conditions.

Mangrove sediments of South Andaman Island : The clays sediments of mangrove areas of Chowldari (Plate 1, fig. B) are collected for live foraminiferal studies. An attempt is made here for the first time to study the foraminiferal distribution. The faunal composition is solely made up of agglutinated foraminifera only.

The samples were analysed from high and low marsh lines and it is observed that there is no change in faunal complexion and is dominantly represented by *Trochammina inflata*. The faunal diversity is very low among the agglutinated foraminifera. The genus *Trochammina* is the characteristic of hyposaline to hypersaline, muddy sediment, 0-30°C intertidal and tidal marshes habitat. *Trochammina inflata* thrives in the middle and upper marshes (Murray, 1973). Murray (1973) has observed that the foraminiferal assemblages of tidal marshes exhibits very low diversity and the foraminiferal assemblage of typical mangrove environment solely composed of only agglutinated foraminifera (Gehrels, 2002).

The clays of these mangroves are studied with the objective to find out the modern distribution of marsh foraminifera so that they may be used to differentiate the high and low marsh fauna. The recovered fauna does not permit to differentiate between high and low marsh assemblages and hence may not be useful for sea level interpretations.

CONCLUSIONS

Modern foraminiferal (Protozoa) distribution of mangroves from South Andaman reveals the dominance of agglutinated foraminifera represented by *Trochammina inflata*. The foraminiferal assemblage from the sediments associated with mangroves can not be differentiated between high and low marsh fauna as there is no marked change in their composition and hence may not be very useful in the interpretation of sea level variations. The foraminiferal assemblage from the sediments (beach rock, beach sand and raised beaches) of last 6000 years does not show any differences applicable and their composition resembles present day foraminiferal distribution associated with coral reefs. There is a decrease in diversity of foraminifera with reference to the benthic group being highest in the Andaman sediments of Miocene (23 million years), Pliocene (3.42 ma) ages to lowest in beach sediments of Holocene epoch.

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Plate 1

A

B

C

D

A. Sandy beach at Mauvadera during low tide; **B.** Mangroves at Chouldhari during low tide; **C.** Beach rock exposures at Chidyatapu; **D.** Raised beach at Wandoor Coast

Chapter 05

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 89-104, 2010

DIVERSITY OF MEIOBENTHOS OF THE ANDAMAN AND NICOBAR WATERS

P.M. MOHAN and P. DHIVYA
Department of Ocean Studies and Marine Biology, Pondicherry University, Port Blair 744 102
Andaman and Nicobar Islands
E-mail : pmmtu@yahoo.com; pmmpu@rediffmail.com

INTRODUCTION

Meiofauna are the organisms which are smaller than the macrofauna and larger than the microfauna. The upper size limit of the meiofauna is 500 µm to 63 µm of lower end. The fauna passing through the coarser mesh (1000 µm) size and retained on the finer one (42 µm) are normally fall on the above size range. Even though this size is an arbitrary, but studies on benthic animals proves that this classifications are real and genuine bimodal distribution (Schwinghamer, 1981; Warwick, 1984, 1989). Further, these ecologically distinct faunal assemblages are in situ breeders, no specific dispersal phase and most juveniles resemble the adults. The meiofaunal research is also relatively recent discipline, the term meiofauna first being used in 1942 (Mare, 1942). Meiofaunal research was developed as separate discipline from general benthic ecology, because of difficulty in conducting research as well as need of specialized equipments for sample collection and taxonomic expertise. The recent trend of simplified techniques and standardization, pictorial keys made this study as an integral part of benthic research. Here it is also worth mentioning of three books authored by Higgins and Thiel (1988), about comprehensive treatments of research methods used in meiofauna.

In India, the scenario on meiofaunal research is very less. Eventhough there are good amount of work has been reported for terrestrial meiofauna when it comes to the marine environment it will be still scarce. This is the case for mainland coastal environments. Only a few studies have been carried out in selected Islands of Andaman and Nicobar group of Islands and these studies mainly carried out by Zoological Survey of India, Kolkata.

Study area

India is endowed with a coastline of 7,516 km. The Exclusive Economic Zone (EEZ) of India is about 2.02 million square kilometer which is spanned in the Arabian Sea and Bay of Bengal. The southern peninsula extends into the tropical waters of the Indian Ocean with the Bay of Bengal lying to the south-east and the Arabian Sea to the south-west. In the Bay of Bengal and Arabian Sea it has a group of islands called the islands of Lakshadweep and Andaman and Nicobar. The sea around Andaman and Nicobar Islands is very much important with reference to living and non-living resources and also covers an area of 1/3 of India's EEZ. The marine environment of Andaman and Nicobar waters are rich in biodiversity and the entire coast is unexploited for the fishery resources. The available area for the fishing ground is 16,000 km^2 and the estimated total marine fishery resources identified in this islands are around 2,43,500 tonnes, as against a current (official) catch of 30, 000 tonnes. There are more than 550 islands, islets and rock masses are available in this group of islands.

MATERIALS AND METHODS

The marine ecosystem is well represented in the intertidal zone on sandy, muddy, rocky beaches, mangrove, coral reefs and deep sea. Even though these ecosystem had been investigated by Sewell, International Indian Ocean expeditions, Soviet Fisheries investigations, National Institute of Oceanography, Central Marine Fishery Research Institute, Zoological Survey of India and different academic institutes, the studies on marine faunal distributions are scarce as well as not in full geographic distributions. Further in the case of meiofauna the difficult nature of study itself made still worsen the situation. The important studies of meiofauna as well as their review are Wells and Rao (1987), Tikadar *et al.* (1986), Jairajpuri (1991), Rao (1993) and Ghosh (1995).

An attempt has been made to understand the biodiversity nature of meiofaunal distribution in Andaman and Nicobar Islands environment. For this biodiversity study Higgins and Thiel (1988) work has been taken as a basic classification for the availability of diversity in Andaman and Nicobar waters.

RESULTS AND DISCUSSION

According to Higgins and Theil (1988) thirty eight different groups of meiofauna are distributed in the marine environments. They are Sarcomastigophora, Ciliophora, Cnidaria, Turbellaria, Gnathostomulida, Nemertina, Nematoda, Gastrotricha, Rotifera, Loricifera, Priapulida, Kinorhyncha, Polychaeta, Aeolososomatidae and Potamodrilidae, Oligochaeta, Sipuncula, Tardigrada, Cladocera, Ostracoda, Mystacocarida, Copepoda, Syncarida, Thermosbaenacea, Isopoda, Tanaidacea, Amphipoda, Cumacea, Halacaroidea, Pycnogonida, Palpigradida, Insecta, Bryozoa, Entoprocta, Brachiopoda, Aplacophora, Gastropoda and Bivalvia, Holothuroidea and Tunicata. Out of thirty group of meiofauna, only 10 groups have been reported from Andaman and Nicobar Islands. They are Cnidaria, Turbellaria, Nematoda, Gastritricha, Kinorhyncha, Polychaeta, Arthoropoda (Copepoda, Isopoda), Mollusc (Bivalvia, Gastropoda) Pycnogonida and Tardigrada. Total of 316 species of meiofauna were recorded in Andaman water (Table 1 and 2).

CONCLUSION

Twenty five groups which are not representated in the identified groups of islands meiofaunal distribution (Isopoda, Copepoda and Gastropoda are separately given in the meiofaunal community and in Andaman and Nicobar Islands work it is included in Artropoda and Mollusc). They are Sarcomastigophora, Ciliophora, Gnathostomulida, Nemertina, Rotifera, Loricifera, Priapulida, Aeolososomatidae and Potamodrilidae, Oligochaeta, Sipuncula, Cladocera, Ostracoda, Mystacocarida, Syncarida, Thermosbaenacea, Tanaidacea, Amphipoda, Cumacea, Halacaroidea, Palpigradida, Insecta, Bryozoa, Entoprocta, Brachiopoda, Aplacophora, and Tunicata. This may be due to the incomplete study of these environments or really a missing community in the island environments. A detailed study for this faunal community for all these islands only may reveal the real nature of the distribution of these communities and its interpretation. Further, the 2004 mega earthquake also plays a major role by the way of subsidence of the landmasses to a depth of 1 meter. The study of meiofauna on this environment may also provide how the colonisation of these animlas taken place in this new environment, what biotic preference is needed, etc., for the marine scientific community to understand this animals behaviour.

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Table 1. Diversity of Meiofauna and its classification in Andaman and Nicobar Islands.

Sl. No.	Specis name	Reference
1.	Phylum CNIDARIA	
	Class CNIDARIA	
	Anthohydra psammobionta	Tikader *et al.*, 1986
	Antenella secondaria	Tikader *et al.*, 1986
	Clytia noliformis	Tikader *et al.*, 1986
	Halamohydra andamanensis	Tikader *et al.*, 1986
	Halamohydra chouhani	Tikader *et al.*, 1986
	Hebella crateroides	Tikader *et al.*, 1986
	Laomedea (Obelia) bristriata	Tikader *et al.*, 1986
	Macrorhynchia phillipina	Tikader *et al.*, 1986
	Macrorhynchia phoenacea	Tikader *et al.*, 1986
	Monoserius pennarius	Tikader *et al.*, 1986
	Nigellastrum mutulatum	Tikader *et al.*, 1986
	Sertularella polyzonias	Tikader *et al.*, 1986
	Sertularella guardridens	Tikader *et al.*, 1986
	Order ACTINULIDA	
	Family HALAMMOHYDRIDAE	
	Halammohydra intermedium	Rao, 1993
2.	Phylum PLATYHELMINTHES	
	Class TURBELLARIA	
	Order MACROSTOMIDA	
	Family MACROSTOMIDAE	
	Acanthomacrostomum gerlachi	Rao, 1993
	Order Neorhabdocoela	
	Family Polycystidae	
	Gyratrix hermaphrodites	Rao, 1993
3.	Phylum NEMATODA	
	Class APHASMIDAE	
	Order ENOPLIDA	
	Family ANTICOMIDAE	
	Anticoma arctica	Rao, 1993
	Anticoma acuminata	Rao, 1993
	Anticoma anticoma	Rao, 1993
	Family OXYSTOMINDAE	
	Oxystomina alpatovi	Rao, 1993
	Halalaimus setosus	Rao, 1993
	Halalaimus filicollis	Rao, 1993
	Halalaimus halalaimus	Rao, 1993
	Family ONCHOLAMIDAE	
	Oncholaimus brachycercus	Rao, 1993

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Order CHROMADORIDA	
	Family COMESOMATIDAE	
	Sabatieria hilarula	Rao, 1993
	Sabatieria abyssalis	Rao, 1993
	Family CHROMADORIDAE	
	Chromadora vulgaris	Rao, 1993
	Family CHONIOLAIMIDAE	
	Latronema orcinum	Rao, 1993
	Family SELACHINEMATIDAE	
	Synochium obtusum	Rao, 1993
	Family SPIRINIIDAE	
	Spirinia spirinia	Rao, 1993
	Order DESMADORIDA	
	Family DESMODORIDAE	
	Desmodora megalosoma	Rao, 1993
	Desmodora brevicollis	Rao, 1993
	Desmodora Desmodora	Rao, 1993
	Family MONOPOSTHIIDAE	
	Rhinema exquisite	Rao, 1993
	Order MONHYSTERIDA	
	Family SPHAEROLAIMIDE	
	Sphaerolaimus pacificus	Rao, 1993
	Family MONHYSTERIDAE	
	Theristus tortuosa	Rao, 1993
	Theristus theristus	Rao, 1993
	Rhynchonema cinctum	Rao, 1993
4.	Phylum GASTROTRICHA	
	Order MACRODASYIDA	
	Family MACRODASYIDAE	
	Macrodasys andamanensis	Rao, 1993
	Family THAUMASTODERMIDAE	
	Acanthodasys aculeatus	Rao, 1993
	Thaumastoderma heideri	Rao, 1993
	Thaumastoderma indica	Rao, 1993
	Thaumastoderma tentaculata	Rao, 1993
	Thaumastoderma tetranchyroderma	Rao, 1993
	Pseudostomella malaycia	Rao, 1993
	Pseudostomella andamanica	Rao, 1993

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Family PLANODASYIDAE	
	Planodasys littoralis	Rao, 1993
	Family TURBANELLIDAE	
	Paraturbanella paraturbanella	Rao, 1993
	Order CHAETONOTIDA	
	Family XENOTRICHULIDAE	
	Xenotrichula velox	Rao, 1993
	Chaetonotus atrox	Rao, 1993
	Chaetonotus chaetonotus	Rao, 1993
5.	Phylum KINORHYNCHA	
	Class CYCLORHAGEA	
	Order NOMOSOMATIDA	
	Family ECHINODERIDAE	
	Echinoderes andamanensis	Rao, 1993
	Echinoderes echinoderes	Rao, 1993
6.	Phylum ANNELIDA	
	Class ARCHIANNELIDA	
	Family POLYGORDIIDAE	
	Polygordius madrasensis	Rao, 1993
	Polygordius polygordius	Rao, 1993
	Family PROTODRILIDAE	
	Polygordius indicus	Rao, 1993
	Polygordius protodrilusok	Rao, 1993
	Family SACCOCIRRIDAE	
	Saccocirrus minor	Rao, 1993
	Saccocirrus krusadensis	Rao, 1993
	Family DINOPHILIDAE	
	Diurodrillus benazzii	Rao, 1993
	Family NERILLIDAE	
	Nerilla antennata	Rao, 1993
	Class POLYCHAETA	
	Order ERRANTIA	
	Family PISIONIDAE	
	Pisione complexa	Rao, 1993
	Pisionidens indica	Rao, 1993
	Family Hesionidae	
	Hesionidae arenaria	Rao, 1993
	Hesionidae gohari	Rao, 1993
	Hesionidae indooceanica	Rao, 1993

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Hesionidae andamanensis	Rao, 1993
	Family PHYLLODOCIDAE	
	Hesionura elongata	Rao, 1993
	Family SYLLIDAE	
	Eusyllis homocirrata	Rao, 1993
	Typosyllis variegate	Rao, 1993
	Typosyllis typosyllis	Rao, 1993
	Sphaerosyllis bengalensis	Rao, 1993
	Brania subterranean	Rao, 1993
	Ehlersia cornuta	Rao, 1993
	Family GLYCERIDAE	
	Goniadides aciculate	Rao, 1993
	Family APHRODITIDAE Aphroditinae (= Hermioninae)	
	Aphrodita talpa	Tikader *et al.*, 1986
	Aphrogenia alba	Tikader *et al.*, 1986
	Hermonia hystrix	Tikader *et al.*, 1986
	Pontogenia nuda	Tikader *et al.*, 1986
	Family APHRODITIDAE	
	Subfamily POLYNOINAE	
	Admetella longipedata	Tikader *et al.*, 1986
	Allmaniella ptycholepi	Tikader *et al.*, 1986
	Eunoe pallid	Tikader *et al.*, 1986
	Gastrolepidia clavigera	Tikader *et al.*, 1986
	Halosydna (Hyperhalosydna) striata	Tikader *et al.*, 1986
	Harmothoe ampullifera	Tikader *et al.*, 1986
	Harmothoe dictyophora	Tikader *et al.*, 1986
	Harmothoe imbricata	Tikader *et al.*, 1986
	Harmothoe minuta	Tikader *et al.*, 1986
	Lphione muricata	Tikader *et al.*, 1986
	Lepidasthenia microlepis	Tikader *et al.*, 1986
	Lepidonotus cristatus	Tikader *et al.*, 1986
	Lepidonotus glaucus	Tikader *et al.*, 1986
	Lepidonotus jacksoni	Tikader *et al.*, 1986
	Lepidonotus melanogrammus	Tikader *et al.*, 1986
	Lepidonotus tenuisetosus	Tikader *et al.*, 1986
	Lepidonotus jukesi	Tikader *et al.*, 1986
	Scalisetosus fragile	Tikader *et al.*, 1986

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Family POLYODONTINAE	
	Panthalis oerstedi	Tikader *et al.*, 1986
	Polyodontes maxillosus	Tikader *et al.*, 1986
	Polyodontes melanonotus	Tikader *et al.*, 1986
	Family SIGALIONINAE	
	Psammolyce zeylanica	Tikader *et al.*, 1986
	Sthenolepsis japonica	Tikader *et al.*, 1986
	Family PALMYRIDAE (= Chrysopetalidae)	
	Bhawania goodie	Tikader *et al.*, 1986
	Family AMPHINOMIDAE	
	Amphinome rostrata	Tikader *et al.*, 1986
	Chloeia amphora	Tikader *et al.*, 1986
	Chloeia flava	Tikader *et al.*, 1986
	Chloeia pulchella	Tikader *et al.*, 1986
	Chloeia fusca	Tikader *et al.*, 1986
	Chloeia parva	Tikader *et al.*, 1986
	Euphrosine foliosa	Tikader *et al.*, 1986
	Eurythoe complanata	Tikader *et al.*, 1986
	Eurythoe pervecarunculata	Tikader *et al.*, 1986
	Notopygos hispidus	Tikader *et al.*, 1986
	Notopygos varibilis	Tikader *et al.*, 1986
	Notopygos labiatus	Tikader *et al.*, 1986
	Family PHYLLOCIDAE Phyllodocinae	
	Eualia albo-picta	Tikader *et al.*, 1986
	Phyllodoce Fristedti	Tikader *et al.*, 1986
	Phyllodoce malmgreni	Tikader *et al.*, 1986
	Phyllodoce quadraticeps	Tikader *et al.*, 1986
	Phyllodoce madeirensis	Tikader *et al.*, 1986
	Phyllodoce tenussima	Tikader *et al.*, 1986
	Family PILARCIDAE	
	Synelmis_albini	Tikader *et al.*, 1986
	Family HESIONIDAE	
	Hesione intertexta	Tikader *et al.*, 1986
	Hesione splendid	Tikader *et al.*, 1986
	Leocrates claparedii	Tikader *et al.*, 1986
	Leocrates filamentosus	Tikader *et al.*, 1986
	Ophiodromus angustifrons	Tikader *et al.*, 1986

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Family SYLLIDAE	
	Syllis gracilis	Tikader *et al.*, 1986
	Syllis armillaris	Tikader *et al.*, 1986
	Syllis exilis	Tikader *et al.*, 1986
	Syllis okadai	Tikader *et al.*, 1986
	Typonosyllis gigantean	Tikader *et al.*, 1986
	Typonosyllis zebra	Tikader *et al.*, 1986
	Family NEREIDAE	
	Ceratonereis anchylochaeta	Tikader *et al.*, 1986
	Ceratonereis mirabilis	Tikader *et al.*, 1986
	Namalycastis indica	Tikader *et al.*, 1986
	Nereis cricognatha	Tikader *et al.*, 1986
	Nereis coutierei	Tikader *et al.*, 1986
	Nereis jacksoni	Tikader *et al.*, 1986
	Perinereis aibuhitensis	Tikader *et al.*, 1986
	Perinereis brevicirris	Tikader *et al.*, 1986
	Perinereis cultrifera	Tikader *et al.*, 1986
	Perinereis neocaledonia	Tikader *et al.*, 1986
	Perinereis nigropunctata	Tikader *et al.*, 1986
	Perinereis nuntia	Tikader *et al.*, 1986
	Perinereis singaporiensis	Tikader *et al.*, 1986
	Perinereis suluana	Tikader *et al.*, 1986
	Perinereis vancaurica	Tikader *et al.*, 1986
	Platynereis dumerihi	Tikader *et al.*, 1986
	Platynereis pulchella	Tikader *et al.*, 1986
	Platynereis polyscalma	Tikader *et al.*, 1986
	Pseudonereis anomala	Tikader *et al.*, 1986
	Pseudonereis rottnestiana	Tikader *et al.*, 1986
	Pseudonereis variegate	Tikader *et al.*, 1986
	Tylonereis Bogoyawlenskyi	Tikader *et al.*, 1986
	Family NEPHTYIDAE	
	Nephtys (Aqlaophamus) malmgreni	Tikader *et al.*, 1986
	Family GLYCERIDAE	
	Glycera cirrata	Tikader *ct al.*, 1986
	Glycera rouxii	Tikader *et al.*, 1986
	Glycera tessellata	Tikader *et al.*, 1986
	Family EUNICIDAE EUNICINAE	
	Eunice afra afra	Tikader *et al.*, 1986

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Eunice afra pauper	Tikader *et al.*, 1986
	Eunice afra punctata	Tikader *et al.*, 1986
	Eunice antennata	Tikader *et al.*, 1986
	Eunice aphroditois	Tikader *et al.*, 1986
	Eunice australis	Tikader *et al.*, 1986
	Eunice grubei	Tikader *et al.*, 1986
	Eunice indica	Tikader *et al.*, 1986
	Eunice marenzelleri	Tikader *et al.*, 1986
	Eunice norvegica	Tikader *et al.*, 1986
	Eunice tentaculata	Tikader *et al.*, 1986
	Eunice siciliensis	Tikader *et al.*, 1986
	Lysidice collaris	Tikader *et al.*, 1986
	Marphysa mossambica	Tikader *et al.*, 1986
	Marphysa sanguine	Tikader *et al.*, 1986
	Family ONUPHINAE	
	Hyalinoecia tubicola	Tikader *et al.*, 1986
	Onuphis (Nothria) conchylega	Tikader *et al.*, 1986
	Onuphis (Nothria) holobranchiata	Tikader *et al.*, 1986
	Onuphis (Nothria) aucklandensis	Tikader *et al.*, 1986
	Ehamphobrachium chuni	Tikader *et al.*, 1986
	Family LYSARETINAE	
	Oenone fulgida	Tikader *et al.*, 1986
	Family LUMBRINEREINAE	
	Lumbrinereis sphaerocephale	Tikader *et al.*, 1986
	Lumbrinereis tetraura	Tikader *et al.*, 1986
	Family ARABELLINAE	
	Arabella iricolor	Tikader *et al.*, 1986
	Arabella mutans	Tikader *et al.*, 1986
	Drilonereis filum	Tikader *et al.*, 1986
	Family SPIONIDAE	
	Nerinides knight-jonesi	Tikader *et al.*, 1986
	Family MAGELONIDAE	
	Megelona japonica	Tikader *et al.*, 1986
	Family CIRRATULIDAE	
	Cirriformia filigera	Tikader *et al.*, 1986
	Cirriformia punctata	Tikader *et al.*, 1986
	Cirriformia tentaculata	Tikader *et al.*, 1986
	Family TROCHOCHAETIDAE	
	Poecilochaetus serpens	Tikader *et al.*, 1986

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Family MESOCHAETOPTRIDAE	
	Mesochaetopterus minutes	Tikader *et al.*, 1986
	Family ORBINIINAE	
	Nainreis laevigate	Tikader *et al.*, 1986
	Scoloplos marsupalis	Tikader *et al.*, 1986
	Family OPHELIIDAE	
	Armandia lanceolata	Tikader *et al.*, 1986
	Armandia leptocirris	Tikader *et al.*, 1986
	Travisia arborifera	Tikader *et al.*, 1986
	Family CAPITELIIDAE	
	Capitellethus dispar	Tikader *et al.*, 1986
	Dasybranchus caducus	Tikader *et al.*, 1986
	Notomastus latericeus	Tikader *et al.*, 1986
	Family ARENICOLIDAE	
	Arenicoloa brasiliensis	Tikader *et al.*, 1986
	Family MALDANIDAE	
	Asychis gotoi	Tikader *et al.*, 1986
	Axiothella australis	Tikader *et al.*, 1986
	Euclymene annaandalei	Tikader *et al.*, 1986
	Euclymene grossa	Tikader *et al.*, 1986
	Maldane sarsi	Tikader *et al.*, 1986
	Family STERNASPIDAE	
	Sternaspis scutata	Tikader *et al.*, 1986
	Family OWENIIDAE	
	Owenia fusiformis	Tikader *et al.*, 1986
	Family FLABELLIGERIDAE	
	Pherusaeruca indica	Tikader *et al.*, 1986
	Family SABELLARIIDAE	
	Idanthyrsus pennatus	Tikader *et al.*, 1986
	Lygdamis indicus	Tikader *et al.*, 1986
	Family PECTINARIIDAE	
	Pectinaria antipoda	Tikader *et al.*, 1986
	Pectinaria crassa	Tikader *et al.*, 1986
	Family AMPHARETIDAE	
	Ampaharetinae	
	Amphicteis gunneri	Tikader *et al.*, 1986
	Family TEREBELLIDAE	
	Trichobranchinae	
	Terebellides stroemi	Tikader *et al.*, 1986
	Family THELEPINAE	
	Streblosoma persica	Tikader *et al.*, 1986

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Thelepusc cincinnatus	Tikader *et al.*, 1986
	Family TEREBELLINAE	
	Eupolymnia nebulosa	Tikader *et al.*, 1986
	Loimia medusa	Tikader *et al.*, 1986
	Nicolea gracilibranchis	Tikader *et al.*, 1986
	Terebella ehrenbergi	Tikader *et al.*, 1986
	Family SABELLIDAE SABELLINAE	
	Branciomma nigromaculata	Tikader *et al.*, 1986
	Hypsicomus phaeotaenia	Tikader *et al.*, 1986
	Sabella fusca	Tikader *et al.*, 1986
	Sabella melanostigma	Tikader *et al.*, 1986
	Sabellastrare sanctijosephi	Tikader *et al.*, 1986
	Family SERPULIDAE	
	Spirobinae	
	Spirobis (Dexiospira) foraminosus	Tikader *et al.*, 1986
	Family SERPULLINAE	
	Ditrupa arietina	Tikader *et al.*, 1986
	Pomatostegus stellatus	Tikader *et al.*, 1986
	Spirobranchus giganteus	Tikader *et al.*, 1986
7.	Phylum PYCNOGONIDA	
	Family NYMPHONIDAE	
	Nymphon andamanense	Tikader *et al.*, 1986
	Family PALLENIDAE	
	Pallenopsis alcock	Tikader *et al.*, 1986
	Pallenopsis ovalis	Tikader *et al.*, 1986
	Family PHOXICHILIDIIDAE	
	Anoplodactylus cribellatus	Tikader *et al.*, 1986
	Family AMMOTHEIDAE	
	Endeis mollis	Tikader *et al.*, 1986
	Family COLOSSENDEIDAE	
	Colossendeis colossea	Tikader *et al.*, 1986
	Colossendeis macerrima	Tikader *et al.*, 1986
	Rhopalorhyncus kroyeri	Tikader *et al.*, 1986
8.	Phylum ARTHROPODA	
	Class CRUSTACEA	
	Order COPEPODA	
	Family LONGIPEDIIDAE	
	Longipedia eberi	Rao, 1993

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Longipedia kikuchii	Rao, 1993
	Family CANUELLIDAE	
	Canuellina nicobaris	Rao, 1993
	Scottolana longipes	Rao, 1993
	Scottolana rostrata	Rao, 1993
	Family ECHINODERMATIDAE	
	Ectinosoma melaniceps	Rao, 1993
	Ectinosoma dentatum	Rao, 1993
	Ectinosoma andamanica	Rao, 1993
	Halectinosoma tenuirema	Rao, 1993
	Halophytophilus simplex	Rao, 1993
	Arenosetella germanica	Rao, 1993
	Lineosoma intermedia	Rao, 1993
	Hastigerella leptoderma	Rao, 1993
	Family HARPACTICIDAE	
	Harpacticus gracilis	Rao, 1993
	Family PORCELLIDIIDAE	
	Porcellidium ravanae	Rao, 1993
	Family PELTIDIDAE	
	Peltidium ovale	Rao, 1993
	Family THALESTRIDAE	
	Peltidium angulatum	Rao, 1993
	Phyllothalestris mysis	Rao, 1993
	Family THALESTRIDAE	
	Rhynchothalestris rufocincta	Rao, 1993
	Diathrodes andrewi	Rao, 1993
	Family PARASTENHELIIDAE	
	Idomene maldivae	Rao, 1993
	Parastenhelia hornelli	Rao, 1993
	Family DIOSACCIDAE	
	Stenhelia polluta	Rao, 1993
	Stenhelia madrasensis	Rao, 1993
	Stenhelia breviseta	Rao, 1993
	Stenhelia ovalis	Rao, 1993
	Stenhelia andamanica	Rao, 1993
	Diosaccus monardi	Rao, 1993
	Robertsonia adduensis	Rao, 1993
	Amphiascoids subdebilis	Rao, 1993
	Amphiascopsis cinctus	Rao, 1993

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Metamphiascopsis nicobaricus	Rao, 1993
	Balucopsyla triarticulata	Rao, 1993
	Family AMEIRIDAE	
	Ameira parvula	Rao, 1993
	Sicameira langi	Rao, 1993
	Paraleptomesochra minima	Rao, 1993
	Family PARAMESOCHRIDAE	
	Kliopsyllus kilopsyllus	Rao, 1993
	Apodopsyllus camptus	Rao, 1993
	Family TETRAGONICIPITIDAE	
	Phyllopodopsyllus aegypticus	Rao, 1993
	Phyllopodopsyllus gracilipes	Rao, 1993
	Family CANTHOCAMPTIDAE	
	Mesochra pygmaea	Rao, 1993
	Psammastacus spinicaudatus	Rao, 1993
	Psammopsyllus operculatus	Rao, 1993
	Family LAOPHONTIDAE	
	Laophonte cornuta	Rao, 1993
	Quinquelaophonte quinquespinosa	Rao, 1993
	Langia maculate	Rao, 1993
	Laophontina sensillata	Rao, 1993
	Order ISOPODAE	
	Family MICROPARASELLIDAE	
	Angeliera cosettae	Rao, 1993
	Family ANTHURIDAE	
	Microcerberus andamanensis	Rao, 1993
9.	Phylum TARDIGRADA	
	Order HETEROTARDIGRADA	
	Family BATILLIPEDIDAE	
	Batillipes mitus	Rao, 1993
10.	Phylum MOLLUSCA	
	Class GASTROPODA	
	Order CAENOGASTROPODA	
	Family CAECIDAE	
	Caecum glabrum	Rao, 1993
	Order NUDIBRANCHIAA	
	Family PSEUDOVERMIDAE	
	Pseudovermis soleatus	Rao, 1993

Table 1. *Contd.*

Sl. No.	Specis name	Reference
	Order ARCHAEOGASTROPODA	
	Family HALIOTIDAE	
	Haliotis (Haliotis) asinine	Tikader *et al.*, 1986
	Haliotis (Haliotis) diversicolor	Tikader *et al.*, 1986
	Haliotis (Ovintotis) ovina	Tikader *et al.*, 1986
	Haliotis ruqosa	Tikader *et al.*, 1986
	Haliotis (Sanhaliotis) varia	Tikader *et al.*, 1986
	Family FISSURELLIDAE	
	Diadora bombayana	Tikader *et al.*, 1986
	Diadora granifera	Tikader *et al.*, 1986
	Diadora funiculate	Tikader *et al.*, 1986
	Diadora pipleopsoides	Tikader *et al.*, 1986
	Diadora rupelli	Tikader *et al.*, 1986
	Diadora subquadrata	Tikader *et al.*, 1986
	Diadora ticaonica	Tikader *et al.*, 1986
	Emarginula clypea	Tikader *et al.*, 1986
	Emarginula eximia	Tikader *et al.*, 1986
	Emarginula scabriuscula	Tikader *et al.*, 1986
	Macroschisma canalifera	Tikader *et al.*, 1986
	Class BIVALVIA	
	Order NUCULOIDA	
	Family NUCULIDAE	
	Nucula (Leionucula) cumingii	Tikader *et al.*, 1986
	Nucula (Leionucula) layardi	Tikader *et al.*, 1986
	Nucula marmoreal	Tikader *et al.*, 1986
	Nucula mltralis	Tikader *et al.*, 1986

Table 2. Comparative table of different works of meiofaunal diversity

Sl. No.	Phylum	Class			Order			Family			Sub Family			Genus			Species		
		TK	GC	T	TK	GC	T	TK	GC	T	TK	GC	T	TK	GC	T	TK	GC	T
1.	Cnidaria	01	01	02		02	02		02	02				10	01	011	012	01	013
2.	Platyhelminthus		01	01		02	02		02	02					02	002		02	002
3.	Nematoda		01	01		04	04		12	12					14	014		22	022
4.	Gastrotricha	-				02	02		05	05					08	008		13	013
5.	Kinorhyncha		01	01		01	01		01	01					01	001		02	002
6.	Annelida	01	02	02		01	01	25	11	36	17		17	91	15	106	159	22	181
7.	Pycnogonida							05		05			-	06		006	008		008
8.	Arthropoda		01	01		02	02		17	17				-	39	039		52	052
9.	Tardigada					01	01		01	01					01	001		01	001
10.	Mollusc	02	01	02	02	02	04	03	02	05				09	02	011	020	02	022
Total																	316		

TK Tikader, *et al.*, 1986; GC Rao, G.C. 1993; T Total

Chapter 06

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 105-111, 2010

DIVERSITY OF NEMATODES OF ANDAMAN AND NICOBAR ISLANDS

PADMA BOHRA
Desert Regional Centre, Zoological Survey of India, Pali Road, Jhalamand-342 005, Jodhpur

INTRODUCTION

Each ecosystem on earth makes important contribution to human welfare and every species plays an important role in its ecosystem and thus, we must have a comprehensive approach for conserving genes, species and ecosystem. The database of each group of animals or plants is pre-requisite before chalking out any conservation strategy of biological resources, so that we may know what wealth of biodiversity exists in the particular ecosystem or region.

In terms of diversity and economic importance, the nematodes are considered to be highly diversified and important group. Nematodes constitute one of the largest and most ubiquitous groups of the multicellular organisms. They are found in almost in every type of habitat, geographic regions, snowy mountains to deserts, in oceans and lakes. On the basis of their feeding habit, the nematodes have been divided under the following categories (Poinar, 1983) :

(i) Microbial feeders or microbivorous nematodes that feed on bacteria, diatoms etc.

(ii) Predatory nematodes that feed on protozoa to small nematodes.

(iii) Plant feeders or phytophagous nematodes which feed on living plants.

(iv) Omnivorus or parasites of plant or animals.

Plant parasitic nematodes attack all kinds of plants and generally belong to Orders Tylenchida, Aphelenchida, Dorylaimida and Triplonchida. These nematodes are generally found in the soil except the species of the few genera like *Aphelenchoides, Ditylenchus,* and *Anguina* which attack above ground parts of plants (leaves, stem or flowers). Plant parasitic nematodes may be divided into two groups according to their parasitic habits, *i.e.* ectoparasite and endoparasite.

During the year 1990 to 1991, random surveys were conducted for collecting the plant and soil nematodes in the following islands: Diglipur, Mayabander, Rangat, Barantang, Havelock, Ross, Port Blair, Car Nicobar, Kamorta, Katchal and Great Nicobar by Dr. Q.H. Baqri, Former Additional Director, Zoological Survey of India. Total of 110 soil samples were collected from 30 localities around soil of coconut (*Coccus nucifera*), cashew nut (*Anacardium occidentale*), Arecanut (*Areca catechu*), Banana (*Musa paradisica*) and Paddy (*Oryza sativa*) fields. The literature reveals that the information on plant and soil nematodes from Andaman and Nicobar island is meager except some references (Jairajpuri, 1965; Khan, 1968; Sukul, 1968-69; Rao, 1975; Baqri and Khera 1976; Rahman *et al.*, 1993; Bohra and Baqri, 2005) and a few others.

The present paper reports 88 species of plant and soil nematodes of the Orders : Tylenchida (14 species), Aphelenchica (2 species), Dorylaimida (59 species) and Mononchida (13 species). However, in order to provide overall information on the known diversity of these economically important organisms, already known species from Andaman and Nicobar Islands have also been listed in the paper.

MATERIAL AND METHODS

The collected nematodes were preserved in hot 4 per cent formalin and mounted in anhydrous glycerine.

RESULTS

The updated nematode species of Andaman and Nicobar Islands are listed below according to their systematic position (Table 1).

Table 1. Updated list of nematode species

Sl. No.	Order	Family	Species name
1.	Tylenchida Thorne, 1949	Tylenchidae Orley, 1880	*Aglenchus agricola* (de Man, 1884) Meyl., 1961
2.		Hoplolaimidae Filipjev, 1934 (Wieser, 1953)	*Hoplolaimus indicus* Sher, 1963
3.			*Hoplolaimus (Basirolaimus) seinhorsti* Luc, 1958
4.			*Helicotylenchus dihystera* (Cobb, 1893) Sher, 1961
5.			*Helicotylenchus crenacauda* Sher, 1966
6.			*Helicotylenchus exallus* Sher, 1966
7.			*Helicotylenchus multicinctus* (Cobb, 1893) Golden, 1956
8.		Telotylenchidae Siddiqi, 1960	*Tylenchorhynchus martini* Fielding
9.			*Tylenchorhynchus annulatus* (Cassidy, 1930) Golden, 1971
10.			*Tylenchorhynchus nudus* Allen, 1955
11.			*Tylenchorhynchus robustus* Thorne & Malek, 1968
12.			*Quinisulcius curvus* (Williams, 1960) Siddiqi, 1971
13.		Criconematidae Taylor, 1936 (1914) (Geraert, 1966)	*Hemicriconemoides cocophillus* (Loos, 1949) Chitwood & Birchfield, 1957
14.			*Hemicriconemoides mangiferae* Siddiqi, 1961
15.	Aphelenchida Siddiqi, 1980	Aphelenchidae Fuchs, 1937 (Steiner, 1949)	*Aphelenchus avenae* Bastian, 1865
16.		Aphlenchoididae Skarbilovich, 1947 (Paramonov, 1953)	*Aphelenchoides besseyi* Christie, 1942
17.	Dorylaimida Pearse, 1942	Dorylaimidae	*Mesodorylaimus recurvus* Andrassy, 1964
18.			*Laimydorus baldus* Baqri & Jana, 1982

Table 1. *Contd.*

Sl. No.	Order	Family	Species name
19.			*Thornenema mauritianum* (Williams, 1959) Baqri & Jairajpuri, 1969
20.			*Thornenema longicaudatum* Jairajpuri, Ahmad and Dhanachand, 1980
21.			*Paratimminema brevibulum* Rahman, Ahmad & Khan, 1994
22.		Aporcelaimidae Heyns, 196	*Aporcelaimellus heynsi* Baqri & Jairajpuri, 1968
23.			*Aporcelaimellus paracaudatus* (Meyl, 1956) Heyns, 1968
24.			*Aporcelaimellus porcus* Thorne, 1974
25.		Qudsianematidae Jairajpuri, 1965	*Labronema obesum* Thorne, 1974
26.			*Eudorylaimus sabulophilus* Tijpkema, Ferris & Ferris, 1971
27.			*Labronemella andrassyi* (Baqri & Khera, 1975) Andrassy, 1985
28.			*Discolaimus major* Thorne, 1939
29.			*Discolaimium clavatum* Baqri & Khera, 1976
30.			*Mylodiscus nanus* Thorne, 1939
31.			*Discolaimoides bulbiferus* (Cobb, 1906) Heyns, 1963
32.			*Moshajia warriari* (Jairajpuri, 1965) Siddiqi, 1982
33.			*Moshajia idiofora* Siddiqi, 1982
34.		Nordiidae Jairajpuri & A.H. Siddiqi, 1964	*Oriverutus labiatus* Ahmad & Jairajpuri, 1987
35.		Longidoridae, Thorne, 1935	*Paralongidorus rosundatus* Khan, 1987
36.		Xiphinematidae Dalmasso, 1969	*Xiphinema elongatum* Sch. Stekhoven & Teunissen, 1938
37.			*X. elitum* Khan, Chawla & Saha, 1978
38.			*X. insigne* Loos, 1949
39.		Belondiridae Thorne, 1939	*Belondira apitica* Thorne, 1939
40.			*B. ortha* Thorne, 1939
41.			*B. tenuidens* Thorne, 1964
42.			*B. thornei* Suryawanshi, 1972

Table 1. *Contd.*

Sl. No.	Order	Family	Species name
43.			*Axonchium (Axonchium) amplicolle* Cobb, 1920
44.			*Axonchium (A.) shamimi* Baqri & Khera, 1976
45.			*Dorylaimellus (Dorylaimellus) indicus* Siddiqi, 1964
46.			*Dorylaimellus sewaki* Bohra & Baqri, 2005
47.			*Dorylaimellus (Belondorylaimellus) belondirelloides* Siddiqi, 1968
48.			*Oxydirus elongates* Altherr, 1963
49.			*Paraoxydirus novus* (Jairajpuri, 1965) Jairajpuri & Ahmad, 1979
50.			*Roques indica* Rahman, Ahmad & Khan, 1994
51.		Tylencholaimidae Filipjev, 1934	*Discomyctus cephalatus* Thorne, 1939
52.		Leptonchidae Thorne, 1935	*Leptonchus granulosus* Cobb, 1920
53.			*Proleptonchus clarus* Timm, 1964
54.			*P. indicus* Siddiqi & Khan, 1964
55.			*P. aestivus* Laordello, 1955
56.			*Tyleptus projectus* Thorne, 1939
57.			*T. variabilis* Jairajpuri & Loof, 1966
58.			*Doryllium minor* Jairajpuri, 1963
59.			*Meylis dicephalus* (Yeates, 1967) Goseco, Ferris & Ferris, 1974
60.			*Oostenbrinkella oostenbrinki* Jairajpuri, 1965
61.		Mydonomidae Thorne, 1964	*Dorylaimoides (Digidorylaimoides) pakistanensis* Siddiqi, 1964
62.			*D. (D.) micoletzky* (De Man, 1922), Thorne & Swanger, 1936
63.			*Dorylaimoides (Longidorylaimoides) lepidus* Timm, 1964
64.			*D. (L) leptura* Siddiqi, 1995
65.			*Dorylaimoides (Tarjania) bulbosa* (Brzeski & Szczgiel, 1961) Szczgiel, 1965

Table 1. *Contd.*

Sl. No.	Order	Family	Species name
66.			*D. (Arcidorylaimoides) arcuatus* Siddiqi, 1964
67.			*D. (A.) saueri* Baqri & Jairajpuri, 1969
68.			*Morasia dimorphicauda* Baqri & Jairajpuri, 1969
69.		Nygolaimidae Thorne, 1935	*Nygolaimus anneckei* Heyns, 1968
70.			*Nygolaimium denticulatum** (Cobb, 1922) Heyns, 1968
71.			*Clavicaudoides trophurus* (Heyns, 1968) Ahmad & Jairajpuri, 1982
72.			*Laevides laevis* (Thorne, 1939) Thorne, 1974
73.			*Aquatides thornei* * (Schneider, 1937) Ahmad & Jairajpuri, 1982
74.			*A.shadini** (Filipjev, 1928) Ahmad & Jairajpuri, 1982
75.			*Solidenes bisexualis* (Thorne, 1930) Thorne, 1974
76.	Mononchida Jairajpuri, 1969	Mononchidae Chitwood, 1937	*Mononchus aquaticus* Coetzee, 1968
77.		Mylonchulidae Jairajpuri, 1969	*Mylonchulus brachyuris* (Butschli, 1873) Andrassy, 1958
78.			*Mylonchulus minor* (Cobb, 1893) Andrassy, 1958
79.			*M. contractus* Jairajpuri, 1970
80.			*M. dentatus* Jairajpuri, 1970
81.			*M. hawaiiensis* (Cassidy, 1931) Andrassy, 1958
82.			*M. lacustris* (N.A. Cobb in M.V. Cobb, 1915) Andrrassy, 1958
83.		Anatonchidae Jairajpuri, 1969	*Miconchoides studeri* (Steiner, 1914) Jairajpuri, 1982
84.		Iotonchidae Jairajpuri, 1969	*Iotonchus indicus* Jairajpuri, 1969
85.			*Iotonchus trichuris* (Cobb, 1917) Andrassy, 1958
86.			*Parahadronchus shakili* (Jairajpuri, 1969) Mulvey, 1978
87.		Bathyodontidae Clark, 1961	*Oionchus obtusus**, Cobb, 1913
88.			*Oionchus paraobtusus** Jairajpuri & Khan, 1981

* Species have been reported for the first time from Andaman & Nicobar Island.

DISCUSSION

The review of nematology literature reveals that information of plant and soil nematodes from Andaman and Nicobar Islands is not significant. The nematodes associated with Coconut, Arecanut, cashewnut, banana and paddy are not significantly surveyed. The Key and Potential pests of these crops are listed in Table 2. The other horticulture plants and corps are still to be surveyed. The nematodes like root-knot (*Meloidogyne spp.*), which are not only cosmopolitan in their distribution but also polyphagous are yet to be recorded. This is further to be noted that the cyst nematode (*Heterodera* spp.), have not been recorded from Andaman and Nicobar Islands till date. Baqri & Khera (1976) described and illustrated two species new to science from Long Island, and Neill Islands, (Andaman). Similarly, some families of Order Dorylaimida like Nordiidae, Longidoridae, Tylencholaimidae, Nygolaimidae and of order Triplonchida (Trichodoirdae) are poorly represented in the Islands. Predatory nematodes of families like Mononchidae, Cobbonchidae of the Order Monochida, which are abundantly found Indo-Malayan region, still remain unrecorded.

It is evident from our existing information about the fauna of plant and soil nematodes from Island that

- More surveys to be conducted in unexplored area.
- Important ecosystems like mangroves and sea coast, forest, estuaries, coral reefs are to be surveyed because information from these ecosystems is meagre.
- Exclusive surveys are required for the identification of endo and semi-endo phytophagous nematodes.
- Information of Saprophagous nematodes from the Islands is also meagre.
- Diversity of Plant and soil nematodes fauna from Andaman and Nicobar in comparison to known nematode fauna of India comes to about 4.63%

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Table 2. Key/Potential Pest

Sl. No.	Nematode Species	Hosts
1.	*Aglenchus agricola*	Coconut, Cashewnut)
2.	*Hoplolaimus indicus*	Banana, Arecanut, Coconut, Paddy
3.	*Helicotylenchus dihystera*	Cashewnut, Banana, Arecanut
4.	*Helicotylenchus cenacauda*	Paddy, Banana, Coconut
5.	*Helicoytlenchus multiicnctus*	Cashewnut
6.	*Helicotylenchus exallus*	Paddy, Banana, Arecanut
7.	*Tylenchorhynchus annulatus*	Coconut, Arecanut, Paddy
8.	*Tylenchorhynchus nudus*	Banana, Arecanut
9.	*Qunisulcius curvus*	Arecanut
10.	*Hemicriconemoides mangiferae*	Paddy, Coconut, Banana
11.	*Hemicriconemoides coccophilus*	Banana, Arecanut, Cashewnut
12.	*Macroposthonia ornate*	Paddy, Coconut
13.	*Aphelenchoides besseyi*	Paddy, Coconut
14.	*Paralongidorus rosudatus*	Cashewnut, Arecanut
15.	*Xiphinema elongatum*	Paddy, Banana
16.	*Xiphinema ellitum*	Banana, Coconut
17.	*Xiphinema insigne*	Coconut, Arecanut

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Chapter 07

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 113-129, 2010

ZOOPLANKTON DIEL VERTICAL MIGRATION AT ANDAMAN SEA

I.K. PAI*, S. TERDALKAR and M.L. PEREIRA**
Department of Zoology, Goa University Goa, India

INTRODUCTION

Migration in zooplankton may be studied under two broad headings, on time scale-seasonal / annual migration, as studied by Turner (1982). Villatte (1991) related this to life history patterns and diurnal pattern in which, hours of darkness are spent near to the surface and day light hours at deeper depths as studied by Castel and Courties (1982), Paffenhoper (1983), Piatskowski (1985), Mackas and Anderson (1986), Ryan *et al.* (1986), Kimmerer and McKinnen (1987), Okemwa (1992), Valdes *et al.* (1990), Checkley (1992), Mackas (1992), Lafontaine (1994), Heywood (1996), which is said to be beneficial for the organism (Ohman, 1990) and helps in their population budget and diurnal deficiency (Desstasio, 1993).

During Dial Vertical Migration (DVM), members of zooplankton move as much as 400M an average small body sized species and over 600M in larger ones. They move rapidly at a speed of 12-200M per hour (Durbaum and Kunnemenn, 1999). The DVM may some times be undertaken twice a day in a diel cycle. During day time, they live in deeper depths of water, but during dark they ascend to surface. They then disperse through the water column in the middle of the night, the phenomenon is termed as 'midnight sinking' as explained by Russel, 1937 (cf: Raymont, 1983). They rise towards the surface again just before dawn, which is termed as 'dawn rise'. Some species may also exhibit reverse migration as reported by Parsons and Takahashi (1979). Further, the plankton can also be classified as drifting and residual one based on their behavior (Kaartvedt, 1993).

Several workers who are working in different parts of the world, have assigned various reasons for phenomenon of DVM in zooplankton (Zaret and Suffern, 1976; Enright, 1977; Stich and Lampret, 1981; Hauris, 1988; Bollens and Frost, 1989a, b,c; Magnesen, 1989; Neuman, 1989; Hansson *et al.*, 1990; Ohman, 1990; Jerling and Wooldridge, 1992; De Stasio, 1993).

The Andaman Sea, which is located south eastern side of Bay of Bengal, which is partially isolated portion of south eastern Indian Ocean, lying enclosed between the coasts of Myanmar, Thailand, Malaysia on the east and chain of Andaman and Nicobar islands and Sumatra in the west, and occupies 6.02 X 10^3 km^2 with a volume of 6.6 X 10^5 km^3 with an average depth of 1096M. Unlike temperate seas, where spring bloom with regards to biomass is recorded (Lignell *et. al.* 1993), Andaman Sea shows some what constant biomass, all through the year. Further, due to its oligotrophic nature, it has low primary and secondary productivity (Anonymous, 1981) and hence has rich diversity of life. In this region, apart from a few stray works (Bhattathiri and Devassi,

* Corresponding author : E-mail : ikpai@unigoa.ac.in;
** Department of Biology, Aveiro University, Aveiro, Portugal

1981; Goswami, 1981; Madhupratap, 1981; Vijayalaxmi, 1981), not much work has been carried out on zooplanktology in general and DVM in particular. Hence, an attempt has been made to study DVM of zooplankton in Andaman Sea.

MATERIALS AND METHODS

During the Department of Ocean development (Government of India) and National Institute of Oceanography, Goa organized multidisciplinary cruise SK-118 on ORV Sagar Kanya, which had predetermined area of operation as Andaman sea, the ship was stationed and experiments were conducted at 10°30'23" N latitude and 93°15'25" E longitude, where the depth was about 2300M. The zooplankton samples required for the present studies were collected for a period of 24 hrs at an interval of 2 hrs, from the upper most euphotic zone, i.e., from 30M to surface by Bongo net (Dia 0.6M, Length 2.5M and mesh width 300 mm). A pre-calibrated flow meter (T.S. Flow meter model no.4512) was attached to calculate the amount of water filtered through the mouth of the net.

The zooplankton biomass was determined by displacement volume method and collected samples were preserved in 4 per cent formaldehyde. The wet weight was determined by the following method (Omori and Ikeda, 1984). Later the samples were brought to the laboratory and analyzed for abundance of major zooplanktonic groups and identified up to species level by using available literature (Kasturirangan, 1963; Mon, 1964; Daniel, 1985; Zheng Zhong, 1989 and Santhanam and Srinivasan, 1994). The diversity was calculated by using the indices given by Margalef (1968) for species of zooplankton encountered in the samples. All the zooplankton groups as well as species under study were analyzed for their presence/absence in every sample of day / night individually and separately. The 12 sets three replicates of the samples were subjected for linkage clustering within the similarity matrix, which is considered as a convenient method for illustrating relationships. The method used was simple linkage method as described by Omori and Ikeda (1984).

RESULTS

The samples collected during the entire diel cycle of 24 hrs with an interval of 2 hrs showed the biomass fluctuating from 0.01 mlm^{-1} to 0.05mlm^{-1}, with an average of 0.018 mlm^{-1}, The night samples exhibited higher biomass ranging from 0.02 to 0.05 mlm^{-1} with an average of 0.028 mlm^{-1}, thus showing higher quantity and concentration of zooplankton, at 0-30M depth at night (Fig. 1). Similarly, wet weight varied from 0.4 to 2.2mgm^{-3} (Fig. 2), with an average of 0.65mgm^{-3} for day samples and from 1.0 to 2.2 mgm^{-3} (average I .55mgm^{-3}) for night samples (Fig. 2), thus recording considerably higher wet weight for night samples. The zooplankton groups encountered in the samples were copepods, chaetognaths, amphipods, crustaceans, siphonophores, pelagic tunicates, fish eggs / larvae etc.

Though more than 65 species of copepods such as *Candacia pachydactyla, Eucheata concinna, Sapphiria negromaculata, Copilia mirabilis, Rhinocalanus nasutus, Corycaeus affinis, Oncaea*

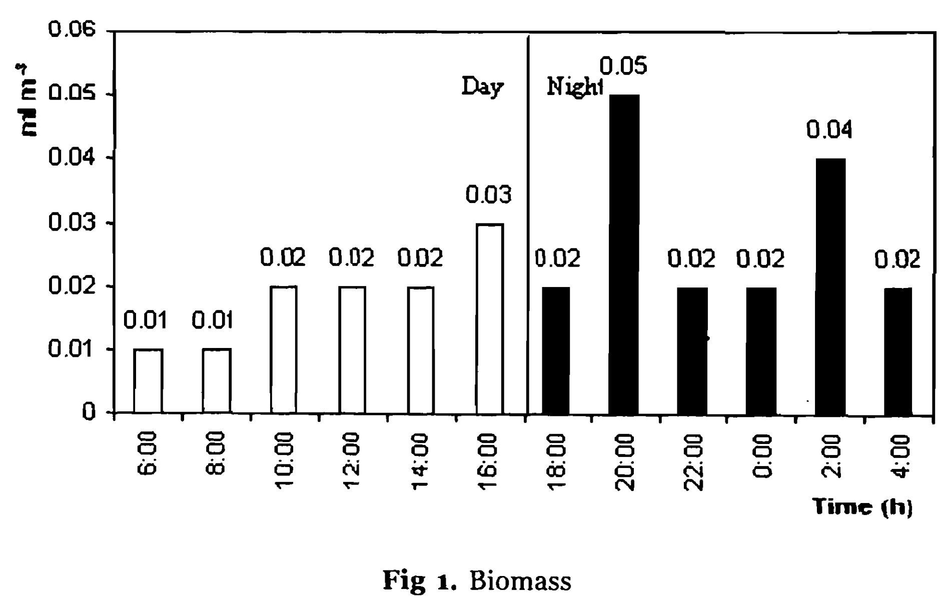

Fig 1. Biomass

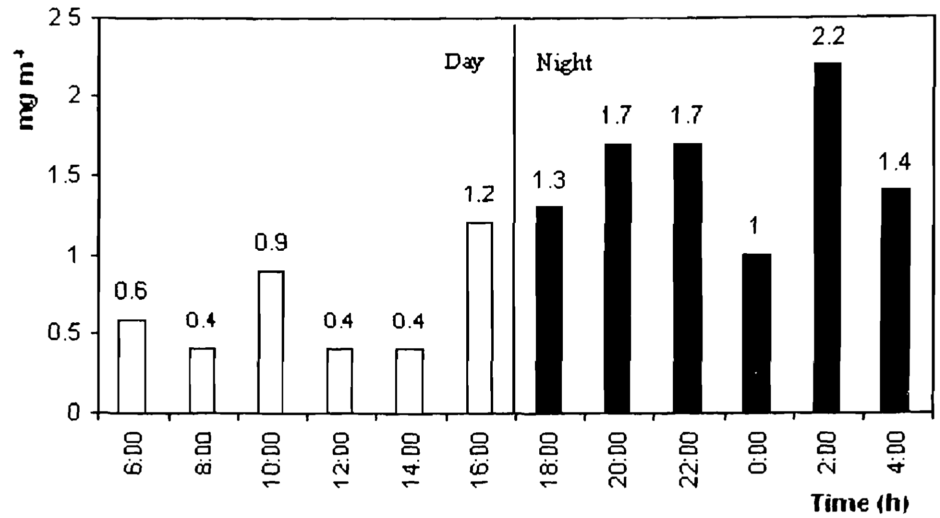

Fig 2. Wet Weight

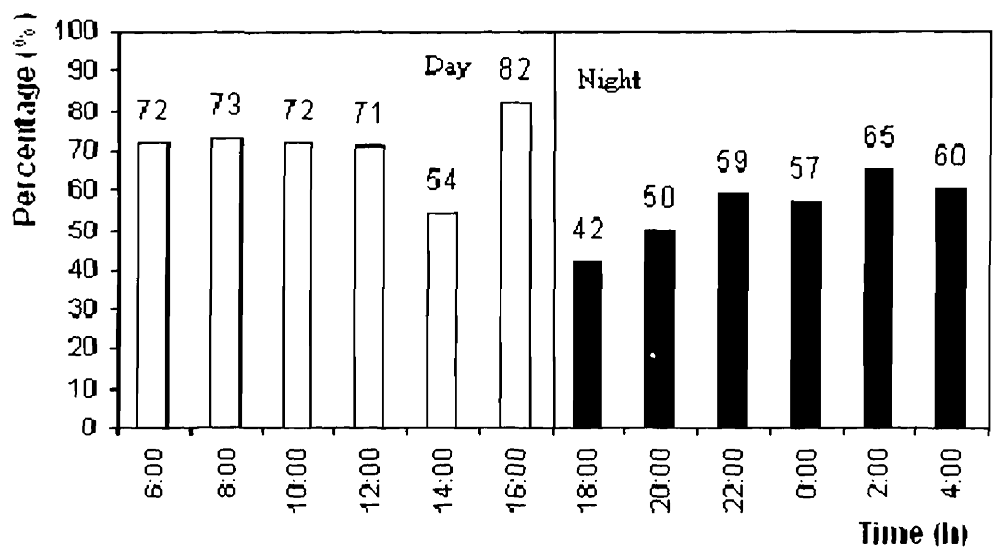

Fig 3. Percentage of Copepods in collection

venusta, Oncaea media, Pontellopsis tenuicaudata, Pontellopsis sacurifer, Schmackria popleisa, Subeucalanus longiceps, Unidula vulgaris, Acartia spp., Clausocalanus breviceps, Sinocalanus spp., Acartia tonsi, Corycaues speciosus, Thysanopoda tricuspidata, Stylocherion carinatum, Chaelophyses appendiculata were encountered in the studies, only first five species mentioned above have been considered for present detailed DVM studies. Fig. 3 demonstrates the percentage of copepods in entire day and night collections. It can be seen that, during day time, their percentage ranged from 54.0 per cent to 82.0 per cent (Average. 70.66 per cent), of total catches, while at night, it was ranging from 42.0 per cent to 65.0 per cent (Average 55.5 per cent) indicating, comparatively low percentage of their existence at upper layer of water at night.

Fig. 4 explains the percentage of *Candacia pachydactyla* in the entire diel cycle. It clearly exhibits two peaks of its existence (one at 0600 hrs and other at 0000 hrs), exhibiting its diel vertical migration pattern. Their existence, in the catches ranged from 0 per cent (at 1400 hrs and 1600 hrs) to 24 per cent at 0000 hrs. Further, at an average, they were found in relatively abundant in night collection than daytime collection. *Eucheate concinna*, though exhibits its presence in upper water column (0-30M) all through the diel cycle, it ranges at an average of 9.33 per cent at day to 13.33 per cent at night, with their day peak at 1400 hrs and night peak of their existence at 2200hrs, thus exhibiting DVM (Fig. 5). Fig. 6

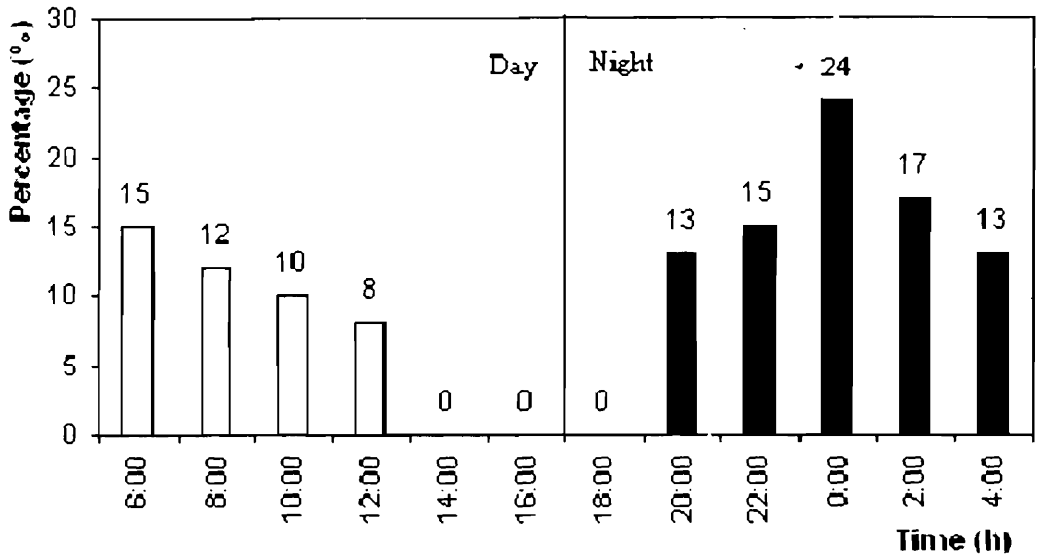

Fig 4. Pecentage of *Candacia paechydactyla* among copepods

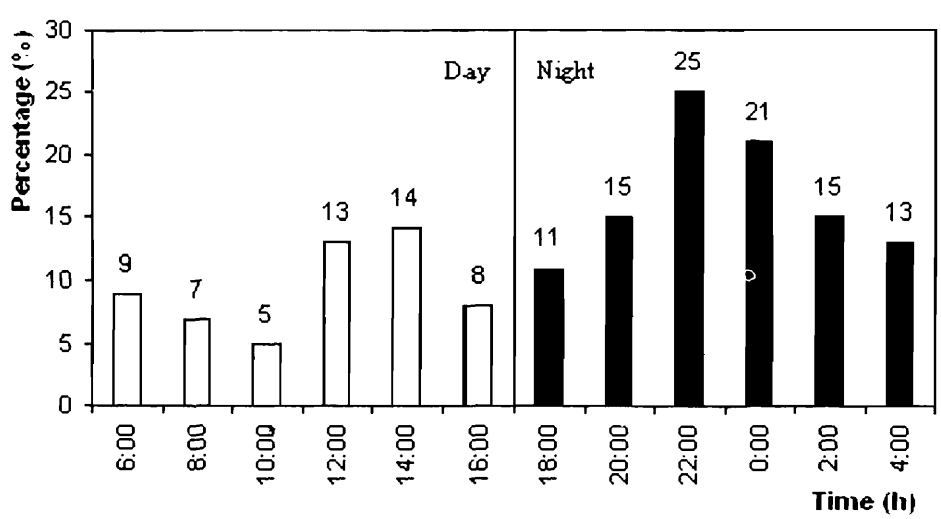

Fig 5. Percentage of *Eucheata concinna* among copepods

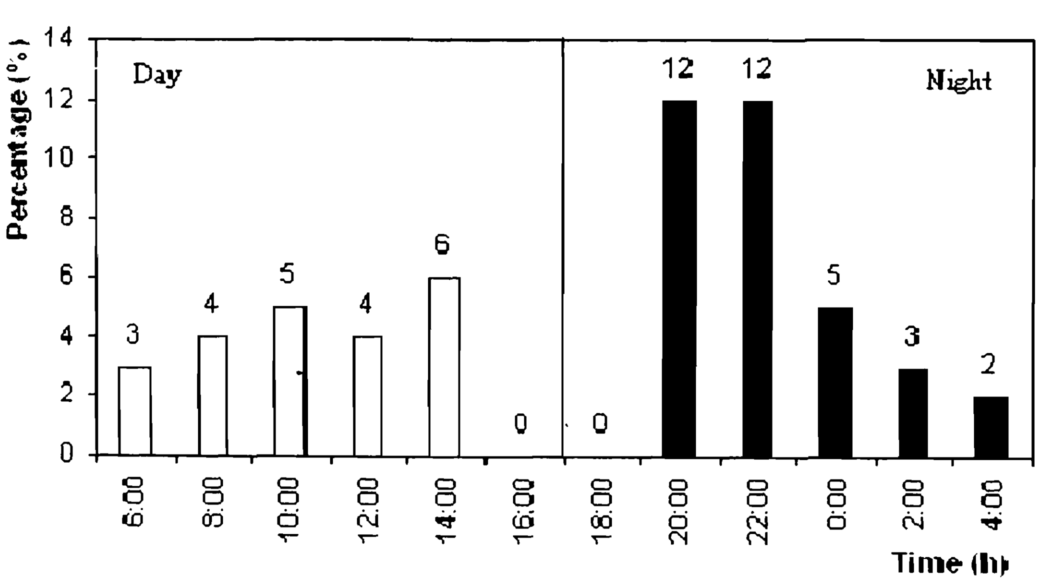

Fig 6. Percentage of *Sapphirina negromcullata* among copepods.

shows the existence of *Sappherina negromacculata* in 0-30M water column. During the day it ranges from 0 per cent (at 1600hrs) to 6.0 per cent (at 1400 hrs) with an average of 3.66 per cent. While at night it ranges from 0 per cent (at 1800 hrs) to 12.0 per cent (at 0000 hrs and 0200 hrs) with an average of 6.0 per cent, clearly indicating peaks at corpuscular period of the diel cycle. The figure also demonstrates the DVM in *Sappherina negromacculata.*

Diel vertical migration of copepod *Copilia mirabilis* has been explained in Fig. 7. It can be seen that at 1400 and between 0400hrs and 0600 they are not found in the surface waters. While, between 0800 hrs and 1200hrs as well between 1600hrs and 2000hrs they are found at a percentage ranging from 9.0 per cent to 12.0 per cent. Further it can also be seen that whenever they are there, their existence is almost similar. *Rhinocalanus nasutus*, though exhibits its presence in surface waters at all the time, higher percentage of 22.0 per cent and 20.0 per cent was seen at 1400hrs and 0200hrs respectively, while the minimum of 5.0 per cent and 7.0 per cent between 1600hrs and 1800hrs and 11.0 per cent and 12.0 per cent between 0400hrs and 0800hrs, clearly exhibiting two diel cycles (Fig. 8). Though individuals belonging to 10 species of amphipods were collected during the studies, *Brachyscelus crusculum*, *Lestrigonus schizogeneios*, *Cranocephalus* spp. and *Rhabdosome* spp. were prominent ones.

Amphipods seem to come to surface waters only at night. They also show a clear "mid-night sinking" It can be seen from Fig. 9, amphipods start showing their presence in 0-30M water

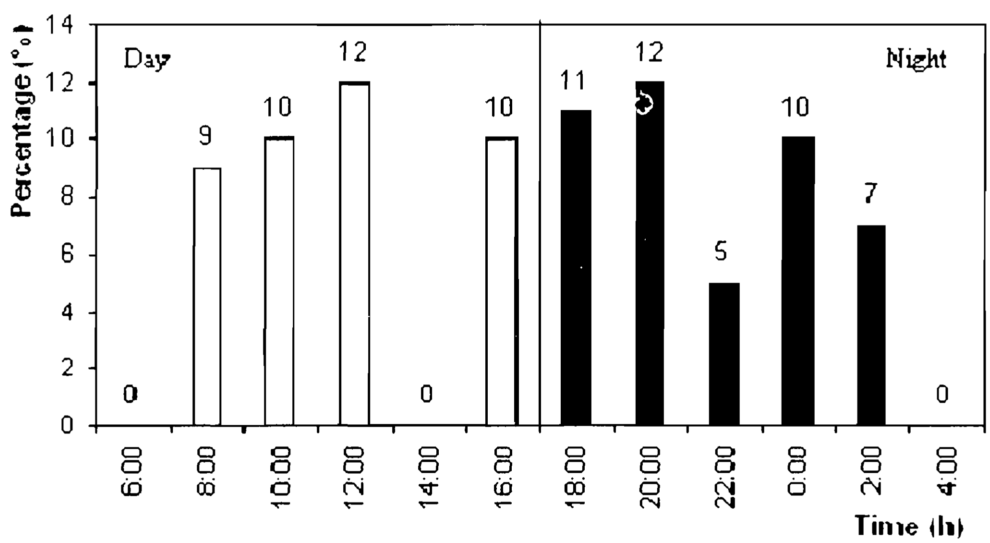

Fig 7. Percentage of *Copilia mirabilis* among copepods.

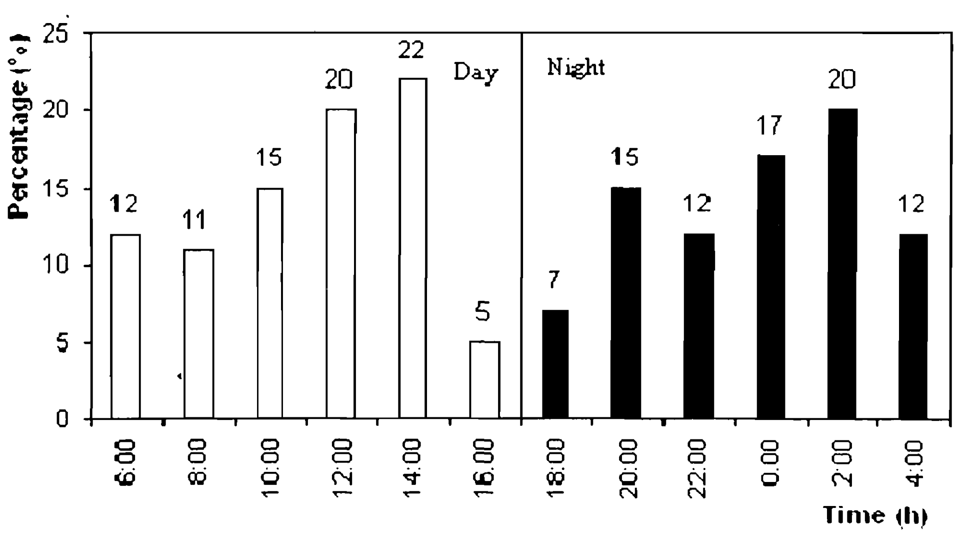

Fig 8. Percentage of *Rhinocalanus nasutus* among copepods.

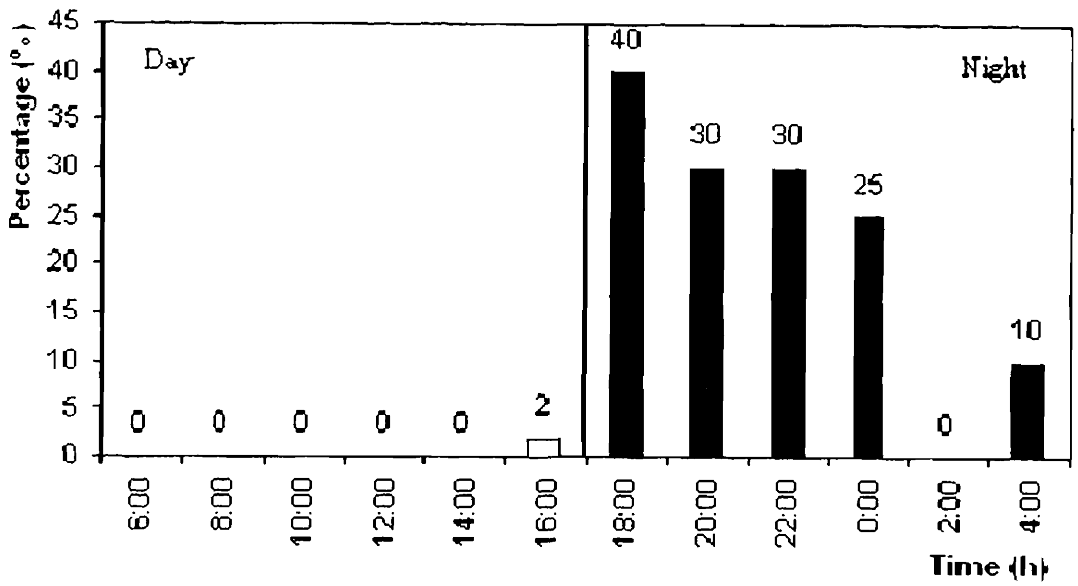

Fig 9. Percentage of Amphipods in collection.

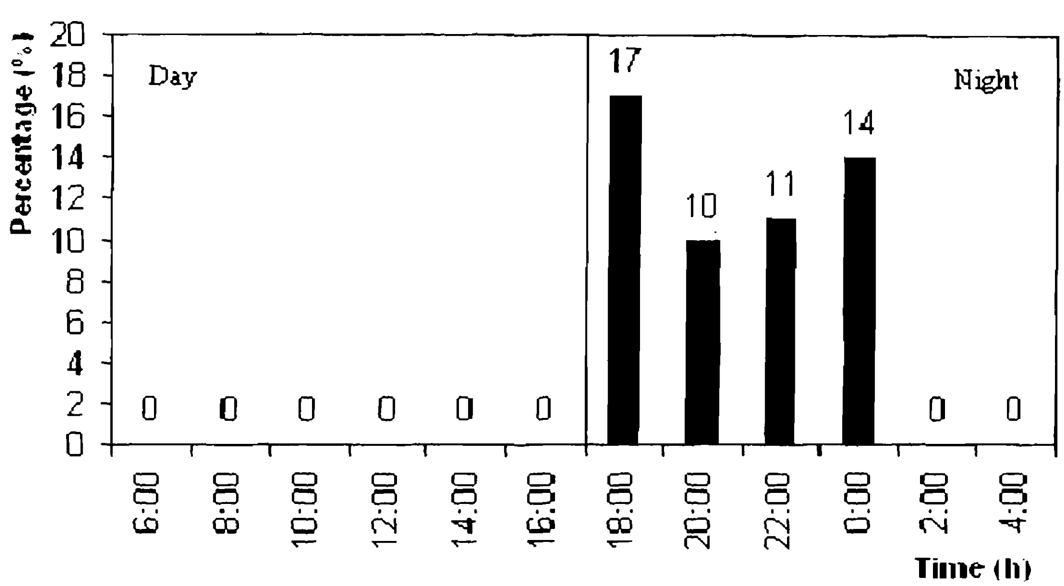

Fig 10. Percentage of *Brachyscelus crusculum* among *Amphipods.*

column at around 1600hrs with peak immediately after sun set, i.e., at 1800hrs and later show reduction in their population and by 0200hrs show a "mid-night sinking" to re-appear at 0400hrs. Fig. 10 indicates the pattern of DVM of amphipod *Brachyscelus crusculum*, which shows that the organism comes to surface water only between 1800hrs and 0000hrs and they complete their feeding and other activities in about 6hrs and they move down to spend rest of the part of their dial cycle.

Similarly, *Lestrigonus schizogeneios* shows its presence in 0-30M water column from 1800hrs to 0000hrs and after completing their feeding of phytoplankton they sink down to spend other part of their diel cycle (Fig. 11), like other amphipod *Brachyscelus crusculum*. Amphipod *Cranocephalus* spp. also exhibits its presence in 0-30 M water column between 1800 hrs to 0000 hrs. After peak existence (26.0 per cent among amphipods) they sink down to spend other time of their diel cycle (Fig. 12). *Rhabdosoma spp.* also exhibit similar pattern of diel cycle as that of *Cranocephalus spp.*, *Lestrigonus schizogeneios* and *Brachysceles crusculum* by spending 1800hrs to 0000hrs at surface waters with maximum density of 27 per cent among amphipods at 22000hrs and spend rest of the time of their diel cycle at deeper water column (Fig. 13), thus

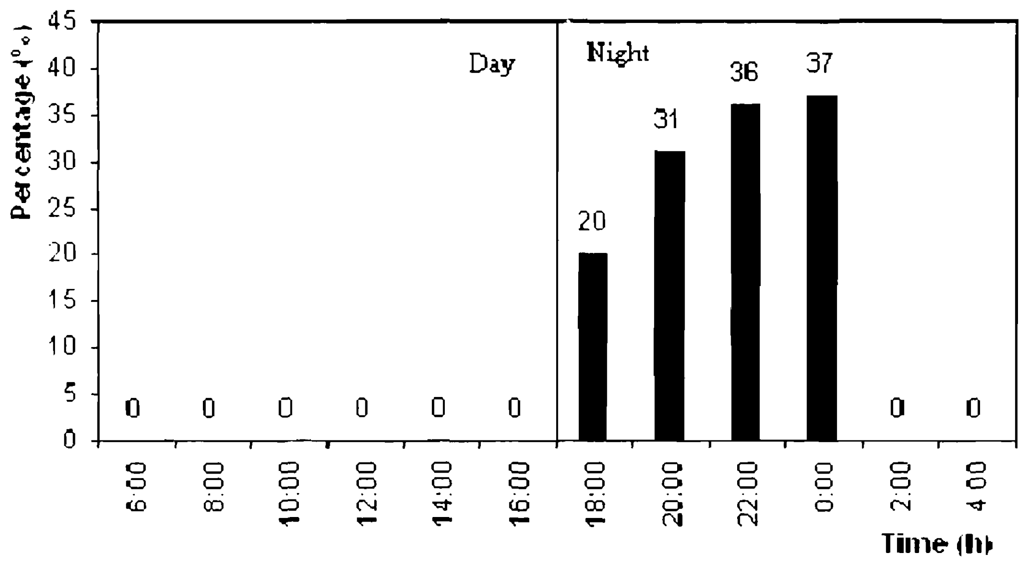

Fig 11. Percentage of Lestrigonus schizogeneios among *Amphipods*.

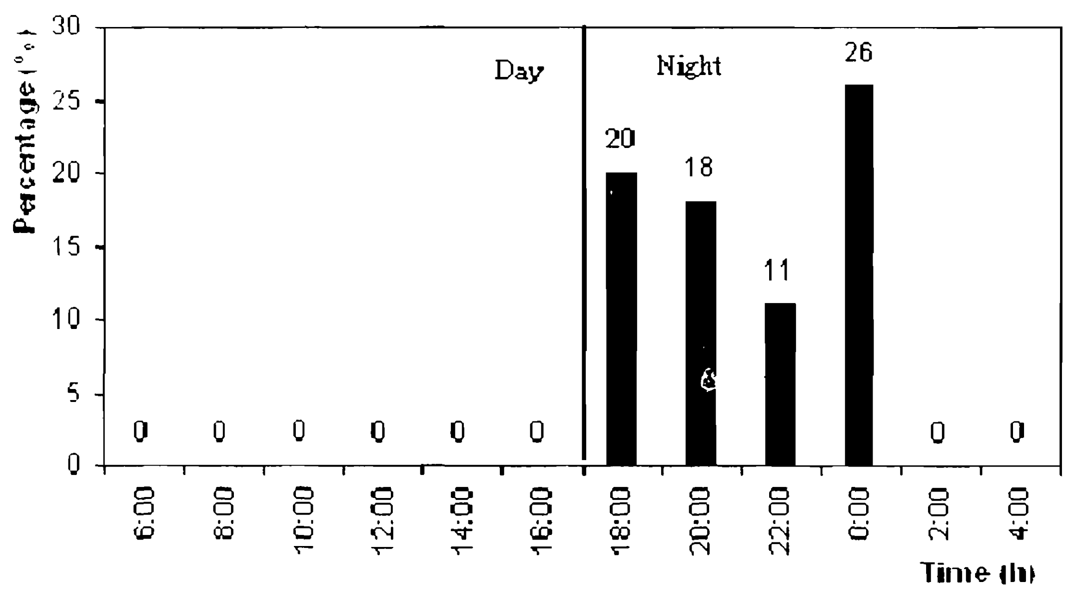

Fig 12. Percentage of *Cranocephalus* spp. among *Amphipods*.

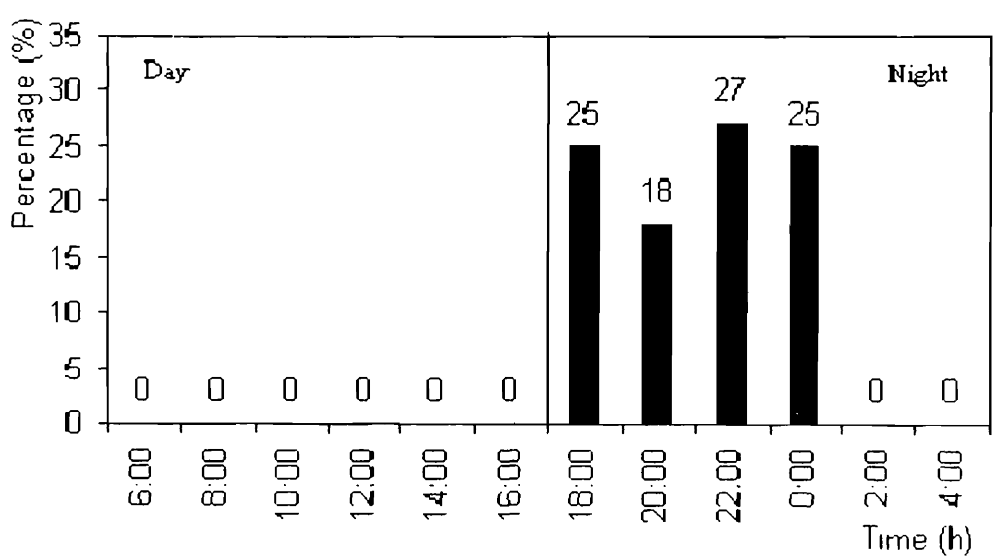

Fig 13. Percentage of *Rhabdosoma* spp. among *Amphipods*.

indicating that all four species under study under take a single DVM cycle a day.

Cheatognaths in general, as they have larger body size and prominent eye, seems from Fig. 14, that they spend more day time at surface waters. But they too show a peak existence of 30 per cent at 0800 hrs and 0200 hrs. While, a minimum of 0 per cent was seen at 1800hrs indicating their cyclic movements. *Pterosagitta draco*, a chaetognath with larger body size and large eyes seems to prefer grazing at upper layers during 0600 hrs to 1400 hrs, when there are less plankton grazers at that time. Fig. 15 demonstrates *P. draco* 's presence at 23.0 per cent to 43.0 per cent from 0600 hrs to 1400 hrs and later they move down to lower water column to spend rest of the time of their diel cycle. It looks as if they follow one DVM cycle a day.

Sagitta robusta, one more example for chaetognath, shows its presence during day time as well at night time (Fig. 16), but at relatively a lower percentage (15.0 per cent to 30 per cent) among chaetognaths at day compared to 31.0 to 44.0 per cent at night whenever they are present. Apart from the above, it can also be seen from Fig. 16 that, they move to lower waters from 1600hrs to 2200hrs, to demonstrate that they too undertake diel vertical migration, though once a day. Apart from the above, it seems both *P. draco* and *Sagitta* spp, to avoid competition among themselves, size of the populations present during daytime is inversely proportional to each other.

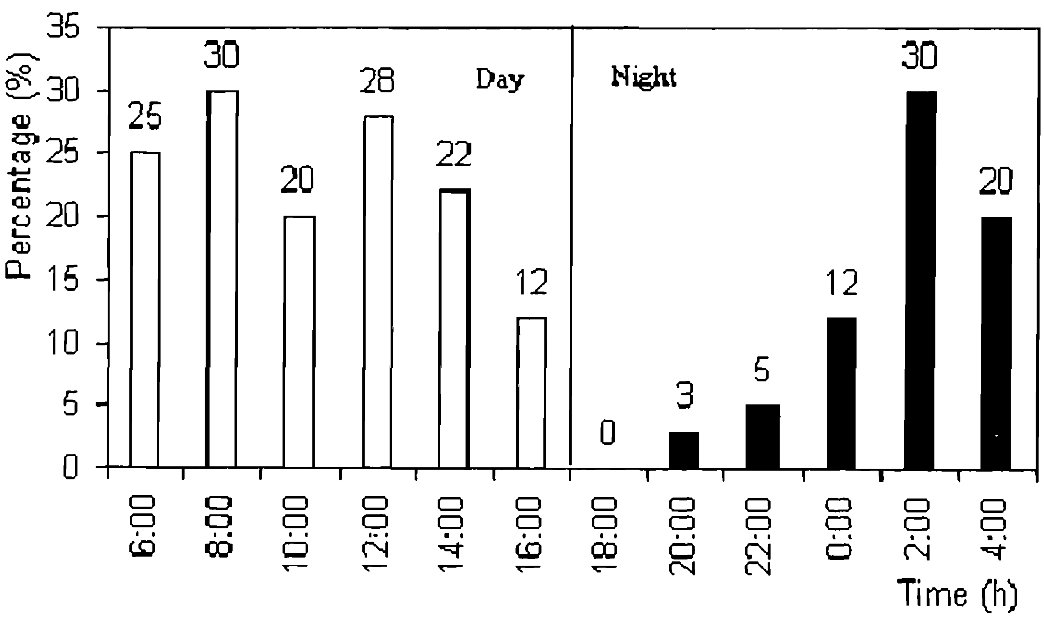

Fig 14. Percentage of Chaetognaths in collection.

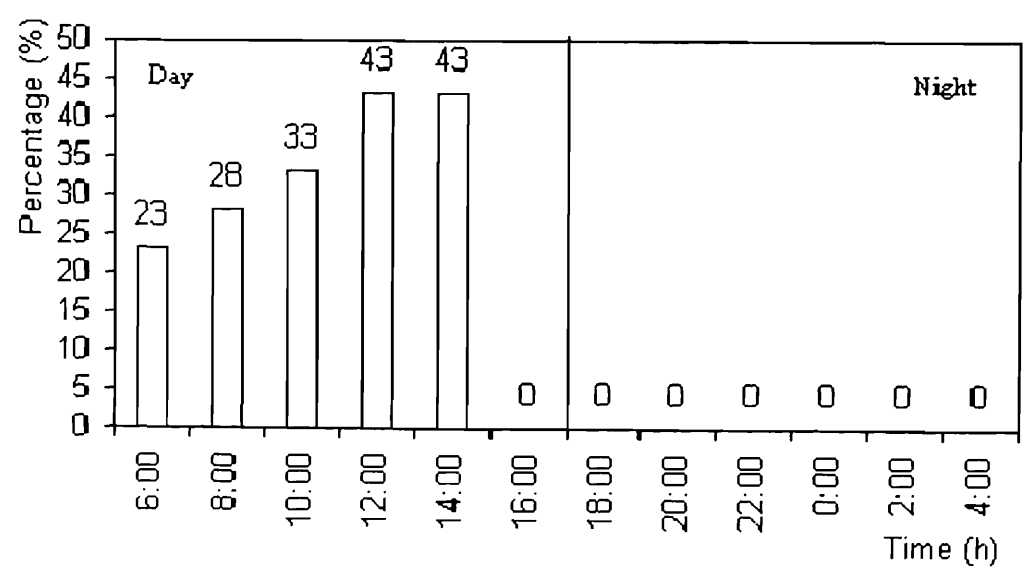

Fig. 15. Percentage of *Pterosagitta draco* among chaetognaths.

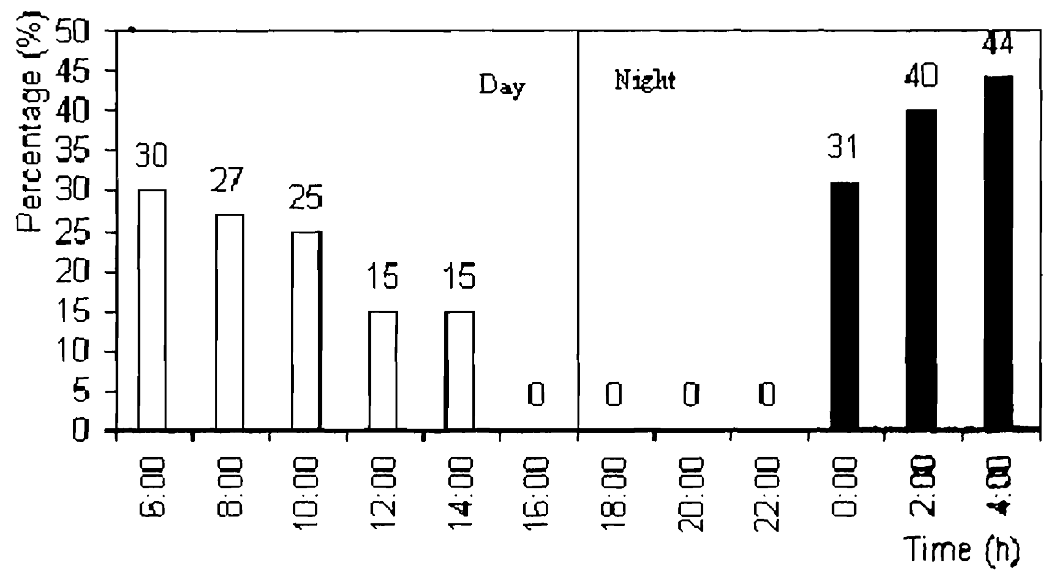

Fig. 16. Percentage of *Sagitta robusta* among chaetognaths.

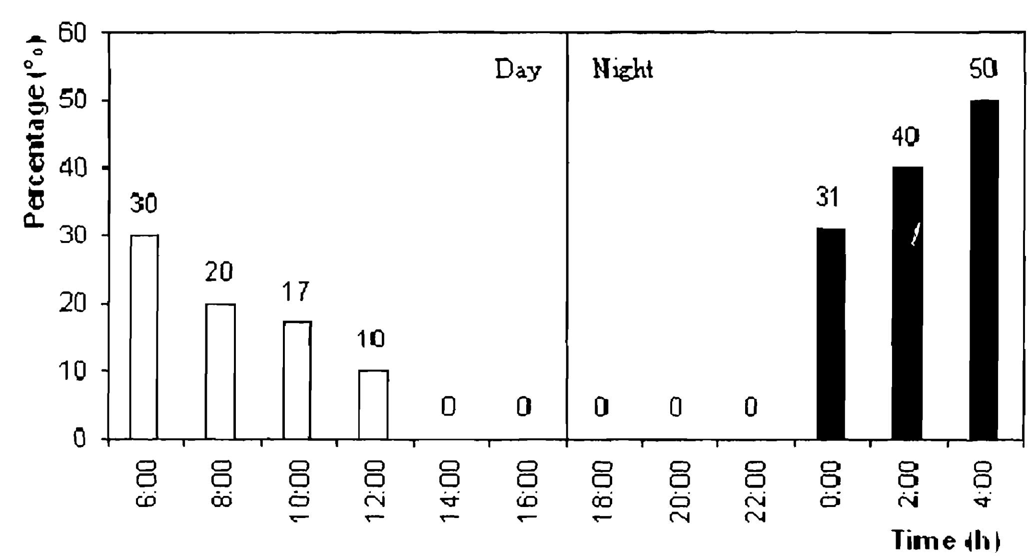

Fig 17. Percentage of *Sagitta bipunctata* among chaetognaths.

Sagitta bipuncta, also falls in line with *S. robusta* with regard to its diel vertical movements. It can be seen from Fig. 17, the peak existence of this organism among chaetognaths is 50.0 per cent at 0400hrs while from 1400-2200 hrs, they do not show their existence in 0-30 M water column, indicating that they too have one DVM cycle per day. As there is no existence of *P. draco* at night, probably there is sufficient food for both *S. robusta* and *S. bipunctata*, if they are feeding on same kind of food, or else, they must be feeding on different kind of food to avoid competition for same source of food. Fig. 18 exhibits the percentage of adult crustaceans among the total collection. It ranged from 1.0 per cent to 10.0 per cent between 1600hrs and 0000hrs and later they sink down, thus exhibiting a diel migratory cycle.

Siphonophores, clearly show two cycles of their vertical migration in a day with zero presence between 1200hrs and 1600 hrs and between 2200 and 0200hrs, with peak presence of 10 per cent at 1800hrs and 2000hrs and 14.0 per cent at 0400hrs (Fig. 19). It can also be seen that they prefer night (presence 10.0 per cent to 14.0 per cent) than day (presence 3.0 per cent to 5.0 per cent) time to come to surface of the water. Further, by going though Fig. 19, one can see that they appear at corpuscular period of the day, when most of the other predator species like amphipods and chaetognaths are absent or at a low density, though

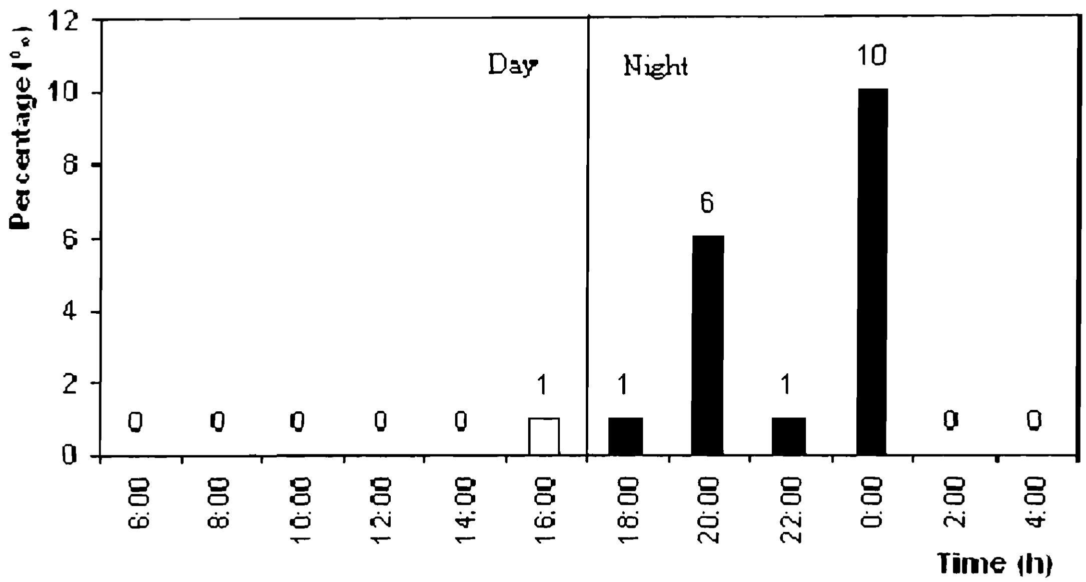

Fig. 18. Percentage of Crustaceans in the collection

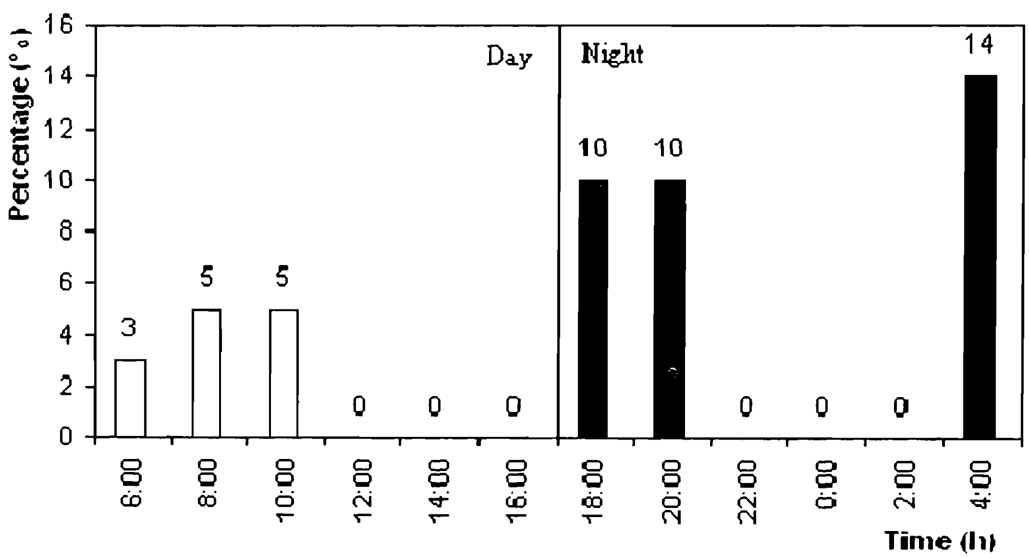

Fig. 19. Percentage of Siphonophores in the collection

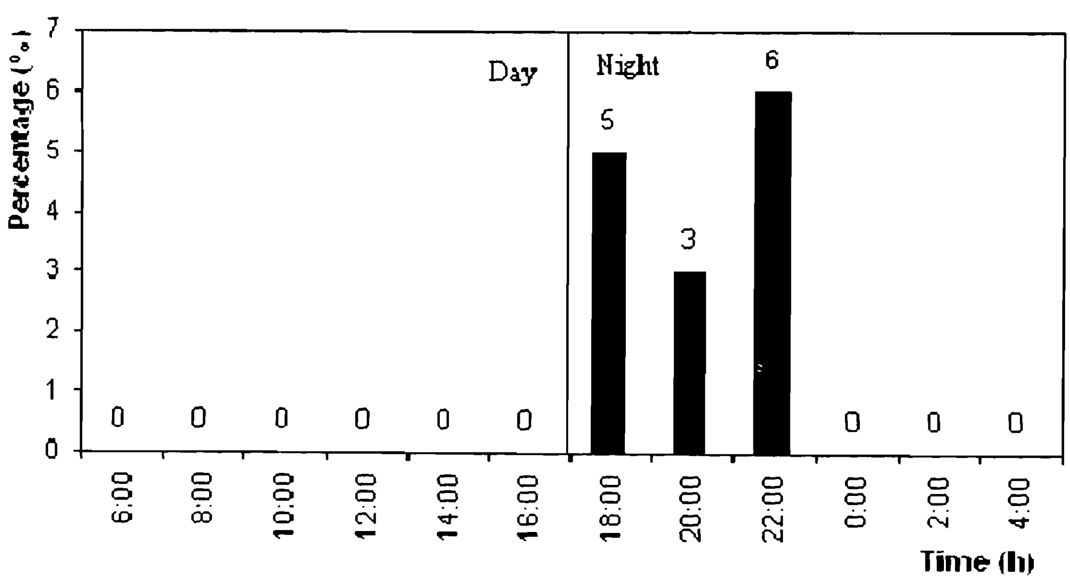

Fig. 20. Percentage of Tunicates in the collection

the siphonophores are also predators in general, but with smaller body size.

Tunicates spend less time of about 6 hrs in 0.30M water column that too after sunset and finish their activity quickly and sink down (Fig. 20). Fig. 21, explains the diel fluctuations of species diversity index for zooplankton in Andaman Sea. It is interesting to see that, though the zooplankton exhibit vertical migration, and the range of species diversity varies from 6.7 at 0200hrs to 11.3 at 1600hrs, with an average of 9.15 and 9.23 diversity index for day and night respectively, which is all most similar.

Diel fluctuations with regard to evenness of zooplankton, at Andaman Sea are represented in Fig. 22. It can be seen that evenness varies during day as well at night. The maximum evenness was 2.0 at 0800hrs for day and 2.2 at 2000hrs for night and the least evenness for day time was 1.3 at 1400hrs, while for night it was 1.5 at 0000hrs, indicating the fluctuation of populations, thus providing support for vertical migration.

Fig. 23 demonstrates the result of cluster analyses and dendrogram comparing similarity matrix with time of sampling. It can be seen that the highest value of 0.91 for sample collected at 1200hrs and 1000hrs thus linking them together at 0.91 level. Second highest similarity was at 0.81 between samples collected at 0600hrs and 0800hrs thus linking them together. Third highest link was at 0.78 between the sample collected at 0800hrs and 1000hrs, thus forming a group. The

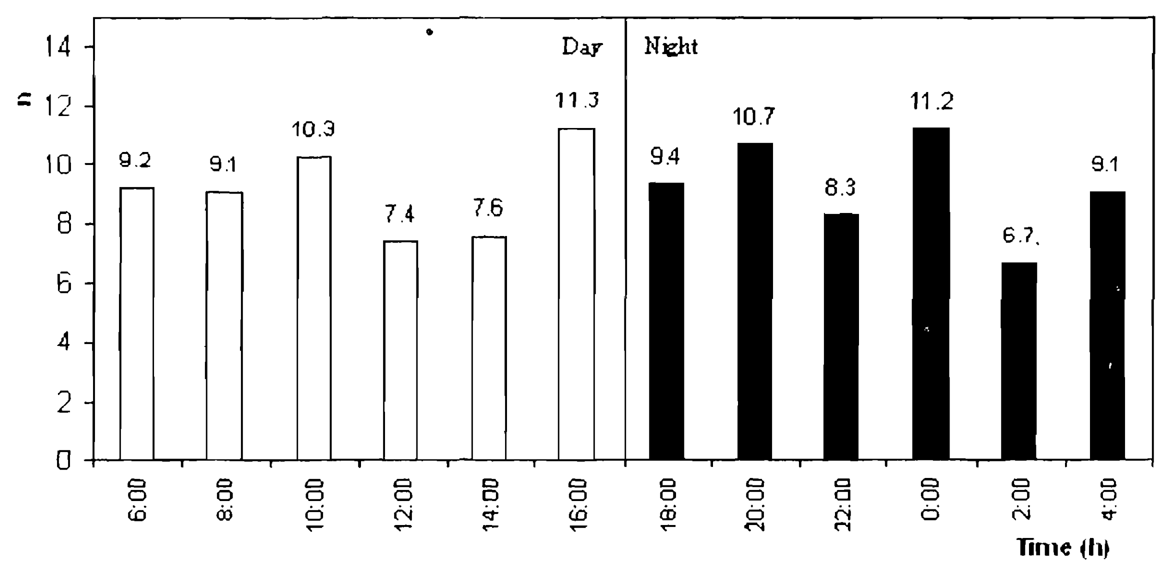

Fig. 21. Diel fluctuation of species diversity index of zooplankton in Andaman Sea.

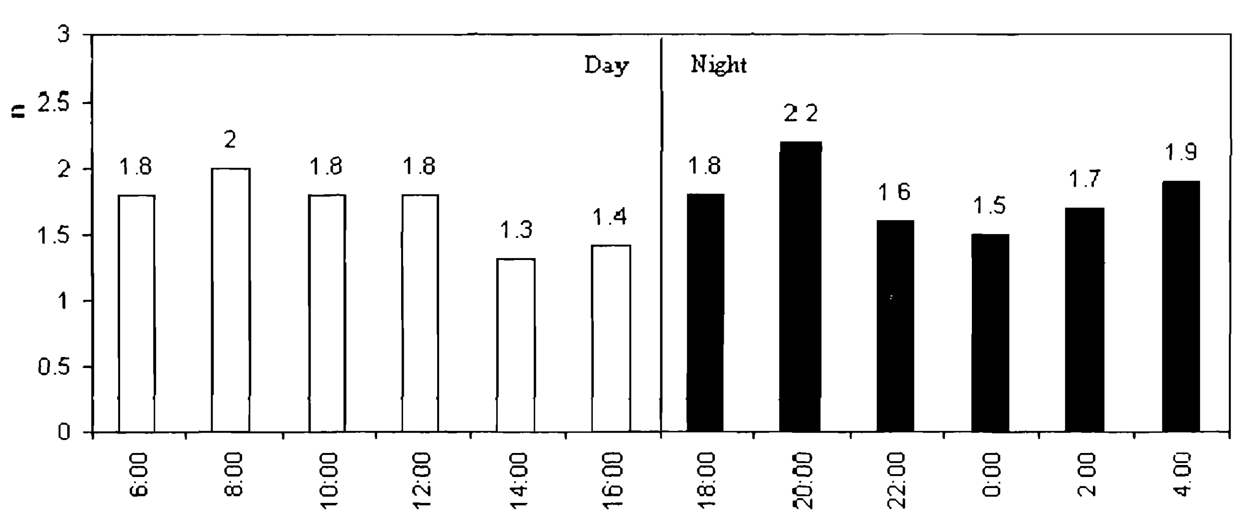

Fig. 22. Diel fluctuation of Evenness of zooplankton in Andaman Sea.

next groups was at 0.66 level by the samples collected at 2000hrs and 2200hrs and finally the least similarity value was 0.25 recorded for the samples collected at 1600hrs and 1400hrs.

DISCUSSION

Biomass and wet weight analyses are two well known yard sticks to analyze the density of living organisms, generally in marine environment. Fig. 1 and Fig. 2 clearly shows that both biomass and wet weight is higher for samples collected during night time, than the day samples, indicating higher density of organisms at night. Lesser biomass and wet weight of the samples during the day time indicates that the organisms descend down to lower depths for several reasons as mentioned by earlier workers.(Zaret and Suffern, 1976; Enright, 1977; Stich and Lampret, 1981; Hauris, 1988; Bollens and Frost, 1989 a,b,c; Magnesen, 1989; Neuman, 1989; Hansson *et al.*, 1990; Ohman, 1990; Jerling and Wooldridge, 1992; De Stasio, 1993), one of the major reason is said to be avoidance of predators. The second is said to be passively to facilitate the phytoplankton to grow during day time thus to ensure continuous food for zooplankton.

In animal kingdom, members of different groups exhibit distinct behaviors, which are specific to a particular group, though among the members of the same group one can find variation with regard to that behavior. Diel Vertical Migration (DVM) though known to be prominent and well studied in zooplankton by earlier workers (Raymond, 1939; Koslow, 1979) is poorly understood. Several workers have assigned various reasons for migratory and non-migratory behavior of zooplankton (Vinogradov, 1970 and Chae, 1995). One of the major cues for migration has been assigned to light intensity (Neuman, 1989; Jerling and Wooldridge, 1992). They have suggested that, while changing light intensity is significant for migration to "optimum zone" of light intensity, it is not only the determining factor. Animal has to either adapt to changing light intensity during the day, which will trigger off other behavioral patterns, like copepod in general and *Euchaeta concinna* and *Rinocalanus nasuta* in particular, which show their presence throughout the diel cycle, though in varied degree. But, among copepods, one can also see the species like *Candacia polydactyla*, *Sapphirina negromaculata*, *Copilia mirabills*, which can not adapt to surface waters all the time. Hence, they sink to lower depths between 1400hrs and 1800hrs, 1600hrs-1800hrs and around 1400hrs respectively, indicating variation in adaptability among the species of same group. While some other species like *Schmackeria poplosia*, *Subeucalanus Iongiceps*, *Unadula vulgaris* etc., appeared at the surface waters, only for a short period, that too during 2200hrs to 0600hrs. The reason for this may be, the daytime distribution of sapphirinids are determined under water light conditions as proximal cue as hypothesized by Chae (1995), that the well developed eyes, the iridescence of the males and day time shoaling in sapphirinids are closely related and constitute presumed mate finding mechanisms, which may be unique in oceanic planktons. Further, as explained by Raymont (1983) marked pigmentation reduces the photo damage to copepods and make it easily visible to predators. This seems to be the case with copepods like *Subeucalanus Iongiceps.*, *Unadula vulgaris*, which remain in lower depths, where the light intensity if low during day time and surface at night.

Regarding amphipods, from the present experiments, it is seen that they come to the surface water twice a day, once for long duration from around 1600hrs to 0000hrs and after a short "midnight sinking" reappear for a short period at around 0400hrs and then they will have a long sinking from 0600hrs to 1600hrs, may be to avoid predators at day time or this may also be a natural phenomenon, where nature allows the phytoplankton to grow during the day time when sunlight is available, to ensure continuous food supply as suggested by Hauris (1988).

About Amphipods, all the species under study (Fig.10-13) showed their existence in 0.30M water column, from 1800hrs to 0000hrs, indicating their group behavior. All the species under study showed, simultaneous appearance for about 6hrs and after completing their feeding and other activities at upper layer, seems to descend to lower levels together, to re-appear in next cycle. As the size of the organism is relatively small, it seems, to avoid the predators at day time they do not come to surface layers. Further, as they show a short period of grazing, due to less consumption, to save energy, they may be sinking down to lower water column, where metabolic rate is low, due to low temperature. Thus needing less energy requirements, as suggested by De Stasio (1993), Further, appearance and disappearance of amphipoda as a group may be a strategy to make way to other groups, to come to surface layers, for feeding. It seems like a natural adjustment and adaptability phenomenon, to reduce competition for same resource as suggested by Rothaupt (1990).

It is interesting to see from Fig. 14 that, though chaetognaths, a relatively larger animals with prominent eyes, can afford to stay at upper layer of waters during day as well at night time, but indicates that, they too undertake DVM, which is evident from the total absence of chaetognaths at 1800 hrs and re-appearance at a later stage, to show their maximum percentage (30 per cent) at 0200 hrs. They also show, the fluctuation with regards to their percentage of existence, though they exhibit their existence all through the daytime. It can be seen from Fig. 9 and 14 that, when amphipod population decreases from 40.0 per cent to 0 per cent from 1800 hrs to 0200hrs, the chaetognath population increases from 0 per cent to 30 per cent, indicating that, they avoid competition in grazing the same ground at the same time.

However, it can also be seen that among chaetognaths too, seemingly to avoid inter and intra-specific competition, they distribute themselves during day and night. For example, *Pterosagitta draco* surfaces for grazing at day time and do not show its existence at night (Fig. 15); while *Sagifta robusta* shows its presence day as well at night. With a zero presence from 1600hrs to 2200 hrs (Fig. 16) the *Sagitta bipunctata*, shows its presence from 0000hrs (31.0 per cent) and peaks to 50.0 per cent at 0400hrs and then, reduces its presence steadily, from 0600hrs to reach 0 per cent at 1400hrs. This not only reduces the competition among the members of the same groups, but also gives enough time for phytoplankton to grow, during the day time.

When copepods, amphipods, chaetognaths, tunicates, siphonophores are not present at their maximum concentration (Fig. 3, 9, 14, 19, 20), adult crustaceans are found to be present, at their maximum, at the surface layer (at around 0000 hrs). This phenomenon provides evidence for avoidance of competition for same source of food as reported by Rothaupt (1990). As the curstaceans are generally smaller in size and exhibit prolonged larval stages, it seems to avoid of being predated, they start surfacing from 1600 hrs, when the light intensity reduces and spends time up to 0000 hrs and then sink to lower layers of water.

While the siphonophores, by showing their presence at 0-30M water column, at 1800-2000 hrs and 0400 to 1000 hrs, clearly exhibit two diel cycles of their vertical migration (Fig. 19). They exhibit midnight sinking too (Fig. 19), It can also be seen from the above that, they show their existence at day and night, their density demonstrates that, they prefer night time, than day. From the collections, it was also observed that, day time surfacers have relatively larger body size and large eyes, indicating that, the body size has a bearing on day / night migration as reported by Mackas (1992). Further, siphonophores appear, when competition pressure from other fellow predators is less, which is evident from Fig. 19. Apart from that, they appear strictly during corpuscular hours of the diel cycle, when most of the other larger predator species such as, amphipods, chaetognaths are either absent or in their low population. This may be a natural phenomenon of avoiding competition among various groups of organism for same source of food.

From Fig. 20, it can be concluded that, tunicates have relatively small range of timing for feeding and other activities at surface waters. As they are not known as long migrants, show a quick appearance at 1800hrs and sink down to certain level at 2000 hrs to reappear at 2200 hrs and sink down to re-appear at next cycle. This short period of spending time at surface layer seems that they are either quick feeders or feed on surface phytoplankton to a less extent and prefer to stay at lower water columns, may be safety or for their probable capacity to feed at that level too.

It is Pielou (1966) explained the importance of study of species diversity and its pattern, while studying ecological succession. Later Peet (1974) described role and method of measuring species diversity. Hence, based on the importance, when an attempt was made to analyze the zooplankton diversity in the study area, the results obtained has been represented in Fig. 21. It can be seen from the figure, though there is a species diversity fluctuation during day or night time, a some what constant number of species (9.15 during day and 9.23 during night) was recorded. There is a record of higher species diversity during corpuscular period. Similarly patchiness also shows its higher value at corpuscular period. Though the biomass of zooplankton at night was comparatively higher (2.83mlm^{-3}), than the day time (1.83 mlm^{-3}), which may be a strategy of nature to see that, all planktonic groups get an opportunity to graze, though at different times of the diel cycle. At the same time, by keeping low grazing pressure at day time, provides sufficient time for phytoplankton to grow in order to provide a continuous food supply for zooplankton. Thus, maintaining the food chain, in an efficiently operating manner. This indicates that, Andaman Sea ecosystem sustains a large, mature community with stability, where in a number of organisms live in absolute harmony for their as well as community success.

Similarity index, patchiness and evenness are important criteria to determine the pattern of distribution of any organism (Omori and Hamner, 1982. Washington 1989., Davies *et al.*, 1991). Hence, the results obtained in the present experiments, were subjected for cluster analyses and dendrogram were prepared from comparing similarity index. The results obtained are represented in Fig. 23, which clearly demonstrates that, there is a distinct grouping with regard to cluster formation in terms of similarity matrix. For example, sampling at 1200 hrs and 1000 hrs belong to same cluster, with similarity matrix around 0.91, between 0600hrs and 0800 hrs (0.81).

From the present studies, it becomes clear that, the biomass in Andaman Sea remains some what similar, during entire diel cycle, though whose higher peak at 2000 hrs and 0200 hrs, mainly due to the presence of maximum number of zooplankton. While, the wet weight of the collected sample is significantly high at night, than the day.

Regarding copepod groups, they seem to occupy the surface waters at all the times, with some what equal distribution, though certain specie like *Candacia pachydactyla*, *Sapphirina negromacculata*, *Copilia mirabilis* exhibt a complete (2 cycles per day) diel vertical migration; while, *Rhinocalanus nasutus*, *Euchaeta concinna* exhibit single cyclic migration in a day. This leads to the fluctuation of population size, at the surface layers. Amphipods show a general tendency as a group, to be at the surface waters, at 1800 hrs to 0000 hrs, as exemplified by *Brachyscelus crusculum*, *Lestrigonus schizogeneios*, *Cranocephalus spp*. *Rhabdosoma spp*. etc., There are other amphipod species, which may surface slightly early (1600 hrs) or at a slightly later stage (at around 0400 hrs), but they do not surface between 0600 hrs to 1400 hrs.

Similarly chaetognaths show, fluctuation with regard to their existence. They do surface at all the times of the diel cycle, except at around 1800 hrs i.e., immediately after sunset. There are chaetognaths, which surface during day time (eg., *Pterosagitta draco*) or at day and night (eg., *Sagitta robusta* and *S. bipunctata*), with distinct sinking between 1600 hrs and 2200 hrs.

The Crustaceans have a short span of surfacing from 1600 hrs to 0000 hrs with peak at 0000 hrs, before sinking to re-appear at next cycle. While the siphonophores show, clearly two cycles, in a day, by appearing between 0400 hrs and 1000 hrs and later between 1800 hrs and 2000 hrs. The tunicates appear in surface waters only once a diel cycle from 1800 hrs to 2200 hrs. The present studies indicate that, at all given times of a diel cycle, an average of 9.15 species of zooplankton will be at surface, compared to 9.23 species at night, indicating no significant variation with regard to species diversity. While the density of zooplankton varies from 1.3 to 2.0 at day (Avg. 1.68) and between 1.5 to 2.2 at night (Avg. 1.78) indicating, higher evenness of grazers at night.

The studies also leads one to conclude that, at Andaman Sea, the biotic community supports, some what same number of species during day, as well at night, though the biomass varies. This indicates ecological and trophic maturity of the community and thus exhibits equilibrium. One can also see the equilibrium between day and night time productions. There also exists equilibrium for competition for same resource, between and among the members of different groups of organism. Another aspect revealed by the present studies is, the formation of distinct clusters of similarity, with the time of sampling of zooplankton. For example, there is a day group (0400, 0600, 0800, 1000 and 1200 hrs) and an evening group (1600 and 1800 hrs). The catches at 1400hrs do not show clustering with any group. However, the catches at 0200hrs, based on their numerical biomass and wet weight, seems to be near to evening group.

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Chapter 08

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 131-140, 2010

ZOOPLANKTON ABUNDANCE AND DIVERSITY IN ANDAMAN NICOBAR ISLANDS, INDIA

J. SANTHANAKUMAR[1]*, N.V. VINITHKUMAR*, G. DHARANI, D. MAGESH PETER*, A. K. ABDUL NAZAR, R. KIRUBAGARAN, R. VENKATESAN and S. KATHIROLI

Ocean Science and Technology for Islands, National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Govt. of India, Narayanapuram, Pallikaranai, Chennai–600100, Tamil Nadu, India

INTRODUCTION

Zooplankton is an economically and ecologically important group of aquatic animals and their ecological processes influence the biological productivity and fishery. The present study attempts to analyse distribution, abundance, density and diversity of zooplankton in the eastern coastal areas of Andaman Sea. The Andaman and Nicobar Islands comprise of a chain of 572 islands, lying between 6°45′ N and 13°45′ N latitude and 92°12′ E and 93°57′ E longitude, spread over a distance of 1120 Km between lower Burma and upper Sumatra in between the Bay of Bengal and the Andaman Sea. The Andaman Sea extends to about 650 km east from the Malaysian peninsula to about 1200 km south wards from the Irrawaddy delta in Burma (Rodolfo 1966). It has the total area of about 0.602×10^6 km ^{2} with the volume of 0.660×10^6 km^2 (Lyman 1966). The Andaman and Nicobar archipelago's coastal line is 1962 km in length and the EEZ comprises of 0.6 million km^2, which is roughly about 30per cent of Indian EEZ (Rodolfo, 1966; Gazetteer and Dhingra, 2006). Most of the coastal areas support rich growth of mangrove vegetation and fringing coral reefs. The beaches are narrow and extensive. These islands have steep continental slopes, because of which oceanic conditions prevail close to the shore. The coastline with innumerable creeks, bays and backwaters harbouring highly productive mangrove and coral ecosystems serve as a natural habitat for the development of a luxuriant fauna around the islands. The surrounding seas represent an ecosystem typical of the tropical waters with rich biodiversity. The climate of these islands is typically tropical, hot and humid conditions (80 per cent). The annual temperature ranges from 18°C to 36°C, with slight increase from north to south. Rainfall is heavy with an average of about 3100 mm/y and is prolonged from May to December. Major rainfall occurs during late May to early October (southwest monsoon), while a weak spell of northeast monsoon brings rain during November - December. The qualitative and quantitative analyses of zooplankton data of previous studies of this region were not of highly informative. This article deals with zooplankton biomass, composition and abundance of inshore region lined with mangroves and open sea areas close to few kilometers from the shore.

Andaman and Nicobar Centre for Ocean Science and Technology, National Institute of Ocean Technology (NIOT), Dollygunj, Port Blair–744103, A&N Islands, India.
E-mail : sanpraus2003@yahoo.co.uk

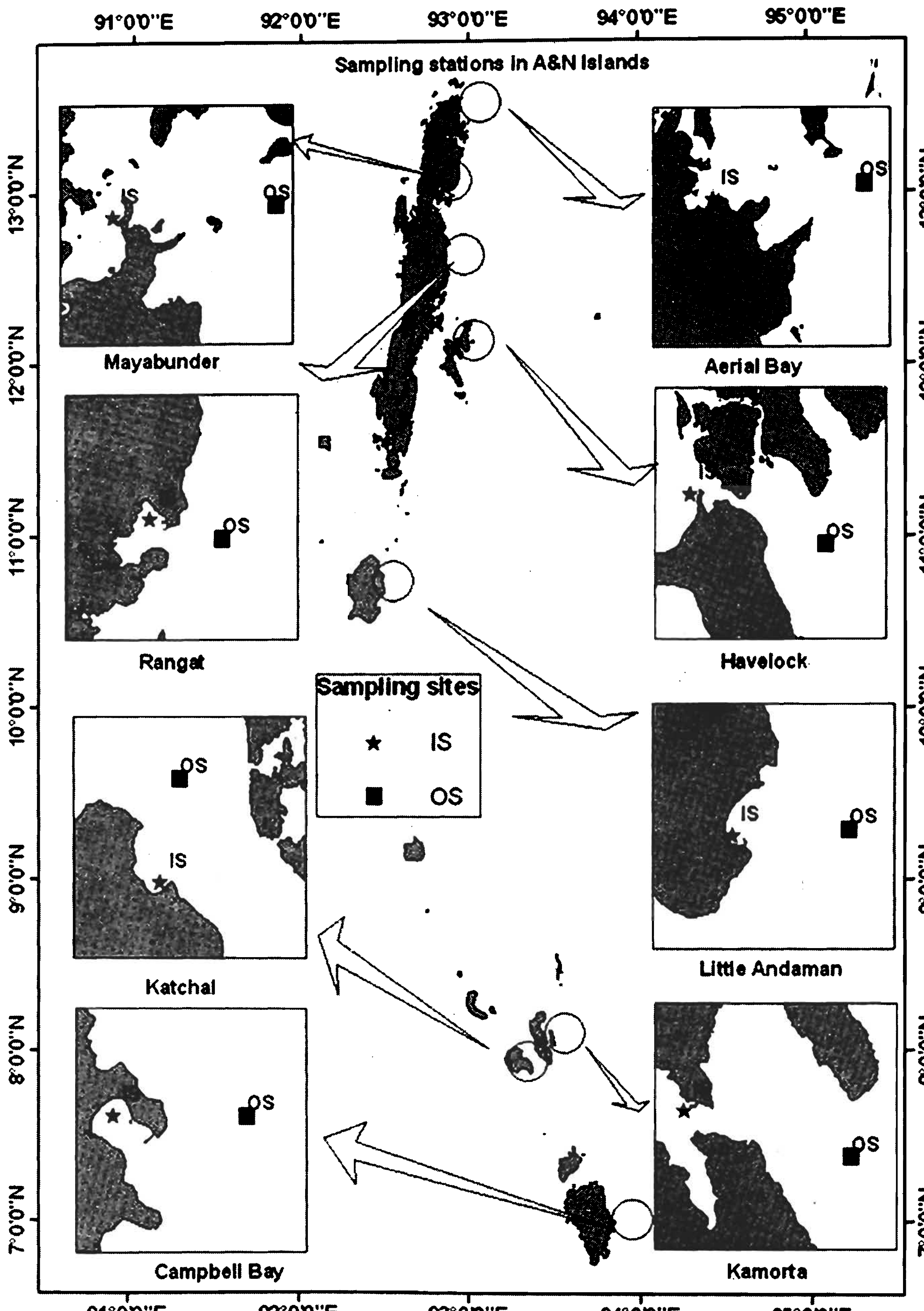

Fig. 1. Map showing sampling stations in Andaman Nicobar Islands (IS–Inshore, OS–Open Sea).

MATERIALS AND METHODS

The sampling was carried out during the months between January and March 2004. Zooplankton samples were collected from 8 locations each comprising of inshore and open sea waters a total of 16 stations of all over the A & N coastal regions. Arial Bay (Diglipur), Mayabunder, Ranghat, Havelock and Hut bay at Little Andaman were recorded from Andaman group of islands and Kamorta, Katchal and Great Nicobar (Campbell Bay) were recorded from Nicobar group of islands. Most of the inshore stations of the study areas are influenced by the freshwater input through small rivers and streams. Sampling was carried out by using motorized boats with the length of 15 m during high tide periods. The list of sampling stations and their locations are given in figure 1. Zooplankton samples were collected at each station by obliquely towing a plankton net with mesh size of 250 micron and a mouth radius of 50 cm (make: Hydro Bios) in sub surface water for a period of 5 to 10 minutes. The mouth of the net was tied with a flowmeter (make: Hydro Bios) to estimate the volume of water filtered through the net. Samples were immediately preserved in 5 per cent formalin. Whole zooplankton was first observed to remove bigger fish larvae and medusae. Biomasses of the samples were estimated by displacement volume method (Goswami, 2004). Lensia and other salps with size of more than 1mm were sieved through 1000-micron mesh and they were observed under stereo zoom microscope (make: Nikon SMZ800). Each sample was further sub sampled and the total quantitative analysis was made in Sedgwick rafter plankton counting chamber. Generic identification of zooplankton was inspected under Optiphot microscope (make : Nikon Eclipse E600).

RESULTS

In general, zooplankton density, biomass and species diversity showed wide variations among the stations between Andaman group and Nicobar group of islands. Total wet biomass of zooplankton observed from all the stations were ranged from 0.14 mL/m^3 to 4.0 mL/m^3. Maximum biomass was observed from the inshore waters than open sea stations as higher mean biomass of inshore was1.17 ±1.15 mL/m^3 than open sea stations as 0.80 ± 0.70 mL/m^3. The maximum biomass of 4 mL was recorded from the inshore water of Havelock Island, whereas the minimum of 0.14 mL was recorded from the open sea station of Kamorta Island.

The average biomasses recorded from northern and southern stations were 1.30 mL/m^3 and 0.46 mL/m^3 respectively. In case of species diversity, a maximum of 31 numbers of species were recorded from the inshore station of Campbell Bay at Great Nicobar and the minimum 19 species was recorded in open sea station at Hut Bay of Little Andaman. Higher species diversity of 28 ± 3 numbers was recorded from inshore stations than the open sea stations where the number was found to be 24

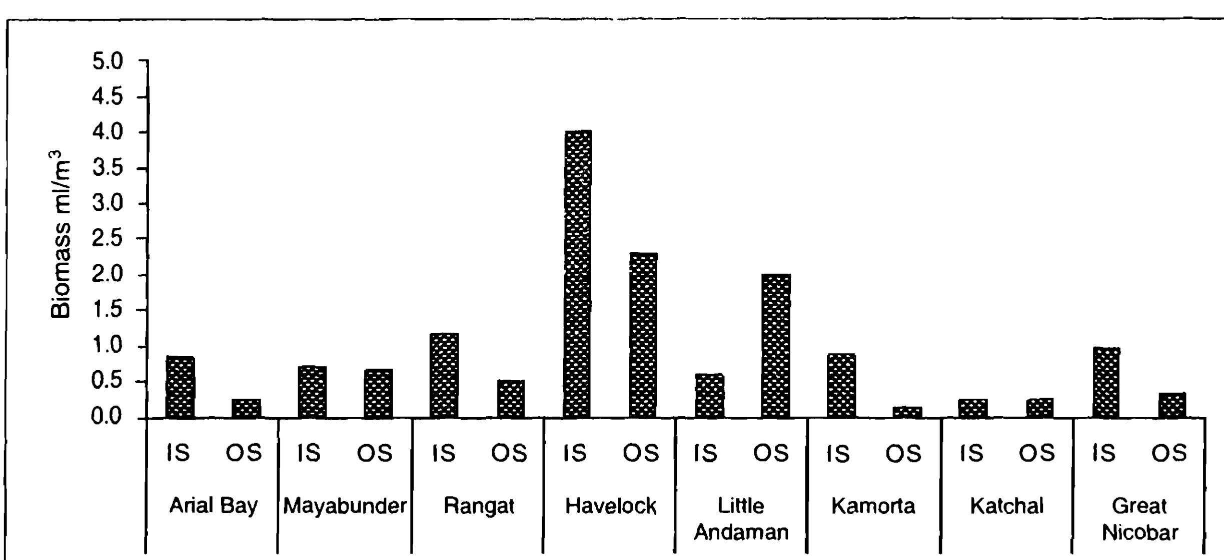

Fig. 2. Biomass of zooplankton mL/m^3 recorded in different stations of Andaman and Nicobar (IS – Inshore; OS–Open sea)

± 3. On an average 26 numbers of species were recorded from northern and southern stations.

Zooplankton population density showed wide variations in all the northern and southern stations. Zooplankton population density in the entire Andaman islands ranged from 5797 to 48178 no/m³ with an average of 19579 ± 15142 no/m³ and from 4539 to 17493 no/m³ with an average of 9467 ± 5298 no/m³ in the inshore stations and open sea stations respectively. The minimum zooplankton population density of 4539 no/m³ was encountered from open sea station of Kamorta Island. The maximum zooplankton population of 48178 no/m³ was observed at inshore station of Havelock Island. The average population density of the northern and southern stations was 16668 and 10948 no/m³ respectively.

DISCUSSION

The zooplankton population density, biomass and diversity of species composition showed considerable variations between the stations of Andaman and Nicobar group of islands. The population density and biomass in the stations around Andaman group (northern stations) showed that these areas were comparatively productive than southern Nicobar group of islands. This could be attributed to the abundance of productive mangrove areas of Andaman group of islands, which is estimated to be around 929 km² in contrast to only 37 km² in Nicobar group of islands (Dagar *et al.*, 1991. Roy and Krishnan,

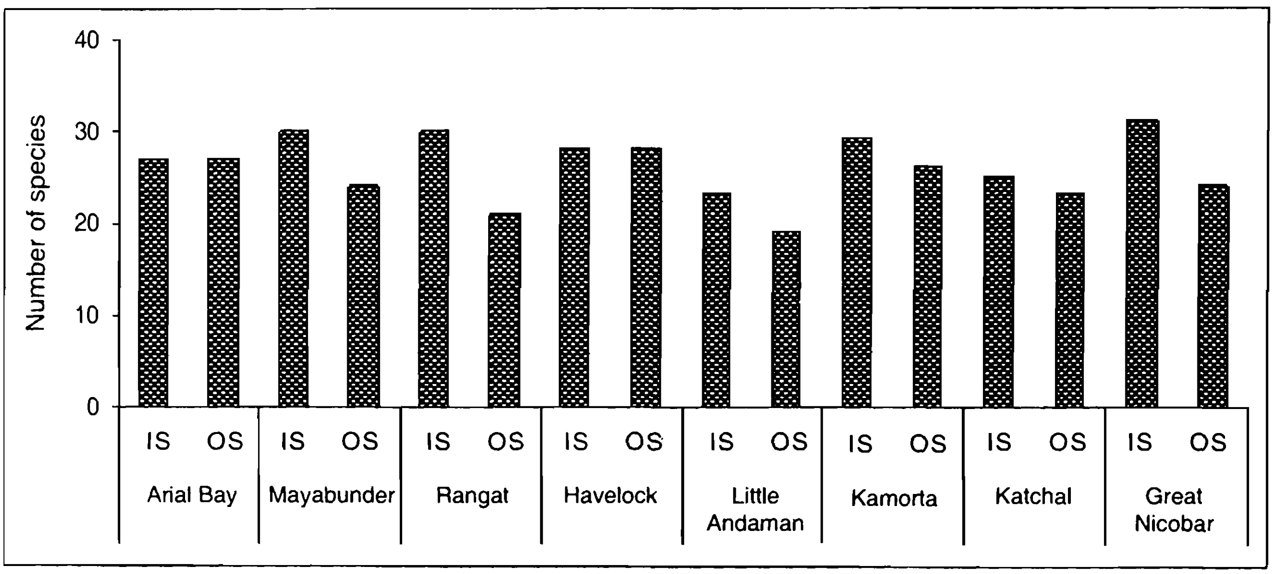

Fig. 3. Number of zooplankton species recorded in different stations of Andaman and Nicobar (IS – Inshore; OS–Open sea)

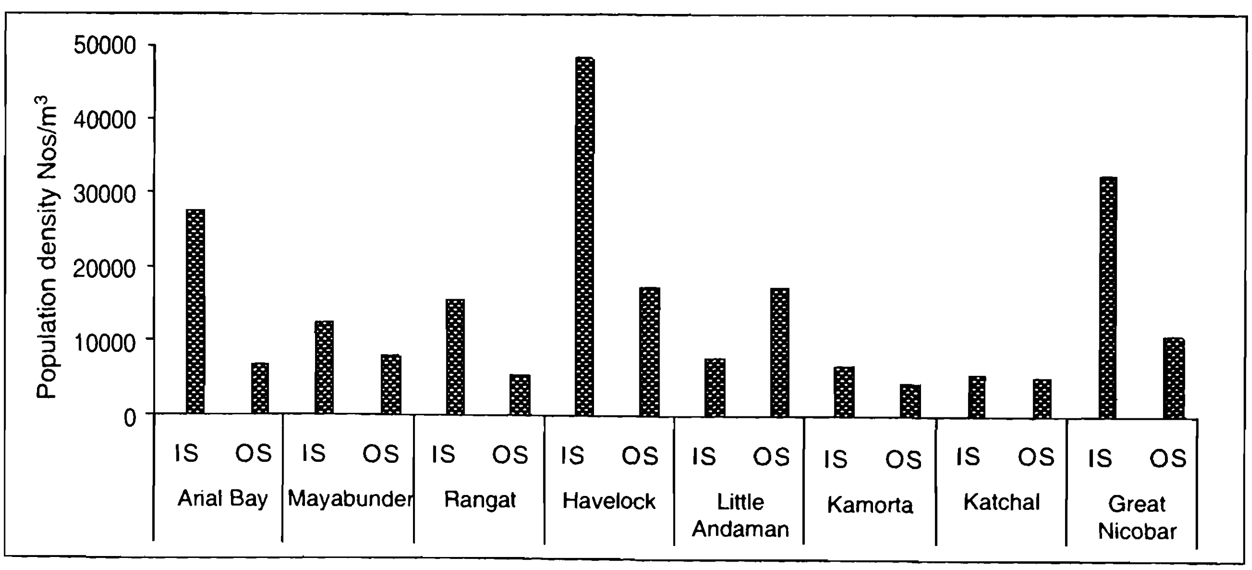

Fig. 4. Zooplankton population density Nos/m³ recorded in different stations of Andaman and Nicobar Islands (IS–Inshore; OS–Open sea)

2005). When compared to the total land and coastal areas of Andaman Islands, the southern groups of Nicobar Islands are having considerably much lower coastal area thus the mangrove areas are also found to be lower. In these islands mangroves are occurring mostly in creeks, backwater and muddy shores. The southern groups of islands are having less mangrove area due to narrow less width of creeks, backwater and muddy shores. In the case of Great Nicobar Island a river Magar nallah mixes in to the waters of Campbell Bay, which is also bordered with mangroves. The waters from this brackish water mangrove area bring lot of nutrients, which could have contributed to the higher zooplankton productivity. Due to this suitable environmental condition in Campbell Bay (Great Nicobar), the inshore station showed second highest population density of 32504 no/m^3 in the present study.

Copepods are the most abundant group in the mangrove mesoplankton (Kathiresan and Bingham, 2001). It is also mentioned that diverse communities of zooplankton exist in mangrove habitats and abundances can be extremely high, reaching 10^5 no/m^3. The densities in mangroves are significantly higher than the open sea waters as reviewed by Robertson and Blaber (1992). Also high densities of copepods that is 25974 to 138420 no/m^3 were recoded in Andaman Bay region as by Goswami and Rao, 1981. Similarly abundance of copepods in Cananeia lagoon estuarine system in Sao Paulo, Brazil was recorded as from 1.90×10^4 to 6.55×10^4 no/m^3 (Ara, 2004). Godhantaraman (1994) recorded the maximum abundance of 80740 no/m^3 of copepods in mangrove zone of Pichavaram, South east coast of India. The copepods were constantly occurred in all the stations and most dominant group in terms of composition as it ranges from 65.42 per cent at Open sea station of Mayabunder to 85.56 per cent at Open sea station of Campbell Bay at Great Nicobar Island. Similar values were observed by others in tropical mangrove region (Osore *et al.*, 1992). Percentage composition of copepod in total zooplankton abundance is higher in Andaman Islands during the present study when compared to the February, 1979 survey at Andaman Sea by Madupratap *et al.*, 1981 who have reported the copepod dominance as 53.9 per cent. The study was carried out only from the offshore waters at Andaman sea, whereas present study, samples were collected from the eastern coastal region of Andaman and Nicoabr Islands. The copepod percentage was ranged from 65.42 per cent at open sea station of Mayabunder to 85.56 per cent at open station of Campbell Bay. Comparatively very high density of copepod from inshore and open sea waters were recorded in Great Nicobar as 85.08 per cent and 85.56 per cent respectively. Similarly Goswamy and Rao (1981) recorded the maximum density of copepods as 85 per cent of total percentage with the population density of 138420 no/m^3 at Campbell Bay. Variations were observed in population density between northern stations (72.73 per cent) and southern group of islands (80.38 per cent). Calanoid, Cyclopoid and Harpacticoid were the major order of representatives in copepod community. The dominant Calanoids recorded were *Paracalanus* sp., *Calanopia* sp., *Acrocalanus* sp. *Acartia* sp., and *Paracalanus* sp., The other notable species of calanoids were *Eucalanus* sp., *Centropages* sp., *Labidocera* sp. and *Rhyncalanus* sp. Similarly *Oithona* sp., *Corycaeus* sp. and *Oncaea* sp. were dominating in cyclopoids whereas *Euterpinna* and *Macrosetella* were dominating in Harpacticoids. The maximum number of copepods recorded was 48178 no/m^3 at inshore waters of Havelock and minimum recorded was 2958 no/m^3 at open sea waters of Kamorta.

Tunicates were represented as second dominating group, and among them, Appendicularians and Salps were found to be the common representatives. *Oikopleura* and *Fratilaria* were the common genera of Appendicularians. In the class Thaliacea, *Thalia* sp. and doliolum larvae were represented in lesser quantity. Their minimum density was recorded at open sea of Katchal with 1.83 per cent and maximum density recorded was 15.99 per cent at Open Sea of Havelock Island. Stations in Andaman Islands recorded higher level of tunicates comprising of 9.59 per cent than southern and Nicobar group Islands as 4.14 per cent. The over all percentage of tunicates observed was 7.55 per cent. Earlier Madupratap *et al.*, (1981) recorded tunicates with total density of 8.0 per cent which is closer to the value observed in this study. Tunicates were found to contribute 9.59 per cent of total zooplankton population in the northern group of islands than the southern group of islands with an average of 4.14 per cent. The maximum

Table 1. Zooplankton abundance in terms of Taxon recorded at the different sampling station of Andaman and Nicobar Islands

Stations	**Arial Bay**		**Maya bunder**		**Ranghat**		**Havelock**		**Little Andaman**		**Kamorta**		**Katchal**		**Campbell Bay**	
Taxon	**IS**	**OS**	**IS**	**OS**	**IS**	**OS**	**IS**	**OS**	**IS**	**OS**	**IS**	**OS**	**IS**	**OS**	**IS**	**OS**
Protozoans	+++	++	++	++	+++	0	0	0	++	0	+	++	++	0	++	0
Coelenterata	++	0	0	0	0	0	++	++	0	0	0	+	0	0	+	0
Annelida	0	+	++	++	++	+	++	++	++	0	+	+	0	++	+	++
Calanoids	#++#	xxx	xxx	xxx	xxx	xxx	#++#	xxx	xxx	###	xxx	xxx	xxx	xxx	#++#	xxx
Harpacticoids	++	++	++	0	++	++	+++	xxx	++	++	+++	++	++	++	++	++
Cyclopoids	###	xxx	xxx	xxx	xxx	xxx	#++#	###	xxx	###	xxx	+++	xxx	+++	###	xxx
Cirripedia	0	0	++	++	xxx	++	++	0	0	0	0	++	++	0	0	0
Mysidacea	0	0	0	0	0	0	+++	++	0	0	0	0	0	0	0	0
Euphausiacea	++	0	++	++	++	0	++	0	0	0	+	+	0	0	++	++
Lucifer sp.	++	0	+	0	++	++	0	++	+	0	+	+	0	0	++	0
Decapods	++	+	0	0	0	0	0	0	++	0	+	0	0	+	++	0
Mollusca	xxx	++	+++	+++	+++	++	###	+++	+	+++	++	++	++	++	xxx	+++
Echinodermata	0	0	0	0	++	0	++	++	0	0	0	0	+	+	0	0
Tunicates	xxx	++	+++	+++	+++	++	###	+++	+	+++	++	++	++	++	xxx	+++
Chaetognatha	++	+	++	++	0	0	++	0	0	++	+	0	++	+	++	+
Pisces	0	+	+	0	0	0	+++	0	0	0	0	0	++	+	0	0

Key; (0) – Negligible; (+) – Less than 100; (++) – Between 100-500; (+++) – Between 500-1000
(xxx) Between 1000-5000; (###) – Between 5000 -10000 and (#++#) – Above 10000.

Table 2. Average numbers and percentage composition (in brackets) of each Taxon represented in zooplankton population at various stations of Andaman and Nicobar Islands (IS–Inshore, OS–Open sea).

Stations	Arial Bay		Mayabunder		Ranghat		Havelock		Lit. Andaman		Kamorta		Katchal		Cam. Bay	
Locations	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS	IS	OS
Date	12.2.04	12.2.04	13.2.04	13.2.04	14.2.04	14.2.04	8.2.04	8.2.04	9.3.04	9.3.04	10.1.04	10.1.04	10.1.4	10.1.04	14.1.04	14.1.04
Time (24 Hrs)	8.30	10.30	8.00	10.00	11.07	10.15	8.45	7.00	10.00	11.30	7.30	9.00	13.30	14.40	7.30	8.40
Protozoans	1207 (4.64)	272 (4.69)	187 (1.60)	102 (1.19)	1003 (6.39)	0	0	0	391 (5.40)	0	68 (1.04)	221 (4.90)	153 (2.77)	0	340 (1.05)	0
Coelenterata	306 (1.18)	0	0	0	0	0	255 (0.53)	289 (1.99)	0	0	0	68 (1.51)	0	0	85 (0.26)	0
Annelida	0	68 (1.17)	187 (1.60)	187 (2.19)	170 (1.08)	68 (1.34)	510 (1.06)	289 (1.99)	102 (1.41)	0	68 (1.04)	68 (1.51)	0	170 (3.53)	85 (0.26)	136 (1.22)
Calanoids	11985 (46.08)	2108 (36.36)	3825 (32.70)	2856 (33.40)	5576 (35.50)	2227 (43.96)	13277 (27.56)	3706 (25.53)	2788 (38.50)	7752 (46.77)	2414 (36.88)	1951 (43.24)	1887 (34.15)	2737 (56.89)	20961 (64.79)	5729 (51.37)
Harpacticoids	153 (0.59)	136 (2.35)	578 (4.94)	0	510 (3.25)	527 (10.40)	765 (1.59)	1428 (9.84)	204 (2.82)	357 (2.15)	901 (13.77)	136 (3.01)	136 (2.46)	442 (9.19)	170 (0.53)	136 (1.22)
Cyclopoids	8109 (31.18)	2297 (39.62)	3349 (28.63)	2091 (24.45)	4216 (26.84)	1632 (32.21)	18649 (38.71)	5695 (39.23)	3264 (45.07)	6851 (41.33)	2142 (32.73)	1371 (30.39)	2091 (37.85)	612 (12.72)	6307 (19.50)	3298 (29.57)
Cirripedia	0	0	391 (3.34)	374 (4.37)	1513 (9.63)	204 (4.03)	300 (0. 62)	0	0	0	0	153 (3.39)	153 (2.77)	0	0	0
Mysidacea	0	0	0	0	0	0	782 (1.62)	289 (1.99)	0	0	0	0	0	0	0	0
Euphausiacea	306 (1.18)	0	578 (4.94)	187 (2.19)	170 (1.08)	0	255 (0.53)	0	0	0	68 (1.04)	68 (1.51)	0	0	425 (1.31)	357 (3.20)
Lucifer sp	153 (0. 59)	0	102 (0.87)	0	170 (1.08)	136 (2.68)	0	289 (1.99)	102 (1.41)	0	68 (1.04)	68 (1.51)	0	0	255 (0.79)	0
Decapod larvae	306 (1.18)	68 (1.17)	0	0	0	0	0	0	187 (2.58)	0	68 (1.04)	0	0	85 (1.77)	170 (0.53)	0
Mollusca	1513 (5.82)	340 (5.87)	1054 (9.01)	1139 (13.32)	1020 (6.49)	136 (2.68)	5650 (11.73)	1122 (7.73)	102 (1.41)	714 (4.31)	340 (5.19)	204 (4.52)	374 (6.77)	255 (5.30)	1564 (4.83)	714 (6.40)
Echinodermata	0	0	0	0	340 (2.16)	0	510 (1.06)	289 (1.99)	0	0	0	0	68 (1.23)	85 (1.77)	0	0
Tunicates	1513 (5.82)	340 (5.87)	1054 (9.01)	1139 (13.32)	1020 (6. 49)	136 (2.68)	5950 (12.35)	1122 (7. 73)	102 (1.41)	714 (4.31)	340 (5.19)	204 (4.52)	374 (6.77)	255 (5.30)	1564 (4.83)	714 (6.40)
Chaetognatha	459 (1.76)	88 (1.52)	289 (2.47)	476 (5.57)	0	0	255 (0.53)	0	0	187 (1.13)	68 (1.04)	0	153 (2.77)	85 (1.77)	425 (1.31)	68 (0.61)
Pisces	0	80 (1.38)	102 (0.87)	0	0	0	1020 (2.12)	0	0	0	0	0	136 (2.46)	85 (1.77)	0	0
TOTAL	**26010**	**5797**	**11696**	**8551**	**15708**	**5066**	**48178**	**14518**	**7242**	**16575**	**6545**	**4512**	**5525**	**4811**	**32351**	**11152**

numbers of tunicates recorded was 5950 no/m^3 at inshore station of Havelock and minimum was 102 no/m^3 at inshore station of Little Andaman Island. Molluscan forms were found to be the most abundant groups observed after Copepods and Larvaceans in the present study.

Bivalve, Gastropod larvae, Heteropods and Pteropods, were observed as common representatives of Mollusca. Among them bivalve larvae, *Creseis acicula*, *Hyalocyclix* sp., *Firoloida* sp., and *Limacina* sp., were the dominating forms. Over all average contribution of Molluscan forms was 6.41 per cent. The minimum density recorded was 1.29 per cent at inshore station of Little Andaman and maximum was 14.19 per cent at open sea station of Mayabunder. Heteropods and bivalve larvae were most abundant among Molluscans forms and their maximum abundance was found to be 3366 and 2854 no/m^3 respectively from the inshore station of Havelock. Their minimum abundance was found to be 68 no/m^3 at inshore station of Kamorta. In case of Molluscan form of zooplankton, Southern and Northern waters did not showed significant variation and the percentage of density recorded was 6.85 per cent and 5.67 per cent respectively. The maximum number of Molluscans forms recorded were 5950 no/m^3 at inshore of Havelock and minimum recorded was 102 Nos./m^3 at inshore waters of Little Andaman.

Among Crustacean forms, the representatives of Decapoda, Cirripedia, Mysidacea and Euphausiacea were encountered in all the stations except open sea station of Little Andaman. In which no representatives of above said Taxon were recorded during the study period. In case of other crustacean forms excluding copepods, their average values from northern stations were observed to be about 4.81 per cent and in southern stations about 3.96 per cent. Among them Cirriped nauplei of barnacle were dominating in most of the stations. Their maximum abundance was 1513 no/m^3 at inshore waters of Ranghat and minimum was 56 no/m^3 at open sea station of Katchal. Among zooplankton, minor crustacean forms were observed to be most the common forms and their contribution of total zooplankton was high in northern stations (2091 no/m^3), when compared to southern stations (459 no/m^3). Presence of more decapod larvae in northern stations shows the possibility of seasonal breeding and availability of suitable environmental conditions. Calyptopis larva, cyprid larva and *Lucifer* sp. were other common representatives. Mysidacea, Amphipoda and Euphausiacea were in general poorly represented in all the stations. Apart from the above mentioned groups, the other groups such as Protozoa, Coelenterata, Polychaeta, Echinodermata, Chaetognatha and Pisces were recorded in all the stations. However, they contributed only a small percentage of total zooplankton density. In groups such as Protozoa, the common representatives recorded were *Elphedium* sp., *Dictyocha* sp., *Globigerina* sp., *Acanthometra* sp. and *Tintinnopsis* sp. The overall average contribution of protozoa was 2.07 per cent in total density and their contribution in northern and southern stations were 2.29 per cent and 1.69 per cent respectively. Hydromedusae, *Pleurobrachia* sp., Siphonophores were represented in Coelenterates and their total contribution was least with 0.33 per cent in total zooplankton population. The average contribution of coelenterates in the northern and southern groups of islands were 0.34 per cent and 0.31 per cent respectively. In case of Polychaetes, spionid and Nereid larvae were commonly observed and their average contribution was 1.21 per cent in all over Andaman region. The average compositions of polychaetes in northern and southern stations were 1.16 per cent and 1.30 per cent respectively.

In Chaetognatha group, the genus such as *Krohnitta* and *Sagitta* were found to be most common forms. Vijalakshmi *et al.*, (1981) recorded about 8 per cent of Chaetognaths as second highly abundant organism in zooplankton population in Andaman area. However, during the present study 1.29 per cent only observed. The average abundance of northern and southern stations were 1.29 per cent and 1.28 per cent respectively. Presence of average number of *Krohnitta* sp., was higher in inshore stations as 103 Nos./m^3 than open sea stations *Sagitta* sp., as 55 no/m^3. This observation is also contradicted with the earlier observations of Vijalakshmi *et al.*, (1981). The group Echinodermata was represented by Ophiopluteus, pluteus and bipinnaria larva an their overall average contribution for Andaman Islands was 0.51 per cent only. The abundance recorded from the northern and southern group of islands were 0.51 per cent and 0.53 per cent respectively. Fish eggs and fish larva were the representatives of the group of Pisces. Their overall contribution was 0.53 per cent whereas Madupratap *et al.*, (1981) observed slightly higher population of 1.4 per cent during their study. The Average contributions in northern and southern stations were 0.40 per cent and 0.73 per cent respectively. The eastern side stations of these islands show poor biomass values in open sea stations during the earlier studies (Madupratap *et al.*, 1981). Goswami, (1992) has recorded lower zooplankton biomass in the mangroves than in contiguous estuarine and neritic habitats in western coasts of India.

CONCLUSION

In general the zooplankton diversity and density showed wider variation between inshore and open sea waters. The same is the case of northern and southern groups of islands. Also copepods were dominant groups in both northern and southern group of Islands. Further considerable numbers of seasonal coverage of both inshore and open sea waters for zooplankton analysis is highly desirable to get more definite conclusions about zooplankton faunal abundance, biodiversity, distribution, composition of groups and productivity.

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Chapter 09

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 141-146, 2010

OCCURRENCE AND DISTRIBUTIUON OF SEAGRASSES IN GREAT NICOBAR ISLANDS

T. THANGARADJOU*, VINOTH S. RAVIENDRAN, K. SIVAKUMAR, L. KANNAN and S. AJMAL KHAN**

Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502

INTRODUCTION

Seagrasses are submerged flowering plants. They comprise <0.02 per cent of the angiosperm flora, representing surprisingly small number of species compared with the other groups of marine organisms. Seagrasses belong to the families, Potamogetonaceae and Hydrocharitaceae, encompassing 13 genera containing about 58 species. Scrutiny of the literature indicates that there is 20 per cent uncertainty about the total number of seagrass species (Waycott, 1999). The small size of the seagrass flora might be considered as an indicator of a recent origin, but fossil records fail to support this. Seagrasses occur in all coastal areas of the world, except along Antarctic zones. Seagrass species are often separated into temperate and tropical genera. Most seagrass meadows are monospecific, even if it is multispecific the evenness is low. Where space is available, seagrass populations can develop only if the substrate is suitable. Most seagrass species are confined to sandy and muddy sediments.

Seagrass meadows are one of the most productive ecosystems in the marine environment. The average net primary production of seagrass meadows are about 1012 g DW m^{-2} Yr^{-1} (Duarke and Chiscano, 1999). Seagrasses are also one of the most important components of the marine carbon cycle, being responsible for a significant fraction of net CO_2 uptake.

The seagrass meadows are suitable habitat for many species of animals. The high primary productivity of seagrasses ensures an abundant supply of organic matter that can be used as the basic energy source for more or less complicated food-webs. The forage and refuge functions of seagrasses lodge a miscellany of fish-fry and larvae. They also provide with food for turtles, manatees and a variety of forms, act as habitat for filter feeding organisms and serve as forage ground for a plethora of organisms including sea urchins and sea cucumbers. Seagrass meadows are nursery grounds for pink shrimp, lobsters, snappers and other sea life. They also have habitat complexity, species diversity and play a major role in community ecology. About 340 animals directly feed on seagrasses, besides which nearly 153 marine micro- algae, 359 macro-algae and 178 invertebrates live as epiphytes and epizooties on the seagrass blades (Philips and Mc Roy, 1980). Above all, the IUCN red listed marine mammal dugongs and sea turtles exclusively feed on seagrasses.

In recent years, destruction of seagrass meadows has occurred world-wide (Cambridge and McComb 1984; Neversauskas 1987). The loss may result from natural events (den Hartog 1987),

* Corresponding author : E-mail : umaradjou@gmail.com

**Thiruvalluvar University, Fort Campus, Vellore–632 004; E-mail: kannanlk69@yahoo.com

such as high-energy storms (Patriquin, 1975), but most seagrass loss has resulted from human activities such as eutrophication (Orth and Moore, 1983), land reclamation, or changes in land use (Kemp *et al.*, 1983). These factors apparently affect the seagrass ecosystem and subsequently the populations of marine fauna they support (Carter, 1988). The need to study the seagrass habitats in the Andaman and Nicobar has been stressed by several workers (Silas and Fernando, 1995; Bhaskar, 1994). Jagtap (1985) reported 3 species of seagrasses belonging to 3 genera from the entire Andaman group of islands. Later, Jagtap (1992) reported 7 species of seagrasses belonging to 6 genera from the entire Andaman and Nicobar islands including 4 species belonging to 4 genera from the Great Nicobar Island. Das (1996) also reported 4 species of seagrasses from the Great Nicobar Island of which 3 species occurred on its east coast.

The Great Nicobar Islands are endowed with varied seascapes such as rocky shores, sandy beaches, bays, mangrove forests and coral reefs. The coastal area is generally rocky and muddy but in few cases sandy also. Varied soil textures such as, clay to clay loams, sandy loams and sand are seen in this island. The seagrass ecosystem of the Great Nicobar Island, inspite of it's uniqueness in its diversity and distribution, has not been inventoried in detail and the present effort has been made to explore the bounties of this ecosystem, status and threats of this ecosystem in this island.

MATERIALS AND METHODS

Flowering in seagrasses is rare and ephemeral and hence sufficient care was taken to collect seagrasses with all the developmental stages of male and female flowers and fruits, as suggested by Ramamurthy *et al.* (1992). During the collections, seagrasses were uprooted with care to keep the underground parts intact. Samples were washed in the field itself to remove sediments and epiphytes and kept in polythene bags. At each station, a quadrat (0.25 m^2) was placed six times at random and all the seagrasses within the quadrat were collected, weighed and the biomass was calculated. Then, the specimens were poisoned with 1 per cent mercury chloride solution and pressed and dried for preservation by following the method described by Jain and Rao (1977). The preserved materials were pasted on to the mounting boards. They were also preserved in seawater formalin. The specimens were identified using the standard seagrass works including the keys given by Ramamurthy *et al.* (1992) and den Hartog (1970).

RESULTS

The total number of seagrasses recorded from the entire coast of the Great Nicobar Island during the three years collection period was 9 species belonging to 6 genera (Table 1). Seagrasses were found at most all the stations but there were also some stations where no seagrasses was recorded (Table 2). *C. serrulata, H. pinifolia* and *E. acoroides* are the new distributional records to the Great Nicobar Island.

In the east coast, maximum number of 6 species was recorded at stations *viz.* Dongi nallah, Prem nallah, Campbell Bay, Sastri nagar and Galathea Bay. This was followed by Dubey nallah,

Table 1. Checklist of seagrass species recorded from the Great Nicobar Island

Class MONOCOTYLEDONS		
Order HELOBIAE		
Family HYDROCHARITACEAE		
Genus *Enhalus*		
Species	*E. acoroides*	—1
Genus *Halophila*		
Species	*H. ovalis* (R.Br) Hook	—2
	H. ovata Gaud	—3
Genus ***Thalassia***		
Species	*T. hemprichii*	—4
Family POTAMOGETANACEAE		
Genus *Cymodocea*		
Species	*C. rotundata* Ehrenb. and Hempr. Ex Asch	—5
	C. serrulata (R.Br) Asch. and Magnus	—6
Genus ***Halodule***		
Species	*H. uninervis* (Forsk.) Asch	—7
	H. pinifolia (miki) Hartog	—8
Genus *Syringodium*		
Species	*S. isoetifolium* (Asch.) Dandy	—9

Table 2. Distribution of seagrasses along the various stations in the Great Nicobar Island.

Sl. No.	Species	Stations																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	*Enhalus acoroides*																+							
2	*Halophila ovalis*	+			+	+	+	+		+	+	+	+	+			+							+
3	*H. ovata*						+			+	+	+	+	+		+	+		+	+				+
4	*Thalassia hemprichii*	+			+	+		+		+	+		+	+	+				+					+
5	*Cymodocea rotundata*	+		+	+		+			+	+	+	+	+				+	+					
6	*C. serrulata*	+		+	+	+	+			+	+		+	+	+		+	+		+	+		+	+
7	*Halodule uninervis*	+			+			+			+													
8	*H. pinifolia*											+		+										
9	*Syringodium isoetifolium*	+			+			+		+			+			+	+	+						
	Total	**6**		**2**	**6**	**3**	**4**	**4**		**6**	**6**	**4**	**6**	**6**	**2**	**2**	**5**	**3**	**3**	**2**	**1**		**1**	**4**

+ presence of species ; – absence of species

Table. 3. Seagrass biomass (g. fw/m²) recorded during third year at different stations in the Great Nicobar Island.

Sl. No.	Species	Stations																						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	*Enhalus acoroides*																457.0							
2	*Halophila ovalis*	4.5			7.0		8.0	5.4		N.G		N.G		15.4			12.7							
3	*H.ovata*						10.3			4.0	6.2	N.G	9.0	12.9		15.1	8.8		3.8	N..G				N.G
4	*Thalassia hemprichii*	64.3			72.9	39.1		28.0			52.5			61.6	21.8				15.5					40.3
5	*Cymodocea rotundata*	184.9		94.7			58.0			43.3		50.8		83.6				73	107.5					
6	*C. serrulata*	215.7		72.6			115			77.2	104.8		154.3	91.2	141.5		69.8	138.3		176	81.3			73.6
7	*Syringodium isoetifolium*	13.4			21.9			15.2		9.5						11.6	10.7	4.8						
	Total Biomass	**482.8**		**167.3**	**101.8**	**39.1**	**191.3**	**48.6**		**134**	**163.5**	**50.8**	**163.3**	**264.7**	**163.3**	**26.7**	**559**	**216.1**	**126.8**	**176**	**81.3**			**113.9**

Swarup Nallh and Lakshmi nagar, recording 4 species in each of the stations. Dillon nallah ranked next with 3 species of seagrasses. Minimum of 2 species was noticed at Sippy nallah, Chingen Basthi and Pigeon Island. No seagrasses were recorded at Magar nallah and Laful Bay. In the west coast, maximum species diversity was noticed at Inhengloi (5 species), followed by Pilobhabi and Kopenheat (3 species). Alexandria Bay recorded 2 species of seagrasses, whereas, only one species was recorded from Pilokunji. No seagrasses were noticed at Kiched nallah. In the south coast, Indira Point recorded 4 species of seagrasses while the north, Trinket Champlong Bay recorded only one seagrass species.

On the whole,maximum species diversity was noticed at Dongi nallah, Prem nallah, Campbell Bay, Vijay nagar, Sastri nagar and Galathea Bay and the minimum diversity was noticed at Pilokunji and Trinket Champlong Bay. At certain stations such as Magar nallah, Laful Bay and Kiched nallah, no seagrass species could be recorded.

Quantitative analysis during the second year collections revealed the maximum seagrass biomass (289.4 g.fw/m^2) at Dongi nallah and the minimum (2.0 g.fw/m^2). was recorded at Lakshmi nagar. In the east coast, maximum biomass was noticed at Galathea Bay recording 297.8 g.fw/m^2 and the minimum biomass was recorded at Swarup nallah with 52.0 g.fw/m^2. Along the west coast, Inhengloi recorded the maximum seagrasses biomass (258.2 g.fw/m^2) and the lowest biomass (93 g.fw/m^2). was recorded at Kopenheat. In the north, Trinket Champlong Bay recorded a biomass of 158.0 g.fw/m^2. In the south, Indira Point recorded a biomass of 988.0 g.fw/m^2.

Quantitative survey on the seagrasses of the Great Nicobar Island during the third year (Table 3) was revealed overall maximum seagrasses biomass at Inhengloi (559 g.fw/m^2) and the minimum biomass at Galathea Bay (26.7 g.fw/m^2). Along the east coast, maximum biomass was recorded at Dongi nallah (482.8 g.fw/m^2), followed by Galathea Bay (264.7 g.fw/m^2), Dubey Nallah (191.3 g.fw/m^2), Sippy nallah (167.3 g.fw/m^2). Vijay nagar and Chingen basthi recorded a seagrass biomass of 163.5 g.fw/m^2 each. Sastri nagar had a biomass of 163.5 g.fw/m^2 followed by Campbell Bay (134.0 g.fw/m^2) and Prem nallah (101.8 g.fw/m^2). Comparatively lower biomass values (50.8 g.fw/m^2) were recorded at Lakshmi nagar, Swarup nallah (48.6 g.fw/m^2), Dillon nallah (39.1 g.fw/m^2) and Galathea Bay (26.7 g.fw/m^2). In the west coast, the highest biomass was recorded at Inhengloi (559 g.fw/m^2) followed by Pilobhabi (216.1 g.fw/m^2), Alexandria Bay (176 g.fw/m^2) Kopenheat (126.1 g.fw/m^2) and the lowest (81.3 g.fw/m^2) biomass was recorded at Pilokunji. In the south, Indira Point recorded a biomass of 113.9 g.fw/m^2.

DISCUSSION

Survey of the entire coast of the Great Nicobar Island has brought out the existence of 9 species of seagrasses belonging to 6 genera, with a limited and discontinuous pattern of distribution. Earlier, Jagtap (1992) has reported 4 species of seagrasses and Das (1996) has reported 4 species of seagrasses belonging to 4 genera from the Great Nicobar Island.

In the presently study, from the three years collections, it was evident that Dongi nallah, Galathea Bay, Prem nallah, Campbell Bay, Vijay nagar and Sastri nagar are resourceful with seagrasses. Among these stations, Dongi nallah, Prem nallah, Campbell Bay and Vijay nagar had sandy coasts whereas the Campbell Bay had sandy to muddy substratum, supporting good growth of seagrass vegetation.

When analysing the data coast wise, it was found that in the east coast, Dongi nallah, Prem nallah, Campbell Bay, Vijay nagar, Sastri nagar and Galathea Bay were found with more species diversity. At these stations, *Halophila ovalis, H. ovata, Thalassia henprechii, Cymodocea rotundata* and *C. serrulta* had a wide spread distribution. This could be attributed to the nutrient enrichment at these stations by the nallahs that open into the sea along the east coast. Dominance of *H. ovalis* and *H. ovata* could be due to their tolerance to a wide range of salinities and light intensities (Jagtap, 1996). The minimum species diversity noticed at Sippy nallah, Chingen basthi and Pigeon Island could be due to the fact that these three stations have long stretches of dead corals which do not offer a suitable substrateum for the growth of the seagrasses. No seagrass species could be recorded from Magar nallah and Laful Bay during all the three years collections. This could be ascribed to the clayey nature of the substratum at Magar nallah and the high wave action at Laful Bay.

