Conservation of Mangrove Forest Genetic Resources

CONSERVATION OF MANGROVE FOREST GENETIC RESOURCES

A TRAINING MANUAL

M.S. SWAMINATHAN
RESEARCH
FOUNDATION
MADRAS, INDIA

INTERNATIONA
TROPICAL TIMB
ORGANISATIO
YOKOHAMA, JA

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EDITED BY

SANJAY V. DESHMUKH AND V. BALAJI

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CENTRE FOR RESEARCH ON SUSTAINABLE AGRICULTURAL AND RURAL DEVELOPMENT (CRSARD), MADRAS, INDIA

INTERNATIONAL TROPICAL TIMBER ORGANISATION
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Mangroves at Krusadai island, in the Gulf of Mannar Marine Biosphere Reserve, Tamil Nadu, India (Photo : Dr. Sanjay Deshmukh)

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PREFACE

During my stay in the Philippines from 1982–88 as Director General of the International Rice Research Institute, I was struck by the beauty and utility of mangrove forests in many of the islands of that country. It was then I took a fascination for the mangrove ecosystems. Later, I witnessed with sorrow fairly rapid damage to several of these valuable ecosystems as a result of the expansion of coastal aquaculture and urbanisation. Quite often coastal development projects, including aquaculture, were environmentally destructive and socially disruptive. I then felt that concerted action to save the remaining mangrove forests should be initiated. On my return to India, I observed that the fate of many mangrove forest areas was in grave jeopardy as a result of anthropogenic pressures. Therefore, the highest priority was given in the research and training agenda of the Centre for Research on Sustainable Agricultural and Rural Development (CRSARD) established in Madras in 1990 to the conservation and sustainable management of mangrove forest areas. In 1990, I was elected the first President of the International Society of Mangrove Ecosystems (ISME) with its headquarters at Okinawa, Japan and I took this opportunity to suggest the preparation of a *Charter for Mangroves* on the model of the World Charter for Nature adopted by the United Nations in 1982. ISME prepared such a Charter under the guidance of Dr. Colin Field and this Charter finds a place in this publication.

In September 1989, I was invited to deliver a lecture by the Government of Japan on the potential problems which may arise from changes in sea level due to global warming. I then pleaded for special attention to the conservation of genetic diversity in mangrove species since it may be possible to transfer genes for tolerance to sea water intrusion from them to other plants through recombinant DNA technology. The late Dr. Saburo Okita, who was the Chairman of the Tokyo Conference, recommended that the International Tropical Timber Organization (ITTO) located at Yokohama should initiate work on the conservation of mangrove ecosystems. Fortunately, immediately after this meeting, Dr. B.C.Y. Freezailah, Executive Director, ITTO and I happened to travel in the same plane to New Delhi. I then mentioned to Dr. Freezailah that we would like to prepare a proposal for assembling mangrove experts from different parts of the World to prepare a proposal for saving for posterity a representative sample of the genetic diversity occurring in mangrove species. He enthusiastically welcomed the idea. I then prepared a proposal which was forwarded by the Government of India to ITTO and was approved by the ITTO Governing Council. Funds for the Global Consultation were provided by the Governments of Japan and the UK. The group of experts who met in Madras in January 1991 helped to prepare a proposal titled "Establishment of a Global Network of Mangrove Genetic Resource Centres". This proposal was approved by the ITTO Council in May 1991.

Our proposal comprised of the following components :

1. Organisation of a global network of mangrove genetic resources centres;
2. A detailed study of mangrove genetic resources in West Africa;
3. Organisation of a Trainers' Training Programme for developing a cadre of professionals well-versed in the art and science of genetic conservation with reference to mangroves; and
4. Establishment of a Mangrove Ecosystems Information Service (MEIS) as a global data base service facility.

With the generous support of the Governments of Japan and Australia and with the technical guidance of an International Steering Committee the work on this project was started in September 1991. A 3-month Trainers' Training Programme was organised from 16th March, 1992 at Madras. A wide range of experts delivered lectures and conducted practicals. 20 participants from 12 countries whose names are included in this publication participated. Towards the end of the Course, the trainees prepared a Charter for Mangroves for their own countries based on the ISME Charter. Mr. Mai Sy Tuan from Vietnam, who produced the most imaginative and implementable Charter for Mangroves, was awarded the N.I. Vavilov Medal.

The various papers presented in the Training Course have been compiled by my colleagues Drs. Sanjay V. Deshmukh and V. Balaji and are included in this publication. We were fortunate to have the services of Prof. A.N. Rao of the National University of Singapore to serve as the Course Director. His untiring efforts contributed greatly to the success of the Course.

In the editing of this publication, we have had the kind assistance of Prof. A.N. Rao, Prof. S.M. Karmarkar and Mr. A. Narayanan. Many others from our Research Centre, particularly Ms. Stella Saleth, Ms. Solai Annamalai and Mr. N. Parasuraman rendered very valuable assistance. Our thanks go to all of them.

This Training Manual is becoming available at an appropriate time when the global interest in biodiversity has been heightened by the coming into force of the Global Biodiversity Convention on 29th December, 1993. It is a matter for great satisfaction that many of the participants who attended the Course are now in the forefront of arresting genetic erosion in their respective countries. Encouraged by the success of the Trainers' Training Programme, the Steering Committee of the Project urged that a second training programme should be held soon as a part of a capacity building exercise for conserving mangrove genetic resources. On the basis of the recommendation of the Steering Committee, a project proposal was submitted in 1993 to ITTO and we are grateful to the ITTO Council for approving this project at their meeting in May 1994. This will enable us to improve the global capacity for genetic conservation in mangrove ecosystems.

Our work would not have been possible but for the continuing guidance and encouragement of Dr. B.C.Y. Freezailah, Executive Director of ITTO, who personally came to Madras in December 1993 to dedicate the Mangrove Ecosystems Information Service to the global scientific community. Drs. David Cassells and Gary M. Burniske of ITTO have guided us at every step and have been pillars of strength to this project. We cannot thank them adequately.

Finally, our gratitude goes to Shri. R. Rajamani, Secretary, Ministry of Environment and Forests and Shri. Tejendra Khanna, Secretary, Ministry of Commerce for their constant encouragement and support. To the Governments of Japan and Australia we are deeply indebted for their financial support without which this Project could not have been undertaken.

It is our hope that this Training Manual will be found useful not only by mangrove research workers but also by all others interested in the conservation and sustainable utilisation of coastal biodiversity.

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HUMAN RESOURCES DEVELOPMENT FOR THE CONSERVATION OF MANGROVES

SANJAY DESHMUKH AND A.N. RAO

INTRODUCTION

Environment and development problems are complex and there cannot be generalised and simplified solutions. Answers are to be found which are ecologically, economically and socio-culturally consistent in the particular milieu. For achieving the integration of environmental consideration into development planning there has to be "capacity building" ameliorative action.

One of the most serious challenges facing contemporary development planners and agencies has been the growing damage to our basic life support systems, comprising land, water, flora, fauna and the atmosphere thereby rendering current patterns of economic development ecologically unsustainable. This was highlighted at the UN conference on Environment and Development (UNCED) held at Rio de Janeiro in June 1992. UNCED urged the development at the global and country levels, and Agenda 21 plan of action which would help to foster economic growth based on sound ecological ground rules. For implementing this, an urgent need is the development of national and local level capacity for formulating and implementing an Agenda 21 (highlighting the conservation of biological diversity in respective countries) based on the principle " think and plan locally while acting nationally and globally".

TROPICAL TIDAL ECOSYSTEMS

Mangroves are salt-tolerant forest ecosystems of tropical and sub-tropical Intertidal regions of the World. Under suitable conditions, the mangroves form extensive and productive forests in the sheltered coastlines. They are rich reservoirs of species of plants and animals, associated together over a long evolutionary time, and still imperfectly known and not fully understood. Sometimes, the word "mangal" is used for the whole mangrove community and "mangrove" for the individual species of plants.

Mangrove forests provide a wide range of services including prevention of damage by coastal storms and promotion of sustainable fisheries. Unfortunately coastal ecosystems which protect the livelihood security of over half the human population are under varying degrees of threat due to reasons such as the following :

a. Deforestation for human and industrial uses,
b. Waste disposal-garbage, sewage and solid and toxic wastes dumped or discharged into mangrove areas,
c. Mining and oil spills,
d. Land reclamation for purposes like housing, industries, ports, roads and canals,
e. Coastal aquaculture, and
f. Salt manufacture.

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Edited by Sanjay V. Deshmukh and V. Balaji.

HUMAN RESOURCES DEVELOPMENT

In the above context, there is a growing interest in the conservation and sustainable management of the mangrove ecosystem. This interest is reflected in the establishment of an International Society for Mangrove Ecosystems (ISME) at Okinawa, Japan in 1990 and in the International Tropical Timber Organisation (ITTO) according high priority to the conservation of mangrove forests and their sustainable utilisation. Prospects for sea level rise, on the one hand, and for moving genes across sexual barriers through genetic engineering, on the other, have heightened the urgency of arresting further genetic erosion in mangrove species. Globally, mangroves show two distinct patterns of distribution. The majority of species occur in the Indo-Pacific region, while several distinct species occur in East and West Africa, the Carribean region and North, Central and South America. Most regions are experiencing genetic erosion and conservation efforts are important nearly everywhere. Human resource development with reference to mangrove genetic resources conservation has hence acquired urgency.

As a part of the global efforts in the conservation and sustainable utilisation of mangrove ecosystems, an International Project Design Workshop was held at Madras under the joint auspices of the Centre for Research on Sustainable Agricultural and Rural Development (CRSARD) of the M.S. Swaminathan Research Foundation and the International Tropical Timber Organisation (ITTO), Japan for developing an action plan for the conservation of mangrove genetic resources. The recommendation of the participants in the workshop were considered by the ITTO Governing Council in May 1991 which approved the initiation of Phase I of the project to (a) identify sites for conservation of mangrove genetic resources; (b) develop a Mangrove Ecosystem Information System (MEIS); and (c) organise a Trainers' Training Programme at CRSARD, Madras, for developing a cadre of well-trained managers of Genetic Resources Centres.

An International Trainers' Training Programme on the Conservation of Mangrove Forest Genetic Resources was thus initiated in 1992 with twin goals :

1. to train a cadre of specialists in forest genetic resources conservation and sustainable management with particular reference to mangrove forests, and
2. to assist in developing a national biodiversity conservation strategy with emphasis on mangrove and coastal ecosystems for the country to which the participant belongs.

This course is probably the first of its kind in the World. It started on February 18, in the respective countries from where the candidates came and ended on May 22, 1992, at Madras.

The course consisted of the following four components :

February 18 to March 13, 1992

Location : Home Country
Identifying threats to genetic resources at "hot spot" locations needing urgent attention and preparing an inventory of the genetic heritage of the country in mangrove species.

March 16 to April 5, 1992

Location : Madras
Lectures and Practicals

April 6 to 26, 1992

Field Visits

April 27 to May 22, 1992

Location : Madras

Lectures, practicals and preparation of a dissertation on a National Mangrove Forest Conservation Strategy for the country to which the candidate belongs. It was expected that the dissertation would help the concerned authorities to develop a Charter for Mangroves for their respective countries.

STRUCTURE OF THE COURSE

The emphasis in the training programme was to accomplish genetic conservation in mangroves at three levels *viz.*, the ecosystem as a whole (conservation of the habitat); between species (genera and families) and within a particular species (intra species variability).

Topics of the lectures included the ecology of mangroves; genetics and improvement of forest trees; assessment of genetic resources and diversity; genetic structure of populations, gene and genetic conservation, seed viability and production; reproduction, regeneration and propagation in mangrove plants; biogeography of mangroves; silvicultural practices; sustainable utilisation; carbon fixation in the photosynthetic process and the effects of light, temperature, salinity and tidal changes on the photosynthetic rates of mangrove plants; floral morphology; phenology; flower varieties and breeding patterns; tree shoot systems and control of transpiration; socio-economic aspects of mangrove ecosystems; role of fauna and avifauna in mangroves; role of bacteria and micro-organisms in mangrove ecosystems; physiology with special reference to salt tolerance and nitrogen metabolism; biotechnological methods applicable to mangroves; application of remote-sensing in the study of mangrove ecosystem; soil-plant-atmosphere interaction in mangroves; global change and mangrove management implications; genetic classification, evaluation, cataloguing and data base management; and the development of a National Mangrove Genetic Resources Conservation Strategy.

Field trips were organised to Pichavaram, Andaman and Nicobar Islands, Goa, Ratnagiri and Bombay in Maharashtra.

DISSERTATION

The dissertation was designed to include information on the following :

Chapter I : Biological Wealth – Current Status

a. Description of nation's biological wealth and agro-ecological features
b. Description of coastal ecosystems
c. Description of mangrove wealth

Chapter II : Status of Current Conservation Efforts

a. National policies and programmes

b. Organised national efforts with legal protection
c. Facilities for research, training and awareness generation

Chapter III : Threats to the Conservation of Mangrove Ecosystems

a. Development programmes such as industry, salt production, aquaculture, etc.
b. anthropogenic pressures
c. Unsustainable exploitation
d. Other factors

Chapter IV : Components for a National Conservation Strategy for Mangroves

a. Knowledge base
b. Sustainable utilisation
c. Conserving habitats
d. Rehabilitation of degraded mangrove ecosystem
e. Conservation measures at macro and micro levels
f. Conservation methodologies
g. Evaluation, classification and data base development
h. Research and training needs
i. Conservation efforts through awareness and public participation

Chapter V : Designing a Genetic Garden for Mangrove Germplasm Conservation

a. Material to be conserved
b. *In situ* and *ex situ* integrated strategy
c. Sampling techniques and identification of genetic clusters
d. Enriching cytological and genetic knowledge
e. Role of molecular genetics and RFLP mapping
f. Hybridisation and development of new genetic stocks
g. quarantine facilities

Chapter VI : Resource Requirements

a. Physical facilities
b. Administrative resources
c. Financial resources

Chapter VII : Charter for Mangroves

a. Charter for conservation and sustainable management at the national level
b. Charter for international collaboration
c. Role of each country in a global grid of mangrove genetic resources

Chapter VIII : Conclusions

DIPLOMAS

The candidates, on the successful completion of the course, qualified for the award of the Diploma of the Associateship of the N.I. Vavilov Centre for Research and Training on the Sustainable Management of Biological Diversity of the M.S. Swaminathan Research Foundation.

Mr. Mai Sy Tuan (Vietnam), whose dissertation was adjudged as outstanding received the N.I. Vavilov Biodiversity Medal together with a cash prize of Rs. 5000.00.

FOLLOW-UP

It is hoped that the outputs of this training course will be the following :

1. Organisation of similar training programmes at the country level by the candidates, and
2. Development of a collaborative research network involving the trainees in order to promote the growth of a global grid of mangrove genetic research and conservation centres.

The collection of relevant chapters on fourteen topics in this manual is the first attempt to integrate theory and policy relating to the subject of conservation biology for its use in developing training programmes and courses, not only for scientists but administrators and policy makers also. It is essential to have increased collaboration between field experts and resource managers for meeting the demands from research scientists and decision makers which will help to meet the growing challenge of protecting biological diversity prevailing in the tropical tidal forests.

THE ITTO AND MANGROVES*

DAVID S. CASSELLS

When the International Tropical Timber Agreement (ITTA) was finally negotiated in the early 1980's, it was fundamentally different to other commodity agreements negotiated under the auspices of the United Nations Conference on Trade and Development (UNCTAD). For unlike other commodity agreements, ITTA recognised that if tropical timber was to remain a significant commodity resource in the future, discussions should be held about the production, utilisation and trade in tropical timber, which could never be realistically divorced from discussions about the conservation and wise management of the tropical forest resource.

ITTA took nearly a full decade to negotiate, and the latter days of these negotiations straddled the release of the World Conservation Strategy by the International Union for Conservation of Nature and Natural Resources (IUCN) in 1980. With its concern with both the commodity of tropical timber and the conservation of the tropical forest resources, the final constitution of ITTA adopted the same perspective as the World Conservation Strategy with regard to the relationship between conservation and development. Like the Conference on Environment and Development (June 1992), both the World Conservation Strategy and ITTA recognised that without economic and social development it would not be possible to mobilise the resources needed for environmental conservation. Equally, it was also recognised that without conservation, none of the benefits of economic development would be sustainable in the long run.

In recognition of this linkage, the fundamental objectives of the World Conservation Strategy were incorporated into the heart of ITTA through its objective 1(h). This objective of ITTA aims "to encourage the development of national policies aimed at the sustainable utilisation and conservation of tropical forests and their genetic resources, and at maintaining the ecological balance in the regions concerned".

The objective has become the primary orientation for the actions of the ITTO. Early reviews of the status of forestry in our producer member-countries revealed that only an insignificantly small proportion of the World's tropical forests were then being managed on a demonstrably sustainable basis. Since then, ITTO and its member-countries have wrestled with the problems of both defining sustainability and ensuring that sustainable forest management becomes a field reality in the tropics more than just an admirable theoretical construct.

With this focus within ITTO, the concept of sustainability has been directly linked to the related objectives of the World Conservation Strategy—the conservation of genetic diversity and the maintenance of ecological life support systems. Thus, within the organisation, the traditional concept of sustained yield timber management has been extended and replaced by a broader concept of resource sustainability through integrated natural resource management to protect all forest values, not just the immediately obvious economic values. Within ITTO, one of the important topics in these discussions on sustainability has been the crucial importance of the conservation and management of mangrove forests.

*Concluding Address at the convocation on May 22, 1992.

While little timber from mangrove forests enters the international tropical timber trade, mangroves are resources of crucial importance to many of ITTO's producer member countries. They provide important non-timber products like honey. They also provide timber products ranging from fuelwood to construction timbers and furniture-grade timbers. They provide habitat protection for fisheries, buffers against coastal storm surges and stabilisation of fragile coastal and delta areas. In mangroves, the ecological life support functions are much more direct and obvious than in many other tropical forest types.

Because of these key values ITTO has chosen to support a total of six mangrove projects with US $5.5 million over the past 2–3 years. The project that brought today's graduating students to Madras is one of the most important of these projects because it is global in scope and it focuses on the conservation of the mangrove genetic resources that are likely to be so important for humankind in the future if current predictions about global climate change and potential sea-level changes prove correct.

The project is also important because it focuses on human resource development, a key element of the ITTO Action Plan in the field of sustainable reforestation and forest management. It is therefore my fervent hope that today's graduation will not be seen by any of the participating students as the end of a process. Rather I hope you see it as the beginning of the process whereby you return to your country to begin to better manage your mangrove forest resources and indeed all your country's forest resources. We hope you will remember that this was meant to be a "training a trainer" course and that you will indeed share what you have learnt with your colleagues in your home countries and extend the concepts and practices of forest conservation and management.

We also hope you will stay in contact with each other, with the M.S. Swaminathan Research Foundation and with ITTO. We hope you become active nuclei for concerted action to conserve and manage mangroves and other forest resources for both present and future generations.

INAUGURAL ADDRESS

T.S. SADASIVAN

Biodiversity is nature's gift to mankind. The flora and fauna of today are probably a fraction of what was there in the various epochs down the geological scale of the earth. Great upheavals right from the Pre-cambrian, through Triassic, Jurassic, Cretaceous, Eocene to the Quaternary period brought profound changes in the flora and fauna. Giant trees, lianas and a whole host of remarkable plant wealth disappeared. Similarly, ferocious animals of gigantic proportions down to small animals also disappeared. The reasons were very many.

Dr. M.S. Swaminathan's uncanny ability in identifying problems like the far-reaching significance of man's quest for stable ecosystems has landed in organising in-depth studies of the mangroves. Who else could have visualised the neglected field of conservation of mangroves than Dr. Swaminathan? To many, mangroves are a disappearing ecosystem and their attitude has been one of complacency, not so to the discerning scientist. Mangroves represent an ancient habitat and are part of the transition in the origin of a land flora. They can, perhaps, be compared to the shola vegetation of terrestrial trees and shrubs in our hilly terrains. Professor F.O. Bower's masterly treatises on the " Origin of Land Flora" and " Primitive Land Plants" bring home the point that the algae were the primary colonisers of our earth. In particular, he points to the alga *Fritschiella tuberosa,* which was first described by the distinguished algologist, Professor M.O.P. Iyengar of Madras. It is not quite correct to say that the saline habitat is a primitive ecosystem. There are, of course, many questions yet unanswered. As a student of plant physiology, I would like to mention that it would be exciting to work out anatomy of mangrove plants which is so well adjusted to a marine-estuarine niche. Some of the questions we can address ourselves are :

1. The extraordinary ability of tolerance of a saline substrate by the plants of the mangroves is reflected by the osmoregulatory nature and the plasma membranes of their roots,
2. The respiration and photo-respiration of various species of mangroves,
3. The photosynthetic efficiency of these plants, and
4. Are there C_3 plants in mangroves? How many of them are C_4 plants?

I realise that this training programme is aimed at conservation of mangrove forest genetic resources. Nevertheless, it may be a kind of intellectual stimulation if one were to think in terms of the origin of mangroves and their specific niches which are favourable for establishing themselves. Some of their physiological characteristics, which are different from terrestrial plants in a fresh water situation, may be useful in any selection process. I feel certain that Dr. Swaminathan is planning to take up these problems when his new laboratory is ready to do so.

Nation-building, especially in the developing parts of the World is an uphill task, and in this, training of personnel for specific programmes occupies a high priority. India is fortunate in having an able scientist in Dr. Swaminathan, whose wide experience and expertise in so many areas of agricultural science has given the country an edge in organising our forward-looking programmes of Research and Development. To him we owe much, and it is my privilege to wish him godspeed in every project he undertakes at the national or international level.

I believe that every scientist must be exposed to the history of science and culture of its country of origin. Today, palaeobiology is being taught in many universities in the West. There is no doubt this subject will be introduced in the curricula of biology teaching in Indian universities. The geological and biological history of the universe assumes new significance in light of our great concern at the deteriorating environment. Industrial growth should not be at the expense of our agriculture and forestry, and if the participants in this workshop can take this message with them, the future of their country as a land worth living in would not be a dream.

I am delighted to have this opportunity of meeting the participants and resource personnel in this Training Programme. I have genuine pleasure in inaugurating this workshop and wish you all a very useful and informative programme of learning so many aspects of coastal ecosystems. In this learning process you are guided by a number of experienced Gurus of proven competence, and I feel certain you will take home the knowledge received and embark on your specialist assignments in your respective countries with confidence and vigour.

BIOLOGICAL DIVERSITY AND GLOBAL FOOD SECURITY

M.S. SWAMINATHAN

INTRODUCTION

Towards the close of the 20th century we are rediscovering once again the eternal truth that all life on earth is one great interdependent system, and that economic progress has to remain within the carrying capacity of the earth's ecosystems, if it is to confer lasting benefits. The perpetuation of poverty and the spread of environmental degradation reminds us that development has to be both people-centred and conservation based. With the global population growing fast towards six billion, we realise that sustainable advances in biological productivity are essential for safe-guarding both global food security as well as security of the livelihoods of millions of rural families in developing countries. Such advances have to take place in the context of diminishing land and fresh water resources for agriculture and expanding biotic and abiotic stresses.

The experience of the last 30 years reveals that given access to a wide range of plant and animal genetic resources, it is possible to keep grain, milk and meat production above population growth levels and, in addition, prevent the further denudation of forests for expansion of agriculture. We can neither sustain a global food security system nor face the challenge of climate change and enhanced ultraviolet-B radiation if we fail to conserve biological diversity through conventional and frontier technologies. The conservation of biodiversity is thus fundamental to the success of the development process.

GENETIC EROSION

Many experts believe that at present species are being lost throughout the World at a rate which is at least 1000 times background rate. What we are witnessing is more severe than any that has occurred during the past 65 million years, since the end of the Cretaceous period, when the dinosaurs disappeared. Such extinction is occurring at a time when genetic engineering has opened up possibilities for moving genes across sexual barriers and thus generate novel genetic combinations to meet new needs and situations.

We do not even know what we are losing. Wilson (1988) estimated that about 1.4 million species of organisms have been named so far. These include about 750,000 insects, 41,000 vertebrates, and 250,000 plants. The remaining species comprise bacteria, protozoa, algae, fungi and invertebrates. Participants at a symposium held at the Royal Society, London, in 1990 under the auspices of C.A.B. International concluded that if extensive biosystematic work is undertaken in invertebrates and micro-organisms, the total number of species on our planet may exceed 50 million. Erwin (1988) places it at 80 million or more. May (1988) lamented at the fact that there is no area on earth, large or small, where we have a complete census of living organisms. Raven (1990) has therefore pleaded for systematic efforts in the organisms on earth. A global biological inventory network coupled with a conservation monitoring network is essential to understand the rates of species extinction and genetic erosion.