In the west coast, Inhengloi recorded the maximum number of species as this station provides with sandy-muddy substratum and favourable environmental factors such as low wave action which best suits the growth of seagrasses, especially Enhalus acoroides, which is found only at this station. Minimum record along the west coast was found at Pilokunji. This could be due the disturbance caused to the seagrass beds due to anchorage of boats at Pilokunji. Kiched nallah being a station with hard substratum made up of dead corals, might have put up a check on the growth of seagrasses and hence, no seagrass species was recorded from here.

In the north, Trinket had the minimum diversity of seagrasses and it could be due to the fact that Trinket was observed to have wave actions of higher velocities. In the south, Indira Point, characterized by long stretches of dead corals, has supported only a little vegetation of seagrasses and here seagrasses are found in patches.

Quantitative seagrass survey of the coasts of the Great Nicobar Island has revealed that some stations such as Inhengloi in the west and Dongi nallah in the east have proved to be the most productive of all the stations surveyed. At both these stations, luxuriant growth of seagrasses could be noticed. The beds were mostly monospecific. *Cymodocea seriate* was the dominant species at Dongi nallah and *Enhalus acoroides* was the dominant species at Inhengloi. Reason could be that the substrate provided with at these stations would have suited best for the establishment of these seagrass beds, encompassing a sandy substrate with low or minimal wave action. It was quite interesting to note that *E. acoroides* was found only at Inhengloi and in abundance, but not in any other station all along the coast.

All the other stations had a mediocre level of biomass of seagrasses, whereas, the biomass values recorded at Pigeon Island, Swarup nallah, Dillon nallah, Lakshmi nagar and Prem nallah in the east coast and Pilokunji in the west, Trinket in the north and Indira Point in the south were comparatively low. This is because of the presence of long stretches of dead corals, not suitable for seagrass growth.

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Chapter 10

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 147-156, 2010

CURRENT SCENARIO OF SEAWEED RESOURCES IN GREAT NICOBAR ISLAND

VINOTH S. RAVIENDRAN, T. THANGARADJOU*, K. SIVAKUMAR, L. KANNAN and S. AJMAL KHAN**

Centre of Advanced Study in Marine Biology, Annamalai University Parangipettai–608 502

INTRODUCTION

Algae can be classified as photosynthetic non-vascular plants that contain chlorophyll and have simple reproductive structures (Trainor, 1978). It is difficult to determine algal biodiversity because of the limited biogeographic inventories worldwide (Norton *et al.*, 1996). Macro algae which are classified as Chlorophyta (green algae), Phaeophyta (brown algae) and Rhodophyta (red algae) are commonly called seaweeds.

Distribution of seaweeds is widespread and their abundance is noticed in the waters of South Australia, North-East Pacific and Mediterranean regions. Among tropical seas, rich algal flora occurs in the far west central Pacific, Caribbean and South India (Kaliaperumal, 1994). In India, dense covers of seaweeds are noticed along the coasts and rocky shores of Gujarat and Maharashtra in the west and Andhra Pradesh and Tamil Nadu in the east. The Andaman and Nicobar and Lakshadweep islands also support a rich and diverse vegetation of marine algae (Kaladharan and Kaliaperumal, 1999).

Seaweed communities are one of the most productive and extensive marine plant communities in the world. The zones of intertidal and subtidal regions occupy a narrow coastal area and account for less than 1 per cent of the earth surface (10^6 km^2). Yet, the productivity of this region can equal or exceed that of the most productive terrestrial communities, due to the presence of seaweeds. The production of intertidal and sub tidal seaweeds is estimated to be 0.5 to 1 kg $m^{-2}Y^{-1}$ and 0.5 to 2.5 kg $m^{-2}Y^{-1}$ respectively (Mann and Chapman, 1975; Valiela, 1984). By comparison, tropical rain forests have an annual productivity of 0.4 to 2 kg m^{-2} Y^{-1}.

About 500 species of seaweeds are used as food, fodder and chemicals. However less than 20 species are farmed worldwide (Lobban and Harrison, 1994). Five dominant genera that are subjected to mariculture is large scale including three red seaweeds (*Eucheuma, Gracilaria* and *Porphyra*) and two brown seaweeds (*Laminaria* and *Undaria*). The principal uses of seaweeds are as direct food and as a source for the extraction of soluble carbohydrate products (phycocolloids). In addition, seaweeds are used as a source of medicine, animal fodder, fertilizers and fuel. Currently, human consumption of green (0.4 per cent), brown (66.5 per cent) and red (33 per cent) seaweeds is high in Asia, particularly Japan, China and Korea. Seaweed ash is used to obtain soda, potash and iodine. Seaweeds have been used as direct food and additives in animal feeds (Round, 1981). Seaweeds are also used as manure.

* *Corresponding author :* E-mail : umaradjou@gmail.com

***Thiruvalluvar University, Fort Campus, Vellore–632 004.* E-mail : kannanlk69@yahoo.com

Apart from all these, seaweeds support a wide range of associated organisms such as amphipods, isopods, crustaceans, fish larvae etc. The Great Nicobar Island has stretches of dead corals, rocky costs and sandy beaches as part of the marine ecosystem. The island lodges a multitude of seaweed species on account of the gratifying environment provided. The present investigation is an attempt to unearth present stations of the seaweed diversity, and to evaluate the threats posed to them along the Great Nicobar Island.

MATERIALS AND METHODS

A total of 23 stations were selected for investigation of seaweed diversity. Of these 16 stations were along the east coast namely Dongi nallah, Sippy nallah, Prem nallah, Dillon nallah, Dubey nallah, Swarup nallah, Laful Bay, Campbell Bay, Vijay nagar, Lakshmi nagar, Shastry Nagar, Galathea Bay, Chingen basthi and Pigeon Island, 6 were along the west coast namely Inhengloi (shore), Pilobhabi, Kopenheat, Alexandria Bay, Pilokunji and Kiched nallah, Indira Point is the south cost and Trinket Champlong Bay are the north coast.

Seaweed samples were collected during the low tide periods from the intertidal region (up to 0.5 m depth). At each station, a quadrate ($0.25m^2$) was placed six times at random and all the seaweeds within the quadrate were collected and mean biomass was calculated and reported as $gr.fw/m^2$. The samples were first washed thoroughly with seawater to remove silt, debris and phytal-fauna associated with them and the moisture from the seaweeds was removed using blotting papers. The seaweeds were sorted out species-wise and pressed for herbarium preparation, in addition to their preservation in 5% seawater formalin. The seaweeds were identified using the standard systematic key reference (Edwards, 1970; Umamaheswara Rao, 1970, 1987).

RESULTS

The survey of the Great Nicobar Island for a period of three years has revealed the occurrence of 80 species of seaweeds belonging to 45 genera (Table 1) besides 5 unidentified taxa. Out of the 80 species identified, 32 species belongs to 18 genera of Chlorophyceae, 17 species belongs to 7 genera of Phaecophyceae and 31 species belongs to 20 genera of Rhodophyceae. Of these, 19 species of Chlorophyceae, 14 species of Phaeophyceae and 25 species of Rhodophyceae are new distributional records to the Great Nicobar waters (Table 2). The occurrence of seaweeds was recorded in most of the stations, and their diversity varied in few stations.

During the first year (2001) a total of 32 species of seaweeds belonging to 22 genera were recorded besides 5 unidentified taxa with the maximum occurrence (27 species) from the Galathea Bay and the minimum occurrence from the Laful Bay (2 species). During second year (2002) collections recorded a total of 51 species of seaweeds belonging to 33 genera were recorded besides 4 unidentified taxa. The maximum number of seaweeds were recorded from the Indira Point (24 species) and the minimum number of species were recorded from Alexandria Bay (3 species).

During the third year collections (2003), a total of 48 species belonging to 34 genera were recorded. Among them, 20 species belongs to 13 genera of Chlorophyceae, 10 species to 6 genera of Phaeophyceae and 18 species to 15 genera of Rhodophyceae. The maximum number of species were recorded at Indira Point and Galathea Bay (25 species each) and the minimum number of species were recorded at Vijay nagar (4 species).

Among the stations surveyed for a period of three years, the maximum species diversity was recorded at Galathea Bay in the east coast (50 species) and the minimum diversity was recorded at Laful Bay also in the east coast (2 species). In the east coast, maximum number of species (50 species) was recorded at Galathea Bay followed by Sippy Nallah and Sastri nagar with 35 species. Dongi nallah had a species diversity of 31 species followed by Prem nallah (28 species) and Chingen basthi (26 species). Dillon nallah and Prem nallah recorded 24 species each. The total number of species recorded at Dubey nallah, Vijay nagar and Pigeon Island was 22 species in each of the stations. Twenty one species of seaweeds were recorded at Swarup nallah and 14 species at Magar nallah. The recorded species diversity was very low at Laful Bay with only two species. Along the west coast, the maximum species diversity was recorded at Pilobhabi (25 species) followed by Inhengloi (21 species), Kiched nallah (18 species), Kopenheat (14

Table 1. Checklist of seaweed species recorded from the Great Nicobar Island.

Division	**Chlorophyta**	
Class	CHLORPHYCEAE	
Order	ULVALES	
Family	ULVACEAE	
Genus	***Enteromorpha***	
Species	*E. clathrata* J. Agardh	– 1
	E. compressa (Linnaeus) Grev.	– 2
	E. intestinalis (Linnaeus) Linn.	– 3
Genus	***Ulva***	
Species	*U. lactuca* (Linn.)	– 4
Order	CLADOPHORALES	
Family	CLADOPHORACEAE	
Genus	***Cladophora***	
Species	*C. rugulosa*	–5
	Cladophora sp.	–6
Genus	***Chaetomorpha***	
Species	*C. antennia* (Bory) Kuetz	–7
	C. linum (O.F. Muller) Kutzing	–8
Order	SIPHONALES	
Family	PROTOSIPHONACEAE	
Genus	***Halicystis***	
Species	*Halicystis* sp.	–9
Genus	***Bryopsis***	
Species	*Bryopsis* sp.	–10
Family	CAULERPACEAE	
Genus	***Caulerpa***	
Species	*C. cupresisoides* (Vahl.) C. Agardh	–11
	C. peltata Lamour	–12
	C. racemosa (Forssk.) Weber V. Bose	–13
	C. scalpelliformis (R. Brown ex. Turner) C. Agardh.	–14
	C. sertularioides (Gmelin) Howe	–15
Genus	***Trichosolen***	
Species	*Trichosolen* sp.	–16
Family	DASYCLADACEAE	
Genus	***Neomeris***	
Species	*N. annulata* Dickie	–17
Family	CODIACEAE	
Genus	***Avrainvillea***	
Species	*A. erecta* (Berktey) A. Gepp and E. Gepp	–18
Genus	***Codium***	
Species	*C. spongiosum* Harvey	–19
	C. tomentosum Stackhouse	–20
Genus	***Halimeda***	
Species	*H. gracilis* Harvey ex. J. Agardh	–21
	H. macroloba Decaisne	–22
	H. opuntia Barton	–23
	H. tuna (Ellis and Solander) (Lamouroux)	–24
	H. micronesica Yamada	–25
Family	VALONIACEAE	
Genus	***Udotea***	
Species	*U. indica* A. and E.S. Gepp	–26
Genus	***Valonia***	
Species	*V. aegagrophila* C. Agardh	–27
	Valonia sp.	–28
Genus	***Dictyospheria***	
Species	*Dictyosphaeria sp.*	–29
Genus	***Boergesenia***	
Species	*B. forbesii* (Harvey) J. Feldmann	–30
Genus	***Valoniopsis***	
Species	*V. pachynema* (g. Martens) Borgesen	–31
Order	DASYCLADALES	
Family	DASYCLADACEAE	
Genus	***Bornetella***	
Species	*Bornetella* sp.	– 32
Division	**Phaeophyta**	
Class	PHAEOPHYCEAE	
Order	ECTOCARPALES	
Family	ECTOCARPACEAE	
Genus	***Ectocarpus***	
Species	*E. fasciculatus* Harvey	–33
Order	DICTYOTALES	
Family	DICTYOTACEAE	
Genus	***Dictyota***	
Species	*D. dichotoma* (Hudson) Lamouroux	–34
	D. divaricata Lamouroux	–35
Genus	***Padina***	
Species	*P. gymnospora* (Kutzing) Sonder	–36

Table 1. *Contd.*

	P. tetrastromatica Hauck	–37
	P. boergesenii Allender and Kraft	–38
Genus	***Zonaria***	
Species	*Z. spiralis* (J. Agardh) Papenjuss	–39
	Z. variegata (Lamouroux) C. Agardh	–40
Order	DICTYOSIPHONALES	
Family	PUNCTARIAECEAE	
Genus	***Colpomenia***	
Species	*C. sinuosa* (Merpens ex Roter) Derbes and Solier	–41
Family	SARGASSACEAE	
Genus	***Sargassum***	
Species	*S. cymosum* C. Agardh	–42
	S. illicifolium (Turner) C. Agardh	–43
	S. johnstonii Setchell and Gardner	–44
	S. myriocystum J. Agardh	–45
	S. tenerrimum J. Agardh	–46
	S. wightii Greville	–47
Genus	*Turbinaria*	
Species	*T. conoides* (J. Agardh) Kutzing	–48
	T. ornata (Turner) J. Agardh	–49
Division	**Rhodophyta**	
Class	FLORIDIOPHYCEAE	
Order	NEMALIONALES	
Family	HELMINTHOCLADIACEAE	
Genus	***Liagora***	
Species	*Liagora* sp.	–50
Family	CHAETANGIACEAE	
Genus	***Galaxaura***	
Species	*G. oblongata* Lamour	–51
	G. lapidesens (Ellis and Solander) Lamouroux	–52
Order	GELIDIALES	
Family	GELIDIACEAE	
Genus	***Gelidium***	
Species	*Gelidium* sp.	–53
Family	GELIDIELLACEAE	
Genus	***Gellidiella***	
Species	*G. acerosa* (Forsskal) J. Feldmann and G. Hamel	–54
Order	CRYPTONEMIALES	
Family	RHIZOPHYLLIDACEAE	
Genus	***Chondrococcus***	
Species	*Cchondrococcus* sp.	–55
Family	CORALLINACEAE	
Genus	***Amphiroa***	
Species	*A. anceps* (Lamark) Decaisne	–56
Genus	***Jania***	
Species	*J. adhaerens* Lamouroux	–57
Genus	***Cryptonemia***	
Species	*Cryptonemia sp.*	–58
Family	GRATELOUPIACEAE	
Genus	***Grateloupia***	
Species	*G. filicina* (Lamouroux) C. Agardh	–59
	G. lithophila Borgesen	–60
Genus	***Halymenia***	
Species	*H. porphyraeformis* Parkinson	–61
	H. polydactyla Borgesen	–62
Family	GRACILARIACEAE	
Genus	***Gracilaria***	
Species	*G. corticata* (J. Agardh). Agardh	–63
	G. crassa Harvey ex. J. Agardh	–64
	G. edulis (S. Gmelin) P. silva	–65
	G. foliifera (Forsskal) Boergesen	–66
Family	HYPNEACEAE	
Genus	***Hypnea***	
Species	*H. musciformis* (Wulfen) Lamouroux	–67
	H. pannosa J. Agardh S (Wulfen) Lamouroux	–68
Order	RHODYMENIALES	
Family	RHODYMENIACEAE	
Genus	*Coelarthrum*	
Species	*C. opuntia* (Endlicher) Boergesen	–69
Class	BANGIOPHYCEAE	
Order	CRYPTONEMIALES	
Family	LOMENTARIACEAE	
Genus	***Champia***	
Species	*C. compressa* Harvey	–70

Table 1. *Contd.*

Order CERAMIALES		Family RHODOMELACEAE	
Family CERAMIACEAE		Genus ***Acanthophora***	
Genus ***Centroceras***		Species *A. spicifera* (Vahl) Borgesen	—75
Species *Centroceras sp.*	—71	Genus ***Laurencia***	
Genus ***Griffithsia***		Species *L. papillosa* (C. Agardh) Greville	—76
Species *Griffithsia* sp.	—72	*L. obtusa* (Hudson) Lamouroux	—77
G. ovalis Harvey	—73	*L. botryoides* (C. Agardh) Gaillon	—78
Family CERAMIACEAE		*Laurenscia* sp.	—79
Genus ***Wrangelia***		Genus *Polysiphonia*	
Species *Wrangelia* sp.	—74	Species *P. platycarpa* Borgesen	—80

Table 2. New distributional records of seaweed species to the Great Nicobar waters

Sl. No.	Rhodophyceae	Sl. No.	Chlorophyceae	Sl. No.	Phaeophyceae
1	*Liagora* sp.	26	*Enteromorpha clathrata*	45	*Ectocarpus fasciculatus*
2	*Galaxura lapidescens*	27	*E. compressa*	46	*Dictyota dichotoma*
3	*Gelidium* sp.	28	*Ulva lactuca*	47	*D. divaricata*
4	*Gelidiella acerosa*	29	*Cladphora regulosa*	48	*Padina boergesenii*
5	*Chondrococcus* sp.	30	*Halicystis* sp.	49	*P. tetrastromatica*
6	*Jania adhaerens*	31	*Caulerpa cupressoides*	50	*Zonaria spiralis*
7	*Cryptonemia* sp.	32	*C. racemosa*	51	*Z. variegata*
8	*Grateloupia filicina*	33	*C. scalpelliformis*	52	*Colpomenia sinuosa*
9	*Halymenia porphyraeformis*	34	*Valonia* sp.	53	*Sargassum cymosum*
10	*H. polydactyla*	35	*Trichosolen* sp.	54	*S. myriocystum*
11	*Gracilaria edulis*	36	*Neomeris annulata*	55	*S. ilicifolium*
12	*G. corticata*	37	*Codium spongiosum*	56	*S. johnstonii*
13	*G. crassa*	38	*Halimeda macorloba*	57	*S. wightii*
14	*Hypnea pannosa*	39	*H. micronesica*	58	*S. tenerrimum*
15	*H. musciformis*	40	*Valoniopsis pachynema*		
16	*Champia compressa*	41	*Valonia aegagrophila*		
17	*Coelarthum opuntia*	42	*Dictyosphaeria* sp.		
18	*Griffithsia lithophila*	43	*Udotea indica*		
19	*G. ovalis*	44	*Bornetella* sp.		
20	*Wrangelia* sp.				
21	*Acanthophora spicifera*				
22	*Laurencia* sp.				
23	*Laurencia obtusa*				
24	*L. papillosa*				
25	*Polysiphonia platycarpa*				

species), Pilobet (13 species) and the lowest species diversity was recorded at Alexandria Bay (3 species). In the north, Trinket Champlong Bay recorded a total species diversity of 8 species. In the south coast, Indira Point recorded 47 species of seaweeds.

Along the east coast, the maximum species diversity was recorded at Galathea Bay (25 species), followed by Sippy nallah (19 species) and Sastri nagar and Chingen basthi recording 18 species each. Twelve species were recorded at Pigeon Island and 11 species were recorded each at Prem nallah and Dubey nallah. Campbell Bay recorded 10 species of seaweeds and this was followed by Lakshmi nagar (9 species), Dongi nallah and Swarup nallah (8 species each), Magar nallah (7 species), Dillon nallah (5 species) and the lowest record was at Vijay nagar (4 species).

In the west coast, species diversity was its maximum at Pilobhabi recording 20 species of seaweeds and it was followed by Inhengloi (17 species), Pilobet (13 species) and Kiched nallah (12 species) and the minimum number of species was at Kopenheat, recording 9 species of seaweeds. Indira Point in the south coast recorded 24 species of seaweeds. Thus, the qualitative analysis of the seaweeds of the Great Nicobar Island has revealed that the seaweed diversity is varying with the varying marine environ.

Seaweed biomass along the east coast varied from a maximum of 1137.9 g.fw/m^2 at Sastri nagar to a minimum of 201.8 g.fw/m^2 at Laful Bay, during the second year collections,. In the west coast, maximum biomass was recorded at Inhengloi (711.1 g.fw/m^2) and the minimum record was made at Pilokunji (177.2 g.fw/m^2). In the south coast, Indira Point had an impressive biomass of 1244.6 g.fw/m^2 and it is the highest biomass recorded among all the stations during the second year collections. In the north coast, Trinket Champlong Bay recorded a biomass of 539.6 g.fw/m^2. In all, the maximum biomass was recorded from Indira Point (1244.6 g.fw/m^2) and the minimum was from Pilokunji (177.2 g.fw/m^2).

During the third year collections, the maximum biomass recorded along the east coast was at Galathea Bay with a biomass of 651.4 g.fw/m^2 followed by Chingen basthi (475.8 g.fw/m^2), Sastri nagar (465.9 g.fw/m^2), Lakshmi nagar (364 g.fw/m^2), Dongi nallah (346.8 g.fw/m^2), Sippy nallah (328.9 g.fw/m^2), Dubey nallah (321.9 g.fw/m^2), Pigeon Island (263.3 g.fw/m^2), Magar nallah (253.9 g.fw/m^2), Campbell Bay (242. g.fw/m^2), Swarup nallah (180.5 g.fw/m^2), Prem nallah (163.1 g.fw/m^2), Dillon nallah (101.4 g.fw/m^2) and the lowest value for biomass was recorded at Vijay nagar (85.2 g.fw/m^2) (Table 3).

Along the west coast, maximum biomass was recorded at Pilobhabi (511.1 g.fw/m^2) followed by Inhengloi (440.3 g.fw/m^2), Kiched nallah (388.8 g.fw/m^2), Pilobet (366.9 g.fw/m^2) and the minimum biomass recorded was at Kopenheat (226.6 g.fw/m^2). Indira Point (south coast) recorded a biomass of 1094.9 g.fw/m^2 which is the maximum biomass recorded among all the coastal stations of the Great Nicobar Island and the minimum biomass was recorded at Vijay nagar (85.2 g.fw/m^2) and this station is situated along the east coast.

Qualitative and quantitative analyses reveal that *Halimeda gracilis, Halimeda opuntia, Boergesenia forbesii, Padina gymnospora, Amphroa anceps,* and *Acanthophora spicifera* had a widespread distribution all along the island coast and their biomass was also higher though not found in 'harvestable' amount. Genera *viz. Caulerpa, Halimeda, Padina, Sargassum, Gracilaria* and *Laurencia* were represented by more number of species.

DISCUSSION

The survey along the entire coast of the Great Nicobar Island revealed the presence of 80 species of seaweeds belonging to 45 genera besides 5 unidentified taxa. The only work pertaining to seaweeds of the Great Nicobar Island was that of Jagtap (1992), who reported 48 species of seaweeds and some unidentified taxa. Pooling the present works and that of Jagtap (1992), an updated list of the seaweeds recorded from the Great Nicobar Island has been estimated to be 109 species of seaweeds of which 44 species belong to 20 genera of Chlorophyceae, 23 species belong to 10 genera of Phaeophyceae and 42 species belong to 24 genera of Rhodophyceae.

In general, there was a slight dominance of Chlorophycean and Rhodophycean members over Phaeophycean members, thus lending support to the earlier work of Jagtap (1992) who has also observed a similar feature from the Great Nicobar

Table 3. Biomass of seaweeds (g.fw/m^2) recorded at different stations of the Great Nicobar Island (Third year).

Sl. No.	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	CHLOROPHYCEAE																							
1.	*Enteromorpha clathrata*						**67.4**											**44.8**						
2.	**Ulva lactuca**						25.6					19.4	48.0			37.2							15.1	
3.	*C. linum*															25.0								
4.	*Halicystis sp.*												8.4					12.1					7.0	
5.	*Bryopsis sp.*			13.0				17.8						27.2			10	15.8						
6.	*Caulerpa cupressoides*			16.0										43.5										
7.	*C. peltata*	53.0										76.7	37.4	63.6			124.0	33.2				84.5	40.7	
8.	*C.racemosa*			29.1						35.8														
9.	*C. scalpelliformis*						52.4								29.7			31.3						
10.	*C. sertularoides*									23.7				15.9	26.0			37.3						
11.	*Neomeris annulata*			N.G	N.G	N.G	7.6			N.G			6.0	N.G	N.G			N.G	N.G			3.8		
12.	*Avrainvillea erecta*	73.5										89.7					33.1							
13.	*Halimeda gracilis*	23.4	59.7	12.4	16.2	40.3	10.9	22.0			14.0		35.0	42.9	31.0	15.8		12.1	22.9			37.5	20.3	
14.	*H.macroloba*			8.0						17.3				21.6	85.4							11.9		
15.	*H. opuntia*	42.4								60.0		71.4		54.2			21.2	19.1						
16.	*H.micronesia*			14.4											10.7		24.2							
17.	*Udotea indica*					7.9								12.1	15.0	16.3	5.0					9.0		
18.	*Bornetella sp.*				N.G											N.G								
19.	*Boergesenia forbesii*				18.8			17.1					22.0	15.8	13.1	11.7	16.9					10.1		
20.	*Valoniopsis pachynema*			15.1								6.4	13.3	9.0			12.1							
	Total	**192.3**	**59.7**	**108**	**35**	**48.2**	**163.9**	**56.9**		**136.8**	**14**	**263.6**	**170.1**	**305.8**	**210.9**	**106**	**246.5**	**205.7**	**22.9**			**156.8**	**83.1**	
	PHAEOPHYCEAE																							
21.	*Dictyota dichotoma*							31.9							42.7	53.9		29.3						
22.	*Padina gymnospora*							15.0								10.4								
23.	*P .tetrastromatica*	36.3	29.1	15.8	12.4		22.6			32.9	33.2		16.5	24.1	44.8	23.0		12.2					84.6	
24.	*P. boergesinii*	18.0			23.6							27.6				12.7		25.8					30.4	
25.	*Zonaria spiralis*																							
26.	*Colpomenia sinosa*			17.2										12.1	8.6		15.4	10.9				18		

Table 3. *Contd.*

Sl. No.	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
27.	*Sargassum cymosum*	47.8																						
28.	*S. illicifolium*	52.4	68.7									72.8				43								
29.	*Turbinaria conoides*												50.4	62.6					39.3			74.0		
30.	*T. ornata*													46.1				53.4						
	Total	**154.5**	**97.8**	**33**	**36**		**22.6**	**46.9**		**32.9**	**33.2**	**100.4**	**66.9**	**144.9**	**96.1**	**143**	**15.4**	**131.6**	**39.3**			**92**	**115**	
	RHODOPHYCEAE																							
31.	*Liagora sp.*						12.4																	
32.	*Galaxaura oblongata*						21.2			6.8				15.8	21.2		17.2					14.5		
33.	*Gelidium sp.*					7.2								N.G										
34.	*Gelidiella acerosa*		25.8		18.7			26.6		34.2	29.2		32.8	59.7	42.3		60.0	15.2	34.7			51.4	38.7	
35.	*Chondrococcus sp.*			N.G										5.4			5.0					N.G		
36.	*Amphiroa anceps*			+52.3	29.2	46.0	34.1						28.3		33.7		12.7	67.3	14.9			41.0		
37.	*Jania adhaerens*													23.0	19.1			10.4	21.8					
38.	*Cryptonemia sp.*											N.G	N.G										N.G	
39.	*Gracilaria corticata*			31.8									27.1											
40.	*G. crassa*		53.1	45.8	36.2		44.0	28.7					61.6	81.8	18.7		51.6	35.2	77.5				94.2	
41.	*H. pannosa*			38.1									54.6											
42.	*Griffithsia lithophila*													N.G										
43.	*Coelarthrum opuntia*		6.1	N.G	8.0		22.9	21.4					11.7	9.8	14.2		17.7	32.0	15.5				23.8	
44.	*Champia compressa*																							
45.	*Wrangelia sp.*											N.G		N.G										
46.	*Acanthophora spicifera*		11.4		N.G					16.1	8.8		12.8	5.2	19.6	14.3	7.2	13.7				11.2	20.5	
47.	*Laurentia sp.*			9.7													7.0						13.5	
48.	*L. papillosa*			10.2						15.2														
	Total		**96.4**	**187.9**	**92.1**	**53.2**	**134.6**	**76.7**		**72.3**	**38**	**N.G**	**228.9**	**200.7**	**168.8**	**14.3**	**178.4**	**173.8**	**164.4**			**118.1**	**190.7**	
	Grand Total	**346.8**	**253.9**	**328.9**	**163.1**	**101.4**	**321.1**	**180.5**		**242**	**85.2**	**364.0**	**465.9**	**651.4**	**475.8**	**263.3**	**440.3**	**511.1**	**226.6**			**366.9**	**388.8**	

Island. One of the most encouraging results regarding the biodiversity of seaweeds in the Great Nicobar is that, no single species showed any specific dominance. This is an indication of a healthy ecosystem. In the present investigation, it could be noticed that the brown algae such as *Sargassum*, *Padina* and *Turbinaria* had a widespread distribution, as also reported by Gopinathan and Panigrahy (1983).

During the three years collection period, Galathea Bay and Indira Point recorded the maximum number of seaweed species, revealing that these two stations are resourceful than any other station in the Great Nicobar Island. This could be attributed to the long stretches of dead corals that are found at these stations, acting as suitable substratum for seaweed growth and also providing with $CaCO_3$, which is very essential for the growth of coralline algae, whose occurrence was invariably higher at these two stations.

For the rich species diversity at Indira Point, apart from the stretches of dead corals, the undisturbed nature of the site is yet another reason. The Galathea Bay also lodges a rich vegetation of seaweeds on account of nutrient enrichment due to the inflow of fresh water through Galathea River. Species of *Halimeda, Caulerpa, Padina* and *Amphiroa* showed widespread distribution and the good growth of the coralline algae might be due to the availability of copious amount of $CaCo_3$. The seaweed species diversity at Sastri nagar, Dongi nallah, Prem nallah, Vijay nagar and Pigeon Island was also good due to the presence of suitable substratum for the growth of seaweeds at these stations. Contrastingly, seaweed diversity at Laful Bay, Alexandria (river) Bay and Magar nallah was very low. This could be attributed to the sandy nature of the coast at these sites and mixed clay substratum at Magar nallah.

During the study period, higher seaweed biomass was recorded from Sastri nagar, Indira Point, Galathea Bay, Prem nallah, Vijay nagar and Dongi nallah. The main reason for having a higher algal biomass at these stations could be due to the fact that these stations had a higher number of species with alginophytes such as *Turbinaria*, having a rigid thallus and *Caulerpa, Sargassum* and *Padina* having fleshy thalli, contributing more to the biomass. Lower values of biomass were recorded at Laful Bay, Pilokunji, Pigeon Island, Magar nallah, Campbell Bay, Swarup nallah, Dillon nallah and Vijay nagar. Presence of fringing reefs at Pilokunji and the Nallah stations having mixed clay to sandy substratum might not have been suitable for more number of species, which is quite evident from the qualitative analysis. This reduction in the species count might account for the reduction in the biomass values. In the north coast (Trinket Champlong Bay), despite the strenuous efforts, due to the extreme rough conditions of the sea that prevailed during the collections, a correct qualitative and quantitative estimate of seaweeds could not be made.

Scrutinizing both the qualitative and quantitative distribution of seaweeds along the different coasts (west, east, north and south) of the Great Nicobar Island, it is inferred that the east coast and the only station in the south coast viz. Indira Point, have higher species diversity and biomass. This could be explained by the fact that the east coast is endowed with a number of nallahs which bring copious amount of nutrient rich waters from the terrain and this would facilitate the growth of the macroalgal species along with the presence of long stretches of dead corals that offer the suitable substratum for the seaweeds. In contrast, the west coast is less diverse and the seaweed abundance is also low. This might be due to the presence of fringing reefs and lesser fresh water inflow.

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Chapter 11

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 157-160, 2010

DISTRIBUTION OF SEAGRASSES ALONG THE ANDAMAN AND NICOBAR ISLANDS : A POST TSUNAMI SURVEY

T. THANGARADJOU*, K. SIVAKUMAR, E.P. NOBI and E. DILIPAN
Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, Tamil Nadu, India

INTRODUCTION

Seagrass ecosystems represent one of the important coastal ecosystems of tropical coasts. These systems are well known for their high primary and secondary productivity, ability to stabilize sediments, production of vast quantities of detritus and support of diverse floral and faunal communities. Though these groups of plants are represented by less than 60 species (Short *et al.*, 2007) they are distributed throughout the world except in Polar regions. Indian coast have 14 species in its credit (Kannan *et al.*, 1999), among them Gulf of Mannar waters harbours 13 species. In India, major seagrasses beds are distributed along Coromandal coast, Gulf of Mannar, Palk Bay, Lakshadweep and Andaman and Nicobar Islands.

Even though literatures are available for the distribution of seagrass species in Andaman and Nicobar islands, it is restricted to only few islands and there is only one report (Kannan, 2006) on seagrasses of Andaman and Nicobar islands after tsunami. Earlier, Jagatap (1985) reported 3 seagrass species from the Andaman Islands later 7 species of seagrasses were identified from Nicobar group of islands (Jagtap, 1992) and 9 species from Great Nicobar Island alone (Kannan and Ajmal Khan, 2004). Except, Das (1996) no detailed work has been carried out on the entire stretch of Andaman and Nicobar Islands who has reported the presence of 9 seagrass species. Assessment and evaluation of seagrass resources were carried out in Indian mainland especially from Gulf of Mannar after tsunami but the devastation caused to the seagrass resources of the Andaman and Nicobar island groups was unknown.

MATERIAL AND METHODS

Andaman and Nicobar Islands are located in the Bay of Bengal (Lat : 6°-14° and Long : 92°-94°) approximately 1190km off east coast of India. The islands have a total land area of about 8249 km^2, 86 per cent of which is covered by luxuriant tropical forest and a long coastline of 1962 km which is highly indented and several creeks penetrate into the islands from inland bays (Tigga and Rao, 2004).

Survey was carried out in 11 locations from the northern part of Andaman to southern tip of Great Nicobar Island. Line transects and quadrate survey was carried out to understand the distribution of the seagrass species. Skin diving using snorkelers was made to understand the distribution of seagrass species up to 5m depth, which is safe for skin diving. Herbarium specimens of the seagrasses were prepared and the species were identified following the field keys of Kannan and Thangaradjou (2006) and confirmed by the keys of Ramamurthy *et al.* (1992).

* E-mail : umaradjou@gmail.com

RESULTS AND DISCUSSION

In India, seagrass habitats are mainly limited to mud flat and sandy regions from the lower intertidal zones to a depth of 10-15m along the open shores (Ramamurthy *et al.*, 1992), in the lagoons around islands (Jagtap, 1991) and on dead coral rocks and pebbles (Das, 1996). During the present survey, 11 locations were surveyed and found the occurrence of 9 seagrass species (Table 1). Henry Lawrence Island, having the presence of 8 seagrass species, while only one species was recorded from Car Nicobar Island.

Destruction to the marine and coastal resources of Andaman and Nicobar Islands due to tsunami was reported earlier by Ramachandran *et al.* (2005) and Sridhar *et al.* (2006). Previous survey carried out by Das (1996) reported seagrasses from Interview and North Reef Islands, but now there is no seagrasses in these areas and only dead coral reefs are found. This may be occurred due to the upliftment of northern part of Andaman Islands due to tsunami (GSI, 2006). During the present survey 8 species were recorded in from Henry Lawrence Island, whereas Tigga and Rao (2004) reported only 6 seagrass species from this region but Das (1996) reported 8 species from this island with area coverage of nearly 90ha. *Enhalus acoroides, Halophila ovalis, Halophila ovata, Thalassia hemprichii, Cymodocea rotundata, Halodule uninervis, Halodule pinifolia* and *Syringodium isoetifolium* were found to occur in this region. Fine sand, muddy substrata and clear waters favours good growth of seagrasses in Henry Lawrence Island. On the other hand, high wave and current action prevailing in this region cause damage to seagrass standing crop.

Seagrasses were recorded in both east and west coast off Havelock Island, 6 seagrass species were identified in this region. East coast of Havelock Island anchors 3 species where as in West coast from Jetty to Kalapathar, 6 species were identified. This may due to the low wave action in this region and its geographical alignment. The present survey did not find the occurrence of *Enhalus acoroides* which is reported earlier by Das (1996) from Kalapathar. The distribution of seagrass in eastern side is a new addition to this island flora. During the present survey 5 seagrass species were recorded from Neil Island. This is the first report of seagrass distribution to this island. Seagrass meadows were recorded from this island at stretch of 2 to 4 km from both side of the jetty. The distribution of *Halophila ovalis, Cymodocea rotundata* and *Halodule uninervis* are new report to Red Skin Island which was not reported in earlier surveys (Das, 1996). Seagrasses at Chidiyatapu are found to occur in between pebbles and in dead coral rocks. At Chidiyatapu, 60ha of area is covered by seagrass with a diversity of 5 species (Das, 1996). During the present investigation 6 species were identified from this region and the distribution of *Cymodocea rotundata* was the new record to this area. More importantly, now this region is less covered by

Table 1. Distribution of seagrasses in different locations of Andaman and Nicobar Islands

Seagrass	St1	St2	St3	St4	St5	St6	St7	St8	St9	St10	St11
Enhalus acoroides				+			-	-	-		-
Halophila ovalis		-		+	+	+	+	+		-	
Halophila ovata				+	+		+	+	-	-	
Thalassia hemprichii	+			+	+	+	-	+	+		+
Cymodocea rotundata	+			+	+	+	+	+	+	+	+
Cymodocea serrulata		-				-	-	-	+	-	+
Halodule uninervis				+	+	+	+	+		-	+
Halodule pinifolia				+	+	+	+	+			-
Syringodium isoetifolium			-	+				-		-	-
Total	**2**	**0**	**0**	**8**	**6**	**5**	**5**	**6**	**3**	**1**	**4**

St1 :Kalipur; St2 : North Reef; St3 : Interview; St4 : Henry Lawrence; St5 : Havelock; St6 : Niel; St7 : Red Skin; St8 : Chidiyatapu; St9 : Little Andaman; St10 : Car Nicobar; St11 : Great Nicobar.

the seagrasses and the most portion of 60ha of seagrass is physically destructed and not showing any sort of regeneration in this site. At present seagrasses are distributed very sparsely in this site. Three species of seagrasses reported earlier by Kannan (2006) were identified from Little Andaman island during the present survey, however Das (1996) reported 5 species from this region. The loss of seagrass may be due to the impact of tsunami as opinioned by Kannan (2006).

Jagtap (1992) reported 7 species from Nicobar group of islands. Large seagrass area coverage from Teressa, Nancowrie, Katchal and Great Nicobar were reported (Jagtap, 1992; Das, 1996), however heavy destruction to seagrasses and other ecosystems were occurred due to the killer tsunami waves (Ramachandran *et al.*, 2005). Tsunami can have adverse impact on seagrass ecosystem (Obura and Abdulla, 2005; Kumaraguru *et al.*, 2005). Jagtap (1992) reported two seagrass species from Car Nicobar which include *C. rotundata* and *Halodule uninervis* where as Das (1996) reported *C. rotundata* and *Thalassia hemprichii* from this region. However, during the present investigation only *C.rotundata* was identified from Car Nicobar Island that too very scattered in patches. This indicates the total destruction of seagrasses from this island and most seagrass sites were buried by the deposition of sand. This confirmed the report of Kannan *et al.* (2005) who predicted that the seagrasses of Andaman and Nicobar Islands might have been destructed due to tsunami water by means of physical destruction and also by deposition of sediments over the seagrass beds. During the present survey only 4 seagrass species were identified from Great Nicobar Island. However, 4 seagrass species were reported by Das (1996) and 9 species of seagrass by Kannan and Ajmalkhan (2004) from these islands. But the seagrass meadows are highly disturbed due to tsunami and in most locations it is sparsely distributed. Das and Dey (1999) emphasized that the dugong populations are less abundant in this region than in the past and loss of potential habitat was found to be important reason for this loss. Under this condition impact of tsunami on sea grasses as supporting ecosystem for the marine flora and fauna especially to seaturtles and seacow would lead to extinction of this organism from this region. In addition to over environmental threats, both natural and made effects were also found to affect the seagrass resources of this islands ecosystem. Hence, it is paramount importance to restore the seagrass ecosystems of this island group so as to restore the population of these endangered reptiles and mammals.

CONCLUSION

The clear waters of Andaman and Nicobar Islands supports nine species of seagrass out of the 14 species reported from India. But the present data are not showing any supporting evidence for this. Only Henry Lawrence Island has good growth of seagrasses, as this island is in the Middle Andaman group of islands which is less affected by tsunami waters when compared to South Andaman and entire Nicobar group of islands. So there is an urgent need to conserve the seagrass ecosystems of Andaman and Nicobar group of islands by providing suitable environment for its survival and growth. More over planned large scale transplantation of seagrasses in the identified degraded areas would help to restore the ecosystem functions and there by conserve the remaining populations of the sea cows and sea turtles of this region. Still there are many areas unexplored to understand the occurrence and diversity of seagrass ecosystem in these islands that are also to be carried out to develop proper action plans for conservation and management of seagrasses of this island groups.

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Chapter 12

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 161-171, 2010

MANGROVE DIVERSITY AND PROSPECTS OF RESTORATION AND MANAGEMENT IN ANDAMAN AND NICOBAR ISLANDS

OSWIN D. STANLEY*
Eco Balance Consultancy, 6 B, Umiya Park Scoiety, Subhanpura 390 023, Vadodara, Gujarat, India

INTRODUCTION

Forest Survey of India statistics (2003), portraits the total area under mangrove vegetation in India as 4,461 km^2. Out of this, 671 km^2 area (dense mangrove 262 km^2, moderate mangrove 312 km^2 and open mangrove 97 km^2) of mangrove vegetation occurs in Andaman and Nicobar Islands (15.04 per cent of the total mangrove area of the Indian Territory). In Andaman district, the area under mangroves is 644 km^2 (dense mangrove 262 km^2, moderate mangrove 286 km^2, and open mangrove 96 km^2); while in Nicobar district mangroves occupy only 27 km^2 (moderate 26 km^2 and open mangrove 1 km^2). The luxuriant mangroves are seen in Shoal Bay (South Andaman), Yerrata (Middle Andaman), Austin Creek, Kalighat Creek and Cadell Bay (North Andaman). The Andaman and Nicobar Islands comprise a chain of 572 islands, islets, reefs and isolated rock outcrops spread in the Bay of Bengal. They extend to a length of 700 km between the lower Myanmar and the upper Sumatra region of Indonesia (Fig. 1).

Mangroves in India account for about 5 per cent of the World's mangrove vegetation and are spread over an area of about 4,500 km^2 along the coastal States/UTs of the country. We have lost over half of our planet's original mangrove forest cover today; roughly 16 million hectares remain from a former area of 32 million hectares. Yet, our planet is losing 2,25,000 ha of mangroves annually. Overall our nation has lost around 21 km^2 whereas, Andaman and Nicobars has lost around 118 km^2 mangrove area during the years 2001 to 2003. The decrease in Andaman and Nicobar Islands is justified by FSI as interpretational corrections as some open forest was incorrectly classified as mangrove in the earlier assessment. However, encroachment and reclamation of mangrove areas in Andamans for agriculture and for settlement is prominent. In many places the process starts with dumping the soil in mangrove area or disrupting the water regime, subsequently planting a small temple in the degraded area and elaborating reclamation. Encroachment regularization (Supreme Court of India order dated 07.05.2002) needs to be reinforced before further losing mangrove areas.

Earthquake (9.0 Richter scale) which struck Andaman and Nicobar Islands on 26 December 2004 and the consequent tsunami have caused considerable change on the mangrove stands of Andamans. Press Information Bureau, Government of India (2008) states that Mangroves have undergone severe destruction in Andaman and Nicobar Islands to the extent of 18 per cent. In Andaman Islands 3850 ha of mangroves were lost, while, 7750 mangroves were damaged. In Nicobar about 390 ha of mangroves were

*E-mail : ebcbaroda@yahoo.co.in; oswinbaby@rediffmail.com

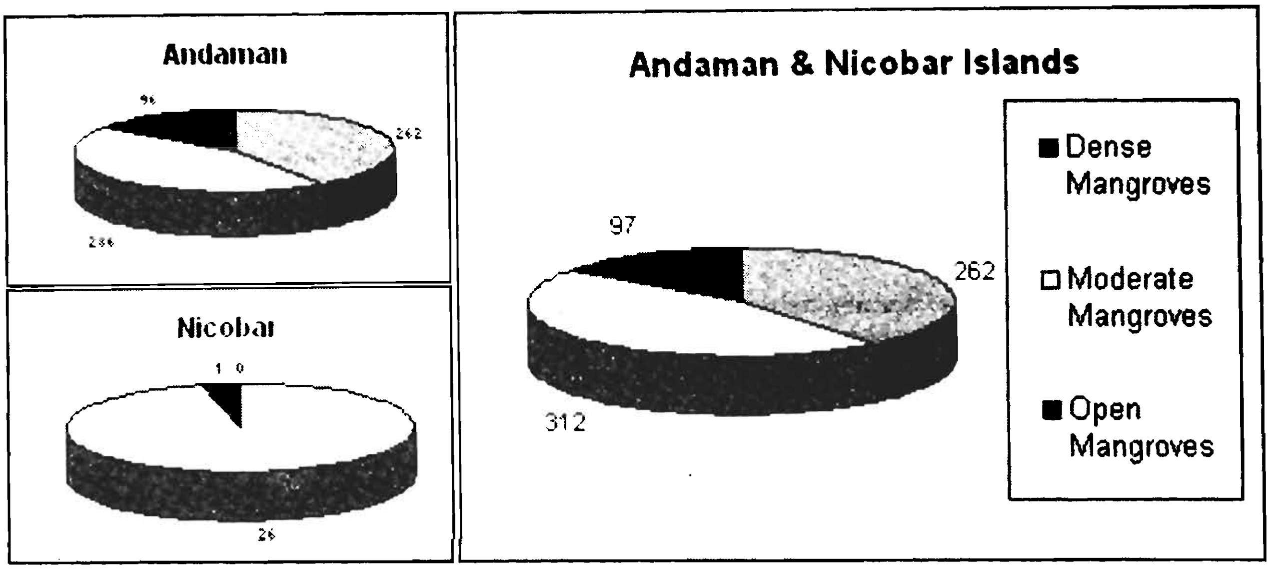

Fig. 1. Mangrove Area Coverage (in km^2) in Andaman & Nicobar Islands, FSI 2003

damaged. It is revealed that the mangroves, coral reefs, beaches etc., are in the process of reformation and revival of these features and ecosystems would take about 5 to 10 years. However, it is suggested that, the process of restoration of mangroves can be facilitated and accelerated by Ecological Mangrove Restoration Technique (EMR).

MATERIAL AND METHODS

Having personal experience in mangroves, especially in Andaman mangroves before and after Tsunami, the information on mangrove floral diversity of the islands were collated along with personal observation from all possible sources like reports, papers and articles. This would serve as a valuable document for the researchers, students, policy makers and law enforcing agencies to conserve the wealth of the 'biological paradise' of our country.

RESULTS AND DISCUSSION

Need for Mangrove Diversity Preservation and Restoration

Mangroves are dominant ecosystems interfacing the land and the sea in tropical and sub-tropical regions and gains importance in the economy of many of these areas in terms of mangrove-linked fisheries and forestry. The amount of fish caught in ocean is directly proportional to the area of healthy mangrove waters. One hectare of mangroves can yield 767 kg per year of wild fish and crustaceans. Each hectare of managed mangrove system produces as much as $11, 300 (Rupees. 5, 31, 100) a year (Primavera, 1991).

Intertidal occurrence of mangroves makes the ecosystem likely to be the early indicators of the effects of climate change. Of late, mangroves have been of particular interest globally, because of the possible high carbon sequestration as well as being in the 'forefront' of any sea-level change. Recent studies reveal that one hectare of mangroves sequesters 3.2 tonnes of carbon per annum (Quarto, 2007). Wetlands Evaluation Estimate reveals that the total value per hectare specifically for tidal marshes and mangroves is $9,990 per annum. Total global value per year for tidal marshes and mangroves is $1.6 trillion. "Ecosystem services" used to come up with these value figures include gas regulation, disturbance regulation, water regulation, waste treatment, habitat refuge, water supply, food production, flow materials, recreation, and cultural services (Costanza *et al.*, 1997).

Recent global awareness on the role of mangroves and coastal vegetation in protecting the coastal and inland resources including human lives during oceanic natural disasters is a good sign. The major cause of the extensive damage in the coastal states identified by local and international agencies is the decrease in the mangrove cover along the coasts and unsustainable mangrove management systems. Hence it is mandate to preserve the existing mangroves and restore the degraded coastal areas.

Ecology of Mangroves

The historical interest has been largely engendered by the unique adaptations (eg. Prop roots, pneumatophores, and viviparous seeds) of certain mangrove species and by their ubiquitous ability to function in a saline environment.

Coping with saline situations

Mangroves have specific adaptations both in leaves and root, morphologically, anatomically and physiologically. These survive in the hyper saline situations with their salt coping mechanism. Based on the mechanism adapted by each species, mangroves can be classified into three categories.

Salt excluding-Ultra Filtration Mechanism

Mangroves such as *Rhizophora, Ceriops* and *Bruguiera* species are 'salt-excluders' These species prevent much of the salt from entering the plant system by filtering it out at root level by the 'ultra filtration' mechanism in the root caps. Some species can exclude more than 90 per cent of salt in seawaters

Salt Excreting

Species such as *Avicennia, Sonneratia* and *Acanthus* are 'salt-secretors' These plants perform quick excretion of salt, which has entered the system through the special active salt-secreting salt glands on the lamina. The pure form of salt crystals can be viewed or tasted from the surface of the leaf blades.

Salt Accumulating

Lumnitzera, Avicennia, Ceriops and *Sonneratia* species and mangrove associates such as *Sesuvium, Suaeda, Salicornia*, are 'salt accumulators' These species concentrate the salt entered inside the plant system in the bark or in older leaves, which carry it with them when they fall off.

Some mangroves apply only one of these methods but there are species having more than one type of salt coping mechanism. In addition, a number of features serve to prevent water loss from the plant. These include a thick waxy cuticle or dense hairs to reduce transpiration. Most evaporation loss occurs through stomata, so these are often sunken below the leaf surface where they are protected from drying winds. Leaves are also commonly succulent, storing water in fleshy internal tissue.

Coping with shifting mud and anoxic conditions

Mangrove substratum is water logged, muddy and unstable with shifting nature due to the tidal forces. Therefore an extensive root system is essential to keep the trees upright. Mangroves do not have established deep tap root system as the substratum that they live lack good oxygen supply. Hence many mangroves are adapted with unique root systems like prop/aerial stilts (*Rhizophora*), buttress (*Heritiera*), Cable Knee roots (*Bruguiera, Xylocarpus granatum* is buttressed with cable knee roots) and pnuematophores (*Avicennia*) for better anchorage and gas exchange.

The mangrove substratum is rich in sulphur-di-oxides and poor in oxygen. Species such as *Avicennia, Kandelia*, etc. is adapted with roots systems called breathing roots or Puematophores. These roots have small pores on the surface called lenticels to enable diffused atmospheric gaseous exchange. The lenticels are inactive during high tide. Sedimentation is a major threat to the pneumatophores where silt interfere gas exchange and suffocates the plants. In a normal mangrove ecosystem the sedimentation rate is 1.5 to 2 cm per year (Walshand and Nittrouer 2004).

Special adaptation for seed dispersal

Dispersal of seeds in the unstable environment is another challenge for the survival of mangroves. Mangroves such as *Rhizophora, Ceriops* and *Bruguiera* produce the seeds, which matures while attached to the parent plant. When ripe, these seeds eventually would fall in the muddy substratum underneath the parent and start growing. This adaptation is called Vivipary (embryo germination begins on the parent tree itself, accumulating the carbohydrates and other compounds required for later autonomous growth and developed embryos dropping as propagules). The propagules of *Rhizophora* may float in the waters even up to one year, travel to other shores and stay viable. However the duration of viability varies with species and environmental conditions. Soil conditions and environment preferred by different genus of mangroves is presented in Table 1.

Table 1. Soil conditions and environment preferred by different genus of mangroves

Species	Soil	Environment/Remarks
Acanthus ilicifolius	• Sand clay • Silt clay	• Colonize highest high tide water • Suitable for areas with high organic load • Thrive well in abundant flow of fresh water
Avicennia sp.	• Wide range of soil conditions • Dry Tidal lands, river banks or high saline flats, arid zones • Sandy areas • Broad tidal mud banks or shallow sand banks in the seaward edge • Borders coastal saline herb lands	• Adapted to early colonization • Able to tolerate low temperatures and variety of other inter tidal conditions • Colonize newly-emerged mud banks • Found throughout river systems, including the upper limit of tidal influence where fresh water is abundant • Prefer middle tide amplitude • Survive better in mean tide water • Prefer soil with high organic load • Resistant to high solar radiation • Cannot tolerate long period of pheumatophore submergence
Bruguiera sp.	• Stiff clay containing little organic matter • Sand/loam substrate • Less saline soils covered with a thick forest	• Prefer low tide amplitude • Thrive well in abundant flow of fresh water
Ceriops sp.	• Sand/loam substrate • Bordering coastal saline herb lands • *C. tagal*-High saline areas	• Zone inundated only by periodic spring tides at the times of new and full moons • *C. tagal*-Not suitable for areas with high rate of sand movement
Excoecaria agallocha	• Sand/loam substrate	• Colonize highest high tide water
Heritiera sp.	• Sand/loam substrate	• Prefer low tide amplitude
Nypa fruticans	• Main river bank or lagoon • Fringing	• Prefer low tide amplitude • Can colonize highest high tide water
Rhizophora sp.	• Soft humus • Rich mud • Mouth of tidal creeks and rivers where salt and fresh water mix	• Water front • Prefer high tide amplitude • Survive on aged mangrove mud rich in Hydrogen sulphide • Muddy environment • Resistant to high solar radiation and UV-B tolerance • Respond well to CO_2 for biomass production • Tolerant to high wind action (Cyclone/ Storms) • Suitable for the sites with metal and oil pollution

Table 1. *Contd.*

Species	Soil	Environment/Remarks
Sonneratia sp.	● Sandy areas ● Broad tidal mud banks or shallow sand banks in the seaward	● Water front but a more tropical species ● Newly-emerged mud banks ● Prefer high tide amplitude ● Thrive well in abundant flow of fresh water ● *S. alba*-close to sea, high saline areas edge
Xylocarpus sp.	● Sand/loam substrate	● Prefer low tide amplitude ● Thrive well in abundant flow of fresh water ● Low saline areas

Biology of Andaman and Nicobar Mangroves

The mangrove vegetation of these islands constitutes 9.4 per cent of the land area or 10.85 per cent of the total forest area (http:// forest.and.nic.in). Mangroves occurring in these islands are mostly fringing the creeks, backwater and muddy shores. Along the creeks the width ranges from 0.5 km to 1 km. Mangroves do occur on rock shores subjected to tidal action and regular deposits of mud. Mangroves in Andaman are represented by 35 species and other common associated flora represents 62 species (Tables 2 and 3).

Table 2. Mangrove Flora of Andaman

S. No.	Mangroves of Andaman	Family
1.	*Acanthus ebracteatus*	Acanthaceae
2.	*A. ilicifolius*	Acanthaceae
3.	*Avolubilis*	Acanthaceae
4.	*Acrostichum aureum*	Pteridaceae
5.	*Aegialitis rotundifolia*	Plumbaginaceae
6.	*Aegiceras corniculatum*	Myrsinaceae
7.	*Avicennia alba*	Verbenaceae/Avicenniaceae
8.	*Avicennia marina*	Verbenaceae/Avicenniaceae
9.	*Avicennia officinalis*	Verbenaceae/Avicenniaceae
10.	*Bruguiera cylindrica*	Rhizophoraceae
11.	*Bruguiera gymnorrhiza*	Rhizophoraceae
12.	*Bruguiera parviflora*	Rhizophoraceae
13.	*Bruguiera .sexangula*	Rhizophoraceae
14.	*Ceriops decandra*	Rhizophoraceae
15.	*Ceriops tagal*	Rhizophoraceae
16.	*Excoecaria agallocha*	Euphorbiaceae
17.	*Heritiera littoralis*	Sterculiaceae
18.	*Kandelia candel*	Rhizophoraceae
19.	*Kandelia rheedii*	Rhizophoraceae
20.	*Lumnitzera littorea*	Combretaceae

Table 2. *Contd.*

S. No.	Mangroves of Andaman	Family
21.	*Lumnitzera racimosa*	Combretaceae
22.	*Nypa fruiticans*	Palmaceae
23.	*Phoenix paludosa*	Arecaceae
24.	*Rhizophora apiculata*	Rhizophoraceae
25.	*Rhizophora lamarckii*	Rhizophoraceae
26.	*Rhizophora mucronata*	Rhizophoraceae
27.	*Rhizophora stylosa*	Rhizophoraceae
28.	*Scyphiphora hydrophyllacea*	Rubiaceae
29.	*Sonneratia alba*	Lythraceae
30.	*Sonneratia apetala*	Lythraceae
31.	*Sonneratia caseolaris*	Lythraceae
32.	*Sonneratia griffithii*	Lythraceae
33.	*Xylocarpus granatum*	Meliaceae
34.	*Xylocarpus mekongensis (= X-gangeticus)*	Meliaceae
35.	*Xylocarpus moluccensis*	Meliaceae

Table 3. Other Mangrove associated coastal flora in Andaman

1.	*Adenanthera pavonina*	22.	*Derris heterophylla*
2.	*Aglaia cucullata*	23.	*Derris trifoliata*
3.	*Aisandra butyracea*	24.	*Ehretia acuminate*
4.	*Ardisia solanacea*	25.	*Euphorbia nerifolia*
5.	*Atalantia monophylla*	26.	*Ficus altissimai*
6.	*Barringtonia asiatica*	27.	*Finlaysonia obovata*
7.	*Barringtonia racemosa*	28.	*Fimbrisstylis littoralis*
8.	*Boswellia serrata*	29.	*Glochidion calocarpum*
9.	*Brownlowia lanceolata*	30.	*Glycosmis mauritiana*
10.	*Calophyllum innophyllum*	31.	*Guettarda speciosaI*
11.	*Centotheca lappacea*	32.	*Hernandia peltata*
12.	*Cerbera manghas*	33.	*Hibiscus tiliaceus*
13.	*Chydenanthus excelsus*	34.	*Indigofera glandulosa*
14.	*Clerodendrum inerme*	35.	*Indigofera zollingeriana*
15.	*Cocos nucifera (introduced between the years 1789 and 1796)*	36.	*Ipomoea pes-caprae*
16.	*Cycas rumphii*	37.	*Ischaemum muticum*
17.	*Cynometra iripa*	38.	*Manilkara littoralis*
18.	*Cynometra ramiflora*	39.	*Messerschmidia argentea*
19.	*Cyperus kyllinga*	40.	*Mimusops species*
20.	*Dalbergia spinosa*	41.	*Morinda citrifolia*
21.	*Dendrolobium umbellatum*	42.	*Mucuna gigantean*

Table 3. *Contd.*

43.	*Ochrosia oppositifolia*	53.	*Scaevola sericea*
44.	*Olax imbricata*	54.	*Scaevola taccada*
45.	*Ophiorrhiza mungos*	55.	*Sophora tomentosa*
46.	*Pandanus andamanensis*	56.	*Sporobolus virginicus*
47.	*Pandanus leram*	57.	*Syzigium samarangense*
48.	*Pandanus odoratissimus*	58.	*Tabernaemontana crispa*
49.	*Pandanus tectorius*	59.	*Thespesia populnea*
50.	*Pemphis acidula*	60.	*Triphasia trifolia*
51.	*Pongamia pinnata*	61.	*Vitex diversifolia*
52.	*Scaevola plumierii*	62.	*Vitex trifoliata L.*

Geology of Andaman and Nicobar Islands

George Weber (2005) explains geologically, the Andamans and Nicobars represent the highest peaks of an under-water mountain range which is itself an extension of the Arakan range in Burma and the Sumatran Barisan ranges to the south. The islands lie parallel to a geological fault line to the east, crossing the Andaman Sea from north to south. The line marks two tectonic plates rubbing against each other: the eastern plate, an extension of the huge Eurasian plate, is stationary, while the Indian plate to the west is moving north to northeast at the rate of a few centimetres a year, taking the Andaman Islands with it. This slow movement is still pushing up the Himalayan Mountains and causes earthquakes and volcanic activity in and around the islands. India's only active volcanoes, on Barren and Narcondam Islands, are caused by the fault line. The Andamans are rising and falling with the erratic local movement of the earth's crust.

On a geological time-scale these are mere shudders, small and rapid. While the large-scale geological trend still continues to cause a slow rising of the Andamans, in the relatively short term of a few thousand years, the islands have both sunk and risen. On the still shorter timescale of a few hundred years and quite independently of any geological movements, the sea has also been rising and falling. The interaction of all these movements has resulted in a complex rising and falling, a growing and shrinking of the land area available to plants, animals and people. (George, 2005).

Recent tilting of Andaman plates during 2004 exposed or submerged several hectares of corals and mangroves. In South Andaman, in particular localities 30–80 per cent of mangrove stands got affected. In Middle Andaman the impact is negligible, whereas in the North Andaman due to tilting and elevation of land, the sea water is not reaching some of the mangrove stands. The tidal waves that swamped the mangrove stands have affected the giant fern *Acrostichum aureum* and the aquatic sedge *Fimbrisstylis littoralis*. The mangroves such as *Rhizophora* spp, *Bruguiera* spp, *Avicennia* spp, *Sonneratia* spp, etc. have also got affected in various degrees based on their physiological response to the continuous inundation or exposure under the changed scenario.

Mangroves and Sea Level Rise

Mangrove ecosystems could keep up with a sea-level rise of up to 8-9 cm/100 years, but at rates of over 12 cm/100 years could not persist. This is due to low rates of sediment accumulation, with limited sources from outside the mangrove zone, such as from rivers or soil erosion sources (Ellison and Stoddart, 1991). Scenario of overall impact on sea level rise would be different on Andaman Islands where mangroves are already restricted in areas by coastal topography and tidal amplitude. Mangroves in these areas, especially in Andaman and Nicobar Islands may come under stress or may not persist in moderate to high rate of sea level rise. As about 260 km of the coast of Andaman and Nicobar Islands are lined with mangroves and they have restricted scope of adjustment in response to sea level rise, the impact of climate change on extent and species composition of mangroves may be devastative when sea level rise exceed about 10cm/100 years (Singh, 2000). It is suggested that a rise in mean sea-level may be the most important factor influencing the future distribution of mangroves but that the effect will vary dramatically depending on the local rate of sea-level rise and the availability of sediment to support reestablishment of the mangroves (Field, 1995).

Mangrove Restoration Practices

There are basically three approaches which are used in mangrove restoration programs:

1) Hydrologic restoration with no planting
2) Hydrologic restoration with planting
3) Planting without consideration for hydrology

Though method 1 and 2 are the best, however in India, method 3 is the only method tried and almost always has significant problems in achieving success. It is not easy to create a garden of mangroves where none existed before and ideal combination of factors for best mangrove establishment is depicted in Table 4.

Understanding the restoration site

Several efforts to restore coastal mangrove areas involved simple planting of mangrove seedlings and propagules. In many instances, seedlings raised in nurseries to be hand-planted in neat, regularly spaced rows, are often placed in inappropriate locations, such as mud flats or salt flats, where the present hydrology and soil conditions are all wrong and mangroves do not belong. Already, there have been numerous failures due to planting of inappropriate species, in inappropriate locations, but in general failure occurs due to a lack of understanding of the restoration site itself.

Knowing not, the history, existed mangroves, area of existence, hydrological requirements of species, substrate depth in which mangroves were growing earlier, freshwater inputs during their existence, exchange of tidal and sea water regime in the past etc is the major drawback of any mangrove restoration attempt. Contrary to popular belief mangroves require some freshwater to grow well, and they are submerged only around 33 per cent of the time. Planting mangroves along an exposed coastline, in too deep water without fresh water input will also end up in failure (Lewis, 2005).

Planting on Mudflats

Mangrove ecosystems are so specialized that any minor variation in their hydrological or tidal regimes causes noticeable mortality. Each species of mangrove occurs in ecological conditions that approach its limit of tolerance with regard to salinity of the water and soil, as well as the inundation regime (Blasco and Saenger *et al.,* 1996). Generally coastal mudflats are defined as the potential sites for mangrove restoration by foresters and restoration practitioners. For example, Gujarat State government has notified large areas of coastal mudflats about 63,710 ha of mud flats as potential areas for mangrove restoration (Singh, 2000). Restoring mangroves does not mean converting one good habitat (*i.e.,* mudflats or seagrass meadows) into mangroves. That makes no ecological sense (Lewis, 2005).

Most of the attempts of mangrove plantation activities have been carried out in areas that previously did not support mangroves, like mudflats in front of existing mangroves. Essentially all of these projects, many costing several crores of rupees have not worked for success. If the mudflat did not normally support mangroves, there was a reason that mudflats are too wet to allow mangroves to grow. They are flooded too often. Like people, mangroves need to take a deep breath very regularly and can easily drown. This fact is not obvious to the casual observer who intends restoring mangroves.

Potential Site Selection and successful mangrove restoration

The six step approach of Ecological Mangrove Restoration (EMR) (Lewis and Marshall, 1997; Lewis, 1999; Lewis and Streever, 2000; Lewis 2005) on mangrove restoration projects are successfully evidenced in eleven countries, including Unites States, Nigeria, Vietnam, Hong Kong, Thailand, Cuba, Mexico, and Costa Rica and the technology is applicable all over the world. We along with Mangrove Action Project (MAP) suggest the active use of the six-step EMR method as an effective long-term solution to degraded mangrove forests worldwide especially in India.

The initial act before restoration is finding a place that historically supported mangroves (based upon confirmation with maps, aerial photos and local knowledge) and finding out the reason for

Table 4. Ideal Combination of Factors for Best Mangrove Establishment

Parameters	Nursery	Establishment
Restoration of Hydrology should be the preliminary step to establish mangroves		
Temperature (Soil)	23-30°C	23-38°C
Temperature (Water)	23-28°C	25-30°C
Salinity (Soil)	5-30 ppt	20-37 ppt
Salinity (Water)	5-25 ppt	15-35 ppt
pH (Soil)	7.5-8.5	7.5-8.5
pH (Water)	7-8	7-8
Anoxic Condition	Low	Low
Age of the soil	Moderate to new	Moderate to new Very old degraded soils withoutgood flushing will be highly anoxic which restrict the growth of plants
Soil Texture	Silt Clay	Silt Clay Loam Clay
Area	Banks of Back Waters Estuarine banks River banks Shaded areas not much exposed to Sun/depending on species	Banks of Back Waters Estuarine banks River banks (Increasing Mangroves in banks should not interrupt the hydrology or carrying capacity of the estuaries/ rivers in future) Degraded Mangroves
Organic Load	Heavy/Moderate	Heavy
Land Elevation	Mild	Mild (3-4m)
Tidal Pattern	Semidiurnal	Semidiurnal
Inundation Pattern	Regular	Regular
Seed Size	Big/Mature	Big/Mature
Seed/seedling Quality	Good/un-infected by predators	Good/un-infected by predators; healthy seedlings
Technique	Developing nursery in the plantation premises	Direct Dibbling Nursery raised seedlings may be used if volunteer seedling fails in water front areas
Best Technique	Volunteer Seedling establishment	Ecological mangrove restoration Volunteer seedling establishment - Little planting for acceleration

their absence today. The most common reasons perhaps are : (a) they have been cut so fast they could not re-grow or; (b) the normal hydrology for mangroves (i.e., tidal inundation for 2-5, hours a day on average, year round, and dry 19-22 hours a day) has been disrupted. Either too much water via impoundment, or too little via blockage of tides and rainfall entry or construction of dikes for other purposes ultimately disruption of normal hydrology.

Important feature in designing a successful mangrove restoration project is determining the normal hydrology (depth, duration and frequency and of tidal flooding) of the existing natural mangrove plant communities (a reference site) in the proposed restoration area (Lewis, 2005).

Six Steps to Successful Mangrove Restoration (Lewis, 2005), explains understanding both autecology (individual species ecology) and community ecology; understanding the normal hydrologic patterns; assess modifications of the previous mangrove environment that currently prevent natural secondary succession; select an appropriate mangrove restoration site through application of above, and also take into consideration resolution of land ownership/use issues necessary for ensuring long-term access to and conservation of sites; and design restoration programs initially to restore the appropriate hydrology and take advantage of natural volunteer recruitment of mangrove propagules; and finally try actual planting process of nursery cultivated seedlings only after determining that natural recruitment will not be able to provide the quantity of natural volunteer seedlings, to achieve the quantitative goals of the restoration project.

An Emerging Threat : Massive mangrove plantation drives

The species most often selected for mangrove plantation drives are the *Avicennia, Rhizophora, Sonneratia, Kandelia, Ceriops, Bruguiera, Aegiceras, Lumnitzera,* and *Nipa* palm. These tree species are chosen for their availability and ease of collecting and propagating their seeds. Such large-scale mangrove plantings are actually afforestation efforts, not restoration, and high failure rates ensue. Most of these mangrove "restoration" projects are planting only one species, usually the *Rhizophora* or *Avicennia*. Those few projects that do succeed in establishing mangroves are more of a monoculture, rather than a healthy multi-species mangrove forest as naturally occurs in the tropics.

The emerging threats to existing mangroves due to mangrove plantation are, a) seed collection from a target candidate species, b) unreasonable target area for restoration, c) unaccountable implementing agencies, d) unchecked survival or growth performance of such mangrove establishments by funding agencies or Government, e) prospect of protection right of such establishments, f) lack of proper guidelines for mangrove development or restoration for funding and implementing agencies. The mangrove plantation projects even possess fantasy targets up to 5000 ha and in order to cater such large areas, seeds from the natural forests near by are depleted in abundant. Therefore, the process of natural regeneration in that particular area as well as the area up to the seed reaches is interrupted.

It is important to understand and appreciate the fact that mangroves normally produce thousands of floating seedlings per tree every year, and these spread far and wide and allow mangroves to colonize nearly every place where they can survive. The seed output was 95,000-1,50,000/tree and >28.5x106 seeds per hectare in Muthupet forest, south east of India and 95 per cent seeds fall under the parent tree and 50 per cent of these were carried away by tidal action (Oswin, 1998 and 2006). For this significant reason the natural regeneration of forests by allowing the seeds to travel and germinate in potential areas, should be facilitated and not interrupted.

Continuous process of razing off seeds 'every season from natural patches from target species' would in long term affect the existing mangroves from regenerating future forests. Neither the developed mangrove plantation would exist due to the improper management nor do the natural forests exist in future, due to severe stress of seed extraction and continuous utilization for fodder and grazing. Hence, it is high time switching on to EMR for restoring large target areas.

CONCLUSION

The significance of conserving and managing mangroves is not exaggerated as recent catastrophic events of nature emphasize the urgency in Anadman and Nicobar islands. Mangrove floral and associated coastal floral diversity depicted represents the wealth of the island. The detail on soil conditions and environment preferred by different genus of mangroves and ideal combination of factors for best mangrove establishment would help restoration practitioners to plan mangrove development projects. Controlling mangrove area encroachment is a challenge. An alarm is raised to understand the emerging threat to existing mangroves in the term of plantation drives. The right approach to restore mangroves through Ecological Mangrove Restoration technique is proclaimed for large area restoration and for long term ecological sustenance.

Mangrove Action Project together with different NGO's facilitates many workshops and Trainings on Ecological Mangrove Restoration. These hands-on workshops and training are designed in such a way that local mangrove restoration practitioners, local NGOs and community members could actively participate in learning the basic principles of ecological mangrove restoration (EMR) techniques. Conserving and restoring mangroves is a win-win solution for protecting life on this planet.

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Chapter 13

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 173-177, 2010

DIVERSITY OF WILD LEGUMES AND ASSOCIATED RHIZOBIA IN THE COASTAL REGIONS OF SOUTH ANDAMAN

V. JAYAKUMAR*, S. RAJALAKSHMI and M. PALANISAMY
Division of Field Crops, Central Agricultural Research Institute, Port Blair–744101
Andaman & Nicobar Islands

INTRODUCTION

In India after Green revolution the productivity levels of cereals and oil seeds increased substantially, whereas it remains almost stagnant in pulses alike earlier. In spite of large area brought under cultivaticn the low production levels of pulses has been often attributed to the inherent constraints in productivity (Jeswani and Baldev, 1990). Fabaceae is the one of the largest families of angiosperms, which is remarkable for its wide evolutionary diversification (Polhil *et al.*, 1981) and wide distribution (Raven *et al.*, 1981). Many of the members of this family are having significant agricultural importance due to their useful diversity and ability to grow in wide ecological niche. It is also mentionable that *Rhizobium* legume components would play key role in inflating the productivity of pulse crops. Some members of leguminous plants with its rhizobial association account for ~80 per cent of the biologically fixed nitrogen and contribute 25-30 per cent of the worldwide protein intake (Vance, 1996). In addition to cultivated legumes, wild legumes also posses potential for nitrogen fixation (Ahamad *et al.*, 1984) and a novel, suitable wild legumes-*Rhizobium* association was useful in improving the degraded lands (Jha *et al.*, 1995). In recent year exploration of a number of tropical wild legume species, trees, shrubs and herbs showed wide range of unexpected diversity in the legume nodulating bacteria (de Lajudie *et al.*, 1998, Williams *et al.*, 2000). The effective rhizobia isolated from these legumes, have been used for inoculation of another legume (Zahran *et al.*, 1999) whereas, until now nodulation of wild legumes has been poorly documented (Nour *et al.*, 1995).

Andaman & Nicobar Islands is a hot spot for biological diversity and the coastal regions of these Islands are ecologically important as they provide niches for variety of flora and associated micro biota, especially the wild legumes. This study was aimed to uncover the diversity of wild legumes and their bacterial symbionts in their native environments, which will be useful for future agricultural research.

MATERIALS AND METHODS

An exploration was conducted in the coastal areas of South Andaman to identify the wild legumes occurrence and selectively five legume plants were taken for this study. The plants were collected in their natural habitat, brought to the laboratory and the specimen was preserved in herbarium. Each legume plant was uprooted at flowering stage and their nodulation patterns were recorded. The soil samples from the wild legume habitat was collected and analysed for the

* Corresponding author, Email : jkpath@rediffmail.com
**Botanical Survey of India, Southern Circle, TNAU Campus, Coimbatore- 641 003

properties like pH, Ece and Cation Exchange Capacity by following standard procedure.

Nodules from these legumes were collected, surface sterilized, crushed and the exudates were streaked onto yeast mannitol agar plates. The bacteria were sub-cultured and pure cultures are being maintained at the laboratory. Seeds of each wild legume were surface sterilized and raised in sterile soil after inoculating with associated *Rhizobium* spp under sterile pot culture to check the legume-*Rhizobium* symbiosis. All *Rhizobium* species produced nodules with associated host grown in pot. The pure cultures of *Rhizobium* species were subjected to staining, C-source utilisation ability (Amarger *et al.*, 1997) and biochemical tests as per the procedures of Bergy's manual of determinative bacteriology. Salt tolerance ability of *Rhizobium* spp was studied *in vitro* by pour plate technique by inoculating 0.2ml of each isolate on YEMA plates enriched with NaCl of varying concentration ranging from 100mM to 1000mM. The number of colonies produced in each plate was recorded at 24, 48 and 72 h after inoculation. The number of colony per plate is recorded as poor growth (<25 colonies per plate), moderate growth (25 to 200 colonies per plate) and heavy growth (>200 colonies per plate).

The places of collection of wild legumes are given in Table 1 and pictures are depicted in plate 2 (Figs 1-5.).

Taxonomic enumeration of wild legumes

1. ***Vigna marina*** (Burm.f.) Merr. Inter. Herb. Amb. 285. 1917; Sans., Legumes of India. 274. 1992. Baker and Hook. f., Fl. Brit. India. 2 : 205. 1876. The plant is climbing herb, stems pale yellowish, striate, glabrescent. Leaves 30cm long; leaflets ovate, elliptic or orbicular obtuse at apex, cuneate or rounded at base, entire; lateral nerves 4-5 pairs. Flowers pale yellow, pods linear, sub-compressed, with a lateral beak at apex, seeds grayish or grayish-brown.

Distribution : Pongibalu and Jollybuoy Island. Abundant near to the seashore and mangrove areas, where the sea water intrudes the crop area during high tide.

Soil property : Sandy loam, pH 6.9, Ece 0.7 dS/m, CEC 14.6 c.mol/kg soil.

2. ***Vigna ungiculata*** Walp ssp *cylindrica* L van Eseltine in Hedrick, Veg. New York 1(2): 11. 1931. The plant is twining herb; stems pale yellowish to pale pinkish, striate. Leaves up to 25 cm long; leaflets terminal; ovate-deltoid or rarely rhomboid, shortly acuminate at apex, cuneate at base, entire or faintly lobed at base, lateral leaflets oblong to ovoid-deltoid. Flowers pinkish-blue or yellowish, pods linear; seeds brownish white.

Distribution : Manglutan and in parts of North, Middle and South Andaman.

Soil property : pH 5.7, Ece 3.7 dS/m, CEC 10.8 c.mol/kg soil.

3. ***Cajanus crasses*** (Prain & King) van der Maesen in Agric. Univ. Wageningen Pap. 85(4): 105. 1986. The plant is climbing shrub, branches brownish, ribbed, pubescent. Leaves up to 12 cm long; leaflets coriaceous, terminal rhomboid, round or slightly cordate at base, lateral ovate, obliquely rounded at base. Flowers yellow, pods oblong, soflty brownish tomentose, 3-6 seeded; seeds are orbicular and black.

Distribution : Nayashar and also located in other parts of South Andaman.

Soil property : pH 5.9, Ece 6.32 dS/m, CEC 15.3 c.mol/kg soil.

4. ***Centrosema pubescens*** Bth., Comm. Legum. Gen. 55. 1837. The plant is climbing shrub; branchlets pale brownish to brownish pubescent. Leaves up to 13 cm long; leaflets pubescent, elliptic, acute to shortly acuminate at apex, rounded or slightly cordate at base. Flowers pink or white, pods glabrescent.

Distribution : Manglutan and also common in North Andaman.

Soil property : pH 5.6, Ece 3.4 dS/m, CEC 11.3 c.mol/kg soil.

5. ***Mucuna monosperma*** DC.ex Wight in Hook. Bot. Misc. 2:346. 1831. The plant is a liana; branchlets pale grayish to blackish, lenticellate, striate, glabrescent. Leaves upto 22.5 cm long; leaflets obliquely ovate-lanceolate or sometimes elliptic, rarely oblanceolate, acute to shortly acuminate at apex, rounded, cuneate or slightly cordate at base. Flowers purple, pods ellipsoid-oblong.

Distribution : Manjery and other parts of Middle and South Andaman. The plant is found growing in marshy area near the sea shore and back water range.

Soil property : pH 6.5, Ece 0.9 dS/m, CEC 13.7 c.mol/kg soil.

RESULTS

The wild legumes had lush green growth, especially the growth of *V. marina* that survives under sea water submergence during high tide had abundant canopy, flowers and pods and the crop growth covered entire sand dune area (Plate 2 Fig 1a and 1b). The nodulation pattern varied with the legume and mostly these wild legumes produced abundant viable nodules (Table 1). It is mentionable that *V. marina* and *M. monosperma* that grow in extreme salinity had abundant viable nodules.

The five isolates recovered from YEMA were Gram negative, capsulated, non spore forming rods producing white, mucilaginous, circular shaped, elevated colonies. Results show that the five *Rhizobum* isolates exhibit similar kind of reaction to various biochemical tests with few exceptions (Table 2). All the isolates were indole negative and catalase and nitrate reduction positive. Except WL5 all other cultures flourished well in the three C- sources which was confirmed by the production of acid and isolates WL8 and WL12 hydrolyzed starch thereby forming a clear zone around the culture growth. It was noted that in the NaCl amended media WL1 and WL12 grew up to 1000mM (Fig. 6), which is unique property of any *Rhizobium* spp.

DISCUSSION

The present study revealed the presence of diverse and useful legume crops and associated *Rhizobium* spp in the coastal areas of Andaman & Nicobar Islands. The wild legumes, especially the growth of *V. marina* had lush green growth even under sea water submergence during high tide. It was also noted that *V. marina* and *V. ungiculata* ssp *cylindrica* are wild relative of cultivated legume cowpea. Coastal sand dunes, mangroves and other areas of India are already reported to host such wild relatives of diverse unexploited useful legumes with rich source of nutrition (Seena and Sridhar, 2006; Bhavesh Kumar *et al.*, 2006). Apart from lush growth, *V. marina* and *M. monosperma* that grow in extreme salinity had abundant viable nodules. Salinity normally reduces shoot and root weights in several legumes (Zahran and Sprent, 1986; Grattan and Maas, 1988), whereas in the present study the plant was found to produce greater biomass even in the high saline environment.

Survey and evaluation of wild legumes and their associated *Rhizobium* spp in the coastal regions of Andaman revealed the presence of diverse group of associations with potentially useful properties. The growth of WL1 and WL12 up to 1000mM NaCl concentration is unique property of any *Rhizobium* spp. It was earlier reported that rhizobia growth was inhibited by 100mM NaCl, while a few found to be tolerant at 600-700mM NaCl concentrations (Mohammad *et al.*, 1991). A few rhizobial strains from *Acacia*,

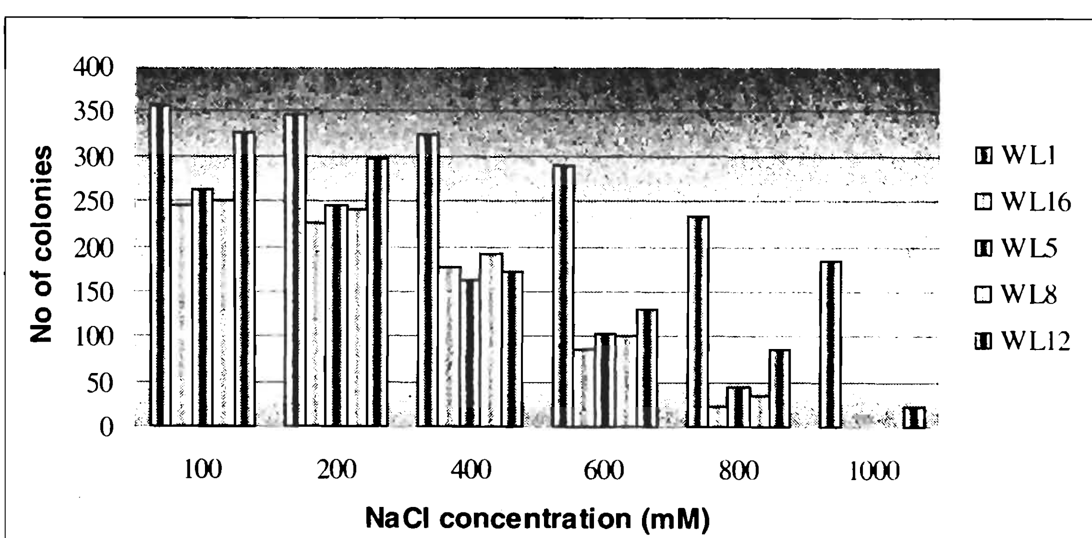

Fig. 6. Colony growth of *Rhizabium* on salt amended medium

Table 1. Places of collection and nodulation pattern of wild legumes

Sl. No	Place of collection	Legume species	*Rhizobium* Isolate name	Nodulation pattern		
				No of nodules/ plant	Fresh weight of nodules (g)	Dry weight of nodules (g)
1	Pongibalu	*Vigna marina*	WL1	42	0.47	0.18
2	Manglutan	*Vigna ungiculata* ssp *cylindrica*	WL16	56	0.48	0.21
3	Nayasahar	*Cajanus crasses*	WL5	31	0.28	0.09
4	Manglutan	*Centrosema pubescens*	WL8	54	0.51	0.23
5	Manjery	*Mucuna monosperma*	WL12	29	0.27	0.14

Table 2. Biochemical characters of *Rhizobium* spp isolated from wild legumes

Tests\Isolate	WL1	WL16	WL5	WL8	WL12
Gram reaction	-	-	-	-	-
Capsule staining	+	+	+	+	+
Indole test	-	-	-	-	-
Nitrate test	+	+	+	+	+
Catalase test	+	+	+	+	+
H_2S production	-	+	-	-	+
C- source utilization					
Glucose	A	A		A	A
Lactose	A	A	A	A	A
Sucrose	A	A	A	A	A
Starch utilization	-		-	+	+

Negative reaction; + Positive reaction; A–Acid production

Prosopis and *Leucaena* were reported to be tolerant up to 850mM NaCl (Lal and Khanna, 1995; Zahran *et al.*, 1994), which is in proximity to our findings. The high salt tolerant nature of WL1 and WL 12 may be attributed to the inherent nature of these two *Rhizobium* spp that survives in sea water during high tide.

The extreme salt tolerant properties of *V. marina* and *M. monosperma* and the associated *Rhizobium* spp can be well exploited to improve the productivity and nutritive value of cultivated pulses. The stress tolerant traits of these wild legumes and *Rhizobium* spp associations are potential value for crop and strain improvement in agriculture and also possess high biotechnological importance. The utilization of such diversity should be based on further studies on nutritive value of wild legumes, utilization of them in breeding program and ability of these salt tolerant *Rhizobium* spp to nodulate other cultivated legumes.

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Plate 2

Figs. 1-5. Habi and nodulation pattern of wild legumes. 1a-b. *V. marina*; 2a-b. *C. crasses*; 3a-b. *C. pubescens*; 4. M. monosperma; 5. *V. ungiculata* ssp. *cylindrica*.

2a. Flowers dimerous .... 9. ***Neolitsea***
b. Flowers trimerous 3
3a. Leaves verticillate .... 1. ***Actinodaphne***
b. Leaves alternate, rarely subopposite or opposite 4
4a. Anthers 4-locular .... 8. ***Litsea***
b. Anthers 2-locular .... 7. ***Lindera***
5a. Anthers 4-locular 6
b. Anthers 2-locular 7
6a. Leaves opposite, triplinerved ....4. ***Cinnamomum***
b. Leaves alternate, penninerved .... 2. ***Alseodaphne***
7a. Outer sepals smaller than the inner ones ... . 6. ***Dehaasia***
b. Sepals equal to subequal 8
8a. Flowers with a deep, tubular receptacle, this enclosing the ovary and later the fruits .... 5. ***Cryptocarya***
b. Flowers with a shallow receptacle, the fruits unprotected on the pedicel .... 3. ***Beilschmiedia***

1. **Actinodaphne** Nees

Shrubs or trees; terminal buds usually perulate, leaving distinct scars on twigs. Leaves verticillate, often glaucous beneath, usually penninerved. Inflorescences axillary or between the leaves or cauliflorous, paniculate or umbellate (umbels sessile or pedunculate), with clusters of bract-scars at the very base. Flowers trimerous, unisexual; sepals 6, equal to subequal; stamens 9; anthers 4-locular; ovary ovoid, narrowed to style; stigma capitate. Fruits on a flat cupule.

About 100 species in tropical Asia with a few species in Southern China, ca 15 species in India, 2 species in Andaman and Nicobar Islands.

Key to the species

1a. Branchlets, petioles and leaves glabrous; lateral nerves of leaves 8–10 pairs; umbels shortly pedunculate .... 1. *A. angustifolia* var. *latior*
b. Branchlets, petioles and leaves beneath tomentellous; lateral nerves of leaves 10-15 pairs .... 2. *A. sesquipedalis*

1. *Actinodaphne angustifolia* (Blume) Nees var. *latior* Nees in Wall., Pl. Asiat. Rar. 3 : 34. 1831. *A. procera* sensu B.K. Sinha, Fl. Great Nicobar Isl. 364. 1999, non Nees, 1836. (Plate 3, Photo 1).

Tree, 12-30 m high; branchlets glabrous. Leaves narrowly elliptic to lanceolate-elliptic or occasionally ovate-lanceolate, 15-30 × 5-9 cm, acute or cuneate at base, acuminate at apex, coriaceous, glabrous, coppery or dark brown above, glaucescent beneath; lateral nerves slender, 8-10 per side; petioles 1.5-4 cm long, glabrous. Male: umbels along internodes or cauliflorous, ca 5 in fascicles; peduncles 7-10 mm long; sepals suborbicular, ca 3 × 3 mm, brown-puberulous outside; filaments ca 1.5 mm long; anthers ca 1 mm long. Female flowers: not seen. Infructescences as in male, each fascicle containing about 5 fruits; peduncles 5-7 mm long. Fruits depressed-subglobose, ca 1.2 × 2 cm, blackish-brown; cupule ca 3 × 10 mm.

Flowering & fruiting : Apr.–Sept. (fruits red when ripe).

Habitat : Scarce in inland hill forests on clayey loam up to 200 m altitude.

Distribution : India (Nicobar Is.), Myanmar, Malaysia.

Specimens examined : Great Nicobar Is. : 34 km on East–West Road, 22 July 1976, *Balakrishnan* 3939 (PBL); Laful forest, 3 June 1981, *Hore* 8712 (PBL); ibid., 19 May 1981, *Dwivedi* 8546 (PBL); Between Chingenh and Pygmalion Point, 29 June 1981, *Hore* 8854 (PBL).

Note : This variety is recorded here for India for the first time.

2. *Actinodaphne sesquipedalis* Hook.f. & Thomson ex Meisn. in DC., Prodr. 15(1): 216. 1864; Hook.f., Fl. Brit. India 5 : 151. 1886; S.P. Mathew & P.L. Narasimhan in *J. Bombay Nat. Hist. Soc.* 89: 272, ff. 1-9. 1992.

Tree, 8-10 m high; branchlets brown tomentose. Leaves elliptic, obovate, elliptic-oblanceolate to cuneate-oblanceolate, 22-40 × 9-21 cm, cuneate at base, rounded, acute or acuminate at apex, coriaceous, puberulous to glabrous above, brown tomentellous (mainly on nerves) beneath; brown above when dry, glaucescent beneath; lateral nerves 10-15 per side; petioles 2.5-4 cm long, brown tomentellous. Male: umbels axillary or in fascicles on internodes, each 4 – 5-flowered; sepals ovate-oblong, ca 3 x 2 mm;

filaments ca 1.5 mm long; anthers ca 1 mm long. Female flowers: not seen. Fruits not seen (reported to be globose, up to 3 cm in diam. with patelliform cupule).

Flowering : May.

Habitat : Rare in inland evergreen forests at low altitudes.

Distribution : India (Andaman Is.), Myanmar, Penang, Malaysia, Indonesia.

Specimen examined : South Andaman Islands : Shoal Bay, 16 May 1990, S.P. Mathew 20503 (PBL).

2. ***Alseodaphne*** Nees (including *Nothaphoebe* Blume)

Trees or shrubs; twigs often with conspicuous bright-coloured bark; terminal buds not perulate. Leaves alternate, sometimes clustered near the tips of the twigs, often glaucous beneath, penninerved. Inflorescences axillary, paniculate-cymose, repeatedly branched, ultimate flowers arranged in dichasia; lateral flowers of dichasia always opposite. Flowers: trimerous, bisexual; sepals 6, unequal, the outer 3 usually smaller than the inner ones, usually deciduous; stamens 9; anthers 4-locular; ovary ovoid; style slender; stigma peltate. Fruits with juicy mesocarp or woody, seated unprotected on the pedicels; pedicels somewhat swollen and brightly coloured.

About 90 species in tropical Asia; ca 20 species in India, 2 species in Andaman and Nicobar Islands.

Key to the species

1a. Leaves 5-14 cm broad, narrowly cordate at base .... 1. *A. panduriformis*

b. Leaves 3.5-6.5 cm broad, cuneate-attenuate at base .... 2. *A. umbelliflora*

1. ***Alseodaphne panduriformis*** Hook.f., Fl. Brit. India 5 : 145. 1886. *Nothaphoebe panduriformis* (Hook.f.) Gamble in *J. Asiat. Soc. Bengal* 101 : 75. 1912. *N. panduriformis* var. *paucinervia* Chakrab. & Vasudeva Rao in J. Econ. Taxon. Bot. 5 : 997. 1994; B.K. Sinha, Fl. Great Nicobar Islands 369. 1999. *Alseodaphne panduriformis* var. *paucinervia* (Chakrab. & Vasudeva Rao) Chakrab. in J. Econ. Taxon. Bot. 26 : 676. 2002.

Tree, 12-20 m high; branchlets glabrous. Leaves broadly cuneate-obovate to panduriform, 12-26 × 5-14 cm, narrowly cordate at base, caudate at apex, coriaceous, glabrous, blackish or brownish above when dry; lateral nerves 7-12 per side; petioles 3-10 mm long. Panicles 7-15 cm long; peduncles rusty-tomentellous. Flowers : pedicels ca 5 mm long; perianth ca 3 mm in diam., rusty-puberulous outside; outer sepals broadly ovate-deltoid or suborbicular, ca 1.2 mm long; inner ones wide elliptic-obovate to suborbicular, ca 2 mm long; filaments ca 0.2 mm long, pilose; anthers squarish, ca 0.5 mm across; ovary ca 1.5 mm long; style ca 0.3 mm long; stigma peltate. Fruits not seen (reported to be cylindric-oblong, ca 6 × 2.5 cm, black).

Flowering : July - Nov.

Habitat : Scarce in inland hill forests up to 100 m altitude.

Distribution : India (Great Nicobar Islands), Malaysia.

Specimens examined : Great Nicobar Islands : 18-19 km on East-West Road, 29 July 1976, *Balakrishnan* 4082 (PBL); 25 km on East-West Road, 17 Oct. 1979, *Hore* 7222 (CAL, PBL).

2. ***Alseodaphne umbelliflora*** (Blume) Hook.f., Fl. Brit. India 5 : 145. 1887. *Ocotea umbelliflora* Blume, Bijdr. 573. 1825. *Nothaphoebe umbelliflora* (Blume) Blume, Ann. Mus. Bot. Lugd. 1(21): 328. 1851; M.Gangop. in Bull. Bot. Surv. India 48 : 156. 2007. *N. nicobarica* Chakrab. & Vasudeva Rao in J. Econ. Taxon. Bot. 6 : 443. 1985. *Alseodaphne nicobarica* (Chakrab. and Vasudeva Rao) Chakrab. in *J. Econ. Taxon. Bot.* 26 : 676. 2002.

Tree, 30-40 m high; branchlets glabrous. Leaves broadly obovate to oblanceolate or occasionally obovate-elliptic, 8-17 × 3.5-6.5 cm, cuneate-attenuate at base, acuminate at apex, stiffly coriaceous, glabrous, bluish or blackish-brown above when dry; midrib raised above; lateral nerves 5-9 per side; petioles 0.5-2.5 cm long, glabrous. Panicles up to 10 cm long, pedunculate; branches ochraceous-puberulous. Flowers: pedicels 3-4 mm long; perianth ca 2 mm across, densely ochraceous-puberulous outside; outer sepals broadly deltoid-triangular to ovate, 0.5-1 mm long, inner ones broadly ovate to suborbicular, ca 1.7 × 1.3 mm; stamens sessile;

anthers squarish, ca 0.4 mm across; ovary ca 1 mm long; style ca 0.3 mm long; stigma peltate. Fruits not seen (reported to be oblong, ca 3 × 1 cm).

Flowering : February - March.

Habitat : Common in inland forests at sea level.

Distribution : India (Great Nicobar Islands.), Malaysia, Indonesia.

Specimens examined : Great Nicobar Islands : 40 km on East-West Road, 22 Feb. 1980, *Dwivedi* 7893 (CAL, PBL); ibid., 14 Feb. 1980, *Dwivedi* 7890 (PBL).

3. *Beilschmiedia* Nees

Trees or shrubs; terminal buds not perulate. Leaves alternate or subopposite, penninerved. Inflorescences axillary, lateral or subterminal, paniculate; lateral flowers of the ultimate cymes alternate. Flowers: small, trimerous, bisexual; sepals 6, equal, erect at anthesis, deciduous in older flowers; stamens 9; anthers 2-locular; ovary sessile, narrowed to style; stigma inconspicuous. Fruits seated unprotected on the pedicels; pedicels not or slightly thickened.

About 200 species, pantropical; ca 20 species in India, 1 species in Andaman and Nicobar Islands.

1. *Beilschmiedia roxburghiana* Nees in Wall., Pl. Asiat. Rar. 2: 61. 1831 & Syst. Laur. 198. 1836; Kurz, For. Fl. Brit. Burma 2 : 293. 1877; Hook.f., Fl. Brit. India 5: 121. 1886; Chakrab. and G.S. Lakra in *J. Econ. Taxon. Bot.* 26 : 719. 2002.

Tree, 20-25 m high; branchlets brown to dark brown, glabrous. Leaves elliptic, oblong-elliptic to ovate-oblong, 10-20 × 4-7 cm, acute at base and slightly decurrent into petioles, apiculate to acuminate at apex, thinly coriaceous, glabrous, greenish-brown when dry; midrib flat above; lateral nerves slender, 7-10 per side; petioles 1-2 cm long, glabrous. Panicles axillary, up to 9 cm long, puberulous. Flowers: pedicels ca 3 mm long; sepals oblong, ca 3 × 1 mm, puberulous outside; filaments ca 1 mm long; anthers oblong, ca 1 mm long; ovary ovoid, ca 1 mm long; style ca 0.5 mm long. Fruits cylindric-oblong, 4-4.5 × 1.8-2 cm, rounded at apex, slightly narrowed at base, blackish-brown; pedicels not thickened.

Flowering & fruiting : March – Oct.

Habitat : Scarce in inland forests at low altitudes.

Distribution : India (Himalayas, NE. India, Andaman Is.), Bhutan, Bangladesh, Myanmar.

Specimens examined : North Andaman Is. : Way to Patti Level, 26 Sept. 1995, *G.S.Lakra* 21229 (CAL, PBL). Middle Andaman Is. : Bomlungta, 17 Feb. 1916, *Parkinson* 1013 (CAL). South Andaman Is. : Port Mouat, n. d., *Kurz* s. n. (CAL, herb. acc. no. 351445).

4. *Cinnamomum* Schaeffer

Shrubs or trees. Leaves opposite and triplinerved or alternate and penninerved, rarely alternate and triplinerved; terminal perulate buds absent in species with triplinerved leaves and present in penninerved species. Inflorescences axillary and terminal, paniculate-cymose, repeatedly branched; ultimately flowers arranged in dichasia; lateral flowers of dichasia opposite. Flowers: trimerous, bisexual; sepals 6, equal, half erect at anthesis; stamens 9; anthers 4-locular; ovary sessile, at the bottom of the perianth tube; style short; stigma discoid or peltate. Fruits seated on a small cupule which with or without persistent tepals.

About 350 species, mostly in tropical and subtropical Asia, but also in Australia, Oceania and tropical America; ca 50 species in India, 2 species in Andaman and Nicobar Islands.

Key to the species

1a. Native tree; net-venation of leaves faint .... 1. *C. bejolghota*

b. Cultivated garden tree; net-venation of leaves very prominent beneath .... 2. *C. verum*

1. *Cinnamomum bejolghota* (Buch.-Ham.) Sweet, Hort. Brit. ed. 1, 344. 1826; B.K.Sinha, Fl. Great Nicobar Isl. 364. 1999. *Laurus bejolghota* Buch.-Ham. in Trans. Linn. Soc. London 13(2) : 559-560. 1822. *L. obtusifolia* Roxb. [Hort. Beng. 30. 1814, nom. nud.] Fl. Ind. 2 : 302. 1824. *Cinnamomum obtusifolium* (Roxb.) Nees in Wall., Pl. Asiat. Rar. 2 : 73. 1831; Kurz, For. Fl. Brit. Burma 2 : 287. 1877; Hook.f., Fl. Brit. India 5 : 128. 1886; C.E. Parkinson, For. Fl. Andaman Isl. 225. 1923.

Tree, 10-16 m high; branchlets glabrous. Leaves opposite, oblong, oblong-elliptic to oblong-lanceolate, 15-25 × 4-9 cm, obtuse, rounded or cuneate at base, obtuse, acute or acuminate at apex, stiffly coriaceous, glabrous, greenish above when dry, glaucescent beneath, triplinerved; midrib slightly impressed or raised above; lateral and tertiary nerves inconspicuous above; reticulations faint. Panicles axillary, up to 15 cm long, pedunculate, sparsely puberulous. Flowers: sepals ovate-oblong, ca 3 x 1.5 mm, puberulous outside; stamens ca 3.5 mm long; ovary oblong; style ca 3 mm long; stigma discoid. Fruits oblong to ellipsoid, 1–1.2 cm long; cupule yellow, ca 5 mm across.

Flowering & fruiting : March–June.

Local names : Burmese : *Thit kyabo, Nalingyaw*.

Habitat : Rare in inland forests, often along streams, at low altitudes.

Distribution : India (Himalayas, NE. India, Andaman Is.).

Elsewhere : Nepal, Bangladesh, Myanmar, Vietnam, China.

Specimen examined : Rutland : June 1919, *Parkinson* 2135 (CAL).

2. *Cinnamomum verum* J.S. Presl., Rostlin 2 : 36 & 37-44, f. 7. 1825. *Laurus cinnamomum* Roxb., Fl. Ind. 2 : 294. 1824. *Cinnamomum zeylanicum* Blume, Bijdr. 568. 1825; Hook.f., Fl. Brit. India 5 : 131. 1886; C.E. Parkinson, For. Fl. Andaman Isl. 225. 1923.

Tree, 5-10 m high; branchlets blackish, glabrous. Leaves opposite, ovate, oblong-elliptic or lanceolate-elliptic, 7-21 × 4-10 cm, acute, obtuse to rounded at base, slightly decurrent into petioles, acute, obtuse or acuminate at apex, coriaceous, glabrous, greenish or brown when dry, 3-plinerved; midrib raised above; lateral nerves faint; tertiary nerves prominent, at right angles to the midrib; reticulations prominent beneath; petioles 1-2 cm long, glabrous. Panicles terminal and axillary, up to 10 cm long; peduncles often puberulous. Flowers: sepals oblong, ca 4 × 2 mm, appressed fulvous-puberulous outside; stamens ca 3 mm long; ovary ovoid; stigma discoid. Fruits ovoid, 1 – 1.5 cm long; cupule dilated.

Flowering & fruiting : Sept. – March.

Habitat : Cultivated.

Distribution : Native of Sri Lanka; widely cultivated.

Specimens examined : South Andaman Is. : Without precise locality, *King* s. n. (CAL, herb. acc. nos. 383850–52); Haddo, 8 March 1915, *Parkinson* 403 (CAL). Car Nicobar Is. : Without precise locality, 25 Feb. 1894, *King's collector* s. n. (CAL); Head Quarter Agri-Garden, 23 Sept. 1976, *N.G. Nair 4486 (PBL)*.

5. *Cryptocarya* R.Br.

Trees; terminal buds not perulate. Leaves alternate, penninerved. Inflorescences axillary and terminal, paniculate, pedunculate. Flowers: trimerous, bisexual, sessile or shortly pedicellate; calyx connate at base into a tube; sepals 6, equal to subequal, half erect to spreading at anthesis; stamens 9; anthers 2-celled; ovary enclosed in the perianth tube; style simple. Fruits fully enclosed and adnate to the accrescent perianth tube with minute scar of fallen sepals at the tip.

About 300 species; pantropical but the majority in tropical Asia; 15 species in India, 5 species in Andaman and Nicobar Islands.

Key to the species

1a. Fruiting pedicels 5–15 mm long 2

b. Fruiting pedicels less than 5 mm long 3

2a. Fruits broadly ellipsoid, ca 2 x 1.5 cm, rounded at both ends .... 2. *C. balakrishnanii*

b. Fruits ovoid to ovoid-ellipsoid, 2.5–3 × 1.2–1.5 cm, acute at both ends .... 1. *C. andamanica*

3a. Fruiting pedicels and/or ultimate branchlets of infructescences subtending the fruits thickened (2–3 mm thick) .... 3. *C. ferrarsi*

b. Fruiting pedicels and/or ultimate branchlets of infructescences subtending the fruits not thickened (1–2 mm thick) 4

4a. Leaves rounded, obtuse or acute (or rarely apiculate) at apex .... 4. *C. insularis*

b. Leaves apiculate to acuminate at apex .... 5. *C. wightiana*

1. *Cryptocarya andamanica* Hook.f., Fl. Brit. India 5 : 118. 1886; C.E. Parkinson, For. Fl.

Andaman Isl. 227. 1923; M. Gangop. & Chakrab. in J. Econ. Taxon. Bot. 29 : 279. 2005.

Tree, 6–10 m high; branchlets rufous or rusty-tomentose to velutinous. Leaves oblong (or narrowly so), ovate-oblong to ovate-lanceolate, 10–20 × 3.5–8 cm, acute, obtuse to rounded at base, apiculate to caudate at apex, coriaceous, velutinous on midrib above, rusty or rufous-tomentellous beneath; brown to reddish-brown when dry; lateral nerves 10–15 per side, obscure above, raised beneath; reticulations prominent beneath; petioles 7–15 mm long, tomentose. Panicles 5–15 cm long, pedunculate. Flowers: ca 3.5 × 3 mm, tomentose outside; pedicels ca 1 mm long; perianth tube ca 1 mm long; sepals ovate to ovate-oblong, 1–1.5 × 0.8–1.2 mm; stamens 0.8–1.2 mm long; ovary ovoid-oblong, ca 1 mm long; style ca 1 mm long; stigma capitate. Fruits ovoid to ovoid-ellipsoid, 2.5–3 × 1.2–1.5 cm, acute at both ends, shining, black when dry; stalk (5-) 10–15 mm long, ca 2 mm thick.

Flowering & fruiting : Feb. - Apr.

Habitat : Rare in inland hill forests at about 100 m altitude.

Distribution : Endemic to Andaman Islands.

Specimens examined : Middle Andaman Is. : Bomlungta, 14 Apr. 1916, *Parkinson* 1912 (CAL). South Andaman Is. : Storegunj, 28 Feb. 1884, *King's collector* 143 (CAL); Mount Harriet, 22 Feb. 1884, *King's collector* 127 (CAL); ibid., 10 March 1916, *Parkinson* 1098 (CAL); Without precise locality, 1884, *King's collector* s. n. (CAL–6 sheets).

2. *Cryptocarya balakrishnanii* M.Gangop. & Chakrab. in J. Econ. Taxon. Bot., 26 : 722. 2002 & 29 : 280. 2005.

Tree; branchlets ochraceous or rusty-tomentose or velutinous, glabrescent in age. Leaves narrowly oblong to ovate-oblong or oblong-elliptic, 10–23 × 3–8 cm, acute or unequal at base, acuminate at apex, coriaceous, velutinous on midrib above, scattered pilose beneath, brown to reddish brown above when dry; lateral nerves 10–14 per side, sunken above, raised beneath; tertiary nerves obscure above, raised beneath; petioles 0.5–1.6 cm long, rufous or rusty-tomentellous. Panicles 5–20 cm long; pedunculate, tomentose. Flowers ca 3.5 × 2.5 mm, tomentellous outside; pedicels ca 0.5 mm long; perianth tube ca 1 × 2 mm; sepals wide ovate to ovate-oblong, ca 1.5 × 0.8 mm; stamens 1.2–1.5 mm; ovary ovoid, ca 0.5 mm long; style ca 1.5 mm long. Fruits broadly ellipsoid, ca 2 × 1.5 cm, rounded at both ends, glabrous, brown to black when dry; pedicels ca 10 × 2.5 mm, thickened at apex.

Flowering & fruiting : March – Apr.

Habitat : Rare in inland forests.

Distribution : Endemic to Andaman Islands.

Specimens examined : South Andaman Is. : Manglutan, 31 March 1894, *King's collector* s. n. (CAL, herb. acc. no. 382969); Port Mouat, 11 March 1893, *King's collector* s. n. (CAL – 2 sheets); ibid., 18 March 1893, *King's collector* s. n. (CAL–3 sheets).

Note : Similar to *C. andamanica* but distinct in the broadly ellipsoid, smaller fruits, rounded at both ends.

3. *Cryptocarya ferrarsi* King ex Hook.f., Fl. Brit. India 5 : 118. 1886 (as *ferrarsii*); C.E. Parkinson, For. Fl. Andaman Isl. 227. 1923; M.Gangop. & Chakrab. in J. Econ. Taxon. Bot. 26 : 477. 2002 & 29 : 283. 2005. *C. floribunda* Nees var. *angustifolia* Meisn. in DC., Prodr. 15(1) : 71. 1864.

Shrub or tree, up to 8 m high; branchlets rusty tomentose, glabrescent in age. Leaves lanceolate-oblong to narrowly oblong, 8–25 × 2.5–6.5 cm, acute or often rounded or unequal at base, apiculate to caudate-acuminate at apex, thinly coriaceous, rusty-tomentose to glabrous above, tomentellous on nerves to glabrous beneath, coppery or reddish brown above when dry; lateral nerves 9–15 per side, inconspicuous above, raised beneath; tertiary nerves obscure above, faint to prominent beneath; petioles 0.3–1 cm long, tomentose to pilose. Panicles 3.5–8 cm long, up to 15 cm long in fruiting, pedunculate, tomentose. Flowers : ca 3.5 × 2.5 mm, rusty-tomentellous outside; pedicels ca 1 mm long; perianth tube ca 1.5 × 1.5 mm; sepals wide ovate to ovate-oblong, ca 1.5 × 0.6 mm; stamens 1–1.7 mm long; ovary ovoid-oblong, ca 1 mm long; style ca 0.8 mm long; stigma simple. Fruits ovoid to narrowly ovoid-conoid, 1.2–1.5 × 0.6–0.7 cm, rounded at base, tapering at apex, glabrous, smooth, black when dry; pedicels 1–4 mm long, thickened.

Flowering & fruiting : March–Nov.

Habitat : Scarce in inland hill forests at low altitudes.

Distribution : India (North-East, Andaman Is.), Bangladesh, Myanmar.

Specimens examined : Baratang Is. : 20 Oct. 1884, *King's collector* 546 (CAL). South Andaman Is. : Mithakhari, 26 Aug. 1893, *King's collector* s. n. (CAL); Kalatang, 14 March 1976, *Balakrishnan & Bhargava* 3480 (PBL).

4. *Cryptocarya insularis* Vasudeva Rao & Chakrab. in J. Econ. Taxon. Bot. 6 : 446. 1985; M.Gangop. & Chakrab. in J. Econ. Taxon. Bot. 29 : 284. 2005.

Tree, ca 10 m high; branchlets densely greyish or tawny papillose-puberulous, glabrescent in age. Leaves oblong, ovate to ovate-oblong, 6.5–13 × 3–5.5 cm, acute, obtuse, rounded, truncate or unequal at base, rounded, obtuse to acute or rarely apiculate at apex, coriaceous, glabrous or appressed puberulous (on midrib) above and beneath, brown to dark brown above when dry, glaucescent beneath; lateral nerves 5–8 per side, faint above, prominent beneath; petioles 0.6–1.5 cm long. Panicles 5–12 cm long, pedunculate. Flowers : sessile, 3–4 × 2.5 3 mm, tomentellous; perianth tube 1.5–2 mm long; sepals broadly ovate to suborbicular, 1.5–2 × 1–1.5 mm; stamens 0.6–1.5 mm long; ovary ovoid, ca 1 mm long; style ca 1 mm long; stigma simple. Fruits sessile, ovoid, ca 2 × 1.1–1.5 cm, rounded at base, rounded, subacute to acute at apex, smooth, blackish-brown when dry.

Flowering & fruiting : Jan.–May.

Habitat : Rare in inland forests at low altitudes.

Distribution : Endemic to Andaman Islands.

Specimens examined : North Andaman Is. : Saddle Peak, 9 Aug. 1982, *Vasudeva Rao* 8932 (CAL, PBL). South Andaman Is. : Dhanikhari, 6 Feb. 1974, *N.G. Nair* 852 (CAL, PBL).

Note : Differs from *C. andamanica* and *C. balakrishnanii* in the glabrescent undersurface of the leaves and sessile flowers and fruits.

5. *Cryptocarya wightiana* Thwaites, Enum. Pl. Zeyl. 254. 1861; Hook.f., Fl. Brit. India 5 : 120. 1886; M.Gangop. & Chakrab. in J. Econ. Taxon. Bot. 26 : 475. 2002 & 29 : 291. 2005. *C. caesia* auct. non Blume, 1851 : Hook.f., l. c., 119. 1886; C.E. Parkinson, For. Fl. Andaman Isl. 227. 1923.

Tree, 6–30 m high; branchlets appressed tomentose to velutinous, glabrescent in age. Leaves narrow to broad, oblong, elliptic-oblong to ovate-oblong, 6–20 × 2–8 cm, acute, obtuse to rounded at base, apiculate to acuminate at apex, coriaceous, glabrous or puberulous on midrib above, puberulous on major nerves to glabrous beneath, green, brown to reddish brown above when dry, glaucous beneath; lateral nerves 5–12 per side; petioles 0.5–2 cm long, tomentellous, glabrescent in age. Panicles 3–15 cm long; peduncles 1–5 cm long; branches tomentose. Flowers : 3.5–4 × 2–3 mm, appressed tomentellous; pedicels ca 0.5 mm long; perianth tube 1–2 mm long; sepals ovate or obovate, 1.5–2 × 0.6–1 mm; filaments ca 2 mm long; anthers ca 1 mm long; ovary ovoid-oblong, ca 1 mm long; style 0.5–0.8 mm long; stigma capitate. Fruits subglobose, 1–1.7 cm in diam., black when dry; pedicels 1–4 mm long.

Flowering & fruiting : Feb. – Dec.

Habitat : Scarce in evergreen hill forests at low altitudes.

Distribution : India (South India, Andaman Is.), Sri Lanka, Myanmar.

Specimens examined : Long Is. : 20 Feb. 1916, *Parkinson* 1023 (CAL). South Andaman Is. : Without precise locality, 1885, *King's collector* s. n. (CAL–2 sheets); North Bay, 20 Jan. 1894, *King's collector* s. n. (CAL); Namunaghar, March 1884, *King's collector* 172 (CAL).

6. *Dehaasia* Blume

Shrubs or trees; twigs usually whitish; terminal buds not perulate. Leaves alternate, crowded near tips of branches, often glaucous beneath, penninerved. Inflorescences axillary, paniculate-cymose, repeatedly branched; ultimately flowers arranged in dichasia; lateral flowers of dichasia opposite. Flowers : trimerous, bisexual, distinctly stalked; sepals 6, unequal, the outer 3 usually smaller than the inner 3; deciduous or persistent; stamens 9; anthers 2-locular; ovary sessile; style short or long; stigma simple. Fruits with thin mesocarp, seated unprotected on pedicels, often with small persistent sepals at base; pedicels often thickened and coloured.

About 35 species in tropical Asia; ca 7 species in India, 3 species in Andaman and Nicobar Islands.

Note: Very close to *Alseodaphne*, differing in the 2-locular stamens.

Key to the species

1a. Leaves 6–10 × 2–3.5 cm; fruiting pedicels up to 1 cm long, scarcely thickened .... 2. *D. firma*

b. Leaves 10–35 × 4–12 cm; fruiting pedicels 1–4 cm long, much thickened 2

2a. Leaves dark brown, reddish-brown or blackish-brown above when dry, glaucescent beneath; midrib sunken above; reticulations conspicuous .... 1. *D. candolleana*

b. Leaves usually remaining green when dry, not glaucescent beneath; midrib flat or slightly raised above; reticulations inconspicuous .... 3. *D. incrassata*

1. *Dehaasia candolleana* (Meisn.) Kosterm. in Bot. Jahrb. Syst. 93 : 431. 1973; Kochummen in Whitmore, Tree Fl. Malaya 4 : 138. 1989. *Dictyodaphne candolleana* Meisn. in DC. Prodr. 15(1) : 80. 1864. ?*Alseodaphne grandis* sensu Kurz, For. Fl. Brit. Burma 2 : 293. 1877; non Nees, 1831. *Dehaasia kurzii* King ex Hook.f., Fl. Brit. India 5 : 125. 1886, p. p., tantum quoad 'Andaman Islands'; C.E. Parkinson, For. Fl. Andaman Isl. 228. 1923; ?*D. elongata* sensu Hook.f., l. c. 126. 1886, non Blume, 1836, sens. lat.

Tree, 5–10 m high; branchlets glabrous. Leaves cuneate-obovate, orbicular-obovate, obovate-elliptic, cuneate-oblanceolate to subpanduriform, 10–27 × 4–12 cm, cuneate at base and slightly decurrent into petioles, rounded or apiculate at apex, coriaceous, glabrous, reddish-brown, black-brown or dark brown when dry, often glaucescent beneath; midrib sunken above; lateral nerves 7–12 per side; reticulations conspicuous; petioles 1–4 cm long, glabrous. Panicles 6–15 cm long, pedunculate, glabrous. Flowers : pedicels ca 3 mm long; outer sepals deltoid to suborbicular, ca 1 × 1.2 mm, glabrous; inner sepals ca 2.5 × 2 mm; stamens ca 3 mm long; ovary ca 2 mm long. Fruits subglobose to globose (1.5–2.5 cm in diam.) or cylindric-oblong (ca 3.5 × 2.5 cm) with rounded apex or ellipsoid (2–3.5 × 1.5–2.5 cm); pedicels fleshy, red, 1.5–4 cm long, 5–7 mm thick at apex, 2–3 mm thick at base; often thickened upwards only and then 1–1.5 cm long with thickened upper portion 4–5 × 2–5 mm.

Flowering & fruiting : Feb.–Dec.

Habitat : Scarce in inland forests, often along streams, up to 200 m altitude.

Distribution : India (Andaman Is.), Myanmar, Thailand, Malaysia.

Specimens examined : North Andaman Is. : Durgapur, 26 Nov. 1976, *N.G. Nair* 4923 (CAL, PBL); Lamia Bay, Kalipur, 1 Apr. 1977, *Balakrishnan* 5429 (PBL). South Andaman Is. : Without precise locality, 1884, *King's collector* s. n. (CAL – 4 sheets); ibid., *King's collector* 108 (CAL); East coast of Port Blair, 14 March 1891, *King* s. n. (CAL); Balughat, 16 July 1892, *King's collector* s. n. (CAL); Port Mouat, 28 Feb. 1891, *King* s. n. (CAL); Anikhet, 11 Aug. 1894, *King's collector* s. n. (CAL). Mount Harriet, 1884, *King's collector* 68 (CAL).

Note : The species exhibits variation in the size and shape of the fruits and in the length and thickness of the fruiting pedicels. It is possible that more than one species or at least varieties are involved. Further gatherings and critical studies on the materials of the adjacent areas are necessary to clarify the situation.

2. *Dehaasia firma* Blume, Ann. Mus. Bot. Lugd. 1(21) : 333. 1851; S.P. Mathew & P.L. Narasimhan in Indian J. For. 16 : 79, ff. 1–2. 1993.

Tree, 10–15 m high; branchlets pubescent when young, soon glabrous. Leaves elliptic, oblong to oblong-lanceolate, 6–10 × 2–3.5 cm, cuneate at base, acuminate at apex, coriaceous, glabrous, greyish above when dry, coppery-brown beneath; midrib flat above; lateral nerves 5–9 per side, faint; nervules faint; petioles 0.5–1.3 cm long, glabrous. Panicles up to 6 cm long (in fruiting), pedunculate, glabrous. Flowers (immature ones seen) : ca 2 mm in diam., pedicellate; the outer sepals smaller than the inner. Fruits ellipsoid, ca 2.4 × 1.4 cm, narrowed at both ends, pointed at tip, green; pedicels 0.8–1 cm long, ca 2 mm in diam., scarcely thickened.

Flowering & fruiting : March–May.

Habitat : Rare in inland forests at low altitudes.

Distribution : India (Andaman Is.), Malaysia, Indonesia (Borneo).

Specimen examined : South Andaman Is. : Shoal Bay, 16 May 1990, *S.P. Mathew* 20498 (PBL).

3. ***Dehaasia incrassata*** (Jack) Kosterm. in J. Sci. Res. Indones. 1 : 120. 1952 (June) & in Reinwardtia 4 : 228, 246. 1957; Merr. in J. Arn. Arb. 33 : 220. 1952 (July); M.Gangop. in Bull. Bot. Surv. India 48 : 152. 2007. *Laurus incrassata* Jack in Mal. Misc. 2(7) : 33. 1822. *Dehaasia candolleana* sensu B.K. Sinha, Fl. Great Nicobar Isl. 365. 1999, excl. descr., non (Meisn.) Kosterm., 1973.

Tree, 5–20 m high; branchlets glabrous. Leaves elliptic, oblong-elliptic (or narrowly so) to obovate, 14–35 × 4–11 cm, acute or cuneate at base and slightly decurrent into petioles, acuminate at apex, thinly coriaceous, glabrous, green or often pale brown when dry; midrib flat or slightly raised above; lateral nerves slender, 7–14 per side, faint above, prominent beneath; tertiary nerves faint above, conspicuous beneath, scalariform; reticulations inconspicuous; petioles 0.8–2 cm long, glabrous. Panicles 3–10 cm long, slender, pedunculate, glabrous. Flowers : pedicels 2.5–4 mm long; outer sepals deltoid to suborbicular, ca 1 × 1 mm; inner sepals wide ovate to suborbicular, 2–3 × 1.8–2.5 mm, glabrous; stamens ca 3.5 mm long; ovary compressed; style short. Fruits not seen (reported to be oblong, 3–5 cm long; pedicels 2.5–3 cm long, thickened, red).

Flowering : Feb.–Oct.

Habitat : Common in edges of forests or inland forests at low altitudes.

Distribution : India (Nicobar Is.), Thailand, Malaysia, Indonesia, Philippines, New Guinea.

Specimens examined : Katchal Is. : West Bay, Delhi village, 14 June 1977, *P.Chakraborty* 6038 (CAL, PBL); Way to Jula, 13 Aug. 1974, *P.Chakraborty* 2068 (CAL, PBL). Great Nicobar Is. : 40 km on East-West Road, 24 Sept. 1980, *Hore* 8201 (CAL, PBL); 27 km on North-South Road, 7 March 1980, *Dwivedi* 7916 (CAL, PBL); Laful forest, 10 May 1981, *Dwivedi* 8530 (CAL, PBL).

7. ***Lindera*** Thunb.

Shrubs or trees; terminal buds perulate or not. Leaves alternate, often crowded towards ends of branches, often glaucous beneath, penninerved or 3-nerved. Inflorescences axillary or along a short shoot, umbellate, arising singly or few together in fascicles, sessile or shortly peduncled, each umbel usually 5-flowered. Involucral bracts usually 4, decussate, deciduous. Flowers : trimerous, unisexual; sepals 6, mostly equal. Male flowers : stamens 9; anthers 2-locular; pistillode absent. Female flowers : ovary superior; styles short, thick; stigma peltate. Fruits sessile or pedicellate, usually seated on a small cupule.

About 100 species, mostly in tropical and subtropical Asia with a few species in temperate N. America; 12 species in India, 1 species in Andaman and Nicobar Islands.

1. ***Lindera andamanica*** Chakrab., G.S. Lakra & P.G. Diwakar, sp. nov., *L. nacusae* (D. Don) Merr. affinis sed differt plantis omnino glabris, foliis oblong-lanceolatis vel elliptico-lanceolatis, petiolis longioribus, umbellis masculis singulis ad axillares. HOLOTYPUS : *N.P. Balakrishnan* 5393 A (CAL) et ISOTYPUS : *N.P. Balakrishnan* 5393 B (PBL). (Fig. 1).

Allied to *Lindera nacusua* (D.Don) Merr. but differs in plants being completely glabrous, leaves oblong-lanceolate or elliptic-lanceolate, petioles longer, male umbels single at axils.

Tree, 3–5 m high; branchlets brownish, slightly flattened and striate towards apices, terete towards base, glabrous. Leaves oblong-lanceolate to elliptic-lanceolate, 7–10 × 2–2.5 cm, cuneate at base, slightly decurrent into petioles at the extreme base, acute to acuminate (acumen ca 5 mm long, acute) at apex, thinly coriaceous, glabrous, brown above when dry, chocolate-brown beneath, penninerved; midrib slightly raised above, raised beneath; lateral nerves slender, 8–10 per side, faint above, more or less prominent beneath, brochidodromous; tertiary nerves obscure above, faint beneath, reticulate. Male umbels axillary, solitary, epedunculate, each 5-flowered; involucral bracts orbicular, ca 4 mm across, glabrous. Flowers : pedicels ca 2.5 × 0.8 mm, glabrous; sepals 6, obovate, oblong-elliptic to ovate, ca 2 × 1.2–1.8 mm, glabrous; stamens 9, those of the third row with biglandular filaments; filaments 2–2.5 mm

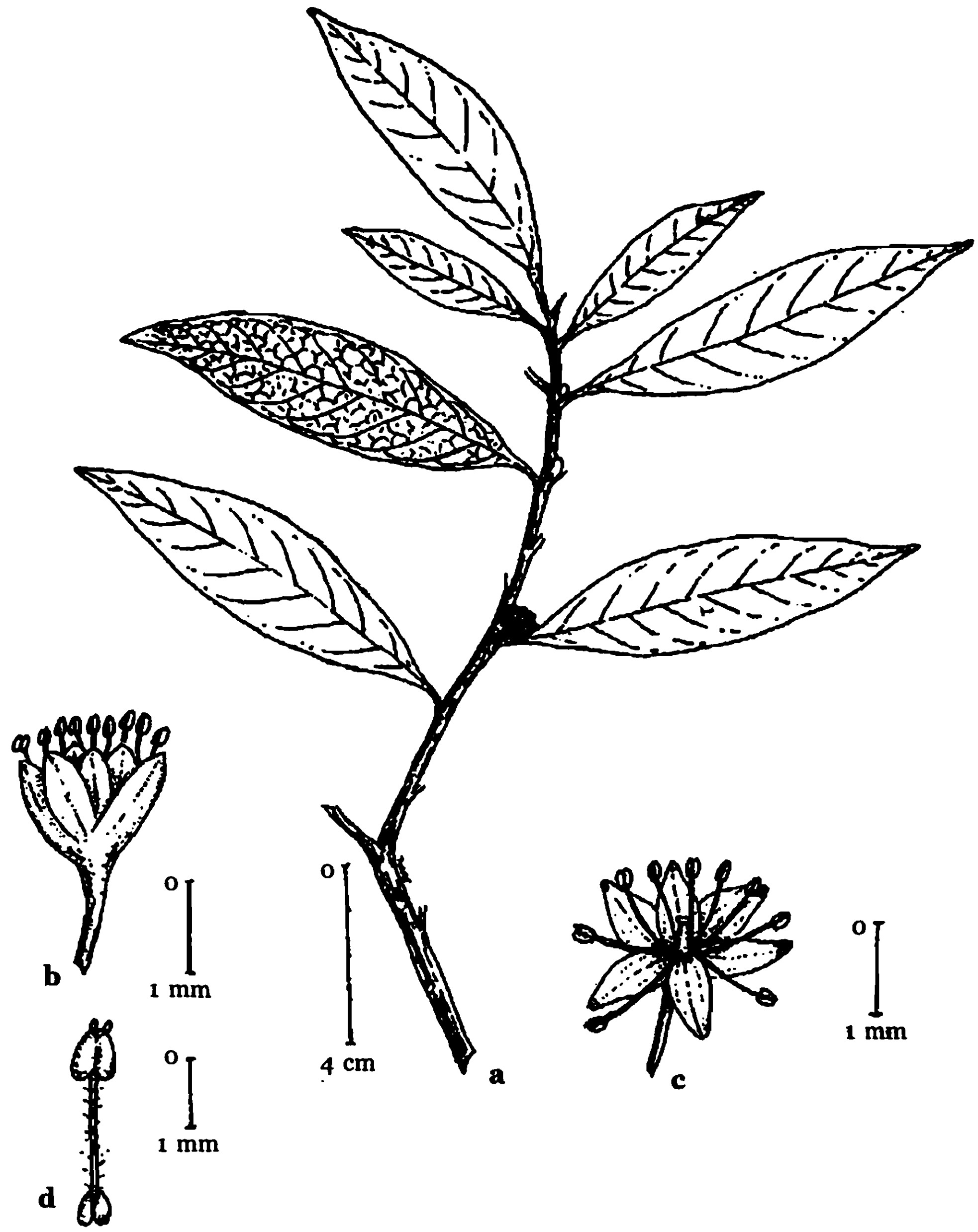

Fig 1. *Lindera andamanica* Chakrab., G.S. Lakra & P.G. Diwakar : a. habit; b. male flower (side view); c. male flower (top view); d. stamen.

long, pilose; anthers oblong, ca 1 mm long, 2-locular. Female flowers and fruits not seen.

Flowering : March–Apr.

Habitat : Scattered in inland forests on rocky loam at about 500 m altitude.

Distribution : Endemic to Andaman Islands.

Specimens examined : North Andaman Is. : Saddle Peak, 31 March 1977, *N.P. Balakrishnan* 5393 A (CAL – Holotype); ibid., *N.P. Balakrishnan* 5393 B (PBL – Isotype).

8. *Litsea* Lam.

Trees or shrubs; terminal buds perulate or not. Leaves alternate or rarely opposite, petiolate, sometimes glaucous beneath, penninerved. Inflorescences axillary or along short shoots (racemes), umbellate, usually pedunculate. Flowers : unisexual, trimerous, usually 4–6 in an umbel; each umbel surrounded by 4–6 decussate involucral bracts; sepals 6, equal, often lacking. Male flowers : stamens usually 9; anthers 4-locular; pistillode present or absent. Female flowers : pedicels usually enlarged in fruit; ovary globose or ovoid; style usually thick; stigma peltate. Fruits smooth or rugose when dry, with a small or large cupule.

More than 300 species, mostly in tropical Asia, also present in Oceania, Australia and N. and C.

America; about 50 species in India, 4 species in Andaman and Nicobar Islands.

Key to the species

1a. Inflorescences with both primary and secondary peduncles .... 2. *L. glutinosa*

b. Inflorescences with primary peduncles only 2

2a. Branchlets and leaves (at least on the undersurface) tomentose .... 3. *L. kurzii*

b. Branchlets and leaves glabrous 3

3a. Peduncles arising singly in leaf axils; fruits oblate, 0.5–0.7 × 0.8–1.2 cm, shallowly bilobed, depressed .... 5. *L. panamonja*

b. Peduncles arising singly on short racemes of if axillary, then in fascicles; fruits otherwise (unknown in *L. leiantha*) 4

4a. Leaves glaucescent beneath; lateral nerves faint or sunken above; male peduncles arising singly on short racemes .... 1. *L. costata*

b. Leaves not glaucescent beneath; lateral nerves prominent above; male peduncles arising in fascicles in axils of leaves or slightly above the axils .... 4. *L. leiantha*

1. ***Litsea costata*** (Blume) Boerl., Handl. Fl. Ned. Ind. 3 : 144. 1900; Kochummen in Whitmore, Tree Fl. Malaya 4 : 154. 1989. *Cylicodaphne costata* Blume, Mus. Bot. Lugd. 2 : 13. 1852. *Litsea pustulata* Gamble in Bull. Misc. Inf. Kew. 1910 : 359. 1910; A.K. Roy in J. Econ. Taxon. Bot. 7 : 443. 1985; B.K. Sinha, Fl. Great Nicobar Isl. 366. 1999.

Tree, 4–10 m high; branchlets brownish, smooth, glabrous. Leaves elliptic, oblong-elliptic to obovate, 17–30 × 6–11 cm, acute, rounded or cuneate at base, obtuse, rounded or shortly acuminate at apex, coriaceous, glabrous, glaucescent beneath; midrib flat or slightly sunken above, raised beneath; lateral nerves 7–14 per side, faint or sunken above, prominent beneath; tertiary nerves obscure above, faint beneath; nervules somewhat prominent beneath; petioles 1–3 cm long. Umbels not seen (reported to be on ca 1 cm long racemes with up to 1 cm long peduncle). Fruits globose, 1–1.5 cm in diam., black when dry; cupule ca 1 cm across, entire; pedicels 0.8–1.2 cm long, thick.

Fruiting : June (fruits red when ripe).

Habitat : Rare in shaded places of inland forests at low altitudes.

Distribution : India (Nicobars), Malaysia.

Specimen examined : Great Nicobar Is. : 25 km on East-West Road, Near Galathea river, 15 June 1977, *Balakrishnan* 5783 (PBL).

2. ***Litsea glutinosa*** (Lour.) C.B. Robinson in Philipp. J. Sci. (Bot.) 6 : 326. 1911; Vasudeva Rao in J. Econ. Taxon. Bot. 8 : 141. 1986; B.K. Sinha, Fl. Great Nicobar Isl. 366. 1999. *Sebifera glutinosa* Lour., Fl. Cochinch. 2 : 638. 1790. *Tomex sebifera* Willd., Sp. Pl. 2 : 840. 1805. *Litsea sebifera* (Willd.) Pers., Syn. Pl. 2 : 4. 1806; Hook.f., Fl. Brit. India 5 : 157. 1886; Vasudeva Rao, l. c. 141. 1986. *L. chinensis* Lam., Encycl. Meth. Bot. 3 : 574. 1789; C.E. Parkinson, For. Fl. Andaman Isl. 226. 1923.

Tree, 5–12 m high; branchlets brown-puberulous when young, soon glabrous. Leaves elliptic, oblong (or broadly so) to obovate, 14–27 × 5–13 cm, acute to obtuse at base, apiculate to acuminate at apex, coriaceous, glabrous above, glabrous or sparsely puberulous on midrib beneath; green to brown above when dry; midrib flat or slightly incised above; lateral nerves 7–10 per side; tertiary nerves percurrent to scalariform; petioles 1.5–3.5 cm long, sparsely puberulous to glabrous. Male umbels axillary or ramiflorous, each 5–10-flowered; primary peduncles arising singly, 1–3 cm long, puberulous; secondary peduncles 2–5 (umbelliform or corymbiform), 5–10 mm long; involucral bracts suborbicular, 4–6 mm across. Flowers : pedicels 2–3 mm long; sepals ovate-triangular, ca 2 × 1 mm; filaments ca 3 mm long; anthers oblong, ca 1.2 mm long. Female flowers : not seen. Infructescences as in male; primary peduncles 2–3 cm long; secondary peduncles ca 3, 7–10 mm long, each with about 3 fruits. Fruits globose, 1–1.2 cm in diam., glabrous, black, shining; cupule 2–3 mm across; pedicels 4–6 mm long, slightly thickened.

Flowering & fruiting : Jan.–Oct.

Habitat : Common in coastal forests, scrub jungles or inland forests on sandy or clayey loam at low altitudes.

Distribution : India to Malesia.

Specimens examined : South Andaman Is. : Near Port Blair, 24 Apr. 1884, *King's collector* 359 (CAL); Garacharma, 29 Aug. 1884, *King's collector* 472 (CAL); Humfray's Ghat, n. d., *Kurz* s. n. (CAL, herb. acc. no. 386412); Dhanikhari, 14 July 1973, *Balakrishnan* 316 (PBL). Car Nicobar Is. : Aukchung, 5 June 1975, *N.G. Nair* 2697 (CAL, PBL); Chuckchucka, 8 June 1974, *N.G. Nair* 1559 (PBL). Katchal Is. : Towards Kapanga, 22 Apr. 1974, *P. Chakraborty* 1149 (CAL, PBL). Great Nicobar Is. : 38 km on North–South Road, 4 March 1980, *Dwivedi* 7909 (CAL, PBL). Alexandra river bank, 9 Feb. 1980, *Dwivedi* 7843 (CAL, PBL); Chingenh, 27 June 1981, *Hore* 8852 (CAL, PBL).

Note : The specimen, *Parkinson* 553 from Long Island, identified as *L. chinensis*, agrees well with the other materials of the species except for the narrow oblong-elliptic leaves.

3. ***Litsea kurzii*** King ex Hook.f., Fl. Brit. India 5 : 164. 1886; C.E. Parkinson, For. Fl. Andaman Isl. 126. 1923; B.K. Sinha, Fl. Great Nicobar Isl. 367. 1999. (Plate 4, Photo 2).

Tree, 4–15 m high; branchlets rufous-tomentose. Leaves oblong, oblong-elliptic, obovate-oblong to obovate-elliptic, 12–25 × 5–10 cm, acute, obtuse to rounded at base, subacute, apiculate or acuminate at apex, thinly coriaceous, tawny-tomentose or rufous-puberulous on major nerves above and beneath, brown to blackish-brown above when dry, often glaucescent beneath; midrib sunken above, raised beneath; lateral nerves 8–15 per side, impressed above, raised beneath; tertiary nerves inconspicuous above, raised beneath, percurrent; petioles 0.7–2 cm long, rufous-tomentose. Male umbels axillary or ramiflorous, each ca 5-flowered; peduncles up to 5 in fascicles, on short pulvini, 7–10 mm long, puberulous; involucral bracts suborbicular, ca 5 mm across, puberulous to glabrous. Flowers : subsessile; sepals ovate, ca 2 × 1.5 mm, puberulous on both surfaces; filaments ca 2 mm long; anthers oblong, ca 1 mm long. Female umbels as in male; peduncles 5–8 mm long; Flowers : pedicels ca 2 mm long; sepals ovate, ca 2 × 1 mm; style ca 3 mm long. Fruits ovoid-globose, 7–8 × 5–6 mm, puberulous, brown when dry; cupule ca 4 mm across, flat, puberulous; pedicels 3–5 mm long.

Flowering & fruiting : Nov. – June.

Local name : Burmese : *Tamasok*.

Habitat : Common in inland forests or moist evergreen forests up to 200 m altitude.

Distribution : Endemic to Andaman and Nicobar Islands.

Specimens examined : Middle Andaman Is. : Way towards Parnashala, 7 Nov. 1977, *Bhargava* 6427 (CAL, PBL). Havelock Is. : 24 Feb. 1916, *Parkinson* 1040 (CAL). South Andaman Is. : Without exact locality, 1884, *King's collector* s. n. (CAL – 3 sheets, excluding herb. acc. no. 386845); Near Carbyn's Cove, n. d., *Kurz* s. n. (CAL–5 sheets); Mount Harriet, 28 Apr. 1884, *King's collector* 241 (CAL); ibid., 15 Feb. 1975, *Bhargava & N.G. Nair* 2244 (CAL, PBL); Sipigat, 25 March 1974, *Ansari* 1013 (CAL, PBL); Kalatang, 15 June 1974, *Thothathri* 1493 (CAL, PBL). Little Andaman Is. : 2 km from Hut Bay, 17 Feb. 1981, *Premanath* 8484 (CAL, PBL). Katchal Is. : Behind Marine Store, 29 Apr. 1974, *P. Chakraborty* 1214 (CAL, PBL); Forest behind Beechdera and Delhi village, 4 Apr. 1979, *Vasudeva Rao* 7519 (CAL, PBL). Great Nicobar Is. : Casuarina Bay, 2 Apr. 1966, *Thothathri* 11560 (PBL).

Note : A material, *King's collector* s. n. (CAL, herb. acc. no. 386845) contains detached flowers and fruits in a packet. The fruits are ovoid-globose, ca 2 cm long, ca 1.5 cm in diameter, glabrous and verruculose. In case these larger fruits belong to the specimen mounted on the sheet, the material warrants recognition as a distinct species or at least a variety of *L. kurzii*. Further gatherings are required to clarify the situation.

4. ***Litsea leiantha*** (Kurz) Hook.f., Fl. Brit. India 5 : 170. 1886; C.E. Parkinson, For. Fl. Andaman Isl. 226. 1923; Vasudeva Rao in J. Econ. Taxon. Bot. 18 : 141. 1986. *Tetranthera leiantha* Kurz, For. Fl. Brit. Burma 2 : 300. 1877.

Tree, 10–15 m high, entirely glabrous; branchlets brownish to black, terete. Leaves elliptic, wide oblong-elliptic, obovate-oblong to obovate, 10–21 × 6–10 cm, acute, obtuse to rounded at base, obtuse to rounded at apex, coriaceous, brown or black above when dry; midrib flat above, raised beneath; lateral nerves 6–10 per side, more or less prominent above, raised beneath; tertiary nerves inconspicuous above, faint beneath, percurrent; petioles 2.5–3.5 (-5) cm long. Male umbels axillary or supra-axillary, each 5-flowered; peduncles up to 7 in fascicles, 1–1.5 cm long, slender, on small pulvini; involucral bracts suborbicular, ca 5 mm across. Flowers (only immature ones seen) : sessile; sepals linear-oblong, scarious; filaments pilose; anthers oblong. Female flowers and fruits not seen.

Flowering : Jan.–Feb.

Habitat : Rare in inland hill forests.

Distribution : Endemic to Andaman Islands.

Specimen examined : South Andaman Is. : Mount Harriet, 2 Feb. 1875, *Kurz* s. n. (CAL, herb. acc. no. 387604).

5. ***Litsea panamonja*** (Nees) Hook.f., Fl. Brit. India 5 : 175. 1886; C.E. Parkinson, For. Fl. Andaman Isl. 126. 1923; Vasudeva Rao in J. Econ. Taxon. Bot. 8 : 141. 1986. *Tetranthera panamonja* Nees in Wall., Pl. Asiat. Rar. 2 : 67. 1831 & Syst. Laur. 561, 677. 1836; Kurz, For. Fl. Brit. Burma 2 : 302. 1877 (Plate 4, Photo 3).

Tree, 5–10 m high; branchlets brown, terete, glabrous. Leaves ovate to elliptic, 10–20 × 5–11 cm, acute, obtuse to rounded at base, apiculate to acuminate at apex, coriaceous, glabrous above, glabrous or sparsely puberulous on midrib beneath; green to brown above when dry; midrib flat above; lateral nerves 7–10 per side; tertiary nerves percurrent to scalariform; petioles 1.5–4 cm long, glabrous. Flowers : not seen. Infructescences axillary, solitary; peduncles 1–3 cm long, each with about three fruits. Fruits oblate, 0.5–0.7 × 0.8–1.2 cm, shallowly bilobed, depressed; pedicels 1–1.5 cm long; cupule 2–3 mm across.

Flowering & fruiting : March–May.

Habitat : Scarce along streams at low altitudes.

Distribution : India (Himalayas, NE. India, Andaman Is.) to SE. Asia.

Specimens examined : Tenasserim and Andamans, *Helfer* EIC 4279 (CAL); Middle Andaman Is. : Bomlungta, 20 May 1916, *Parkinson* 1220 (CAL).

9. ***Neolitsea*** (Benth.) Merr.

Shrubs or trees, dioecious; terminal buds perulate. Leaves usually clustered towards apices of branchlets, usually areolate-reticulate, 3-plinerved, often glaucous and pellucid-dotted beneath. Inflorescences axillary, also in the axils of fallen leaves, umbellate; umbels arising singly or several in fascicles, epedunculate, each (3-)5 (-7)-flowered; involucral bracts 4, decussate. Flowers : dimerous, unisexual; sepals 4, equal, spreading at anthesis. Male flowers : stamens 6; anthers 4-locular. Female flowers : ovary usually ovoid; style distinct; stigma peltate. Fruits seated on a small, discoid cupule.

About 100 species in tropical Asia, extending to Australia; 8 species in India, 1 species in Andaman and Nicobar Islands.

1. ***Neolitsea cassia*** (L.) Kosterm. in J. Sci. Res. Indones. 1 : 85. 1952. *Laurus cassia* L., Sp. Pl. 369. 1753. *Litsea zeylanica* Nees, Amoen. Bot. Bonn. 1 : 58, t. 5. 1823; Hook.f., Fl. Brit. India 5 : 178.1886, p. p. *Neolitsea zeylanica* (Nees) Merr. in Philipp. J. Sci., Bot. Suppl. 1(1) : 57. 1906. *N. balakrishnanii* Chakrab. & A.K. Goel in J. Econ. Taxon. Bot. 6 : 449. 1985, syn. nov. *N. nicobarica* A.K. Goel & Chakrab. in J. Econ. Taxon. Bot. 6 : 450. 1985, syn. nov.

Shrub or tree, 2–10 m high, almost entirely glabrous. Leaves elliptic, oblong-elliptic to lanceolate, 4–16 × 1.5–6 cm. acute at base and decurrent into petioles, apiculate or caudate-acuminate at apex, coriaceous, greenish-brown to dark brown above when dry; midrib slightly raised above; lateral nerves 3–5 pairs above the basal; tertiary nerves conspicuous; areolations prominent; petioles 0.5–2 cm long; involucral bracts orbicular, 4–6 mm across, golden brown puberulous outside. Male umbels arising singly or in pairs, each 5-flowered; pedicels up to 1.5 mm long; sepals oblong or ovate, 2–2.5 × 1–1.5 mm, pilose outside; filaments 0.5–1.5 mm long, pilose; anthers squarish, ca 0.8 mm long. Female umbels as in male; pedicels 2.5–3 mm long, pilose; sepals ovate-triangular, ca 2 × 1 mm; ovary ca 1 mm long; style ca 1 mm long. Fruits globose, 0.7–1.2 cm in diam., reddish-brown or black when dry; pedicels 3.5–10 mm long; cupule 6–7 mm across, entire.

Flowering & fruiting : March – Oct.

Habitat : Common in inland hill forests or scrub vegetation or red rocky loam up to 700 m altitude.

Distribution : Sri Lanka and India.

Specimens examined : North Andaman Is. : Saddle Peak, 1 Dec. 1976, *Balakrishnan & N.G.*

Nair 4710 (PBL); ibid., 31 March 1977, *Balakrishnan* 5379 (CAL, PBL). Narcondam Is. : 3 Oct. 1904, *C.G.Rogers* 30 (CAL). Kamorta Is. : Feb. 1875, *Kurz* s. n. (CAL, herb. acc. nos. 387993/95). Nicobars : Exped. Novara, *Jelinek* 137 (CAL); Without precise locality, 4 Apr. 1884, *King's collector* 491 (CAL).

DOUBTFUL/EXCLUDED TAXA

1. ***Actinodaphne macroptera*** Miq., Fl. Ind. Bat. 1(1) : 970. 1855; Vasudeva Rao in J. Econ. Taxon. Bot. 8 : 141. 1986.

Note : No material seen during the course of the present work.

2. ***Actinodaphne procera*** Nees, Syst. Laur. 605. 1836; Vasudeva Rao in J. Econ. Taxon. Bot. 8 : 141. 1986.

Note : Recorded for the Andaman and Nicobar Islands but no specimen is available in CAL and PBL.

3. ***Dehaasia cuneata*** (Blume) Blume in Rumphia 1(8) : 164. 1836; Hook.f., Fl. Brit. India 5 : 125. 1886; Vasudeva Rao in J. Econ. Taxon. Bot. 8 : 141. 1986. *Cryptocarya cuneata* Blume, Bijdr. 558. 1826.

Note : The specimens identified as *D. cuneata* are all referable to *D. candolleana*.

4. ***Litsea amara*** Blume, Bijdr. 563. 1826; Hook.f., Fl. Brit. India 5 : 163. 1886; Vasudeva Rao in J. Econ. Taxon. Bot. 8 : 141. 1986. *Tetranthera amara* (Blume) Kurz, For. Fl. Brit. Burma 2 : 299. 1877.

Note : Recorded by Kurz (l. c.). However, no specimen could be examined.

5. ***Litsea monopetala*** (Roxb.) Pers., Syn. Pl. 2 : 4. 1807; Vasudeva Rao in J. Econ. Taxon. Bot. 8 : 141. 1986; B.K. Sinha, Fl. Great Nicobar Isl. 367. 1999. *Tetranthera monopetala* Roxb., Pl. Corom. 2 : 26, t. 148. 1798; Kurz, For. Fl. Brit. Burma 2 : 299. 1877. *Litsea polyantha* A. Juss. in Ann. Mus. Bot. Lugd. Bat. 6 : 211. 1805; Hook.f., Fl. Brit. India 5 : 162. 1886.

Specimen examined : Tenasserim and Andamans, *Helfer* EIC 4289 (CAL).

Note : No material seen except for the above cited specimen and its place of collection is doubtful.

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Plate 3

Photo 1. A herbarium specimen of *Actinodaphne angustifolia* (Blume) Nees var. *latior* Nees

Plate 4

Photo 2. *Litsea kurzii* King ex Hook. f.

Photo 3. *Litsea panamonja* (Nees) Hook.f.

Chapter 15

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 195-205, 2010

GLOBAL IMPORTANCE OF MEDICINAL PLANTS WITH RELEVANCE TO BAY ISLANDS

M.U. SHARIEF*
Botanical Survey of India, National Orchidarium and Experimental Garden, Yercaud–636 602, Salem, Tamil Nadu

INTRODUCTION

Plants provide man food, fuel, materials for clothing and shelter for ages and they have also been the source of many life saving drugs including herbal medicines (Hussain, 1983). Of late, medicinal plants have claimed an unique place due to their therapeutic values of prevention and cure of several diseases. Unfortunately, our knowledge of the medicinal plants in our environment is far from complete. Medicinal plants are a sovereign and irreparable resource, which is exhaustible if over used and sustainable if used with care and wisdom. From the last two decades, the branch of medicinal plants has gained immense importance though these plants have the longest history of healing and health since 2000 - 3000 B.C (Kirtikar and Basu, 1935). World is endowed with a rich wealth of medicinal plants. Herbs have always been the principal form of medicine in India and they are becoming popular throughout the world (Prajapathi *et al.*, 2003). Presently, there exists a global interest and revival of plant based herbal materials, not as medicines but also for various herbal health products for the present day conscious people. This resurgence is due to the increasing realization that plant based materials are relatively cheaper and safer than synthetic modern medicines which are costly and having side effects.

Medicinal plants are found in forest areas throughout South Asia with the greatest concentration in the tropical and subtropical belts (Ross, 1999). India recognizes more than 2,500 medicinal plant species, Sri Lanka about 1,400 and Nepal around 700. The global market for medicinal plants and herbal medicines is estimated to be worth US $ 800 billions a year (Rajashekharan and Ganeshan, 2002). International export trade in medicinal plants had been dominated by China, which exports 1,21,900 tones per year and India exports 32,600 tones per year. Unfortunately, this valuable plant resource is under serious threat due to various reasons. As per one estimate, in India, about 29 important medicinal plants are on the verge of extinction and many more are earmarked as endangered medicinal plants. The importance of medicinal plants has been overlooked in the past. However, at present medicinal plants are looked upon not only as a source of affordable health care but also as a source of income.

Indian traditions, beliefs, customs and philosophies, all have great reverence for nature and India is bestowed with unique diversity in culture and natural vegetation exhibiting rich plant diversity. India harbours 17,500 flowering plants, out of these 2500 plants are used in various classical systems of medicine (Parrotta, 2001; Yoganarasimhan, 1996). The tribals and other

*E-mail : shariefbsi@yahoo.co.in

communities use about 800 species of wild plants as traditional medicine. Owing to this, India is considered as the botanical garden of the world and treasure trove of medicinal plant diversity. Thus the potential of this branch of botany cannot be under estimated.

MATERIALS AND METHODS

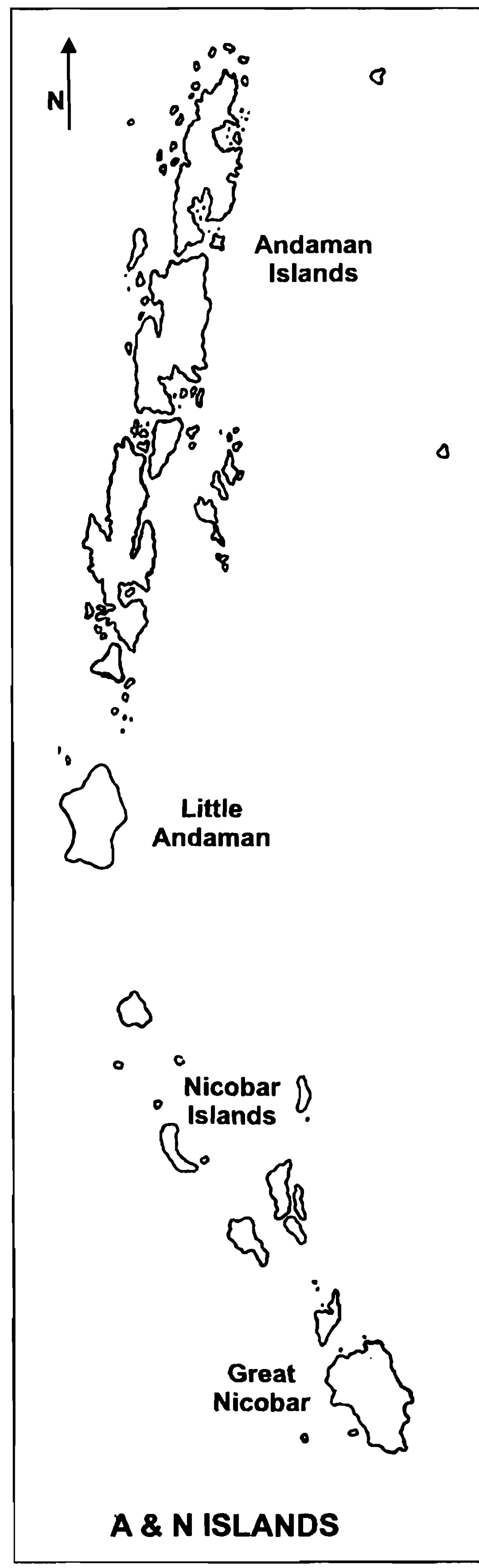
Medicinal plants for the present study were collected from different Islands of Andaman and Nicobar Archipelago. Plant collections were made both at flowering and fruiting stages at various seasons. Propagules like rhizomes, bulbs fruits and seeds were collected for the *ex-situ* studies. The field notes for collected plants were prepared at the spot covering the information related to habit, habitat, association with other plants and ethno-botanical aspects what ever available. Medicinal plants collected in wild were taxonomically identified using regional floras (Hajra *et al.*, 1999; Hajra and Rao, 1999; Parkinson, 1923; Gamble and Fisher, 1959) and confirmed with the PBL herbarium of Botanical Survey of India, Andaman and Nicobar Circle, Port Blair. The specimens were deposited in the PBL, Port Blair.

For *ex situ* studies, the seedlings, rhizomes, bulbs and seeds which are collected from field were planted in the 3 X 3 feet pits raised in the medicinal plants plot of Dhanikhari Botanic Garden, Port Blair. Each pit was initially filled with 1 basket full of organic manure before introducing the plant propagules. They were regularly watered twice a day during morning and evening hours. The germination and growth of the plants was regularly monitored and data relating to growth pattern, flowering, fruiting were recorded.

RESULTS

Medicinal Plant Wealth of Bay Islands

Bay Islands popularly known as 'Green Emeralds' in Bay of Bengal stretches from Myanmar in the north to Sumatra in South in the form of an arched necklace. These Islands are located between 6°-14° N latitudes and 92°-94° E longitudes covering an area of 8249 km^2 and stretches to a length of 912 km. The maximum width of these Islands is about 57 km. Totally, there are 349 Islands divided into two groups of 325 Islands of Andaman group and 24 Islands of Nicobar group (Map. 1). Biodiversity profile of the Bay Islands shows 2500 flowering plants and 5500 animal species, which is a unique composition mainly due to tropical humid climate and insular nature of the territory. Representing 700 genera belonging to 140 families, about 14 per cent of the angiosperm species are endemic to the Islands (Balakrishnan and Rao 1983). It is also interesting



to note that the flora of Andaman group of Islands shows striking dissimilarities with the flora of Nicobar Islands. The floristic analysis also indicates that 14 per cent of angiosperm species are endemic to the Islands, about 54 per cent also occur in mainland (Dagar and Singh, 1999). The remaining 32 per cent extend to the south East Asian countries and Malaysia, but are not recorded in mainland India.

Andaman and Nicobar Island annually receives rainfall of 300 to 380 cm and the relative humidity builds up to 85 per cent. Generally temperature varies from 23° 33° C. With these parameters, the Bay Islands bear warm humid tropical climatic conditions permitting luxuriant and greatly diverse vegetation. This vegetation is also a treasure trove of potentially important medicinal plants. The most fascinating feature of this hotspot floral bounty is the high degree of endemism and mixed type of taxa associated with last aboriginals which belongs to six tribes *viz.* Great Andamanese, Onges, Jarawas, Sentinelese, Shompens and Nicobarese. From ages, these aboriginal tribes are depending on the wild medicinal plants existing in the forests for curing their ailments. According to one report, about 72 species belonging to 63 genera and 39 families are used by the aborigines as the source of tribal medicine (Anonymous, 2002). Botanical Survey of India has documented more than 250 medicinal plants of the Bay Islands in the recent surveys. Further, it has been noticed that many of the plants which are in application in the folklore medicine are less known to the scientific community also. Author has made an attempt to document such potential plants which are native to the Bay Islands as well as plants well established in different groups of Islands. Some of these plants are alphabetically enlisted and enumerated herewith giving the botanical name, family, local or Hindi name, brief description of the plant, the medicinal use, time of flowering and fruiting and the ecology. Abbreviations used are 'H' for Hindi, 'N' for Nicobarese, 'O' for Onges, 'S' for Shompens and 'J' for Jarawas.

ENUMERATION

1. ***Abrus precatorius*** L. (Fabaceae) 'Gunchi' (H), 'Pon-Yamoh' (N)

A climber with paripinnate compound leaves. Flowers white, pink. Fruits oblong , seeds bright red with black dot. Very frequent among hedges and bushes. (Plate 5, Fig. 1).

Uses : Seed paste applied locally in sciatica, stiffness of shoulder joint and paralysis. Leaves useful in leucoderma, itching and other skin diseases.

Fl. and Fr. : September November.

Place of Collection : Rutland island.

2. ***Alstonia kurzii*** Hook.f. (Apocynaceae) 'Chattiyan'(H) 'Taung-meok' (S)

Large trees with whorled leaves. Inflorescence terminal cymes. Flowers white, fruit a follicle. Common in littoral forests and endemic. (Plate 5, Fig. 2).

Uses : Leaves, bark and roots boiled and vapours inhaled to cure fever. Plant used in epilepsy and filaria.

Fl. and Fr. : February April.

Place of Collection : Little Andaman.

3. ***Aphanamixis polystachya*** (Wall.) Parker (Meliaceae) 'Kinya' (N)

Trees, leaves 60-75 cm long. Female inflorescence as long as leaves. Fruit obovoid, seeds ellipsoid, brown. Rare along streams (Plate 5, Fig. 3).

Uses : Leaves used for cuts, wounds and ulcers.

Fl. and Fr. : March-April.

Place of Collection : Dogmar river.

4. ***Ardisia solanacea*** Roxb. (Myrsinaceae) 'Khadiphal', 'Minkuon' (N)

Shrubs of small trees with dark brown bark. Leaves glossy and succulent. Flower buds pink in colour. Common in littoral forests. (Plate 5, Fig. 4).

Uses : Bark paste used in snake bite. Root decoction used in treatment of women after delivery. Nicobarese use the leaves for curing mumps.

Fl. and Fr. : June-February

Place of Collection : Kichadnala of Rutland

5. ***Baccaurea ramiflora*** Lour. (Euphorbiaceae) 'Kataphal' (H)

An evergreen tree. Bark brownish grey. Leaves elliptic. Fruits yellow berries in bunches arising from the bark. Common in inland forests. (Plate 5, Fig. 5).

Uses : Fruits used for making wine. Bark used in constipation. Fruits eaten by Jarawas.

Fl. and Fr. : December June,

Place of Collection : Anarkali of Rutland island.

6. ***Calophyllum inophyllum*** L. (Clusiaceae) 'Poon' (H)

Large littoral trees. Leaves dark green shining. Flowers white. Drupes globose. Common along the sea shores.

Uses : Bark applied to swollen glands. Leaves used in bone fracture. Resin as tonic for ulcers. Seed oil used in rheumatism.

Fl. and Fr. : May October,

Place of Collection : Havelock Island.

7. ***Canarium euphyllum*** Kurz (Burseraceae) 'Dhup' (H)

A large deciduous tree with small buttresses. Leaves 1 m long. Flowers in axillary panicles. Rare in inland forests.

Uses : Resin used as mosquito repellent and antiseptic.

Fl. and Fr. : November February,

Place of Collection : Campbell Bay.

8. ***Carissa spinarum*** L. (Apocynaceae) 'Karunda' (H).

An evergreen shrub with sharp spines. Leaves ovate to ovate-rotund. Flowers white, fragrant in corymbiform cymes. Berries dark purple. Not common along the coast of South Andamans (Plate 5, Fig. 6).

Uses : Fruits edible. Roots posses purgative properties. Roots remedy for animal sores.

Fl. and Fr. : May July,

Place of Collection : Kichadnala of Rutland.

9. ***Cassia alata*** L. (Caesalpiniaceae) 'Thinbaw' (N)

Shrubs. Leaves subsessile with no glands. Flowers large, yellow. Pods linear-oblong. Naturalised in A and N Islands. (Plate 5, Fig. 7).

Uses : Leaves used in skin diseases. Leaf paste also used externally for swellings and body pain.

Fl. and Fr. : August - February,

Place of Collection : Nayashar, Port Blair.

10. ***Cassytha filiformis*** L. (Lauraceae)

Filiform leafless twining parasitic herb. Flowers small. Fruits white, globose, smooth. Common throughout the Islands especially near sea shores (Plate 5, Fig. 8).

Uses : An ayurvedic drug is obtained which is used in rheumatism, blood disesses and urinary disorders.

Fl. and Fr. : Through out the year.

Place of Collection. : Manjery, Navy Dera.

11. ***Cerbera odallam*** Gaertn. (Apocynaceae)

Moderate sized tree with grey bark. Leaves glossy. Inflorescence terminal. Flowers white with yellow throat. Rare in coastal forests of A and N Islands (Plate 5, Fig. 9).

Uses : Seed oil used as hair oil. Also used in cold, rheumatism and Scabies.

Fl. and Fr. : January – December,

Place of Collection : Wandoor, Laful.

12. ***Claoxylon indicum*** Hassk. (Euphorbiaceae) 'Sing-ke-ra' (N)

Shrubs. Leaves broadly ovate, elliptic. Capsules sub-globose. Frequent in beach forests of A and N Islands (Plate 5, Fig. 10).

Uses : Leaves used in cuts, wounds, headache and pyorrhea. Leaves mashed in coconut oil are applied on sores and pimples.

Fl. and Fr. : January September,

Place of Collection : Middle Strait, Laful.

13. ***Croton argyratus*** Bl. (Euphorbiaceae) 'Mintunah'(S)

Small trees. Leaves elliptic, petioles 12 cm. Flowers white. Capsules subglobose. Common along edges of forests of A and N Islands.

Uses : Seeds used as laxative and stomach disorders.

Fl. and Fr. : January - December,

Place of Collection : Chidiyatapu, Shastrinagar.

14. ***Curcuma zeodaria*** (Christin) Rosc. (Zingiberaceae) 'Jangli Haldi'(H)

Rhizomatous attractive herb with yellow flowers. Found in marshy places of south and north Andaman and Great Nicobar island. (Plate 5, Fig. 11).

Uses : Rhizome is tonic. Promotes circulation. Used in Cholera, heart complaints, irregular menstruation and snake bite. Decoction used in cold.

Fl. and Fr. : July November,

Place of Collection : Kichadnala of Rutland island.

15. ***Donax cannaeformis*** (Forst.) K. Schum. (Marantaceae) 'Kalapatthi' (H) 'Kagle'(O)

Herbs or undershrubs. Stem dark green. Flowers white. Rare in inland forests of A and N Islands.

Uses : Leaves used in eye disorders. Stem decoction taken to cure internal hemorrhage. Root decoction antidote to snake bite and used in fever.

Fl. and Fr. : July – November,

Place of Collection : Mayabunder.

16. ***Entada rheedei*** Spreng. (Mimosaceae) 'Gila' (H)

A gigantic climber with twisted stem. Leaves pinnate. Flowers pale yellow. Pods woody, very long. Seeds copper coloured. Common in inland forests of A and N Islands. (Plate 5, Fig. 12).

Uses : Pounded stem and roots used to treat dysentery. Decoction taken to treat rigid abdomen. Ashes of pods applied to abdomen for internal complaints.

Fl. and Fr. : August March,

Place of Collection : Dhanikhari.

17. ***Eryngium foetidum*** L. (Apiaceae) 'Dhaniapatti' (H)

Perennial aromatic herb with fleshy leaves. Glabrous. Fruits densely papillose. Cultivated commonly in kitchen gardens.

Uses : Plant used as a substitute for coriander. Plant extract used as hair tonic and also as febrifuge. Root is a remedy for stomachache.

Fl. and Fr. : November Feb.

Place of Collection : Nayashar.

18. ***Fagraea racemosa*** Jack. ex Wall. (Loganiaceae) 'Inveh'(N)

A moderate sized tree. Flowers funnel shaped, white tinged beneath with orange. Common in all groups of Islands. (Plate 5, Fig. 13).

Uses : Pounded roots used as poultice. Leaf decoction a tonic after fever. Heated leaves applied to abdomen to treat malaria. Bark and flowers antidote for snakebite. Fruits used in rheumatism.

Fl. and Fr. : Feb. June.

Place of Collection : Pandera of Rutland

19. ***Grewia calophylla*** Kurz (Tiliaceae) 'Khataphal', 'Mariyam'(H)

Moderate sized tree. Leaves elliptic or ovate. Flowers cream coloured with pungent smell. Drupes orange yellow when ripe. (Plate 5, Fig. 14).

Uses : Leaves help in digestion and fruits used as cooling drink.

Fl. and Fr. : May Feb.

Place of Collection : Dhanikhari, Navy Dera.

20. ***Gloriosa superba*** L. (Liliaceae) 'Kalihari' (H)

A tuberous climber. Flowers solitary, orange, yellow or red. Common in all groups of Islands. (Plate 6, Fig. 15).

Uses : Tubers used as anthelmintic, in skin diseases, snake bite and scorpion bite. Seeds used in rheumatic pains and act as muscle relaxant.

Fl. and Fr. : September December,

Place of Collection : Chidyatapu.

21. ***Hibiscus tiliaceus*** L. (Malvaceae) 'Chelwa' (H), 'Touku' (N)

Small trees (15m high). Leaves unlobed, stipules ovate to oblong. Flowers yellow with dark purple center. Capsules globose with short beak. Common in littoral forests.

Uses : Leaves used in urinary troubles. Leaf juice given 3 times a day for urine block and to check blood flow with urine.

Fl. and Fr. : January December,

Place of Collection : Wandoor, Campbell Bay.

22. ***Hornstedtia fenzlii*** (Kurz) K. Schum. (Zingiberaceae) 'Narkafur'(H), 'Hami' (N)

Robust, perennial rhizomatous shrub. Leaves broadly lanceolate. Spikes many flowered arise laterally from rhizome near base of spurious stem. Endemic to Nicobar Islands. (Plate 6, Fig. 16).

Uses : Stem and leaves used as powerful bee-repellent. Rhizome used for fever and stomach disorder.

Fl. and Fr. : November July,

Place of Collection : East west road.

23. ***Jatropha gossipifolia*** L. (Euphorbiaceae) 'Jamalgotta' (H)

Large shrubs. Leaves alternate, palmately lobed. Flowers in loose panicles or cymes, dark red. Fruits capsules. Common in all Islands. (Plate 6, Fig. 17).

Uses : Stem twigs used for curing toothache. Seeds purgative.

Fl. and Fr. : July March.

Place of Collection : Chidyatapu

24. ***Knema andamanica*** (Warb.) de. Wilde (Myristicaceae) 'Jungli Jaiphal' (H)

Tree with dark coloured bark. Leaves lanceolate, dark green above, glaucous beneath. Flowers small, pinkish inside. Fruits ellipsoid, covered with brown tomentum. Seeds blood red in colour. Rare in dense mixed forests of A and N Islands.

Uses : Tree a source of ayurvedic drug 'Jatiphalam' used in indigestion and diarrhoea. Seeds are stimulant.

Fl. and Fr. : November June,

Place of Collection : Badakhadi of Rutland.

25. ***Leea indica*** (Burm.f.) Merr. (Leeaceae) 'Chayapatti' (H)

Erect herb. Leaves 50 cm. long, leaflets opposite, oblong, elliptic. Flowers many in corymbose cymes. Berries ripens greenish brown or bluish black. Common in beach forests.

Uses : Leaves used as antiseptic for cuts and wounds. Roots used in diarrhoea, colic, dysentery. Root bark is astringent. Leaf poultice applied in skin complaints.

Fl. and Fr. : January December,

Place of Collection : Baratang, Campbell Bay

26. ***Macaranga nicobarica*** Balak. and Chakrab. (Euphorbiaceae) 'Panah' (N)

Trees about 15m high. Leaves peltate, rounded at base, 100 × 70 cm., palminerved. Inflorescences spicate - paniculate. Capsules transverse, didymous. Rare in lowland forests and endemic to Nicobar. (Plate 6, Fig. 18).

Uses : Leaf decoction used in stomach troubles.

Fl. and Fr. : July October.

Place of Collection : Navy Dera, Laful.

27. ***Mallotus peltatus*** Muell.-Arg. (Euphorbiaceae) 'Kisoh' (S)

Shrubs or small trees. Leaves peltate. Inflorescence racemose. Capsules tricoccous, depressed. Common in littoral forests.

Uses : Leaf decoction used in stomach disorders.

Fl. and Fr. : January - December,

Place of Collection : Chidyatapu, Navy Dera.

28. ***Melastoma malabathricum*** L. (Melastomataceae) 'Tinrok' (N)

Shrub covered with hairy bristles of scales. Leaves strongly 3-nerved. Cymes terminal or subterminal. Flowers rose or purplish coloured. Common in inland forests.

Uses : Plant is astringent and used in diarrhoea and dysentery. Bark and roots used in skin troubles. Leaves used in joint pains.

Fl. and Fr. : January December,

Place of Collection : Carbyn's Cow, east west road.

29. ***Morinda citrifolia*** L. (Rubiaceae) 'Nibase' (N)

Small tree with white bark. Leaves broadly elliptic or ovate. Flowers small, head globose, corolla white. Fruits fleshy, white. Common in mixed inland forests. (Plate 6, Fig. 19).

Uses : Leaf paste used as antiseptic for cuts and wounds. Leaf juice used to cure stomach troubles.

Fl. and Fr. : April July.

Place of Collection : Shoalbay, Indira point.

30. ***Myristica andamanica*** Hook.f. (Myristicaceae) 'Jangli Jaiphal' (H)

Slender handsome tree. Bark blackish green. Leaves oblong to elliptic- lanceolate, coppery beneath. Flowers few in leaf axils. Fruits ovoid, brown. Seeds blood red. Not common in evergreen forests, endemic to Andaman Islands. (Plate 6, Fig. 20).

Uses : Leaves and twigs used in sickness and to stop bleeding.

Fl. and Fr. : July Feb.

Place of Collection : Badakhadi of Rutland.

31. ***Ophiorrhiza nicobarica*** Balakr. (Rubiaceae) 'Sarpakshi' (S)

Herbs. Leaves ovate, lanceolate. Inflorescence cymose, dichotomous, hirsute. Flowers white. Fruits laterally compressed, brownish red. Rare in stream sides. Endemic to Great Nicobar Island.

Uses : Fresh leaf paste antiseptic for cuts and wounds.

Fl. and Fr. : September – November,

Place of Collection : Campbell Bay, E-west Road

32. ***Oroxylum indicum*** (L.) Vent. (Bignoniaceae) 'Hathpanjar' (H)

Tree with thick grey bark. Flowers purple or yellow. Capsules long, sword shaped with numerous white winged seeds. Frequent in Andaman group of Islands. (Plate 6, Fig. 21).

Uses : Bark is tonic, diaphoretic and astringent. Used in diarrhea, dysentery and rheumatism. Bark juice used in Malarial fever. Seeds are purgative used to treat stomach troubles.

Fl. and Fr. : January – May.

Place of Collection : Mt. Harriet.

33. ***Paramignya andamanica*** (King ex Hook. f.) Tanaka (Rutaceae)

Scandent shrubs with greenish stem armed with curved axillary spines. Leaves unifoliate. Flowers white. Berries globular or obscurely two lobed. (Plate 6, Fig. 22).

It is endemic to Bay Islands.

Uses : Aromatic leaves used in cough and bronchitis. Roots used as diuretic.

Fl. and Fr. : September December.

Place of Collection : Wandoor, Lakshman Beach.

34. ***Pometia pinnata*** Forst. (Sapindaceae) 'Chitrgandu' (H)

Moderate sized evergreen trees. Bark reddish brown. Leaves paripinnate. Flowers small, yellow in large panicles. Fruits oblong, purple when when ripe. A common tree found in most groups of Islands in low moist places. (Plate 6, Fig. 23).

Uses : Decoction of the bark or leaves used to bathe patients with fever.

Bark paste used in sores or wounds.

Fl. and Fr. : December–May,

Place of Collection : Badakhadi, Laful.

35. ***Pongamia pinnata*** (L.) Pierre (Fabaceae) 'Karanj' (H), 'Tangkua' (N)

Moderate sized deciduous tree. Leaves dark green with pink-violet flowers. Pods woody. Very common along the sea shores of all groups of Islands.

Uses : Bark used in intermittent fever. Twigs used as toothbrush. Ayurvedic drug 'Karanj' used in worms and skin diseases.

Fl. and Fr. : February April.

Place of Collection : Brother island, Campbell Bay

36. ***Salacia chinensis*** L. (Hippocrateaceae) 'Saptarangi' (H), 'Lana-cho' (N)

Shrub with angular branchlets. Leaves opposite, broadly elliptic. Lateral nerves 3-10 pairs. Flowers pale green. Flowers globose ripen orange red. Common in beach forests.

Uses : Source of Ayurvedic drug 'Saptarangi' used in diabetes. Roots used as astringent. Decoction is given in amenorrhoea and veneral diseases. Leaf paste applied on abdomen for relieving labour pain in ladies.

Fl. and Fr. : June May.

Place of Collection : Wandoor, Lakshman beach.

37. ***Saraca asoca*** (Roxb.) de Wilde. (Caesalpiniaceae) 'Sitaashok' (H)

A small evergreen tree with orange coloured flowers changing red. It is the most sacred tree of Hindus and Buddhists. It is found as an introduced in the Islands. (Plate 6, Fig. 24).

Uses : Bark used in biliousness, dysentery, colic, piles and ulcers. Leaves posses blood purifying properties. Dried flowers used in diabetes and considered as uterine tonic.

Fl. and Fr. : April December.

Place of Collection : Little Andaman, Nayashar.

38. ***Scaevola sericea*** Vahl (Goodeniaceae) 'Tuful' (N)

A littoral shrub or small tree with light green fleshy leaves. Flowers and fruits white. Plant common along all the seashores. More frequent in Nicobar groups of Islands. (Plate 6, Fig. 25).

Uses : Leaf paste applied to leg fractures. Leaf juice an effective remedy for respiratory problems. Plant also used to cure cough and headache. Leaf paste in coconut oil used in rheumatism and lumbago.

Fl. and Fr. : January December,

Place of Collection : Wandoor, Campbell Bay.

39. ***Sophora tomentosa*** L. (Fabaceae) 'Pantangkul' (N)

Small tree. Branchlets greyish tomentose. Leaflets subcoriaceous. Racemes terminal. Flowers yellowish. Corolla bright yellow. Pods finely tomentose, separated by many narrow joints like a necklace. (Plate 6, Fig. 26).

Uses : Plant used in stomach disorders. Decoction of roots, stem and seeds used in cholera.

Fl. and Fr. : November - May.

Place of Collection : Wandoor, Chengappa Bay.

40. ***Sterculia rubiginosa*** Vent. (Sterculiaceae) 'Fuk' (N)

Trees about 18 m high. Leaves oblong, glabrous above, pubescent below. Panicles many flowered. Flowers reddish brown. Fruits follicle, woody. Seeds black. It is frequent along the coasts of all groups of Islands (Plate 6, Fig. 27).

Uses : Leaves used for fever, asthma and also in cough. Pounded leaves mixed with pig blood are applied on the body during fever.

Fl. and Fr. : November-March.

Place of Collection : Wandoor, East-west road.

41. ***Syzygium samarangense*** (Bl.) Merr. (Myrtaceae) 'Jungli Jamun' (H), 'Mileul' (N)

Medium sized trees. Bark dark brown. Leaves ovate. Flowers white, 2 to 3 in short axillary or terminal racemes. Fruits depressed (Plate 6, Fig. 28).

Rare in littoral forests.

Uses : Leaf juice along with coconut oil used in rheumatic pains and lumbago.

Fl. and Fr. : February August.

Place of Collection : Mt. Harriet, Kopenheat.

42. ***Thottea tomentosa*** (Bl.) Ding. (Aristolochiaceae) 'Jungli Panpatti' (H)

Under shrubs. Stem bearing 1-5 normal leaves at apex. Leaves coriaceous, Glabrous above, tomentose beneath. Perianth yellow with purple. Capsules dark purple, quadrangular. Common in the inland forests of Bay Islands under the shady places (Plate 6, Fig. 29).

Uses : Plant used for cough, as a diuretic and also used in skin diseases. It is also useful remedy for snake bites and stings.

Fl. and Fr. : November – February,

Place of Collection : Chidyatapu, Chengappa Bay.

43. ***Urena lobata*** L. (Malvaceae)
'Kasinrih' (N)

Annual undershrubs. Leaves variably lobed. Flowers pink, funnel shaped. Fruit a mericarp. Plant is common in all groups of Islands in open places.

Uses : Roots are diuretic and used to treat rheumatism. Twigs are chewed for toothache. Leaf juice used to treat gonorrhoea. Root infusion given to treat abdominal pains, fever, colic, stomachache and malaria.

Fl. and Fr. : August December.

Place of Collection : Shoal Bay, Lakshman Beach.

44. ***Wedelia biflora*** (L.) DC. (Asteraceae)
'Kotan' (N)

Spreading perennial herb. Common in all groups of Islands on moist waste lands.

Uses : Plant juice applied to sores, wounds and cuts. Leaves used for headache and as antiseptic for cuts and wounds.

Fl. and Fr. : September December.

Place of Collection : Dhanikhari.

45. ***Xylocarpus moluccensis*** (Lam.) Roem.
(Meliaceae) 'Puzzle Fruit Tree'

Small tree with pungent bark. Leaflets elliptic-ovate, subacute at apex, broad at base. Flowers white. Capsules large, globose, green. Seeds brown. Common in interior forests and mangrove swamps (Plate 6, Fig. 30).

Uses : Root is astringent and used to treat cholera. Bark used as febrifuge and also in dysentery, diarrhoea and other abdominal troubles. Fruit is a cure for elephantiasis. Seed paste applied on mumps, boils, swollen breast and toothache.

Fl. and Fr. : November March,

Place of Collection : Rutland island, East west Road.

46. ***Zingiber zerumbet*** (L.) Rosc.
(Zingiberaceae) 'Narkachur' (H)

Stem about 2m tall. Leaves sessile, lanceolate, narrowed at base. Spikes ovoid, oblong or globose. Flowers cream coloured. Capsules oblong, seeds ellipsoid, black.

Uses : Rhizomes employed against cough, stomach ache, asthma and Vermifuge.

Fl. and Fr. : March October

Place of Collection : Mayabunder, Indira Point.

Ex Situ conservation involves collection of desired plants and their storage in such a way as to maintain their genetic integrity and regeneration. Propagules of medicinal plants like rhizomes, bulbs, fruits and seeds collected from the field were used to propagate them in Dhanikhari Botanic Garden. The rare and endemic medicinal plant species are acclimatized in pots as well as in some nursery beds (Plate 6, Fig. 31) and multiplied. Some of the medicinal plants of Bay Islands successfully conserved in the garden include *Ardisia solanacea, Baccaurea ramiflora, Cerbera odallam, Curcuma zeodaria, Eryngium foetidum, Fagraea racemosa, Hornstedtia fenzlii, Horsfeldia glabra, Knema andamanica, Melastoma malabathricum, Myristica andmanica, Oroxylum indicum, Pometia pinnata* and *Zingiber zerumbet.*

DISCUSSIONS

Consciousness about the threat to biological diversity has become more intense during last few decades (Heywood, 1990). It is a proved fact that forests of Bay Islands harbours many of the medicinal plants whose identity is still poorly known not only taxonomically, but also from the economic point of view. This is a serious deficiency considering the potential importance of some of these medicinal plants. Hence the medicinal plants of Bay Islands await their screening and improvement for their proper utilization and conservation. The enormous germplasm wealth of the Islands may be conserved generally by *in-situ* and *ex-situ* means. Andaman and Nicobar Administration has set up one Biosphere Reserve, 96 Wildlife Sanctuaries and nine National Parks. However, they are not specifically aimed at medicinal plant conservation. Botanical Survey of India, Port Blair has initiated steps to conserve the medicinal plants by some of the above mentioned methods. At the first step, documentation and enlistment of these plants has been carried out besides conserving and multiplying some of them in the Dhanikhari Botanic Garden, Port Blair.

In recent decades, the Bay Islands have witnessed many fold increase in the developmental activities (Dagar and Singh, 1999). The aboriginal tribes of the Bay Islands hoard tremendous indigenous knowledge regarding the medicinal plants (Sinha and Malik, 1995; Sharief, 2007). This can be best exemplified from the fact that some researchers have tried to patent a plant species to a cure for cerebral malaria, which is used by Onge tribe for stomach disorder (Sekhsaria, 1999). This hidden secret has to be tapped rationally. Full fledge efforts should be made to document all the existing medicinal plants of Bay Islands. Recently, Andaman and Nicobar Administration has formulated Andaman and Nicobar Medicinal Plant Board which has taken up the task of red listing the rare and endemic medicinal plants of Bay Islands besides recommending some of these plants to farmers to cultivate in their plots. These efforts not only help in conservation and propagation of rare medicinal plants but also fetches some daily earning to the local farmers as cultivation is one way to prevent the genetic erosion of medicinal plants. The information gathered on the medicinal plants of Bay Islands may be considered as clues for prioritizing species for further critical scientific evaluation and bioprospection leading to development of value added products for human welfare.

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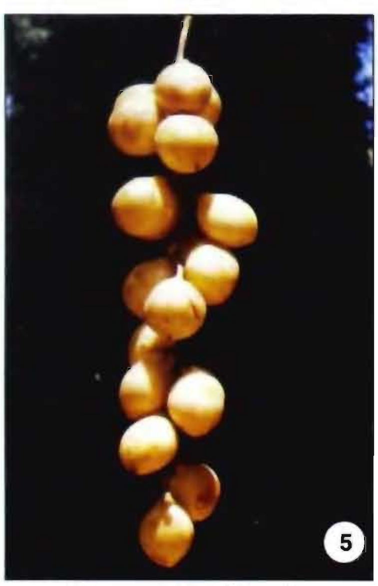
Plate 5

Abrus precatorius L.

Alstonia kurzil Hook.f.

Aphanamixis polystachya (Wall.) Parker

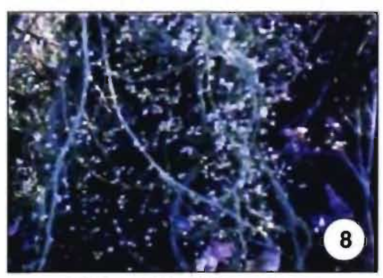
Ardisia solanaces Roxb.



Baccaurea ramiflora Lour.

Carrissa spinarum L.

Cassia alata L.



Cassytha fillformis L.

Cerbara odollam Gaertn.

Claoxylon Indicum Hassk.

Curcuma zeodaria (Christin) Rosc.

Entada rheedei Spreng.

Fagraea racemosa Jack. ex Wall.

Grewia calophylla Kurz

Plate 6

Gloriosa superba L.

Oroxylum indicum (L.) Vent.

Sophora tomentosa L.

Hornstedtia fenzil (Kurz) K. Schum.

Sterculia rubiginesa Vent.

Jatropha gossipifolia L.

Paramignya andamanics (King ex Hook.f.) Tanaka

Syzygium samarangense (Bl.) Merr.

Macaranga nicobarica Balak. & Chakrab.

Pometia pinnata Forst.

Thottea tomentosa (Bl.) Ding.

Morinda citrifolia L.

Saraca asoca (Roxb.) de Wilde.

Xylocarpus moluccensis (Lam.) Roem.

Myristica andamanica Hook.f.

Scaevola sericea Vahl.

Ex-situ conservation at Dhanikhari Garden

Chapter 16

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 207-214, 2010

AN ANALYSIS OF FLORAL DIVERSITY IN VOLCANIC BARREN ISLAND, ANDAMANS, INDIA

V. SAMPATH KUMAR, VINOD MAINA and R. SUMATHI*
Botanical Survey of India, Southern circle, TNAU Campus, Lawley Road (P.O.), Coimbatore 641 003, Tamil Nadu; E-mail. : vskumar10@rediffmail.com

INTRODUCTION

The Andaman and Nicobar Islands comprise more than 350 Islands and islets, form an arc from North to South in the Bay of Bengal. The Barren Island is part of the Andaman group of islands situated at 12°16'40" N and 93°51'30" E in the Andaman Sea and about 135 km northeast of the Union Territory's Capital, PortBlair. The island is almost circular in shape with total surface area of about 10 km^2. The Barren Island is the only active volcano in South Asia although volcano activity was reported from Narcondam Island also, which is located at 13°26' N and 95°15' E and about 120 km away from Barren Island in the Northeast direction. Both these islands stand in the midst of a volcanic belt on the edge of the Indian and Myanmarese tectonic plates. There are other extinct sea and land volcanoes reported in and around these regions.

The first recorded eruption of the Volcano in the Barren Island date back to 1787. Since then, eruptions were recorded for more than half-a-dozen times *viz*., 1789, 1795, 1803-04, 1852?, 1991, 1994-95, 2000 and 2005-06. Almost after one and half century of dormancy, the eruption in 1991 has lasted for nearly six months and caused considerable damage to the flora as well as fauna of this island. The Lava paths are seen towards the northern part of main caldera (Plate 7, a-d). As its name itself indicates the island is uninhabited, but various species of insects, reptiles, birds and mammals have been reported (Rao *et al*., 1990). Nevertheless, feral goats (*Capra hircus* L.) and rats (*Rattus* spp.) are quite large in number and the rodents really become a menace in the night. The drinking water source for the goats are fresh water springs found in the Southeastern part of the island and they survive not by drinking saline sea water as speculated earlier.

Compared to Andaman group of islands the floristic diversity in the Barren Island is very poor since this island has faced volcanic eruptions in the past centuries and the regeneration of the vegetation might have taken place after cooling of the island. Except the Northwestern part of the island, where scoria fall beds, ash tuff and cinder deposits are noticed (Plate 8, e-h), in almost all other parts luxuriant growth of vegetation was observed. As mentioned by Diwakar and Kathigeyan (2005) the base of the central cinder cone is virtually barren and bordering the cone some Cyperaceae members are noticed. Encircling this zone many herbaceous and arborescent species are seen which include *Ardisia solanacea* (Poir.) Roxb., *Boerhaavia diffusa* L., *Dioscorea*

*Foundation for Revitalisation of Local Health Traditions, Bangalore spp., *Euphorbia hirta* L., *Hedyotis* spp., *Lindernia crustacea* (L.) F. V. Muell., *Physalis minima* L. and some members of Poaceae. These species might have regenerated recently by overcoming the worse edaphic conditions. The luxuriant growths of the lush evergreen vegetation with trees attaining 5 to 15 m height are observed especially in Southern and Northern parts of the island. Some of the common tree species encountered during the surveys are *Canarium euphyllum* Kurz, *Ficus* spp., *Garuga pinnata* Roxb., *Lepisanthes rubiginosa* (Roxb.) Leenh., *Macranga tanarius* (L.) Muell.-Arg., *Oroxylum indicum* (L.) Kurz, *Semecarpus* spp., *Syzygium cuminii* (L.) Skeels and *Terminalia catappa* L. In 1893, Prain has been provided the first comprehensive and exclusive account of plants of Barren Island and stated that *T. catappa* is the most abundant tree on the island and the statement till, after two centuries found to hold true.

Several explorations were carried out to analyse and study the flora and fauna of the volcanic island, particularly after the eruptions in 1991. During these surveys some additions to the flora were reported (Sreekumar and Chandra, 1993; Sinha *et al.*, 1994). Although Diwakar and Karthigeyan (2005) has not mentioned few species as additions to the flora of Barren Island based only on their report (Table 1 and 2). The plant names provided in the tables are updated with the presently accepted names as far as possible and many names listed originally in the Prain's (1893) work are provided in parenthesis as synonyms for easy reference.

Analysis of floral diversity

The floral elements in Barren Island are generally composed of almost same as that of Andaman group of islands, which in turn have the affinity with Myanmar and Thailand elements due to their geographical proximity (Balakrishnan and Vasudeva Rao, 1983, 1986; Balakrishnan, 1987, 1989; Mathew, 1998). Total 85 taxa of indigenous Angiosperms were recorded from Barren Island (Table 1), of which 8 species were reported here for the first time based on the collections and different surveys during the period of study. Of these new records, two species, *Manilkara littoralis* and *Semecarpus kurzii* are endemic to Andaman and Nicobar Islands. Besides these, three more endemics of Andamans are also found in this island *viz.*, *Sterculia rubiginosa, Ixora brunnescens* and *Glochidion calocarpum*. Hence, from this volcanic island only five endemics of Andaman and Nicobar Islands are recorded, which is poor in number since about 14 per cent of the endemics are reported from Andamans (Balakrishnan, 1987, 1989; Rao, 1996, 1999). On the other hand, 29 taxa confined to Andaman group of islands are reported from Barren Island *i.e.* these taxa do not occur in Nicobar group. Similarly eight taxa, which are known to India, were recorded from this volcanic island of Andaman and Nicobar.

Although 85 Phanerogams are listed in this work, apart from 8 non-indigenous species (Table 1), occurrence of all the species at present on this island is somewhat doubtful! The authors made an attempt to locate all the taxa listed by Prain (1893), but species like *Acacia concinna, Ixora cuneifolia, Mitreola petiolata, Phyllanthus reticulatus, Sterculia rubiginosa* and some *Ficus* spp. could not be located. Mention should be made that the authors came across few fig trees, but they were not able to identify at specific level due to lack of either flowers or fruits. These trees seem to be of *Ficus arnottiana* and *Ficus microcarpa*, reported by Diwakar and Karthigeyan (2005).

Analysis of habits of indigenous Phanerogams reveals that out of 85 taxa, tree species dominate with 39 numbers, followed by herbs and climbing species (both herbaceous and woody) with 21 and 20 taxa respectively. As regards to non-indigenous species, except two species, *Cocos nucifera* and *Ficus rumphii*, all other species are herbaceous.

Table 1. List of Angiosperm taxa reported from Barren Island

Sl. No.	Name of the taxa	Family	Habit	A	N	M	O
1.	*Abrus precatorius* L.	Fabaceae	Climber	+	+	+	+
2.	*Acacia concinna* (Willd.) DC.	Mimosaceae	Scandent shrub	+	–	+	+
3.	*Aganosma marginata* (Roxb.) G. Don	Apocynaceae	Woody climber	+	–	–	+
4.	*Ampelocissus barbatus* (Wall.) Planch* (= *Vitis barbata* Wall.)	Vitaceae	Liana	+	+	+	+
5.	*Ardisia solancea* (Poir.) Roxb. (= *A. humilis* Vahl)	Myrsinaceae	Tree	+	+	+	+
6.	*Bulbostylis barbata* (Rottb.) C. B. Clarke*	Cyperaceae	Annual herb	+	+	+	+
7.	*Callicarpa arborea* Roxb.	Verbenaceae	Tree	+	–	+	+
8.	*Canarium euphyllum* Kurz	Burseraceae	Tree	+	+	–	+
9.	*Capparis sepiaria* L.	Capparaceae	Scandent shrub	+	–	+	+
10.	*Cissus repens* Lam. (= *Vitis repens* Wight & Arnold)	Vitaceae	Large climber	+	+	+	+
11.	*Colubrina asiatica* (L.) Brongn.∞	Rhamnaceae	Shrub/tree	+	+	+	+
12.	*Cyclea peltata* (Lam.) Diels	Menispermaceae	Twining shrub	+	+	+	+
13.	*Cyperus cuspidatus* Kunth#	Cyperaceae	Annual sedge	+	+	+	+
14.	*Cyperus javanicus* Houtt.∞ (= *C. pennatus* Lamk.)	Cyperaceae	Perennial tufted sedge	+	+	+	+
15.	*Dalbergia pinnata* (Lour.) Prain (= *D. tamarindifolia* Roxb.)	Fabaceae	Tree	+	–	+	+
16.	*Derris scandens* (Roxb.) Benth.*∞	Fabaceae	Liana	+	+	+	+
17.	*Desmodium heterocarpon* (L.) DC. (= *D. polycarpum* (Poir.) DC.)	Fabaceae	Undershrub	+	+	+	+
18.	*Digitaria sanguinalis* Scop.#	Poaceae	Erect herb	+	+	+	+
19.	*Dioscorea bulbifera* L.	Dioscoreaceae	Climber	+	–	+	+
20.	*Dioscorea glabra* Roxb.	Dioscoreaceae	Climber	+	–	+	+
21.	*Dioscorea sativa* L.	Dioscoreaceae	Climber	+	–	+	+
22.	*Dodonea viscosa* L.	Sapindaceae	Shrub/tree	+	+	+	+
23.	*Eragrostis tenella* (L.) Beauv. ex Roem. & Schult.#	Poaceae	Erect herb	+	+	+	+
24.	*Eragrostis uniloides* (Retz.) Nees ex Steud.*	Poaceae	Tufted erect herb	+	+	+	+
25.	*Eranthemum succifolium* Kurz$	Acanthaceae	Undershrub	+	–	+	+
26.	*Ficus arnottiana* (Miq.) Miq.	Moraceae	Tree	+	–	+	+
27.	*Ficus benjamiana* L. (= *F. retusa* L. var. *nitida* Thunb.) Miq.)	Moraceae	Tree	+	+	+	+
28.	*Ficus brevicuspis* Miq.	Moraceae	Tree	+	–	–	+

Table 1. *Contd.*

Sl. No.	Name of the taxa	Family	Habit	A	N	M	O
29.	*Ficus hispida* L.f.	Moraceae	Tree	+	+	+	+
30.	*Ficus microcarpa* L.f. #	Moraceae	Tree	+	–	+	+
31.	*Ficus racemosa* L. (= *F. glomerata* Roxb.)*	Moraceae	Tree	+	–	+	+
32.	*Ficus tinctoria* Forst.f. ssp. *gibbosa* (Blume) Corner (= *F. gibbosa* Blume var. *cuspidifera* King)	Moraceae	Tree	+	+	+	+
33.	*Ficus variegata* Blume	Moraceae	Tree	+	–	+	+
34.	*Fimbristylis cymosa* R.Br.#	Cyperaceae	Perennial tufted sedge	+	+	+	+
35.	*Fimbristylis dichotoma* (L.) Vahl (= *F. diphylla* Vahl)	Cyperaceae	Annual/ perennial sedge	+	+	+	+
36.	*Fimbristylis ferruginea* (L.) Vahl	Cyperaceae sedge	Perennial tufted	+	+	+	+
37.	*Flueggia virosa* (Roxb. ex Willd.) Voigt (= *F. microcarpa* Blume)	Euphorbiaceae	Bushy shrub/tree	+	+	+	+
38.	*Garuga pinnata* Roxb.	Burseraceae	Tree	+	–	+	+
39.	*Glochidion calocarpum* Kurz^∞	Euphorbiaceae	Shrub/tree	+	+	–	–
40.	*Gloriosa superba* L.	Liliaceae	Climber	+	–	+	+
41.	*Hedyotis corymbosa* (L.) Lam. (= *Oldenlandia corymbosa* L.)	Rubiaceae	Suffruticose herb	+	–	+	+
42.	*Hedyotis diffusa* Willd.* (= *Oldenlandia diffusa* (Willd.) Roxb.	Rubiaceae	Diffuse herb	+	+	+	+
43.	*Hibiscus tiliaceus* L.∞	Malvaceae	Tree	+	+	+	+
44.	*Hoya diversifolia* Blume	Asclepiadaceae	Climbing epiphyte	+	–	–	+
45.	*Hoya parasitica* Wall.∞	Asclepiadaceae	Climbing epiphyte	+	+	+	+
46.	*Indigofera glandulosa* Wendl.*	Fabaceae	Shrub	+	–	+	+
47.	*Ipomoea macrantha* Roem. & Schult. (= *I. grandiflora auct. non* Lamk.)	Convolvulaceae	Climber	+	+	+	+
48.	*Ipomoea pes–caprae* (L.) R.Br. (= *I. biloba* Forsk.)	Convolvulaceae	Prostrate herb	+	+	+	+
49.	*Ischaemum muticum* L.	Poaceae	Herb	+	+	+	+
50.	*Ixora brunnescens* Kurz^	Rubiaceae	Shrub/small tree	+	+	–	–
51.	*Ixora cuneifolia* Roxb.	Rubiaceae	Shrub	+	–	–	+
52.	*Leea indica* (Burm. f.) Merr. (= *L. sambucina* Willd.)	Leeaceae	Shrub/ small tree	+	+	+	+
53.	*Lepisanthes rubiginosa* (Roxb.) Leenh. (=*Erioglossum edule* Blume)	Sapindaceae	Tree	+	+	+	+

Table 1. *Contd.*

Sl. No.	Name of the taxa	Family	Habit	A	N	M	O
54.	*Lindernia crustacea* (L.) F.V. Muell. (= *Vandelia crustacea* (L.) Benth.)	Scrophulariaceae	Herb	+	–	+	+
55.	*Macranga peltata* Muell.-Arg.#	Euphorbiaceae	Tree	+	+	+	+
56.	*Macranga tanarius* (L.) Muell.-Arg.	Euphorbiaceae	Tree	+	+	–	+
57.	*Mallotus resinosus* (Blanco) Merr.#	Euphorbiaceae	Tree	+	+	+	+
58.	*Manilkora littoralis* (Kurz) Dub.*^ (= *Mimusops littoralis* Kurz)	Sapotaceae	Tree	+	+	–	–
59.	*Mitreola petiolata* (Gmel.) Torr. & Gray (= *M. oldenlandoides* G. Don)	Loganiaceae	Herb	+	–	+	+
60.	*Morinda citrifolia* L. var. *bracteata* (Roxb.) Hook.f.	Rubiaceae	Tree	+	+	+	+
61.	*Mussaenda macrophylla* Wall.	Rubiaceae	Subscandent shrub	+	+	+	+
62.	*Oplismenus burmanni* Kunth	Poaceae	Decumbent herb	+	–	+	+
63.	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	Tree	+	–	+	+
64.	*Pandanus odoratissimus* L.f.∞	Pandanaceae	Tree	+	+	+	+
65.	*Pholidota imbricata* (Roxb.) Lindl.∞	Orchidaceae	Epiphytic herb	+	+	+	+
66.	*Phyllanthus reticulatus* Poir.	Euphorbiaceae	Shrub/small tree	+	+	+	+
67.	*Pluchea indica* Less.	Asteraceae	Shrub	+	+	+	+
68.	*Pogonatherum crinitum* (Thunb.) Kunth†	Poaceae	Erect herb	+	+	+	+
69.	*Pogonatherum paniceum* (Lam.) Hack. (= *P. saccharoideum* P. Beauv.)	Poaceae	Tufted herb	+	–	+	+
70.	*Pongamia pinnata* (L.) Pierre∞ (= *P. glbra* Vent.)	Fabaceae	Tree	+	+	+	+
71.	*Premna obtusifolia* R. Br.∞ (= *P. integrifolia* L.)	Verbenaceae	Shrub/small tree	+	+	+	+
72.	*Scaveola sericea* Vahl (= *S. koenigii* Vahl)	Goodeniaceae	Shrub/small tree	+	+	+	+
73.	*Semecarpus heterophyllus* Blume	Anacardiaceae	Tree	+	–	–	+
74.	*Semecarpus kurzii* Engl.*^	Anacardiaceae	Tree	+	+	–	–
75.	*Sterculia rubiginosa* Vent.^	Sterculiaceae	Tree	+	–	–	–
76.	*Suregada multiflora* (Juss.) Baill.∞ (=*Gelonium bifarium* Roxb.)	Euphorbiaceae	Shrub/small tree	+	+	+	+
77.	*Syzygium cumini* (L.) Skeels (= *Eugenia jambolana* L.)	Myrtaceae	Tree	+	–	+	+
78.	*Syzygium samarangense* (Blume) Merr. & Perry∞#	Myrtaceae	Tree	+	+	–	+
79.	*Terminalia catappa* L.	Combretaceae	Tree	+	+	+	+
80.	*Tetracera sarmentosa* (L.) Vahl#	Dilleniaceae	Liana	+	–	+	+

Table 1. *Contd.*

Sl. No.	Name of the taxa	Family	Habit	A	N	M	O
81.	*Trema orientalis* Blume#	Ulmaceae	Tree	+	+	+	+
82.	*Trema tomentosa* (Roxb.) Hara (= *T. amboinensis* Blume)	Ulmaceae	Shrub/small tree	+	+	+	+
83.	*Urena lobata* L. #	Malvaceae	Herb	+	+	+	+
84.	*Vitex negundo* L.	Verbenaceae	Shrub	+	+	+	+
85.	*Wedelia biflora* (L.) DC. 8 (= *W. scandens* C.B. Clarke in *p.p.*)	Asteraceae	Climbing shrub	+	+	+	+

A : Andaman group of Islands; N : Nicobar group of Islands; M : Main land India; O : Outside India; + : Present; – : Absent

* Reported first time from Barren Island based on our collections and the specimens are deposited at PBL.

∞ Listed as Mangrove associate species by Sampath Kumar (2005).

Included here based on the report of Diwakar & Karthikeyan (2005).

$ Treated as variety of *E. cinnabarium* Wall. by Dagar and Singh (1999).

^ Endemic to Andaman & Nicobar Islands.

† So far reported only in two localities in Andaman & Nicobar Islands–Barren Island and Laful (Greater Nicobar Island).

Non–indigenous Angiosperm Taxa recorded from Barren Island :

1. *Boerhaavia diffusa* L. (= *B. repens* L.) (Nyctaginaceae)
2. *Cocos nucifera* L. (Arecaceae)
3. *Cyperus iria* L. (Cyperaceae)
4. *Euphorbia hirta* L. (Euphorbiaceae)
5. *Ficus rumphii* Blume (Moraceae)
6. *Heteropogon contortus* (L.) P. Beauv. (Poaceae)
7. *Imperata cylindrica* P. Beauv. (Poaceae)
8. *Physalis minima* L. (Solanaceae)

In figure 1, number of indigenous species of Angiosperms (Dicots and Monocots) and Pteridophytes distributed in Barren Island are depicted. No Gymnosperm species is recorded from this volcanic island. Of the 16 Pteridophytes recorded (Table 2), one species *Reediella humilis* is reported here for the first time based on our collection. Regarding other Cryptogamic groups, only one Bryophyte *Bryum coronatum* Schwaegr is reported from this island so far. Similarly, except the report of six Fungi species and one Lichen species by Prain (1893) no additions were reported. However, in Algae Diwakar and Karthigeyan (2005) reported the profuse growth of the species of *Turbinaria, Sargassum* and *Padina* on the rocky shores, which are additional reports to this volcanic island as Prain (*l.c.*) reported the occurrence of *Calothrix* spp. only.

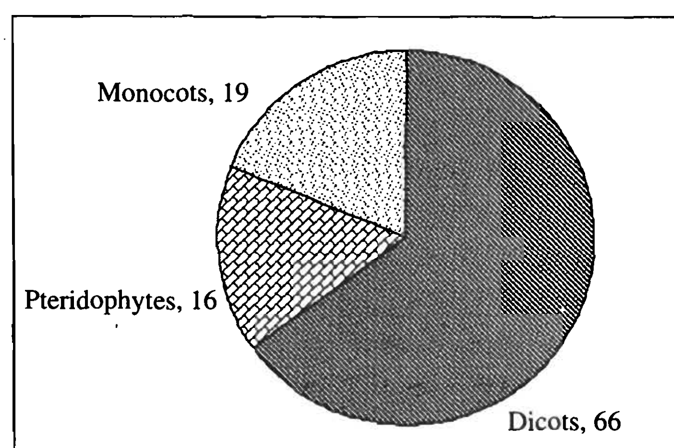


Fig. 1. Number of indigenous Dicots, Monocots and Pteridophytes distributed in Barren Island

The mangroves, characteristic of Andaman and Nicobar Islands, are totally absent on this volcanic island due to the absence of flat and sheltered beaches with clayey soil. Interestingly, one-fifth of the mangrove associate species *i.e.* 14 out of 74 listed out by Sampath Kumar (2005) for Andaman

Table 2. List of Pteridophytes recorded from Barren Island

Sl. No.	Name of the taxa	Family	Habit	A	N	M	O
1.	*Acrostichum aureum* L.$^{\infty}$	Acrostichaceae	Terrestrial shrub	+	+	+	+
2.	*Stenochlaena palustris* (Burm.f.) Bedd. (=*Acrostichum scandens* J. Sm.)	Stenochlaenaceae	Terrestrial scandent herb/ shrub	+	+	+	+
3.	*Adiantum philippense* L. (= *A. lunulatum* Burm.f.)	Adiantaceae	Terrestrial herb	+	–	+	+
4.	*Asplenium falcatum* Lamk. var. *urophyllum* Bak.	Aspleniaceae	Epiphytic herb	+	+	+	+
5.	*Cheilanthes tenuifolia* (Burm.f.) Sw.	Cheilanthaceae	Terrestrial herb	+	–	+	+
6.	*Drynaria quercifolia* (L.) J. Sm. (= *Polypodium quercifolium* L.)	Polypodiaceae	Epiphytic herb	+	+	+	+
7.	*Nephrolepis cordifolia* (L.) Presl.$ (= *N. tuberosa* Presl.)	Nephrolepidaceae	Terrestrial or epiphytic herb	+	–	+	+
8.	*Onychium siliculosum* (Desv.) C.Chr. (= *O. auratum* Kaulf.)	Cryptogrammaceae	Terrestrial herb	+	–	+	+
9.	*Palhinhaea cernua* (L.) Franco & Vasc. (= *Lycopodium cernum* L.)	Lycopodiaceae	Terrestrial herb	+	+	+	+
10.	*Pityrogramma calomelanos* (L.) Link#	Hemionitidaceae	Terrestrial herb	+	+	+	+
11.	*Psilotum nudum* (L.) P. Beauv. (= *P. triquetrum* Sw.)	Psilotaceae	Epiphytic herb	+	+	+	+
12.	*Pteris biaurita* L.	Pteridaceae	Terrestrial herb	+	–	+	+
13.	*Pteris vittata* L. (= *Pteris longifolia auctt. non* L.)	Pteridaceae	Terrestrial herb	+	+	+	+
14.	*Pyrrosia adnascens* (Sw.) Ching (= *Polypodium adnascens* Sw.)	Polypodiaceae	Epiphytic herb	+	+	+	+
15.	*Reediella humilis* (Forst.) Pic.-Ser.*	Hymenophyllaceae	Terrestrial herb	+	+	–	+
16.	*Selaginella delicatula* (Desv. ex Poir.) Alston#	Selaginellaceae	Terrestrial decumbent herb	+	+	+	+

A : Andaman group of Islands; N : Nicobar group of Islands; M : Main land India; O : Outside India; + : Present; – : Absent

$^{\infty}$ Listed as Mangrove associate species by Sampath Kumar (2005).

$ Listed here based on Prain (1893), not recorded in Dixit & Sinha (2001).

Recorded here based on Diwakar & Karthikeyan (2005).

* Reported first time from Barren Island from our collections and specimens are deposited at PBL.

and Nicobar Islands are found in Barren Island. Of these, only the fern species, *Acrostichum aureum* is abundant near the seashores and as opined by Prain (*l.c.*) it might be a sea-introduced one. The fruits of *Heriteria littoralis* Dryand (true mangrove) and *Barringtonia asiatica* (L.) Kurz (mangrove associate and not true mangrove as suggested by many authors) were reportedly collected from the shorelines of Barren Island. The authors could not trace these tree species in spite of their intensive survey and with conformity state that these species are not found growing on this island. There are possibilities that these two species fruits might be washed away from the islands of middle Andaman group, which harbour gregarious mangrove vegetation.

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Gratitude is expressed to the Scientist-in-charge, Andaman and Nicobar Circle, Botanical Survey of India for deputing us as one of the members of multidisciplinary team formed by Andaman and Nicobar Administration, Port Blair for the visits to the Barren Island in different explorations. Also grateful to the Indian Coast Guard, who has provided accommodation in their Patrolling Ship and extended all the facilities to conduct the survey, without this help visit to this volcanic island would have become a distant dream. Thanks are to the Joint Director, Southern Circle, Botanical Survey of India, Coimbatore for providing facilities to prepare this manuscript.

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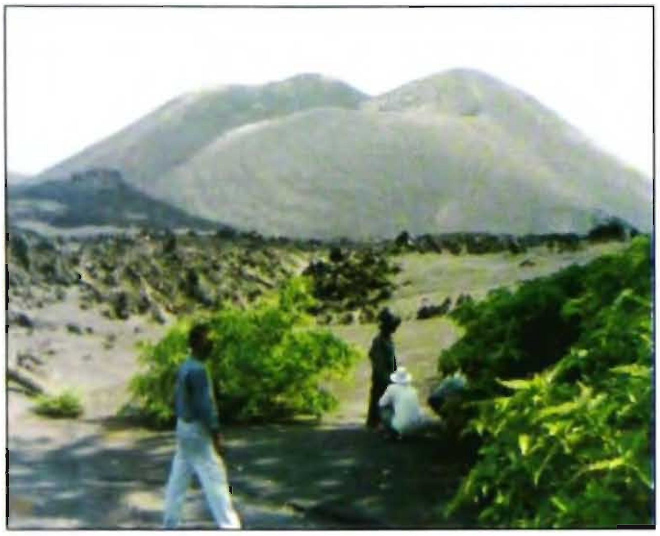
Plate 7



(a) Central cinder cone showing Caldera

(b) A view of Volcano with Lava path
& regenerated vegetation

(c) Dyke with fine to medium grains

(d) A view of Solidified Magma

Plate 8

(e) Scoria fall beds & cinder deposits

(f) A view of Volcanic ash tuff with poor vegetation

(g) A spatter cone & close up view of Volcanic slag

(h) Feral goat with back view of Fig tree

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 215-222, 2010

ASSESSMENT OF SPECIES COMPOSITION WITHIN LARGE AREA ECOLOGICAL PLOT OF EVERGREEN FOREST, ANDAMAN, INDIA

C.S. REDDY*, P.R. PRASAD and C.B.S. DUTT*****
Forestry and Ecology Division, National Remote Sensing Agency, Balanagar, Hyderabad-500 037, India

INTRODUCTION

Tropical rain forests show high species richness and diversity due to the favourable environmental factors (Prasad *et al.*, 2007). Species composition, assemblage and their distributional pattern defines the nature and type of the forest community. If species richness is high and all species are equally abundant and dominant, then the community is described as ecologically stable and biologically rich. However this type of situation is rare and usually communities may have either high species richness with low evenness or they may be mono-specific dominant with few species assemblage, and often those communities are referred with the name of dominant species.

The community level phytodiversity studies can be made at various spatial scales using parameters like species composition, cover, frequency, basal area (Negi, 2001). Phytodiversity is generally described as a composite property that reflects both the number of species (richness) in a biological community and the evenness with which abundance is distributed among the different species. Large permanent plot sampling was done in Pasoh forest reserve (Malaysia), Khao Chong National Park (Thailand) and in Sinharaja world Heritage Site (Sri Lanka), to understand the vegetation structure and species diversity pattern. In Indian scenario forest community studies were carried out in Western Ghats by various researchers (Parthasarathy, 1988; Sukumar *et al.*, 1992; Ganesh *et al.*, 1996; Pascal *et al.*, 1998). The present 'Large Area Ecological Plot' analysis is the first study in Andaman and Nicobar Islands region, which deals phytosociological attributes of large sample plot.

Study area

Andaman and Nicobar Islands are one among the 26 mega diversity centers of plant biodiversity in world. Of all the Andaman and Nicobar islands, North Andaman harbours a good variety of endemicity (Reddy *et al.*, 2004) and species diversity (Reddy and Prasad, 2008). As per the Champion and Seth (1968) the predominant terrestrial vegetation types are North Andaman forest Tropical Evergreen Forest (1A/C2), Andaman Semi-evergreen forest (2A/C1) and Andaman Moist deciduous forest. The existence of different forest types is due to the slight micro topographic and soil variations, which gives the scenario of top hill Evergreen forest and low land Moist Deciduous forest, with scattered Semi-

*E-mail : csreddy_nrsa@rediffmail.com; drsudhakarreddy@gmail.com
**Lab for Spatial Informatics, International Institute of Information Technology, Gachibowli, Hyderabad-500 082, India
***Indian Space Research Organization, Dept. of Space, Anthariksh Bhavan, Bangalore, India

evergreen. Irrespective of type, all the forest types show dense vegetation with climbers, canes, shrubs and herbs signifying the tropical wet evergreen nature. Presence of 66 per cent of area under large patches in North Andaman is an indicative of low fragmentation rates and intactness of forest (Prasad *et al.*, 2008). The present study provided comprehensive vegetation ecological analysis for community structure and composition.

MATERIALS AND METHODS

In the present study "Large Area Ecological Plot (LAEP)" of the size of three ha in Evergreen forest was laid at Mohanpur Reserved Forest, north Andaman keeping in view of the relatively natural patch, where topographical and edaphic factors are similar (Fig. 1). Three ha square plot was sub girded into thirty 0.1 ha subplots for systematic survey. In each sub plot all living higher angiospermic taxa (trees) above 30 cm girth, total tree height, shrub, herb, sapling and seedling were collected.

An attempt has been made to characterize the site in respect of five basic vegetation parameters *viz.* species richness, diversity, density, basal area and height. Tree species number of stems, frequency, density, basal area (m^2), relative frequency, relative density, relative dominance, IVI, abundance values were calculated for each species. Diversity, evenness and dominance measurements are computed using Shannon, Hill evenness index and Simpson index. Abundance to frequency ratio was used for determining the spatial pattern of species as regular if value <0.025, random between 0.025-0.05 and clumped/contiguous >0.05 (Curtis and Cottam, 1956). Girth class wise tree frequency distribution was analyzed to know the contribution of various girth classes for species richness, diversity, and density.

RESULTS

Altogether 167 species of flowering plants were inventoried during the vegetation survey of 3 ha plot of Evergreen forest. Overall 1544 individuals having >30 cm gbh with a combined basal area of 130 m^2 belonging to 94 species, 67 genera and 37 families were recorded (Table 1). Of the 94 tree species 23 are endemic. While Climbers make significant proportion of non-tree category with representation of 51 species followed by herbs (13) and shrubs (9).

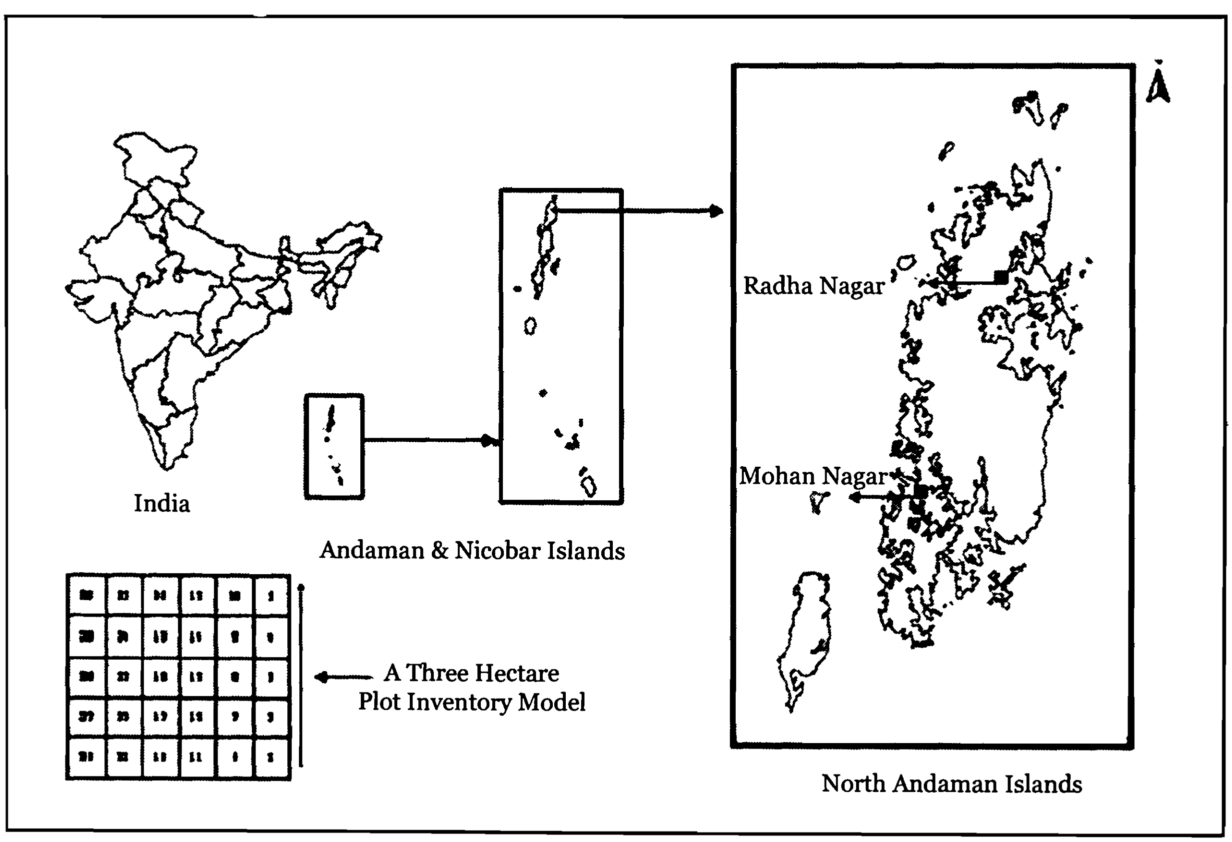


Fig. 1. Location Map of North Andaman islands, India

Table 1. Tree Species Contributions in contiguous 3 ha plot (In decreasing order of IVI)

Sl. No	Species Name	Families	Species Density	Basal area(m^2)	Species IVI	Endemic
1	*Myristica andamanica*	*Myristicaceae*	770	14.16	30.59	Yes
2	*Dipterocarpus grandiflorus*	*Dipterocarpaceae*	543	18.24	28.92	—
3	*Pterygota alata*	*Sterculiaceae*	627	11.75	26.35	—
4	*Pometia pinnata*	*Sapindaceae*	207	13.49	18.92	—
5	*Celtis wightii*	*Ulmaceae*	350	2.72	14.22	—
6	*Pterospermum acerifolium*	*Sterculiaceae*	310	3.06	13.49	—
7	*Xanthophyllum andamanicum*	*Polygalaceae*	160	7.72	11.31	Yes
8	*Myristica glaucescens*	*Myristicaceae*	273	3.66	9.16	—
9	*Tetrameles nudiflora*	*Tetramelaceae*	33	7.01	7.69	—
10	*Dipterccarpus gracilis*	*Dipterocarpaceae*	133	4.35	7.38	—
11	*Artocarpus chaplasha*	*Moraceae*	83	2.75	6.20	—
12	*Dracantomelum mangiferum*	*Anacardiaceae*	63	2.09	5.09	—
13	*Diospyros pyrrhocarpa*	*Ebenaceae*	67	0.83	5.00	—
14	*Lagerstroemia hypoleuca*	*Lythraceae*	117	1.79	4.88	Yes
15	*Spondias mangifera*	*Anacardiaceae*	67	1.40	4.83	—
16	*Hopea odorata*	*Dipterocarpaceae*	67	1.85	4.77	—
17	*Gelonium tenuifolium*	*Euphorbiaceae*	73	0.72	4.44	—
18	*Amoora wallichi*	*Meliaceae*	53	1.42	4.18	—
19	*Canarium euphyllum*	*Burseraceae*	30	2.40	3.86	—
20	*Albizia lebbek*	*Mimosaceae*	63	1.50	3.82	—
21	*Unidentified 1*	*unidentified*	43	0.20	3.66	—
22	*Dillenia andamanica*	*Dilleniaceae*	43	2.23	3.59	Yes
23	*Sterculia villosa*	*Sterculiaceae*	57	1.59	3.56	—
24	*Sideroxylon longipetiolatum*	*Sapotaceae*	57	1.31	3.34	—
25	*Pterocymbium tinctorium*	*Sterculiaceae*	43	1.10	3.33	—
26	*Unidentified 2*	*unidentified*	37	0.33	3.22	—
27	*Pisonia excelsa*	*Nyctaginaceae*	37	2.22	3.04	—
28	*Artocarpus lakoocha*	*Moraceae*	40	0.74	2.98	—
29	*Madhuca butyracea*	*Sapotaceae*	17	2.06	2.93	—
30	*Eugenia kurzii*	*Myrtaceae*	23	1.25	2.85	—
31	*Baccaurea sapida*	*Euphorbiaceae*	57	0.22	2.70	—
32	*Hydnocarpus castanea*	*Flacourtiaceae*	47	0.26	2.54	—
33	*Semecarpus kurzii*	*Anacardiaceae*	30	0.78	2.42	Yes
34	*Unidentified 3*	*unidentified*	30	0.46	2.37	—
35	*Anacolosa frutescens*	*Olacaceae*	27	0.22	2.32	—
36	*Pajanelia rheedi*	*Bignoniaceae*	30	1.04	2.20	—
37	*Unidentified 4*	*unidentified*	20	0.68	2.14	—
38	*Planchonia andamanica*	*Lecythidaceae*	23	0.70	1.81	—
39	*Dipterocarpus* sp	*Dipterocarpaceae*	40	0.39	1.69	—

Table 1. *Contd.*

Sl. No	Species Name	Families	Species Density	Basal area(m^2)	Species IVI	Endemic
40	*Parishia insignis*	*Anacardiaceae*	13	1.05	1.68	—
41	*Diospyros oocarpa*	*Ebenaceae*	23	0.08	1.54	Yes
42	*Unidentified-5*	*unidentified*	13	0.54	1.49	—
43	*Knema andamanica*	*Myristicaceae*	17	0.18	1.48	—
44	*Aglaia andamanica*	*Meliaceae*	20	0.20	1.36	—
45	*Decaspermum parviflora*	*Myrtaceae*	17	0.09	1.22	—
46	*Adenanthera microsperma*	*Mimosaceae*	10	0.27	1.02	—
47	*Pterocarpus dalbergoides*	*Fabaceae*	3	0.81	0.90	Yes
48	*Terminalia manii*	*Combretaceae*	3	0.81	0.90	Yes
49	*Myristica glabra*	*Myristicaceae*	10	0.09	0.88	—
50	*Buchanania splendens*	*Anacardiaceae*	10	0.33	0.86	—
51	*Sageraea elliptica*	*Anonaceae*	10	0.06	0.85	—
52	*Streblus asper*	*Moraceae*	10	0.06	0.85	—
53	*Gardenia coronaria*	*Rubiaceae*	10	0.22	0.77	—
54	*Canarium manii*	*Burseraceae*	10	0.45	0.75	Yes
55	*Miliusa tectona*	*Anonaceae*	10	0.17	0.73	—
56	*Sterculia parviflora*	*Sterculiaceae*	7	0.51	0.73	—
57	*Terminalia bialata*	*Combretaceae*	7	0.23	0.72	—
58	*Gmelina elliptica*	*Verbanaceae*	7	0.14	0.65	—
59	*Mangifera sylvatica*	*Anacardiaceae*	7	0.07	0.59	—
60	*Aglaia glaucescens*	*Meliaceae*	7	0.04	0.57	Yes
61	*Nauclea gageana*	*Rubiaceae*	7	0.04	0.57	—
62	*Garcinia sp*	*Clusiaceae*	3	0.35	0.54	—
63	*Myristica irya*	*Myristicaceae*	7	0.24	0.52	—
64	*Lannea coromandelica*	*Anacardiaceae*	3	0.30	0.50	—
65	*Terminalia procera*	*Combretaceae*	3	0.26	0.47	Yes
66	*Eugenia claviflora*	*Myrtaceae*	3	0.23	0.45	—
67	*Calophyllum soulattri*	*Clusiaceae*	7	0.12	0.43	—
68	*Bouea oppositifolia*	*Anacardiaceae*	7	0.10	0.41	—
69	*Mangifera andamanica*	*Anacardiaceae*	7	0.09	0.41	Yes
70	*Mesua ferrea*	*Clusiaceae*	3	0.17	0.40	—
71	*Wrightia arborea*	*Apocyanaceae*	7	0.02	0.35	—
72	*Sygyzium samarangense*	*Myrtaceae*	3	0.10	0.35	—
73	*Mallotus peltatus*	*Euphorbiaceae*	3	0.09	0.34	Yes
74	*Sterculia rubiginosa*	*Sterculiaceae*	3	0.07	0.32	—
75	*Endospermum chinense*	*Euphorbiaceae*	3	0.05	0.31	—
76	*Aglaia oligophylla*	*Meliaceae*	3	0.05	0.31	—
77	*Aglaia argentea*	*Meliaceae*	3	0.03	0.29	—
78	*Bombax insigne*	*Bombacaceae*	3	0.02	0.29	Yes

Table 1. *Contd.*

Sl. No	Species Name	Families	Species Density	Basal area(m^2)	Species IVI	Endemic
79	*Memecylon edule*	*Melastomaceae*	3	0.02	0.29	—
80	*Artocarpus gomeziana*	*Moraceae*	3	0.02	0.28	—
81	*Pleiospermium alatum*	*Rutaceae*	3	0.02	0.28	—
82	*Eugenia manii*	*Myrtaceae*	3	0.01	0.28	Yes
83	*Litsea kurzii*	*Lauraceae*	3	0.01	0.28	Yes
84	*Neolitsea andamanica*	*Lauraceae*	3	0.01	0.28	Yes
85	*Pandanus andamanensium*	*Pandanaceae*	3	0.01	0.28	—
86	*Firmiana colorata*	*Sterculiaceae*	3	0.01	0.28	—
87	*Albizia procera*	*Mimosaceae*	3	0.01	0.28	—
88	*Glyptopetalum calcocarpum*	*Celastraceae*	3	0.01	0.28	Yes
89	*Mallotus oblongifolius*	*Euphorbiaceae*	3	0.01	0.28	Yes
90	*Memecylon collinum*	*Melastomaceae*	3	0.01	0.28	Yes
91	*Dipterocarpus costatus*	*Dipterocarpaceae*	3	0.01	0.28	—
92	*Orophea katschallica*	*Anonaceae*	3	0.01	0.28	Yes
93	*Alstonia kurzii*	*Apocynaceae*	3	0.01	0.27	Yes
94	*Miliusa andamanica*	*Anonaceae*	3	0.01	0.27	Yes

Species richness within the subplots varied from 9 (1^{st}, 30^{th} subplots) to 28 (26^{th} subplot) with a mean value of 31 species ha^{-1}. Within the tree girth classes' species richness showed decreased trend from lower to higher and about 46 per cent of species richness is contributed by 30-60 cms (25 per cent) and 60-90 cm (21 per cent) girth range. Shannon diversity, Simpson index and Hill evenness were 4.8, 0.07 and 0.70 respectively. Based on Importance Value Index (IVI) analysis, the study site is mainly dominated by *Myristica andamanica* (30.59), *Dipterocarpus grandiflorus* (28.92), *Pterygota alata* (26.35) and *Pometia pinnata* (18.92), *Celtis wightii* (14.22), *Pterospermum acerifolium* (13.49), *Xanthophyllum andamanicum* (11.31), *Myristica glaucescens* (9.16), *Tetrameles nudiflora* (7.69) and *Dipterocarpus gracilis* (7.38). The IVI values showed that top 10 species contributed 56 per cent of IVI. Out of 37 families Anacardiaceae (with 9 species), Myristicaceae, Sterculiaceae (stem density 323, 315) and Dipterocarpaceae (19 per cent of total basal area) dominated the entire plot. The spatial distribution pattern of species showed regular pattern for one unidentified species (could not be ascertained its botanical name) random for 14 species and majority clumped pattern.

The population density for species varied from 1 (30 species) to 231. The mean stem density was 515 per ha and 50 per cent of the stem density is contributed by five species *Myristica andamanica* (15 per cent, 77 stems per ha), *Pterygota alata* (12.2 per cent, 63) *Dipterocarpus grandiflorus* (10.6 per cent, 54), *Celtis wightii* (6.8 per cent, 35), *Pterospermum acerifolium* (6.0 per cent, 31). The girth class frequency distribution of trees did not follow any trend of decreasing or increasing but indicates that 70 per cent of the stand density is formed by 30-60 cms (44 per cent) and 60-90 cms (26 per cent) girth classes (Fig. 2).

Basal area with in the subplots ranged from 2.2 (2^{nd}, 10^{th} sub plots) to 8.7 sq.mts (9^{th} subplot) for 0.1 ha sub plots. Mean Basal area revealed at 43.2 m^2 per ha and 50 per cent of basal area is contributed by *Dipteropcarpus grandiflorus* (14 per cent), *Myristica andamanica* (11 per cent), *Pometia pinnata* (10 per cent), *Pterygota alata* (9 per cent), *Xanthophyllum andamanicum* (6 per cent). The basal area contribution of girth classes showed intermittent trend of decreasing and increasing values with maximum contribution by girth class >210 cms (31 m^2). In overall analysis of entire 3 ha plot *Myrisitica andamanica* dominated the plot and is found as ubiquitous species of the site.

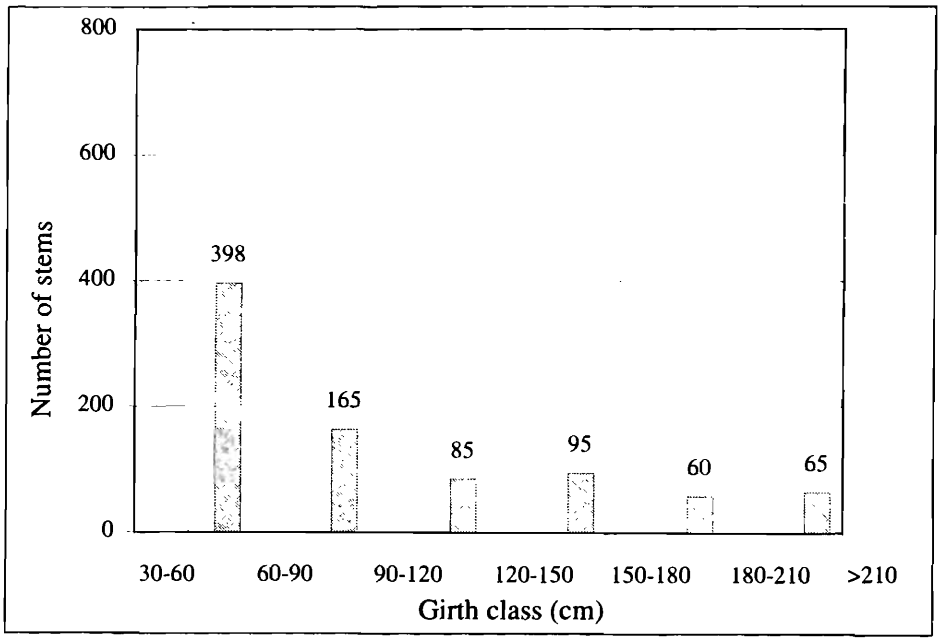


Fig. 2. Distribution of individuals of Tree Species across girth classes

Out of 1544 stems, 56 per cent are within the height class of 5-10 m, 36 per cent in 10-15m and 9 per cent in >15 m class. An analysis of height and girth class relation showed that the lower girth classes are within the height range of 5-10 and with increasing girth class height also increased. The analysis reveals that in Evergreen forest, majority of subplots showed species richness in the range of 10-20 (number), diversity values within 3-4, stem density between 40-60 (individuals) basal area from 4–6 m^2 and stems mean height above 10 mts.

The common climbers of plot are *Dinochloa andamanica, Pothos scandens, Calamus andamanicus, Tetracera sarmentosa* var. *andamanica, Calamus viminalis, Calamus palustris, Calamus longisetus, Ancistrocladus extensus, Entada scandens* and *Cayratia japonica*. The common shrubs are *Anaxagorea luzoniensis, Areca triandra, Caryota mitis, Clerodendrum viscosum, Leea asiatica, Leea indica, Licuala peltata* and *Miliusa andamanica*. The commonly found herbs are *Colocasia virosa, Costus speciosus, Curcuma petiolata, Donax cannaeiformis, Dracaena angustifolia, Strobilanthus glandulosus* and *Zingiber spectabile.*

DISCUSSION

Overall LAEP inventory recorded about 94 tree species. This value of 94 species out of three ha LAEP is found to be more when compared with the species recorded in similar permanent large area plot sampling done by Ayyappan and Parthasarathy (1999) at Vargalaiaar (30 ha per 148 species), Condit *et al.* (1996) at Mudumalai (50 ha per 63 species), Pascal and Pelissier (1996) at Uppangala (28 ha per 103 species). The mean species richness is 31 per ha which is found to be high compared with Evergreen richness is high compared to Nelliampathy (30 per ha), Western Ghats (Chandrasekhara and Ramakrishnan, 1994). But overall species richness is low when compared with other sites (Amazon Eucador (307 per ha), Valencia *et al.*, 1994).

The mean stem density found in Evergreen forest of the present study i.e. 515 stems per ha is high in comparison to other Evergreen forest studies which are 482 per ha, (Parathasarathy and Karthikeyan, 1997), 419 per ha, (Ghate *et al.*, 1998) and low with reference to Ganesh *et al.*, 1996 (583 per ha), Pascal and Pelissier, 1996 (635 per ha). The tree girth class frequency distribution (Fig. 3) revealed decreasing number of stems with increasing girth class. This clearly indicates a regenerative nature of natural forest by having younger individuals contributing low basal area and fewer dominant older stems occupying much of the basal area in the community. Presence of more number of stems in lower girth classes forms a sign of good index for potential regeneration status.

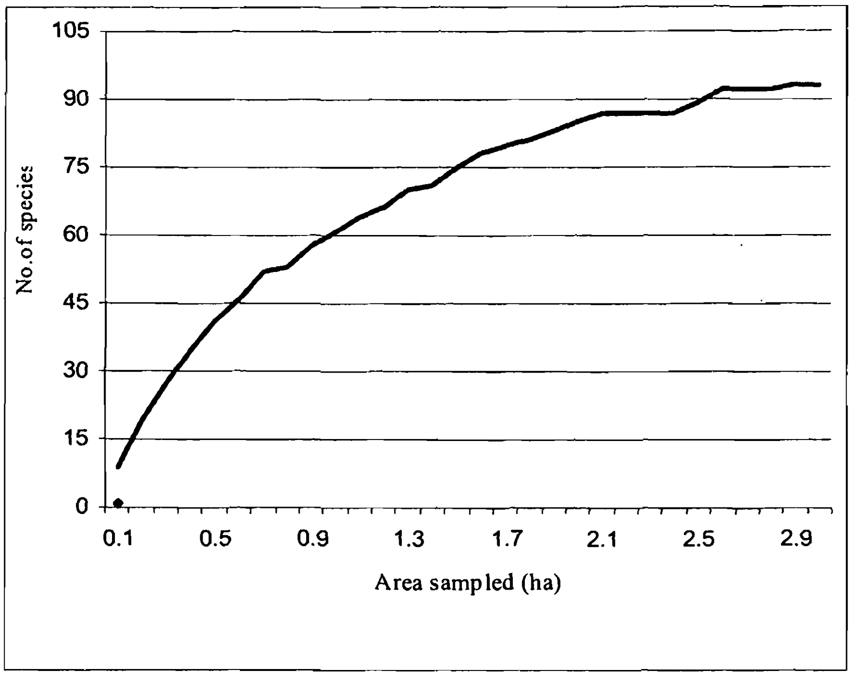


Fig. 3. Species area curve for 3-ha Evergreen forest plot

In three forest communities (LAEP) species exhibited (using abundance frequency ratio) either random or clumped (majority) distributional pattern. Random distribution is an indicative of disturbance factor (Armesto *et al.,* 1986) that might have dispersed the species at different locations randomly. Clumped nature of species distribution is attributed to the dispersal syndrome of species where species either lack a suitable dispersal agent or inefficient in dispersing the seeds (Richards, 1996) to the new environment as a result, they grow under the same parental niche forming clumps or groups. Regular dispersion in the present study is rare and is exhibited by only one unidentified species.

Species area curve was prepared using the incremental area of 0.1 ha unit plot to a size of three ha large area plot by cumulating 30 times and the ultimate area achieved was 3 ha (0.1 X 30). Likewise for all the three forest types species area curves were constructed. The curve clearly showed the plateau at 3 ha area in respect of species occurrence supporting the adequacy of the large area ecological plot selected in the present investigation and for the benefit of ambiguity it would be ideal for future investigations an area larger than 3 ha. However here only tree species were considered for plotting the graph, but if species from non tree groups (climbers, shrubs, herbs) are also included then probably the curve may attain saturation capturing the required species count to represent the forest community. It is evident that non tree species (73 species) contribute a good increase to species richness and quantitatively hikes the species area curve, proving the sampled area (3ha) adequate enough to analyze the community diversity.

Singletons and doubletons were considered as rare and form about 46 per cent (41 species) in Evergreen forest patch of the total sampled area. The observation is comparable with the species rarity as studied in different areas of Western Ghats (Parthasarathy and Karthikeyan, 1997 – 47 per cent; Pascal and Pelissier, 1996 – 40 per cent). The present phytosociological analysis indicates that the forests of north Andaman are potential sites of species richness and diversity.

CONCLUSIONS

Identification of conservation areas and species status ideally requires exhaustive knowledge of species composition and their distribution. Biodiversity conservation has faced difficulty in Andaman forests due to lack of sufficient quantitative ecological information.

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Chapter 18

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 223-230, 2010

INTRA-VARIABILITY ANALYSIS IN THE HETEROGENEOUS TROPICAL ISLAND SYSTEM OF SOUTH ASIA

P.R. PRASAD[1]* N. NAGABHATLA and C.B.S. DUTt*****
Lab for Spatial Informatics, International Institute of Information Technology, Gachibowli, Hyderabad-500 032, India

INTRODUCTION

Gradient in distribution and diversity of tropical formations across the earth surface is potentially governed by the rainfall value and the moisture availability (Denslow, 1987). In the Indian sub continent these tropical forests occur in pockets of eastern Himalayan region, Western Ghats and in the isolated Andaman and Nicobar Islands. Andaman and Nicobar Islands houses vivid ecological habitats with diverse set of ecosystems varying from low altitude sandy beach forest to high altitude dense humid evergreen forests. Roger and Panwar (1988) classified these islands into separate biogeographical zone (Islands) based on their intra variable ecological systems and the unique biological diversity. MacKinnon (1997) referred these islands as a distinct eco-region due to their contribution of nearly 0.25 per cent of the total biological-rich area of the country. The islands on account of their isolation, harbors a phenomenal degree of endemic plants and animals species along with rich marine life. The state forest report (2001), depict about 87 per cent (7171 km^2) of the total geographical area of these islands under recorded forest [highest percentage of forest cover in the country] (Anon., 2002). Luxuriant mangroves, perhaps the richest in the world occupy nearly 10 per cent of the territory (Anon., 2001). Overall, there are 9 national parks and 94 wildlife sanctuaries spread across the isles' [covering about 20 per cent of the island area] that reflects its network of protected area.

A review of the past studies represent that they had profound focus on the floristic side (Wallich, 1850; Kurz, 1870; Prain, 1890; Sahni, 1953; Bharagava, 1958; Thothathri 1960, 1961, 1962, 1980; Balakrishnan and Nair, 1976, 1977; Balakrishnan and Chakraborthy 1978; Singh *et al.* 1987; Balakrishnan and Vasudeva Rao, 1983; Balachandra, 1988, Dagar, 1989) and relatively less towards a holistic ecosystem based management approach (Busch *et al.*, 2003). Considering this limitation, the geospatial tools (remote sensing and GIS technology) have facilitated the rapid assessment of landscape units and in addition provide a set of meaningful information required for sustainable conservation approach (Chauhan, 2004; Prasad *et al.*, 2007a; Nagabhatla *et al.*, 2007a). The present study is further extension of the above exercise to comment on the application of earth observation system and geospatial tools to compare and explore the intra variability of

* *Corresponding author* E-mail: rcprasad@iiit.ac.in
***Global Research Division, International Water Management Institute, Colombo, Sri Lanka.*
Email: N.Nagabhatla@CGIAR.ORG
****Indian Space Research Organization, Department of space, Anthariksh Bhavan, Bangalore-560094, India.*
E-mail : dutt_cbs@isro.org

landscape structure as well as the diverse vegetation pattern in North Andaman and Baratang Islands of the Andaman group.

Study area

Andaman and Nicobar Islands popularly known as "Emerald Isles" is a repository of unique flora and fauna comprising of 572 islands, covering an area of 8249 km² (6408 km² in Andaman and 1841 km² in the Nicobar group). The Andaman group forms separate district with three major sub divisions viz., North, Middle and South Andaman, covering more than two–third of the island area, while smaller regions like Baratang and Little Andaman form the part of the archipelago (Anon., 2003). Geologically, these islands belong to a geosynclinal basin and the structural land pattern clearly indicates that these islands being the visible ridges and summits of sunken ranges of mountains (Devraj, 2001).The isles have tropical climate, with two seasons chiefly rainy and summer. Rainfall is mainly by the southwest and northeast monsoons and the average relative humidity range between 68 to 86 percent. The two islands groups have been described separately and shown in Fig. 1.

North Andaman Islands (NAI)

Comprises of nearly 70 islands and lies about 285 km south of Myanmar, between 12°95" N and 92°86" E covering an area of 1458 km² (Plate 9, Fig. 1). The important islands are Landfall, Paget, Interview, Stewart, Narcondam, Smith and Sound. Kalpong, the only major perennial fresh water river in Andaman flows in North Andaman. Major settlement areas include Diglipur, Radhanagar, Shyamnagar, Aerial Bay, Mohanpur, Ramnagar, Kishori nagar and Kalighat. Vegetation typically constitutes of evergreen, semi evergreen, moist deciduous, mangroves and littoral forest types. In addition, North Andaman is one among the 14 identified Biosphere Reserves of India (Negi, 1996) constituting two important zones *viz.,* core zone and the buffer zone. The saddle peak (732 m) that harbors a wide variety of species due to varied topographic and climatic conditions has been proposed as core zone and its surrounding areas as the buffer zone (Devraj, 2001). The anthropogenic influx from West Bengal, Tamil Nadu and Andhra Pradesh had adversely affected the natural resources of these islands by increasing logging and encroachments, hence disturbing its ecological dynamics.

Baratang Islands (BI)

Fall under the Baratang forest division, created in 1979. It is one of the six territorial divisions of Andaman group lying between Middle Andaman in the north and South Andaman at its tail with a total area of 690.49 km² (Plate 9, Fig. 1), the group consists of 28 islands of which the principal one are Baratang, Evergreen, Colebrook, Spike, Havelock, Peel, Wilson, Henry Lawrence, John Lawrence, Outram and Neil. Fourteen islands of the group are under protected area status attributed to the diverse ecology, geo-morphological and the zoological significance. The Nilumbur and Ritchie's archipelago [the two administrative zones of the island] houses the Inglis (or East) Island and Sir Hugh Rose Island sanctuaries and the Rani Jhansi Marine National Park (RJMNP), while the Bluff and Spike island form the tribal reserve zone (Chauhan, 2004). In summary, the landscape is unique with well-distributed flora and luxuriant evergreen forest covering the hills, while the semi-evergreen forest wrapping the slopes.

MATERIAL AND METHODS

The methodology was framed based on the 'Biodiversity Characterization at Landscape Level' {BCLL}(Roy *et al.*, 2005) that encompass the preparation of thematic maps for spatial representation of landscape followed by analysis of landscape parameters using a three-tier approach, viz., landscape analysis, field data extrapolation and geospatial analysis.

Landscape mapping

Andaman area is predominantly cloudy for most part of the year hence, restricting the availability of cloud free satellite data. However, the transient seasons of February to April generally provide an opportunity to obtain cloud free data. The multi-spectral IRS 1C/1D LISS III (March 1999) data coupled with Landsat TM (Jan.-2001) and geo-coded LISS PAN merged product (April 2001) was used to classify the landscape (Plate 10, Fig. 2). Land cover (use) maps were prepared by combining the satellite resource data and the ancillary information collected from ground. Initially a spectral cluster map depicting various land cover (use) was prepared using automated unsupervised classification approach. The generated map was thus used for the reconnaissance survey to collect the ground control points (GCP's) using a Global positioning systems (GPS) and to identify predominant vegetation types and land cover classes. The spectral signatures generated from the GCP's collected from survey was used for preparation of image interpretation key. The unique spectral response of the forest communities formed the basis for on-screen classification method. Finally, the visual interpretation technique was adopted for delineating various forest types *viz,* Andaman tropical evergreen, southern hill top evergreen, secondary evergreen, semi evergreen, moist deciduous, littoral, mangroves and other important land cover classes (for details refer Nagabhatla *et al.* 2007b and Prasad *et al.,* 2007a).

Field inventory and data analysis

The spatially defined vegetation categories were used for the field inventory to collect phytosociological data based on the stratified random sampling method. About 108 sample plots of (0.1 ha) in NAI (Prasad 2006) and 127 in BI (Chauhan, 2004) were collected covering different forest communities along with data on phytosociological parameters like DBH, height, type of species, their count, along with information on herbs, shrubs, climbers, saplings and seedlings encountered within the plot. The field collected data was further analyzed for species richness, Important value Index, ecosystem uniqueness (Dhar *et al.* 1997), Total Important Value of species (Nayar, 1996; Dagar and Singh, 1999; IUCN, 2001).

Geospatial modelling

Landscape characterization was completed by using the SPLAM model (Roy *et al.,* 2005) to identify fragmented areas, disturbance regimes and biological richness separately for both the regions. The spatial data on forest/vegetation or land cover (use) map generated using satellite data was incorporated in Grid format into GIS domain for landscape analysis. The spatial and non-spatial data from other ancillary data sources were combined to generate habitat fragmentation, disturbance and biological richness thematic layer.

Fragmentation Analysis : The fragmentation module of the model was used to generate the fragmented landscape map of the study area by running model at a window size of 100 X100 m. Substantially the model classified the entire area into four different zones as intact, low, medium and high fragmented areas. Disturbance Analysis: Disturbance in forest is the sum of the changes introduced either by anthropogenic or natural factors. These changes can be quantified with the landscape analysis parameters like fragmentation, porosity, juxta position (adjacency of forest to human interference) Interspersion, proximity from settlements and roads, and other patch characteristics available with in the model finally deriving disturbance index map.

Biological Richness Mapping: The knowledge based data with respect to ecosystem uniqueness, species richness and biodiversity value, obtained from phytosociological data was used to create attribute information of the composite strata of vegetation type and disturbance regimes. Finally the terrain complexity and disturbance index along with the attribute data of phytosociological data were spatially combined to model the biological richness.

RESULTS AND DISCUSSION

Both the islands form the part of Andaman group, but interestingly the intra-variability can be explained by understanding the landscape pattern and ecological makeup of the region in depth. The land cover (use) map for island ecosystem, both in case of BI and NAI, is composed of five major natural classes which are defined based on the nature of the soil, elevation and topographical structures and inspired by the classification of Champion and Seth (1968) The aerial statistics is shown in Table 1.

Forest types

Andaman evergreen forest is most luxuriant type, with canopy formed by giant Dipterocarps. Tropical semi-evergreen forests include both evergreen and deciduous species growing on parched and shallow soiled slopes of high hills. Deciduous forests have a leaf shedding character, irregular top storey and buttressed roots and are dominated by *Pterocarpus dalbergioides, Lagerstroemia hypoleuca* and *Terminalia bialata.* Mangrove forest, confines itself to sea washed soil dominated by *Rhizophora mucornata* while the

Table 1. Comparative Area Statistics for the two island group

Vegetation Type / Land Cover Classes	North Andaman*		**Baratang	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Interior Terrestrial vegetation types				
Evergreen	310.03	21.3	155.26	27.59
Semi-evergreen	451.31	31.0	157.89	28.06
Moist deciduous	226.22	15.5	70.61	12.55
Sub total	**987.56**	**67.8**	**383.76**	**68.20**
Coastal vegetation types				
Littoral	48.25	3.3	1.73	0.26
Dense mangrove	95.81	6.6	85.32	12.59
Open mangrove	121.62	8.4	26.94	3.97
Degraded mangrove	19.80	1.4	1.67	0.25
Sub total	**285.48**	**19.6**	**115.56**	**17.06**
Non-forest classes				
Agriculture / Settlements	123.96	8.5	31.91	4.31
Plantations	9.65	0.7	17.78	2.40
Mud flats	29.50	2.0	10.35	1.40
Barren land/Degraded Forest	0.25	0.0	1.14	0.15
Sand	19.86	1.4	1.51	0.20
Sub total	**183.21**	**12.6**	**62.69**	**8.47**
Total forest and non-forest area	**1456**		**562.7**	

(*Prasad *et al.*, 2007a and **Nagabhatla *et al.*, 2007a)

littoral forest is dominated by *Manilkara littoralis* (sea mahwa) forms a pure fringe on sandy beaches. Distribution of forest resources is uniform and mostly semi-evergreen formations are seen flourishing well and covering a major percentage of the area (31 per cent in NAI and 28.06 per cent in BI). Within, NAI about 67.8 per cent is under interior (inland-terrestrial) and 19.6 per cent under coastal type where as in BI it 68.20 per cent and 17.06 per cent respectively. The uninhabited islands namely Landfall, Point, Stewart, Sound and North reef islands of NAI and John Lawrence, Wilson, and Henry Lawrence in BI harbors intact, non-fragmented, forest patches, possessing only threat from poachers.

Biodiversity characterization at landscape level : The base map (land cover) along with the ancillary data was subjected to customized geospatial model, 'SPLAM' (Roy *et al.*, 2005, Nagabhatla *et al.*, 2007b) to study the response of both the island systems to natural fluctuations and anthropogenic pressure. The observations have been explained independently and in conjunction (Plate 11, Fig. 3).

Forest fragmentation

NAI : The fragmentation analysis reflects evergreen and semi evergreen forests as most intact zones while the littoral and moist deciduous under high porosity. It also reveals that most of the intact forest lies in and around Saddle Peak National Park. Large patches of size greater than 1000 ha were recorded more in semi evergreen while the patches of size less than 50 ha were recorded in moist deciduous (Prasad *et al.*, 2007a). Overall about 77.87 per cent of forest falls under intact or non-fragmented category while 1.02 per cent under highly fragmented area which was observed around major settlements areas like

Diglipur, Kalighat, Mohanpur. Some of the isolated islands showed moderate fragmentation driven by expanding encroachments. To a major, extent all the vegetation types reflect low fragmentation rates.

BI : The extent of fragmentation was noticeable, this can be attributed to developmental and tourist activities (especially in Havelock and Neil island). About 87.26 per cent of total area is under intact zone while 1.74 per cent falls under medium to high fragmentation.

Forest Disturbances

NAI : The disturbance analysis reveal Diglipur region as most disturbed followed by moderate level of disturbance around its adjoining settlements. Whilst, 51.68 per cent of the evergreen forest still lies intact, medium level of disturbance was observed in semi-evergreen and moist deciduous forest. A total of 6.2 per cent of the area is under high disturbance.

BI : The disturbance analysis reflect that the western coast of Nilumbur and Havelock are most disturbed areas, while moderate levels of disturbance was reported from Neil islands; whilst the other isles were less disturbed or intact. Overall, it is estimated that about 79.5 per cent of area lies in intact zone while 1.9 per cent under high disturbance

Biological richness

NAI : Analysis depicts that most of the evergreen (32.11 per cent) and mangrove forests (33.41 per cent) are under high to highest biological richness. More than 50 per cent of the semi-evergreen and moist deciduous forests fall under moderately high richness. High richness is observed in and around area of Saddle peak and in isolated islands due to least impact of disturbance factors (Reddy and Prasad 2008) (Table 2).

BI : With in these islands a total of 98.6 km^2 (19.49 per cent) fall under high biological rich area and 265.68 km^2 (52.52 per cent) under medium zone. It was observed that major part of evergreen and semi evergreen forest fall in biologically rich zone (Table 2).

Intra-variability analysis for NAI and BI

High forest fragmentation and disturbances along with high biological richness was observed (Table 2) in NAI compared to BI. The high fragmentation and disturbance rates in NAI are mainly due to the increasing influx of people to

Table 2. Landscape level analysis to a assess the human-environment linkages

Landscape Parameters	Status	North Andaman islands		Baratang islands	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)
Forest fragmentation	Intact	1003.87	77.87	308.02	87.26
	Low	224.18	17.39	38.83	11
	Medium	48.01	3.72	4.36	1.23
	High	13.13	1.02	1.83	0.51
Disturbance	Intact	913.42	64.83	355.56	79.5
	Low	238.14	16.9	54.96	12.3
	Medium	168.79	11.98	28.26	6.3
	High	88.59	6.29	8.48	1.9
Biological Richness	Low	46.11	3.21	141.19	27.97
	Medium	98.58	6.86	265.68	52.52
	Moderately High	829.99	57.73	92.73	18.33
	High	378.23	26.31	5.87	1.16
	Highest	84.91	5.91		

these islands. Comparatively most of the BI was declared as protected islands and national parks hence the anthropogenic interference is less, maintaining high intact zone. The penal settlement colonies were first established in Chatham island of South Andaman which was later shifted to NAI. Hence NAI show oldest settlement zones, which were expanded in due course along with the growing population. These anthropogenic interventions have adversely impacted the primary forest region through activities such forest land encroachment and logging, hence governing the forest fragmentation and disturbance. However the inaccessible areas in and around of Saddle Peak and few isolated islands maintains still intact undisturbed forest with high biological richness. Within NAI, overall about 230 tree, 113 climber, 55 shrub and 45 herb species were recorded from all the vegetation types covering 67 families while the phytosociological analysis in BI reveal 352 tree,111 shrub, 148 climber and 95 herb species.

In context of landscape characterisation in BI, whilst most of the islands in the group are uninhabited hence restricting the anthropogenic interventions [resulting in fragmented areas] in the inhabited zone. The inaccessible remote islands *viz.*, John Lawrence, Henry Lawrence, Colebrook, Spike, Outran and Wilson harbour relatively intact forest owing to less disturbance activities. It is also interesting to note that the disturbed forest patches show continuously increasing in proportion of the invasive *Lagerstroemia hypoleuca* mainly at the extracted sites. In addition, the expansion in tourism, cash crop plantations and the bee hiving of the timber industries had governed the vast scale primary forest extraction in Baratang, Havelock and Neil Islands. Furthermore, the transboundary [Bangladesh, Burma] migrants add to the forest encroachment practice both in NAI and BI groups.

CONCLUSION

The landscape analysis reflects that both the NAI and BI are rich and diverse ecosystems with high biological diversity and ecological integrity. The configuration of the landscape in terms of biological diversity reflects that anthropogenic pressure has caused considerable change in the landscape structure and natural boundaries of landforms. Expansion of agricultural activities has ever added more changes in the spatial diversity in last few decades. The disturbance areas are ones, which are modified due to human interventions and developmental activities as also analyzed by Nagabhatla *et al.* (2007a) and Prasad *et al.* (2008). Much of the biological richness is represented as dense evergreen, semi evergreen and mangrove vegetation. However the ever-increasing population along with the state developmental plans, posed threat to the forest richness by depleting them drastically leading to the species extinction in both the zones. Therefore, the intensity and scale can be comparable or distinct, the database generated from landscape analysis helps in identifying the disturbance gradient and scale of biological richness zones; whilst, providing insight to the gaps in management planning. The present analysis has provided a set of reference data base for policy planning and conservation prioritization at the national level. Furthermore as it was the most recent pre-tsunami study (2000-2004); hence has opened new research avenues both at national and global level for comparing the post-tsunami scenarios {in terms of investigating change} in the island landscape.

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Plate 9

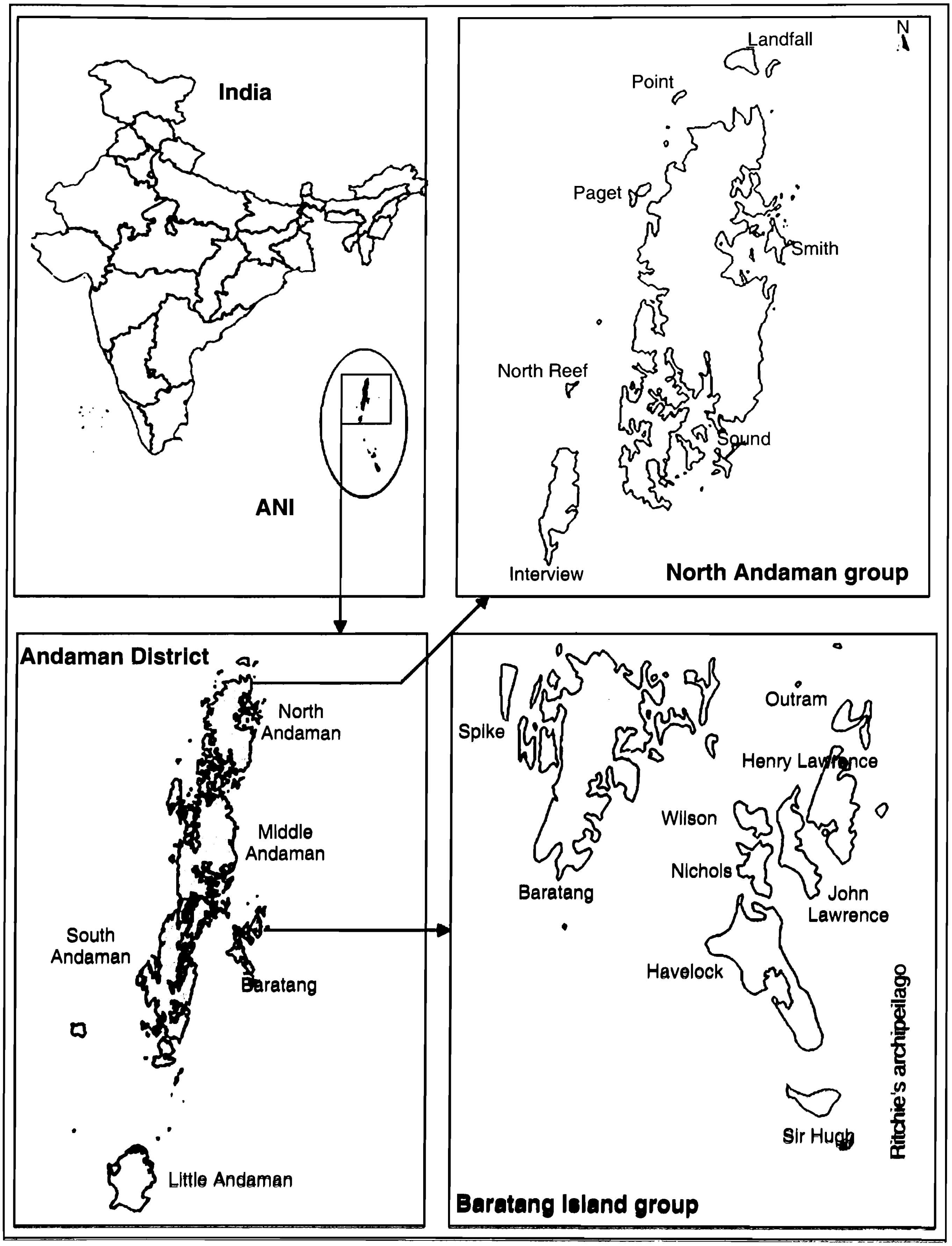

Fig. 1. Geographical location of the North Andaman and the Baratang Islands

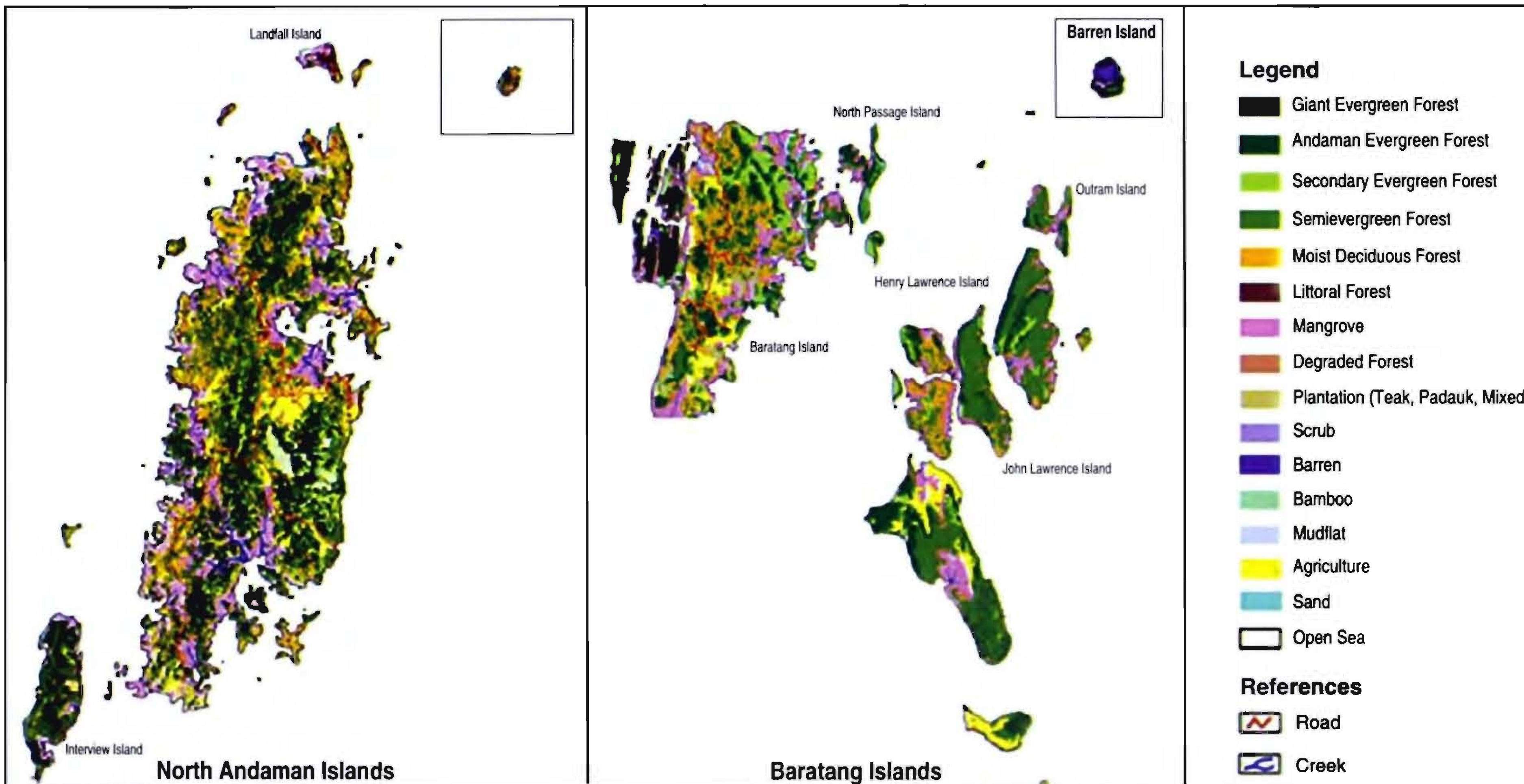

Fig. 2. Vegetation cover map of study area

Plate 11

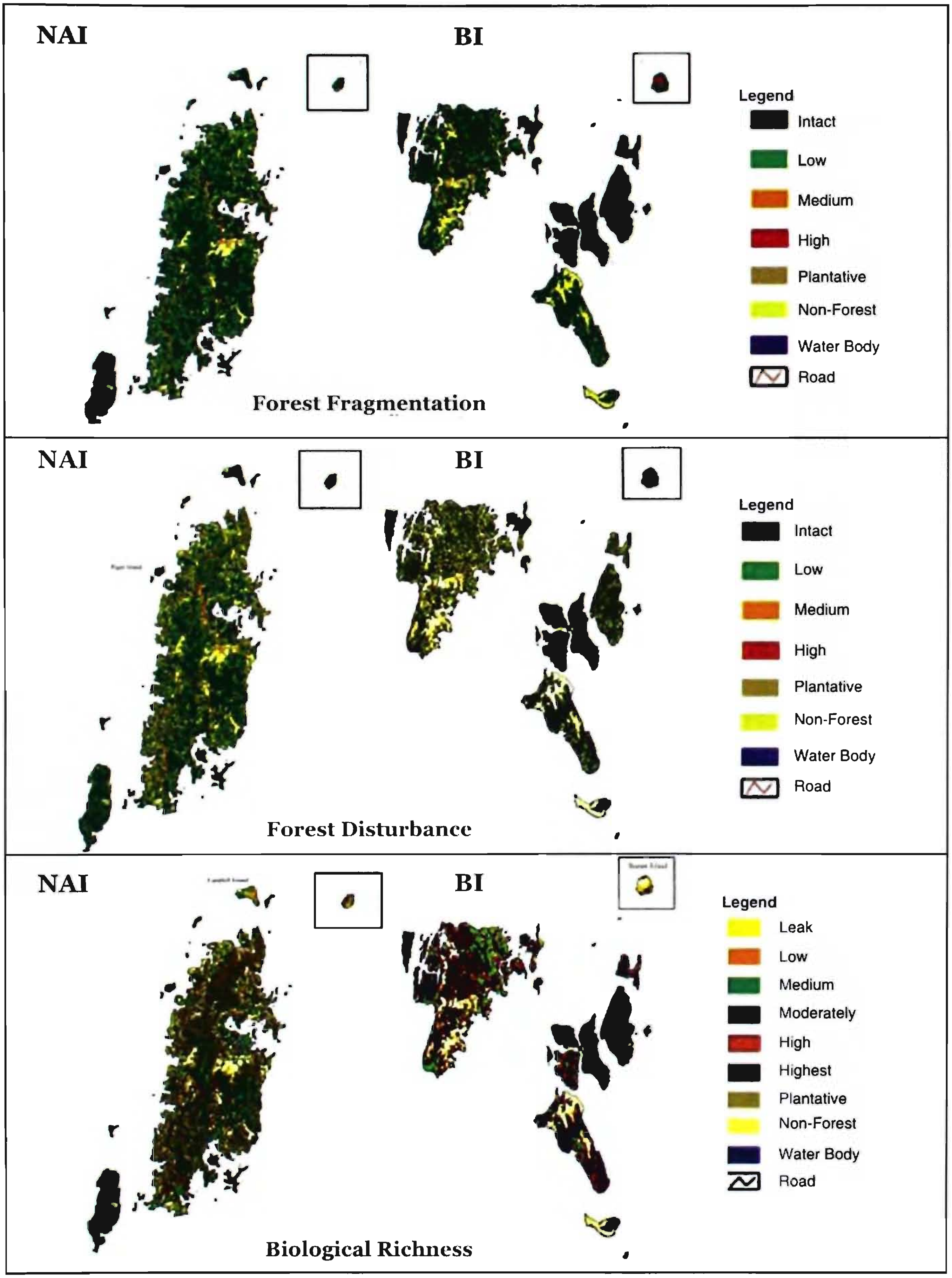

Fig 3. Comparative analysis of landscape-level characterization in North Andaman and Baratang Islands

Chapter 19

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 231-237, 2010

THE REPRODUCTIVE BIOLOGY OF ANDAMAN PADAUK (*PTEROCARPUS DALBERGIOIDES ROXB.*)

B. NAGARAJAN and N. KALA*
Institute of Forest Genetics and Tree Breeding, Coimbatore 641 002

INTRODUCTION

Padauk (*Pterocarpus dalbergioides Roxb.*) is a narrowly endemic exquisite ornamental timber tree belonging to the family Fabaceae. Its natural distribution is restricted to the Andaman group of Islands, India with about 150 large small Islets in an approximate land area of 6400 km^2 (Fig. 1). Annual rainfall in the region varies from 2400 to 4000 mm and the temperature ranges from 18 32°C.

Padauk is a very large semi-deciduous or practically evergreen tree with large butresses (Troup, 1921). They grow upto 45.0 meters in height and 5.5 meters in girth with usually a clean cylindrical bole upto 15 meters above the buttresses. Padauk has broad heartwood in a gorgeous deep pinkish red color with narrow gray sapwood. In international trade padauk timber is referred to as East Indian Mahogany or Vermillion. It is suitable for paneling, furniture, veneer, ply, carving and making musical instruments and is priced about Rs. 40,000/m^{-3}. In terms of retention of shape, shear and hardness it is estimatedly superior to teak (Nagarajan and Kala, 2006).

Sufficient data on distribution, economic traits and natural regeneration are available for most trees in Andaman group of Islands (Troup, 1921). Yet IUCN catalogues Padauk as a data deficient species (*www.redlist.org*). But detailed information on reproduction and life history traits are definitely inadequate (Ganapathy and Rangarajan, 1952). Investigations on these lines are mandatory to develop effective breeding and conservation strategies manage forest genetic resources of padauk.

In terms of population structure, Troup (1921) was the first to note preponderance of large stems in padauk populations. He observed that regeneration was woefully inadequate and recommended the necessary management practices. Based on this from 1905 to 1960 padauk plantations were raised in small areas of 1- 4 ha in different areas within Andamans. These trials indicated the suitability of padauk as a plantation species. However, the results were not translated in to large scale. Meanwhile timber extraction over a century had constantly eroded padauk genetic resources. Currently, padauk is not extracted in wild and availability of padauk timber on a commercial scale in posterity seems to be a possibility with human assisted regeneration.

Owing to high endemism the Andaman forest management deploys only native genetic resources in afforestation programs. Thus padauk the state tree is a potential candidate for enriching flora outside forests in Andamans. In terms of domestication padauk is at its early juvenile stage. Activities like plus tree selection and developing seed production areas have been initiated. Knowledge on reproduction is vital at this stage so that ascertaining variations at population level,

* *Department of Environment and Forests, Andaman and Nicobar Islands*

seed collection regimes and nursery activities could be well planned. Hence a preliminary study was conducted to comprehend the following: phenology, floral biology, pollination biology and breeding system, Reproductive success.

MATERIALS AND METHODS

Phenology

Studies on the period of leaf flushing, bud emergence, flower initiation and proportion of individuals flowering within a population were estimated during 2005 and 2006. Trees measuring 15-30 meters in height and 90-260 cm in GBH were sampled in twelve locations across the natural distribution range of about four hundred kilometers (Table 1).

Floral biology

Five trees were marked at Shoalbay 9 for recording open pollination fruit set. Fifty inflorescences (= 300 flowers) in each tree were sampled to quantify size and number of flowers produced. One hundred flowers in each tree were observed for anthesis, behavior, pollen production, pollen-ovule ratio and insect visit. To understand flower life one hundred inflorescences were observed for a period of 3 days in three trees at Shoal Bay 9. Flower samples were harvested as and when required. Inflorescences were tagged and insect visits were observed from 0600 to 2400 hr.

Table 1. Details of the study sites

Location	Geographical Position	
	Latitude	Longitude
North Andaman		
Kishori Nagar	13°11'12.32"	92°53'08.25"
Mayabunder	12°55'12.17"	92°54'02.43"
Karmatang	12°51'17.12"	92°55'31.76"
Webi	12°51'16.89"	92°52'43.18"
Tugapur	12°49'46.45"	92°50'13.89"
Rangat	12°30'36.53"	92°54'47.42"
Kadamtala	12°20'30.56"	92°46'38.73"
Baratang		
Udaygarh	12°13'06.95"	92°46'31.88"
Nilambur	12°10'29.03"	92°46'09.23"
South Andaman		
Shoal Bay IX	11°51'10.97"	92°44'24.41"
Kalatang	11°48'15.37"	92°42'53.27"
Chidiyatapu	11°29'33.61"	92°42'27.67"

Pollen fertility

To quantify pollen fertility fully dehisced anthers were gently pressed upon dry glass slides and smeared with a drop of differential cytoplasm stain (Alexander, 1969) and left undisturbed overnight. Pollen with pink stained cytoplasm was scored as viable, while those found green or colourless were recorded as aborted. Palynological data was sampled according standard procedures (Radford *et al.*, 1974). To estimate pollen to ovule ratio the methodology by Dafni (2000) was used.

Open and controlled pollination

Fruit set in open pollination was observed in one hundred inflorescences in each of the five trees (Shoal Bay 9 populations). One hundred fruits were harvested from each tree randomly to record seed filling. Reproductive Success was estimated using Wiens *et al.*, (1987) method (*Fruit/flower ratio X Seed/Ovule ratio = Pre Emergent Reproductive Success*).

Three trees were control pollinated to know stigma receptivity, pollen-pistil interaction and fruit set with self and cross pollen. For each treatment one hundred flowers were pollinated in each of the trees. Flowers were emasculated using a fine tipped surgical forceps between 05 45–06 45 hours and were caged in paper bags (in 7 × 5 cm size). Pollen of self and cross origin was dusted between 07 00–17 00 hr. For stigma receptivity and pollen-pistil interaction studies, twenty-five pistils (2 samples/hour) were harvested in hourly intervals.

Fruit size and weight

To quantify variations in fruit shape, size, weight and seed filling twenty trees were sampled in each of the thirteen locations. Twenty fruits from each of the single tree collections were subjected to image analysis (QMAC 500, Leica, United Kingdom). Fruits were weighed on a Sartorius Electronic balance (R100 D, Sartorius Inc., Germany).

Pollen pistil interaction

Pistils were washed in running tap water for

40 minutes, soaked in 8N Sodium hydroxide for 1 hour and then transferred to 0.1 N Tri Calcium Phosphate for about 20 minutes. The pistils were then stained with 0.1 per cent water soluble Aniline Blue (MARTIN, 1959). Tissues were the placed on a clean and dry slide, topped with a glycerine drop and gently squashed using a dry cover glass. Specimens were viewed under an Epi-fluorescent microscope (Optiphot, Nikon Inc., Japan) using a UV-2A filter block. Sizes of pollen and stigma were quantified by calibrating with a 100μm ocular micrometer (Erma Inc, Japan) over a 1000μm stage micrometer. Images were recorded using microscopic camera (Nikon UFX-DX, Nikon Inc, Japan) on an ASA 400 Kodak film (Messrs Kodak Film Inc. USA).

RESULTS

Phenology

Padauk sheds leaves in April and new flush initiates by early May (Plate 12, Fig. 1). In the initial stages foliage is yellowish green in colour and eventually turns dark green within a week. Considerable variations exist in phenological response among and within populations (Table 2). Flowering patterns vary within and among populations. In South Andaman trees are practically evergreen and in a partial leafless state only for two to three weeks. However, populations in Middle Andaman and patches of North Andaman have an extended leafless phase. Further in dry patches leaves start shedding starts as early as February.

Floral buds develop only after complete leaf flushing. They are dark brown in colour and are produced in thousands on individual trees. Entire crown of the trees flower profusely and are recognizable from very long distances. Flowering is staggered, not all individuals within a population flower simultaneously (Table 2). Flowering rhythm in Padauk is quite unusual, individual trees flower once in two days and not on all days.

The southern populations flower ahead of those distributed in the north and middle of Andaman. Fruits are completely mature by late November and are harvestable during late January through March.

Floral and pollen biology

Inflorescence is a raceme, each subtending 12-24 flowers, eight to ten such units get compounded on terminal branches. Flowers vary in colour from bright yellow to orange yellow, bisexual, sub sessile and zygomorphic. They are very fragile, open only for a day and abort in masses during heavy rains. The flower is typically papilionaceous with a standard petal in 15 mm in length and 10 mm in

Table 2. Variation in phenology among and within Padauk populations

Location	Trees observed	Phenological stages*		
		Leaf flush	Bud	Bloom
Kishori Nagar	50	35 (70)	11(22)	4 (8.0)
Mayabunder	23	10 (43.4)	9 (39.1)	3(13.0)
Karmatang	45	20(44.4)	18(40)	8(17.7)
Webi	54	18(33.3)	32(59.2)	4(7.4)
Tugapur	55	16(29.0)	37(67.2)	2(3.6)
Rangat	43	15(34.8)	20(46.5)	8(18.6)
Kadamtala	48	10(20.8)	30(62.5)	8(16.6)
Udaygarh	46	15(32.6)	25(52.3)	6(13.04)
Nilambur,	46	9(19.5)	27(58.6)	10(21.7)
Shoal Bay IX	36	6(16.6)	15(41.6)	15(41.6)
Kalatang,	79#	12(15.1)	55(69.2)	12(15.1)
Chidiyatapu,	44	9(20.5)	10(22.7)	23(52.2)

* Observed during Late May, Values in parenthesis is %, # Plantation

breadth. The wing petals are 7.0 mm in length and 5.0-6.0 mm in breadth. The keel petals are 4.0 - 5.0 mm in length and 3-3.5 in breadth. Other floral characteristics have been described in Table. 3.

Flowers unwind in nights (21.00 hr) and are completely open by 05 30 hr. Padauk exhibits temporal dichogamy. Flowers are weakly protandrous, anthers start dehiscing by 06 30 hr and end by 0730 0745 hr. Each anther produces 3600 ± 120 sticky pollen grains that are highly fertile (99 per cent) (Table 3). The stigma protrudes well above the stamen (4-5mm) and curves downward ensuring spatial separation. The stigma is of wet type and receptive by 0745 – 0800 hours. Control pollinated pistils show about 11 ± 4 pollen grains traversing the style at this state. During peak receptivity (at 11.30 hours) pollen tube count in style steadily increases to 22 ± 6. Pollen count declines to 8 ± 2 pollen by 12.30 and the stigma is practically dry by the 1500 hours.

Self and crossed pollen do not exhibit any significant difference in growth pattern and fertilization. Under heavy rains anthesis is prolonged. Consequently with no visitors flowers abort in masses. Petals start abscising 1230 hr and by 1630 - 1700 hr most flowers are naked exposing the staminal column. The style and stigma remain intact until the first two weeks. The base of the developing ovary is clothed with dark coloured uni-seriate hairs. The calyx along with stamens persists on fruits even after complete maturation. Ovaries contain only two ovules (Table 3). Young fruits are linear in shape during the first week become dorsi-ventrally flat round samara within three weeks.

Table 3. Floral features of *Pterocarpus dalbergioides*

Characteristic	Observation
Flowering period	May-June
Flower type	Entomophilous
Flower colour	Bright Yellow–Deep orange
Symmetry	Zygomorphic
Odour	Absent
Nectar	Present
Anthesis	Midnight to early morning
Anthers/flower	10, dithecous
Pollens/anther	3600+20
Pollen fertility	99%
Pollen size	30 38μm
Pollen type	Yellow, spherical, smooth walled, tricolpate
Pollen/ovule ratio	18000 : 1
Stigma type	Stigma wet, pointed, projected above anthers
Ovules per flower	2

Insect visitors

No large visitors like bats and birds were recorded; only diurnal pollinators were noticed. Taxonomically wide diverse taxa of insects like Honeybees (*Apis dorsata, Apis cerana indica, Apis mellifera*), Bumblebees, Wasps and Hawk moths visited the padauk. Among the bees Apis dorsata was found to be major visitor (50-60 per cent) (Plate 12, Fig. 2). A sizeable number of thrips were also found residing within flowers. The most visiting insect group was honeybees followed by bumblebees, wasps and hawk moths (Plate 12, Fig. 2). In terms of foraging efficiency honeybees exhibited the longest duration of stay on flowers and the least was by sphingids.

Open and control pollination

Open pollination fruit set varies from 1.9 - 6.4 per cent (Table 4 and 5) (Plate 13, Fig. 3). In control pollination fruit set in cross pollen was higher than self. No fruit set was noticeable in apomixis. Self and crossed pollen are equally effective in fertilizing ovules and fruits develop regardless of the pollen quality. In most fruits only one ovule matured into a seed. Fruit set in cross-pollination is higher than in self-pollination (Table 4). Padauk fruit is a winged Samara that grows rapidly into full size within a period of 2-3 weeks.

Table 4. Fruit set in open, cross and pollination in *P. dalbergioides*

Treatment	Tree1 (%)	Tree2 (%)	Tree3 (%)
Apomixis	0	0	0
Open pollination	4.9	2.5	6.4
Cross pollination	18	22	24
Self pollination	5	4	5

Table 5. Mature fruit/flower ratio, seed/ovule ratio and reproductive success under open pollination in a *P. dalbergioides* natural population

Trees	Fruit/flower ratio	Seed/ovule ratio	PERS*
T 1	0.049	0.42	0.0205
T 2	0.025	0.54	0.0135
T 3	0.064	0.37	0.0236
T 4	0.034	0.56	0.0190
T 5	0.019	0.57	0.0180

*–Pre Emergent Reproductive Success values Wiens *et al.*, 1987., method

Fruit size and weight

Considerable variations exist in fruit size and shape within and among populations (4-7 cm length; 1.6–7 cm breadth) (Plate 13, Fig. 4). Fruits weighed 0.2 grams 2.7 grams. Among populations Long Island fruits were the heaviest weighing 2.2 to 2.7 grams.

Seed filling and size

Among the twelve populations studied fruits with single seed set was the commonest trend (41-57 per cent). Fruits with no seed filling varied from 13-35 per cent. Two seed filling was found to be 11-40 per cent. Rarely three seed filling was also noticed in most populations 1-8 per cent. The shape of Padauk seed is quite distinct when compared to other species. The seed is of sickle shape (Plate 13, Fig. 5). Its size seems to be constant in most populations except that the Long Island collections showed large sized seeds.

Reproductive Success

Fruit set varied from 1-6 per cent, while seed set was ranging 37–67 per cent. The reproductive success varies from 0.01 to 0.02 (Table 5).

DISCUSSION

Tropical trees distributed in wide agro-climatic ranges exhibit varying phenological responses. In padauk the Eastern group of Islands flowers in a different period compared to the main Andaman group of Islands in the west. A similar trend has been reported in P. indicus a close relative of padauk which is widely distributed in South East Asia (Thompson, 2006). Such phenological variations have implication on population structure in time and space (Loveless and Hamrick, 1984). While cataloguing wild genetic resources this could be useful tool in delineating unique populations.

In individual Padauk trees are the flowering rhythm in is quite unique. Unlike most tropical trees Padauk does not flower in consecutive days instead they flower once in two or three days. A similar behaviour was noted by Rao and Raju (2002) in *P. santalinus* natural populations. Once pollinators recognize greater floral rewards within a population their movements attain constancy. In apiphilous species it is likely to promote geitonogamy or related selfing. Thus tripping of flowering is probably an adaptation to randomize pollen pool, pollinator movement and consequently increase outcrossing. This could be of consequence while developing Seed Production Areas. Thinning regimes should be based on phenological rhythm.

In terms of period and frequency of visitation Apis dorsata is the most effective pollinator (nearing 50 per cent). It is also observed Apis dorsata plays the key role of opening of keel petals in flowers to expose the stamens. There is a need to survey the availability of bee colonies and formulate conservation strategies. The species shows high pollen fertility and there are no signs of any kind of sterility. Such high rates indicate that the species has specialized in male functions and that no significant inbreeding has occurred.

Ganapathy and Rangarajan (1964) observed only 50 per cent germination in Padauk nurseries. In tropical trees with massive crowns and profuse flowering geitinogamy cannot be averted (Hedegart, 1973). However, through high rates of flower, fruit and seed abortion tropical trees maintain heterozygosity within populations (Bawa and Webb, 1984; Tangmitcharoen and Owens, 1997). The present study confirms that about 50 per cent seeds abort at very early stage of fruit development. A large proportion of fruits do not show any trace of seed filling. A similar trend in fecundity was noticed in *P. santalinus* (Rao and Raju, 2002). Further in Padauk nurseries plenty of weak seedlings are noticed that fail to survive (Ganapathy and Rangarajan, 1964) could be resultant of crown selfing. Thus practicing foresters should intensively screen nurseries seedlings for at least six months to eliminate inbred progeny.

Studies on mating systems in species like *P. offficinalis* (Rivera-Ocasio *et al.*, 2002), *P. macrocarpus* (Leingsiri *et al.*, 1998) and *P. indicus* (Changtragoon, 2002) confirm very high outcrossing rates. The breeding system of Padauk can be no different from the above said species. In the present study high flower, fruit and seed abortions indicate that Padauk is high out crossing species. The values are comparable to Teak which is a highly self-incompatible species (Nagarajan *et al.*, 1996). Based on open and control pollination experiments it is understandable that Padauk is a preferential out crosser. Even though selfed products are eliminated through flower abortion a low proportion does mature in to fruits. However, these do not contribute in producing zygotes.

In terms of reproductive output, no significant differences could be noticed between wild and planted Padauk. Thus developing Seed Production Areas (SPAs) and seed stands is an immediate deployable strategy. In SPAs seed collections from very early and late flowering individuals need to be avoided, as they are likely to bear greater proportion of selfed offspring. Harvesting seeds from individuals that have greater overlap of phenology would be advantageous.

The present investigation on reproduction leads us to infer that variations in wild are ample and the species has specialized through male reproductive functions. Padauk does not have any reproduction related bottleneck. It has an optimal reproductive success comparable to most self-incompatible tropical trees. All populations sampled in this study reserve good seed bank. Phenologically isolated populations could be treated as unique genetic resources.

Further there are a few aspects that deserve our attention in our process of cataloguing Padauk:

- Intensive Screening Inter and Intra Population variations to delineate Genetically Diverse Hot Spots (GDHS).
- Ascertaining provenance variations using DNA markers
- Estimation of out crossing rates and understanding seed migration

Clarifications on the said aspect could be supportive to develop an effective domestication program for the future.

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Plate 12

Fig. 1. A tree in deciduous phase

Fig. 2. Apis dorsata pollinating a Padauk flower

Plate 13

Fig. 3. Control Pollination studies in Padauk at Kalatang

Fig. 4. Fruit size variation in Padauk

Fig. 5. Padauk Seeds

Chapter 20

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 239-247, 2010

DIVERSITY OF DECAPOD CRUSTACEANS IN GREAT NICOBAR ISLAND

THOMAS J. KARIATHIL, S. M.RAFFI, S. AJMAL KHAN* and L. KANNAN
Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608502 Tamil Nadu

INTRODUCTION

Decapoda is the most highly developed Order in Crustaceans, which has about 8500 species. The members of Decapoda are found at all depths and levels of the sea, some lead semi-terrestrial life and others terrestrial life. As per Latreille (1825), prawns, shrimps, lobsters and stomatopods belong to Macrura division of Decapoda, crabs belong to Brachyura, and hermit crabs belong to the intermediate division, Anomura. Decapoda is classified into 2 groups namely the Natantia or swimming decapods and the Reptantia or crawling decapods. Crustaceans are found in a number of habitats such as sea, estuary, sandy, muddy and rocky intertidal areas, mangroves, sheltered creeks, algal weeds, tide pools, sand beaches, coral reefs and other marine areas. Crustaceans reside at all these habitats above the high waters to the deep abyssal zones.

Shrimps, lobsters, crabs and stomatopods occur in the mangroves, seaweeds, seagrasses, and coral reefs benthic regions. Brachyuran and hermit crabs are mostly distributed in the coral reefs, mangroves, intertidal areas, seagrass beds, sandy beaches, sheltered creeks and lagoons. They exhibit varied density and diversity in these habitats. Some species are found specifically in some of these habitats, while a majority of the species overlaps and they live in more than one habitat.

Majority of the littoral crabs are nocturnal in nature, most of them hide under rocks, or dead corals, or in their crevices or in burrows of soft sediments. Certain crabs remain buried in intertidal mud and sandy beaches and others occupy the prop roots of mangroves and rocks. Coral reefs have diverse habitats and a good number of holes, crevices and cavities, which provide sufficient shelter or hideout for crustaceans. All these serve as sufficient reasons for the impressive diversity of crustaceans in coral reef ecosystems.

Crabs are having greater medicinal and pharmaceutical uses. Crab meat has many therapeutic properties; it is free from cholesterol and is good for cardiac disorders. Crab curry is regarded as reputed cure for asthma. A soup prepared from swimming crabs is used during the coalescing stage after getting malaria and typhoid. The crab *Scylla* is consumed as a cure for dysentery. The ghost crab *Ocypode platytarsis* is considered good for curing diarrhoea and dysentery. The crushed carapace of *Uca* spp. is given for hyperacidity as a paste. Vitamins are extracted from the hepatopancreas of crabs.

University of Delaware Sea Grant researchers suggest that discarded crab shells can be used in manufacturing surgical suture threads, which are non-allergic and easily dissolvable. Chitin threads

*E.mail : s_ajmalkhan@rediffmail.com

made from crabs enhance wound healing. Nowadays, pulverized crab shells are made use of for making wound healing ointments (Lyla *et al.*, 1989). In the light of the above said aspects, the present study was carried out to assess the distribution, abundance and diversity of major marine crustaceans in the coastal area in and around the Great Nicobar Island. Moreover, a comparison of the present findings with the results of the previous years has also been made.

MATERIALS AND METHODS

Decapod crustaceans *viz.* brachyuran crabs, hermit crabs, shrimps, stomatopods and lobsters were collected from 33 stations located in the eastern, southern, western and northern parts of the Great Nicobar Island during the study period. The stations were sampled and their latitude and longitude positions were given in Table 1. In addition, regular data were obtained from crustacean fishery landings at Campbell Bay fish market. Generally, hand picking method was adopted for the collection of crabs in the intertidal and subtidal zones. Netting and trapping are the existing commercial fishing practices in the islands. The intertidal burrowing crabs were collected by digging or by pouring dilute formalin or weak acid inside the burrow. The brachyuran and hermit crabs and stomatopods were collected during low tides from various stations. Quantitative sampling was done by the quadrat method. A quadrat of 50 × 50 cm was placed for sampling at an interval of 5 m in a transect parallel to the shore for about 200 m. The number of animals which fell inside the quadrat was counted each time and the density has been expressed as individuals/m^2 (Reys, 1964).

The collected crabs were preserved in 10 per cent formalin, neutralized with Hexamine *i.e.* 100g per 1000ml formalin. Some preservatives were added to preserve the colouration of the samples. Aqueous solution of sodium arsenite (5 per cent) was used to preserve the crabs with red and related colours. Neutralised formalin with glycerine was used for grey or black coloured specimens. A mixture of 5 gm sodium arsenite and 5cc formalin in 95cc water was found effective for preserving crabs with white iridescent colouration of carapace.

RESULTS AND DISCUSSION

Distribution of fauna in the nallahs of the east coast

a) Brachyuran crabs : Of the total of 51 species belonging to 33 genera of brachyuran crabs recorded from various nallahs of the study area, the families Portunidae, Xanthidae, Ocypodidae and Grapsidae topped the list with 7 species each (13.73 per cent), followed by Leucosiidae with 6 species (11.76 per cent), Majidae with 4 species (7.84 per cent), Carpilidae, Pilumnidae, Calappidae, Dromiidae, Dorippidae and Plagusidae, each with 2 species (3.92 per cent) and Mictyridae with 1 species (1.96 per cent).

Among the 33 genera recorded, *Thalamita* ranked first with 4 species, *Charybdis, Atergatis, Ocypode, Uca* and *Grapsus* with 3 species each followed by *Carpilius, Pilumnus, Doclea, Matuta* and *Calappa*, each with 2 species. The rest of the genera were represented with one species each.

A total of 988 brachyuran crabs were recorded from all the nallahs. Family Ocypodidae was in abundance 253 numbers (25.61 per cent) followed by Grapsidae 232 numbers (23.48 per cent), Xanthidae (98 numbers, 9.92 per cent), Portunidae (95 numbers, 9.62 per cent), Plagusidae (68 numbers, 6.88 per cent), Leucosiidae (67 numbers, 6.78 per cent), Majidae (40 numbers, 4.05 per cent), Pilumnidae (33 numbers, 3.34 per cent), Dromiidae (26 numbers, 2.63 per cent), Carpilidae (24 numbers, 2.43 per cent), Calappidae (21 numbers, 2.13 per cent), Dorippidae (20 numbers, 2.02 per cent) and Mictyridae (11 numbers, 1.11 per cent) (Fig. 1).

b) Hermit crabs : 18 species of hermit crabs were recorded from various nallahs. Family Diogenidae topped the list with 13 species (72.22 per cent), followed by Paguridae with 3 species (16.67 per cent) and Coenobitidae with 2 species (11.11 per cent) (Table 1). Totally, there were 8 genera. Genus *Clibanarius* came first in the list with 4 species, followed by *Dardanus* with 3 species, and *Calcinus, Diogenes, Paguristes, Pagurus* and *Coenobita* with 2 species each. *Aniculus* was represented by one species. The total number of hermit crabs identified from all the nallahs was 579. Family Diogenidae came first with 394 numbers (68.05 per cent) and Paguridae second with 114 numbers (19.69 per cent) in the order of abundance. This was succeeded by Coenobitidae (71 numbers, 12.26 per cent) (Fig. 2).

c) *Shrimps and stomatopods* : A total of 48 shrimps and 63 stomatopods were recorded from the above nallahs (Table 1). However, shrimps and stomatopods were not recorded in the first year of the study.

Table 1. Stations sampled in the Great Nicobar Island

Sl. No.	Station	Coast line*	Location
1.	Dongi nallah	E	Lat. 07°01.700′ N; long. 093°53.933′ E
2.	Magar nallah	E	Lat. 06°59.605′ N; long. 093°55.001′ E
3.	Sippy nallah	E	Lat. 06°58.612′ N; long. 093°55.681′ E
4.	Prem nallah	E	Lat. 06°56.659′ N; long. 093°55.008′ E
5.	Dillon nallah	E	Lat. 06°55.962′ N; long 093°54.770′ E
6.	Dubey nallah	E	Lat. 06°53.209′ N; long 093°53.913′ E
7.	Swarup nallah	E	Lat. 06°49.339′ N; long 093°54.181′ E
8.	Laful Bay	E	Lat. 07°10.620′ N; long 093°52.792′ E
9.	Campbell Bay	E	Lat. 06°59.863′ N; long 93°55.896′ E
10.	Vijay nagar	E	Lat. 06°54.606′ N; long 93°55.770′ E
11.	Lakshmi nagar	E	Lat. 06°52.993′ N; long. 093°55.990′ E
12.	Sastry nagar	E	Lat. 06°48.163′ N; long. 093°53.304′ E
13.	Galathea Bay	E	Lat. 06°49.166′ N; long 093°51.544′ E
14.	Galathea river mouth	E	Lat. 06°48.961′ N; long 93°51.130′ E
15.	Galathea estuary	E	Lat. 06°48.974′ N; long 93°51.810′ E
16.	Indira point	S	Lat. 06°45.293′ N; long 093°49.648′ E
17.	Chingen basthi	E	Lat. 06°48.360′ N; long 93°51.218′ E
18.	Inhengloi (shore)	W	Lat. 06°48.185′ N; long 93°47.871′ E
19.	Inhengloi (open sea)	W	Lat. 06°48.185′ N; long 93°47.871′ E
20.	Pilobhabi	W	Lat. 06°53.886′ N; long 93°45.670′ E
21.	Koshindon	W	Lat. 06°54.972′ N; long 93°44.543′ E
22.	Kopen heat	W	Lat. 06°57.592′ N; long 93°44.026′ E
23.	Alexandria (river) Bay	W	Lat. 06°59.353′ N; long 93°43.536′ E
24.	Dagmar	W	Lat. 06°59.162′ N; long 93°41.748′ E
25.	Casuarina Bay	W	Lat. 06°59.676′ N; long 09°42.032′ E
26.	Pilokunji	W	Lat. 07°01.004′ N; long 09°39.783′ E
27.	Pilobet	W	Lat. 07°04.058′ N; long 093°39.463′ E
28.	Kiched nallah	W	Lat. 07°14.252′ N; long 93°39.620′ E
29.	Safeath balu	N	Lat. 07°11.400′ N; long 93°40.919′ E
30.	Pryce Channel	N	Lat. 07°12.230′ N; long 93°42.412′ E
31.	Trinket choplong Bay	N	Lat. 07°13.200′ N; long 93°50.962′ E
32.	Pigeon island (Goltekri)	E	Lat. 07°05.823′ N; long 93°53.010′ E

*E = East, W = West, S = South, N = North

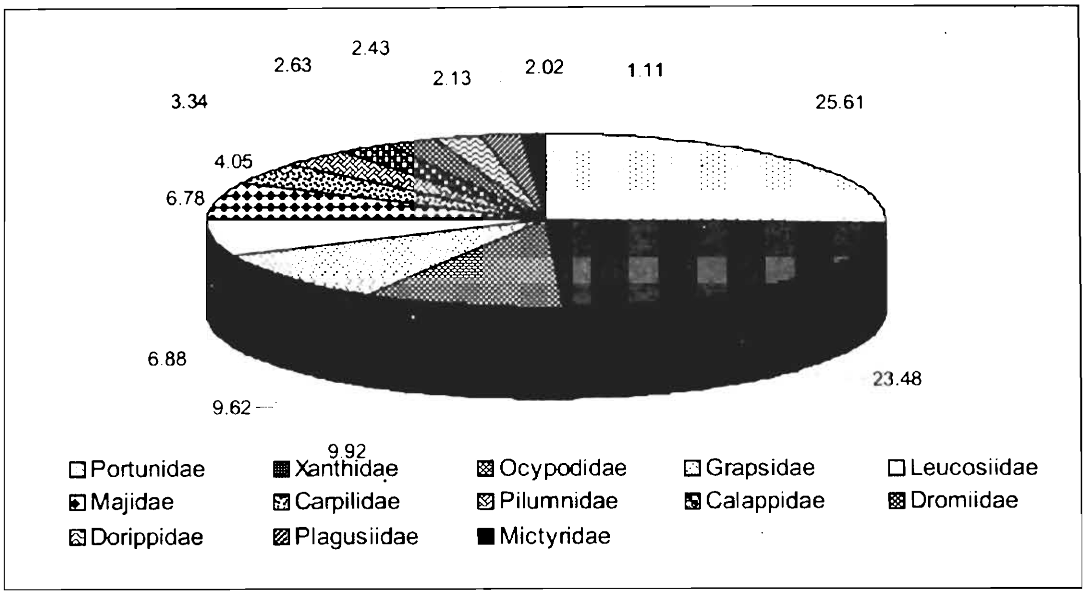

Fig. 1. Family abundance (per cent) of brachyuran crabs in the nallahs of east coast of the Great Nicobar Island

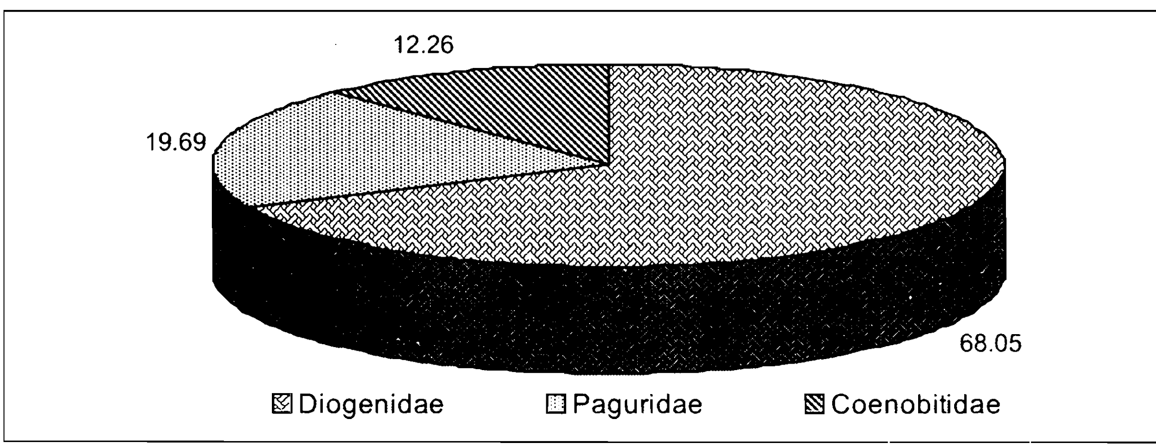

Fig. 2. Family abundance of hermit crabs in the nallahs of the east coast of the Great Nicobar Island

Distribution of fauna in the nagars and Galathea Bay of the east coast

a) Brachyuran crabs : As in the case of nallahs, 51 species of brachyuran crabs were recorded only from all the nagars including the Galathea Bay, Chingen basthi and Indira Point (station in the south coast). Families Portunidae, Xanthidae, Ocypodidae and Grapsidae dominated each with 7 species (13.73 per cent) and Leucosiidae with 6 species (11.76 per cent), followed by Majidae with 4 species (7.84 per cent), Carpilidae, Pilumnidae, Calappidae, Dromiidae, Dorippidae and Plagusiidae each with 2 species (3.92 per cent) and Mictyridae with 1 species (1.96 per cent). In total, 33 genera were found. Of these, *Thalamita* top ranked with 4 species, followed by *Charybdis*, *Atergatis*, *Ocypode*, *Uca* and *Grapsus* each with 3 species. *Carpilius*, *Pilumnus*, *Doclea*, *Matuta* and *Calappa* had 2 species each and the rest one species each.

Total number of brachyuran crabs listed from all the nagar stations was 1062. Family Ocypodidae ranked first in the order of abundance (329 numbers, 30.98 per cent) and Grapsidae (194 numbers, 18.27 per cent) came second. These were followed by Xanthidae (112 numbers, 10.55 per cent), Portunidae (91 numbers, 8.57 per cent), Leucosiidae (75 numbers, 7.06 per cent), Plagusiidae (54 numbers, 5.08 per cent), Majidae (51 numbers, 4.80 per cent), Dromiidae (39 numbers, 3.67 per cent), Pilumnidae (38 numbers, 3.58 per cent), Carpilidae (30 numbers, 2.82 per cent), Calappidae (26 numbers, 2.45 per cent), Dorippidae (13 numbers, 1.22 per cent) and finally Mictyridae (10 numbers, 0.94 per cent) (Fig. 3).

b) Hermit crabs : As observed in nallahs, 18 species of hermit crabs were recorded from all the nagars. Family Diogenidae topped with 13 species (72.22 per cent), followed by Paguridae with 3 species (16.67 per cent) and Coenobitidae with 2 species (11.11 per cent) as observed in nallah samplings (Table 2). As a whole, there were 8 genera. Genus *Clibanarius* topped the list with 4 species. Genus *Dardanus* was having 3 species and genera *Calcinus, Diogenes, Paguristes, Pagurus* and *Coenobita* were represented each with 2 species. The genus *Aniculus* was represented by one species.

In total, there were 436 hermit crabs in all the nagar stations. Family Diogenidae dominated with 334 numbers (76.61 per cent), which was followed by Coenobitidae (53 numbers, 12.16 per cent) and Paguridae (49 numbers, 11.24 per cent) in the order of abundance (Fig. 4).

c) Shrimps and stomatopods : In all the nagar stations, a total of 48 shrimps and 81 stomatopods were recorded. In these stations, there were also 2 species each of shrimps and stomatopods.

Distribution of fauna in the west coast

a) Brachyuran crabs : Thirty nine species of brachyuran crabs were found in various stations of the west coast. Family Grapsidae ranked first with 6 species (15.38 per cent), and Leucosiidae and Ocypodidae followed with 5 species each (12.82 per cent). These were followed by Portunidae and Xanthidae with 4 species each (10.26 per cent), Majidae with 3 species (7.69 per

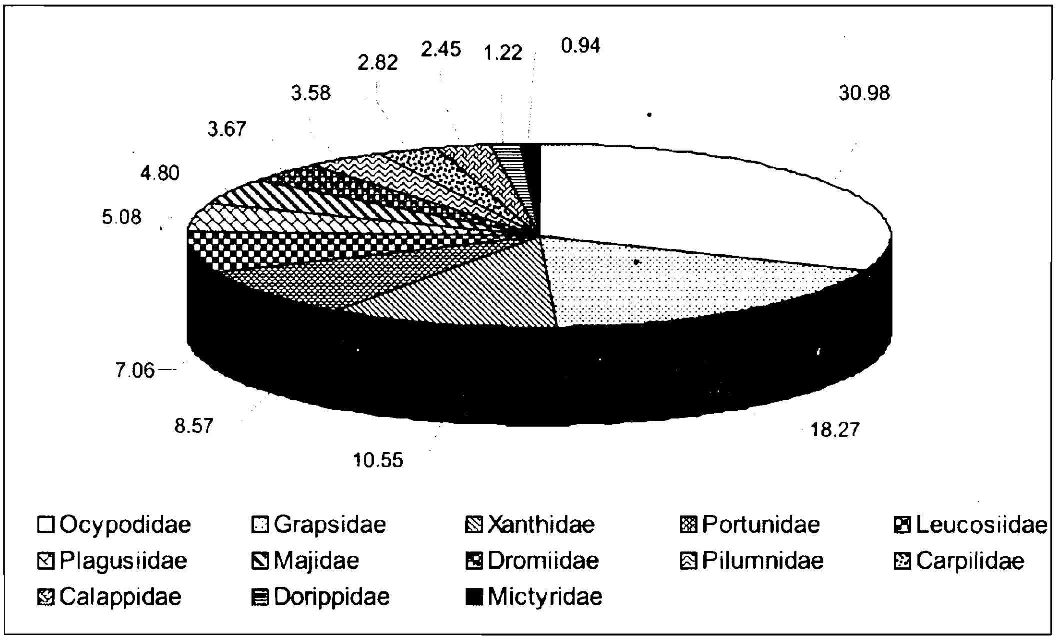

Fig. 3. Family abundance of brachyuran crabs in the nagars of east coast of Great Nicobar Island

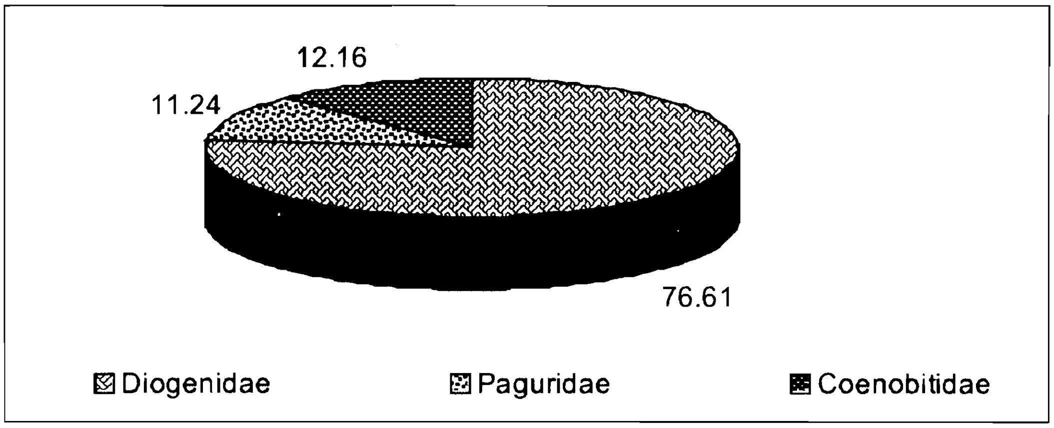

Fig. 4. Family abundance of hermit crabs in the nagars of the east coast of the Great Nicobar Island

Table 2. List of new distributional records of crustaceans to the Great Nicobar Island.

Brachyuran crabs			
1.	*Scylla serrata*	29.	*Leucosia rhomboidalis*
2.	*Portunus pelagicus*	30.	*Randallia lanata*
3.	*P. sanguinolentus*	31.	*Matuta banksii*
4.	*Charybdis (Charybdis) feriata*	32.	*M. lunaris*
5.	*C. (Charybdis) annulata*	33.	*Calappa gallus capellonis*
6.	*C. truncata*	34.	*Calappa bicornis*
7.	*Thalamita crenata*	35.	*Ocypode ceratophthalma*
8.	*T. prymna*	36.	*O. cordimana*
9.	*T. sima*	37.	*O. macrocera*
10.	*T. stimpsoni*	38.	*Uca annulipes*
11.	*T. sima*	39.	*U. dussumieri*
12.	*Carpilius convexus*	40.	*U. marionis excisa*
13.	*C. maculatus*	41.	*Dotilla myctiroides*
14.	*Galene bispinosa*	42.	*Mictyris longicarpus*
15.	*Atergatis floridus*	43.	*Dromia dehanni*
16.	*A. integerrimus*	44.	*Petalomera granulata indica*
17.	*A. roseus*	45.	*Dorippe astuta*
18.	*Eriphia sebana*	46.	*Ethusa indica*
19.	*Zosymus aeneus*	47.	*Grapsus albolineatus*
20.	*Platypodia cristata*	48.	*G. strigosus*
21.	*Pilumnus hirsutus*	49.	*G. tenuicrustatus*
22.	*P. vespertilio*	50.	*Metopograpsus frontalis*
23.	*Doclea alcocki*	51.	*Sesarma (Chiromantes) bidens*
24.	*D. ovis*	52.	*Metaplax distincta*
25.	*Hyastenus oryx*	53.	*Nanosesarma (Nanosesarma) minutum*
26.	*Phalangipus hystrix*		
27.	*Arcania quinquespinosa*	54.	*Plagusia depressa* var. *immaculata*
28.	*Myra fugax*	55.	*Percnon planissimum*
Hermit crabs			
1.	*Calcinus gaimardi*	10.	*Diogenes avarus*
2.	*C. herbsti*	11.	*D. custos*
3.	*Clibanarius corallinus*	12.	*Paguristes balanophilus*
4.	*C. longitarsus*	13.	*P. ciliatus*
5.	*C. merguiensis*	14.	*Aniculus aniculus*
6.	*C. striolatus*	15.	*Pagurus pergranualatus*
7.	*Dardanus asper*	16.	*P. zebra*
8.	*D. deformis*	17.	*Coenobita cavipes*
9.	*D. megistos*	18.	*C. rugosa*

cent), and Carpilidae, Pilumnidae, Calappidae, Dromiidae, Dorippidae and Plagusiidae each with 2 species (5.13 per cent).

Among the total 29 genera recorded, *Thalamita* topped the list with 3 species, and *Carpilius, Atergatis, Pilumnus, Matuta, Calappa, Ocypode, Uca* and *Grapsus* were represented with 2 species each and the rest, by one species each.

Altogether 1441 brachyuran crabs were collected from the stations of the west coast. Families Ocypodidae and Grapsidae came first with 341 numbers in each (23.66 per cent) in the order of abundance. These were succeeded by Xanthidae (180 numbers, 12.49 per cent), Portunidae (127 numbers, 8.81 per cent), Plagusiidae (99 numbers, 6.87 per cent), Leucosiidae (88 numbers, 6.11 per cent), Dromiidae (62 numbers, 4.30 per cent), Majidae (48 numbers, 3.33 per cent), Calappidae (47 numbers, 3.26 per cent), Carpilidae (45 numbers, 3.12 per cent), Pilumnidae (39 numbers, 2.71 per cent) and lastly Dorippidae (24 numbers, 1.67 per cent) (Fig. 5).

b) Hermit crabs : A total of 15 species of hermit crabs were recorded from the west coast. Family Diogenidae topped the list with 10 species (66.67 per cent), followed by Paguridae with 3 species (20.00 per cent) and Coenobitidae with 2 species (13.33 per cent). Totally, there were 8 genera of crabs, of which *Calcinus, Clibanarius, Dardanus, Diogenes, Paguristes, Pagurus* and *Coenobita* contributed 2 species each. The genus *Aniculus* was represented by one species. As a whole, 556 hermit crabs were recorded from the stations of the west coast. Family Diogenidae came first with 391 numbers (70.32 per cent) and Paguridae second with 91 numbers (16.37 per cent) in the order of abundance. This was followed by Coenobitidae (74 numbers, 13.31 per cent) (Fig. 6).

c) Shrimps and stomatopods : In all the above stations, totally 114 shrimps and 76 stomatopods were recorded. As found in nallahs and nagars in the east coast, there were 2 species each of shrimps and stomatopods in the west coast.

There were no regular and established trawling operations due to the increased prevalence of coral reefs all around the island. However, shrimps and lobsters were collected from the daily landings of the fish market at Campbell Bay and also from the fishermen. Penaeid shrimps collected from Campbell Bay fish market and breakwater region were *Metapenaeus dobsoni, M. monoceros* and *Penaeus indicus*. Lobsters such as *Panulirus penicillatus* and *P. ornatus* were obtained from the Campbell Bay fish market. *P. penicillatus* was collected from Galathea Bay and Chingen basthi in the east coast. *P. penicillatus, P. ornatus* and *P. versicolor* were also recorded from Inhengloi, Kopenheat, Casuarina Bay and Megapod Island in the west coast. Measurements like total length and total weight were taken. The total length and total weight recorded for the shrimp *M. dobsoni* were in the ranges of 5 cm–7 cm and 5 g–9 g respectively. The ranges of total length and total

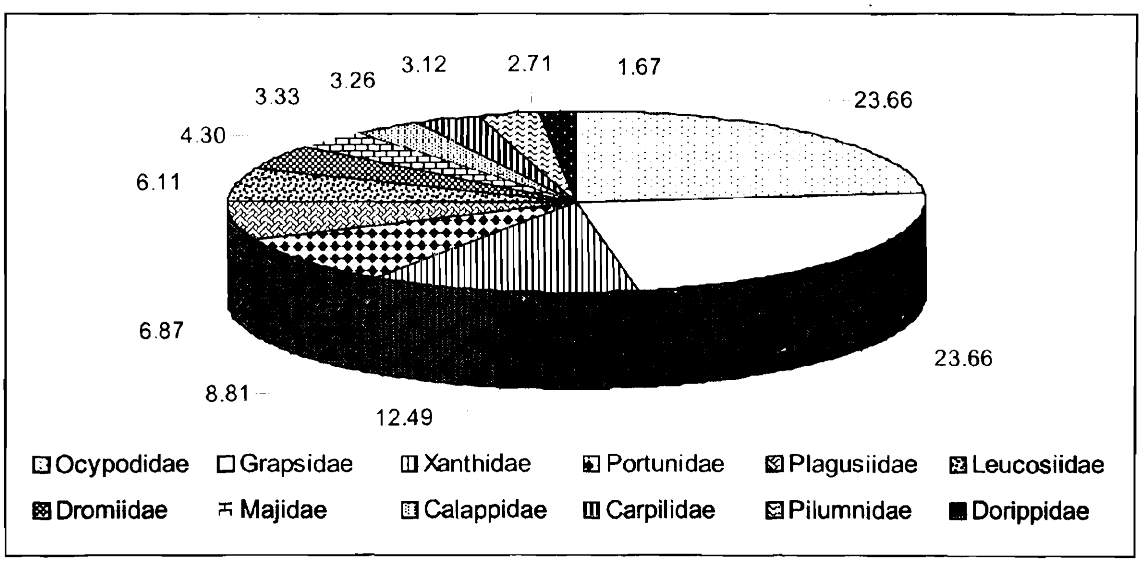

Fig. 5. Family abundance of brachyuran crabs in the west coast of the Great Nicobar Island.

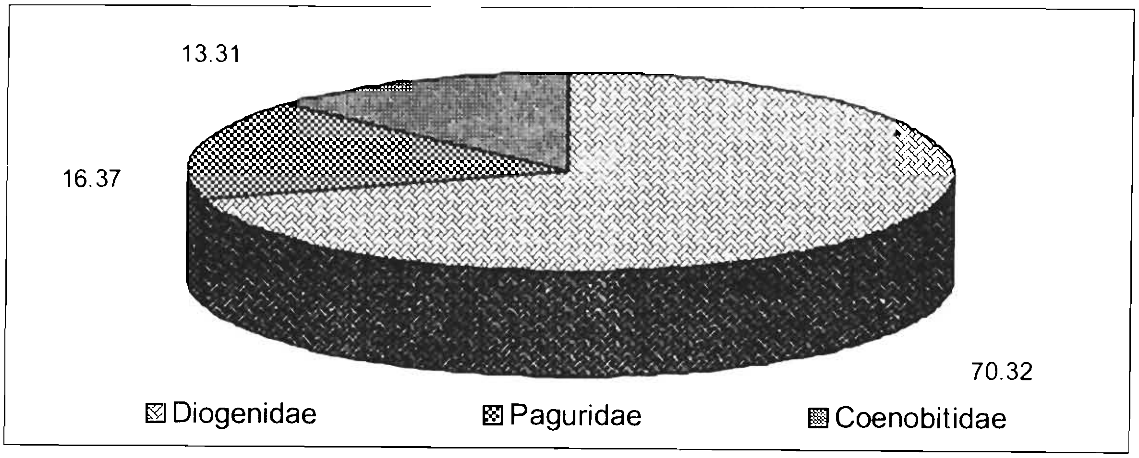

Fig. 6. Family abundance of hermit crabs in the west coast of the Great Nicobar Island

weight for *M. monoceros* and *P. indicus* were 6.5 cm–7 cm and 6 g–9 g; and 4 cm–6 cm and 4 g–7 g respectively. Lobsters were found in the range of 13 cm–20 cm in total length and 200 g - 600 g in total weight.

Station-wise abundance in nallahs (East coast)

As for as the abundance of brachyuran crabs among various nallahs is concerned, Dillon nallah (20.45 per cent) ranked first in the list, followed by Prem nallah (19.33 per cent), Magar nallah (14.88 per cent), Sippy nallah (13.06 per cent), Dubey nallah (12.25 per cent), Dongi nallah (10.83 per cent) and Swarup nallah (9.21 per cent).

With respect to the abundance of hermit crabs, Magar nallah (21.59 per cent) topped the list, followed by Swarup nallah (20.90 per cent), Sippy nallah (13.47 per cent), Dongi nallah (12.61 per cent), Dillon nallah (11.23 per cent), Dubey nallah (10.54 per cent), and finally Prem nallah (9.67 per cent). In the abundance of shrimps, Dubey nallah (25.00 per cent) topped the list, followed by Dillon nallah (16.67 per cent), Swarup nallah (14.58 per cent), Dongi and Prem nallahs (each 12.50per cent), Magar nallah (10.42 per cent) and Sippy nallah (8.33 per cent). In the case of stomatopods, Swarup nallah (20.63 per cent) topped the list, followed by Dubey nallah (19.05 per cent), Dillon nallah (17.46 per cent), Prem nallah (14.29 per cent), Magar nallah (12.70 per cent), and finally Dongi and Sippy nallahs (each 7.94 per cent).

Species richness in nallahs (East coast)

The species richness of brachyuran crabs was found to be higher in Dillon nallah (51 species) and lower in Dubey nallah (38 species) and the order of descend of richness was, Dillon nallah > Magar nallah > Prem nallah > Dongi nallah > Swarup nallah and Sippy nallah > Dubey nallah. Regarding hermit crabs, the highest number of species was recorded in Swarup nallah and Magar nallah (each 18 species) and the lowest in Prem nallah, Dubey nallah and Dillon nallah (each 12 species) and the order of descend of richness was, Swarup nallah and Magar nallah > Dongi nallah > Sippy nallah > Prem nallah, Dubey nallah and Dillon nallah. The two species each of shrimps and stomatopods were present at all the stations.

Species richness in nagars (East coast)

Regarding species richness of brachyuran crabs in various nagars, higher value was recorded in Galathea Bay (51 species) and the lower value, in Campbell Bay (41 species) and the order of descend of richness was,

Galathea Bay > Indira Point > Sastri nagar > Laful Bay, Vijay nagar, Lakshmi nagar and Chingen basthi > Campbell Bay > Pigeon Island

Regarding hermit crabs, the maximum number of species was found in Indira Point (18 species) and the minimum in Campbell Bay (10 species). The order of descend of species richness was, Indira Point > Chingen basthi > Vijay nagar > Lakshmi nagar and Galathea Bay > Pigeon Island > Laful Bay and Sastri nagar > Campbell Bay As a whole, 2 species of shrimps were recorded at all the stations except Laful Bay, Vijay nagar and Lakshmi nagar, and 2 species of stomatopods were noticed at all the stations except Campbell Bay.

Species richness in the west coast

As for as the species richness of brachyuran crabs in all the stations of the west coast is concerned, Kopenheat, Kiched nallah and Pigeon Island recorded the higher values (each 39 species) and the lower value (26 species) was recorded by Megapod Island. The order of descend of species richness was, Kopenheat and Kiched nallah > Casuarina Bay > Koshindon > Pilobet > Alexandria (river) Bay and Pilokunji > Inhengloi > Pilobhabi > Dagmar > Megapod Island. In the case of hermit crabs, the highest richness was found in Kopenheat and Dagmar (each 15 species) and the lowest in Megapod Island, Koshindon and Alexandria river (each 9 species). The order of descend of richness was, Kopenheat and Dagmar > Inhengloi, Casuarina Bay > Pilobhabi, Pilobet and Kiched nallah > Pilokunji > Megapod Island, Koshindon and Alexandria (river) Bay Two species of shrimps were present at all the stations. Likewise, only two species of stomatopods were noticed at all the stations except Kopenheat.

In general, the increased abundance and species richness of brachyuran crabs noticed in Swarup nallah, Magar nallah, Galathea Bay and Indira Point might be due to the increased habitat diversity in these environs. Similarly, the higher species richness of hermit crabs noticed in Indira Point could be ascribed to the elevated habitat diversity prevalent here. Illegal and unauthorized poaching activities were also noticed in both east and west coasts of the island. Hunting of lobsters and crabs was greatly encountered in areas of Sastri nagar, Chingen basthi, South Bay and Laful Bay in the east coast. Regular hunting of lobsters was noted in Kopenheat, Megapod Island and Casuarina Bay in the west coast.

Details of the new distributional records of brachyuran crabs and hermit crabs (Table 2) for Great Nicobar Island based on the collections are given hereunder. A total of 87 species of crustacean have been found as new distributional records for the Great Nicobar Island in the three years of collections. Among these 55 species were Brachyuran crabs belonging to families Portunidae (11 species), Xanthidae, Ocypodidae and Grapsidae (7 species each), Leucosiidae (6 species), Majidae (4 species), Carpilidae, Pilumnidae, Calappidae, Dromiidae, Dorippidae and Plagusiidae (2 species each) and Mictyridae (1 species); 18 species are hermit crabs belonging to families, Diogenidae (13 species), Paguridae (3 species) and Coenobitidae (2 species) besides 9 species of shrimps, 3 species of lobsters, 2 species of stomatopods. Previous study on the decapod crustaceans of the Great Nicorbar island is very much limited. Therefore effective comparison of the present results with the previous one is not possible. Roy and Das (2000) reported the occurrence of 51 species of brachyuran crabs from the mangrove ecosystems in Andaman islands. Compared to this the diversity in the Great Nicobar island is on the higher side. However they were so many limitations when this study was carried out. As fishing activity was less (continues to be so) in the island brachyuran crabs, hermit crabs, shrimps and stomatopods occurring in the inshore waters could not be collected properly. Operation of trawl net and other nets besides organizing fishing cruises will help in proper understanding of the diversity of the above group.

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Chapter 21

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 249-273, 2010

DIVERSITY OF LITTORAL CORALS AND THEIR ASSOCIATED MOLLUSCS AND ECHINODERMS IN ANDAMAN SEA, SOUTH ANDAMAN

C. RAGHUNATHAN*, C. SIVAPERUMAN and RAMAKRISHNA**
Zoological Survey of India, Andaman and Nicobar Regional Centre, Port Blair-744 102, Andaman & Nicobar Islands

INTRODUCTION

With their diverse physical and climate habitats, the Andaman and Nicobar Islands are endowed with a unique and rich heritage of faunal communities. The coastal ecosystem around these islands is well known to support a variety of animal life characteristics of tropical oceanic islands. Having large number of bays, lagoons and creeks fringed with rocky, sandy and muddy beaches, coral reefs, mangrove swamps etc., these islands harbour diverse groups of animals, reputing the inshore areas as a paradise of littoral life (Rao, 1998).