A systems approach is needed in such studies, since understanding biodiversity involves a study of both the variety and variability among living organisms and the ecological complexes in which they occur. As pointed out by the U.S. Congressional Office of Technology Assessment in 1987, diversity can be defined as the number of different items and their relative frequency. For biological diversity, these items are organised at many different levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity.

Species-rich ecosystems exist primarily in tropical regions; species-poor ones in areas such as the arctic, where conditions for growth are more limiting.

RECENT EFFORTS IN ARRESTING GENETIC EROSION

The following are some recent efforts in this direction :

1. Past and present contribution of farmers in conserving, improving and making available plant and animal genetic resources as part of their farming operations over centuries, in particular those in the centres of origin/diversity,
2. Activities initiated by the Russian geneticist N.I. Vavilov in the late 1920s for collecting, evaluating, conserving and utilising genetic resources from the major centres of diversity of crop plants; this effort stimulated similar interest among animal breeders,
3. Steps initiated by FAO from the late fifties to focus attention on the conservation of PGR, leading ultimately to the establishment of a Global System and an FAO Commission for Plant Genetic Resources in 1983; FAO has also initiated similar efforts in the conservation of animal genetic resources,
4. The significance of genetic resources was stressed by the first United Nations Conference on the Human Environment in Stockholm in 1972,
5. Steps initiated by UNESCO in the International Board for Plant Genetic Resources (IBPGR) by the Consultative Group on International Agricultural Research (CGIAR) in 1974 [in 1991 renamed the International Plant Genetic Resources Institute (IPGRI)],
6. The World Commission on Environment and Development (WCED) in its report submitted in 1987, stressed the urgency of conserving global biological diversity for ensuring both food and ecological security,
7. The emphasis placed on prevention of genetic erosion in UNEP's 'Environmental Perspectives to the year 2000 and Beyond', published in 1987,
8. The decision by CGIAR in 1991 to establish a new International Forestry Research Entity for global forestry research within CGIAR and the admittance of the International Centre (formerly Council) for Research on Agro-Forestry (ICRAF). These institutes will be concerned with genetic resources of those ecosystems that are relevant for their mandates,
9. The recent initiative by the World Bank, UNDP and UNEP to form a three year pilot programme, the Global Environment Facility (GEF), supported by a Core Trust Fund together with various co-financing arrangements. One of its four major objectives concerns the protection of biodiversity,
10. Report titled "Caring for the Earth" issued by IUCN, WWF and UNEP in October 1991, which calls for a major global effort in protecting biological diversity and promoting its sustainable utilisation, and

11. A global biodiversity strategy prepared in 1992 by the World Resources Institute, the World Conservation Union and the United Nations Environment Programme.

Several other activities of a legislative nature have taken place at the international level. These include a recently concluded revision of the International Union for the Protection of New Varieties of Plants (UPOV) Convention and the patenting of plant related biotechnological inventions. In addition, the Trade Related Intellectual Property Rights (TRIPS) issues in the negotiations of the current Uruguay Round of the General Agreement of Tariffs and Trade (GATT) also deal with the patenting of products in addition to processes and of living organisms.

At the national level also, several significant developments have taken place. In India, for example, the Indian Council of Agricultural Research has established National Bureaus of Plant, Animal, Fish and Forest genetic resources. The World Wide Fund for Nature-India is establishing with the support of the Ministry of Environmental and Forest of the Government of India, a national conservation monitoring centre.

The three basic principles which should govern action are :

1. Contain and prevent genetic erosion,
2. Use genetic resources effectively and sustainably, and
3. Share the benefits equitably.

If these principles are followed, we can usher in a new paradigm of biodiversity conservation based on the integration of principles of ecological sustainability, economic efficiency and social equity.

BIODIVERSITY AND ANIMAL HUSBANDRY

Unfortunately, efforts in the conservation of animal genetic resources have not been as systematic as in the case of plants. *In situ* conservation through National Parks and Protected Areas has centred around wildlife. It is only in recent years that interest in the conservation of wild relatives and biotypes of domesticated animals has grown. The best form of conservation will be the involvement of local communities in the *in situ* preservation of germplasm. *In vitro* preservation of germ cells and embryos is also gaining ground.

There is need for greater efforts in the training of biosystematists and genetic resources managers. Special courses need to be taught. There is also need for laboratory exercises for providing experience with sampling and collection strategies, with techniques for assessing genetic variability of isozyme analysis and DNA sequence analysis, with sterile culture and production techniques, and with computer data base development and use. An integrated national conservation strategy involving *in situ* and *ex situ* and *in vitro* and *in vivo* methods needs to be developed for every animal species.

GLOBAL BIODIVERSITY STRATEGY

The World Resources Institute, IUCN and UNEP (1992) have recently compiled guidelines for action to save, study, and use the earth's biotic wealth sustainably and equitably. The strategy includes the following components :

1. Establish a national policy framework for biodiversity conservation,
2. Create an international policy environment that supports national biodiversity conservation,
3. Create conditions and incentives for local biodiversity conservation,
4. Manage biodiversity throughout the human environment,
5. Strengthen protected areas,
6. Conserve species, populations and genetic diversity, and
7. Expand human capacity to conserve biodiversity.

The Inter-Governmental Convention on Biological Diversity currently being negotiated under the auspices of UNEP aims to serve as a key, coordinating, catalyzing, and monitoring mechanisms for international biodiversity conservation. From the point of view of the developing countries three issues are pivotal.

First, it is not only important to conserve, but there is equally urgent need for utilising genetic diversity for strengthening the livelihoods of the poor.

Secondly, the patenting of living forms will create numerous problems in the free exchange of genetic material and in sharing the economic benefits. The relative roles of formal and informal innovations in animal and plant breeding will have to be articulated in terms of reward and recognition.

Thirdly, protecting the protected areas is itself becoming a serious problem in many developing countries. Local communities feel that biosphere reserves and national parks often erode their livelihood security rather than strengthen it. There is urgent need for arresting this alienation and for restoring the ancient tradition of involving local people in the management and use of common property resources. Unless the poor and the panda receive concurrent attention, conservation of habitats rich in biological diversity will be a lost cause.

GENETIC RESOURCES FOR NATIONAL FOOD SECURITY

Sustainable advances in biological productivity are ecological and economic imperatives in most parts of the World. The conservation, evaluation and sustainable utilisation of plant animal genetic resources are essential for achieving such advances. Sustainable agriculture has many dimensions such as ecological, economic, technological, social and political. The ultimate goal of sustainable agriculture should be the improvement of the food and nutrition security of a country and the livelihood security of its rural families, with due consideration to the carrying capacity of the supporting ecosystems.

The conservation of plant, animal and fish genetic resources should be viewed in an integrated manner in tropical countries, since mixed farming is both a way of life and means to livelihood security in countries like India. A farming system-based conservation programme should be implemented at the ecosystem, species and sub-specific level.

In situ conservation of land-races and wild relatives of crop plants by farm women and men has been an important factor in the maintenance of genetic heterogeneity in cultivated plants. Such informal innovation systems have played a pivotal role in the conservation of genotypes with desirable qualities, particularly tolerance or resistance to biotic and abiotic stresses, and have consequently been the backbone of traditional sustainable agriculture systems. It is important that such informal innovation systems are recognised, rewarded and encouraged. Community involvement in the conservation of biological diversity is essential for ensuring that the fruits of thousands of years of natural and human selection are preserved for current and future use.

The participants at a workshop held in Madras in November 1991 recommended that in every country a Genetic Resources Consortium for Sustainable Agriculture be established comprising the following :

1. Non-governmental conservation organisations,
2. Government organisations such as National Bureaus of Plant, Animal, Fish and Forest genetic resources, and
3. Appropriate International Agricultural Research Centres (IARCs) and Gene Banks like the Vavilov Institute of Plant Industry at St. Petersburg, the Bari gene bank in Italy, the University of Viterbo in Italy, the Nordic gene bank and the Tsukuba gene bank. In India, it was suggested that the Scarascia Mugnozza Genetic Resources Centre of the M.S. Swaminathan Research Foundation at Madras may take the lead in organising such a Consortium.

The Genetic Resources Consortium for Sustainable Agriculture could have the following mission and mandate :

Identify key scientific and socio-economic components of a sustainable crop-livestock integrated production system and assemble specialised gene pools for selecting/breeding crop and animal species and strains adapted to the production system, both through conventional and genetic engineering techniques. For this purpose, the consortium should promote the establishment of Genetic Gardens for Sustainable Agriculture to cater to the following needs :

1. Genetic heterogeneity and genetic adaptation to the biotic stresses which a particular farming system is subjected to,
2. Provide to the maximum possible extent the nutrient requirements of a high yield farming system through biological nitrogen fixation, biofertilisers and cooperations and residues and assemble for this purpose germplasm of green manure crops, *Azolla*, blue-green algae and pulse crops suitable for inclusion in the farming system,
3. Accord priority to irrigated and complex, risk-prone and diverse rainfed farming systems as well as to coastal and hill ecosystems,
4. Assemble genotypes suitable for an agroforestry system of land management, with special emphasis on silvi-horticultural and silvi-pastoral systems, and
5. Assemble candidate genes for use in recombinant DNA experiments leading to new genetic combinations of interest in imparting the dimension of ecological sustainability to the recommended cropping/farming system.

The Genetic Resources Consortium for Sustainable Agriculture should promote not only *in situ* and *ex situ* conservation by local communities and official agencies, but should also ensure attention to evaluation, classification, utilisation and monitoring. Bioindicators and bio-monitoring techniques should be standardised and popularised among local schools and village communities.

In addition, there is need for undertaking the following tasks:

1. Organisation of awareness generation programmes and educational and media resources centres,

2. Mobilisation of school children in the application of bio-indicators in pollution monitoring work,
3. Research on methods of according recognition to informal innovation by rural women and men,
4. Training of grass-roots level conservation workers in the conservation of plant and animal genetic resources,
5. Development of a political constituency for genetic resources through organisation of dialogues involving scientists and political leaders,
6. Mobilising public opinion for the conservation of economic and ecological key species are well as special genotypes like mangroves, seagrasses and coral reefs, and
7. Setting priorities in collection, evaluation and conservation work.

Obviously, priority in conservation should go to the species listed in Red Data books and to life-support species and underutilised plants. Local breeds of farm animals and fishes should also receive priority attention. The different members of the consortium can divide the work among themselves, in accordance with their own mandate, priorities and facilities.

WORLD BIODIVERSITY CONSERVATION DAY

In order to spread public awareness of the fact that loss of every species and ecosystem limits our options for the future in terms of adaptation to new needs and climatic situations, it is suggested that November 24 of each year be commemorated World-wide as "World Biodiversity Conservation Day". November 24 represents the birthday of N.I. Vavilov. This will help to promote public understanding of the urgency of conserving the genetic wealth of our planet.

BIOTECHNOLOGY AND BIODIVERSITY

Sustainable development demands the integration of the principles of ecological soundness and of equity with those of economic efficiency in the development of both technology and public policy. The broad group of technologies associated with modern biotechnology offer new opportunities for promoting a better quality of life for all, while living within the carrying capacity of supporting ecosystems, provided proper research priorities and strategies and public policies are followed.

The scientific principles and tools underpinning are largely the outcome of research done in universities and public-funded institutions. On the other hand, the conversion of scientific discoveries into economically viable technologies is being done largely in the private sector in industrialised nations. The hard core of modern biotechnology is genetic engineering or recombinant DNA methodology, which enables the creation of novel genetic combinations. Research of novel combinations needs access to a wide range of genetic material, thereby resulting in a feedback relationship between biotechnology and biodiversity.

These features of biotechnology have resulted in international debates and dialogues between industrialised and developing countries on matters relating to intellectual property rights and patenting procedures for living organisms on the one hand, and reward and recognition to the informal innovation systems of rural women and men responsible for the preservation of a wide range of *inter-specific* genetic variability, on the other. The recent adoption of a revised UPOV convention for the protection of new plant varieties and the patenting of plant-related biotechnological inventions, the statement of the Green Industry Biotechnology Platform and the acceptance of the concept of "Farmer's Rights" in FAO meetings are significant events in the ongoing debate on biotechnology and IPR. The establishment of an International Centre for Genetic Engineering and Biotechnology (ICGEB) by UNIDO is an important milestone in the history of biotechnology development for developing countries.

Biotechnological innovations offer scope for making substantial impacts on crop and animal husbandry, fisheries, forestry, biomass-based energy, bioremediation, health, industry, pollution control and a wide range of human activities having a bearing in sustainable development (Swaminathan 1991). No wonder many members of the Asian, African and Inter-American Development Banks, are playing a pivotal role in the development of biotechnological innovations and their widespread dissemination in developing countries. In addition, international scientific bodies like the International Council of Scientific Unions (ICSU), regional association like the Commission of the European Communities and private industry are actively involved in various aspects of biotechnology research and development.

The human population is likely to double in about 35 years. More than 10 billion people will have to be fed, clothed and provided with jobs under conditions of shrinking land and water resources for agriculture, expanding biotic and abiotic stresses, increasing genetic erosion and rising cost of fossil fuel energy reserves. Compounding these social and economic problems is the possibility of alterations in climate, rise in sea levels and greater incidence of ultraviolet-B radiation, caused by both unsustainable lifestyles and the undesirable consequences of some of the current industrial and agricultural technologies.

It is in the above context that the Preparatory Committee for the United Nations Conference on Environment and Development (UNCED) concluded at its Third Session, held in Geneva from August 12 to September 4, 1991, that the environmentally sound and safe application of biotechnology is essential for health care and food security, pollution control, higher efficiency of industrial development processes and biodegradation of industrial wastes. The Committee therefore urged the acceleration of current efforts on the development and application of biotechnologies, particularly in developing countries.

How can such a goal be achieved? Obviously this will call for institutional mechanism which can ensure that public good and private profit are not naturally antagonistic. The UN principle of "one vote" helps to keep all points of view in decision-making. The UN principles are the ones which will promote harmony and understanding under conditions of diversity in needs, perceptions, socio-economic conditions, technological capability and biological wealth. How can the power of modern biotechnologies be used for promoting economic development without damage to the ecological health of our planet and for ensuring that the welfare of the poor is enriched and not eroded by technological progress?

During the last two decades, the institutional structure represented by the Consultative Group on International Agricultural Research (CGIAR), co-sponsored by FAO, UNDP and IBRD, has proved to be an effective mechanism for reaching the resource-poor farmers as well as for inspiring donor confidence. As a consequence, the annual budget of CGIAR, comprising voluntary contributions by bilateral and multilateral donors and philanthropic foundations, rose from about US$ 10 million in 1971 to about US$ 350 million in 1991.

Considering the far-reaching implications of biotechnology for human welfare and planet protection, it would be appropriate if a global coalition is formed through a Consultative Group for Biotechnology (CG-Biotech), which can bring together appropriate members of the UN system, bilateral and multilateral donors, foundations, private and public sector industries, and governmental and non-governmental organisation. The CG-Biotech could help to mobilise the necessary financial, technical and institutional resources for ensuring that the benefits of "green" or environmentally benign biotechnologies reach the unreached.

The participants of the International Conference on "An agenda of science for environment and development into the 21st century" (ASCEND 21), sponsored by ICSU and held at Vienna from November 25–29, 1991, concluded that unprecedented crises are likely within the lifetime of half of the World's population, arising from such changes as :

1. World population doubling to 10 billion in only 35 years,
2. Migration and urbanisation assuming dramatic proportions, with notable consequences on coastal zones,
3. Continuing rise of energy consumption exerting increasing pressures on the global ecosystem,
4. Climate change, sea-level rise and associated impacts on the biosphere,
5. Irreversible loss of a substantial part of the total number of living species,
6. Continued reduction and deterioration (including chemical pollution) of the quality of the natural resource base, including the exhaustion, degradation, salinisation and loss of a major proportion of the World's soils, and
7. Growing and widespread water scarcity.

Biotechnology can be a powerful ally in the development of avoidance and adaptation mechanisms which can prevent or mitigate the adverse impact of such crises.

Hence, no further time should be lost in the development of a suitable institutional framework which can foster the growth of a global coalition committed to removing the technological component of the wall dividing prosperity and poverty. Innovative and dynamic institutional structures are essential for dealing with the human implications of a dynamic science.

At the same time, it should be emphasised, as was done by participants at the Keystone International Dialogue on Plant Genetic Resources, that the traditional donor-recipient concept is not relevant while dealing with biodiversity and biotechnology. The GIFTS concept is more appropriate. This involves all countries giving and/or receiving one or the other of the following :

G – Germplasm
I – Information
F – Funds
T – Technology
S – Systems

If seen in this light, differences between developing and industrialised nations on patenting new strains of crops and farm animals can be resolved.

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IN SITU CONSERVATION OF BIOLOGICAL DIVERSITY : IMPORTANT ACTION POINTS

T.N. KHOSHOO

INTRODUCTION

The major environmental concerns facing the human race are population escalation, tropical deforestation, loss of biodiversity, climate change, and AIDS epidemic. Loss of biodiversity is interconnected with population escalation and tropical deforestation. Much of the biodiversity on which the human race depends is located in tropical, sub-tropical, and hot temperate areas of the World. Biodiversity is expressed in individuals, populations, communities, and ecosystems. As to the loss of biodiversity, it is well recognised that species are not static; extinctions and even corresponding renewals have been common in geological times. Extinctions in the past have been the result of many cataclysmic changes on the earth. However, causes of the present high rate of loss of biodiversity can be traced to the doings of only one specie : Homo sapiens. Furthermore, corresponding renewals are not in sight. It is on this account that the loss of biodiversity becomes a major problem.

It is also well known that the human being has lived in a hunter-gatherer society for 99% of the time since its origin and has depended entirely on biodiversity for its sustenance. However, it is during the last 1% of the time that it has lived in agricultural societies followed by industrial societies. The latter resulted in total social and economic transformation of the human society with relatively less emphasis on biodiversity. However, conservation of the total spectrum of biodiversity (plants, animals, and micro-organisms) can no longer be regarded as an esoteric exercise, but something that affects the totality of environment, on which the very existence of life (including human life) depends. Therefore, biodiversity is critical to our survival and more of the poor—assetless section of our society—whose well-being depends on biomass. The basic reason for this is that biodiversity and bioproductivity are on biomass. The basic reason for this is that biodiversity and bioproductivity are interdependent.

Essentially, it is a question of survival. Furthermore, the prospect of climate change would invoke change in the biotic composition of ecosystems and also their migration. In the absence of knowledge about the exact nature of genetic changes, there is a most urgent need to have as wide a genetic base as possible.

BIOLOGICAL DIVERSITY

Biological diversity is the sum total of species richness, i.e., the number of species of plants, animals, and micro-organisms living in a community or an ecosystem. It is a part of the biosphere supported by biological processes and organic [evolution]: these three elements are interdependent.

Genetic diversity pertains essentially to the domesticated plants and animals and is the result of the domestication process to feed the escalating human population. This led to expansion of agriculture and animal husbandry. In course of time, in actual practice, it meant great dependence on only high-yielding varieties, and consequently shrinkage of genetic base and increased crop vulnerability. The present 'green revolution' agriculture is based on high productivity and low diversity. There is now a need to combine high productivity and high genetic diversity not only for enhancing food production but also as insulation against threats from global climatic changes and pollutants in air, water and land.

The conservation of biodiversity is a holistic concept and encompasses the whole spectrum of biota and of activities ranging from ecosystems at macro level (*in situ*) to DNA libraries at molecular level (*ex situ*), and everything in between.

Biodiversity in general and genetic diversity in particular, have become highly politicised issues, much to the disappointment of geneticists and breeders who care more for the underlying science and service to the society. Accordingly, there is now talk of a 'gene drain' from the South to the North' star wars are being replaced with seed wars. Such politicisation has been the direct result of the recent interest taken by multinational corporations, businessmen, diplomats, bureaucrats, politicians, and the press. However, the traditional caretakers have been the subsistence farmers, tribals, and individual breeders in universities, government departments, and industry. All kept genetic diversity alive for different reasons. The breeders used to exchange genetically important material without any reservations. In fact, the 'green revolution' in India is the result of such scientific exchanges of the very advanced breeding material of Mexican dwarf wheats that were subjected to selection under local environmental conditions.

India has done commendably well as far as *ex situ* conservation of crop genetic resources is concerned but it has not paid adequate attention to the biological resources on a holistic basis (*in situ*) under different ecosystems.

The important point in *in situ* conservation is that forest trees, wild animals, and micro-organisms all occur together in a given ecosystem. Therefore, if we try to conserve and enrich the ecosystem, much can be achieved in a single step. This would be particularly advantageous in tropical forests where many species occur in low densities and are endemic to a high degree. Obviously, there is an urgent need to co-ordinate our efforts on the ground level. This would not only save time and effort but also scarce fiscal resources and infrastructure. With small modifications, programmes on crop and non-crop plants, wild animals, and forest trees could form components of the whole whereby plants in general and crop relatives in particular, forest trees, and wild and semi-domesticated animals as well as associated micro-organisms could be saved in one operation.

The people's participation has to be ensured by meeting all their needs for which they depend on a particular ecosystem. This can be done by helping the people to meet their needs from the buffer zone. In this way, it is possible to integrate rural development with ecosystem conservation. In brief, not only wild animals and forest trees, but the full complement of biota, can generate valuable products and services, Obviously, such areas will have to be selected by design and not on an ad hoc basis. The minimum area of the ecosystem will have to be related to the population size of the major species of forest trees and other plants and animals.

In order to identify ecosystems that have been left out and are in urgent need of conservation, it is necessary to match the twelve bio-geographical provinces of India with the provinces of India with the present-day protected area network (PAN). Such a study will point out additional areas in need of conservation.

So far, the approach has been 'ad hoc' and oriented at saving fauna, especially large mammals and big cats, perhaps because they are more obvious and occupy the top of the food chain. In general, decision-making has been based on the presence of wild mammals and birds. Unfortunately, plant and other biotic wealth has never been taken into consideration. Such an omission is to be rectified now, and the restricted outlook must change in favour of a holistic one in order to enable the country to save as much of the biological wealth as possible.

So far the top donors of germplasm have been the developing countries whereas the beneficiaries have been the developed ones. Furthermore, the priorities have also been dictated by the developed World. According to this author, these must now be changed in favour of the needs of the developing countries.

Another aspect requiring attention is the evolution of a system, both nationally and internationally, where rights of both breeders and farmers are guaranteed. Although biodiversity is the heritage of all humankind, the situation has changed on account of the application of biotechnology and genetic engineering, leading to the involvement of multinational corporations in this area. These aspects need to be looked into very carefully, so as to safeguard the interests of the country and its breeders and farmers.

Furthermore, those countries that the maximum biological diversity are the ones which have hardly any worthwhile economic means and professional competence to ensure conservation on a sustained basis. India and some countries in Central and South America are notable exceptions. In other developing countries, the social benefits of biological diversity are intangible and, for want of a value in the market-place, the dire need to conserve biodiversity is never realised. The same is true of the ecosystem, which is not at all conducive to conservation.

The term wildlife theoretically include all non-domesticated biota growing under wild conditions. However, the World has lost its utility because over the years, it has come to mean only wild mammals (especially the big cats) and birds. To conserve such biota may have been a historical necessity, but today even the WWF (World Wildlife Fund), from which all wildlife enthusiasts have been drawing inspiration, has changed its name to World Wide Fund for Nature, realising the widening frontiers and importance of biodiversity and environmental issues. It is high time that the Indian Board for Wildlife is scrapped and replaced by an interdisciplinary National Biodiversity Conservation Board, not merely in name but in substance and in actual functioning. This Board should be the guardian of our biodiversity and deal with whole gamut of issues connected with it.

In the developing countries, which are gene-rich, the most urgent need is trained manpower. However, it is the developed countries which used this biodiversity and are crop-rich today. Thus the developing countries, which have the basic raw material, are not often aware of its importance, and it has eventually been exploited by the developed ones. This is a major infirmity prevailing in the World is eventually and must be corrected at the earliest. Training, among other subjects, must involve genetics (including population genetics, conservation biology, and breeding). Meaningful conservation can be done only by such trained manpower and not by generalists.

IMPORTANT ACTION POINTS

1. Declare biological diversity a national resource, its conservation a national goal, and its implementation a national priority. Conserver biodiversity in local, state, national, regional, and global contexts.
2. Constitute an interdisciplinary National Biodiversity Conservation Board for conservation, monitoring and overseeing implementation of the work plan, and managing conservation of different biota and the PAN (Protected Areas Network).
3. Evolve a national policy on conservation of biodiversity and update the same periodically.
4. Review existing PAN, which includes biosphere reserves, national parks, wildlife sanctuaries, sacred groves, preservation plots, game reserves, etc., with reference to

   a. bio-geographical aspects involving all habitats from sea to alpine levels, and from moist tropical forests to cold and hot deserts,
   b. biological holdings and size of each protected area in relation to population size of biota to be conserved, forest types, threatened biota, centres of diversity of plant and animal species and their relatives,
   c. anthropological aspects,
   d. national information base on biological wealth, together with its value in economic terms, and
   e. management patterns.