The sub-littoral and neritic waters in the planet earth is about 6.0 lakhs sq km. area covered by coral reefs, rich in myriad forms of marine life (Munro, 1984). This area is almost equivalent to the total exclusive economic zone of Andaman and Nicobar Islands sprawling between latitude 6°45′ N and 13°45′ N and longitude 92°15′ E and 94°00′ E. The continental shelf around the archipelago which is quite narrow spreading for about 3-8 km having an area of 34,965 sq km (Anon, 1977) is the abode of India's richest tropical coral reef ecosystem comparable to any tropical rain forest in productivity and diversity. Corals are perhaps the 'base' animals in the ecological pyramid of Andaman Sea (Whitaker, 1985) and these islands are surrounded by fringing reef on the eastern under and the barrier reef in the western side covers an area of 948.8 sq km. The coral reef fauna known from these islands includes 750 species of fishes, 1422 species of molluscs, 430 species of echinoderms, 112 species of sponges, 235 species of hard corals and 111 species of soft corals, 411 species of crustaceans and 64 species of algae.

Due to topography, the distribution of fauna in the islands varies considerably from area to area and from island to island (Rao and Dev Roy, 1985). Although considerable studies conducted on coral reef faunal communities of these islands, many remote areas in Andaman archipelago still remained biologically unexplored or under-explored. Earlier studies on coral reefs and its faunal resources are also available (Rao and Dev Roy, 1985; Mustafa *et al.*, Mustafa, 1990; Rao *et al.*, 1991; Dorairaj and Soundarajan, 1998, Venkataraman and Alfred, 2002, Venkataraman *et al.*, 2003). Pillai (1996) published a series of account on the coral reefs of Andaman and Nicobar Islands with the impetus gained from the earlier collections made from these islands (Scheer and Pillai, 1974). The molluscan fauna in these islands were better studied by several scientific teams of Zoological Survey of India and among

*E-mail : kscraghu@rediffmail.com
**Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata-700 053

them, Nevill (1874, 1875, 1880), Smith (1878, 1896, 1899), Melvill and Sykes (1897, 1899ab), Preston (1908, 1916), Prashad and Rao (1933, 1934), Rajagopal and Daniel (1973), Rajagopal and Subba Rao (1977), Subba Rao (1970, 1980), Subba Rao and Dey (1991) and Subba Rao and Dey (2000) are noteworthy. The coral reefs in the littoral region of these islands harbour a rich variety of echinoderms which is approximately half of the echinoderm fauna of Indian subcontinent (Sastry, 2005). Bell (1887) for the first time listed the echinoderms of these islands. During the cruises and collections of Royal Indian Marine Survey Steamer *Investigator*, specimens of several species of echinoderms were collected from shallow as well as deep waters. Chief among these investigations, reports of Crinoidea (Clark, 1912 a,b), Asterioide (Wood-Mason and Alcock, 1891; Alcock, 1893, 1894; Koehler, 1914, 1922a, 1927), Holothuroidea (Koehler and Vaney, 1905, 1908; James, 1967-2001; Julka and Das, 1978 and Sastry, 1977-2001) are worth mentioning. However, most of these are stray reports restricted to individual or few species. The studies pertaining to diversity, density and distribution of macrobenthic fauna associated with coral reefs is imperative especially after the devastative earthquake cum tsunami and tidal waves struck upon these islands and hence the present study has been undertaken.

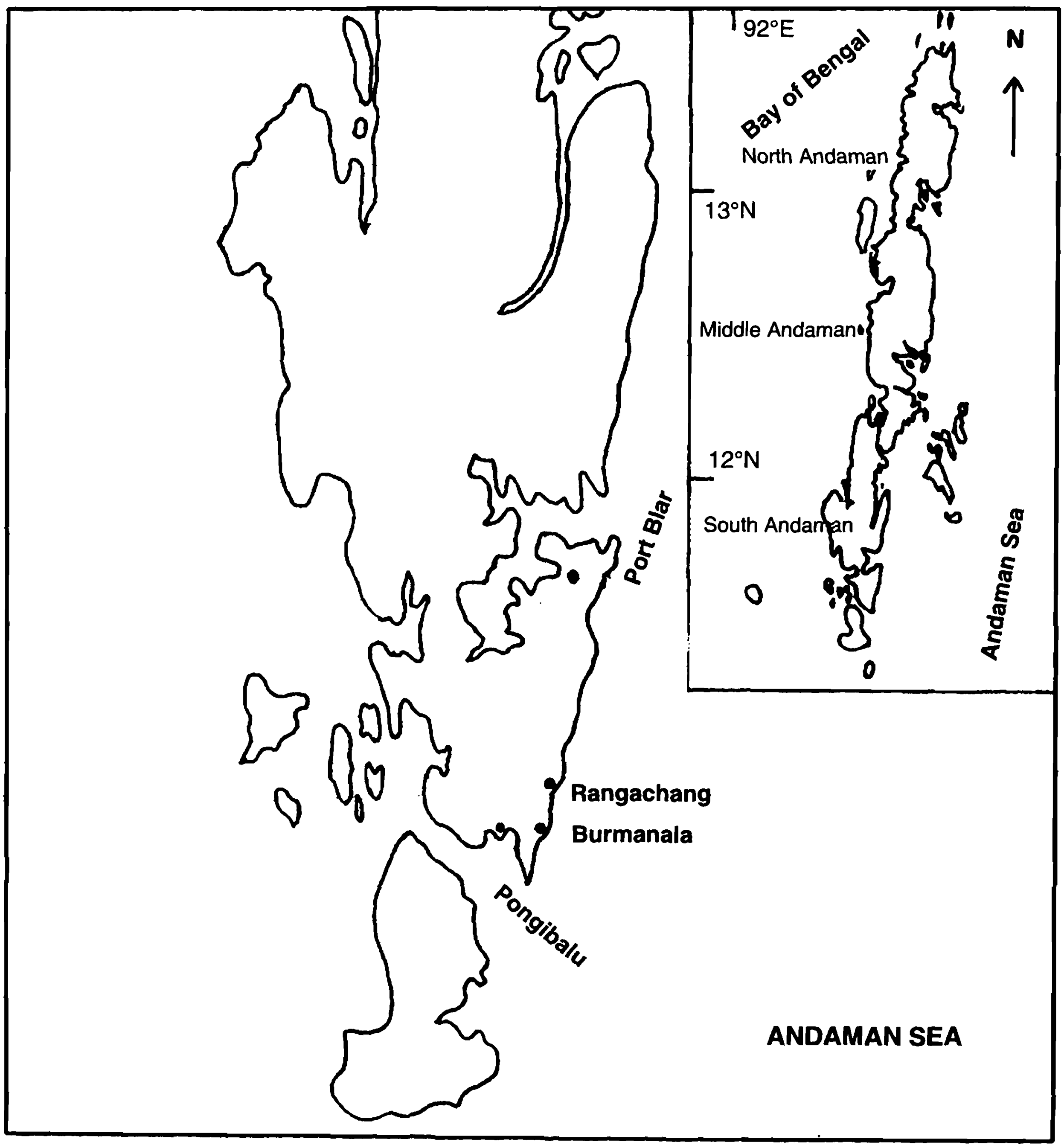

Fig. 1. Map showing the study area

MATERIALS AND METHODS

The present study was conducted in three coral reef areas i.e. Pongibalu (Lat. 11°31.030′ N, Long. 92°39.15.9′ E), Rangachang (Lat. 11°31.030′ N, Long. 92°44.133′ E) and Burmanala (Lat. 11°31.468′ N, Long. 92°43.573′ E) of Andaman Sea in South Andaman during January to March 2008 (Fig. 1). All these sites were severely affected by earthquake during December 24, 2004 where the new coral recruitment is under progress. Apart from corals, molluscs and echninoderms were taken consideration in the present investigation as these macro faunal groups are major reef associated inhabitants. The assemblages of corals, molluscs and echinoderms were studied by estimating their density, diversity and distribution at all three selected sites by conducting series of field surveys during the study period. The Line Intercept Transect (LIT) method (English *et al.*, 1994) was adapted for estimating density of these organisms. In this method quadrant was employed at 10, 25, 50, 75 and 100 meters from the mid littoral zone to infra littoral zone with a depth of 0–5 m water column by snorkeling during low tides. The number of coral colonies, molluscs and echinoderms were quantified at every quadrant. A total of three LIT were operated at an interval of 1km in all three stations and the mean values were calculated for every quadrants.

The species diversity of all three faunal communities was calculated according to the Shanon-Weiner formula;

$H' = \Sigma Pi \log. Pi$

Where Pi = proportion of the *i*th species in the collection, H′ = diversity of a theoretically infinite population.

The similarity of species between stations were calculated using Jaccard index as follows,

$C_j = J/a+b - J$

Where, J = number of species common at any two stations and a = number of species at one station and b = number of species at other station.

RESULTS

The density, diversity and distribution of corals and their associated molluscs and echinoderms estimated through Line Intercept Transect method (English *et al.*, 1994) along the littoral region of Pongibalu, Rangachang and Burmanala areas of Andaman Sea, South Andaman are depicted in tables 1-12. The total area of LIT covers 900 m² at each station and results were calculated for 10m² area of reef flat. The present study reports 30 species of sleractinian corals under 14 genera, 39 species of molluscs under 23 genera and 34 species of echinoderms belongs to 25 genera along the littoral region of aforesaid study area during low tides. *Acropora* was the dominant coral fauna as it recorded 8 species. Among the fauna recorded during this survey, all 30 species of corals reported at Pongibalu, while 26 and 24 species encountered at Rangachang and Burmanala respectively. However, the total number of coral colonies found in Pongibalu ranged from 12/10m² at zero meter depth (10m distance from shore) to 190/10m² at 4.0 m depth where the distance was 75m from the shore. Accordingly the total number of species recorded at different distances and depth varied from 2 to 25 at this station. However in Rangachang the coral colonies varied from 28/10m² to 144/10m² at zero meter depth to 2.5m with a distance of 10m and 50m respectively. The number of species reported from this station was also 5 to 22 for the same set of depths. Whereas in Burmanala the number of colonies of corals ranged from 28/10m² at zero meter depth to 152/10m² at 3.5 m depth(75m distance from shore) with species range of 2 to 20 at these depths. *Porites* and *Pocillopora* were found only at zero meter i.e. 10m from the shore at all the three places of study except Pongibalu where only *Porties* encountered. The LIT data revealed that none of the species of corals was commonly distributed from 10-100 m at all quadrants except *Pocillopora demicornis*, which was recorded at all quadrants in Burmanala. However, species of *Acropra, Ctenacis, Favia, Fungia* and *Porites* were observed at depths from 1m to 5m during low tides. It is also to state that *Montipora digitata* recorded only at 1.0m depth at Pongibalu, *Acropora rudis* only at 2.5m depth at Rangachang and *Acropora muricata, Seriastopora hystrix* and *Symphyllia recta* reported at 100 m distance from the shore i.e. 4.5 to 5.0m depth. The LIT observation also found that the individual species density of coral recruits at all there stations ranged from 4 to 16/10m².

Molluscs were the dominant in numerical density as well as diversity in the presently surveyed reef areas. Among molluscs reported, 33 species belongs to gastropods and 4 species belongs to bivalves while 2 species under polyplacophorans. A total of 39 species of molluscs were recorded from Pongibalu while 35 and 37 species encountered at Rangachang and Burmanala respectively. The numerical density of molluscs at Pongibalu ranged from 68/10 m^2 (100m distance from the shore) to 228/10m^2 (25 m distance from the shore). The composition of molluscan communities in this area was high upto 50m distance from the shore with the depth of 3.0m during low tides. In Rangachang its density varied from 16/10 m^2 to 232/10 m^2 at a depth of 4.5 and zero meter respectively. The number of species reported over this station also ranged from 4 to 24 for the same set of depths. Whereas in Burmanala, their density was maximum (84/10 m^2) at 4.5 m depth (100 m distance from the shore), where the number of species encountered from this transect was 14 to 34 at zero meter and 2.5 m depths respectively. The pattern of molluscan distribution observed from the study showed that, this faunal group was dominantly occurred both in density and diversity at depths between zero and 3m with a distance between 10 and 50 m from the shore. The density and distribution of individual species of molluscs varied from 4/10 m^2 for quite a number of species to 40/10 m^2 for *Modioulus metalfei* in Pongibalu, 32/10 m^2 for *Chiton granoradius* in Rangachang and 48/10 m^2 for *Nerita (Ritena) maxima* in Burmanala. Among the molluscs *Trochus niloticus* at Rangchang and Burmanala, *Thais bufo, Bursa granulosa* and *Modiolus metcalfei* at Burmanala were recorded at all the quadrants and depths of transect employed during the study. Other species have different degree of distribution.

The echinoderms associated with the coral reefs of the study area belong to Asteroids, Holothurians, Ophiuroids, Crinoids and Echinoids and their representative species were 10, 11, 3, 3 and 7 respectively. A total of 31 species of echinoderms were reported at Pongibalu with the density ranged from 12/10 m^2 at zero meter depth to 108/10 m^2 at 30 m depth i.e. 50 m away from the shore. The number of species also followed the similar pattern and it varied from 3 to 21 at these depths. The numerical density among 32 echinoderm species recorded in Rangachang varied from 88/10 m^2 at 4.5 m depth (100 m away from the shore) to 164/10 m^2 at 2.5 m depth i.e. 50m away from the shore. However the range of number of species in this transect was 9-24 for the depths zero meter and 2.5 m respectively. In Burmanala total species of echinoderms recorded was 24 and their numerical density ranged from 68/10 m^2 at 5.0 m depth (100 m distance from the shore) to 168/10 m^2 at 2.5 m depth (50m distance from the shore). The number of species recorded over this station also followed the similar trend and it varied from 15 to 30. In general, the echinoderm density was high in the area between 1.0m and 3.5m depths with a distance of 10m to 74m from the shore. The individual species density of echinoderm ranged from 4/10m^2 for *Ophinastrix annulosa* and *Cenometa emendatrix* at Rangachang and 20/10m^2 for *Ophiocoma erinaceus* at Burmanala was observed. It is to note that the ophiuroids *Opiocoma erinaceus Ophicoma valenciae* and *Ophinastrix annulosa*, crinoids *Herometra crenulata, Capillaster multiradiatus* and *Cenometra emendatrix* and echinoid *Diadema savignyi* are distributed at all depths of the survey in Rangachang, and all species of holothurians, ophiruoids and crinoids were observed for Burmanala also found in all three places of study.

The species diversity for corals, molluscs and echinoderm studied at three reef areas were calculated at all transects as well as quadrants. The diversity of corals ranged from 0.92 to 2.18 in Pongibalu, 0.83 to 2.92 in Rangachang and 0.62 to 2.58 in Burmanala. The results indicated that the diversity was high in 1.0-4.0m depth i.e. 10-75m distance for the shore than the intertidal area (zero meter depth) and 100m distance from the shore. The diversity of molluscs was 1.15 – 2.84, 0.52-2.83, 2.10-3.83, while for echinoderms 0.17-2.72, 1.80-2.53, 1.70-2.95 recorded for the above said period of study. Among these groups least diversity was recorded for echinoderm ie. 0.17 in zero meter depth of Pongibalu and maximum diversity for molluscs ie. 3.83 in 2.5m depth (50m from the shore) at Burmanala (Table-).

Data obtained through the Jaccard similarity index showed that, the highest species similarity was observed as 0.86 for corals between Pongibalu and Rangachang, 0.92 for molluscs between Rangachang and Burmanala and for echinoderm between 0.91 for Rangachang and Burmalana (Fig. 2)

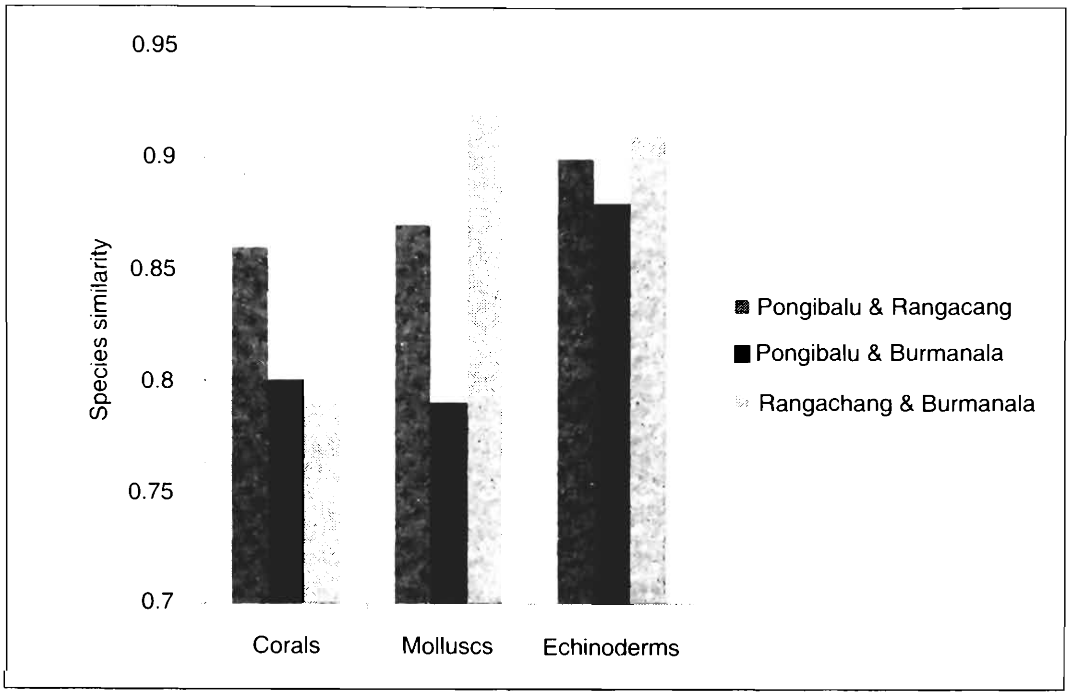

Fig. 2. Species Similarity Index between Stations

Table 1. Density and diversity of corals of Pongibalu

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***3.0***	***4.0***	***5.0***
Sl. No.	***Species***	***Density (No of Colonies/10 m²)***				
	Family ACROPORIDAE Verrill, 1902					
1.	*Acropora muricata* (Linnaeus, 1758)	-	8	8	12	16
2.	*Acropora humilis* (Dana, 1846)	-		12	8	16
3.	*Acropora lutkeni* (Crossland, 1952)	-	8	12	12	12
4.	*Acropora aspera* (Dana, 1846)	-	8	8	8	
5.	*Acropora gemmifera* (Brook, 1892)	-			8	12
6.	*Acropora rudis* (Rehberg, 1892)	-		8	8	12
7.	*Acropora robusta* (Dana, 1846)	-	12	12	16	16
8.	*Acropora spicifera* (Dana, 1846)	-	8	8	8	8
	Family MUSSIDAE Ortmann, 1890					
9.	*Acanthastrea echinata* Milne Edwards and Haime, 1848	-		4	4	4
	Family AGARICIIDAE Gray, 1847					
10.	*Coeloseris mayeri* Vaughan, 1918	-		8	12	8
	Family FUNGIIDAE Dana, 1846					
11.	*Ctenactis crassa* (Gardiner, 1905)	-	4	4	4	8
12.	*Ctenactis echinata* (Pallas, 1766)	-		8	8	8
13.	*Favia pallida* (Dana, 1846)	-	8	8	12	8
14.	*Favia stelligera* (Dana, 1846)	-			4	

Table 1. *Contd.*

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	3.0	4.0	5.0
Sl. No.	***Species***	***Density (No of Colonies/10 m²)***				
15.	*Fungia paumotensis* (Stutchbury, 1833)				8	
16.	*Fungia danai* Milne Edwards and Haime, 1851				8	4
17.	*Fungia repanda* Dana, 1846			4		4
18.	*Fungia scutaria* Lamarck, 1801					
19.	*Merulina ampliata* (Ellis and Solander, 1786)			8	4	4
20.	*Montipora digitata* (Dana, 1846)		8			
21.	*Pavona cactus* (Forskal, 1775)		4	4		
22.	*Pavona maldivensis* (Gardiner, 1905)			8	8	8
23.	*Platygyra pini* Chevalier, 1795				8	8
24.	*Pocillopora damicornis* (Linnaeus, 1758)			8	4	
25.	*Pocillopora verrucosa* (Ellis and Solander, 1786)		4	4	8	
26.	*Porties lutea* Milne Edwards and Haime, 1860	4	8	8		
27.	*Porties solida* (Forskal, 1775)	8		8	12	12
28.	*Porties lobata* Dana, 1846			4	4	8
29.	*Seriastopora hystrix* Dana, 1846			4	4	4
30.	*Symphyllia recta* (Dana, 1848)				8	4
	Total number of colonies	**12**	**80**	**182**	**190**	**174**
	Total number of species	**2**	**11**	**22**	**25**	**21**
	Species diversity (H')	**0.12**	**0.93**	**2.10**	**2.18**	**2.07**

Table 2. Density and diversity of molluscs in Pongibalu

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	3.0	4.0	5.0
Sl. No.	***Species***	***Density (No/10 m²)***				
	Gastropods					
1.	*Trochus niloticus* Linnaeus, 1758)		8	8	12	8
2.	*Thais bufo* (Lamarck, 1822)		12	8	8	
3.	*Thais echinata* (Blainville, 1892)		8	8	8	4
4.	*Bursa granulosa* (Roding, 1798)	12	12			
5.	*Cypraea (Mauritia) arabica* (Linnaeus, 1756)		8	8	4	
6.	*Cypraea (Mauritia) mauritiana regina* (Linnaeus, 1758)		8	8	4	
7.	*Cypraea annulus* (Linnaeus, 1758)		4			
8.	*Cypraea moneta* (Linnaeus, 1758)		8	4	4	
9.	*Cypraea (Talparia) talpa* (Linnaeus, 1758)		4	4	8	
10.	*Lambis (Harpago) chiragra chiragra* (Linnaeus, 1758)		4	8		4

Table 2. *Contd.*

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***3.0***	***4.0***	***5.0***
Sl. No.	***Species***	***Density (No/10 m²)***				
11.	*Conus marmoreus* (Linnaeus, 1758)		4			
12.	*Conus mutabilis* Reeve, 1844			4		
13.	*Conus ebraeus* Linnaeus, 1758		4		4	8
14.	*Conus eburneus* Hwass in Bruguiere, 1792			8	4	8
15.	*Conus nussatella* Linnaeus, 1758			4		
16.	*Conus geographus* Linnaeus, 1758			4		
17.	*Vasum turbinellus* Linnaeus, 1758			4	8	4
18.	*Chicoreus ramosus* (Linnaeus, 1758)			4	8	4
19.	*Chicoreus virgineus* (Linnaeus, 1758)	4		4	8	12
20.	*Turritella attenuata* Reeve, 1849	8	12	8	4	
21.	*Nerita (Ritena) maxima* Reclux, 1843	24	8	8		
22.	*Turbo (Marmarostoma) sparverius* Gmelin, 1791	12	8	8		
23.	*Turbo (Marmarostoma) crassus* Wood, 1828	4	4	4		
24.	*Turbo bruneus* (Roeding, 1798)	8	4	4		
25.	*Nerita (Retina) costata* Gemlin, 1791	12	8			
26.	*Turbinella pyrum* (Linnaeus, 1758)			4	4	4
27.	*Thais tuberosa* (Roeding, 1798)		4			
28.	*Thais armigera* (Link, 1807)			4		
29.	*Pleuroploca trapezium* (Linnaeus, 1758)					4
30.	*Trochus (Infundibulum) ochroleucus* Gmelin, 1791	12	8	8		
31.	*Strombus (Canarium) marginatus succinctus* Linnaeus, 1758			4	4	
32.	*Siphonaria funiculata* Reeve, 1856				12	
33.	*Haliotis asinina* Linnaeus, 1758		8	4		
	Total	**96**	**148**	**144**	**104**	**60**
	Bivalves					
34.	*Mentellum hians* (Gemlin)		8			
35.	*Tridacna gigas*		16	12	8	8
36.	*Modiolus metcalfei*	12	12			
37.	*Crassostrea cuculata*	40	32			
	Total	**52**	**68**	**12**	**8**	**8**
	Polyplacophorans					
38.	*Acanthopleura spiniger* (Sowerby, 1840)	20	8			
39.	*Chiton granoradiatus* Leloup, 1937	24	4			
	Total	**44**	**12**			
	Total number of animals	**192**	**228**	**156**	**112**	**68**
	Total number of species	**13**	**26**	**26**	**17**	**11**
	Species diversity (H')	**1.31**	**2.36**	**2.17**	**2.84**	**1.15**

Table 3. Density and diversity of echinoderms in Pongibalu

Distance from shore (m)		*10*	*25*	*50*	*75*	*100*
Depth (m)		*0*	*1.0*	*3.0*	*4.0*	*5.0*
Sl. No.	***Species***	***Density (No/10 m²)***				
	Asteroids (Star fishes)					
1.	*Culcita schmideliana* (Retzius)			4	4	
2.	*Linckia laevigata* (Linnaeus, 1758)		4	4	4	4
3.	*Linckia guildingi* Gray			4	4	4
4.	*Luidia macualta* (Muller and Trochel)					
5.	*Pentaceraster regulus*				4	
6.	*Protoreaster lincki* (de Blainville)				4	4
	Total		**4**	**12**	**20**	**12**
	Holothurians (Sea cucumbers)					
8.	*Acadina molpadionoides* (Samper)	4	4	4		
9.	*Actinopyga mauritiana* (Quoy and Gaimard)	4	4	8	4	
10.	*Actinopyga miliaris* (Quoy and Gaimard)	4		8	8	
11.	*Bohadschia marmorata* Jager			8	8	4
12.	*Holothuria (Halodeima) edulis* Lesson		8	8	4	4
13.	*Holothuria hilla* (Lesson)		8	8	8	8
14.	*Holothuria pyxis* Solenka			4	4	8
15.	*Holothuria scabra* Jger				8	
16.	*Stichopus variegatus* Semper			4		
17.	*Stolus buccalis* (Stimpson)		4			
18.	*Synaptula recta* (Semper)		4	4	4	
	Total	**12**	**32**	**56**	**48**	**24**
	Ophiuroids (Brittle Stars)					
19.	*Ophiocoma erinaceus* Muller and Trochel			4	8	4
20.	*Ophiocoma valenciae* Muller and Trochel			4	4	4
21.	*Ophinastrix annulosa* (Lamarck)			4		4
	Total		**8**	**16**	**20**	**16**
	Crinoids (Feather stars)					
22.	*Heterometra crenulata* (P.H. Carpenter)		4		4	
23.	*Capillaster multiradiatus* (Linnaeus)		4		4	
24.	*Cenometra emendatrix* (Bell)			4		4
	Total		**8**	**16**	**20**	**16**
	Echinoids (Sea urchins)					
25.	*Diadema savignyi* Michelin		8	4	4	4
26.	*Echinometra mathaei* (de Blainville)			4		4
27.	*Heterocentrotris trigonarius* (Lamarck)		8	4	4	
28.	*Laganum laganum* Klein			8	4	4

Table 3. *Contd.*

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	3.0	4.0	5.0
Sl. No.	Species	Density (No/10 m²)				
29.	*Mespilia globulus* (Linnaeus)			4	4	4
30.	*Stomopneustes variolaris*		4			
31.	*Temnopleurus alexandri* (Bell, 1884)		4			
	Total		**32**	**24**	**16**	**16**
	Total number of animals	**12**	**68**	**108**	**104**	**68**
	Total number of species	**3**	**13**	**21**	**21**	**15**
	Species diversity (H')	**0.17**	**1.50**	**2.72**	**2.58**	**2.0**

Table 4. Density and diversity of corals in Rangachang

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	2.5	3.0	4.5
Sl. No.	Species	Density (No of Colonies/10 m²)				
1.	*Acropora muricata* (Linnaeus, 1758)		8	12	8	4
2.	*Acropora humilis* (Dana, 1846)		4	8	8	8
3.	*Acropora lutkeni* (Crossland, 1952)		8	12	8	4
4.	*Acropora aspera* (Dana, 1846)		4	4	4	
5.	*Acropora gemmifera* (Brook, 1892)			4	8	4
6.	*Acropora rudis* (Rehberg, 1892)			12		
7.	*Acropora robusta* (Dana, 1846)				8	16
8.	*Acropora spicifera* (Dana, 1846)		8	8	8	
9.	*Acanthastrea echinata* Milne Edwards and Haime, 1848			4	4	8
10.	*Coeloseris mayeri* Vaughan, 1918		4	4		4
11.	*Ctenactis crassa* (Gardiner, 1905)		4	4	4	8
12.	*Ctenactis echinata* (Pallas, 1766)		4	8	8	8
13.	*Favia pallida* (Dana, 1846)			8	8	8
14.	*Favia stelligera* (Dana, 1846)		4	12	12	8
15.	*Fungia paumotensis* (Stutchbury, 1833)		4	4	4	8
16.	*Fungia danai* Milne Edwards and Haime, 1851			8	8	
17.	*Fungia repanda* Dana, 1846				4	8
18.	*Fungia scutaria* Lamarck, 1801			4	4	4
19.	*Merulina ampliata* (Ellis and Solander, 1786)			8		
20.	*Montipora digitata* (Dana, 1846)				8	8
21.	*Platygyra pini* Chevalier, 1795		4	4	4	
22.	*Pocillopora damicornis* (Linnaeus, 1758)	8	8	4		
23.	*Pocillopora verrucosa* (Ellis and Solander, 1786)	8	8	4		

Table 4. *Contd.*

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	2.5	3.0	4.5
Sl. No.	*Species*	*Density (No of Colonies/10 m²)*				
24.	*Porties lutea* Milne Edwards and Haime, 1860	4	8	8		
25.	*Porties solida* (Forskal, 1775)	4	8	8		
26.	*Porties lobata* Dana, 1846	4	8			
	Total number of colonies	**28**	**96**	**144**	**120**	**108**
	Total number of species	**5**	**16**	**22**	**18**	**15**
	Species diversity (H')	**0.83**	**1.60**	**2.92**	**2.80**	**2.18**

Table 5. Density and diversity of molluscs in Rangachang

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	2.5	3.0	4.5
Sl. No.	*Species*	*Density (No/10 m²)*				
	Gastropods					
1.	*Trochus niloticus* Linnaeus, 1758)	8	12	8	4	4
2.	*Thais bufo* (Lamarck, 1822)	16	20	8	8	
3.	*Thais echinata* (Blainville, 1892)	4	12	8	8	
4.	*Bursa uberose* (Roding, 1798)	16				
5.	*Cypraea (Mauritia) uberos* (Linnaeus, 1756)	4	8	4		
6.	*Cypraea (Mauritia) mauritiana regina* (Linnaeus, 1758)		4	4		
7.	*Cypraea annulus* (Linnaeus, 1758)			8	4	
8.	*Cypraea moneta* (Linnaeus, 1758)			8	8	
9.	*Cypraea (Talparia) talpa* (Linnaeus, 1758)		4	4		
10.	*Lambis (Harpago) chiragra chiragra* (Linnaeus, 1758)		8	12		
11.	*Conus marmoreus* (Linnaeus, 1758)		8	12		
12.	*Conus mutabilis* Reeve, 1844		8	8	4	4
13.	*Conus ebraeus* Linnaeus, 1758		8	4	4	4
14.	*Conus eburneus* Hwass in Bruguiere, 1792		4	8	8	
15.	*Conus nussatella* Linnaeus, 1758			8	8	
16.	*Conus geographus* Linnaeus, 1758			12	8	
17.	*Vasum turbinellus* Linnaeus, 1758			8	8	
18.	*Chicoreus ramosus* (Linnaeus, 1758)				4	4
19.	*Chicoreus virgineus* (Linnaeus, 1758)	4	4	8	4	
20.	*Turritella attenuata* Reeve, 1849	8	8			
21.	*Nerita (Ritena) maxima* Reclux, 1843	20	12			
22.	*Turbo (Marmarostoma) sparverius* Gmelin, 1791	8	8			
23.	*Turbo (Marmarostoma) crassus* Wood, 1828	8	8			

Table 5. *Contd*

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***2.5***	***3.0***	***4.5***
Sl. No.	***Species***	***Density (No/10 m²)***				
24.	*Turbo bruneus* (Roeding, 1798)	4	4	4		
25.	*Nerita (Retina) costata* Gemlin, 1791	16	12	8		
26.	*Thais uberose* (Roeding, 1798)		4			
27.	*Thais armigera* (Link, 1807)		8			
28.	*Trochus (Infundibulum) ochroleucus* Gmelin, 1791		8	8		
29.	*Strombus (Canarium) marginatus succinctus* Linnaeus, 1758			4		
	Total	**106**	**170**	**156**	**80**	**16**
	Bivalves					
30.	*Mentellum hians* (Gemlin)	8	8			
31.	*Tridacna gigas*			16		
32.	*Modiolus metcalfei*	16	20	8		
33.	*Crassostrea cuculata*	32	24			
	Total	**56**	**52**	**24**		
	Polyplacophorans					
34.	*Acanthopleura spiniger* (Sowerby, 1840)	28			16	
35.	*Chiton granoradiatus* Leloup, 1937	32				
	Total	**60**			**16**	
	Total number of animals	**232**	**222**	**180**	**96**	**16**
	Total number of species	**17**	**24**	**23**	**14**	**4**
	Species diversity (H')	**2.10**	**2.83**	**2.78**	**2.05**	**0.52**

Table 6. Density and diversity of echinoderms in Rangachang

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***2.5***	***3.0***	***4.5***
Sl. No.	***Species***	***Density (No/10 m²)***				
	Asteroids (Star fishes)					
1.	*Anthenea tuberculosa* Gray, 1847		8	4	4	
2.	*Astropecten indicus* Doderlein		4			
3.	*Culcita novaeguinea* Muller and Trochel		4	4		
4.	*Culcita schmideliana* (Retzius)			4		
5.	*Linckia laevigata* (Linnaeus, 1758)				4	
6.	*Linckia guildingi* Gray					4
7.	*Luidia macualta* (Muller and Trochel)			4	4	
8.	*Protoreaster lincki* (de Blainville)		4	4	4	
	Total		**12**	**20**	**16**	**4**

Table 6. *Contd.*

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***2.5***	***3.0***	***4.5***
Sl. No.	***Species***	***Density (No/10 m²)***				
	Holothurians (Sea cucumbers)					
9.	*Acadina molpadionoides* (Samper)				4	8
10.	*Actinopyga mauritiana* (Quoy and Gaimard)			8	4	4
11.	*Actinopyga miliaris* (Quoy and Gaimard)			4	4	
12.	*Bohadschia marmorata* Jager		4	8		
13.	*Holothuria (Halodeima) edulis* Lesson	4	8	8	8	
14.	*Holothuria hilla* (Lesson)	4		8	8	
15.	*Holothuria pyxis* Solenka			4	8	
16.	*Holothuria scabra* Jager			4	4	
17.	*Stichopus variegatus* Semper			8	8	8
18.	*Stolus buccalis* (Stimpson)			4	4	4
19.	*Synaptula recta* (Semper)			4	8	8
	Total	**8**	**12**	**60**	**60**	**32**
	Ophiuroids (Brittle Stars)					
20.	*Ophiocoma erinaceus* Muller and Trochel	16	12	8	8	8
21.	*Ophiocoma valenciae* Muller and Trochel	16	16	8	8	8
22.	*Ophinastrix annulosa* (Lamarck)	24	16	16	8	8
	Total	**56**	**44**	**32**	**24**	**24**
	Crinoids (Feather stars)					
23.	*Heterometra crenulata* (P.H. Carpenter)	12	8	8	4	4
24.	*Capillaster multiradiatus* (Linnaeus)	20	12	8	4	4
25.	*Cenometra emendatrix* (Bell)	24	12	8	8	4
	Total	**60**	**60**	**52**	**44**	**28**
	Echinoids (Sea urchins)					
26.	*Diadema savignyi* Michelin	4	8	8	4	4
27.	*Echinometra mathaei* (de Blainville)		8	4	4	
28.	*Heterocentrotris trigonarius* (Lamarck)			4	4	
29.	*Laganum laganum* Klein		8	8	4	4
30.	*Mespilia globulus* (Linnaeus)				4	4
31.	*Stomopneustes variolaris*				8	4
32.	*Temnopleurus alexandri* (Bell, 1884)		4	4		
	Total	**60**	**60**	**52**	**44**	**28**
	Total number of animals	**9**	**16**	**26**	**26**	**16**
	Total number of species	**9**	**16**	**26**	**26**	**16**
	Species diversity (H')	**1.80**	**1.96**	**2.53**	**2.40**	**2.17**

Table 7. Density and diversity of corals in Burmanala

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***2.5***	***3.0***	***4.5***
Sl. No.	***Species***	***Density (No of Colonies /10 m²)***				
1.	*Acropora muricata* (Linnaeus, 1758)					16
2.	*Acropora humilis* (Dana, 1846)				8	12
3.	*Acropora lutkeni* (Crossland, 1952)			8	8	8
4.	*Acropora aspera* (Dana, 1846)				8	8
5.	*Acropora gemmifera* (Brook, 1892)				4	4
6.	*Acropora rudis* (Rehberg, 1892)					8
7.	*Acropora robusta* (Dana, 1846)			4	4	4
8.	*Acropora spicifera* (Dana, 1846)				4	4
9.	*Acanthastrea echinata* Milne Edwards and Haime, 1848			4	4	
10.	*Coeloseris mayeri* Vaughan, 1918			8	8	
11.	*Ctenactis crassa* (Gardiner, 1905)			8	8	12
12.	*Ctenactis echinata* (Pallas, 1766)		4	4	4	4
13.	*Favia pallida* (Dana, 1846)		4	4	4	4
14.	*Favia stelligera* (Dana, 1846)		8	8	8	8
15.	*Merulina ampliata* (Ellis and Solander, 1786)			4	4	4
16.	*Montipora digitata* (Dana, 1846)		4	8	8	
17.	*Platygyra pini* Chevalier, 1795		8	4	8	
18.	*Pocillopora damicornis* (Linnaeus, 1758)	12	8	8	8	
19.	*Pocillopora verrucosa* (Ellis and Solander, 1786)	16	12	12	8	4
20.	*Porties lutea* Milne Edwards and Haime, 1860		8	12	12	4
21.	*Porties solida* (Forskal, 1775)		8	12	16	4
22.	*Porties lobata* Dana, 1846		4	8	16	
23.	*Seriastopora hystrix* Dana, 1846					8
24.	*Symphyllia recta* (Dana, 1848)					8
	Total number of animals	**28**	**68**	**104**	**152**	**124**
	Total number of species	**2**	**10**	**16**	**20**	**18**
	Species diversity (H')	**0.62**	**1.47**	**1.61**	**2.58**	**2.44**

Table 8. Density and diversity of molluscs in Burmanala

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***2.5***	***3.0***	***4.5***
Sl. No.	***Species***	***Density (No /10 m²)***				
	Gastropods					
1.	*Trochus niloticus* Linnaeus, 1758)	4	8	8	4	4
2.	*Thais bufo* (Lamarck, 1822)	16	20	16	8	

Table 8. *Contd.*

Distance from shore (m)		***10***	***25***	***50***	***75***	***100***
Depth (m)		***0***	***1.0***	***2.5***	***3.0***	***4.5***
Sl. No.	***Species***	***Density (No /10 m²)***				
3.	*Bursa granulosa* (Roding, 1798)	8	8	4	4	4
4.	*Cypraea (Mauritia) arabica* (Linnaeus, 1756)		8	8	4	4
5.	*Cypraea (Mauritia) mauritiana regina* (Linnaeus, 1758)		12	8	4	4
6.	*Cypraea annulus* (Linnaeus, 1758)	4	4	4	4	4
7.	*Cypraea moneta* (Linnaeus, 1758)	4	4			
8.	*Cypraea (Talparia) talpa* (Linnaeus, 1758)		8	8		
9.	*Lambis (Harpago) chiragra chiragra* (Linnaeus, 1758)			4	4	4
10.	*Conus marmoreus* (Linnaeus, 1758)		4	8	8	4
11.	*Conus mutabilis* Reeve, 1844		4	8	8	
12.	*Conus ebraeus* Linnaeus, 1758			20	8	
13.	*Conus eburneus* Hwass in Bruguiere, 1792			4	12	
14.	*Conus nussatella* Linnaeus, 1758			12	8	4
15.	*Conus geographus* Linnaeus, 1758			4	4	4
16.	*Vasum turbinellus* Linnaeus, 1758		4	4	8	4
17.	*Chicoreus ramosus* (Linnaeus, 1758)			4	4	
18.	*Chicoreus virgineus* (Linnaeus, 1758)			8	8	
19.	*Turritella attenuata* Reeve, 1849	8	16	8		
20.	*Nerita (Ritena) maxima* Reclux, 1843	48	32	20		
21.	*Turbo (Marmarostoma) sparverius* Gmelin, 1791		8	8	8	8
22.	*Turbo (Marmarostoma) crassus* Wood, 1828		4	4		
23.	*Turbo bruneus* (Roeding, 1798)			4	4	
24.	*Nerita (Retina) costata* Gemlin, 1791	20	20	8	4	
25.	*Thais tuberosa* (Roeding, 1798)	16	8	8		
26.	*Thais armigera* (Link, 1807)		8	8	4	
27.	*Pleuroploca trapezium* (Linnaeus, 1758)		4	4	4	4
28.	*Trochus (Infundibulum) ochroleucus* Gmelin, 1791		8	8	8	4
29.	*Strombus (Canarium) marginatus succinctus* Linnaeus, 1758			8	8	4
30.	*Siphonaria funiculata* Reeve, 1856				4	
31.	*Haliotis asinina* Linnaeus, 1758			4	4	
	Total	**128**	**192**	**220**	**148**	**60**
	Bivalves					
32.	*Mentellum hians* (Gemlin)	8	8	4		
33.	*Tridacna gigas*		32	28	24	20
34.	*Modiolus metcalfei*	28	32	28	8	4
35.	*Crassostrea cuculata*	44	24			
	Total	**80**	**96**	**60**	**32**	**24**

Table 8. *Contd.*

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	2.5	3.0	4.5
Sl. No.	*Species*	*Density (No /10 m²)*				
	Polyplacophorans					
36.	*Acanthopleura spiniger* (Sowerby, 1840)	32	20	8		
37.	*Chiton granoradiatus* Leloup, 1937	28	20	8		
	Total	**60**	**40**	**16**		
	Total number of colonies	**268**	**328**	**296**	**180**	**84**
	Total number of species	**14**	**26**	**34**	**27**	**16**
	Species diversity (H')	**2.10**	**2.62**	**3.83**	**3.08**	**2.40**

Table 9. Density and diversity of echinoderms in Burmanala

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	2.5	3.0	4.5
Sl. No.	*Species*	*Density (No/10m²)*				
	Asteroids (Star fishes)					
1.	*Anthenea tuberculosa* Gray, 1847		4	8	4	
2.	*Astropecten monocanthus* Sladen			4		
3.	*Culcita novaeguinea* Muller and Trochel				4	
4.	*Culcita schmideliana* (Retzius)			4	4	
5.	*Linckia laevigata* (Linnaeus, 1758)			4	4	
6.	*Linckia guildingi* Gray				4	4
7.	*Luidia macualta* (Muller and Trochel)				4	4
8.	*Pentaceraster regulus*			4	4	4
9.	*Protoreaster lincki* (de Blainville)			4		
	Total		**4**	**28**	**28**	**12**
	Holothurians (Sea cucumbers)					
10.	*Acadina molpadionoides* (Samper)	8	8	4	8	
11.	*Actinopyga mauritiana* (Quoy and Gaimard)	16	12	8	4	4
12.	*Actinopyga miliaris* (Quoy and Gaimard)	12	8	4	4	4
13.	*Bohadschia marmorata* Jager	8	8	8	4	8
14.	*Holothuria (Halodeima) edulis* Lesson	12	8	8	4	4
15.	*Holothuria hilla* (Lesson)	8	8	4	4	4
16.	*Holothuria pyxis* Solenka		4	12	4	
17.	*Holothuria scabra* Jager			8	8	
18.	*Stichopus variegatus* Semper		4	4	4	
19.	*Stolus buccalis* (Stimpson)		4	8	4	
20.	*Synaptula recta* (Semper)			8	4	4
	Total		**64**	**76**	**52**	**28**

Table 9. *Contd.*

Distance from shore (m)		10	25	50	75	100
Depth (m)		0	1.0	2.5	3.0	4.5
Sl. No.	*Species*	*Density (No/10m²)*				
	Ophiuroids (Brittle Stars)					
21.	*Ophiocoma erinaceus* Muller and Trochel	20	8	8	4	4
22.	*Ophiocoma valenciae* Muller and Trochel	16	8	8	4	4
23.	*Ophinastrix annulosa* (Lamarck)	12	8	8	4	4
	Total	**48**	**24**	**24**	**12**	**12**
	Crinoids (Feather star)					
24.	*Heterometra crenulata* (P.H. Carpenter)	8	8	4	4	4
25.	*Capillaster multiradiatus* (Linnaeus)	8	4	4	4	
26.	*Cenometra emendatrix* (Bell)		8	4	4	8
	Total	**16**	**20**	**12**	**12**	**12**
	Echinoids (Sea urchins)					
28.	*Diadema savignyi* Michelin	8	4	4	4	
29.	*Echinometra mathaei* (de Blainville)	12	4	4		
30.	*Heterocentrotris trigonarius* (Lamarck)	4	4	8	4	
31.	*Laganum laganum* Klein		8	4	4	
32.	*Mespilia globulus* (Linnaeus)	4	8	4	4	4
33.	*Stomopneustes variolaris*		8	4	4	
34.	*Temnopleurus alexandri* (Bell, 1884)	4	4			
	Total	**32**	**40**	**28**	**20**	**4**
	Total number of animals	**160**	**152**	**168**	**124**	**68**
	Total number of species	**16**	**23**	**30**	**29**	**15**
	Species diversity (H')	**1.85**	**2.23**	**2.95**	**2.90**	**1.70**

Table 10. Distribution of corals along the study area

Sl. No.	**Species**	**Phongibalu**	**Rangachang**	**Burmanala**
	Family ACROPORIDAE Verrill, 1902			
1.	*Acropora muricata* (Linnaeus, 1758)	+	+	+
2.	*Acropora humilis* (Dana, 1846)	+	+	+
3.	*Acropora lutkeni* (Crossland, 1952)	+	+	+
4.	*Acropora aspera* (Dana, 1846)	+	+	+
5.	*Acropora gemmifera* (Brook, 1892)	+	+	+
6.	*Acropora rudis* (Rehberg, 1892)	+	+	+
7.	*Acropora robusta* (Dana, 1846)	+	+	+
8.	*Acropora spicifera* (Dana, 1846)	+	+	+
9.	*Montipora digitata* (Dana, 1846)	+	+	+

Table 10. *Contd.*

Sl. No.	Species	Phongibalu	Rangachang	Burmanala
	Family MUSSIDAE Ortmann, 1890			
10.	*Acanthastrea echinata* Milne Edwards and Haime, 1848	+	+	+
11.	*Symphyllia recta* (Dana, 1848)	+		+
	Family AGARICIIDAE Gray, 1847			
12.	*Coeloseris mayeri* Vaughan, 1918	+	+	+
13.	*Pavona cactus* (Forskal, 1775)	+		
14.	*Pavona maldivensis* (Gardiner, 1905)	+		
	Family FUNGIIDAE Dana, 1846			
15.	*Ctenactis crassa* (Gardiner, 1905)	+	+	+
16.	*Ctenactis echinata* (Pallas, 1766)	+	+	+
17.	*Fungia paumotensis* (Stutchbury, 1833)	+	+	
18.	*Fungia danai* Milne Edwards and Haime, 1851	+	+	
19.	*Fungia repanda* Dana, 1846	+	+	
20.	*Fungia scutaria* Lamarck, 1801	+	+	
	Family FAVIIDAE Gregory, 1900			
21.	*Favia pallida* (Dana, 1846)	+	+	+
22.	*Favia stelligera* (Dana, 1846)	+	+	+
23.	*Platygyra pini* Chevalier, 1795	+	+	+
	Family MERULINIDAE Verrill, 1866			
24.	*Merulina ampliata* (Ellis and Solander, 1786)	+	+	+
	Family POCILLOPORIDAE Gray, 1842			
25.	*Pocillopora damicornis* (Linnaeus, 1758)	+	+	+
26.	*Pocillopora verrucosa* (Ellis and Solander, 1786)	+	+	+
	Family PORITIDAE Gray, 1842			
27.	*Porties lutea* Milne Edwards and Haime, 1860	+	+	+
28.	*Porties solida* (Forskal, 1775)	+	+	+
29.	*Porties lobata* Dana, 1846	+	+	+
30.	*Seriatopora hystrix* Dana, 1846	+		+
	Total number of species	**30**	**26**	**24**

+ present, – absent

Table 11. Distribution of molluscs along the study area

Sl. No.	Species	Phongibalu	Rangachang	Burmanala
	Gastropods			
	Family TROCHIDAE Rafinesque, 1815			
1.	*Trochus niloticus* Linnaeus, 1758)	+	+	+
2.	*Trochus (Infundibulum) ochroleucus* Gmelin, 1791	+	+	+
	Family MURICIDAE Rafinesque, 1815			
3.	*Chicoreus ramosus* (Linnaeus, 1758)	+	+	+
4.	*Chicoreus virgineus* (Linnaeus, 1758)	+	+	+
5.	*Thais bufo* (Lamarck, 1822)	+	+	+
6.	*Thais echinata* (Blainville, 1892)	+	+	
7.	*Thais tuberosa* (Roeding, 1798)		+	+
8.	*Thais armigera* (Link, 1807)	+	+	+
	Family BURSIDAE			
9.	*Bursa granulosa* (Roding, 1798)	+	+	+
	Family CYPRAEIDAE Rafinesque, 1015			
10.	*Cypraea (Mauritia) arabica* (Linnaeus, 1756)	+	+	+
11.	*Cypraea (Mauritia) mauritiana regina* (Linnaeus, 1758)	+	+	+
12.	*Cypraea annulus* (Linnaeus, 1758)	+	+	+
13.	*Cypraea moneta* (Linnaeus, 1758)	+	+	+
14.	*Cypraea (Talparia) talpa* (Linnaeus, 1758)	+	+	+
	Family STROMBIDAE Rafinesque, 1815			
15.	*Lambis (Harpago) chiragra chiragra* (Linnaeus, 1758)	+	+	+
16.	*Strombus (Canarium) marginatus succinctus* Linnaeus, 1758	+	+	+
	Family CONIDAE Rafinesque, 1815			
17.	*Conus marmoreus* (Linnaeus, 1758)	+	+	+
18.	*Conus mutabilis* Reeve, 1844	+	+	+
19.	*Conus ebraeus* Linnaeus, 1758	+	+	+
20.	*Conus eburneus* Hwass in Bruguiere, 1792	+	+	+
21.	*Conus nussatella* Linnaeus, 1758	+	+	+
22.	*Conus geographus* Linnaeus, 1758	+	+	+
	Family VASIDAE			
23.	*Vasum turbinellus* Linnaeus, 1758	+	+	+
	Family TURRITELLIDAE Woodward, 1851			
24.	*Turritella attenuata* Reeve, 1849	+	+	+
	Family NERITIDAE Rafinesque, 1815			
25.	*Nerita (Ritena) maxima* Reclux, 1843	+	+	+
26.	*Nerita (Retina) costata* Gemlin, 1791	+	+	+

Table 11. *Contd.*

Sl. No.	Species	Phongibalu	Rangachang	Burmanala
	Family TURBINIDAE Ratinesqe, 1815			
27.	*Turbo (Marmarostoma) sparverius* Gmelin, 1791	+	+	+
28.	*Turbo (Marmarostoma) crassus* Wood, 1828	+	+	+
29.	*Turbo bruneus* (Roeding, 1798)	+	+	+
	Family VASIDAE			
30.	*Turbinella pyrum* (Linnaeus, 1758)	+		
	Family FASCIOLARIIDAE			
31.	*Pleuroploca trapezium* (Linnaeus, 1758)	+		+
	Family SIPHONARIIDAE			
32.	*Siphonaria funiculata* Reeve, 1856	+		+
	Family HALIOTIDAE			
33.	*Haliotis asinina* Linnaeus, 1758	+		+
	Bivalves			
34.	*Mentellum hians* (Gemlin)	+	+	+
	Family TRIDACNIDAE Lamarck, 1819			
35.	*Tridacna gigas*	+	+	+
	Family MYTILIDAE Rafinesque, 1815			
36.	*Modiolus metcalfei*	+	+	+
	Family OSTREIDAE Rafinesque, 1815			
37.	*Crassostrea cuculata*	+	+	+
	Polyplacophorans			
	Family CHITONIDAE			
38.	*Acanthopleura spiniger* (Sowerby, 1840)	+	+	+
39.	*Chiton granoradiatus* Leloup, 1937	+	+	+
	Total number of species	**38**	**35**	**37**

+ present, absent

Table 12. Distribution of echinoderms along the study area

Sl. No.	Species	Phongibalu	Rangachang	Burmanala
	Asteroids (Star fishes)			
	Family OREASTERIDAE			
1.	*Anthenea tuberculosa* Gray, 1847		+	+
	Family ASTROPECTINIDAE			
2.	*Astropecten indicus* Doderlein		+	
3.	*Astropecten monacanthus* Sladen			+
4.	*Culcita novaeguinea* Muller and Trochel		+	+
5.	*Culcita schmideliana* (Retzius)	+	+	+

Table 12. *Contd.*

Sl. No.	Species	Phongibalu	Rangachang	Burmanala
	Family OPHIDIASTERIDAE			
6.	*Linckia laevigata* (Linnaeus, 1758)	+	+	+
7.	*Linckia guildingi* Gray	+	+	+
8.	*Linckia multifora* (Lamarck)	+	+	+
9.	*Pentaceraster regulus*	+	+	
10.	*Protoreaster lincki* (de Blainville)	+	+	+
	Holothurians (Sea cucumbers)			
	Family HOLOTHURIIDAE			
11.	*Acadina molpadionoides* (Samper)	+	+	+
12.	*Actinopyga mauritiana* (Quoy and Gaimard)	+	+	+
13.	*Actinopyga miliaris* (Quoy and Gaimard)	+	+	+
14.	*Bohadschia marmorata* Jager	+	+	+
15.	*Holothuria (Halodeima) edulis* Lesson	+	+	+
16.	*Holothuria hilla* (Lesson)	+	+	+
17.	*Holothuria pyxis* Solenka	+	+	+
18.	*Holothuria scabra* Jger	+	+	+
	Family STICHOPODIDAE			
19.	*Stichopus variegatus* Semper	+	+	+
20.	*Stolus buccalis* (Stimpson)	+	+	+
	Family SYNAPTIDAE			
21.	*Synaptula recta* (Semper)	+	+	+
	Ophiuroids (Brittle Stars)			
	Family OPHIOCOMIDAE			
22.	*Ophiocoma erinaceus* Muller and Trochel	+	+	+
23.	*Ophiocoma valenciae* Muller and Trochel	+	+	+
24.	*Ophimastrix annulosa* (Lamarck)	+	+	+
	Crinoids			
	Family HIMEROMETRIDAE			
25.	*Heterometra crenulata* (P.H. Carpenter)	+	+	+
	Family COMASTERIDAE			
26.	*Capillaster multiradiatus* (Linnaeus)	+	+	+
27.	*Cenometra emendatrix* (Bell)	+	+	+
	Echinoids (Sea urchins)			
	Family DIADEMATIDAE			
28.	*Diadema savignyi* Michelin	+	+	+
	Family ECHINOMETRIDAE			
29.	*Echinometra mathaei* (de Blainville)	+	+	+
30.	*Heterocentrotus trigonarius* (Lamarck)	+	+	+

Table 12. *Contd.*

Sl. No.	Species	Phongibalu	Rangachang	Burmanala
	Family LAGANIDAE			
31.	*Laganum laganum* Klein	+	+	+
	Family TEMNOPLEURIDAE			
32.	*Mespilia globulus* (Linnaeus)	+	+	+
33.	*Temnopleurus alexandri* (Bell, 1884)	+	+	+
	Family STOMECHINIDAE			
34.	*Stomopneustes variolaris*	+	+	+
	Total number of species	**30**	**33**	**32**

+ present, absent

DISCUSSION

The epitome of the results obtained from the present study revealed that the reef area of Pongibalu, Rangachang and Burmanala supported rich density and diversity of corals and their associated macrofaunal communities of molluscs and echinoderms on the littoral region. Corals in these areas were destructed due to December 2004 disastrous event of earthquake cum tidal waves, being under the progress of recovery and most of the colonies presently reported from the study are newly formed. A spectacular feature of the littoral region of this presently studied area is the occurrence of corals and rock flat forms. The stony coral occurring in this zone are mostly wave-resistant, massive and encrusting type, which are capable of withstanding severe wave action. These coral species includes *Porties, Favia, Fungia, Pocillopora, Montipora* and *Acropora*. The data collected from study sites showed the similar pattern of faunal component observed earlier from the other parts of Andaman and Nicobar Islands (Rao *et al.*, 1994; Rao, 1991; Subba Rao and Dey, 1991; James, 1991; Rao and Dev Roy, 1985; Daniel and Haldar, 1974; Julka and Das, 1978; James, 1983, Soota *et al.*, 1984 and Tikader *et al.*, 1986).

Porites and *Favia* species are the reef builders of Andaman and Nicobar Islands. The protected bays have better growth of corals as compared to exposed coast and the Nicobar have a richer growth than Andaman (Mustafa *et al.*, 1998). The most common verities of stony coral reported during this study area Acroporidae (*Acropora* sp. and *Montipora* sp.), Poritidae (*Porites* sp.), Faviidae (*Favia* sp.) and Fungiidae (*Fungia* sp.). The density and diversity of corals, molluscs and echinoderms estimated in the present investigation revealed that the highest value observed for Pongibalu region than other two places. The Pongbalu reef area is fall under protected area where the sea is calm as this enclosed by Rutland Island. Rangachang and Burmanala facing open sea with strong currents and wave action. The density of corals was recorded up to 152 colonies/ $10m^2$ indicates the coral reef system in this area steadily improved after impact of earthquake and tsunami and most of the coral colonies were new recruits. The occurrence of *Pocillopra demicornis* at all the quadrants as well as transects of the study indicated that the species withstand during the tidal exposure in intertidal area for longer duration. Relatively less density of corals in the Rangachang and Pongibalu might be due to turbidity of the water column coupled strong wave action. The maximum numerical density of molluscs found in Pongibalu is coincided with the results of coral colonies reported at Pongibalu at this coral ecosystem is abode for these communities. However, the density of echinoderms slightly higher in Rangachang area where the reef flat is about 3km long and 800m wide with crevices and rocks as well as corals. This area supports large number of ophiuroids and crinoids and allowing them to prevent desiccation due to tidal exposure. The density of economically important schedule-I holothurians recorded at the range of 8-60 individuals/$10m^2$ area indicates their improvement in their density through effective management and conservations imposed on this group. In general species diversity of corals, molluscs and echinoderms in the three localities were also moderately high ie. 0.62 – 2.92 indicates the balanced ecosystem. Species similarity between stations showed higher values (0.92) might be due to the similar ecological characteristic existing as these places are close to each other.

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Chapter 22

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 275-282, 2010

STUDIES ON MOLLUSCAN DIVERSITY OF GREAT NICOBAR ISLAND–A PRE TSUNAMI SCENARIO

M. ARUMUGAM*, A. SHANMUGAM., T. BALASUBRAMANIAN., L. KANNAN and S. AJMALKHAN

Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 50, Tamil Nadu

INTRODUCTION

The Andaman and Nicobar groups of Islands are receiving much attention for their scenic beauty and for their vast bio resources in which molluscs form an important group. The seas around Andaman and Nicobar Islands are well known for their rich molluscan diversity, constituted by a vast array of forms distributed along the coastal areas, protected bays, inlets and the inshore and offshore regions of the islands. Marine molluscs considerably contribute in maintaining the ecosystem and more importantly some species can be directly utilized as indicators of environmental health or degradation.

Out of the seven recognized classes of Mollusca, only five major classes, namely Polyplacophora, Gastropoda, Scaphopoda, Bivalvia and Cephalopoda are represented in the Indian region. Global estimates of molluscan diversity vary between 50,000 and 1,50,000 species. Molluscan diversity in India is represented by 7.62 per cent of the total global molluscan diversity which is in fact higher than that of the total faunal percentage of India (6.67 per cent). The higher diversity of molluscs is mainly because of their adaptation to live in diverse habitats from the deep sea (300 m) of Andamans to higher elevations (5000m) in the Himalayas. But the diversity and abundance are more in the rocky intertidal zone along the coasts and in the coral reef ecosystem of the Gulf of Mannar, Gulf of Kutchchh and Andaman and Nicobar Islands. This is mainly because of the presence of their preferred habitats such as crevices, creeks of rocks and rock pools.

Certain marine molluscs such as scallops, mussels, abalones, squids, octopii etc. are extensively used as human food and they are among the most valuable fished species, accounting for a high proportion of fisheries income, depending upon the quantity of harvesting. Screening of marine molluscs for novel compounds and bioactive substances is a rapidly expanding area of research in biotechnological and pharmaceutical industry. Such novel compounds range from new drugs to antifouling paints. Further, marine ornamental shell collection and aquarium keeping have become great enjoyment and hobby for many people and in some instances the aesthetic and recreational values of marine molluscs also translate into enormous economic gain.

MATERIALS AND METHODS

The molluscan animals were collected randomly by hand picking from all the stations chosen along the east as well as the west coast of the Great Nicobar Island at a depth of 0.5 to 2.0

*E-mail : aru_hep@yahoo.com

m, from the sandy and rocky shores and also from the coral reef areas. Wherever possible, quadrates were laid to collect the samples for quantitative analysis. The animals thus collected were preserved in 5 per cent formalin for identification.

The gastropods were identified based on their morphometric characters such as the shape, operculum, number of whorls, colour pattern of shell etc. The bivalves were identified based on their morphometric characters such as shape of the shell, umbo, number of hinge teeth, pallial line etc. Cephalopods were identified based on their morphometric characters such as the shape, arm order, web order, hectocotlyzed arm structure, penis shape, cuttle bone, funnel organ, colour of the animal, shape of the gladius etc.

The molluscs species was identification using the standard manuals *viz.* State Fauna Series 2: Fauna of Lakshadweep (1991), Indo-Pacific Coral Reef by Gerald Allen and Roger Steene (1994) and help of the molluscan experts of the Zoological Survey of India, Kolkata.

RESULTS

Gastropods

From the three years of collections along the entire coast of the Great Nicobar Island, a total of 83 species of gastropods belonging to 27 families were identified (Table.1). Of these 83 species, along the west coast, Inhengloi shore recorded a maximum of 49 species followed by Kopenheat and Pilokunji (48 species each) and Alexandria Bay (47 species). Trinket Champlong Bay recorded 46 species along the north coast. In the case of the east coast, a maximum of 39 species were recorded from Vijay nagar followed by Lakshmi nagar and Galathea Bay (37 species each) and Dillon nallah (35 species), while Indira Point, the only station in south, recorded 30 species.

Table 1. Checklist of gastropods recorded from the Great Nicobar Island

Phylum MOLLUSCA

Class GASTROPODA

Family TROCHIDAE

1. *Angaria delphinus* (Linnaeus, 1758)
2. *Trochus maculates* (Linnaeus, 1758)
3. *T. ochroleucus* (Gmelin, 1791)
4. *T. radiates* (Gmellin, 1791)
5. *Tectus niloticus* (Gmelin, 1791)

Family HALIOTIDAE

6. *Haliotis jacknensis* (Linn. 1758)
7. *H. planatae* (Sowerby, 1855)

Family TURBINADAE

8. *Turbo aggyrostoma* (Linnaeus, 1758)
9. *T. sparvariaus* (Gmelin, 1791)
10. *T. brunneus* (Roeding, 1758)
11. *T. intercostalis* (Menke)

Family NERITIDAE

12. *Nerita plicata* (Linnaeus, 1758)
13. *N. maxima* (Linnaeus, 1758)
14. *N. albicilla* (Linnaeus, 1758)
15. *N. chamaeleon* (Linnaeus, 1758)
16. *N. polita* (Linnaeus, 1758)
17. *N. costata* (Linnaeus, 1758)
18. *N. peloronta* (Linnaeus, 1758)
19. *N. versicolor* (Linnaeus, 1758)
20. *N. scabricosta* (Linnaeus, 1758)
21. *N. squamulata* (Le Guillou, 1841)

Family LITTORINIDAE

22. *Littorina undulata* (Gray, 1839)

Family POTAMIDIDAE

23. *Terebralia palustris* (Linnaeus, 1767)

Family COLUMBELLIDAE

24. *Pictocolumbella ocellata* (Link, 1807)

Family CERITHIIDAE

25. *Cerithium trailli* (Sowerby, 1855)
26. *C. nodulosum* (Bruguiere, 1792)
27. *Cerithidea obtusea* (Lamarck, 1822)
28. *Clypeomorus batillariaeformis* (Habe and Ksuge, 1966)

Family STROMBIDAE

29. *Strombus gibberulus* (Linnaeus, 1758)
30. *Lambis lambis* (Linnaeus, 1758)
31. *L. chiragra* (Linnaeus, 1758)
32. *L. scorpius* (Linnaeus,1758)

Family MURICIDAE

33. *Drupa ricinus* (Linnaeus, 1758)
34. *D. morum* (Roeding, 1758)
35. *Thais armigera* (Roeding, 1807)
36. *T. hippocastatum* (Linnaeus, 1758)

37. *T. rudolphi* (Lamarck, 1822)
38. *T. bitubercularis* (Lamarck, 1822)
39. *Nasa serta*(Bruguiere, 1827)
40. *Chicoreus ramosus* (Linnaeus, 1758)
41. *Murex trapa* (Roding, 1798)

Family MITRIDAE

42. *Mitra mitra* (Lamarck, 1798)
43. *M. stictica* (Link, 1807)
44. *M. (S) trigdatella* (*litterata*) Lamarck, 1758)
45. *M. (S) decurtala* (Reeve, 1845)
46. *M. (S) paupercula* (Linnaeus, 1758)
47. *M. (S) cucumarina* (lamarck, 1811)

Family BUCCINIDAE

48. *Cantharus undosus* (Linnaeus, 1758)

Family FACIOLARIIDAE

49. *Pleuroploca filamentosa* (Roeding, 1798) (*Fasciolariae filamentosa*)
50. *Latirus craticulatus* (Linnaeus, 1758)

Family VASIDAE

51. *Vasum turbinellus* (Linnaeus,1758)

Family ELLOBIDAE

52. *Hydantina albocineta* (Gmelin, 1791)
53. *Ellobium gangeticum* (Linnaeus, 1758)

Family CYPRAEDAE

54. *Cypraea lynx* (Linnaeus, 1758)
55. *C. annulus* (Linnaeus, 1758)
56. *C. maurutiana* (Linne, 1758)
57. *C. moneta* (Linne, 1758)
58. *C. isabella* (Linnaeus, 1758)
59. *C. tigris* (Linnaeus, 1758)
60. *C. caput-serpentis* (Linnaeus, 1758)

Family CONIDAE

61. *Conus lividus* (Hwass, 1792)
62. *C. coronatus* (Gmelin, 1791)
63. *C. ebraeus* (Linnaeus, 1758)
64. *C. frigidus* (Reeve, 1848)
65. *C. renaniculus* (Reeve, 1848)
66. *C. miles* (Linnaeus, 1758)
67. *C. geographus* (Linnaeus, 1758)
68. *C. striatus* (Linnaeus, 1758)

Family CYMATIDAE

69. *Cymatium pileare* (Linnaeus, 1758)
70. *Tona dolium* (Linne, 1758)

Family CASSIDAE

71. *Casis rufa* (Linnaeus, 1758)
72. *C. cornuta* (Linnaeus, 1758)

Family PLANAXIDAE

73. *Planaxis sulcatus* (Born, 1780)

Family ACAMAEIDAE

74. *Acmaea stellaris* (Pilsbry, 1891)

Family PATELLIDAS

75. *Patelloidea saccharina* (Linnaeus, 1758)

Family RANELLIDAE

76. *Charonia tritonis*

Nudibranchs

Family PHYLLIDIIDAE

77. *Phyllidia varicose* (Lamarck)
78. *P. coelestis* (Beegh)

Family ONCHIDIDAE

79. *Onchidium vernucullatum* (Cuvier)

Family KENTRODORIDIDAE

80. *Jorunna funebris*

Family GLAUCIDAE

81. *Pteraeolidia ianthina* (Angea)

Family HEXABRANCHIDAE

82. *Hexabranchus sanguineus*

Family PLAKOBRANCHIDAE

83. *Plakobranchus sp.*

In the Great Nicobar Island, percentage of gastropod abundance was more at Inhengloi shore (10.07 per cent) followed by Pilobhabi (8.23 per cent), Megapod Island (7.67), all in the west coast and Swarup nallah (7.62 per cent), Dubey nallah (7.61 per cent) and Dillon nallah (6.92 per cent) of the east coast. Minimum percentage of gastropods was observed at Indira Point (0.46 per cent) of the south coast. At Kiched nallah, from the north coast of the island, 4.17 per cent was recorded (Fig. 1).

The order of abundance of gastropods in different stations of the Great Nicobar Island was as follows :

Inhengloi (shore) > Pilobhabi > Megapod Island > Swarup nallah > Dubey nallah > Dillon nallah > Dongi nallah > Prem nallah > Trinket Champlong Bay > Kopenheat > Alexandria Bay > Pilokunji > Kiched nallah > Sippy nallah > Magar

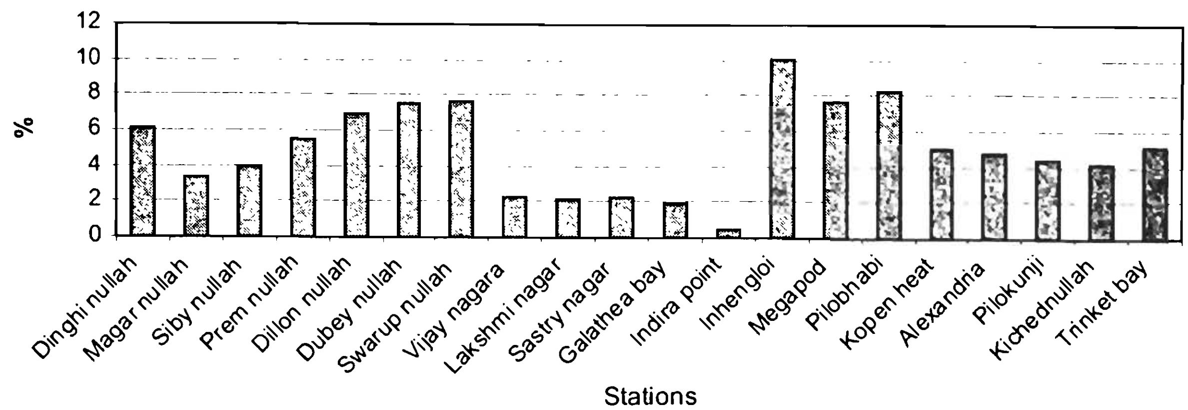

Fig. 1. Percentage of gastropod contribution recorded at different stations of the Great Nicobar Island

nallah > Vijay nagar > Lakshmi nagar > Sastri nagar > Galathea Bay > Indira Point.

Galathea Bay recorded good population density of some species like *Cyprea caputserpentis* (2-5/m^2), *C. moneta* (3-6/m^2) and *C. lynx* (2-5/m^2).

Bivalves

Bivalves are the second largest sub-class of the phylum Mollusca. It contains a variety of familiar bivalves that are often easily seen in their natural habitats. In the present study, bivalves were represented by 15 families *viz.* Pseummobiidae, Veneridae, Pinnidae, Tridacnidae, Mytilldae, Carditidae, Pteriidae, Mactridae, Ostreidae, Arcidae, Tellinidae, Pectinidae, Corbiculidae, Limidae and Spondylidae, embracing 30 species, recorded from the east, west, north and south coasts of the Great Nicobar Island (Table. 2). Among them, 18 species were common.

Table 2. Checklist of bivalves recorded from the Great Nicobar Island.

Phylum MOLLUSCA

Class BIVALVIA

Family PSAMMOBIIDAE

1. *Asaphis violascensis*(Forskal, 1775)

Family VENERIDAE

2. *Periglypta reticulata* (Linnaeus, 1758)
3. *P. crispata* (Deshayes, 1853)
4. *P. puerpera* (Linnaeus, 1771)
5. *Divaricella cumingii* (Sowerby, 1833)
6. *Tivella stultorum* (Linnaeus, 1758)

Family PINNIDAE

7. *Pinna bicolor* (Gmelin,1792)
8. *Atrina vexillum* (Born, 1778)

Family TRIDACNIDAE

9. *Tridacna maxima* (Roeding, 1798)
10. *T. crocea* (Lamarck, 1819)
11. *T. squmosa* (Lamarck, 1819)
12. *Hippopus hippopus* (Linnaeus, 1758)

Family MYTILIDAE

13. *Septifer biocularis* (Linnaeus, 1758)

Family CARDITIDAE

14. *Cardita varigata* (Bruiere, 1789) (*Cardita varigata*)
15. *Trachycardium elongatum* (Bruguiere, 1789)
16. *T. flavum* (Linnaeus, 1758)

Family PTERIDAE

17. *Pteria penguin* (Roeding, 1778)
18. *Pinctada margaritifera*(Linnaeus,1758)

Family MACTRIDAE

19. *Mactra olurina* (Philippi, 1846)
20. *M. achatina* (Holten, 1802) (*Mactra eliptica*)

Family OSTREIDAE

21. *Saccostrea cucullata* (Born, 1778)

Family ARCIDAE

22. *Barbatia fusca* (Bruiguiere, 1789)
23. *Arca antiqualata* (Linnaeus, 1758)
24. *Anadara scapha* (Linnaeus, 1758)

Family TELLINIDAE

25. *Tellina remies* (Linnaeus, 1758)
26. *T. scobinata* (Linnaeus, 1758)

Family PECTINIDAE

27. *Gloripallium pallium pallium* (Linnaeus, 1758)

Family CORBICULIDAE

28. *Gelonia erosa* (Linnaeus, 1758)

Family LIMIDAE

29. *Lima lima* (Linnaeus, 1758)

Family SPONDYLIDAE

30. *Spondylus hastrix* (Roeding, 1798)

Unlike the gastropods, bivalves were distributed in all the coasts, a maximum of 17 species each were recorded from Indira Point and Inhengloi shore followed by Trinket Champlong Bay (16 species) and Galathea Bay and Megapod Island (15 species each). Minimum number of species at Campbell Bay and Prem nallah (5 species each) followed by Dongi nallah (6 species) in the east coast and Pilokunji (6 species) in the west coast.

Higher percentage of bivalve abundance was recorded at Inhengloi (shore) (18 per cent) and Megapod Island (17 per cent), both on the west coast and Trinket Champlong Bay (14 per cent) along the north coast of the island. The minimum percentage was observed at Prem nallah (0.5 per cent) and Indira Point (0.8 per cent), east and south coasts respectively (Fig. 2.).

Cephalopods

In the present study, a total of 6 species belonging to 3 families of cephalopods (Table 3.) were identified from the entire coast of the Great Nicobar Island. Higher number of species (4) was recorded at Inhengloi shore followed by Megapod Island and Alexandria Bay (2 species each), all in the west coast. Indira Point and Trinket Champlong Bay along the south and north coasts also recorded 2 species each. Whereas in the east, only Lakshmi nagar and Galathea Bay recorded 1 species each.

Higher percentage of cephalopod abundance was recorded at Inhengloi (shore) (27 per cent) followed by Megapod Island and Alexandria Bay (21 per cent each), all in the west coast and Trinket recorded 11 per cent in the north coast. The minimum percentage was recorded in Dongi nallah (1 per cent) followed by Lakshmi nagar (4 per cent) and Galathea Bay (4 per cent) in the east and Indira Point (6 per cent) in the south coast while Pilobhabi recorded 4 per cent. From the other stations, cephalopod species could not be recorded. An important feature of the present study is that three species of cephalopods (*Octopus filose, O. jobbing* and *O. unicirhus*) have been found to be the new distributional records to the Andaman and Nicobar waters as well as Indian waters.

Table 3. Checklist of cephalopods recorded from the Great Nicobar Island.

Phylum MOLLUSCA

Class CEPHALOPODA

Family OCTOPODIDAE

1. *Hapalochlaena maculosa* (Robson, 1929)
2. *Octopus unicirhus* (Orbigny, 1840)
3. *O. filosus* (Howell, 1868)
4. *O. joubini* (Robsen, 1929)

Family NAUTILIDAE

5. *Nautilius pompillus* (Linnaeus, 1758)

Family LOLIGINIDAE

6. *Sepioteuthis lessoniana* (Blainville, 1824)

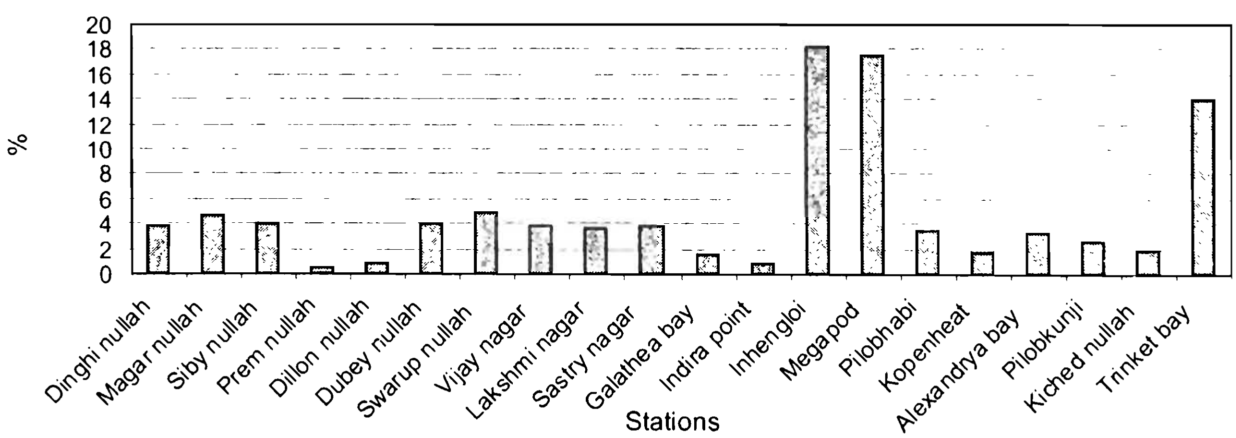

Fig. 2. Percentage of bivalve contribution recorded at different stations of the Great Nicobar Island

DISCUSSION

Out of the 1900 species of gastropods reported from India, only 83 species belonging to 27 families have been recorded from the Great Nicobar Island during the present study. This could be ascribed to the fact that most of the gastropods were found in the sub-tidal areas but our collections were from the inter-tidal areas as sub-tidal collections were not possible in such areas for the reason that the wave action was more in these areas.

Remarkably some rare and colorful opisthobranchs were seen in the coral reef, seaweed and seagrass areas of the island. A total of 7 species of opisthobranchs were recorded (*Phylidia varicoseae, P colesties, Onchidium varriculattum, Jorunna funebris, Pteraeolidia ianthina, Hexabranchus sanguineus* and *Plakobranchus sp.*). Among these, *O. varriculattum* was common and found on the surface of the rocks and also reported earlier from the Nicobar group of islands (Surya Rao and Subba Rao, 1991). But, the remaining six species are the first time records from the Great Nicobar waters and these species are commonly found in the Indo-Pacific coral reef areas (Allen Gerald, 1994).

Contribution of the bivalves to the mollusca fauna of the Great Nicobar Island was less, as exemplified by the presence of only 30 species of bivalves. This could be attributed to the dominance of rocky nature of the coast, as most of the bivalves prefer sandy shores for their dwelling. Number of species of bivalves varied from station to station. Some of them (*Asaphis violoscensis, Septifer bilocularis, Tridacna maxima* and *Tridacna squmosa*) were found commonly at all the stations. Particularly *Tridacna spp.* were abundant in the Galathea Bay, probably due to the fact that this Bay is relatively pollution free and embraces higher plankton density.

Present survey at various stations of the Great Nicobar Island revealed the presence of large populations of oysters and clams. Earlier, population density of *Saccostrea cuculata* (5-7/m^2), *Asaphis viaosensis* (3-6/m^2) and *Tridacna spp.* (3-5/m^2) was reported by CMFRI (1978). Ramadoss (1983) recorded the presence of *Crasosstrea madrasensis* and *S. cuculata* from the intertidal areas of Port Blair, Ross Island and Chidiyatapu with a total number of 105, 20 and 40 animals per meter square respectively. In the present study, it was noticed that the oyster population (*Saccostrea cuculata*) was higher at Dongi nallah(30-40/m^2), Magar nallah(20-40/m^2), Sippy nallah(20-40/m^2), Swarup nallah(15-40/m^2), Megapod Island (30-40/m^2) and Trinket Champlong bay (20-30/m^2).

Though the bivalve species were found distributed throughout the island coast, west coast registered more density when compared to the east coast. The order of abundance of bivalves at the different stations of the Great Nicobar Island was as follows :

Inhengloi (shore) > Megapod Island > Trinket Bay > Magar nallah> Sippy nallah> Swarup nallah> Dubey nallah>Vijay nagar > Sastri Nagar > Dongi nallah> Lakshmi nagar > Pilobhabi > Kiched nallah> Kopenheat > Galathea Bay > Indira Point > Dillon nallah> Prem nallah.

In the Class Cephalopoda, there are about 660 species in the world oceans, which are diverse in form, size and nature (Voss, 1973,1977; Voss and Williamson, 1971; Worms, 1983). Of these, less than hundred species are commercially important. However, only 6 species were identified during the present study period. This could be due to the lack of suitable crafts and gears in catching them (Fig. 3).

Though there is an estimated amount of 1,04,354 tonnes of annual cephalopod landing in the Indian coast during 2002, cephalopod fishing in the Great Nicobar Island is very limited due to the fact that the fisherman lack knowledge about the suitable catching techniques. Moreover, the cephalopod diversity is also comparatively less than that of the other two groups of molluscs viz. gastropods and bivalves in the Great Nicobar waters. The total percentage of cephalopods recorded in this island was very low (0.9 per cent) than that of the other groups of molluscs. However, similar percentage contributions of molluscan fauna were reported by Rao and Dey (1991) who registered 60 per cent of gastropods and 35 per cent of bivalves and the remaining 5 per cent was contributed by cephalopods, polyplacaphora and scaphopoda. (Fig. 4). The blue ringed octopus, *H. maculosa* recorded in the present study is very dangerous as it has venom, which is 200 times more effective than the cobra venom.

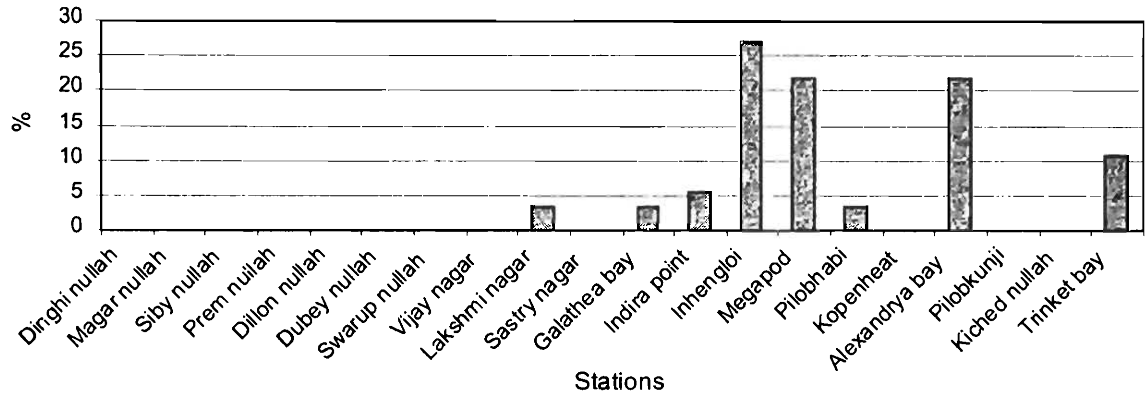

Fig. 3. Percentage of cephalopod contribution recorded at different stations of the Great Nicobar Island

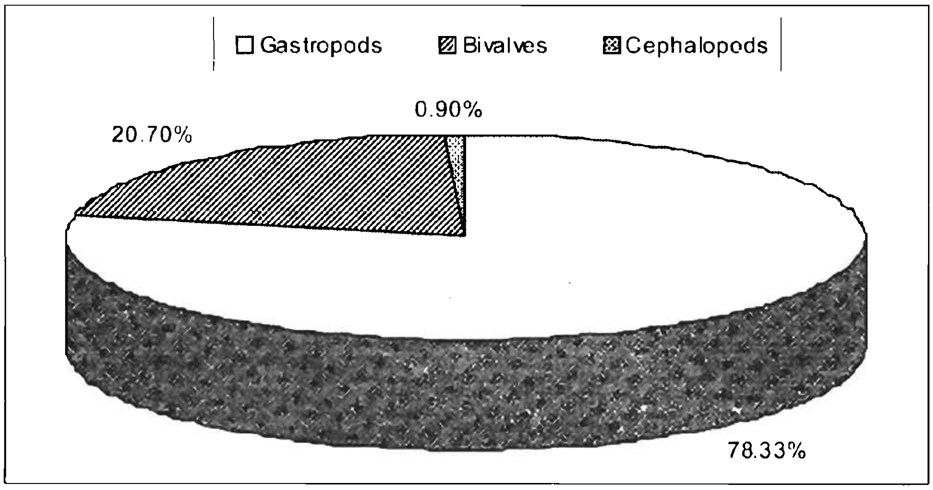

Fig. 4. Percentage contribution of gastropods, bivalves and cephalopods recorded in the Great Nicobar coastal water

From the present investigation, it is inferred that the gastropods contribute 78.33 per cent to the total molluscan resource of the Great Nicobar waters followed by bivalves (20.7 per cent) and cephalopods (0.9 per cent) (Fig. 2). It is also evident that the west and north coasts of the Great Nicobar Islands harbour rich molluscan diversity and density when compared to the east and south coasts. This clearly indicates that the west and north coast molluscan resources are not disturbed by human interventions. The difficulty in reaching the west and north coasts might be the reason for this whereas the east and south coasts are easily accessible through roads.

The present study has brought out new distributional records of molluscs i.e. 11 species of gastropods, 3 species of bivalves and 3 species of cephalopods to the Great Nicobar Island. This includes 9 species of gastropods, 2 species of bivalves and 3 species of cephalopods which are new distributional records to India.

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Chapter 23

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 283-288, 2010

AN ACCOUNT ON NEWLY RECORDED FIVE SPECIES OF NUDIBRANCHS (OPISTHOBRANCHIA, GASTROPODA) IN ANDAMAN & NICOBAR ISLANDS

C. RAGHUNATHAN*, C. SIVAPERUMAN and RAMAKRISHNA**

Zoological Survey of India, Andaman and Nicobar Regional Centre, Port Blair-744 102, Andaman & Nicobar Islands

INTRODUCTION

Nudibranchs are conspicuous shell-less marine gastropod mollusc under the Order Opisthobranch. More than 3000 species of Nudibranchs are described around the world. Nudibranchs live at virtually all depths of ocean, but reach their greatest size and variation in tropical shallow waters ranged from 20 to 600m. They are hermaphroditic and thus have a set of reproductive organs of both genders and deposit their eggs within a gelatinous spiral (Klussmann-Kolb, 2001). Nudibranchs are carnivorous and feed on sponges, hydroids, bryozoans, tunicates, barnacles and anemones and in some occasions members of their own species. These animals have camouflage and protect themselves from predators by releasing sour liquid from skin. Their cephalic tentacles are sensitive to touch, taste and smell.

Five species of Nudibranchs *viz. Hexabranchus sanguineus* (Ruppell and Leuckart, 1828), *Aglaja tricolorata* Renier, 1807, *Phyllidia varicosa* Lamarck, 1801, *Phyllidiella pustulosa* and *Jorunna funebris* (Kelaart, 1858) were reported from Andaman waters while conducting underwater survey on coral reefs and its associated fauna of Andaman & Nicobar Islands. In Indian waters only 2 species of nudibranchs, *Aglaja pilsbryi* Eliot and *Aglaja lineolata* H. & A. Adams under the family Aglagidae were reported in Andaman and Nicobar Islands (Subba Rao and Dey, 2000), while the other nudibranch genera such as *Hexobranchus, Phyllidea, Phyllidiella* and *Jorunna* were not encountered so far. Hence it is observed that the occurrence of these five nudibranch species have been new record not only to Andaman & Nicobar Islands but also to Indian subcontinent as a whole.

Studies on biology and development of *Hexabranchus* (Gohar and Soliman, 1963) and its observation in Australian Great Barrier Reef (Thompson, 1972), an account on the family Aglajidae in the Iberian Peninsula (Martinez *et al.*, 1993), comparative study on the genus *Aglaja, Philinopsis, Novanax* and *Chelidonura* for its taxonomical and anatomical status (Rudman, 1972, 1974) and habitat, food and reproductive activity of *Hexobranchus* on Tongatapu Island (Francis, 1980) have been documented earlier. In addition, Guo *et al.* (1998) elucidated the structure of hurghadin pigment from the Red Sea nudibranch *Hexabranchus sanguineus*. This species derives the potent chemical defense from a sponge (*Halichondria* sp.) that it eats. The

*E-mail : kscraghu@rediffmail.com

***Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata 700 053*

striking colour pattern and behavioural responses of *Hexabranchus* may have arisen with concomitant elaboration of dietary derived chemical defenses (Pawlik *et al.*, 1988). Chattopadhyay and Pattenden (1998) synthesized the ulapaulide A, a novel *tris*-oxazole containing macrolide from *Hexabranchus sanguineus*. The remarkable diversity of trepenoid metabolites possessed by this species supports some recent phylogenic studies that place the mollusc near the steam of the dorid nudibranch tree and suggest some cues on studying evolutionary trends in dorid nudibranchs (Zhang *et al.*, 2007). The dietary transfer of sesquiterpene isocyanide and isothioyanates from marine sponges *Acanthella cavernosa* and *Phakellia carduus* to *Phyllidiella pustulosa* (Dumdei *et al.*, 1997 and Wright, 2003) were also been reported.

MATERIALS AND METHODS

Presently recorded five species of nudibranchs were collected by snorkeling and skin diving at a depth of 3-6m in the infra-littoral zone of Andaman Sea at three locations viz. Pongibalu (11°31.030′ N, 92°39.159′ E), Burmanella (11°31.468′ N, 92°43.573′ E) and Rutland Island (11°29.288′ N, 92°40.141′ E) where the diversity of corals are luxuriant. Among them each one specimen of *Hexabranchus sanguineus* and *Aglaja tricolorata* were found at Burmanella on January 27, 2008, while three specimens of *Phyllidia varicosa* encountered at both Pongibalu (1 specimen) on December 22, 2008 and Rutland Island (2 specimens) on June 24, 2008. Single specimen of both *Phyllidiella pustulosa* and *Jurunna funebris* were collected at Rutland Island on June 24, 2008 during the survey. The morphological features of all the specimens were carefully studied and their ambient environment also observed thoroughly. All the specimens were deposited in the National Zoological Collection of Zoological Survey of India, Andaman and Nicobar Regional Centre, Port Blair.

RESULTS AND DISCUSSION

The description, distribution and morphological features of the nudibranch species collected from Andaman and Nicobar Islands are given below.

1. ***Hexabranchus sanguineus*** (Ruppell & Leuckart, 1828)
(Plate 14, Fig. 1)

Order NUDIBRANCHIA

Suborder DORIDINA

Family HEXABRANCHIDAE

Description : *Hexabranchus sanguineus* is commonly called as 'Spanish Dancer'. The body is bright red in colour and have six branched gills inserted separately in to the body wall within distinct pockets. The oral tentacles have a hand like appearance and are divided into a pair of fringed (digitate) lobes. The rhinophores have a smooth stalk and enlarged upper section like a clavus bearing numerous lamellate and it has orange to red orange with white stripes along the outer faces of the lamellae. Animal usually curl the lateral areas of the mantle inwards leaving only the central section of the dorsum exposed. The length of the presently collected specimen is 12.3cm with a width of 4.2 cm.

Geographic range : *Hexabranchus sanguineus* was first described from the Red Sea followed by Hawaii and Tanzania (Rudman, 1999). It is distributed in tropical Indo-Pacific region and it can be found from intertidal to 50m deep waters. Recently it was reported from Myanmar in the coral reef area at a depth of 10-17m (Adams, 2003). The occurrence of this species in Burmanella region of Andaman Sea was obsereved at a depth of 4 m in the infralittoral zone. However it is also reported from Australia (New South Wales, Queensland and Western Australia), Egypt (Sinai), Indonesia (Sulawesi), New Caledonia, Philippines and South Africa (www.zipcodezoo.com).

Remarks : *Hexabranchus sanguineus* is one of the largest of all nudibranchs with animals being recorded at over 40cm in length. This species has varying colour pattern ranged from red to yellow (Rudman, 1999). There are approximately 7 species under the genus *Hexabranchus* viz. *Hexabranchus digitatus*, *Hexabranchus imperialis*, *Hexabranchus marginatus*, *Hexabranchus morsomus*, *Hexabranchus petersi* and *Hexabranchus sanguineus* were reported worldwide. Except the presently reported species, none of the species under this genus was encountered from India. In Andaman waters this species was associated with the corals *Acropora* *humilis* and *Montipora digitata* as well as soft corals *Sinularia* sp. and *Lobophytum* sp. which is coincided with the earlier observation of its occurrence in coral reef of Great Barrier Reef (Thompson, 1972) and reefs of Burma (Adams, 2003). *Hexabranchus sanguineus* is a sponge feeder but does not seem to be specialized feeder on a particular species of sponge and the skeletal spicules of many encrusting sponges have been found in its stomach (Young, 1969). They protect themselves from predators by its distastefulness and potentially toxic chemicals in its body and egg masses. These chemical molecules found in *Halichondria,* one of the sponges that *Hexabranchus sanguineus* eats. The sponge produces the molecules to protect itself from fish predation. It is proved that *Hexabranchus sanguineus* obtains the molecules from the sponge during feeding, and after modifying the structures of the molecules slightly and store them in its skin and egg masses for its own protection (Pawlik *et al.*, 1988).

2. ***Aglaja tricolarata*** Renier, 1807
(Plate 14, Fig. 2)

Order CEPHALASPIDEA

Family AGLAJIIDAE

Description : *Aglaja tricolorata* observed from Burmanella region of Andaman Sea having a length of 9.7 cm and width of 3.4cm. The animal is translucent brown with opalescent dark spots scattered all over dorsal and lateral surface of the body. On ventral surface the background colour is very translucent and the spots larger. There are blue and orange lines along the parapodial edge. This species has distinctive tentacular corners on the anterior parapodia and a thin posterior flagellum extending out from the ventral fold of the posterior shield.

Geographic range : This species was first known from the Mediterranean and the west coast of Africa (Rudman, 2007). The occurrence of this species in Spain is also reported (www.zipcodezoo.com). Recently this has been reported from Malta on June 2004 at a depth of 32m (Rudman, 2007). In Andaman waters *Aglaja triolorata* was collected at a depth of 3m in the Burmanella region of Andaman Sea.

Remarks : Approximately 12 species of the genus *Aglaja* were reported around the globe, and are *Aglaja adella, Aglaja cyanea, Aglaja depicta, Aglaja diomedea, Aglaja nuttalli, Aglaja ocelligera, Aglaja phaeoreticulata, Aglaja pilsbryi, Alaja pilsbryi elloit, Aglaja queritor, Aglaja regiscorona* and *Aglaja tricolorata.* Like *Hexabranchus sanguineus, Aglaja tricolorata* also found associated with coral reef area of presently reported region of Andaman waters especially on the *Goniopora* and *Montipora* colonies.

3. ***Phyllidia varicosa*** (Lamarck, 1801)
(Plate 14, Fig. 3)

Order NUDIBRANCHIA

Suborder DORIDINA

Family PHYLLIDIIDAE

Description : *Phyllidia varicosa* is commonly called as 'sea slug'. The length of the presently collected specimens is ranged from 7.3-9.7 cm and the width varied between 2.9 and 3.3 cm. The body is firm, 3-6 longitudinal tuberculate notal ridges on the dorsum. The ridge and bases of the tubercles are blue-grey in colour and the tubercles are capped in yellow. The foot sole possesses a black longitudinal foot stripe. The rhinophoral clavus possesses 27-30 lamellae. This animal can grow the maximum length of 12 cm (Rudman, 1999).

Geographic range : This species is known throughout the Indo-West Pacific Oceans including the central Pacific and the Red Sea. However this was first described from Murat Point of Western Australia. Apart from that it is also distributed in New South Wales and Queensland in Australia, Sulawesi in Indonesia, Maldives, Mozambique, New Caledonia, Papua New Guinea, Philippines, Reunion Island, Solomon Island, Tanzania, Thailand and Vamiata (www.zipcodezoo.com). Presently in Andaman waters it was reported at a depth of 4m in Pongibalu as well as Rutland Islands. However this specimen has been found in 22m depth at Apara Harbour, Guam during July 1988 having a length of 10.4 cm and 4-10 m depth at Phi Phi Island, Southern Thailand during November 1989 (Brunckhorst, 1993).

Remarks : Twenty three species under the genus *Phyllidia* were recorded all over the world. *Phyllidia varicosa* also found associated with corals such as *Porites lutea and Acropora* *muricata* and *Goniastrea retiformis* at the presently reported site. This species has chemical defenses and producing toxin to protect themselves from predators. *Phyllidia varicosa* morphologically appears to be closest to *Phyllidia tula*. But *Phyllidia tula* is known only from Micronesia and their noturm possesses single rounded tubercles which are isolated and do not form ridges (Brunckhorst, 1993). It is also have close resemblances with *Phyllidia coelestis* which has a brown black band down the midline while in *Phyllidia varicosa* there is a bluish grey ridge down the middle line. This species has also been confused with *Phyllidia alyta* who possesses a solid black median line in the sole of the foot. However, *Phyllidia varicosa* has many yellow capped notal tubercles on all the rows while only few notal tubercles in the inner three rows found in *Phyllidia alyta* (Brunckhorst, 1993).

4. ***Phyllidiella pustulosa*** (Cuvier, 1804)
(Plate 15, Fig. 4)

Order NUDIBRANCHIA

Suborder DORIDINA

Family PHYLLIDIIDAE

Description : *Phyllidiella pustulosa* has three median clusters of pink tubercles. The tubercles are in a cluster which is separated in adult specimen, however it is amalgamated on juvenile stage. The intensity of pink colouration is possibly related to diet and time since feeding (Brunckhorst, 1993). The mantle has pale pink edge, the broad and oral tentacles are triangular, black tipped and the rhinophoral clavus possessing 22-26 lamellae. The total length of the specimen collected from Andaman waters is 4.2cm with the width of 1.8 cm.

Geographic range : *Phyllidiella pustulosa* is one of the most common nudibranchs distributed throughout the tropical Indo-West Pacific. It is reported from Australia (New South Wales, Queensland, southern and western Australia), Fiji, Indonesia (Sulawesi), Japan, Madagascar, New Caledonia, Papua New Guinea and Thailand (www.zipcodezoo.com). In Andaman waters this species was encountered at 4m depth in Rutland Island while it was collected from 22m deep at 'Sponge Mound' Apara Harbour, Guam during July 1998 (Brunckhorst, 1993).

Remarks : Fourteen species of the genus *Phyllidiella* were recorded worldwide. Except *Phyllidiella pustulosa* reported from through present paper, none of the species was noticed from Andaman waters. This species was found associated with corals and sponges in the study area. *Phyllidiella pustulosa* is closest in appearance to *Phyllidiella annulata, Phyllidiella zeylonica* and *Phyllidiella granulata*. However, *Phyllidiella annulata* differs by having many pink rings with low angular tubercles, lack of pale edge to the mantle and possession of 17-20 lamellae on each rhinophoral calvus. Whereas, *Phyllidiella zeylonica* has pink compound tubercles which are coalesced into the longitudinal ridges and has 20-23 lamella on each rhinophoral clavus while *Phyllidiella granulata* has three medium groups of tubercles and 17-20 lamellae on each rhinophoral clavus (Brunckhorst, 1993). The occurrence of *Phyllidiella pustulosa* in sponge dominated area of the present study is in conformity with the lipophilic extract of this species and the sponge *Phakellia carduus* clearly observed that sponge formed a major part of the nudibranch diet and it is also indicated that the nudibranch accumulates some of the sponge as metabolites in preference of others (Wright, 2003).

5. ***Jorunna funebris*** (Kelaart, 1858)
(Plate 15, Fig. 5)

Order NUDIBRANCHIA

Suborder DORIDINA

Family DORIDIDAE

Description : The length of the presently recorded *Jorunna funebris* is 3.2 cm with a width of 1.7 cm. The body is white with irregular black and brown rings. Rhinophore is black with white base. Their mantles covered in small speculate papillae (caryophyllidia) which are the characteristics of the genus. However in juveniles, the black spots are in act open rings and as they grow the other apparent spots will also expand in size and become rings (Rudman, 1998).

Geographic range : *Jorunna funebris* was first described from Ceylon by Kelaart (1858). It is distributed along tropical Indo-West Pacific. They are also observed from Australia (New South Wales), Indonesia (Sulawesi), Malaysia, New Caledonia, Papua New Guinea, Philippines, Solomon Islands and Tokelau. In Andaman waters it was collected at a depth of 4 m in Rutland Island.

Remarks : Seven species under the genus *Jorunna* viz. *Jorunna funebris, Jorunna hartleyi, Jorunna luisiae, Jorunna pantherina, Jorunna pardus, Jorunna tomentosa* and *Jorunna zania* were observed worldwide. The presently reported species was found in close association with sponges in coral reef ecosystem like other species of nudibranchs newly recorded over here. *Jorunna funebris* was collected at a depth of 3 m in Rutland Island of Andaman waters. It is a sponge feeder and eats different species of sponges (Rudman, 1998). This species has been observed with blue sponge *Xestrospongia* sp. in eastern Gulf of Thailand, on *Haliclona* sp. in Marcanas Island and on *Euplacella cf. australis* in Great Barrier Reef, Queensland (Rudman, 1998).

In conclusion, the presently reported 5 species of nudibranchs from Andaman Sea of Andaman & Nicobar of Islands are contributing towards the faunal diversity of India as they recorded for the first time in Indian subcontinent. Although more than 3000 species of nudibranchs reported around the globe, the exploration of this particular group received meagre attention in Indian territorial waters as relatively very few species of nudibranchs recorded in India. As it is evinced that most of these organisms are the inhabitant of coral reef ecosystem where the abundance of sponge diversity, and having 2,379 km^2 of coral reef cover in India, the intensive exploration on the nudibranchs and its taxonomical studies will certainly leads to the invention of several new species as well as new records under the opisthobranch molluscs.

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Plate 14

Fig. 1. *Hexabranchus sanguineus* (Ruppell & Leuckart, 1828)

Fig. 2. *Aglaja tricolorata* Renier, 1807

Fig. 3. *Phyllidia varicosa* Lamarck, 1801

Plate 15

Fig. 4. *Phyllidiella pustulosa* (Cuvier, 1804)

Fig. 5. *Jorunna funberis* (Kelaart, 1858)

Chapter 24

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 289-298, 2010

ON SOME NEW RECORDS OF SEA SLUGS (CLASS GASTROPODA, SUBCLASS OPISTHOBRANCHIA) FROM ANDAMAN AND NICOBAR ISLANDS

C.R. SREERAJ, P.T. RAJAN, R. RAGHURAMAN, C. RAGHUNATHAN, R. RAJKUMAR RAJAN, TITUS IMMANUEL and RAMAKRISHNA***

Zoological Survey of India, Andaman and Nicobar Regional Centre, Port Blair–744 102, Andaman and Nicobar Islands

INTRODUCTION

Prismatic, conspicuous invertebrates that live in coral reefs are the nudibranchs (Class: Gastropoda, Subclass: Opisthobranchia). Seemingly defenseless, these gaudy creatures are one of the excellent candidates for biomedical research. The Opisthobranchiate fauna, even though endowed with numerous promising beneficial substances, unfortunately falls under the least studied category not only from Andaman and Nicobar Islands but also in entire Indian waters. There were no available reports on nudibranch fauna published from these Islands so far except the recent report on 5 species of nudibranchs by Raghunathan (In press). Most of the information available on the Indian opisthobranchs are pertaining to the peninsular coast. During the past several years, the described opisthobranch taxa of the western Pacific have increased dramatically (Brunckhorst 1993; Gosliner 1994; Gosliner and Drahein 1996; Gosliner and Behrens 1997; 1998a and b, 2000; Johnson and Gosliner 1998; Gosliner and Fahey 1998; Carlson and Hoff 2000; Fahey and Gosliner 2003; Hamatani 2001; Smith and Gosliner 2003; Gosliner and Smith 2003). The Indian Ocean, however, has a richly diverse but reasonably unknown oipsthobranch gastropod fauna (Coleman 2001; Gosliner 1994; Gosliner and Behrens 2000; Valdes, Mollo and Ortea 1999; Yonow 1984, 1994, Yonow *et al.* 2002).

In the beginning of 20th century, few studies on Opisthobranchiate fauna of India have been made by Eliot (1906; 1910; 1916). However detailed reports on the Opisthobranchiate fauna were published during late 20th century (Burn. R., 1970; Narayan, 1968, 1968a; 1968b, 1970. Rao and Krishna Kumary, 1973., Rao *et al.* 1974). Subba Rao (2003) reported the occurrence of eight orders and as many as fifty families consisting of about 150 species which is considerably a poor representation of the richly diversified sea slugs in India compared to 3400 species estimated to occur in the Indo-West Pacific Province. Previously 29 species of opisthobranchs were reported from Andaman and Nicobar Islands belonging to 11 families and 4 orders (Subba Rao and Dey, 2000) including the occurrence of a species of nudibranch, *Pseudovermis solcatus*.

This paper reports the occurrence of 17 nudibranchs from Andaman and Nicobar Islands which are not hitherto reported. Three species which were already recorded from Andaman was also observed during this study, such as *Phillidiella*

*Zoological Survey of India, M Block, New Alipore, Kolkata-700 053
**crsreeraj@gmail.com

pustulosa, *Phillidia varicora* and *Jorunna funebris* (Raghunathan, in press). The specimens examined in the study are deposited in the Andaman and Nicobar Regional Centre of Zoological Survey of India.

METHODOLOGY

An extensive survey of sea slugs and their occurrence was conducted during the months of April to July 2009 in various regions of Andaman Islands. SCUBA gears are used for surveying and collection of the specimens at sub-tidal regions. Organisms were observed, photographed in underwater and collected for identification. Live specimens brought to the laboratory are subjected to detail observation to reveal their exclusive morphological characters and measurements. Specimens were preserved in 90% ethyl alcohol after narcotizing with magnesium chloride for further studies.

Characters used in this study are: general shape and body profile; colour and pattern; morphology of notal tubercles, ridges, and the mantle margin; rhinophoral colour; morphology of foot and foot sole and oral tentacles.

RESULTS

A total of 17 species of sea slugs belonging to 2 orders and 7 families were recorded for the first time from Andaman during our survey.

1. ***Plakobranchus ocellatus*** Van Hasselt, 1824 (Plate 16, Fig. 1)

Hasselt, J.C.V. (1824) In : Andre Férussac. Extrait d'une lettre du Dr. J.C. van Hasselt au Prof. van Swinderen, sur mollusques de Java (traduit de l'Algem. konst en letterbode, 1824, nos. 2, 3, 4.) Tjuringe (île Java), le 25 mai 1823 (I). *Bulletin des Sciences Naturelle et de Géologie*, **3** : 237-245.

Order SACOGLOSSA

Super family ELYSIOIDEA

Family PLAKOBRANCHIDAE

Material examined : Locality : Carbyn's cove; (Lat. 11 38.468 N, Long. 92 45.151 E) from the rocky intertidal zone. Bottom consists of rocks covered with algae and sand in between; coral recruits were also observed. Size : 4.5 cm total length. Reg. No. ZSI/ANRC 4370, 14.08.2009.

Remarks : *Plakobranchus ocellatus* is a common inhabitant of shallow waters of Andaman Islands. This species was reported from India four decades ago (Virabhadra Rao, 1961). Although a number of names exist for various color forms, the general consensus is that there is only one species. It is mostly seen half buried in the sandy area or coral reef of intertidal area. Like species of *Elysia*, it has parapodia which fold over the backside of the animal. The green patch in the mantle is from the green ridges, packed full of microscopic chloroplasts, which line inside of the parapodia. The species available in this area has a creamy white rhinopore instead of the common black rhinopore as reported elsewhere.

Distribution : Found throughout the tropical Indo-West Pacific.

2. ***Cerberilla annulata*** (Quoy and Gaimard, 1832) (Plate 16, Fig. 2)

Quoy, J.R. & Gaimard, J.P. (1832). Voyages de découvertes de l'Astrolabe pendant les annees 1826-1829 sous le commandement de M.J. Dumont d'Urville. *Zoologie*, **2** : 1-686.

Order NUDIBRANCHIA

Suborder AEOLIDINA

Family AEOLIDIIDAE

Material examined : Locality : Rail Island (Mayabunder); (Lat. 12 56.860 N, Long. 92 54.620 E). Depth: 1 m. Size : 4.5 cm total length. Reg. No : ZSI/ANRC 4377, 14.08.2009.

Remarks : Mantle and cerata are white in colour. This sand dwelling aeolid has a wide tropical Indo-West Pacific distribution. It is characterised by the relatively long cerata, white body and cerata, and yellow (upper) and black (lower) band near the ceratal tip. The yellow and black bands are divided with a small white band. The cerata are numerous in number and are arranged irregularly.

Distribution : Wide Indo-West Pacific distribution.

3. ***Pteraeolidia ianthina*** (Angas, 1864) (Plate 16, Fig. 3)

Angas, G.F. (1864). Description d'espèces nouvelles appartenant à plusieurs genres de Mollusques Nudibranches des environs de Port-Jackson (Nouvelles-Galles du Sud), accompagnée de dessins faits d'après nature. *Journal de Conchyliologie*, **12** : 43-70.

Order NUDIBRANCHIA

Suborder AEOLIDINA

Family GLAUCIDAE

Material examined : Locality : North Bay; (Lat. 11 42.084 N, Long. 92 45.102 E) off to Port Blair; from the south eastern side of the bay; bottom consists of hard corals dominated by *Porites* sp. Depth: 3 m. Size: 8 cm total length. Reg. No. ZSI/ ANRC 4378, 14.08.2009.

Remarks : The mantle greyish in colour; the colour varies from place to place. Distinguished by the length and branched ceratal group at particular interval. A greenish to white stripe from the anterior of the mantle to the end. *Pteraeolidia* stores zooxanthellae in its body, which helps them to stay without taking food for few days. The white animal is a juvenile which has not yet developed its crop of zooxanthellae. White juveniles are usually found in lush growths of short turfing hydroids. The large solitary hydroid is the preferred adult food. The animal was collected from a massive porites coral from the reef flat area.

Distribution : Throughout the tropical and subtropical Indo-West Pacific.

4. ***Gymnodoris rubropapulosa*** (Bergh, 1905) (Plate 16, Fig. 4)

Bergh, L.S.R. 1905. Malacologische Untersuchungen. In : Reisen im Archipel der Philippinen von Dr. Carl Gottfried Semper. Zweiter Theil. Wissenschaftliche Resultate. Band 9, Theil 6, Lief. 2, pp. 57-118, pls. 5-8.

Order NUDIBRANCHIA

Suborder DORIDINA

Family GYMNODORIDIDAE

Material observed : Locality : Kamorta Island, Nicobar group of Islands; Depth : 8 m. Size : 4 cm total length.

Remarks : This species has a wide Indo-West Pacific distribution. The mantle is white in colour with orange spots. It has similarities in colour pattern to G. ceylonica but the orange spots are much larger and more densely arranged, the body is more elongate and the gills relatively small. The rhinopore is orange in colour with a white base. The gills are also orange in colour. The gills are branched. It was observed that this species feeds on algae.

Distribution : Indo-West Pacific.

5. ***Hypselodoris bullocki*** (Collingwood, 1881) (Plate 16, Fig. 5)

Collingwood, C. (1881) On some new species of nudibranchiate Mollusca from the eastern seas. *Transactions of the Linnean Society of London, Zoology,* series 2, **2**(2) : 123-140, pls. 9-10.

Order NUDIBRANCHIA

Suborder DORIDINA

Family CHROMODORIDIDAE

Material observed : Locality : Katchall Island, Nicobar group of Islands; Depth: 10 m. Size: 3.5 cm total length.

Remarks : It ranges in color from a pale straw, or even white background to a deep purplish pink. The species observed was bluish in color. There is a thin opaque white line at the mantle border. Typically the gills and rhinophores are yellow or orange with a basal pink or purplish band. The mantle is smooth and without any color or other ornamentations. Rhinopore is yellow to orange in color with a dark blue to purple base. Seen feeding on algae.

Distribution : Tropical western Pacific and eastern Indian Ocean.

6. ***Risbecia pulchella*** (Ruppell and Leuckart, 1828) (Plate 17, Fig. 6)

Rüppell, Wilhelm Peter Eduard Simon, and F. S. LEUCKART. 1831. [for 1828]. Mollusca. In: Atlas zu der Reise im nördlichen Afrika von Eduard Ruppell Erste Abtheilung Zoologie Neue wirbellose Thiere des Rothen Meers, pp. 15-47, pls. 1-12.

Order NUDIBRANCHIA

Suborder DORIDINA

Family CHROMODORIDIDAE

Material examined : Locality: Karlo Island (Mayabunder); (Lat. 12 56.210 N, Long. 92 53.378 E). Depth: 2 m. Size: 6 cm total length. Reg. No: ZSI/ANRC 4374, 14.08.2009.

Remarks : Opaque creamy white mantle, marked by a bluish purple tinge in irregular areas on the mantle and sides of the foot. All the dorsal surface of the mantle and the foot is covered with yellowish orange spots of irregular shape and different sizes. The mantle margin is fringed with a thin border of bright bluish violet. The rhinophores are blue in colour. The gills are simple and creamy yellow in colour with an orange coloured line. The gills are often branched and wave rhythmically from side to side. The front part of mantle has an inward curving typical to this species.

Distribution : Indian Ocean. Relatively common in the Red Sea and East Africa.

7. ***Hypselodoris maculosa*** (Pease, 1871)
(Plate 17, Fig. 7)

Pease, W.H. (1871) Descriptions of new species of nudibranchiate Mollusca inhabiting Polynesia. No. 2. *American Journal of Conchology*, 7(1) : 11-19, pls. 3-9.

Order NUDIBRANCHIA
Suborder DORIDINA
Family CHROMODORIDIDAE

Material observed : Locality : Aberdeen jetty (Port Blair); (Lat. 11 40.195 N, Long. 92 45.008 E); Jetty is dominated by oysters and sponges; corals are very few in number; seen on a sponge (*Ircinia* sp.). Depth : 2 m. Size : 2.5 cm total length.

Remarks : The mantle colour varies from place to place.The background color of the mantle is a pale milky orange-brown. Around the anterior of the mantle is a broad translucent pinkish-purple margin with scattered white and darker pinkish-purple spots. At the posterior end the margin is similarly coloured but the band is not as broad. From the level of the rhinophores back to the gill pocket, there is a broad orange band at the edge. Running down the central part of the mantle is a purple line which is not continuous. The rhinophore stalks are translucent white and the clubs are white with a broad orange band at the base and another just below the tip. On the sides of the body there are white lines and streaks running parallel to the edge of the foot and some pinkish-purple spots.

Distribution : Found throughout the tropical western Pacific and Indian Oceans.

8. ***Chromodoris striatella*** Bergh, 1876
(Plate 17, Fig. 8)

Bergh, L.S.R. (1876) Malacologische Untersuchungen. In: Reisen im Archipel der Philippinen von Dr. Carl Gottfried Semper. Zweiter Theil. Wissenschaftliche Resultate. Band 2, Theil 2, Heft 10, pp. 377-427, pls. 49-53.

Order NUDIBRANCHIA
Suborder DORIDINA
Family CHROMODORIDIDAE

Material examined : Locality : Chidiyatappu; (Lat. 11 29.580 N, Long. 92 42.075 E) Southern most part of South Andaman Island; in the reef flat area; mangroves and other flora line the shore area. Depth: 2 m. Size : 3.5 cm total length.

Remarks : Can be described as being yellowish with thin black lines as distinct from *C. lineolata* which is black with white lines. The difference is particularly clear in paler specimens in which the background colour is clearly a translucent white or straw colour. Unlike *C. lineolata*, this species has a white line along the inner edge of the orange border, rather than black. The mantle edge is bordered by an orange band. Rhinopore is black in colour with white spots. The colour pattern of the gills are also similar to the rhinopore.

Distribution : Tropical Indo-West Pacific.

9. ***Glossodoris atromarginata*** (Cuvier, 1804)
(Plate 17, Fig. 9)

Cuvier, G.L.C.F.D. (1804) Suite de l'extrait des memoires sur les mollusques, par M. Cuvier, contenant la partie anatomique. *Bulletin des Sciences par la Société Philomathique*, Paris **3**(94) : 261-263.

Order NUDIBRANCHIA
Suborder DORIDINA
Family CHROMODORIDIDAE

Material examined : Locality : Katchall Island, Nicobar group of Islands; Depth: 9 m. Size : 3 cm total length.

Remarks : This species ranges in colour from creamy-white to a pale brown. It is characterized by the black line bordering the very sinuous mantle edge, the black edge to the rhinophore pockets, the black rhinophore clubs and the black edging to the simple gills. Although this is the most common species of the group it has been shown recently (Rudman 1986) that there are a number of almost identically coloured species difficult to separate from *G. atromarginata*. Foot without any bordering or any colouration.

Distribution : Found throughout the tropical and subtropical Pacific and Indian Oceans.

10. ***Chromodoris gleniei*** (Kelaart, 1858)
(Plate 17, Fig. 10)

Kelaart, Edward Frederick. 1858. Descriptions of new and little known species of Ceylon nudibranchiate molluscs and zoophytes. *Journal of the Royal Asiatic Society Ceylon Branch, Colombo*, **3**(1) : 84-139, 2 pls.

Order NUDIBRANCHIA
Suborder DORIDINA
Family CHROMODORIDIDAE

Material examined : Locality : Aberdeen Jetty, (Lat. 11 40.195 N, Long. 92 45.008 E) Port Blair; Depth: 3 m; Size : (crawling length of live specimen) 65 mm total length.

Remarks : A brightly coloured chromodorid. Mantle oval in shape and becomes more prominent while crawling. From its colour pattern it seems to be a sibling species of the western Pacific species *Chromodoris coi*. In *C. glenei*, the central part of the mantle is an orange-brown colour with deep purple or black markings. In *C. coi* the central region is a dull brown colour with a darker mottling of the same color. In both species there is a very similarly shaped wavy edge to the central region of the mantle and in both species the mantle margin consists of an inner dull purple band and outer white band. Rhinopores orange brown in colour. Gills are simple and also orange brown in colour.

Distribution : Indian Ocean.

11. ***Jorunna rubescens*** Bergh, 1876
(Plate 17, Fig. 11)

Bergh, L.S.R. (1876) Malacologische Untersuchungen. In : Reisen im Archipel der Philippinen von Dr. Carl Gottfried Semper. Zweiter Theil. Wissenschaftliche Resultate. Band 2, Theil 2, Heft 10, pp. 377-427, pls. 49-53.

Order NUDIBRANCHIA
Suborder DORIDINA
Super family EUDORIDOIDEA
Family DORIDIDAE

Material examined : Locality : North Bay; (Lat. 11 42.084 N, Long. 92 45.102 E) off to Port Blair; from the south eastern side of the bay; bottom consists of hard corals dominated by *Porites* sp. Depth : 3 m; Size : (crawling length of live specimen) 165 mm total length.

Remarks : The largest chromodorid recorded in Andaman and Nicobar Islands. Pinkish colour mantle with brown lines. Its mantle is covered in small spiculate papillae (caryophyllidia) which are characteristic of that genus. Presence of the caryophyllidia is one of the reasons that this nembrothid-like dorid is placed in the genus *Jorunna*. Observed to be feeding on algae. Gills are complex in structure and gill sockets are well developed. Rhinopore sockets are also well developed and raised from the mantle. The foot also have the brown coloured markings or the caryophyllidia.

Distribution : Indo-West Pacific.

12. ***Phyllidiella cooraburrama*** Brunckhorst, 1993
(Plate 18, Fig. 12)

Brunckhorst, D.J. (1993) The systematics and phylogeny of Phyllidiid Nudibranchs (Doridoidea). *Records of the Australian Museum, Supplement*, **1** : 1-107.

Order NUDIBRANCHIA
Suborder DORIDINA
Family PHYLLIDIIDAE

Material examined : Locality : Elephant beach, Havelock Island (Rani Jhansi Marine National Park); (Lat. 11 42.084 N, Long. 92 45.102 E); mangroves and other flora lines the shore area; healthy coral reef with good diversity. Depth: 6 m. Size: 4.5 cm total length. Reg. No. ZSI/ANRC 4372, 14.08.2009.

Remarks : *P. cooraburrama* is particularly striking nudibranch. It is characterized by its extremely large, isolated, notal tubercles which have a very broad pink base, are steep sided, tall and multicompound with flattish apices. The rhinopores are black in colour. *P. cooraburrama* is easily separated from other phyllidids with pink tubercles by the form of its large tubercles. *Phyllidiella pustulosa* has grouped clusters of low tubercles. *Phyllidiella annulata* has rings of pink with low angular tubercles. *Phyllidiella nigra* has single rounded red-pink tubercles. *Phyllidiella rosans* has low, rounded, smooth, straight ridges. *Phyllidiella zeylanica* has highly tuberculate ridges which join together anteriorly and posteriorly. *Phyllidiella granulata* is superficially similar to *P. cooraburrama*, but differs in having smaller conical or acute white tubercles on a granular grey background.

Distribution : Known from inshore reef areas in Ponape, Fiji, and the Great Barrier Reef, Australia.

13. ***Phyllidia coelestis*** Bergh, 1905
(Plate 18, Fig. 13)

Bergh, L.S.R. (1905) Malacologische Untersuchungen. In : Reisen im Archipel der Philippinen von Dr. Carl Gottfried Semper. Zweiter Theil. Wissenschaftliche Resultate. Band 9, Theil 6, Lief. 2, pp. 57-118, pls. 5-8.

Order NUDIBRANCHIA
Suborder DORIDINA
Family PHYLLIDIIDAE

Material examined : Locality : Outram Island (Rani Jhansi Marine National Park); (Lat. 12 13.297 N, Long. 93 06.515 E); mangroves and other flora lines the shore area; patchy reef. Depth: 6 m. Size: 2.5 cm total length. Reg. No. ZSI/ANRC 4373, 14.08.2009.

Remarks : Body white with two black lines on both sides of the mantle. A median black line with three large tubercles of yellow colour. *P. coelestis* is a smaller species which has neither a foot stripe nor a median ridge. *P. coelestis* can be distinguished from other similar-looking phyllidiids by colour and pattern: in particular the "Y" shape of the blue-grey dorsal ridges; the yellow-capped mid-dorsal tubercles (which never form a median ridge as in *P. varicosa*); the evenly tuberculate, broad, blue-grey mantle margin; and the uniformly grey foot without a dark stripe.

Distribution : Common on tropical reefs throughout the Indo-West Pacific Ocean. Known from the western Pacific Ocean, South China Sea, Timor Sea and across the Indian Ocean to South Africa.

14. ***Phyllidiella zeylanica*** (Kelaart, 1859)
(Plate 18, Fig. 14)

Kelaart, E.F. (1859). Descriptions of new and little known species of Ceylonese nudibranchiate mollusks. *Ann. Mag. Nat. Hist.*, **3**(3) : 291-304: **3**(3) : 488-496.

Order NUDIBRANCHIA
Suborder DORIDINA
Family PHYLLIDIIDAE

Material examined : Locality : Pongibalu; (Lat. 11 42.084 N, Long. 92 45.102 E) included in the Mahatma Gandhi Marine National Park, Wandoor; sandy bottom with patchy reef in between; mangroves and associated flora lining the beach. Depth: 2 m. Size : 4 cm total length. Reg. No. ZSI/ANRS 4306, 29.06.2009; ZSI/ANRC 4371, 14.08.2009.

Remarks : The species is characterized by the presence of three black concentric bands running round the notum and an interrupted median dark band. The median band and the first concentric dark band close to the former are prominent. The concentric band is incomplete posteriorly leaving a small gap. The other two more marginally situated bands are very narrow and inconspicuous. In between the dark concentric bands are prominently elevated greenish yellow longitudinal ridges bearing tubercles of varying sizes. These ridges run across in front of the rhinopore and behind the anal region.

Distribution : Restricted to the tropical Indian Ocean where it occurs from eastern Africa to Java.

15. ***Phyllidia madangensis*** Brunckhorst, 1993
(Plate 19, Fig. 15)

Brunckhorst, D.J. (1993). The systematics and phylogeny of Phyllidiid Nudibranchs (Doridoidea). *Records of the Australian Museum, Supplement* **16** : 1-107.

Order NUDIBRANCHIA
Suborder DORIDINA
Family PHYLLIDIIDAE

Material observed : Locality : Rail Island (Lat. 12 56.860 N, Long. 92 54.620 E), Mayabunder, Middle Andaman; from intertidal area, over a dead coral covered with algae; Size: (crawling length of live specimens) maximum length 75 mm, Body width 45 mm; Date of collection : 11.07.2009. Reg. No. ZSI/ANRC 4379, 14.08.2009.

Remarks : *P. madangensis* is characterised by having few, sparsely scattered notal tubercles on a black mantle, the black colour runs up to the edge of the mantle. Another character that can be noticed by keen observation is the presence of an alternating smaller tubercle between the larger notal tubercle. Presence of rhinotubercles is a common occurance in all *Phyllidia* species, but a small tubercle is present immediately in front of each rhinophoral pocket which is characteristic to *P. madangensis*. *P. madangensis* is very similar

P. carlsonhoffi, *P. varicosa* and *P. tula*, but the absence of black line on the foot sole distinguishes it from the rest.

Distribution : Known from the tropical western Pacific Ocean (Guam, Vanuatu, Solomon Islands and Papua New Guinea).

16. ***Phyllidiopsis phiphiensis*** Brunckhorst, 1993
(Plate 19, Fig. 16)

Brunckhorst, D.J. (1993). The systematics and phylogeny of Phyllidiid Nudibranchs (Doridoidea). *Records of the Australian Museum, Supplement*, **16** : 1-107.

Order NUDIBRANCHIA
Suborder DORIDINA
Family PHYLLIDIIDAE

Material observed : Locality: Sound Island (Lat. 12 53.092 N, Long. 92 56.834 E), Mayabunder, Middle Andaman; from intertidal area, under a dead coral covered with many sponges; Size: maximum length 20 mm, Body width 8 mm; Date of collection: 11.07.2009.

Remarks : *Phyllidiopsis phiphiensis* is characteristically noticed by two low white ridges which are separated by three furrows lined with black. The central furrow is anteriorly longer than the two adjacent furrows almost reaching up to the mantle margin. Whereas posteriorly the adjacent furrows are longer and generally join together to form a 'U' shaped furrow. The mantle margin is white with black spots. Rhinophores were pale white in colour. The ventral side is white in colour with black spots on the margin of the hyponotum and on the side of the foot.

P. phiphiensis shares close resemblances with three species of the same genera which can be confused one for the other as they are all longitudinally striped phyllidiids. In *P. striata* the central black furrow is separated into two from the posterior side to the anterior side by a centrally running white ridge. Thus *P. striata* has four black striations whereas *P. phiphiensis* has only three. In *P. sphingis* and *P. annae* the rhinopores are yellow and black coloured respectively whereas in *P. phiphiensis* it is white to very pale brown. *P. sphingis* and *P. annae* have a bluish colour more toward the periphery on their body which is absent in *P. phiphiensis*.

Distribution : Known only from southern Thailand (Andaman Sea, north-eastern Indian Ocean).

17. ***Phyllidiopsis shireenae*** Brunckhorst, 1993
(Plate 19, Fig. 17)

Brunckhorst, D.J. (1993). The systematics and phylogeny of Phyllidiid Nudibranchs (Doridoidea). *Records of the Australian Museum, Supplement*, **16** : 1-107.

Order NUDIBRANCHIA
Suborder DORIDINA
Family PHYLLIDIIDAE

Material observed : Locality : Light house, Havelock Island, Ritchie's archipelago; from 15 m depth, on top of rocks covered with algae; Size: maximum length of the crawling specimen 70 mm, Body width 45 mm; Date of collection: 19.09.2009.

Remarks : *Phyllidiopsis shireenae* is characteristically noticed by its mid-dorsal crest (i.e., the body is not dorsoventrally flattened as in other phyllidiids). The crest is lined with a black furrow which is extended toward the mantle edge into thinner line anteriorly and posteriorly. In most specimens the line diverges mid dorsally from the central furrow toward both the sides. The mantle is white in colour with salmon pink rhinophores. Each rhinophoral clavus has 18 lamellae.

Other phyllidiids do not possess a large dorsal crest and salmon pink rhinophores like *P. shireenae*. *Phyllidiopsis gemmata* has black rhinophores. *Phyllidiopsis krempfi* has multicompound pink tubercles, black and pink rhinophores, and possesses 26-28 lamellae on each rhinophoral clavus whereas in *P. shireenae* it is 17-20. *Phyllidiopsis pipeki*, *Phyllidiopsis burni* and *Phyllidiopsis fissuratus* differ from *P. shireenae* in having large compound tubercles, black and pink rhinophores and pink to grey ventral coloration.

Distribution : Tropical Indo-West Pacific.

DISCUSSION

The knowledge about opisthobranchiate faunal diversity of Indian subcontinent is too little to interpret. Although variegated, these organisms could drag the attention of only a few scientists.

Profound studies on sea slugs from India were initiated in 20th century which can be categorized into two phases: First phase is from 1906-1916 and the latter from 1968-2003. But none of the studies were carried out in Andaman and Nicobar Islands.

It was reported that *P. zeylanica* is a very rare nudibranch in India (Burn, 1970), but this study portrays that it is common in Andaman Islands. *Plakobranchus ocellatus* was reported from the Indian waters four decades ago (Virabhadhra Rao, 1961). Out of 17, except *Plakobranchus ocellatus* and *Phyllidiella zeylanica*, *Chromodons gleniei* are new record to the Indian waters. Among them the literature survey on the distribution and occurrence of presently reported opisthobranchs revealed that the earlier record of *P. phiphiensis* was restricted to Thailand only (Rudman, 1999) and it was considered as an endemic species of Thailand till now. The occurrence of a species of nudibranch in the Andaman Islands believed to be endemic to Thailand probably due to similar composition of biodiversity and geographical proximity. *Phyllidia madangensis* was first described by Brunckhorst in 1993. Subsequently few reports on the occurrence of the species are reported in the Australian museum web page (www.seaslugforum.net), all from various parts of the South Western part of Pacific Ocean (Sulawesi, Vanuatu, Papua New Guinea etc.). It has been observed that in the Pacific Ocean the same species has a yellow tipped tubercle but in the specimen observed here, the tubercles where whitish in colour.

The preliminary study shows the abundance of opisthobranchiate fauna in these Islands. These gastropods with exposed gills should be explored effectively in order to derive some beneficial bioactive compounds which would serve the human. There are about 572 islands in the Andaman and Nicobar group, with a total land area of 8293 sq. km., and the estimated coral reef area of 934.26 sq. Km (MWRD 2000); which is the largest coral reef ecosystem in India. With an extensive survey in these areas, the opisthobranchiate faunal diversity can be explored to a maximum.

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Plate 16

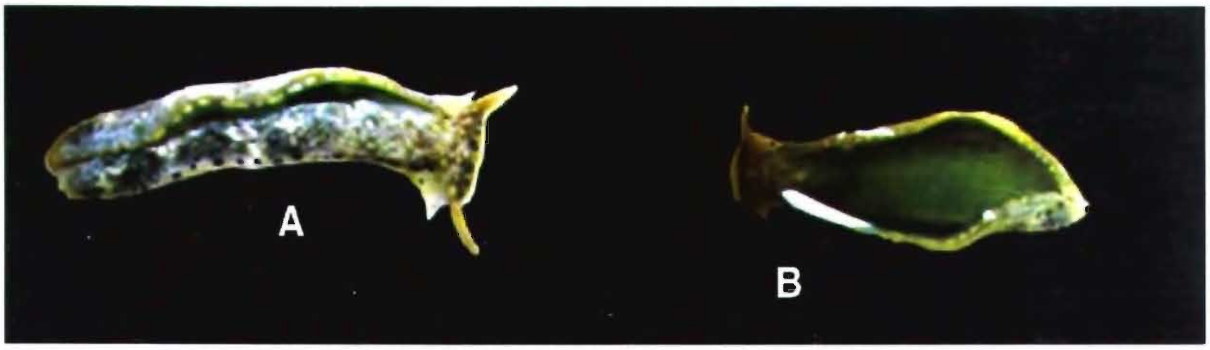

Fig. 1. *Plakobranchus ocellatus* (A)Dorsal view showing the spots on the body. (B)Dorsal view showing the parapodial flap with chloroplast.

Fig. 2. *Cerberilla annulata*

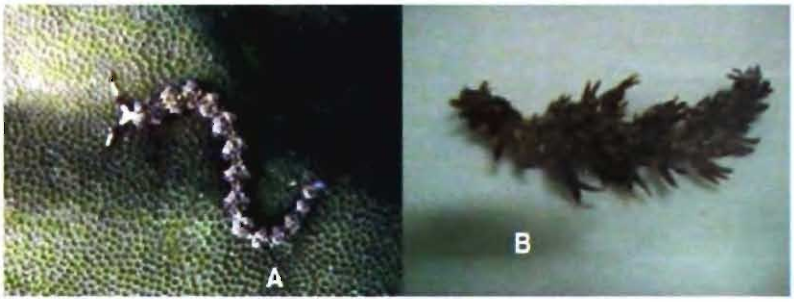

Fig. 3. *Pteraeolidia ianthina* (A) On a coral *Porites solida*. (B)Lab photo showing the colouration on the body

Fig. 4. *Gymnodoris rubropapulosa*

Fig. 5. *Hypselodoris bullocki*

Plate 17

Fig. 6. *Risbecia pulchella*

Fig. 7. *Hypselodoris maculosa* feeding on sponge (*Ircinia* sp.)

Fig. 8. *Chromodoris striatella*

Fig. 9. *Glossodoris atromarginata*

Fig. 10. *Chromodoris gleniei,* feeding on sponge (*Ircinia* sp.)

Fig. 11. *Jorunna rubescens, feeding on algae.*

Plate 18

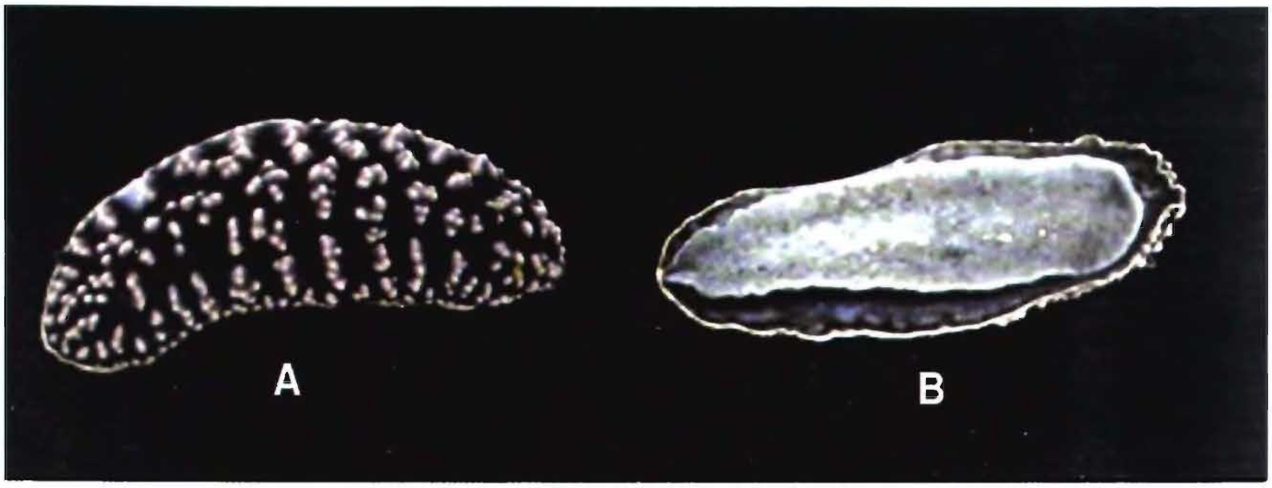

Fig. 12. *Phyllidiella cooraburrama* (A) Dorsal view showing the black rhinopore. (B)Ventral view showing the absence of stripe on the foot.

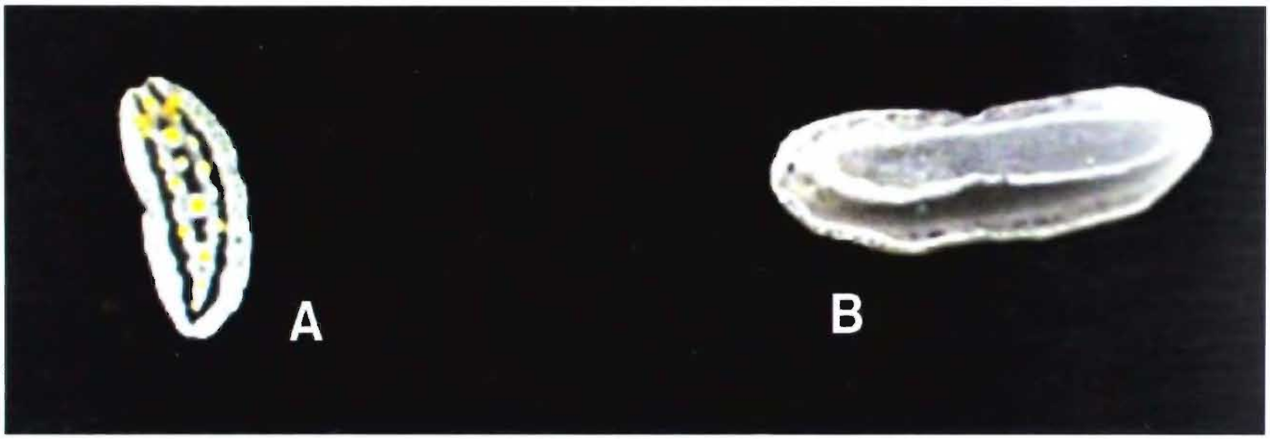

Fig. 13. *Phyllidia coelestis* (A) Dorsal view showing the yellow caped tubercles. (B) Ventral view showing the absence of dark stripe on the foot.

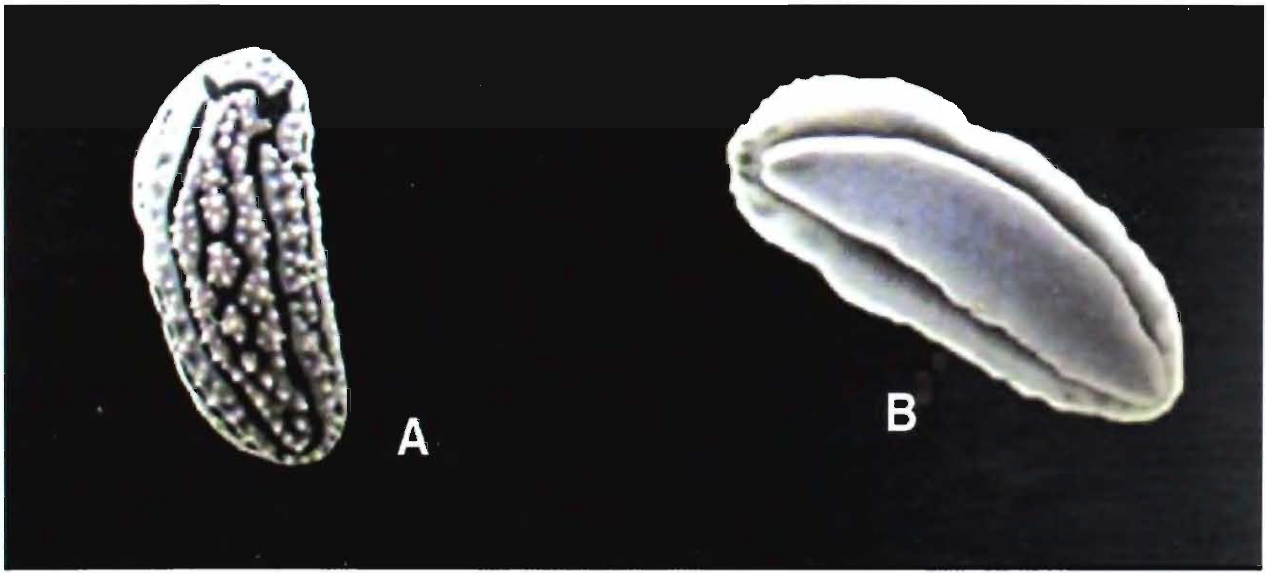

Fig. 14. *Phyllidiella zeylanica* (A) Dorsal view showing the rhinopore and ridges. (B) Ventral view showing the absence of dark stripe on the foot.

Plate 19

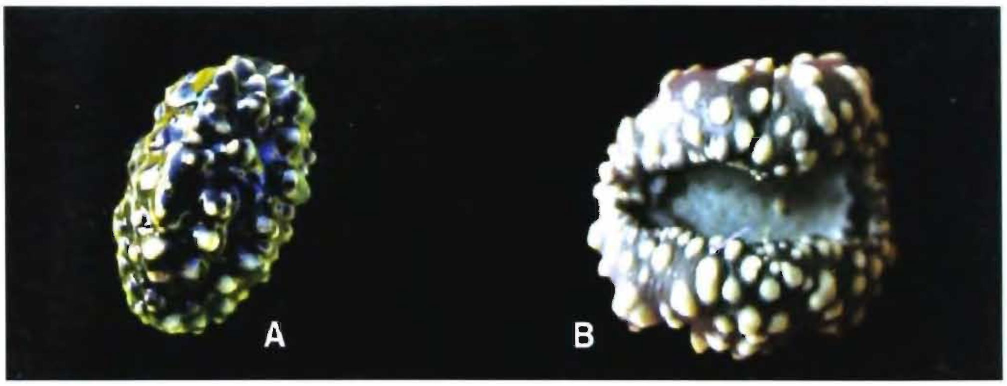

Fig. 15. *Phyllidia madangensis* (A) Dorsal view (B) Ventral view showing the absence of foot stripe.

Fig. 16. *Phyllidiopsis phiphiensis*

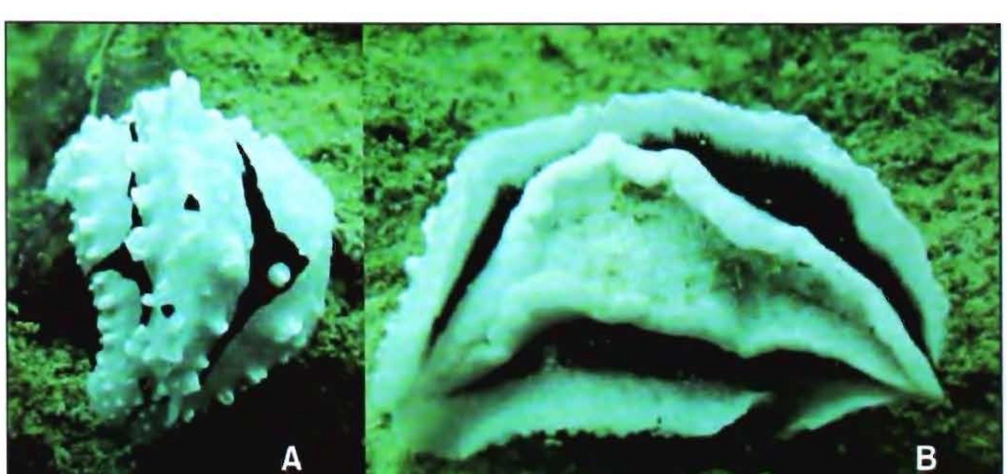

Fig. 17.*Phyllidiopsis shireenae*. A) Showing the dorsal view. B) Ventral view.

Chapter 25

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 299-312, 2010

BIODIVERSITY OF BARREN ISLAND, ANDAMAN AND NICOBAR ISLANDS

KAILASH CHANDRA* and P.T. RAJAN
Andaman Nicobar Regional Station, Zoological Survey of India, Haddo, Port Blair - 744102

INTRODUCTION

Andaman and Nicobar Islands often described as: Emerald Island" and "*Kalapani*" are situated in the Bay of Bengal. These islands are conventionally divisible into three groups, *viz.* (I) Andaman Group, (II) Nicobar Group and (III) Volcanic islands group. Third group comprises Narcondum and Barren Islands. The origin of these volcanic islands had taken place about 26 million years ago (Tikader, 1985). Of these, Narcondum volcano seems to be apparently extinct, while the Barren Island volcano is still active. After 107 year long phase of dormancy, Barren Island again erupted in April 1991 (Halder, 1992b). It caused a great concern to the scientists and environmentalists to undertake scientific investigation in various aspects of volcanism, particularly related to the field of Geology and Biology.

Barren Island lies at latitude $12^{\circ}17'30''$ N and longitude $93^{\circ}52'10''$ E in Andaman Sea (Plate 20, Figs. 1-3). It is an uninhabited island at 132 km NNE of Port Blair, the capital of the Union Territory of Andaman and Nicobar Islands. The island is nearly circular in shape of about 3 km in diameter and covers an area of 8.10 sq. km. (810 hectares, Pande *et al.*, 1991). The island consists of huge crater of ancient period, which abruptly rises from the deep sea, and all around the island about half km from island and shore nearly everywhere is more than 160 fathoms deep. Its mouth is around 2 km wide and the circumference rim is more than a km wide at base in southern half, where its height ranges from 316 to 354 m, while about 75 km wide at base in northern side and height ranges from 185 to 282 m. The rim of ancient cone on northwestern side had been broken down during second phase of volcanism and resulted to a large gap of 400 m near sea. In the middle of amphitheater of ancient cone, towards 400 m north of center of Island, a newer cone in slight truncated form of about 305 m height and perhaps 600 m in diameter was formed during last eruption and its angle from the surface was 45°. The cone was almost symmetrical in outline. The seaward slope of ancient cone is much steeper in northern part (40-60) than in southern part of island (30-40). At landing place on north-eastern bay hot springs are also reported.

The perennial freshwater stream and creeks are completely lacking in the island. The whole island is surrounded by rocky shores with large stones and sandy beaches are rarely present except at two landing sites, which are formed due to lava flow on NW coast and also during rainy season for the outlet of water from the valley.

The scientific teams of Zoological Survey of India, Port Blair with the help of Geological Survey of India conducted various investigations to study the impact of volcanism on flora and fauna of the Barren Island. Priór to eruption in March 1990,

*Central Regional Station, Zoological Survey of India, Jabalpur-482002

preliminary survey of the Island was undertaken by the scientists of ZSI. to collect and study the biological resources of land and marine ecosystems and the results were also published (Rao, *et al.*, 1990). The scientists of other organizations *i.e.* Central Agricultural Research Institute and Department of Ocean Development of Port Blair, Wildlife Authorities of Andaman Administration and Institute of Public Administration, New Delhi also visited the island to study the environmental effects of volcanism on biodiversity in 1991-92. Besides the representatives of NGOs like Indian National Trust for Art and Cultural Heritage (INTACH) and Save Andaman Nicobar Ecology of Port Blair also conducted the tour to assess the impact of eruption on ecosystem of the island. Recently, the authors with other party members of ZSI and GSI visited the island to assess the impact of volcanic eruption on changes in the biological components with reference to their distribution, habit and abundance. Collection and observations of biota were made all around the island from 1990-2005. Besides, night collection of nocturnal animals was also made in the interior island by installing a 160-Watt - Mercury Bulb connected with generator.

HISTORY OF VOLCANISM OF BARREN ISLAND

The island is known to be a part of inner volcanic arc, which extends from Burma, Narcondum and Barren Island to Malaysia. The island was formed during the late to Post–Pleistocene times by submarine volcanic activity which was the first phase of volcano (ancient cone) .In the later phase of volcanic activity, the top of the original cone (which was probably more than 600 m in height) and the side rim on north – western of crater have been blown off and a wide gap was formed during that period. The records of these two eruptions are not authentically documented place and new crater was formed. The height of central cone was even less than the height of southern peaks of outer cone and the area between the outer circumference and central cone was very steep. The base of the central cone was slightly above than sea level in 1979 (Feraud, 1993).

The lava produced during the 1803 eruption reached to the western coast and filled the space between the cone and outer ridge and formed a valley. Apart from main crater, three subsidiary vents were also formed in the subsequent period. The activity continued intermittently up to 1832 and finally it lasted up to 1884.

CURRENT ERUPTION

The March, 1991 eruption was first sighted by a Merchantile ship while voyaging in Andaman Sea, and subsequently an aerial survey of Island was also made by the coast Guard on 6^{th} April and it was known to the public on 11 May. It was a great event for the scientific community and first of all a team of Geological Survey of India rushed to the spot to make the assessment and few ash samples were only collected. After this various scientific investigation of volcano on 4, 8, 11, 16 May, 18, 26, 27 June, 6 August, 2 October, 30 November, 1991; 4–6 January, 8–9 February, 92; 8–9 April, 93, March 2000, October, 2003, April, 2005 were conducted and following observations were made. The smoke column was coming out continuously up to a height of 20 to 25 m from NE subsidiary vent and whole Island was covered with 10–15 cm thick ash and dust in May 91. The temperature around the vent was observed about 1100 C by the Satellite Monitoring on 6 May 91. Subsequently a subsidiary vent, little below the mouth of crater, towards the NE face of cone was venting huge amount of lava. Gas and smoke continuously and filled up the gap of NW coast area of about 800 × 200 m with more than 5–6 m. thickness. This fresh lava also filled up the valley towards NE. As a result, a light house of 12 meter height was completely buried in the escading lava flowing towards NW coast in June 1991. Active cone grown up to about 320 m above sea level (ASL) and its crater was estimated to be 250–300 m in diameter. The pH of water considerably decreased and visibility of water rear the shore was less than 10 cm. The erupting vent extended towards Northern part of main crater in August 1991. The eruption continued up to September and cone probably collapsed in October 1991. The smoke was intermittently observed and eruption activity ceased completely in November 1991. Re-growth of some scorched plants and very few birds were observed in January 1992. Cones were emitting from rootless vents of 2–3 m in diameter and 1 m in deep in ash covered area of the lava flow, where the Sulphur and reddish oxides were being deposited. The contiguous area of cone was shown with broken blocks ranging in size from 2 to 75 cm and sometimes even larger. The height of the new crescent-shaped crater had declined from 305 m to not more than 225 m ASL, but its diameter had increased from a pre eruption period up to 200 m. Two cinder cones about 15–20 m in diameter and 10–15 m in height has developed in western part of the lava filled, 100 m & 130 m away of main crater. The 1991 lava flows that extended to western coast covered with scoriae and ash had became almost like a smooth flat surface after rains in 1992. The surface temperature of the island was 40°C but at 0.5 m depth its temperature exceeded up to 360°C. Gases were still emitting from crevices and small holes from the NW lava flows in April 1993, 2000, 2005 and August, 2008.

IMPACT OF VOLCANO ERUPTION ON BIODIVERSITY OF BARREN ISLAND

Fauna

Barren Island supports poorer vegetation than all other adjacent islands, which also affects directly the density and diversity of terrestrial fauna. The faunal elements are almost similar to Andamans and also have affinity with Burmese and Malayan fauna. Prior to Volcano eruption, more than 130 species of various groups of animals such as mammals, birds, reptiles, fishes, echinoderms, mollusks, crustaceans, insects, spiders and corals were reported (Rao *et al.*, 1990; Boden Kloss, 1902; Tikader, 1984; Tikader and Das, 1985; Tikader *et al.*, 1986; Panda *et al.*, 1991). The comprehensive list of animals recorded prior to eruption is given in Annexure I. Due to devastation of vegetation during the volcano eruption, the terrestrial fauna is very much affected and marine fauna is only affected up to 100 meter distance from sea shore. The terrestrial fauna comprises of mammals, birds, reptiles, crabs, insects, centipedes and spiders. Hitherto, only six mammals viz. feral goat, Dobson's horse shoe bat, Andaman flying fox and 3 types of rats were known from the island. The largest animal of this island is feral goat (*Capra hircus*). A score of these goats were left in this island in 1891 by the steamer from Port Blair and their population was thriving well in this hot aid atmosphere. It is probably due to presence of particular vegetation such as Goat's food creeper (*Ipomoea pescaprae*) and Buckeri pathi (*Trema tomentosa*). Jungli Jamun (*Sisygium cumini*) and *Ficus sp.*, on which these goats are greatly dependent for the food and water requirement. During the present observations, three groups each of 12–15 goats including the aged beard male and kids were found hearing towards the eastern and southern side of inner slope on outer cone. These goats are robust dark-brown to black coloured, wandering in shady areas during day and night. It is observed that these goats are generally eating coriaceous leaves of above mentioned plants to counter their thirst and not drinking the sea water, as has been reported earlier. The island was declared as Wildlife Sanctuary on 9th February, 1977 by the Andaman and Nicobar Administration for the protection of these feral goats from poaching and other activities. Out of three known variety of rats, only one species of rat (*Rattus rattus*) was encountered during night survey. The holes of rats were found at few places beneath the small trees and shrubs. The charred bodies below the ash and skeletons of rats were also seen on the southern side. The shrieking sounds of Andaman's flying fox (*Pteropus melanotus*) and horse shoe bat (*Rhinolophus affinis*) was not heard during the night survey. Probably the eruption has severely effected the population of these two nocturnal animals and remaining ones have taken the shelter on rock crevices on outer slope of southern and eastern jungle (Plate 21, Figs. 4-5a).

Among the avifauna of the island, total 20 species of birds are reported during all the expeditions and only 13 species were observed before the eruption (Rao *et al.* 1990). Out of them, only six species were observed during April, 1993; only a couple of white-bellied sea eagle *(Haliaeetus lecogaster*) were found flying near the outer rim of northern part. Andaman Koel (*Eudynamys scolopacea*), Andaman Wood pigeon (*Columba palumboides*), Pied Imperial pigeon (*Ducula bicolor)* were also observed frequently during day time near the densely vegetated path on southern part. Pied Imperial pigeon was the dominant one feeding on fruits of Jungli Jamun (*Sisygium cumini*) and Bhilwa (*Semecarous heterophylla*). The white-bellied swiftlet *(Callocalia esculenta*) were observed in 8–10 numbers flying in low height at evening towards the south-western part, while waterhen (*Amauronis phoenicus*) having less power of fight were found moving in ground near shady places of inner slope of southern part. It seems that many other species, which have migrated during the volcano eruption, have not yet returned to the island, but it presumes that most of the birds will return to the island following the cooling down of volcano with in 2–3 years or so, because of the less competition of food in the island. In spite of having great power of flight in birds small population was burned during the eruption and their charred bones are seen strewn here and there on the island. Only two reptiles, Water monitor lizard (*Varanus salvator)* and Garden lizard (*Calotes* sp.) known from the island are not encountered from anywhere during the present survey. It is very surprising that none of the amphibians are known from the island and it may be due to absence of perennial fresh water resource in the island.

Among the terrestrial invertebrates, insects are generally represented in maximum numbers. Prior to eruption, the insect fauna of island was comprised of beetles, butterflies, moths, plant bugs, grasshoppers, bees, ants, wasps, flies, mosquitoes, and dragonflies and termites. During the present survey 51 species belonging to various orders viz. Coleoptera (17 spp.), Embioptera (1 spp.), Hymenoptera (6 spp.), Hemiptera (10 spp.), Neuroptera (1 sp.), Diptera (6 spp.), Lepidoptera (9 spp.) and Isoptera (1 spp.) were collected during the day and night (Chandra, 1997). The population of Cerambycid beetles was comparatively higher than other beetles. The long horned beetle (*Olenocamptus bilobus*) was recorded for the first time as a pest Jangli jamun (*Sisygium cumini*) from the Barren Island. These population of these beetles were more than 300, and were found defoliating the tree and making the holes on leaves of a single tree. An another long horned beetle (*Desisa marmorata*) known to be pest of various economic trees, was also collected in hundreds during the night. The darkling beetles (*Conocephalus* sp.) along with the termites (*Odentotermes* sp.) were found infesting the dead log in contact with the soil. Five species of ants were also found on the various plants and particularly on *Ficus brevicuspis*, which branch lets were hollow and offered good number of specimens. Only one metallic wood borer was collected on wing near the north-western flat surfaces. Seven types of jassids and plant hoppers were collected during night. Not a single specimen of butterfly or dragonfly was observed during the survey, while 9 species of moths were collected from the light source. Out of them, *Plutella maculipennis* Curtis and *Glyphodes itysalis* Walker were reported for the first time from the Island. Besides, two examples of web-spinner (Embioptera) were also collected during dawn hours. In addition, two juveniles of millipedes were also found from the soil litter.

The marine fauna around the island mainly comprises of dolphins, sharks, fishes, echinoderms, mollusks, crustaceans and corals. Prior to eruption, common dolphin (*Delphinus delphis*) and fishes viz., serranids (*Cephalopholis miniata, Epinephelus* sp.), snapper (*Lutjanus kashmira*), and Barracuda (*sphysaena jello*), were very common all around the island are not sighted so frequently during April 1993. Blennids (*Entomacrodus striatus, Salarias bleekerei*) and skippers (*Andamia heteroptera* and *A. reyi*) were not observed in the rocky shores. The Barren Island is generally encircles with the rocky shores, which supports the number of species of echinoderms, molluscs and crustaceans. Two known species of urchin (*Diadema setosum* and *Echinometra mathiea*) were not found any where in rocky shores. Among the molluscs, the periwinkle (*Littorina undulata*) Ox-plate nerite (*Nerita albicella*), costal nerite (*Nerita costata*), Plicate nerite (*Nerita plicata*), common turtle limpet (*Cellana testudinaria)*, star shaped limpet (*Patella flexuoss*) and rock oyster (*Saccostrea cucullata*) were only founds landing sites. Among these, nerites and rock oyster were common. Not much effect has been occurred on the deep sea molluscs. Out of 18 crustacean species, only three species of grapsid crabs *(Grapsus grapsus, G. albolineatus, Metapograpsus frontalis*) and two species of Xanthid crabs (*Leptodius sp. Chlorodopsis spinipes*) were found lurking in between the rocks and crevices in the mid littoral zone rocky shore. None of the examples of barnacles and hermit crabs are encountered from the shore. Besides burned skeletons of land crabs (*Pelocarcinus humei*) are commonly seen in the valley and north-western gap of the island. The island comprises of very little area of coral reef patch near the landing site on south – western coast. Which is completely destroyed by the lava flow of June 1991 and the coral polyps are fully covered with the thick layer of ash and pyroclastics.

Flora

Barren Island is sparsely covered with tropical evergreen deciduous and littoral vegetation is more or less similar to Andamans and closely related to Burma, Indo-China and Malayan flora (Balakrishanan, 1989). Mangrove forest is completely lacking due to very steep sea shore all around the island. Prain (1892) comprehensively dealth the flora of island and recorded 88 species belonging to 75 genera and 35 orders. Hitherto 130 species belonging to 43 orders are reported from the island. Prior to eruption, the vegetation of island was mainly comprised of trees, shrubs, herbs, climbers, algae, moss, fungi, and lichens. Almost whole island excluding the central crater and its surrounding areas was covered with green vegetation. While the central cone was sparsely covered with bushes, creepers and herbs. The vegetation around the inner slopes of outer cone on southern and eastern part because of the high water absorbing capacity of the soil and formation of small stream lets during the monsoon.

Due to increase in the area of central cone on northern and southern side rising of temperature of lava upto 1100 C during eruption and deposition of ash, under the pyroclastics on more than 80 percent area of island, the floral elements are tremendously affected. It seems to be very interesting that being the whole island as a volcanic crater during ancient period, how more than 130 species of plants were introduced to the island and what was the mode of migration. Prain (1892) elaborated that generally all the plants are introduced through birds, wind or sea.

The central old cone, which was sparsely clothed with few examples of tree (*Trema tomentosa*), herbs (*Fimbrystylis ferruginea, Pathinhaea cernua, Psilotum nudum, Lindernia crustacea, Hedyotis corymbosa)*, ferns (*Nephrolepis cardifolia, Cheilanthus tenuifolia*) and on orchid (*Pholidots imbricata)* are completely vanished during the month of May 1991. prior to eruption, at landing sites on north – western parts rocks were covered with fresh water algae (*Calothrix pulvinata* and *C. tasmanica*) are not found during the present observations. The trees (*Impomoea perscaprae, Derris indica, Metrcola oldenlandioides)*, shrubs (*Mussuenda macrophylla*), herb (*Securinega virosa*) climber (*Aganosma marginata*) and grass (*Ischaemum muticum*) reported from the plain area of inner cone to the landing sites are destroyed by the lava flow during the month of June, 1991. the plain area between the central cone lava and inner wall of outer cone was occupied with the shrub vegetation comprised of shrubs (*Securinega virosa, Dodonoea viscose, Calicarpa arborea*), trees (*Suregada multiflora, Trema tomentosa, Dalbergia pinnata*), shruby climber (*Phyllanthus reticulates)*, grass (*Pegonantherum crinitum, Ischaemum muticum*) are completely burned and only few trees with cancerous growth in the stem were also observed southern side of recent cone in April, 1993. The inner northern wall of outer cone, which was generally covered with shrub (*Dodonoea viscose)* and herb (*Fim bristylis dichoma*) were buried with the lava ash and cinder during June–July, 1991.

The inner wall of outer cone, which was evenly clothed with dense green vegetation including the trees (*Desmodium heterocarpum*) ferns (*Onychium siliculosum, Pteris biaurita, P. vittata, Nephrolepis cordifolia*), herbs (*Fimbristylis dichoma, physalis minima, Lindernia crustaces*) and grass (*Oplimenes burmanni, Pogonatherum paniceum*) were affected and the population density of grass, herbs and ferns are reduced to 20 percent. The inner southern wall of outer cone supports comparatively richer vegetation and it includes the most abundant free (*Terminalia catappa)*, followed by the very common (*Sisygium cumini, Callicarpa catappa*), follwed by the very common (*Sisygium cumini, Callicarpa arbores*) and the Ficus trees (*F. rumphii, F. microcarpa, F. tinctoria*) are common. The trees (*Senucaspus heterophyla, Gariiya pinnata, Oryxylum indicum, Macarpanga tanarius, Trema lomentosa*) and small trees (*Ixora brunnescens, I. Cuneifolia*) were also associated with the patches of above mentioned trees. The wild vine (*Cissus repens)* was not seen during the present survey. The climbers (*Abrus precautorius, Dioscorea bulbifera, D. glabra*) and Creeper (*Cyclea peltata*) were also observed climbing the trees at various places. The orchid (*Dendodium)* was not seen in the island. The tree (*Terminalis catappa, Ficus* spp., *Sisygium cumini*), climbers (*Dioscorea bulbifera, D. glabra, Capparis sepiaris*) and fern (*Adiantum philippenses)* were very common on outside of the outer cone. From the base of sea shore to the top of the outer cone, the deciduous and littoral species are also present, which includes trees (Hibiscus liliaceus, Sterculia rubigniosa, Colubrina asiatica, Ixora brunnescons, Premna corymbosa, Glochidion calocarpum, Suregada multifolra), shrub (Scaavola koenigii) and herbs (*Pluches inidca, Wadelia biflora*). On the base rocks near sea shores a prostate shrub (*Boerxhoavia diffusa*) was also observed occasionally on southern slope.

The coconut (*Cocos nucifera*) and Pandanus (*Pandanus fascicularis*), which were recorded from south west side of the island in 19th Century are not observed during the present survey. Due to high atmospheric temperature prevailing in the island, none of moss, fungus and fresh water algae was observed, while lichen (*Collema nigrescens*) was found in stunned stage, attached with the bark of *Ficus* trees on the southern inner slope of outer cone.

Sreekumar and Chandra (1993) reported three species of vascular plants viz. *Canarium euphyllum* Kurz (Burseraceae), *Imperata cylindrus* (L.) (Poaceae) and *Pityogramma calomelanous* (L.) (Hemionitidaceae) from Barren Island. Subsequently, two more species of vascular plants viz., *Ficus arnottiana* (Mig.) family Poaceae and *Euphorbia hirta* L. family Euphorbiaceae were also recorded by Sinha *et al.* (1994).

The impact of volcanic activity on the fauna and flora is immense. About 500 ha. area of the island has again became the barren, which lead to the intensive impact on terrestrial ecosystem than marine ecosystem. During the eruption, more than 25 species of animals and around 20 species of plants are lost from the island. This eruption may have long term effect on faunal and floral elements, which may also lead to the speciation of biological elements. Following the cooling down of island, regeneration of fauna and flora will take place and it will require more than hundred of years to recover the same intensity of the biota of island. The natural migration will play an important role in recovering the biota of the island and it may also end to the change of composition of bio-diversity. Authors feel that in-depth study of this particular island will reveal many unknown biological phenomenon of the existing life in the island. Authors also propose to constitute "Scientific Monitoring Committee" of various specialist particularly on the field of physiology, ecology and migration of animal and plants for the continuous monitoring of the biotic components in fixed intervals to study how the regeneration of fauna and flora takes place in such a hot and arid atmosphere and its duration: It is to be investigated in species to species level to see the impact of volcanic eruption and make effective measures to save the environment and it's constructive from disappearance.

List of fauna & flora recorded from Barren Island (Prior to eruption)

Fauna

Common name	Scientific name
Mammals	
Dobson's Horseshoe Bat	*Rhinolophus affinis andamanensis* Dobson
Common Dolphin	*Delphinus delphis* Linn.
Andaman Flying Fox	*Pteropus melanotus tytleri* Mason
Feral Goat	*Capra hircus* Linn.
Miller's Long-footed Rat	*Rattus stoichus* (Miller)
House Rat	*Rattus rattus atridorsum* (Miller)
Rat	*Rattus* sp.
Birds	
Asian Emerald Cuckoo	*Chrysococcyx maculatus* (Gmelin)
Indian Cuckoo	*Cuculus micropterus* Gould
Andaman Emerald Dove	*Chalcophaps indica maxima* Hartert

Common name	Scientific name
White-bellied Sea eagle	*Haliaeetus leucogaster* (Gmelin)
Brown Fly-catcher	*Muscicapa dauurica* Pallas
Pacific Reef-Egret	*Egretta sacra* (Gmelin)
Andaman Ruddy King Fisher	*Halcyon coromanda mizorhina* (Oberholser)
Andaman Koel	*Eudynamys scolopacea dolosa* Ripley
Andaman Hill Myna	*Gracula religiosa andamanensis* (Beavan)
Andaman Red-breasted Parakeet	*Psiffacula alexandri abbotti* (Oberholser)
Andaman Red-cheeked Parakeet	*Psittacula longicauda tytleri* (Hume)
Andaman Green Imperial Pigeon	*Ducula aenea andamanica* Abdulali
Andaman Wood-Pigeon	*Columba palumboides* (Hume)
Pied Imperial-Pigeon	*Ducula bicolor* (Scopoli)
Red-throated Pipit	*Anthus cervinus* (Pallas)
Andaman Olive-backed Sunbird	*Nectarinia jugularis andamanica* (Hume)
White-bellied swiftlet	*Collocalia esculenta affinis* Beavan
Andaman Teal	*Anas gibberifrons* (Muller)
White-breasted Waterhen	*Amaurornis phoenicurus insularis* Sharpe
White-eye	*Zosterops palpebrosus nicobarica* Blyth
Reptiles	
Water Monitor	*Varanus salvator andamaensis* Deraniyagala
Garden Lizard	*Calotes sp.* (Rao, *et al.* 1990)

Fishes

Class OSTEICHTHYES

Order PERCIFORMES

Family SERRANIDAE (Sea basses, Groupers)

Cephalopholis miniata (Forsskal)
Cephalopholis sonnerati (Val.)
Epinepheles reavocaeruleus (Lacepode)
Epinephelus chlorostigma (Val.)
Epinophelus quoyanus (Val.)
Epinephelus fuscoguttatus (Forsk)
Plectropomus areolatus (Ruppl.)

Family CARANGIDAE (King fishes)

Caranx oblongus Cuv. & Val.
Scomberoides commersonnianus Lacepede

Family LUFJANIDAE (Snapper)

Aprion virescens Val.
Etelis carbunculus Cuvier
Lutjanus bohar (Forsk.)
Lutjanus kashmira (Forsskal)
Lutjanus malabaricus (Schr.)
Lutjanus rivulatus (Cuvier)
Pinjalo lewisi Rendall
Pristipomoides filamentosus (Val.)
Pristipomoides typus Bleckes

Common name	Scientific name
	Family SPHYRAENIDAE (Barracuda)
	Sphyraena jello Cuvier
	Family BLENNIIDAE (Blennies)
	Andamia heteroptera (Bleeker)
	Andamia reyi (Sauvage)
	Entomacrodus striatus (Quoy & Gaimard)
	Salarias bleekeri Beaufort and Champman
	Order TETROODONTIFORMES
	Family BALISFIDAE (Atrigger fish)
	Balistes erythrodon Gunther
Echinoderms	
Sea urchins	*Echinometra mathaei* (Blainville)
Haptim Urchin	*Diadema setosum* (Leske)
Molluscs	
Spiny Chiton	*Acanthopleura spiniger* (Sowerby)
Chiton	*Chiton* sp.
Indo Pacific Limpet	*Cellana radiata* (Born)
Common Turtle Limpet	*Cellana testudinaria* (Linn.)
Star-shaped Limpet	*Patella flexuosa* Quoy & Gaimard
Commercial Trochus	*Trochus niloficus* Linnaeus
Great green turban	*Turbo marmoratus* Linnaues
Ox –Palate Nerrite	*Nerita albicella* Linnaeus
Costate Nerite	*Nerita costata* Linnaeus
Plicate Nerite	*Nerita plicata* Linnaeus
Nerite	*Nerita semirugosa* Recluz
Periovinkle	*Littorina* sp.
Undulata periovinkle	*Littorina undualata* Gray
Nodi Periovinkle	*Nodilittorina millegrana* (Phillippi)
Tiger cowrie	*Cypraea tigris pardalis* Shaw
Hump-back Cowrie	*Cypraea tigris pardalis* Shaw
Hump back Cowrie	*Mauritia mauritiana* (Linnaeus)
Muricid Shells	*Morula marginata* (Blaiville)
Crocus Giant Clam	*Tridacna croces* Kamarck
Crustaceans	
Acorna Barnacle	*Chthamalus malayensis* Pilsbry
Rock Barnacle	*Balanus tintinnabulum tintinnabulum* Linnaeus
Common Hermit Crab	*Clibanarius humilis* Dana
Hermit Crab	*Clibanarius* sp.
	Dardanus varipes (Heller)
	Diogenes austos (Fabricius)
	Paguristes sp.
	Pagurius sp.
Grapsid Crab	*Geograpsus crinipes* (Dana)
	Grapsus albolineatus Lamarck
	Grapsus sp.

Common name	Scientific name
Xanthid Crab	*Chlorodopsis spinipes* (Heller)
	Leptodius sp.
	Trapezia sp.
	Eriphia laevimana Latreille
	Ozius rugulosa Stimpson
Insects	
	Order COLEOPTERA (Beetles)
	Family SCOLYTIDAE
Bark Beetles	*Coccotrypes littoralis* Beeson
	Arixyleborus sp.
	Xyleborus cognatus Blanford
	Xyleborus sp.
	Family CURCULIONIDAE
Weevil	*Mecopus* sp.
	Family TENEBRIONIDAE
Darkling Beetle	*Conocephalus* sp.
	Family BUPRESTIDAE
Metallic Wood Borer	*Chrysochroa* sp.
	Family CERAMBYCIDAE
Long-horned Beetles	*Desisa marmorata* Breuning
Long- horned Beetles	*Pterolophia* sp.
	Order DIPTERA (True-flies)
	Family SARCOPHAGIDAE
	Parasarcophaga misera (Walker)
	Boettoherisea peregrina (Rob-Des.)
	Family ASILIDAE
	Leptogastor sp.
	Ommantius sp.
	Order HEMIPTERA (True-bugs)
	Family PENTATOMIDAE
	Chrysocoris purpureus Westw.
	Rhyparothesus sp.
	Order ISOPTERA (Termites)
	Family MACROTERMITIDAE
	Odontotermes latigula Synder
	Family COPTOTERMITIDAE
	Coptotermes sp.
	Order LEPIDOPTERA
	Suborder RHOPALOCERA (Butterflies)
	Family DANAIDAE
	Euploeacore andamanensis Walker
	Family LYCAENIDAE
	Rapala varuna orseis Hew
	Rapala dieneces intermedia Stg.

Common name	Scientific name
	Family NYMPHALIDAE
	Neptis sp.
	Precis sp.
	Suborder HETEROCERA (Moths)
	Family HYPSIDAE
	Hypsa producta Buttler
	Family PYRALIDAE
	Sylepta lunalis (Guenee)
	Hymenia recurvalis (Fabricius)
Centipedes	
	Scolopendra morsitans Linnaeus
	Otostigmatus sp.
Arachnida (Spiders)	
	Lycosa birmanica Simon
	Oxyopes sp.
Coelenterates - Corals	
Stag-horn Corals	*Acropora digitifera* (Dana)
	Acropora robusta (Dana)
	Acropora sp.
Plate Coral	*Montipora foliosa* (Pallas)
Fragile coloured corals	*Pocillopora brevicornis* (Lamarck)
	Pocillopora sp.
Boulder Coral	*Favites abdits* (Ellis & Solander)
Reef-building Coral	*Porites* sp.
	Flora
Menispermaceae	
	Cyclea peltata (Laml.) H.F & T.
Dilleniaceae	
	Tetracera sp.
Capparaceae	
	Capparis sepiaria Linn. Var. *grandifolia* Kurz.
Malvaceae	
Safed Chilka or Coast Cotton Tree	*Hibiscus tiliaceus* Linn.
Sterculiaceae	
Shaw	*Sterculia rubigniosa* Vent. Var *glabresocens* king
Burseraceae	
Chinyok	*Garuga pinnata* Roxb.
Rhamneae	
Kanay wet (Indian Snake Wood)	*Colubrina asiatica* (L.) Brogn.
Vitcseae	
	Cissus repens Lmk. *Vitis repens* W. & A
Leeaceae	
	Leea indica (Burn. F.) Merril = *L. sambucina* will

Common name	Scientific name
Sapindaceae	
	Lepisanthes rubignosa (Roxb.) Leenhouts = *Erioglossum edule* Bl.
Clammy Hop-seed Bush	*Dodonaea viscosa* Linn.
Anacardiaceae	
Bhilwa	*Semecarpus heterophylla* Bl.
Leguminosae-Fabaceae	
	Desmodium heterocarpum (L.) DC. Var. *Strigosus* van Meeuwen = *D. polycarpum DC*
Gunchi	*Abrus precatorius* Linn.
	Dalbergia pinnata (Lour.) Prain = *D. tamarindifolia* Roxb.
	Derris indica (Lamk.) Bennet = *Pongamia glabra* Vent.
Mimosaceae	
	Acacia sinuata (Lour.) Merril = *Acacia concina* Dc.
Combretaceae	
Badam (Indian Almond Tree)	*Terminalia catappa* Linn.
Myrtaceae	
Junglie Jamun	*Syzygium cumini* (L.) Skeels = *Eugenis jambolana* Linn.
Rubiaceae	
	Hedyotis corymbosa (L.) Lamk. = *Oldenlandia corymbosa* Linn.
	Mussaenda macrophylla Wall
	Ixora brunnescens Kurz
	Ixora cuneifolia Roxb.
Compositae-Asteraceae	
	Pluchea indica Less.
	Wedelia biflora Dc. = *W. scandens* C.B. Clarke
Goodeniaceae	
The Fan flower or	*Scaevola sericea* Vehl. = *S. koenigii* Vahl. Pintetan
Myrsinaceae	
Eyetmauk	*Ardisia humilis* Vahl.
Apocynaceae	
Ke-aung-new	*Aganosma marginata* (Rexb.) G. Don.
Asclepiadaceae	
	Hoya parasitica Wall
	Hoya diversifolia Bl.
Loganiceae	
	Mitreola petiolata (Gmel.) Torr & Gray = *M. olden landiodes* Wall.
Convolvulaceae	
	Ipomoea macrantha R. & S. = *I. Grandiflora* Lamk.
The Goat's foot Creeper	= *Ipomoea pescaprae* ssp. *Brasiliensis* (L.) Oost. = *I. Biloba* Forsk.
Solanaceae	
	Physalis minima Linn.

Common name	Scientific name
Scrophularinae	
	Lindernia crustacea (L.) Muell. = *Vandellia crustaces* Benth.
Bignoniaceae	
The Sword – fruit Tree/Kyaung – ya	*Orxylum indicum* Vent.
Acanthaceae	
	Eranthemum suffruticosus Kurz.
Verbenaceae	
	Callicarpa arborea Roxb.
Taungtangyi	*Premna corymbosa* Rottl. = *P. intergrifolia* Linn. *Vites negundo* Linn.
Nyctaginaceae	
	Boerhavia diffusa L. = *B. repens* Linn.
Euphurbiaceae	
	Phyllanthus reticulatus Poir
	Glochidion calocarpum Kurz
	Fluggea virosa (Roxb.) Baillon = *flueggea microcarpa* BI.
Golpapita petwaing	*Macaranga tanarius* (L.) Muell Arg.
	Actephila puberula Kurz.
	Suregada multiflora (Juss.) Baillon = *Gelonium bifarium* Roxb.
	Mallotus sp.
Ulmaceae	
Buckeri pathi	*Trema tomentosa* (Roxb.) Hora = *T. anbeinensis* BI.
Moraceae	
Nyaung thabe	*Ficus tinctoria* Forest. F. sp. *Gibbosa* (Bi.) Corner = *F. gibbosa* BI.
The swamp fig. Tree	*Ficus microcarpa* L.F.var. *nitida* King = *F. retusa* Linn.
Pipal/Nyaungbyn	*Ficus rumphii* B1.
	Ficus brevicuspis Mig.
	Ficus hispida Linn.
	Ficus variegata B1.
Orchidaceae	
	Dendrobium sp.
	Pholidota imbricata (Roxb.) Lind1.
Dioscoreaceae	
	Dioscorea bulbifera L. = *D. saliva* Linn.
	Dioscorea glabra Roxb.
Liliaceae	
	Gloriosa superba Linn.
Arecaceae	
	Cocos nucifera Linn.
	Licuala sp.
Pandanaceae	
Screw pine	*Pandanus fascicularis* Lamk.
	P. odoratissimus Linn.
Cyperaceae	
	Cyperus javanicus Goult = *C. pennatus* Lamk.

Common name	Scientific name
	Fimbristylis dichotoma (L.) Vahl. = *F. diphylia* Vahl.
	Fimbristylis ferruginea (L.) Vahl.
Gramineae	
	Oplismenus burmanni Roem. & Schutt.
	Pogonstherum paniceum (Lamk.) Hack. = *P. saccharoideum* Beauv.
	Pogonatherum crinitum Trim.
	Ischemum muticum Retz.
Lycopodineae	
	Palhinhaea cernua (L.) Franco & Vasc. = *Lycopodium cernuum* Linn.
	Psilotum nudum (L.) Beauv. = *P. triquetrum* Sw.
Filices	
	Adiantum philippensa L. = *A. lunulatum* Burm.
	Cheilanthes tenufolia (Burm.f) Sw.
	Onychium siliculosum (Desv.) C. Chr. = *O. auratum* Kaulf.
	Pteris vittata L. = *P. longifolia* Linn.
	Pteris biarita Linn.
	Asplenium adiantoides (L.) C. Chr. = *A. falcatum* Lamk.
	Nephrolepis cordifolia (L.) Presl. = *N. tuberosa* (Bory ex Willdena) Presl.
	Pseudodrynaris adnascens (Sw.) Ching = *Polypodium adnascens* Sw.
	Drynaria quercifolia (L.) J.SM. = *Polypodium quercifolium* Linn.
	Acrostichum scandens J.SM.
	Acrostichum aureum Linn.
	Stenochlaena palustris (Burm.) Bedd. = *Acrostichum scandens* J.SM
Musci	
	Bryum coronatum Schwaegr
Lichens	
	Collema nigrescens Achar.
Fungi	
	Polyporus australis Fries
	Dedaelea griercina Fries
	Peniophora papyrina Monf.
	Hirneola polytricha Mont
	Thelephora incrustans Pers
	Rhytisma sp.
Algae	
	Calothrix pulvinata Ag.
	Calothrix tasmanica Kg.
	Enteromorpha compressa Greville
	Dictyots dichotoma (Hudson)
	Gracilaria sp.
	Caulerpa racemosa (Forsskal) Weberv. Bosse
	Turbinaria arnata J. Ag.
	Padina gymnomorpha Vickers
	Ulva sp.

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Plate 20

Fig. 1. Aerial view of Barren Island 2008

Fig. 2. Barren Island during eruption (1991)

Fig. 3. Barren Island during eruption (1993)

Plate 21

Fig. 4. Common Crow *Euploea core andamanensis*

Fig. 5. *Trochus niloticus*

Fig. 5a. *Turbo marmoratus*

Chapter 26

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 313-321, 2010

INSECT DIVERSITY ON TEAK PLANTATION IN ANDAMAN ISLANDS

SANJEEV KUMAR and SEEMA KUMAR*
Desert Regional Centre, Zoological Survey of India, Pali Road Jhalamand, Jodhpur, Rajasthan

INTRODUCTION

Andaman Forests abounds in a plethora of forest tree species out of which 200 are timber species and major commercial timber species being Gurjan (*Dipterocarpous* spp.), Padauk (*Pterocarpus dalbergioides*) and Teak (*Tectona grandis* Linn. F.). Teak is predominantly tropical or sub-tropical in distribution and a paragon among timber tree species of Peninsular India, Myanmar (Burma), Indonesia and Thailand. But surprisingly natural teak is absent in Andaman and Nicobar islands. The Andaman and Nicobar Islands are part of a broken string of land-beeds between Myanmar (Burma) and Sumatra, both natural habitat of teak and renowned for its teak timber due to its greater oil content and lack of imperfections and highly valuable in marine applications. Teak was planted extensively in warm climate throughout the world both inside and outside of its natural zone. The attempt to raise teak forest in Andaman Islands was first made in 1883 when teak from Myanmar was planted mixed with Padauk (*Pterocarpus dalbergiodes*) at Wimberlygunj, South Andaman (Whitaker, 1985). Later in years 1890-1904, teak plantation was raised at Mannarghat, South Andaman. In the Middle Andaman Division, teak was raised from 1918-1932 successfully. The teak was also raised in preference to other species over extensive areas in North Andaman. Regular plantations of teak in these islands have been taken up since 1957. The teak plantation raised in these islands generally corresponds to quality class II/III of All India Quality Class under Andaman Moist Deciduous and Andaman Semi-Evergreen Forests (Tewari, 1992). The timber tree teak holds a number of uses. Its various parts attract number of insects which feeds on them and in turn serve as food for other faunal elements especially the birds. The termite enriches the soil nutrients and also helps in easy germination of teak by feeding on the hard seed testa. The present paper reports the insect fauna and their role on teak plantation in Andaman Islands.

Study area

The Andaman and Nicobar islands, situated in south-eastern region of Bay of Bengal between 16°45′ N and 13°30′ N and 92°20′ E and 93°56′ E are broadly divided into two groups of islands *viz.* Andaman and Nicobars. The main stretch of Andaman Island is collectively known as the Great Andamans, consisting of five adjoining islands *viz.* North Andamans, Middle Andamans, Baratang, South Andaman and Rutland Islands. The middle Andaman, the central island of the Great Andaman archipelago is home to many Jarawa tribes. Its coastline was inundated by the tsunami resulting from 2004 Indian ocean earthquake. It is believed that the aboriginal people survived because oral traditions passed down from generations ago warned them to evacuate from large waves that follow large earthquakes. South Andaman Islands

*Arid Forest Research Institute, Pali Road, Jodhpur, Rajasthan

is the most populated island with some areas of the island are restricted areas for non-Indians. It was also struck by the 2004 Indian Ocean Earthquake. North Andaman experiences fairly large earthquakes and suffered inundation from the 2004 Indian Ocean earthquake tsunami. Baratang contains the only known examples of mud volcanoes in India with sporadic eruption. Rutland Island is another island which forms the southernmost main of the closely-situated Great Andaman archipelago. The island was formerly home to the Jangil, Rutland Jarawa one of the indigenous Andamanese groups and now extinct. Other indigenous Andamanese such as the Onge from Little Andaman Island and Great Andamanese tribes had also set up fishing communities on Rutland. The island is presently without any permanent indigenous settlement.

The climate of the Great Andamans is a unique tropical rainforest canopy of mixed flora with elements from Indian, Myanmarese, Malaysian and endemic floral strains. The south Andaman forests have a profuse growth of epiphytic vegetation, mostly ferns and orchids. The middle Andamans harbours mostly moist deciduous forests. North Andamans is characterized by the wet evergreen type, with plenty of woody climbers. Deciduous forests are common in the Andamans. The temperature varies from 23° C to 31° C with the precipitation up to 300 cm annually. Winter is practically unknown, the period from December to February being comparatively pleasant due to the effect of north-east monsoon. The vegetation of Andaman Islands consists of tropical rain forests. The soil of these islands is alluvial and diluvial in nature on ridges and valleys where as coastal flats are covered with the admixture of sand, silty clay and diluvial material together with fragments of coral lime.

Areas under teak plantation

Teak plantation covers an area of approximately 14,000 ha of land distributed over South Andaman, Baratang, Middle Andaman and North Andaman Divisions. Selected teak plantation areas were surveyed to record the damage of standing teak trees due to insect pest (Table 1). In South Andamans teak plantation is distributed over Tushnabad, Jirkatang, Farrarganj, Kalatang and Mannarghat areas. Among various plantations of Andaman islands, Mannarghat excels in having the best and the oldest plantation (1890-1904) of teak. In Baratang Division, the teak plantation was started in year 1952-53. From 1954 onwards, regular plantation was carried out covering an area of approximately 2864 ha. which is the second largest area under teak plantation in Andaman Island (Table 2). Middle Andaman Division is having approximately 9625 ha of land under teak plantation and the largest in Andaman Island. Four teak plantations were extensively surveyed. North Andaman Division had five major areas of teak plantation out of which only two were surveyed.

Table 1. List of areas under teak plantations in Andaman Islands

South Andamans		*2.	Bakultala-Sabari
*1.	Tushnabad	*3.	Parnshala
*2.	Jirkatang	4.	Dhuratang
*3.	Fararganj	5.	Boron Valley
*4.	Kalatang	6.	Boroniyal
*5.	Mannarghat	7.	Prolob jig
Baratang Division		8.	Prolob Island
1.	Wraftar's creek	*9.	Long Island
*2.	Neelambur	10.	Charalaungta
3.	South Creek	**North Andamans**	
4.	Rogolachang	*1.	Tugapur N/S
5.	Middle Strait	2.	Zilabighum
6.	North Creek	*3.	Austen Island
Middle Andamans		4.	Swamp Island
*1.	Kalsi	5.	Interview Island

* Areas surveyed for insect pest study.

MATERIALS AND METHODS

The insect fauna was collected by the first author during survey to teak plantations during May 1993 and January-February, 1994. The faunal elements were collected from various teak plantations in Andaman Islands by using light trap, beating of trees and also by butterfly nets. Lepidoptera were preserved dry in butter- paper envelops. Other insect fauna was preserved in 70 per cent alcohol.

RESULTS AND DISCUSSION

About 280 insects have been associated with teak from India. They cause heavy damage to teak

Table 2. Teak Plantation in Baratang Division. (Area wise distribution)

Locality	Year	Area (ha)	Year	Area
Waftar's Creek (1954-1982)	1954	1	1970	30
	1955	8	1971	40
	1956	22	1972	52
	1957	18	1973	44
	1959	15	1974	50
	1961	24	1975	40
	1963	42	1976	35
	1964	45	1977	20
	1965	49	1978	20
	1966	44	1979	20
	1967	22	1980	20
	1968	28	1981	20
	1969	20	1982	20
Neelambur (1959-1964)	1959	16	1962	16
	1960	41	1963	26
	1961	100	1964	40
South Creek (1962-1977)	1962-1963	112	1972	18
	1964	44	1973	40
		18	1977	40
Rogolachang (1963-1972)	1963	16	1968	40
	1964	41	1969	40
	1965	44	1970	30
	1966	40	1971	40
	1967	44	1972	20
Middle Strait (1965-1974)	1965	56	1970	30
	1966	56	1971	40
	1967	54	1972	88
	1968	32	1973	30
	1969	40	1974	30
North Creek (1974-1975)	1974	40	1975	35
Evergreen	1961	32	1963	44
	1962	38		
J/Creek	1958	36		

plantation and reduce the green matter affecting the growth of the teak tree (Beeson, 1941; Browne, 1968; Tewari, 1992). Though teak timber is more resistant to the insect borers but susceptible in plantation stage. Very little is known about the insect fauna of teak in Andaman Islands. Insect fauna of teak in Andaman Islands is grouped into chafers, termites, defoliators, skeletonizers, sap suckers, stem borers and leaf feeders. The insect fauna associated with teak either as pest or food plant serves as major protein rich food for the other existing parasitic and predatory faunal diversity.

The common bird species associated with teak forests in Andaman Islands are White-bellied Sea Eagle; Andaman Serpent Eagle; Crested Serpent Eagle, Andaman Wood Pigeon (the state bird of the Andamans), Andaman Cuckoo-dove; Long-tailed Parakeet, Vernal Hanging Parrot, Brown Coucal, Andaman Scops Owl, Brown Hawk Owl, Andaman Hawk Owl, Glossy Swiftlet, Edible-nest

Swiftlet, Brown-backed Needletail, Blue-tailed Bee-eater, Black-capped Kingfisher, Andaman Woodpecker; Forest Wagtail, Bar-bellied Cuckoo-shrike,, Black-headed Bulbul, White-rumped shama, Asian Brown Flycatcher, Olive-backed Sunbird, Black-naped Oriole, Brown Shrike, Andaman Drongo, White-breasted Wood swallow, Andaman Treepie, Hill Myna, White-headed Starling, Andaman Pacific Reef Egret, Pacific Golden Plover, Lesser Sand Plover, Greater Sand Plover, Bar-tailed Godwit, Red-necked Stint, Long-toed Stint, Curlew Sandpiper, Broad-billed Sandpiper, Pacific (House) Swallow, Asian Glossy Starling and Black Baza. Other fauna associated with teak plantations are reptiles, rodents and Andaman Wild Boar.

List of insect fauna associated with teak in Andaman Island is given in Table 3. There are twenty six teak plantations at different places in Andaman Island. Out of which insect fauna form twelve plantations were surveyed. Out of 23 faunal species, dominance of *Thosea andamanica*, *Hybleaea puera* and *Eutectona machaeralis* were recorded in all the teak plantations surveyed (Fig. 1). Though forking, epicornic branching was observed in these plantations, the insects were found as pest mostly on the recent plantations as compared to the older plantations. Infact, the insects associated with the plantation are serving as good food for other faunal elements especially avian diversity found in Andaman Islands. Six species of wood eating and mound building termites have been identified from teak plantation areas surveyed under the project. The termites feed on the outer portion of bark which causes girdling effect. Termite mounds have been observed at Tushnabad, Kalsi and Tugapur teak plantations causing considerable damage to standing trees resulting into uprooting of the tree during severe wind action. The soil enrichment by termite and in natural regeneration of teak in these islands is a value added topic of future research in these plantations of Andaman Islands.

Table 3. List of Insect Fauna associated with Teak Forest in Andaman Islands

Family	Species Name
Order LEPIDOPTERA	
Arctiidae	*Utethesia pulchelloides* Hampson
Cossidae	*Xyleutes kapuri* Arora
Geometridae	*Boarmia bhurmitra* (Walker)
	Hyposidra talaca (Walker)
Hyblaeidae	*Hyblaea puera* Cramer
Indarbelidae	*Indarbela quadrinotata* Walker
Limacodidae	*Thosea andamanica* Holloway
Lymantridae	*Euproctis* sp.
Noctuidae	*Achaea janata* (Fabricius)
	Penicillaria jocosatrix (Gunee)
Pyralidae	*Eutectona machaeralis* Walker
	Syllepte derogata (Fabricius)
Sphingidae	*Acherontia lachesis* Fabricius
	Psilogramma menephron (Cramer)
Thyrididae	*Stringlina* sp.
Order COLEOPTERA	
Scarabaeidae	*Apogonia andamana* Mosor
	Adoretus versutus Harold
	Holotrichia andamana Brenske
Chrysomelidae	*Hyphasis* sp.
Curculionidae	*Myllocerus dorsatus* (Fabricius)
Order DIPTERA	
Itonididae	*Asphondylia tectonae* Mani
Order HOMOPTERA	
Margagodidae	*Icerya schellorum* Newstead
Order HETEROPTERA	
Pyrrhocoridae	*Dysdercus cingulatus* (Fabricius)
Order ISOPTERA	
Kalotermitidae	*Neotermes andamanensis* Snyder
Rhinotermitidae	*Coptotermes heimi* (Wasmann)
	Coptotermes travians Haviland
Termitidae	*Microcerotermes danieli* Roonwal & Bose
	Odontotermes latigula Snyder
	Nasutitermes krishna Roonwal and Bose

INSECT FAUNA OF VARIOUS TEAK PLANTATIONS IN ANDAMAN ISLANDS

South Andamans

Among various teak plantations in Andaman, Mannarghat excels in having best plantation with maximum growth increment and negligible pest infestation. In this area teak and paddauk are grown in juxtaposition. The Tushnabad teak plantation was found to be heavily infested by defoliators and skeletonizers with severe biotic interference.

Baratang

Teak plantation in Baratang Division had a serious problem of root fungus attack because of which many of the plantations were not successful. As reported by the Forest Department of Andaman and Nicobar Islands, the teak plantation at Rogolachang was the most successful and least disturbed plantation. The defoliators and sap suckers were found to have the maximum infestation in the Neelambur teak plantation.

Middle Andaman Division

In Middle Andaman Division, the teak plantation from Bakultala to Sabri, planted in 1973 did not show sufficient growth due to moderate to heavy infestation of moth defoliators. Termite attack was severe in certain pockets near Sabari (40 ha). Sap suckers were in abundance in the interior areas of the plantation. About 5-6 plots of 50 ha of land are under teak plantation in Parnasala area which was having very less foliage and mostly damaged by insect pest activity. The plantation was affected severely during Cyclonic hit in November, 1989. As a result large numbers of trees were uprooted in this area and the fallen logs became a good breeding ground for timber borers.

North Andaman Division

Tugapur teak plantation was found to be the most successful in terms of annual growth increment in North Andaman Division. Although the plantation suffers from defoliators and skeletonizers regularly but saved from extreme pest infestation effects. In certain coups of Tugapur teak plantations, the infestation of defoliators were reported to be in high proportions resulting in complete defoliation. Teak plantation of Austen Island was not well attended and had a severe pest infestation problem.

The teak though was found severely infected with insect pests did not suffer much and instead of controlling them by harmful chemical pesticides old age traditional silvicultural-biological practices need to adopted in case of mortality. Avoiding monoculture plantation also reduces the pest load factor which was well evident from plantations of Mannarghat were teak was grown with Paudak. These defoliators, chafers, sap suckers, wood feeders are all key indicators of the value this multipurpose teak tree holds. Wood of teak has medicinal properties, flowers are useful in biliousness, bronchitis and urinary discharges, seeds are diuretic and the leaf extracts are inhibitor of *Mycobacterium tuberoculosis*. The leaves also contain tannin and a yellow or red dye which can be used for dyeing silk, wool and cotton. The leaves serve the purpose of plates for dining, for making cheap umbrellas and for thatching temporary huts in some places. The bark of teak is regarded as an astringent useful in bronchitis and is a good source of oxalic acid. Activated charcoal is prepared from its sawdust. Lops, tops and other rejected portions are used as fuel.

Its various parts attracts number of insects which feeds on them and in turn serve as good food especially for avian fauna found in teak forests of Andaman Islands. The termites enriches the soil nutrients and also helps in easy germination of teak by feeding on the hard seed testa.

These teak forests also did not suffer during the recent Tsunami, the destruction by the tsunami in the Andamans was limited mostly to low-lying coastal areas, mangrove swamps and suchlike. However the environment overall has suffered far more damage from illegal logging and settlers moving along the Andaman Trunk Road than from the tsunami. On the positive side, much of the Andaman environment is not yet damaged beyond repair and that large areas - especially on the west coast in the Jarawa reservation, is still in remarkably good condition and remain well worth any effort to save them. Moreover these value added teak forests will create employment opportunities for the people on one hand on the other will serve to enrich the soil and conserve the existing avian faunal diversity. Locality wise distribution of insect species is given in Table 4 and 5.

SUMMARY

There are twenty six teak plantations at different places in Andaman Island. Out of which twelve were surveyed recently. The paper report twenty nine species of insect fauna associated with teak plantations. Severe infestation of only six viz. *Xyleutes kapuri* Arora, *Hyposidra talaca* (Walker), *Hyblaea puera* Cramer, *Inderbela quadrinotata* Walker, Thosea andamanica

Table 4. Locality wise distribution of insect species in Teak Plantation at Andaman Islands.

Family	**Name**	**South Andaman**					**Middle Andaman**				**Baratang Division**		**North Andaman**
Order LEPIDOPTERA													
Arctiidae	*Utethesia pulchelloides* Hampson	Tushnabad	Kalatang			Mannarghat					Neelambur		
Cossidae	*Xyleutes kapuri* Arora		Kalatang	Jirkatang	Fararganj		Kalsi	Parnsala		Long Island	Neelambur		Tugapur
Geometridae	*Boarmia bhurmitra* (Walker)	Kalatang				Mannarghat	Kalsi		Bakultala		Neelambur		
	Hyposidra talaca (Walker)	Tushnabad		Jirkatang		Mannarghat	Kalsi	Parnsala			Neelambur	Austen Island	
Hyblaeidae	*Hyblaea puera* Cramer	Tushnabad	Kalatang	Jirkatang			Kalsi	Parnsala	Bakultala	Long Island	Neelambur	Austen Island	Tugapur
Indarbelidae	*Indarbela quadrinotata* Walker	Tushnabad	Kalatang		Fararganj			Parnsala	Bakultala-Sabari				Tugapur
Limacodidae	*Thosea andamanica* Holloway	Tushnabad	Kalatang	Jirkatang	Fararganj		Kalsi		Bakultala	Long Island	Neelambur	Austen Islands	Tugapur
Lymantridae	*Euproctis* sp.	Tushnabad					Kalsi						Tugapur
Noctuidae	*Achaea janata* (Fabricius)	Tushnabad	Kalatang					Parnsala			Neelambur		
	Penicillaria jocosatrix (Gunee)		Kalatang							Long Island		Austen Island	
Pyralidae	*Eutectona machaeralis* Walker	Tushnabad	Kalatang	*Jirkatang*		Mannarghat	Kalsi	Parnsala	Bakultala-Sabari	Long Island	Neelambur	Austen Islands	Tugapur
	Syllepte derogata (Fabricius)			Jirkatang		Mannarghat		Parnsala			Neelambur		
Sphingidae	*Acherontia lachesis* Fabricius	Tushnabad	Kalatang										Tugapur
	Psilogramma menephron (Cramer)						Kalsi	Parnsala			Neelambur		
Thyrididae	*Stringlina* sp.		Kalatang		Fararganj			Parnsala					Tugapur
Order COLEOPTERA													
Scarabaeidae	*Apogonia andamana* Mosor		Kalatang				Kalsi				Neelambur	Austen Islands	

Table 4. *Contd.*

Family	Name	South Andaman					Middle Andaman				Baratang Division		North Andaman
	Adoretus versutus Harold		Kalatang			Mannarghat	Kalsi		Bakultala				Tugapur
	Holotrichia andamana Brenske	Tushnabad										Austen Islands	Tugapur
Chrysomelidae	*Hyphasis* sp.	Tushnabad											Tugapur
Curculionidae	*Myllocerus dorsatus* (Fabricius)	Tushnabad	Kalatang						Bakultala				
Order DIPTERA													
Itonididae	*Asphondylia tectonae* Mani			Jirkatang	Fararganj						Neelambur		Tugapur
Order HOMOPTERA													
Margagodidae	*Icerya schellorum* Newstead			Jirkatang			Kalsi		Bakultala-Sabari	Long Island			
Order HETEROPTERA													
Pyrrhocoridae	*Dysdercus cingulatus* (Fabricius)	Tushnabad					Kalsi			Long islands		Austen Islands	Tugapur
Order ISOPTERA													
Kalotermitidae	*Neotermes andamanensis* Snyder	Tushnabad							Bakultala				
Rhinotermitidae	*Coptotermes heimi* (Wasmann)		Kalatang	Jirkatang									
	Coptotermes travians Haviland								Bakultala-Sabari				
Termitidae	*Microcerotermes danieli* Roonwal & Bose	Tushnabad									Neelambur		
	Odontotermes latigula Snyder	Tushnabad							Bakultala				
	Nasutitermes krishna Roonwal and Bose												Tugapur

Table 5a. Total number of insect species in different Teak localities of South Andaman Islands

ORDER	South Andaman														
	Tushnabad			Kalatang			Jirkatang			Fararganj			Mannarghat		
	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species
Lepidoptera	8	10	10	10	11	11	5	6	6	4	4	4	3	5	5
Coleoptera	3	3	3	2	3	3	0	0	0	0	0	0	0	0	0
Diptera	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
Homoptera	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
Heteroptera	1	1	1	0	0	.0	0	0	0	0	0	0	0	0	0
Isoptera	2	3	3	1	1	1	1	1	1	0	0	0	0	0	0

Table 5b. Total number of insect species in different Teak localities of Middle Andaman Islands

ORDER	Middle Andaman														
	Kalsi			Parnsala			Long Island			Bakultala			Sabari		
	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species
Lepidoptera	7	10	10	8	8	8	4	4	4	5	5	5	2	2	2
Coleoptera	1	2	2	0	0	0	0	0	0	2	2	2	0	0	0
Diptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Homoptera	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1
Heteroptera	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Isoptera	0	0	0	0	0	0	0	0	0	3	3	3	1	1	1

Table 5c. Total number of insect species in different Teak localities of North Andaman and Baratang Islands

Order	North Andaman						Baratang		
	Tugapur			Austen			Neelambur		
	Family	Genus	Species	Family	Genus	Species	Family	Genus	Species
Lepidoptera	8	8	8	5	5	5	9	11	11
Coleoptera	2	3	3	1	2	2	1	1	1
Diptera	1	1	1	0	0	0	1	1	1
Homoptera	0	0	0	0	0	0	0	0	0
Heteroptera	1	1	1	1	1	1	0	0	0
Isoptera	1	1	1	0	0	0	1	1	1

Holloway and *Eutectona machaeralis* Walker was reported. Insect species *Thosea andamanica, Hybleaea puera* and *Eutectona machaeralis* were recorded in all the teak plantations surveyed. Six species of wood eating and mound building termites have also been identified. The termites feed on the outer portion of bark which causes girdling effect. Termite mounds have been observed at Tushnabad, Kalsi and Tugapur teak plantations causing considerable damage to standing trees thereby resulting into uprooting of the tree. Among various teak plantations in Andaman, Mannarghat excels in having best plantation with maximum growth increment and negligible pest infestation. Here teak is grown with Padauk. The Tushnabad plantation was heavily infested by defoliators with severe biotic interference. Neelambur teak plantation was the most infested one in Baratang division. Teak plantation at Parnasala had little foliage and severely infested. The fallen trees are serving as good site for timber borers. In North Andaman division Tugapur teak plantation was found to have maximum growth. Teak plantation of Austen Island had a severe pest infestation. These insects rather as pests are serving as good food especially for avian fauna found in teak forests of Andaman Islands. Moreover these value added teak forests will not only serve in environmental conservation but also create alternate sources of wealth employment opportunities for the livelihood of the people of the islands.

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Chapter 27

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 323-328, 2010

POST-TSUNAMI CONSERVATION OF BUTTERFLIES OF BAY ISLANDS

T.C. KHATRI and TRIPTA KHATRI
J. N. Government College, Port Blair 744104, Andaman, India

INTRODUCTION

The Andaman and Nicobar Islands pre-historically were home to one of the richest tropical humid forest areas of India. The islands remained in pristine condition until 1788. More than 2300 species of flowering plants with an abundant diverse and rich habitat for butterflies were characteristics over 301 plant species are endemic. These islands are included in India's bio-diversity "hot spot" With the arrival of the penal settlement in 1858, the sheltered ecosystem experienced its first major human impact. The magnitude of impacts gradually intensified beginning in 1941, when convicts along with repatriates from Myanmar, Sri Lanka and Bangladesh were settled in these islands. During the post independence period from 1947 onward, ex-service men and more refugees from West Bengal, South India and Sri Lanka brought further habitat degeneration. Environmental degradation accelerated with the implementation of agriculture and forest based industries and tourism pose irreversible threats to the fauna and flora of these islands.

Continuing development of the islands causes habitat destruction through deforestation, with correlative decrease predicted in population viability of the butterfly fauna. Because of host specificity of many butterflies, they are unable to adapt to ecological changes including loss of host plants below critical levels. A number of species of the islands may already be extinct as a result of habitat destruction during the past sixty years. The massive earthquake of magnitude 9 on December 26, 2004 tilted the islands in South North direction submerging costal from 4.57 to 4.0 m. The earthquake set tsunami which permanently inundating huge area and low-lying forest destructing the breeding grounds of butterflies. This paper presents impact of tsunami on butterfly fauna of Andaman and Nicobar Islands.

The Andaman and Nicobar archipelago comprising of 572 islands, islets and rocks is situated 1200 km off the southeastern coast of India in the Bay of Bengal. The islands are notoriously called "Kalapani" Together they constitute one of the Union Territories of India, and are divided into three districts. South Andaman and Middle and North Andaman to the north of the 10 degree channel and Nicobar to its south. Andaman and Nicobar islands are separated by about 160 km of sea. Being close to the equator and surrounded by the sea, these islands have a tropical climate. Precipitation is heavy with both North-east and South-west *monsoons* being received. It rains for about eight months a year (3100 mm). Cyclones do occur, temperature is moderate, and relative humidity is high. These islands once believed to be a continuation of the Arakan Yoma mountatin range of Myanmar up to Achin head of Indonesia, have undulating terrains with main ridges running north to south.

*E-mail : tikamtulsi@rediffmail.com

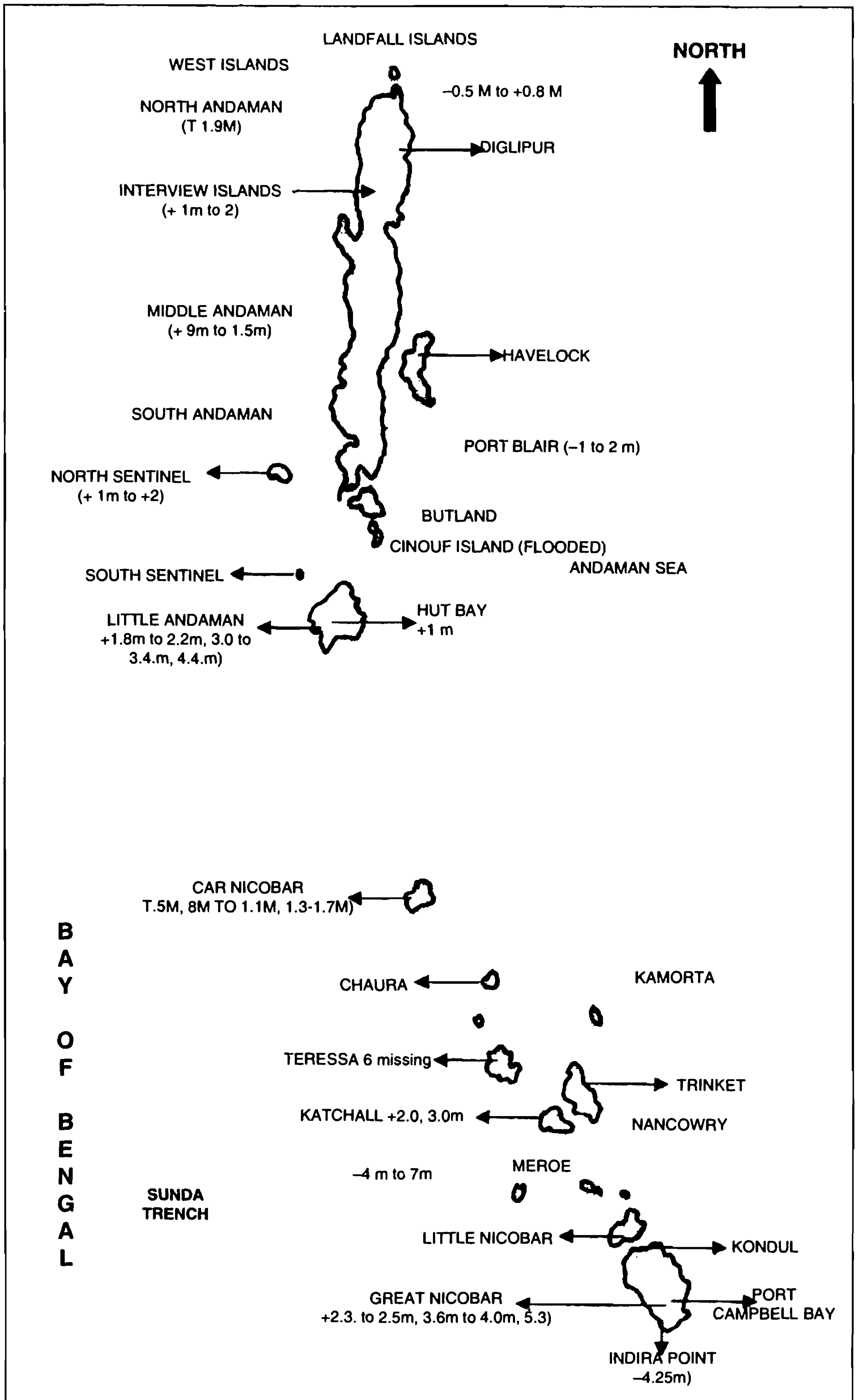

Fig. 1. Andaman and Nicobar islands after the Tsunami

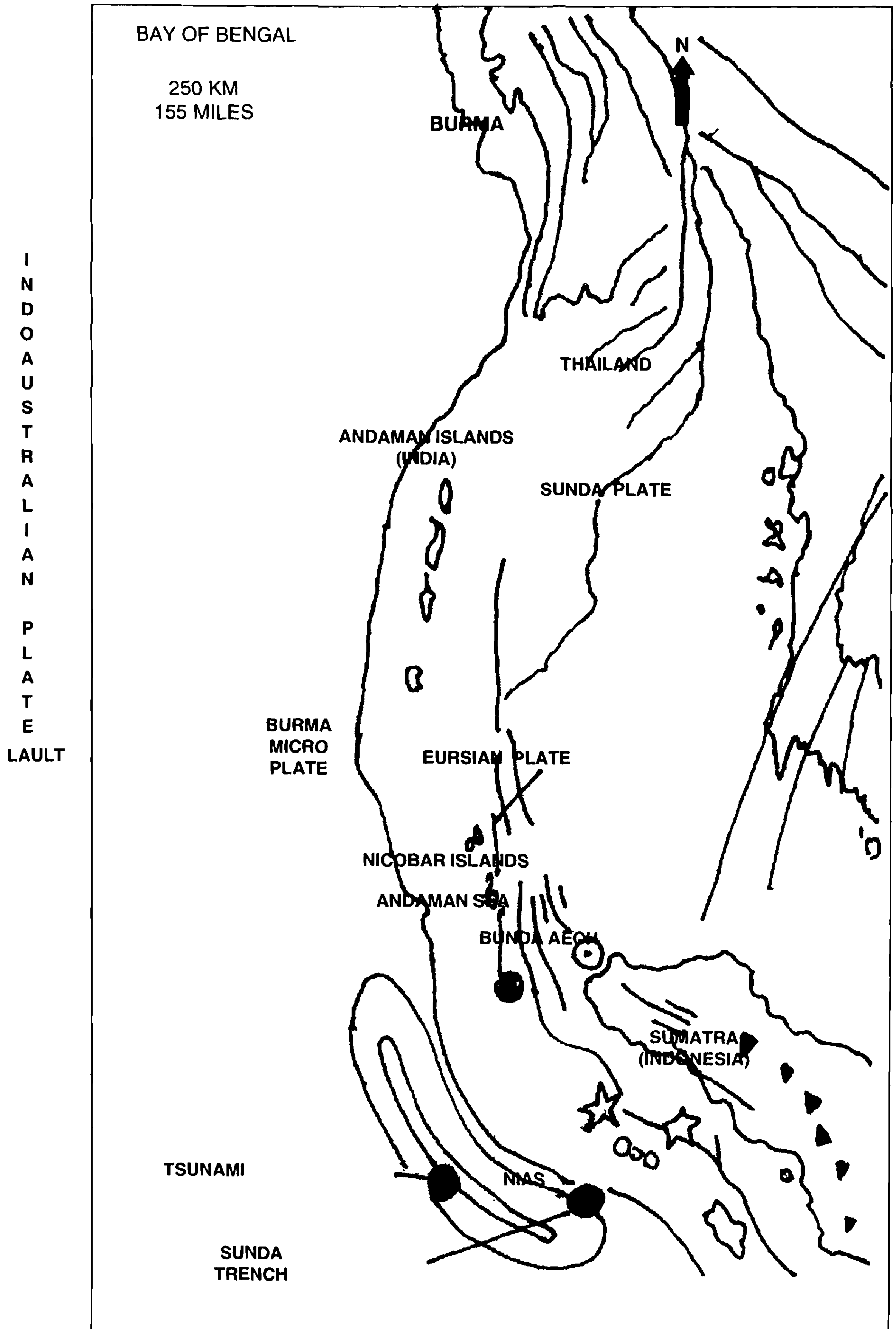

Fig. 2. Tectonic Position of Andaman and Nicobar Islands

There are a new hills running east west. In between the main ridges, deep inlets and creeks exist. The average width is about 20 km. There are a few flatlands and perennial streams. Ground water reserve is limited; and soil is mostly acidic and poor in nutrients. Soil types vary, from heavy clay to loamy sand. The cumulative land area is 8249 km^2, out of which 7094 km^2 including 1070 km^2 of tribal reserve area is claimed to be under forest cover.

Butterfly fauna before tsunami

The butterfly fauna of the Andaman and Nicobar islands is insular with its origin in the fauna of the Indo-Malayan regions. The Andaman elements have their closest affinities to Myanmnar and mainland elements whereas the Nicobar elements appear most closely related to Malayan elements. The long isolation of these islands from the Asian Continent, if the island indeed ever has a continental connection, and their until recently undisturbed ecology provided optimal conditions for the evolution of may local and endemic taxa. Evan (1932) described 260 forms, followed by Ferrar (1951) who described 268 forms from these islands (Plate 22). There are 214 species and 236 subspecies in 116 genera belonging to five families and three subfamilies. More than 50 per cent of the taxa are endemic to these islands. Many endemic taxa in each family are rare, very rare, or stragglers.

Zoo-geographically the butterfly fauna of the islands can be classified into six major group: a. wide ranging fauna b. similar to Myanmar fauna c. similar to Malayan fauna d. fauna common to the Andamans and Nicobars, e. endemic to the Andamans, and f. endemeic to the Nicobars. Wide ranging taxa which show affinities with Indian mainland elements form 10 per cent of the total fauna and are rare in these islands. Half the taxa are endemic to these islands and 20 per cent of the species are common to both groups of islands. The remaining taxa show similarities with Myanmar and Malayan elements

Out of 236 taxa gave been recorded in recent years (since 1985). New records of the past twenty years are 20 from Andaman and 10 from Nicobar. The recent trends of the fauna elements of the Andamans are mixing with the Nicobar elements and vice versa.

DISCUSSION

The Andaman and Nicobar Islands is earthquake pore zone falling under Zone of 6th earthquake. Tectonically, the Andaman and Nicobar Islands are located near the boundary of the Indian plate and the Myanmar Micro plate. The Andaman trench marks this boundary and lies in the Bay of Bengal to the west of the archipelago. Another prominent feature is the North-South west Andaman fault which is strike-slip in nature and lies in the Andaman Sea, to the east of this island chain.

The Andaman Sea, like the Atlantic Ocean is presently widened by a tectonic process called "sea floor spreading" This is taking place along under sea ridges (Yellow lines) on the sea floor. The Indian plate is dividing beneath the Myanmarese Micro plate along with Andaman Trench in a process known as "Subduction" Shallow and occasional intermediate- depth earthquake delineate the subducted slap under the Andaman-Nciobar islands joining the seism city trend of the Indo-Myanmar ranges. In recent and historic time only two high magnitude earthquakes have occurred in this region. The first was in 1881, in the Andaman sea, near the Nicobar islands and the second, off the west coast of Middle Andaman Islands in June 1941.

The huge earthquake of magnitude of 9.0 on the Richter scale took place in the seabed off the coast of Acch Province on the Indonesian Islands of Sumatra with result the Indian plate slipped below Myanmar plate, on 26th December 2004. The pressure so built forced the seawater upwards with the results a series of waves rushed outwards and started racing across the surface of the ocean towards the shoreline in the shape of tsunami.

This disaster of December 26th 2004 had battered the Archipelago of Andaman and Nicobar Islands. Tsunami was ferocious worst at Campbell Bay of Great Nicobar Biosphere Reserve. The western coastal area is submerged upto 4.25 m in seawater. The flat and ferrile Car Nicobar islands 10 km is diameter and having circumference of 45 km flooded up to 1 to 1.5 km by salt water. Coconut plantation leveled down the ground by 10m high wave. Katchal, Chowra, Kamorta, Tersa, Champion and Trinket had faced the fury of the sea. Hutbay in little Andaman too suffered as the waves stamped in. Sand banks holding together such as

Katchal and Pillow Millow gave away and two islands appear in place of one. Tiny Tirknet was flood entirely.

The ecological impact of tsunami on Andaman's was less evident except that low laying coastal agriculture land submerged in seawater because of rise in sea level by 1.0 me restricting the habitat of butterflies. Creeks of mangrove forests reduced the impact of tsunami to great extent in the Andamans. Nicobar islands were closer to the epicenter with little or no mangrove cover, some island too small in size, other flat, faced maximum ecological damage specially Car Nicobar, Central Nicobar and Great Nicobar Biosphere Reserve.

It is feared that many coastal native butterflies along with their food plants and immature stages are washed away by tsunami waves. The flooding of these islands has further affected the insect by drying of their food plants in salt water. Butterflies inhabiting in forest seems to be safe in all islands of archipelago. The tsunami of December 26th 2004 has affected the butterfly fauna of these islands. A number butterflies recorded after tsunami were not know earlier from that area. e.g *Precis lemonias,* an exotic species collected from Port Blair on July 13th 2005. This species has established in South Andaman. *Danaus melanippus nesippus* a native butterfly of Nicobar Islands collected from North Andaman from Mayabunder in December 7th 2005 a place 600 km away from Nicobars. *Hypolimnas atilope anomal* a Nicobar butterfly collect from South Andaman Port Blair on July 8th 2005.

Similarly, *Pachliopta rhodifer* an endemic species use to be very common in South Andaman sighted on road side has become rare even in the forest after tsunami. *Cethocia biblies andamana* is not recorded after tsunami from Andaman islands. *Cethocia cyanae* an exotic species native of Myanmar and India mainland can be seen very where through out the Andaman islands. This is only a tip of iceberg there may be many more butterflies displaced from their niches to other islands. It seems that tsunami has reshuffled the butterfly fauna with addition of some exotic species.

The butterfly fauna of Andaman and Nicobar islands is already under Estress due to deforestation and various development activities in the islands (Khatri, 1993). The loss of breeding habitat of butterflies due to tilting of archipelago after earthquake of December 2004. The resultant tsunami has flooded, flushed and salinated coastal area of the islands. The area lost as a result of earthquake and tsunami is given in table 1.

In addition to that the Andaman and Nicobar Administration had planned to distribute land

Table 1. Area lost due to Tsunami of December 26th 2004 in Andaman and Nicobar Islands (Important Islands only).

Sl. No.	Name of Islands	Total Area (in Km²)	Area lost in tsunami (in Km²)	Present area (in Km²)
1	North Andaman	1376.0	89.6	1286.4
2	Interview Islands	133.4	28.1	105.3
3	Middle Andaman	1535.5	141.5	1394.0
4	South Andaman	1347.97	91.4	1256.57
5	Little Andaman	731.6	37.2	694.4
6	Car Nicobar	126.9	27.0	100.0
7	Teresa and Bompoka	114.7	17.7	94.0
8	Camorta and Triket	224.5	60.4	164.1
9	Katchal	174.4	41.7	132.7
10	Little Nicobar	159.1	20.9	132.2
11	Great Nicobar	1045.1	86.1	959.1
	Total		**641.5**	

equal to submerged area to farmers for agriculture by clearing pristine forest. For rehabilitation of tsunami displaced people forest has cleared as shown in table 2. The shrunk habitat up to 19.4 per cent of butterflies has posed serious ecological threat. Butterflies manage to escape from tsunami impact, had moved in interior forest. This has increased inter and intra species struggle for their existence, which will be suicidal for rare, very rare endemic taxa. Common butterflies will withstand the impact but rare and very rare butterflies inhabiting in specified niches in small population, have the danger of extinction.

Table 2. Forest cover removed for rehabilitation in Andaman and Nicobar islands

Sl. No.	Name of Island	Area lost due to clearing of forest (in km^2)
1	South Andaman	264.0
2	Little Andaman	100.0
3	Camplbell Bay	600.0
	Total	964.0

Overall area lost due to earthquake, tsunami and rehabilitation in Andaman and Nicobar Islands

Earth quake/Tsunami	641.5 km^2
Rehabilitation	964.0 km^2
Total	1605.5 km^2

Percentage of area lost due to earthquake and tsunami : 641.5/8249 × 100 = 7.8

Percentage of area lost due to rehabilitation : 954/8249 × 100 = 11.6

Total geographical area lost = 19.4 per cent

The butterfly fauna of these islands has not fully explored till date, even biology, ecology and niches of some of the endemic butterflies yet to be studied. Conservation measures are suggested by the author for protecting endemic taxa has been ignored by the concerned authorities. Impact assessment of tsunami affected islands is significant in the light of their changed ecological condition and should be done at top priority which requires huge man power and financial assistance as islands are spread over 800 km in the Bay of Bengal and some islands have no landing facilities. There is urgent need to carryout butterfly survey of these islands to know the status of butterfly fauna after December 26, 2004 so that necessary steps can be taken to save rare, very rare and struggler butterflies listed in India and IUCN Red Data Book.

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Plate 22

Precis lemonias

Danaus melanippus nesippus

Hypolimnas atilope anomala

Chapter 28

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 329-336, 2010

FRESHWATER FISHES OF ANDAMAN ISLANDS

K. REMA DEVI
Marine Biological Centre, Zoological Survey of India, 130, Santhome High Road, Chennai-600 028

INTRODUCTION

The fishes of the Andaman Islands have been studied and reported earlier by several fish workers, incorporated subsequently in the monumental work of Day (1875-78). The earliest consolidated account of the fishes of Andaman Islands is that of Herre (1939) listing 112 species including littoral and freshwater fishes from the Andaman Islands and Herre (1941) wherein 490 species including shoreline and coral reef fishes and very few freshwater fishes from the streamlets were listed. Subsequently there has been several reports on the marine and reef fishes (Rao, 1993) of the Andamans, which account for 1200 species, but there has been no account on the freshwater fishes. The present paper lists the freshwater fishes so far known from the streams in the Andaman Islands. Systematic list along with the specimens examined by Herre (1939) from various freshwater bodies in Andaman is given along with the distribution, habitat and size of the species. Only 8 primary freshwater fishes are known from the Andaman. Others are secondary freshwater species that have been actually collected from various freshwater bodies in the Andaman by Herre (op.cit.). These are quoted as such in this paper for the benefit of future workers. Other secondary freshwater fishes whose collection details are not known are also included. The primary and secondary freshwater species have been classified following Menon (1999) and Jayaram (1999). During routine identification and advisory services to outside institutions, another species of the genus *Schismatogobius* has been observed in the freshwater collections from Andamans. The presence of this naked goby is of significance since in the Indian ocean islands, this was first discovered in the freshwaters of Sri Lanks and described as *Schismatogobius deraniyagalai* Kottelat and Pethiyagoda and recently the species has also been collected from southern western Ghats of India.

SYSTEMATIC ACCOUNT OF FISHES COLLECTED FROM RESHWATERS OF ANDAMAN ISLANDS (Herre, 1939)

(* Primary freshwater fishes)

Order ANGUILLIFORMES

Family ANGUILLIDAE

1. ***Anguilla bicolor* McClelland***

1845. *Anguilla bicolor* McClelland, *Cal. Journ. Nat. Hist.*, V, pl. 178, pl. vi, fig. 1.

1999. *Anguilla bicolor*, Menon, Check list-Freshwater Fishes of India, *Rec. Zool. Surv. India, Occ. Paper No.* **175** : 6-7. (Published – Director, ZSI).

Distribution and Remarks : India and Sri Lanka and most countries bordering the Bay of Bengal.

"This eel is common in the Andaman. Twelve examples, 90 to 315 mm. in length, were taken from pools in the bed of a dried-up stream near the Fisheries Laboratory, Port Blair, and another of 66 mm. was taken from Dhanikhari stream, South Andaman" (Herre, 1939). Also 6 juvenile specimens ranging in length from 45–50 mm from Phoenix Bay, Port Blair which were badly preserved due to strong preservatives, have also been placed as belonging to this species by Herre (op.cit).

Habitat : Freshwater streams and pools, preferring marshy habitats, in coastal areas descending to sea to spawn.

Size : 100 cm in length.

Order CYPRINIFORMES

Family CYPRINIDAE

2. ***Rasbora daniconius*** (Hamilton)*

1822. *Cyprinus daniconius* Hamilton, *Fishes Ganges*, p.327, pl. XV, fig. 89.

1935. *Rasbora daniconius*, Mukerji, *Rec. Ind. Mus.* XXXVII, 259.

1999. *Rasbora daniconius*, Jayaram, *The Fresh water Fishes of the Indian Region*, 82-83. Narendra Publishing House, Delhi.

Distribution and Remarks : Throughout India. Sri Lanka. Pakistan. Nepal. Bangladesh. Myanmar and Thailand.

"This handsome little Cyprinid is evidently abundant in places. The collection contains 29 examples, 28 to 54 mm. in length, from a stream near Base Camp. North Andaman" (Herre, 1939). He further remarks that the species occurs throughout India, Burma and Ceylon, but it is replaced by *Rasbora einthoveni* (Bleeker) in the Malay Peninsula and Malay Archipelgo, with which it has been confused.

Habitat : Clear but slow flowing streams, pools and ditches in the plains chiefly with sandy substrate.

Size : 10.0 cm TL.

3. ***Labeo rohita* (Hamilton)***

1822. *Cyprinus rohita* Hamilton, *Fishes of Ganges* : 301, 388, pl. 36, fig. 85.

1941. *Labeo rohita*, Herre, Fishes from the Andaman Islands, *Mem. Indian Mus.*, Xiii, p. 340.

Distribution : India : Naturally in North and Central India, now introduced elsewhere for culture. Pakistan. Bangladesh. Terai region of Nepal. Myanmar.

Reported from the freshwaters of Andaman by Annandale and Hora (1925) and Mukerji (1935). They remark that it is an introduced species.

Habitat : Rivers and culture ponds.

Size : 91.0 cm TL.

Order MUGILIFORMES

Family MUGILIDAE

4. ***Crenimugil crenilabis*** (Forsskal)

1775. *Mugil crenilabis*, Forsskal, *Descrip. Anim.*, p. 73.

1922. *Crenimugil crenilabis*, Thomson, *FAO Species Identification Sheets for Fishery Purposes, Western Indian Ocean*, Vol.III, Food and Agriculture Organization of the United Nations, Rome.

Distribution and Remarks : Natal to the Red Sea and in the Laccadive Islands. Elsewhere extending eastward to the Western Pacific, including Hawaii.

"5 specimens, 34 to 75 mm. in length, were taken in Murdakhari Bay, Port Blair, and one of 59 mm. from a rock pool near South Corbyn's Cove, Port Blair"(Herre, 1939).

Habitat : Shallow coastal waters, especially coral reef areas, but nowhere abundant.

Size : Maximum 40 cm; common to 26 cm.

5. ***Valamugil cunnesius*** (Valenciennes)

1836. *Mugil cunnesius* Valenciennes, *Hist. Nat. Poiss.*, XI : 114.

1836. *Mugil amarulus* Cuvier and Valenciennes, *Hist. Nat. Poiss.* XI, p. 128.

1991. *Valamugil cunnesius*, Talwar & Jhingran, *Inland Fishes of India and Adjacent Countries*, Vol. 2, p. 901-902. Oxford & IBH Publishing Co. Pvt. Ltd.

Distribution and Remarks : India, Sri Lanka, Bangladesh, through the East Indies, to the Western Pacific.

"5 specimens, 25 to 37 mm. in length, were taken from freshwater pools near South Corbyn's Cove, Port Blair" (Herre, 1939).

Habitat : Occuring in shallow coastal waters, estuaries, backwaters, frequently entering freshwaters.

Size : Grows to 30 cm in length.

6. ***Liza melinoptera*** (Valenciennes)

1836. *Mugil melinopterus* Valenciennes, *Hist. Nat. Poiss.*, XI : 146, pl. 313

1991. *Liza melinoptera*, Talwar & Jhingran, *Inland Fishes of India and Adjacent Countries*, Vol. 2, p.892-893. Oxford & IBH Publishing Co. Pvt. Ltd.

Distribution and Remarks : "3 examples, 18 to 34 mm. in length, from South Corbyn's Cove, Port Blair, and one of 37 mm. from a stream west of Sipi Ghat, South Andamans.

Habitat : Occuring in shallow coastal waters, entering estuaries and freshwaters.

Size : Grows to 20 cm in length.

Order BELONIFORMES

Family ADRIANICHTHYIDAE

7. ***Oryzias carnaticus*** (Jerdon)*

1849. *Aplocheilus carnaticus* Jerdon, *Madras J. Lit & Sci.*, **15** : 331

1998. *Oryzias carnaticus*, Tyson R. Roberts, Ichthyological Research. *The Ichthyological Society of Japan* : 213-224.

Distribution and Remarks : India : Widely distributed in eastern India. Bangladesh.

Herre (1939) remarks that this species is common and widespread in the freshwater streams of Andamans and that it could also have been accidentally introduced accidentally along with the fry of various carps imported from India to stock Andaman waters. Specimens collected by him are as follows: "Five examples from a shallow stream near Base Camp, North Andaman, are 26 to 28 mm. long. The following are from South Andamans : 26 specimens, 11 to 22 mm. in length, from Tytler's Ghat; 16 specimens, 20 to 34 mm., from a creek north of Corbyn's Cove, Port Blair; and 26 specimens from 22 to 29 mm. in length taken at Austinabad Nala, Port Blair; these last were subject to tidal influence." The Indian species were earlier known as *O. melastigma* until the revision by Roberts (1998).

Habitat : Brackish waters and estuaries, usually found in shallow lagoons and swamps among roots and mangroves along the margins of waters.

Size : Grows to 4.0 cm in length.

Order CYPRINODONTIFORMES

Family APLOCHEILIDAE

8. ***Aplocheilus panchax*** (Hamilton)*

1822. *Esox panchax* Hamilton, *Fishes Ganges*, p. 211, pl. iii, fig. 69.

1999. *Aplocheilus panchax*, Menon, Check list-Freshwater Fishes of India, *Rec. Zool. Surv. India, Occ. Paper No.* **175** : 269. (Published–Director, ZSI).

Distribution and Remarks : India : Northern India. Pakistan. Bangladesh. Myanmar. Thailand. Indo-Malayan Archipelago.

Though Annandale and Hora (1925) stated that this species was common in the quieter parts of jungle-stream in South Andaman, Herre (1939) opined that the species occurs plentifully throughout the Andamans. The specimens examined from him are "1 of 30 mm. from a ditch in the jungle near Port Bonington, North Andaman; 50 from 23 to 47 mm. in length, from a fresh-water stream, Rangat Camp, Middle Andaman; 10 from 30 to 65 mm. near Port Blair; 1 of 21 mm. from a stream south of a creed near South Corbyn's Cove, Port Blair, South Andaman; 8 from 18 to 31 mm. from a stream near Manglutan, South Andaman" (Herre, 1939). According to Day the specimens in Andamans grow to a larger size than those in India.

Habitat : Clear shallow fresh and brackish waters.

Size : Grows to 9.0 cm TL. Commonly 5 cms.

Order GASTEROSTEIFORMES

Family SYNGNTHIDAE

9. ***Microphis insularis*** (Hora)*

1925. *Doryichthys insularis* Hora, *Rec. Ind. Mus.* XXVII, p. 38, pl.ii, fig. 1.

1991. *Microphis insularis*, Talwar & Jhingran, *Inland Fishes of India and Adjacent Countries*, Vol. 2, p. 772-773. Oxford & IBH Publishing Co. Pvt. Ltd.

Distribution and Remarks : India : Andaman Is.

"Fifteen examples of this interesting Pipe-fish, 67 to 89 mm. long, were taken from a stream near the wireless station, Port Blair, and a specimen, 133 mm. long, was caught in a stream west of Sipi Ghat, South Andaman. Hora had but 6 examples, the largest 97 mm. long" Herre (1939). This species is endemic to Andaman Is.

Habitat : Inhabits rivers and streams.

Size : 97 mm in length.

Order PERCIFORMES

Family GOBIIDAE

10. *Awous ocellaris* (Broussonet)

1782. *Gobius ocellaris* Broussonet, *Encyclop. Meth., Dec. Ichth.*, fig. 142.

1927. *Chonophorus ocellaris*, Herre, *Gobies Philip.*, p. 218, pl. xvii, fig. 2.

1984. *Awous ocellaris*, Masuda *et al.* (Eds.). *The Fishes of Japanese Archipelago*. Tokai Uni., Japan. p. 263, pl. 245-K,L.

Distribution and Remarks : Distributed in Chiba Pref., Kanagawa Pref., Amamioshima, the Ryukyu Islands, the Philippines and India. (M. Hayashi).

"An example, 30 mm. long, was taken from Dhanikhari stream, South Andaman." Herre (1939).

Habitat :Found on fine gravel bottoms from estuaries to freshwater of rivers.

Size : Attains a length of 13 cm.

11. *Glossogobius celebius* (Valenciennes)

1837. *Gobius celebius* Cuvier and Valenciennes, *Hist. Nat. Poiss.* XII, p. 56.

1927. *Glossogobius celebius*, Herre, *Gobies Philip.*, p. 156, pl.xxii, fig.4.

1984. *Glossogobius celebius*, Masuda *et al.* (Eds.). *The Fishes of Japanese Archipelago*. Tokai Uni. Press, Japan. p. 274-275, pl. 251-I.

Distribution and Remarks : Distributed in Iriomotejima, the Philippines, along the east coast of northern Australia, and in the South Pacific. (Prince Akihito). Its presence in the Andamans has not been reported after Herre (1939). Kottelat *et al.* (1993) limit its distribution to Sulawesi.

"2 specimens, 45 and 67 mm. long, were taken from a small stream, North Andaman." Herre (1939).

Habitat : Inhabits the rocky bottom of freshwater streams.

Size : Attains a length of 13 cm.

12. *Sicyopterus microcephalus* leeker*

1854. *Sicydium microceplalus* Bleeker, *Nat. Tijds. Ned. Ind.* VII, p. 437.

1925. *Sicyopterus garra* Hora, *Rec. Indian Mus.*, XXVII, p. 35, pl. ii, figs. 2-5.

1941. *Sicyopterus microcephalus*, Koumans, Gobioid Fishes of India, *Mem. Indian Mus.*, XIII, p.295.

Distribution and Remarks : Andaman, Java,? Celebes, Timor.

"The following were collected at various times about Port Blair : 9 from 15 to 40 mm. near the wireless station; 40 from 17 to 35 mm. from a freshwater stream south of South Corbyn's Cove; 11 from 19 to 21 mm. from Dhanikhari stream and two 32 and 39 mm. long from a creek near Dhoby Line, Aberdeen. One of 52 mm. was taken at the foot of Mount Tytler, South Andaman." Herre (1939).

Habitat : "This little fish is evidently abundant in Andaman streams. The members of this group live in stony or gravelly brooks and rivers, often in swift hill streams, going down to the sea to spawn. Inhabits the rocky bottom of freshwater streams" Herre (1939).

Size : Attains a length of 112 mm.

13. *Redigobius roemeri* (M. Weber)

1911. *Gobius romeri* M.Weber, *Abh. Senck. Ges.* XXXIV, p. 39, fig. 8.

1935. *Vaimosa koumansi* Mukerji, *Rec. Ind. Mus.*, XXXVII, p. 268, pl. v, figs. 3,4.

1941. *Pseudogobiopsis romeri*, Koumans, Gobioid Fishes of India, *Mem. Indian Mus.*, XIII, p. 244.

1993. *Redigobius roemeri*, Kottelat *et al. Freshwater Fishes of Western Indonesia and Sulawesi.* Periplus Editions, Indonesia, p. 151-152, fig. 308.

Distribution and Remarks : Sulawesi, Moluccas, New Guinea, Philippines, Fiji, Australia and India.

"93 examples, 8 to 25 mm. in length, from a creek north of South Corbyn's Cove, Port Blair, South Andaman; 86 specimens 12 to 27 mm. in length from Dhanikhari stream near the junction of the Maymyo and Manglutan roads, South Andaman; 6 specimens from the same locality, 14 to 20 mm. in length; and 7 specimens 17 to 21 mm. in length from a fresh water stream near Weli village, Base Camp, Middle Andaman" Herre (1939).

Habitat : Inhabits creeks and freshwaters.

Size : Attains a length of 43 mm.

Family ELEOTRIDAE

14. ***Eleotris fusca*** (Bloch & Schneider)

1801. *Poecilia fusca* Bloch and Schneider, *Syst. Ichth.* p. 453.

1991. *Eleotris fusca*, Talwar & Jhingran, *Inland Fishes of India and Adjacent Countries*, Vol. 2, p. 975-976. Oxford & IBH Publishing Co. Pvt. Ltd.

Distribution and Remarks : Indo-West Pacific.

"*Eleotris fusca* is the commonest and most widely distributed member of the genus, ranging from Madagascar and the rivers of east Africa to the Philippines, Guam and the Marquesas. 6 specimens, 45 to 46 mm. in length, from Aberdeen, Port Blair, South Andaman, and 2 specimens, 21 and 23 mm. in length, from a freshwater stream at Beadonabad, Port Blair. From a freshwater pond on South Island, North Andamans were taken 3 examples, 73 to 84 mm. in length." Herre (1939).

Habitat : Inhabits estuaries and freshwaters.

Size : Attains a length of 17 cm.

15. ***Eleotris andamensis*** Herre

1939. *Eleotris andamensis* Herre, *Rec. Ind. Mus.*, XLI, p. 344.

1941. *Eleotris andamensis*, Koumans, Gobioid Fishes of India, *Mem. Indian Mus.*, XIII, p. 312.

Distribution and Remarks : "Type, 50 mm. long, and 2 paratypes, 43 and 49 mm. long. They were taken from a stream near Machligaon, Port Blair. 7 paratypes, 25 to 43 mm. Long, were caught in a freshwater stream north of the wireless station, Port Blair." Herre (1939). Endemic to Andamans.

Habitat : Known only from its collection from freshwaters.

Size : Attains a length of 50 mm. standard length.

16. ***Ophiocara aporos*** (Bleeker)

1854. *Eleotris aporos* Bleeker, *Nat. Tijds. Ned. Ind.* VI, p. 59.

1941. *Ophiocara aporos*, Koumans, Gobioid Fishes of India, *Mem. Indian Mus.*, XIII, p. 323.

Distribution and Remarks : India to the Pacific.

"Common in the Andamans. From Port Blair are 6 specimens, 41 to 60 mm. in length, taken from a freshwater stream near Machchi Line, and 2 of 28 and 34 mm., caught near bridge over a freshwater stream at Beadonabad... " Herre (1939).

Habitat : Inhabits estuaries and freshwaters.

Size : 245 mm.

17. ***Ophiocara porocephala*** (Cuv. and Val.)

1837. *Eleotris porocephala* Cuvier & Valenciennes, *Hist. Nat. Poiss.*, XII, p.237.

1941. *Ophiocara porocephala*, Koumans, Gobioid Fishes of India, *Mem. Indian Mus.*, XIII, p. 322-323.

Distribution and Remarks : From India to the Pacific.

"4 Specimens from 44 to 67 mm. in length were obtained from freshwater pools near South Corbyn's Cove, Port Blair" Herre (1939).

Habitat : Inhabits estuaries and freshwaters.

Size : 320 mm.

Family GERREIDAE

18. ***Gerres kapas*** Bleeker

1851. *Gerres kapas* Bleeker, *Nat. Tijds. Ned. Ind.* II. P. 482.

1931. *Gerres kapas*, Weber and de Beaufort, *Fishes Indo-Austr. Arch.* VI, p. 348.

Distribution and Remarks : Indo-West Pacific.

"A juvenile specimen, 21 mm. long was taken from a freshwater pool near South Corbyn's Cove, Port Blair" Herre (1939).

Habitat : Inhabits coastal waters, enters brackish and freshwaters.

Family KUHLIDAE

19. ***Kuhlia marginata*** (Cuvier and Valenciennes)

1829. *Dules marginatus* Cuvier and Valenciennes, *Hist. Nat. Poiss.* III, p.116, pl. lii.

1829. *Kuhlia marginata,* Weber and de Beaufort, *Fishes Indo-Austr. Arch.* VI, p. 271, fig. 72.

Distribution and Remarks : Indo-West Pacific.

"A specimen, 31 mm. was caught in a freshwater stream south of South Corbyn's Cove, Port Blair" Herre (1939).

Habitat : On coral reefs, in estuaries and freshwaters.

Size : About 40 cm.

20. ***Kuhlia mugil*** (Forster)

1801. *Sciaena mugil* Forster (in Bloch & Schneider), Systema Ichthyol : 541.

1829. *Dules taeniurus* Cuvier and Valenciennes, *Hist. Nat. Poiss.* III, p. 114.

1984. *Kuhlia mugil,* Talwar and Kacker, *Commercial Sea Fishes of India,* Edited by the Director, Zoological Survey of India : p. 411.

Distribution and Remarks : Indo-Pacific.

"A very young example, 16 mm. long was taken in a freshwater stream south of South Corbyn's Cove, Port Blair" Herre (1939).

Habitat : On coral reefs, in estuaries and freshwaters.

Size : Attains 20 cm.

Family SCATOPHAGIDAE

21. ***Scatophagus argus*** (Linnaeus)

1766. *Chaetodon argus* Linnaeus, *Systema Naturae* (ed. 12), i : 464.

1991. *Scatophagus argus,* Talwar & Jhingran, *Inland Fishes of India and Adjacent Countries,* Vol.2, p.875-876. Oxford & IBH Publishing Co. Pvt. Ltd.

Distribution and Remarks : India, Sri Lanka, through the East Indies, to Australia, the New Hebrides and Solomon Islands.

"A fine example, 108 mm. long, from North Bay, Port Blair; one 21 mm. from a stream at Flat Bay, South Andamanm and 2 very young specimens, 8 and 9 mm. long, from Viper Island, Port Blair" Herre (1939).

Habitat : Inhabits natural embayments, estuaries and the lower reaches of freshwater rivers.

Size : 30.0 cm in length.

Family POMACENTRIDAE

22. ***Abudefduf bonang*** (Bleeker)

1853. *Glyphisodon bonang* Bleeker, *Nat. Tijds. Ned. Ind.* II. P. 522.

1928. *Abudefduf oning,* Fowler and Bean, *Bull. 100, U.S. Nat. Mus.* VII, p.170.

Distribution and Remarks : Indo-West Pacific.

"A juvenile, a distinctively marked specimen 10 mm. long, from a freshwater stream, Middle Andaman" Herre (1939).

Distribution elsewhere :

Habitat : Found in shallow rocky and reef areas, entering estuaries and freshwaters.

Size : About 20.0 cm in length.

Subordr CHANNOIDEI

Family CHANNIDAE

23. ***Channa orientalis*** Hamilton*

1801. *Channa orientalis* Bloch and Schneider, *Syst. Ichth.* P. 496, Pl.90, fig. 2

1822. *Ophicephalus gachua* Hamilton, *Fishes Ganges,* p. 68, 367, pl. 90, fig. 2.

1999. *Channa orientalis,* Menon, Check list-Freshwater Fishes of India, *Rec. Zool. Surv. India, Occ. Paper No.* **175** : 274-276. (Published–Director, ZSI).

Distribution and Remarks : Iran. Afghanistan. Pakistan. India. Nepal. Sri Lanks. Bangladesh. Myanmar. Thailand. Yunan. Malaya. Malay-Archipelago. Hainan and Taiwan.

"Four specimens, 57 to 120 mm, in length, were taken from stagnant pools in the bed of a stream, North Andaman, and one of 69 mm. was from Dhanikhari stream, South Andaman" Herre (1939).

Habitat : Freshwater streams and ponds of plains to those in very high elevations; also tolerant of poorly oxygenated stagnant dirty ponds.

Size : 33.0 cm Tl., usually 16 cm.

SPECIES VISITING FRESHWATER

(From the List of species from Andaman Islands reported by Herre (1941)

Order ELOPIFORMES

Family ELOPIDAE

1. *Elops machnata* (Forsskal)

Family MEGALOPIDAE

2. *Megalops cyprinoides* (Broussonet)

Order ANGUILLIFORMES

Family ANGUILLIDAE

3. *Anguilla bengalensis* Gray

Order SILURIFORMES

Family ARIIDAE

4. *Arius thalassinus* (Ruppell)
5. *Ketengus typus* Bleeker

Family PLOTOSIDAE

6. *Plotosus canius* Hamilton

Order MUGILIFORMES

Family MUGILIDAE

7. *Liza macrolepis* (Smith)
8. *Liza tade* (Forsskal)
9. *Liza vaigiensis* (Quoy & Gaimard)
10. *Valamugil seheli* (Forsskal)

Order BELONIFORMES

Family HEMIRAMPHIDAE

11. *Zenarchopterus buffonis* (Cuvier & Valenciennes)

Family BELONIDAE

12. *Strongylura strongylura* van Hasselt

Order PERCIFORMES

Family CENTROPOMIDAE

13. *Lates calcarifer* (Bloch)

Family CHANDIDAE

14. *Ambassis commersoni* Cuvier
15. *Ambassis gymnocephalus* (Lacepede)
16. *Ambassis nalua* (Hamilton)

Family SILLAGINIDAE

17. *Sillago sihama* (Forsskal)

Family CARANGIDAE

18. *Caranx sexfasciatus* Quoy & Gaimard

Family LEIOGNATHIDAE

19. *Leiognathus equulus* (Forsskal)
20. *Leiognathus splendus* (Cuvier)

Family LUTJANIDAE

21. *Lutjanus johni* (Bloch)

Family HAEMULIDAE

22. *Pomadasys argyreus* (Cuvier & Valenciennes)

Family POLYNEMIDAE

23, *Eleutheronema tetradactylum* (Shaw)

Family TERAPONTIDAE

24. *Terapon jarbua* (Forsskal)

Family TOXOTIDAE

25. *Toxotes jaculator* (Pallas)

Family DREPANIDAE

26. *Drepane punctatus* (Linnaeus)

Family SCATOPHAGIDAE

27. *Scatophagus argus* (Linnaeus)

Subfamily GOBIOIDEA

Family ELEOTRIDAE

28. *Eleotris lutea* Day
29. *Butis butis* (Hamilton)

Family GOBIIDAE

30. *Bathygobius fuscus* (Ruppell)
31. *Glossogobius biocellatus* (Valenciennes)
32. *Glossogius giuris* (Hamilton)
33. *Psudapocryptes lanceloatus* (Bloch & Schneider)
34. *Boleophthalmus boddarti* (Pallas)
35. *Periophthalmodon schlosseri*(Pallas)

Family GOBIOIDIDAE

36. *Taenioides anguillaris* (Linnaeus)
37. *Taenioides cirratus* (Blyth)
38. *Odontamblyopus rubicundus* (Hamilton)

Order TETRAODONTIFORMES

Family TETRAODONTIDAE

39. *Chelonodon patoca* (Hamilton)

DISCUSSION

From available literature on fishes of Andamans including freshwater species, especially by Herre (1959), it has been observed that of the 112 fish species reported from the Andaman Islands, 23 fish species had been collected from freshwater streams. Of these only 8 are primary freshwater fishes. Others are secondary freshwater species encountered in freshwater habitats by Herre (op.cit.).

Further 39 other species known to visit freshwaters from among the species reported by Herre (1941) have been appended at the end of the paper. Though the number of primary freshwater species are few there are 2 species endemic to Andaman waters viz. the syngnathid *Microphis insularis* (Hora) and the eleotrid *Eleotris andamanensis* Hora. Further the hill stream gobiid species *Sicyopterus garra* Hora, described from Andaman and currently synonymised with *Sicyopterus microcephalus* Bleeker could turn out to be another interesting taxon. This is replaced in mainland India (western ghats :South Canara to Trivandrum) and Sri Lanka by *Sicyopterus griseus* (Day). Molecular studies could throw more light on the exact identity of *S. garra* described from Andamans.

Day (1875-78) while examining specimens from Andamans remarked on the larger size of the insular species when compared to the mainland forms. This phenomena has been observed in other groups of organisms also.

Recently some freshwater collections made from Andaman by Vijay Kumar Palavai, SRF of Pondicherry University were examined for identification and about 12 species were identified, which constituted mostly of gobioids and eleotrids. Of these an interesting naked goby was seen belonging to the genus *Schismatogobius*. From the Indian region this genus is represented by a single species viz. *Schismatogobius deraniyagalai* Kottelat & Pethiyagoda described from the We River (Kelani basin) of Sri lanka (Pethiyagoda, 1991). Recently this species has been reported from southern western ghats of India. The species collected form the freshwaters of Andamans needs further study.

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Chapter 29

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 337-342, 2010

DIVERSITY OF BUTTERFLYFISHES (*CHAETODONTIDAE*) OF ANDAMAN AND NICOBAR ISLANDS : INDICATORS IN CORAL REEF HABITAT MONITORING AND MANAGEMENT

P.T. RAJAN*

Zoological Survey of India, Andaman and Nicobar Islands, Port Blair-744 102

INTRODUCTION

The Andaman and Nicobar Islands fall in the Indo-Pacific realm – the world's richest region of marine biodiversity perspective. Andaman and Nicobar Islands have unique ecological systems mainly contributed by coral reefs (as spawning and feeding grounds), seagrass beds (as nursery grounds) and mangroves (as shelter and feeding grounds) for many species of commercially important finfish and shellfish. There are 572 islands, islets, rocky out crops which extend between 92nd and 94th meridians of East latitude and 6th and 14th parallels of North latitude *i.e.*, these islands form part of a long, irregular chain that seems to continue from the Eastern Himalaya ranges through Myanmar's Arakan Yoma Southwards in an arch over 1100 km in the sea into Sumatra. The total coast line of Andaman and Nicobar Islands is 1962 km.

The butterfly fishes under the family Chaetodontidae are one of the most conspicuous elements of the coral reef community. The butterflyfishes are very closely related to angelfishes in their colour pattern. The butterflyfishes gets its name because of its comb shaped teeth. They are brightly coloured. Burgess (1978) estimated 114 species in 10 genera with *Chaetodon* (90 species), Kuiter (2002) updated to 125 species distributed worldwide in tropical and temperate coral reef habitats. Butterfly species richness is greatest in the central Indo-Pacific region. At least 40 species are known from the Great Barrier Reef (Steene, 1977), and perhaps high numbers may occur somewhat further to the north and west. Fourteen species are recorded from the Red Sea. Eastward across the equatorial Pacific numbers drop gradually to 28 in the Society Islands, 14 in the Marquesas (Randall, 1983), Tropical Eastern Pacific only 3-4 species have been reported (Burgess, 1978; Thomson *et al.*, 1979). In addition, Caribbean 5-6 species are known (Randall, 1968). The recorded species have exclusive ornamental value and are not considered as food fishes. Coastal waters are highly structured, covering a large variety of different bottom types that are inhabited by a diverse assemblage of organisms. Many of these habitats are still insufficiently known and require continued effort to sample, describe and register all species. However, due to increasing signs of human induced local and global impacts (Cohen *et al.*, 1997; Gommes *et al.*, 1998; Phillippart, 2007), there is also a pressing need to study further coastal organisms to understand their ecological role and function and to evaluate their potential use as indicators and/or key species for coastal ecosystem monitoring and management.

Indicators are here defined as a subset of organisms that strongly and transparently respond

*E-mail : rajanptandaman@rediffmail.com

to distinct natural or human-induced factors or changes. 'Strongly and transparently' shall signify that observed responses should be directly related to distinct factors, relatively easy to measure and, hence, cost- and time-effective. The measuring of such responses can be based on occurrence and distribution patterns, local abundance, weight, size, behaviour or physiology (Nicholls, 2002). Indicators should be relatively abundant and widespread, easy to sample and tolerant to a wide variety of environmental conditions. Key species interact tightly with an entire assemblage and are able to modify it directly or indirectly. Some key species act as 'ecosystem engineers', as they physically change the environment, either by themselves or by manipulating distinct habitat features. Due to their interactive role, key species provide important information on ecosystem processes and, hence, can also be used as indicators of ecosystem integrity and state. Most parsimonious, time- and cost-effective ecosystem monitoring and management may be achieved by using groups of easily accessible and widely distributed species that to some extent combine the features of indicator and key species (Nicholls 2002). Because these species will allow essential information to be obtained about distinct habitat features as well as about an overall assemblage within a certain area, they would be 'ecosystem indicators' in a very integrative way. This study highlights the butterfly fish, family Chaetodontidae, as a group of mainly coral reef organisms that have a high value for ecosystem monitoring and management, but also require intensified systematic and ecological research. This study investigates if butterfly fishes qualify as coastal habitat indicators and if they may also play a role as key species in coastal assemblages. Gaps in the knowledge in butterfly fish ecology and basic systematics are pointed out to stimulate further research. In the last few years, considerable research on coral reef fishes has been carried out to examine the effects of both naturally varying factors and human induced modifications on habitat utilization at different scales and the use of Butterfly fishes as habitat. Today several species of butterfly fishes are used by conservation Zoologists as indicator species to identify habitat that are critical and need to protected. Butterfly fishes are also monitored to indicate climate change and environmental degradation. Thus, like other animals and birds, butterfly fishes are now studied as living ecological mechanism.

MATERIALS AND METHODS

Almost all the finding detailed in this paper involves direct observation of butterfly fishes on the coral reefs of Andaman and Nicobar Islands, locations mentioned in (Table 1) from 1998-2008. The underwater survey was made using scuba, at the depth between 4-20 m. Fortunately, butterfly fishes are diurnal so all work is done during daylight hours at different places of Andaman and Nicobar Islands. Since reef fishes don't behave under conditions of high turbulence and surge and poor visibility, most work is done under favourable weather conditions. At study site four 100m transects were placed in a parallel pattern. To minimize diver's impact each fish census commenced 10 minute after the tape had been laid out. Since the study was focus on living corals and coral feeding butterfly fishes, transects are established in areas of high coral cover. The next step is to count the numbers of each species of butterfly fishes within 10m of either side of the transect lines, English *et al.* (1977). Abundance, distribution and diversity of fishes were calculated. Observation was also focused on fish species and the species of coral fed upon. Data were recorded on under water plastic sheet with a pencil. The species identification was made through the underwater plastics.

RESULTS AND DISCUSSION

Coral reefs are being highly degraded by many types of disturbances such as cyclones, earthquake, tsunami, outbreaks of crown- of-thorns starfish that can vary in their effect at small scales and further increase spatial variability in benthic habitats (Brown, 1997). The increasing prevalence of disturbances on coral reefs, such as coral bleaching (Hoegh-Guldberg, 1999), is leading to worldwide degradation of habitats for reef organisms. This degradation, when combined with naturally occurring habitat variation at small scales (Done, 1982), is likely to affect fishes with close links to their habitat, especially fishes with obligate coral feeding requirements, such as butterflyfishes (Hourigan *et al.*, 1988). The distribution patterns of butterflyfishes are often closely related to the distribution of their particular prey resources, (Birkeland and Neudecker, 1981; Carpenter *et al.*,

Table 1. Occurrence of Butterflyfishes and mean number of individuals at Islands studied.

Species	North Reef	Rani Jhansi Marine National Park	Mahatma Gandhi Marine National Park	Great Nicobar	Nancowry Island	Cinque Island	Little Andaman
Chaetodon auriga	+, 4.5	+, 5.5	+, 3.2	+, 4.3	+, 2.5	+, 4.2	+, 3.1
Chaetodon bennetti	–			+, 0.4			
Chaetodon citrinellus				+, 0.2			
Chaetodon collare	+, 2.2	+, 4	+, 1.2	+, 1.9	+, 4.0	+, 3.5	
Chaetodon decussatus	+, 2.7	+, 3.0	+, 0.4		+, 2.8		
Chaetodon ephippium	+, 2.0	+, 0.4		+, 1.2		+, 0.8	
Chaetodon falcula	+, 3.2	+, 4.7	+, 2.8	+, 3.0	+, 5.0	+, 3.25	+. 2.0
Chaetodon guttatissimus	+, 4.5	+, 3.2	+, 4.6		+, 2.1	–	–
Chaetodon kleinii	+, 2.6	+, 4.5	+, 3.2	+, 2.8	+, 2.6	+, 0.1	–
Chaetodon lineolatus				+, 0.8	–	+, 0.6	
Chaetodon lunula	+, 0.8	+, 1.5	+, 1.2	+, 1.1	+, 2.6	+, 0.8	+, 1.5
Chaetodon melannotus	+, 1.2		+, 0.6	+, 1.7	+, 2.2		
Chaetodon meyeri	+, 1.0	+, 1.5	+, 1.2	+, 2.6	+, 0.9	+, 1.2	+, 3.0
Chaetodon ornatissimus	+, 0.9	+, 1.6	+, 2.1		+, 0.2		
Chaetodon octofasciatus	+, 0.5	+, 1.6				+, 0.7	
Chaetodon oxycephalus		–	+, 0.4			–	+, 1.8
Chaetodon plebeius	+, 2.3	+, 6.5	+, 4.8	+, 3.6	+, 3.5	+, 2.2	+, 3.7
Chaetodon rafflesi	+, 3.6	+, 2.4	+, 3.6		+, 2.6		
Chaetodon semeion					+,0.2		
Chaetodon triangulam	+, 6.7	+, 5.0	+, 4.5	+, 2.0	+, 3.0	+, 3.2	+, 2.6
Chaetodon trifascialis	+, 8.6	+, 6.0	+, 3.6	+, 4.0	+, 3.8	+, 4.6	+, 2.9
Chaetodon trifasciatus	+, 12.5	+, 7.5	+6.6	+, 4.1	+, 3.2	+, 5.6	+, 1.7
Chaetodon unimaculatus				+, 1.2	+, 0.8		
Chaetodon vagabundus	+, 3.2	+, 1.5	+, 0.2	+, 0.3	+, 1.1	+, 0.8	+, 0.6
Chaetodon xanthurus	+, 0.7						+, 0.2
Chelmon rostratus	+, 0.8				-		
Forcipiger flavissimus	+, 0.2	+, 0.8	+, 0.1	+, 0.6	+1.3	+, 1.0	+, 1.5
Forcipiger longirostris	+, 0.9	+, 0.2	+, 1.2		+, 2.6		
Hemitaurichthys zoster			+, 0.6			+, 0.5	
Heniochus acuminatus	+, 2.6	+, 3.1	+, 1.2	+, 2.2	+, 0.8	+, 0.2	+, 0.7
Heniochus chrysostomus			+, 0.2			+, 1.1	
Heniochus diphreutes	+, 1.6			+, 2.6			+, 1.8
Heniochus monoceros	+, 0.6	+, 0.2		+, 0.1			
Heniochus pleurotaenia	+, 1.2	+, 1.6	+, 0.8				
Heniochus singularis	+, 1.8			+, 0.7		+, 2.3	
Total Number of species	**27**	**22**	**23**	**22**	**20**	**19**	**14**

1981). For coral-feeding fishes, the composition and quantity of prey resources varies greatly across a range of different spatial and temporal scales. It has been well documented that butterflyfish abundances often vary in accordance with coral cover and often decline following extensive coral depletion, even the notion that this family may be useful as an indicator of environmental quality on coral reefs (Crosby and Reese, 1996). Degradation of coral resources may also lead to sublethal stresses in butterflyfishes (Pratchett *et al.*, 2004). Butterflyfish occur mainly in coral reef habitats, mostly close to or near the bottom of the littoral are most frequently found on coral reefs. They are territorial and daily short-distance movements within and among foraging and resting sites in the reef areas. Butterflyfish species are relevant to fisheries in many areas worldwide and several species have high economic importance for aquarium trade. There is least fishing pressure in Andaman and Nicobar Islands as regarding exploitation of butterflyfish is concerned, only small collection are made by the Department of Fisheries and Navy for their aquarium use. Human-made constructions, such as artificial reefs, may lead to increased visits by butterflyfishes of the respective area and enhance abundance in the immediate surroundings. (Golani and Diamant, 1999). This change in distribution and abundance has happened during a phase with temperature increase due to global climate change and habitat degradation due to earth quake-tsunami of December 2004, mainly observed in some of the islands of Nicobar group of Islands. The immigration of butterflyfishes into nearby healthy reef areas was observed in Nancowry group of Islands. Butterflyfishes have very active foraging behaviour. These and additional characteristics of their resource use may render butterflyfishes essential components of food webs in coral reef ecosystems. Currently, 35 species of butterflyfishes are reported, the most diverse being *Chaetodon*, which consists of 25 species (Plate 23, 24 & 25). Some species have a rather restricted occurrence, such as *Chaetodon plebeius, C. triangulam*, which are restricted to Eastern Indian Ocean. With future revisions, more detailed systematic information can be obtained and from further explorations of remote islands, new discoveries of butterfly fish species can be expected. All descriptions of butterfly fish species so far have been based exclusively on morphological data. Even among populations from neighbouring or close-by habitats considerable morphological variation exists. Butterflyfishes may be more speciose in the Indo-West Pacific because they have suffered fewer extinctions there, because of greater area effect with increased habitat diversity and opportunity for speciation or because of diversity and density of resources available to them is greater. Out of the Islands studied the reefs of the North Reef Island, where the effects of siltation are minimal, corals are healthy, similarly the butterflyfishes is well represented with 27 species (Table 1) and the obligate coral feeder *C. trifasciatus* is abundant. In Andaman and Nicobar former species is the most abundant shallow water chaetodontid, occurring at all stations in good numbers. They are usually observed in pairs picking at scleractinians. Each pair appears to forage within a limited area. The study areas of the fringing reefs in North Reef, Rani Jhansi Marine National Park, Mahatma Ghandhi Marine National Park, Great Nicobar in Andaman and Nicobar Islands seems to be the richest in terms of suitable habitats for butterflyfishes. Here the amount of healthy, living sceractinian coral and other reef invertebrates was high and other habitats and sources of food were readily available. At Nancowry Island, the calm sheltered bays, rich in soft corals, containing only 19 species, *C. ornatissimus* and *C. unimaculatus* were seen only on the outer reef. At some of the islands in Nancowry group namely Camorta, Terrasa, Chowra due to submergence of coastal areas after the earthquake and Tsunami silt filling up the holes and crevices of the reef which under normal conditions provide shelter for benthic invertebrates. A large set of species included members that occurred at most islands sampled, including *C. auriga, C. falcula, C. lunula, C. meyeri, C. plebeius, C. vagabundus, F. flavissimus, H. acuminatus* were most common in sheltered sites with fair amounts of soft coral and *C. trifasciatus* was most common where hard corals were best developed.

CONCLUSION

Many gaps in our knowledge still exist regarding the ecology and systematics of butterfly fishes. However, the currently available data suggest that butterflyfishes may indeed be suitable habitat indicators and may also qualify as key species in coral reef ecosystems. Because of considerable inter- and intraspecific variations in habitat preferences, food selection, behaviour, and body structure, special attention should be paid to treat species, populations, and size classes separately from each other. Because not all butterfly fish species are equally well known and even some new ones may be encountered, exploration, monitoring, and management focusing on this group should be co-ordinated worldwide, thus enhancing information exchange and initiating joint research efforts in butterflyfish ecology and systematics. At the same time, this study may also serve as a model for screening other organisms for their potential as ecosystem indicators. Obligate corallivorous butterflyfishes (Chaetodontidae) have been suggested as indicators of the health of coral reefs. There has been a call to relate specific changes in butterflyfish ecology and behaviour to identified stress. For the first time it is reported here that there is a breakdown of the normal rigid territorial butterflyfish behaviour at the onset of an intense, large-scale coral degradation event in the Andaman and Nicobar Islands due to climate change also by earthquake and tsunami of December, 2004. The three main species, *Chaetodon trifascialis, C. triangulam* and *C. trifasciatus*, fed almost exclusively on *Acropora* spp. These species of coral are among the first to die during stress, due to climate change. It is speculated that the early excursion behavioural response by these butterflyfishes is because their prime food resource is the first to perish. It is recommended that baseline data be gathered on corallivorous butterflyfish territory size and rate of excursion on healthy, unstressed reefs. Deviation from these baseline results, along with early bleaching corals such as *Montipora* spp. and branching *Acropora* spp., is highly likely to indicate the coming of a bleaching event. Once suitable indicator species are identified, the monitoring programme is inexpensive and easily learned by non-specialists. Thus it is useful in our area where funds for conservation and management are scarce.

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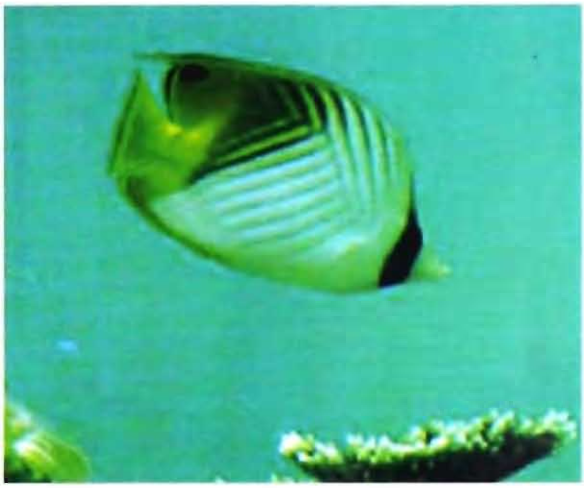
Plate 23

Succession in Coral Reef : Soft Corals grows over hard corals, after earthquake and Tsunami in Nancowry Island. February 2008

Triangle butterflyfish *Chaetodon triangulum*



Threadfin butterfly fish *Chaetodon auriga*

Indian vagabond butterflyfish *Chaetodon decussatus*

Vagabond butterfly fish *Chaetodon vagabundus*

Plate 24

Meyer's butterfly fish *Chaetodon meyeri*

Blue spot butterflyfish *Chaetodon plebeius*

Plate Coral under stress due to Climate Change, Grub Island, March 2008

Latticed butterfly fish *Chaetodon rafflesi*

Long nose butterfly fish *Forcipiger flavissimus*

Plate 25

Black backed butterfly fish *Chaetodon melannotus*

Long fin banner fish *Heniochus acuminatus*

Big long-nose butterfly fish *Forcipiger longirostris*

Chapter 30

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 343-359, 2010

DIVERSITY OF PERCH RESOURCES IN ANDAMAN AND NICOBAR WATERS

A. ANROSE, M.K. SINHA, A.B. KAR and S.K. PATTNAYAK
Fishery Survey of India, Port Blair, Andaman and Nicobar Islands

INTRODUCTION

Perch like fishes are represented by more than 20 Families as far as Indian waters are concerned. Commercially important ones come under the Family *Serranidae, Lutjanidae, Lethrinidae, Nemipteridae, Priacanthidae, Sparidae, Acanthuridae* and *Siganidae*. The Perch and allied resources are highly valued for the quality of their flesh and most of the species fetch very high market prices. A large portion of the perch fisheries are caught in artisanal fisheries and even low level of artisanal fisheries can adversely affect the stocks. Few families of these fisheries have importance of recreational or sport fishery. Secondly, the live fish trade of these fishes has expended rapidly in recent years and now targets many species. Among the perches, Groupers are the most intensively exploited group in live fish trade and high prices paid by the exporters to the traditional fishermen implies the demand of these fishes in Southeast Asian region. Among the Groupers, few species are also cultured in many Southeast Asian countries. The capture based aquaculture of these Perch species also represents an alternative livelihood for the coastal poor communities and can have significance in improving their livelihood. As the marine capture fisheries sector plays a significant role in the food and nutritional security, economy, employment generation and export trade, it is important to develop this sector by exploiting the vast potential with a clear knowledge of its present potential and rich biodiversity in the Island waters.

Due to the above cited scientific and economical advantages, the perch resources have gained high importance very recently in India. The advantage of coral reef ecosystem which is the best suited habitat for these perch fisheries can be an added advantage in development of Perch fisheries as a whole. Keeping in view of the consumer preference, high market value and the requirement of local fishers and traders, it is essential to have clear cut knowledge about their biodiversity. This paper aimed to exaggerate a new concept of distribution and abundance of perch and allied resources by focusing on their biodiversity.

BOTTOM TOPOGRAPHY OF ANDAMAN SEA

This Island territory from its highest peak to the deepest depth possesses a unique and sensitive ecosystem. It possesses different geological, topographic, oceanographical features. Being a volcanic island it is endowed with a shallow continental shelf of about 35000 km^2. The shelf topography of the islands is highly irregular. The upper surface of the shelf is marked by frequent rises supporting coral reefs and depressions known as passages and straits. The archipelago of geographical area 8249 km^2 is surrounded by the coral reefs; rocky areas, mangrove swamps. A deep oceanic trench above 1000 fathoms deep runs between the Nicobar and Sumatra and extends upto Norcondam Island. The continental shelf which runs upto 100 fathoms depth is very narrow, only 2 25 miles in width, broader on the western side and becomes very deep there after the deepest known depth is 4198 m east of car Nicobar Island. The shores are rocky with fringing coral reefs with a few sandy beaches. The sea bed too is rocky with coral growths. Muddy grounds are limited and are found only in protected bays and creeks. The Little Andaman and Nicobar Islands except Great Nicobar lying on the south are flat, sandy islands, probably of most recent origin, formed by coral formations. The sea water is less saline on the east coast than in the west which for this reason has more coral reefs. Ocean currents sweep the sea floor and upwell on the east coast thus bringing rich nutrients and it makes the water more potential.

SPECIES INVENTORY OF PERCH AND ALLIED RESOURCES IN ANDAMAN AND NICOBAR WATERS

The species composition of Perch resources recorded from the Andaman and Nicobar waters and the commercially important species reported till Dec 2007 are summarized in Table 1.

Table 1. Details on the species richness of the Perciformes fishes in the Andaman and Nicobar waters

Family	No. of Genera	No. of Species	per cent of total species richness
Ambassidae	1	8	2.92
Carangidae	13	44	16.06
Caesionidae	4	14	5.11
Gerridae	3	9	3.29
Kuhlidae	1	2	0.73
Leognathidae	3	16	5.83
Lethrinidae	5	23	8.39
Lutjanidae	9	43	15.69
Nemipteridae	3	30	10.96
Pomadasyidae	3	15	5.48
Serranidae	7	47	17.15
Sciaenidae	6	9	3.29
Sillaginidae	1	3	1.09
Teraponidae	2	4	1.45
Family representing single genera and single species	7	7	2.56
Total	**68**	**274**	**100**

Taxa	Remarks
Family AMBASSIDAE (Glass fishes)	
Ambassis buton Popta	Minor fishery importance. Used as poultry feed.
Ambassis buruensis Bleeker	
Ambassis commersoni Cuvier	
Ambassis dussumieri Cuvier	
Ambassis gymnocephalus (Lacepede)	
Ambassis interruptus Bleeker	
Ambassis kosii Bleeker	
Ambassis nalula (Hamilton-Buchnan)	
Ambassis urotaenia Bleeker	

Taxa	Remarks
Family SERRANIDAE (Groupers)	
Subfamily EPINEHELINAE	
Aethaloperca rogaa (Forsskal)	All the species are commercially important. Few species of *Epinephelus* and *Plectopomus* are exported in the form of frozen and live.
Anyperodon *leucogrammicus* (Valenciennes)	
Cephalopholis argus Bloch and Schneider	
Cephalopholis boenak (Bloch)	
Cephalopholis cyanostigma (Valenciennes)	
Cephalopholis formosa (Shaw and Nodder)	
Cephalopholis leopardus (Lacepede)	
Cephalopholis microprion (Bleeker)	
Cepalopholis miniata (Forsskal)	
Cepalopholis sonnerati (Valenciennes)	
Cepalopholis urodeta (Forsskal)	
Cromileptes altivelis (Valenciennes)	
Epinephelus areolatus (Forsskal)	
Epinephelus bleekeri (Vaillant)	
Epinephelus caeruleopunctatus (Bloch)	
Epinephelus chlorostigma (Valenciennes)	
Epinephelus coioides (Hamilton)	
Epinephelus corallicola (Valenciennes)	
Epinephelus erythrurus (Valenciennes)	
Epinephelus fasciatus (Forsskal)	
Epinephelus faveatus (Valenciennes)	
Epinephelus flavocaeruleus (Lacepede)	
Epinephelus fuscoguttatus (Forsskal)	
Epinephelus hexagonatus (Schneider)	
Epinephelus lanceolatus (Bloch)	
Epinephelus longispinis (Kner)	
Epinephelus macrospilos (Bleeker)	
Epinephelus malabaricus (Bloch and Schneider)	
Epinephelus megachir (Richardson)	
Epinephelus melanostigma Schultz	
Epinephelus merra Bloch	
Epinephelus miliaris (Valenciennes)	
Epinephelus ongus (Bloch)	
Epinephelus polyphekadion (Bleeker)	
Epinephelus polystigma (Bleeker)	
Epinephelus quoyanus (Valenciennes)	
Epinephelus radiatus (Day)	
Epinephelus sexfasciatus (Valenciennes)	
Epinephelus spilotoceps Schultz	
Epinephelus tauvina (Forsskal)	
Epinephelus undulosus (Quoy and Gaimard)	
Plectopomus areolatus (Ruppell)	
Plectopomus laevis (Lacepede)	

Taxa	Remarks
Plectopomus maculatus (Bloch)	
Plectropomus pessuliferus (Fowler)	
Variola albimarginata Baissac	
Variola louti (Forsskal)	
Family CARANGIDAE (Kingfishes)	
Alectis ciliaris (Blocks)	All species are commercially important.
Alectis indicus (Ruppell)	
Alepes melanoptera (Swainson)	
Alepes djedaba (Forsskal)	
Alepes kleinni (Bloch)	
Alepes para (Cuvier)	
Alepes vari (Cuvier)	
Atule mate (Cuvier)	
Carangoides armatus (Ruppell)	
Carangoides chrysophrys (Cuvier)	
Carangoides caeruleopinnatus (Ruppell)	
Carangoides dinema Bleeker	
Carangoides fulvoguttattus (Forssakal)	
Carangoides gymnostethus (Cuvier)	
Carangoides hedlandensis (whitleg)	
Carangoids humerosus (MeCulloch)	
Carangoids malabaricus (Bloch and Schmeider)	
Carangoids oblongus (cuvier)	
Carangoids *plagiotaenia* Bleeker	
Carangoids talamparoides Bleeker	
Carangoids *uii* celakiya	
Caranx carangus Bloch	
Caranx ignobilis (Forsskal)	
Caranx melampygus Cuvier	
Caranx para Cuvier	
Caranx sexfasciatus Quoy and Gaimard	
Carnax tille (Cuvier)	
Decapterus macrosoma Bleeker	
Decapterus maruadsi (Temmnick and Schlegel)	
Decapterus russelli (Ruppell)	
Elagatis bipinnulata (Quoy and Gaimard)	
Gnathanodon speciosus (Forsskal)	
Megalaspis cordyla (Linnaeus)	
Scomberoides commersonianus Lacepede	
Scomboeroides lysan (Forsskal)	
Scomberoides tala (Cuvier)	
Scomberoides tol (Cuvier)	
Selar boops (Cuvier)	
Selar crumenophthalmus (Bloch)	
Selariode leptolepis (Cuvier)	

Taxa	Remarks
Seriolina nigrofasciata (Ruppell)	
Seriolina rivolina Valenciennes	
Trachinotus baillonii (Lacepede)	
Trachinotus blochii (Lacepede)	
Family LUTJANIDAE (Snappers)	
Aphareus furcatus (Lacepede)	All species are commercially important.
Aphareus rutilans Cuvier	
Aprion virescens Valenciennes	
Etelis carbunculus Cuvier	
Etelis coruscans Valenciennes	
Etelis radiosus Anderson	
Lipocheilus carnolabrum (Chan)	
Lutjanus argentimaculatus (Forsskal)	
Lutjanus bengalensis (Bloch)	
Lutjanus biguttatus (Valenciennes)	
Lutjanus bohar (Forsskal)	
Lutjanus boutton (Lacepede)	
Lutjanus carponotatus (Richardson)	
Lutjanus decussatus (Cuvier)	
Lutjanus ehrenbergii Peters	
Lutjanus erythropterus Bloch	
Lutjanus fulviflamma (Forsskal)	
Lutjanus fulvus (Schneider)	
Lutjanus gibbus (Forsskal)	
Lutjanus gulcheri Forurrnanoir	
Lutjanus johnii (Bloch)	
Lutjanus kasmira (Forsskal)	
Lutjanus lemniscatus (Valenciennes)	
Lutjanus lunulatus (Park)	
Lutjanus lutjanus Bloch	
Lutjanus madras (Valenliennes)	
Lutjanus malabaricus (Schneider)	
Lutjanus monostigma (Cuvier)	
Lutjanus quinquelineatus Bloch	
Lutjanus rivulatus (Cuvier)	
Lutjanus russelli (Bleeker)	
Lutjanus sanguineus (Cuvier)	
Lutjanus sebae (Cuvier)	
Lutjanus vitta (Quoy and Gaimard)	
Macolor niger (Forsskal)	
Paracaesio sordidus Abe and Shinohara	
Paracaesio xanthurus (Bleeker)	
Pinjalo pinjalo (Bleeker)	
Pinjalo lewisi Randall, Allen and Anderson	
Pristipomoides filamentosus (Valenciennes)	

Taxa	Remarks
Pristipomoides multidens (Day)	
Pristipomoides seiboldii (Bleeker)	
Pristipomoides typus Bleeker	
Pristipomoides zonatus (Valenciennes)	
Family NEMIPTERIDAE (Threadfin breams)	
Nemipterus bipunctatus (Ehrenberg)	*Nemipterus* species are commercially important. *Scolopsis* species are of minor value.
Nemipterus bleekeri (Day)	
Nemipterus hexodon (Cuvier and Gaimard)	
Nemipterus japonicus (Bloch)	
Nemipterus luteus (Schneider)	
Nemipterus metopias Bleeker	
Nemipterus mesoprion (Bleeker)	
Nemipterus nematophorus (Bleeker)	
Nemipterus nemurus (Bleeker)	
Nemipterus personii (Valenciennes)	
Nemipterus randalli Russell	
Nemipterus tolu (Valenciennes)	
Nemipterus zysron (Bleeker)	
Parascolopsis eriomma (Jordon and Richardson)	
Scolopsos auratus (Park)	
Scolopsos bilineatus (Bloch)	
Scolopsos cancellatus Valenciennes	
Scolopsos ciliatus (Lacepede)	
Scolopsos dubiosus Weber	
Scolopsos frenatus (Cuvier)	
Scolopsos ghanam (Forsskal)	
Scolopsos eeucotaenia(Bleeker)	
Scolopsos lieatus (Quoy and Gaimard)	
Scolopsos margaritifer (Valenciennes)	
Scolopsos monogramma (Cuvier)	
Scolopsos personatus (Cuvier)	
Scolopsos taeniopterus (Cuvier)	
Scolopsos trilineatus Kner	
Scolopsos vosmeri (Bloch)	
Scolopsos xenochrous Gunther	
Family POMADASYIDAE (Sweetlips)	
Diagramma pictum (Thumb erg)	All species are commercially important
Plectorhinchus albovittatus (Ruppell)	
Plectorhinchus chaetodonoides Lacepede	
Plectorhinchus chubbi (Regan)	
Plectorhinchus diagrammus (Linnaeus)	
Plectorhinchus flavomaculatus (Ehrenberg)	
Plectorhinchus gaterinoides (Forsskal)	
Plectorhinchus gibbosus (Lacepede)	
Plectorhinchus orientalis (Bloch)	

Taxa	Remarks
Plectorhinchus rayi (Menon and Talwar)	
Plectorhinchus schotaf(Forsskal)	
Pomadasys argyreus (Valenciennes)	
Pomadasys furcatum (Bloch and Schneider)	
Pomadasys kaakam (Cuvier)	
Pomadasys maculatum (Bloch)	
Family LETHRINIDAE (Emperors)	
Gnathodentex aurolineatus (Lacepede)	All species are commercially important
Gymnocranius elongatus Senta	
Gymnocranius griseus (Schlegel)	
Gymnocranius grandoculis (V alnciennes)	
Lethrinus amboinensis Bleeker	
Lethrinus barbonicus' Valenciennes	
Lethrinus conchyliatus (Smith)	
Lethrinus erythracanthus Valenciennes	
Lethrinus erythropterus Valenciennes	
Lethrinus harak (Forsskal)	
Lethrinus lentjan (Lacepede)	
Lethrinus mahsena (Forsskal)	
Lethrinus microdon Valenciennes	
Lethrinus nebulosus (Forsskal)	
Lethrinus obsoletus (Forsskal)	
Lethrinus olivaceus Valenciennes	
Lethrinus ornatus Valenciennes	
Lethrinus rubrioperculatus Sato	
Lethrinus variegatus Ehrenberg	
Lethrinus xanthochilus Klunzinger	
Lethrinus elongatus	
Monotaxis grandoculis (Forsskal)	
Wattasia mosambica (Smith)	
Family CAESIONIDAE (Fusiliers)	
Caesio caerulaurea Lacepede #	# Few species are Commercially important.
Caesio cuning (Bloch) #	
Caesio lunaris Cuvier #	
Caesio teres Seale #	
Caesio varilineata Carpenter	
Caesio xanthonota Bleeker #	
Dipterygonotus balteatus (Valenciennes)	
Gymnocaesio gymnoptera (Bleeker)	
Pterocaesio chrysozona (Cuvier) #	
Pterocaesio marri Schultz	
Pterocaesio pisang (Bleeker)	
Pterocaesio randalli Carpenter	
Pterocaesio tessellate Carpenter	
Pterocaesio tile (Cuvier) #	

Taxa	Remarks
Family SCIAENIDAE (Croakers)	
Dendrophysa russelli (Cuvier)	All species are commercially important.
Johnius amblycephalus (Bleeker)	
Johnius belangerii (Cuvier)	
Johnius carouna (Cuvier)	
Johnius macropterus (Bleeker)	
Johnieops dussumieri (Cuvier)	
Nibea soldado (Lacepede)	
Otolithes ruber (Schneider)	
Pennahia macrophthalmus (Bleeker)	
Family GERREIDAE (Silver biddies)	
Gerres abbreviatus Bleeker	All species are commercially important.
Gerres acinaces Bleeker	
Gerres filamentosus Cuvier	
Gerres lucidus Cuvier	
Gerres oblongus Cuvier	
Gerres oyena (Forsskal)	
Gerres poieti Cuvier	
Gerromorpha setifer Hamilton- Buchan	
Pentaprion longimanus (Cantor)	
Family LEIOGNATHIDAE (Ponyfishes)	
Gazza achlamys Jordan and Starks	All species are commercially important.
Gazza minuta (bloch)	
Leiognathus berbis (Valenciennes)	
Leiognathus blochii (Valenciennes)	
Leiognathus brevirostris (Valenciennes)	
Leiognathus daura (Cuvier)	
Leiognathus decorus (de Vis)	
Leiognathus dussumieri (Valenciennes)	
Leiognathus equulus (Forsskal)	
Leiognathus fasciatus (Lacepede)	
Leiognathus jonesi James	
Leiognathus leucisus (Gunther)	
Leiognathus lineolatus (Valenciennes)	
Leiognathus longispinis (Valenciennes)	
Leiognathus splendens (Cuvier)	
Macilentichthys indicus (Singh and Talwar)	
Family TERAPONIDAE (Grunters)	
Pelates quadrilineatus (Bloch)	All species are commercially important
Terapon jarbua (Forsskal)	
Terapon puta (cuvier)	
Terapon theraps (Cuvier)	

Taxa	Remarks
Family KUHLIIDAE (Flagtails)	
Kuhlia rupestris (Lacepede)	All species are commercially importan.
Kuhlia mugil (Schneider)	
Family SILLAGINIDAE (Whitings)	
Sillago (Parasillago) maculatus Jordan and Evermann	All species are commercially important.
Sillago (Sillaginopodys) cho Bleeker	
Sillago sihama (Forsskal)	
Family LACTARIIDAE (false travelies)	
Lactarius lactarius (Schneider)	Commercially important
Family RACHYCENTRIDAE	
Rachycentron canadus (Linnaeus)	Commercially important
Family CORYPHAENIDAE (Dolphin Fishes)	
Coryphaena hippurus Linnaeus	Commercially important
Family APOLECTIDAE (Black-Pomfrets)	
Parastromateus niger (Bloch)	Commercially important
Family MENIDAE (Moon Fishes)	
Mene maculata (Bloch and Schneider)	Minor value
Family LOBOTIDAE (Triples tails)	
Lobotes surinamensis (Bloch)	Commercially important
Family SPARIDAE (Seabreams)	
Acanthopargus berda (Forsskal)	Commercially important

Source : Zoological Survey of India, Port Blair

A total of 274 Perch species distributed among 21 families under 68 genera were recorded in the waters of Andaman and Nicobar Islands. Among them, the dominant species are 47 species of the family Serranidae, 44 species of the family Carangidae, 43 species of the family Lutjanidae, 30 species of the family Nemipteridae and 23 species of the family Lethrinidae. Details on the family, number of genera and number of species recorded are given above.

Eco-friendly fishing method

Perch being the dominant and one of the target fisheries in the Andaman and Nicobar Islands, suitable fishing methods for the harvest of Perches are essentially required. As such, hand lines, long lines and gill nets are operated to exploit these resources. It was suggested that the practice of multi hook bottom set vertical long line method can also be introduced in addition to the existing gears. It was also suggested to employ trap fishing as one of the eco-friendly fishing methods for the harvest of Perch resources.

MATERIALS AND METHODS

a. Fishing Craft

The vessel MFV Blue Marlin attached to Port Blair base of Fishery survey of India was engaged for the survey programme. The vessel is a Japanese aided Tuna long liner and has OAL of 35.76 m with 310 tons GRT. Its endurance period is 20days.

b. Bottom Set Vertical Long Lining (BSVLL) Gear and Methods of operation

The main line gear of tuna long line made up of 6.5mm dia tetron was used as mainline for the Bottom set vertical long lining (BSVLL). The length of each main line was 50m. The branch lines were made up of 4.5mm dia tetron material and each branch line of 15m length and one end of the branch line was provided with the snap clip which was used to connect the main line to branch line. The clip was attached to the loop of 20cm length. The other end of the loop was connected to a swivel which served to avoid kinks of line. The lower part of the branch line was provided with sinkers of 2.5 to 3.0

kg. made of cement concrete. After leaving about 5.5 m length of branch line on the upper portion, the rest of the line was provided with six numbers of nylon gut hook lines at 1.5 m interval. The one end of hook line was attached to the branch line and the other end was provided with perch hook No. 4. The total length of hook line was 0.75 metre. The distance between last hook line and the weight was about 1.5 metre. The PVC float of six inch dia was attached to the snap clip. The float and sinker were provided to keep the branch line in vertical position. The specifications are provided in Table 2.

While shooting the line for fishing firstly the Radio buoy was lowered into the water which was connected with a flag pole provided a polyfoam float in between the two so as to easily locate the radio buoy, in case the line is parted and the radio buoy fails to emit the signal. A line length of 25-50 m is connected to the flag pole and then the main line was connected to it. Each basket consists of five branch lines and every basket of line is provided with 300 mm PVC float which is connected to the float line. The float line length was adjusted depending upon the depth of operation. At the end of the shooting of the line, again it was provided with flag pole, polyfoam float and a radio buoy. Further two ends of the line was provided with a grapnel anchor to set the line horizontally as well as to avoid the drifting of the line. The average timing for shooting of 10 baskets is about 45 minutes. Similarly the hauling requires around an hour for 10 baskets depending upon the catch. One hour was provided as immersion time. Every day two sets with each set of 300 hooks were operated.

To the mustard No. 4 hook cut pieces, *Ambligaster sirm* locally known as Kapatharani and commonly known as spotted sardine and *Rastrelliger brachysoma*, locally known as Bhangdi commonly knows as Mackerel was used as bait. The length of the cut pieces was varying between 50–100 mm. The frozen bait was used through out the operation period.

The operation was carried out in a depth range of 30–150 m i.e., in the edges of the continental slope and within the territorial waters. Before shooting of the line efforts were oriented to find a suitable fishing ground by means of echo sounder which is generally used for observation of bottom topography and water depth. The above precautionary measure was taken to prevent the branch line and hooks to entangle with the bottom substrata as A and N waters are dominated with corals and coral reef grounds.

RESULTS

Abundance and seasonality of Perch resources

The area wise abundance and seasonal distribution of Perch resources in Andaman and Nicobar waters and the results reported during the survey operations of Bottom Set Vertical Long lining by the vessel M.V. Blue Marlin is given in table-9. The aggregate hooking rate of Perch resources and the hooking rate of individual groups registered in respect of *Serranids, Lutjanids, Lethrinids* and *Carangids* are furnished in the table 5 and Fig. 1 (a, b, c, d, e, f, g, h). The highest aggregate hooking rate of Perch and allied resources registered from Andaman waters was 2.92 per cent whereas it was 4.26 per cent from Nicobar waters. Similarly, while analyzing the data on group wise it was found that the hooking rate registered from Nicobar waters was more than the Andaman waters.

Table 2.

Main Line (Tetron)	6.5 mm dia	50m	06 pcs.
Branch Line (Tetron)	4.5 mm dia	15m	06 pcs.
Hook Line (Nylon gut)	2 mm dia	0.75m	06 pcs.
Hook (Perch)	No.4	—	06 nos.
Float Line (Tetron)	6.5 mm dia	50m	01 no.
Float 13 kg. Bugyancy	300 mm dia	—	01 no.
Branch Line Float	150mm dia	—	06 nos.
Sinker (Cement concrete block)	—	—	02 kg.

Species composition of perch resources

Species of perch resources recorded during the exploratory survey conducted by Fishery Survey of India, Port Blair Base mainly fall under the families Lutjanidae, Lethrinidae, and Serranidae. Among the families Lutjanidae, Species of genus *Lutjanus spp.* dominanted the catch followed by *Pristipomoides* spp. and *Aprion* spp. Among the family Lethrinidae species of the genus *Lethrinus* dominated the catch whereas from the genus *Gymnocranius* and *Wattasia* only one species each were recorded. Among the family Serranidae, species of the genus *Epinephelus spp.* dominated the catch followed by *Plectopomos* spp., *Cephalopholis* spp. and *Variola* spp. The percentage composition observed among the various genus are *Lutjanus* 26 per cent; *Aprion* 21 per cent; *Epinephelus* 17.63 per cent; *Lethrinus* 16.58 per cent, *Pristopomoids* 5.53 per cent; *Gymnocranius* 4.3 per cent; *Variola* 4.21 per cent; *Plectopomos* 2.5 per cent; *Cephalopholis* 1.84 per cent; and *Wattasia* 0.14 per cent. It is observed that among the families Lutjanidae dominates the groups followed by Serranidae and Lethrinidae.

Diversity

From the results of experimental survey it is seen that a total no. of 47 species belonging to 6 families were recorded. The Lutjanidae family consisted of 13 species belonging to 4 genera, Lethrinidae family contributed 10 species belonging to 3 genera, Serranidae family contributed 13 species belonging to 4 genera, Ephipidae family contributed 1 species, Haemulidae family contributed 1 species, Carangidae family contributed 7 species belonging to 4 genera and Sphyraenidae family contributed by 2 species among the perches (Table 3). The survey results are also given in table 7 and table 8. Table 7 represents the month wise and group wise hooking rate of perches in the survey conducted by FSI and table 8 represents year wise and group wise hooking rate of perches in the survey conducted by FSI during 2000-2007. The species composition recorded during the survey is given in Table 10. From the table it is seen that Snapper dominates the catch with 33.4 per cent followed by 16.2 per cent and Emperor with 10.6 per cent among the major perches.

Results of Experimental and Commercial Fishing

Considering the nature of the bottom which in most of the areas around the Andaman and Nicobar Islands is corals it was felt necessary to explore for the demersal fish by lines similar to Kalva lines. The vessel Meena Khojini was rigged for this purpose during April, 1974 to March, 1976. The total effort spent in this method was 137 hours. The overall catch/hour worked out to 4.66 Kg. The highest catch was obtained in April, 1975 with a catch per hour of 18.3 Kg from north east of Havelock Island in the area 12°N/92°E.

During the survey miscellaneous fishes constituted 45.78 per cent of the total catch, sparidae being the important group. Perches and small sharks constituted 23.02 per cent and 14.69 per cent respectively, Aprion (7.34 per cent), Carangids (5.3 per cent), (Tuna 3.3 per cent) and Barracuda (0.37 per cent) was also obtained during the survey.

Where the commercial landing of perch resources shows a CUPE of 565.5 Kg/unit/month through mono or branched vertical line fishing and the rate of harvest per Sq.Km per annum from the identified grounds is 0.15 tons per fishing unit (John *et al.*, 2005). He also pointed out that there are two major landing centers namely Wandoor and Guptapara with a total fleet strength of 56 units operating at 40 to 70 per cent level *i.e.,* in western fishing zone of South Andaman.

By the chartered vessels operated in and around A and N Islands which did hook and hand line fishing during 1999 – 2000 could exploit 100 Kg. – 250 Kg/day.

Commercial landing

The details of commercial landing in the island is represented in Table 4(a) and 4(b). Table 4(a) represents the year wise landing of perches in Andaman and Nicobar waters and table 4(b) represents the monthwise landing in Andaman and Nicobar waters. From the table it is seen that the perches contributes about 17.2 to 35.0 per cent during last 7 years. The maximum percentage 35.0 per cent was contributed during 2005. Table 5 represents the month wise landing of major perch resources during 2005-06 and table 6 represents the region wise landing during 2006 at A and N group of Islands.

Table 3. Perch resources recorded from Andaman and Nicobar waters By FSI during the Period 2000-07

Family	Genus	Scientific Name	Common Name
Lutjanidae	*Lutjanus*	*Lutjanus rivulatus*	Blubber lip snapper
		Lutjanus argentimaculatus	Mangrove red snapper
		Lutjanus longippinis	
		Lutjanus bohar	Two spot red snapper
		Lutjanus malabaricus	Malabar red snapper
		Lutjanus sebae	Emperor red snapper
		Lutjanus vittae	Brown stripped red snapper
		Lutjanus gibbus	Humpback red snapper
	Aprion	*Aprion virescens*	Green job fish
	Aphareus	*Aphareus rutilans*	Rusti job fish
	Pristipomoids	*Pristipomoids multiden*	Gold banded job fish
		Pristipomoids typus	Sharp tooth snapper
		Pristipomoids sieboldii	Job fish
Lethrinidae	*Gymnocranium*	*Gymnocranius grandoculis*	Robinson's sea bream
	Lethrinus	*Lethrinus xanthochilus*	Yellow lip emperor
		Lethrinus conchiliatus	Red axil emperor
		Lethrinus microdon	Small tooth emperor
		Lethrinus olivaceus	Large face emperor
		Lethrinus orantus	Ornate emperor
		Lethrinus elongatus	Large nose emperor
		Lethrinus letjan	Red spot emperor
		Lethrinus rhodopterus	
	Wattasia	*Wattasia mosambica*	Mozambique large eye bream
Serranidae	*Cephalopholis*	*Cephalopholis sonnerati*	Tomato grouper
	Plectopomus	*Plectopomus pessuliferus*	Roving coral trout
		Plectopomus maculatus	Spotted Coral trout
	Variola	*Variola albimarginata*	Yellow edge lyre tail
	Epinephelus	*Epinephelus tauvina*	Greasy grouper
		Epinephelus longispinis	Long spine grouper
		Epinephelus malabaricus	Malabar grouper
		Epinephelus undulosus	Wavy lined grouper
		Epinephelus areolatus	Aerolate grouper
		Epinephelus caeruleopunctatus	White spotted grouper
		Epinephelus flavocaerulus	Blue yellow grouper
		Epinephelus chlorostigma	Brown spotted grouper
		Epinephelus albimarginatus	White edged rock cod
Ephippidae	*Platax*	*Platax pinnatus*	Pinnate batfish
Haemulidae	*Plectorhynchus*	*Plectorhinchus gibosus*	Blubbler lip sweet lips
Carangidae	*Carangoids*	*Carangoids fulvoguttatus*	Gold spotted trevally
		Carangoids gymnostethus	
	Caranx	*Caranx malabaricus*	Malabar trevally
		Caranx ignobilis	Yellowfin trevally
		Caranx melampygus	
	Alectis	*Alectis indicus*	Indian thread fish
	Alepes	*Alepes djedaba*	Shrimp shad
Sphyraenidae	*Sphyraena*	*Sphyraena jello*	Spotted barracuda
		Sphyraena forsteri	Big eye barracuda

Table 4(a). Year wise production and percentage of Perch resources in Andaman and Nicobar islands during the year 2000-2007

Sl. No.	Year	Qty (in tonnes)	Percentage composition
1.	2000	5636	18.6
2.	2001	7029	25.9
3.	2002	5330	20.8
4.	2003	9065	29.6
5.	2004	9303	34.6
6.	2005	3019	35.0
7.	2006	4366	18.1
8.	2007	4808	17.2

Source : Dept. of Fisheries, A and N Administration

Table 4(b) : Month wise production of perch resources in Andaman and Nicobar waters during the year 2006–07

Sl. No.	Month	Qty (kg)
1.	April	533667
2.	May	494467
3.	June	422651
4.	July	401390
5.	August	384971
6.	September	390228
7.	October	394728
8.	November	432735
9.	December	479562
10.	January	516285
11.	February	523739
12.	March	545777
	TOTAL	5520200

Source : Dept. of Fisheries, A and N Administration.

CONCLUSION

The resources potential of demersal fishes in the region has been estimated at 22,500 tons. However the species or group wise potential data is lacking. At present the perches, mullets and silver bellies account major part of the landing. Perches, (*i.e.*, Grouper, Snapper and rabbit fish), a major commercial group both from the point of view of export as well as domestic marketing which contributes about 4000 tons and are exclusively from the near shore water using hook and line. Off shore resources are remain untouched and still under exploited. However, the composition of the present landing from Andaman and Nicobar waters, landing from the chartered vessels and this experimental exploratory survey indicates that perches, silver bellies, Nemipterids, Goat fish, Elasmobranchs, mullets, Scianids, Cat fish, Barracuda, Carangids constitute the demersal resources and has vast potentials.

From the present study it can be concluded that the Biodiversity and potential of the perch resources is very vast which can be exploited by means of the hook and line fishing which is a selective gear without adding any threat to the non-commercial and bottom dwelling fish habitats as in case of trawling. The perches can be air lifted in live condition also which has a promising market in the international market.

Nevertheless, it is reported that few commercial charted vessels were already deployed for fishing in and around these Island and the results seems to be very promising. Finally it can help the small traditional fishermen of the Islands for the exploitation of such a sleeping giant resource with little awareness and training.

In the Andaman and Nicobar Islands fishery development is yet to assume importance as a major source of economic development. The Oceanic waters around the islands offer immense scope for the exploitation of oceanic resource along with the reef fisheries. Thus there is a need for diversification of fishing effort, keeping in view of the varied fishery resources of A and N waters. So at this juncture diversification of the fishing methods to bottom set vertical long line to exploit the reef fishes like, Groupers, Snappers, Emperors

Table 5. Month wise landings of major perch resources in Andaman waters during the year 2005 2006

Sl. No.	Name of fish	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
1.	Perches	3468	4304	3693	3723	3890	4471	4799	4817	4606	4737	4868	4980	**52356**
2.	Groupers	22560	35463	37407	46992	46857	41413	46549	56515	54066	59213	64343	66628	**578006**
3.	Red Snappers	38670	69439	77644	112515	108647	90520	98949	120790	113784	126772	140166	145360	**1243256**
4.	White Snappers	23697	48450	53525	74111	18712	62293	68448	83225	78734	87247	95739	99204	**793385**
5.	Emperors	25837	75661	85435	126799	121761	100253	109200	133562	125523	140504	155482	161147	**1361164**
6.	Others	10037	20527	21790	30172	29311	25398	27375	32673	30887	34198	37509	39037	**338914**
	Total	**124269**	**253844**	**279494**	**394312**	**329178**	**324348**	**355320**	**431582**	**407600**	**452671**	**498107**	**516356**	**4367081**

Source : Dept. of Fisheries, A and N Administration.

Table 6. Region wise perch landing during 2006

Region	Distance from Port Blair	Perch Landing (kg)	Total landing (kg)	Percentage (per cent)
Diglipur	185 Km	2000000	6823300	29.31
Mayabunder	157 Km	50000	714300	7.00
Billiground	–	10000	338450	2.95
Ranghat	93 Km.	51000	801400	6.40
Kadamtala	–	48000	365450	13.13
South Andaman	–	2151000	14323800	15.02
Little Andaman	122 Km.	16000	170750	9.40
Car Nicobar	278 Km.	5000	71260	7.02
Nancowry	435 Km.	13000	264550	4.91
Katchal	–	10000	62080	16.11
Campbell Bay and Teressa	482 Km.	12000	149660	8.02

Table 7. Month wise hooking rate of perch resources recorded by FSI in A and N waters during 2000-07 by deploying BSVLL

Year/ Month	Effort	Catch (No.)	Agg. HR	Snapper	HR	Grouper	HR	Emperor	HR	Caranx	HR	Shark	HR	Others	HR
January	5280	38	0.72	13	0.25	14	0.27	1	0.02	4	0.08	2	0.04	4	0.08
February	9000	217	2.41	81	0.90	54	0.60	17	0.19	30	0.33	32	0.36	3	0.03
March	13260	349	2.63	77	0.58	40	0.3	24	0.18	22	0.17	177	1.33	9	0.07
April	9000	225	2.5	68	0.76	31	0.34	59	0.66	9	0.1	50	0.56	8	0.09
May	16080	255	1.59	103	0.64	47	0.29	18	0.11	6	0.04	77	0.48	4	0.02
June	13020	161	1.24	71	0.55	37	0.28	15	0.12	11	0.08	27	0.21	0	0.00
July	28170	669	2.37	232	0.82	76	0.27	54	0.19	96	0.34	183	0.65	28	0.10
August	27060	851	3.14	278	1.03	150	0.55	106	0.39	93	0.34	201	0.74	23	0.08
Total	**120 870**	**2765**	**2.29**	**923**	**0.76**	**449**	**0.37**	**294**	**0.24**	**271**	**0.22**	**749**	**0.62**	**79**	**0.07**

Table. 8 Year wise hooking rate of perch resources recorded by FSI in A and N waters during 2000-07 by deploying BSVLLS

Year	Effort	Catch (No.)	Agg. HR	Snapper	HR	Grouper	HR	Emperor	HR	Caranx	HR	Shark	HR	Others	HR
2000	19740	369	1.9	102	0.5	84	0.4	23	0.1	47	0.2	105	0.5	8	0.04
2001	16800	460	2.7	137	0.8	55	0.3	78	0.5	20	0.1	154	0.9	16	0.1
2002	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2003	6300	37	0.6	16	0.2	7	0.1	3	0.1	1	0.01	9	0.1	1	0.01
2004	15000	497	3.3	166	1.1	88	0.6	51	0.3	64	0.4	100	0.7	28	0.2
2005	18660	563	3.1	169	0.9	105	0.6	68	0.4	64	0.3	147	0.8	10	0.05
2006	19590	493	2.5	213	1.1	40	0.2	32	0.2	54	0.3	141	0.7	13	0.07
2007	24780	346	1.4	120	0.5	70	0.3	39	0.2	23	0.1	91	0.4	3	0.01
Total	**1,20,870**	**2,765**	**2.29**	**923**	**0.76**	**449**	**0.37**	**294**	**0.24**	**271**	**0.22**	**749**	**0.62**	**79**	**0.07**

Table 9. Area wise hooking rate of perch resources recorded by FSI in Andaman and Nicobar waters during 2000-07 by deploying BSVLL

	Area (Lat.°N - Long.°E)	Effort	Catch (No.)	Agg. HR	Snapper	HR	Grouper	HR	Emperor	HR	Caranx	HR	Shark	HR	Others	HR
Nicobar	6-93	840	13	1.55	4	0.48	3	0.36	3	0.36	0	0.00	3	0.36	0	0.00
	7-92	420	16	3.81	4	0.95	1	0.24	3	0.71	1	0.24	7	1.67	0	0.00
	7-93	7860	313	3.98	43	0.55	35	0.45	21	0.27	69	0.88	138	1.76	7	0.09
	8-92	4200	110	2.62	56	1.33	18	0.43	21	0.50	1	0.02	11	0.26	3	0.07
	8-93	14070	490	4.26	175	1.24	97	0.69	66	0.47	20	0.14	116	0.82	16	0.11
	9-92	4110	75	1.82	21	0.51	19	0.46	11	0.27	5	0.12	18	0.44	1	0.02
Sub Total		**31500**	**1017**	**3.2**	**303**	**0.96**	**173**	**0.55**	**125**	**0.4**	**96**	**0.3**	**293**	**0.93**	**27**	**0.09**
Andaman	10-92	12210	109	0.89	35	0.29	28	0.23	13	0.11	10	0.08	14	0.11	9	0.07
	10-93	330	12	3.64	7	2.12	2	0.61	1	0.30	0	0.00	1	0.30	1	0.30
	11-92	22410	402	1.79	111	0.50	92	0.41	29	0.13	46	0.21	120	0.54	4	0.02
	11-93	600	12	2.00	3	0.50	3	0.50	4	0.67	0	0.00	2	0.33	0	0.00
	12-92	7920	125	1.58	33	0.42	19	0.24	19	0.24	12	0.15	32	0.40	10	0.13

Table 10. Percentage of Catch composition obtained by FSI during 2000-07 (By numbers and weight)

Species	Catch composition Numbers	Percentage (per cent)	Weight (kg)	Percentage (per cent)
Grouper	449	16.2	874.0	10.4
Snapper	923	33.4	2977.3	35.3
Emperor	294	10.6	686.5	8.2
Caranx	271	9.8	936.6	11.4
Shark	749	27.2	2622.0	31.2
Others	79	2.8	303.8	3.5

should be aimed at private sector also to be promoted for game fishing or sport fishing activity to attract the tourist to visit the island and for the fishing as these reef fishes seems to have a tremendous potential as game fishing. The development of fishing industry and simultaneous economic development of this island can be aimed at by promoting and exploiting these demersal resources.

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Chapter 31

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 361-371, 2010

DIVERSITY AND POTENTIAL OF OCEANIC FISHERY RESOURCES IN ANDAMAN AND NICOBAR ISLANDS

A. ANROSE, M.K. SINHA, A.B. KAR, S.K. PATTNAYAK and K. GOVINDARAJ
Fishery Survey of India, Port Blair, Andaman and Nicobar Islands

INTRODUCTION

The fisheries forms a major natural resources of the Island, the knowledge of marine biodiversity to harvest the fishery resources especially in the oceanic region which is still under exploitation is to be acquired as the world fishery scenario has, over the years, undergone vast changes due to the technological advancements made in harvesting the resources and in the post harvest sectors, the increasing demand for sea food by the growing human population and for earning foreign exchange. The means of marine biodiversity such as diversity within species, between species and in a ecosystem and their present estimated potential is important aspect in order to have a plan for developing fisheries in oceanic region.

The Andaman and Nicobar groups of Islands are situated between Latitude 6°45'N and 13°41'N and Longitude 92°12'E and 93°57'E in the South East Bay of Bengal. The archipelago with 575 islands are fringed by lagoons and coral reefs and experiences both north east and south west monsoons and some Islands are blessed with perennial streams and rivers. The islands have a coast line of 1962 Kms, which is about one fourth of the total coast line of India. Out of India's 2.02 million km^2 of EEZ, 0.6 million km^2 lies around these islands which is almost 30 per cent of the total EEZ. Being oceanic islands there is practically no continental slope. The union-territory has a continental shelf of 16,000 km^2 which offers rich potential for coastal marine fisheries and the oceanic region of these islands provides vast scope for exploitation of oceanic resources such as tunas, bill fishes, sharks etc. As the marine capture fisheries sector plays a significant role in the food and nutritional security, economy, employment generation and export trade, it is important to develop this sector by exploiting the vast potential of oceanic fishery resources with a clear knowledge of its present potential and rich biodiversity in the Island waters. This paper attempts to review the oceanic fishery biodiversity and their potential in the Island waters.

MARINE FISH PRODUCTION AND ITS PRESENT STATUS

The Andaman and Nicobar Islands marine ecosystem is known to harbour a large number of species *i.e.* 1200 species of fishes, 580 species of crustaceans, 900 species of mollusks and 300 species of echinoderms. Out of 1200 fish species, about 350 species are commercially important at present (Krishnamurthy and Soundarajan, 1999). The total marine fish production in the islands was characterized by wide fluctuations during the 05 year period 2003-2007 (Table 1). The increase in landing was mainly due to the improvement in the fishing gear design, introduction of synthetic fibres in the gears, mechanisation and motorisation of fishing crafts. During the last seven years, the marine fish landings in the islands varied between minimum of 8635 tonnes in 2005 and a maximum of 30636 tonnes in 2003. The trend of total marine fish landings in the islands was determined by the landings of demersal and

Table 1. Estimates of Fishery Potential in Andaman and Nicobar waters

Area	Potential yield (tonnes)	Method of estimation	Author
Shelf area	1,00,000	Tertiary production	Cushing, 1971
Latitude–6°20′-15° Longitude–92°-93°	50,000	Primary production	Kumaran, 1973
Shelf area	12,000	Primary production	
Shelf area	12,000	Fish production per unit area	Jones and Banerjee, 1973
Shelf area	1,60,000	Primary production, Tertiary production	George *et al.*, 1977
Shelf area	45,000 Standing stock of demersal resources	Swept area method.	Sudarsan, 1978
Shelf area	90,000–1,00,000	Tertiary production	Antony Raja, 1980
Shelf area	72,500	Fish production per unit	Joseph, 1985
EEZ area	4,900 (Oceanic tuna and allied species)	Long line survey	Sudarsan *et al.*, 1989
EEZ area	6,90,000	Secondary production	Mathew *et al.*, 1990
Shelf area	2,43,500	Survey based on secondary and tertiary exploratory production	Sudarsan *et al.*, 1990
EEZ area	9,20,000	Secondary production	Bhargava, 1996
EEZ area	1,48,000	Survey based on secondary and tertiary exploratory production	John *et al.*, 2005

pelagic resources viz., Sardines, Mackerel and Perches. The landings which was 30636 tonnes in 2003 decreased considerably to 8635 tonnes in 2005 accounting for a decrease of 72 per cent just after the tsunami which struck this island group in 26th December 2004. But the landings gradually increased to 24096 tonnes and 28005 tonnes in the succeeding years *i.e.*2006 and 2007 respectively. During this 05 years period the average landing of the islands was about 23658.5 tonnes.

REGION WISE MARINE FISH LANDINGS

The Fishing activities in the islands are mainly concentrated at a few major fishing centres like Diglipur, Mayabunder, Rangat, South Andaman, Little Andaman, Car Nicobar, Nancowry and Campbell Bay and the marine fish landings from these centres during the period 2003-2007 are given in Table 3. South Andaman was the most active fishing centre in the islands which alone accounted for about 74 per cent of the total marine fishing landings. Besides, South Andaman, Diglipur is another important centre which contributed 17 per cent of the total landings of the islands. The fish landings at Rangat and Mayabunder contributed to the order of 2 per cent and 1.5 per cent of the total landings of the islands respectively.

BIODIVERSITY OF OCEANIC FISHES

The marine fish landings in the islands can be divided into three groups namely the demersal, pelagic and oceanic. The demersal group consists of Elasmobranchs, Silver bellies, Pomfrets, Perches, Cat fish, Polynemids, Sciaenids, Prawns, Crabs and Other miscellaneous fishes. The pelagic and oceanic group comprise of fishes like Sardines,

Table 2. Marine Fish Production in Andaman and Nicobar Islands during 2003 – 2007 (tonnes)

Sl. No.	Year	Total fish production (Demersal, Pelagic and Oceanic) (tonnes)	Oceanic fish production (In tonnes)	per cent Contribution
1.	2003	30636	370	1.21
2.	2004	26920	182	0.68
3.	2005	8635	107	1.24
4.	2006	24096	11	0.05
5.	2007	28005	12	0.04
	Total	**1,71,026**	**1304**	**0.76**

Table 3. Marine fish production in Andaman and Nicobar islands during 2003 2007

Region	Distance from Port Blair (km)	2003	2004	2005	2006	2007	Total
Diglipur	185	1336	1374.9	914.0	6823.3	9823	20271.2
Mayabunder	157	221	201.1	174.1	714.3	687	1997.5
Billiground	–		8.3	36.5	338.4	222	605.2
Ranghat	93	847	192.5	159.6	801.4	769	2769.5
Kadamtala	–		387.1	224.5	365.4	231	1208
South Andaman	–	27157	23818.2	6965.4	14323.8	15461	87725.4
Little Andaman	122	619	498.9	35.8	170.7	261	1585.3
Car Nicobar	278	6	8.5	–	71.3	64	149.8
Nancowry	435	331	275.8	73.3	264.5	217	1161.6
Katchal	–		20.3	5.2	62.1	93	180.6
Campbell Bay and Teressa	482	119	121.5	27.0	149.7	165	582.2
Total		**30636**	**26907.1**	**8615.4**	**24085**	**27993**	**118236.3**

Thrissocles, Chirocentrus, Anchovies, Mackerels, Carangids, Mullets, Hilsa, Ribbon fishes, Tunas, Bill fishes, Barracudas, deep sea sharks, Seer fishes and other miscellaneous varieties. The major varieties of oceanic fishery resources are given below :

Tunas **:** The tuna fishery is mainly contributed by the coastal species viz. little tunny (*Euthynnus affinis*), long tail tuna (*Thunnus tonggol*), Oriental bonito (*Sarda orientalis*), Frigate tuna *(Auxis thazard)* and Dog tooth tuna (*Gymnosarda unicolor*) in A and N islands. The contribution of tunas to the marine fish landings in the Islands varied from 1.4 per cent in 2003 to 8.6 per cent in 2006. A maximum landing of 2359 tonnes was recorded during 2007. However the tuna and tuna like fishes belong to 6 genera, namely, *Thunnus, Katsuwonus*, *Euthynnus, Auxis* and the bonitos *i.e. Sarda* and *Gymnosarda*. The tunas perform considerable and some times even transoceanic migrations. Being highly valued table fishes, they are of significant importance both as commercial and recreational fishery. Out of these 6 genera, mainly 3 genera are recorded from oceanic region of A and N waters; those are *Thunnus albacares* (Yellow fin tuna), *Thunnus obesus (Big eye tuna), Thunnus alalunga* (Albacore tuna), *Katsuwonus pelamis* (Skipjack tuna) and *Gymnosarda unicolor* (Dogtooth Tuna). The oceanic species contributes a very little to the tuna fishery of the islands. The fishing area for the coastal tunas extends mainly from the eastern part of Little Andaman to North Andaman (10°N to 15°N) up to the depth of 200m.This area is influenced considerably by both Southwest and Northeast monsoons. The coastal tunas from the waters of the islands are mainly caught by drift gill nets and hook and lines. The plank built boats ranging from 5.4 to 7.5m and motorized dug out canoes ranging from 7.5m to 12m size are engaged in the operation of both the gears for exploitation of the resource. The common species of tunas represented in the fishery and their common size range and maximum weight are given below.

Name of the species	Common name	Common size (in cm)	Maximum Weight (in kg)
Euthynnus affinis	Little tunny	40-60	13
Thunnus tonggol	Long tail tuna	40-70	43
Auxis thazard	Frigate tuna	40-60	10
Sarda orientalis	Oriental bonito	30-50	06
Gymnosarda unicolor	Dog tooth tuna	40-60	130
Thunnus albacares	Yellow fin tuna	50-150	170
Katsuwonus pelamis	Skipjack tuna	40-80	34
Thunnus obesus	Big eye tuna	60-180	197
Thunnus alalunga	Albacore tuna	40-100	50

Bill fishes : Four genera of Billfishes, namely, *Istiophorous*, *Makaira*, and *Tetrapterus* from (Family Istiophoridae) and *Xiphias* (Family Xiphidae) are available and all the 4 genera are recorded in A and N waters, those are *Istiophorous platypterus*(Indo-pacific Sailfish), *Makaira mazara* (Blue Marlin), *Makaira indica* (Black Marlin), *Tetrapterus audax* (Striped Marlin) and *Xiphias gladias* (Sword Fish). The contribution of Billfishes to the marine fish landings in the Islands varied from 0.004 per cent in 2006 to 0.83 per cent in 2003. A maximum landing of 253 tonnes was recorded during 2003. The common size and maximum weight of bill fishes recorded in A and N waters are given below :

Name of the species	Common name	Common size (cm)	Maximum Weight (kg)
Istiophorus platypterus	Indo-Pacific sail fish	131-230	100
Makaira mazara	Blue Marlin	141-230	820
Makaira indica	Black marlin	151-220	700
Tetrapterus audax	Striped marlin	151-200	230
Xiphias gladius	Sword fish	131-190	500

Sharks : These are having widely distributed genera among all the marine fishery resources. The demersal and oceanic distribution of these resources is of highly predatory nature. They belong to the Class Chondrichthyes and Subclass Elasmobranchii and form one of the important commercial fisheries of India. These are widely used as food either in fresh or cured condition. There is an export trade in dried fins and maws of sharks to the far eastern countries. There are 7 genera from 4 families were recorded in oceanic region by Fishery Survey of India, namely *Alopias* (Family Alopiidae), *Isurus* (Family Lamnidae), *Carcharhinus, Prionace, Galeocerdo,* (Family

Carcharhinidae), *Sphyrna* (Family: Sphyrnidae). The species wise classification of these genera is given in Table 4. The contribution of Elasmobranches (Sharks, Skates and Rays) to the marine fish landings in the Islands varied from 9.24 per cent in 2006 to 1.29 per cent in 2003. A maximum landing of 2,227 tonnes was recorded during 2006. The common size and maximum weight of few commonly occurring sharks recorded in A and N waters are given below :

Name of the species	Common name	Common size (cm)
Carcarhinus sorrah	Spot tail shark	61-220
Carcarhinus limbatus	Black tip shark	96-180
Carcarhinus albimarginatus	Silver tip shark	111-205
Carcarhinus longimanus	Oceanic white tip shark	61-180
Carcarhinus melenopterus	Black tip reef shark	101-160
Galeoceredo cuvier	Tiger shark	96-265
Prionace glauca	Blue shark	80-180
Alopias spp.	Thresher shark	71-180
Sphyrna spp.	Hammer head shark	121-200
Isurus oxyrinchus	Short fin mako shark	121-250

FISH PRODUCTION AND FISHERY DEVELOPMENT IN ANDAMAN AND NICOBAR ISLANDS

The average annual marine fish production during 2003-2007 is around 23658 tonnes in Andaman and Nicobar Islands which forms about 16 per cent of the total estimated fishery potential. Among this the average production of Tunas, Bill fishes, Sharks are 1122 tonnes, 7 tonnes and 99 tonnes, respectively, which contributes about 1.74 per cent, 0.1 per cent and 3.5 per cent of their estimated potential. The exploratory surveys carried out by Fishery Survey of India in the oceanic water have indicated that the abundance of oceanic resources such as tunas, Bill fishes, Sharks and other miscellaneous fishes like Bonitos, Barracuda, Dolphin fish etc. and these resources provide great potentiality for exploitation.

The total average fish production per year corresponding to its potential indicates that still 84 per cent of the fishery resources remain unexploited. Thus there is a great opportunity and scope for generating revenue and employment to the islands from marine capture fisheries. The important oceanic fishery resources of A and N Islands are Oceanic tunas, Bill fishes and Pelagic Sharks which are under exploited.

As per the FSI estimate, the Coastal tuna and Oceanic tuna fishery resources aggregate to an estimated fishery potential of 64,500 (18,000 tonnes of coastal tuna and 46,500 of oceanic tuna). The average catch of tuna is 1122 tonnes only contributing 1.74 per cent to the fishery which is mainly of coastal tunas. As such there is no targeted fishery for tuna in Andaman and Nicobar waters. The Bill fish resources have been estimated to be around 2800 tonnes. The average landing during 2003-07 was 7 tonnes, which implies that these resources are not at all exploited and can also be exploited from these oceanic waters.

Pelagic sharks are among the other potential resource available in Andaman seas. It has been estimated that about 7000 tonnes of pelagic sharks available in the A and N waters where as in an average 99 tons (which is about 3.5 per cent only being harvested per annum) which is mainly from the coastal water i.e. 6-12 NM from the shore. Mainly the oil sharks are exploited from the depth of 300mtrs.