5. Review the present conservation effort on different biota and prepare a special management plan for conservation of forest and micro-organisms.
6. Draw up a plan to establish a representative PAN by

   a. excluding those areas that do not satisfy the minimum criteria, and
   b. including new areas in order to rectify the deficiencies such as genetic reserves for rice, sugarcane, mango, forage plants, banana, citrus, buffalo, fish, etc.

7. Establish minimal data bases for each protected area with regard to

   a. climate, soil, water, air and other abiotic characteristics,
   b. total biotic wealth with taxonomic identification,
   c. wild relatives of domesticated biota,
   d. threatened biota and nature of threats, and
   e. linking of such data bases to a central point.

8. Draw management plans for PAN by ensuring

   a. all-round involvement of people in order to develop their stake in PAN, including the welfare and developmental measures, so as to reduce to the minimum, their dependence on Pan for goods, and
   b. build-up a cradle of PAN conservators and science and technology professionals fully trained in various aspects of management of these areas and the underlying science and technology. (Since these are often far away from cities and towns, and these personnel

have to deal with dangerous animals, the rules regarding recruitment, training, salary, promotion and career development need re-examination).

9. Examine the tenurial status as well as land and water use patterns. Wherever necessary, take steps to guarantee tenurial status in particular habitats on account of developmental projects. Such a disruption would mark the continuity of the biological process.
10. Draw up plans for rehabilitation of the priority species both *ex situ* and *in situ* and for purposes of restoring the natural populations. In all cases, the basis has to be ecosystem dynamics, population genetics and conservation biology, so as to avoid genetic drift in future.
11. Domesticate, where required, those wild biota that have a trade value but are under constant threat, such as butterflies, frogs, turtles, fish, fur animals, herbal drugs, ornamentals, botanical varieties, teaching materials, etc. This would reduce the presence on the natural populations and help in their conservation, provided breeding methodology is based on evolutionary biology and population genetics.
12. Draw up plans for education and awareness about various aspects of PAN for students, the lay public, administrators, decision-makers and politicians.
13. Promote awareness among people, particularly those who are a part of the ecosystems, and, if required, look into the compensatory mechanisms for the people.
14. Drawing up plans for basic and applied research at individual, population, community, and ecosystem levels regarding ecosystem dynamics, conservation biology, population genetics, reproductive biology, and other related subjects.
15. Support PAN with an effective network of botanical and zoological gardens, zoo, arboreta, aquaria, and bio-banks concerned chiefly with *ex situ* conservation.
16. Guarantee continued financial support.

SOIL-PLANT-ATMOSPHERE INTERACTIONS

BARRY F. CLOUGH

THEMES

- Strategies for accommodating environmental stress
- Regulation of forest primary production and growth
- Impact of possible global climatic changes
- Implications for management

STRESS FACTORS

Main stress factors experienced by mangroves

- Anaerobic or anoxic soils
- Nutrient unavailability
- High soil salinity
- Water availability
- Temperature
- Excessive solar radiation/light

ANAEROBIC SOILS: ANOXIA

CAUSES

- Most mangrove soils are water-logged
- Very slow rate of diffusion of O_2 in water
- Consumption of O_2 due to bacterial and other biological activity in the soil

CONSEQUENCES

- Mangrove soil are mostly anaerobic, with oxidation)reduction (redox) potentials < 100 mV
- In general, redox potential decreases with depth in the soil
- Mangrove roots cannot obtain O_2 from the soil to satisfy their respiratory requirements
- Availability of nutrients, especially N, P, Fe, Mn

ACCOMMODATION BY MANGROVES

- Spatial distribution of roots
- Specialised root morphology and structures to facilitate O_2 transport from the air to the below-ground roots

- Oxidised rhizosphere

NUTRIENT AVAILABILITY

GENERALISATIONS

- Sands or sandy soil and calcareous soils derived chiefly from the marine environment tend to be nutrient-deficient (e.g., coral cays, barrier and other low islands)
- Silty and clayey soils derived from the land tend to be nutrient-rich (e.g., river and estuary deltas)

SALINITY

- Effect of high Na^+ and Cl^-
- Effect on water balance
- Osmoregulation and uptake of Na^+ and Cl^-
- Osmoregulation and compatible organic solutes
- Salinity and growth

WATER AVAILABILITY

- Effect of salinity
- Effect of soil water content
- Influence of tidal range and topographic level
- Some ecological implications for zonation

TEMPERATURE

- Effects of low temperature on species distributions
- Genotypic variation in low temperature responses
- Effect of high temperature on photosynthesis
- Effect of high temperature on water loss

SOLAR RADIATION

INFRARED RADIATION (> 800 nm)

- Effect on leaf temperature
- Effect on water loss
- Effect on respiration
- Effect on general metabolism

VISIBLE RADIATION (400–700 nm)

- Effect on Photosynthesis
- Photoinhibition

ULTRA-VIOLET RADIATION (< 400 nm)

- General effects
- Tannins as UV blockers

FACTORS AFFECTING DISTRIBUTION, ZONATION AND GROWTH

GLOBALLY AND REGIONALLY

- Temperature
- Dispersal
  - Ocean currents
  - Propagule buoyance
  - Propagule longevity
- Aridity
  - rainfall/cloudiness
  - seasonality

LOCALLY

- Geomorphic setting
- Tidal regime and topographic level
- Soil properties
  - salinity
  - water content
  - composition
  - nutrient availability

IMPACTS OF POSSIBLE GLOBAL CHANGES

SOME PREDICTIONS

According to the WMO/UNEP Inter-governmental Panel on Climate Change (IPCC):

Temperature

- The earth's crust has warmed by 0.5–1.2 °C since the industrial revolution

- Further warming of 0.8–2.0 °C is yet to be realised owing to inertia of the system
- Doubling of CO_2 levels in the next 40–50 year is expected to lead to a further increase in mean temperature of 1.5–4.5 °C
- Atmospheric CO_2 levels are expected to double (to about 700 ppm) by 2030 or 2040 A.D.
- Rise in relative sea level
  - globally eustatic sea level has rise of 10 cm over the last 100 years
  - expect a rise of 30–50 cm by 2050 and 100 cm by 2100
  - giving an expected average rise of 50–90 cm over the next 100 years
- Changing patterns of rainfall, cloud cover and aridity
- Increase in frequency and severity of storms, cyclone and hurricanes, and a shift polewards of severe storm activity

POSSIBLE CONSEQUENCES

- Poleward migration as result of increased temperature
- Increase in primary productivity and growth due to effect of elevated CO_2 levels on photo synthesis
  - depends on whether or not CO_2 is a major limiting factor
  - increased water use efficiency—less salt loading?
- Changes in primary productivity and growth due to interaction between limiting climatic factors
  - high temperature—thermal stress
  - rainfall cloudiness, relative humidity and seasonality
- In general, predicted climatic changes favour higher primary productivity and growth
- Greater instability due to severe episodic event such as storms, surges, wave action
- Local landward contraction or migration of mangroves, which might to offset in deltaic settings by increased sedimentation

SOME UNCERTAINTIES

- Predictions are based on large-scale global circulation models, all of which have a degree of uncertainty
- Various models predict differing outcomes
- Thermal inertia in the earth's crust and the ocean is also a cause for uncertainty about the outcomes of climatic change
- Past warming and eustatic sea level rise have not been uniform globally, and are unlikely to be so in the future

IMPLICATION FOR MANAGEMENT

- Anticipating possible impact of global climate change

- management strategies
- Selecting appropriate sites for specific types of management

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CLIMATIC IMPACTS ON MANGROVE ECOSYSTEMS

BARRY F. CLOUGH

INTRODUCTION

Mangroves are woody trees or shrubs that grow in Intertidal region along tropical and sub-tropical coasts. With favourable geomorphic conditions, mangroves commonly form extensive tidal forests in moist, humid equatorial climates. Under these conditions, individual trees may attain heights of 40–45 metres and have stem diameters of more than 1 meter. Tidal mangrove forests under the favourable conditions of humid production climates and low to moderate soil salinity commonly have high rates of primary production and growth that are equivalent to those of the best terrestrial forests. On the other hand, under less favourable conditions, such as high soil salinity or arid climates, rates of primary production and growth are generally somewhat less. There are approximately 60 species of mangroves World-wide. About 45 of these occur in the South-east Asian/Western Pacific region, commonly referred to as the New World. The Old World region of Central and South America has 45-species, while there are about 10–12 species of Africa and Arabia. Asia and the Western Pacific are thus rich in terms of mangrove flora.

In addition to differences in species richness between major continental regions, their is also a marked reduction in the number of species with increasing latitude. Thus, while there are about 35 species on the North-eastern tip of Cape York Peninsula, only 4–5 species of mangrove occur near Brisbane, reducing to a solitary species, *Avicennia marina,* at the Southernmost limit of distribution of mangroves at Corner Inlet on the Southern coastline of mainland Australia. There is a similar reduction in the number of species with increasing latitude in the Northern hemisphere.

Mangrove forests are important for a number of reasons :

1. Mangrove forests and estuaries are the primary nursery area for a number of commercially important shrimp, crab and fish species. They are also important nursery areas for other species which are themselves not used commercially, but which for, part of the food chain for commercial species offshore.
2. Mangrove vegetation stabilises shorelines and the banks of rivers and estuaries, providing them with some protection from tidal bores, ocean currents and storm surges.
3. In many countries of South-east Asia and the Pacific, mangroves are used commercially for the production of timber for building, firewood and charcoal. Experience has shown that when these activities are managed appropriately it is possible to derive timber products from mangrove forests without significant environmental degradation, and while maintaining their value as a nursery and source of food for commercial capture fisheries.

ENVIRONMENTAL AND ECOLOGICAL CONSTRAINTS

GEOMORPHIC SETTINGS

Mangroves are opportunistic colonisers of suitable habitats. Within each broad range of habitat settings, each species grows in areas where the topographic level, tidal inundation frequency and duration, and soil characteristics suit its ecological tolerances. For this reason it is common to find distinct zonation patterns in which each zone is dominated by one or two species. These zonation patterns may be aligned along gradients of topography from low to high Intertidal regions, as well as along gradients of salinity from river mouths to the upstream limit of salt intrusion or tidal influence.

A number of geomorphic settings for the development of mangrove vegetation have been recognised. These, however, can be generalised into three broad settings :

1. River-dominated settings, where the dominant influence is the influx of freshwater and sedimentary materials from upland catchments. This setting is often characterised by the presence of extensive mangrove-dominated deltaic floodplains and mud-flats with a relatively small topographic gradient. Mangrove forests in this settings are often both extensive and exceptionally luxuriant owing to the influx of freshwater and nutrient rich silt.
2. Tide-dominated settings, where the dominant influence is largely that of regular tidal inundation with seawater of marine origin. Lack of freshwater influx in this type of setting, coupled with less extensive deltaic floodplain development, often restricts both the areal extent of mangroves and their rate of growth. As will be pointed out later, growth rate is much reduced due to high salinities.
3. Carbonate settings, where mangroves occur on coral rubble from former coral reefs, or on calcareous sands of marine origin. These environments, which are quite common in small island countries of the Western Pacific, are generally low in nutrients, lack significant freshwater influx, and may be exposed to onshore waves and other high-energy natural phenomena. In consequence, mangrove vegetation in this setting is often depauperate in terms of species diversity, and generally has a comparatively low rate of growth.

TOPOGRAPHY

As indicated above, many mangrove areas show quite distinct zonation patterns, where species are zoned according to their tolerance to soil type, water content, salinity, soil type, tidal frequency and amplitude, and perhaps many other soil factors. Many of thee soil characteristics are determined by topographic level and tidal range. Some mangroves, such a Ceriops, Heritiera, Lumnitzera for example, show a clear preference for the mid to upper tidal range; others, such as Rhizophora and *Sonneratia,* show a clear preference for the lower Intertidal range. One genus, *Avicennia,* appears to be well adapted to both the low Intertidal and high Intertidal regions, but is generally absent from mid-Intertidal regions. While biotic factors such as predation by crabs might explain some zonation patterns, there is nevertheless clear evidence that the frequency and duration of tidal inundation is a major factor determining zonation patterns.

In areas where tidal amplitude is large (> 4 m) and the shoreline is steeply sloped, mangrove areas are often contracted to a narrow fringe close to the upper tidal limit.

SOIL FACTORS

Salinity and water content are probably the two key soil factors influencing zonation, patterns. Both of these properties are influenced by the geomorphic, setting, the physical composition of the soil, tidal frequency and amplitude. Each species of mangrove appears to have an ecological amplitude that is dictated to a major extent by the interaction of soil water content and soil salinity. As will be clear later, a change in relative sea level will change tidal inundation patterns, which in turn would be expected to lead to landward shift in present zonation patterns.

CLIMATIC FACTORS

Light, temperature and aridity appear to be the most important climatic parameters influencing mangrove growth and geographic distribution. As pointed out earlier, there is a marked reduction in the number of species with increasing latitude. This appears to be associated with a corresponding decrease in air and sea surface temperature with increasing latitude. However, the physiological basis for the apparent inability of most species to withstand moderately low temperatures is not understood. Moreover, no species of mangroves can withstand persistent forest.

Apart from the apparent effect of temperature on geographical distribution, all these climatic factors (i.e, light, temperature and aridity) have a profound effect on growth. Their effect is largely at the canopy level, where they interact to influence the water and carbon balance of mangroves. In general terms, cloudy overcast conditions, coupled with moderate to low salinities, are most advantageous for the growth of mangroves. In arid climates or in monsoonal climates where the monsoon is strongly seasonal, growth is much reduced by climatic conditions which promote excessive water loss and hence water stress in mangrove trees. This problem is further exacerbated by high soil salinity, which effectively makes it more difficult for the trees to take up water.

IMPACTS OF EXPECTED GLOBAL CHANGES

CHANGE IN RELATIVE SEA LEVEL

Coastlines in many parts of the World are unstable because of tectonic activity and isostatic adjustment. Changes in sea level must therefore be considered in terms relative to any such shifts in coastal topography as a result of continuing geological activity. The notion of absolute changes in sea level globally is therefore misleading, and is more appropriate to talk in terms of relative sea level change.

Relative seal level has shown marked changes over the last 200,000 to 250,000 years. Globally, sea level is thought to have been 120–130 m below present levels as recently as 10,000 years BP (before present). Since then there has been a relatively rapid rise to more or less the present level. Most evidence suggests that sea level in the Western Pacific has in fact fallen by 1–1.2 m in the last 2000 years, but has continued to rise by few cm in the Atlantic. These apparent differences in past relative sea level changes between the Atlantic and Pacific oceans suggest that future changes in relative sea level will similarly not be globally uniform.

Based on evidence from cores of mangrove peat taken along the coast of Florida, Northern Australia and Western Pacific islands like Fiji, Ponape, Western Samoa and Tonga. Ellison and Stoddart (1991) conclude that mangroves :

(a). can keep pace with a relative sea level rise of 8–9 cm/100 years,

(b). are under stress with a relative seal level rise of 9–12 cm/100 years, and

(c). cannot persist as expansive areas with a relative sea level rise of >12 cm/100 years.

On the other hand, most predictions suggest that future rises in relative sea level will be of the order of 100–200 cm/100 years.

These conclusions suggest significant contraction of mangrove areas in response to predicted rises in relative sea level as a result of global warming. However, the most compelling evidence to support these conclusions comes from low island countries in the Western Pacific, where mangroves are already restricted in area by coastal topography and tidal amplitude. Such systems are mainly, but not exclusively, the carbonate and tide-dominated geomorphic settings of Woodroffe (1990). The situation may well be much different in river-dominated systems where large gently sloping deltaic areas are formed by river-borne silt. Here the topography is such that landward migration of mangroves, coupled with accretion of sediment on deltaic flats, might more of less keep pace with rising sea level. The extensive mangrove systems of the Gulf of Papua and the Sundarbans in the Bay of Bengal, are examples of river-dominated systems where relative sea level may rise less owing to the influx of large amount of silt. This raises a second issue that whether mangroves can adjust to rapid accretion. There is little information on his aspect of mangrove ecology, but circumstantial evidence suggests that mangroves can cope with accretion rates of the order of 10 cm/100 years, albeit with some change in community structure and species composition.

EPISODIC EVENTS

Most predictions of future global change indicate an increase in the frequency and intensity of episodic cyclones, hurricanes, storms and floods. Furthermore, these episodic events are likely to extend their influence further South in the Southern hemisphere and further North in the Northern hemisphere. While mangroves do provide a protective buffer that minimises the impact of sever storms on coastal regions, such events inevitably cause some destruction of mangroves and instability in mangrove areas. If predictions for future global climate are correct, it is likely that cyclones and other severe episodic climate events will have an increasing impact on mangrove ecosystems.

CLIMATIC CHANGES

Global climatic change is expected to lead to further rises in atmospheric CO_2 levels, and increase in temperature, increased UV radiation, and changes in rainfall pattern. These will probably not be uniform around the World. In particular, there is great uncertainty about which areas of the World are likely to become wetter or drier.

Mangroves, like most other tree species and most crop plants, use the C_3 biochemical pathway for photosynthesis. Studies with crop plants indicate that rising atmospheric CO_2 levels will result in increased growth, biomass production and commercial yield. Comparable studies with mangroves have not been done. However, based on our present understanding of mangrove physiology, it seems likely that higher atmospheric CO_2 concentrations will also lead potentially to higher rates of photosynthesis. Whether or not this will lead to a corresponding increase in growth rate is not yet clear. As pointed out earlier, mangroves seem to have adopted a strategy of minimising their water loss for a given amount of carbon gained in photosynthesis. This strategy is well suited to highly saline soils which place stress on the water balance of the plant. Thus it is possible that greater photosynthetic carbon fixation in response to elevated CO_2 levels will simply result in the use of less water rather than being translated into a corresponding increase in growth rate. The question of how to respond to a rise in CO_2 concentration and to temperature depends very much on whether rainfall increases or decreases. In general, it can be expected that increasing rainfall, and in particular increasing cloudiness, couples with decreasing salinity would favour increased rates of photosynthesis and more rapid growth.

An overall increase in global temperatures is also likely to lead to an increase in species migration polewards as temperatures at temperate latitudes reach levels that are suitable for those species that are presently restricted to latitudes closer to the equator.

MANAGEMENT IMPLICATIONS

As pointed out above, mangroves are now managed on a sustainable basis for a variety of timber and other products. Some countries have also gazetted green belts (of mangrove forest) along their coastal fringe as a buffer between land and sea and to maintain coastal capture fisheries. Options for management for mangrove areas will need to consider the impact of a possible rise in relative sea level on the long-term sustainability of present and future use of mangrove forests. In addition, it needs to be remembered that in many cases development of land behind mangrove areas will likely restrict the landward migration of mangroves in response to an increase in relative sea level.

MONITORING THE RESPONSE OF MANGROVES TO ENVIRONMENTAL CHANGE

UNESCO, UNEP and other UN agencies are now establishing a series of sites globally to monitor the possible impact of global change on mangrove ecosystems. Baseline information on topography, sedimentation rate, salinity, stand structure and growth will be monitored on a regular (probably annual or biennial) basis.

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BIOLOGICAL INVESTIGATION TO UNDERSTAND AND MITIGATE THE EFFECTS OF GLOBAL CHANGE AND SEA LEVEL RISE

S.N. DWIVEDI

INTRODUCTION

The climate change and global Sea Level Rise (SLR) apart from directly submerging some coastal areas is going to result in many ecological changes and these may pose a major pollution in coastal areas. In order to understand the implications, answers to following questions are needed:

1. What these changes are likely to be ?
2. How they are going to effect coastal areas and islands in the Pacific, Atlantic and the Indian Ocean ?
3. What action can be taken to combat and mitigate their adverse effects if such changes occur ?
4. What are the other likely changes - salt water incursion from sea towards land ?
5. How are biological resources and production rates going to be influenced ?
6. What are likely changes in the hydrology of estuaries and coastal lagoons ?

It is therefore necessary to understand the present state of art of coastal areas with reference to the biological aspects and design simple experiments which can be conducted on national and regional basis for understanding the changes and the manner in which they are likely to influence the ecosystems and suggest advance action to mitigate their adverse effects. The effects of these changes are likely to be felt intensely in developing countries and also in the small islands.

The developing countries at present do not have :

1. Enough S & T data to predict the levels of change,
2. Manpower and equipment to understand and define the associate changes which are likely to occur, e.g., ingress of salt water from sea towards land, erosion and accretion, supratidal areas suitable for plantation along beaches,
3. Infrastructural and scientific support for investigation in the area of marine sciences which help in the better definition of the above, demonstrate changes which may occur in different nations and region, and
4. Suggestions for S & T action for enhancement of preparedness to mitigate the adverse effects of global changes.

The impact of global warming will also increase the discharge of rivers. These rivers apart from water also transport a large amount of withered material in solution and in suspension. It has been estimated that the total river borne fluxes of suspended sediment is about 12 billion tons per annum in Bay of Bengal.

The water increase has bought about morphological and ecological changes which influence the biology and production of the Bay of Bengal. The countries influenced by these changes are India, Bangladesh, Burma and Thailand. Some of the changes which have occurred are :

1. Seasonal fluctuation in the hydrology of Hoogly Malta estuary, e.g.,

a. Discharge of fresh water into the estuary and associated change in salinity, temperature, transparence, dissolved and suspended matter in the estuary.

b. Changes in the expanse of estuarine region in the limits as defined by the salinity range O to 25%. Changes in such ecosystems based on range in the estuary namely

   - low salinity range (0.5 to 5%),
   - medium salinity range (5 to 15%), and
   - high Salinity range (15 to 25%).

The changes in the physico-chemical parameters would bring about changes in ecology, e.g.,

1. Change in the volumes of waste disposal and dispersal,
2. Decomposition of organic matter,
3. Changes in ecology of mangrove swamps caused due to changes in silt disposition, salinity, and survival of mangrove species and preponderance of mono specie populations,
4. Changes in productivity and distribution of production at different trophic levels, pelagic, column and demersal,
5. Species distribution and species diversity in the region, and
6. Identification and characterisation of mangroves which occur in low (0 to 5%) and high salinity (15 to 25%) ranges.

OBJECTIVES OF STUDYING EFFECTS OF GLOBAL CHANGES

To enhance competence to develop a model involving key interactions between geosphere and biosphere to enable prediction of long term changes at global, regional and national levels due to global warming and Sea Level Rise (SLR), following methodology is proposed :

1. In the marine ecosystems, the physical, chemical and biological process are in a state of continuous interaction and are influenced by changes in physical and chemical parameters of the ecosystems. The ecosystems are also influenced by the current and anticipated anthropogenic changes. This requires long-term series of global data and monitoring network to measure most sensitive parameters so as to standardise integrate analyses and document small changes that may occur in different ecosystems.
2. The data proposed to be collected should be carefully and accurately calibrated. The data and proposed models should be able to test the combined effect of natural and anthropogenic impacts. Therefore IGB programme has envisaged and understanding of couplings between biochemical process, physical and climate system.
3. The changes in physical and chemical parameters result in biological changes which have impact on the environment and influence animals and plants, their growth, survival, abundance and reproduction. Changes are also caused due to earth processes and these include long and short term changes in solar system like 11 to 22 year solar cycles (caused due to orbital changes) which bring about changes in solar radiation and photosynthesis on the globe. It is therefore necessary to adopt holistic approach for understanding nature of these variety of changes.

INTERACTIVE PROCESS IN TOTAL EARTH SYSTEM

As discussed, physical and chemical changes bring about biological changes in the environment which are nonlinear, e.g., growth under favorable circumstances may be exponential and that under unfavorable circumstances may be exponential and that under unfavorable circumstances, some populations may decrease suddenly or die out. Such changes have been recorded in some plankton and fish populations off California coast and off Peru due to *El-nino*. The changes in *El-nino* were caused due to changes in physico-chemical characters of the ecosystem in the open ocean and coastal waters.

These small changes become important if we consider magnitude of environmental changes which are likely to occur in next half century. The magnitude of these then changes could be of the same order as were experienced by earth's ecosystem since the glacial period (about 18,000 years ago). The plants and animals have survived in temperature and tropical latitudes for few million years, even though climate had warmed and cooled. They adapted both in numbers and in their geographical distribution. The climate change projected for the future may be beyond the experience of the biota and they may be unprecedented. Therefore the research considerations of International Geosphere Programme (IGP) under this theme are

1. Improving our understanding of interactive phenomena in the total earth system, and
2. Assessing the effects of global change that would cause largescale and important modifications that affect the availability of renewable and non-renewable resources.

LARGESCALE EFFECT OF GLOBAL CHANGES ON RENEWABLE RESOURCES

The International Geosphere Biosphere Programme (IGBP) is concerned with assessing the impact of climate change on biological resources and develop predictive capability to assess the natural resources that may be available for future generation.