FSI'S CONTRIBUTION TOWARDS OCEANIC FISHERY RESOURCES AND ITS BIODIVERSITY

The Port Blair base of Fishery Survey of India (FSI) established in the year 1971 is the nodal agency responsible for conducting exploratory surveys in the waters of Andaman and Nicobar Islands for estimation of fish stocks. In order to assess the oceanic tunas and allied resources in

Table 4. Oceanic species recorded by fishery survey of India

Family	Scientific name	English name
Scombridae	*Thunnus albacares*	Yellow fin tuna
	Thunnus obesus	Big eye tuna
	Katsuwonus pelamis	Skipjack tuna
Istiophoridae	*Makaira mazara*	Blue marlin
	Makaira indica	Black marlin
	Tetrapterus audax	Stripped marlin
Xiphidae	*Xiphias gladius*	Sword fish
Istiophoridae	*Istiophorus platypterus*	Sail fish
Coryphaenidae	*Coryphyaena hippurus*	Dolphin fish
Sphyrnidae	*Sphyraena jello*	Barracuda
Scombridae	*Acanthocybium solandri*	Seer fish
	Scomberomorus commerson	Seer fish
Carcharhinidae	*Galeoceredo cuvier*	Tiger shark
	Rhizoprionodon acutus	Milk shark
	Scoliodon laticaudus	Spade nose shark
	Carcharhinus limbatus	Black tip shark
	Carcharhinus albimarginatus	Silvertip shark
	Carcharhinus melanopterus	Black tip reef shark
Carcharhinidae	*Carcharhinus macloti*	Hard nose shark
	Carcharhinus sorrah	Spot tail shark
	Carcharhinus longimanus	Oceanic white tip shark
Lamnidae	*Isurus oxyrhincus*	Short fin mako shark
Sphyrnidae	*Sphyraena zygaena*	Hammer head shark
Alopidae	*Alopias pelagicus*	Pelagic threser shark
	Alopias supercilliosus	Big eye threser shark
	Alopias vulpinus	Thresser shark
Rare species recorded by FSI		
Molidae	*Mola mola*	Sun fish
Brammidae	*Taractichthys longipinnis*	Big scale pomfret
Tunas		
Scombridae	*Thunnus albacares*	Yellow fin tuna
	Thunnus obesus	Big eye tuna
	Katsuwonus pelamis	Skipjack tuna
	Gymnosarda unicolor	Dogtooth tuna
Bill fishes		
Xiphidae	*Xiphias gladius*	Sword fish
Istiophoridae	*Istiophorus platypterus*	Indian sailfish
	Tetrapterus audax	Striped marlin
	Makaira mazara	Blue marlin
	Makaira indica	Black marlin

Table 4. *Contd.*

Family	Scientific name	English name
Sharks		
Carcharinidae	*Carcharinus limbatus*	Black tip shark
	Carcharinus longimanus	Oceanic white tip shark
	Carcharinus albimarginatus	Silvertip shark
	Carcharinus sorrah	Spot-tail shark
	Carcharinus macloti	Hard nose shark
	Carcharinus melanopterus	Black tip reef shark
	Prionace glauca	Blue shark
	Galeocereda cuvier	Tiger shark
	Loxodon macrorhinus	Slitey shark
	Scoliodon laticaudus	Spade nose shark
	Rhizoprionodon acutus	Milk shark
Alopiidae	*Alopias vulpinus*	Thresher shark
	Alopias pelagicus	Pelagic Thresher shark
	Alopias superciliosus	Big eye thresher shark
Lamnidae	*Isurus oxyrinchus*	Short fin mako shark
Sphyrnidae	*Sphyrna zygaena*	Smooth Hammerhead shark
	Sphyrna lewini	Scalloped Hammerhead shark
	Sphyrna mokarran	Great Hammerhead shark
Other fishes		
Scombridae	*Acanthocybium solandri*	Wahoo (Seer fish)
	Scomberomorus commerson	Seer fish
Sphyraenidae	*Sphyraena barracuda*	Barracuda
	Sphyraena jello	Barracuda
Coryphaenidae	*Coryphaena hippurus*	Dolphin fish
Rare fishes		
Molidae	*Mola mola*	Sun fish
Bramnidae	*Taractichthys longipinnis*	Big scale Pomfret

Andaman and Nicobar waters, Fishery Survey of India has been conducting regular systematic exploratory surveys since 1991 by deploying fishery survey vessel MFV Blue Marlin; a tuna long liner. Since then the vessel is continuously deployed for survey of deep swimming tunas and allied resources in the Indian EEZ around Andaman and Nicobar Islands and collecting valuable data to study the stock position, abundance and distribution pattern of these resources. The catch data collected by the vessel MFV Blue Marlin during the period 2003-2007 is given in various forms i.e. species-wise, latitude-wise, year-wise, month-wise and sector-wise in the tables from 4 to 8. The abundance index and distribution pattern of tunas and allied resources have also been studied during the survey period. The survey results indicates that tunas are more abundant in the areas off Hutbay, West of Car Nicobar, South West of Nancowry group of Islands West of South Andaman Islands and North East of North sentinel Islands. So far as the biodiversity is concerned FSI has been contributing a lot to the biodiversity in this sector.

Table 5. Lattitude-wise and Species-wise Hooking Rates (HR) obtained in exploratory survey in Andaman and Nicobar waters during 2003-07

Area		Effort (In hooks)	Agg. HR (per cent)	Hooking rate (per cent)							
				YFT	SKJ	BET	SAI	SWD	MAR	SHK	OTH
NICOBAR	5°	3135	1.02	0.06	0.03	--	--	--	0.03	0.51	0.38
	6°	16190	0.53	0.07	0.006	0.012	0.03	0.018	--	0.234	0.15
	7°	29665	0.67	0.19	0.006	0.006	0.03	0.03	0.003	0.24	0.17
	8°	35625	0.62	0.09	--	0.022	0.025	0.01	0.006	0.34	0.12
	9°	30000	0.83	0.14	0.01	0.05	0.02	0.06	0.01	0.37	.018
Total		**114615**	**0.69**	**0.12**	**0.01**	**0.02**	**0.02**	**0.02**	**0.03**	**0.01**	**0.31**
ANDAMAN	10°	28125	0.92	0.22	0.004	0.007	0.05	0.07	0.02	0.37	0.18
	11°	58750	0.92	0.29	0.02	0.01	0.05	0.04	0.01	0.32	0.19
	12°	45510	0.77	0.34	0.013	0.004	0.05	0.02	0.01	0.19	0.15
	13°	46250	0.77	0.29	0.13	--	0.06	0.02	0.01	0.24	0.13
	14°	7500	0.61	0.36	0.05	--	0.03	0.03	--	0.09	0.05
Sub Total		**186135**	**0.83**	**0.29**	**0.02**	**0.01**	**0.01**	**0.05**	**0.03**	**0.01**	**0.27**
Grand Total		**300750**	**0.78**	**0.23**	**0.012**	**0.012**	**0.043**	**0.03**	**0.008**	**0.29**	**0.16**

MARINE FISHERY RESOURCES POTENTIAL

The marine fishery potential of the islands has been assessed by various authors. The estimates vary widely. Most of the estimates in Andaman sea are based on primary/secondary/tertiary production and exploratory survey data. These estimates range from 12,000 tonnes to 9, 20,000 tonnes per year for the Andaman and Nicobar Islands. (Kumaran, 1973; Jones and Banerjee, 1973; George *et al.*, 1977; Sudarsan, 1978; Antony Raja, 1980; Joseph, 1985; John *et al.*, 2005). Cushing (1971) estimated the potential yield of demersal and pelagic resources of the islands as 1,00,000 tonnes based on the tertiary production. Kumaran (1973) estimated the potential yield as 62,000 tonnes based on the organic production. Jones and Banerjee (1973) gave an estimate of 12,000 tonnes. George *et al*, (1977) while estimating the potential yield based on the rate of production gave an estimate of 1,60,000 tonnes. Similarly, Mathew *et al.*, 1990 and Bhargava, 1996 estimated the potential yield of marine fishery resources in the Andaman and Nicobar Islands as 6, 90,000 tonnes and 9, 20,000 tonnes based on secondary production method. However, the survey data during last two decades have considerably strengthened the data base on the structure, distribution, relative abundance and magnitude of fishery resources in the island archipelago enabling more precise assessment of the fish stocks. Based on this survey data, John *et al.*, (2005) estimated the marine fishery resource potential of Andaman and Nicobar EEZ as 1, 48,000 tonnes which comprised of demersal resources (32,000 tonnes), Neritic-pelagic resources (56,000 tonnes) and Oceanic resources (60,000 tonnes). The major components of the oceanic resources are tunas (76.7 per cent), shark (11.7 per cent) and bill fishes (4.7 per cent) and the potential yield of oceanic fishery resources estimated in the Exclusive Economic Zone around the Andaman and Nicobar Islands are furnished below.

Table 6. Month-wise and Species-wise Hooking Rates (HR) obtained in the exploratory survey in Andaman and Nicobar waters during 2003-07

Months	Effort (In hooks)	Total catch (No./Weight in kg)	Agg. HR (per cent)	Hooking rate (per cent)							
				YET	SKJ	BET	SAI	SWD	MAR	SHK	OTH
January	36875	454/13303.5	1.23	0.62	0.01	0.003	0.06	0.05	0.01	0.31	0.17
February	26921	213/7368	0.79	0.18	0.007	0.03	0.04	0.01	0.02	0.33	0.19
March	28639	173/4745	0.60	0.11	—	0.06	0.01	0.02	0.003	0.24	0.16
April	24900	192/4051.5	0.77	0.14	0.01	0.01	0.02	0.13	0.004	0.21	0.24
May	13405	76/2209	0.57	0.13	—	—	0.022	0.04	0.015	0.15	0.21
June	24775	170/4970.5	0.69	0.15	0.04	—	0.08	0.01	0.03	0.28	0.09
July	14375	69/1651.5	0.48	0.10	0.03	—	0.04	0.01	0.01	0.21	0.08
August	13750	94/1876	0.68	0.22	0.01	—	0.06	—	0.01	0.13	0.25
September	27306	151/5557	0.55	0.07	0.003	0.003	0.03	0.03	—	0.31	0.09
October	35963	233/6701	0.65	0.22	0.008	0.008	0.025	0.006	0.008	0.30	0.07
November	26250	221/5117.5	0.84	0.23	0.03	0.008	0.08	0.016	—	0.30	0.18
December	27591	294/8189	1.10	0.26	—	0.02	0.05	0.02	—	0.50	0.21
Total	**3,00,750**	**2,340/65,739.5**	**0.78**	**0.23**	**0.012**	**0.012**	**0.043**	**0.03**	**0.008**	**0.29**	**0.16**

Table 7. Year-wise and Species-wise Hooking Rates (HR) obtained in the exploratory survey Andaman and Nicobar waters during 2003-07

Year	Effort (in hooks)	Total catch (No /Weight in kg)	Agg. HR (per cent)	Hooking rate (per cent)							
				YFT	SKJ	BET	SAI	SWD	MAR	SHK	OTH
2003	51600	362/10546.5	0.70	0.16	0.012	0.008	0.06	0.06	0.02	0.29	0.1
2004	56164	428/12015	0.76	0.18	0.009	0.018	0.04	0.02	—	0.32	0.18
2005	59429	576/17183	0.97	0.39	0.03	0.003	0.055	0.022	0.003	0.37	0.09
2006	57860	384/13287	0.66	0.22	0.005	0.026	0.045	0.021	0.02	0.23	0.09
2007	75697	590/12708	0.78	0.18	0.005	0.01	0.021	0.03	0.004	0.25	0.29
Total	**3,00,750**	**2,340/65,739.5**	**0.78**	**0.224**	**0.012**	**0.013**	**0.043**	**0.03**	**0.008**	**0.29**	**0.16**

Species /Group	Potential (tones)
1. Yellow fin tuna	24,000
2. Skipjack tuna	22,000
3. Big eye tuna	500
4. Bill fishes (Marlin, Sail fish, Sword fish)	2,800
5. Wahoo (*Acanthocybium solandri*)	200
6. Pelagic sharks	7,000
7. Dolphin fish (*Coryphaena* spp.)	200
8. Barracuda (*Sphyraena* spp.)	200
9. Flying fish (Exocoetidae)	300
10. Oceanic squids	2,000
11. Others	800
Total	**60,000**

The aggregate potential yield of fishery resources in the EEZ around the Andaman and Nicobar Islands forms about 10 per cent of the total projected fishery potential of the entire Indian EEZ. The aggregate potential yield of fishery resources in Andaman and Nicobar Islands as per John *et al.*, 2005 is as below :

Resources	Potential (tones)
1. Demersal	32,000
2. Neritic-pelagic	56,000
3. Oceanic	60,000
Total	**1,48,000**

DISCUSSION AND CONCLUSIONS

The study reveals that plenty of marine fishery resources are available and 30 per cent of their estimated potential is not yet exploited. Though it is observed from the study that the exploitation level of Oceanic fishery resources as compared to demersal fisheries in Andaman and Nicobar Islands is very meager which is due to lack of adequate knowledge and non availability of infrastructure facilities in the islands. Moreover the entrepreneurship temperament among the business community in the island is lacking as the deep sea fishing is capital intensive. So, keeping in view the vast potential of oceanic resources and their exploitation level, their importance in the foreign market at the present scenario and also to generate employment in fisheries sector, it is required to impart training on the deep sea fishing and also to create awareness among the industry and the fishermen is the need of the hour. In order to augment the marine fish production of the Islands, efforts are to be made to introduce medium sized and larger vessels which can fish in the distant and deeper waters by using eco-friendly fishing methods namely drift long lining, hand lining, bottom set long lining and trapping. Further it is also essential to safeguard the unique marine ecosystem of the Islands while developing the marine fisheries sector in future. So far as the Marine Biodiversity of A and N Islands is concerned, it is very rich and sensitive. So proper management, protection, conservation and sustainable utilization of marine biodiversity is to be taken care before under taking for fully commercial ventures in this sector. Most importantly the exploitation of marine fishery

Table 8. Percentage of Catch Composition recorded in exploratory survey during 2003-07

Name of species	Catch			
	Number	Percentage	Weight	Percentage
Yellow fin tuna (YFT)	688	29.4	22125.5	33.7
Skipjack tuna (SKJ)	35	1.5	113	0.2
Big eye tuna (BET)	38	1.6	1736	2.6
Sail fish (SAI)	124	5.3	3114	4.7
Sword fish (SWD)	97	4.1	2311.5	3.5
Marlins (MAR)	25	1.1	1486	2.3
Sharks (SHK)	856	36.7	33429	50.8
Others (Misc.) (OTH)	477	20.5	1424.5	2.2
Total	2,340	100.00	65,739.5	100.00

resources of the Islands is to be carried out in a manner consistent with the principles of ecologically sustainable development.

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Chapter 32

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 373-385, 2010

SPATIO-TEMPORAL DISTRIBUTION, ABUNDANCE AND DIVERSITY OF OCEANIC SHARKS OCCURING IN ANDAMAN AND NICOBAR WATERS

M.K. SINHA, P. PAUL PANDIAN, S.K. PATTNAYAK and A.B. KAR
Fishery Survey of India, Port Blair, Andaman and Nicobar Islands

INTRODUCTION

The Andaman and Nicobar Islands are essentially oceanic in nature, volcanic in origin and endowed with various coastal and marine ecosystems like mangroves, coral reefs, invisible banks, etc., with varieties of living organisms in addition to rich fishery resources. These islands located in the south east of Bay of Bengal between 6.45'- 13°45' N and 92.15' E 94°00' E and about 1200 km from mainland. The 10° channel separates the island into Andaman and Nicobar groups. The land area of the island is 8249 km^2 of which 6408 km^2 is in the Andaman group and 1841 km^2 is in the Nicobar group. Total of 38 islands are inhabited comprising 20 in Andaman and 18 in Nicobar group of islands.

The island has a coast line of 1962 km which is almost one-fourth of the coast line of India and bestowed with about 6 lakh km^2 of Exclusive Economic Zone, which is about 30 per cent of Indian EEZ with 16,000 km^2 within continental shelf. The coast is characterized by fringing and barrier reefs and in some cases atoll formation with lagoons. The bathymetry of coastal water is rather uneven with varying depths. In view of the oceanic nature of seas surrounding islands the primary productivity even though rather low, there is a possibility of increasing it through fertilization and circulation of deep water to the surface to augment production of marine fishery resources.

The average column primary production in the Andaman and Nicobar Sea during monsoon period was 587.7 mg C $m^{-2}d^{-1}$ followed by pre monsoon period 465.6 mg C $m^{-2}d^{-1}$) and post monsoon period 440.7 mg C $m^{-2}d^{-1}$). The annual secondary production for Andaman Sea was 4.12 mg C $m^{-2}d^{-1}$ (Goswami, 2004).

The elasmobranch resource comprising of sharks, rays and skates has assured commercial importance world wide and in India only recently. Shark constitutes one of the major by-catch components in resource specific tuna long line fishing. The Indian Ocean has a diverse shark fauna with about 115 species out of 350 species of sharks available in the world which belongs to 30 families and 96 genera. The sharks are generally utilized for human food, ornamental and asthetic purposes. The flesh is used as human food, fin rays as soups, livers as liver oils; teeth for necklaces and buttons, skin for fancy bags and smaller sharks as fish meal. They are generally caught by long lines, fixed and floating gill nets, bottom trawls and purse seines.

PRESENT STATUS

During the past four decades, the average annual landing of the elasmobranch resource is just above 53,000 tonnes, which constitute about 2.5 per cent of the total marine fish landings of the country. But, in the past decade due to the increase in the demand for shark fin in the south East Asian countries the catch was showing a progressive trend to reach to a maximum of 75,623 tonnes in the year 1998. During the year 2004, the estimated shark landing was about 60,984 tonnes out of the total estimated marine fish landing of 2.59 million metric tonnes. Of the total landing in year 2004, the pelagic resources constituted about 56 per cent, Demersal (26 per cent), Molluscans (4 per cent) and the Crustacean 14 per cent (Fig. 1). The elasmobranches, which are included in the Demersal resources contribute about 9per cent of the total landing of year 2004 (Fig. 2).

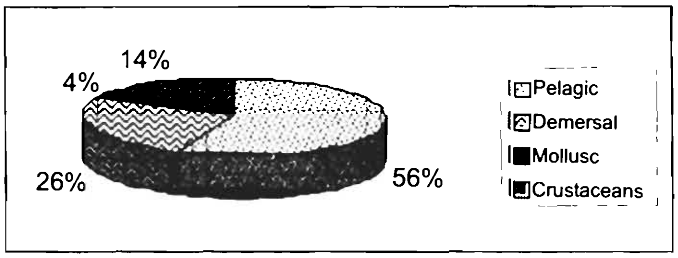


Fig. 1. Percentage of Marine Fish landing of India of different realms and groups during 2004

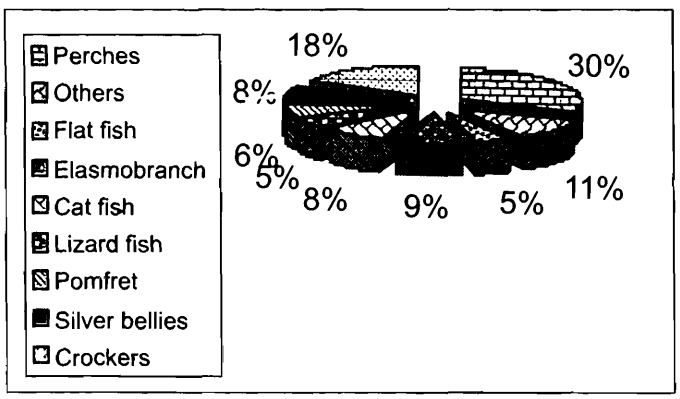


Fig. 2. Demersal fin fish landings of India during 2004

The estimated marine fish production in Andaman and Nicobar waters was 30,339 tonnes in the year 2000 and 26,920 tonnes in the year 2004. The total fish production during the period from 2000 – 2004 was in the range of 25,561 to 30,636 tonnes with an average fish production of 28,126 tonnes per annum (Table 1).

The elasmobranch landing in Andaman and Nicobar waters varies between 395 tonnes in 2003 to 1523 tonnes in 2000. However, the average landing of elasmobranch is about 667 tonnes which constitutes about 2.3 per cent of the total landings.

Fishery potential

The Andaman and Nicobar water is bestowed with enormous fishery potential. The fishery potential of the island water ranges from 0.51 to 2.43 lakh metric tonnes as estimated by various researchers (Table 2).

As the oceanic resources are highly migratory, their assessment for all oceanic province has obvious limitations. However, tentative estimates were projected to enable planning of the developmental strategies.

From the exploratory survey results in Indian waters and relative proportion of surface and sub-surface fisheries in the Indian Ocean, the potential yield of tuna and allied resources in Indian Exclusive Economic Zone is estimated as 2,46,000 tonnes (Sudarsan *et al.*, 1990). Recently the potential yield of oceanic resources has been re-estimated as 60,000 tonnes of which the pelagic shark constitutes about 7,000 tonnes. (Table 3). The potential yield of Elasmobranch resources in Andaman waters (less than 30m depth) assessed as 4200 tonnes out of a total demersal resources stock of 32000 tonnes (John *et al.*, 2005). This implies that the potential yield of both pelagic and demersal sharks of Andaman and Nicobar waters is about 11,200 tonnes.

While analysing the potential and the present landing of Elasmobranchs, it is very clear that the resource is least exploited which is about 5.9 per cent only. However there is a vast scope for exploitation of these under exploited resources by tuna long lining or by diversified fishing methods.

MATERIALS AND METHODS

To carryout the exploratory survey, Fishery Survey of India has deployed the vessel M.F.V. Blue Marlin (OAL 35.76m) for survey of oceanic tuna and allied resources by long lining since November, 1991. The major specifications of the vessel M.F.V. Blue Marlin is given Table 4 and details of the gear are furnished in Table 5.

Kapatharini (*Ambligaster sirm*) and Mackerel (*Rastrelliger* spp.) were the main baits used for the survey. The survey results for a period of Five years from April, 2000 to March, 2005 are analysed to know the distribution, abundance and diversity of sharks. During the period under survey the vessel has undertaken 35 number of cruises of a total of 2,41,555 hooks were operated in Andaman and Nicobar waters. The entire Exclusive Economic Zone of Andaman and Nicobar Islands was covered during the period under report.

Table 1. Year wise and Species wise Fish Production from Andaman & Nicobar Waters (in tonnes)

Species group	2000	2001	2002	2003	2004	per cent
Elasmobranchs	1523	467	217	395	735	2.3
Sardines	3823	2389	3048	3695	2906	**11.27**
Thrissocles	738	485	615	216	338	1.70
Anchovies	1216	1106	1103	760	1218	3.84
Silver Bellies	1557	1467	965	662	1128	4.10
Mackerel	1939	1512	2843	1128	1363	6.24
Carangids	1007	2144	3750	4725	3037	**10.42**
Seer fish	1210	1019	1007	1842	915	4.26
Tuna	467	801	217	536	643	1.89
Sail & Sword fish	1307	316	82	253	168	1.51
Barracuda	617	1489	946	1277	870	3.69
Pomfrets	1856	192	107	180	318	1.88
Mullets	1417	1682	1043	1197	1147	4.61
Hilsa	416	159	228	180	292	0.90
Perches	5636	7029	5330	9062	1849	**20.55**
Belonids	364	242	43	70	87	0.57
Chirocentrids	237	129	15	312	—	0.50
Cat fish	510	321	170	101	453	0.10
Polynemids	62	17	20	85	12	1.39
Sciaenids	86	41	64	60	39	0.20
Shrimps	351	534	489	709	287	1.68
Crabs	738	542	352	154	386	1.54
Ribbon fish	424	253	97	62	64	0.64
Miscellaneous	2838	2838	2810	2975	1654	9.32
Total	**30339**	**27173**	**25561**	**30636**	**26920**	

Table 2. Marine fishery potential of Andaman and Nicobar waters

Sl. No.	Area	Resources	Potential	Methods adopted	Author
1.	Continental shelf	Demersal & Pelagic	1,00,000	Tertiary Production	Cushing, 1971
2.	Continental shelf	Demersal	4,000 8,000	Fish Production per unit area	James and Banerjee, 1973
3.	Between Lat 06°20′–15° N 91°-95° E	Demersal & Pelagic	50,000	Primary Production	Kumaran, 1973
	Continental shelf	Demersal & Pelagic	12,000	Primary Production	
4.	Continental shelf	Demersal & Pelagic	1,60,000	Primary Production and Tertiary Production	George *et al.*, 1977

Table 2. *Contd.*

Sl. No.	Area	Resources	Potential	Methods adopted	Author
5.	Continental shelf	Demersal	45,000 (standing stock)	Trawl survey, Swept area method	Sudarsan, 1978
6.	Continental shelf	Demersal & Pelagic	90,000 -1,00,000	Tertiary Production	Antony Raja, 1980
7.	Continental shelf	Demersal & Pelagic	72,500	Fish Production per unit area	Joseph, 1985
8.	EEZ	Deep Swimming tunas & allied species	4,900	Long line survey	Sudarsan *et al.*, 1989
9.	Continental shelf	Demersal, Pelagic & & Oceanic	22,500 1,39,000 82,000	Trawl survey	Sudarsan *et al.*, 1990
10.	EEZ	Demersal & Pelagic	6,90,000	Secondary Production	Mathew *et al.*, 1990
11.	EEZ	Pelagic	9,20,000	Secondary Production	Bhargava, 1996
12.	EEZ	Demersal, Pelagic & Oceanic	32,000 56,000 60,000	Swept area method Emperial approach Fish Production per unit area & resources survey. Primary Production & resources survey data.	John *et al.*, 2005

Table 3. Estimates on potential yield of oceanic fishery resources in the EEZ around Andaman & Nicobar islands.

Sl. No.	Species/group	Potential yield (Tons)
1.	Yellow fin tuna	24,000
2.	Skipjack tuna	22,000
3.	Big eye tuna	500
4.	Bill Fishes (Marlin, Sail fish & Sword fish)	2,800
5.	Wahoo (Seer fish)	200
6.	Pelagic sharks	7,000+ 4200*
7.	Dolfin fish	200
8.	Barracuda	200
9.	Flying fish	300
10.	Oceanic squids	2,000
11.	Others	800
	TOTAL	**60,000**

(*) additional demersal stock in less than 30 mtrs.

Table 4. Major specifications of M.F.V. Blue Marlin

Length Over all (m)	35.76
Breadth (m)	7.60
Draft (m)	3.10
Gross Registered Tonnage	310 tonnes
Net Registered Tonnage	93 tonnes
Main Engine Power	800 BHP
Speed	10.50 Knots
Fuel Storage Capacity	111.04 m^3
Fresh water storage capacity	61.68 m^3
Fish hold capacity (-50°c)	117.18 m^3
Freezing Room (-60°c)	50.60 m^3
Pre-cooling Room	19.51 m^3

Table 5. Details Regular tuna long line gear

Main line	6.7 tetron	50m × 6 pieces
Branch line	4.5 tetron	12.5m × 5 pieces
Swivel	Box type	No. 9 × 05 pieces
Sekiyama	wire serve with twine (30×4×3)	10m × 5 pieces
Snood wire	Stainless steel (30×4×3)	2.5 m × 5 pieces
Tuna hook	3.6 Sun with ring	5 pieces
Float line	6.7 mm tetron	25 m × 1 piece
Snap clip	'L' type	05 pieces
Float	Polyvinyl 300 mm with single eye	1 piece

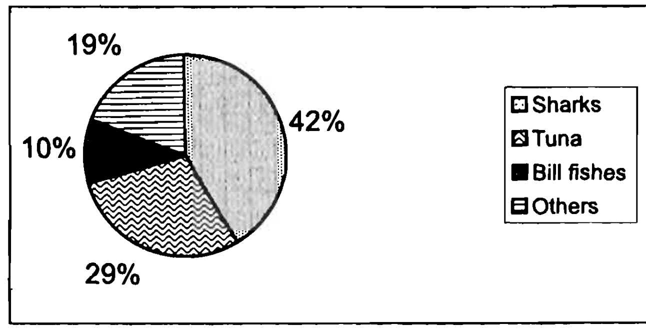


Fig. 3a. Diagramatic representation of catch composition of different groups by number

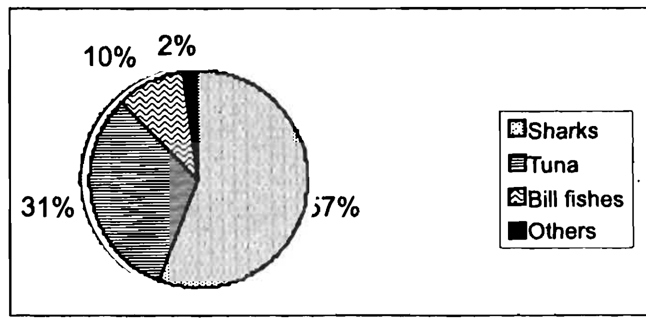


Fig. 3b. Diagramatic presentation of catch composition of different groups by weight

RESULTS

Catch composition

During the period under report a total no. of 2044 fishes weighing about 55,922 kg. was caught out of which shark dominates the catch followed by Tunas. The details of the catch composition are given Table 6.

By number sharks constituted 41.58 per cent followed by Tuna (29.30 per cent) and Others (18.83 per cent). The similar trend was also reported by Bhargava et.al 2002 (49.8 per cent) and John and Somvanshi 2000 (46.36 per cent) Fig. 3.a. By weight also the catch composition of sharks shows similar trend as that of numbers Fig. 3.b sharks recorded 56.56 per cent followed by Tuna and Bill fishes. John and Somvanshi reported about 58.70 per cent by weight which supports the present study.

Table 6. Catch composition of different groups by Number and Weight in percentage

Groups	Percentage by Number	Percentage by Weight
Sharks	41.58	56.56
Tuna	29.30	31.41
Bill fishes	10.27	10.20
Others	18.83	2.02

Diversity

During the course of survey 14 species of sharks were recorded and identified from the oceanic region of Andaman and Nicobar waters. The details of the biology of the species caught are given in Table 7.

Out of 14 species of sharks, 7 species frequently occurring in the catch. They are *Alopias pelagicus, Alopias supercilliosus, Alopias vulpinus, Carcharhinus limbatus, C. albimarginatus, C. sorrah* and *G. cuvier*. Therefore for length frequency these species were selected for analyzing the data.

Seasonal Distribution and Abundance

From Table 8, it is seen that an aggregate hooking rate of 0.846 per cent was obtained for all fishes out of which sharks dominate the catch with 0.351per cent followed by tuna with 0.248 per cent for the period April, 2000 - March, 2005. The month wise analysis indicates that the shark hooking rate is very pronounced more than 0.5 per cent during the month of October, November, December and March. While a deviation is seen in the month of January and February. This implies that sharks are more abundant in the month October, November, December and March.

Table 7. Detailed biology of different species of sharks occurs in Oceanic region of Andaman and Nicobar waters

Sl. No.	Species	Common name	Size range (in cm)	Size at Birth (in cm)	Life span (in yrs)	No. of pups	Gestation period	Season at Birth
1.	*Galeoceredo cuvier*	Tiger shark	500–910	51–76	12	10–82	12	Spring & early summer
2.	*Rhizoprionodon acutus*	Milk shark	110–178	25–39	8	2–8	12	Summer
3.	*Sphyraena zygaena*	Smooth Hammer Headed shark	370–400	50–60	—	29–37	—	—
4.	*Scoliodon laticaudus*	Spade nose shark	74–120	13–15	5–6	5–14	—	Throughout the year
5.	*Isurus oxyrinchus*	Shortfin mako shark	394–400	60–70	—	1–10	—	—
6.	*Carcharhinus limbatus*	Black tip shark	225	38–72	12	1–10	10–12	Late spring & early summer.
7.	*C. melanopterus*	Black tip shark	200	33–52	—	2–4	16	Late winter & early summer
8.	*C. macloti*	Hard nose shark	100	45–50	--	1–2	—	—
9.	*C. longimanus*	Oceanic white tip shark	350–395	60–65	—	1–15	12	Early summer
10.	*C. albimarginatus*	Silvertip shark	300	63–68	—	1–11	12	Summer
11.	*C. sorrah*	Spot tail shark	160	50–60	—	2–6	—	Spring & summer
12.	*Alopias pelagicus*	Pelagic threser shark	264–330	96	—	2–4	—	—
13.	*A. supercilliosus*	Big eye threser shark	461	64–106	—	2–4	—	—
14.	*A. vulpinus*	Threser shark	549–609	114–150	—	2–4	—	—

Table 8. Month wise hooking rates of different groups in Andaman and Nicobar waters during April, 2000 March, 2005 (in Percentage)

Month	Effort	Aggregate	Tuna	Bill fish	Shark	Others
April	19725	0.618	0.136	0.182	0.187	0.111
May	19780	0.423	0.20	0.029	0.095	0.095
June	26045	0.718	0.10	0.08	0.34	0.19
July	26635	0.664	0.18	0.075	0.25	0.15
August	23435	0.53	0.149	0.055	0.234	0.089
September	16285	0.65	0.055	0.09	0.30	0.19
October	14175	1.18	0.211	0.05	0.68	0.232
November	23150	1.06	0.129	0.133	0.518	0.285
December	16650	1.55	0.58	0.12	0.57	0.17
January	30515	1.16	0.681	0.052	0.334	0.097
February	13785	0.70	0.23	0.15	0.26	0.06
March	14375	0.925	0.146	0.028	0.598	0.153
Total	**241555**	**0.846**	**0.248**	**0.087**	**0.351**	**0.16**

Bhargava *et al.*, (2002) reported that Andaman and Nicobar waters yielded a hooking rate of 1.10 per cent for sharks after analyzing the data of various survey vessels during October 1983 to 1999 where as in the present study it is seen that the hooking rate of shark has shown a decreasing trend i.e., 0.35 per cent during the period of April, 2000 to March, 2005 These significant variation may be due to the fishing effort, climatic changes, etc., The details of month wise variation of sharks presented in Fig. 4.

The present study, showed maximum hooking rate (0.68 per cent) during October followed by March, December and November whereas the hooking rate is very low in the month of May, June, July, August and September. This indicates that May to September is a lean period for sharks.

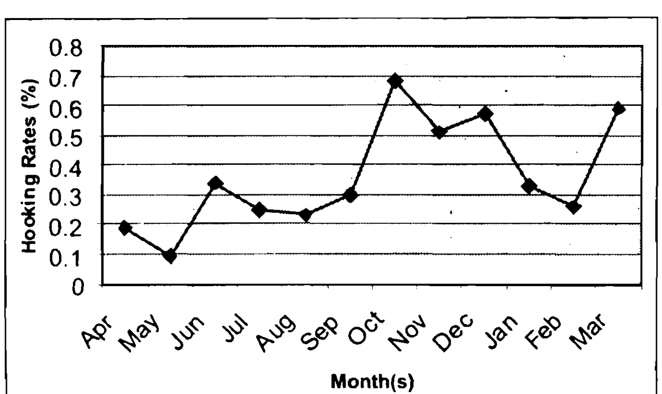


Fig. 4. Seasonal variation of sharks in A & N waters during Apr, 2000 - Mar, 2005

Similar results are also reported by John and Somvanshi, (2000), Bhargava *et al.*, (2002). This clearly indicates that the best fishing season for sharks in the Andaman and Nicobar waters is from October to April.

It is seen that all the species are dominant between October and December in Nicobar waters (Table 9). However, a few species are quite well distributed in Andaman waters. The year wise hooking rate of all fishes and sharks are given in Fig. 5. The catch composition which varies annually is given in Fig. 6.

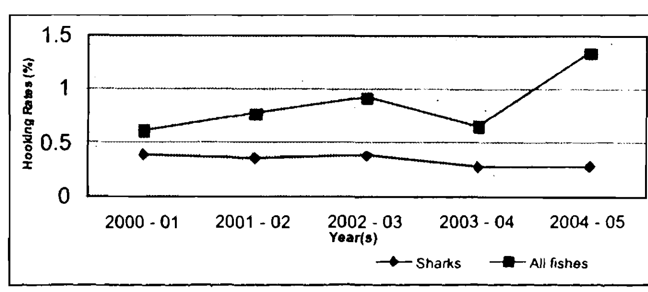


Fig. 5. Yearwise hooking rate of all fishes and sharks

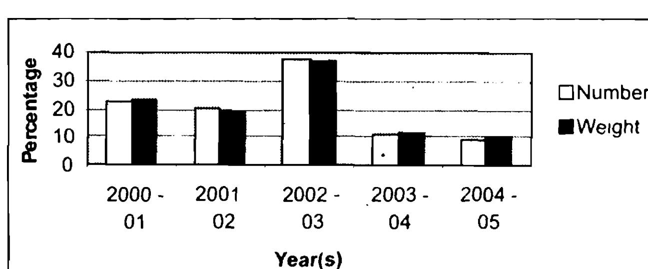


Fig. 6. Annual variation of Sharks by Number and Weight

Table 9. Predominance of species in different month and areas

Species Name	Month(s) of Abundance	Area (Lat/Long) of Abundance
A. pelagicus	Jun, Sep, Oct, Dec	05°/92°, 07°/90°, 07°/92°, 08°/90°, 08°/93°, 11°/91°, 11°/92°, 12°/91°, 13°/93°
A. supercilliosus	Feb, Aug, Sep, Nov.	09°/89°, 09°/90°, 11°/90°, 12°/93°, 12°/94°
A. vulpinus	Jan, Apr, Dec.	05°/93°, 07°/94°, 10°/90°, 11°/90°,
C. sorrah	Jan, May, Nov	06°/92°, 11°/90°, 12°/93°
C. longimanus	May, Sep, Oct	12°/92°, 12°/93°, 13°/93°
C. melanopterus	Sep.	12°/94°
C. limbatus	Jan, Sep, Oct, Dec	05°/91°, 06°/90°, 10°/91°, 11°/92°, 12°/89°
C. albimarginatus	Jan, Jun, Aug, Sep.	07°/93°, 07°/94°, 10°/91°, 12°/93°
C. macloti	Jun, Nov	09°/94°, 10°/94°, 11°/90°
Scoliodon laticaudus	July, Aug.	07°/92°, 11°/93°, 12°/93°
Galeoceredo cuvier	Apr, Jun, Jul	11°/91°, 11°/94°, 12°/94°
Rhizoprionodon acutus	Nov, Dec	05°/92°, 13°/89°
Isurus oxyrinhcus	Sep, Dec	07°/94°, 08°/94°, 08°/95°
Sphyraena zygaena	Jan, Aug, Dec	08°/92°, 10°/91°, 13°/94°

Fig. 6 showed high degree of annual variability in catch indices by number and weight. It is also clear that 2002–2003 showed maximum percentage of sharks caught by number and weight followed by 2000–2001 and 2001–2002. The variation is due to the maximum efforts given in 2002–2003 (85,000 hooks) followed by 2000–2001 (48,105 hooks) and 2001–2002 (47,075). During the last two years i.e., 2003–2004 and 2004–2005 the efforts were less due to more diversified method of fishing i.e., Deep long lining, Bottom set vertical long lining, Drift long line with light sticks, etc., adopted by the base office.

Area wise distribution and abundance

The area wise distribution is given in Fig. 7. The figure indicates the fishing effort hooking rate of all fishes and sharks in Andaman and Nicobar Exclusive Economic Zone during the April, 2000–March, 2005.

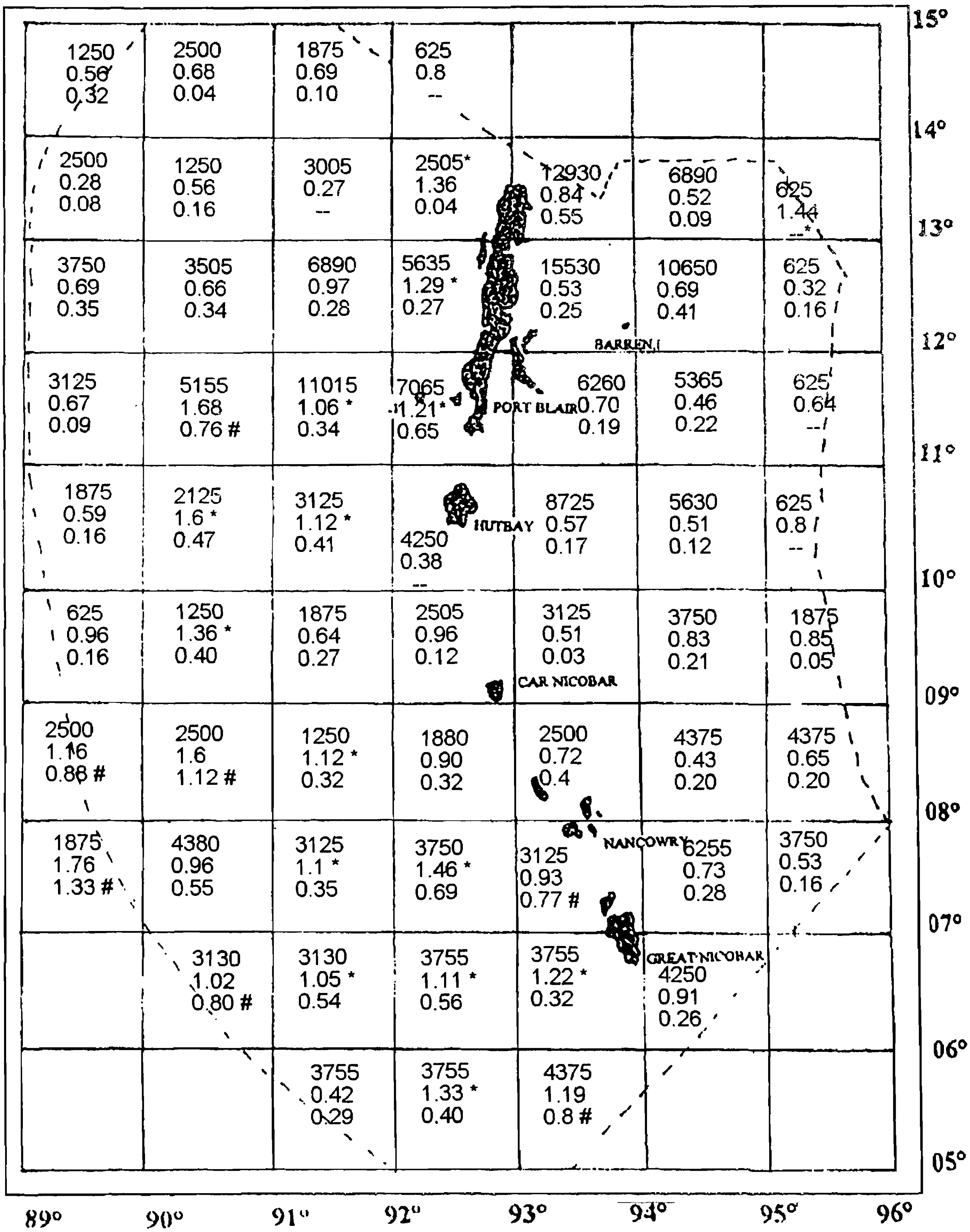
From the Fig. 7, it is clear that the hooking rates of sharks are more pronounced in Nicobar waters (05°–10° N) than the Andaman waters. The area 07°/89° and 08°/90° showed a hooking rate of 1.33per cent and 1.12per cent for sharks which is the maximum among all areas. However area 14° / 92°, 13°/91°, 13°/95°, 11°/95°, 10°/92° and 10° / 95° showed no sign of sharks presence during the period under report.

The aggregate hooking rate for all fishes were maximum (more than 1per cent) in areas 13°/92°, 13°/95°, 12°/92°, 11°/90°, 11°/91°, 11°/92°, 10°/90°, 10°/91°, 09°/90°, 08°/89°, 08°/90°, 08°/91°, 07°/89°, 07°/91°, 07°/92°, 06°/90°, 06°/91°, 06°/92°, 06°/93°, 05°/92° and 05°/93°.

Spatio temporal distribution

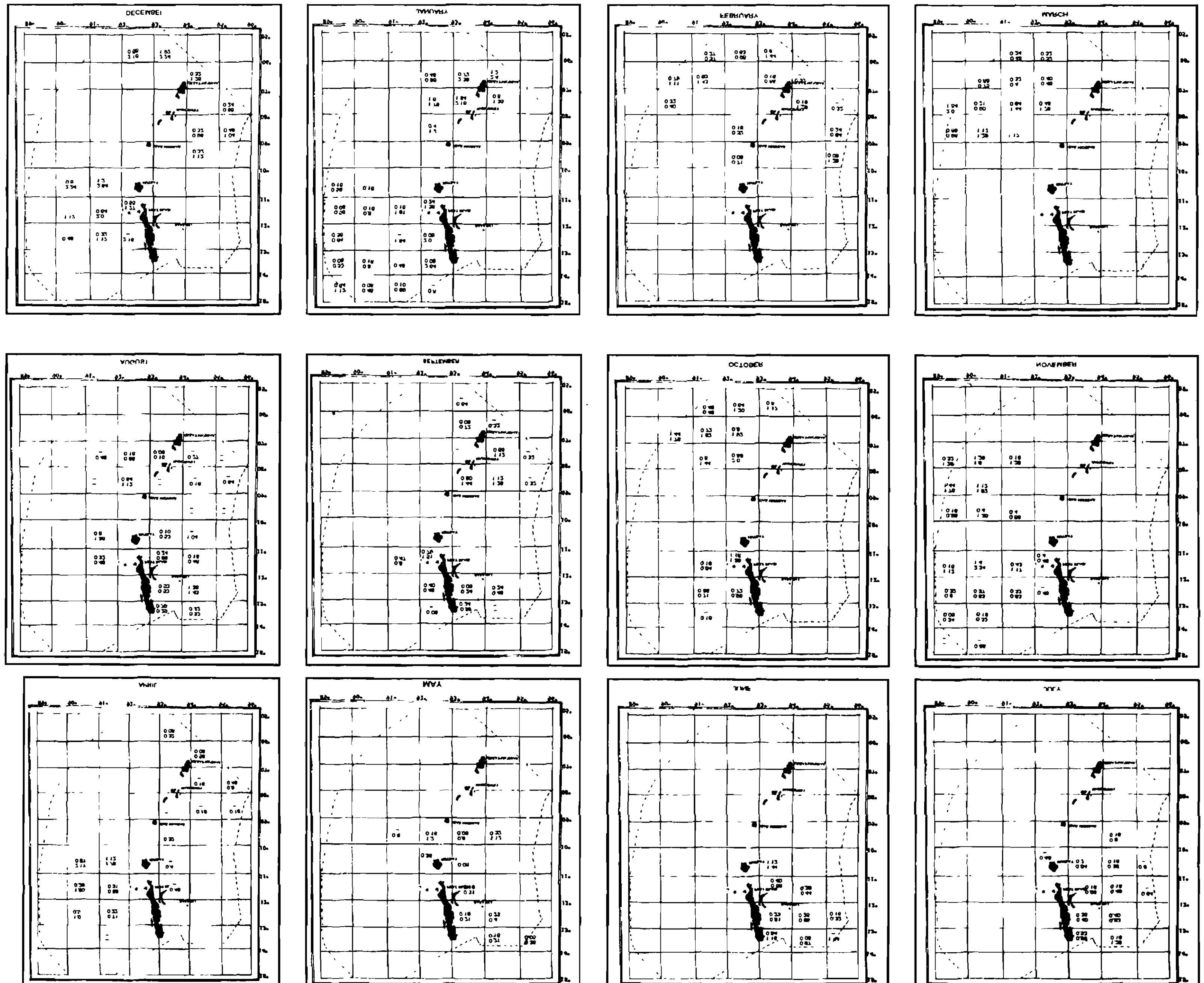
Spatio-temporal distribution of sharks indicates in the month of October March the occurrence of shark is more pronounced. In the month of October, all most in all areas the shark predominance is observed. The hooking rate of shark in the month of October has reached up to 1.44 per cent. However the maximum hooking rate of 1.92 per cent was obtained in the month of December from area 05° / 93° followed by 1.84 in January and March from area 07° / 93° and 07° / 89° respectively. The spatio-temporal distribution also indicates that May to September is a lean period for the shark occurrence. The spatio-temporal distribution of sharks is given in Fig. 8.

The fluctuation in the catch rate may be due to the fluctuation in the water temperature. The winter months of mainland i.e., December to March are characterized by relatively low temperature at mixed layer depth (26°–26.8° C) whereas high temperature (28°–29° C) prevails during April to June. It may be referred that the sea surface temperature in Andaman and Nicobar



Effort; Aggr. H.R., SKH H.R.

Fig. 7. Fishing effort and distribution of all fishes and sharks in A&N EEZ during April, 2000 March 2005



– Agg. Hooking Rate
– Shark Hooking Rage

Fig. 8. Spatio-temporal distribution of sharks in different months

water varies from 26.4° C to 31.2° C and the month mean value ranges from 27.0° C in February to 30.0° C in May. However it is clear that the temperature affects the occurrence for not only sharks but also for all the oceanic species due to the variation in the thermocline layer. Similar pattern of distribution is also reported by John and Somvanshi (2000) and John *et al.* 2005 in Andaman and Nicobar waters.

BIOLOGY

Length frequency

The data on length frequency of different species of sharks are scanty however an attempt has been made in the present study to cover up certain details. The details of length frequency is given in Fig. 9a-g. It is clear that Alopias supercilliosus, *A. pelagicus, C. sorrah, C.*

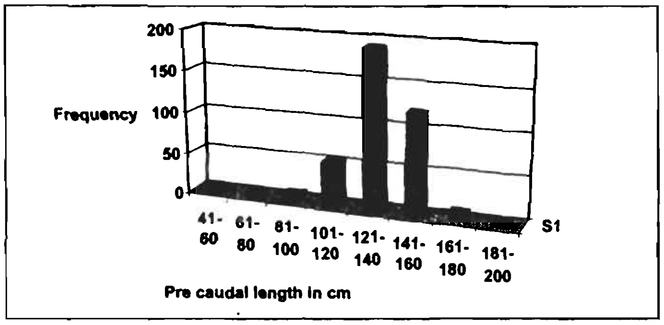


Fig. 9a. Length frequency of *A. pelagicus*

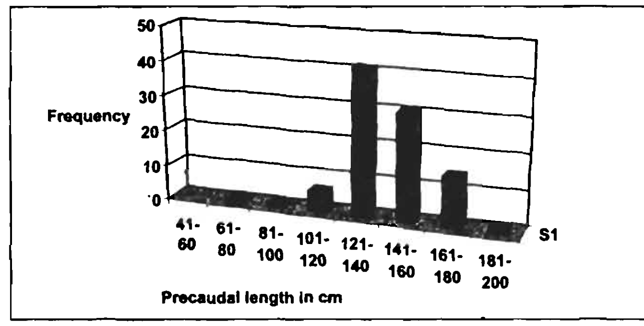


Fig. 9b. Length frequency of *A. superciliosus*

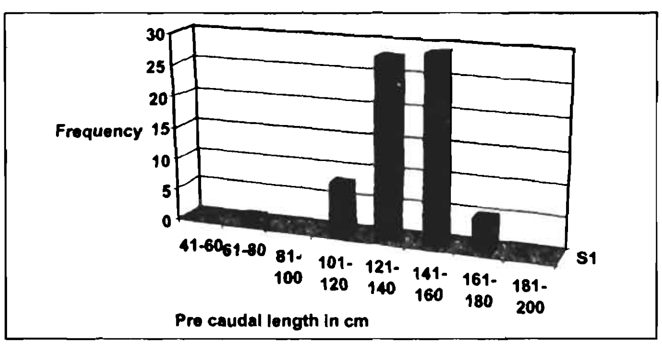


Fig. 9c. Length frequency of *A. vulpinus*

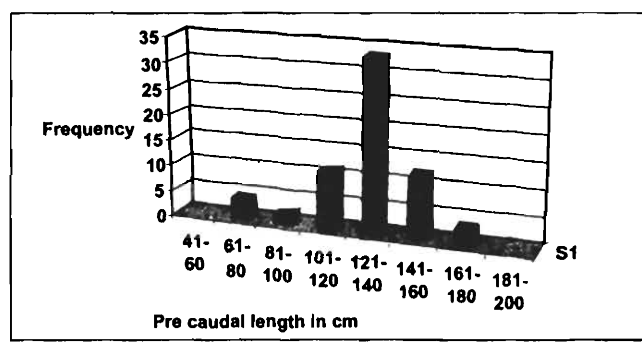


Fig. 9d. Length frequency of *C. limbatus*

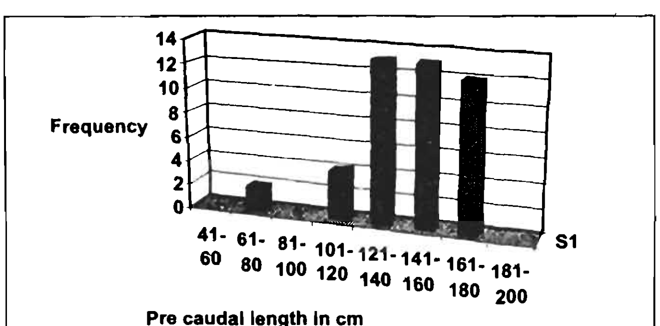


Fig. 9e. Length frequency of *C. albimarginatus*

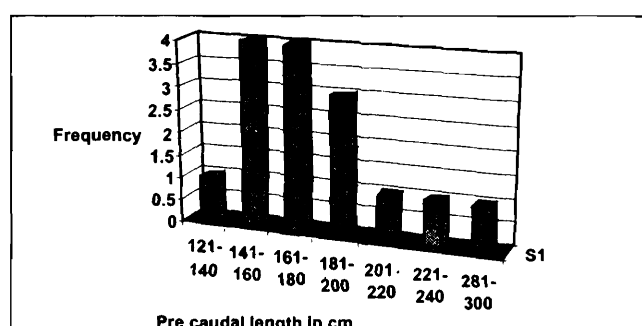


Fig. 9f. Length frequency of *G. cuvier*

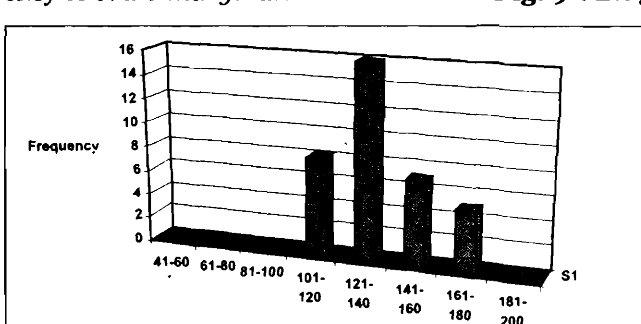


Fig. 9g. Length frequency of *C. sorrah*

albimarginatus and *C. limbatus* are frequently caught in the size range of 121-140 cm followed by 141-160 cm whereas, *A. vulpinus* are frequently occur in the size of 141-160 cm followed by 121-140 cm. *Galeoceredo cuvier* are frequently caught in the size range of 141-160 cm and 161-180 cm.

The details of size range, mean length and mean weight for all fishes, sharks are given in Table. 10. In the present study it is seen that the mean weight revolves around 40 kg for all most all specimens. The range of mean weight is in between 25.00 - 71.66 kg, whereas the mean length range is in-between 109.12 to 181.66 cm. It is important to note that in the present study the precaudal length has been taken into consideration. Similar results were also reported by John and Somvanshi, 2000 and Bhargava *et al.*, 2002.

Table 10. Mean length and Mean weight of different shark species

Species	Pre-caudal length range (in cm)	Mean length at Precaudal (in cm)	Mean weight (in kg)
A. pelagicus	53-191	134.55	36.60
A. supercilliosus	52-186	141.22	40.01
A. vulpinus	80-175	137.76	36.51
C. sorrah	107-176	142.51	41.97
C. limbatus	75-170	137.88	39.16
C. albimarginatus	78-175	128.03	31.2
G. cuvier	137-293	181.66	71.66
Isurus oxyrinchus	103-211	169.12	59.37
Sphyraena zygaena	133-197	159.14	46.42
C. longimanus	59-172	125.92	27.35
C. melanopterus	110	110	25.00
C. macloti	135-170	147.33	60.83
Scoliodon laticaudus	148-171	162.66	63.33
Rhizoprionodon acutus	113-173	144.5	30.00

Table 11. Sex ratio of different species of sharks in Andaman and Nicobar waters

Sl. No.	Species	Sex ratio (M : F)
1.	*A. pelagicus*	1 : 0.54
2.	*A. supercilliosus*	1 : 0.66
3.	*A. vulpinus*	1 : 2.55
4.	*C. sorrah*	1 : 0.85
5.	*C. longimanus*	1 : 2.25
6.	*C. melanopterus*	100 : 0
7.	*C. limbatus*	1 : 0.97
8.	*C. macloti*	1 : 0.5
9.	*C. albimarginatus*	1 : 0.25
10.	*G. cuvier*	1 : 0.66
11.	*Scoliodon laticaudus*	1 : 0.5
12.	*Rhizoprionodon acutus*	1 : 1
13.	*Isurus oxyrinchus*	1 : 1.6
14.	*Sphyraena zygaena*	1 : 2.5

Sex ratio

The study in sex ratio indicates that males are predominant in almost all the species except *A. vulpinus, C. longimanus, Isurus oxyrinchus* and *Sphyraena zygaena*. A detailed sex ratio of all the 14 varieties of sharks are given in Table 11.

DISCUSSION

The occurrence of sharks as a by-catch in long line fishery targeting the tunas indicates the ample scope and prospects for developing the resource specific fishery for sharks in Andaman and Nicobar waters. Though the fishery was more or less neglected and the resources are not estimated systematically up to the species level, if proper attention is paid the challenge can be achieved.

The hooking rates and occurrence of 14 species in regular tuna long line obtained in the survey indicates the commercially viable fishery for sharks in the area. Further the spatio-temporal distribution shows the hooking rate of above one percent in many of the areas of Nicobar waters. The month wise hooking rates obtained from all the sectors in the Exclusive Economic Zone of Andaman and Nicobar islands suggests the peak fishing season for sharks i.e., October April though the occurrence is round the year. The species mainly caught belong to the genera *Carcharhinus* and *Alopias*, which have got high demand for its fin and flesh; so the fishing of sharks in these island should be encouraged. As per the recent estimate the sharks has got a potential of about 11,200 tonnes per annum from this emerald island waters whereas the landing is less than 6 per cent on an average. The scope for exploitation is bright and it needs resource specific gear for yielding higher catch rates as also suggested by Bhargava *et al.*, (2002).

The hooking rates, the catch composition, the size range, the species composition, the distribution pattern thus amply indicates that the long line fishery for sharks can sustain in long run in the oceanic sector of Andaman and Nicobar waters. However a more detailed study on the breeding biology, food and feeding habits, growth parameters of different species is the need of the hour for taking more sustainable management and conservation measures as fishery progresses from developing to advanced stage.

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Recent Trends in Biodiversity of Andaman and Nicobar Islands, 387-398, 2010

A REVIEW OF HERPETOFAUNAL DESCRIPTIONS AND STUDIES FROM ANDAMAN AND NICOBAR ISLANDS, WITH AN UPDATED CHECKLIST

S. HARIKRISHNAN, KARTHIKEYAN VASUDEVAN* and B.C. CHOUDHURY
Wildlife Institute of India, Dehra Dun, Uttarakhand

INTRODUCTION

The Andaman and Nicobar Archipelago : The so-called 'Bay Islands' are situated in the Bay of Bengal, approximately between latitudes 7° N and 14° N, and at longitude $92^{\circ}10'$ E. These islands are considered an extension of the Arakan Yomas/ Rakhine Yoma mountain range of Myanmar, composed of a chain of submarine mountains that extend from Cape Negrais in Myanmar to Achin Head in Sumatra, the Indonesian island. The total area of the Bay Islands is about 8293 km^2, with about 6340 km^2 forming the Andamans and about 1953 km^2 in Nicobars (Das, 1996). The Andamans, composing of 291 islands in total, are further divided in to Great Andamans to the North and Little Andaman to the south. The Great Andamans is composed of North Andaman, Middle Andaman, South Andaman, and Rutland, all of which lie in a north-south direction. Ritchie's Archipelago to the east of Great Andamans is composed of the islands of Havelock, Outram, Nicholson, John Lawrence, Henry Lawrence, Inglish East, Sir Huge Ross and Neil as well as a number of much smaller islands. Little Andaman and Great Andamans are separated by 55 km of sea, the passage called Duncan Passage. Cocos Islands lie to the north of Great Andamans. The Preparis Channel separates the whole of Bay Islands from the southern tip of Myanmar. Narcondum in the Andaman sea is an extinct volcano while Barren is an active one. The archipelago of Nicobars is separated from Little Andaman by a 140 km wide Ten-Degree Channel. The Great Channel separates southern group from Mentawai islands and Sumatra. Nicobars is composed of three groups of islands, totaling 28 islands. The northern group is composed of the island of Car Nicobar and the small Islets of Balti Malv. The central group is composed of the major islands Camorta, Katchal, Teressa, Nancowry, Bompoka, Chowra, Trinkat and Tilanchong. The Sombrero Channel separates the central group from the southern group, which is composed of two relatively large islands Great Nicobar and Little Nicobar as well as smaller islands like Kondul, Pilo Milo and Menchal.

The average annual rainfall exceeds 3000 mm, but the northern islands show greater seasonal climatic variation that the southern islands. The habitats represented in the islands include bays, mangroves, moist deciduous forests and evergreen forests. Grasslands, which are probably a result of habitat degradation by human activities, also occur in some of the islands in Nicobars. Floristically, the Andamans are more similar to the Tenasserim coast of Myanmar while Nicobars seem to have flora more similar to Malay Peninsula and Archipelago (Ripley and Beehler, 1989). Various workers have discussed the faunal affinities of these islands and it is generally concluded that

*E-mail : karthik@wii.gov.in

the fauna of Andamans show greater affinities towards that of Myanmar while that of Nicobars show greater affinities towards that of Southern Peninsular Thailand, Malaysia and the Sunda Islands (Elwes, 1873; Blanford, 1901; Mani, 1974; Das, 1996; Das 1999). However, Ripley and Beehler (1989) concluded that the avifauna of Nicobars is a depauperate subset of that of Andamans.

LITERATURE ON THE HERPETOFAUNA OF ANDAMAN AND NICOBAR ISLANDS

Ninteenth century

The study of herpetofauna of Andaman and Nicobar Islands began in the middle of the 19th century when Edward Blyth published his "Notes on the Fauna of Nicobar Islands", in the erstwhile *Journal of Asiatic Society of Bengal* (Blyth, 1846). A decade later, during the "Novara Reise," more reptiles were collected from the islands, which were studied and published by Steindachner (1867). Tytler (1864) described a new species of Giant gecko *Gecko verreauxi* from Andaman (This species was recently revived from the synonymy of *Gekko smithii* Gray, 1842 by Ota *et al.*, 1991) which is endemic to Andamans. In 1870, Stoliczka made the first organized collection and study of reptiles of Andaman and Nicobars, and reported the presence of 13 species of lizards, 10 species of snakes and three species of frogs. Later, he described a new species of lizard *Tiaris humei* from Tillanchong Island in Nicobars (Stoliczka, 1873). This species is now considered a synonym of *Coryphophylax subcristatus* (Blyth, 1861). Further contributions were made by Sclater (1891).

Twentieth century

Annandale in 1904 and 1905 made some contributions. In 1935, Malcolm Smith provided an updated account of the lizards in his Fauna of British India series (Smith, 1935). Smith (1940) listed 60 species of squamate reptiles from Andaman and Nicobar Islands. Later, he listed and described 29 species of snakes from these islands (Smith, 1943). Cherchi (1954) described a Microhylid frog *Kaloula baleata ghoshi* from Little Andaman. Biswas and Sanyal (1965) described a new species of wolf snake *Lycodon tiwarii*, from Andaman and Nicobar islands. Tiwari and Biswas (1973) described a new species of Agamid lizard *Calotes danieli* (currently known as *Bronchocela danieli* (Tiwari and Biswas, 1973) and a new species of snake, *Dendrelaphis humayuni* from Great Nicobar. Whitaker (1975) reported 35 species of snakes, 28 species of lizards and nine species of amphibians from Andaman and Nicobars. Pillai (1977) reported two species of Microhylid frogs from Andamans, including a new species *Microhyla chakrapanii*. Biswas and Sanyal (1977a) reported the skink *Sphenomorphus quadrivittatum* (Peters, 1867) from Great Nicobar (The specimen was later identified as *Lipinia macrotympana* (Stoliczka, 1873) by Das (1997a)). Biswas and Sanyal (1977b) described a new species of tree skink *Dasia nicobarensis* from the island of Car Nicobar. Biswas and Sanyal (1978) described a new species of krait *Bungarus andamanensis* from Andaman. Biswas and Sanyal (1980) reported a collection of 29 squamate reptiles from Andaman and Nicobar islands. Mansukhani and Sarkar (1980) described *"Bufo" camortensis* from Camorta in Nicobars. This species was considered a synonym of *"Bufo" spinipes* Steindachner, 1867 that was the very first species of Amphibian described from Nicobars (Crombie, 1986). As pointed out by Crombie (1986), the characters used by Mansukhani and Sarkar for the recognition of *"Bufo" camortensis* fall within the range of variation exhibited by *Duttaphrynus melanostictus* Schneider, 1799. According to Dutta (1997), the taxonomic status of the toads from Nicobars is unclear, and if they belong to a species distinct from *Duttaphrynus melanostictus* Schneider, 1799 the name, *"Bufo" spinipes* Steindachner, 1867 has priority over the name *"Bufo" camortensis* Mansukhani and Sarkar, 1980. Murthy and Chakrapani (1983) rediscovered the blind snake *Typhlops oatesii* Boulenger, 1890 that was originally described from Table Island, Cocos Group north of Andamans, from Middle Andaman. Mehta and Rao (1987) reported *Microhyla heymonsi* Vogt, 1911 from Great Nicobar. Sarkar (1990) in his review listed nine species of Amphibians from Nicobars. Pillai (1991) recorded *Fejervarya cancrivora* from the islands. Ratnam (1993) provided information on the natural history of the Andaman day gecko *Phelsuma andamanense*. Tiwari (1992) reported the sunbeam snake *Xenopeltis unicolor* Reinwardt, 1827 from Great Nicobar. Das (1994) listed 17 species of amphibians, 31 species of lizards and 39 species of snakes from Andaman and Nicobar Islands. Das and Chandra (1994) added two more species of snakes to the fauna; *Boiga cyaneum*

(Dumeril and Bibron, 1864) from Great Nicobar and *Microcephalophis cantoris* Gunther, 1864 from Andaman. Das (1995) described a new tree frog, *Polypedates insularis* from Great Nicobar. The population of cobras from Andamans previously considered as conspecific with *Naja kaouthia* Lesson in Ferussac, 1831 was elevated by Wuster *et al.* (1995) to the level of species, as *Naja sagittifera* Wall, 1913. Das (1996a) described a new species of Ranid frog, *Limnonectes shompenorum* and reported the presence of another frog *Hylarana chalconota* (Schlegel, 1837) from Great Nicobar (Das, 1996b). Das (1996d) revived *Dibamus nicobaricus* (Fitzinger in Steindachner, 1867) from the synonymy of *Dibamus leucrurus* (Bleeker, 1860) and considered the former as endemic to Nicobars. Daniels and David (1996) reported eight species of frogs, six species of lizards and six species of snakes from Great Nicobar. In 1997, Das described a new species of gecko, *Cyrtodactylus adleri* from the island of Great Nicobar (Das, 1997a). Das (1997b) rediscovered the skink *Lipinia macrotympana* (Stoliczka, 1873) from the islands of Little Nicobar and Great Nicobar. This species was originally described based on a single specimen collected from South Andaman by Stoliczka (1873). Das (1998) described a new species of frog *Ingerana charlsdarwini* from Mount Harriet in Andamans. Das (1999) listed 40 species of squamate reptiles and 12 species of amphibians from Andamans and, 37 species of reptiles and 11 species of amphibians from Nicobars.

Twenty first century

Das and Gemel (2000) confirmed the existence of the largely Malayan species *Bronchocela cristatella* from the island of Car Nicobar. Ghodke and Andrews (2001a and 2001b) recorded the snakes *Cantoria violacea* (Girard, 1857) from North and Middle Andamans and *Enhydris plumbea* (Boie, 1827) from Great Nicobar. Based on collections from 15 islands in the Nicobars, Vijayakumar (2005) recorded 24 species of lizards, 14 species of snakes and 10 species of amphibians, including several suspected new species. Based on this survey and previous collections for which voucher specimens are available, Vijayakumar and David (2006) listed 22 species of snakes from Nicobar Islands.

The accompanying checklists are updated accounts (Appendix 1 & 2) of the amphibians and reptiles reported from Andaman and Nicobar Islands, with a few comments (Appendix 3). It is largely based on published literature, especially Das (1996 and 1999) and Frost (2008) along with personal observations. The sources cited are only the most recent or particularly relevant ones and do not cover the bibliography on that species. The reference list covers several other papers that deal with various aspects of the biology of frogs, lizards and snakes of Andaman and Nicobar Islands.

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Appendix 1. Checklist of reptiles and amphibians in Andamans

REPTILES

Sl. No.	Gekkonidae	Source
1	*Cnemaspis aff. kandianus* (Kelaart, 1852)	Das, 1999
2	*Cosymbotus aff. platyurus* (Schneider, 1792)	Das, 1999; Pers. Obs.
3	*Gehyra mutilata* (Weigmann, 1853)	Das, 1999
4	*Gekko verreauxi* (Tytler, 1864)[1]	Ota *et al.* 1991; Das, 1999; Pers. Obs.
5	*Cyrtodactylus rubidus* (Blyth, "1860", 1861)	Das, 1999; Pers. Obs.
6	*Hemidactylus frenatus* Dumeril and Bibron, 1836	Das, 1999; Pers. Obs.
7	*Lepidodactylus lugubris* (Dumeril and Bibron, 1836)	Das, 1999; Pers. Obs.
8	*Phelsuma andamanense* Blyth, "1860", 1861	Das, 1999; Pers. Obs.
	Agamidae	
9	*Calotes versicolor* (Daudin, 1802)	Das, 1999; Pers. Obs.
10	*Coryphophylax subcristatus* (Blyth, "1860", 1861)	Das, 1999; Pers. Obs.
	Scincidae	
11	*Lipinia macrotympana* (Stoliczka, 1873)	Das, 1997; Das, 1999
12	*Lygosoma aff. bowringii* (Gunther, 1864)	Das, 1999
13	*Mabuya andamanensis* Smith, 1935	Das, 1999; Pers. Obs.
14	*Mabuya tytleri* (Theobald, 1868)	Das, 1999; Pers. Obs.
15	*Sphenomorphus indicus*	Das, 1999; Pers. Obs.
	Varanidae	
16	*Varanus salvator* (Laurenti, 1768) [2]	Deraniyagala, 1961; Das, 1999; Pers. Obs.
	Typhlopidae	
17	*Ramphotyphlops braminus* (Daudin, 1803)	Das, 1999.
18	*Typhlops andamanensis* Stoliczka, 1871	Das, 1999
19	*Typhlops oatesi* Boulenger, 1890	Murthy and Chakrapani, 1983; Das, 1999
	Achrochordidae	
20	*Acrochordus granulatus* (Schneider, 1779)	Das, 1999
	Colubridae	
21	*Boiga andamanensis* (Wall, 1909)	Das, 1999; Pers. Obs.
22	*Boiga ochracea walli* Smith, 1943[3]	Smith, 1943; Das, 1999
23	*Cantoria violacea* Girard, 1857	Das, 1999
24	*Cerberus rynchops* (Schneider, 1799)	Das, 1999; Pers. Obs.
25	*Chrysopelea paradisi* Boie, 1827	Das, 1999
26	*Dendrelaphis pictus andamanensis* (Anderson, 1871) [4]	Gernot Vogel Pers. Comm. ; Pers. Obs.
27	*Coelognathus flavolineatus* (Schlegel, 1837)	Das, 1999
28	*Gonyosoma oxycephalum* (Boie, 1827)	Das, 1999

* *Dendrelaphis cyanochloris*

Appendix 1. *Contd.*

Sl. No.	Gekkonidae	Source
29	*Lycodon capucinus* (Boie, 1827)	Das, 1999
30	*Lycodon tiwarii* Biswas and Sanyal, 1965[5] Vijayakumar and David, 2006; Pers. Obs.	Biswas and Sanyal, 1965; Das, 1999;
31	*Ptyas mucosa* (Linnaeus, 1758)	Das, 1999; Pers. Obs.
32	*Xenochrophis melanzostus* (Gravenhorst, 1807) [6]	Das, 1999; Pers. Obs.
	Elapidae	
33	*Bungarus andamanensis* Biswas and Sanyal, 1978	Das, 1999; Pers. Obs.
34	*Naja sagittifera* Wall, 1913	Das, 1999
35	*Ophiophagus hannah* (Cantor, 1836)	Das, 1999
	Hydrophidae	
36	*Laticauda colubrina* (Schneider, 1799)	Das, 1999
37	*Laticauda laticaudata* (Linnaeus, 1758)	Das, 1999
38	*Pelamis paturus* (Linnaeus, 1766)	Das, 1999
39	*Microcephalophis cantoris* (Gunther, 1864)	Das and Chandra, 1994
	Viperidae	
40	*Cryptelytrops andersoni* (Theobald, 1868)	Das, 1999; Pers. Obs.

AMPHIBIANS

Sl. No.	Dicroglossidae	Source
1	*Fejervarya andamanensis*(Stoliczka, 1870)	Frost, 2008; Das, 1999
2	*Fejervarya limnocharis* (Gravenhorst, 1829)	Frost, 2008; Das, 1999
3	*Limnonectes hascheanus* (Stoliczka, 1870)	Frost, 2008; Das, 1999
4	*Ingerana charlesdarwini* (Das, 1998)	Frost, 2008; Das, 1999
	Microhylidae	
5	*Kaloula baleata* (Müller in Van Oort and Müller, 1833)	Frost, 2008; Das, 1999; Pers. Obs.
6	*Microhyla chakrapanii* Pillai, 1977	Frost, 2008; Das, 1999
7	*Micryletta inornata* (Boulenger, 1890)	Frost, 2008; Das, 1999
	Bufonidae	
8	*Duttaphrynus melanostictus* Schneider, 1799	Frost, 2008; Das, 1999; Pers. Obs.

Appendix 2. Checklist of reptiles and amphibians from Nicobar

REPTILES

Sl. No.	Gekkonidae	Source
1	*Cnemaspis aff. kandianus* (Kelaart, 1852)	Das, 1999; Pers. Obs.
2	*Cosymbotus patyurus* (Schneider, 1792)[7]	Das, 1999; Tiwari and Biswas, 1973
3	*Cyrtodactylus adleri* Das, 1998	Das, 1998; Pers. Obs.
4	*Gehyra mutilata* (Weigmann, 1835)	Das, 1999; Pers. Obs.
5	*Gekko smithii* (Gray, 1842)	Das, 1999; Pers. Obs.
6	*Hemidactylus frenatus* Dumeril and Bibron, 1836	Das, 1999; Pers. Obs.
7	*Hemidactylus garnotii*	Vijayakumar, 2005
8	*Hemiphyllodactylus typus* Bleeker, 1860	Das, 1999
9	*Ptychozoon kuhli* Stejneger, 1902	Das, 1999; Pers. Obs.
	Agamidae	
10	*Bronchocela cristatella* (Kuhl, 1820)	Das, 1999; Pers. Obs.
11	*Bronchocela danieli* (Tiwari and Biswas, 1973)	Das, 1999; Pers. Obs.
12	*Calotes versicolor* (Daudin, 1802)	Pers. Obs.
13	*Calotes andamanensis* (Boulenger, 1891)[8]	Smith, 1943
14	*Coryphophylax subcristatus* (Blyth, "1860", 1861)	Das, 1999; Pers. Obs.
	Scincidae	
15	*Dasia nicobarensis* Biswas and Sanyal, 1977	Das, 1999; Pers. Obs.
16	*Dasia olivacea* Gray, 1839	Das, 1999; Pers. Obs.
17	*Lipinia macrotympana* (Stoliczka, 1873)	Das, 1997; Das, 1999
18	*Mabuya rudis* (Boulenger, 1887)	Das, 1999; Pers. Obs.
19	*Mabuya rugifera* (	Vijayakumar, 2005; Pers. Obs,
20	*Mabuya multifasciata* (Kuhl, 1820)	Vijayakumar, 2005; Pers. Obs.
21	*Scincella macrotis* (Fitzinger in Steindachner, 1867)	Das, 1999; Vijayakumar, 2005
22	*Sphenomorphus maculatus* (Blyth, 1853)	Vijayakumar, 2005; Pers. Obs.
	Dibamidae	
23	*Dibamus nicobaricus* (Fitzinger in Steindachner,1867)	Das, 1999; Vijayakumar, 2005
	Varanidae	
24	*Varanus salvator* (Laurenti, 1768)	Vijayakumar, 2005; Pers. Obs.
	Typhlopidae	
25	*Rhamphotyphlops braminus* (Daudin, 1803)	Vijayakumar, 2005; Pers. Obs.
	Acrochordidae	
26	*Acrochordus granulatus* (Schneider, 1779)	Das, 1999
	Xenopeltidae	
27	*Xenopeltis unicolor* Reinwardt in Boie, 1827	Das, 1999; Pers. Obs.
	Boidae	
28	*Python reticulatus* (Schneider, 1801)	Vijayakumar, 2005; Pers. Obs.
	Colubridae	
29	*Amphiesma nicobariense* (Sclater, 1891)	Sclater, 1891; Das, 1999

Appendix 2. *Contd.*

Sl. No.	Gekkonidae	Source
30	*Boiga cyanea* (Dumeril and Bibron, 1854)	Das and Chandra, 1994; Das, 1999
31	*Boiga wallachi* Das, 1998	Das, 1998; Pers. Obs.
32	*Cerberus rhynchops* (Schneider, 1799)	Vijayakumar, 2005; Pers. Obs.
33	*Coelognathus* sp. [9]	Pers. Obs.
34	*Dendrelaphis humayuni* Tiwari and Biswas, 1973[10]	Vijayakumar and David, 2006; Pers. Obs.
35	*Gongylosoma nicobarense* (Stoliczka, 1870)	Das, 1999; Vijayakumar and David, 2006
36	*Lycodon subcinctus* Boie, 1827	Pers. Obs.
37	*Lycodon tiwarii* Biswas and Sanyal, 1965[11]	Vijayakumar and David, 2006; Pers. Obs.
38	*Oligodon woodmasoni* (Sclater, 1891)	Das, 1999; Vijayakumar and David, 2006
39	*Sibynophis bistrigatus* (Gunther, 1868)	Smith, 1943; Das, 1999; Vijayakumar and David, 2006
40	*Xenochrophis trianguligerus* (Boie, 1827)	Vijayakumar and David, 2006; Pers. Obs.
41	*Enhydris plumbea* (Boie, 1827)	Ghodke and Andrews, 2001b
	Hydrophidae	
42	*Laticauda colubrina* (Schneider, 1799)	Das, 1999; Pers. Obs.
43	*Pelamis platurus* (Linnaeus, 1766)	Vijayakumar and David 2006; Pers. Obs.
	Viperidae	
44	*Cryptelytrops andersoni* (Theobald, 1868)	Vijayakumar and David, 2006
45	*Cryptelytrops cf. albolabris* (Gray, 1842)[12]	Vijayakumar and David, 2006; Pers. Obs.
46	*Cryptelytrops cantorii* (Blyth, 1846)	Das, 1999; Vijayakumar and David, 2006
47	*Cryptelytrops labialis* (Fitzinger in Steindachner, 1867)	Vijayakumar and David, 2006; Pers. Obs.

AMPHIBIANS

Sl. No.	Dicroglossidae	Source
1	*Fejervarya cancrivora* (Gravenhorst, 1829)	Frost, 2008; Das, 1999
2	*Fejervarya nicobariensis* (Stoliczka, 1870)	Frost, 2008; Das, 1999
3	*Limnonectes doriae* (Boulenger, 1887)	Frost, 2008; Das, 1999
4	*Limnonectes shompenorum* Das, 1998	Frost, 2008; Das, 1999; Pers. Obs.
5	*Microhyla heymonsi* Vogt, 1911	Frost, 2008; Das, 1999; Pers. Obs.
	Ranidae	
6	*Hylarana chalconota* (Schlegel, 1837)	Frost, 2008; Das, 1999; Pers. Obs.
7	*Hylarana erythraea* (Schlegel, 1837)	Frost, 2008; Das, 1999; Pers. Obs.
8	*Hylarana nicobariensis* (Stoliczka, 1870)	Frost, 2008; Das, 1999; Pers. Obs.
	Rhacophoridae	
9	*Polypedates insularis* Das, 1995	Frost, 2008; Das, 1999; Pers.Obs.
	Bufonidae	
10	*Duttaphrynus melanostictus* Schneider, 1799	Frost, 2008; Das, 1999; Pers. Obs.

APPENDIX–3

1. This species was revived from the synonymy of Gekko smithii (Gray, 1842) by Ota *et al.* 1991.
2. Deraniyagala (1961) has described the population from Andaman Islands as a distinct subspecies Varanus salvator andamanensis.
3. Although the specimens from Andaman are thought to be of B. ochracea walli, it is more likely to be the southern form Boiga ochracea ochracea (Smith, 1943; Das, 1999)
4. There is a fair amount of confusion regarding the status of this species. Smith (1943) gave the range of the species Dendrelaphis pictus andamanensis (as Ahaetulla ahaetulla andamanensis) as "The Andamans" which is also the type locality. Das (1996 and 1999) considered this species to be endemic to Nicobars. However, Vijayakumar and David (2006) found specimens of only one species of *Dendrelaphis* from Nicobars, which they identified as *Dendrelaphis humayuni* Tiwari and Biswas, (1973). Our own fieldwork in Great Nicobar supports the conclusion of Vijayakumar and David (2006) and we regard *Dendrelaphis pictus andamanensis* (Anderson, 1871) to be restricted to Andamans. According to Gernot Vogel (pers. com.), there is no *Dendrelaphis pictus* or *Dendrelaphis cyanochloris* in Andaman. All the specimens from Andaman islands should be referred to the species *Dendrelaphis andamanensis* which was described as a subspecies of *Dendrelaphis pictus* by Anderson in 1871 (as *Dendrophis picta var. andamanensis*).
5. The type locality of this species is "Mayabunder, North Andaman" according to Biswas and Sanyal (1965). The paratype was donated by the Government Hospital in Car Nicobar. Das (1999) considered this species to be endemic to Andamans. Vijayakumar and David (2006) reported this species from the central group of islands in Nicobars. We recorded this species from Car Nicobar in April, 2008. There is no record of this species from Andamans since its original description.
6. Das, 1999 listed this species from Nicobars. However, an extensive survey by Vijayakumar and David (2006) failed to collect any specimens from Nicobars. This species is one of the most common snakes in localities from where it is known with certainty (Andamans) and so, it seems unlikely that it occurs in Nicobars.
7. Tiwari and Biswas, 1973 report, "The paratype of *Dendrelaphis humayuni* was collected below a tree while devouring a lizard identified as *Platyurus platyurus* (Schneider)" As far as we know, this is the only report of this species from Nicobar.
8. Ishwar and Das, 1998 considered the record of *Calotes andamanensis* Boulenger, 1891 to be erroneous and concluded that this species is naturally distributed in southern Western Ghats. However, the population in Western Ghats belong to a new species being described by Shreyas Krishnan (*in press*).
9. Daniels and David (1996) reported *Coelognathus flavolineatus* from Great Nicobar Biosphere Reserve. Owing to the lack of voucher specimens, this species was omitted from subsequent checklists. We found a *Coelognathus sp.* in Great Nicobar Biosphere Reserve in June, 2008. A detailed study and collection of new specimens is required before the identity of the population from Great Nicobar can be confirmed.
10. This species was omitted from the checklist by Das (1999) who considered the specimens from Nicobars to be *Dendrelaphis pictus andamanensis* (Anderson, 1871). *Dendrelaphis humayuni* Tiwari and Biswas, 1973 is the only species of *Dendrelaphis* known with certainty from Nicobars. For a discussion, see Vijayakumar and David (2006)
11. The type locality of this species is "Mayabunder, North Andaman" according to Biswas and Sanyal (1965). The paratype was donated by the Goverment Hospital in Car Nicobar. Das (1999) considered this species to be endemic to Andamans. Vijayakumar and David (2006) reported this species from the central group of islands in Nicobars. We

recorded this species from Car Nicobar in April, 2008. There is no record of this species from Andamans since its original description.

12. The first specimens, three males and three females were collected by Lord Moyne's expedition as is mentioned in Smith (1943). Smith remarked upon the absence of light ventrolateral stripe that is typical of *Trimeresurus albolabris* Gray, 1842 males from other parts of its distribution. Subseqent authors overlooked these specimens and omitted the species from checklists. Vijayakumar and David (2006) recorded a single specimen from Car Nicobar which they identified as *Trimeresurus albolabris* Gray, 1842 based on morphological characters. We encountered two individuals of this species in Car Nicobar, both of which lacked the light ventrolateral stripe as mentioned by Smith (1943). This consistent difference between the island population and mainland population requires further examination. We feel that a more thorough examination of this population, perhaps at molecular level, is necessary to assess its specific status.

Chapter 34

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 399-414, 2010

AVIFAUNA OF ANDAMAN AND NICOBAR ISLANDS : A REVIEW

C. SIVAPERUMAN*, C. VENKATRAMAN, C. RAGHUNATHAN, RAMAKRISHNA*****

Zoological Survey of India, Andaman and Nicobar Regional Centre, Port Blair-744 102 Andaman and Nicobar Islands

INTRODUCTION

The Andaman and Nicobar Islands, popularly known as 'Bay Islands' are situated in the Bay of Bengal, mid way between peninsular India and Mayanmar, spreading like a broken necklace in the North-south direction. These islands are located between 6°45′ and 13°41′ N and 92°12′ and 93°57′ E. There are 572 islands lies 193 km away from Cape Negrais in Myanmar, 1255 km from Kolkata and 1190 km from Chennai. Total geographic area of Andaman and Nicobar Islands is 8249 km^2, of which Andaman group of islands cover 6408 km^2 while Nicobar group cover 1841 km^2. Out of 572 islands, 37 islands (24 in Andaman and 13 in Nicobar group of islands) are inhabited by human beings. The two important groups of islets are Ritchie's Archipelago and Labyrinth Islands. The islands attain maximum altitude at Saddle Peak (730 m), formed mainly of limestone, sandstone, and clay. Two islands of volcanic origin are found in the Narcondum and the Barren islands. The former is now apparently extinct while the latter is still active. The climate is typical of tropical islands of similar latitude. It is always warm, but with sea-breezes. Rainfall is irregular, but usually dry during the north-east, and wet during the south-west, monsoons.

The Andaman and Nicobar Islands comes under the zone of tropical rain forest of the world. The tropical hot and humid climate with abundant rains has resulted in very luxuriant and rich vegetation in these islands. According to Champion and Seth (1968), the forests of islands can be classified as follows : giant evergreen, Andaman tropical evergreen, southern hill top tropical evergreen, Andaman semi evergreen, Andaman moist deciduous, littoral and mangrove forest.

Scientific studies on the birds of Andaman and Nicobar Islands commenced with listing the avifauna by Blyth (1845, 1846, 1863 and 1866) followed Beavan (1867), Hume (1873, 1874a, 1874b, 1876), Butler (1899a, 1899b, 1899c, 1900). Later, Bombay Natural History Society, conducted many avifaunal surveys in the Andaman and Nicobar Islands (Abduali, 1964, 1965, 1967, 1971, 1976, 1979, and 1981). Zoological Survey of India also carried out several surveys (Das, 1971; Tikader, 1984; Mukherjee and Dasgupta, 1975; Dasgupta, 1976; Saha and Dasgupta, 1980; Mukherjee, 1981; Chandra and Rajan, 1996) and Pande *et al.* (2007). Recently various researchers have been studied the population of ecology of particular species *e.g.* Nicobar Magapode (Sankaran, 1995a, 1995b, and 1995c), Andaman Teal (Vijayan, 1996), Edible-Nest Swiftlets

*E-mail : c_sivaperuman@yahoo.co.in
**Marine Biological Centre, Zoological Survey of India Chennai-600 028 E-mail: cvramanmbs@yahoo.com
***Zoological Survey of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata 700 053

(Sankaran, 2001), Narcondam Hornbill (Yahya and Zarri, 2003).

Though, many surveys were conducted in the past, there is no complete list of avifauna of Andaman and Nicobar Islands are available. Therefore, an attempt has been made to compile the list of avifauna based on the field surveys and published literature. Birds were classified as migratory or resident species based on Ali and Ripley (1983). The Common and scientific names are after Manakadan and Pittie (2001).

RESULTS AND DISCUSSION

A total of two hundred and eight four taxa of birds were recorded from Andaman and Nicobar Islands, belonging 56 Families under 17 Orders (Table 1). Of which, 155 species were residents, 58 were local migrants, 64 were trans-continental migrants, 6 were Vagrant and one species is a straggler. The Order Passeriformes was the dominant group followed by Charadriiformes, Falconiformes, and Corafiiformes (Table. 2).

Table 1. List of birds of Andaman and Nicobar Islands

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
	Procellariiformes				
	Hydrobatidae				
1.	Wilson's Storm-Petrel	*Oceanites oceanicus* (Kuhl)	R	√	
2.	Black-bellied Storm-Petrel	*Fregetta tropica* (Gould)	V	√	
	Pelecaniformes				
	Phaethontidae				
3.	Grey-backed Tropicbird	*Phaethon aethereus* Linnaeus	R	√	
4.	Red-tailed Tropicbird	*Phaethon rubricauda* Boddaert	R		√
5.	Yellow-billed Tropicbird	*Phaethon lepturus* Daudin	R	√	√
	Pelecanidae				
6.	Spot-billed Pelican	*Pelecanus philippensis* Gmelin	RM		√
	Sulidae				
7.	Red-footed Booby	*Sula sula* (Linnaeus)	M	√	
	Fregatidae				
8.	Lesser Frigatebird	*Fregata ariel* (G.R. Gray)	R	√	
	Ciconiiformes				
	Ardeidae				
9.	Little Egret	*Egretta garzetta* (Linnaeus)	R	√	√
10.	Pacific Reef-Egret	*Egretta sacra* (Gmelin)	RM	√	√
11.	Great-billed Heron	*Areda sumatrana* Raffles	R		√
12.	Purple Heron	*Ardea purpurea* Linnaeus	RM	√	√
13.	Grey Heron	*Ardea cinerea* Linnaeus	RM	√	√
14.	Large Egret	*Casmerodius albus* (Linnaeus)	RM	√	
15.	Median Egret	*Mesophoyx intermedia* (Wagler)	RM	√	√
16.	Cattle Egret	*Bubulcus ibis* (Linnaeus)	RM	√	√
17.	Indian Pond-Heron	*Ardeola grayii* (Sykes)	R	√	√
18.	Chinese Pond-Heron	*Ardeola bacchus* (Bonaparte)	RM	√	
19.	Little Green Heron	*Butorides striatus* (Linnaeus)	R	√	√
20.	Black-crowned Night-Heron	*Nycticorax nycticorax* (Linnaeus)	R	√	√
21.	Malayan Night-Heron	*Gorsachius melanolophus* (Raffles)	RM	√	
22.	Yellow Bittern	*Ixobrychus sinensis* (Gmelin)	RM	√	√
23.	Chestnut Bittern	*Ixobrychus cinnamomeus* (Gmelin)	RM	√	√

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
	Anseriformes				
	Anatidae				
24.	Lesser Whistling-Duck	*Dendrocygna javanica* (Horsfield)	R	√	√
25.	Cotton Teal	*Nettapus coromandelianu* (Gmelin)	R	√	
26.	Brahminy Shelduck	*Tadorna ferruginea* (Pallas)	RM	√	
27.	Mallard	*Anas platyrhynchos* Linnaeus	RM	√	
28.	Andaman Teal	*Anas gibberifrons* (Muller)	R	√	
29.	Common Teal	*Anas crecca* Linnaeus	M	√	√
30.	Spot-billed Duck	*Anas poecilorhyncha* J.R. Forester	RM	√	
	Falconiformes				
	Accipitridae				
31.	Black Baza	*Aviceda leuphotes* (Dumont)	RM	√	
32.	Andaman Blackcrested Baza	*Aviceda leuphotes andamanica* Abdulali	R	√	
33.	Black Kite	*Milvus migrans* (Boddaert)	R	√	
34.	Brahminy Kite	*Haliastur indus* (Boddaert)	R	√	
35.	White-bellied Sea-Eagle	*Haliaeetus leucogaster* (Gmelin)	R	√	√
36.	Greater Grey-headed Fish Eagle	*Ichthyophaga ichthyaetus* (Horsfield)	R	√	
37.	Andaman Serpent-Eagle	*Spilornis cheela davisoni* Hume	R	√	√
38.	Nicobar Crested Serpent-Eagle	*Spilornis cheela minimus* Hume	R		√
39.	Malayan Serpent-Eagle	*Spilornis cheela malayensis* (Swann)	R		√
40.	Great Nicobar Crested Serpent Eagle	*Spilornis klossi* Richmond	R		√
41.	Andaman Serpent-Eagle	*Spilornis elgini* (Blyth)	R	√	
42.	Western Marsh-Harrier	*Circus aeruginosus* (Linnaeus)	M	√	√
43.	Pallid Harrier	*Circus macrourus* (S.G. Gmelin)	M	√	
44.	Montagu's Harrier	*Circus pygargus* (Linnaeus)	M	√	
45.	Kachal Shikra	*Accipiter badius obsoletus* (Richmond)	R		√
46.	Nicobar Sparrowhawk	*Accipiter butleri* (Gurney)	R		√
47.	Car Nicobar Sparrowhawk	*Accipiter badius* (Gmelin)	R		√
48.	Chines Sparrowhawk	*Accipiter soloensis* (Horsfield)	M	√	√
49.	Besra Sparrowhawk	*Accipiter virgatus* (Temminck)	RM	√	√
50.	Eurasian Sparrowhawk	*Accipiter nisus* (Linnaeus)	M	√	
51.	Black Eagle	*Ictinaetus malayensis* (Temminck)	R		
52.	Changeable Hawk-Eagle	*Spizaetus cirrhatus andamensis* (Gmelin)	R	√	
	Pandionidae				
53.	Osprey	*Pandion haliaetus* (Linnaeus)	RM	√	
	Falconidae				
54.	Lesser Kestrel	*Falco naumanni* Fleischer	M	√	
55.	Common Kestrel	*Falco tinnunculus* Linnaeus	RM	√	

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
56.	Saker	*Falco cherrug* J.E. Gray	R		
57.	Peregrine Falcon	*Falco peregrinus* Tunstall	M	√	√
58.	Shaheen Falcon	*Falco peregrinus peregrinator* Sundevall	R		√
	Galliformes				
	Megapodiidae				
59.	North Nicobar Megapode	*Megapodius frycinet nicobariensis* Blyth	R		√
60.	South Nicobar Megapode	*Megapodius freycinet abbotti* Obserholser	R		
	Phasianidae				
61.	Grey Francolin	*Francolinus pondicerianus* (Gmelin)	R	√	
62.	Blue-breasted Quail	*Coturnix chinensis* (Linnaeus)	R		√
63.	Indian Peafowl	*Pavo cristatus* Linnaeus	R	√	
	Gruiformes				
	Turnicidae				
64.	Yellow-legged Button Quail	*Turnix tanki blanfordii* Blyth	R	√	√
65.	Indian Yellow-legged Button Quail	*Turnix tanki tanki* Blyth	R	√	√
	Rallidae				
66.	Andaman Crake	*Rallina canningi* (Blyth)	R	√	
67.	Blue-breasted Rail	*Gallirallus striatus* Linnaeus	R	√	√
68.	Nicobar Blue-breasted Rail	*Gallirallus striatus nicobariensis* Abdulali	R		√
69.	Andaman White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant)	R	√	√
70.	White-breasted Waterhen	*Amaurornis phoenicurus leucocephalus* Abdulali	R		√
71.	Baillon's Crake	*Porzana pusilla* (Pallas)	RM	√	
72.	Water Cock	*Gallicrex cinerea* (Gmelin)	R	√	√
73.	Purple Moorhen	*Porphyrio porphyrio* (Linnaeus)	R	√	√
74.	Common Moorhen	*Gallinula chloropus* (Linnaeus)	RM	√	
	Charadriiformes				
	Charadriidae				
75.	Pacific Golden-Plover	*Pluvialis fulva* (Gmelin)	M	√	√
76.	Grey Plover	*Pluvialis squatarola* (Linnaeus)	M	√	√
77.	Little Ringed Plover	*Charadrius dubius* Scopoli	RM	√	
78.	Lesser Sand Plover	*Charadrius mongolus* Pallas	RM	√	√
79.	Greater Sand Plover	*Charadrius leschenaultia* Lesson	M	√	√
80.	Caspian Plover	*Charadrius asiatucus* Pallas	V	√	
81.	Kentish Plover	*Charadrius alexandrinus* Linnaeus	RM	√	
82.	Grey-headed Lapwing	*Venellus cinereus* (Linnaeus)	M	√	
	Scolopacidae				
83.	Pintail Snipe	*Gallinago stenura* (Bonaparte)	M	√	√

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
84.	Great Snipe	*Gallinago media* (Latham)	V	√	
85.	Swinhoe's Snipe	*Gallinago megala* Swinhoe	M	√	
86.	Common Snipe	*Gallinago gallinago* (Linnaeus)	RM	√	
87.	Jack Snipe	*Lymnocryptes minimus* (Brunnich)	M	√	
88.	Bar-tailed Godwit	*Limosa lapponica* (Linnaeus)	M		√
89.	Eastern Whimbrel	*Numenius phaeopus variegates* (Scolopi)	M	√	
90.	Whimbrel	*Numenius phaeopus phaeopus* (Linnaeus)	M	√	
91.	Eurasian Curlew	*Numenius arauata* (Linnaeus)	M	√	√
92.	Common Redshank	*Tringa totanus* (Linnaeus)	M	√	√
93.	Common Greenshank	*Tringa nebularia* (Gunner)	M	√	√
94.	Green Sandpiper	*Tringa ochropus* Linnaeus	M	√	
95.	Wood Sandpiper	*Tringa glareola* Linnaeus	M	√	
96.	Terek Sandpiper	*Xenus cinereus* (Guldenstadt)	M	√	√
97.	Common Sandpiper	*Actitis hypoleucos* Linnaeus	M	√	√
98.	Ruddy Turnstone	*Arenaria interpres* (Linnaeus)	M	√	√
99.	Great Knot	*Calidris tenuirostris* (Horsfield)	M	√	
100.	Little Stint	*Calidris minuta* (Leisler)	M	√	
101.	Rufos-necked Stint	*Calidris ruficollis* (Pallas)	M	√	√
102.	Temminck's Stint	*Calidris temminckii* (Leisler)	M	√	
103.	Long-toed Stint	*Calidris subminuta* (Middendorff)	M	√	
104.	Curlew Sandpiper	*Calidris ferrugines* (Pontoppidan)	M		
105.	Broad-billed Sandpiper	*Limicola falcinellus* (Pontoppidan)	M	√	√
106.	Sanderling	*Calidris alba* (Pallas)	M		
	Dromadidae				
107.	Crab-Plover	*Dromas ardeola* Paykull	M	√	√
	Burhinidae				
108.	Beach Stone-Plover	*Esacus magnirostris* (Vieillot)	R	√	
	Glareolidae				
109.	Collared Pratincole	*Glareola pratincola* (Linnaeus)	RM	√	√
	Laridae				
110.	Gull-billed Tern	*Gelochelidon nilotica* (Gmelin)	RM	√	
111.	Roseate Tern	*Sterna dougallii* Montagu	R	√	
112.	Black-naped Tern	*Sterna sumatrana* Raffles	R	√	√
113.	Bridled Tern	*Sterna anaethetus* Scopoli	R	√	
114.	Sooty Tern	*Sterna fuscata* Linnaeus	R	√	
115.	Large Crested Tern	*Sterna bergii* Lichtenstein	R		
116.	Lesser Crested Tern	*Sterna bengalensis* Lesson	R	√	√
117.	White-winged Black Tern	*Chlidonias leucopterus* (Temminck)	M	√	
118.	Brown Noddy	*Anous stolidus* (Linnaeus)	R	√	
119.	Lesser Noddy	*Anous tenuirostris* (Temminck)	S	√	

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
	Colimbiformes				
	Columbidae				
120.	Blue Rock Pigeon	*Columba livia* Gmelin	R	√	√
121.	Andaman Wood-Pigeon	*Columba palumboides* (Hume)	R	√	
122.	Nicobar Wood-Pigeon	*Columba palumboides nicobaria* (Abdualali)	R		√
123.	Red Collared-Dove	*Streptopelia tranquebarica* (Hermann)	R	√	√
124.	Spotted Dove	*Streptopelia chinensis (Scopoli)*	R	√	√
125.	Little Brown Dove	*Streptopelia senegalensis* (Linnaeus)	R	√	
126.	Andaman Cuckoo-Dove	*Macropygia rufipennis andamanica* Abdulali	R	√	
127.	Nicobar Cuckoo-Dove	*Macropygia rufipennis rufipennis* Blyth	R		√
128.	Emerald Dove	*Chalcophaps indica* (Linnaeus)	R	√	
129.	Nicobar Emerald Dove	*Chalcophaps indica augusta* Bonaparte	R	√	
130.	Nicobar Pigeon	*Caloenas nicobarica* (Linnaeus)	R	√	√
131.	Andaman Pompadour Green-Pigeon	*Treron pompadora andamanica* (Richmond)	R	√	
132.	Pompadour Green-Pigeon	*Treron pompadora chlorptera* Blyth	R	√	√
133.	Nicobar Green Imperial-Pigeon	*Ducula aenea nicobarica*) (Linnaeus)	R		√
134.	Andaman Green Imperial-Pigeon	*Ducula aenea andamanica* Abdulali	R	√	
135.	Pied Imperial-Pigeon	*Ducula bicolor* (Scopoli)	R	√	√
	Psittaciformes				
	Psittacidae				
136.	Indian Hanging-Parrot	*Loriculus vernalis* (Sparrman)	R	√	√
137.	Alexandrina Parakeet	*Psittacula eupatria* (Linnaeus)	R	√	
138.	Red-breasted Parakeet	*Psittacula alexandri* (Linnaeus)	R	√	
139.	Nicobar Parakeet	*Psittacula caniceps* (Blyth)	R		√
140.	Red-cheeked Parakeet	*Psittacula longicauda* (Boddaert)	R	√	
141.	Nicobar Redcheeked Parakeet	*Psittacula longicauda nicobarica* (Gould)	R		√
	Cuculiformes				
	Cuculidae				
142.	Large Hawk-cuckoo	*Hierococcyx sparverioides* (Vigors)	RM	√	
143.	Indian Cuckoo	*Cuculus micropterus* Gould	RM	√	√
144.	Brainfever Bird	*Hierococ yx varius* (Vahl)	R	√	
145.	Common Cuckoo	*Cuculus canorus* Linnaeus	RM	√	
146.	Oriental Cuckoo	*Cuculus saturatus* Blyth	RM	√	√
147.	Lesser Cuckoo	*Cuculus poliocephalus* Latham	RM	√	
148.	Asian Emerald Cuckoo	*Chrysococcyx maculates* (Gmelin)	RM	√	√
149.	Violet Cuckoo	*Chrysococcyx xanthorhynchus* (Horsfield)	R	√	√

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
150.	Asian Koel	*Eudynamys scolopacea* (Linnaeus)	R	√	√
151.	Andaman Coucal	*Centropus andamanensis* Beavan	R	√	√
152.	Drongo Cuckoo	*Surniculus lugubris* (Horsfield)	R	√	√
	Strigiformes				
153.	Barn Owl	*Tyto alba* (Scopoli)	R	√	
	Strigidae				
154.	Andaman Scops-Owl	*Otus balli* (Hume)	R	√	
155.	Oriental Scops-Owl	*Otus scops* (Linnaeus)	RM	√	
156.	Nicobar Scops Owl	*Otus scops nicobaricus* (Hume)	R		√
157.	Brown Hawk-Owl	*Ninox scutulata* (Raffles)	R	√	√
158.	Andaman Hawk-Owl	*Ninox affinis* Beavan	R	√	
159.	Nicobar Brown-Hawk Owl	*Ninox affinis isolate* Baker	R		√
160.	Spotted Wood Owl	*Strix seloputo* Horsfield	M	√	√
161.	Ceylon Brown Fish Owl	*Bubo zeylonensis zeylonensis* (Gmelin)	R	√	
	Caprimulgiformes				
	Caprimulgidae				
162.	Indian Jungle Nightjar	*Caprimulgus indicus* Latham	RM	√	
163.	Large-tailed Nightjar	*Caprimulgus macrurus* Horsfield	RM	√	
	Apodiformes				
	Apodidae				
164.	White-bellied Swiftlet	*Collocalia esculenta* (Linnaeus)	R	√	√
165.	Himalaya Swiftlet	*Collocalia brevirostris* (Horsfield)	R	√	
166.	Common Edible-nest	*Collocalia fuciphaga* Thunberg Swiftlet	R	√	√
167.	Hume's Swiftlet	*Collocalia brevirostris innominata* Hume	M	√	
168.	Brown-back Needletail-Swift	*Hirundapus giganteus* (Temminck)	R	√	
169.	Common Swift	*Apus apus* (Linnaeus)	M	√	
	Coraciformes				
	Alcedinidae				
170.	Small Blue Kingfisher	*Alcedo atthis* (Linnaeus)	RM	√	√
171.	Blue-eared Kingfisher	*Alcedo meninting* Horsfield	R	√	
172.	Oriental Dwarf Kingfisher	*Ceyx erithacus* (Linnaeus)	R	√	√
173.	Stork-billed Kingfisher	*Halcyon capensis* (Linnaeus)	R	√	
174.	Nicobar Storkbilled Kingfisher	*Pelargopsis capensis intermedia* Hume	R		√
175.	Ruddy Kingfisher	*Halcyon coromanda* (Latham)	R	√	
176.	White-breasted Kingfisher	*Halcyon smyrnensis* (Linnaeus)	R	√	√
177.	Black-capped Kingfisher	*Halcyon pileata* (Boddaert)	R	√	√
178.	Andaman Collared Kingfisher	*Halcyon chloris davisoni* Sharpe	R	√	
179.	Nicobar Whitecollared Kingfisher	*Halcyon chloris occipitalis* (Blyth)	R		√

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
	Meropidae				
180.	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus	RM	√	√
181.	Chestnut-headed Bee-eater	*Merops leschenaultia* Vieillot	R	√	
	Coraciidae				
182.	Oriental Broad-billed Roller	*Eurystomus orientalis* (Linnaeus)	R	√	
	Upupidae				
183.	Common Hoopoe	*Upupa epops* Linnaeus	RM	√	
	Bucerotidae				
184.	Narcondam Hornbil	*Aceros narcondami* (Hume)	R	√	
	Piciformes				
	Picidae				
185.	Fulvus-breasted Pied Woodpecker	*Dendrocopos macei* (Vieillot)	R	√	
186.	Great Black Woodpecker	*Dryocopus javensis* (Horsfield)	R	√	√
187.	Andaman Black Woodpecker	*Dryocopus hodgei* (Blyth)	R	√	
	Passeriformes				
	Pittidae				]
188.	Hooded Pitta	*Pitta sordida* (P.L.S. Muller)	R		√
	Hirundinidae				
189.	Common Swallow	*Hirundo rustica* Linnaeus	RM	√	√
190.	House Swallow	*Hirundo tahitica* Gmelin	R	√	
191.	Red-rumped Swallow	*Hirundo daurica* Linnaeus	RM	√	
	Motacillidae				
192.	Forest Wagtail	*Dendronanthus indicus* (Gmelin)	RM	√	√
193.	White Wagtail	*Motacilla alba* Linnaeus	RM	√	
194.	Large Pied Wagtail	*Motacilla maderaspatensis* Gmelin	R	√	√
195.	Citrine Wagtail	*Motacilla citreola* Pallas	RM	√	
196.	Yellow Wagtail	*Motacilla flava* Linnaeus	RM	√	√
197.	Short-tailed Greyheaded Yellow Wagtail	*Motacilla flava simillima* Hartert	RM	√	
198.	Blueheaded Yellow Wagtail	*Motacilla flava beema* (Sykes)	RM		√
199.	Grey Wagtail	*Motacilla cinerea* Tunstall	M	√	√
200.	Richard's Pipit	*Anthus richardi* Vieillot	M	√	
201.	Blyth's Pipit	*Anthus godlewskii* (Taczanowski)	RM	√	
202.	Red-throated Pipit	*Anthus certinus* (Pallas)	M	√	√
	Campephagidae				
203.	Large Cuckoo-Shrike	*Coracina macei* (Lesson)	R	√	
204.	Bar-bellied Cuckoo-Shrike	*Coracina striata* (Boddaert)	R	√	
205.	Pied Triller	*Lalage nigra* (Forster).	R	√	
206.	Ashy Minivet	*Pericrocotus divaricatus* (Raffles)	V	√	
207.	Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus)	R	√	
208.	Scarlet Minivet	*Pericrocotus flammeus* (Forster)	R	√	

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
	Pycnonotidae				
209.	Black-headed Bulbul	*Pycnonotus atriceps* (Temminck)	R	√	
210.	Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus)	R	√	
211.	Nicobar Bulbul	*Hypsipetes nicobariensis* Moore	R		√
	Irenidae				
212.	Asian Fairy-Bluebird	*Irena puella* (Latham)	R	√	√
	Lanidae				
213.	Brown Shrike	*Lanius cristatus* Linnaeus	M	√	√
214.	Burmese Shrike	*Lanius collurioides* Lesson	R	√	√
215.	Philippine Shrike	*Lanius cristatus lucionensis* Linnaeus	M	√	√
	Turdinae				
216.	Blue Rock-Thrush	*Monticola solitarius* (Linnaeus)	RM	√	√
217.	Orange-headed Thrush	*Zoothera citrina* (Latham)	M	√	√
218.	Andaman Ground Thrush	*Zoothera citrina andamanensis* (Walden)	R	√	
219.	Nicobar Ground Thrush	*Zoothera citrina albogularis* (Blyth)	R		√
220.	Siberian Thrush	*Zoothera sibirica* (Pallas)	M	√	
221.	Whitebrowed Ground Thrush	*Zoothera sibirica sibirica* (Pallas)	M	√	
222.	Eyebrowed Thrush	*Turdus obscurus* Gmelin	M	√	
223.	Bluethroat	*Luscinia svecica* (Linnaeus)	RM	√	
224.	Siberian Blue Robin	*Luscinia cyane* (Pallas)	V	√	
225.	Oriental Magpie-Robin	*Copsychus saularis* (Linnaeus)	R	√	
226.	White-rumped Shama	*Copsychus malabaricus* (Scopoli)	R	√	
227.	Common Stonechat	*Saxicola torquata* (Linnaeus)	RM	√	
	Sylviinae				
228.	Streaked Fantail-Warbler	*Cisticola juncidis* (Rafinesque)	R		
229.	Blanford's Bush-Warbler	*Cettia pallidipes* (Blanford)	R	√	
230.	Rusty-rumped Grasshopper-Warbler	*Locustella certhiola* (Pallas)	M	√	
231.	Pallas's Siberian Grasshopper Warbler	*Locustella certhiola rubescens* (Pallas)	M	√	
232.	Streaked Grasshopper-Warbler	*Locustella lanceolata* (Temminck)	M	√	√
233.	Thick-billed Warbler	*Acrocephalus aedon* (Pallas)	M	√	√
234.	Dusky Warbler	*Phylloscopus fuscatus* (Blyth)	M	√	
235.	Siberian Leaf Warbler	*Phylloscopus trochilus yakutensis* Ticehurst	M	√	
236.	Yellow-browed Warbler	*Phylloscopus inornatus* (Blyth)	RM	√	
237.	Arctic Leaf-Warbler	*Phylloscopus borealis* (Blasius)	M	√	
238.	Grenish Leaf-Warbler	*Phylloscopus trochiloides* (Sundevall)	M	√	
239.	Pale-legged Leaf-Warbler	*Phylloscopus tenellipes* Swinhoe	M	√	√
240.	Large-billed Leaf-Warbler	*Phylloscopus magnirostris* Blyth	M	√	

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
	Muscicapinae				
241.	Brown-chested Jungle-Flycatcher	*Rhinomyias bruneata* (Slater)	M	√	√
242.	Asian Brown Flycatcher	*Muscicapa dauurica* Pallas	RM	√	√
243.	Red-throated Flycatcher	*Ficedula parva* (Bechstein)	M	√	
244.	Tickell's Blue Flycatcher	*Cyornis tickelliae* Blyth	R	√	√
	Monarchinae				
245.	Asian Paradise-Flycatcher	*Terpsiphone paradisi* (Linnaeus)	RM	√	√
246.	Blacknaped Monarch-Flycatcher	*Hypothymis azurea* (Boddaert)	R		√
247.	Car Nicobar Blacknaped Monarch-Flycatcher	*Monarcha azurea idiochroa* (Oberholser)	R		√
248.	Nicobar Black-naped Monarch Flycatcher	*Monarcha azurea nicobarica* (Bianchi)	R		√
	Pachycephalinae				
249.	Mangrove Whistler	*Pacycephala grisola* (Blyth)	R	√	
	Dicaeidae				
250.	Plain Flowerpecker	*Dicaeum concolor* Jerdon	R	√	
	Nectariniidae				
251.	Olive-backed Sunbird	*Nectarinia jugularis andamanica* Linnaeus	R	√	
252.	Nicobar Olive-backed Sunbird	*Nectarinia jugularis klossi* Linnaeus	R		
253.	Nicobar Olive-backed Sunbird	*Nectarinia jugularis proselia* Linnaeus	R		
254.	Crimson Sunbird	*Aethopyga siparaja* (Raffles)	R		
	Zosteropidae				
255.	Oriental White-eye	*Zosterops palpebrosus* (Temminck)	R	√	√
	Emberizinae				
256.	Little Bunting	*Emberiza pusilla* Pallas	M	√	
257.	Yellow-breasted Bunting	*Emberiza aureola* Pallas	M		
	Estrildidae				
258.	White-rumped Munia	*Loncghura striata* (Linnaeus)	R	√	
259.	Nicobar White-rumped Munia	*Loncghura striata nicobarica* (Linnaeus)	R		√
	Passerinae				
260.	House Sparrow	*Passer domesticus* (Linnaeus)	R	√	
	Sturnidae				
261.	Asian Glossy Starling	*Aplonis panayensis* (Scopoli)	R	√	√
262.	Asian Glossy Starling	*Aplonis panayensis albiris* Abdulali	R		√
263.	White-headed Starling	*Sturnus erythropygius* (Blyth)	R	√	
264.	Nicobar White-headed Starling	*Sturnus erythropygius erythropygius* (Blyth)	R		√

Table 1. *Contd.*

Sl. No.	Common Name	Scientific Name	Status*	Distribution*	
				Andaman	Nicobar
265.	Katchal White-headed Starling	*Sturnus erythropygius katchalensis* (Richmond)	R	√	
266.	Daurian Starling	*Sturnus sturninus* (Pallas)	V	√	√
267.	Rosy Starling	*Sturnus roseus* (Linnaeus)	M	√	
268.	Common Myna	*Acridotheres tristis* (Linnaeus)	R	√	
269.	Common Hill-Myna	*Gracula religiosa* Linnaeus	R	√	√
270.	Hill-Myna	*Gracula religiosa halibrecta* Abudulaali	R		√
	Oriolidae				
271.	Eurasian Golden Oriole	*Oriolus oriolus* (Linnaeus)	RM	√	√
272.	Andaman Black-naped Oriole	*Oriolus chinensis andamansis* Tytler	RM	√	
273.	Nicobar Black-naped Oriole	*Oriolus chinensis macrourus* Blyth	RM		√
274.	Black-headed Oriole	*Oriolus xanthornus* (Linnaeus)	R	√	
	Dicruridae				
275.	Crow-billed Drongo	*Dicrurus annectans* (Hodgson)	R	√	
276.	Ashy Drongo	*Dicrurus leucophaeus* Vieillot	RM	√	
277.	Whitecheeked Grey Drongo	*Dicrurus leucophaeus salangenis* Reichenow	RM	√	
278.	Large Andaman Drongo	*Dicrurus andamanensis dicruriformes* (Hume)	RM	√	
279.	Small Andaman Drongo	*Dicrurus andamanensis andamanensis* Tytler	R	√	
280.	Greater Racket-tailed Drongo	*Dicrurus paradiseus* (Linnaeus)	R	√	
281.	Nicobar Rackettailed Drongo	*Dicrurus paradiseus nicobariensis* Baker	R	√	
	Artamidae				
282.	White-breasted Woodswallow	*Artamus leucorynchus* (Linnaeus)	R	√	
	Corvidae				
283.	Andaman Treepie	*Dendrocitta bayleyi* Tytler	R	√	
284.	Jungle Crow	*Corvus macrothynchos* Wagler	R	√	

R = Residents, RM = Llocal migrants, M = Trans-continental migrants, V = Vagrant S = Straggler.
* Ali and Ripley (1983); Tikader (1984); Sankaran (1995a, b & c)

Highest number of insectivores (105) followed by omnivores (47), aquatic feeders (40), carnivores (37), granivores (30), frugivores (20) and nectar-frugivores (5) were recorded so far (Table 2). Out of the 284 species of birds found in Andaman and Nicobar Islands, 22 species namely, *Pelecanus philippensis, Accipiter butleri, Falco naumanni, Megapodius nicobariensis, Aceros narcondami, Hypsipetes nicobariensis, Rallina canningi, Otus alius, Spilornis elgini, Spilornis minimus, Gallinago media, Esacus magnirostris, Columba palumboides, Macropygia rufipennis, Caloenas nicobarica, Psittacula longicauda, Psittacula caniceps, Otus balli, Ninox affinis, Dryocopus hodgei, Dicrurus andamanensis. Dendrocitta bayleyi* were listed in the threatened birds of the world (BirdLife International, 2001).

Table 2. Status of birds recorded from Andaman & Nicobar Islands

Sl. No.	Order	Feeding guilds						
		A	I	G	N/F	C	F	O
1.	Procellariiformes	02						
2.	Pelecaniformes	06	-	-	-	-	-	-
3.	Ciconiiformes	15	-	-	-	-	-	-
4.	Anseriformes	07	-	-	-	-	-	-
5.	Falconiformes	-	-	-	-	28	-	-
6.	Galliformes	-	05		-	-	-	-
7.	Gruiformes	-	-	11	-	-	-	-
8.	Charadriiformes	-	-	-	-	-	-	45
9.	Columbiformes	-	-	16	-	-	-	-
10.	Psittaciformes	-	-	-	-	-	06	-
11.	Cuculiformes	-	-	-	-	-	11	-
12.	Strigiformes	-	-	-	-	09	-	-
13.	Caprimulgiformes	-	02	-	-	-	-	-
14.	Apodiformes		06					
15.	Coraciiformes	10	04	-	-	-	-	01
16.	Piciformes	-	03	-	-	-	-	
17.	Passeriformes	-	85	03	05	-	03	01
	Total	**40**	**105**	**30**	**05**	**37**	**20**	**47**

A = Aquatic feeders, **I** = Insectivores, **C** = Carnivores, **G** = Granivores, **F** = Frugivores, **N/F** = Nectar-frugivores, **O** = Omnivores

Occurrence of bird species

A comparison of number of bird species recorded from Andaman and Nicobar Islands with those from Indian subcontinent are given in Table 3. Out of 1340 species of birds recorded from Indian subcontinent, 21 per cent are found in Andaman and Nicobar Islands.

Table 3. Occurrence bird species in Andaman and Nicobar Islands

Sl. No.	Order	World[1]	Indian sub continent[2]	Andaman & Nicobar[3]
1.	Archaeopterygiformes*	01		
2.	Hesperornithiformes**	07		
3.	Ichthyornithiformes**	09		
4.	Struthioniformes	01		
5.	Rheiformes	02		
6.	Casuariiformes	04		
7.	Aepyornithiformes**	04		-
8.	Dinornithiformes**	12		
9.	Apterygiformes	08		
10.	Tinamiformes	50		
11.	Sphenisciformes	18		

Table 3. *Contd.*

Sl. No.	Order	World [1]	Indian sub continent[2]	Andaman & Nicobar[3]
12.	Gaviiformes	05	02	
13.	Podicipediformes	22	05	
14.	Procellariiformes	32	21	02
15.	Odontopterygiformes**	03		
16.	Pelecaniformes	45	17	06
17.	Ciconiiformes	88	34	15
18.	Phoenifopteriformes	06	02	
19.	Anseriformes	145	44	07
20.	Falconiformes	285	71	28
21.	Galliformes	235	49	05
22.	Diatrymiformes	04		
23.	Gruiformes	186	33	11
24.	Charadriiformes	199	121	45
25.	Columbiformes	274	40	16
26.	Psittaciformes	330	15	06
27.	Cuculiformes	133	24	11
28.	Strigiformes	129	33	09
29.	Caprimulgiformes	96	11	02
30.	Apodiformes	403	17	06
31.	Coliiformes	06		
32.	Trogoniformes	40	03	
33.	Coraciiformes	183	33	15
34.	Piciformes	343	46	03
35.	Passeriformes	4978	719	97
	Total	**8286**	**1340**	**284**

1–Harrison (1978); 2–Ali and Ripley (1983) and Manakadan and Pittie (2001); 3–Ali and Ripley (1983); Tikader (1984); Sankaran (1995 a, b & c); * Fossil bird; ** Extinct birds

Endemic species of birds to the Andaman and Nicobar Islands

Twenty birds species are endemic to Andaman group of islands namely *Anas albogularis, Spilorinis elgini, Rallina canningi, Columba palumboides, Macropygia rufipennis, Treron chloroperus, Tyto deroepstorffi, Ninox affinis, Ninox obscura, Otus balli, Caprimulgus andamanicus, Aceros narcondami, Dryocopus hodgei, Coracina dobsoni, Pycnonotus fuscoflavescens, Copyschus albiventris, Dicaeum virescens, Sturnia erythropygia, Dicrurus andamanensis, Dendrocitta bayleyi and* eight species to the Nicobar Islands namely *Accipiter butleri, Spilornis klossi, Megapodius nicobariensis, Ducula nicobarica, Psittacula caniceps, Otus alius, Hypsipetes nicobariensis, Rhinomyias nicobaricus* (Jathar and Rahmani, 2006)

The higher number of species reported in this paper is not surprising because of the intensive surveys carried out in the past by various ornithologist and amateurs in the Andaman and Nicobar Islands. Of the reported number of species, 155 species were residents, 58 were local migrants, 64 were trans-continental migrants, 6 were Vagrant and one species is a straggler. The highest number of avifauna recorded from the Andaman and Nicobar Islands is due to the presence of diverse vegetation types and microhabitats.

The main threat to the avifauna is the degradation of forests and loss of habitat. The remaining forests in the Andaman and Nicoabar Islands faces many anthropogenic pressures such as encroachment of forest lands, livestock grazing, fuel wood collection and indiscriminate collection of non-timber forest products such as bamboo and canes. Need of the time is to protect the diversity of avifauna in the islands which are the best indicators of environmental degradation.

Suggestions for conservation

Small oceanic islands represent a fragile ecosystem and are susceptible to severe threat to their highly diverse ecosystem due to developmental activities. With the ever increasing developments, change in the patterns of land and resource use, the conservation of our limited natural resources has gained greater significance. The causes by environmental damages can be controlled only by the implementation of serious conservation measures. Tourism activities and uncontrolled immigration from the mainland should be checked since the present population exceeds the carrying capacity of the island. Illegal poaching, hunting and extraction of wild resources should be completely banned. Felling of trees for cultivation, construction of jetties, and expansion of settlement areas should be discouraged. Biodiversity awareness campaigning for local settlers as well as the tourists should be initiated and this could prove very useful in the protection of the island's natural resources.

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Chapter 35

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 415-422, 2010

FORAGING ECOLOGY OF ANDAMAN CRAKE AND ITS CONSERVATION

***EZHILARASI, N. and L. VIJAYAN**

Salim Ali Center for Ornithology and Natural History Anaikatty (PO), Coimbatore, Tamil Nadu, India

INTRODUCTION

The genus Rallina (Family RALLIDAE) comprises eight species of distinctively plumaged rails which inhabits forest or marshland in forest and are confined to Asia and Australia (Taylor, 1998). Although Rails are of worldwide distribution, many rails are rarely seen and are very poorly known. The ecology of 23 species of rails remains undescribed, even many well-studied species, good quantitative analyses of diet are lacking (Taylor, 1998). For effective conservation measures, a sound understanding of the status, distribution, biology and ecology of the species is paramount.

The Andaman Crake *Rallina canningi* is endemic to the Andaman Islands and considered potentially globally threatened but Data Deficient (Ali and Ripley, 1969; Collar *et al.*, 1994; Stattersfield *et al.*, 1998; BirdLife International, 2001; Vijayan *et al.*, 2000, 2005). It is a medium to large rail (length 34 cm), and the largest Rallina species found in the Andaman Islands (Ali and Ripley, 1987) where it inhabits marshland inside the forests (Taylor, 1998). It is great sulkers in reeds and herbage in marshland, seldom seen but readily snared as reported by Butler (1900). Nothing is known about the breeding and non-breeding ecology of this species except few casual records. There exists no detailed description ecology of the Andaman Crake (Ali and Ripley, 1969; Taylor, 1998; BirdLife International, 2001). This paper presents the foraging ecology of the Andaman crake.

STUDY AREA AND METHODS

The Andaman and Nicobar Islands form a major group of oceanic islands in the Bay of Bengal, India, located from 6°5′ to 14°45′ N and 92° to 94° E (Das, 1999; Das and Palden, 2001). The entire Andaman Island group covers 8,249 km^2 of which the Andaman group is 6,408 km^2 with more than 325 islands (21 inhabited) (Saldanha, 1989). The Andaman and Nicobar Island receive both the southwest and the northeast monsoon and hence average rainfall in the Andaman is high at 3,200 mm. Mean rainfall is 86-450 mm per month, the number of rainy days per month ranges from 1-21 days (Kumar and Gangwar, 1985) and the mean maximum and minimum temperature in 2006 were 34° C and 22° C (DES, 2005).

The study was carried out in Chidiyatapu Biological Park (11°30′ 35.6 092°42′ 33.1) at the southern most tip of South Andaman Island. The area of this park is about 40 ha. Park is composed of moist deciduous, semi-evergreen and littoral forest. Currently human disturbance high due to construction of the Zoo.

The activity budget and pattern was studied by following the focal animal sampling method

*E-mail : ezhilarasinatarajan@gmail.com

(Altman, 1974) during 2004-2006. Andaman Crakes were observed from dawn to dusk. The day light hour was divided into three equal parts, and one day light period was covered over three consecutive days. Observations were done for six such daylight periods in a month. The bird was observed as long as possible, whenever it was spotted. All occurrences of specific activities of individuals were recorded during each sampling period. The activities such as feeding, calling, bathing, preening, roosting and agnostic behavior were noted on the data sheets. The duration of each observation was noted with an electronic stopwatch. Temperature was recorded every hour.

Diet composition (Indirect Method)

Faecal samples were collected from each habitat to determine what the birds were eating. Analysis of fecal samples is a non-intrusive method for diet determination and appropriate for endangered species (Rosenberg and Cooper, 1990). Scleritized body parts of most arthropods will pass through the bird's digestive system, and many can be identified. Fecal samples were collected during the observation on the behaviour of the bird.

The collected individual sample was transferred to Petri dishes and then viewed under variable power dissecting microscope. Body fragments or hard exoskeleton, wings or wing fragments, leg segments, head capsules, antennal segments, mouthparts and sometimes whole invertebrates were separated out of the faecal sample and identified to the lowest taxonomic level possible (generally order or family) with the aid of standard invertebrate taxonomy literature (Imms, 1965; Ayyar and Krishanan, 1982; Mani, 1988). Only hard parts of the prey passed out through the gut. Thus, the available information such as elytra or wing case of beetles, head, leg or almost complete exoskeleton of ants, leg of spiders and grasshoppers and fragments of snail shells were noted for each prey taxon identified in each sample. Number of individuals of the taxon, percent of the total sample represented by the taxon and description of the remains including notes on identification were recorded.

Individual fecal samples are often pooled to create a single sample for a particular season. Samples were sorted and identified for food items. Percentage of occurrence of each taxon was calculated. Percentage refers to the number of samples in which a particular food type appeared. Percent occurrence is the simplest and crudest measure of diet. Its primary advantage is that virtually all food items can be counted, even if individual items ingested cannot be quantified (Rosenberg and Cooper, 1990).

Data analysis

Observations were grouped into four seasons : winter (December-February), summer (March-May), south-west monsoon (June-August) and north-east monsoon (Septembe-November). Mann-Whitney U test were performed to explain the variation in the activities and food items between breeding and non-breeding season. Kruskal-Wallis test was performed to explain the variation in activities and food items among various seasons. All statistical tests were evaluated at the $P < 0.05$ level of significance and analyses were performed using SPSS software version 10.

RESULTS

Foraging habitat

Total of 1113 foraging observations were made. Foraging habitat of the Andaman Crake was forest area dominated by trees with undergrowth of different species of shrub, grasses and ground having fine soil with leaf litter of around four cm above ground. Most of the sighting of Crake were within 30 m of the wet streams (80.65 per cent), the encounter were negatively associated with distance from of stream ($r = -0.569$; $p < 0.001$). Andaman crake was recorded throughout the year in the study area, even though the streams are dried during summer the encounter rate and location of sighting does not vary. The locations of sightings were characterised with high canopy height, moderate canopy cover (50.22 ± 22.40), low ground cover (28.47±27.21), and high number of saplings (191.7 ± 85.33). During dry period crake was recorded in the area where moisture was there but not very from its territory and comes to the territory often and also for roosting. No large scale variables such as, slope were significantly associated with the presence of crake.

Food

Although 1113 foraging observations were made exact feeding observation could not be recorded for all the months because of the dense undergrowth secretive nature of the bird and size of the prey. In general, the Andaman Crake were noted to feed on invertebrates. The direct feeding observations indicates the intake of earthworms (Oligochaeta), caterpillars (Lepidoptera), termites (Isoptera), ants (Hymenoptera) and snail (Mollusca) (Table 1). On a few occasions (N = 8), it was noted to glean ecto-parasites from spotted deer.

Table 1. List of food items recorded from direct observation.

Sl. No.	Food Items
1	Red ant
2	Black ant
3	Termite
4	Silverfish
5	Earthworm
6	Leaf worm
7	Grasshopper
8	Snail
9	Cater pillar

Diet composition (Indirect method)

Totally 60 fecal samples of Andaman Crake were collected and analyzed. The mouthparts of ants, termites, and broken pieces of shell (snail) and cuticle of beetles are recorded from the faecal samples. Fecal material showed that it comprises of five different prey items. The major prey materials include mouthparts of ants, termites and broken pieces of shells and cuticle of beetles.

During winter and summer isopterans and hymenopterans were recorded more while during monsoon molluscs were high (Fig. 1). Coleopterans were more or less same throughout the year. When the food items taken by the crake were compared among different seasons (Kruskal Wallis H test $P < 0.05$; Table 2), and also between breeding and non-breeding season (Mann-Whitney U test - $P < 0.005$; Table 3) significant difference were recorded in isopteran, hymenoptera, and mollusc whereas no significant difference were recorded in coleopterans among different seasons and between breeding and non-breeding season.

Table 2. Kruskal-Wallis H test to analyze food items of Andaman Crake among different seasons

Variables	χ^2	*df*	*p*-value
Isoptera	13.28	3	0.04*
Hymenoptera	22.08	3	0.00*
Coleoptera	6.15	3	0.10
Mollusca	35.44	3	0.00*
Sand	0.09	3	0.81

*Significant

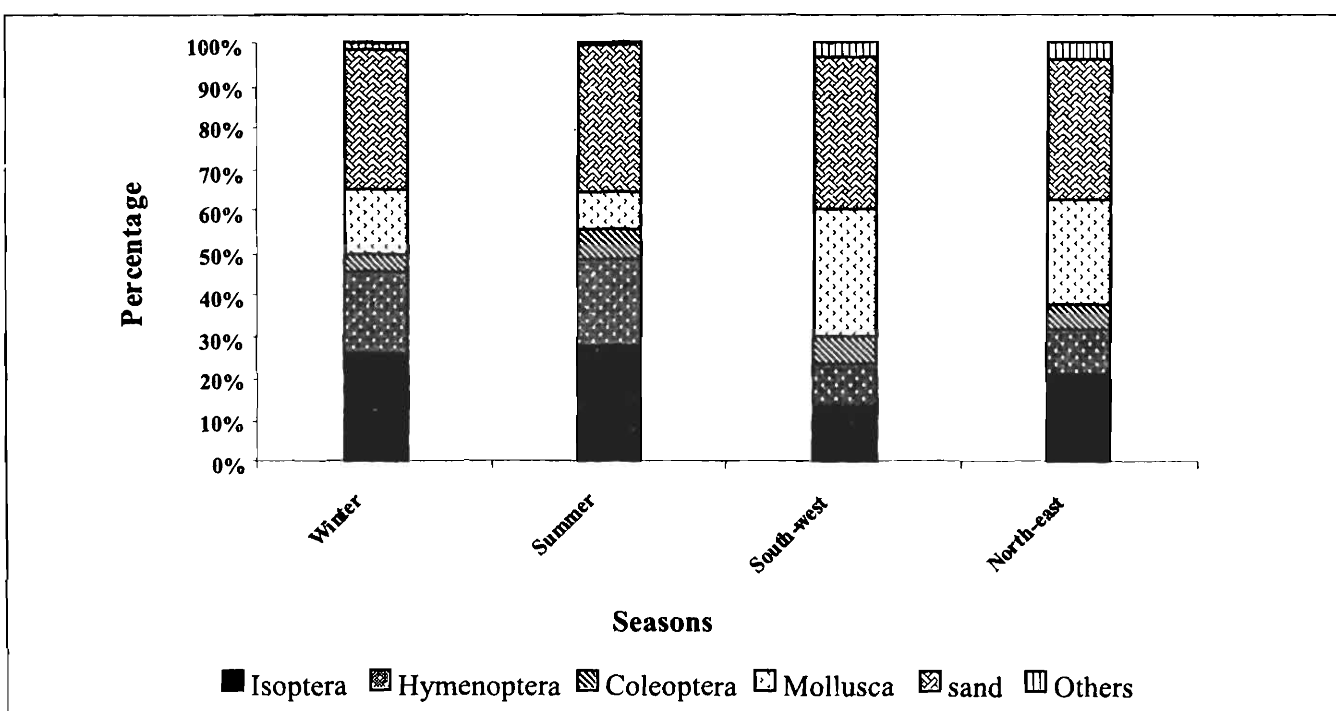

Fig. 1. Food of Andaman Crake from faecal analysis

Table 3. Mann-Whitney 'U' test to analyze food items of Andaman Crake between breeding and non-breeding season

Variables	U	*p*-value
Isoptera	141	0.00*
Hymenoptera	175	0.01*
Coleoptera	306	0.57
Mollusca	119	0.00*
Sand	303	0.55

*- Significant

Food of the fledglings

The chicks were noted to feed bill to bill. Six prey items were recorded to be taken by fledglings which include earthworm, caterpillar, ants, termite, beetles and grasshoppers. Out of this earthworm and caterpillar were mostly fed by parents.

Foraging behaviour

Andaman Crake seem to feed throughout the day by following very characteristic feeding method. When they are undisturbed they walk with tail down and dart their head to either side. They obtain food only with the bill; no crake was seen scratching the ground with its feet. Pecking was the major method used by the Crake to explore the food items (61 per cent). Apart from pecking, it used the flake method (34 per cent) while other methods such as stabbing, pulling and gleaning (5 per cent) were negligible (Fig. 2).

Although there was slight difference in feeding method in different seasons it was not significant ($\div^2 = 0.389$; df = 3; $P = 0.943$). Whenever it took larger food items such as earthworm, caterpillar and big insects it was noted to kill the prey before it swallowed. It used successive pecks (Hammer method) whenever it encountered ant and termite colonies.

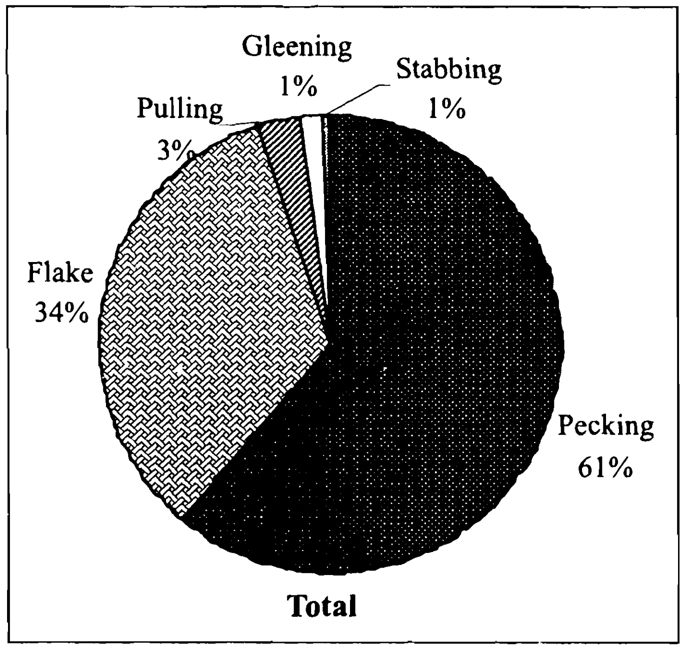

Fig. 2. Feeding methods of the Andaman Crake (Total)

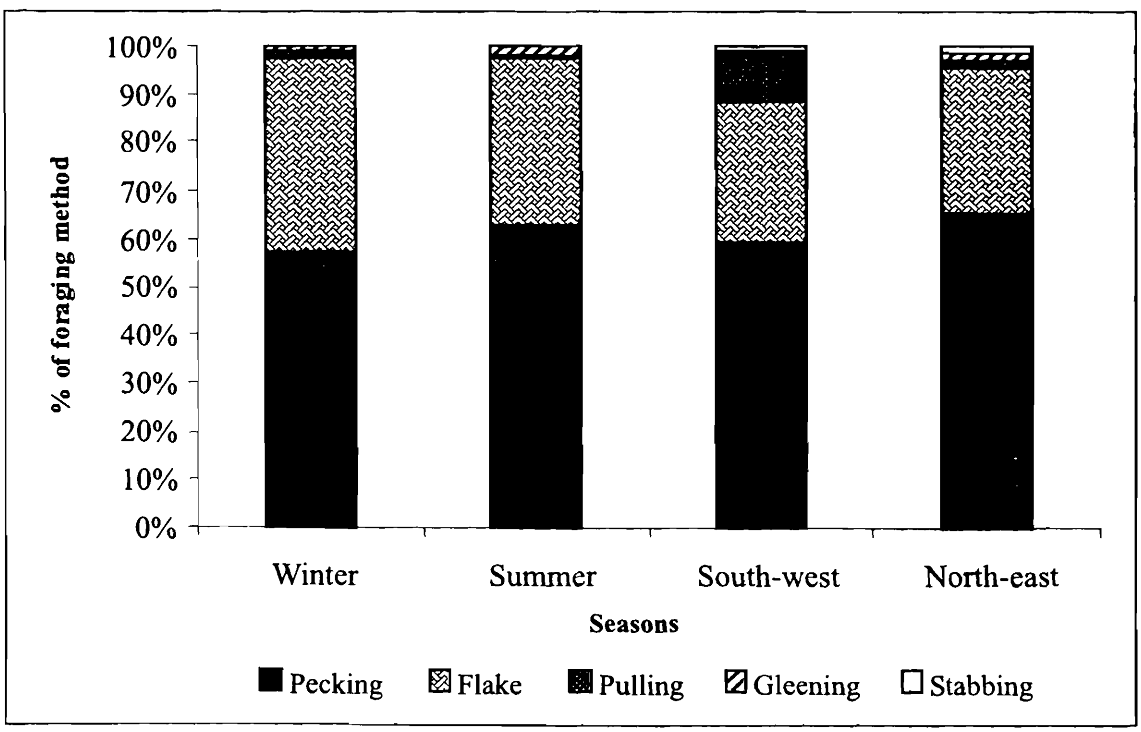

Fig. 3. Feeding methods of the Andaman Crake in different seasons

Foraging pattern

Foraging is the major activity. The overall budget of the crake shows that it spends nearly 56 per cent of the time for foraging. Foraging activity of the crake among different seasons varied and it was the maximum in summer (78 per cent) followed by winter (68 per cent) and north-east monsoon (62 per cent) and the minimum in south-west monsoon (38 per cent). Significant difference in foraging was recorded among different seasons (Kruskal Wallis $\div^2 = 3.62$; df = 3; $P < 0.05$).

The average rate of foraging in each hour of the day was calculated to find out the foraging pattern or feeding rhythm during the day. Foraging rhythm shows alternative up and down peaks with more in early morning and late evening (Fig. 4).

The data were analyzed season-wise to compare and understand the differences if any (Fig. 5). There were no significant difference in foraging pattern was recorded for different season ($\div^2 = 0.392$; df=3; $p < 0.392$). The feeding rate had negative correlation with temperature ($r = -0.514$; $p > 0.06$).

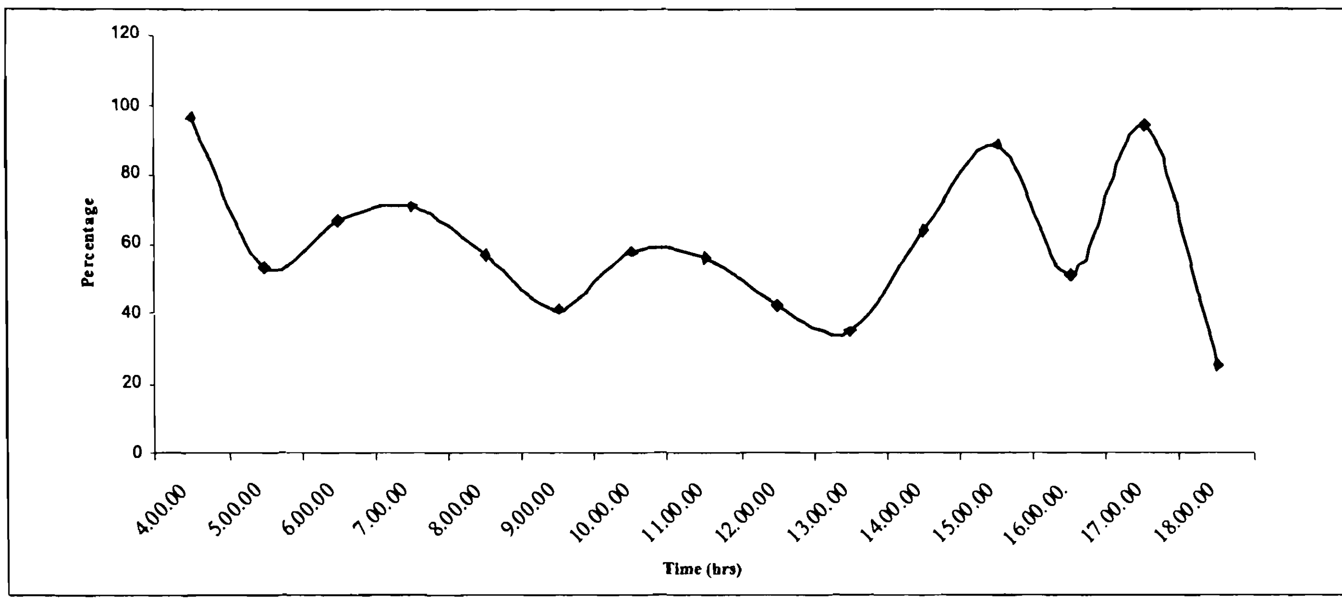

Fig. 4. Foraging rhythm (pattern) of Andaman Crake (Total)

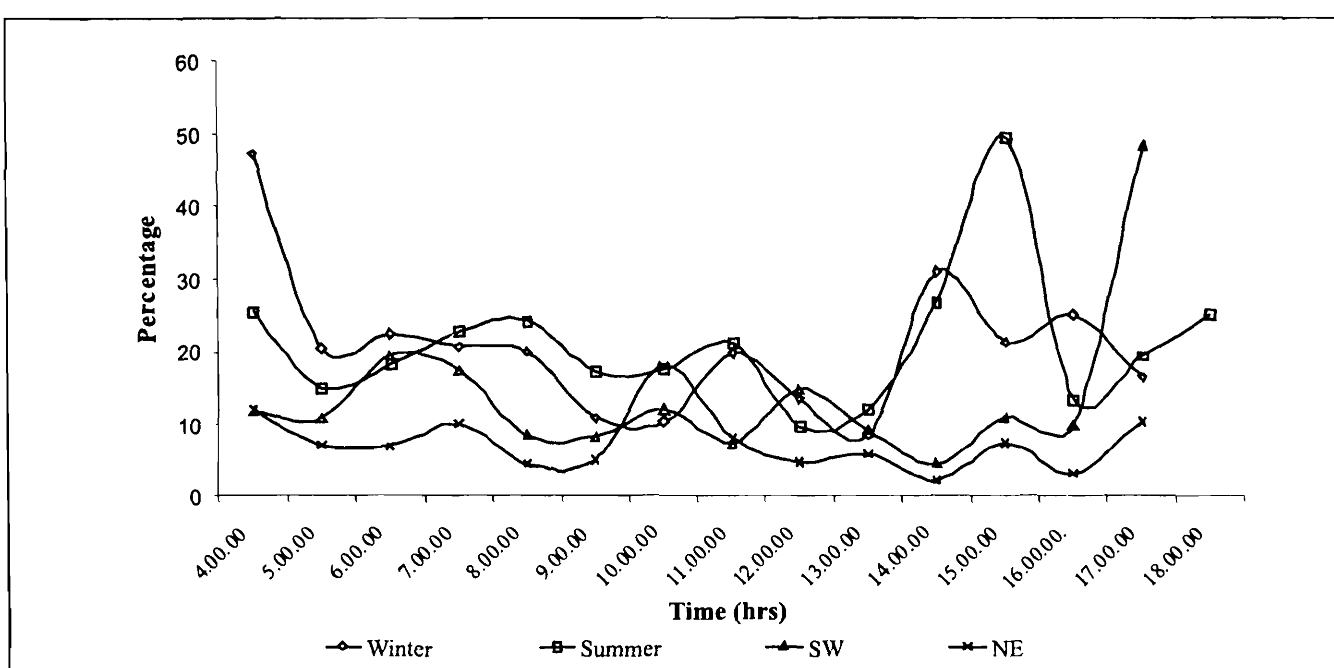

Fig. 5. Foraging rhythm (pattern) of Andaman Crake (different seasons)

Association of Andaman Crake with other birds while foraging

Andaman Crake were noted to forage in single or in pairs rarely in small groups. Out of 1113 foraging observations, 280 observations were made while the Andaman Crake fed along with other species. The association was more with the Emerald dove followed by Ground Thrush, Magpie Robin, Red-whiskered Bulbul, Andaman Shama and less with Common Myna, White-breasted Water-hen and White-headed Starling (Table 4).

DISCUSSION

Feeding is the major activity of any animal for sustaining life and it varied according to the environmental and physiological conditions of the bird as in many species (Huntingford, 1984; Rosenberg, 1993). The Andaman Crake is primarily an invertebrate feeder and opportunistic. Earthworm (Annelida), caterpillar (Insecta) and snail (Mollusca) were recorded more in the diet from monsoon till winter, which corresponded with the abundance. On a few occasions, it was noted to glean ectoparasites from the large mammals (Spotter Deer) as found in Black Crakes *Amaurornis flavirostris* (Taylor and Van Perlo, 1998). Sand or grit was almost at the same level in all the seasons as found in many ground-dwelling birds which might have been taken along with the food items, used for grinding food, or providing calcium supplement (Griminger, 1983).

As Buff-spotted flufftail (Taylor, 1994), large live food items are usually killed before swallowing. Seasonal variation in the proportion of food items are recorded in Andaman Crake as many rallid species (Taylor, 1998). Birds inherent flexibility allows them to adapt to changes by altering their foraging behaviour or primary food item (Alatalo, 1980). Because birds are flexible in both their foraging behaviour and the food they select, they may locate sufficient food without having to leave areas of low insect abundance (Petit, 2000).

Feeding method is a function of the morphology of the species and its habitat (Rosenberg, 1993). The feeding method adopted by the Crake in all the seasons was pecking showing the specificity of the Crake which was probably most suitable for feeding on the ground invertebrates. For searching, it turns over the dead leaves, dig and probe with the bill. The same kind of foraging method such as pecking picking up leaves and twigs and tossing or pushing them aside with the bill (flake method), was recorded Galapagos Rail (Franklin, 1979), Buff-spotted flufftail (Taylor, 1994), Red-chested flufftail (Taylor, 1994) and Henderson Island Rail (Jones *et al.*, 1995). Terrestrial species which forage in leaf litter and soil use the bill to move or toss aside leaves and debris, and to turn over small stones, while searching for invertebrates (del Hoyo *et al.*, 1996). Andaman Crake was not noted to scratch with their food while searching the food as Henderson Island Rail (Jones *et al.*, 1995). In all the seasons, pecking was the prominent method showing its specificity. Birds with relatively unspecialized, straight bills of moderate length and depth take a wide verity of small to large food items, chiefly by probing, gleaning digging, sifting litter, stabbing at large prey and raking in soft earth (del Hoyo *et al.*, 1996). The rise in temperature influences the feeding adversely as found in many birds (Bhupathy and Vijayan, 1999; Coraco, 1980 and Tidemann, 2004).

Table 4. Percentage frequency occurrence of the Andaman Crake with other birds (N=280).

Species	Scientific Name	# of times	Frequency (%)
Ground Thrush	*Zoothera citrina*	61	21.79
Red-whiskred Bulbul	*Pycnonotus jocosus*	21	7.50
Emerald Dove	*Chalcophaps indica*	135	48.21
Magpie Robin	*Copsuchus saularis*	35	12.50
White-breasted Waterhen	*Amaurornis phoenicurus*	2	0.71
White-headed Starling	*Sturnus erythropygius*	2	0.71
Common Myna	*Acridotheres tristis*	6	2.14
Andaman Shama	*Copsychus malabaricus*	18	6.43

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Chapter 36

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 423-434, 2010

SAVING GLOBALLY THREATENED AND ENDEMIC BIRDS USING THE IBAS APPROACH IN ANDAMAN AND NICOBAR ISLANDS

M.Z. ISLAM* and A.R. RAHMANI

Bombay Natural History Society, Hornbill House, Shaheed Bhagat Singh Road, Mumbai–400001, India

INTRODUCTION

The Andaman and Nicobar Islands, consisting of over 572 islands and rocks, covering about 8,249 km^2, are the peaks of a submerged mountain range, arching from Myanmar to Sumatra. The vegetation is mainly tropical evergreen, with some grassland in the inland areas (Islam and Rahmani, 2004). The coastline of 1,962 km^2 is mainly covered by mangrove. About 270 species and subspecies of birds have been recorded from the Andaman and Nicobar by various workers (Sankaran, 1995), of which 105 are endemic species and subspecies (Sankaran and Vijayan, 1993). Of the 142 endemic bird species of the Indian subcontinent, 22 are found in Andaman and Nicobar Islands. Thus, while the islands form only 0.25 per cent of the landmass of the India, they have 12 per cent of the endemic avifauna of the region (Sankaran, 1998), making the islands priority areas for conservation (Islam and Rahmani 2004).

The highest conservation priority species are the Nicobar Megapode *Megapodius nicobariensis*, Edible-nest Swiftlet *Collocalia fuciphaga inexpectata* and Narcondam Hornbill *Aceros narcondami*. There are two subspecies of the Nicobar Megapode (North Nicobar Megapode *Megapodius nicobariensis nicobariensis* and South Nicobar Megapode *M. n. abbotti*). The Nicobar Megapode was considered as a rare species for many years (Tikadar, and Das, 1985), but recent studies shows that both the subspecies are quite common (Sankaran, 1995). Sankaran (1998) estimated that there could be between 600-2,100 breeding pairs of the North Nicobar Megapode and 3,400-6,000 of the South subspecies. The species is not endangered but is under pressure of habitat loss and poaching with air guns and snares. Egg collection is apparently not a problem (Sankaran, 1995).

The Edible-nest Swiftlets are widely distributed on the islands with a population estimation of 2,500 to 3,600 breeding pairs (Sankaran, 2001). The major threat is excessive and unregulated nest collection. This species belongs to the 'white nest swiftlet' groups, whose nests are made entirely of agglutinated saliva, and are of a very high commercial value in the international market. At Port Blair, a kilogram of nests (one kg normally consists of between 70-125 nests) fetches between Rs. 15,000 to Rs. 20,000 or more. Sankaran reported that virtually all colonies are exploited,

*Research and Field Monitoring Manager (Reintroduction Programs), National Wildlife Research Center, Taif, Saudi Arabia [email : mzafarul.islam@gmail.com or zafar@nwrc-sa.org]

and nests are collected irrespective of whether there are eggs or chicks in them, with serious effects on the species.

According to Rodgers *et al.* (2000), the Islands which constitute only 0.25 per cent of India's geographical area, have eight national parks and 94 wildlife sanctuaries, covering a total area of about 1,529 km^2. This is about 18.54 per cent of the land surface. It should be noted that many of the larger Protected areas are tribal areas and not strictly free from human occupation. Nevertheless, as the tribal pressure is low and sustainable, some of the finest forests of India are seen in the Andaman and Nicobar Islands (Islam and Rahmani, 2004).

Restricted Range species in the Andaman and Nicobar Islands

There are 20 restricted range species in Andaman and eight in the Nicobar Islands (Jathar and Rahmani, 2006). All of them are mostly forest-dwelling species but a few appear to be quite common in disturbed forest also. Some of the species could be seen near the capital, Port Blair, in South Andaman (Curson 1989). Many islands in Middle and South Andaman have limited access so information is lacking. The Narcondam Hornbill *Aceros narcondami* has an extraordinarily small range, being confined to the small, isolated island of Narcondam with an area of 6.82 km^2 (Stattersfield *et al.* 1998).

Restricted Range species of Andaman Islands

Sl. No.	Common name	Scientific Name	Global Status	Number of IBAs
1.	Andaman Teal	*Anas albogularis*	LC	9
2.	Andaman Serpent-eagle	*Spilornis elgini*	VU	15
3.	Andaman Crake	*Rallina canningi*	DD	13
4.	Andaman Wood-pigeon	*Columba palumboides*	NT	16
5.	Andaman Cuckoo-dove	*Macropygia rufipennis*	NT	16
6.	Andaman Green-pigeon	*Treron chloroperus*	LC	6
7.	Andaman Barn-owl	*Tyto deroepstorffi*	LC	7
8.	Andaman Hawk-owl	*Ninox affinis*	NT	16
9.	Hume's Hawk-owl	*Ninox obscura*	LC	3
10.	Andaman Scops-owl	*Otus balli*	NT	11
11.	Andaman Nightjar	*Caprimulgus andamanicus*	LC	5
12.	Narcondam Hornbill	*Aceros narcondami*	VU	1
13.	Andaman Woodpecker	*Dryocopus hodgei*	NT	13
14.	Andaman Cuckoo-shrike	*Coracina dobsoni*	LC	8
15.	Andaman Bulbul	*Pycnonotus fuscoflavescens*	LC	12
16.	Andaman Shama	*Copyschus albiventris*	LC	6
17.	Andaman Flowerpecker	*Dicaeum virescens*	LC	8
18.	Andaman White-headed Starling	*Sturnia erythropygius*	NT	17
19.	Andaman Drongo	*Dicrurus andamanensis*	NT	15
20.	Andaman Treepie	*Dendrocitta bayleyi*	NT	7

VU = Vulnerable, NT = Near Threatened; DD = Data Deficient; LC = Least Concern

Restricted Range species of Nicobar Islands

1.	Nicobar Sparrowhawk	*Accipiter butleri*	VU	3
2.	Great Nicobar Serpent-eagle	*Spilornis klossi*	NT	3
3.	Nicobar Megapode	*Megapodius nicobariensis*	VU	2

Sl. No.	Common name	Scientific Name	Global Status	Number of IBAs
4.	Nicobar Imperial-pigeon	*Ducula nicobarica*	LC	4
5.	Nicobar Parakeet	*Psittacula caniceps*	NT	3
6.	Nicobar Scops-owl	*Otus alius*	LC	3
7.	Nicobar Bulbul	*Hypsipetes nicobariensis*	VU	1
8.	Nicobar Jungle-flycatcher	*Rhinomyias nicobaricus*	LC	3

VU = Vulnerable, NT = Near Threatened; DD = Data Deficient; LC = Least Concern

METHODOLOGY

The IBA programme has recognised sites vital for the conservation of birds. These sites were identified using a set of four standard global criteria: (A1) presence of globally threatened species (A2) restricted range or endemic birds, (A3) biome restricted assemblages and (A4) sites having large congregations of birds. These criteria were designed by BirdLife International to select representative areas of the most important bird habitats, particularly those which are under the most severe pressure (Islam and Rahmani, 2004). Given that birds are good indicators of overall biological diversity, most IBAs will be important for other species as well.

Several bird species could be conserved by protection of their habitats (Islam and Rahmani 2004). The selection of sites with rich biological diversity could save many species at the same time, making the best use of the scarce resources that are available for conservation. IBAs form a network throughout a species' range. As habitats become more threatened, this network will become increasingly important to ensure that birds survive across their ranges. IBAs may include the best examples of the species' natural habitat. They might have high numbers or densities, or be 'typical examples' Some IBA sites could be the last refuge for certain species, and if we lose such sites, the species would be in danger of extinction (Islam and Rahmani 2004).

RESULTS AND DISCUSSION

There are nine national parks and 94 wildlife sanctuaries covering an area of 1,529 km^2 of which only 18.53 per cent is terrestrial. The major part of the Great Nicobar Island has been declared a Biosphere Reserve. The following 19 sites have been identified as IBAs (Plate 26).

List of IBA sites and site codes

IBA Codes	IBA site name	IBA criteria
IN-AN-01	Austin Strait	A1, A2
IN-AN-02	Barangtang-Rafters Creek	A1, A2
IN-AN-03	Car Nicobar	A1, A2
IN-AN-04	Chainpur and Hanspuri	A1, A2
IN-AN-05	Great Nicobar, Little Nicobar	A1, A2
IN-AN-06	Interview Island WLS	A1, A2
IN-AN-07	Jarawa Reserve (Middle Andaman and South Andaman)	A1, A2
IN-AN-08	Kadakachang	A1, A2
IN-AN-09	Landfall Island WLS	A1, A2
IN-AN-10	Little Andaman	A1, A2
IN-AN-11	Mahatma Gandhi Marine NP	A1, A2
IN-AN-12	Mount Diavalo/Cuthbert Bay	A1, A2
IN-AN-13	Mount Harriett NP	A1, A2

IBA Codes	IBA site name	IBA criteria
IN-AN-14	Narcondam Island WLS	A1, A2
IN-AN-15	North and South Sentinel	A1, A2
IN-AN-16	North Reef Island WLS	A1, A2
IN-AN-17	Rani Jhansi Marine NP	A1, A2
IN-AN-18	Saddle Peak NP	A1, A2
IN-AN-19	Tilangchong, Camorta, Katchal, Nancowry, Trinkat	A1, A2

Bird diversity in the Islands

The Andaman and Nicobar Islands constitute a globally important biodiversity hotspot. Because they are off the mainland and isolated, endemicity is very high in all taxa, but especially in reptiles, plants, fish and corals (Chakraborthy, 1978; Rao *et al.* 1980; Rosalind, 1992-2002; Das, 1999a, 1999b and Andrews, 2001) The forests on the islands are classified into twelve different types. The coral reefs and marine habitats support an extraordinary faunal diversity (Gandhi, 2000). The diversity at the subspecies level is very high, with different subspecies present on different islands on account of their geographical separations (Gandhi, 2000). These islands are one of the Endemic Bird Areas (Stattersfield *et al.*, 1998). Thirteen bird species are considered Restricted. Range in the Andaman group, and nine in the Nicobar Island (Stattersfield *et al.*, 1998). Most of the Restricted Range birds are forest species in the Andamans and many can be seen near Port Blair (Curson, 1989). Most of them can be seen easily in the Middle and South Andaman, and the Great Nicobar group, and many of them are restricted to these islands (Stattersfield *et al.*, 1998). For example, Nicobar Parakeet *Psittacula caniceps* is confined to the Great Nicobar group while Nicobar Bulbul *Hypsipetes nicobariensis* is present only in the Nancowry group. Similarly, the Andaman Scops-owl *Otus balli* is found in Narcondam and South Andaman, (Stattersfield *et al.*, 1998). An extreme form of endemicity is shown by the Narcondam Hornbill *Aceros narcondami* which is confined to an area of only 6.82 km^2 of Narcondam island. Among Indian birds, the Narcondam Hornbill haqs the smallest area of occupancy (Islam and Rahmani, 2004).

Globally threatened distribution in various IBAs

Vulnerable

Nicobar Sparrowhawk	*Accipiter butleri*	IN-AN-03, 05, 19
Nicobar Megapode	*Megapodius nicobariensis*	IN-AN-05, 19
Narcondam Hornbill	*Aceros narcondami*	IN-AN-14
Nicobar Bulbul	*Hypsipetes nicobariensis*	IN-AN-19

Data Deficient

Andaman Crake	*Rallina canningi*	IN-AN-01, 02, 04, 06, 07, 08, 09, 11, 12, 13, 15,17, 18

Near Threatened

Nicobar Serpent-Eagle	*Spilornis minimus*	IN-AN-03, 05, 19
Andaman Serpent-Eagle	*Spilornis elgini*	IN-AN-01, 02, 04, 06, 07, 08, 09, 10, 11, 12, 13, 15, 16, 17, 18
Andaman Wood-Pigeon	*Columba palumboides*	IN-AN-01, 02, 03, 04, 05, 06, 07, 08, 10, 11, 12, 13, 15, 17, 18, 19

Andaman Cuckoo-Dove	*Macropygia rufipennis*	IN-AN-01, 02, 03, 04, 05, 06, 07, 08, 10, 11, 12, 13, 15, 17, 18, 19
Nicobar Parakeet	*Psittacula caniceps*	IN-AN-05
Andaman Scops-Owl	*Otus balli*	IN-AN-02, 07, 08, 10, 11, 12, 13, 14, 15, 17, 18
Andaman Hawk-Owl	*Ninox affinis*	IN-AN-01, 02, 03, 04, 05, 06, 07, 08, 10, 11, 12, 13, 15, 17, 18, 19
Andaman Black Woodpecker	*Dryocopus hodgei*	IN-AN-01, 02, 04, 06, 07, 08, 10, 11, 12, 13, 15, 17, 18
Andaman Drongo	*Dicrurus andamanensis*	IN-AN-01, 02, 04, 06, 07, 08, 09, 10, 11, 12, 13, 15, 16, 17, 18
Andaman Treepie	*Dendrocitta bayleyi*	IN-AN-01, 02, 04, 06, 07, 08, 10, 11, 12, 13, 15, 17, 18

Among the 13 restricted range species, three are globally threatened species, the Nicobar Megapode found in the forest and secondary growth, the Andaman Crake, the bird of marshland in the forested areas, streams and mangrove creeks and the third is the Narcondam Hornbill found on Narcondam island. In the Nicobar group of islands, the Nicobar Scrubfowl and Nicobar Bulbul are found in forested areas, but the Bulbul can also be seen in gardens (Islam and Rahmani, 2004).

Globally Threatened and Restricted Range birds in the Islands

Andaman Serpent-Eagle *Spilornis elgini* : The Serpent eagle is one of the 52 Near Threatened species in India. It is endemic to South Andaman islands where it is common and can be seen easily in inland forest clearings, near hills (BirdLife International 2001) and mostly in the mangrove marshes and mangrove creeks where they nest (H. Andrews *per. comm.* 2003). Recently, it was reported from the Middle Andaman and even on a small island like South Reef (H. Andrews *per. comm.* 2003). The main threat is the rapidly rising human population, the bird habitat is consequently under great pressure from agriculture, grazing and logging.

Nicobar Scrubfowl (Megapode) *Megapodius nicobariensis* : The Nicobar Megapode comes under the Vulnerable category of IUCN and has a declining population as a result of the destruction of coastal forests (BirdLife International 2001). The Megapode is one of the three bird species entirely restricted and endemic to the Nicobar islands (Stattersfield *et al.*, 1998). The main threat to this bird are the mainland Indian settlers who hunt for meat and collect egg (Sankaran, 1995, BirdLife International, 2001, H. Andrews, *per. comm.* 2003). The population of this bird is estimated to be about 625-1,090 breeding pairs (BirdLife International, 2001). It has been reported from Batti Malv, Tillanchong, Little Nicobar, and all around the Great Nicobar Island.

Andaman Crake *Rallina canningi* : This crake is a rarely encountered endemic of the Andaman islands which is absent from the Nicobars (Ali and Ripley, 1987) and is one of the globally threatened species (BirdLife International, 2001). It is mainly found in the Middle and South Andaman (Vijayan 1997). It was reported to be common in Mount Harriet National Park, though encountered only twice (BirdLife International, 2001). According to Rauf Ali (*pers. comm.* 2003) it is quite common near Wandoor. H. Andrews (*per. comm.* 2003) also considers it to be one of the most common bird species, but is data deficient. It is found from South to North Andamans, including several outlying islands right up to Landfall Island, the northernmost island in the Andamans. Its status needs reassessment. It has been reported from 13 IBA sites such as Landfall Island, Austin Strait, Saddle Peak NP, Jarwa Reserve (Middle Andaman), Mount Harriet, North Sentinel and others.

Andaman Wood Pigeon *Columba palumboides* : This is one of the Near Threatened species, endemic to the Andaman and Nicobar Islands (BirdLife International, 2001, Stattersfield *et al.*, 1998). It is an uncommon bird in the Andamans, but small parties wander from one island to another. It is potentially threatened by extensive hunting and trapping by settlers, habitat loss and fragmentation, because of the growing human population on the larger islands resulting in pressure from agriculture and grazing (Stattersfield *et al.*, 1998, H. Andrews, *pers. comm.*, 2003). It has been reported from Mount Diavalo/Cuthbert Bay, Mahatma Gandhi Marine National Park, Interview Island Wildlife Sanctuary, Car Nicobar, Chainpur and Hanspuri, Great Nicobar, Little Nicobar, Little Andaman, and other IBA sites.

Andaman Cuckoo Dove *Macropygia rufipennis* : It is one of the Near Threatened species endemic to the Andaman and Nicobar (Nancowry sub-group and Great Nicobar) archipelagos (BirdLife International 2001, Stattersfield *et al.* 1998). The Andaman Cuckoo Dove is found in dense, broadleaf, primary and secondary evergreen forest. It is reported from Mount Diavalo/Cuthbert Bay, Mahatma Gandhi Marine NP (Wandoor NP), Interview Island WLS, Car Nicobar, Chainpur and Hanspuri, Great Nicobar, Little Nicobar, Little Andaman, and other IBA sites.

Andaman Coucal *Centropus andamanensis* : The Andaman Coucal or Brown Coucal is Near Threatened and endemic to these islands and is found in forest-edge gardens, cultivation and mangrove areas. It is mainly reported from the Table and Coco islands, Middle Andaman, South Andaman, and Little Andaman (Stattersfield *et al.* 1998). It is also reported from Mount Diavalo / Cuthbert Bay, Mahatma Gandhi Marine NP, Landfall Island WLS, Little Andaman, Baratang-Rafters Creek, Mount Harriet NP, North and South Sentinel, North Reef Island WLS, and other IBA sites.

Andaman Scops Owl *Otus balli* : It is a Near Threatened species, endemic to the Andaman Islands, where it is common and can be seen in trees in semi-open or cultivated areas and around human settlements (del Hoyo *et al.*, 1999). Very few studies have been conducted and its present status is unclear. Though commonly seen, more research is required to know about bird's ecological requirements, population size and trends (Stattersfield *et al.*, 1998). This Owl has been reported mainly from Narcondam, South Andamans, Middle Andamans, North Andamans, Baratang Island and from several outlying islands. Some of the IBA sites from where it is reported are Little Andaman, Baratang-Rafters Creek, Mount Harriet NP -Shoal Bay, Narcondam Island WLS, North and South Sentinel and Rani Jhansi Marine NP.

Andaman Hawk Owl *Ninox affinis* : It is a Near Threatened species and endemic to the Andaman and Nicobar archipelagos, where it occurs in the mangrove forest, lightly wooded areas and forest clearings, and is commonly seen hawking insects at dusk (BirdLife International, 2001). Its population is also reducing due to habitat degradation on an account the growing human population increase on the larger islands in the Andamans. It is found in North, Middle and South Andaman Islands and is reported from some of the IBAs such as Rani Jhansi Marine NP, Tillanchong, Camorta, Katchal, Nancowry, Trinkat, Saddle Peak NP, Jarawa Reserve, Kadakachang, Austin Strait, Mount Diavalo/Cuthbert Bay, Mahatma Gandhi Marine NP, and other IBA sites.

Narcondam Hornbill *Aceros narcondami* : This endemic and vulnerable hornbill has a very small population on a tiny, island less than seven km^2 in area known as Narcondam Island. Its population is stable since feral goats were culled by the armed forces. It is roughly estimated that about 68-85 breeding pairs are present on the island (BirdLife International, 2001), with a population of about 400 hornbills (Yahya and Zarri, 2002). The main threat could be the felling of trees for fuel and hunting by policemen posted on the island. Hunting is strictly prohibited now.

Nicobar Bulbul *Hypsipetes nicobariensis* : This bulbul is one of the 78 globally vulnerable species with a small, declining population as a result of the clearance and degradation of forests for plantation, agriculture and infrastructure projects (BirdLife International, 2001). This bird is endemic to the Nancowry group of Islands in the Nicobar islands (Abdulali, 1965). It was reported by Humayun Abdulali that there were up to 100 in Tillanchang, but in recent studies by Sankaran (1998), only one was seen on Tillanchang and one on Nanchowry. It shows a sharp decline but it is suspected that a healthy population could be seen on Teressa and Katchall islands.

South Nicobar Serpent-Eagle *Spilornis klossi* : This Eagle which is treated as separate from "Nicobar [or Small] Serpent-eagle *S. minimus*" which is instead provisionally placed with *S. cheela*) is endemic to the islands of Great Nicobar (including Pulo Kunji), Little Nicobar and Menchal in the South Nicobar island group, Nicobar islands (Richmond 1902, Abdulali 1967, 1978, Sankaran 1998, K. Sivakumar verbally 1999). Increased settlement of the islands has led to increased pressure on natural resources, and planned development projects could severely affect the habitat of this species (Stattersfield *et al.*, 1998).

Nicobar Parakeet *Psittacula caniceps* : This Parakeet Near Threatned and endemic to the Nicobar archipelago, where it inhabits tall forest on Great Nicobar, Little Nicobar, Menchal and Kondul islands, feeding in small groups in the canopy on the fruit of *Pandanus* palms (Grimmett *et al.*, 1998). It is apparently common, but fairly large numbers are trapped for the cagebird trade (del Hoyo *et al.*, 1997). Furthermore, increased settlement of the islands has led to increased pressure on natural resources, and planned development projects could severely affect the habitat of this species (Stattersfield *et al.*, 1998).

Nicobar Scops-Owl *Otus alius* : The Nicobar Scops-owl is known only from a single locality on Campbell Bay (Rasmussen 1998). The species may occur on other islands in the group, but equally it may be endemic to Great Nicobar, and indeed restricted in range on that island. The most likely other island where it may be found is Little Nicobar which, like Great Nicobar, is relatively poorly explored (Rasmussen 1998).

Andaman Black Woodpecker *Dryocopus hodgei* : This Woodpecker is Near Threatened species and endemic to the Andaman islands, where it is a common resident in large trees of evergreen forest (Davidar *et al.*, 1996; Grimmett *et al.*, 1998). Although forest remains fairly extensive on the Andamans, the human population on larger islands is rising rapidly and habitat is consequently under severe pressure from agriculture, grazing and logging (Pande *et al.*, 1991; Stattersfield *et al.*, 1998).

Andaman Drongo *Dicrurus andamanensis* : This Drongo is endemic to the Andaman archipelago also recorded from Coco Island in Myanmar, where it is a common resident of forests (Davidar *et al.*, 1996; Grimmett *et al.*, 1998). Although its range is very small, forested habitat is relatively intact on the Andamans and insufficiently disturbed or fragmented to be of immediate concern. However, there are signs that pressure on forests is increasing in the Andamans through increasing human populations and consequent conversion of habitat to cultivation, grazing, increased logging and development (Pande *et al.*, 1991; Stattersfield *et al.*, 1998; BirdLife International, 2001).

Andaman Treepie *Dendrocitta bayleyi* : This Treepie is Near Threatened and endemic to the Andaman archipelago, where it is usually found in pairs or parties of up to 20 birds, or in mixed flocks in tall trees in dense broadleaved evergreen forest (Grimmett *et al.*, 1998). It is uncommon (Davidar *et al.*, 1996) to locally fairly common (Grimmett *et al.*, 1998), and although habitat on the Andamans remains relatively intact, there are indications that an increase in human populations and habitat loss is occurring in the archipelago suggesting that the very small range of this species might rapidly shrink and fragment (Pande *et al.*, 1991; Stattersfield *et al.*, 1998; BirdLife International, 2001).

Endemic Bird Areas 125 : Andaman Islands

Common Name	Species name	Number of IBA's	Global Status
Andaman Serpent-Eagle	*Spilornis elgini*	IN-AN-01, 02, 04, 06, 07, 08, 09, 10, 11, 12, 13, 15, 16, 17, **18**	NT
Andaman Crake	*Rallina canningi*	IN-AN-01, 02, 04, 06, 07, 08, 09, 11, 12, 13, 15, 17, **18**	NT
Andaman Wood-Pigeon	*Columba palumboides*	IN-AN-01, 02, 04, 06, 07, 08, 10, 11, 12, 13, 15, 17, **18**	NT
Andaman Cuckoo-Dove	*Macropygia rufipennis*	IN-AN-01, 02, 04, 06, 07, 08, 10,11, 12, 13, 15, 17, **18**	NT
Andaman Coucal	*Centropus andamanensis*	IN-AN-02, 07, 08, 09, 10, 11, 12, 13, 15, 16, 17, **18**	LC
Andaman Scops-Owl	*Otus balli*	IN-AN-02, 07, 08, 10, 11, 12, 13, 14, 15, 17, 18	NT
Andaman Hawk-Owl	*Ninox affinis*	IN-AN-01, 02, 04, 06, 07, 08, 10, 11, 12, 13, 15, 17, **18**	NT
Narcondam Hornbill	*Aceros narcondami*	IN-AN-14	VU
Andaman Black Woodpecker	*Dryocopus hodgei*	IN-AN-01, 02, 04, 06, 07, 08, 10, 11, 12, 13, 15, 17, **18**	NT
White-headed Starling	*Sturnus erythropygius*	IN-AN-01, 02, 04, 06, 07, 08, 09, 10, 11, 12, 13, 15, 17, **18**	LC
Andaman Drongo	*Dicrurus andamanensis*	IN-AN-01, 02, 04, 06, 07, 08, 09, 10, 11, 12, 13, 15, 16, 17, **18**	NT
Andaman Treepie	*Dendrocitta bayleyi*	IN-AN-01, 02, 04, 06, 07, 08, 10, 11, 12, 13, 15, 17, **18**	NT

Endemic Bird Areas 126 : Nicobar Islands

Common Name	Species name	Number of IBA's	Global Status
Nicobar Serpent-Eagle	*Spilornis minimus*	IN-AN-03, 05, 19	LC
Nicobar Sparrowhawk	*Accipiter butleri*	IN-AN-03, 05, 19	VU
Nicobar Megapode	*Megapodius nicobariensis*	IN-AN-05, 19	VU
Andaman Wood-Pigeon	*Columba palumboides*	IN-AN-03, 05, 19	NT
Andaman Cuckoo-Dove	*Macropygia rufipennis*	IN-AN-03, 05, 19	NT
Nicobar Parakeet	*Psittacula caniceps*	IN-AN-05	NT
Andaman Hawk-Owl	*Ninox affinis*	IN-AN-03, 05, 19	NT
Nicobar Bulbul	*Hypsipetes nicobariensis*	IN-AN-19	VU
White-headed Starling	*Sturnus erythropygius*	IN-AN-03, 05, 19	LC

Key threats to IBAs

On these islands the human population has registered a growth rate of 27 per cent as against the national average of 21 per cent during the decade 1991-2001. This is mainly due to settlers, sometimes with the encouragement of the Government of India, coming from the mainland. This rapid growth in human population has adversely affected the natural ecosystems of the islands. Expansion of agriculture and grazing that leads to habitat loss, and degradation from logging is some key threats to the birds and their habitat (Curson, 1989; Andrews and Sankaran, 2002). Introduced or invasive species also pose a threat to the native birds, for example goats disturb the habitat of the endemic Narcondam Hornbill (Vijayan and Sankaran, 2000), and Spotted deer and Elephants adversely affect forest regeneration and cause serious crop losses (Aul and Ali, 2001; Aul, 2002a, 2002b). Infrastructure development such as road construction, expanding urban and rural areas, modern agriculture practices, and poaching are some of the factors posing serious threats to the avifauna of these islands (Islam and Rahmani, 2004).

It is essential to eliminate the invasive species at the earliest to prevent further degradation of the forests. The protected area (PA) network in the Andaman and Nicobar Islands needs to be reassessed as several small PAs were created without proper justification and should be clumped with adjoining larger PAs. The PA network in the marine ecosystem, at present inadequate, needs expansion by declaring them as marine sanctuaries. Any infrastructure development can be allowed only after carrying out EIA studies by reputed organizations/ individuals. Poaching by settlers and foreigners needs to be controlled by strengthening the Forest Department and in collaboration with other departments such as the Coast Guard and the Indian Navy. A conservation awareness programme is also required for local people, especially settlers. A monitoring protocol needs to be prepared for insular birds and all endemic birds should be monitored regularly. There should be strict control in the introduction of non-native species.

Another endemic species of serious concern is the Narcondam Hornbill. This species is found only on the 6.82 km^2 Narcondam Island. Hussain (1984) recorded about 400 birds in 1972. Unfortunately, in 1976, goats were introduced to supply meat to the policemen posted there. Recent studies conducted in 1998 by Ravi Sankaran have indicated that the introduced goats are having a negative impact on the regeneration of natural vegetation. The goat population has increased to 130-150 in the police camp, and some have escaped and now number about 250 in the wild. These feral goats are the major problem as they eat saplings of trees and prevent regeneration. The hornbills nest in the hollows of old trees and every year, many old trees die or fall down due to storms which are prevalent in the area. If there is no regeneration of trees, then there is a probability that in another 60-80 years, when all the old trees are gone, the Narcondam Hornbills will face a problem of scarcity of nesting holes. This is a long-term problem which can be solved by eliminating the feral goats, and keep only male goats for food so there will not be further chance of a feral population. However, the immediate problem is poaching of Hornbills by policemen. Dr. Sankaran, during his three-month stay on Narcondam Island, found that 8-10 birds were shot. He thinks that the annual loss of Hornbills due to poaching could be as high as 40 birds. This illegal hunting could be reduced considerably by environmental education and strict enforcement of the Wildlife Protection Act (Islam and Rahmani 2004).

Conservation Issues

The island ecosystem of Andaman and Nicobar are under threat due to one or more of the following reasons: Encroachment on forestland, mining of sand, inappropriate fisheries, inappropriate and excessive forest working, introduction of exotics, extraction of corals, poaching for corals, impact of agriculture and human habitation (Islam and Rahmani 2004).

Encroachment

The forested land is a source of useful forest produce that sustain many livelihood patterns. Villagers know this and are aware of the effects of deforestation. In spite of this, encroachment in forest area continuous without much control, as there is a great demand for living space. New Wandoor (Protected forest I & II) has the largest number of forest encroachments. Being widespread and uncontrolled, this constitutes a serious threat to the forest of Andaman Islands.

Coastal erosion due to sand mining

Two of the major threats to marine and coastal biodiversity include sand mining on the sandy beaches and siltation of costal areas. Increasing population and accelerated development have spurred the growth of construction activity. The cement used for construction requires sand to be mixed with it to make concrete and, as the islands do not have large streams from which the sand can be collected, most of the sand is mined from the coastal areas. To facilitate sand extraction from beaches, a temporary CRZ waiver has been authorized by the Central Ministry for Environment and Forest. A Sand Allocation Committee has also been established in Andaman and Nicobar Islands, but surveillance and enforcement are difficult, there is extensive illicit collection, leading to rampant erosion.

Impacts due to Forestry Operation

A number of forest management plans were formulated from 1906. Private companies were also given permission to have their own felling coupes. The Forest Department follows the 'Andaman Canopy Lifting Shelterwood System' for regenerating worked forest. However, this system has led to the depletion of forest and biodiversity. One major impetus for extensive working the forests and promoting commercial species has been the imperative to supply raw material to the wood-based industries.

Introduction of alien species

The introduction of alien or exotic species has had adverse impacts through their unchecked proliferation, for example the Spotted Deer, which were originally introduced for sport. In the absence of natural predator, they multiplied extensively. The deer now has become pest as they browse indiscriminately and prevent regeneration in the protected areas. Abondoned after forest operations the feral elephants are also causing damage in some PAs. The introduction of hardy and adaptable birds like common mynah is a threat since they compete more vulnerable indigenous species.

Impacts due to tourism

Tourists activities in the Islands have also led to serious threats to the environment. For one, the infrastructure required to service the growing number of tourist, especially airports, hotels and roads. Besides increase in number of tourist, means an increase in energy consumption, in pollution because of transport in inadequate waste management.

Source: Sustainable Management of Protected Areas in the Andaman and Nicobar Islands - Harry V. Andrews and Vasumathi Sankaran (2002).

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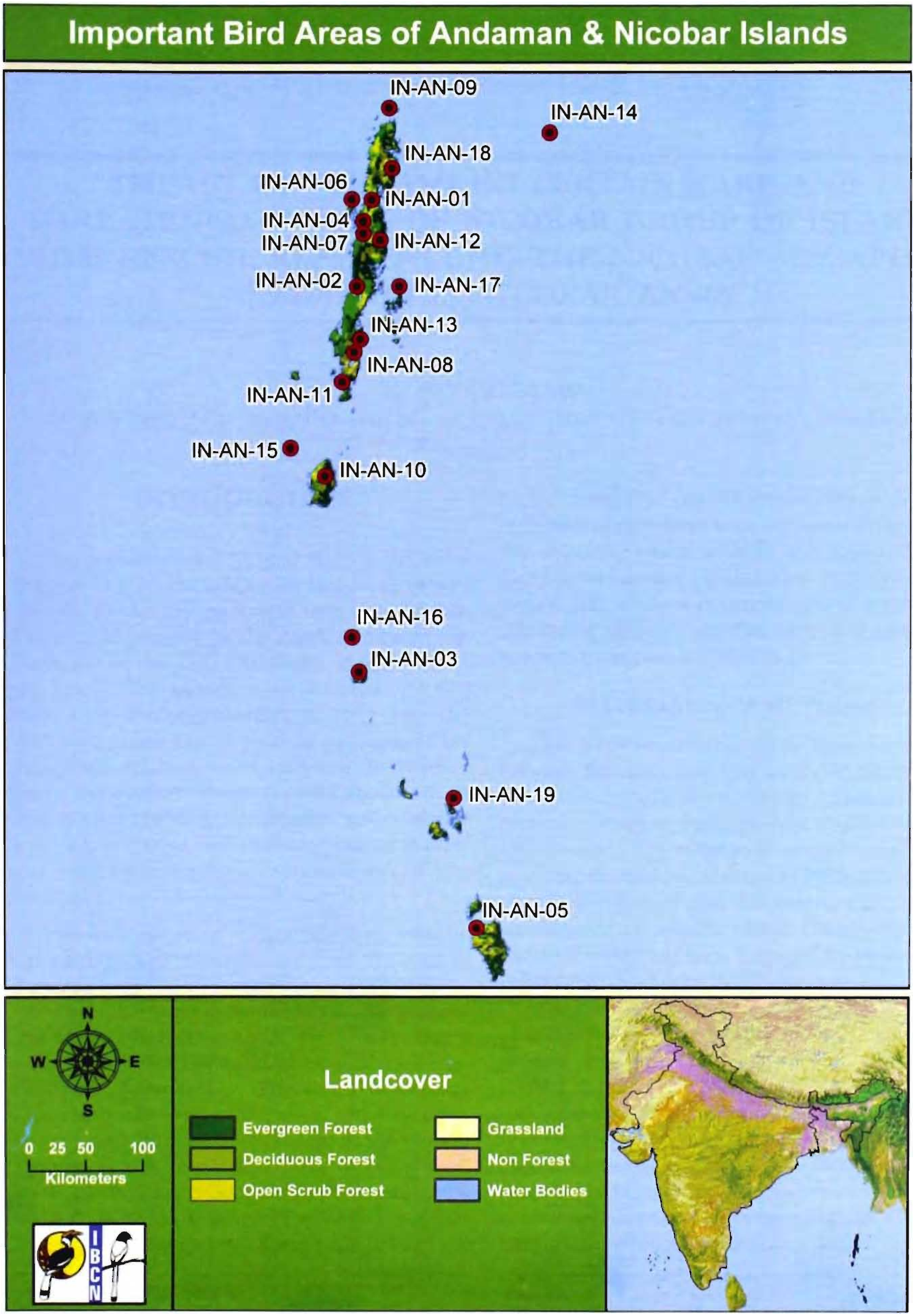
Plate 26


Important Bird Areas of Andaman & Nicobar Islands
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Open Scrub Forest
Grassland
Non Forest
Water Bodies

Chapter 37

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 435-441, 2010

IMPACT OF TSUNAMI ON CERTAIN RARE AND THREATENED SPECIES OF NICOBAR GROUP OF ISLANDS WITH SPECIAL REFERENCE TO THE NICOBAR MEGAPODE *MEGAPODIUS NICOBARIENSIS*

K. SIVAKUMAR*

Wildlife Institute of India, P.O. Box. No. 18, Chandrabani, Dehradun-248 001, Uttarakhand

INTRODUCTION

The Andaman and Nicobar Islands (latitudes 6°45' and 13°41' and longitudes 92°12' and 93°57') situated in the Bay of Bengal arch from Arakan Yoma in Mayanmar in the north to Sumatra in Indonesia in the south (Saldanha, 1989; Dagar *et al.*, 1991). The Islands cover an area of 8,249 km^2, with a total coastline of 1962 km; the Andaman group has more than 325 Islands (21 inhabited) covering 6,408 km^2, and the Nicobar group has over 23 Islands (12 inhabited) with an area of 1,841 km^2 (Fig. 1) (Saldanha, 1989). Islands have a hot, humid and uniform tropical climate and vegetation is mostly evergreen forests and mangrove.

The earthquake of magnitude 9.15 with its epicentre at 3.29° N and 95.94° E off the coast of Sumatra with a focal depth of 30 km occurred on 26th December 2004 at 06:28:50 hrs. The tsunami waves reached the coast first, causing a phenomenon called draw down, where the sea level dropped considerably. The draw down was followed by the crest of the wave, which resulted in sea inundating land, also known as the run-up. The waters took several days to recede completely, leaving in its wake a devastation of unimaginable magnitude on the people and wildlife of Nicobar Islands (Sankaran, 2005). It was expected that the highly diversified coastal biodiversity with high endemism might have been adversely affected by the tsunami, which include the coastal living Nicobar megapodes (*Megapodius nicobariensis*). Hence, this study was carried out to assess the impact of tsunami on the certain threatened species in the Nicobar Islands.

MATERIAL AND METHODS

The Nicobar Islands have been surveyed between February and May 2006. As mounds of Nicobar megapode are stationary, inanimate and represent breeding signs, the best way to estimate and monitor the megapode populations is by assessing the number of active mounds (Sankaran, 1995b; Sivakumar and Sankaran, 2003). The coastline of 15 islands where the species was reported earlier has been surveyed for mounds by following standardized survey protocols (Sankaran, 1995b). To estimate the total number of active mounds, the coastline of each island was divided into two segments such as 'Potential Coastal Habitat for Megapode (PCHM)' and 'Non-conducive Coastal Habitat for Megapode (NCHM)' Potential coastal habitat of megapode was identified based on habitat preference of this species (Sivakumar, 2000). Extent of these two coastal habitats was measured using the satellite imageries (2006) and vegetation map.

Email : ksivakumar@wii.gov.in

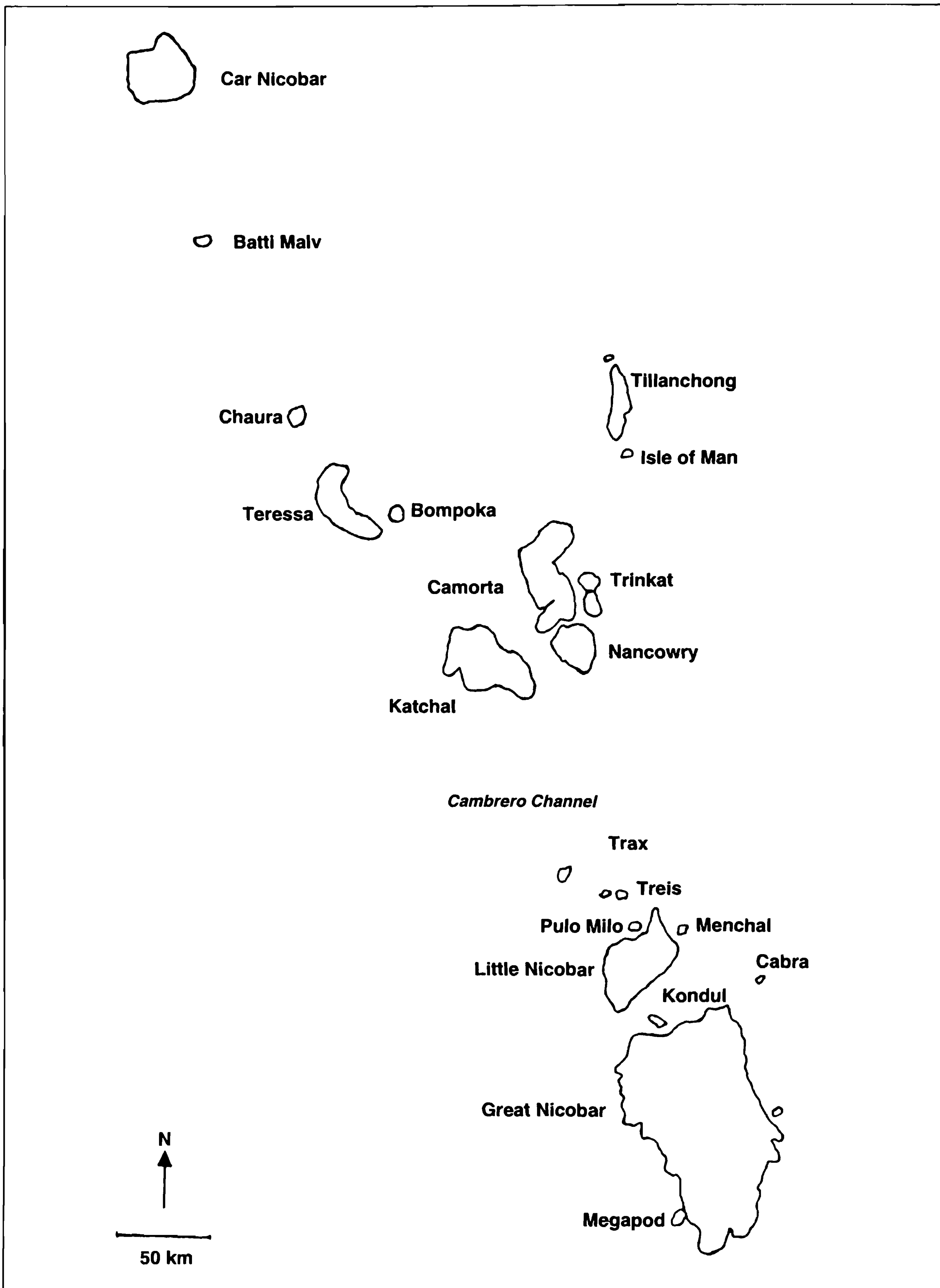

Fig 1. The Nicobar group of islands.

Variable width belt transect was used to count all the mounds and presence of other threatened species within sampled area. Length of transect, and distance between the two transects was set according to the size of the islands but it was uniform for any given islands. Average length of belt transect was 2 km, however, in some cases the length of transect was small due to smaller sizes of islands. Width of the each transect varied depending upon the extent of low lying forest from the shore to near by hills The census was carried out with seven observers walking at 20 m interval abreast parallel to the seashore. Interior forests of Great Nicobar, Little Nicobar, Kamorta, Katchal and Teressa islands were also sampled with fixed width transect i.e. 140 m width and 1 km long. A total of 328 km long coastal habitat was identified as PCHM; of these, 157.5 km coastal forests were sampled in 80 transects. Of the 80 transects, 68 transects were 2 km long, 10 transects were less than 2 km and two transects were more than 2 km. Of the 358.8 km long NCHM, 77.9 km long coastal stretches have been sampled in 39 transects. Boat survey also carried out in the nearest offshore water along the coastline of the all Nicobar islands. Total number of active mounds of the Nicobar megapode *Megapodius nicobariensis*, presence of Coconut Crab *Birgus latro*, Long-tailed Macaque *Macaca fascicularis umbrosa*, Reticulated Python *Python reticulatus* and Malayan Box Turtle *Cuora amboinensis* were also recorded in the each transects.

RESULTS

Present distribution and status of certain threatened fauna of the Nicobar Islands

Giant coconut crab *Birgus latro* : Giant coconut crab usually prefers coastal habitat which have been severely affected due to tsunami. There was no sign of adult giant coconut crab presence in most of these islands; however, evidence of their presence was seen in the Menchal, Tillanchang and Katchal islands, five sites in Menchal, 21 sites from Katchal and one site from Tillanchang Island were recorded.

Malayan box turtle *Cuora amboinensis* : This is the only semi-aquatic land turtle present in this group of islands. A total of 16 dead shells were found on various parts of the coastal habitat of Great Nicobar islands showing that this species has also been badly hit by the tsunami.

Reticulated python *Python reticulatus* : Though this species was reported all over the Great Nicobar Island and young ones were commonly seen in the lowland forests (coastal region) during 1996-98 (Sivakumar, 2000) but, during this survey after spending 42 field days there was no single record of python in this group of islands especially in the lowland forests which have been badly destroyed by the tsunami.

Sea turtles : Though the survey periods was not coincide with the sea turtles peak nesting season, 140 sea turtles crawls were found on the Great Nicobar Island and 54 sea turtles crawls were observed on the Trinket and Tillanchang islands. Several new nesting beaches have been formed all along the west coast of the Great Nicobar Island. Northern part of the Galathea bay which was known for leatherback turtle nesting has severally damaged, however, southern beach has improved for the turtle nesting. Pigs and monitor lizards were observed eating turtle's eggs on most of the beaches.

Coral reef : Good patches of coral reefs were seen around the Nicobar group of islands before tsunami (Baskar and Rao, 1992; Sivakumar, 2000). Of these, most of the coral reefs, especially from the west coast of all islands were damaged by the tsunami. However, patches of coral reefs were seen undisturbed from the North-eastern coasts of most of the islands.

Sea grass beds and Dugong *Dugong dugon* : Of the 15 islands were surveyed by boat for sea-grass beds and dugong, two patches of sea grass beds were seen between Camorta jetty and Champin jetty of Nancowry Island. A dugong mother with a calf was sighted in this patch. Apart from this, it could not locate any other seagrass patches of these islands. It is believed that sea grass are also one of the most affected habitats due to tsunami and hence Dugong.

Nicobar megapode *Megapodius nicobariensis* : After tsunami 2004, the Nicobar megapode continued to be found on all but two islands *viz.* Trax and Megapode in the Nicobars from where it had been reported earlier. The Megapode Island was fully submerged due to rise in sea water level due to tsunami. More than 90 per cent of mound nests were built within 30 m distance from the shore. Of these, around 16 per cent of active mounds were found within 5 m distance from shore.

Of the total 687 km long coastal line of megapode lands, 328 km long coastal forest was identified as the 'Potential Coastal Habitat for Megapode' and remaining 359 km long coastal forests were identified as 'Non-conducive Coastal Habitat for Megapode'. It was estimated that about 800 breeding pairs of the Nicobar megapode occur on the coastal habitat of the Nicobar islands, which is nearly 70 per cent less than what was reported a decade ago (Table 1).

Blue-breasted quail *Coturnix chinensis* : Blue-breasted quail, a sub species endemic to Nicobars, was common on Car Nicobar, Trinket and Camorta Islands. Around 12-15 sightings were recorded during year 1993-04 (Sankaran, 1995a). However, a rapid survey which was carried out in grasslands of Camorta, Trinket, Teressa and Bamboka islands during the month of June 2006. Total of 54 birds were recorded while flushing out these birds in the grasslands by walking by six people. More number of birds recorded in the grasslands of Camorta (29 birds) followed by Teressa, Bomboka and Trinket. Blue-breasted quail were sighted often with Yellow-legged button quail *Turnix tanki*, however, sightings of this button quail was not rare in the Nicobar islands.

Long-tailed Macaque *Macaca fascicularis umbrosa* : A total of 16 troops of Long-tailed Macaque were sighted from the 62 sampling stations. 11 troops from Great Nicobar, two troops from Little Nicobar and three troops from Katchal Island. The group size ranged from seven to 98 individuals with a mean size of 23 individuals. The largest group was sighted in the Katchal (Kapanga). Near Indira Point, a skull of Long-tailed Macaque was found near the sea shore, which may have been killed by tsunami waves.

DISCUSSION

Status and distribution of the Nicobar megapode

After tsunami 2004, the Nicobar megapode continued to be found on all but two islands *viz* Trax and Megapode in the Nicobars from where it had been reported earlier. Compared to previous survey (Sankaran, 1995b), the concentration of mounds towards fringe of sea shore was high and

Table 1. Past and present status of the Nicobar megapode

Island	Estimated no. of active mounds in 1994*	Estimated no. of breeding pairs 1994*	Estimated no. of active mounds in 2006	Estimated no. of breeding pairs 2006
Great Nicobar	515	1416	203	405
Kondul	11	31	1	2
Little Nicobar	311	855	82	165
Menchal	2	6	6	12
Meroe	1	3	2	4
Pilo Milo	0	0	0	0
Trax	3	9	0	0
Treis	4	10	3	6
Nancowry	60	165	7	15
Katchal	69	190	9	1
Camorta	20	55	7	13
Tillanchang	10	28	27	53
Trinket	8	22	26	52
Teressa	119	328	9	18
Bampoka	26	72	13	25
Total	**1159**	**3190**	**394**	**788**

* Source Sankaran, 1995b.

it might be due to tsunami which had significantly reduced the coastal habitat. Around 16% of active mounds were found within 5 m distance from shore which may probably be influenced by high-tide water during full or new moon days. Maintaining mound temperature at a constant rate is important for the successful egg hatching (Sivakumar and Sankaran, 2003), however, influence of sea water on the incubation temperature is expected to adversely affect the hatching success of those mounds which are very close to the shore. Maximum of 800 breeding pairs of the Nicobar megapode occur on the coastal habitat of the Nicobar islands, which is nearly 70% less than what was reported a decade ago. Tsuanmi was believed to be the major cause for this decline.

It is believed that the temperature generated through fermentation of vegetative materials inside the mound is a major source of incubation temperature (Sivakumar and Sankaran, 2003), however, ambient temperature is also thought to contribute to the incubation process. Most of active mounds found on Nicobars were built at the base of available trees on the coastal area. Since most of trees dried due to tsunami waves, green canopy cover over mounds was less or nil. Direct fall of sunlight on the mound through day may not be good for the incubation mound of the Nicobar megapode, as direct sunlight for a longer period may warm up the mound quickly and killing the embryo in an egg. It is a serious concern for the long term survival of this species. However, natural resilience of coastal ecosystem of islands may change this situation provided there is no human intervention.

Status and distribution of certain other threatened fauna of the Nicobar group of islands

Blue-breasted quail was common on Car Nicobar, Trinket and Camorta islands before tsunami (Sankaran, 1995b). Since there was no detailed and systematic survey carried out on this species before and after tsunami it would be difficult to comment on their status with respect to tsunami. However, after tsunami, most of the grasslands in Camorta and Teressa were used for housing and plantations without considering their ecological values, which definitely have endangered this species and its habitat.

Before tsunami, a status survey of the Long tailed macaque, which was also mainly carried out along the coastal areas had recorded 788 groups and the group size ranged from 25 to 56 individuals with a mean size of 36 (Umapathy *et al.*, 2003). During the present survey, only 16 troops and troop size ranged from seven to 98 individuals with a mean size of 23 individuals were recorded during this survey which was carried out after tsunami. However, this data may not be compared with previous survey as the previous survey had few transects interior forests. It is believed that majority of the macaque may have escaped from the killer waves but they have lost their important food resources such as *Pandanus spp.*, *Terminalia spp.* and coconut and coastal habitat due to tsunami.

Giant coconut crab was commonly sighted along the undisturbed coastal areas of the Nicobar islands (Baskar and Rao, 1992; Sivakumar, 2000). They prefer to live inside the fallen log, under the base of the *Barringtonia asiatica* tree or sometimes in a small burrow (Sivakumar, 2000). These crabs normally were seen in more numbers, where barringtonia, pandanus and coconut strands were more (Sivakumar, 2000). After tsunami the habitat of coconut and pandanus were severally damaged or washed away from majority of the coastal areas. However, evidence of their presence in the Menchal, Tillanchang and Katchal islands are giving a hope for resilience of this species in the islands in future.

The other important threatened terrestrial species, which have been adversely affected by the tsunami are Malayan box turtle and Reticulated python These two species were not common even before the tsunami (Baskar and Rao, 1992) and now it become very rare. Juveniles of Reticulated python were commonly seen in the lowland forests of the Nicobar islands (Sivakumar, 2000), however, during this entire survey period, not even single python sighted. Another critically endangered mammal Dugong, which was often sighted from the west and southern coast of Great Nicobar, Katchal Nancowery and Camorta islands (Baskar and Rao, 1992; Das 1996) was also assumed to be severally affected by the tsunami. Presently, during this survey this species was sighted between Nancowry and Camorta islands. This endangered species already under severe threat due to poaching and habitat loss (Baskar and Rao, 1992; Das, 1996). After tsunami, which damaged most of the sea grass beds had left this species at the verge of extinction.

Post tsunami impact

The tsunami waves have washed away most of the planted as well as wild coastal coconut (*Cocos nucifera*) and acreca nut (*Areca catechu*) palms, therefore, plantation of these palms has become important for the future survival of people in this region. It is highly possible that in the absence of appropriate measures, the ongoing plantation activity would encroach upon the majority of the Nicobar megapode and its associated species. After tsunami, most of the low-lying coastal areas submerged and megapodes have built their mounds in evacuated villages. But when the people started returning, they began hunting the megapodes. In years to come, it is expected that tribals will be left with fishing and hunting of wildlife for their survival apart from livelihood support from the Government.

CONSERVATION

The island ecosystem is known for their resilience due to their ability for re-populating habitats and promoting regeneration (Lance, 2000; Thomas *et al.*, 2003). However, the restoration of the original biodiversity is possible only if the natural process such as re-colonization is actively facilitated (Lance, 2000). The aftermath of the tsunami has left the trail of homeless families who need rehabilitation. Finding proper homes and alternate livelihood for them should not undermine ecosystem resilience. Raising plantation crops to generate revenue in the littoral forests should take into account the long term effects of habitat alteration.

The Nicobar megapode and other above mentioned threatened fauna are protected by the various Schedules of the Wildlife (Protection) Act, 1972. Around 70 % of the population of Nicobar megapode had disappeared over the last 12 years. The major reason for the sharp decline is believed to be the tsunami which washed away their habitat along with nests. However, habitat destruction and hunting are the major human induced factors still adversely affect the megapodes, and these forces are likely to continue until a serious conservation programme is implemented.

At present, two National Parks and two Wildlife Sanctuaries cover the megapode and other coastal living fauna. Yet major portions of the potential coastal habitat especially along the west coast are outside protected areas. Inadequate coverage of Protected Areas in the Nicobar group of islands has already threatened several endemic fauna here (Sanakaran, 1997). Therefore, Nancowry group of islands may be declared as the 'Conservation or Community Reserve after obtaining the willingness from the local communities so that the Nicobar megapode and its associates in this region will get a better protection.

Symptoms of avian cholera were noticed in megapodes when the outbreak of this disease killed more than 50% of introduced domestic fowl in the Great Nicobar in 1997 (Sivakumar, 2004). After tsunami, the State Administration had a plan to supply 4,00,000 fowl and 9000 ducks to farmers and tribals which may threaten the native birds including megapode. Introduced dogs and cats are also known for threatening egg laying Nicobar megapodes (Sivakumar, 2000). Therefore, invasive species eradication programme need to be initiated immediately in this region.

After tsunami, hunting on megapodes seems to be on increase in several folds. Though, the Nicobarese attach traditionally cultural values to megapodes, scarcity of animal protein has forced them to hunt megapodes intensively. The two aboriginal tribes of Nicobar islands *viz.* Nicobarese and Shompens are exempt from the Wildlife (Protection) Act, 1972. Considering the changing lifestyle of these tribes, this immunity may be reviewed. In particular, the Nicobarese should be brought under the purview of the Wildlife Protection Act, 1972, while Shombens may be allowed to hunt wild animals.

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Sharma R. Jayapal, R.W.R.J. Dekker, Darryl Jones, Guntram S. K. Mukerjee, V.B. Sawarkar, A.J.T. Johnsingh, Asad Rahmani, Karthikeyan Vasudevan, B.S. Adhikari, K. Ramesh, Samuel Andrew, Jugulu Mehato, Chandrasekar Rao, S. Sivakumar, Koruma Rao, Damodhar Rao, Alkana, Rajan, Maianeus, Simos, James, Samuel and Rahul for their help during this study.

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Chapter 38

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 443-448, 2010

STATUS OF *DUGONG DUGON* (MULLER) IN ANDAMAN AND NICOBAR ISLANDS BASED ON PAST RECORDS AND TRADITIONAL HUNTING BY INDIGENOUS TRIBES

ELRIKA D'SOUZA*, E.K. RAVEENDRAN[1], P.T. RAJAN[2] and VARDHAN PATANKAR
Reef Watch Marine Conservation, Priyanka Building, 50 St. Paul's Rd., Bandra (W), Mumbai - 400050,

INTRODUCTION

The *Dugong dugon* (Muller) or sea cow is the only existing species in the family Dugongidae under the Order Sirenia and the only herbivorous mammal in the marine ecosystem. The geographical range of the dugong extends over the coastal waters of some 37 countries ranging from east Africa, through south and south-east Asia to Australia. This herbivorous mammal, inhabiting the marine environment was once abundant in many parts of its range but numbers have declined and its geographical distribution has decreased in recent times due to exploitation and loss of habitat. (Marsh *et al.*, 2001).

The dugong is currently listed in the IUCN Red List of Threatened Species as being vulnerable to extinction throughout its global range (IUCN, 2007). It is also listed in Appendix I of the Convention on International Trade in Endangered species of Wild Fauna and Flora (CITES), which prohibits all trades of this species or any products derived from it. In India, dugong has been given the highest level of legal protection and is listed under Schedule I of the Indian Wildlife Protection Act (1972 as amended up to 2006).

Dugongs have been reported from Gulf of Kutch, Saurashtra Coast, Konkan Coast, Malabar Coast, Gulf of Mannar and Palk Bay of the Indian sub continent (Lal Mohan, 1963, 1980; Mani, 1960; Silas, 1961; Frazier and Mundkur, 1990; Kumar, 2000; Alfred *et al.*, 2006). Dugongs have also been reported to be found in the Andaman and Nicobar Islands (Jones, 1980; James, 1988; Bhaskar and Rao, 1992; Rao, 1990).

All the above cited reference have reported sporadic records of stranded, accidentally caught and dead dugongs and no long-term data base is available on any particular region where dugongs are known to occur. The present article reporting current status is paper prepared based on published information, personal communications from other field scientists, enquiries from local inhabitants, tribal members, fishermen and our own personal observations. Information on Dugong hunting practices by the tribes is included in this article. The underwater sighting of dugongs in the wild from the Andaman Islands has been included along with photographs.

MATERIALS AND METHODS

Study area

The Andaman and Nicobar Islands in the south-eastern part of the Bay of Bengal located

*Corresponding author Email : elrikad@gmail.com
1. Directorate of Fisheries, Andaman & Nicobar Islands, Port Blair–744 101
2. Zoological Survey of India, Andaman & Nicobar Islands, Port Blair–744 101

between 06°45′ to 13°41′ N and 92°12 to 93°57′ E are one of the biodiversity hotspots of the world (Fig. 1). The island group comprises over 300 named and unnamed islands and over 260 named and unnamed rocks, with a total coastline of about 1,962 km. The entire island group covers an area of 8,249 km^2; the Andaman group with over 325 islands (21 inhabited) covering an area of 6,408 km^2, and the Nicobar group with more than 24 islands (12 inhabited) with an area of 1,841 km^2.

The Andaman group consists of 4 large islands, North, Middle, Baratang and South Andaman Islands forming a super island of over 5,000 km^2 in area, surrounded by archipelagoes and isolated islands. The Nicobar Islands are divided into three distinct subgroups. To the south is the Great Nicobar group consisting of two islands larger than 100 km^2, nine islets smaller than 5 km^2, and a few rocks. About 58 km north of the Great Nicobar group is the Nancowry group, which consists of three islands larger than 100 km^2, two of 36 and 67 km^2, three less than 17 km^2, two islets and a few rocks. The northern most subgroup comprising of Batti Malv and Car Nicobar is 88 km north of the Nancowry group.

Data on the occurrence of dugong and hunting from the Andaman and Nicobar waters was based on published information, personal communications from other field scientists, enquiries from local inhabitants, tribal members, fishermen and our own personal observations. The gathered information was set into a database containing the year, location, method, condition, number and the source of information. Data has been recorded from the year 1959 to 2008, with a gap in data between 2001 and 2005. The data was cross checked for its reliability with a number of fishermen, tribes and settlers of the same area. Records for the numbers and locations of dugongs hunted by indigenous tribes remains incomplete, as entry into tribal areas is regulated since 1956 under the *Andaman and Nicobar Protection of Aboriginal Tribal Regulation*. Records of traditional dugong hunting by the Shompens, Nicobaris and Onges were gathered from interaction with the tribal members, secondary information from settlers and government officials. Sightings of dugongs in the wild were made between February 2007 and March 2008. Photo-documentation of the reported specimens was done at the time of occurrence.

RESULTS

Number and distribution of stranding

A total of 57 stranded, dead and accidentally caught dugongs were reported, of which 33 were from the Andaman Islands and 24 were from the Nicobar Islands (Table 1 and 2). The maximum number was reported from Great Nicobar Island of the Nicobar Group followed by Diglipur of the Andaman group. Three dugongs were sighted during the period in the wild at Neil (Plate 27, Fig. 2), Havelock (Plate 27, Fig. 3) and Kodiaghat (Plate 27, Fig. 4) of South Andaman.

Table 1. Year wise list of Dugongs sighted locations in Andaman and source of information

Sl. No.	Year	Location	Method	Condition	No. caught	Source of Information
1	1959	Pokkadera (Mayabunder)	Gillnet	Dead	1	Fishermen
2	1979	Paschim Sagar (Mayabunder)	Gillnet	Dead	1	K. Venkanna (Fisherman)
3	1979	Tarmugli (Diglipur)	Gillnet	Dead	1	Saw Pawa (Fisherman)
4	1960 – 64	Diglipur			4	D.B. James (CMFRI)
5	1974	Ross Island (Diglipur)	Gillnet	Dead	1	G. Desh Pillai (Settler)
6	1974	Durgapur (Diglipur)	Shore seine	Dead	1	K. Venkanna (Fisherman)
7	1976	Aberdeen Jetty (South Andaman)	Gillnet	Dead	1	D.B. James, (CMFRI) Figure 8
8	1980	Long Island (Rangat)	Shore seine	Dead	1	J.J. Rao (Fisherman)
9	1983	Little Andaman (near Jetty)	Gillnet	Live	2	Local fisherman
10	1985	Ross Island (Mayabunder)	Gillnet	Live	1	A. Thatha Rao (fisherman)
11	1986	Sound Island (Mayabunder)	Gillnet	Dead	1	S. Dandasi (fisherman)

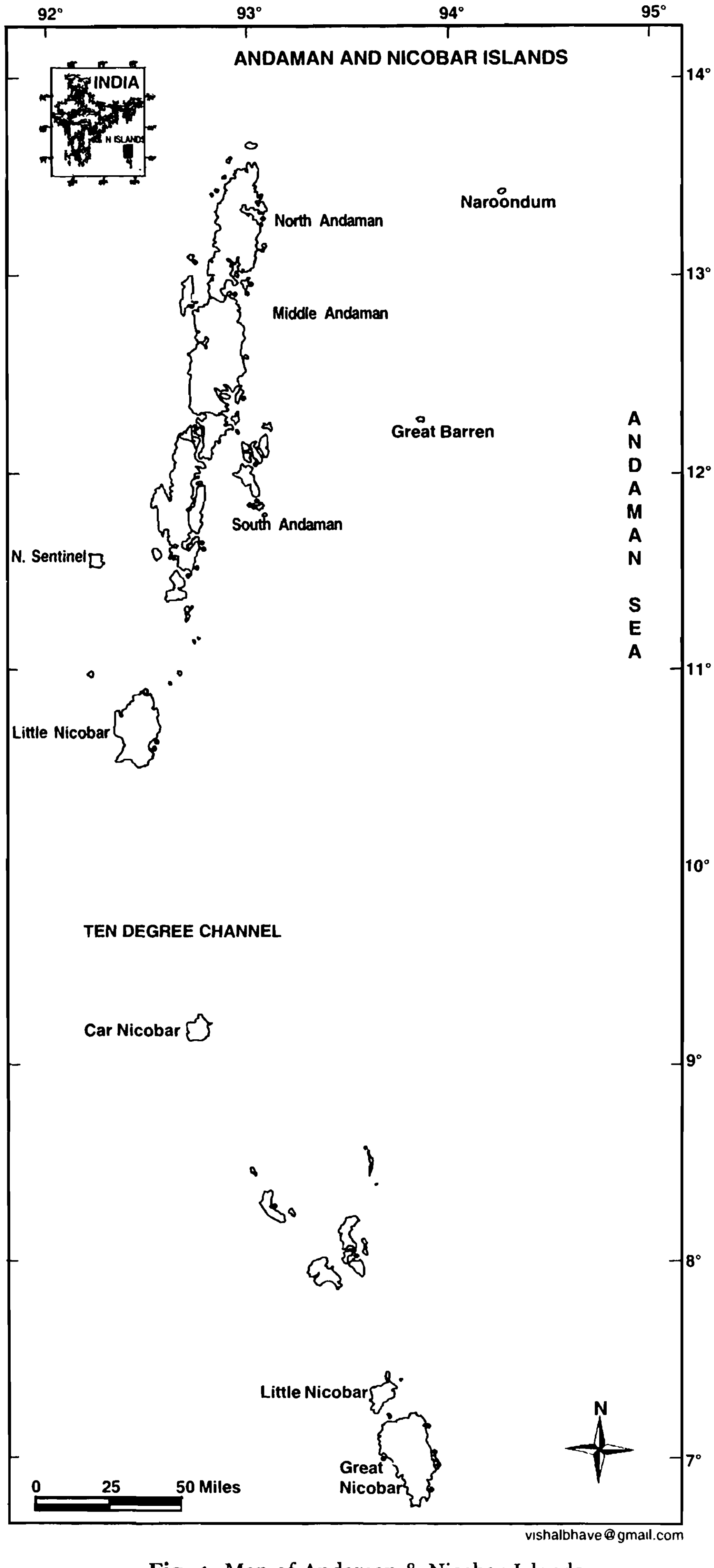

Fig. 1. Map of Andaman & Nicobar Islands

Table 1. *Contd.*

Sl. No.	Year	Location	Method	Condition	No. caught	Source of Information
12	1986	Long Island (Rangat)	Gillnet	Dead	1	J.J. Rao, (Fisherman)
13	1987	Long Island (Rangat)	Gillnet	Dead	1	Kamaiah (Fisherman)
14	1987	Tarmugli (Mayabunder)	Gillnet	Dead	1	Dandasi (Fisherman)
15	1987	Paschimsagar (Diglipur)	Gillnet	Dead	1	Dandasi (Fisherman)
16	1987	Chidiatapu (South Andaman)			1	G.C. Rao, (Zoological Survey of India).
17	1987	John Lawrence (S/Andaman)			1	G.C. Rao, (Zoological Survey of India).
18	1988	Little Andaman	Shore seine	Live	1	T.M. Koya, (Fisheries Department).
19	1988	Smith Island (Diglipur)			1	G.C. Rao, (Zoological Survey of India)
20	1988	Paschimsagar (Diglipur)	Gillnet	Dead	1	Dandasi (Fisherman)
21	1988	North Reef (Mayabunder)	Gillnet	Dead	1	Dandasi (Fisherman)
22	1989	Long Island (Rangat)			1	G.C. Rao, (Zoological Survey of India)
23	1989	Stwert Island (Diglipur)			1	G.C. Rao, Zoological Survey of India)
24	1997	Netaji nagar, Little Andaman	Gillnet	Dead	1	S.C. Dey, Fisheries Department. Figure 10
25	1999	Burmanallah, South Andaman	Gillnet	Dead	1	E.K. Raveendran, (Fisheries Department), P.T.Rajan, (Zoolgical Survey of India) Figure 9
26	2006	Karmatang (Middle Andaman)	Harpoon	Dead	1	Thete, (Karen settler)
27	2007	Neil		Dead	1	Elrika D'souza, (Reef Watch Marine Consevation)
28	2007	Corbyn Cove		Dead	1	Vijai, (Pondichery University student) (Figure 11.)
29	2008	Neil		Dead	1	Hasmukh Jiva, (Greenlife Society)
Total				**33**		

Table 2. Year wise list of Dugongs sighted locations in Nicobar and source of information

Sl. No.	Year	Location	Method	Condition	No. caught	Source of Information
1	1967	Teressa Island (Nancowry)			1	James, (CMFRI)
2	1972	Campbell Bay (Great Nicobar)	Gillnet	Live	1	Local inhabitants
3	1972	Magar nallah (Great Nicobar)	Gillnet	Live	1	Local inhabitants
4	1975	Lakshman beach (Great Nicobar)	Gillnet	Live	1	Local inhabitants
5	1976	Teressa Island (Nancowry)			1	James, (CMFRI)
6	1977	Campbell Bay (Great Nicobar)			1	James, (CMFRI)
7	1981	Campbell Bay (Great Nicobar)			1	James, (CMFRI)

Table 2. *Contd.*

Sl. No.	Year	Location	Method	Condition	No. caught	Source of Information
8	1982	Laful Bay (Great Nicobar)	Gillnet	Live	1	Local inhabitants
9	1984	Lakshman beach (Great Nicobar)	Gillnet	Live	4	Local inhabitants
10	1984	Laful Bay (Great Nicobar)	Gillnet	Live	1	Local inhabitants
11	1985	Laful Bay (Great Nicobar)	Gillnet	Live	1	Local inhabitants
12	1986	Lakshman beach (Great Nicobar)	Shore seine	Live	1	Local inhabitants
13	1988	Lakshman beach (Great Nicobar)	Shore seine	Live	1	Local inhabitants
14	1988	Campbell Bay (Great Nicobar)	Shore seine	Live	1	Local inhabitants
15	1988	Nancowry	Gillnet	Dead	1	Fisheries Department
16	1989	Pilo Kunji (Great Nicobar)		Dead	1	Das & Dey (1996)
17	1989	Campbell Bay (Great Nicobar	Shore seine	Live	1	Fisherman
18	1990	Nancowry (near jetty)			1	Rao, (Zoological Survey of India)
19	2000	Campbell Bay (Great Nicobar)		Dead	1	Yesu Ratnam, Forest Department
20	2002	Hitui (Nancowry)	Harpoon	Dead	1	Emanual, Nicobari
21	2008	Laxmi nagar (Great Nicobar)		Dead	1	Local inhabitants
Total					**24**	

DISCUSSION

The status of dugong population in the Andaman and Nicobar islands are poorly documented. The lack of information is partly due to the relatively sparse population, the distances between islands, the logistic constraints for field work and lack of awareness among the inhabitants. In view of the vulnerability of the dugong to extinction and our present data, the following recommendations are proposed :

1. The main cause of mortality of dugongs is by entanglement in gill nets, as dugongs must surface for 1 or 2 seconds to breathe at regular and frequent intervals (Anderson, 1981). Therefore, the use of gill nets and shore seines for fishing in dugong feeding grounds should be stopped by legislation after identifying such areas.
2. From the database, it is evident that dugongs have been killed in the Andaman and Nicobar waters in recent years. Therefore the situation calls for strict enforcement of wildlife protection act against hunters and poachers.
3. Sea grass which is the staple food of dugongs is likely to have been affected by the tsunami of 2004. Therefore, there is a need to map and monitor the feeding grounds of dugongs along the Andaman and Nicobar coast.
4. Use of modern techniques for a detailed study of the dugong in the Andaman and Nicobar islands in relation to its habitat may be initiated.
5. Extensive public awareness and education programs among the local communities about the conservation of dugongs should be implemented.

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Plate 27

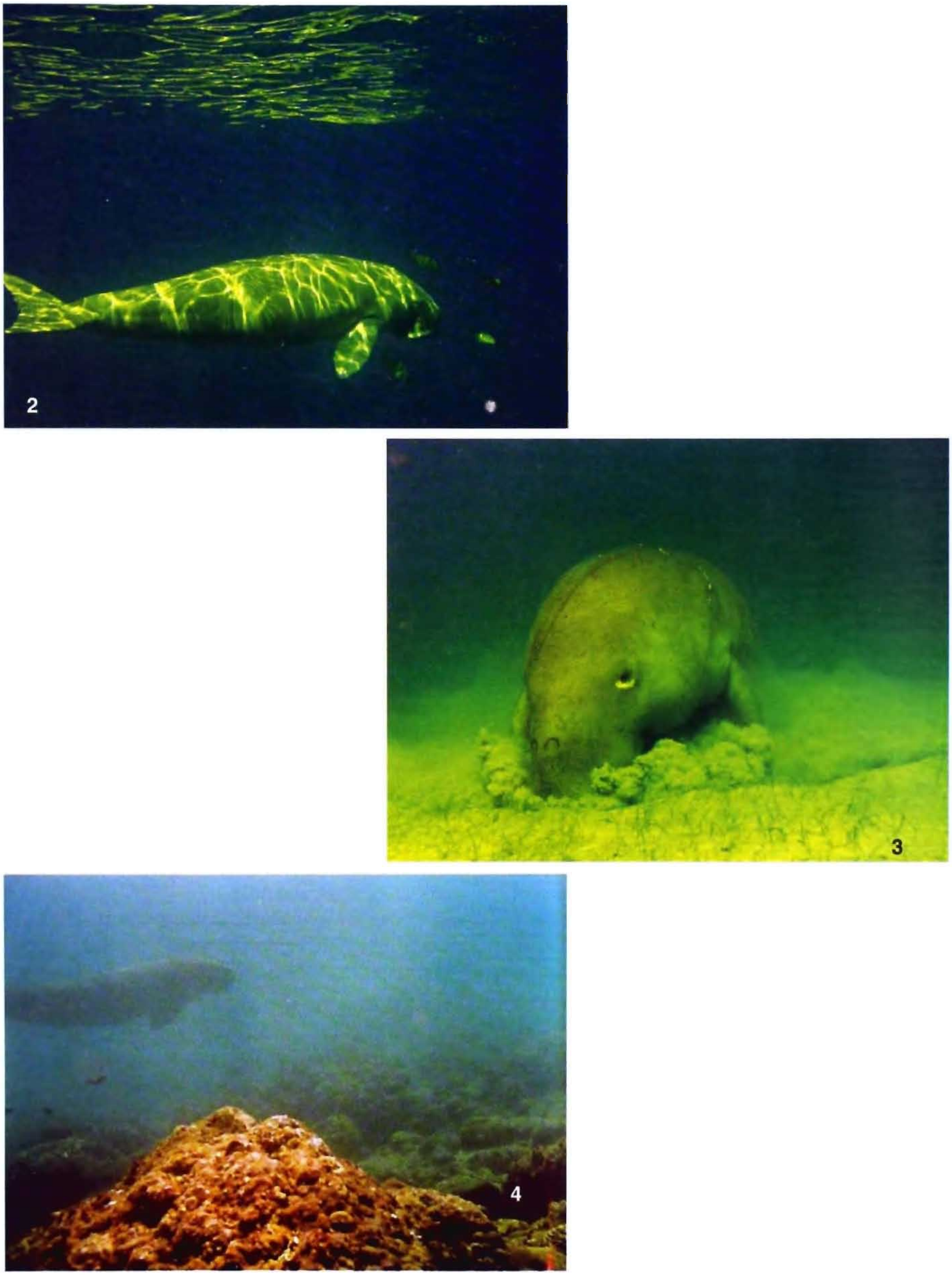

Fig. 2-4. Dugong sighted in wild at Neil, Havelock and Kodiaghat of South Andaman

Chapter 39

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 449-454, 2010

LONG-TAILED MACAQUES (*MACACA FASCICULARIS UMBROSA*) IN NICOBAR ISLANDS, INDIA$

G. UMAPATHY and MEWA SINGH*
Laboratory for the Conservation of Endangered Species (LaCONES), Centre for Cellular and Molecular Biology Annexe-1, Attapur Ring Road, Hyderabad 500 048

INTRODUCTION

Tropical rainforests cover only about 6 to 7 per cent of the earth's surface but they contain more than 50 per cent and possibly as much as 90 per cent of all species of plants and animals (WRI, 1990). Tropical wet forests are characterized by high species diversity (Whitmore, 1986). The rainforest species are highly susceptible to habitat disturbance and loss due to their low rate of production and dispersal, and a high degree of specialization. The island ecosystems are more susceptible to human disturbance due to their limited resources (Carew-Reid, 1990). The increasing human activity in the form of tourism, agriculture in such forests causes severe threats to the endemic flora and fauna in the islands. The objective of the present study was to assess the distribution and status of Long-tailed macaque in the East Coast Islands of India.

The Long-tailed Macaque (*Macaca fascicularis umbrosa*) is the only primate found in the Nicobar Islands. The other subspecies of the Long-tailed Macaque occur in Myanmar, Thailand, Malaysia, Indonesia and the Philippines (Tikader and Das, 1982; Rodman, 1991). Since the subspecies *umbrosa* is found only in the Nicobar Islands, the Long-tailed Macaque is considered as one of the endangered primates of India and it is listed in Schedule-I of the Wildlife Protection Act (Anonymous, 1972 as amended up to 2006). Because of its wide distribution, this species is one of the most widely studied primates in other countries except in India. However, no published information is available on the distribution, status and ecology of the sub-species found in the Indian islands. The present study focuses on the status and distribution of the Long-tailed Macaque in the Indian islands.

STUDY AREA

The Andaman and Nicobar islands in the Bay of Bengal cover an area of about 8,249 km^2. These islands are the remnant ranges, which at one time stretched from Arcon in Myanmar to Achin in Indonesia between latitudes 6°45′ and 13°41′ and longitudes 92°45′ and 93°57′ (Saldanha, 1989). The Andaman subgroup of islands with an area of about 6,408 km^2 consists of 325 islands (21 are inhabited), and the Nicobar subgroup of islands with an area of about 1,841 km^2 consists of 24 islands (12 islands are inhabited). Being close to the equator and surrounded by the sea, the islands have a tropical climate. The islands receive both northeast and southwest monsoons and the rainfall is heavy and the annual average rainfall is about 3800 mm. The temperature varies from 10° C to 32° C (Dager *et al.*, 1991). Whereas the

*Department of Psychology, Mysore University, Mysore.
$ adopted from Umapathy G, *et al.* 2003 International Journal of Primatology **24**(2) : 281-293

Nicobar Islands are oceanic, the Andaman Islands are continental.

The Andaman and Nicobar islands come under the zone of tropical rainforests of the world. The forest types of these islands are classified as tropical evergreen with minor variation from north to south depending on rainfall, type of soil and degree of salinity (Balakrishnan, 1989). These islands are very rich in fauna and several animal species are threatened. About 5357 species of animals covering all major phyla have been recorded, of which 487 (about 9 per cent) are endemic (Rao, 1989). A total of about 2100 species belonging to all major groups were recorded from the terrestrial animal community, of which 200 (10.5 per cent) are endemic. Endemism is especially high in some taxa: 39 per cent of 270 species of birds, 60 per cent of 58 species of mammals, 31.9 per cent of 83 species of reptiles, and 20 per cent of 10 species of amphibians (Rao, 1989). Of the 58 mammalian species, *Chiroptera* (26 species) and *Rodentia* (14 species) dominate.

The long-tailed macaque does not occur in the Andaman Islands and occurs only in the Nicobar Islands (Alfred *et al.*, 2006). The Nicobar Islands were classified into three distinct groups of islands (the northern, middle and southern). The northern group includes two major islands–Battimalv which is not inhabited by humans, and Car Nicobar is inhabited with a population of over 19,000 people of whom, 80 per cent are the indigenous tribes. The latter is flat with a highly modified plant cover. The middle groups have 9 major islands : Chowra, Teressa, Bompotra and Katchal form a series on the west; Nancowry and Trinkat make up the eastern cluster; and Tillanchong and Isle of Man are slightly to the north-east. Seven islands in the middle group are inhabited with a population of about 12,464 people of which 64 per cent are tribes. The tribes are distributed all around the islands. A striking feature of these islands is the presence of large patches of grassland surrounded by good forest cover. The southern group includes two major islands *viz.* the Little Nicobar and the Great Nicobar and eight small islands. The human population in the Great Nicobar includes both the tribes (8 per cent) and the mainlanders. Half of the mainlanders live in Campbell Bay, the only township. An interesting feature of the island is the presence of several fresh water rivers including Galethea, Alexandra, Dagmar and Jubelle. Indira Gandhi Point (also known as Pygmalion Point), the southernmost boundary of India, is only about 144 km from Achin Head of Sumatra, Indonesia.

MATERIAL AND METHOD

The Nicobar Islands were surveyed between December 1999 and February 2000. Nine islands were visited but Long-tailed Macaques were found only in three islands including Great Nicobar, Little Nicobar and Katchal. These three islands were later intensively surveyed for distribution and abundance of long-tailed macaque. The islands were surveyed by walking on the existing trails, paths and roads. Whenever a group was sighted, the sighting distance (visual estimate) and the sighting angle from transect were recorded (using a field compass). Records were also maintained on the approximate location of the group on the map, nearest landmark and the latitude, longitude and altitude (using Megallan GPS). Attempt was also made to record the group size and age-sex composition. The surveys were carried out between 0700 and 1100 hrs. The abundance of long-tailed macaque was estimated as the number of groups sighted per km. Sixteen transects covering a distance of 227.9 km, 12 transects covering a distance of 62.7 km and 12 transects covering a distance of 92.5 km in Great Nicobar, Little Nicobar and Katchal respectively were laid. In order to record the vegetation related habitat parameters, 5-meter radius circular plots were laid at every 500 steps along some transects (representing different habitat types). In each plot, data were collected on number of trees (>15 cms GBH), GBH of each tree (measured with a tape), tree height (visually estimated) and canopy cover (estimated using a gridded mirror). This information was then converted into tree density, basal area (m^2/ha), canopy height (m) and canopy cover (per cent). The number of plots was 45, 31 and 34 in Great Nicobar, Little Nicobar and Katchal respectively (Table 1). Wherever possible, records were also maintained on feeding by macaques.

RESULTS AND DISCUSSION

Distribution and abundance

In Great Nicobar Island the long-tailed macaque groups were found more in southern region than the northern region. In southern

Table 1. Summary of the survey of long-tailed macaques in Nicobar Islands

Island	Area (km^2)	No. of transects	Length of transects (km)	No. of vegetation plots	Groups sighted	Groups Per km
Great Nicobar	1045.1	16	227.9	45	53	0.23
Little Nicobar	159.1	12	62.7	31	17	0.27
Katchal	174.4	12	92.5	34	18	0.19
Total	1378.6	40	383.1	110	88	0.23

region, there are fresh water streams and rivers. There are plenty of *Pandanus* and coconut trees along the riverbanks and edges of water sources. As a result, food sources are more in the southern region. Further more groups were sighted at the seashore than inside the forests. The tendency of long-tailed macaque to forage and refuge more in trees near water sources, specifically riverine vegetation, has also been recorded in other areas of its distribution (van Shaik *et al.*, 1996). In the Little Nicobar, the groups were found to be more evenly distributed throughout the islands. The groups were also evenly distributed in the Katchal islands, though the sighting of groups was more near human settlements as compared to the uninhabited areas. People grow orchards, especially mango and guava, near the settlements, which provide abundant food for the monkeys. The number of groups sighted and their abundance in the three islands have been presented in Table 1. A total of 53, 17 and 18 groups were sighted in Great Nicobar (227.9 km walk), Little Nicobar (62.7 km walk) and Katchal (92.5 km walk) respectively and it provided an abundance of 0.23, 0.27 and 0.19 groups/km in the three islands respectively. A chi-square test for k-proportions (Gibbons, 1971) indicated that the abundance of long-tailed macaque did not differ among the islands ($x^2=1.27$; df=2; NS).

Demographic parameters

Group size was counted for 8 groups (6 in Great Nicobar and 2 in Katchal). It ranged from 25 to 56 monkeys with a mean of 36.13 animals per group. No group could be properly counted in Little Nicobar as the monkeys here was very shy as compared to the monkeys in other two islands. The demographic data, *viz.* age-sex structure estimated by size and morphological features known from monkeys in the mini zoo at Port Blair, Andaman Islands are presented in Table 2. The long-tailed macaque in these islands is a multimale-mutlifemale society. The number of adult males in groups ranged from 2 to 5 and the number of adult females ranged from11 to 20. The adult male to adult female ratio was found to be 1:4.5. Adult males, adult females and immatures constituted 9.7 per cent, 43.2 per cent and 47.1 per cent of the population respectively. The immature to adult female ratio was 1:0.9.

Table 2. Age-sex structure and group size in long-tailed macaque in Nicobar Islands

Groups	Adult males	Adult females	Immatures	Total	% immatures
Great Nicobar-I	5	17	23	45	51.1
Great Nicobar-II	3	11	11	25	44.0
Great Nicobar-III	4	17	20	41	48.8
Great Nicobar-IV	3	12	17	32	53.1
Great Nicobar-V	3	17	19	39	48.7
Great Nicobar-VI	4	20	19	43	44.2
Katchal-I	2	17	16	35	45.7
Katchal-II	4	14	11	29	37.9
Total	28	125	136	289	47.1

Vegetation structure

Tree density was highest in Great Nicobar (996.9/ha) followed by Little Nicobar (910.3/ha) and Katchal (825.5/ha). The canopy was also denser (92.8 per cent) in Great Nicobar as compared to Little Nicobar (90.1 per cent) and Katchal (87.3 per cent). Canopy height was more or less the same in Great Nicobar, Little Nicobar and Katchal being 17.0m, 16.8m and 16.0m respectively. Great Nicobar also had a greater basal area (91.3 m^2/ha) as against Little Nicobar (87.3 m^2/ha) and Katchal (75.2 m^2/ha) (Table 3). However, in all the islands, the vegetation parameters except tree height have even higher values than the prime rainforests of mainland Western Ghats in India (Kumar *et al.*, 1995; Umapathy and Kumar 2000), and they indicate that the habitat conditions in all the three islands are still healthy. Some observations were also made on the feeding behavior of long-tailed macaques during the survey. One of the major food species was *Pandanus* fruit, which was available in plenty along coastal areas and near other water sources. The monkeys also spent considerable amount of time feeding on insects. However, they were never seen feeding on crabs!

THREATS

Hunting and killing by dogs

There is not much hunting of monkeys by humans in these islands though some traps and fresh baits of *Pandanus* fruits to capture monkeys were detected in some villages. Monkeys often raid crops and coconut trees. In order to chase the monkeys away, the farmers keep pet dogs. There were several cases reported where dogs had killed monkeys. During the survey, there were two instances when the dogs chasing the monkeys from a cropland in Great Nicobar killed a subadult and an infant long-tailed macaque. The Nicobarese and the Shompen tribes hunt wild pigs and megapode in the islands. There are also occasional poachers from Thailand who illegally visit the islands for collecting crocodiles. It is possible that monkeys are also hunted.

Habitat loss

As is the case with other primate species everywhere in the world, habitat loss in these islands is the major threat to long-tailed macaques apart from the isolation of population. The local tribes as well as the settlers subsist on coconut and they have converted coastal areas near their villages into coconut, banana and tuber-bearing plants. Most damage has occurred in Katchal where tribes have the highest numbers as compared to other Islands. In Great Nicobar too, about 35 km long strip of forest along the southeastern coast has been depleted for settling the mainland Indians. Nearly 600 ha of primary forest were replaced with rubber plantations in Katchal. Increasing number of townships, villages, roads, airstrips and infrastructure for defense establishments have all resulted in habitat loss. *Pandanus* fruit is the staple diet of long-tailed macaques and this is also the primary target of removal for crop cultivation. The effect on the monkeys is severe especially during the lean season. In Great Nicobar and Katchal, legal and illegal logging is rampant. Collection of deadwood in truckloads is fairly common. The deadwood trees are cut down to barrel size logs and then rolled down to the road. The smaller plants on the way get crushed resulting in the lack of forest regeneration. The area with least threat is Little Nicobar where only native tribes live and their number is less than 200.

CONSERVATION

Although the long-tailed macaque is widespread in several countries and it does not have any special status accorded by IUCN Near Threatened based on version 2.3 (CAMP Report, 2003), the population in the three Indian islands

Table 3. Habitat profile in Nicobar Islands

Island	Tree density/ ha	Canopy cover (%)	Canopy height (m)	Basal area m^2/ha
Great Nicobar	996.9	92.7	17.0	91.3
Little Nicobar	910.3	90.1	16.8	87.3
Katchal	825.5	87.3	16.0	75.2

is of immense biological significance. Since conservation is becoming increasingly taxa oriented rather than species oriented, it is necessary to conserve the *umbrosa* subspecies inhabiting these islands. The small population of this subspecies is already divided into subpopulations in three islands. Continuing habitat loss may result in forest fragmentation and the groups even within a single island may become isolated and smaller demes. This kind of fragmentation in the rainforests of Western Ghats in mainland India has already made the lion-tailed macaque a critically endangered species (Kumar *et al.*, 1995; Umapathy and Kumar 2000). Further habitat destruction, especially by the mainland settlers, therefore needs to be immediately curbed. The most immediate threat the Nicobar region is the proposal to make Great Nicobar a free port and to create a dry dock as a refueling base for international shipping at the mouth of Galethea river. If and when implemented, this project would signal the possible drastic reduction of Nicobar forests. Killing of monkeys by dogs and by hunting also needs to be checked. Since no behavioral data are available on this subspecies, a long term ecological and behavioral study must be immediately initiated. On one hand, such a study would contribute to further understanding of the total behavioral repertoire of a species widely studied elsewhere, and on the other hand, the study may help design scientific conservation and management plans to ensure the survival of this subspecies.

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Chapter 40

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 455-460, 2010

POST- TSUNAMI STATUS OF LONG TAILED MACAQUE *(MACACA FASCICULARIS UMBROSA)* IN NICOBAR ISLANDS, INDIA : FUTURE CONCERNS

T.C. KHATRI and TRIPTA KHATRI
J.N. Government College Port Blair 744104, Andaman, India
E-mail : tkamtulsi@rediffmail.com

INTRODUCTION

The Long tailed macaque *(Macaca fascicularis umbrosa)* is the only primate found in the Nicobar Islands and is considered as one of the endangered species of India and is listed in the schedule-I of Wildlife (Protection) Act, 1972 as amended up to 2006. Indo-US Primate Research Centre conducted a study in 1999-2000 to know the status and distribution of this subspecies in Great Nicobar, Katchal and Little Nicobar (Umapathy *et al.* 2000). The present study is focused on post-tsunami status of Long-tailed macaque.

STUDY AREA

The archipelago of the Andaman and Nicobar Islands stretches over 800 km in the Bay of Bengal and is a global hotspot for biological diversity. It comprises of 572 islands, reefs and rocks, but only 38 islands are inhabited of which 12 are in Nicobars. The islands lie between 6°5'-13°30' N and 92°20'-93°56' E with a total geographical area of 8249 km^2. The Andaman islands are separated from the Nicobar by a channel of 155 km known as ten degree channel. There is an active volcanic activity with major eruption on Barren islands in 1991, 1994 and May 2005. Geographic locations of these islands are shown in Fig. 1 and 2.

The Andaman and Nicobar Islands have a warm, humid tropical climate. There are two monsoons, a main one from May to October and a second shorter one in December to January. Average annual rainfall is 380 cm and highest rainfall received in the month of June and July. The temperature ranges from 16° to 34° C and relative humidity for 66 to 99 per cent. The Nicobar are oceanic islands. The forests of Nicobar fall under tropical rainforests of the world and can be broadly classified as evergreen rainforests. The Nicobar Islands can be separated into north, middle and south island (Fig. 3). The North group represented by Battimaly and Car Nicobar; the middle group has 9 major islands: Chowra, Teressa, Bompoka and Katchal form a series on the west; Nancowry, Camorta and Tinkat make the eastern cluster and Tilanchong and Isle of Man are slightly to the north-east. The southern group includes 2 major islands *i.e.* Little Nicobar and Great Nicobar and 8 small islands. The interesting feature of Nicobar is that their main inhabitants are tribals with small population of mainlanders. The southern most point of India is India point (formerly known as Pygmalion point) is in Great Nicobar. The long tail macaque is found only in 3 islands of Nicobar, namely Great Nicobar, Litter Nicobar and Katchal.

MATERIALS AND METHOD

The status survey of long tail macaque immediately after the earthquake of December 26, 2004 followed by tsunami was not possible as there were no means of transport available to reach

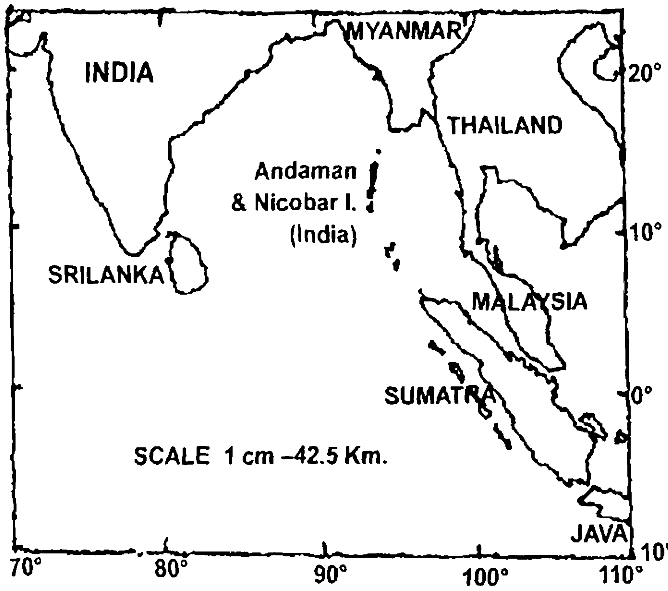

Fig. 1. Map showing location of Andaman and Nicobar Islands in relation to India. Malaysia and Indonesia.

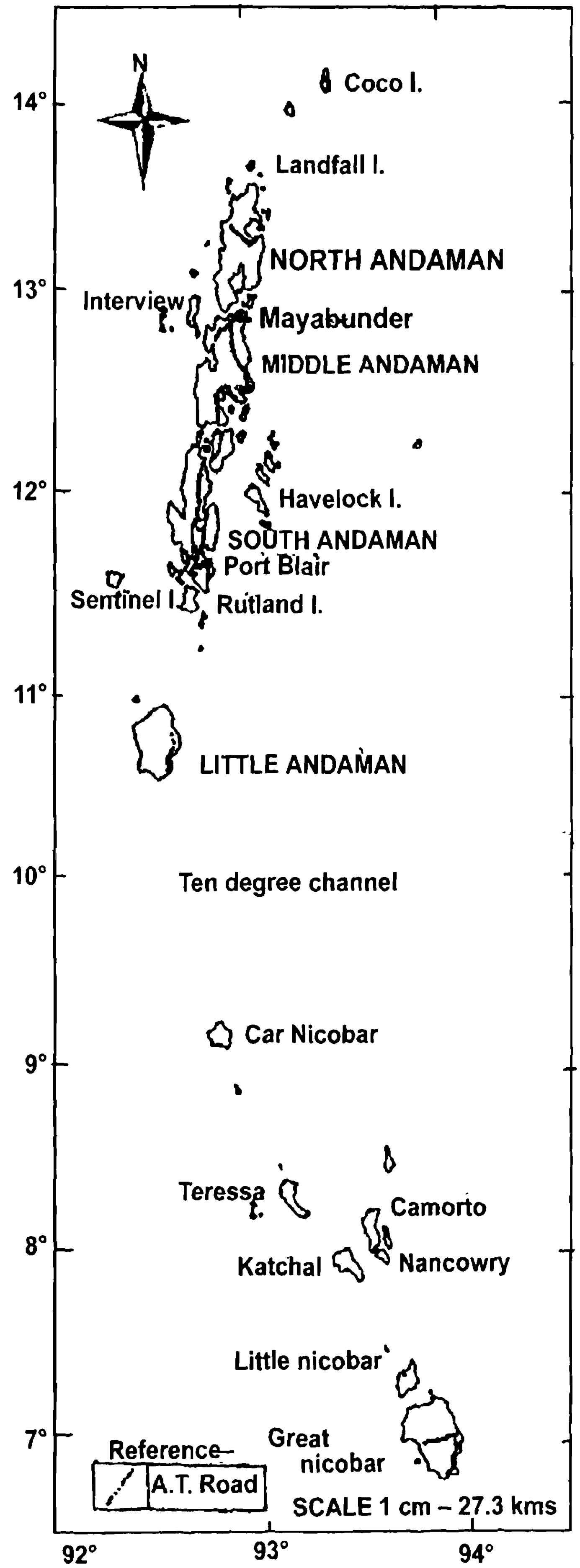

Fig. 2. Map of Andaman and Nicobar Islands

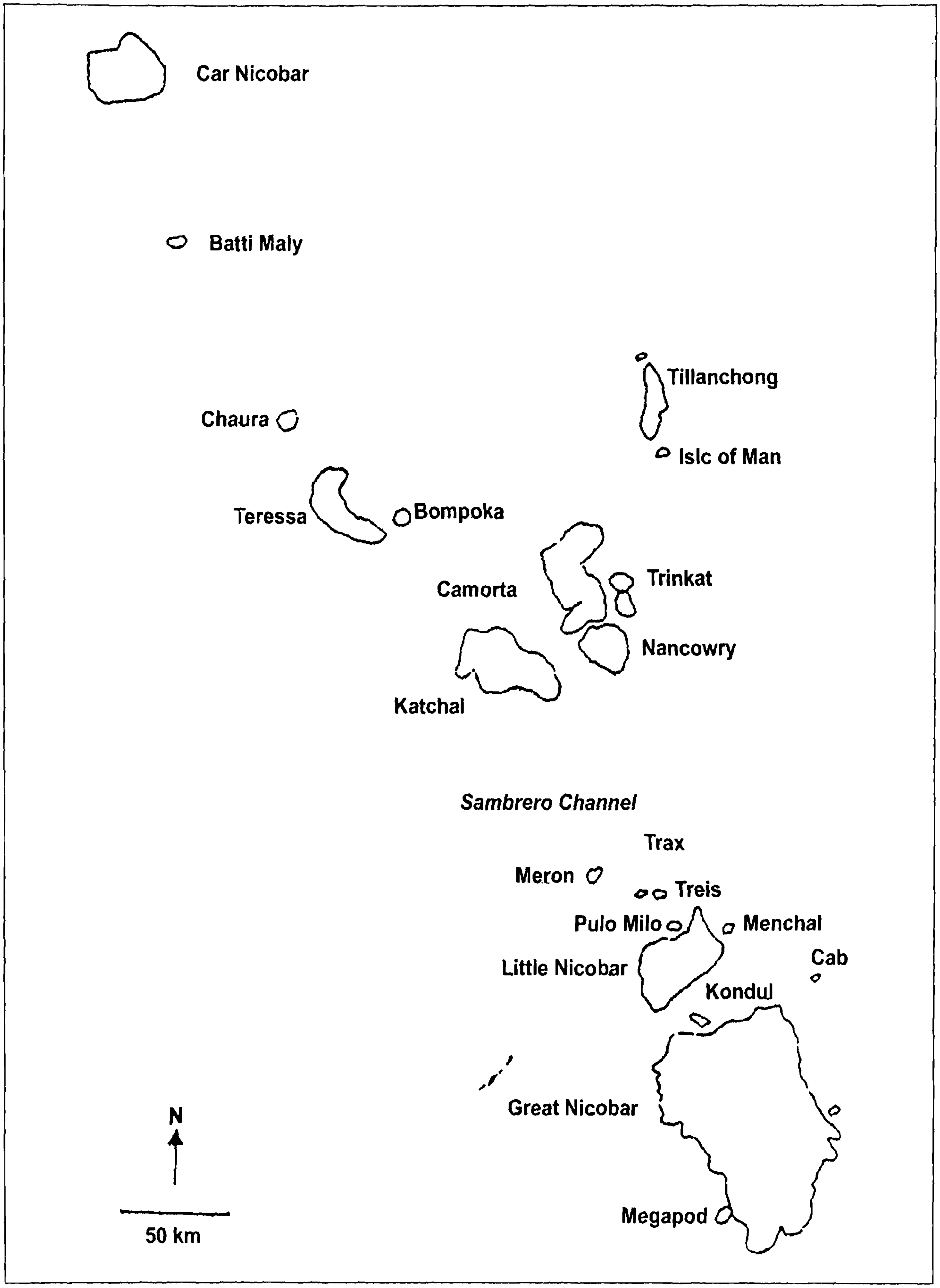

Fig. 3. Map of Nicobar Islands

the affected sites as all the jetties were badly damaged by earthquake and tsunami. By the time the first author of this papers arrived in the study area, the monsoon was already started. So no option was left, but to collect the data from the concerned forest, agriculture and police authorities of Andaman and Nicobar Islands. Extensive interviews were carried out to confirm the information from the local residents living in various relief camps set in Port Blair.

RESULTS AND DICUSSION

After computing the data on the number of existing groups of Long-tailed macaque, the picture which emerged out showed escape of the then groups from the affected areas to the safer places on these islands after tsunami. The displaces groups have been indicated in Fig. 4, 5 and 6.

The disaster of December 26, 2004 had battered the archipelago. Tsunami was worst at Campbell Bay of Great Nicobar. The western coast area is submerged up to 2.8 m in seawater. The float and far rile Car Nicobar island, 10 km in diameter and having circumference of 45 km was flooded up to 1 to 1.5 km by salt water. Coconut plantation leveled down to the ground by 10 m high waves. Katchal, Chowra, Karmorta, Teressa, Champion and Trinkat faced the fury of the sea. The sand banks holding together the island such as Katachall and Pillow Millow gave away and two islands appear in place of one. Tiny Trinkat was flooded entirely.

Nicobar islands were closer to the epicenter with little or no mangroves cover. The islands, faced maximum ecological damage specially Car Nicobar, Middle Nicobars and south Nicobar (Great Nicobar). The submerged area after earthquake and tsunami in Great Nicobar, Little Nicobar and Katchal is shown in Table 1 and maps 4, 5 and 6. There appears to be less variation in vegetation structure in the three islands except that one of two major food-Pandanus (Kavari) fruit has become rare due to flooding of coastal area and flushing of seawater in river beds. But the other fruits such as coconut, banana etc are available in abundant in unguarded agricultural fields of Great Nicobar, Katchal and Little Nicobar.

The threats reported by Umapathy *et al.* (2000) still exists such as domestic dogs escape the tsunami disaster. The poaching of monkey by poachers can pose a threat to the surviving monkey population. The main threat is from habitat loss. Prior to earthquake and tsunami, tribals and settlers had already converted forest land into agricultural land in the coastal areas of Great Nicobar, Little Nicobar and Katachal. Most of this land is submerged in seawater after earthquake and tsunami. Roads will be constructed in new and safer places. Tsunami affected population will be resettled by allotting 2 ha. to tribals and 20 ha non tribals of each family. Clearing of fresh forest area in all the three islands will revive the agriculture. This will displace monkeys from their present habitat further to the newer places. The revival of agriculture by tribals will intensify man-monkeys conflict posing a threat to their survival. Hence, there is an urgent need to formulate future strategy to conserve and manage the surviving population of *unbrosa* subspecies in the three islands of Nicobars.

ACKNOWLEDGEMENT

We express our sincere thanks to Prof. S.M. Mohnot, Director, Primate Research Center, Jodhpur for giving us an opportunity to attend and present paper in Indo-US international workshop for Indian primates from September 12 to 14 2005. Thanks are also due to T.B. Chatterjee, ACF, Great Nicobar, Achan Singh Yadav, Agriculture Extension Officer, Katchal and V.K. Pandey, DSP Home guard, Port Blair for providing for desired information about long-tailed macaque.

Table 1. Geographical area of the three islands in pre and post tsunami of December 26^{th} 2005

Islands	Pre-tsunami area (km^2)	Area (km^2) Under submergence	Post-tsunami area (km^2)
Great Nicobar	1045.1	60.00	985.00
Little Nicobar	159.1	10.00	149.00
Katchal	174.4	45.50	128.90
Total	1378.6	115.5	1262.9

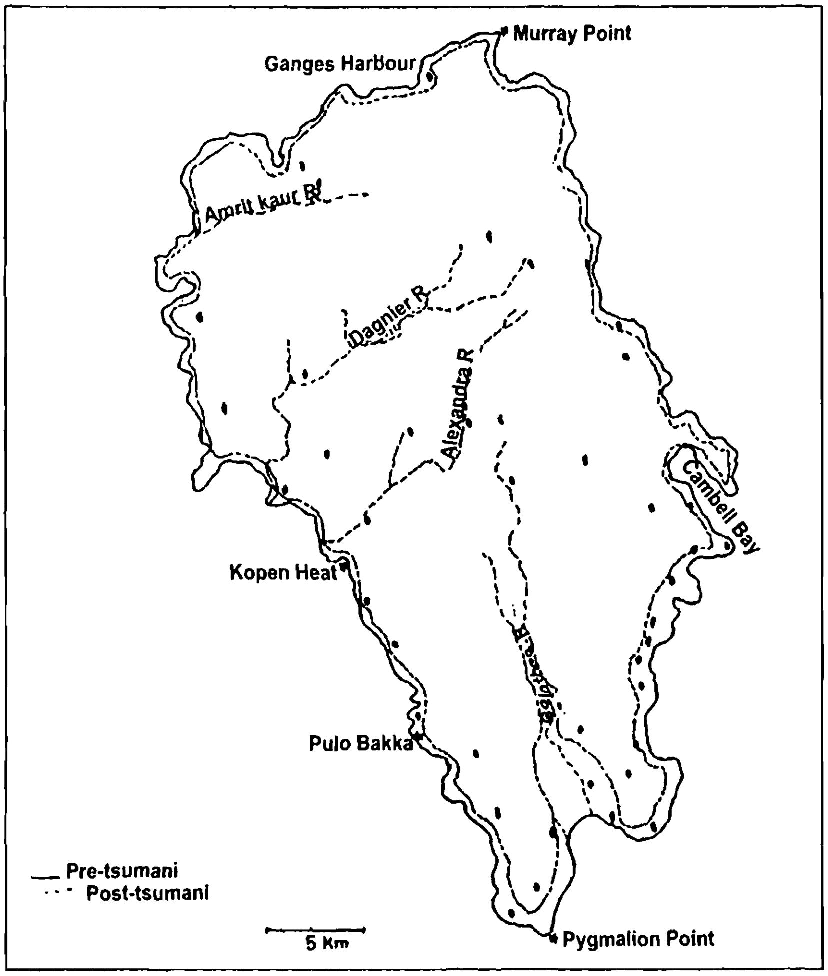

Fig. 4. Map of Great Nicobar (Pre and Post tsunami)

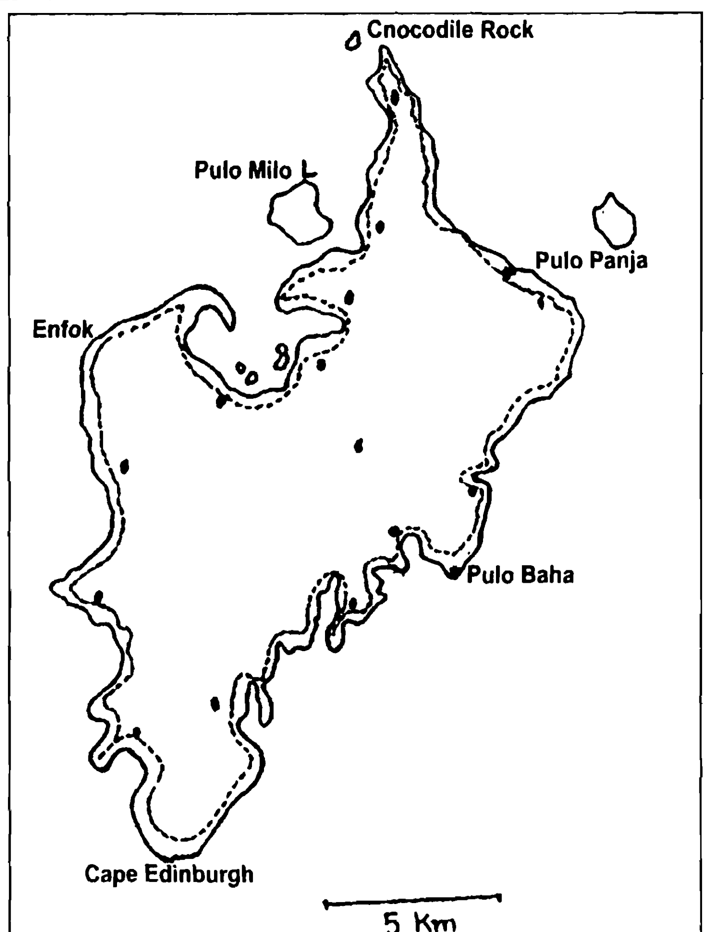

Fig. 5. Map of Little Nocibar (Pre and Post tsumani)

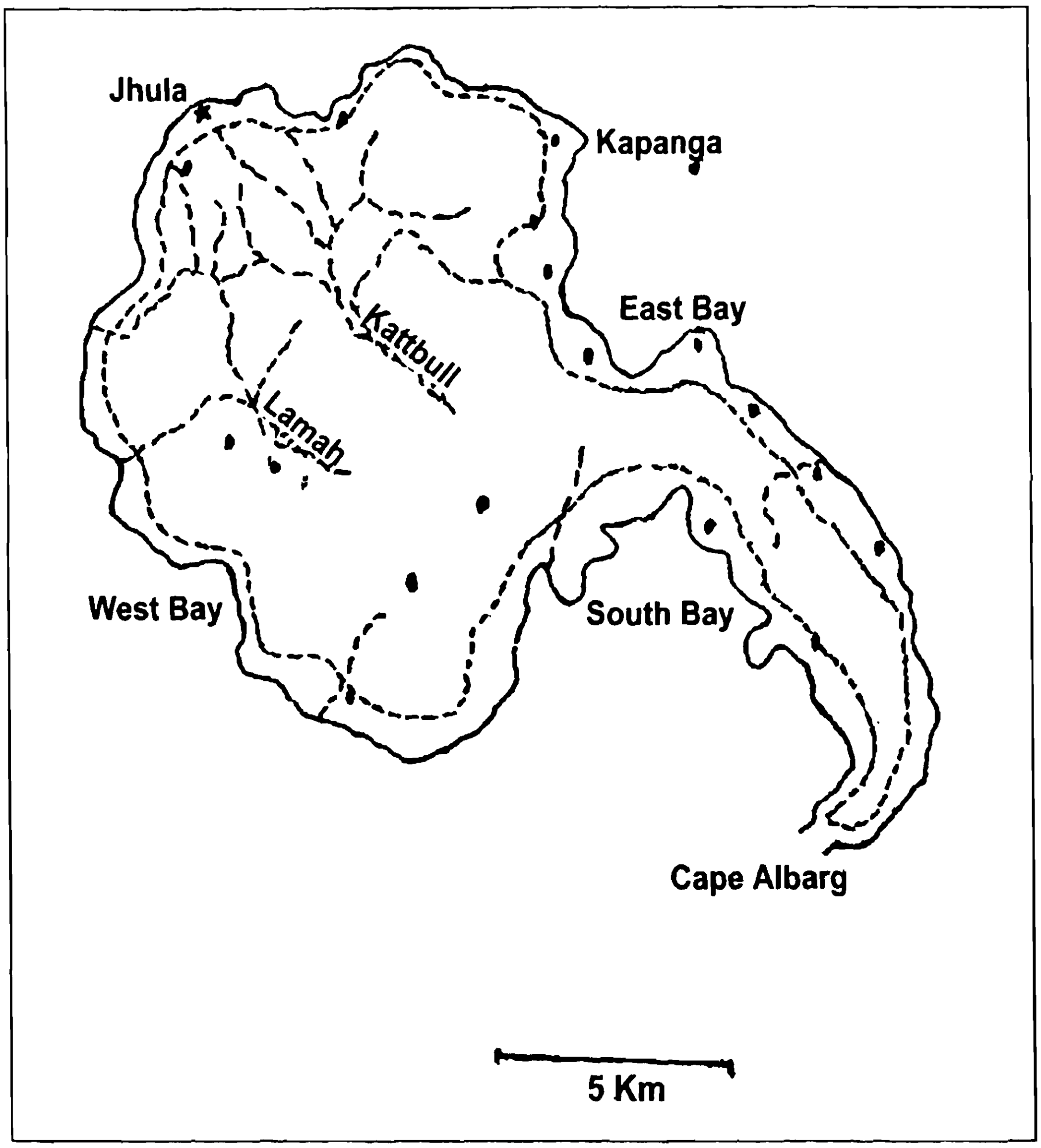

Fig. 6. Map of Katchal (Pre and Post tsumani)

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Recent Trends in Biodiversity of Andaman and Nicobar Islands, 461-466, 2010

DISTRIBUTIONAL PATTERNS OF SOME FAUNAL GROUPS IN THE ANDAMAN ISLANDS : CONSERVATION IMPLICATIONS

P. DAVIDAR[$], V. PALAVAI, K. YOGANAND*, T. GANESH* and M. S. DEVY*
Department of Ecology and Environmental Science, Pondicherry University, Pondicherry-605 014, India

INTRODUCTION

The patterns of species distribution over space and time can provide insights in to fundamental ecological processes and provide guidelines for conservation action. Much of the insights into ecology and evolutionary biology have come from the study of island systems. Ecosystems on islands are less complex than their continental surrogates and can provide understanding of the dynamics and evolution of populations and communities. Darwin's (1872) and Alfred Russel Wallace's (1878) theory of evolution through natural selection was developed by observations of species on island archipelagoes. The fundamental law describing the relationship between island species richness and area, where the number of species on an island is positively related to the island area and negatively to distance from the mainland was proposed by MacArthur and Wilson (1967). This theory has been applied to predict how many species would be lost if an area of a particular size is deforested, and the size and shape of nature reserves (Wilson and Willis, 1975). We now examine patterns of bird, butterfly and fresh water fish distributions in the main island groups in the Andamans and interpret it in the light of biogeographical patterns.

Study Area

The Andaman Island archipelagos, which include over 200 islands of different sizes, provide a natural laboratory for looking at factors that influence species diversity. The Andaman group is organized along the north-south axis from the North Andamans, the northernmost island, to the Little Andaman Island, which is the southernmost (Table 1).

Ripley and Beehler (1989) listed 104 species of breeding birds on the Andaman and Nicobars. This includes 17 endemic species (Inskipp pers. comm.),

Table 1. Annual rainfall and length of the dry season from the southern to the Northern islands

Island group	Rainfall station	Latitude	Annual rainfall (mean ±SD)	Seasonality (mean ±SD)
Little Andaman	Hut Bay	10.38	2383 ± 456	2.2 ± 1.1
South Andaman	Port Blair	11.38	2935 ± 294	2.6 ± 1.1
Middle and North Andaman	Mayabunder	12.54	2970 ± 425	4.4 ± 1.3

*Ashoka Trust for Research in Ecology and the Environment Hebbal, Bangalore- 560024, India
$E-mail : pdavidar@yahoo.com

and 86 endemic races. Their affinities are predominantly with Myanmar and the Malay Peninsula, 81 of the species also breed in southwestern Myanmar and 75 in the Malay Peninsula.

Butterflies of the Andaman and Nicobar islands were documented originally by Evans (1932) who described 260 species. Later Ferrer (1951) listed 268 species. 214 species and 236 subspecies in 116 genera from five families and three subfamilies have been reported by Khatri (1989 and 1993). Only 118 have been recorded in recent years, due to the extensive loss and degradation of their favoured habitat (Khatri, 1993). However, widespread and invasive species are more common on these islands (Khatri, 1993) again indicating that the loss of primary forests can drastically affect butterfly species through loss of food plants and habitat. Herre (1939) compiled a comprehensive list of 112 species of freshwater and littoral fish, the only systematic survey that has been conducted.

MATERIALS AND METHODS

Surveys

The bird and fresh water fish surveys were conducted over all the four large islands in the Andaman group: North, Middle, South and Little Andaman islands and their associated smaller islands. A total of 45 islands were surveyed for birds in the Andaman group during the dry seasons, from February to May 1992, 1993 and February 1994. The butterflies were surveyed from February to May 1992 in the South Andaman group and the Little Andaman Island, and in February 1994 in the North Andaman group and Little Andaman islands. A total of 25 islands were surveyed (Devy *et al.*, 1998).

Stream fishes were surveyed in the dry seasons of 2005 to 2008, and a total of 77 streams and one river were sampled. The majority of the streams were medium and small, since larger streams were relatively rare. Only the perennial streams were surveyed since the seasonal streams were dry during the dry season.

Latitudinal climatic trends

Using information on the distribution of monthly rainfall in different stations, we assessed whether there was a latitudinal trend in annual rainfall and seasonality, as reported earlier by Ellis (1989). We then evaluated whether the species richness of birds, butterflies, and fresh water fishes is related to latitudinal trends in annual rainfall and seasonality. Rainfall data was obtained for meteorological stations located at Hut Bay in the Little Andamans, Port Blair in the South Andamans and Mayabunder which lies between the Middle and North Andamans (Table 1). There were no stations located further north. Monthly rainfall data for these stations were obtained over a period of five years from 2000 to 2004. The average annual rainfall was calculated from the monthly figures. Seasonality was estimated as the consecutive number of months where rainfall was <100mm.

Species richness of birds, butterflies and fresh water fishes

Bird lists for each island were compiled on 1 km long transects through each forest type on a larger island or across all forest types on a smaller island. These transects were walked in the mornings starting at dawn. The number of transects was related to the size of the habitat. All birds seen and heard were recorded and identified using Ali and Ripley (1987) and King *et al.*, (1975). Each transect was walked several times until the species accumulation curve reached an asymptote. Casual bird sightings were also recorded.

Butterflies were sampled through variable length transects walked between 8.00 h 12.00 h. Transects were laid in each habitat type on large and medium islands, whereas small islands were completely surveyed. A minimum of 2 days was spent on each island and whenever more species were encountered the survey was extended to several days. Butterflies were identified to species, whenever possible, otherwise to genus or family (Devy *et al.*, 1998).

Fresh water fishes were sampled in streams from the North Andaman to the Little Andaman Island. Streams were walked upstream from the mouth and fish were collected with cast nets of various sizes (2.5 m × 7 mm and 2 m × 10 mm) at regular intervals, and for very small fishes, traps (cloth) of size 1 m × 0.6 m and 1 m × 0.4 5m and plastic jars were used. The sampling effort increased with the size of the water body. Fishes were identified with help of taxonomic keys (Koumans, 1953); Masuda *et al.*, 1984; Talwar and

Jhingran, 1991; Pethiyagoda, 1991; Kottelat *et al.*, 1993; Jayaram, 1999) and expertise from the Zoological Survey of India, Chennai

RESULTS AND DISCUSSION

The results indicated that annual rainfall between the three islands groups differed less significantly (ANOVA, $F_{2,12} = 3.42$, $P = 0.07$) than seasonality (ANOVA, $F_{2,12} = 4.79$, $P = 0.02$). The proportion of islands with dry forests increased towards the north and the proportion of islands with evergreen forests increased towards the south (Davidar *et al.*, 1995 and 2001) Table 2. Therefore the length of the dry season probably influenced forest types more strongly than annual rainfall, which does not differ significantly across the latitudinal gradient (Table 1). Studies in the Western Ghats have also shown similar trends where seasonality increased from south to north along the latitudinal gradient, and diversity of rain forest trees increased with decreasing seasonality (Davidar *et al.*, 2005).

A total of 78 bird species were recorded during the survey, the majority of which were forest birds. Sixty five species of butterflies from 6 families were recorded during the study period (Devy *et al.*, 1998). This included 3 of the 4 endemic species currently recognized. A total of 15 freshwater fishes and 18 estuarine fishes were recorded during the survey. Of the 15 freshwater fishes, 7 were primary and 8 were secondary freshwater fishes. Only one species of the primary freshwater fishes was native to the Andamans, and the rest were introduced by the settlers for food.

Birds and butterfly species richness was marginally lower in the North Andaman Islands (Table 2). This is probably because wet evergreen forests were uncommon in the North Andaman group except for the main North Andaman Island. Birds and butterflies appear to be strongly influenced by habitat. Wet evergreen forests in the Andamans harboured more species than drier forests and are probably reservoirs of many habitat specialists (Devy *et al.*, 1998; Yoganand and Davidar, 2000). When rare bird species with limited local abundances and restricted distributions (Davidar *et al.*, 1996) were considered, it was seen that 5 of the 9 rare species preferred wet evergreen forests (Yoganand and Davidar, 2000).

Butterfly distributions in the Andamans were also strongly influenced by wet forests and about 8 evergreen forest specialists were recorded in the South Andaman island and four in the North Andaman island. There were no evergreen forest specialists in the smaller islands off North Andaman island whereas there were seven in the smaller islands off South Andaman island (Davidar *et al.*, 1995; Devy *et al.*, 1998). Therefore habitat had an obvious impact on the species richness of birds and butterflies.

The size of the island also directly influenced species richness. Larger islands harboured more bird and butterfly species than smaller islands. This was related to island area, habitat diversity and the presence of wet forests (Davidar *et al.*, 2001). Both wet evergreen and deciduous forest types became rarer with decreasing island size, the former more rapidly than the latter resulting in smaller islands having more deciduous than wet forests (Davidar *et al.*, 2001, Table 2). Comparison of islands with similar sizes showed that evergreen forest supported more species of birds and butterflies than islands with deciduous forest. The degree of isolation is another factor that influences species richness. The Little Andaman Island that is relatively more isolated than the other island groups has fewer species of birds, butterflies and freshwater fishes (Table 2).

Table 2. The species richness of birds, butterflies and fresh water fishes in the Andaman Islands

Island group	Latitude N (approx.)	Islands with evergreen forest (%)	Number of species			
			Birds	Butterflies	Fresh water Fishes	
					Primary	Secondary
North	13° to 14°	2 (15)	60	40	1	7
Middle	12° to 13°	8 (44)	62		1	6
South	11° to 12°	8 (61)	65	44	1	6
Little	10°3′ to 10°5′	1 (100)	54	21	1	3
	Total	**78**	**65**	**1**	**8**	

The presence of primary freshwater fish species in the Andaman Islands indicates that these islands were connected to the continent at one time in their geological history, or that a flooding event could have dispersed fish from the continental rivers, such as the Irrawaddy basin. Several of freshwater fish species recorded in this study are also distributed in South and South East Asia. Few species have congenerics in South, South East region and Indo-Pacific islands. However, the levels of endemism were low, comparable to birds and butterflies indicating that the period of isolation from the continental populations was not lengthy. Many species of birds are also widespread (Ripley and Beehler, 1989) indicating that dispersal ability is one of the main characteristics of the Andaman fauna.

CONSERVATION IMPLICATIONS

We have suggested that conservation of wet evergreen forests is critical for the conservation of Andaman biodiversity (Davidar *et al.*, 1995). The wet forests of the Andamans, which commonly occur on the larger islands, are endangered due to their limited distribution and due to extensive and intensive commercial logging in the past, ongoing development, encroachment and other human impact (Whitaker, 1985; Saldanha, 1989; Davidar *et al.*, 1995). The primary forests form a habitat for unique and rare butterfly species with localised distributions, and many habitat specialized birds (Khatri, 1993; Yoganand and Davidar, 2000). One of the important reasons for the decline of rare and localized butterfly species has been the destruction of primary forests (Khatri, 1993). These distinctive wet evergreen forests of the Andaman Islands are severely endangered and strict protection measures should be taken to preserve whatever remains, for posterity.

The fresh water fishes of the Andamans are unique with a few endemics. Like elsewhere in the world, native fish species are threatened due to habitat loss (Petts, 1984; Machado, 1994; Glenn *et al.*, 1996; Richter *et al.*, 1997) and exotic invasive species (Moyle and Leidy, 1992; Ward *et al.*, 2001). Uncontrolled fish introductions have resulted in many of the introduced fishes becoming invasive. These invasive species are a major threat to the native fish fauna. Many of the streams near settlements are extremely polluted from agriculture run off and solid waste. Wastewater management and sewage treatment are greatly felt need for these islands. Fresh water streams are the only source of drinking water for the local population and needs to be protected against pollution.

The Jarawa Tribal Reserve is the only area in the Andaman group of islands with unpolluted streams lacking in invasive exotic fishes, undisturbed primary forest and rich in biodiversity. However, due to increasing encroachment, poaching, illegal logging and other disturbances by settlers, these forest and their denizens are severely threatened. Only strict and rigorous protection will save the last remnant biodiversity of these islands.

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Chapter 42

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 467-493, 2010

DIVERSITY AND DISTRIBUTION OF TRUE FLIES (INSECTA : DIPTERA) IN THE ANDAMAN AND NICOBAR ISLANDS

BULGANIN MITRA, DHRITI BANERJEE and P. PARUI
Diptera Section, Zoological Survey of India, Kolkata

INTRODUCTION

The study of island fauna to understand the evolutionary history, distribution pattern and habitat diversity has been proven since the time of Darwin and Wallace. The fauna of the oceanic islands generally offers unique opportunity to understand the process of evolution in more simple communities than those of the Continent. The study of the diversity of the island fauna is hence interesting because of their relatively high extinction rates, small population size, competition for suitable habitats, and food sources and probable immigration from the adjoining lands.

The islands of Andaman and Nicobar (lying between 6°45′ and 13°41′ North latitudes, and 92°12′ and 93°57′ East longitude), an union territory of the Indian Union, are the summits of a long submarine mountain range (ca, 1125 km long) in the Bay of Bengal, Indian Ocean, having contiguity with the cape Negarais and are in continuation with the Arakan Yomah range of Myanmar in the North, to the Achin Head (the Mentawei groups) of Sumatra in the south.

The bay islands being oceanic in origin and also being isolated from the adjoining land masses for long periods of time, have acted as crucibles of evolution. Endemism for both floral (14% Rao, 1996) and terrestrial faunal elements (26.3%, Das 2001) is quite high. These high levels of endemism have attributed the status of a 'biodiversity hotspot' to these islands. The diversity of the floral elements has always gained more attention, hence explorations have been extensive and it is only in the recent past faunal explorations have been prioritized. The flora of these islands are more akin to the Indo Chinese and Indo-Malayan than to the Indian sub region of the Orient (Rao, 1996), again the terrestrial faunal studies have revealed that faunal elements of the Andamans have greater geographical affinities to the Indo-Chinese elements and the Nicobar fauna have closer affinities to Indo-Malayan sub region. However Mitra and Maiti (1992) in their entomofaunal studies of the Great Nicobar Islands have concluded that the Nicobar entomofauna have strong affinities to the Indian sub region, rather to the Indo-Malayan or the Indo-Chinese sub regions. Hence the geographical affinities of the faunal elements especially the entomofauna are a subject of controversy.

The progress of faunal study on the Diptera, occuring in these islands, is not at all commensurate with the economic importance of the group. Faunistic surveys targeting the Diptera as a comprehensive group have rarely been taken up. In most occasions the study material have sporadically come up as an add on to a general insect survey materials. Some of the families are well studied because experts of that particular group visited the islands and had given an extra thrust during collection. Inaccessibility and restrained access to various areas have been an impediment to intensive surveys thus belittling the faunistic potential of these islands. As a whole, the knowledge of the Diptera fauna of these insular areas have been fragmentary.

As far as knowledge goes, Schiner (1868) had described the first dipteran species from these islands (Nicobar Islands). Thereafter, faunistic surveys had been conducted during the British era which had been mostly accounted for in the Fauna of British India, in and around the early 90's. Subsequently many workers like Krishnan and Bhatnagar (1968), Gupta and Roy Chowdhury (1970), Prasad and Singh (1972) Sharma *et al.* (1983), Nagpal and Sharma (1983), Joseph & Parui (1991), Nandi (2002), Kumar & Kumar (1991, 1992), Mitra and Parui (1995), Maheswari & Maheswari (2001), Parui *et al.* (2002), Banerjee *et.al* (2005), Rajavel & Natarajan (2006) have made substantial contributions on this economically important group of insects.

The present article is a consoiidated account of the Diptera fauna so far studied with an attempt to examine the diversity as well as the geographical affinities of the dipterans of the Andaman and Nicobar Islands. It includes a complete list of species from these islands, along with the list of endemic species (Table 2), their relative representation worldwide and their proportional representation in India (Table 1) as well as distribution of the species in the Andamans in the Nicobars and in the Oriental sub-regions (Table 3, Figs. 1 & 2).

A list of 303 dipteran species belonging to 132 genera (36 species endemic) from the Andaman and Nicobar Islands have been reported here and their distribution in the Andaman and the Nicobar group of Islands has been individually considered. Distribution of the species in the different Oriental sub regions like, the Indian sub region, IS (India, Sri Lanka, Bangladesh, Nepal, Bhutan, and Pakistan), the Indo-Chinese, IC (Myanmar, Thailand, South China, Vietnam and Tibet) and Indo-Malayan, IM (Indonesia, Malaysia, Java, Sumatra, and Philippines) sub regions have been discussed. Further, diversity studies based on analyses of faunal strength of the species and geographical affinity studies based on their distribution patterns have also been dealt with. All the species listed here have been recorded before the devastation by Tsunami in these islands (26th December, 2004).

BIO DIVERSITY OF FLIES

Diptera commonly known as 'true – flies'are an important but under appreciated part of our planet's biodiversity. Since their origin (either from Mecoptera, Siphonaptera or Strepsiptera) in the early middle Triassic they have diversified to every corner of the earth and established themselves as one of the largest group of organisms today.

The traditional grouping of Diptera have been critically re-examined within a cladistic framework in the past decade by a group of workers beginning with the great dipterist Willy Hennig. But the most comprehensive treatment of the dipteran phylogeny and contemporary views on morphological character evidence can be found in

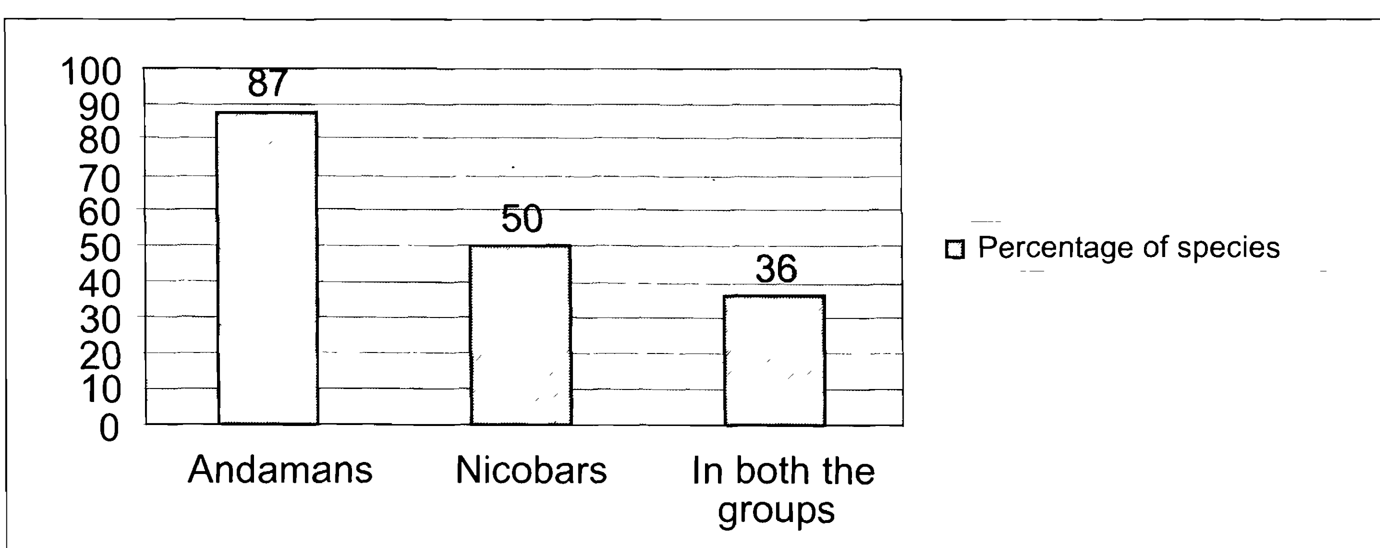

Fig. 1. Distribution of dipteran species in the Bay Islands (%)

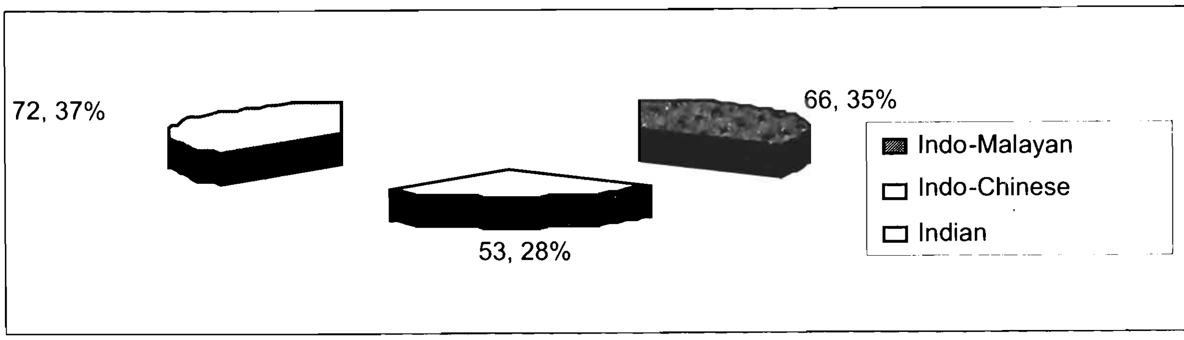

Fig. 2. Distribution of Diptera fauna of bay Islands in the Oriental subregions

the Volume 3 of the Manual of Nearctic Diptera (Mc Alpine & Wood, 1989). Today, they have been classified into 150,000 species, 10,000 genera and 150 families, 22-32 super families, 8-10 infra orders and 2 sub orders Nematocera and Brachycera.

In India, within the Nematocera, 6 infra orders and 23 families have been recognized of which 4 infra orders, 8 families, 46 genera and 141 species are reported from these islands. Whereas, the sub order Brachycera is reported in India by 3 infra orders and 58 families of which 2 infra orders, 23 families, 86 genera and 162 species are already known from the bay islands. Altogether 303 species under 132 genera of 31 families are reported from these islands of which 36 species of 14 families are endemic to these islands.

Flies are minute to large insects (about 0.5 to 75 mm long), extremely variable in form and colour, but are rather soft bodied, flying forms with only one pair of wings. The main differences in between the Nematocera and the Brachycera are in the structure of the antennae, maxillary palps and larval mandibles. The basic number of segments in the antennal flagellum of the most ancestral Brachycera is eight and 3-4 segments in the present day higher Brachycera. Most nematocerans have more than eight segments in the flagellum and having fewer is considered a secondary reduction.

The astounding success of flies is owing to their great versatility in the exploitation of habitats and their ability to utilize every possible sort of food. Because of their extremely wide range of larval habitats, flies are found nearly everywhere. The feeding habits of flies have profound impact on ecosystems and the Earth as a whole. Among the 31 families of Diptera reported from the Andaman & Nicobar Islands, some are root feeders (Family Bibionidae), some are stem borers (Agromyzidae, Chloropidae, Cecidomyiidae), some are also flower-head feeders (Cecidomyiidae, Tephritidae, Chloropidae). Carrion feeding dipterans are the members of the families like Calliphoridae, Sepsidae, Sarcophagidae; blood sucking families are Tabanidae, Hippoboscidae and Culicidae. Others are predators (Asilidae and Bombyliidae), parasites or parasitoids (Phoridae, Sarcophagidae) and pollinators (Syrphidae, Bombyliidae, Stratiomyidae, Calliphoridae and Muscidae), each play an important role in maintaining the balance among populations of organisms.

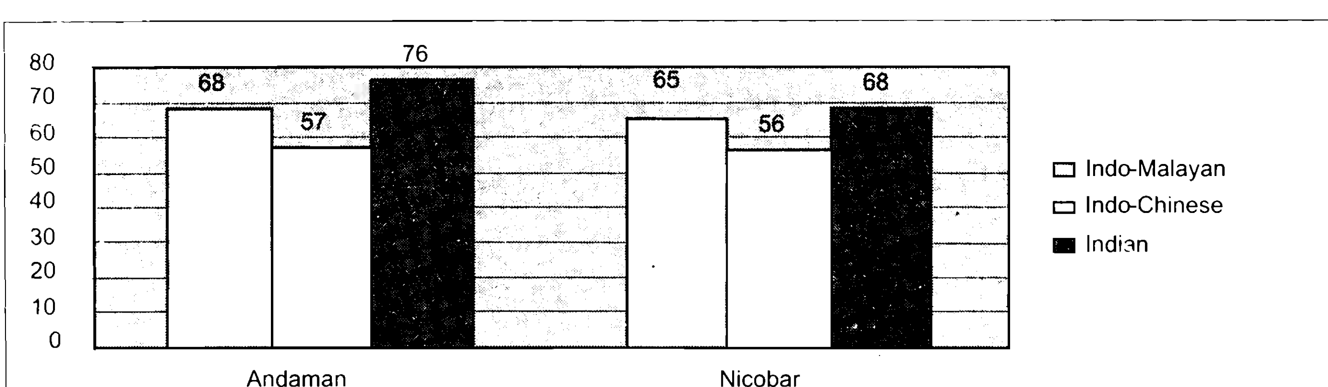

Fig. 3. Showing the geographical affinities of dipteran species of bay Islands with the Oriental sub regions(%)

DIVERSITY AND DISTRIBUTION OF DIPTERA FAUNA (FAMILY-WISE)

Suborder NEMATOCERA

Infraorder TIPULOMORPHA

1. Family TIPULIDAE

Common names : Crane Flies, Daddy Longlegs.

One of the largest and primitive dipteran families, the family Tipulidae includes some of the largest species of sub order Nematocera. They are normally slender, long-legged flies with wingspans ranging from 5 to 85 mm. The head is variable in shape, often expanded forward into a snout-like rostrum, with long 6-10 segmented antennae.

Approximately 15,270 species of 38 genera are described in the world and around 366 species under 9 genera from India. Of them only 3 species (0.82% of the Indian species) under 3 genera have been reported from these islands (Table 1). All the 3 species are reported from the Andamans and a single species *Nephrotoma serricornis* (Brunetti) recorded from both the group of islands. It is evident from the Table-3, that the crane flies show more geographical affinities to IS (67%) than IM (33%). Tipulids are not distributed in the Indo-Chinese subregion.

Contributions from : Alexander & Alexander, 1973

2. Family LIMONIIDAE

Common names : Limonid flies

Recently, the separation of Limoniidae, Cylindrotomidae, and Tipulidae has been made on the basis of their phylogenetic relationships. Therefore, limoniids share many characteristics with tipulids, but are normally smaller in size, though exceptions occur. The number of antennal segments are 14 to 16 in the family Limoniidae; antennal segments are sometimes branched in males, but rarely branched in both sexes. In extant forms, immatures are found in aquatic or semi-aquatic environments where they feed on decaying plant matter, fungi, and algae. Adult males of certain species may swarm.

The family is found worldwide with approximately 11,000 species of 147 genera and 958 species under 51 genera in India. Among the 8 species (0.83% of the Indian species) of 5 genera distributed in the Andaman & Nicobar Islands (Table 1), almost 75 % species of the Andaman & Nicobar Islands are found in the Andamans and 50 % in the Nicobar Islands. On the other hand, limoniids show more geographical affinities to IS (75%) than IM (50%) and IC (13%).

It is interesting to note that, one species *Gonomyia (Gonomyia) dyas* Alexender found in these islands is Palaearctic in distribution and not is known from other parts of the Oriental Region.

Contributions from : Alexander& Alexander, 1973

Infraorder PSYCOMORPHA

3. Family PSYCHODIDAE

Common names : Moth Flies, Owl Midges, Sand Flies.

The Psychodidae includes both "moth flies" and "sand flies" (previously considered as a separate family Phlebotomidae). They are minute flies with broadly ovate and densely setose, wings folded tent-like over the abdomen, with short legs and are weak fliers.

Adult flies are usually to be found in moist protected areas, mainly active nocturnally. During the day, adults usually rest in shaded habitats. The maggots live in moist or sub-aquatic habitats, with a few species often found in compost heaps and sewage disposal systems.Immatures of the sub family Phlebotominae live in soil, often in semi-desert areas.

The family is found worldwide. 67 species under 10 genera are known from India. In Andaman & Nicobar Islands, the family is represented by 3 species (4. 47% of the Indian species) under 2 genera and all the 3 species are reported from the Andaman islands as well as from IS (100.00%) (Table 2).

Contributions from : Duckhouse, 1973, Brunetti, 1912

Infraorder CULICOMORPHA

4. Family CULICIDAE

Common names : Mosquitoes

Mosquitoes are delicate, long-legged, slender flies, 3 to 9 mm long and with scales usually clothing most of the body, legs, the veins and hind margin of the wings. These scales vary in colour and often form patterns that are useful in species identification. The first segment of the antenna is small, the second large and spherical and the other 13 are slender and bear a whorl of setae; these setae are longer and more abundant in males than in females.

Adult males are phytophagous and nectarivores, many do not feed; females are haematophagous. Adults are crepuscular or nocturnal, oviposit in stagnant water of moist habitats and are vectors of deadly diseases. Both larva and pupa are aquatic, phytophagous or carnivorous.

The Culicidae is a large cosmopolitan family of about 3600 described extant species in 42 genera in the world and approximately 425 species under 35 genera in India. Rajavel & Natarajan (2006) updated the species list of mosquito fauna of bay islands and reported 113 species (27% of the Indian species) under 25 genera from these islands (Table 1). Around 59% of the culicids of these islands are found in the Andamans and 12% are found in the Nicobars and show maximal affinity to the IC (80%)followed by IM (78%) and IS (75%).

Contributions from : Barraud, 1934, Rajavel & Natarajan, 2006

5. Family CHIRONOMIDAE

Common names : Non-Biting Midges

Chironomid midges are delicate, small to medium-sized flies (1 to 10 mm long). Most are brown or black, but green, reddish and yellow ; many have the abdomen and legs banded and some have patterned wings. Larvae live mainly in the fresh water ponds, lakes and streams, but many species occur in brackish habitats or the salty waters of desert and grassland alkaline lakes. Sometimes they live parasitically, on the bodies of mayflies, stoneflies, molluscs and other organisms.

Worldwide there are about 5,000 described species of Chironomidae in 330 genera In India they are represented by 168 species (1.78 % of the Indian species) under 25 genera (Table 1). This is the only family showing 100% endemicity, with two new genera described by Maheshwari and Maheswari (2001), represented by 3 species *Andamanus manii* Maheshwari and Maheswari, *Lindebergia kadamtullaensis* Maheshwari and Maheswari, and *Indoaxurus santokhi* Maheshwari and Maheswari from these Islands.

Contributions from : Maheshwari and Maheswari, 2001

Infra Order BIBINOMORPHA

6. Family BIBIONIDAE

Common names : St. Mark's Flies Fever Flies, Love bugs, March flies.

The bibionids are robust flies, often pubescent, with shorter legs and wings than most Nematocera. The adult body shows varying degrees of hairiness and measures about 5 to 12 mm

They form a part of the "decomposer" fauna and are responsible for biodegradation and natural recycling of organic materials. The adults frequent meadows, grassy hillsides or decaying vegetation and often appear in large swarms. They feed on nectar of flowers and are relatively short lived. In general the bibionids should probably be considered as beneficial.

The bibionids are common, distributed worldwide, with about 700 described extant species in 6 genera and 39 species under 4 genera in India (Table 1). Under a single genus *Plecia*, 2 species (5.12% of the Indian species) are reported from these islands. Of them, *fulvicollis* (Fabricius) is reported only from the Andamans and *mallochi* Hardy is reported from the Nicobars (Table 2). As a whole, the family shows more affinities to IS (100%) than IM (50%). Bibionids are not found in the Indo-Chinese subregion.

Contributions from : Brunetti, 1912, Hardy 1973

7. Family SCIARIDAE

Common names : Dark-winged Fungus Gnats

The sciarids are small delicate flies, 1.0 to 11 mm long, usually blackish, brownish or yellowish in colour. Dark-winged, adult fungus gnats are usually found in moist places wherever fungus grows. Larvae generally feed on decaying plant material, animal excreta, or fungus.

There are over 1800 described species in about 90 genera worldwide and 61 species under 8 genera in India. 3 species (4.92% of the Indian species) of 3 genera are reported from these islands and all are known from the Andamans (Table 1). *Bradysia asiatica* Steffan is reported from both the group of islands. The family shows more affinities to IS (100%) than IM & IC (67%).

Contributions from : Steffan, 1973

8. Family CECIDOMYIIDAE

Common names : Gall Midges

The cecidomyids (gall-midges) are minute delicate flies, usually 1.0 to 5.0 mm long. The antennal characters and the greatly simplified venation, enable the midges to be easily recognised. The subfamily Cecidomyiinae contains numerous gall-makers, hence the family's common name. However, other species are phytophagous in flower-heads or stems, without making a gall.

The Cecidomyiidae, with over 5451 currently recognized valid species under 598 genera in the world, is represented in India by 394 species under 125 genera (Sharma, 2009). 6 species under 4 genera (1.52% of the Indian species) reported from these islands (Table 1) and all the species are known to occur in the Andamans whereas only 4 species from the Nicobars. It is evident from the Table-3 that 83% of island fauna is distributed in IS and 33% in IM but nothing is known from IC

Contributions from : Sharma, 1989

Suborder BRACHYCERA

Infra Order STRATIOMYOMORPHA

9. Family STRATIOMYIDAE

Common names : Stratiomyids or Soldier flies

The adults are slender to robust, 2 to 18 mm long; the body ranges from rather bare to densely setose, but bristles are absent. These are often colourful and patterned flies – usually black, green, blue or yellow. The antennae are variable; the second segment is often lengthened (often creating elbowed antennae) and the flagellum (5 to 8 segments) varies from simple and annulate to aristate. Adult soldier flies rest and feed on flowers and are frequently found on grasses, meadows and other plants of wet habitats near marshes and the margins of streams and ponds. They love to bask in the sun.

Stratiomyids are found throughout the world but are particularly diverse in tropical regions. This is a widespread family; With over 2650 species under 400 genera are recognised throughout the world, 73 species under 34 genera are reported from India. 12 species (16.44% of the Indian species) of 10 genera are reported from Andaman & Nicobar Islands (Table 1), of them 11 species (92%) from Andamans and 6 species (50%) from Nicobars have been known so far. Considering geographical affinities to the sub regions, all the species are found in IS (100%) whereas 92% species are distributed in IM and 33% in IC.

Contributions from : Brunetti, 1912, Das *et al*, 1984, Kumar and Kumar, 1991,

Infra Order TABANOMORPHA

10. Family TABANIDAE

Common Names : Clegs, Green Heads, Hippo Flies, Horseflies, Gad Flies, Deer Flies, Elephant Flies

Tabanids are mostly sturdy flies and usually strong fliers (5 to 30 mm long). They are large-headed flies, black, grey or brown, often coloured in orange or yellow; their bodies are more or less finely setulose, but lack enlarged bristles. The large compound eyes, often brightly coloured, iridescent, striped or spotted, are separated in females, but meet dorsally in males.

The adults of both sexes feed on nectar and pollen of flowers. Females of most species have piercing mandibles and also take blood meals. They can be serious pests of cattle, horses, and other mammals and may be very annoying to man with their persistent attacks. Adults are only of minor importance as mechanical transmitters of disease within the regions covered here.

Worldwide in distribution, the family Tabanidae consists of about 4,200 named species in 201 genera and in India 240 species under 15 genera has been recorded. 11 species (4.58 % of the Indian species) under 2 genera are reported from Andaman & Nicobar Islands (Table 1), of them 8 species (72%) from Andamans and 5 species (45%) from Nicobars have been known so far. 3 species (27%) are endemic to these islands (Table 1). It is evident from the Table-3 that, geographical affinities of the tabanids are more to IS and IC (64%) than IM (45%).

Contributions from : Mitra *et al*, 2007, Kumar and Kumar, 1993.

11. Family RHAGIONIDAE

Common Names : Snipe flies

The Rhagionidae are perhaps the most primitive Brachycera. They are sparsely setose almost bristle less, 4 to 15 mm long, with an elongate, tapering abdomen and rather long, slender legs. They have non annulated antennae, flagellum with 8 segments with sharp separation of basal flagellomere. Colours range from grey to brown to black, and sometimes yellow or orange markings occur. Adults usually perch on foliage and grasses; the feeding habits of most are not well known, but presumably many are predators of small insects. Larvae are carnivorous, preying on other insects or their larvae and occur in damp soil, leaf mould etc.

The family is one of the oldest dipteran families with 500 extant species under 18 genera worldwide and in India there are around 30 species under 5 genera. A single species (3.33% of the Indian species) (Table 1) *Chrysopilus insularis* Schiner reported from the Nicobars, is endemic to the bay Islands (Table 2) and incidentally is the first.

Contributions from : Schiner, 1868

Superfamily NEMESTRINIOIDEA

12. Family NEMESTRINIDAE

Common Names : Tangle-veined flies

The family comprises of medium to large sized, bristle- less flies with many of the veins running parallel with the hind margins of the wing. The colours are variable, often black, brown, yellow or white and frequently the thorax and abdomen are striped and banded, respectively. The head is large, usually about as wide as the thorax. The antennae are small with the first three segments about equal in size and terminal stylus, usually of three segments. The legs are slender and lack tibial spurs. The wings are rather narrow.

Adult tangle-veined flies are fast fliers and are most often seen at flowers hovering, motionless, with a high-pitched hum. The adults of several tropical species are known to be pollinators of plants such as orchids. The larvae parasitizing grasshoppers feed mainly on the fat body and ovaries of the host. There are approximately 300 named species under 23 genera worldwide and only 6 species under 2 genera are known from India. A single species (17% of the Indian species) (Table 1), *Nycterimyia dohrni* (Wandolleck) is reported from the Andamans and distributed only in IM among the 3 sub regions of the Oriental region.

Contributions from : Lyne Borg, 1975

Superfamily ASILOIDEA

13. Family BOMBYLIIDAE

Common Names : Bee flies

The bombyliids are a group of moderate to large sized, usually stout bodied and hairy, attractively patterned wings and beautifully coloured flies. Most species have a compact form both in abdomen (which is usually broad and short) and thorax. Many species have long and slender proboscis. Wings distinctive; show highly variable venation and may be hyaline, dark brown, or show beautiful pattern of spots. Adult bee-flies are nectar feeders, females are obligatory pollen feeders, obtaining pollen from anthophilous plants and are often the major pollinators of many flowering plants.

Around 4547 species under 234 genera are known worldwide with 138 species under 36 genera are reported from India. All the 12 species (8.69% of the Indian species) under 6 genera are reported from the Andamans and only 2 species from the Nicobars. It is evident from the Table-3 that, this family show close affinity with IS (75 %) than IM (42%) and IC (25%).

Contributions from : Banerjee *et al*, 2005

14. Family ASILIDAE

Common Names : Assassin flies, Robber flies

Adults widely vary, from delicate and slender to heavy and stout, from almost bare to bristly or setulose. Some are tiny only 3 mm long, but others are gigantic, over 50 mm long. Species vary in appearance, some mimic wasps and bees. Most species are gray to black, have a long, narrow, tapering abdomen containing segments that may be banded, patterned or contrasting in color. They have long, strong legs for grabbing prey. Adults have piercing-sucking mouthparts. They feed on bees, beetles, dragonflies, other flies, grasshoppers, leafhoppers, wasps, and other insects. Larvae live in the soil, in wood and other habitats, feeding on organic matter, other arthropods such as white grubs, beetle pupae and grasshopper egg masses, and may be carnivorous.

Asilids are cosmopolitan in distribution with 6700 described species worldwide with over 400 genera and around 482 species under 55 genera are known from India. In the bay islands, this family is represented by 24 species (4.97% of the Indian species) under 12 genera (Table 1). Of them, the Andamans share 16 species (67%) and the Nicobars, 11 species (46%). It is evident from the Table-3 that, asilid fauna of bay islands show more affinities to IM (33%) followed by IS (29%) and IC (4%).

Contributions from : Joseph & Parui, 1991

Superfamily EMPIDOIDEA

15. Family DOLICHOPODIDAE

Common Names : Long-legged flies

Most dolichopodids are recognised by their small and slender bristly bodies (1 to 9 mm), typically shining metallic blue or green, but may be brown or black, and somewhat pruinose. Adults of many species are known to feed on nectar. Most larvae are predaceous and occur under the bark of trees, or in decaying vegetation.

The dolichopodids are distributed throughout the world with 7221 species under 261 genera. 134 species under 27 genera are found in India (Table 1). Only a single species *Chrysoma loriseta* Parent is reported from the Andamans and endemic to these islands.

Contributions from : Dyte, 1975

Division ASCHIZA

16. Family PHORIDAE

Common names : Mushroom Flies, Scuttle flies, Coffin flies, Humpbacked flies

Minute to small, inconspicuous, blackish, brownish or yellowish flies, 0.5 to 6.0 mm long, with bristles on head, legs and other parts of the body characteristically feathered. The thorax has a characteristic hump-backed appearance. Legs are well developed with the hind femur often enlarged, and more or less laterally compressed. Adults move about with a characteristic quick, jerky movement. They are common around decaying vegetation or animal matter, and sometimes in and around the nest of ants, termites and bees. Larval habits are varied, some are scavengers, and some are parasites.

Worldwide there are about 245 described genera and over 3000 described species. 48 species under 18 genera are found in India (Table 1). A solitary species *Dohrniphora orientalis* (Schiner), is reported from the Nicobars and endemic to these islands.

Contributions from : Brunetti, 1912, Delfinado *et al*, 1975

17. Family SYRPHIDAE

Common names : Flower flies, Hover flies, Rat Tailed Maggots

Slender to robust flies, 4 to 25 mm long, with body usually black and strikingly marked with yellow or orange on the head, thorax and abdomen. Many such species are mimics of bees and wasps. The body is usually covered with dense, short setae, but rarely almost bare, or with long setae or stout bristles. The wings are usually hyaline, but sometimes somewhat darkened or with distinct markings, and with the spurious vein (*vena spurea*). The legs are usually slender, but can be somewhat modified, especially in males. The abdomen is usually suboval, but can be elongate or even petiolate. Adults are habitual visitors of flowers for obtaining pollen, nectar and honeydew, and are important pollinators. Larvae have a wide variety of food habits.

Worldwide there are about 180 recognized genera, and 6000 species, of which 269 species and 5 subspecies under 62 genera are reported from India. 10 species (3.72% of the Indian species) under 8 genera are reported from Andaman & Nicobar Islands (Table 1) and equally distributed (7 species) in both the group of islands. But in the sub regions, 100 percent species are distributed in IS whereas 60 percent and 50 percent in IM and IC respectively (Table 3).

Contributions from : Parui *et al.* 2002

Division SCHIZOPHORA

Section ACALYPTRATE

Superfamily NERIOIDEA

18. Family NERIIDAE

Members of the Neriidae are long-legged flies closely related to the Micropezidae, of which they were once considered a subfamily. Adults are seen in rotten wood where larvae are believed to inhabit.

There are about 100 species in 20 genera distributed mainly in tropical regions. In India they are represented by 4 species under 2 genera. 2 species (50% of the Indian species) under 2 genera are distributed in these islands (Table 1) of them *Chaetonerius inermis* (Schiner) is reported from the Nicobars and also distributed only in IM. The other species *Gymnoneris fuscus andamanensis* Hennig is reported from the Andamans and endemic to these islands.

Contributions from : Schiner 1868, Steyskal, 1977

19. FAMILY MICROPEZIDAE

Common names : Stilt Flies, Stilt legged Flies

Micropezids are small to medium-sized (3.5 to 20 mm), without bristles or setulae, long-bodied, long-legged, often black flies usually with infuscated wings. The wings are clear or coloured, often with spots or bands of brown. The head is usually globular or sometimes conical and pointed in front. The third segment of the antenna is oval, on top near its base it bears a setose or bare arista. The thorax is elongate, with the front legs placed well forward of the middle pair. The wings are long and slender. Adults are either predaceous on small insects or are attracted to excrement or decaying fruit. Larvae develop in decaying wood, fruit and other vegetable matter.

It is a cosmopolitan, but mainly tropical family containing about 520 described species under 50 genera, 10 species under 3 genera are reported from India. 3 species (30% of the Indian species) (Table 1), under the genus *Mimegralla* are reported from these islands. Of them *Mimegralla albitarsis splendens* (Wiedmann) is reported from the Nicobars and only found in IS. The other species, *Mimegralla albimana macropus* (Thomson) is reported from the Andamans and only found in IC. The third species *Mimegralla albitarsis stylophora* (Schiner) is reported from the Nicobars and endemic to these islands.

Contributions from : Schiner 1868, Steyskal, 1977

Superfamily CARNOIDEA

20. Family CHLOROPIDAE

Common names : Eye gnats, Gout flies, Grass flies

The chloropids are small (1.5 to 5.0 mm), bare, often light coloured flies. The body is black, grey, black and yellow, or black and red. They are recognized by the presence of large plate-like frontal triangle. Adults occur in grasses, flowers, and some (the "eye gnats") are attracted to the eyes and open wounds of humans and animals. Larvae are mostly saprophagous or phytophagous, feeding in a variety of habitats including cereals and grasses, decaying plant matter, and fungi.

Over 2,000 species are described under 160 genera in the world and 23 species under 15 genera are reported from India. 3 species (13.04% of the Indian species) under 3 genera are reported from these islands (Table 1). 67 percent of the chloropids of these islands occur in the Andamans whereas 100 percent in the Nicobars. It is evident from the Table-3 that the chloropids show more geographical affinities to IS (100%) than IM and IC (67%).

Contributions from : Cherian, 2002

Superfamily EPHYDROIDEA

21. Family EPHYDRIDAE

Common Names : Shore Flies

Ephydrids are small to medium-sized flies (1 to 11 mm long), usually dark and dull in colour, highly variable in structure and difficult to characterize. The frons usually wider than long. The antennae are short, the second segment often has a single bristle above; the third segment bears a dorsal arista, which is bare, finely setulose or comb-like, with aristal rays almost always on the upper surface only. The thorax is extremely variable in surface features–shiny, dull, or densely pruinose, sculptured or smooth. The wings are clear or spotted ,with both humeral and sub costal breaks of the costa. They typically live in aquatic and semi-aquatic habitats. It is in these harsh saline habitats that the most distinctive forms have evolved and where the family has reached its greatest biological importance.

About 1800 described species in 114 genera worldwide,are known ,of them 45 species under 24 genera are reported from India. 2 species (4.44% of the Indian species) under 2 genera reported from these islands are known to occur only in the Nicobars (Table 1). 100 percent species of these islands are distributed in IC and 50 percent in IS and IM.

Contributions from : Cogan & Wirth, 1977

22. Family DROSOPHILIDAE

Common names : Vinegar flies, Pomace flies, Small fruit flies

Pomace flies are small to medium-sized, 1 to 6 mm long; body colour varies from yellow to brown or black, and can be shiny or grey pruinose, frequently with stripes or spots on the thorax and abdomen. The compound eyes are usually covered in a distinct micro-pubescence and are often bright red in life. The larvae of drosophilids mostly eat yeasts and other microorganisms in fermenting organic matter. Adults live around garbage, compost, rotting fruits and vegetables.

The family is represented, with about 60 genera and 3000 species worldwide with many of them in the tropics. 287 species under 25 genera are reported from India. 11 species (3.83% of the Indian species) under 2 genera are reported from these islands (Table 1). Of them, the Andamans share 10 species (91%) and the Nicobars 6 species (55%) of the total drosophilid fauna. Drosophilidae fauna of the bay islands show more affinities to IS (82%) than IM (73%) and IC (36%).

Contributions from : Fartyal &Singh, 2001; Gupta & Roy Chowdhury, 1970, Prasad & Singh, 1972

Superfamily TEPHRITOIDEA

23. Family TEPHRITIDAE

Common names : Fruit flies, Gall flies

Tephritidae is a large family of predominantly picture-winged, usually highly ornate flies with brightly contrasting color patterns on the body. The head is variable; in some exotic species the compound eyes are stalked. Although members of this family are commonly called fruit flies, the vast majority of the world's species are not frugivorous.

The family is cosmopolitan, with about 4350 known species under 481 genera. 187 species under 70 genera are recorded from India. 15 species (8.02% of the Indian species) under 3 genera are reported from bay islands (Table 1), of them 13 and 11 species are found in the Andamans and the Nicobars respectively. A single species *Dacus (Bactrocera) andamanensis* Kapoor is endemic to the Andamans. Table-3 shows that, 73 % of tephritids of these islands are reported from IM followed by IS (47%) and IC (40%).

Contributions from : Ranganathan & Veenakumari, (I&II) 1995.

Superfamily LAUXANIOIDEA

24. Family LAUXANIIDAE

Common Names : Beach Flies, Lauxaniid Flies

Small robust flies, 2.5 to 5.5 mm long. Yellow, brown, black or a combination of these colours, dull or shiny, sometimes with dark spots or vittae. The shape of the head is quite variable, but the eyes are bare or sparsely micropubescent, and the antennal arista is bare to long plumose. The vertex is not strongly excavate, but rounded or carinate. The wings are often tinged with yellow, and sometimes spotted or clouded. Adults are normally found in woodlands and in dense vegetation around water or in the shade. They may come to light and to traps baited for fruit flies or flesh flies. Larvae are saprophagous, and typically live in leaf litter, vegetable trash, in rotting tree stumps, dung and bird's nests.

Worldwide there are about 1,600 species, in 128 genera. There are 30 species under 12 genera are known from India (Table 1). The solitary species *Homoneura (Homoneura) poecila* (Schiner) is endemic to these islands and reported from the Nicobars.

Contributions from : Schewell, 1977

Superfamily SCIOMYZOIDEA

25. Family SEPSIDAE

Common names : Black scavenger flies

Slender flies, 2 to 6 mm long, mostly shiny black, but also can be dull black, brownish or yellowish. The head is more or less globular, with large compound eyes and bare antennal arista. The thorax has a silvery pruinescence on at least part of the pleuron. The legs are slender, males have the fore femora and the fore tibiae with characteristic bristles, tubercles or emarginations, for grasping the base of the wing of the female during copulation. The wings are narrow and hyaline, usually with a dark spot near the tip of vein, sometimes blackish at the base. Adults are scavengers, and most often can be caught by sweeping grass in meadows or woods, or on dung. Larvae are often found in carrion or excrement.

The Sepsidae with about 250 described species in 21 genera occur worldwide, of them, 17 species under 8 genera are known from India (Table 1). *Australosepsis niveipennis* Nan is the only species of this family reported from the Nicobar islands, which is distributed only in IS and IM.

Contributions from : Zuska, 1977

Superfamily OPOMYZOIDEA

26. Family AGROMYZIDAE

Common names : Leaf miners

The Agromyzidae is a large family of minute to small, stocky flies (1 to 6 mm) ranging from yellow to brown, grey and black in colour; often they are black with yellow markings. The wings are normally clear, but are patterned in some tropical forms. The compound eyes are vertical or slanting, bare or sometimes setulose. The third segment of the antenna varies from small and globular to elongate; the arista is bare or short-setose. Agromyzid larvae eat living plant tissue. Most species feed between the upper and lower surfaces of leaves, making conspicuous mines, but others attack stems, roots and seeds.

The family Agromyzidae occur throughout the world, inhabiting all environments from arctic tundra to tropical forests. There are over 2700 named species in 29 genera, of them 137 species under 17 genera are reported from India (Table 1). *Ophiomyia phaseoli* (Tryon) is the only species reported from both the group of islands and distributed only in IM and IS.

Contributions from : Singh & Ipe, 1973

Section CALYPTRATE

27. Family HIPPOBOSCIDAE

Common names : Louse flies, deer keds, forest flies, bat flies

The Family Nycteribiidae and Streblidae are now included under the family Hippoboscidae as subfamilies. Flies of this family are flattened, rather tough and leathery looking, ranging from 1.5 to 12.0 mm long (subfamily Hippoboscinae). Some are wingless, dorsoventrally flattened, spider-like flies, about 1.5 to 5 mm long (subfamily Nycteribiinae). The members of the subfamily Streblinae are small, rather setose and bristly. The body shape is usually normal, rarely bilaterally compressed and flea like, never strongly flattened and spider like. The wings are almost always fully developed, rarely reduced and nonfunctional.

The family is cosmopolitan, but is most diverse in the tropics and subtropics; about 717 species belonging to 65 genera worldwide and comprises of only 62 Indian species belonging to 22 genera. Of them only 5 species (8%) species are reported from the bay islands, three species reported from the Andamans and 2 from the Nicobars (Table 1). The members show maximum affinities to IM (100%) then IC (80%) and IS (60%).

Contributions from : Maa, 1973

28. Family MUSCIDAE

Common names : Face Flies, Horn Flies, House Flies, Stable Flies

The muscids, or common house flies are a group of small to medium sized flies (2 to 14 mm), colour ranges from yellow to grey or black, some are metallic blue or green, and resemble the blue-bottle calliphorids. Of these, only *Neomyia* is shinning metallic green, without the fine dusty layer. The representatives of this family are closely associated with decaying organic matter, especially dung and also responsible for spreading several diseases of man and animals. Adults can be predaceous, haematophagous, saprophagous, or feed on a number of types of plant and animal exudates. They can be attracted to various substances including sugar, filth, sweat, tears and blood. Larvae occur in various habitats including decaying vegetation, dry and wet soil, nests of insects and birds, fresh water, and carrion. They can be predaceous, coprophagous, or saprophagous.

Out of 3800 species under 72 genera of Muscidae in the world, Indian fauna is represented by 258 species under 39 genera. One of the largest families of Diptera in bay islands the muscids are represented by 23 species (8.53% of the Indian species) under 9 genera (Table 1). 21 species (91%) of the total muscid fauna of the bay islands are found in the Andamans and 13 species (57%) in the Nicobars. Table-3 shows that, the muscid fauna of these islands has close affinities to IS (91%) then IC (83%) and lastly IM (74%)

Contributions from : Mitra & Parui, 1995

29. Family FANNIDAE

The Fanniidae is a small, primitive group of calyptrate flies, largely confined to the Holarctic and temperate Neotropical regions. Adults are medium-sized to small, are often dark in body and leg color. Males congregate in characteristic dancing swarms beneath trees; females are more retiring in habit and can be collected by sweeping vegetation. Larvae are characterized by their flattened bodies with striking lateral protuberances, and live as scavengers in various kinds of decaying organic matter.

There are some 265 species of 4 genera in the world. Only 5 species have been recorded under a single genus *Fannia* from India (Table 1). *Fannia canicularis* (Linnaeus), a solitary species of these islands is reported from Nicobar and distributed only in IS among the 3 sub regions.

Contributions from : Pont, 1977

30. Family CALLIPHORIDAE

Common Names : Blow Flies

Most species of blow flies are stocky, medium-sized to large, 4.0 to 16 mm long, with bodies partly or completely metallic blue, green, black or brassy. Less frequently, they are small, slender and without metallic coloration. The sexes often differ distinctly in colour. The head is distinctly higher than long and the compound eyes in males rarely meet above. The antennal arista is long plumose on at least the basal two-thirds. The wings have bend of vein M right-angled or acute.

The family is distributed worldwide, with about 1000 described species in 150 genera. In India 112 species under 30 genera are known. 9 species (8.03 % of the Indian species) under 6 genera have been reported from these islands. Of them the Andamans share 8 species (89%) and the Nicobars share 4 species (44%) of the total known species. Calliphorids show stronger affinities to IM (100%) than IS (89%) and IC (44%).

Contributions from : Senior White *et al*, 1940

31. Family SARCOPHAGIDAE

Common name : Flesh flies

Members of this family are robust, mostly grey, flies ranging from 2.5 to 23 mm long. The thorax usually has three dark stripes on top and the abdomen is striped, banded or spotted with markings that shift tones depending on the angle of the light. The abdomen is sometimes partly red. The antennal arista is bare or finely setulose to plumose, especially on the basal half or two-thirds.

There are over 3000 named species of sarcophagids worldwide, placed in 108 genera. Of them 117 species under 38 genera are known from India. 12 species (10.26% of the Indian species) under 7 genera are reported from the bay islands (Table 1). 11 species (92%) are found in the Andamans and only 4 species (33%) in the Nicobars. 3 species, *Sarcosolomonia (Parkerimyia) andamanensis* Nandi, *Thyrsocnema (Pseudothyrsocnema) nicobarensis* Nandi, *Phytosarcophaga sawainensis* Nandi are reported as endemics. The members of this family show more affinities to IM (75%) followed by IS (67%) and IC (50%).

Contributions from : Nandy, 1989.

ANALYSIS

Of the 81 families of Diptera found in the Indian peninsula, the Andaman and Nicobar islands are represented by 31 families, which is about 38% of the Indian dipteran families. 303 species belonging to 132 genera have been reported from the Andaman and Nicobar Islands. 262 species (87% of the island fauna) have been reported from the Andaman group of islands and 151 species (50%) have been reported from the Nicobar group of islands while 111 species (36%) are common to both the group of islands (Table-1, Table-2 & Fig. 1).

Species diversity in simplified terms of numerical strength of species is highest for the dipteran family of Culicidae reported as 113 species followed by family Asilidae (24 species), Muscidae (23 species), Tephritidae (15 species), Stratiomyidae, Bombyliidae and Sarcophagidae (12 species each), Tabanidae and Drosophilidae (11 species each), Syrphidae (10 species), Calliphoridae

(9 species), Limoniidae (8 species), Cecidomyiidae (6 species) and Hippoboscidae (5 species). The less speciose groups are the Tipulidae, Psychodidae, Chironomidae, Sciaridae, Micropezidae, Chloropidae (3 species each) followed by Bibionidae, Ephydridae, Neriidae (2 species each). The Raghionidae, Nemestrinidae, Dolichopodidae, Phoridae, Lauxanidae, Sepsidae, Agromyzidae, and Fannidae have single species each (Table 1).

Generic diversity in such similar context is highest again in the family Culicidae with 25 genera, followed by the families Asilidae (12), Stratiomyidae (10) Muscidae (9), Syrphidae (8), Sarcophagidae (7), Bombyliidae, Calliphoridae (6), and Limoniidae and Hippoboscidae (5), Cecidomyiidae (4). The families Tipulidae, Tephritidae, Chironomidae, Sciaridae, Chloropidae, are represented by 3 genera each, Tabanidae, Psychodidae, Bibionidae, Neriidae, Ephydridae and Drosophilidae are all with 2 genera each while the rest are (Rhagionidae, Nemestrinidae, Dolichopodidae, Phoridae, Micropezidae, Lauxanidae, Sepsidae, Agromyzidae, Fanniidae) represented by only 1 genus each (Table 1).

36 species (12%) of the bay islands are endemic. Endemism is highest in the family Asilidae (11) followed by Culicidae (4), Chironomidae, Sarcophagidae and Bombyliidae (3 species each) Drosophilidae (2), Raghionidae, Dolichopodidae, Phoridae, Neriidae, Micropezidae, Tephritidae and Lauxaniidae (1 species each) (Table 2&3). The genera *Andamanus* Maheswari & Maheswari and *Indoaxarus* Maheswari & Maheswari are two newly erected genera under the family Chironomidae from the bay Islands.

The affinity of the fauna of these islands and their probable mode of dispersal has been a subject of discussion. As believed that the majority of the Andaman fauna (as revealed from avifaunal studies) were closely allied to the Indo-Chinese elements while the Nicobars had a greater Malayan affinity (Mohanraj and Veenakumari, 1996). However Mitra and Maiti (1992) had observed that the entomo faunal elements of the Nicobar Islands are more allied to the entomofaunal elements of the Indian sub region rather than the Indo-Malayan sub region or the Indo-Chinese sub region.

The present analysis of the diptera fauna of the Andaman and Nicobar Islands reveal that 39% species of these islands are widespread over the entire Orient. The families Asilidae, Nemestrinidae, Neriidae, Tephritidae, Hippoboscidae, Calliphoridae,and Sarcophagidae show closer affinities to the Indo-Malayan sub region, while the families Culicidae, Tabanidae, and Tephritidae show affinity to the Indo-Chinese sub region. The rest of the families show affinity to the Indian subregion. Overall, 66.35% (200 species) of the Diptera fauna have geographical affinities with the Indo Malayan sub region, 53.28% (161spp.) have affinity with the Indo-Chinese regions while 72.37% (216 species) ie. the majority of the dipteran families have geographical affinities to the Indian sub region (Table 3, Fig. 2).

The present findings also holds true for the Andaman and the Nicobar group of islands when they are individually analyzed. The Diptera fauna of the Andaman groups of island have stronger affinities for the Indian sub region ie. 76 %. Only 68 % of the species of the Andamans show affinity to the species of the Indo-Malayan and 57 % are to the Indo-Chinese sub regions. This is in stark contrast to the views held by previous workers that the Andaman fauna bear closer affinities to the Indo-Chinese elements than to the other sub regions. The Nicobar diptera fauna shows a similar pattern of distribution with the faunal elements showing stronger affinities to the Indian sub region (68%), rather than to the Indo-Malayan (65%) or the Indo-Chinese elements (56%) (Fig. 3). This finding again goes against the prevalent view that of the Nicobar fauna being closely allied to the Indo-Malayan than the Indian sub region but is at par with the observations promulgated by Mitra and Maiti (1992) on their entomofaunal studies of the Nicobar Islands.

Faunistic surveys in these islands have never been extensive as said earlier, and it is evident that when a team studying a particular family visited these islands it had led to a scrupulous exploration of that particular insect family. Probably that is why the family Culicidae has been reported to be the most extensively studied and the most speciose group. The family Asilidae stands next in species strength, followed by the family Muscidae which is usually the most represented family in the collection. It is expected that if more targeted collection procedures are adapted to the families Syrphidae, Tachinidae, Sepsidae, Bibionidae Sarcophagidae, and Calliphoridae, further studies would yield insightful results. Since the islands are tropical with warm and humid climate and lush green vegetation throughout the year, the flower visiting and phytophagous Diptera like Syrphidae, Bombyliidae, Stratiomyiidae, Agromyzidae, Cecidomyiidae and Tephritidae should predictably be abundant ,which is however not the case as has been reflected from our analysis.

Even though, today the bay islands are considered as a part of the 34 "biodiversity hotspots" still the remoteness of archipelago and the difficulties to gain easy access has made explorations difficult and tedious as well as an expensive exercise. As such dipteran faunal affinities of these islands remain mostly speculative since the fauna is not fully studied so far in contrast to the vast and varied dipterous species expected from the area.