The global change will influence temperature, rainfall, and wind pattern over continents and the oceans. The effects in different parts of the globe will be different and this will undergo regional and temporal variations. The global change, regional and local variations are inter-linked. However at regional and local level, local phenomenon, morphology, topography and hydrology and weather play a more important and dominant role. Hence partial and temporal variations and fine resolutions become important. Therefore holistic approach is recommended. Consideration must be given to study the areas given below:

1. Studying sensitive regions of rapid change, which may occur due to climate changes or exploitation and management, or anthropogenic activity. They are
   a. inland saline soils in semi-arid zones,
   b. near shore regions, bays, lagoons, backwaters, coastal lakes and coastal saline soil,
   c. estuaries, and deltaic regions, and
   d. use of improved knowledge technology and manpower capability to monitor and predict global changes.
2. Use of Aerial photography and satellite data for understanding changes in surface temperature of oceans, thermal fronts, zones of upwelling, coastal morphology, mangrove distribution, type and density, chlorophyll concentration, etc.

3. Data storage, documentation, analysis and interpretation to understand real time changes to develop predictive models for biological systems.

In these fields it is necessary to develop research capability. These fields are highly interdisciplinary and would need high degree of coordination in terms of organization, expertise and implementation. IGP has selected five interdisciplinary areas, out of these, the following two are of direct interest to use :

1. Marine Biosphere Ocean and Atmosphere interactions, and
2. Biosphere aspect of hydrological cycle.

MARINE BIOSPHERE AND ATMOSPHERE INTERACTIONS

Phytoplankton in euphotic zone in presence of solar radiation utilizes organic carbon from sea water through photosynthesis. About 90% of this carbon is transferred through the food chain in upper ocean layer. The rest 10% perhaps, with inorganic components of the skeleton of the organisms settle to the greater depths. In turn the CO_2 from the atmosphere replaces this carbon in the oceanic environment. This ocean is a large sink for CO_2. It has also indicated that the seasonal variation of carbon-di-oxide in the ocean is dominated by the territorial while the annually average trend of CO_2 to the atmosphere is a function of the marine process. Thus the role of oceans for contribution of CO_2 to the atmosphere is important and needs meticulous measurements. The rates of photosynthesis in the oceans are influenced by changes in the photosynthesis in euphotic zone and the species composition of the plankton.

The physical processes are responsible for water circulation, transport of nutrients from deep waters to sunlit surface waters. The sea level rise also has impact on circulation and transport of slit, nutrients and phytoplankton in coastal and estuarine environments. The character of coastal and estuarian water also changes due to eutrophication of coastal waters caused due to urbanisation, industrialisation, agriculture and other land use practices. The other contributory factors, sediments and dissolved nutrients, come pollutants through the river systems into the estuary and coastal waters. The sea level rise also effects coastal circulation, estuarine regime, wetland habitat and coastal saline soils and their use for agricultural crops. Therefore to study effects of SLR modelling of coastal and estuarine systems at global, regional and local levels are essential. Some of the river systems which need attention are Mississippi, Amazon, Nile, Niger, Mekong, Ganges, Brahmaputra, Indus, Euphrates-Tigrnia (Shat-el-Arab), Rhine, Danuabe, Volga, Yellow river and few other rivers (China). The Global programme also requires development of regional, national and local programmes to collect intercaliberated data through national programmes. The qualitative checked data should be intercaliberated and should be used to evolve models to suggest effective procedures to understand and deal with eh magnitude of the problem.

The global programmes should be composed of the regional and national programmes, which should be essentially study of the river basins, estuary, back water, low lying areas, mud-flats and supra tidal region. In a more comprehensive approach the integrated affect of weather changes should be studied for conservation and development of the coastal zone. Therefore the observation area may be divided into following zones and ecosystems.

ZONES AND ECOSYSTEMS FOR NATIONAL AND REGIONAL PROGRAMMES

1. Estuaries and deltas ;
2. Coastal water-bodies, back waters, lagoons and lakes ;
3. Mangroves ;
4. Coastal saline soils, wetlands; and marshes ;
5. Coastline - beaches and rock shores ;
6. Near shore area and EEC ;
7. Near shore area and EEZ ;
8. Island ecosystems ;
9. Threatened areas and 'Hot spots' for
   a. Erosion,
   b. Pollution,
   c. Flooding and submergence, and
   d. Silting and island formation;
10. Coral reefs.

BIOLOGICAL MEASURES TO COMBAT SEA LEVEL RISE AND MITIGATE ITS EFFECTS

RECLAMATION OF LAND THROUGH SILT TRAPS

Hoogly Malta is one of the biggest estuarine systems in the World. Weather Watch Research Institute, Washington has estimated that more than 12 billion tonnes of silt is discharged annually by this estuarine system over centuries, this silt has been deposited in the shape of Bengal fan. Some of the coastal areas near the Diamond harbour have also become shallower. Calcutta port also has problems relating to formation of sand bars and siltation. Dredging of Calcutta harbour is a recurring expenditure which is undertaken to maintain navigability of the system. Keeping in view the large amount of aloud which is available annually, it is proposed to undertake following programmes.

BRICK-MAKING AND ESTIMATION OF SUSTAINABLE YIELD FROM SELECTED AREAS

Traditionally, the local people have constructed 'Bheries' along the estuaries in which brick making is undertaken as an artisanal measure. This is a major source of material used for bricks. It is suggested to study these bricks so that they could be used in coastal areas for low cost housing. The constant removal of the silt would also require scientific studies to indicate the quantity of slit which can be deposited annually in the artificially created silt traps.

SILT TRAPS AND SILT BARRIERS

After the monsoon season, large quantities of silt are deposited in the supratidal region. However, on a regular basis this silt is used by the local people for domestic purposes.

Experiments conducted also indicate that if silt is collected in the selected areas, it results in raising of the land. Successive artificial barriers placed in an inclined plain help to arrest the slit but the water is slowly drained away. In this manner large low lying areas of depths less than half a meter can be reclaimed. It is therefore proposed to design experiments to undertake studies on the rate of siltation, the total silt deposited and the time which will be required for reclamation of 1 hectare area with an average depth of half a meter at the high tide level.

PLANTATION AND BEACH CONSERVATION

Supratidal regions are affected by storm, surges and cyclones and are generally devoid of any major vegetation. Extensive experiments have been conducted in Goa and Maharashtra along the West coast of India where it has been found that few trees can be grown in the sand itself. These are casuarina and few other shady trees. The scheme can also be operated under social forestry programme. It is, therefore, suggested to select suitable areas and undertake plantation of Casuarina and other selected varieties of trees and estimate the total production of biomass from these areas which are otherwise barren. It is also proposed to study the extent to which this social forestry project would help in making greater availability of fuel and reducing the adverse affect of winds during storm, surges and cyclones; the role they will play in protection of the small residential houses which would be located behind the social forestry belt.

RECLAMATION THROUGH FISHERY ESTATES

Traditionally, dykes and sea-walls are build to check erosion. In this process, it is suggested that the low lying mud-flats in swampy areas which lie in the vicinity of the estuarine region and coastal lakes can be reclaimed by construction of farms in semi-protected areas which extend upto half a meter depth. These areas are normally rich in prawn and fish larvae and with proper scientific inputs, they can be used for aquaculture purposes. The plantation of trees and coconuts are also useful for construction of 'Bands' and protection of the entire ecosystem. In this way, the coastal belt which is otherwise subject to storm surges and cyclones and in constantly eroded to a large extent can be reclaimed. The experiments conducted in the coastal districts of Andhra Pradesh have shown encouraging results. It is therefore proposed to select protected areas using them for short-term prawn and fish culture. Care should be taken that there are no major civil works. The process helps in raising the level of the land, land alignment and reshaping with the locally available material. Through this process even the areas which could be subjected to half a meter flooding can be checked to provide adequate conservation measures against erosion.

CONSERVATION OF COASTAL LAKES AND LAGOONS

Due to the continuous process of silting the coastal lakes become narrower and the entry of sea water becomes restricted. The examples are Chilka Lake in Orissa and Pulicat Lake in Tamil Nadu. It is suggested to study the ecology and coastal oceanography of these areas to ensure that the silting does not take place so that with the sea level rise the inundation and damage in the interior areas is avoided. The shallower areas adjoining the outer edge of these lakes can also be converted into fishery estates and large farming systems.

AQUACULTURE AND ECONOMICS OF LOCALLY AVAILABLE CULTIVABLE FISH

It is well known that the aquaculture of prawn is very productive and is being traditionally undertaken in West Bengal and Orissa. However, information on aquaculture of fishes like *Etroplus suratensis* are available locally and breeding in confinement can be used for this propose in a closed cycle. It would be useful to study the production cycle, economics and its adoption by the local fishermen. The intention of undertaking fish aquaculture in these areas is to develop a new system by which the local community will be encouraged to reclaim the low lying areas, raise their 'Bands' more than one meter and undertake plantation on these areas. In this way large areas of the coastline which get inundated can be prepared for combating the projected seas level rise.

CORAL REEFS IN THE ISLAND ECOSYSTEM

A small state conference was conducted in Maldives between 14 and 18 November, 1989 in which the question of the history of coral reefs and rate of the fast growing corals was discussed. It has been seen that the coral belts can be grown at different speeds and the breaching corals can be grown upto 12 cm per year. Studies on coral reef ecosystems have been undertaken both in Lakshadweep and Andaman group of islands. In the recent past similar studies have also been suggested in Maldives. It is therefore, suggested to plan artificial colonies of branching corals and study their growth rates. If the projected level of sea level rise by the year 2015 is less than half a metre than it is possible, with the help of proper planning and implementation, to grow artificial coral reefs in the vicinity of islands to combat the adverse effects of sea level rise. This appears to be one of the promising areas by which isolated corals can be saved from submergence due to projected sea level rise.

MANGROVE ECOSYSTEMS

Due to the projected sea level rise, changes are being caused in the mangrove swamps of Sunderbans. In some areas, mangroves have died out while In other areas mangrove swamps have become more saline and the composition of species of both fauna and flora is changing. It is therefore proposed to study the ecology of mangroves of various salinity levels-low, medium and high. In these areas it is proposed to study the physicochemical conditions, productivity of benthos, phyto and zooplankton, availability of juveniles of prawns and fish and use them for growing. In addition, it is also proposed to study the role of different kinds of ecosystems, for the kind of species they will support for breeding and reproduction, as nursery grounds and as habitat for growing adult fish.

MANGROVES AND BIOMASS PRODUCTION

Colonisation of mangrove trees is a very well known phenomenon. The composition of the mangrove species change with the depth, salinity, wave action, Intertidal exposure etc. Large areas which were earlier occupied by Rhizophora were later occupied by Avicennia or Acanthus species. It is therefore proposed to study the zonation and biomass production of different mangrove species so that may be used for plantation in the marshy land and backwaters. The studies will also help in estimating the regenerating capacity of the mangroves and other foliage which could be used by local population which live under different conditions.

PLANTATION AND CULTIVATION OF MANGROVES

Mangroves are slow growing species and young ones only grow under most favorable conditions. The experiments conducted during the last decade have led to the development of nursery of mangroves in which various species of mangroves have been growing successfully. it is suggested to undertake three pilot projects to determine the social forestry use of mangroves. The mangroves help in increasing the silt load and detritus and combating the adverse effects of sea level rise.

EFFECT OF POLLUTANTS ON AQUATIC ENVIRONMENT

Impact of Sea Level Rise on waste disposal and the aquatic environment are subjected to various pollutants due to discharge of sewage through municipal drainage system which contains domestic waste, storm water and surface run-out, industrial discharge of effluent and oil discharge during tanker traffic, oil explorations, presence of pipelines submerged in water etc.

ECOSYSTEM EFFECTS

Sewage discharge large amount of turbidity including heavy and trace metals into aquatic environment. Turbidity depresses phytoplankton production and benthic environment is altered by sedimentation. On the periphery, the effect is usually that of enhancement of biological communities by the addition of organic and inorganic nutrients. If the discharge through the pipeline is on the shore, the growth of sea weeds and Intertidal animal species adapted to high nutrient levels may be encouraged. Such enhancement of limited group of species is an important effect of sewage input which disturbs the energy transfer through food webs which ultimately leads to reduction in species diversity. However, treated sewage from a properly designed and well positioned outfalls is unlikely to have significant detrimental effect over a long range.

EFFECT ON HUMAN LIFE

Sewage discharge on the beaches and in shallow water is likely to cause an offensive odour and as a result deterioration in amenities including possible health effects. Such discharges will result in a continuous flow of pathogenic bacteria, viruses and parasites into coastal waters around urban regions. These organisms can survive for a long time and as a result can get attached to bottom organisms. Where drainage systems are ineffective, feces may be deposited directly on the beach which results in infection to several human beings. Recent investigations have proved that bathing in such contaminated water can result in diseases. Also consumption of fish and shell fish harvested from sewage contaminated water can cause bacterial and viral infection.

EFFECT OF ORGANOCHLORINES

PCBs consist of a large number of homologous and isomers and chlorinated biphenyls. For fish and other marine organisms the acute toxicity is higher for mixture with a low chlorine content and there is also a cumulative effect. Fishes are more sensitive in the early stages of life and the sample applies to marine invertebrates which are, as adults more sensitive than fish.

Since man is one of the species most susceptible to PCBs, residues in marine organisms used as food could represent a public health problem.

DDT has been detected in rain-water, in Antarctic snow and in soils and lakes. Like PCBs, DDT is transported in the atmosphere and in water courses. It cycles in the food web and can be magnified in certain food chains. The concentration of DDT in living organisms may be the result of absorption from water. Marine organisms show large differences in sensitivities to DDT. Thus for zooplankton, the lethal concentration starts at 0.01 mg/1; for fish, 0.1 mg/l is toxic. Phytoplankton, crustaceans and molluscs are affected by concentrations above 1.0 mg/1.

Marine organisms also absorb oil. The toxicity is largely associated with the aromatic hydrocarbon content of the oil, although for some organisms, the non-hydrocarbon components are not toxic. In addition to their acute toxic effects on marine life, crude and refined oils affects marine organisms at concentrations the do not result immediately in death. The oil slicks at sea kill or adversely affect zoo-plankton, including totally planktonic species like Copepods, as well as the planktonic eggs large of fish and benthic invertebrates.

CONCLUSION

It is therefore necessary that the impact of projected Sea Level Rise should be studied to understand the impact or changes in coastal circulation on availability of dilution factor, direction of dispersal, bioaccumulation and benthic changes. The experimental sites should be selected near large coastal metropolitan cities and near industrial outfalls. Further, the experiments should be conducted in temperature and tropical oceans and included in the national programmes of different countries. They should be then studied to design general predictive models to evolve guidelines for protection of waste disposal points to minimise effects against Sea Level Rise.

CARBON DIOXIDE BUDGET AND RESEARCH PROJECT

The changes in Sea Level Rise are likely to influence the total carbon budget. In carbon budget the ocean plays a major role because 70% of the earth's surface is covered by water in which photosysthesis takes place on a continuous basis. The earlier studies conducted for evaluation of chlorophyll has shown regional differences in different oceans. Apart from the regional differences the seasonal differences and inter annual variations are also important. The work done in the Indian ocean has shown that the upwelling occurring along the South-west Coast of Indian results in intensive production of phytoplankton. This in turn alters the food chain. In center in cases when the conditions are more favourable, plankton blooms occur. The plankton blooms have been reported along the West cost of India from early part of 19th century. The problem is also receiving international attention and IOC has constituted a sub-group to develop standard methods of estimation to assess the phytoplankton blooms and their intensity. These blooms apart from having toxic effect on other organisms, also contribute for consumption of oxygen and production of carbon dioxide during the sunlight, the process is reversed in darkness. It has been estimated that there is an extra production of 3 million tons of carbon dioxide from the atmosphere. It is therefore necessary that while estimates are being made regarding production of excess carbon dioxide in the atmosphere, the role played by plankton in oceans for production of oxygen is also estimated.

The earlier studies conducted in the Indian Ocean had estimated the phytoplankton production based on total organic carbon, at 11 million tons of tertiary crop. It is, therefore, necessary that on a continuing basis, experiments should be designed to estimate chlorophyll estimation with reference to carbon dioxide budget. The change in the topical ocean are more rapid and variation are large. A comparative study at three or four centres should be undertaken in the Indian ocean.

It is therefore suggested, to undertake experiments to determine the rates of production of chlorophyll with reference to carbon dioxide budget in different oceanic areas also.

REMOTE SENSING AND SEA LEVEL RISE

Sea Level Rise (SLR) is a slow phenomena, and its impact is gradual. It needs long term and precise observations to understand and predict likely changes that may occur along the coasts of the continents and islands. These impacts of SLR are global in nature but they undergo annual, regional and local variations. They are influenced by the coastal morphology and rainfall particularly in the countries situated in the monsoon belt in Asia.

COASTAL MORPHOLOGY

Due to coastal process, hydrography and currents, the continental margins, estuaries and island undergo seasonal and long terms fluctuations. The occurrence and disappearance of sand bars is caused due to silt movement. It influences closing and opening of the mouths of the estuaries and the coastal lakes and changes the hydrology and biological character of the area. Therefore, it is necessary to study the morphology of the coastal margins, estuaries, coastal lakes, backwaters and lagoons and understand seasonal and annual variations.

The discharge of sewage and organic wastes in estuaries undergo quantitative changes. In many parts the estuaries get connected to ow lying coastal plains, mud-flat, marshes and pollute them, thus large areas become unfit for development. In these areas production of organic debris and detritus is a continuous process. The dispersal and decomposition of detritus and silt depends on coastal currents. Such areas are abundant near Bangkok, Calcutta, Bombay and in Shat-al-Arab in Iraq and are vulnerable to SLR.

MONSOON AND FLOODS

In the delta and estuaries of rivers like Mekong in Thailand, Brahmaputra in Bangladesh, Ganges and Godavari in India and Indus in Pakistan, flooding is almost an annual feature and loss of human life and damage to property in coastal areas occurs frequently. On the other hand the coastal line in the tropical countries is a preferred area, these regions are more productive and have a moderate climate and encourages fast development consequently large metropolitan cities are located in this zone. The coastline is being reclaimed and modified continuously. The cost of development and density of population is very high, therefore if these areas get submerged due to climate change the loss will be very extensive.

The flooding causes changes in the patterns of silt deposition, hydrography, rate of flow and mixing of estuarine waters. Consequently, changes on biology, productivity, diversity of fauna and flora,reproduction and population are caused. It is necessary to develop a comprehensive long-term monitoring system using remote sensing, and satellite imagery supported by aerial photography, photo interpretation and verification by the ground truths to study these areas. The ground truth, requires continuous data updating, data comparison, preparation of charts to catalogue annual changes. The study of long-term changes will help in following areas :

1. Mangroves : Mapping of mangroves areas and identification of major types and diversity. *Rhizophora, Avicennia* and *Achanthas,* different patterns due to foliage, height interconnecting water channels, cause major changes in the area of mangrove coverage and determine ecological changes including continuance or disappearance of the mangrove vegetation.
2. Reclamation, and illegal human settlements.
3. Plantations and social forestry along supratidal region, beaches and bays. (helps to check effect of strong winds caused due to cyclones).
4. Delineation of areas suitable for sewage and industrial outfalls. Monitoring discharged points and their dispersion, e.g., thermal plumes (the thermal plumes cause temperature rise and influence species composition, create single species complex and growth of weeds).
5. Identification of saline areas which have become unsuitable for agriculture, and shallow water areas which become weed-infested (these processes result in meandering of estuaries. The examples are yellow river in China and Brahmaputra in Bangladesh, etc.).
6. Identification of sea surface temperature, thermal fronts and areas of high productivity. The biological productivity is highly diversified and is a continuous changing parameter. However, on annual and long-term basis they depict certain patterns. The recent advances in the remote sensing technology can help in chartering the sea surface temperature distribution, thermal fronts and lead to understanding the productivity of oceans. The generation of scientific data on long term helps to predict changes in biological production and Carbon dioxide budget).

These process are also linked to *El-nino* phenomenon, the occurrence of which indicates largescale changes in climate. It is therefore necessary to develop experiments for monitoring sea surface temperature, sea fronts, chlorophyll estimation and measurement of solar radiation on ocean surface. These experiments have to be designed for regional seas and for the national programmes to cover bays, backwaters, low lying marshes and estuaries.

GENE AND GENETIC CONSERVATION

V. ARUNACHALAM

Conservation is an important component of any programme on biodiversity. While its importance is generally appreciated, the methods and the options open for conservation are increasing. Major questions that need and often defy answers are :

1. what to preserve—gene, genotype, complexes or all?
2. How much to preserve—in terms of importance and size, in terms of space, cost-benefit ratio?
3. How often to renew genetic resources from seeds, tissue cultures and the like, and how to evaluate them for the integrity of the original variability?
4. What kinds of samples and sample sizes that must be considered? While we do not attempt elaborate answers to these questions, we shall look at them from the basic principles and logic behind conservation.

In principle, genes governing rare and important traits and genotypes with co-adapted gene complexes giving rise to desired traits merit conservation. The expression of desired traits can, more often, be site—or environment-dependent. Such genotypes need to be conserved *in situ*, and at the same time it would bee preferable to assess alternate methods of preservation (*in vitro, in vivo,* seed) to account for unforeseen ecological (site) degradation. An important follow-up activity would then be to site-test the material thus preserved to evaluate the integrity of their variability. In the process of field evaluation, especially in the case of complete and partial outbreeders, new genetic variability is created quickly unless pollination is entirely controlled. Most often, maintenance of the stocks by self-pollination creates problems of inbreeding depression; sibbing on the other hand, entails a slow insertion of new variability in addition to loss of heterozygosity. For instance, in a single diallelic gene, the rate of loss of heterozygosity under sibbing is 75% by the fifth generation, while under selfing the loss is much higher, equal to 97% (Table 1).

Table 1 Rate of decay of heterozygosity in a single diallelic gene under selfing and full sib-mating

	Heterozygosity	
Generation	Selfing	Full sibbing
0	1	1
1	1/2	1/2
2	1/4	2/4
3	1/8	3/8
4	1/16	5/16
5	1/32	8/32
10	1/1024	89/1024
20	1/2020	$10946/2^{20}$

However, when many genes are considered, sib-mating will promote higher recombination leading to fresh variability also. When several such accessions are grown in adjacent strips for maintenance, their genetic distinctness may be lost. It is then necessary to decide whether it would be desirable to maintain gene complexes and populations to ensure maintenance of allelic frequencies. The sole purpose of conservation of genetic variability is its immediate or near-distant utility in maintaining biodiversity. It is not always feasible to add on to the number of accessions to be maintained for their possible use in posterity. Thus it warrants a strong justification in terms of probable utility value of an accession before a gene bank commits resources for the maintenance of such material (Holden, 1984). This would imply the need for an effective evaluation of germplasm collections to identify the traits (genes) that may be of utility.

SAMPLING PROCEDURE: SOME BASIC CONSIDERATIONS

Approaches of genetic conservation permitting the collection of the maximum amount of genetically useful variability in the target species while confining to minimum number of samples to be conserved were outlined by Marshall and Brown (1975). Of the various measures of genetic diversity considered, the frequency of alleles in the target species is found to be most useful, since at least one copy of each of the different alleles in the target species needs conservation (Bennett, 1970). But in many cases there is need to conserve adaptive gene complexes instead of single genes. However, in experimental or natural populations, it is impossible to study single loci independently of closely linked ones. Further, co-adapted gene complexes can be regarded as 'alleles' at a 'super gene' and sampling strategies for them are not far different from those for alleles at a single locus. Based on the theoretical model of Kumura and Crow (1964, 1970), the number of neutral alleles is usually two to four pre locus in intermediate to high frequency (greater than 0.05), the others being rare. When an overdominance model in which heterozygote is the fittest (fitness = 1) and homozygotes have an equal selective disadvantage = s (fitness = 1–2) is considered, it is observed that overdominance (s greater than 0) substantially increases the effective number of alleles over neutrality (s = 0). But a look at the distribution of alleles in natural populations of *Avena barbata* for example, indicates that there were usually only two alleles per polymorphic locus occurring in intermediate frequencies (Clegg and Allard, 1972). From these studies, it is possible to consider two classes of alleles in populations—those which are common (probability of allele greater than 0.05; usually four alleles) and those which are rare (probability of allele less than 0.05; many alleles). A third class of alleles are those which are locally common and are important from the point of view of sampling.

Optimum sampling strategy is one which aims to retrieve variability using optimum sample sizes. Optimum sample size per site can be defined as the number of plants required to obtain, with 95% certainty, all the alleles at a random locus occurring in the target population with a frequency greater than 0.05 (Oka, 1969; Marshall and Brown, 1975). An optimum sampling area is best left to the explorer at the time of collection.

Optimum sample sizes can be better defined when some information on the distribution of alleles in the target species is known. But in several cases this information many be unavailable. Marshall and Brown (1975) have considered both the situations in obtaining optimum sizes.