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Table-1. Dipera fauna of the Andaman & Nicobar Islands, India and World

Sl. No.	Family	World		India		A & N Islands		Percentage (%) of Indian species reported from A & N Islands
		Genera	Species	Genera	Species	Genera	Species	
1	Tipulidae	38	15,270	9	366	3	3	0.82
2	Limoniidae	147	11,000	51	958	5	8	0.83
3	Psychodidae			10	67	2	3	4.47
4	Culicidae	42	3600	35	425	25	113	26.58
5	Chironomidae	330	5000	25	168	3	3	1.78
6	Bibionidae	6	700	4	39	1	2	5.13
7	Sciaridae	90	1800	8	61	3	3	4.92
8	Cecidomyiidae	598	5451	125	394	4	6	1.52
9	Stratiomyidae	400	2650	34	73	10	12	16.44
10	Tabanidae	201	4200	15	240	2	11	4.58
11	Rhagionidae	18	500	5	30	1	1	3.33
12	Nemestrinidae	23	300	2	6	1	1	16.67
13	Bombyliidae	234	4547	36	138	6	12	8.69
14	Asilidae	400	6700	55	482	12	24	4.97
15	Dolichopodidae	261	7221	27	134	1	1	0.74
16	Phoridae	245	3000	18	48	1	1	2.08
17	Syrphidae	180	6000	62	269	8	10	3.72
18	Neriidae	20	100	2	4	2	2	50.00
19	Micropezidae	50	520	3	10	1	3	30.00
20	Chloropidae	160	2000	15	23	3	3	13.04
21	Ephydridae	114	1800	24	45	2	2	4.44
22	Drosophilidae	60	3000	25	287	2	11	3.83
23	Tephritidae	481	4350	70	187	3	15	8.02
24	Lauxanidae	128	1600	12	30	1	1	3.33
25	Sepsidae	21	250	8	17	1	1	5.59
26	Agromyzidae	29	2700	17	137	1	1	0.73
27	Hippoboscidae	65	717	22	62	5	5	8.06
28	Muscidae	72	3800	39	258	9	23	8.53
29	Fanniidae	4	265	1	5	1	1	20.00
30	Calliphoridae	150	1000	30	112	6	9	8.03
31	Sarcophagidae	108	3000	38	117	7	12	10.26
	Total					132	303	

Table 2. List of dipteran species reported from the Andaman & Nicobar Islands and their distribution in 3 subregions of the Oriental region

Sl. No.	Speices	A	N	END	IM	IC	IS
	Family TIPULIDAE						
1	*Holorusia ochripes* (Brunetti)	+					+
2	*Nephrotoma serricornis* (Brunetti)	+	+				+
3	*Tipula (Indotipula) walkeri* Brunetti	+			+		
	Family LIMONIIDAE						
1	*Limonia (Dicranomyia) absens* (Brunetti)		+				+
2	*Limonia (Euglochina) saltens* ((Doleschall)		+		+		+
3	*Limonia (Goniodineura) indica* (Brunetti)	+					+
4	*Limonia (Libnotes) thawaitesiana* (Westwood)	+			+		+
5	*Hexatoma (Hexatoma) schimidiana* Alexender	+	+				+
6	*Conosia irrorata* (Wiedemann)	+			+	+	+
7	*Gonomyia (Gonomyia) dyas* Alexender	+	+				
8	*Styringomyia mcgregori* Alexender	+			+		
	Family PSYCHODIDAE						
1	*Telmatoscopus (Clogmia) albipunctatus (Williston)*	+					+
2	*Psychoda alternata* Say	+					+
3	*Psychoda sanctijohani* Ipe & Kishore	+					+
	Family CULICIDAE						
1	*Aedes (Aedimorphus) caecus* (Theobald)	+	+		+	+	+
2	*Aedes (Aedimorphus) jamesi* (Edwards)	+	+				+
3	*Aedes (Aedimorphus) lowisii* (Theobald)	+			+	+	+
4	*Aedes (Aedimorphus) vexans* Meigen	+			+	+	+
5	*Aedes (Cancraedes) cancricomes* Edwards	+	+	+			
6	*Aedes (Cancraedes) simplex* (Theobald)	+					+
7	*Anopheles (Anopheles) aitkenii* James	+	+		+	+	+
8	*Anopheles (Anopheles) annandalei* Prashad	+	+				+
9	*Anopheles (Anopheles) barbirostris* Van der Wulp	+			+	+	+
10	*Anopheles (Anopheles) barbumbrosus* Stickland & Chowdhury	+	+		+	+	
11	*Anopheles (Anopheles) insulaeflorum* S & S de Graf	+	+		+	+	+
12	*Anopheles (Anopheles) nigerimus* Giles	+	+		+	+	+
13	*Anopheles (Anopheles) roperi* Reid	+	+		+		+
14	*Anopheles (Anopheles) umbrosus* (Theobald)	+			+	+	
15	*Anopheles (Anopheles) leucosphyrus* Donitz	+			+		
16	*Anopheles (Cellia) aconitus* Donitz	+	+		+	+	+
17	*Anopheles (Cellia) annularis* vander Wulp	+	+		+	+	+
18	*Anopheles (Cellia) balabacensis* Baisas	+	+		+	+	+

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
19	*Anopheles (Cellia) elegans* (James)	+	+				+
20	*Anopheles (Cellia) karwari* James	+			+	+	+
21	*Anopheles (Cellia) kochi* Donitz	+	+		+	+	+
22	*Anopheles (Cellia) maculatus* Theobald	+	+		+	+	+
23	*Anopheles (Cellia) nivipes* (Theobald)	+			+		
24	*Anopheles (Cellia) philippiensis* Ludlow	+	+		+	+	+
25	*Anopheles (Cellia) stephensi* Liston	+	+		+	+	+
26	*Anopheles (Cellia) subpictus* Grassi	+			+	+	+
27	*Anopheles (Cellia) sundaicus* (Rodenwaldt)	+	+		+	+	+
28	*Anopheles (Cellia) tessellatus* Theobald	+	+		+	+	+
29	*Anopheles (Cellia) vagus* Donitz	+			+	+	+
30	*Anopheles (Cellia) varuna* Iyenger	+	+			+	+
31	*Armigers (Armigeres) kesseli* Ramalingam	+			+	+	+
32	*Armigers (Armigeres) durhami* Edwards	+			+	+	+
33	*Armigers (Armigeres) kuchingensis* Edwards	+			+	+	+
34	*Armigers (Armigeres) subalbatus* (Coquillett)	+	+		+	+	+
35	*Culex (Culex) fuscocephalus* Theobald	+			+	+	+
36	*Culex (Culiciomyia) bailyi* Barraud	+				+	+
37	*Culex (Culiciomyia) fragilis* Ludlow	+	+		+	+	+
38	*Culex (Culiciomyia) nigropunctatus* Edwards	+	+		+	+	+
39	*Culex (Culiciomyia) pallidothorax* Theobald	+			+	+	+
40	*Culex (Culiciomyia) spathifurca* (Edwards)	+			+	+	
41	*Culex (Culex) bitaeniorhynchus* Giles	+	+		+	+	+
42	*Culex (Culex) fuscocephala* Theobald	+			+	+	+
43	*Culex (Culex) gelidus* Theobald	+	+		+	+	+
44	*Culex (Culex) pseudovishnui* Colless	+	+		+	+	+
45	*Culex (Culex) quinquefasciatus* Say	+	+		+	+	+
46	*Culex (Culex) sitiens* Wiedemann	+	+		+	+	+
47	*Culex (Culex) tritaeniorhynchus* Giles	+	+		+	+	+
48	*Culex (Culex) vishnui* Theobald	+	+		+	+	+
49	*Culex (Eumelanomyia) brevipalpis* (Giles)	+			+	+	+
50	*Culex (Eumelanomyia) malayi* (Leicester)	+			+	+	+
51	*Culex (Lophoceraomyia) bengalensis* Barraud	+	+			+	+
52	*Culex (Lophoceraomyia) mammlifer* (Leicester)	+			+	+	+
53	*Culex (Lophoceraomyia) minor* (Leicester)	+			+	+	+
54	*Culex (Lophoceraomyia) minutissimus* (Theobald)	+			+	+	+

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
55	*Culex (Lophoceraomyia) peytoni* Bram & Rattanarithikul	+	+			+	
56	*Culex (Lophoceraomyia) traudatrix* Theobald	+			+		
57	*Culex (Lophoceraomyia) variatus* (Leicester)		+		+	+	
58	*Culex (Lophoceraomyia) wilfredi* Colless	+	+		+	+	
59	*Culex (Mochthogenes) shrivastavi* Wattal, Kalra & Krishnan			+			
60	*Downsiomyia albolateralis* Theobald	+	+		+	+	+
61	*Downsiomyia nivea* (Ludlow)	+			+	+	+
62	*Finlaya falvipennis* Giles	+			+	+	+
63	*Fredwardsius vittatus* (Bigot)	+	+		+	+	+
64	*Heizmannia (Heizamannia) covelli* Barraud	+			+		+
65	*Heizmannia (Heizamannia) indica* (Theobald)	+	+			+	
66	*Hodgesia malayi* Leicester	+	+		+	+	
67	*Kenknightia dissimilis* (Leicester)	+			+	+	+
68	*Lorrainea amesii* (Ludlow)	+	+		+	+	+
69	*Lorrainea fumida* (Edwards)	+	+		+	+	
70	*Lutzia (Metalutzia) fuscana* (Wiedemann)	+			+	+	+
71	*Lutzia (Metalutzia) halifaxi* (Theobald)	+			+	+	+
72	*Malaya genurostris* Leicester	+	+		+	+	+
73	*Mansonia (Mansonioides) annulifera* Theobald	+	+		+	+	+
74	*Mansonia (Mansonioides) indiana* Edwards	+	+		+	+	+
75	*Mansonia (Mansonioides) uniformis* (Theobald)	+	+		+	+	+
76	*Mimomyia (Ingramia)-fusca* (Leicester)	+			+	+	
77	*Neomelaniconion lineatopennis* (Ludlow)	+	+		+	+	+
78	*Ochlerotatus (Bruceharrisonius) greeni* (Theobald)	+			+		+
79	*Orthopodomyia andamanesis* Barraud	+	+		+	+	+
80	*Orthopodomyia anopheloides* (Giles)	+	+		+	+	+
81	*Orthopodomyia flavithorax* Barraud	+	+				+
82	*Rhinoskusea longirostris* (Leicester)	+			+	+	
83	*Rhinoskusea wardi* (Reinert)	+	+		+	+	+
84	*Stegomyia aegypti* (Linnaeus)	+	+		+	+	+
85	*Stegomyia) albopicta* (Skuse)	+			+	+	+
86	*Stegomyia annandalei* (Theobald)	+			+	+	+
87	*Stegomyia edwardsi* Barraud	+	+			+	+
88	*Stegomyia gardnerii imitator* Leicester	+			+	+	
89	*Stegomyia krombeini* (Huang)	+					+
90	*Stegomyia malayensis* (Colless)	+	+		+		
91	*Stegomyia pseudoalbopicta* (Borel)	+	+		+		
92	*Stegomyia seampi* (Huang)	+		+			

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
93	*Stegomyia subalbopicta* (Barraud)	+					+
94	*Toxorhynchites (T) edwardsi* (Barraud)	+	+				+
95	*Toxorhynchites (T) splendens* (Wiedemann)	+			+	+	+
96	*Tripteroides (Tripteroides) affinis* (Edwards)	+				+	+
97	*Tripteroides (Rachionotomyia) aranoides* (Theobald)	+			+	+	+
98	*Tripteroides (Tripteroides) indicus* (Barraud)	+				+	+
99	*Uranotaenia (Pseudoficulbia) atra* Theobald	+	+				+
100	*Uranotaenia (Pseudoficulbia) luteola* Edwards	+				+	+
101	*Uranotaenia (Pseudoficulbia) obscura* Edwards	+			+	+	
102	*Uranotaenia (Uranotaenia) lateralis* Ludlow	+			+	+	+
103	*Uranotaenia (Uranotaenia) christophersi* Barraud			+			
104	*Uranotaenia (Uranotaenia) longirostris* Leicester	+	+		+	+	+
105	*Uranotaenia (Uranotaenia) lutescens* Leicaster	+			+	+	+
106	*Verrallina (Harbachius) consonensis* (Reinert)	+				+	
107	*Verrallina (Harbachius) yusafi* (Barraud)	+					+
108	*Verrallina (Neomacleaya) andamanensis* Edwards	+			+	+	+
109	*Verrallina (Neomacleaya) uncus* (Theobald)	+			+	+	+
110	*Verrallina (Verrallina) butleri* (Theobald)	+			+	+	+
111	*Verrallina (Verrallina) dux* (Dyar & Shanon)	+			+	+	
112	*Verrallina (Verrallina) lugubris* Barraud	+			+	+	
113	*Ficalbia (Ravenalites) deguzmanae* Mattingly	+			+	+	
	Family CHIRONOMIDAE						
1	*Andamanus manii* Maheswari & Maheswari	+		+			
2	*Lindebergia kadamtullaensis* Maheswari & Maheswari	+		+			
3	*Indoaxarus santokhi* Maheswari & Maheswari	+		+			
	Family BIBIONIDAE						
1	*Plecia fulvicollis (Fabricius)*	+			+		+
2	*Plecia mallochi* Hardy		+				+
	Family SCIARIDAE						
1	*Bradysia asiatica* Steffen	+	+				+
2	*Phorodonta exacta* (Brunetti)	+			+	+	+
3	*Trichosia rufithorax* (vander Wulp)	+			+	+	+
	Family CECIDOMYIIDAE						
1	*Gephyraulus indica* (Grover & Prasad)	+	+				+
2	*Asphondylia gennadii* Marchal	+	+				+
3	*Asphondylia pongamiae* Felt	+	+				+
4	*Contarinia eragrostidis* Felt	+			+		
5	*Procontarinia echinogalliperda* Mani	+					+

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
6	*Procontarinia matteina* Keiffer & Cecconi	+	+		+		+
	Family STRATIOMYIDAE						
1	*Ptecticus australis Schiner*	+	+		+	+	+
2	*Sargus metallinus* (Fabricius)	+	+		+		+
3	*Oplodontha rubrithorax* (Macquart)	+			+	+	+
4	*Prosopochrysa vitripennis* (Doleschall)	+			+	+	+
5	*Adoxomyia heminopla* (Wiedemann)	+				+	+
6	*Brachycera ventralis* Thomson	+	+		+		+
7	*Nigrotomyia maculipennis* (Macquart)	+			+		+
8	*Hermetia laeta* de Meijre	+			+		+
9	*Ptilocera continua* Walker	+	+		+		+
10	*Ptilocera fastuosa* Gerstaecker		+		+	+	+
11	*Tinda indica* (Walker)	+			+		+
12	*Tinda javana* (Macquart)	+	+		+		+
	Family TABANIIDAE						
1	*Chrysops fasciatus* Wiedemann	+			+	+	+
2	*Tabanus (Tabanus) andamanicus* (Bigot)	+		+			
3	*Tabanus (Tabanus) andamanensis* Kapoor	+		+			
4	*Tabanus (Tabanus) brunnipennis* Ricardo	+			+	+	+
5	*Tabanus (Tabanus) diversifrons* Ricardo		+		+	+	+
6	*Tabanus (Tabanus) immanis* Wiedemann	+			+	+	
7	*Tabanus (Tabanus) indianus* Ricardo	+	+			+	+
8	*Tabanus (Tabanus) leucohirtus* Ricardo	+					+
9	*Tabanus (Tabanus) nicobarensis* Schiner		+	+			
10	*Tabanus (Tabanus) siamensis* Ricardo		+			+	+
11	*Tabanus (Tabanus) striatus* Fabricus	+	+		+	+	+
	Family RHAGIONIDAE						
1	*Chrysopilus insularis* Schiner		+	+			
	Family NEMESTRINIDAE						
1	*Nycterimyia dohrni* (Wandolleck)	+			+		
	Family BOMBYLIIDAE						
1	*Petrorossia ceylonica* (Brunetti)	+			+		+
2	*Petrorossia nigrofemorata* (Brunetti)	+					+
3	*Anthrax gestroi* Brunetti	+	+				+
4	*Anthrax distigma* Wiedemann	+			+	+	+
5	*Exhyalanthrax keiseri* Francois	+				+	+
6	*Ligyra fuscipennis* (Macq.)	+			+	+	+
7	*Ligyra flaviventris* (Doleschall)	+			+		+

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
8	*Villa andamanensis* Bhalla. Grewal and Kapoor	+		+			
9	*Villa kopanghatensis* Bhalla. Grewal and Kapoor	+		+			
10	*Ligyra tristis Wulp*	+			+		+
11	*Ligyra semifuscata (Brunetti)*	+	+				+
12	*Heterolonia (Acrodisca) andamanica* Pal	+		+			
	Family ASILIDAE						
1	*Laxenecera albibarbis* Macquart	+					+
2	*Maira aurifacies* (Macquart)		+		+		
3	*Maira splendida* (Guerin-Meneville)		+		+		
4	*Orthogonis andamanensis* Joseph & Parui	+		+			
5	*Clinopogon nicobarensis* (Schiner)		+				+
6	*Stichopogon inaequalis* (Loew)	+					+
7	*Stichopogon oldroydi* Joseph & Parui	+		+			
8	*Stichopogon tomentosus* Oldroyd	+					+
9	*Cophinopoda chinensis* (Fabricius)	+			+		+
10	*Ommatius andamanenis* Joseph & Parui	+		+			
11	*Ommatius frauenfeldi* Schiner		+	+			
12	*Ommatis mitrai* Joseph & Parui	+		+			
13	*Ommatis nicobarensis* Joseph & Parui	+	+	+			
14	*Ommatius nigra* Schiner		+		+		
15	*Ommatius rajani* Joseph & Parui	+		+			
16	*Ommatius spathulatus* Doleschall		+		+		
17	*Astochia longistylus* Wiedemann		+		+		
18	*Heligmoneura andamanensis* Joseph & Parui	+		+			
19	*Heligmoneura mehtai* Joseph & Parui	+		+			
20	*Philodicus ceylanicus* Schiner	+			+		+
21	*Philodicus javanus* (Wiedemann)	+	+		+		+
22	*Promachus apivorus* Walker	+				+	
23	*Promachus pseudocontractus* Joseph & Parui	+	+	+			
24	*Machimus nicobarensis* (Schiner)		+	+			
	Family DOLICHOPODIDAE						
1	*Chrysoma loriseta* Parent	+		+			
	Family PHORIDAE						
1	*Dohrniphora orientalis* (Schiner)		+	+			
	Family SYRPHIDAE						
1	*Dideopsis aegrota* (Fabricius)	+					+
2	*Ischiodon scutellaris* (Fabricius)		+		+	+	+
3	*Orthonerva indica* Brunetti		+				+

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
4	*Graptomyza brevirostris* Wiedemann	+			+	+	+
5	*Eumerus nicobarensis* Schiner		+		+		+
6	*Eristalis aenus v. taphicus* (Wiedemann)	+	+				+
7	*Eristalis arvorum (Fabricius)*	+	+		+	+	+
8	*Pseuderistalis fascipennis* Thomson	+			+	+	+
9	*Paragus crenulatus* Thomson	+	+		+	+	+
10	*Paragus yerburiensis* Stuckenberg	+	+				+
	Family NERIIDAE						
1	*Chaetonerius inermis* (Schiner)		+		+		
2	*Gymnoneris fuscus andamanensis* Hennig	+		+			
	Family MICROPEZIDAE						
1	*Mimegralla albitarsis stylophora* (Schiner)		+	+			
2	*Mimegralla albitarsis splendens* (Wiedmann)		+				+
3	*Mimegralla albimana macropus* (Thomson)	+				+	
	Family CHLOROPIDAE						
1	*Siphunculina funicola* (de Meijre)	+	+		+	+	+
2	*Eutropha noctilux* (Walker)	+	+		+	+	+
3	*Neorhodesiella typica* (Cherian)		+				+
	Family EPHYDRIDAE						
1	*Discomyza maculipennis* (Wiedemanno		+			+	
2	*Ochthera rotunda* Schiner		+		+	+	+
	Family DROSOPHILIDAE						
1	*Leucophenga (Leucophenga) insulana* (Schiner)	+	+	+			
2	*Drosophila (Sophophora) anannassae* Doleschall	+			+	+	+
3	*Drosophila (Sophophora) andamanensis* Gupta & Roy Ch	+	+	+			
4	*Drosophila (Sophophora) eugracilis* Bock & Wheeler	+			+	+	+
5	*Drosophila (Sophophora) ficusphila* Kikkawa & Peng	+	+		+		+
6	*Drosophila (Sophophora) malerkotliana* Prasad & Paika	+			+		+
7	*Drosophila (Sophophora) bipectinata* Duda	+	+		+	+	+
8	*Drosophila (Sophophora) nasuta* Okada	+	+		+		+
9	*Drosophila (Sophophora) truncata* Okada	+			+		+
10	*Drosophila (Sophophora) melanogaster* Meigen	+	+		+	+	+
11	*Drosophila (Pholadoris) setarioa* Prashad & Singh	+					+
	Family TEPHRITIDAE						
1	*Dacus (Bactrocera) andamanensis* Kapoor	+		+			
2	*Dacus (Bactrocera) dorsalis* Hendel	+	+		+	+	+
3	*Dacus (Bactrocera) clifer* Hendel	+	+		+	+	
4	*Dacus (Paratridacus) expandius* Walker	+			+		+

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
5	*Dacus (Polistomimetus) mimax* (Enderlein)	+	+				+
6	*Bactrocera (Bactrocera) carambolae* Drew & Hancock	+			+	+	
7	*Bactrocera (Bactrocera) albistrigata* (de Meijre)		+		+		
8	*Bactrocera (Bactrocera) limbifera* (Bezzi)	+	+		+		
9	*Bactrocera (Gymnodacus) callophylli* Perkins & May	+	+		+		
10	*Bactrocera (Zeugodacus) incisa* (Walker)	+					+
11	*Bactrocera (Zeugodacus) cucurbitae* Coquillett	+	+		+	+	+
12	*Bactrocera (Zeugodaeus) tau* (Walkar)	+	+		+	+	+
13	*Bactrocera (Bulladacus) mcgregori (Bezzi)*		+		+		
14	*Bactrocera (Bactrocera) melastomatose* Drew & Hancock	+			+		
15	*Callantra eumenoides (Bezzi)*	+	+			+	+
	Family LAUXANIIDAE						
1	*Homoneura (Homoneura) poecila* (Schiner)		+	+			
	Family SEPSIDAE						
1	*Australosepsis niveipennis* Nan		+		+		+
	Family AGROMYZIDAE						
1	*Ophiomyia phaseoli* (Tryon)	+	+		+		+
	Family HIPPOBOSCIDAE						
1	*Hippobosca variegata* Megerle von Muhlfeld	+			+		+
2	*Cylopodia horsfieldi* de Mejjre	+			+	+	
3	*Leptocyclopodia (Leptocyclopodia) ferrari ferrari* (Rondani)	+			+	+	+
4	*Nycteribia parvuloides* Theodor		+		+	+	
5	*Brachytarsina (Brachytarsina) amboinensis* Rondani		+		+	+	+
	Family MUSCIDAE						
1	*Morellia nigrisquama Malloch*	+			+	+	+
2	*Atherigona (Acritochaeta) orientalis* Schiner		+		+	+	+
3	*Dichactomyia luteiventris* Rondani	+	+		+	+	+
4	*Ophyra chalcogaster* (Wiedemann)	+	+		+	+	+
5	*Musca (Byomya) conduscans* Walker	+	+		+	+	+
6	*Musca (Byomya) pattoni* Austen	+				+	+
7	*Musca (Byomya) sorbens* Wiedemann	+	+			+	
8	*Musca (Eumusca) xanthomelas* Widemann	+	+			+	+
9	*Musca (Byomya) planiceps* Wiedemann	+	+		+		+
10	*Musca (Eumusca) autumnalis* De Geer	+	+		+		+
11	*Musca (Eumusca) lusoria* Wiedeman	+	+			+	+
12	*Musca (Musca) domestica*	+	+		+	+	+
13	*Musca (Ptilolepis) inferior* Stein	+			+	+	+

Table 2. *Contd.*

Sl. No.	Speices	A	N	END	IM	IC	IS
14	*Musca (Philaematomyia) crassirostris* Stein	+			+	+	+
15	*Musca (Viviparomusca) bezzi* Patton &Cragg	+			+	+	+
16	*Neomyia lauta* (Wiedemann)	+			+	+	+
17	*Neomyia gavisa* (Walker)	+			+	+	+
18	*Neomyia indica*	+			+	+	+
19	*Haematobia irritans* exigua de Meijre	+			+	+	+
20	*Haematobosca stimulans* (Meigen)	+					+
21	*Lispe sydneyensis* Schiner		+				
22	*Stomoxys calcitrans* (Linnaeus)	+	+		+	+	+
23	*Stomoxys indicus* Picard	+	+		+	+	+
	Family FANNIDAE						
1	*Fannia canicularis* (Linnaeus)		+				+
	Family CALLIPHORIDAE						
1	*Bengalia jejuna* (Fabricius)	+			+		+
2	*Bengalia torosa* (Wiedemann)	+			+		+
3	*Bengalia varicolor* (Fabricius)	+			+		+
4	*Chrysomya megacephala* (Fabricius)	+	+		+	+	+
5	*Chrysomya. rufifacies* (Macquart)	+	+		+	+	+
6	*Calliphora vicina* R & D	+	+		+	+	+
7	*Isomya coerulana* (Townsend)	+			+		
8	*Metallea notata* vander Wulp	+			+		+
9	*Rhinia apicalis* (Wiedemann)		+		+	+	+
	Family SARCOPHAGIDAE						
1	*Boettcherisca karnyi* (Hardy)	+			+	+	
2	*Boettcherisca peregrina* (R-D)	+	+		+	+	+
3	*Parasarcophaga (Parasarcophaga)* albiceps (Meigen)	+	+		+	+	+
4	*Parasarcophaga (Parasarcophaga) sericea* (Parker)	+			+	+	+
5	*Parasarcophaga (Parasarcophaga) misera* (Boettcher)	+			+	+	+
6	*Parasarcophaga (Liopygia) ruficornis* (Fabricius)	+			+		+
7	*Parasarcophaga (Liosarcophaga) dux*	+	+		+		+
8	*Sarcosolomonia (Parkerimyia) andamanensis* Nandi	+		+			
9	*Thyrsocnema (Pseudothyrsocnema) nicobarensis* Nandi		+	+			
10	*Seniorwhitea reciproca* (Walker)	+			+	+	+
11	*Pierretia (Ascpelotella) calcifera* (Boettcher)	+			+		+
12	*Phytosarcophaga sawainensis* Nandi	+		+			

Abbreviations used : A = Andaman, N = Nicobar, END = Endemic, IM = Indo-Malayan sub region, IC = Indo-Chinese sub region, IS = Indian sub region

Table-3. Family-wise distribution in the Andaman &Nicobar Islands and in the Oriental sub regions

Sl. No.	Families	Total number of species in Bay Islands	A	N	END	IM	IC	IS
1	Family TIPULIDAE	3	3	1	0	1	0	2
2	Family LIMONIIDAE	8	6	4	0	4	1	6
3	Family PSYCHODIDAE	3	3	0	0	0	0	3
4	Family CULICIDAE	113	110	56	4	89	90	86
5	Family CHIRONOMIDAE	3	3	0	3	0	0	0
6	Family BIBIONIDAE	2	1	1	0	1	0	2
7	Family SCIARIDAE	3	3	1	0	2	2	3
8	Family CECIDOMYIDAE	6	6	4	0	2	0	5
9	Family STRATIOMYIDAE	12	11	6	0	11	4	12
10	Family TABANIIDAE	11	8	5	3	5	7	7
11	Family RHAGIONIDAE	1	0	1	1	0	0	0
12	Family NEMESTRINIDAE	1	1	0	0	1	0	0
13	Family BOMBYLIIDAE	12	12	2	3	5	3	9
14	Family ASILIDAE	24	16	11	11	8	1	7
15	Family DOLICHOPODIDAE	1	1	0	1	0	0	0
16	Family PHORIDAE	1	0	1	1	0	0	0
17	Family SYRPHIDAE	10	7	7	0	6	5	10
18	Family NERIIDAE	2	1	1	1	1	0	0
19	Family MICROPEZIDAE	3	1	2	1	0	1	1
20	Family CHLOROPIDAE	3	2	3	0	2	2	3
21	Family EPHYDRIDAE	2	0	2	0	1	2	1
22	Family DROSOPHILIDAE	11	10	6	2	8	4	9
23	Family TEPHRITIDAE	15	13	10	1	11	6	7
24	Family LAUXANIIDAE	1	0	1	1	0	0	0
25	Family SEPSIDAE	1	0	1	0	1	0	1
26	Family AGROMYZIDAE	1	1	1	0	1	0	1
27	Family HIPPOBOSCIDAE	5	3	2	0	5	4	3
28	Family MUSCIDAE	23	21	13	0	17	19	21
29	Family FANNIDAE	1	0	1	0	0	0	1
30	Family CALLIPHORIDAE	9	8	4	0	9	4	8
31	Family SARCOPHAGIDAE	12	11	4	3	9	6	8
	Total	303	262	151	36	200	161	216

Abbreviations used : A =Andaman, N = Nicobar, END = Endemic, IM = Indo-Malayan sub region, IC = Indo-Chinese sub region, IS = Indian sub region

Chapter 43

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 495-502, 2010

ISOLATION AND ANTI-PATHOGENIC ACTIVITY OF MARINE ACTINOBACTERIA FROM RUTLAND OF ANDAMAN AND NICOBAR ISLANDS

P. REVATHI, S.T. SOUMASUNDARAM, K. SIVAKUMAR* and G. VIJAYA BASKARA SETHUPATHI

Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai - 608 502, Tamil Nadu

INTRODUCTION

Actinobacteria have been looked upon as a potential source for bioactive compounds and the past experience proved that they are richest sources for the production of secondary metabolites. They hold a prominent position as targets in screening programmes due to their diversity and their proven ability to produce novel metabolites and other molecules of pharmaceutical interest (Ellaiah *et al.*, 2004). Since, the discovery of actinomycin (Lechevalier, 1982), actinobacteria have been found to produce many commercially important bioactive compounds and antitumor agents in addition to enzymes of industrial interest. It is estimated that approximately two-third of thousands of naturally occurring antibiotics have been isolated from these microorganisms. The abundance of terrestrial actinobacteria and their productivity of metabolites are well known. The marine actinobacteria would be important sources for the discovery of new bioactive compounds. Indeed. Some of the antibiotics produced by these actinobacteria in the marine environment are found to be entirely new and unique (Okazaki and Okami, 1972). It is believed that the marine environment is a potent source for new actinobacteria and for new antibiotics.

Though actinobacteria are known for their bioactive substances, in the past two decades, there has been a decline in the discovery of new compounds from common soil-derived actinobacteria of terrestrial sources. For this reason, isolation of actinobacteria from various marine sources such as mangroves, estuaries, seaweeds, seagrasses, fishes, molluscs become s essential for obtaining novel strains capable of producing secondary metabolites. Considering the importance of secondary metabolites and recognizing actinobacteria as the novel source of secondary metabolites, the present study was carried out to screen antagonistic actinobacterial strains from the marine sediment samples of the Rutland Island.

MATERIALS AND METHODS

Study area

Samplings were conducted in Portman Bay of Rutland Island (1°24'00.0" N; 92°39' 57.1" E) (Fig. 1) in the South Andaman Islands. This area has no anthropogenic activity. This area is not susceptible to any waste disposal and there is no mangrove ecosystem. Scattered distribution of dead coral rock is noted in this area. Portman Bay is well protected from direct wind and high wave actions because of its geographical alignment. The irregular shape of the Bay keeps it away from the

*E-mail : annaikumar@yahoo.com

natural calamities like cyclone and severe current action. The shoreline was preceded by hills, which supports extensive growth of evergreen forest.

Sediment samples were collected from the Rutland Island, Andaman and Nicobar group of Islands. For actinobacterial analysis, pre-sterilized materials were used and sediment samples were stored in sterilized polythene bags.

Isolation and enumeration of actinobacteria

Actinobacteria were isolated from the sediment samples adopting the spread plate technique by using yeast extract-malt extract agar (ISP-2) after suitable serial dilutions. To minimize the fungal and non-spore bearing bacterial populations, cycloheximide (10 µg/ml) and nalidixic acid (10 µg/ml) were added to the medium (Kathiresan *et al.*, 2005). Serially diluted sediment samples were inoculated on ISP-2 medium and plates were then incubated at 28 ± 2°C and the colonies were observed from 5^{th} day onwards for a period of 1 month (Sivakumar *et al.*, 2005). Strains of actinobacteria were picked out and purified by repeated streaking on yeast extract-malt extract agar medium. The pure cultures of the actinobacteria were transferred to ISP-2 slants and preserved at 4 ± 2°C.

Screening of actinobacterial strains for antibacterial activity

Antibacterial activity of isolated actinobacteria were tested against *Bacillus subtilis, Klebsiella pneumonia, Proteus vulgaris, Pseudomonas aurginosa* and *Streptococcus faecalis* which were collected from Institute of Microbial Technology, Chandigrah. The antibacterial activity was tested, using the cross streak method (Waksman and Lechevalier, 1962). Single streak of the

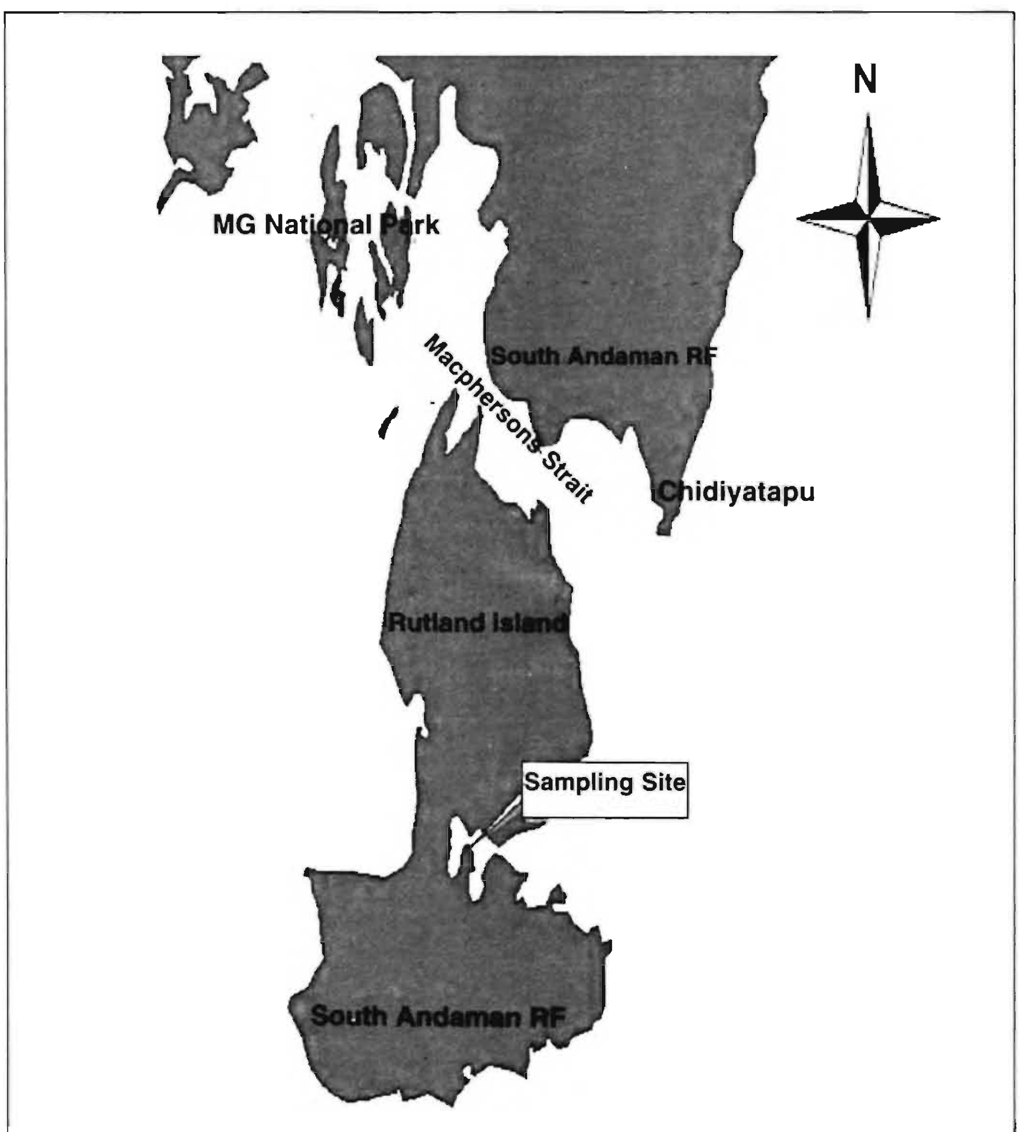

Fig. 1. Map showing the study area -Rutland Island

actinobacteria was made on the surface of the modified nutrient agar (Sivakumar *et al.*, 2005) and incubated at room temperature (28 ± 2°C). After observing a good ribbon-like growth of the actinobacteria on the petriplates, the pathogen was streaked at right angles to the original streak of the actinobacteria and incubated at 28 ± 20°C. The inhibition zone was measured after 24 and 48 h. A control plate was maintained without inoculating the actinobacteria, to assess the normal growth of bacteria. From this screening, strains of potential antagonistic actinobacteria were selected.

Characterization of potential antagonistic actinobacterial strains

The genus level identification was made for the strains which showed good antagonistic activity, using cell wall composition analysis and micromorphological studies (Lechevalier and Lechevalier, 1970). Species level identification of these strains was based on the methods described by Shirling and Gottlieb (1966), key of Nonomura (1974) and Bergey's Manual of Determinative Bacteriology (Buchanan and Gibbons, 1974).

RESULTS AND DISCUSSION

During the present investigation, a total of 10 actinobacterial strains were isolated from the sediment samples with a population density of 10 × 10^3 CFU/g. Murugan *et al.* (2005) reported most of the studies on isolation of actinobacteria have been made from marine, backwater, mangrove and estuarine sediment samples and there are no attempts of isolation of actinibacteria from coral reef environment. In this background, the present study was undertaken in the Rutland Island which is dominated by the coral reefs, instantly it supported higher actinobacterial density. Earlier, Sahu *et al.* (2007) reported higher actinobacterial density in the coral reef environment of the Little Andaman Island.

In the present investigation, among the 10 actinoabcterial strains, 6 strains (60%) were found to be inhibitory to one or more human bacterial pathogens *viz. S. faecalis* (88.89%), *B. subtilis* and *P. auruginosa* (77.78% each), *K. pneumonia* (66.67%) and *P. vulgarius* (44.44%). Among the 6 active actinobacaterial strains, only 4 strains showed (R-3, RL-4, RL-6 and RL-7) activity against all the tested pathogens. In the earlier studies more or less same (61%) antagonistic activity of actinobacteria against bacterial pathogens was recorded (Sahu *et al.*, 2007). However, Sivakumar *et al.* (2005) recorded higher antagonistic activity of actinobacteria (83%) against human bacterial pathogens from the mangrove sediments. It is important to note that out of 44 species of *Streptomyces* reported from the Tamil Nadu coast more than 68% of them were found to have antibacterial activity and 63% of the species found to have antifungal activity (Murugun *et al.*, 2005). This confirms of the importance of *Streptomyces* in the production of antibacterial substances.

Table 1. Antagonistic activity of 10 actinobacterial strains, isolated from the sediments of the Rutland Island

	Human bacterial pathogens (inhibition zone in mm)				
Strain no.	***Bacillus subtilis***	***Klebsiella pneumonia***	***Proteus vulgaris***	***Pseudomonas aurginosa***	***Streptococcus faecalis***
RL-1	11			13	7
RL-2		3			
RL-3	15	11	6	12	9
RL-4	10	12	14	10	7
RL-5					
RL-6	14	11	10	12	5
RL-7	13	6	12	11	3
RL-8	2				2
RL-9	7			10	6
RL-10		4		5	4

Among the 6 strains, 4 strains *viz*. RL-3, RL-4, RL-6 and RL-7 showed comparatively higher antagonistic activity against all the five bacterial pathogens tested. These four strains showed more inhibitory effect to *Bacillus* sp. and lesser effect on *Streptococcus* sp. Results of the analysis of cell wall components of the strains RL-3, RL-4, RL-6 and RL-7 are given in Table 2. The strains possess LL-DAP and contain glycine in its cell wall. Presence of LL-DAP along with glycine indicates the cell wall chemotype I (Lechevalier and Lechevalier, 1970).

The genera belonging to the wall type I are *Streptomyces*, *Streptoverticillium*, *Actinopycnidium*, *Actinosporangium*, *Elyptrosporangium*, *Microellobosporia*, *Sporichthya* and *Intrasporangium* (Lechevalier and Lechevalier, 1970). Branched substrate mycelium and presence of spores on long chains on the aerial mycelium were recorded for the four strains. It is important to note that the presence of spores in a long chain occurring on the aerial mycelium eliminates all the other genera having the cell wall type I except *Streptomyces* (Lechevalier and Lechevalier, 1970). The branched nature of the substrate mycelium confirms that the strains RL-3, RL-4, RL-6 and RL-7 belong to the genus *Streptomyces*.

The predominance of *Streptomyces* in actinobacterial population is a well-known fact (Alexander, 1961). Lakshmanaperumalsamy (1984), Patil *et al.* (2001), Kathiresan *et al.* (2005), Sivakumar *et al.* (2005) and Sahu *et al.* (2006; 2007) have also earlier reported that *Streptomyces* as the dominant actinobacterial component in the marine sediments. More over the selective media ISP-2 used for the present study also allowed only the *Streptomyces* to grow.

Results of cultural, morphological and biochemical characteristics obtained for the four actinobacterial strains were compared with that of the *Streptomyces* species keys given by Nonomura (1974) and the most closely matching species were presented in Table 3 to 6. Table 3 reveals that the strain RL-3 showed variations in only in two characters with that the reference strain, *S. alboniger*. The strain RL-3 failed to produce and utilize the soluble pigment and arabinose respectively. Except these, all the other characters are similar to those of *S. alboniger*. SEM studies also confirmed that the surface of the spore was smooth. Hence, the strain RL-3 has been tentatively identified as *S. alboniger*. Table 4 shows that the strain RL-4 differs from the reference strain, *S. flavochromogenes* by producing the reverse side pigment, failed to utilize the carbon source, xylose and utilized raffinose. SEM studies confirmed the presence of smooth spore surface. Based on the other characters, the strain RL-4 closely matches with *S. flavochromogenes*. Hence, the strain RL-4 has been tentatively identified as *S. flavochromogenes*.

Table 5 shows that the strain RL-6 differed from the reference strain, *S. capoamus* by failing to utilize the carbon compound arabinose and also failed to produce the soluble pigment. Apart from this, the strain RL-6 resembled the reference strain by showing close similarity in all the other characters and hence the strain RL-6 has been tentatively identified as *S. capoamus*. Table 6 reveals that the strain RL-7 shows similar physiological and biochemical characteristics features when compared to the reference strain, S. *orientalis*. Hence, the strain RL-7 has been designated as *S. orientalis*.Hence, the four strains (RL-3, RL-4, RL-6 and RL-7) possessing

Table 2. Cell wall analysis of four actinobacterial strains

Strain No.	DAP		Glysine	Whole cell sugars	Well type
	LL-DAP	Meso-DAP			
RL-3	+		+		I
RL-4	+		+		I
RL-6	+		+		I
RL-7	+		+		I

+ denotes presence; denotes absence

antagonistic activity is assigned with the following species (Table 7). These four species can be taken up for the further detailed investigation to isolate the anti-bacterial compounds. Interestingly, out of these four species, two species were reported earlier, *S. alboniger* by Balagurunathan (1992) and *S. orientalis* by Laksmanaperumalsamy (1978) and the other two species (*S. flavochromogenes* and *S. capoamus*) were additions to the *Streptomyces* species of India. More importantly, *S. orientalis* reported by Laksmanaperumalsamy (1978) possess antibiotic activity while *S. alboniger* reported by

Table 3. Comparison between the strain RL-3 and *Streptomyces alboniger*

Character studied	**Strain RL-3**	***S. alboniger***
Colour of aerial mycelium	White	White
Melanoid pigment		
Reverse side pigment		
Soluble pigment		+
Spore chain	Rectiflexibiles	Rectiflexibiles
Spore surface	Smooth	Smooth
Carbon source assimilation		
Arabinose		+
Xylose	±	±
Inositol	+	+
Mannitol	+	+
Fructose	±	±
Rhamnose		
Sucrose		
Raffinose	±	±

Table 4. Comparison between the strain RL-4 and *Streptomyces flavochromogenes*

Character studied	**Strain RL-4**	***S. flavochromogenes***
Colour of aerial mycelium	White Grey	White Grey
Melanoid pigment	+	+
Reverse side pigment	+	
Soluble pigment	+	+
Spore chain	Rectiflexibiles	Rectiflexibiles
Spore surface	Smooth	Smooth
Carbon source assimilation		
Arabinose	+	+
Xylose		+
Inositol		
Mannitol		
Fructose	±	±
Rhamnose	+	+
Sucrose		
Raffinose	+	

Table 5. Comparison between the strain RL-6 and *Streptomyces capoamus*

Character studied	**Strain RL-6**	***S. capoamus***
Colour of aerial mycelium	White	White
Melanoid pigment	+	+
Reverse side pigment	+	+
Soluble pigment		+
Spore chain	Rectinaculiaperti	Rectinaculiaperti
Spore surface	Smooth	Smooth
Carbon source assimilation		
Arabinose		+
Xylose	+	+
Inositol		
Mannitol	+	+
Fructose	+	+
Rhamnose		
Sucrose		
Raffinose	±	±

Table 6. Comparison of morphological characteristics of strain RL-7 and *S. orientalis*

Character studied	**Strain RL-7**	***S. orientalis***
Colour of aerial mycelium	White	White
Melanoid pigment		
Reverse side pigment		
Soluble pigment		
Spore chain	Rectiflexibiles	Rectiflexibiles
Spore surface	Smooth	Smooth
Carbon source assimilation		
Arabinose	+	+
Xylose	+	+
Inositol	+	+
Mannitol	+	+
Fructose	+	+
Rhamnose	+	+
Sucrose	±	±
Raffinose	±	±

Balagurunathan (1992) not posses any antibiotic activity. This confirms that the species *S. orientalis* as one of the potential candidate for antagonistic substance production. The present study indicates that sediment samples of the Rutland Island are the potential source for screening of antibiotic producing actinobacteria. Further studies are required to isolate the antibacterial compound from these strains.

Table 7. Assignment of different isolates of actinobacterial strains

Serial no.	**Strain no.**	**Species to which assigned**
1.	RL-3	*S. alboniger*
2.	RL-4	*S. flavochromogenes*
3.	RL-6	*S. capoamus*
4.	RL-7	*S. orientalis*

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Recent Trends in Biodiversity of Andaman and Nicobar Islands, 503-510, 2010

STRATEGIC PLAN AND MANAGEMENT OF ALIEN INVASIVE FAUNA IN THE ANDAMAN AND NICOBAR ISLANDS

K. SIVAKUMAR*
Wildlife Institute of India, P.O. Box. No. 18, Chandrabani, Dehradun–248 001, Uttarakhand

INTRODUCTION

Invasive species is often defined as an introduced species that has spread widely and causes harm to native biodiversity. The influence of natural events such as long term rainfall changes or human modifications to the habitat, increase in numbers also become invasive, which are native to particular area (Byers, 2002). Alien invasive species (AIS) are one of the major threats to the ecological and economic well being of the earth biosphere (McNeely *et al.*, 2001; Veitch and Clout, 2002; Sharma *et al.*, 2005) and in the areas with higher chances of invasion by breaking the different barriers (Sawarker, 1984; Sinha, 1976). AIS are highly adaptable and usually widespread and can live in a wide range of environments and have a range of negative effects. Some of these include; weeds cause the degradation of catchment areas and freshwater ecosystems, browsing animals alter the native vegetation structure and composition, extinction of several endemic flora and fauna on several islands (Atkinson, 1989; Sivaganesan and Kumar, 1994; Ali, 2004), increased competition for space and food, and increased predation pressure. Browsing by deer can result in serious losses of young trees, whether amongst natural regeneration or in plantations deliberately established for commercial or amenity purposes (Maxwell, 1967; Putman and Moore, 1998).

The Andaman and Nicobar Islands, India, (6°45′ and 13°41′ and 92°12′ and 93°57′) are located in the Bay of Bengal arch from Arakan Yoma, Mayanmar in the north to Sumatra, Indonesia in the south (Saldanha, 1989; Dagar *et al.*, 1991). The Islands cover an area of 8,249 km^2, with a total coastline of 1962 km, the Andaman group has more than 325 Islands (21 inhabited) covering 6,408 km^2, and the Nicobar group has over 23 Islands (12 inhabited) with an area of 1,841 km^2 (Saldanha, 1989). These islands are home to 5357 species of fauna (Rao, 1989) and 1454 taxa of angiosperm (Balakrishnan, 1989). Of the total species of fauna, 487 are endemic and 221 species of flora are endemic to this island (Rao, 1989). The forest type of the Andaman and Nicobar Islands are broadly classified as tropical evergreen with minor variations from north to south depending on rainfall, type of soil and degree of salinity (Thothathri, 1962; Balakrishnan, 1989). Several species have been introduced in these islands from Indian which later became invasive (Sivaganesan and Kumar, 1994; Ali, 2004).

The primary focus of concern over the role of introduced species within the Islands especially in faunal point of view is the processes of disturbance, competition and predation. Evaluation of the consequences of introductions requires the formulation of evidence of the affects of these processes; however, this assessment is

* Email : ksivakumar@wii.gov.in

difficult due to the lack of historical data. Species were introduced during the early part of the colonisation since then they have been interacting with the native biota. Thus, potential impacts are difficult to discern due to this interaction. Additionally, the island ecology is continually changing as a result of intensified land use and modifications due to human pressure. These changes also alter the conditions of the dynamic relationships between the introduced and native species interactions. In this connection, a review on invasive species in the islands was carried out to prepare a strategic plan and management of invasive species in islands.

MATERIALS AND METHODS

Management of invasive species in the Andaman and Nicobar islands is essential to prevent the further damages to the native biodiversity. In this paper some measures are recommended for the successful management of invasive species in the Andaman and Nicobar Islands which are largely based on:

a. IUCN-Invasive Species Specialist Group Guidelines

b. Studies on impact of invasive species on native biodiversity conducted in other parts of the World.

c. Studies on impact of introduced species on native biodiversity conducted in the Andaman and Nicobar Islands. However, very limited and short term studies were available in this category (Sivaganesan and Kumar 1994; Ali 2004).

d. A rapid assessment survey carried out during July 2004 to know the current extent of certain major mammalian invasive species in North, Middle and South Andaman.

e. Outcome of discussion which took place with villagers of Middle and North Andaman Islands.

f. Outcome of deliberations which took place in the Head Quarter of the Forest Department at Port Blair with various stakeholders on 29th July 2004.

g. Outcome of the Consultative Meeting which took place in the Wildlife Institute of India on 22nd September 2004 with various scientific organizations.

RESULTS AND DISCUSSION

Review on current status of certain major invasive fauna in Andaman and Nicobar islands

Four species of deer, chital *Cervus axis*, barking deer *Muntiacus muntjak*, hog deer *Cervus porcinus* and sambar *Cervus unicolor* were introduced into the Andaman islands around 1905-1940 for recreational purposes (Tikader and Das, 1985; Ali, 2004). Because of good vegetation the population of the chital increased rapidly and became menace to the forest and agriculture (Sivaganesan and Kumar, 1994; Ali, 2004). A small population of barking deer was also seen in the middle and north Andaman. Two male leopards were introduced for controlling the deer population in 1952 but those two leopards were not sighted thereafter. In 1891 domestic goats were initially introduced in Barren Island and Narcondam Island, which number is in hundreds now, however, goats from the Narcondam islands were removed recently. These introduced goats were posing threats to Narcondam Hornbill by destroying its habitats. Elephants *Elephas maximus* were introduced into these islands for timber works in 1908 and after closing the most of the timber factories around 40 elephants were released into the wild in the Interview Island, Northern Andaman in 1962 and now they have become feral and their number around 50. These elephants are responsible for the more gap formations in forests by debarking and hampering the regeneration of several native trees and plants respectively (Sivaganesan and Kumar, 1994; Ali, 2004). Later, Palm squirrel *Funambulus pennati*, cat *Felis sp.*, dog *Canis sp.*, hare, horse *Equus sp.* and domestic cattle were introduced to these Islands by mainlanders for various domestic purposes. It was estimated around 70,000 dogs in these islands (ANET *pers. comm*). Pig-tailed Macaque *Macaca nemestrina leonia* was said to have been transported to Andaman from Burma but it does not occur here at present.

Birds such as common crow *Corvus splendens*, common myna *Acridotheres tristis*, peafowl *Pavo cristatus*, house sparrow *Passer domesticus*, grey partridge *Francolinus pondicerians*, spotbill duck *Anas poecilorhyncha*, common quail *Coturnix coturnix*, jungle bush quail *Perdicula asiatica*, painted bush quail *Perdicula erythrorthyncha*, comb duck *Sarkidiornis melanotos*, openbill duck

Anastomus oscitans, domestic fowl and domestic duck were introduced in these islands between 1862 and 1964. Status and distribution of most of these bird species is unknown (Mohanraj *et al.*, 1999). There are also possibilities of invasion of herpetofauna in these islands which need to be studied. Regarding exotic fishes, five species of carps, four species of mullets, cat fish *Heteropneustes fossilis*, anabas *Anabas testidineus*, tilapia *Oreochromis mossambica* and freshwater eel *Anguilla bicolor* were introduced here but their status and distribution is unknown. Apart from several species of insects, there are more than 500 species of plants were introduced into these islands for agriculture purposes. Along with agriculture and horticulture plants several alien invasive plants were also entered into these islands and their distribution is now extended even into the Protected Areas of Andaman and Nicobar Islands. There is no detailed information available here on AIS belonging to rodents, invertebrates such as insects, annelids, mollusks (except African giant snail) and aquatic organisms (Mohanraj *et al.*, 1999). It was observed that the fast proliferation of African giant snail, *Acatina fulica* which was introduced in 1940s, was affecting the agriculture and horticulture crops and it may also be affecting forestry in the islands. To control this giant snail, two species of predatory snail such as *Euglandina rosea* and *Gonaxis quadrilateralis* were introduced from Hawaii at later stage but these predator snails also poses a serious threat to 75 to 80 native land snails that occur in these islands.

There has been no study on the introduced animal of Andaman Islands with exception of Sivaganesan and Kumar (1994) and Ali (2004) who have studied the status and distribution of feral elephants and its impacts.

Strategic plan for management of invasive fauna in Andaman and Nicobar islands

Island Invasive Species Control and Management Committee (IISCMC)

The impact of invasive species on insular fauna and flora is severer than on the mainland. Therefore, it is urgent to form the Island Invasive Species Control and Management Committee (IISCMC) whose main role is to take up a policy decision on the management of AIS in the Andaman and Nicobar Islands whenever required implement any actions. The IISCMC will also facilitate the development of a database on AIS for planning and executing programmes on management of invasive in islands with the help of State Forest Department Statistics Cell. This database will provide information on exotics introduced in different islands and their impact on ecosystem. It will also provide useful information on the spread of exotics in islands, crucial for evaluating further introduction proposals based on impacts of such introductions elsewhere. The committee will also evaluate any proposals on introduction. However, the IISCMC should not allow the introduction of any AIS into the islands and they may consider any introduction proposal of exotic species which are non-invasive and major interest of public.

Prevention and introductions of invasive species

a) Preventing the introduction of alien invasive species is the cheapest, most effective and most preferred option and warrants the highest priority.

b) Rapid action to prevent the introduction of potential alien invasives is appropriate, even if there is scientific uncertainty about the long-term outcomes of the potential alien invasion.

c) Vulnerable ecosystems should be accorded the highest priority for action, especially for prevention initiatives, and particularly when significant biodiversity values are at risk. Vulnerable ecosystems include islands and isolated ecosystems such as lakes and other freshwater ecosystems, cloud forests, coastal habitats and mountain ecosystems.

d) Since the impacts on biological diversity of many alien species are unpredictable, any intentional introductions and efforts to identify and prevent unintentional introductions should be based on the precautionary principle.

e) In the context of alien species, unless there is a reasonable likelihood that an introduction will be harmless, it should be treated as likely to be harmful.

f) Alien invasives act as "biological pollution" agents that can negatively affect development and quality of life. Hence, part of the regulatory response to the introduction of alien invasive species should be the principle that "the polluter pays" where "pollution" represents the damage to native biological diversity.

g) Biosecurity threats justify the development and implementation of comprehensive legal and institutional frameworks.

h) The risk of unintentional introductions should be minimized.

i) Intentional introductions should only take place with authorization from the relevant agency or authority (State Invasive Species Committee will be the authority in the Andaman and Nicobar islands). Authorization should require comprehensive evaluations based on biodiversity considerations (ecosystem, species, genome). Unauthorized introductions should be prevented.

j)The intentional introduction of an alien species should only be permitted if the positive effects on the environment outweigh the actual and potential adverse effects. This principle is particularly important when applied to isolated habitats and ecosystems, such as islands, fresh water systems or centres of endemism.

k) The intentional introduction of an alien species should not be permitted if experience elsewhere indicates that the probable result will be the extinction or significant loss of biological diversity.

l) The intentional introduction of an alien species should only be considered if no native species is considered suitable for the purposes for which the introduction is being made.

Recommended actions to reduce the likelihood of unintentional introductions are

a) Identify and manage pathways leading to unintentional introductions. Important pathways of unintentional introductions include: national and international trade, tourism, shipping, ballast water, fisheries, agriculture, construction projects, ground and air transport, forestry, horticulture, landscaping, pet trade and aquaculture.

b) Contracting parties to the Convention on Biological Diversity, and other affected countries, should work with the wide range of relevant international trade authorities and industry associations, with the goal of significantly reducing the risk that trade will facilitate the introduction and spread of alien invasive species.

c) Develop collaborative industry guidelines and codes of conduct, which minimize or eliminate unintentional introductions.

d) Examine regional trade organizations and agreements to minimize or eliminate unintentional introductions that are caused by their actions.

e) Explore measures such as: elimination of economic incentives that assist the introduction of alien invasive species; legislative sanctions for introductions of alien species unless no fault can be proved; internationally available information on alien invasive species, by country or region, for use in border and quarantine control, as well as for prevention, eradication and control activities.

f) Implement the appropriate initiatives to reduce the problems of alien invasive arising from ballast water discharges and hull fouling. These include: better ballast water management practices; improved ship design; development of state ballast water programmes; research, sampling and monitoring regimes; information to port authorities and ships' crews on ballast water hazards. Disseminate international guidelines and recommendations, such as the International Maritime Organization's guidelines on ballast water and sediment discharges.

g) Put in place quarantine and border control regulations and facilities and train staff to intercept the unintentional introduction of alien species. Quarantine and border control regulations should not be premised only on narrow economic grounds that primarily relate to agriculture and human health, but, in addition, on the unique biosecurity threats each country is exposed to.

h) Address the risks of unintentional introductions associated with certain types of goods or packaging through border control legislation and procedures.

i) Put in place appropriate fines, penalties or other sanctions to apply to those responsible for unintentional introductions through negligence and bad practice.

j) Develop the most cost-effective options for governments wanting to avoid the high costs of controlling alien invasive species. These include more holistic approaches to biosecurity threats and better resourcing of quarantine and border control operations, including greater inspection and interception capabilities.

k) Have in place the necessary provisions for taking rapid and effective action, including public consultation, should unintentional introductions occur.

Intentional Introductions - Recommended Actions

a) Give utmost importance to effective evaluation and decision-making processes. Carry out an environment impact assessment and risk assessment as part of the evaluation process before coming to a decision on introducing an alien species. (See Appendix)

b) Require the intending importer to provide the burden of proof that a proposed introduction will not adversely affect biological diversity.

c) Include consultation with relevant organizations within government, with NGOs and, in appropriate circumstances, with neighbouring countries, in the evaluation process.

d) Where relevant, require that specific experimental trials (e.g. to test the food preferences or infectivity of alien species) be conducted as part of the assessment process. Such trials are often required for biological control proposals and appropriate protocols for such trials should be developed and followed.

e) Ensure that the evaluation process allows for the likely environmental impacts, risks, costs (direct and indirect, monetary and non-monetary) benefits, and alternatives, to have been identified and assessed by the biosecurity authority in the importing country. This authority is then in a position to decide if the likely benefits outweigh the possible disadvantages. The public release of an interim decision, along with related information, should be made with time for submissions from interested parties before the biosecurity agency makes a final decision.

f) Impose containment conditions on an introduction if and where appropriate. In addition, monitoring requirements are often necessary following release as part of management.

g) Regardless of legal provisions, encourage exporters and importers to meet best practice standards to minimize any invasive risks associated with trade, as well as containing any accidental escapes that may occur.

h) Put in place quarantine and border control regulations and facilities and train staff to intercept unauthorized intentional introductions.

i) Develop criminal penalties and civil liability for the consequent eradication or control costs of unauthorized intentional introductions.

j) Ensure that provisions are in place, including the ability to take rapid and effective action to eradicate or control, in the event that an unauthorized introduction occurs, or that an authorized introduction of an alien species unexpectedly or accidentally results in a potential threat of biological invasion.

ERADICATION AND CONTROL

When a potential or actual alien invasive species has been detected, in other words, when prevention has not been successful, steps to mitigate adverse impacts include eradication, containment and control. Eradication aims to completely remove the alien invasive species. Control aims for the long term reduction in abundance or density of the alien invasive species. A special case of control is containment, where the aim is to limit the spread of the alien invasive species and to contain its presence within defined geographical boundaries.

Management of existing invasive species in the Andaman and Nicobar islands Eradication of weeds in Andaman and Nicobar Islands

a) There are more than 500 plant species introduced either intentionally or accidentally in these islands. Of these most of them are agricultural and ornamental species.

b) Weed species such as *Ageratum conyzoides, Argemone mexicana, Cleome gynandra, cleome viscosa, Ipomoea carnea, Lantana camara, Lantana sellowiana, Mikania cordata, Parthenium hysterophorus,* and *Synedrella nodiflora* are may be considered as the most dangerous weeds in the Andaman and Nicobar islands.

c) Weed Management Areas needs to be prepared by mapping the above mentioned weeds distribution in the Andaman and Nicobar islands.

d) Uprooting and burning the weed plants before fruiting is the best method. This method is quite possible in the Andaman and Nicobar islands and hence it is recommended.

e) After initiating the weed eradication programme the Weed Management Areas needs to monitored regularly and if required then the weed eradication programme will needs to be continued.

Management of invasive mammals in Andaman and Nicobar islands

a) Removal of all major mammalian invasive species (except elephants) from the all Protected Areas, sea turtle nesting beaches and other reserved forests should be taken up immediately.

b) Invasive mammalian species (except elephant) in Andaman and Nicobar islands which are protected under various Schedules of the Indian Wildlife (Protection) Act, 1972 need to be declared as 'Vermin'

c) Forest Department itself or through tourists or local people the removal operations can be taken up.

d) While removing the mammalian invasive species from the forested areas there should not be any damage to the native fauna and flora and also for local communities.

e) Fertility control of invasive deer may not be a feasible solution, moreover, there is no need to keep the invasive deer populations in the wilderness habitats. Hence, controlled public hunts can be used to effectively reduce deer populations. It may be desirable to require the hunters to pass safety and proficiency tests before they are allowed to participate in the hunt. Otherwise, sharp shootings and, trap and kill/translocation programme may also be adopted.

f) Nowhere in the World that the elephant is considered as an invasive species except in the Andaman and Nicobar islands. Hence, there is no enough research and knowledge available regarding management of invasive elephants. Keeping this in mind it is recommended that after having adequate trained man power, capacity and infrastructure facilities, the Island Invasive Species Control and Management Committee may recommend the competent authority to control the populations of both feral and domestic elephants.

g) Project Elephant Directorate and various Elephant Specialist Groups may be consulted in this regard. Several countries have successfully carried out *in situ* translocation of several hundreds of elephants from one place to another e.g. Malaysia. Experts from those countries may be consulted to manage the invasive elephants of Andaman.

h) If the control of elephants is not possible than IISCMC should consider the 'contain or isolation' of elephants populations in one or two islands.

i) Exotic species which are beneficial for the human being are needs to be contained within the human habitations and these species should not be allowed to enter into the Protected Areas or other forests. Offenders must be punished with severe fine and imprisonment.

j) Among the introduced birds, domestic fowl, common crow, house sparrow and common myna are more dangerous in respect of competition (food and niche) with native birds, predation on native insects etc and may be spreading diseases to the endemic birds. For example it was reported in the Great Nicobar islands that an outbreak of avian cholera in domestic fowls was transmitted to the highly threatened endemic bird the Nicobar megapode. Hence it is necessary to remove these bird species using professional bird trappers or bird hunters.

k) A detail study on the distribution and status of the invasive birds is also necessary which will be useful to monitor the success of the removal programme.

l) Nicobar bulbul which is endemic to the Nancowry group of islands is endangered because of the introduction another native bulbul from the Andaman group, hence inter island introduction is also should not be allowed in future.

m) Other animals: There are several species of fishes, insects, snails were introduced in the islands and most of them are invasive in nature. Control of these invasive species without using any bio-control method is recommended.

n) Status, distribution and impact of the invasive mammalian species is also needs to be established.

Surveillance and reporting of diseases due to exotic species in the Andaman and Nicobar islands

Surveillance and reporting system assist in the identification of incidence/prevalence of diseases of interest caused by exotic species. This helps focusing efforts to control and reduce the risk of spread of diseases in the islands. It also provides information on parts in a larger island or group of islands having equal status in respect of a particular disease. Surveillance is required to detect exotic pathogens and to implement control measure. Surveillance is essential to consolidate information on distribution of pathogens, to facilitate the development of zoning policies and to develop disease management strategies for protecting the domestic livestock and the native biodiversity. To confirm disease outbreaks reported by surveillance are exotic in nature, the mode of action is given under reporting.

In Andaman and Nicobar islands a limited manpower may be working on wildlife health. Therefore, pilot level active surveillance can be undertaken by State Animal Husbandry Department in collaboration with IVRI and Veterinary Universities wherever required.

Awareness, training and research

Awareness key is the successful implementation of programmes. There have been several illegal introduction of exotic species in the Andaman and Nicobar Islands in the past and may be continuing. As a result, it is feared that several undesirable species have already established in the islands. Awareness of the entrepreneurs on the risks and benefits of exotics species presence in the islands would have deterred them from clandestine introductions and their post-introduction spread.

Developing a system for managing introduction of invasive species and quarantine depends largely on availability of comprehensive scientific information on this subject. For implementing effective control or introduction of exotics and quarantine, Government must have sufficient capacity in terms of trained manpower and institutional resources. At present the research input on exotics and quarantine is very limited in India in general and in the Andaman in particular.

Institutional mechanism and linkages

There is a need for appropriate state administrative framework for implementing the action plan on invasive species management in the Andaman and Nicobar islands. Already existing organizational framework has to be interlinked to make a cohesive unit. All the organizations to be involved in the suggested plan must have clearly defined responsibilities and the efforts of all these must be coordinated. It is important to involve all the stakeholders and seek their views.

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INVASIVES AND THEIR IMPACT ON ANDAMAN BIODIVERSITY

RAUF ALI*
Foundation for Ecological Research, Advocacy and Learning (FERAL), P.B. 28, Pondicherry - 605 001

INTRODUCTION

Invasive Alien Species (IAS) is species introduced by human agency to areas where they did not occur earlier, from where they have established themselves and spread. They also cause either ecological or economic damage, making their control necessary. An estimated 30 species of mammals, 4 species of birds, 300 species of fish and 1100 species of arthropod can be classified as invasive pests in India, besides 17,000 species of plants (Pimentel *et al.*, 2001). Most of these estimates date back to the mid 1980's, and the number has certainly gone up substantially.

The assessments of economic damage done in India are comparatively recent, but are frightening (Pimentel *et al.*, 2001). The estimated economic damage annually due to invasive pests is US$91.02 billion in India alone; the estimated environmental damage done by rats is estimated at US$25 billion annually (Pimentel *et al.*, 2001). These figures are based on assumptions that may not be realistic and must be treated with caution; however, they give a rough idea of the scale of the problem.

The three main phases in a species becoming an invasive are introduction, establishment, and integration (Vermeij, 1996). Introductions are the mechanism by which species are transported from one place to another. Species can be transported deliberately as pets, or as commensals. They can be food grain contaminants, or be carried in ballast water. They can utilize transport vectors such as roads to move to adjoining areas. How a species is introduced becomes very relevant when control measures are being formulated, since the cheapest form of control is to prevent introductions in the first place.

The establishment of a species also depends on several factors. The species richness of the area where it is introduced, the similarity in latitude between its place of origin and its place of introduction, the presence of predators and parasites, as well as the presence of other introduced species are important factors. Integration is the process by which the invasive becomes part of an ecological community, and its interaction with that community. Methods of dispersal are important while considering integration and consideration of these provide possible control mechanisms for invasives.

RESULTS AND DISCUSSION

Species accounts

Birds : In the 1890's, a number of bird species were introduced into the Andamans. These included the little Brown Dove in 1899, the Rose-ringed Parakeet in 1863 (this died out), and the Common Myna in 1867. A mainland subspecies of the Red Whiskered Bulbul was introduced to the Andamans, while the island subspecies of this species was introduced to Kamorta between 1910

* E-mail : rauf@feralindia.org

and 1920. The Andaman White-headed Mynah was also introduced to Kamorta, and is common there (Ravi Sankaran, personal communication). Several others died out after introduction, and these include the Tree Sparrow in 1866, the Red Munia in 1873 and the Black-headed Munia in 1906.

The most harmful invasive birds found in the islands appear to be the Common Myna and the House Crow. While birds tend to disperse well even by natural means, these two pose a particular problem because of their highly competitive nature. The most ubiquitous is the Common Myna (*Acridotheres tristis*). It was probably introduced as a cage bird which then escaped. It has spread over the settlement areas of South Andaman, south of Jirkatang. It is not found in Middle or North Andaman.

This species is listed as one of the worlds 100 most invasive species. Although no study has been done on it in the Andaman, it is highly likely that it competes for nest holes with the endemic Andaman White headed Mynah, and with the Glossy Starling. There is also a likelihood that it competes with the local woodpecker species, including the endemic (?) Andaman Black Woodpecker.

The House Crow (*Corvus splendens*) was first observed in 2002, when 7 birds arrived as stowaways on a ship and began roosting near the Marina in Port Blair (Ali, 2006). Now there is a roost of several hundred birds in Aberdeen village. While this was brought to the notice of the authorities, no effort was made to control these birds when it would have been relatively simple. These birds are agricultural pests and are known to spread disease. They have become a problem in East and South Africa, in the Seychelles, and in Singapore. Bounties have been offered in the Seychelles to try and eradicate them. In Singapore, the Government has established a management target of less than 10 crows per km^2 this will involve culling 40,000 crows annually. Other introduced bird species include the House Sparrow (*Passer domesticus*), introduced in 1866, which is confined to Port Blair.

MAMMALS

Mammals invasive have been brought in as pets, as stowaways, and have also been deliberate releases. While quantitative studies have not been done, chital, dogs, cats and rats seem to cause the most damage. Goats and elephants cause damage in very restricted areas. A detailed discussion on mammals and bird invasives are reported by Ali (2006). The Chital (*Axis axis*) was introduced into the Andamans reportedly in the 1930's. It has spread all over the Great Andaman group of islands, including Ritchies Archipelago, the Labyrinth Islands, Interview and North Reef. It is not found in Little Andaman Island, or in the Nicobar.

Recent studies showed decreased basal areas in areas where chital were found, as opposed to control areas on Little Andaman (Ali, 2004). Seedlings were browsed heavily wherever chital were found. The exceptions were *Lagerstromea hypoleuca* and *Pongamia pinnata*, with the result that regeneration in a lot of places consisted of only these two species.

The best example of damage by chital can be seen on Ross Island, just off Port Blair. There is no undergrowth here, and chital are seen eating plastic bags. Well-intentioned suggestions to provision the deer will only result in an increase in population numbers, and heavier pressure on the meagre resources there.

Elephants have become a problem on Interview Island (Ali, 2005). These were used for logging here until 1962, when the logging company went bankrupt. About 40 elephants were abandoned here, and few in North Andaman. About 70 elephants have been estimate in the Interview Island during the 1992 (Sivaganesan and Kumar, 1995), though this might have been an overestimate. A more recent survey (Ali, 2005) puts the population at around 30, of which half were adult. The damage done by the elephants here is obvious. Bamboo, *Pandanus*, and reeds have largely disappeared. A large number of trees have been debarked or have been pushed over. Because of the chital, the regeneration is low, and large areas of the island are becoming sparsely vegetated.

Other introductions include Barking Deer, seen occasionally on Middle Andaman, and The Five-striped Palm Squirrel. This last had spread up to Wandoor, and has recently been sighted at North Wandoor. Being a seed predator, it is likely to affect forest dynamics. Rodent invasives have also been recorded in the Andamans. These include the Black rat (*Rattus norvegicus*), House Rat (*Rattus rattus*), and Field Mouse (*Mus musculus*). It is likely that they have an impact on the several species of endemic rodents found in the islands.

Domestic animals

The most obvious problem in the Andaman and Nicobar is created by domestic dogs that have gone feral. These dogs form packs and attack nesting sea turtles. They attack adult turtles and disable them by biting off their flippers, dig up nests to eat the eggs, and eat hatchlings. Packs of these feral dogs can be observed on some turtle breeding beaches, including the Galathea Beach on Great Nicobar Island.

Feral cats are becoming an increasing problem. They attack the nests of breeding birds. In the US it is estimated that each cat eats at least eight birds in a year. While no estimate is available for the number of cats in the Andaman, they are commonly encountered in almost all protected areas. A significant reduction in the populations of nesting birds is likely to have occurred as a consequence.

Goats were released on Barren Island in the 19th Century by British seafarers. They were also released later on Narcondam Island as a food resource for the police party posted there. There is a myth that the goats on Barren Island drink only sea water, and this makes them a special breed worthy of protection! This myth has recently been shattered with the discovery of perennial fresh water sources on Barren Island (Chandrasekharam *et al.*, 2003). Both these goats on Narcondam have seriously impacted the regeneration of indigenous plant species at these sites. Feral cattle have been observed in Jarawa Reserve. While their numbers are still small, control measures should be taken before they become a problem.

Invertebrates

Insect pests are not dealt with here. The most important invasive invertebrate in the islands is the Giant African Snail, *Achatina fulica*. Introduced as a food supplement by the Japanese during World War II, it has spread all over the Andamans and Nicobars (Shyam Prasad *et al.*, 2004).

Plants

Parkinson (1923) recorded over a hundred species of introduced plants in the Andamans. A

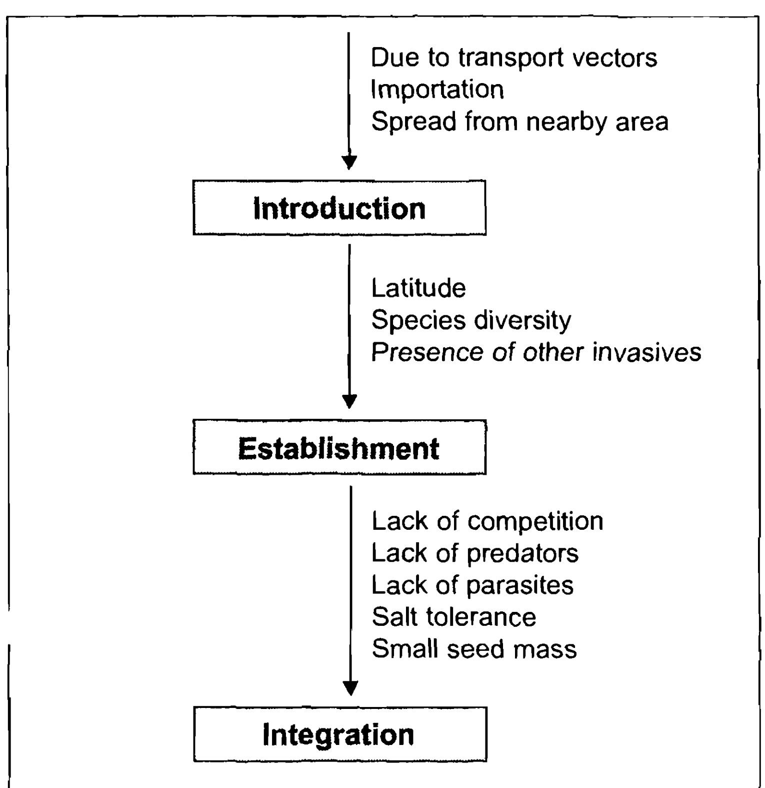

Fig. 1. Steps in a species becoming invasive

Group	Species	Likely time of introduction	Current Location	Threat to	Domesticated	Purpose of introduction
Birds						
	Common Myna	1867	S. Andaman	Hole nesting endemics		Pet
	House Crow	2002	Port Blair	Agri pest, disease vector		
	House Crow	NA	Car Nicobar	Agri pest, disease vector		
	House Sparrow	1892/1895	Port Blair	NA		
Mammals						
	Chital	1912?	Andaman excluding Little A.	Affects forest regeneration		Game
	Elephant	1962	Interview I., N. Andaman	Affects forest regeneration		Timber ops
	Cats	NA	A&N	Predator of endemic birds	Yes	Pet
	Dogs	NA	A&N	Predator on sea turtles	Yes	Pet
	Cattle	NA	S. Andaman	Damage native vegetation	Yes	Livestock
	Palm Squirrel	NA	S. Andaman	Seed predator		Pet
	Black Rat	NA	A&N?	Agri pest, disease vector		
	House Rat	NA	A&N?	Agri pest, disease vector		
	Field Mouse	NA	A&N?	Agri pest, disease vector		
	Barking Deer	NA	M. Andaman	NA		Game
Invertebrates						
	Giant Snail	1943	A&N			Food item
	Insects	not assessed				
	Biocontrol agents	not assessed				
Plants						
	Parthenium	NA	A&N?	Weed		
	Chromolaema	NA	A&N?	Weed		
	Opuntia	NA	A&N?	Weed		
	Water Hyacinth	NA	A&N?	Wee; chokes ponds		Ornamental
	Other plants	not assessed				
Reef organisms		Not yet surveyed				

Fig. 2. Summary of Invasive Alien Species in the A and N Islands

lot of these have become invasive now, and include *Parthenium*, *Chromolaema*, Opuntia, and Water Hyacinth. Babu *et al.* (2003) recorded 36 introductions to Great Nicobar, 12 of which are potentially invasive. These include *Ageratum conyzoides,Mikania macrantha, Chromolena odorata* and *Lantana camara.*

Biocontrol agents

These are being used to control harmful pests on agricultural plants. The biocontrol agents being used in the Andaman include egg parasitoids, larval parasitoids, predators and pathogens. Details are given in Andaman and Nicobar Administration (2004). Its proponents defend its efficacy passionately (Hoddle, 2004). The use of biocontrol agents in the Andaman has also recently been advocated by MSSRF (2005). However, they are being brought in and used without any proper testing to see what their effects are on non-target organisms. The egg parasitoids include *Trichogramma* wasps and the predators include ladybird beetles: both of these are known to turn invasive and attack non target organisms in other areas. The damage these can potentially do to forest pollinators remains to be studied.

Introduction pathways

The introduction pathways noted in the Andaman were :

- **Accidental release** : Both the House sparrow and Common Myna were brought over from mainland India as house hold pets. These would have either escaped or been released deliberately. Several plants species have also been brought over as ornamentals and have established themselves in the wild. The most notable of these is the water hyacinth.
- **Deliberate release** : Chital were brought over in the 1920's or 1930's as a game animal, since there are no large herbivores here. Barking Deer and Hog Deer were also released deliberately as game animals; the barking deer survives in a few pockets of Middle Andaman. As recently as 10 years ago, Chital were transported to North Reef Island. The elephant also belongs to this category, as it was deliberately released on Interview Island in 1962. Goats, dogs and other domesticated animals, as well as biocontrol agents belong to this category.
- **Stowaways** : These would include the House Crow. 7 birds were observed flying off a ship in 2002. These have now multiplied and number in the hundreds. The different introduced rodents found here would also belong to this introduction category.
- **Contaminants** : Weeds contaminating agricultural seeds brought in from mainland India would have resulted in the introduction of these weeds into the Andaman. The 12 potentially invasive plants recorded by Babu *et al.* (2003) would largely belong to this category.
- **Ballast water** : There has been no study done of potentially invasive species transported by this mechanism into the Andaman. Globally, this is one of the most important pathways for invasives to travel from one site to another, and it is estimated that up to 10,000 species are transported daily by this mechanism.
- **Spread to surrounding areas** : Chital have swum over from the larger islands to the smaller islands. They have spread to almost all the islands of the Mahatma Gandhi Marine National Park, and also to all the islands of Ritchies Archipelago.
- **Transport vectors** : Truck and boat traffic almost certainly result in invasives being transported from one island to another. This is an important area for future research.

Control Mechanisms

The most important aspect of controlling invasives is to prevent their introduction in the first place. Checks at both embarkation and disembarkation points would reduce the possibility of accidental or deliberate releases. It must be made illegal for ballast water to be changed in harbour areas; this must be done in the high seas where necessary. Fumigation and pest control measures on ships arriving to the islands is also necessary.

In the case of the larger mammal species, culling, sterilization and translocation are the only options. Translocation and sterilization need expert veterinary input, as well as entailing high costs in capturing animals. Translocation or sterilization may be done for the elephants on Interview Island, where the numbers are still few. In the case of chital, culling seems to be the only viable option.

Several countries offer bounties for shooting invasive species. The Seychelles Government offered a $100 bounty for crows when it was first noticed, leading to complete eradication (Government of Seychelles, 2008). With House Crow, an immediate culling programme will result in the same. This also seems to be the only way of controlling the Common Mynah.

Strict licensing requirements are required for domestic pets. Dogs and cats found in rural areas need to be culled. Considerable expertise has been gained in other parts of the world for controlling these animals that have gone feral. A combination of traps and poisoning has been very effective with house cats (Nogales *et al.*, 2004).

While the culling of goats appears to be relatively straight forward, and has been done recently on Narcondam, care needs to be exercised that the last few animals are eradicated. This has proved problematic in other parts of the world, and has led to the development of special techniques such as using a 'Judas goat' This is a domestic goat which is fitted with a radio transmitter and then released. Since goats are social animals, this then associates with the wild goats, enabling their tracking and culling (Campbell and Donlan, 2005).

Rodents are also problematic to eradicate. A combination of traps and rodenticides are used. In one instance, eliminating the last rat took 18 weeks on a 9.5 ha island (Russell *et al.*, 2005). In the Andaman, the use of rodenticides is not possible because a large number of endemic rodents would also get affected. The use of biocontrol agents is problematic. While some of these may work well in mainland India, their use in an island ecosystem with a great number of endemics requires particular care (Louda *et al.*, 2003; Louda and Stiling, 2004). Stringent protocols for assessing the effect on non-target organisms need to be developed, as has been done elsewhere.

Legal hurdles in control

The lack of any policy on invasives makes their control and eradication difficult. Animals that occur in mainland India are found to be invasive in the Andaman and Nicobar Islands. However the law applicable to their control: the Wildlife Act (1972) is uniformly applicable all over India. This allows the Chief Wildlife Wardens of states to declare a species vermin, after getting clearance from Ministry of Environment and Forests (MoEF), Government of India. However, MoEF is reluctant to do this both because of pressure from the animal rights lobby, and because of the fear of setting a precedent. This would make control of animals such as chital difficult.

Also relevant is the total ban on 'hunting' within protected areas. This would be necessary if Chital populations were to be controlled. It would also be necessary to control invasive birds such as mynahs that are now found in National Parks. India has an obligation under the Convention on Biodiversity to prepare management plans for dealing with at least some invasives by 2010. This looks highly unlikely because there is no invasives policy. The US has a comprehensive policy: the Presidential Executive Order No. 13112 of February 3, 1999. IUCN has comprehensive guidelines, as do most countries in Europe and America. Sadly, we have not woken up to this reality yet.

CONCLUSIONS

There is practically no quantitative data on the distribution and population status, as well as the population trends of the invasives that have been identified. There is a great scope for the Zoological Survey of India, as well as the Botanical Survey of India, to take the initiative and begin work on these aspects. Since the list given above is almost certainly incomplete, a survey needs to be done first to establish how many invasives there actually are in these islands. A programme to eradicate the House Crow can be undertaken straight away. This is because it is listed as vermin under the Wildlife (Protection) Act, and no special permission is required to carry this out.

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Chapter 46

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 519-532, 2010

PROTECTED AREA NETWORK IN ANDAMAN AND NICOBAR ISLANDS : A GAP ANALYSIS FOR BIODIVERSITY REPRESENTATION AND CONSERVATION STATUS

V.B. MATHUR and H. PADALIA*

V. B. Mathur, Professor & Dean, Wildlife Institute of India, Chandrabani, Dehradun-248001, E-mail : vbm@wii.gov.in.

INTRODUCTION

Protected Areas (PAs) are regarded as cornerstones of biodiversity conservation. Creation of a sound network of PAs is regarded as the best and only practical way for *in situ* conservation of biodiversity in species rich countries (Glowka *et al.*, 1994). India has an extensive network of legally designated PAs comprising National Parks and Wildlife Sanctuaries corresponding to IUCN categories II and IV respectively, covering 4.76 per cent of the geographical area of the country. Away from the continental land mass, the oceanic islands of Andaman and Nicobar (hereafter ANI) represent a unique distribution of biodiversity in a contrasting interface of terrestrial and marine habitats. 19.65 per cent area of ANI is under PAs comprising 9 National Parks and 96 Wildlife Sanctuaries.

It is well recognized that world's PA network is not optimally designed to conserve biodiversity (MacKinnon and Mackinnon, 1986; Scott *et al.*, 2001). In ANI also, due to the absence of a comprehensive basis for selection and design of PA, important vegetation types, biologically rich localities and associated marine diversity is not adequately conserved under PA system. Previous attempts to identify gaps in PA network considered adequacy of biogeographical representation (Rodgers and Panwar, 1988), endemicity of avifauna (Sankaran, 1997), faunal assemblages (Gandhi 2000), vegetation and socioeconomic conditions (Elllis *et al.*, 2000), and coral reefs (Kumar, 1997), but all these studies mainly relied on synthesis of available information and no quantitative procedure was followed except Sankaran (1997).

For conserving the rich biological heritage of ANI, establishment of a representative network of PAs based on biodiversity pattern is one of the most cost effective means. As the natural vegetation is being cleared at a faster rate due to growing human population pressure in ANI, it is more important now than ever before to analyze how conservation efforts can be strengthened by maximizing biodiversity representation in the PA network. The first step is to examine whether the current PA network adequately represents the biodiversity of ANI.

The current practice in conservation biology is to combine different approaches in order to fill gaps in representativeness of biological diversity for designing efficient reserve system (Wessel *et al.*, 1999; Noss *et al.*, 1999). Both "coarse filter" and "fine filter" approaches are needed to protect diversity at multiple scales (Dudley and Parrish,

*Hitendra Padalia, Regional Remote Sensing Service Centre(RRSSC), Indian Space Research Organisation Dehra Dun-248001, E-mail : hiten_pa@yahoo.co.in

2005). Vegetation based approach is a very valuable conservation tool in poorly explored areas at regional scales (Strittholt and Boerner, 1995; Awimbo *et al.*, 1996). According to Mittermeier *et al.* (2000), biodiversity priorities must be based on actual data, first and foremost, on species diversity and endemism, on phyletic diversity, on ecosystem diversity, and subsequently on threat. Biodiversity Characterization at Landscape Level (Roy and Tomar, 2000) is one such methodology which scales priority areas of conservation utilizing remote sensing, landscape matrices and field data in GIS domain. The methodology has been validated for its predictive power of scaling phyto diversity variations at landscape level in ANI (Roy *et al.*, 2005). Another globally acknowledged priority setting approach is of BirdLife International that aims to identify protect and where appropriate, manage a minimum network of sites important for the long-term viability of bird populations (Grimmett and Jones, 1989; Fishpool and Evans, 2001). The sites are identified using rigorous, standardized criteria based upon the presence of bird populations at sites. IBAs can therefore be used to indicate the gaps in coverage of a particular species.

We present a complementary approach for prioritization based on sensitivity of issues and available information on biodiversity, providing rationale for extending the current coverage of PA network. Gap analysis has been carried out to know the extent of vegetation / land cover / land use types, biologically rich zones and localities of conservation importance for birds and turtles are represented in PAs in ANI (Anon., 2005; Mathur and Padalia, 2006).

Study Area

Andaman and Nicobar islands (ANI) are an internationally acknowledged biodiversity hot spot (Mayer, 2000), off the Indian mainland and lying isolated (Latitude 6°45′ N to 13°41′ N (extent 740 km) and longitude 92°12′ E to 93°57′ E (extent 190 km), in the Bay of Bengal (Fig. 1). The total area of Andaman and Nicobar is 8249 km^2. There are in all 349 islands which can be distinguished into two groups geographically. There are 325 islands in Andaman group while Nicobar group has 24 islands. The Andaman Islands are separated from the Nicobar by a one-fifty-five kilometer long channel known as the Ten Degree Channel. The physiography of the islands is characterized by undulating topography and intervening valleys. Average annual temperature varies from 24° C to 28°C. Elevations range from 0 to 732 m at Saddle Peak in Andaman and 620 m at Mount Thulier in Great Nicobar. Precipitation is slightly higher in Nicobar with an average annual rainfall of 3000 to 3500 mm. 84.82 per cent area of the islands is forested (FSI, 2003). The regions encompass a very high degree of endemicity in all taxa, especially in plants, reptiles (Das, 1999a and Andrews, 2001), fishes and corals. Flora and fauna in Andaman bears close biogeographical affinities with Myanmar and Thailand while Nicobar has affinities with Indonesia and South-East Asia. A summary of Andaman and Nicobar biodiversity profile has been presented in Table 1. The total population of Andaman and Nicobar is 0.36 million of which 67.3 per cent is rural. About 86 per cent inhabit the Andaman Islands and the rest the Nicobar Islands. Four aboriginal tribes *viz.*, Andamanese, Jarwas, Onges and Sentinelese inhabit the Andaman Islands groups. The Nicobaris and Shompens inhabit the Nicobar group. Tribals constitute 9.54 per cent of the total population. The annual growth rate till 1941 was 0.5 percent which has become 26.94 per cent during 1991-2001. The economy of these islands is mainly based on agriculture and fishing. Paddy is the main food crop and is mostly cultivated in the Andaman group of islands, whereas coconut and areca nut are the main cash crops of the Nicobar group of islands.

Protected Areas

In ANI, PAs (9 NPs and 96 Wildlife Sanctuaries) have been established over an area of 1271.12 (15.41 per cent of ANI) km^2 on land and 349.04 km^2 in surrounding territorial sea (Plate 28, Fig. 1). The Rowe Island and Goose island jointly share the distinction of being smallest sanctuary having 0.01 km^2 area while Campbell Bay NP is the largest (425.23 km^2) among the all the PAs in Andaman and Nicobar. The Great Nicobar Island in Nicobar has a Biosphere Reserve. There are two national parks inside Great Nicobar Biosphere Reserve *viz.*, the Campbell Bay and Galathea. Altogether, PAs occupy 16.71 per cent of the notified forest area. Individually, Andaman has 12.52 per cent of notified forests within PAs while Nicobar has 30.23 per cent. Summary of the number and area under NPs and WLS in ANI are presented in Table 2.

Table 1. ANI biodiversity at a Glance (Number in the parenthesis indicate endemic species)

Level	Number	Reference
Ecoregions	1	MacKinnon and Mackinnon (1986)
Biogeographic Zone	1	Rodgers and Panwar (1988)
Biogeographic Province	2	Rodgers and Panwar (1988)
Communities		
Vegetation Types	24	Roy *et al.* (2005)
Forest Types	12	Champion and Seth (1968)
Local Variations	2	Anon., (2003)
Plant Species		
Angiosperms	2,200	Alfred *et al.* (2002)
Gymnosperms	2	Alfred *et al.* (2002)
Pteriodophytes	130	Alfred *et al.* (2002)
Bryophytes	15	Alfred *et al.* (2002)
Lichens	50	Alfred *et al.* (2002)
Medicinal	427	Dagar and Dagar (1999)
Trees	572	Thothathri (1962)
Endemic	301	Dagar and Singh (1999)
Animal Species		
Mammals	58 (32)	Das (1999a), Andrews (2001)
Birds	270 (105)	Das (1999a), Andrews (2001)
Reptiles	76 (24)	Das (1999a), Andrews (2001)
Turtles	4	Bhasker (1993)
Amphibians	18 (7)	Das (1999a), Andrews (2001)
Fishes	12,00 (2)	Singh (2002)
Coral Reef	197	Vousden (2001)
Butterflies	426 (52)	Singh (2002)
Other Invertebrates	2514	Alfred *et al.* (2002)
Tribal	6	Saldhana (1989)

Table 2. Protected areas in Andaman and Nicobar

	Andaman		Nicobar		Total	
	Number	Area km²	Number	Area km²	Number	Area km²
National Park	7	617.71	2	536.23	9	1153.94
Wildlife Sanctuaries	92	435.60	4	30.62	96	466.22
Total	99	1053.94	6	566.85	105	1620.16

Increasingly high numbers of cases of wildlife offences are now being recorded, mainly from the remotely located islands. This includes poaching of timber, sea cucumbers, shells, coral, crocodiles and sea turtles by the international poachers from Myanmar, Thailand and other South Asian countries (Gandhi, 2000). Uncontrolled collection of turbo, trochus, giant calm, cowrie and nancowrie shells is rampant in the off-shore areas.

MATERIAL AND METHODS

Datasets

The present exercise is primarily based the review of data collected and outputs generated during a nation wide collaborative project of Department of Space (DOS) and Department of Biotechnology (DBT) on Biodiversity Characterization at Landscape Level (BCLL;

www.bisindia.org) in ANI from 2000 to 2003. In this study, vegetation and land cover information was extracted from the satellite images of IRS LISS III and Landsat TM (Year 2000) procured from National Remote Sensing Agency (NRSA; www.nrsa.gov.in), Hyderabad and topo sheets at 1:50,000 scale from Survey of India (SOI), Dehra Dun. In addition to this, the digitally classified coastal land cover and land use data was obtained from Space Application Centre (SAC), Ahemedabad, Forest Department, ANI, provided hard copy maps of PA boundaries. Biogeographical province and protected area point data was provided by the Protected Area Database Cell, Wildlife Institute of India (WII), Dehra Dun. Important Bird Areas (IBAs) data was adapted from a collaborative published report of Bombay Natural History Society (BNHS), the BirdLife International and Indian Bird Conservation Network (IBCN) (Islam and Rahmani, 2004). Distribution data on four species of turtle (Green *Chelonia mydas*; Oliver Ridley *Lepidochelys olivacea*; Hawksbill *Eretmochelys imbricata*; and Leatherback *Dermochelys coriacea*) nesting sites in ANI's beaches was complied from the publications of GOI-UNDP Sea Turtle Project on ANI based on work of Baskar (1993), Das (1996) and Andrews (2000 b and c).

Baseline Database Creation and Compilation

Since spatial data themes were collected from various agencies in different data formats and metadata, this necessitated a preliminary exercise of ensuring compatibility in terms of perfect boundary matching so as to have precision in calculation of area estimates. However, a perfect match between vegetation types/ land cover map from Roy *et al.* (2005) and SAC classified land use maps was not possible due to differences in the classification system. Hard copy maps were digitized, edited and made usable as GIS data layers using Arc GIS and Arc View GIS software packages of Environmental System Research Institute (ESRI), Redland, USA. Point data generated for each IBAs sites was attributed with presence/ absence data of 18 globally threatened and restricted range bird species in ANI. All spatial layers were projected into Lambert Azimuthal Equal Area projection. Height contours were extracted from the toposheets and an elevation surface was generated in form of digital terrain model (DEM) in ERDAS Imagine version 8.7.

Vegetation Types/Land Cover Mapping

A standard detailed vegetation/land cover/ land use classification system was developed. Vegetation type map was prepared following an On-Screen Visual Interpretation techniques on the satellite images of IRS IC LISS III and Landsat TM satellite images and classification accuracy was evaluated using confusion matrix between field gathered locations (using GPS) and interpretation. An overall accuracy of 88 per cent and 85 per cent was achieved in the case of Andaman and Nicobar respectively.

Biological Richness Mapping

The vegetation types map become input to Spatial Landscape Modeling, (SPLAM) package, which is an improved version of Landscape Analysis Package (LAP; Roy and Tomar, 2000) and Biodiversity Characterization Package (Bio_CAP; Behera *et al.* in press). SPLAM has all the functional capabilities provided in Bio_CAP, but is capable of running on Windows operating system, therefore, is more user-friendly. The landscape parameters, *viz.*, fragmentation, patchiness, porosity, interspersion and juxtaposition were calculated and integrated with road and settlement buffers to estimate disturbance index for the two groups of islands. Different biological richness levels were computed by integrating disturbance index with physical (*i.e.* terrain complexity), ecological (*i.e.*, species diversity), phytosociological (*i.e.* species endemism, rarity and threatened) and economical (*i.e.* species importance value) using SPLAM (Roy *et al.* 2005). The ecological, phytosociological and economical records corresponds to analysis of tree, shrub, herb and climber data collected from 544 nested quadrats for 20 X 20 m size following stratified random sampling with probability proportional to size (Padalia, 2004). For details on the methodology see Roy *et al.* (2005).

Important Bird Areas (IBAs)

We assessed PA adequacy with respect to protection to 18 globally threatened and restricted range bird species of ANI. Key selection criteria of IBAs address two central issues for setting site conservation priorities–*vulnerability* and *irreplaceability*. IBAs are thus selected based on the presence of viable populations of birds that are globally threatened and/or geographically concentrated – through small global ranges, congregatory behavior, or restriction to a particular biome (For details see Islam and Rahmani 2004). The set of bird species was tabled across IBAs sites and PAs for analyzing the presence/absence. Consequently, the point coverage of IBAs sites was prepared in GIS domain.

Sea Turtle Nesting Sites

The turtle nesting sites distribution data (based on direct sightings over last 15 years) were converted into point data (~143) records using literature citations. These points were reviewed by species experts.

Gap Analysis

Protected area size and distribution

The current PAs were examined with respect to adequacy in surface area or size and distribution. Looking at the variation of sizes, PAs were scaled into range classes and percentage area within each range class was calculated.

Overlay Analysis

The PAs polygon data were spatially overlaid on vegetation types/land use map, biological richness map, IBAs and turtle nesting sites point coverage using Arc View 3.2a GIS software (ESRI, 2000). Area statistics and representation of above these in existing PA network was calculated and examined.

RESULTS

Protected area size and distribution

PAs in Andaman and Nicobar have total area of 1620.16 km² with a mean of 15.43 km². 58 small island sanctuaries cover only 1.2 per cent area of total area of PAs in Andaman and Nicobar. 25 PAs alone cover about 92.7 per cent area of total PAs extent of Andaman and Nicobar. Campbell Bay National Park in Great Nicobar is the largest PA (27 per cent area) in Andaman and Nicobar (Table 3).

PA distribution map (Fig. 1) of Andaman and Nicobar indicated that 4 PAs *viz.*, Saddle Peak, Mount Harriet, Galathea and Campbell Bay are on the larger 'mainland islands' the rest are on the smaller islets. The biggest island, Middle Andaman, has no PA except the *Jarawa* Tribal Reserve, not designed specifically to protect natural resources. Similarly, in Nicobar, there is no PA in Nancowry, Terresa, Camorta, Katchal Island and little Nicobar. ANI harbor' over 4241 marine animal species but there are only two Marine Protected Area (MPA) *viz.*, the Mahatma Gandhi Marine National Park (281.5 km²) and the Rani Jhansi Marine National Park (256.14 km²) to protect the offshore marine life.

Representativeness of Vegetation Type/ Land Cover

The giant evergreen forests which are considered to be most luxuriant and climatic climax have suffered due to deforestation and land clearance for habitation. They are now found only at two localities *viz.*, the Spike and adjoining islands in Baratang and in the central parts of Little Andaman have only 9.54 per cent of their areas under PAs (Table 4 and Plate 29, Fig. 2). The moist deciduous forests, known for the flagship tree *Pterocarpus dalbergiodes* (locally known as Padauk) have been poorly covered within

Table 3. Size class distribution of PAs in Andaman and Nicobar

Size class (km²)	Number of PAs	Total Area (km²)	Relative %
> 1	58	18.23	1.2
1-2	12	16.11	1.0
2-3	4	9.17	0.6
3-4	5	13.22	0.8
4-10	13	93.00	5.9
10-50	7	126.56	8.0
100-133	3	343.00	21.7
250-300	2	537.61	34.0
400-450	1	426.23	26.9

Table 4. Representativeness of vegetation type/land use in PA system in Andaman and Nicobar (Source : Anon, 2003).

Andaman				Nicobar			
Vegetation/ land use	**Total area (km²)**	**Area inside PAs (km²)**	**% Area**	**Vegetation/land use**	**Total area (km²)**	**Area inside PAs (km²)**	**% Area**
Giant Evergreen	98.1	9.4	9.5	Evergreen	1167.2	495.0	42.4
Andaman Evergreen	1311.2	182.1	13.9	Moist Deciduous	17.5		
Hill-top Evergreen	57.6	10.0	17.4	Mixed Evergreen	95.8	4.4	4.6
Secondary Evergreen	270.7	44.2	16.3	Lowland Swamp	62.6	12.2	19.6
Semi-evergreen	1438.8	129.3	9.0	*Syzygium* Swamp	13.2		
Moist Deciduous	829.1	22.6	2.7	Littoral Forest	23.7	3.3	13.7
Bamboo	14.7	0.4	2.8	Grassland	102.9		
Littoral Evergreen	71.9	12.9	17.9	Riverine Grassland	41.8	18.5	44.3
Rhizophora	254.3	90.9	35.8	*Rhizophora*	9.9	2.4	23.7
Bruguiera	40.3	6.6	16.5	*Bruguiera*	7.6	1.2	15.9
Mixed Mangrove	363.7	41.0	11.3	*Phoenix*	0.2		
Avecinnia	2.6	0.6	22.8	Mixed Mangrove	19.2		
Luminitzera	31.2	1.1	3.5				
Heriteria	2.6						
Xylocarpus-Rhizophora	3.2						
Degraded Forest	141.0	9.9	7.1	Degraded Forest	9.4		
Degraded Mangrove	31.0			Scrub	8.5		
Scrub/Shrub	8.5						
Teak (*Tectona grandis*)	98.9			Teak (*Tectona grandis*)	0.3		
Paduak (*P.dalbergiodes*)	4.8			Paduak (*P. dalbergiodes*)	0.1		
Mixed Plantation	43.8	2.2	5.0				
Agriculture	440.2			Agriculture/Settlement	17.4		
Settlement	10.3			Coconut	94.5		
Forest Blank	12.4			Fallow/Barren	0.8		
Mudflats	154.4	15.6	10.1	Forest Blank	0.1		
Fresh Water	32.1			Mudflats	17.8		
Rocky Outcrop	2.1			Rocky Outcrop	0.8		
Rocky Coast	165.7	89.4	54.0	Rocky Coast	58.8	58.8	
Sandy Beach	56.3	26.2	46.4	Sandy Beach	36.0		
Coral Reef	420.7	176.9	42.0	Coral Reef	95.5		
	6412.02				**1901.30**	**566.92**	

PAs (2.72 per cent). Mangrove found reasonably adequate representation in Andaman on the account of declaration of many small islands lined with fringing mangrove as sanctuary. However, the associations such as *Xylocarpus-Rhizophora* and relatively large patches of *Heriteria* are out of PA network. Littoral forest, mix evergreen and moist deciduous forest types are chief vegetation types in coastal part of Great Nicobar.

Evergreen forest in Nicobar have been reasonably well protected (42.41 per cent of its total area) in its most pristine and luxuriant form within Campbell Bay and Galathea National Parks in Great Nicobar. Deficiencies are with respect to protection of grasslands and unique patches of *Syzygium* swamps in central Nicobar and moist deciduous forests in Great Nicobar. These types are totally absent inside PAs. In general, mangrove have very sparse and narrow patches in Nicobar but a few big patches in Katchal, Nancowry and Kamorta islands along with some of the finest coral reef areas are also remain unprotected. No fraction of marine biodiversity is inside PAs in Nicobar. Despite having reasonably adequate area (42.04 per cent of total area mapped) inside PAs, the largest and longest coral reef barrier formation on the West of Andaman remained unprotected (Plate 30, Fig. 3).

An analysis of National Parks shows conservation preference for inland forest. Since, most of WLS are on small islands, major representation is from coastal habitats. The coverage with regard to the representation of the marine area is more in NPs (i.e. Mahatma Gandhi Marine NP and Rani Jhansi Marine NP) than the WLS (Lohhabarrack Sanctuary).

Representativeness of Biological Richness

Analysis of biological richness map suggests that the evergreen, semi evergreen, moist deciduous and mangrove contribute largely to high level of biological richness in Andaman (Plate 31, Fig. 4). In Nicobar, 38.5 per cent area has significantly high biological richness, while 58.4 per cent is under medium to low biological richness (Table 5). The pattern of distribution of biological rich areas in Nicobar shows that high biological richness level is represented in the order of evergreen > mix evergreen > low land swamp > littoral > mangrove. Great Nicobar shows high biological richness towards Mount Thullier and hill tops areas in Little Nicobar, besides the area covering Galathea NP stands equally rich in diversity. Lowland swamps, littoral forest, grasslands and moist deciduous forest are described in medium rich category. Patches of upland grassland and *Syzigium* swamp, though, bear medium level of biological richness are completely unprotected (Table 6).

The high biologically rich areas of evergreen forests are occupying relatively complex terrain of

Table 5 Area under different levels of biological richness in Andaman and Nicobar

Level	Andaman		Nicobar	
	Area km²	% area	Area km²	% area
Low	473.83	9.02	47.33	3.06
Medium	3538.57	67.41	873.03	58.37
High	1237.12	23.57	575.49	38.47

Table 6 Representativeness of biological richness in PA system in Andaman and Nicobar

Vegetation Type Andaman	% Area inside PAs	Biological Richness (%)		
		Low	Medium	High
Evergreen	14.14		6.62	6.55
Semi-evergreen	8.99		6.62	2.35
Moist Deciduous	2.72		1.22	1.52
Bamboo	2.75	2.45	0.3	
Mangrove	20.18		18.58	1.4
Littoral	17.9	6.02	11.93	
Mixed Plantation	5	4.9	0.11	
Vegetation Type Nicobar	**% Area inside PAs**	**Biological Richness (%)**		
		Low	**Medium**	**High**
Evergreen	42.41		18.2	24.23
Mixed Evergreen	4.45		4.2	0.23
Lowland Swamp	19.41		15.57	3.84
Littoral Forest	13.73	3.74	6.8	3.71
Riverine Grassland	44.26	0.15	44.11	
Mangrove	9.67		9.08	0.6

Mount Harriet NP, Saddle Peak NP and Islands inside Rani Jhansi Marine NP. The persistence of medium level of biological richness in small islands sanctuaries indicates the facts that the habitats gradients are relatively simple and number of species is fewer.

Representativeness of IBAs

Eight (42 per cent) of the 19 IBAs do not occur in any PA. Narcondam Hornbill is a single-site endemic and is only known from one locality (Narcondam Island, Area = 7 km^2; this site is of particular conservation concern identified as "Alliance for Zero Extinction") (Table 7 and Fig. 4). Since the island is a WLS it offers 100 per cent protection to the species. Only 4 species found > 50 per cent representation, another 4 species between 30-40 per cent and 6 species between 30-40 per cent. 4 species (all in Nicobar) are still not represented within this wider conservation network, of which two (Nicobar Megapode and Nicobar Bulbul) are vulnerable and two (Nicobar Parakeet and Nicobar Scops Owl) are near threatened (IUCN 2000).

Representation of Sea Turtle Nesting Sites

C. mydas and *E. imbricata* nesting sites are fairly well protected in Andaman. While in Nicobar, nesting sites of these two are only protected in Tilanchong WLS (Table 8 and Fig. 3). Some of the important nesting sites lying outside PAs in Andaman are beaches lining Casuarina bay in North Andaman, East and West bay of Little Andaman, beaches along the east coast of long island, Horsford, Rawlin and Grieve bays along the eastern coasts of Baratang Island, West and north coast of Little Nicobar, eastern, western and southern tip of Great Nicobar. *D. coriacea* is not protected in any of the PAs in Nicobar while in Andaman also this species is protected only at 3 sites. The next poorly protected species is *L. olivacea*.

DISCUSSION

Gap Analysis

Protected areas in ANI appear to have been established in an adhoc fashion and the criteria used for their selection are not explicit. No rigorous and consistent criterion has been applied in their selection and boundaries have been delineated with little or no ecological basis. The current PA system is not adequately conserving sites that have high species richness, and have restricted range and threatened species. PAs were mostly established considering either the remoteness/inaccessibility of the area or influenced by the presence of some charismatic species (e.g. Narcodam Island Sanctuary for Narcodam Hornbill), based in part on the umbrella species concept (Wilcox, 1984). The fact that the forests in Andaman were always viewed as a source of valuable timber, the intention of retaining good forests areas outside the protected areas on large size islands seems inherent.

In the initial phase remote tiny islands were established as PAs. As the impact of development on natural habitats became more apparent, many more areas were added to include island's biodiversity. The numbers of PAs (i.e. 105) in ANI are very high compared to any other state or union territory in India. At first sight these figures give an impression that rich biological wealth of these islands is well protected. But closer examination of sizes of PAs in ANI suggests a worrying picture of the conservation status. Land use statistics suggest that 86 per cent (or 7,171 km^2) area of the island is under the custody of Forest Department as legally notified forest but PAs are only in 19.65 per cent area.

In fact, most of the PAs in ANI cover a small area from the biological or ecological standpoint. Consequently, even minor perturbations in the adjoining area may affect their viability. Such off site effects include oil pollution, increasing turbidity due to soil erosion and dumping of waste materials. Off-site effects can be minimized only if areas of origin of perturbations are also brought under management. Since in majority cases, coastal habitats and associated marine life has not been included within PAs therefore comprehensive protection is not in place to regulate such activities.

Limited attention has been given to remote tiny island sanctuaries, though they had been included within PA network for their unique biological characteristics. Many of these PAs exists on paper and there is not much scientific management and protection system in place. Management efficiency is an important consideration for *in-situ* biodiversity conservation, due to limited availability of resources to achieve conservation

Table 7. Representativeness (indicated with filled grey cell) of 18 globally threatened and restricted Range bird species (indicated with black round dot) in PA system in ANI

Restricted Range Bird Species	Austin Strait	Barangtang-Rafters Creek	Car Nicobar	Chainpur and Hanspuri	Great Nicobar, Little Nicobar	Interview Island WLS	Jarawa Reserv (Middle & South A.)	Kadakachang	Landfall Island WLS	Little Andaman	Mahatma Gandhi Marine NP	Mount Diavalo/ Curthbert Bay	Mount Harriet NP	NarcondamWLS	North & South Sentinel	North Reef Island WLS	Rani Jhansi Marine NP	Saddle Peak NP	Tillangchong, Camorta, Katchal, Nancowry and Trinket	Localities	Representation	% Representation
Andaman Crake (*Kallina canningi*)	●	●		●		●	●	●	●		●	●	●		●		●	●		13	6	46
Andaman Wood-Pigeon (*Columba palumboides*)	●	●	●	●	●	●	●	●		●	●	●	●		●		●	●	●	16	6	38
Andaman Cuckoo-Dove (*Macropygia rufipennis*)	●	●	●	●	●	●	●	●		●	●	●	●		●		●	●	●	16	6	38
Andaman Coucal (*Centropus andamanensis*)		●					●	●	●	●	●	●	●		●	●	●	●		12	7	58
Andaman Serpent Eagle (*Spilornis elgini*)	●	●		●		●	●	●	●	●	●	●	●		●	●	●	●		15	8	53
Andaman Scoops-Owl (*Otus balli*)		●					●	●		●	●	●	●	●	●		●	●		11	5	45
Andaman Hawk-Owl (*Ninox affinis*)	●	●	●	●	●	●	●	●		●	●	●	●		●		●	●	●	16	6	38
Narcondam Hornbill (*Aceros narcondami*)														●						1	1	100
Andaman Black Wood-pecker (*Dryocopus hodgei*)	●	●	●	●	●	●	●	●		●	●	●	●		●		●	●	●	16	6	38
White-headed Starling (*Sturnus erythropygius*)	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●	●	●	17	7	41
Andaman Drongo (*Dicrurus andamanensis*)	●	●		●		●	●	●	●	●	●	●	●		●	●	●	●		15	7	47
Andaman Treepie (*Dendrocitta bayleyi*)	●	●		●		●	●	●		●	●	●	●		●		●	●		13	5	38
Nicobar Serpent-Eagle (*Spilornis minimus*)			●		●														●	3	2	67
Nicobar Sparrohawk (*Accipiter butleri*)			●		●														●	3	1	33
Nicobar Megapode (*Megapodius nicobariensis*)			●																●	2	0	0
Nicobar Parakeet (*Psittacula caniceps*)			●																	2	0	0
Nicobar Bulbul (*Hypsipetes nicobariensis*)																				2	0	0
Nicobar Scops Owl (*Otus alius*)					●																0	0

goals (Bedward *et al.* 1992). The design of PAs in such situations must be governed by the practicality of defense against present and future threats (Peres and Terborgh, 1995).

Central to the success of reserve strategies is an understanding of regional patterns (Scott *et al.*, 1987; Margules *et al.*, 1988). There is still a lack of information on the marine environment, e.g. on the behaviors, habitat and status of migrating and widely dispersed animals and their movement and/or dispersal patterns which is of utmost importance for offering protection to marine life in surrounding sea. Our approach of conducting gap analyses has been complementary in character. It tries to suggest expansion and creation of new PAs based on areas of ecological transition where the niches (e.g. vegetation types and biological richness areas) of species (e.g. birds and turtle) overlap (Lombard, 1995). However, elements of endemicity, rarity and uniqueness have also to be included in PAs.

The distribution of PAs is also uneven relative to biodiversity pattern. The large size Islands (e.g. Middle Andaman and Little Andaman) and Central Nicobar have not been protected in proportion to their area and biodiversity richness. Mount Harriet and Saddle Peak NPs mainly cover the hill top evergreen forests. Evidently, there is a need to protect available chunks of the typical lowland evergreen forests. Little Andaman have few large remaining patches of giant evergreen forest (Roy *et al.*, 2005) which in other islands of Andaman have been drastically cleared for habitation (Saldhana, 1989) need very high protection. Similarly, no protected area is for conserving the high level of endemism and threatened species (Sankaran, 1997) unique to Nancowry group of islands. Conservation importance of coastal habitats in Great Nicobar is evident through the present analysis and also advocated earlier (Sankaran, 1997) for endemic birds (Nicobar Megapode) and other taxa as well. The Nicobar Megapode (*Megapodius nicobariensis*) is most imperiled species in Nicobar due to the earthquake in December, 2004.

Marine conservation has so far lagged behind and there are only two marine NPs, that too in Andaman only, limited fraction of marine diversity is protected in Nicobar. On the marine side, coastal vegetation, mangroves, mudflats, turtles and off shore bird nesting areas, sandy beaches and coral reef require immediate protection. This situation clearly implies that the conservation of biodiversity on the terrestrial land mass has been the priority focus till now.

Only 8 out of 19 IBAs identified in ANI, find representation in the current PA network. Adequate numbers of sea turtle nesting sites have not been protected and many such sites suffer from disturbance from heavy congregation of human settlements. Turtle species should be selected as focal diversity elements due to their vulnerability at particular life stages, particularly when they congregate for reproduction on sandy beaches of the islands and migrate between the islands. Special protection mechanisms, other than the PAs, are also needed to protect such sites.

Protecting maximum percentage of highlighted priority localities *i.e.*, vegetation, biologically rich areas and bird congregation areas would certainly benefit other taxa in the regions, however, no assumptions can be made that such a network of PAs will be sufficient for other less explored taxonomic groups such as reptiles, amphibians and invertebrates. The recommendations that 10 per

Table 8. Representativeness of sea turtle nesting sites in PA system

Species	Andaman		Nicobar	
	Recorded nesting sites	Within PAs	Recorded nesting sites	Within PAs
C. mydas	25	15	12	1
D. coriacea	14	3	17	
E. imbricata	34	25	11	1
L. olivacea	24	8	6	

cent (IUCN, 1993) of each country or biome be protected will not be effective because biodiversity is not evenly distributed across the planet (Gaston and May, 1992). However, setting up of a series of key quantitative targets at multiple scales is mandatory for evaluating gaps in protection (Dudley and Parrish, 2005). ANI has relatively low human population and the islands are remote and difficult to access, makes them one of the last places in India where, with a little effort, biodiversity can be effectively conserved, and too without serious adverse impacts on the local inhabitants (Singh, 2002).

CONCLUSIONS

Our approach for examining gaps in the conservation of biological diversity shows some of the broader patterns of gaps and illustrates some issues which need further investigation using finer scale data. For example, detailed assessments of plant endemism data being collected by the Botanical Survey of India (BSI), Port Blair can be integrated with the current methodology for allowing more targeted recommendations to be made. Our results indicate that by including areas of high biological richness in the PA system, their conservation status would improve. The study demonstrates that if conservation goal is to represent the uniqueness, diversity and rareness, the PA planning must account for biodiversity pattern, rather on political and logistic considerations. Identification of gaps is only the first step in achieving conservation, and must be followed with advocacy (locally and internationally) and on the ground conservation work, in and outside formal conservation areas for saving unique biodiversity of ANI.

RECOMMENDATIONS

- The territorial water surrounding each island up to a specified buffer distance from terrestrial limits may be brought within PAs to protect offshore environment. Since, at present, fishing and tourism activities are at modest levels, the task of including marine areas within PAs would not be a major impediment.
- In ANI, because of intra-archipelago speciation (Diamond, 1977), a network of PAs that incorporates distinctive flora and fauna is necessary (Diamond, 1986). Hence, high proportion of distinctive sets of habitats and species in each group of islands should be brought within PA system.
- Intensive inventory at the levels of species and communities is urgently needed for small islands sanctuaries and surrounding marine life in order to examine their contribution to protected area biodiversity representation.
- In response to the increasing cases of wildlife offences, small tiny island sanctuaries should be notified into clusters of Marine PAs following internationally accepted guidelines. Spatial clustering of close by islands will reduce the overall perimeter of protected and would provide meaningful area for management effectiveness.
- Adequate proportion of giant evergreen, semi evergreen, moist deciduous, upland grasslands and *Syzygium* swamps should be protected by notifying some more localities as NPs and WLS.
- Identified sites for establishing new PAs will need to be integrated into the political reality of what is possible, what can be achieved quickly and what opportunities exist (Dudley and Parrish. 2005).

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Plate 28

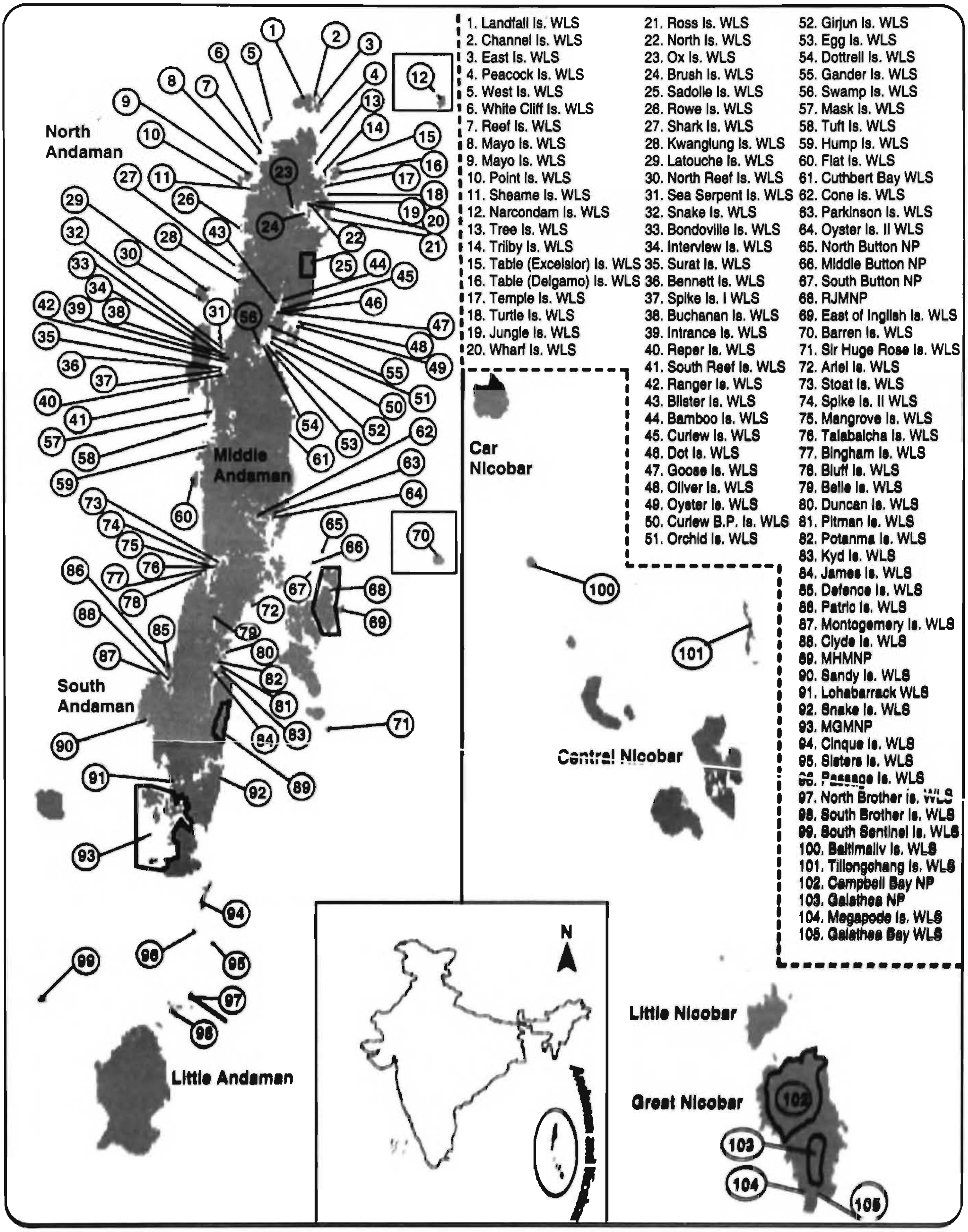

Fig. 1. Map shows the location of ANI (in inset bellow) and NPs and WLS (Total = 105). The no. with in circles refer to PA, in titled for names on the right side of the map. Boundaries with bold line indicate NP.

Plate 29

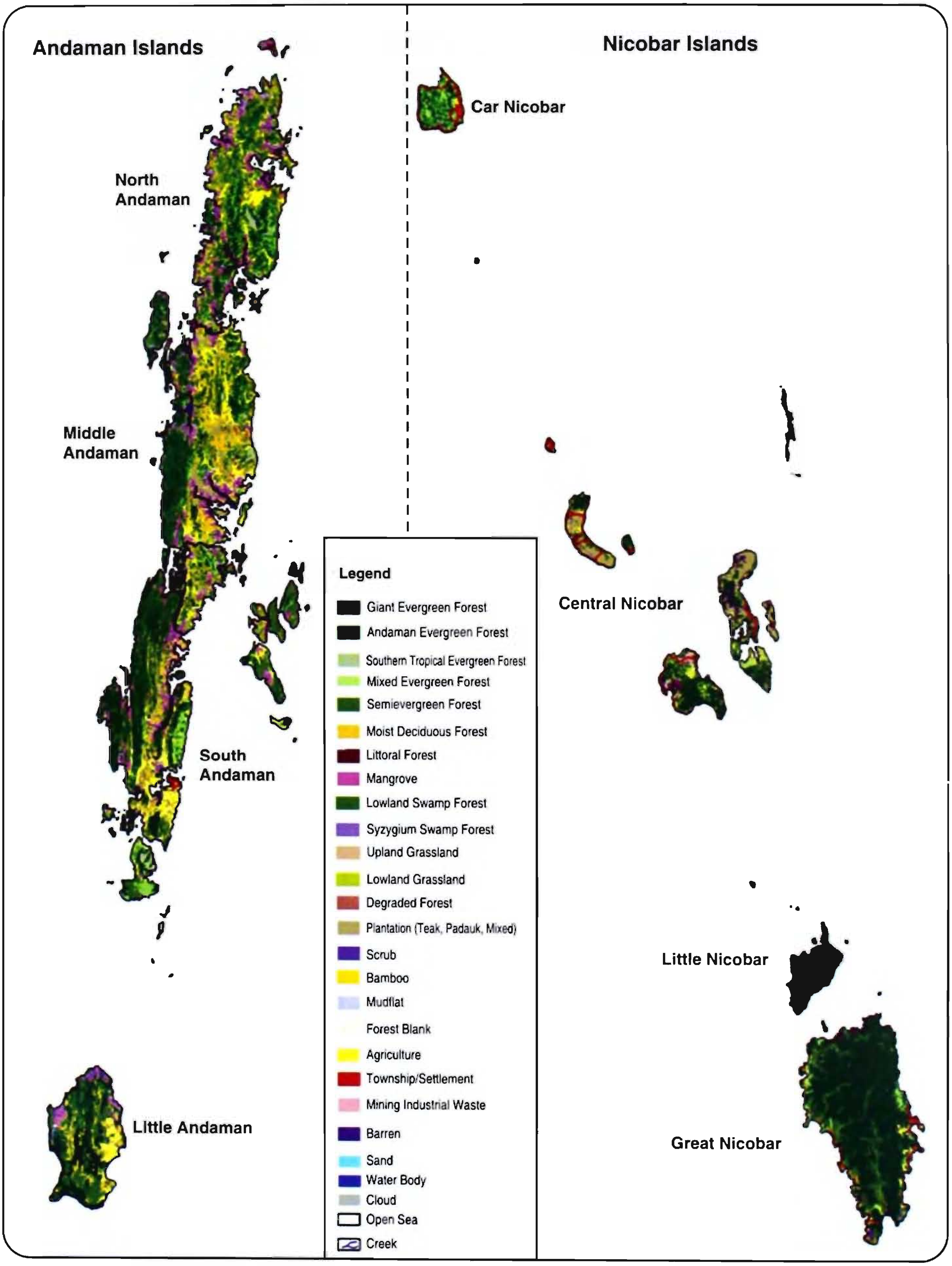

Fig. 2. Vegetation cover types and land use categories in ANI

Plate 30

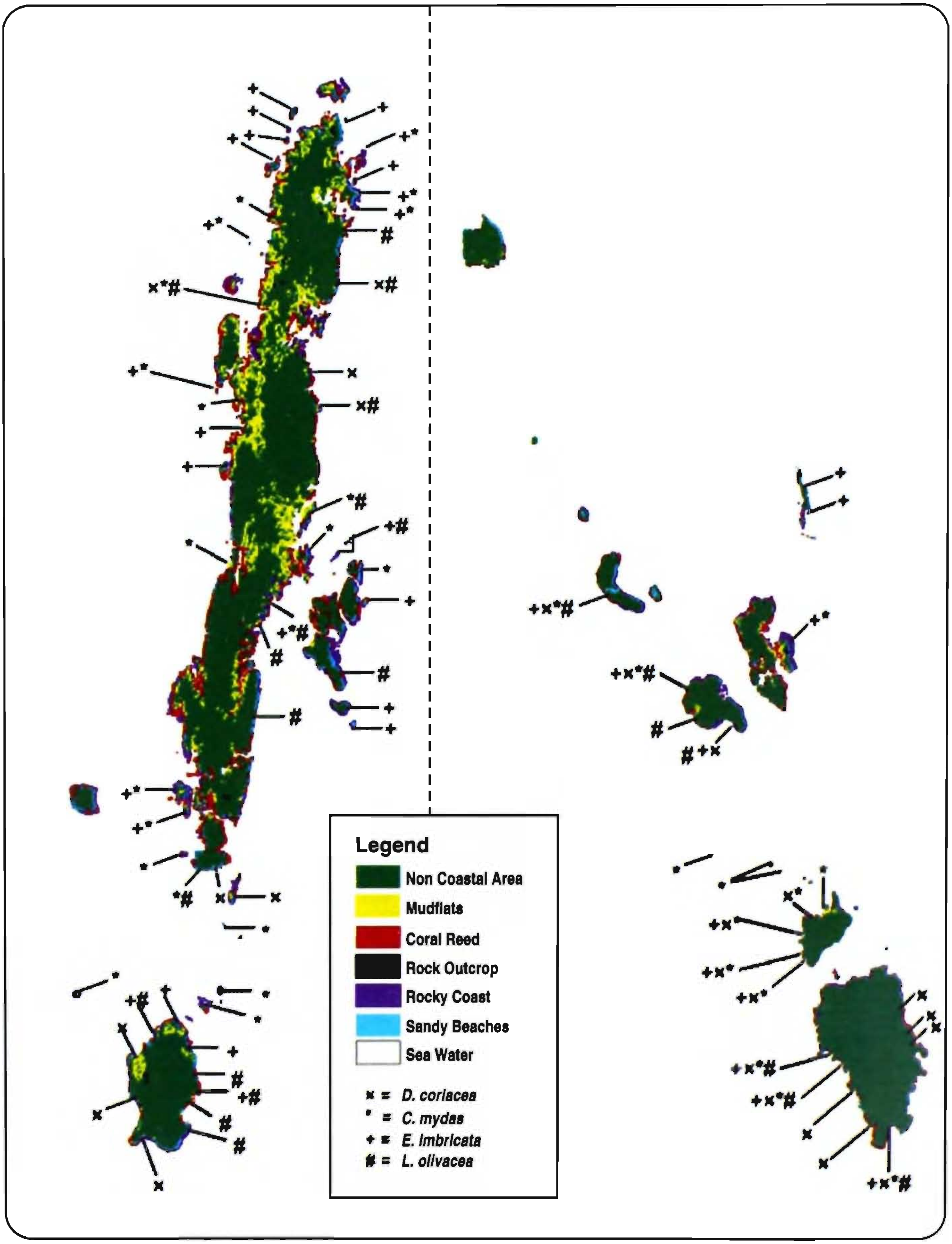

Fig. 3. Map shows the costal land cover types and superimposed are recorded (~143) localities of sea turtle nesting sites in ANI

Plate 31

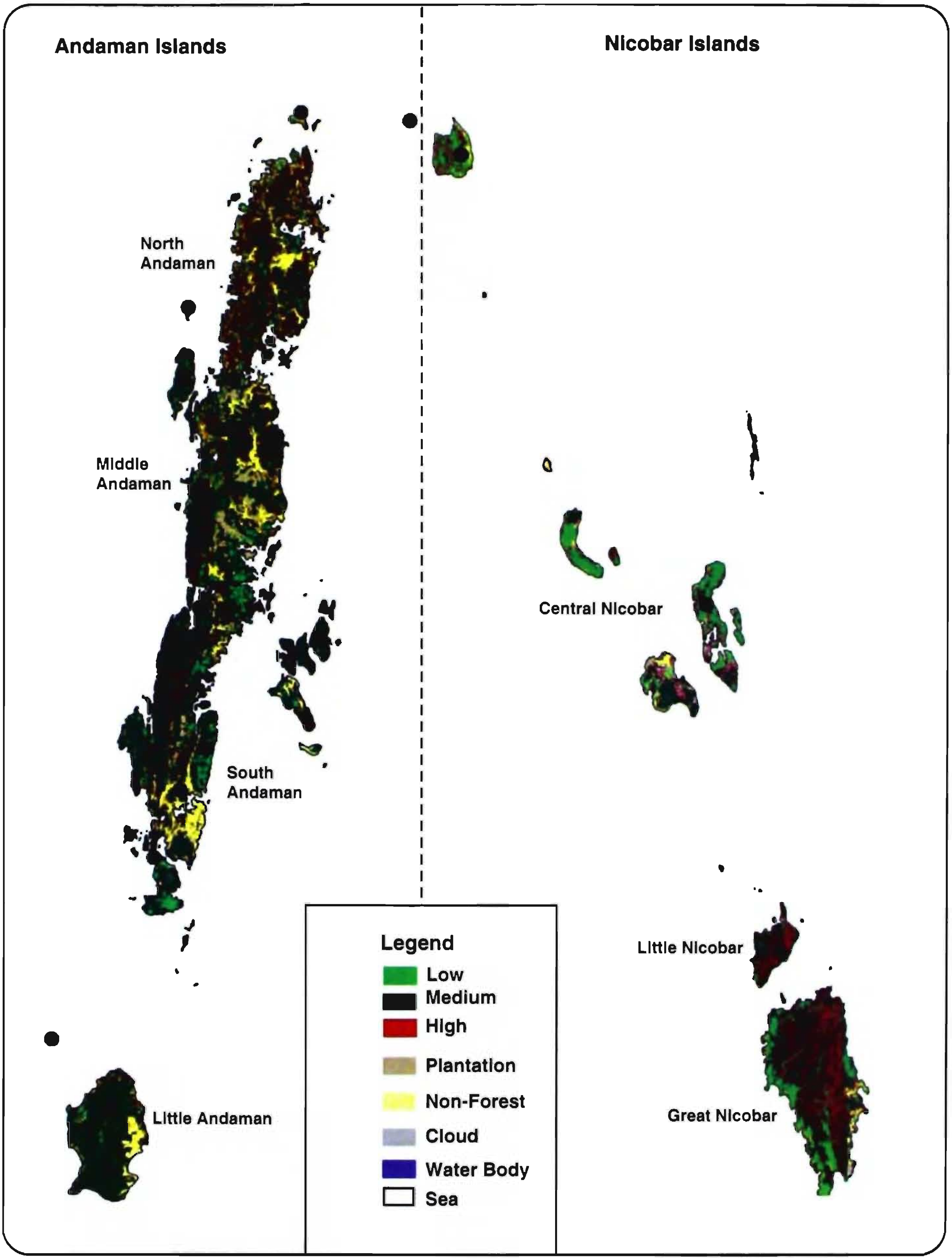

Fig. 4. Patterns of biological richness and distribution of IBAs (indicated with black rounded dots) in ANI.

Recent Trends in Biodiversity of Andaman and Nicobar Islands, 533-542, 2010

PROSPECTS OF ECO-TOURISM IN ANDAMAN AND NICOBAR ISLANDS

SUNITA REDDY*
Centre of Social Medicine and Community Health, School of Social Sciences, Jawaharlal Nehru University, New Delhi 110067, India

INTRODUCTION

Eco-tourism is a buzz word today. With the growing thrust in tourism industry across the world and concerns for environment, most often the policy documents and planning catches this buzz word eco-tourism. However, it is often misunderstood or not understood properly. It is important to understand what does eco-tourism mean? In order to understand eco-tourism, it is pertinent to understand what is eco-system? For sustainable ecosystems, there is a need to promote eco-tourism.

Understanding Ecosystem

An ecosystem is a natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the non-living physical (abiotic) factors of the environment. The term ecosystem was coined in 1930 by Roy Clapham, to denote the physical and biological components of an environment considered in relation to each other as a unit. British ecologist Arthur Tansley later refined the term, describing it as the interactive system established between biocoenosis (a group of living creatures) and their biotope (the environment in which they live). Central to the ecosystem concept is the idea that living organisms are continually engaged in a set of relationships with every other element which constitute the environment. The human ecosystem concept is then grounded in the deconstruction of the human/nature dichotomy, and the emergent premise that all species are ecologically integrated with each other, as well as with the abiotic constituents of their biotope (a).

A system as small as a household or university, or as large as a nation state, may then be suitably discussed as a human ecosystem. While they may be individually discussed, (human) ecosystems do not exist independently, but interact in a complex web of human and ecological relationships connecting all (human) ecosystems to make up the biosphere. Virtually no surface of the earth today is free of human contact, all ecosystems can be more accurately considered as human ecosystems. The human ecosystem concept draws from disciplines such as ecology, anthropology, sociology, philosophy, political science, cybernetics, and psychology, seeking to understand the complex system of relationships in which humans interact.

Most analysis of human ecosystems focuses on particular contexts of relationship, such as biological, individual, socio-cultural, environmental etc. Ecosystem changes, resulting from human interventions (mining, agriculture, urbanisation, etc), driven by the need for subsistence or the forces of economic development, affect current and future well-being, not only for the present, but also for coming generations.

* E-mail : sunitareddy@mail.jnu.ac.in

The declaration from the Earth Summit / Rio Summit on Environment and Development (1992) begins with the statement :

"Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature."

We are becoming increasingly aware that what happens in one of these spheres affects the others and is impacted by geophysical factors, biology, ecology, the economic, social, political and cultural situation, which also influence each other. Thus, what happens in one part of the globe has important repercussions on what is happening in other areas, not only from an economic and social viewpoint, but also due the global circulation of many contaminants through the atmosphere, water, the food chain and consumer goods.

Forests cover a third of our planet's land. They provide raw materials, maintain biodiversity, protect land and water resources, and play a role in climate change mitigation. Forests are heavily exploited, but important efforts are being made to use and manage them more sustain ably. Protected areas of forest are important to conserve biological diversity, although many areas outside protected areas are also managed for conservation purposes. The area of forest designated specifically for biodiversity conservation has increased significantly over the past 15 years. It now exceeds 11% of total forest area. Rare tree species and those with high economic value are often in danger of becoming locally extinct. On average, 5% of the tree species native to a country is threatened. There does not seem to be a clear relationship between loss of forest and number of threatened tree species (b).

With this understanding of eco-systems, the interplay and interaction between the biotic and abiotic factors, and the impact of one over the other, it now important to understand what eco-tourism is, how it is conceived and what are its principles. This article looks at the demographic, socio-economic, and ecological characteristics of the Andaman and Nicobar islands, and the impact of tsunami on the people. Further, critically looks at the long pending tourism development plans for these islands, which are underway. The article further explores some of the good eco-tourism examples which can be replicated. The paper is based on the observations during three field visit to these islands, in 2005 and 2006 and 2007 substantiating these observations with the secondary literature, Andaman Administration documents and policy documents.

Understanding eco-tourism

The ecotourism is about connecting conservation, communities, and sustainable travel. This means that those who implement and participate in responsible tourism activities should pursue the following ecotourism principles (c) :

- minimize impact
- build environmental and cultural awareness and respect
- provide positive experiences for both visitors and hosts
- provide direct financial benefits for conservation
- provide financial benefits and empowerment for local people
- raise sensitivity to host countries' political, environmental, and social climate

Sustainable tourism is : "Tourism that meets the needs of present tourists and host regions while protecting and enhancing opportunities for the future."

"Sustainable tourism development requires the informed participation of all relevant stakeholders, as well as strong political leadership to ensure wide participation and consensus building. Achieving sustainable tourism requires constant monitoring of impacts, introducing the necessary preventive and corrective measures whenever necessary. Sustainable tourism should ensure a meaningful experience to the tourists, raising their awareness about sustainability issues and promoting sustainable tourism practices amongst them (d)"

Sustainable development implies "meeting the needs of the present without compromising the ability of future generations to meet their own needs (e)"

Another concept called Responsible Tourism, the key characteristics are :

- minimizes negative economic, environmental and social impacts
- generates greater economic benefits for local

people and enhances the well being of host communities

- improves working conditions and access to the industry
- involves local people in decisions that affect their lives and life chances
- makes positive contributions to the conservation of natural and cultural heritage embracing diversity
- provides more enjoyable experiences for tourists through more meaningful connections with local people, and a greater understanding of local cultural, social and environmental issues
- provides access for physically challenged people
- is culturally sensitive, encourages respect between tourists and hosts, and builds local pride and confidence (f).

Thus, in order to conserve the nature and sustain tourism activities, it is important to keep these things in mind before planning any developmental activities in any part of the globe. However, it becomes even more important when it is to do with islands, small, fragile, pristine and beautiful.

UNESCO report on sustainable island living, reports that the islanders welcome the economic and social benefits of new roads and airports. However, when it comes to tourism development, they favor a smaller scale hotel rather than a large resort, and they want to take things slowly, keeping overall control in their own hands. Furthermore with all developments, they are very conscious of environmental issues (such as escalating demands on scarce water resources and problems of waste disposal) and wish to see the necessary safeguards taken to maintain health environments (UNESCO, 2007).

Andaman Profile-demographic and ecological

Andaman and Nicobar islands shimmer like emeralds in the Bay of Bengal, a total of 572 islands, islets and rocks, with only 32 inhabitable islands. The total geographical area covered by Andaman and Nicobar Islands is 8249 km^2. The Andaman district have an area of 6408 km^2 while the Nicobar district covers 1841 km^2. The total area of Andaman and Nicobar Islands have 2929 km^2 of reserve forest and 4242 km^2 of protected forest. There by 7171 km^2 out of 8249 km^2 is reserved and protected forest. Andaman and Nicobar islands have unlimited ecological treasures, are endowed by finest tropical evergreen forests in the world and are home to a large number of rare and endangered, even undocumented species of flora and fauna and the forests are a treasure house of biodiversity. It is being suggested that the total number of coral species in these islands should touch around 400. Have some of the finest mangroves which accounts for 18% of the country's total mangrove area. Islands are repository of immense variety of ecosystem and wildlife. The incomplete investigation of the reserves of islands is impressive with over 2200 flowering plants, 120 firns, 58 mammals, 242 birds, 83 reptiles, 10 amphibians, 750 fishes, 320 coelenterates, 407 crustaceans, 941 molluscs, 1500 insects and number of medicinal herbs and plants (Kumar, 2004).

Geologically, the Andaman and Nicobar islands represent the highest peaks of an under-water mountain range which is an extension of the Arakan range in Burma and the Sumatran Barisan ranges to the south. The islands lie parallel to a geological fault line to the east, crossing the Andaman Sea from north to south. The line marks two tectonic plates rubbing against each other; the eastern plate, an extension of the huge Eurasian plate, is stationary while the Indian plate to the west is moving north to northeast at the rate of a few centimeters a year, taking the Andaman islands with it. These movements cause earthquakes and volcanic activity in around the islands. Indian's only active volcanoes, on Barren and Narcondam islands, are sitting directly on the faulty line. Earthquakes are common features, Post tsunami more than 100 shocks have been felt of low intensity.

Forests form the major ecosystem in the islands and developmental activities directly or indirectly affect these forests (Nair, 1989). The exploitation of timber began with the establishment of a penal settlement in the islands, and a Forest Department was started in 1883 (Majumdar, 1974). Though 70% of the forests of Andaman Islands are still forested but much of it is degraded, secondary growth. Over the past thirty years, soil, meteorological, and use and forestry experts stressed the need to keep the islands under forest cover, despite which large clear felling and plantation projects are underway over the period with legal and illegal settlements, clearing the forests for cultivation and encroaching of land. Accelerated immigration from mainland India and the growth of a number of forest based industries have led to extensive settlements and the conversion of forest areas into revenue and agricultural lands. Over the time, there has been a growth in population from 14628 in 1881 to 4 lakhs by 2001 largely made possible due to encroachment and illegal settlements in areas that have been demarcated as "tribal reserves" Large areas of pristine forests have been lost to the timber and plywood industry. Expanding settlements and commercial logging for over a century have destroyed large areas of the islands forests.

Over the years the destructive consequences of sand mining for construction is readily visible in the disappearance of several beaches, with its effects on wildlife on that region, as well as steadily increasing coastal erosion that even newly installed sea walls are not sufficient to control (Ali and Andrews). Accumulated evidence indicates the sharp decrease in mangrove cover, together with the destruction of coral reefs as a consequence of the run off from the land based activities such as logging, agriculture and unchecked use of pesticides (Sekhsaria, 2002).

The Andaman situation is a classic example of unplanned natural resources exploitation, disregarding basic ecological principles. It is primarily an economy determined by the prerogatives of mainland development. In the process, the indigenous islanders have succumbed to a 'proletarian dependence' on the island administration, 'whose commercial transactions and territorial control now determine their daily routine and mode of existence' (Guha and Gadgil, 1989).

The history of the islands itself shows the influx of people who abused and maneuvered the native people and the environment for their own advantage. The indigenous people of Andaman Islands whose habitat for thousands of years have been invaded by British and Japanese Colonizers and later after independence was taken over by Indian Union territory with similar policies, more or less colonial in nature (g). Post independence in order to safe guard the territories of these islands Indian government made special efforts to settle people from different parts of the country (Venkateswar, 2004), again to see that regional separatism doesn't exist, thereby making the island mini-India in nature. Karen Burmese were brought by British in 1925, Refugees from East Pakistan (now Bangladesh), Tamils fleeing the civil war in Sri Lanka, numerous tribal groups from the state of Bihar, Ex-service men of Punjab to settling of fishermen from Andhra, Tamilnadu were brought in to the islands. The current ratio of the remaining groups of Andaman Islanders to surrounding Indian population groups at approximately 500:500,000, a stark testimony to the scale at which the dominant majority has outnumbered them (Venkateswar, 2004). The total number of primitive tribes (h) of Andaman and Nicobar Isalnds; Great Andamanese, Onges, Jarawas, Shompens, and Sentinalese, constitutes below 1% of the total population.

For most of the primitive tribal groups, the subsistence economy is based on fishing, hunting, food gathering. Coral reefs along with mangroves are important nurseries for marine life and are crucial to the livelihood of fisher folk. Copra cultivation is the main livelihood for Nicobar (i). Their local diets are heavily dependent on marine resources, and however, their tools are quite simple and crude. They use canoes and nets and fishing is most often for subsistence and not for commercial purposes. The Department of Fisheries was set up in 1955, but the trust is not to exploit the marine resources. The actual utilization of this resource remains far below potential due to the lack of necessary infrastructure required to tap the marine wealth. The primitive tribe's which livelihoods are based on forests which have been encroached, and some developmental programmes like the construction of Andaman trunk road (j) and policies to integrate the tribals like the 'contact programme' with Jarawas, Onges, Great Andmanaese have proved to be disastrous. Huge amount of money, (over Rs. 15 crores) and timber are used annually to maintain the road. Ecology estimates that this maintenance consumes a minimum of 12,000 cu. m. of timber from the evergreen forests.

The contact programmes with the tribal are criticized the most, which are intruding in to their lives, natural habitat, addicting them to vices like alcohol, gutka and tobacco and introducing various diseases and sexual exploitation. The attitudes of the settlers who today live on the land that belongs to the tribals only reflect the powers relations. They ridicule the tribals as uncivilized, 'junglees' Addiction to alcoholism and is now used by settlers to exploit resources from the forests. Poaching and encroachment inside the Onge reserve too, are ever on the increase. Tribals have incredible knowledge of the forests and the seas. Insensitive development policies and logging operations have, brought them to the brink of extinction today. Non-tribals of these islands are mostly in to government services, and petty business to meet the local needs. Due to historical reasons, and lack of facilities and institutions, the people here in the islands have been always marginal, with no scope to develop and become entrepreneurs. Lack of capital and lack of skills and enterprising nature makes it extremely difficult to propose a major change in a short period of time with all the limitations in place.

Tsunami and its Impact

Tsunami has changed lives of many thousands people. They are not going to have the same life for years to come now. Families which have lost family members, the loss is irreversible. For those who lost their livelihood, houses, the process of rebuilding is underway. Tsunami has changed lives of thousands of people in the islands of Andman and Nicobar (A & N) Islands, India since it struck on 26.12.04 The tsunami has posed certain uncertainties in the minds of people about the kind of houses they are going to stay in, the kind of social structures going to form, the kind of livelihood they are going to indulge in.

Post tsunami there has been some major ecological changes, the coral reefs have been affected. Agricultural lands have been salinated, badly affecting the produce. Plantation like areca, and coconut were badly affected. Some beaches are hardly visible, during high tides, the water come on to the roads. The houses on the coastal areas have been submerged. Even the houses and plantation in the creeks have been badly affected, displacing the people and livestock. The mangroves are drying and dying due to the submergence in the sea water. The corals have been affected. The islands have moved 3 km towards the mainland. Few small Nicobar islands have totally been salinated and submerged making it inhabitable. Some islands are tilted. Making one side go up and exposing the underground and the other end sank in to the sea by one meter, thereby drowning the houses and other structures like jetties farmlands etc. Jetties which are the lifeline transport systems in these islands have been severely smashed and have been reconstructed.

Huge uplift and destruction of coral reef towards west of Interview islands have taken place. In Nicobar nearly 6000 ha (14,826 acres) has been damaged and in Andaman about 1,800 ha (4,447.8) acres. The explanation of this stark contrast lies in the earthquake that set off the tsunami. The tectonic activity initiated in December 2004 caused a significant shift in the lay of the islands. Assessments done by Dr. Roger Bilham of the University of Colorado indicate that the northern parts of the Andaman group of islands experienced a permanent average uplift of four to six feet (1.2 metres to 1.8 metres) while most parts of the Nicobar went significantly under four feet in Car Nicobar and a staggering 15 feet (4.57 m) at the southernmost tip Indira Point on Great Nicobar Island. The pivot of this swing experienced by the islands can be calculated to be roughly located south of Port Blair (k).

Three and half years post disaster, reconstruction is still going on. Most of the displaced people are still in temporary shelters. The permanent houses are still under construction. However, roads, jetties, and other public utility infrastructures have come up. Most important concern is that most of the affected populations have not got back to a sustainable livelihood. Providing livelihood to the islanders is going to be the top most agenda of the administration. The Administrators see this as an opportunity to rebuild the profile of islands, starting from the rebuilding of livelihoods to building of infrastructures, and also reviving and expanding tourism. Naomi Klein in disaster capitalism shows how neo-liberal capitalists' agendas are shoved upon in a situation like disasters, wars, by giving shock doctrine.

It is worthwhile to take stock of the current ecological state of the islands, economic and the entrepreneurial potentials of the people living in these islands. Accessibility to these islands and how far these islands can take the possibilities and pressures of tourism? Whether the fragile ecosystem of the islands can sustain the pressures of the above development? Whether the environmental degradation due to the development can be balanced with the growth in economy? With the proposed pattern of development what irreparable damages will occur to the environment, impact on lives of people and their habitat, their culture and their health?

Limitations of the Islands

Along with the rich biodiversity, flora, fauna, vast tropical forest covers and pristine beaches and tropical climate, there are many constraints or limitations which needs attention before planning for any developmental activity. They are as follows :

1. Andaman and Nicobar islands are union territory of the Government of India, so the decisions have to come from the centre. Development decisions controlled by many players and most often people's voice may remain feeble.
2. Only 8% of revenue land is available, limited for population growth and infrastructure expansion.
3. The geography, of the islands, distance from the mainland and scale of economies are not favorable for any real heavy infrastructural investments.
4. The islands got inhabited recently mainly having the low income group floating population which lacks resources and industrious skills.
5. Lack of human skills and resources to sustain technological innovations and competitiveness.
6. The developers and decision makers vis-à-vis administrators are not rooted to these islands, they are always in transit mode, thereby long term projects are not taken up and sustained.
7. High cost of transportation, no town, no industrial base, narrow production and resource base, with high cost indices.
8. High cost of production and lack of economies of scale.
9. Highly vulnerable to natural hazards.

With these limitations, it is highly uncertain that the opening up of these islands for large scale tourism will in any way going to help the local people who are neither equipped with skill based knowledge nor with the skills to get absorbed in to the new avenues of employment. They may remain at the verge doing the menial and unskilled labour jobs. It would be the outside, entrepreneurial companies and industries like, hotels, tour and travel operators who will come in a big way and make the most of the benefits at the cost of the labour and resources of the local population. The employment opportunities to the local people and more so for tsunami affected people will remain to the extent of extracting the labour. No efforts would be made to augment their skills and employ them in a better position.

Apart from these chronic limitations, there are other crises at times. With four lakh population, the biggest settlement in the islands, Port Blair faces acute shortage of drinking water. Few years back, the officials were sent for long holiday during the summer vacation due to scarcity of water. All the other consumable items, fruits, clothes, comes from mainland and extremely pricey. Though, the vegetables are grown here in the islands, they are quite expensive.The cost of transportation hikes the prices of simple consumable items. One can imagine what would be the state in case of more number of people coming in as tourist and to meet their demands of food and water. Meeting the demands of drinking water, food, shelter, waste disposable will be a challenge especially when the islands are cut of miles away from the mainland.

Historically the tribes have been exploited by the outsiders, to an extent that they are at the verge of extinction. The tribes thriving for centuries are now facing a threat to survival as a result of contact with the outside world. Tourist coming to the islands are eager to go for 'Jarawa tourism' with disregard and insensitive to their socio-cultural life.

Tourism Development plans in Islands-Implications

The Administrators see this as an opportunity to rebuild the profile of islands, by expanding high end ecotourism. It is being anticipated that developing tourism at a massive scale would by default generate employment. It would also rebuild the economy, especially matching its scope with the some of the well known international island tourist spots, like Jamaica, Fiji, Samoa, Marshal islands, Togo, Mauritius etc. However, coastal and island destinations are highly vulnerable to direct and indirect impacts of climate change (such as storms and extreme climatic events, coastal erosion, physical damage to infrastructure, sea level rise, flooding, water shortage and water contamination) given that most infrastructure is located within short distance of the shoreline.

There is a limited scope for the promotion of industrial activity in the islands, due to non-availability of local raw materials, skilled manpower and ready markets. The wood based industry which was providing some direct and indirect employment is also on decline due to environmental considerations.

The objectives of 10^{th} five year plans in A & N islands is to promote eco-friendly and environmentally sustainable tourism. It is also mentioned that the private sector should invest and various sectors like development of high quality resorts, introduction of high speed boats, adventure water sports etc. The privates sector will always look for profits and high quality resorts and high speed boats will be benefiting the small number of business class or outsides rather than the local populations. Further there are plans to bring in expensive equipment, large cruise liners with five star facilities, speed boats, tourist submarines etc. All these are expensive equipment and there is no mention of maintenance, trained manpower to handle. These high end equipment for high end tourist doesn't seems to be pragmatic. More than these high end tourism, the need of the hour is to safety measure at beaches like, coast guards, life saving guards, etc.

The precious resources of the islands which are already depleting, timber, sand, flora, fauna, will all be severely affected. And the most important of all is to appraise whether the fragile ecosystem of the islands; the coral, the limited beaches, most of which have been submerged after tsunami, can sustain the pressures of tourism.

The tourist flow after tsunami has been on rise, it also includes the NGOS, researchers, officials on special duties coming to the islands. In Year = 2004–05, Foreign Tourist = 2860, Domestic Tourist = 72539 , Total = 75399 came to the islands. In Year = 2005–06, Foreign Tourist = 3635, Domestic Tourist = 52378, Total = 56013 came to the islands. In Year = 2006–07, Foreign Tourist = 9051, Domestic Tourist = 118580, Total = 127631 came over. In the year = 2007–08, Foreign Tourist = 10975, Domestic Tourist = 136015, Total = 146990 came over. There is a steady increase in the tourists, both domestic and foreign coming to the islands (1).

A & N Administration has a proposal of Rs 5000 crores for developing tourism in these Islands, it is pertinent to take stock of the current ecological state of the islands, economic and the entrepreneurial potentials of the people living in these islands. Questions like how far these islands can take the possibilities and pressures of tourism? Whether the fragile ecosystem of the islands can sustain the pressures of the above development? Whether the environmental degradation due to the development can be balanced with the growth in economy are important to address. Before embarking on to such a massive project it is pertinent to estimate what irreparable damages will occur to the environment, impact on lives of people and their habitat, their culture and their health?

Potential of developing Sustainable, Responsible, Ecotourism

The question arises, what is a good developmental model for Andaman and Nicoabr islands and also ask, development for whom, who should reap the benefits of the development. The vision for tourism should be Development of a model which should integrate environment policies and economic policies and should benefit directly the people of A & N islands by improving their quality of life, and enhancing their per – capita income without degradation of the environment and go for responsible sustainable ecotourism.

Considering the natural bounty tourism has been identified as one of the thrust areas for the economic development and employment generations in the islands. The development of tourism can change the economic scenario in the islands and brings about significant change in the living standards of the local population. Along with tourism, other economic activities like, piggery, poultry farming, coir industry, local handicrafts, shells and wood should be developed.

BPO industry can be established with less cost and heavy absorption of the educated local youth.

To promote tourism, Andaman tourism department is contemplating to buy high speed boats, five star and three star cruise ships, jet skis, tourist submarines, sea water sports etc. Question is whether the purchase of these huge, expensive ships will bring in the cost of purchase? What about its maintenance, whether there would be enough tourists inflow that it becomes viable is highly unconvinced. Other sea water sports, needs trained people, infrastructures and safety measures which are hardly taken care?

The next important issue would be how far the national and foreign tourists can be permitted, especially insensitive to the local tribal population and their cultures, especially when these forests and tribal areas are reserved. The islands are endowed with vast tropical rain forests, beautiful beaches, meandering creeks, lush flora, rare fauna, rich marine life and under water corals. The cellular jail, where number of freedom fighters ere incarcerated during the struggle for independence is one of the most attractive and significant tourist spot. In view of the fragile ecology and limited carrying capacity of the islands, the tourism has to be planned very meticulously.

It is also proposed to have shopping malls, multiplexed and entertainment and amusement parks. This introduction of metro-culture will do injustice to the flora and fauna. People who value glory of nature, rather than simple conspicuous consumption should be preferred as tourists. In order to keep the islands clean, another important thing is to have scientific waste disposals at various units. Solar energy resources should be used in place of petrol and diesel. Tourism can be a potential source of revenue but it is also a cause of concern since the islands cannot sustain it at its currently rapidly growing rate unless there is a shift in strategy to a high value, low intensity, environmentally friendly eco- tourism. Keeping in view the history of people settled here, keeping in view the topography, geography, environment in view, and the most important the fragile nature and the wide spread location of the islands it would be appropriate to limit the scope of tourism to small scale, local and national in character. The islands are the repository of unexplored, undocumented sources of knowledge plethora of information is waiting to be deciphered and understood for various scientists and social scientists, and linguists. And it is already late for them to preserve and protect these vanishing knowledge systems.

The islands can be developed further to form museum and experimental lab for zoologists, marine biologists, anthropologists, botanists, genetists, evolutionary biologists, environmentalists, ornithologist, gemologist, etc. Limited and constructive, small scale, tourism limited to local and national in character, involving the skills of the local people and the resources available in a sustainable fashion is the need of the hour. Further, the attractions can be in the form of exploring forest ecosystem, marine ecosystem, fishing as sport, camping, trekking, snorkeling, boating, surfing, nature walk, bird watching and appreciating biodiversity.

Local population at present do not have any services, expertise, and capital to offer, thereby the state should provide support systems, capital to invest in small scale tourist spots at household and community level. It is important to equip local youth, men and women, training them in hospitality, housekeeping, catering/ cooking, plumbing, electrical, laundry, receptionists, etc. There is no logic comparing Andamans with other islands tourism, as they are the small nations and it is important for them to sustain their economy at any cost, but it is not the case with A & N islands as they are the union territories with central funding and governance and need not push through the unplanned, unregulated, high end tourism at the cost of the environment and the biodiversity.

However, there are some good examples of ecotourism like Solomon islands close to Australia are truly eco – friendly. Scuba diving has been the mainstay of the Solomons tourism industry for the past forty years. Prior to the 1990s there has been very little bookable tourist accommodation available in other parts of the country and intrepid travellers have often had to rely on friendly locals to take them in. However more recently the increasing number of visitors seeking to visit the rural areas–particularly sites of geophysical, biological or cultural interest – has led to the development of a range of low-cost, "village style" accommodation facilities for those travellers who are more interested in culture and environment than luxury rooms with cable TV. Village stays are the "top-level" ecotourism experience in the Solomons. While this is the most basic (yet comfortable) standard of accommodation, a village homestay is the closest that visitors can get to Solomon Islands culture and lifestyle without undergoing tribal initiation! As a village homestay guest, tourists are accommodated in their own village-style bungalow next to the home of the host family. The hosts will treat the tourist more like a relative visiting from another village rather than a foreign tourist, and one can observe and participate in village life at very close quarters. In addition the hosts will accompany the tourist to explore local attractions. Village homestays only accept one booking at a time so tourist are free to "go native" without other tourists peering down their noses. The other types are Village guest houses - or "rest houses" as they are often called in the Solomons are generally situated outside the main village area. This may offer more privacy from wide-eyed village children but tourists have to share their experience with other visitors. Most village guest houses offer a choice of self-catering or local-style meals provided. Village visits have to be arranged in advance and are therefore rather contrived. Nature lodges are situated in areas with particularly bountiful plant and animal life. Operators offer interpretive tours of the local flora and fauna and cultural tours of villages and "tabu" sites. Most nature lodges are situated in the Marovo Lagoon (built with assistance from the World Heritage Project), and Savo Island near Honiara (an active volcano). Village stays, village guest houses and nature lodges all offer a similar standard of accommodation: bush-material buildings, clean bedding, sitting furniture, fresh running water and proper toilets. Meals are deliciously cooked in local style using mainly fresh seafood, chicken, green vegetables and tubers.

Local-style resorts in the Solomons are not really resorts at all: there are no swimming pools, nightclubs or jet skis. These are rustic hideaways where visitors with no qualms about being treated as bona fide tourists can relax in relative privacy, swim and snorkel, go fishing, visit a few local attractions and enjoy some cultural entertainment from the local village. Generally they offer a better standard of accommodation and more Western-style meals. Most of these properties cannot be booked through overseas travel agents as the villages do not have phone/fax/e-mail. They use a HF radio network to contact accommodation operators in rural areas.

This model of eco-tourism is the most appropriate in the islands with out disturbing the serenity of the islands and not exploiting the natural resources and polluting the environment. The most important is that the local population will be benefited than the shrewd business men and tour operators. And what would be the best possible sustainable tourism, which is pragmatic and constructive.

It can be concluded that following on with the principles of ecotourism, there is a need to minimize impact on the fragile ecosystem of the islands. Build environmental and cultural awareness and respect for the environment and the local people. Provide positive experience for both visitors, and hosts, and provide financial benefits and empowerment for local people.

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h. As on 2001 out of total A & N island population of 356,265, there are only 92 Onge, 43, Great Andamanese, 350 Jarawa,, 100 Sentinelese and over 250 Shompens who constitute Primitive tribes (figures given in Sircar book p. 28)

i. They are non-primitive tribe, Nicobarese languages form an isolated group of six closely-related Mon-Khmer languages, spoken by the majority of the inhabitants of the Nicobar Islands of India. They have a total of about 30,000 speakers (22,100 native). The majority of Nicobarese speakers use the Car language.

J The 340 km long Andaman Trunk Road from Port Blair in South Andaman to Diglipur in North has been constructed through the heart of the very forests the Jarawa call home. It destroyed precious forests and brought in various developments that are proving to the disastrous for them.

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