When no prior information on target species is available, they examined the sample sizes required for five contrasting models of allelic profiles using the expression (Moran, 1968) for the probability that a random sample of n gametes would contain at least one copy of each allele. A safe conclusion is that a random sample of size 50 to 100 will be more than adequate under most circumstances. The number of populations or sites to be sampled will be determined by various factors such as the length of collecting season, relative abundance of target species, roughness of terrain, and so on. However, under ideal conditions this limit can be as high as 1000 per season, although in most cases it will be considerably less (Allard, 1970; Bennett, 1970).

When information on levels of variation within and between populations of target species is available, the fraction of the total genetic variation in the target area captured by a particular sampling procedure is obtained using the formula due to Oka (1969). The number of populations or sites to be sampled and the number of plants (or seeds) sampled per site are extrapolated for the sampling procedure. A careful consideration of various values of relevant parameters estimated for various crops, suggests an adequate sample of a size of about 50 plants per population, in contrast to 200 to 300 plants suggested by Bennett (1970) and Allard (1970). As far as sites are concerned, the best strategy is to sample as many as possible within the available time, ensuring that they represent as broad a range of environments as possible (Marshall and Brown, 1975).

It would thus be seen that resource- and time-efficient strategies neither demand growing a large number of plants per accession nor suggest maintenance of germplasm complexes when genetic distinctness is lost. In general, a progeny size of 25 to 50 per accession appears to be adequate in most of the situations encountered in conservation programmes. Proper management at rejuvenation time can lessen the effects of natural selection and an appropriate mating system (like the biparental mating) coupled with maintenance of equal progeny sizes. Every generation will help to maintain even rare alleles (as found to occur in normal populations) over at least five to ten generations.

MOLECULAR MARKERS IN IDENTIFYING GENETIC DIVERSITY FOR CONSERVATION

Molecular methods are now used for genetic differentiation. In particular, through Restriction Fragment Length Polymorphism (RFLP) technique, one or more molecular markers can be located and used to differentiate between genetic accessories. In general, the restriction fragments are small in size, ranging from 4 to 8 base pairs, and do not code for a gene. As such they do not express phenotypically. However, substantial global research efforts are on to discover such RFLP markers as are closely linked to Quantitative Trait Loci (QTL). For instance, such linkages have been reported in tomato (Paterson *et al.*, 1991).

Despite various advantages reported in favour (see Beckmann and Soller, 1986), the utility of RFLP markers in identifying real genetic variability in accessions may not be above questioning. An analysis of the underlying logic will bring the picture to a sharp focus. Let us consider, for example, 25 accessions of a crop. They are usually grown in a site and a number of phenotypic attributes is measured. The extent of genetic divergence among them can be studied by the methods described earlier. Accessions not differing statistically in the values of most of the traits qualify to be declared as duplicates, in which case a decision is made to maintain them as a single accession complex. We note that decisions result from a phenotypic evaluation. A few component operations need careful scrutiny and analysis in *in situ* conservation of plant species.

ABUNDANCE OF SPECIES

When the number of species is high in frequency with relatively fewer number of individuals per species, conservation concepts need critical examination. If the species as a whole is looked at as a unit for conservation, the future of the species is secure (conservation of *inter-specific* variation). But intra-specific variation, equally important for survival of a particular species against ecological imbalances, also needs conservation. Then sampling schemes need to be carefully chosen so as to prevent extinction due to low population sizes within species.

DECISION-MAKING

Decisions are functions of the magnitude of information and the number of populations from which such information is gathered. It is hence essential to identify the minimum population size and their habitant areas for gathering relevant information. Once decisions are taken, it is equally important to identify appropriate ecosystems for conserving target populations.

POTENTIAL BOUNDARIES OF RESOURCES

It is essential to be sure whether the resources need to be conserved on large contiguous or small natural areas. The former has advantages in the context of maintenance, but mechanisms should be evolved to fill existing gaps in plantations so as to provide continuity. This effort may entail problems of matching natural conservation of existing plantations with the artificially planted new ones. Most important is to avoid unhealthy competition and the suppression of growth of one over the other. Such problems are avoided by using small natural areas, but if they are too sparse and separated by long distances, some of them would be exposed to dangers of extinction. Therefore the ground situation has to be carefully assessed in relation to the material requiring conservation.

MANAGEMENT FACTORS

When mangrove forests are under the care of Government forest departments, prevention of destructive logging by the marginal populations around needs legislative measures which have intricate problems associated with, for example, programmes of tribal welfare and so on. At least compromise plans have to be developed to minimise such acts as destructive logging, which, for example, programmes of tribal welfare and so on. At least compromise plans have to be developed to minimise such acts as destructive logging, which in the long run, can succeed.

ADAPTIVE RESPONSE

To incorporate general adaptation to dynamic environments, it is essential to preserve high genetic diversity. This would be possible only if resort can be made to both *in situ* and *ex situ* conservation strategies.

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UNDERSTANDING GENETIC DIVERSITY IN MANGROVES

SAKTI JANA AND SANJAY DESHMUKH

INTRODUCTION

The mangroves are one of the unique plant communities growing in the Intertidal zones of estuarine regions in the tropical belt of the World. The main tree flora of mangroves consists of highly specialised plant species, well-adapted to the unique conditions of sea water inundation during high tides throughout the year and nearly fresh water conditions during monsoon. Like most of the other genetic resources connected with agriculture and forestry, the mangrove resources are also dwindling - yielding to population pressure, leading to disappearance of many virgin mangrove areas from the coastal regions.

To preserve and protect a growing mangrove population, both genetical and ecological studies are required. Data on the reproductive biology and population genetics of mangrove species are lacking since little or no experimental research has been done on these systems. A basic understanding on those aspects is a prerequisite for any genetic conservation programme. Traditional identification of mangrove species were based on the morphological traits that required extensive observations of mature plants which, in many instances lacks definition and objectively. Furthermore, they can not serve as unambiguous markers because of environmental influences. On the contrary, DNA as also markers provide much higher degree of polymorphism and stability. It is therefore important to study the genetic diversity among mangroves with a combined approach of field and laboratory studies.

GENETIC DIVERSITY

The diversity in a mangrove system has two components, namely (a) species diversity, and (b) genetic diversity within species. These two components are closely intertwined and inseparable. For example, *Avicennia* is present on firmer, exposed seaward side, while *Sonneratia* is in soft, rich much along sheltered river mouths and *Ceriops decandra* is in the sheltered coast. However, *Bruguiera* exists in varied conditions and the same is true for *Rhizophora. Rhizophora mucronata* is abundant in sandy, firmer bottoms and also regions of low tide areas bordering the vegetation, while *R. apiculata* is found in the banks of tidal coasts.

In Mangroves, biological diversity is linked with environmental diversity in a specific pattern. Therefore diversity analysis means pattern analysis and its genetic basis. The components of diversity in any geographical regions are: (a) regional diversity, (b) ecosystem diversity, (c) species diversity, and (d) genetic diversity.

The interesting characteristic of the system is that only a few genera and specific species with convergent adaptation to the group of selection forces are present all over the tropical and sub-tropical estuarine tidal regions of the World.

This living together as a community subject to continuous changes are slicing, colonising and erosion in the seaward side or change of rise in the tides and drainage on the landward side is another feature to be considered. Other important features are the aerial roots, vivipary and new colonies and incipient islands in shallow water which may survive or become extinct over a period of time. The composition of the vegetation is low to medium in tall tress, shrubs and salt marsh herbs.

Mangroves are mostly outbreeders, sexually propagated and with diversity of floral biology, pollination and breeding mechanisms. In such an environment with diurnal and seasonal fluctuations in physical variables, and the patterns of convergent adaptation, make mangroves an ideal material for geneticists both from evolutionary and conservation points of view, and for formulating policy for monitoring and controlling changes. Towards this goal, exploration, collection, evaluation and mobilisation should be based on genetic analysis and conservation of genetic diversity.

VARIABLES INFLUENCING COMPOSITION OF MANGROVE SPECIES

Some of environmental factors affecting mangrove forests are soil type, salinity, duration and frequency of inundation, accretion of substratum strength of tides, exposure/shelter -exploitation by man and interaction of all the above factors. The presence of gradients of environment influences the distribution, zonation and succession of mangrove species and reflect the type of natural selection in progress.

For example, the effect of salt accumulation and organic debris in seen in Niger River delta on the following gradients in the swamp.

Mangrove swamp ⟶ Fresnwater swamp ⟶ Ordinary low-land

The factors influencing responses to physical variables, e.g., flood and inundation area properties of flood water, duration of inundation, which in turn affect the species and genetic composition and age of community.

Some examples of biological responses to flooding are:

a. seed germination, seedling establishment,
b. shoot growth, root and leaf growth,
c. cambial growth,
d. rooting, distribution, root regeneration,
e. biomass and dry weight character,
f. morphological characters, and
g. mortality.

GENETIC FEATURES OF MANGROVES

Some interesting genetic features of mangroves are:

1. They are natural populations with common and few genera with special convergent adaptation and specific delicate ecological requirements for their maintenance,
2. Rich diversity of species and several ecological niches even in the same location are of interest,

3. The gradients of environments provide continuity of gene flow,
4. Fluctuations of environment (daily, seasonal, interactions of seawater, silt, river flow, effect on migration and seedling dispersal),
5. The effect of human activity near or in upper reaches, can alter sedimentation rates and change of habitat resulting in major ecological changes. The discharge of wastes and unplanned destructions can further degenerate the system, and
6. The overlapping of generations, long generation interval, vivipary, migration and species composition changes over seasons and heterozygosity requires more complex analysis of the genetic structure of the changing populations.

GENETIC VARIATION

The major factors of genetic variation in any biological system are:

a. mutation,
b. selection (natural or human),
c. migration, and
d. genetic drift.

The effect of fluctuating environment adds to the complexity. The additional selection forces in mangroves which need careful study are:

1. Overlapping of generation and degree of differences in diversity between age groups,
2. Ploidy, breeding behaviour (variety of breeding structures asexual, temporal isolation, reproductive potential changes over seasons/age groups), and
3. Fluctuating environment and diversity of gradients of soil, water and tidal effects, etc.

PARAMETERS OF PATTERNS OF GENETIC VARIATION

Parameters of patterns of genetic variation are:

1. Proportion of between and within population variances for single variables, and groups of variables,
2. Level of heterozygosity,
3. Allelic frequencies at individual polymorphic loci, and
4. Correlated changes in linked loci. All the above-mentioned parameters are influenced by population structure.

POPULATION STRUCTURE

Population structure is the totality of ecological, and genetic relationships among member individuals and subdivisions of a biological species complex. It varies over time and requires a multivariate approach. Biological and environmental factors influence population structure. Monitoring population structure and relating it to the effect of environmental changes and study of evolutionary changes are important to genetically characterise each ecosystem.

The factors influencing population structure are:

1. Mode of reproduction (sexual, asexual changes in out-crossing),
2. Patterns of distribution (kind and variety of habitats and communities),
3. Inter- and intra-specific hybridisation (rates of gene flow - effect of environmental disturbance),
4. Recombinations system (meiotic),
5. Generation length, life cycle components, survival, population density (reproductive rates, population growth and size),
6. Local dispersion and gene flow,
7. Nature of genetic variation (polymorphism, percentage heterozygosity and frequency of linked loci),
8. Environmental heterogeneity variation over space and time, and
9. Phenotypic plasticity, genetic vs non-genetic variation.

The advantages and disadvantages from the point of view of an ecologist for applying the principles of genetics for the preservation of genetic diversity in mangroves can be summarised as follows:

Table 1 Assessment of mangrove forest genetic resources: advantages and disadvantages

Advantages	Disadvantages
1. Long life cycle, natural population, slow evolution	1. There are very few/and no records of the nature of origin/ propagation method and limited diversity founder populations.
2. Possible to conserve *in situ*, easy resampling and regeneration facilities	2. Scanty information on taxonomy, bio-geography, phenology of species
3. Vegetative propagation possible for resampling and/or in case of non-availability of seed material	3. Sparse populations of some mangrove species require sampling modifications to ensure inclusion of rare alleles or species
4. Distribution of alleles in natural populations permits study of long term effects of the selection forces	4. Need for a multitude of visits, both for species and varieties over time
5. Combined analysis of genetic and ecological diversity is possible	5. The priorities of resource allocation between alternate sites, different genera may be empirical in the absence of a *priori* information

CONSERVING GENETIC RESOURCES OF MANGROVES

The organisational plan of conserving genetic resources of mangroves can be represented as follows:

1. Exploration and collection,

2. Classification,
3. Evaluation and documentation,
4. Conservation,
5. Utilisation and policy formulation, and
6. Monitoring.

For exploration and assessment of mangrove forest areas, three components are essential:

1. Survey techniques and their interpretation,
2. Sampling methods, and
3. Collection and propagation.

CONCLUSION

The need for study of correspondence between genetic diversity and environmental diversity as much *a priori* information is available in mangroves, calls for pilot studies (genetic), and monitoring changes in populations.

For conservation of mangrove forest genetic resources, following aspects need to be considered before any conservation strategy is formulated:

1. Allelic frequencies, their equilibria neutral and selective alleles, and frequency dependent natural selection,
2. Extent of linkage—conservation of variation by co-adapted gene complexes,
3. Linkage disequilibrium—several equilibria may exist influenced by seasons,
4. Breeding behaviour such as vivipary, sexual as compensating mechanisms to preserve variation,
5. Ploidy levels to reduce release of variation,
6. Preservation of constellation of characters than individual characters further control the release of genetic variation, and
7. Monitoring changes by analysing changes in (a) species composition, (b) gene frequency within a species to understand the dynamics of the system, (c) breeding structure and (d) constellation of characters (inter-relations) and the difference in their pattern between sites/seasons in the same site.

It is imperative from the above observation that genetic diversity in mangroves can be measured by different ways, i.e., morphological studies and molecular biology techniques. However, for undertaking studies related to molecular biology it is necessary to identify visually observed diversity at the field level. Identifying criteria and evaluation methods for forest areas for establishment of mangrove genetic resources conservation centres, can thus be done based on the aspects mentioned in this paper.

CONSERVATION OF PLANT GENETIC RESOURCES

S. KEDHARNATH

INTRODUCTION

The necessity of conserving the genetic resources existing in the natural populations of different species crop plants, forest trees, fruit trees, etc., is now well-recognised. While replacement of highly bred varieties of relatively narrow genetic base has not become intensive in forestry practice, the pressure of exploding population often finds an outlet in the felling of forests for use of agriculture and other requirements. Land has become a scarce resource. As the population increases, the land-man ratio falls, and at the same time the demand for wood and other forest products increases.

Man in his quest for economic development has been carrying out many activities. When such developmental activities extend over a wide range of systems with no consideration for ecology, it leads to degradation of nature. There is now a growing awareness of the importance of natural environment and a serious concern that resources essential for human development and survival are being depleted and destroyed at an alarming and increasing pace. Habitat destruction and the extension of agriculture to forest areas and the gradual diversion of forest land for non-forestry uses promote species extinction. Biological diversity is essential for achieving sustainable gains in productivity per unit of land, water, energy and time. In developing countries, the threat to reserve forests and biosphere resources comes from human communities who perceive protection as being in conflict with their economic survival. Conservation strategies should help to strengthen and not erode the livelihood security of the people of the concerned area.

IMPORTANCE OF CONSERVATION OF GENETIC DIVERSITY

"The conservation of genetic diversity is both a matter of insurance and investment. This is necessary not only to sustain and improve production in agriculture, forestry, horticulture, etc., but also to keep future options open and as a buffer against harmful environmental change. We cannot predict what species may become useful to us at a later date. Indeed, we find that only a minute proportion of the World's plants have been investigated for their value as medicines and pharmaceutical products. Modern medicine depends heavily on them. Again, the rapid displacement or replacement of traditional varieties by new ones is a necessary and positive development because of the need for more food. But this effort will prove counter productive if the traditional varieties by new ones is a necessary and positive development because of the need for more food. But this effort will prove counter productive if the traditional varieties and their wild relatives are not saved as well. Primitive population of crops and their wild relatives are an important source of pest and disease resistance, of adaptations to difficult environments and of other agronomically useful and valuable characteristics. For example, one can cite the dwarf habit in rice and wheat which has revolutionised their cultivation and led to greater yields in many parts of the World."

Forest tree species live long, are predominantly allogamous and usually exhibit immense variability for many characters. Many of the species are known to have wide natural distribution. And in most of them distinct provenances and ecotypes have also been documented. The increasing emphasis on raising plantations for raising forest production has generated a lot of interest to identify and use the most productive provenance. This involves intensive sampling of the species in its entire range of distribution and documenting the salient features of each provenance. We have, for example, such information today on Teak (*Tectona grandis*), Chir Pine (*Pinus roxburghii*), Sal (*Shorea robusta*) and Gamari (*Gmelina arborea*). Such information has also been obtained for many of the promising exotic tree species such as *Eucalyptus tereticornis, E. grandis, E. camaldulensis, Pinus caribaea* and *Pinus occarpa.*

The International Union of Forestry Research Organisations (IUFRO), after the World Congress of 1971, established a working party on "Forest Gene Resources Conservation". This working party has been collecting, synthesising and disseminating data on the genetic impoverishment of tree species. An FAO Newsletter entitled "Forest Genetic Resources Information" has been furnishing useful data on genetic variability of tree species. This has in turn facilitated exchange of seeds for use in provenance experiments.

According to Swaminathan (1983), there is need for a greater flow of information on emergency situations where delay in action would result in future generations not deriving the full benefit from our genetic heritage. Ruthless exploitation of forests for short-term financial gains may often lead to deforestation and habitat destruction resulting in extinction of many species. It must not be forgotten that we are the beneficiaries of the resources today and also trustees of the planet's resources for the future.

IMPORTANCE OF RAIN-FORESTS

Rain-forests are a highly structured terrestrial ecosystem. The ecosystem is very stable as long as the magnitude of destruction is kept at a reasonable minimum, but becomes extremely fragile with largescale deforestation as practised by the industrial man. The fragility of the system is accentuated by the large biomass that the rain-forest supports on a nutrient-deficient highly leached soil, resulting in a delicate balancing of nutrient cycling so characteristic of rain-forests. Yet, the rate at which conversion of rain-forests is occurring all over the World, for timber for industrial needs, fuel wood, for the local people and for shifting agriculture by the forest farmer, is really alarming. According to reasonable estimates, all the rain-forests World over, except perhaps few pockets in Central Africa and parts of Western Amazonia, would disappear by the turn of the century if the present rates of conversion persist. In India too, the rain-forests of the Western Ghats and North-east India are being converted so rapidly that very little of the primary forest is still left intact. The Silent Valley rain-forest ecosystem its conservation and an understanding of the ecosystem function become important in this context. According to Singh and Ramakrishnan (1982), the tree species computed for the Silent Valley (114 vascular plants of 84 species in 0.4 hectares) is very high, as compared to the range of 60 to 80 species that characterise the other known tropical rain-forests.

The rain-forest ecosystem is an important World heritage, both for academic and applied reasons. The rich germplasm reserve that the rain-forests harbour would be an important basis for future development of plant resources for human welfare. Apart from wild germplasm for our conventional food resources, man in the developing World would have to depend more and more on "lesser known plants of food" which abound in the humid tropics. With the rapidly increasing human population in developing countries, this food resource would assume greater importance. Much of the needs of the industrial man, such as fibre, medicine and a variety of organic products of diverse use, will come more and more from the genetic diversity of plants in the rain-forests.

Based on most conservative estimate, the tropical moist forests of the World contain about two million plant species, of which only less than one per cent of the plants have been scientifically examined for their usefulness to human beings. Forest management practices currently followed, aim to extract few species which are in demand and are not based on an adequate understanding of the ecological principles. Some of the changes brought about by this approach are irreversible, leading to the loss of valuable genetic resources. Many of the species may become extinct even before their multifarious uses are known. Conservation of these forests which provide important source for sustaining agriculture, horticulture, etc. Breeding for insect resistance and disease resistance is crucially dependent upon the availability of wild cultivars and species. Deforestation and the resultant habitat destruction of species has been the multifaced major threat leading to degradation, depletion and disappearance of the biological diversity of the Western Ghats in India besides affecting ecological balance (Nair and Daniel, 1986). This awareness has led to a global concern, and national and international agencies are devoting considerable attention to evolving appropriate conservation strategies.

GENETIC RESOURCES FOR USE IN AGROFORESTRY

Agroforestry is indeed an ancient form of land use that has been practised by rural people in many parts of the World. However, as an organised scientific activity, it is relatively a new field lacking an established research tradition of its own (Raintree, 1986). There is increasing awareness today that as an approach to integrated land management, agroforestry has a great potential. According to Vergara (1982), some legume trees have a special role in contributing towards sustainable agroforestry production, because they have long tap roots which enable them to have much better capacity to anchor and stabilise the soil and a greater ability to recover and absorb moisture and nutrients from the deeper sub-soil. Furthermore, legume trees usually have small leaflets which decompose more rapidly and enable the nutrients to return more quickly to the soil surface to maintain productivity. Also, small leaves allow sunlight to reach interplanted low-level food crops. Finally, the ability of legumes to fix the atmospheric nitrogen through the symbiotic activity of the Rhizobium and supply nitrogen to the trees themselves and to the interplanted food crops is a desirable attribute. Some of the legume trees such as Acacia auriculiformis are known to thrive well in acidic soils and are being planted extensively in the States of Kerala and Karnataka in India. Some species of Acacia and Albizzia deserve extensive study for their usefulness in agroforestry systems. Species of Casuarina and Eucalyptus in South India and species of Populus, particularly *P. ciliata* and improved clones of *P. deltoides* in North India are becoming very popular with farmers, both small and big, for use in agroforestry.

CONSERVATION STRATEGIES

In situ conservation as part of a viable natural ecosystem is one of the methods recommended as most desirable for conserving forest genetic resources. This often involves large areas and calls for proper protection measures and maintenance so that seed collection is possible for use within the country and also for supply to others interested in testing the species as an exotic. One must consider the plant genetic resources not only from the point of immediate value for direct utilisation or through breeding, but also from the point of possible potential use to meet future needs.

Judicious management of these resources is essential if they are to remain renewable. In India, 188 permanent preservation plots covering a total area of about 8442 hectares, have been established with different forest types (Ghosh and Kaul, 1977). These areas should prove to be important 'gene sanctuaries', where besides the tree species included, the range of species occurring there can evolve under natural selection pressure.

Ex situ conservation is the second method. This applies both for indigenous species, where *in situ* conservation is not possible, and for exotic species. Here, there arises a doubt as to whether the full range of variability of the species is conserved because the quantum of seed used for the regeneration of the new stand may not be fully representative of the initial variability present in the species range. Random sampling or what is known as point sampling over a number of locations in the species range, if practised, should help to ensure a fairly good representation of the initial variability. Gene banks can be established particularly for storing seeds of primitive cultures, improved varieties, etc. They should be stored under special cold storage facilities and grown at periodic intervals for evaluation and screening. This approach is very suitable for many crop plants and medicinal plants which are normally propagated by seeds. The International Rice Germplasm Centre at IRRI, Manila has 67,000 Asian cultivars, 2600 African rices, 1100 wild rices and 690 genetic testers. Obviously, a large collection by itself has no significance unless the collection is carefully studied and used (Swaminathan, 1983). Similar methods should be formed for forest trees gene-pool conservation also.

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CONSERVATION OF FOREST GENETIC RESOURCES

C.S. VENKATESH

INTRODUCTION

Most of our agricultural crop species have had long histories of domestication behind them. This is far from true of forest tree species. The latter are still essentially wild populations that have never been subjected till recently to either unconscious or conscious selection by man. Consequently a good deal of natural variability prevails within forest tree populations.

Although many of the tree species have bisexual flowers or are monoecious (with male and female flower borne on the same individual tree) still out-crossing in nature is the rule in several of them. For example, Pines and most other Conifers are typically wind pollinated which encourage out-crossing, in them, selfing leads to strong inbreeding depression. (*Pinus resinosa* of Canada is a notable exception where selfing does not lead to such depression). In *Leucaena leucocephala,* only the tetraploid race is self-fertile whereas the diploid race and the remaining species are self-incompatible. Out-crossing helps maintain heterozygosity and genetic diversity within species.

NATURAL VARIABILITY WITHIN FOREST TREE POPULATIONS

Natural variability within tree species may involve one or several characters. For example, there can be a flower colour variation. In our country the Red Silk Cotton tree (*Bombax ceiba* L.), as the name indicates, usually bears red flowers. But occasionally we come across yellow flowered variants too. This is true also of the closely related species—*Bombax insigne,* thus exemplifying Vavilov's Law of homologous variation.

In Teak (*Tectona grandis* L.), there occurs a morphologically distinct variety, the 'Teli' variety, The Ashoka (*Polyalthia longifolia*), commonly planted in Madras gardens, comes into two distinct varieties, one with a conical crown and the other with a narrow fastigiate crown and pendulous branches. Among Conifers such narrow-crowned variants occur in several species and have been described by taxonomists under appropriate varietal names such as *pyramidalis, columnaris, fastigiata, pendula,* etc. Recently it has been demonstrated in Finland that in Norway Source and Scots Pine, narrow crown variation is inherited in a simple Mendelian fashion. A single gene with pleiotropic effects is responsible for its inheritance.

Variation in leaf characters, bark colour and bark thickness is also known among forest trees. However, what is economically important for selective breeding are variations in stem form and straightness, branching habit and intrinsic wood properties such as wood density, figure, grain and fibre characters.

Another source of variation in trees is *inter-specific* hybridisation. Natural hybrids and hybrid segregates are known in a number of tree genera, e.g., Pinus, Populus, Eucalyptus, Prosopis, Quercus, etc. In Eucalyptus, species belonging to the same section can and do intercross. In their native (Australia), such inter-crossable species are geographically isolated. However, where there is slight overlap in distribution, natural hybrid swarms occur. Again, when such species are planted close together as exotics outside Australia, geographical barrier is broken down and hybrids result. Controlled hybrids between *Eucalyptus tereticornis* and *E. canaldulensis* (FRI-4) have been produced at Dehra Dun. A trispecific hybrid, *E. canaldulensis* × *E. tereticornis* × *E. grandis*, has also been synthesised there. The hybrid plane or London plane, a familiar avenue tree in European cities, is natural *inter-specific* hybrid of *Platanus orientalis* and *P. occidentals*. It is called *P.* x *acerifolia*.

Example of an inter-generic tree hybrid is Monterey Cypress (*Cupressus macrocarpa* Hartw.) × Nootka Cypress (*Chamaecyparis nootkatensis* Spach)—*Cupressocyparis leylandii* Dallim. This hybrid arose naturally in England. Propagated by cuttings, it is extensively used as a windbreak, hedgerow or ornamental tree. 1R *inter-specific* hybrids of eucalyptus are very fertile and produce larger quantities of seeds than the parental species.

Natural hybridisation is a potent evolutionary force causing the origin of new species, by introgression of genes from one species to another. It may be called that the modern hexaploid breed wheat arose as a trigeneric hybrid involving *Aegilops, Agropyron and Triticum*.

FOREST TREE IMPROVEMENT

Forest trees are difficult material for genetic studies and breeding purposes. Firstly, they have a long juvenile phase and usually take several years to reach reproductive maturity. Correspondingly the turnover of generations essential for conventional in annual agricultural crops which develop from seed to maturity, and are ready for harvest within a single growing season after sowing. Secondly, trees depending upon the species, site and purpose for which they are planted, take 10, 20, 30, 50, 60 or even 100 years to reach commercial maturity (the rotation age of foresters). Further, many of the economically important features of forest trees are assessable ideally only when they have reached commercial maturity (the rotation age of foresters). Further, many of the economically important age. In view of the facts stated above, forest trees improvement projects are, as a rule, necessarily long-term ones. Once started by an individual or group of individuals, they need to be continued by several successive groups and be finally completed by men who were not born when the project were initiated. To take an example, final results of first-generation teak, dipterocarp or conifer improvement projects begun today will not be available before the middle or latter part of the 21st century. On the other hand, an Eucalypt pulpwood improvement project started at the same time reach fruition by the turn of the present century itself. This is because Eucalyptus are very fast growing and are worked in very short notations of only years for pulpwood production. They also start flowering early in life. Thus while an Eucalypt breeder can live to see the full fruits of his efforts, a teak breeder can seldom do so.

The great height to which forest trees, grow poses logistical problems. It becomes difficult to (a) harvest seed for replanting. (b) collection wood for grafting and budding, and (c) carry out controlled pollination. These problems have been overcome by the use of ladders and tree bicycles, and grafting and obtaining flowering and fruiting at low heights in seed orchards.

OBJECTIVES OF GENETIC TREE IMPROVEMENT

Forest trees are stem crops raised and managed for optimum yield wood and timber. The principal yield components are height and diameter of the stem because these determine the volume of wood and timber extractable from a felled tree. In forestry, therefore, the choice is clearly for the tall, straight, clean-boled fast-growing giants and not for dwarf or semi-dwarf varieties as in wheat, rice and coconut palm. Lowering of tree height is resorted to by grafting only in seed orchards and clonal gardens to facilitate controlled pollination and harvest of improved seed. Tree breeding work in forestry aims at :

1. Enhancement of growth rate,
2. Straighter stems,
3. Wider branch angles,
4. Smaller branch sizes,
5. Narrow compact crowns,
6. Improvement in intrinsic wood properties such as density, fibre length, fibre morphology, grain, figure or cellulose content (constituting the special field of wood genetics), and
7. Developing inherent resistance to specific pests or diseases.

In short, a good timber tree should show

a. Strong apical dominance, and
b. Straight, thick, cylindrical stems without forks, flutes and buttresses and with a minimum of taper.

It happens that in tree species that have been genetically studied for stem straightness and the tendency to fork or crook have been shown to be highly heritable. These trails are therefore amenable to improvement by selective breeding.

METHODS OF FOREST TREE IMPROVEMENT

Forest tree improvement by selection and breeding consists of the following two steps :

1. Phenotypic selection of outstanding individual trees, i.e., the 'plus trees', and
2. Establishing the selected 'plus trees' in seed orchards for the commercial production of improved seed.

The above mentioned seed orchard method is today the standard procedure adopted in most forest tree improvement programmes throughout the World. Essentially, it consists of selecting superior phenotypes of the species intended to be improved from natural stands, provenance plots and plantations and marshaling of these in the form of grafted clones and then into commercial quantities for raising future high-yield plantations. Since, with few exceptions, forest trees are by and large widely variable, undomesticated wild species that have never been subjected to either conscious or unconscious selection, such as simple mass selection has proved to be quite effective in bringing about perceptible genetic improvements even from the very first round phenotypic selections.

Usually multiple traits are used in evaluating and selecting plus trees for establishing in the first cycle orchards. The whole tree is evaluated using a total score or selection index. The tandem method of selecting for one trait at a time is used only in certain special circumstances, e.g., breeding for disease resistance, oleoresin yield, bole straightness in habitually crooked stemmed species. With a view to saving time, establishment of first-generation seed orchards is never delayed till the results of progeny testing are available and heritabilities can be calculated, which in tree species is bound to take several years and even decades. Further, such first-cycle seed orchards should be based on many parents selected at low intensity early in the rotation. This is to ensure a wide genetic base. Selection should be continuous and increasingly rigorous as plantation area, experience and staff efficiency increase. Although in such multiple trait selection the differential obtainable per individual trait is reduced, the cumulative effect of increase in growth rate per tree, survival, quality of stem and crown, and in some cases resistance to disease or pests, may greatly add to the total growth and yield per hectare of forest.

The selected 'plus tree' material is establishment as grafts, cuttings if feasible or sometimes as seedlings, in polycross layouts, the seed orchards, where the assembled clones naturally out-cross by wind (in conifers), insects and sometimes birds (in Bombax) to produce improved seed. Plus tree material is concurrently also established in clone banks or clone archives for preservation of the genotype of the plus trees and forestall their loss by lightning, fire or felling.

To reduce selfing and encourage panmixy among the assembled clones, the ramets in a seed orchard (but not in clone banks and clone archives) are planted in a fully randomised manner. Nowadays computer-generated designs effectively ensure this.

Both seed orchards and clone banks facilitate controlled breeding work.

GAINS FROM TREE BREEDING

The benefits from using orchard seed include :

1. Rotation age reduction,
2. Timber volume gain,
3. Timber quality gain, and
4. Crop security in the form of disease and pest resistance.

A good example of rotation age reduction through selective genetic improvement of forest trees is afforded by Slash Pine in the U.S.A. By intensive selection, the rotation age for this important industrial timber species in that country has been brought down from 40 to only 25 years. In the same species, a 25% gain in volume production (at 14 years) has been obtained in Australia. The gain in Loblolly pine in the U.S.A. has been 18%. In the Caribbean pine by selection, the percentage of reasonably straight stems has been lifted from 20% to 70% a gain of 50%. In Douglas fir, after 50 years (1912–1960), the best families had outproduced the poorest by two or even three times in timber volume.

Progeny-tested or elite seed orchards can give 34–45% additional gain. In Finland, birch cultivars developed from advanced generation seed orchards are expected to yield 100% more timber than natural birches.

As for forest produce other than wood and timber, the oleoresin yield of Slash pine has been more than doubled in Florida, U.S.A, by only one generation of selective breeding.

ROLE OF CLONE IN FORESTRY

Asexual, vegetative or clonal propagation has a very important role in forest genetic research and tree improvement. It has the following advantages over sexual propagation by seed :

1. It enables production and use of genetically uniform trees, experimentally for site testing trails and for determining genotype × environment interactions accurately, and
2. Operationally it enables raising of very uniform, high-yielding plantations resistant to specific diseases, pests or adverse environmental conditions. For commercial purpose, however, clonal mixtures or mosaics rather than single clones are recommended as security against unexpected epidemics or environmental changes.

The clonal option has recently been used to achieve a breakthrough in Eucalyptus pulpwood production in Arancruz Florestal in Brazil. Plus trees are selected and simply mass-cloned by rooting coppice shoot cuttings using commercial hormone and mist. Thus improved trees grew 20 m tall only 3 years after field planting of the cuttings. Pulpwood yield in 7-year rotations increased from 23–28 m^3/ha/yr to 70–83 m^3/ha/yr. Wood density increased by 25% and cellulose yield by 135%.

A limitation of purely clonal selection and multiplication, however, is that it is a dead end method and no changes or further improvements are possible without having recourse to sexual breeding. A judicious combination of both sexual and asexual methods therefore is ideal for maintaining genetic diversity and simultaneously obtaining rapid genetic improvements.

1. Pitch pine (*P. rigida*) × Loblolly pine (*P. taeda*) = *P. rigitaeda* artificial hybrid, combining in itself the frost hardlines of the former with the greater vigour and better stem form of the latter, has been mass-produced and planted in South Korea.
2. *Populus tremula* (4n) × *P. tremuloides* (2n) = Triploid hybrid poplar shows hybrid vigour and produced 36% more wood and 30% longer fibres. It is relatively more resistant to the fungus and its heartwood is free from tyloses.
3. European Larch (*Larix europaea*) × Japanese Larch (*L. leptolepis*) = O × *L leurolepis* combined in itself, the good stem form of the European parent and the canker resistance of the Japanese parent. In addition, it also showed hybrid vigour.
4. *Eucalyptus camaldulensis* × *E. tereticornis* (FRRI–5) and its reciprocal cross FRRI-4 displayed pronounced degrees of hybrid vigour in the Fl generation. Even at the early age of 4 years, the hybrids were 30% superior in height and 80% in diameter compared to the parental controls. Such vigour was sustained till full rotation age of 10 years. when they yielded 3–5 times more volume and 11/2–41/2 times were more weight of wood than the controls. Apart from giving higher yields, these hybrids also possessed certain improved wood properties. viz., longer fibres and reduced 'kappa' number' both of which are desirable in pulp production.
5. Slash pine (*Pinus elliottii*) × Caribbean pine (*P. caribaea*) hybrids developed in Queensland, Australia, are promising because they are superior to either parents in economic yield and moreover are more tolerant to waterlogging than the Caribbean parent.
6. West Indian Mahogany (*Switenia mahogoni*) × Honduras Mahogany (*Switenia macrophylla*) combines the drought resistance and wood quality of the former with the faster growth rate of the latter.

By *inter-specific* hybridisation it has been possible to incorporate blister rust resistance into the White pines (*Pinus strobus, P. lambertiana, P. monticola,* etc.) of North America from Himalayan Blue or Kail pine (*P. wallichiana*) and the Japanese (*P. parviflora*) and Balkan (*P. peuce*) white pines. Armand's pine (*P. armandii*) of China is another possible source of blister rust resistance. In North America again, Jeffrey × Coulter (*P. jeffreyi* × *P. coulteri*) × *P. jeffreyi* back-cross hybrids are known to display a degree of resistance of Pine weevil attack.

GENETIC IMPROVEMENT OF MANGROVE TREES

There is no gainsaying that the unique mangrove ecosystem should be protected and its biodiversity conserved for posterity. Exploitative use of mangrove species for one or the other purpose by local inhabitants should be strictly controlled by whatever means available.

As yet, very little information that could be of use in the genetic improvement of mangrove species is available. The chromosome numbers of a few mangrove species have been reported upon. They are as follows:

Avicennia alba	n = 9 to 32 + 1
Ceriops tagal	n = 18
Sonneratia apetala	n = 9
S. alba	n = 11
S. caseolaris	n = 11
S. ovata	n = 11

CONSERVATION OF FOREST GENETIC RESOURCES

In situ conservation is always preferable to *ex situ* conservation because the former allows conservation of an entire forest ecosystem and with it the natural gene pools of its constituent species.

Clone archives/clone banks offer a good method of *ex situ* collection and preservation of forest tree germplasm. It may be pointed out here that there is one advantage in the preservation of forest tree genetic resources. Being perennial with long life-spans, forest trees can be preserved alive for very long periods of time, unlike annual agricultural crop varieties which need to be 'rotated' by seed every now and then in order to preserve them as live plants.

BIOTECHNOLOGY FOR TREE IMPROVEMENT

Biotechnology applications have tremendous scope in forest tree improvement in the future in the following way.

Tissue culture enables :

1. Micropropagation of hard-to-root trees in large numbers,
2. Production of haploid pollen plants and by diploidisation, instant homozygous line for heterosis breeding (to obtain such lines by conventional breeding in trees may require scores of years).
3. Somaclonal selection of spontaneous variants,

4. Induction of flowering-at-will (e.g., Bamboo) for hybridisation.
5. Cryopreservation of rare and endangered species, and
6. Parasexual hybridisation, obviating, sexual breeding barriers.

Genetic engineering using tissue culture enables transfer of genes directly without intercrossing from one tree to another or even from a bacterium to a tree species. Currently efforts are being made to transfer the toxin gene from *Bacillus thuringensis* via Crown gall bacterium into Spruce to develop new varieties of the latter resistant to the Spruce Budworm which causes enormous damage in canadian forests.

TREE IMPROVEMENT/INTER-SPECIFIC HYBRIDISATION

Hybridisation within and between species offers one or more of the following possibilities :

1. It is a way of combining the desirable characters of different parents, varieties, provenances or species of trees,
2. It may generate hybrid vigour,
3. It offers a means of donating genes for resistance to specific diseases, pests, and adverse environmental factors such as drought, swampiness, frost, salinity, etc., and
4. It is a way of increasing variation in tree populations for subsequent selection in advanced generations (F_2 and later.).

Crossability barriers are obstacles to wide hybridisation but as already indicated, biotechnology can help obviate or bypass such barriers. There are a number of examples of useful *inter-specific* tree hybrids.

As regards their breeding system, those species that have bisexual flowers are either protogynous or protandrous and this should encourage natural out-crossing. Further support to their out-crossing nature is afforded by the occurrence of natural hybrids in *Rhizophora, Lumnitzera* and *Sonneratia.*

In Pines and Eucalyptus, elegant electrophoretic techniques have been used to estimate the relative degree of natural selfing and out-crossing in natural stands and seed orchards. The same technique should yield useful results in mangrove species as well.

Aside from the protective role they play in guarding the coastline from sea erosion, many mangrove species are also of economic value. Local inhabitants use them for firewood, fibre, tan bank and so on.

The aims of possible future mangrove tree breeding programme could have different objectives in the different species constituting this ecosystem. In the Sundri (*Heritiera fomes*), which is the most important firewood in the Sunderbans including Calcutta city, breeding aims could be: (a) faster height and diameter growth to increase firewood production in shorter rotations from man-made Sundri plantation; and (b) qualitative improvements in stem straightness, fissility, calorific value and reduced ash content.

Improvement in *Rhizophoras* could aim at longer stilt roots to help them colonise in deeper waters and thereby help in reclaiming more land from the sea.

Conventional tree improvement methods which involve selection of plus trees and their establishment in seed orchards for commercial production of improvement seed could be applied equally successfully to mangrove trees. So also micropropagation through tissue culture and other sophisticated biotechnological techniques.

Just as in forest trees, clone banks and clone archives can advantageously be used for *ex situ* conservation of mangrove germplasm.

Heteroplastic grafting of scions from selected mangrove tree species on to root-stocks of related non-mangrove species of the same family or genus (e.g., *Heritiera fomes* on *H. littoralis, Rhizophora, Bruguiera,* etc., on *Carrallia integerrima,* a non-mangrove species occurring far inland) could be a new and novel way of *ex situ* conservation of mangrove germplasm in non-mangrove locations.

IDENTIFYING CRITERIA AND EVALUATION METHODS FOR FOREST AREAS FOR ESTABLISHMENT OF MANGROVE GENETIC RESOURCES CENTRES

M.S. SWAMINATHAN AND SANJAY DESHMUKH

INTRODUCTION

In the convention on Biological Diversity signed by many nations at the UN Conference on Environment and Development (UNCED) held at Rio De Janeiro, Brazil—early in June 1992, biological diversity has been defined as "the variability among living organisms from all sources, including *inter alia,* terrestrial, marine and other ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems". It is anticipated that by the year 2000, the human population living within 0 km of the shoreline will grow to 75 percent from the present 0 percent. Two thirds of the World's cities, with populations of 2.5 million or more, are near tidal estuaries. Many of the World's poor are crowded in coastal areas and coastal resources are vital for their livelihood security. Therefore, this Exclusive Economic Zone is important for the development as well as protection of natural resources in the coastal areas of the World.

COASTAL ECOSYSTEMS OF SOUTH-EAST ASIA AND OCEANIA

The coastal waters of South-east Asia and Oceania have some of the World's richest ecosystems characterised by extensive coral reefs and dense mangrove forests. Blessed with a warm tropical climate and a high rainfall, and further enriched with nutrients from the land, these areas support a wide diversity of marine life.

The Indo-Malaysian region is known to be a centre of diversity for mangrove species. Hence the flora is rich—both in quantity and quality. Because economic benefits could be derived from them, coastal zones in these countries are full of human settlements. Countries like Malaysia, Thailand, Indonesia and the Philippines are subjected by a variety of coastal activities, notably fishing, coastal aquaculture, waste disposal, salt-making, tin mining, oil drilling, tanker traffic, rural construction and industrialisation.

The increasing use of coastal resources in South and South-east Asia requires that some areas be retained in their pristine condition. For conservation of plant genetic resources, maintaining genetic diversity within an ecosystem is important. Genetic diversity is a natural resource. All nations share the responsibility for its management and the privilege of using it. Individuals, private organisations and universities can contribute to the maintenance of germplasm, but the task of overseeing and managing genetic resources are clearly beyond the capacity of any individual or group. It is for this purpose, the heads of State/Government of many nations signed a Global Biodiversity Convention at Rio-De Janeiro in June 1992, on the occasion of the UN Conference on Environment and Development.

PRESERVING PLANT GERMPLASM

Seeds are the most commonly preserved form of germplasm. Those of the major cereal grains, legumes and most vegetable crops can be dried and stored for longer periods under low humidity and at low subfreezing temperature. For several reasons germplasm of forest tree species, such as mangroves, cannot be easily stored as seed, due to the rapid loss to viability over a long period. Therefore, it is important that mangrove germplasm will have to be maintained as living plants in the field, or under cover (e.g., greenhouse), pollen, tissue culture or cuttings. Because of this, the urgent and critical need for the establishment of a global network of mangrove genetic resources centres is emphasised in this paper.

IDENTIFICATION OF SITES

Recommendations were invited from various countries in South and South-east Asia and Oceania and West and Central Africa on potential sites for the proposed mangrove genetic resources conservation centres. Listed below are the 23 sites recommended from nine countries in these regions :

Country	Number of sites	Name(s) of Site(s)
Papua New Guinea	5	Sagalau, Los Negros, Djaul, Baimuru and Bootless Bay
The Philippines	2	Pagbilao and Ulugan Bay
Indonesia	3	Cilacap, Sembilang, Banyuwedang
Malaysia	5	Sepilok, Rejang, Loba Pulau and Matang
Thailand	1	Ranong
India	4	Chorao island, Pichavaram, Coringa, Bhitar Kanika
Pakistan	2	Khaddi and Shah Bunder
Cameroon	1	Mouanko estuary
Senegal	1	Saloum

Out of the above-mentioned sites, four most suitable sites were selected, two from the 21 sites in Asia and Oceania and one from the two sites in West and Central Africa.

TERMS OF REFERENCE

1. To identify sites for the establishment of an international network of mangrove genetic resources conservation centres, which can help to preserve for current and future use, a representative sample of the existing genetic diversity at the levels of (a) ecosystems, (b) species and genera, and (c) intra-specific variability.
2. To prepare detailed reports on each site with reference to the following:

   a. genetic merits with reference to variability for both, qualitative and quantitative traits.

   b. physiological merits, in relation to estuarine characteristics and nutrient cycling.

   c. socio-political merits, including commitment of Governments.

d. scope offered for both *in situ* and *ex situ* conservation methods.
e. anthropogenic features
f. public awareness.

3. To prepare, in addition to well documented site visit reports, an integrated report on the relative merits of different sites for preserving for posterity, a representative sample of existing genetic variability in mangroves.
4. To rank different sites in order of biological preference and to prepare a plan for an integrated global grid of genetic resources centres, which will together constitute a genetic heritage of inestimable value.
5. To suggest steps for promoting the sustainable management of mangrove genetic resources and for the use of mangrove gene pools in research on genetic enhancement using recombinant DNA technologies.
6. To recommend the composition of specialised gene pools for adaptation to potential changes in sea levels.

CRITERIA FOR IDENTIFICATION

The principal criterion for identification of a site for potential work later is the genetic variability of mangrove species, at the ecosystem, species and intra-specific levels since our purpose is to establish a genetic resources centre. For this purpose, a clear distinction was made between a botanical garden, which serves as a reservoir of different plant species, and a genetic garden which is intended to serve as a reservoir, not only of different plant species, but also of genetic diversity within each of the species chosen for preservation in the garden. All the 25 recommended sites are existing forest reserves with varying degrees of commercial or domestic use. To serve as genetic resources conservation centre, a mangrove forest must be ecologically conducive to optimal growth and development of the maximum or a large of genetic diversity within species. This was therefore the main criterion for assessing the conservation value of a given site, i.e., its suitability for the establishment of a genetic resource centre. Other relevant information on nutrient dynamics, eco-physiology, socio-economic features and political aspects was gathered. This information was considered along with the data on genetic diversity. In an integrated manner. The levels of anthropogenic pressure, preparedness and commitment of local authorities were among other considered criteria.

The suggested criteria are as follows :

1. Genetic factors : Migration and gene flow, introgression, natural out-crossing, competition and selection, and polymorphism.
2. Ecological factors : Local flora and fauna, species richness and evenness, and indicators of biodiversity and pollution level.
3. Environmental features : Topography and environmental variables, level of environmental degradation, heterogeneity of micro-environment, frequency and intensity of cyclones, typhoons and other natural hazards.
4. Physiological factors : Overall forest health, individual species health, nutritional cycle, and estuarine characteristics.

5. Potential for both *in situ* and *ex situ* conservation of biodiversity, seasonal fluctuations in environmental conditions, environmental extremes, and plant population density.
6. Socio-political factors.
7. Economic factors : Long-term funding and degree of priority.
8. Human resources : Training and motivation of staff and commitment of the national government.
9. Reconnaissance and monitoring facilities : Equipment, proximity, and preparedness of staff.
10. Anthropogenic factors : Population density in neighbouring areas, proximity to population centres and industries and conservation awareness.
11. Land size : A minimum of 100 hectares.
12. Land tenure : Ownership of land.
13. Accessibility to the site.

INITIAL INFORMATION ON SITES

While inviting recommendations of sites from various countries, brief basic information was sought on the sites nominated by the respective national governments. This included information on physical, eco-geographic, anthropogenic and biological features. It was made available to the review team prior to site visits. While evaluating the sites for their suitability as MGRCC, respective initial site information was used along with the information gathered during site visits. Following 10 broadly classified criteria were adopted :

1. Genetic aspects : Introgression, potential for *ex situ* preservation, visual polymorphism.
2. Ecological aspects : Species richness, nutritional level, environmental degradation.
3. Utilisation level : Human use and exploration.
4. Neighbouring flora and fauna : Associated ecosystems.
5. State of forest : Levels of degradation.
6. Accessibility : Distance from main population centres, transportation facilities.
7. Personnel : Training, turn-over rate, etc.
8. Anthropogenic factors : Threats, level of dependence, etc.
9. Socio-political factors : National commitment, land tenure and public awareness.
10. Land size : area available at the proposed site for MGRCC.

METHOD OF EVALUATION

Each member of the team evaluated the sites largely according to the 10 criteria listed earlier. However, respective areas of expertise were given due consideration during final discussions and scoring. For each criterion, an ordinal score between 1 and 9 was assigned to each site, where 1—best or most desirable and 9 = worst or least desirable. Scores given independently by the members were averaged to determine the final score of a site for each criterion. These average scores are summarised in Tables 1 to 8.

Table 1 Summary of evaluation of five sites in Papua New Guinea

Criterion	Sagalau	Los Negros	Djaul	Baimuru	Bootless Bay
Genetic aspects	4	4	4	1	5
Ecological aspects	4	3	4	1	6
Utilisation level	4	2	2	2	7
Neighbouring flora/fauna	7	2	2	3	8
State of forest	3	2	2	1	6
Accessibility	3	5	8	7	5
Personnel	5	7	7	5	3
Anthropogenic factors	4	3	2	2	6
Socio-political factors	7	5	6	2	7
Land size	8	7	6	1	7
Overall**	**4.9**	**4**	**4.3**	**2.5**	**6**

Table 2 Summary of evaluation of two sites in the Philippines

Criterion	Pagbilao	Ulugan Bay
Genetic aspects	3.5	4.0
Ecological aspects	3.5	3.0
Utilisation level	2.5	4.0
Neighbouring flora/fauna	4.0	2.5
State of forest	4.0	3.0
Accessibility	2.5	7.0
Personnel	2.5	4.0
Anthropogenic factors	3.0	2.5
Socio-political factors	2.0	2.5
Land size	5.5	2.5
Overall**	**3.3**	**3.5**

Table 3 Summary of evaluation of three sites in Indonesia

Criterion	Sembilang	Cilacap (C.Java)	Banyuwedang
Genetic aspects	3.0	4.5	4.0
Ecological aspects	2.5	5.0	4.5
Utilisation level	3.5	4.5	2.5
Neighbouring flora/fauna	3.5	5.0	6.5
State of forest	3.0	5.5	6.5
Accessibility	8.5	3.5	2.5
Personnel	7.5	3.0	3.5
Anthropogenic factors	3.0	5.0	4.5
Socio-political factors	4.5	3.0	2.5
Land size	1.5	4.0	5.5
Overall**	**4.0**	**4.3**	**4.2**

1 = Best or most desirable, 9 = Worst or least desirable; ** = Based on equal weight for all criteria

Table 4 Summary of evaluation of four sites in Malaysia

Criterion	Sandakan	Rejang	Loba Pulau	Matang
Genetic aspects	2.5	5.5	4.5	4.0
Ecological aspects	3.0	4.5	4.0	4.0
Utilisation level	2.5	4.5	6.0	4.5
Neighbouring flora/fauna	3.0	4.5	4.5	3.5
State of forest	3.0	6.0	5.5	3.0
Accessibility	2.5	3.0	3.0	4.0
Personnel	3.5	3.5	3.5	3.0
Anthropogenic factors	2.5	6.5	7.0	6.0
Socio-political factors	3.0	3.5	3.5	3.0
Land size	2.5	2.5	2.5	3.5
Overall**	**2.8**	**4.6**	**4.4**	**3.9**

Table 5 Summary of evaluation of one site in Thailand

Criterion	Ranong
Genetic aspects	5.0
Ecological aspects	6.0
Utilisation level	6.5
Neighbouring flora/fauna	3.0
State of forest	4.5
Accessibility	3.5
Personnel	3.0
Anthropogenic factors	5.5
Socio-political factors	3.0
Land size	3.0
Overall**	**4.3**

Table 6 Summary of evaluation of four sites in India

Criterion	Chorao	Pichavaram	Bhitar Kanika	Coringa
Genetic aspects	5.0	4.0	1.0	3.0
Ecological aspects	4.0	5.0	2.0	4.0
Utilisation level	5.0	5.0	2.0	4.5
Neighbouring flora/fauna	4.0	5.0	4.0	4.0
State of forest	5.0	5.0	2.0	5.5
Accessibility	2.0	4.0	6.0	5.0
Personnel	2.0	3.0	2.0	4.5
Anthropogenic factors	5.0	4.0	2.0	4.5
Socio-political factors	2.0	4.0	2.0	3.0
Land size	3.0	4.0	2.0	2.0
Overall**	**3.7**	**4.3**	**2.5**	**4.0**

[1] = Best or most desirable, 9 = Worst or least desirable; ** = Based on equal weight for all criteria

Table 7 Summary of evaluation of one site in Cameroon

Criterion	Mouanko Estuary
Genetic aspects	5.0
Ecological aspects	6.0
Utilisation level	6.5
Neighbouring flora/fauna	3.0
State of forest	4.5
Accessibility	3.5
Personnel	3.0
Anthropogenic factors	5.5
Socio-political factors	3.0
Land size	3.0
Overall**	**4.3**

Table 8 Summary of evaluation of one site in Senegal

Criterion	Saloum Estuary
Genetic aspects	5.0
Ecological aspects	6.0
Utilisation level	6.5
Neighbouring flora/fauna	3.0
State of forest	4.5
Accessibility	3.5
Personnel	3.0
Anthropogenic factors	5.5
Socio-political factors	3.0
Land size	3.0
Overall**	**4.3**

[1] = Best or most desirable, 9 = Worst or least desirable; ** = Based on equal weight for all criteria

GENERAL DISCUSSION

The maintenance of Biological diversity has become an important part of national and international development activities. As far as mangroves are concerned, the patterns of distribution and abundance of species in different areas have not been well documented. This was evident from the trips made by site selection team to different mangrove-rich countries in Asia, Oceania and Central, and West Africa.

For the assessment of the nominated forest areas in these countries, visually observed diversity in the predominant species existing in that particular area was considered as the prime criterion, as the degree to which a population represents the genetic diversity available in the species is more important than its size. During field visits, members of the team could define the *inter-specific* differences with the help of samples (flowers, fruits and leaves) collected. Major differences were also observed within individuals. The morphological variation could be related to regional and localised environmental factors, including temperature, rainfall, Intertidal position and upriver range. The state of forest was determined based on the 'stand height' occurrence of species, soils and distribution and association of different species of mangroves.

RECOMMENDATIONS

The following recommendations are made for deriving a strategy for the conservation and management of mangrove forest genetic resources.

GENERAL RECOMMENDATION

1. The tropical habitats, e.g., mangrove ecosystems are all being altered on an unprecedented scale throughout the World. Furthermore, a considerable amount of genetic diversity within species that might survive is likely to be lost. The mangrove forest areas nominated by the governments of the Philippines, Indonesia, Thailand and Malaysia are extraordinarily rich in the number of rare species. However, there are many different types of rarity. The time available with the team for studying these areas was not adequate to (a) determine the exact number of rare species and (b) to assess the frequencies of various types of rare species. The genetic consequences of rarity may vary with the type of rarity. It is therefore, necessary to undertake a detailed survey and prepare an inventory of mangrove forest.
2. Some areas in South-east Asia were earlier treated as 'concession areas' where deforestation and fragmentation of habitats has taken place. Some dominant species must have been reduced to such low numbers due to this activity that they may not constitute viable populations. In such populations, genetic drift and inbreeding may prevail and reduce the level of genetic variation. This can influence the abundance of many common species and the genetic variation contained in such species. Therefore, comparative data on levels of genetic variation, inbreeding and inbreeding depression for populations of rare species should be gathered in addition to the distribution and abundance of common species prevailing in the nominated areas.
3. While assessing the nominated areas for comparative scoring, emphasis was placed on the visually observed diversity in predominant species of mangroves occurring there, as it was more difficult to assess genetic variation than more common species.
4. The conversion of rare species requires large areas as individuals scattered over an extensive area are held together by gene flow. Reduction in the size of an area could gradually lead to inbreeding among the limited number of individuals in a given reserve. It is therefore proposed that more area should be made available for genetic resources conservation centres in case of smaller nominated areas.

RELATIVE STANDING OF SITES

On the basis of the various criteria developed for assessment of different forest areas in all the countries visited during this phase, the areas which attained the highest scores (as seen from Tables 1 to 8) can be considered as the most suitable sites in the respective countries.

There was difficulty in arriving at this conclusion as some of the sites gained almost equal scoring.

It is clear from the foregoing that there are several outstanding sites, worthy of being preserved for posterity. We therefore, recommend that a few of them may be developed into Global Mangrove Germplasm Conservation Centres during 1994. We were impressed by the steps and interest taken by the Governments of these countries in conserving mangrove on the following lines :

1. Strengthening national efforts to conserve and enrich the designated sites in each country through national, bilateral and international resources.
2. Identifying at a workshop organised by ITTO-CRSARD—ISME suitable sites for inclusion in the global grid of Mangrove Genetic Resources Centres, based on a detailed consideration of the reports of the three site visit teams sponsored under the present project.
3. Preparing a detailed proposal for preserving for current and future needs a representative sample of existing genetic variability in Mangrove species and for linking such conservation Centres, for financial support from the Global Environment Facility (GEF).

QUARANTINE

1. It is quite likely that one genetic conservation centre many not be able to hold all types of mangrove germplasm, therefore, it will be advisable to establish link centres at the national level which would make acquisition and maintenance of new germplasm material easier. As collections grow in size, it will be important to develop procedures that would allow them to be used easily and managed efficiently. It will be necessary for the respective governments to develop and enforce quarantine regulations, information management and other aspects of preserving large collections of mangrove genetic resources.
2. Each country should eventually develop "Mangrove Germplasm Quarantine Centre" at the National Level to facilitate exchange and importation. The collections made for maintenance should be managed both as national and regional resources, in accordance with the provisions of the Global Biodiversity Convention.

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PLANTS INHABITING MANGROVE HABITATS

A.N. RAO AND SANJAY DESHMUKH

INTRODUCTION

Mangrove forests are complex ecosystems that occur along intertidal accretive shores in the tropics. Dominated by estuarine trees, they draw many of their physical, chemical and biological characteristics from the influences of the sea, inflowing fresh water and upland forests. They serve as ecotones between land and sea and elements from both are stratified horizontally and vertically, between the forest canopy and subsurface soil.

Mangroves are the characteristic littoral plant formations of sheltered tropical and subtropical coastlines. They have been variously described as "coastal woodland", "mangal", "tidal forest" and "mangrove forest". Where conditions are suitable, they form extensive and productive forests.

A distinctive character of a 'mangal' is its diversity. The most consistent feature is the vegetation itself, easily recognised because there are few species. Nevertheless, in its most commonly expressed features, the community has a distinct aspect. The existence of extensive mangrove communities appears to depend on a number of basic requirements, although there is some disagreement as to the exact number of these requirements. Jennings and Bird (1967) described the six most important geomorphological characteristics which affect estuaries, and thereby provided the first summary of the main factors relating to mangrove establishment. The characteristics as listed by them were: 1. aridity, 2. wave energy, 3. tidal conditions, 4. sedimentation, 5. minerology, and 6. neotectonic effects.

Walsh (1974) identified five characteristics as essential mangrove prerequisites on a global scale to which Chapman (1975, 1977) added two others. These seven, apart from their biological slant, are very similar to the six derived from geomorphological considerations by Jennings and Bird (1967). They are: 1. air temperature within a certain range, 2. mud substrate, 3. protection, 4. salt water, 5. tidal range, 6. ocean currents, and 7. shallow shores. They are reviewed here briefly.

1. Temperature

Walsh (1974) and Chapman (1975, 1977) maintained that extensive mangrove development occurs only when the average air temperature of the coldest month is higher than 20°C and where the seasonal range of variation does not exceed 10 degrees. Also the world distribution of mangroves particularly at the Northern and Southern limits, appears to correlate reasonably well with the 16°C isotherm for the air temperature of the coldest month (Chapman, 1977). However, Barth (1981) has shown that equally good correlations can be obtained using water temperatures; the presence of mangroves seem to correlate with those areas where the water temperature of the warmest month exceeds 24°C, and the limits occur in those waters that never exceed 24°C throughout the year. The occurrences of mangroves in South-western Western Australia and Victoria and in the North Island of New Zealand appears to be an exception regardless of whether air or sea temperatures are used as a criterion of significance.

2. Mud substrate

Although mangroves are able to grow on sand, peat and coral, the most extensive mangroves are invariably associated with mud and muddy soils. Such soils are usually found along deltaic coasts, in lagoons, and along estuarine shorelines. The mangroves themselves, may influence the sediment composition, even accelerating mud accretion on coral islands (Steers, 1977).

3. Protection

Walsh (1974) and Chapman (1975, 1977) argued that protected coastlines are essential as mangrove communities cannot develop on exposed coasts where wave action prevents establishment of seedlings. Bays, lagoons, estuaries and shores behind barrier islands and spits are suitable localities.

4. Salt water

While there is increasing evidence that most mangroves are not obligate halophytes, it has been shown that a number of them have their optimal growth in the presence of some additional sodium chloride (Stern and Voigt, 1959; Connor, 1969; Sidhu, 1975. Chapman (1977) suggested that *Rhizophora* is probably an obligate halophyte, with growth being poor or reduced in the absence of salt. Vu-van-Cuong (1964) reported that *Ceriops tagal* and *Avicennia officinalis* would not grow in the absence of salt. However, Walsh (1974) and Chapman (1975, 1977) maintained that the real importance of salt lies in the fact that mangroves are slow-growing and that they cannot compete with faster-growing species unless these species are eliminated or reduced by salt. In this sense, they argued, salt is an essential ecological requirement for mangrove development, rather than a physiological necessity.

5. Tidal range

Tidal range, coupled with local topography, influences primarily the lateral extent of mangrove development. There greater the tidal range, the greater the vertical range available for mangrove communities. For a given tidal range, steep shores tend to have narrower mangrove zones than do gently sloping ones. Although Walsh (1974) and Chapman (1975, 1977) considered tidal range to be important, there are reports of mangroves from tideless areas (Beard 1967; Stoddart, *et al.*, 1973). Although not a direct physiological requirement, tides play an important role in the functioning of the ecosystem.

6. Ocean currents

Favourable currents are essential since they disperse mangrove propagules and distribute them along coasts. Chapman (1975) noted that the Southern limit of mangroves on the Western coast of Africa coincides with the boundary between a Southern cold-water upwelling and warm currents, and that a similar situation occurs on the Western coasts of Australia and South America. Apart from the temperature of cold currents, Chapman (1975) argued that in all cases in the Southern hemisphere such currents flow Northwards, thereby inhibiting the Southerly drift of floating propagules.

7. Shallow shores

Mangroves grow in relatively shallow water as seedlings cannot become anchored in deep water. The physical size of mangroves and their requirement of having a great proportion of their body above the water but at the same time being anchored in the soil make occupancy of deep water impossible. Chapman (1975) maintained that the shallower the water and the more extensive the shallow, the greater is the extent of mangrove development; on steeply shelving shores, where the zone of shallow water is narrow, only fringe communities develop. Although detailed information on the prerequisites for all the individual mangrove species is lacking, it can be stated that if certain conditions prevail, such as protected shoreline with suitable climate, muddy substrate and suitable tidal regime, then a mangrove community is likely to develop, provided of course, that there is a proximal source of propagules. Furthermore, this mangrove community will consist of some combination of characteristic plant species.

GEOLOGICAL HISTORY

From the beginning, mangroves are considered to be the inhabitants of tropical shores – a climate suitable for their continuous growth. They are always restricted to intertidal regions and river mouth and migrate with tidal current, not towards land. The origin and distribution of mangroves is well-documented. The geological history and evidences show that mangroves appeared between Eocene and Oligocene period (30–40 million years ago). Plant remains or fossils of major mangrove genera like *Rhizophora, Nypa* and others provide important landmarks. Oldest among these species is *Nypa* which is supposed to have originated during end of Cretaceous period, while species like *Pelliciera, Rhizophora* are from Eocene period which perhaps makes them some of the oldest members. Table 1 highlights geological time scale of mangroves.

Table 1 Geological time scale of mangroves

Era	Period	Duration		Species
Geonoic	Pleistocene	10,000–2 million	–	Human beings
63 million	Pliocene	2–10 million	–	Hominids
years	Meiocene	10–2 million	–	Grasslands
	Oliocene	25–40 million		
	Eocene	40–60 million	–	Mangroves
	Paleocene	60–63 million		
Mesozoic	Cretaceous	63–130 million	–	*Nypa,*
63–200 million				Angiosperms
years	Jurassic	130–180 million	–	Gymnosperms
	Triassic	180–230 million		
Paleozoic	Permian	230–270 million	–	Confiners
230–600 million	Carboniferous	270–345 million	–	Early
Years				Gymnosperms
	Devonian	345–400 million	–	Land Plants
	Cambrian	500–600 million	–	Marine plants

GEOGRAPHICAL DISTRIBUTION

Geographical distribution of mangroves is similar in many ways to that of sea grasses and marine angiosperms in general (Good, 1953). The main difference is that some mangrove species occur on both sides of the Atlantic Ocean and on the Atlantic and Pacific coasts of the Americas.

Geographically, mangrove vegetation may be divided into two groups: that of the Indo-Pacific region and that of Western Africa and the Americas. The Indo-Pacific region comprises East Africa, the Red Sea, India, South-East Asia, Southern Japan, the Philippines, Australia, New Zealand, and the South-eastern archipelago as far East as Samoa. The West Africa-Americas region includes the Atlantic coasts of Africa and the Americas, the Pacific coast of tropical America, and the Galapagos Islands. Among individual genera and species, distribution is undoubtedly influenced by whether or not the plant is viviparous, and the ability of the seedling to survive in sea water for an extended period of time. Dispersal of resting seedlings by drift in the open ocean and by alongshore surface currents permits wide geographic range, and temperature and geomorphological characteristics determine distribution along individual coasts.

Geographical distribution is restricted, in general, to the tropics, but Oyama (1950) reported a small stand of mangroves on the Southern tip of Kyushu Island at 35°N latitude. Later Van Steenis (1962) identified the species as *Kandelia candel* (L.) Druce.

Every mangal is composed of two classes of plants:-

1. Genera and higher taxa which are found only in the mangrove habitat, and
2. Species that belong to genera of inland plants but which are adapted for life in the swamp forest.

The world distribution of genera that occur in mangrove swamps is given in Table 2. Vu-van-Cuong (1964) has provided a detailed listing of many forms in class "b" above. The fern *Acrostichum aureum* appears to be a circumtropical associate of mangroves since it has been reported in mangals of Ceylon (Abeywickrama, 1964), India (Biswas, 1927), Africa (Bews, 1916; Boughey, 1957), and the West Indies (Boergesen, 1909).

Table 2 Distribution of plant genera that occur only in mangrove swamps (Chapman, 1970).

Families and genera	Total species	Indian Ocean West Pacific	Pacific America	Atlantic America	West Africa
Rhizophoraceae					
Rhizophora	7	5	2	3	3
Bruguiera	6	6	0	0	0
Ceriops	2	2	0	0	0
Kandelia	1	1	0	0	0
Avicenniaceae					
Avicennia	11	6	3	2	1
Myrsinaceace					
Aegiceras	2	2	0	0	0
Meliaceae					
Xylocarpus	10	8	0	2	1

Families and genera	Total species	Indian Ocean West Pacific	Pacific America	Atlantic America	West Africa
Combretaceae					
Laguncularia	1	0	1	1	1
Conocarpus	1	0	1	1	1
Lumnitzera	2	2	0	0	0
Bombacaceae					
Campostemon	2	2	0	0	0
Plumbaginaceae					
Aegialitis	2	2	0	0	0
Palmae					
Nypa	1	1	0	0	0
Myrtaceae					
Osbornia	1	1	0	0	0
Sonneratiaceae					
Sonneratia	5	5	0	0	0
Rubiaceae					
Scyphiphora	1	1	0	0	0
Total	55	44	7	9	7

The distribution of several species found only in mangrove swamps as per Table 1 shows that (a) the greatest number of genera and species occur along the shores of the Indian and Western Pacific Oceans, (b) there are no species common to East and West Africa and (c) the species of the Americas and West Africa are related taxanomically.

List of plants which form major and minor components of mangroves as well as their associates can be seen from Tables 3–8.

Table 3 Major constituents of mangrove plants

Family (Genera/Species)	Genus	No. of species	No. of mangrove species
Avicenniaceae (Verbenaceae, 70/750)	*Avicennia*	8	8
Combretaceae (16/480)	*Laguncularia*	1	1
	Lumnitzera	2	2
Palmae (200/1500)	*Nypa*	1	1
Rizophoraceae	*Bruguiera*	6	6
	Ceriops	1	1
	Kandelia	1	1
	Rhizophora	8	8
Sonneratiaceae	*Sonneratia*	6	5

Table 4 Minor constituents of mangrove plants

Family (Genera/Species)	Genus	No. of species	No. of mangrove species
Acanthaceae (240/2200)	*Acanthus*	30	
Bombacaceae (29/140)	*Campostemon*	2	2
Euphorbiaceae (220/4000)	*Excoecaria*	30	1
Lythraceae (21/500)	*Pemphis*	1	1
Meliaceae (40/600)	*Xylocarpus*	2	2
Myrsinaceae (35/1000)	*Aegiceras*	2	2
Myrtaceae (90/2800)	*Osbornia*	1	1
Pellicieraceae (Theaceae 24/375)	*Pelliciera*	1	1
Plumbaginaceae (10/280	*Aegialitis*	2	2
Pteridaceae	*Acrostichum*	4	3
Rubiaceae (450/550)	*Scyphiphora*	1	1
Sterculiaceae (48/600)	*Heritiera*	4	3

THREATS TO MANGROVE FOREST RESOURCES

Flora and fauna in a mangrove community are closely inter-related. All the aspects of such relationship are not clearly explained due to paucity of research. Each species has its own degree of tolerance and resilience, and any disturbance to the association can set up a chain reaction to the detriment of other species in the community. This is true for all the species which are genetically different than other forest species. Therefore conservation of these natural resources becomes apparent. The main objectives of conservation of mangrove plants could be,

(a) to save and maintain genetic diversity, especially of the threatened and endemic species,

(b) further utilisation of plant resources and ecosystem managed on a sustainable basis, and

(c) to redevelop or recreate the original habitat and grow the mangrove species in suitably located habitats, easily available for study, research and exchange.

Table 5 Mangrove associates (Trees)

Family (Genera/Species)	Genus	No. of species	No. of mangrove species
Anacardiaceae (60/500)	*Gluta*	20	1(c)
Apocynaceae (8190/1400)	*Cerbera*	3	3(c)
Batidaceae	*Battis*	3	1(a)
(1/2)	*Rhabdadenia*	2	2(c)
Bignoniaceae	*Amphiteena*	2	1(a)
(100/800)	*Anemopaegma*	40	1(a)
	Dolichandrone	10	1(c)
Leguminosae (600/12000)			
(i) **Caesalpinioideae**	*Caesalpinia*	60	2(c)
	Cynometra	40	2(c)
(ii) **Papilionoideae**	*Aganope*	6	1(c)
	Dalbergia	120	2(b)
	Derris	50	1(c)
	Inocarpus	3	1(c)
	Intsia	12	1(c)
	Mora (Dimorphandra)	12	1(c)
	Pongamia	12	1(a)
Celastraceae 38/480)	*Cassine*	40	1(c)
Combretaceae	*Conocarpus*	2	1(a)
(16/480)	*Terminalia*	200	1(c)
Compositae	*Tuberostyles*	2	2(a)
Ebenaceae (7/320)	*Diospyros*	240	1(c)
Euphorbiaceae	*Glochidion*	160	1(c)
(220/4000)	*Hippomane*	1	1(a)
Flacourtiaceae (70/500)	*Scolopia*	37	1(c)
Goodeniaceae (13/300)	*Scaevola*	90	2(b)
Guttiferae (42/850)	*Calophyllum*	80	1(c)
Lecythidaceae (180/150	*Barringtonia*	45	2(c)

contd.

Table 5 (*contd.*)

Family (Genera/Species)	Genus	No. of species	No. of mangrove species
Malvaceae	*Hibiscus*	160	1(c)
(35/700)	*Pavonia*	70	1(a)
	Thespesia	5	2(c)
Melastomataceae (200/2500)	*Ochthoscaris*	8	1(c)
Meliaceae (40/600)	*Amoora*	20	1(c)
Myristicaceae (18/275)	*Myristica*	85	1(c)
Myrsinaceae	*Ardisia*	260	1(c)
(34/1000)	*Myrsine*	10	1(c)
Palmae	*Calamus*	325	1(c)
(200/1500)	*Oncosperma*	8	1(c)
	Phoenix	12	1(c)
	Raphia	10	1(b)
Pandanaceae (3/225)	*Pandanus*	180	2(c)
Rubiaceae (450/5500)	*Rustia*	6	1(a)
Rutaceae (100/800)	*Merope*	1	1(c)
Sapindaceae (120/1000)	*Allophyllus*	120	1(c)
Sapotaceae 35/600)	*Pouteria*	30	1(c)
Tiliaceae (35/380)	*Brownlowia*	10	2(c)

a : new World species; b : new and old World, species; c : old World species

Table 6 Mangrove associates (Climbers)

Family	Genus	Family	Genus
Apocynaceae	*Rhabdadenia*	**Caesalpinaceae**	*Caesalpinia bonduc*
Leguminosae	*Aganope*	**Bignoniaceae**	*Anaemopegma*
	Caesalpinia		*Phyrganocydia*
	Dalbergia		
	Derris		
Rhamnaceae	*Smythea*	**Palmae**	*Calamus erinaceus* (Rattan)

Table 7 Mangrove associates (Epiphytes)

Family	Genus
Asclepiadaceae	*Dischida*
Ericaceae	*Vaccinium*
Melastomataceae	*Medinilla*
Rubiaceae	*Hydnophytum*
	Myrmecodia
Urticaceae	*Pokilospermum*

Table 8 Mangrove associates (Orchids)

Family	Genus
Orchidaceae	*Agrostyphyllum*
	Dendrobium
	Dipodium
	Eria
	Luisia
	Podochilus
	Taeniophyllum
	Trichoglottis
	Vanda
Loranthaceae	*Amyema*
	Lysianthus

DISCUSSION

With application of advanced technologies such as Remote sensing and GIS (Geographical Information Systems) technologies, it is possible to estimate the total mangrove resources available in a community, nation, region and even the whole world. Depending upon the area of the country under consideration, if an attrition rate of 5–10% per annum is allowed, the evaluation would give one, the quantitative value of reduction for a given place or area in relation to time. The genetic losses may not be known by this method, but they could be estimated on the basis of genera or species that were present in a given community. The more the number of speices of their varieties present, the greater will be the genetic value of the community. The qualitative aspects will have to be determined too, comparing the number of species and their varieties present in a given area or the country in question. Incidentally the available information from various countries has shown that mangrove vegetation regrows as a secondary or tertiary formation with changes or depletion in the number of species, size and form of trees. Only in a few of the virgin forest areas, the different species remain intact, which could be used as a baseline to understand the development of the community.

Natural ecosystems will remain viable and continue to flourish if they are left undisturbed. But most of the ecosystems in the world are disturbed or destroyed by human activity, turning them from natural to damaged or altered ecosystems like a secondary forest. Mangroves are no exception to this general trend. Due consideration should be given to the natural factors that contribute to the growth, development, and diversification of the mangrove associations in the first place. Wherever possible, the natural vegetation and the genepool should be saved. The more successful such efforts are, the greater will be the chances for the mangroves to survive and develop themselves in future.

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ECOLOGY OF MANGROVES

A.N. RAO

INTRODUCTION

Mangroves are tropical forest plants that form an Intertidal community. Depending on the richness of vegetation, the community can be an exclusive or a mixed one.

Two terms are commonly used to describes this vegetation; while 'mangal' is the name for the whole community, ' mangrove' represents the constituents of the community. Generally, mangroves are subjected to two changes of daily tidal action and the fresh water at river mouths. The number of density of species change from the coast to the inland, sometimes with the transition from the coastal to inland species. The composition change of the species may be either gradual or abrupt between marine and freshwater swamp forest.

On the sandy coast there may be a gradual transition from herbaceous forms to woody species; the former consisting of beach vegetation - *Ipomoea*, certain grasses, *Scaevola, Glochidion, Pandanus, Casuarina* and others followed by mangrove species. On muddy or muddy-sandy coasts, this gradual transition disappears and the mangroves grow right into the sea or ocean. If the coast is somewhat dry and with little rainfall, only some halophytica herbaceous forms grow. Absence of uniformity in mangrove coastal vegetation is common except in very mature communities like that of *Nypa*. Otherwise the colonisers of various species extend to the sea showing many changes in the habitat.

Extensive mangrove formations have been recorded in tropical areas where the big rivers like Brahmaputra and Ganges in India, Fly and Purari in Papua New Guinea, Mekong in Vietnam and form extensive shallow delta areas at the river mouths. Some of them are very well studied.

IMPORTANT CHARACTERISTICS

The mangrove ecosystem displays several important features, some of which are enunciated below :

1. The community comprises diverse taxonomic groups.
2. Solid is soft, consisting of soft clay mud. It is water-logged, anaerobic and smells of H_2S.
3. Canopy uniform, with short or tall trees or even bushes, depending on the geographical area. Some species grow either luxuriously or in stunted forms depending on water conditions and degree of disturbance.
4. Carps, mudskippers, ants, bees and wasps are the common animals.
5. Undergrowth very little to none, light conditions vary depending on the density of vegetation and height of trees. Epiphytes are common.

FAUNA

Although several lists of mangrove fauna have been published on the basis of habitat, region, locality, country, etc., very few complete records have been prepared. In general the main constituents are :

Molluscs	Fish	Snakes
Crustaceans	Mudskippers	Tigers
Worms	Crabs	Crocodiles
Birds	Oysters	Monkeys
Bats	Snails	Insects (infinite)

Crabs play a very important role, putting survival of seedlings at risk. *Thalassina anomala* – mound lobster is responsible for exchange and upturning of soil. Very few studies are made with respect to plant-animal interactions. Pollination methods are described for some species that involves ants, bees, birds and bats. Very little food material is provided for animals, hence interaction is limited. Most of them living there being benefitted by physical or soil conditions.

Insects and crabs consume 20–30% of available leaf tissues – but details are not available for most cases and areas. Mosquitoes (which cause Malaria and dengue fever) are very common in humid tropics.

SCHEMATIC PROFILES

Schematic Profiles vary from place to place, depending on species richness and distribution. Seaward and Landward profiles and species distribution vary. *Sonneratia, Avicennia* and even *Rhizophora* spp. may become colonisers growing into the open sea or shallow mud-flats. Succession of species is very variable and there is no definite guiding rules.

Salinity of soil and pH play a minor role. Colonisation is largely helped quality of soft soil and mild tidal conditions.

Studies by using quadrats, remote sensing and mapping are the common methods used to determine the quantity and quality of mangrove vegetation.

PLANT SUCCESSION AND ZONATION

Mangrove vegetation shows a characteristic zonation. This zonation is modified by :

- contour of the land topography,
- tidal and fresh water run off, and
- degree of sedimentation and its stability.

A stand my consist of one or several species and the structure is effected by the relative stability of the substrate. When once the community is mature, it generally remains stable for many centuries. By using the method of radio carbon communities as old as 2000 years dating have been identified. The geomorphological pattern of the soil and ground water salinity

The Several limitation factors influences the above processes, Briefly states, some of them are :

1. Rainfall which represent the source of ground water,

2. Topography of the area, which influences water flow,
3. Soil conditions which regulate the retention or flow of water,
4. The nature of the propagules which determines whether a species can establish itself at a given site,
5. Tidal fluctuation which influence the salt concentration, and
6. Coastal geomorphology, which influences sedimentation that rearranges or disappears during storms.

Likewise, there are several other factors which also limit the establishment of mangroves. In all there are 35 variables that are known to influence the establishment of mangroves.

Thus, the processes which ultimately lead to the development of the mangrove ecosystem are very dynamic.

FACTORS AFFECTING MANGROVE ECOSYSTEM

A mangrove ecosystem, more so its development, is affected by several abiotic and biotic factors. They are as follows:

ABIOTIC FACTORS

GEOMORPHOLOGY

Mangroves do not change the major land building processes, but they do contribute in a major way to stabilising the coastline. The presence of mangrove thus safeguard the coasts.

TIDE VARIATIONS

Average 2 per day depending on the coastline/ backwardness, etc.

PHYSIOLOGICAL ADAPTATIONS

Sea water 33-38 ppt; extending upto 90 ppt in extreme conditions. Species of *Avicennia,* can withstand such fluctuation of salinities.

BIOTIC FACTORS

1. Propagules of seaward species are generally heavy. They get themselves fixed in muddy water. Avicennia, Rhizophora, Sonneratia are some examples.
2. Certain species are pioneer and successfully colonise. Having once colonised, they establish and maintain themselves well. There is no successional development, no undergrowth, no under story, no stratifications. Competition is very intra-specific.
3. Species distribution is governed by salinity and frequency of inundation. Once established they increase their numbers by a series of effective reproductive mechanism

Table 1: Ecological functions of mangrove biodiversity

Function	Roles played by species in mangrove ecosystem	Performing Organism
Primary production	Photosynthesis, Food production for themselves and all animal life using simple organic compounds; energy from the Sun	Some bacteria cyanaobacteria all algal groups, lichens, ferns flowering plants
Oxygen production	Generate and supply O_2 to the atmosphere, fresh and marine water; O_2 essential for all life and for ozone layer formation	All chlorophyllus forms
Herbivory and carnivory	Eating of primary producers enriching Biodiversity. Herbivorus moderates populations of primary producers; Eating herbivorus and other carnivores, thus enriching evolution of animal diversity	Filter feeders, protozoans, molluscs, crustaceans, insects, fish amphibians reptiles, birds and mammals.
N_2 fixation	Using free N_2 produce nitrate and nitrates for primary producers	Only one report of Cyanobacteria within the barks of *Avicennia*
Symbiosis	Intimate association of 2 species, interdependence benefits for both; In parasitism one species depends on another	Epiphytes, algae on leaves, stem parasites, and ants
Population moderation	Natural limitations, one control the others, infections and predation	Viruses, bacteria, fungi, invertebrates, carnivorous, herbivores
Nutrient transport	Move nutrient—externally; Tidal actions, NPK—move them from one place to another	Fungi root system, mobile animals, faeces, death
Salt balance	Unique to mangroves, salt absorption, retention, transpiration	Special structures within or outside the plant
Dispersal (vivipary)	Spore/seed dispersal both near and far	Air, water, man, birds, mammals
Soil conditioning Sediment, Bioturbation	Continuous changes of upper layers, nutrients, organics contents, aeration or no aeration required for maintenance, productivity of plant and animal communities	Almost all groups Bacteria, Cyanobacteria, algae, fungi, plant debris (root, leaf, wood), animal matter

Table 1 *(contd.)*

Function	Roles played by species in mangrove ecosystem	Performing Organism
Prevention of soil erosion	Extensive root development; Litter accumulation	All plant remains; Dead organic matter
Mineralisation	Reduction of organic molecules to inorganic phosphate in soil and water; Toxic substances, H_2S	Bacteria – a major function of having a very significant positive global impact
Decomposition; Primary and secondary detritivory	Primary detritivory – absorption of free organic molecular residue of food/life as food and their reduction to harmless substances and nutritive blocks for use of protozoans and plants, herbivores; Dead to living matter, Secondary detrivory – eating animals	Primary detrivores, Bacteria, Secondary detrivores, Algae, Protozoa, worms, rotifers, fish, birds, mammals – food chain
Ecosystems creation Maintenance	Multicellular growth, trees, submergent, aerial, underground systems, floating underwater members, coral reefs, sea grasses all contributes to mangrove diversity	Marine algae, sponges, terrestrial vegetation, fresh water elements, sediments
Microclimate moderation	Sun and shade areas, wind, sun, storm	Trees play a major role
Anaerobic fermentation	Degradation of organic compounds in the absence of O_2 yielding energy, fermented products and H_2S	Anaerobic bacteria, yeasts, fungi
Communication	Communication between individuals – major ecological function, within and between species of diverse groups over long distances – Animals Chemo-communication, airborne pheromones, says, calls night flies, mudskippers, primal way of joining and celebrating, mystery of existence and of life giving creative ecosphere; Mangroves are very unique ecologically	Most life forms in different ways invertebrates, insect sounds, amphibians, reptiles, birds and mammals

MANGROVES : ECOLOGY AND SPECIAL FEATURES

L.P. MALL

INTRODUCTION

Mangrove forests, also known as 'Coastal woodlands' and 'Tidal forests' have aroused great curiosity among scientific community and received almost greatest amount of attention. Theophrastus in his 'Historia plantarum' (305 B.C.) quotes from the reports given by Aristobulus of the voyage by Nearchus in 325 B.C., who describes from Indus Delta to the Persian gulf occurrence of trees around 45 ft. tall, in blossom with white flowers, scented like violets growing in sea with trunks "Led us by their roots like a poly". Mangroves were known only for their wood as timber, fuel and coal wood and many other routine uses like plants of other habitats. The paper by Heald and Odum in 1970 about the mangroves of Florida point out their importance in commercial fisheries. It was a starting point for their recognition as a habitat of human food.

Subsequently in 1978, a SCOR Working Group - 60 (Scientific Committee on Oceanic Research) was formed and this, in collaboration with IUCN's COE (Commission on Ecology) group drafted a paper 'Global status of Mangroves' which was published in 1983 under editorship of Saenger, Hegerl and Davie, with an aim to "present a biosphere inventory of mangrove land, to determine their current status managing institutions and research direction, in order to collate existing information on the global status of mangroves for international use in guiding the management and conservation of this natural resources." A simple definition of mangrove vegetation was given to them as "Mangroves are characteristic littoral plant formations of tropical and sub-tropical sheltered coastlines". Every word of the definition is important and deserves consideration to a length, in the following :

Mangroves are highly characteristic due to their special physiognomy (look) as they are bright to deep green dendroid or shrubby vegetation and become more marked when there is rain-forest in the background with lofty trees having white, shiny and thick bark. Various types of aerial roots—prop, stilt, strut, pneumatophores, knee roots, etc., full of lenticels for exchange of gases with external atmosphere are present.

Likewise apparent vivipary in all the members of the family Rhizophoraceae, which form nearly half of mangrove plants of any mangrove area, give a special look to the vegetation.

MANGROVES ARE LITTORAL PLANT FORMATIONS

Littoral is a technical word used both in freshwater-bodies as well as marine bodies and stands for shore substratum upto which light enters and plants grow. In freshwater it is upto a depth of a few meters but in case of marine habitat it is upto a depth of 50 metres. But mangroves do not grow upto this depth but only up to about half of tidal zone. Thus this word does not describe the habitat of mangroves (see Figure 1).

Clements is accredited for giving the concept of 'ecological succession' and according to him, 'plant formation' is a climatic climax and is in full agreement with general climate of a geographical regions. But many people do not agree to call mangroves as climatic climax, much less as a formation.

Highest astronomical tide		(upto 10.9 m)	Supra tidal Zone
Mean high water spring tide		(upto 10.0 m)	
	MANGROVE ZONE		
High water neap tide		(upto 7.0 m)	Tidal Zone
Mean sea level		(upto 4.5 m)	
Low water neap tide		(upto 2.7 m)	
Low water spring tide		(upto 0.2 m)	
		(0.0 m)	
Lowest astronomical tide		(upto –0.6 m)	

Figure 1:. Tide levels in North-west Australia (Semeniuk, 1980)

Mangroves grow, undoubtedly, in tropical and sub-tropical regions, reaching up 38 to 40°N and S latitudes, if other favourable conditions are present. Of these most favourable habitat is sheltered coastlines. By sheltered coastline is meant a coastline protected against wave action and tidal water rises slowly and also falls slowly. This happens in narrow bay, estuary, creeks, inland sea, narrow straits, etc. Hardly 8-30% of coastlines meet this requirement. Just 8% of Indian Peninsula has mangroves, 22% of Australian coasts had this vegetation as only they are protected against tidal waves.

CLIMATE AS A FACTOR FOR GROWTH AND DEVELOPMENT

Mangroves develop luxuriantly in tropical climate between 25°N and 25°C if other favourable conditions like good rainfall, proper type of substratum and adequate protection against wave action are there. But these have been found to grow in sub-tropical zones upto 35°N (in Izuschizuoka Islands of Japan) where only *Kandelia candel* grows. In South it has been reported from New Zealand (40°S) but only *Avicennia marina* is represented.

Heavy rainfall side of a country shows luxuriant growth of mangroves. In Puerto Rico, the basic mangrove forest on humid North coast (annual rainfall 1631 mM) has basal area 17.8 m^2/ha, canopy height 13.6 m and complexity index 16.7 (Pool et al., 1977) but on direct site (rainfall 860 mM) on the South coast which had canopy height 7.0 m low basal area (6.9 m^2ha) and complexity index only 0.9. Likewise in Costa Rica on Caribbean Coast, (Annual rainfall 3300 mM) show basal area 96.4 m^2/ha, canopy height 16m and complexity index 84.5 whereas mangroves of drier, Pacific coast site (rainfall 1800 mM) showed shorter canopy (9.5 – 10.0 m) and low basal area (2.32-3.29 m^2/ha) and complexity index 10.3 (Pool et al., 1977). The rainfall has no direct influence but it improves growth considerably by bringing sediments and runoff water rich in nutrient from the inner nutrient-rich areas. Also flooding fresh water dilutes the sea water of mangroves as it has been found that best mangrove growth takes places in water with salinity between 10-20° (Teas *et al.*, 1976).

The most favourable annual mean temperature for the growth of mangroves is between 26°C and 28°C. Low temperature is harmful and frost temperature is fatal. Though by what mechanism low temperature, harms mangroves is not understood well.

In South Africa the mangroves grow well at the Bashee Estuary (32°S) where average daily minimum in coldest month (July) is 12°C and absolute minimum recorded in 37 years in 4.4°C but not at East London where the average daily minimum in July is 10°C and the minimum recorded in 68 years is 2.8°C. This suggests that an absolute minimum of around 4°C is extreme that can be tolerated. The yearly mean at Bashee is 19°C, and at East London 17.7°C and these two are almost certainly significant (Macnae, 1968). *A. marina* is much more low temperature tolerant than either the Eastern African or East Asiatic domes).

MANGROVE SITES AND THEIR RELATION WITH TIDE INUNDATION

Watson (1928) wrote about 5 mangrove sites in relation to tidal inundation :

1. Land flooded at all high tides : These sites are usually devoid of mangroves but *Rhizophora* develops exceptionally well on these areas.
2. Land flooded by medium high tides : *Avicennia, Sonneratia,* etc. grow at such sites.
3. Land flooded by normal high tides : majority of mangroves grow at such sites but *Rhizophora* tends to be dominant.
4. Land flooded by spring tides only : Such areas are a little too dry but suit well to *Bruguiera gymnorrhiza, B. cylindrica,* etc.
5. Land flooded by equinoctial or other exceptional tides only : At such sites, *R. apiculata, B. gymnorrhiza,* and *Xylocarpus granatum dominate.*

EDAPHIC AND PHYSIOGRAPHIC FACTORS

Mangroves develop best in estuarine and basin muddy soils. Riverine and basin mangrove forests of South Western Coast of Florida have considerably taller trees (6-9 m) with larger basal areas (20.3 – 38.5 m^2/ha, and complexity index under 27.7) than scrub mangrove growing on South Eastern coast of Florida (low canopy 1.0 m, low basal area, 6.0 m^2/ ha and complexity index under 1.5). The riverine muddy soil receives large quantities of fresh water run off and nutrient-rich sediments from the surrounding inland water shed.

There is also a physiographic element of land shelving very gradually having a gradient equal to 0.7m/km, leaving a vast land of almost flat ground where tidal water arises slowly and also retreats slowly. Muddy soil has poor space in the range of 63.66% and but most of it is of capillary type and remain ill-aerated. Sand spit soil has pore space equal to 44.58%, but mostly non-capillary type and remain aerated to some depth.

BIOLOGICAL FACTORS

The mangroves are richly represented by a very high number of animals. Young ones of several varieties of fish, shrimps, etc. receive shelter and feed and have normal growth. Huge populations of molluscs, crustaceans, polychaetes, etc. are found. Many molluscs damage mangrove seedling. Crabs (*Sesarma taeniolata*) do not cause damage to seedlings. *Thalassima* species of shrimps produce ventilating chimneys by bringing mud from lower level of soil in which live fiddler crabs with one claw monstrously developed and thus *Thalassima* act like earthworm and on hammocks produced by *Thalassima*, grow *Acrostichum* and later some mangroves of dry situation come up.

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MANGROVES : MORPHOLOGY, ANATOMY AND REPRODUCTION

A.N. RAO

MANGROVES : MORPHOLOGY AND ANATOMY

THE ROOT SYSTEM

Aerial roots or exposed roots are common in the tropical swamps and they can serve as organs of O_2 absorption. Several types – descending, emerging, adventitious roots, branching exist and are exposed during tidal fluctuations.

There are many types of roots in mangroves, but very few have been well studied.

STILT ROOTS

Very common in all species of *Rhizophora* and *Avicennia* (only *A. alba,* and *A. officinalis*), are adventitious with limited or extensive dichotomy, sometimes the roots with more secondary growth than in stem. In *Bruguiera* and *Ceriops,* they become hollow and multifunctional after a particular stage.

BREATHING ROOTS (PNEUMATOPHORES)

Angiotropic, erect structures common in many mangroves in general, main part of regular roots buried in soil; aerial roots arise, and emerge out of the soil; frequency, size, number vary. These roots are green and contain chlorophyll. Some of the mangrove species possess peculiar structure of pneumatophores. They are as follows :

1. *Avicennia* : Roots have a length of 20-30 cm; surface smooth/spongy, with very little secondary growth. In Sonneratia, roots exhibit secondary growth upto 3 m, flaky bark present.
2. *Laguncularia* : Blunt tipped, upto 30 cm; such roots absent in some locations;
3. *Bruguiera, Ceriops* : The roots form characteristic loops; uneven secondary growth, more towards the top of the loop, many laterals from the loop size, shape; density variable from species to species. More studies needed.
4. *Lumnitzera* : Knee roots, less conspicuous than in *Bruguiera* and *Ceriops.*
5. *Xylocarpus* : Very prominent erect roots; very intensive cambial activity, 50 cm, very extensive lateral root systems, plank roots.
6. *Aegiceras, Aegialitis, Excoecaria, Kandelia, Osbornia, Scyphiphora, Nypa*: No aerial roots reported in *Nypa,* leaf base forms extensive spongy tissue, providing aeration.

Other mangrove associates hardly produce aerial roots.

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ROOT COMPONENTS

3 components—each has a different or joint function, very characteristic of mangroves.

1. Aerating component—erect part —mainly for gas exchange, morphology and morphogenesis of these are variable; columns of loops in Rhizophora, regular pneumatophores of *Avicennia, Laguncularia, Sonneratia;* Knee roots of *Bruguiera, Ceriops* and *Xylocarpus;* Plank roots in some *Xylocarpus* spp., e.g., *X. granatum.*
2. Absorbing/anchorage part resembles the normal pattern of the land plants; cable component units both aerating, absorbing and anchoring parts; cable system may be either under or above ground.
3. Anchorage, absorption and lateral (cable) roots are common to all land plants and it is the aerating part that is unique to swamp and mangrove species.
4. Absorptive system is poor in mangroves, depth limited because of lack of oxygen; roots do not grow deep enough but remain mostly on or above the soil surface. Roots are best adapted helping the plants to live under anaerobic conditions.
5. Absorption of fresh water from sea water excluding salt is a micromorphological or differential functions of the tissues in roots. Tissues show certain modifications which help this discriminating trend.

ROOT ANATOMY

1. Root anatomy has been well studied.
2. Cortex—full of air spaces separated by spongy parenchyma. Other features; root cap present, lateral roots originate from pericycle (endogenous exarch protoxylem, xylem-phloem alternating, polyarch, wide pith, bicollateral condition in *Rhizophora* sometime reaching endarch conditions. Since these roots are aerial they have thick periderm, with plenty of secondary growth, mixing root-stem characters. Intermediate zones are common. Lenticles are present in *Bruguiera, Ceriops,* and *Rhizophora.*
3. No root hairs in any of the mangroves, as in other aquatic plants.
4. Epidermis and endodermis play an important role in different absorption of substances.

TREE ARCHITECTURE

The number, spread and frequency of branching decides the shape of the three. The model is referred as the architecture of the tree. Other factors such as mechanical damage, predators, light and shade conditions—all influence the growth pattern.

GENERAL PATTERNS : SHOOT GROWTH

a. Monopodial—Leader shoot, spiral or opposite arrangement of branches
b. Sympodial—Trunk, branches, round cylindrical or spreading crowns.
c. Pagoda trees—Monopodial, sympodial types.

ORTHOTROPIC

Main axis, trunk axis, continues to grow.

Plagiotropic

Branch axis, horizontal spread.
Shoot growth and crown development should be studied developmentally. Types of shoot growth are summarised as follows :

Attims's model

Trunk—continuous growth, so also branches, inflorescence lateral, e.g *Rhizophora*

Pattit's model

Trunk with rhythmic growth, branches have terminal inflorescence. There are less number of lateral branches, substitution growth, e.g., *Lumnitzera*

Sympodial

Hypocotyl or adventitious branches, e.g. *Rhizophora*

Rauh's model

Rhythmic growth, branches not differentiated, lateral inflorescence, e.g. *Xylocarpus*

Aubreville's model

Rhythmic growth, plagiotropic condition, e.g., *Terminalia.*

***Nypa* Pattern**

Dichotomous rhizome—keeps on branching, vegetative and reproductive growth.
Axillary buds prominent, alternate, opposite decussate arrangement, all common. Prominent stipules in *Rhizophora* and *Bruguiera*. Collates produce lot of liquid in the stipule sheaths, flooding the apical region.

VEGETATIVE PROPAGATION

Generally very few mangrove species propagate well vegetatively; coppice shoots in Avicennia, Excoecaria
Clumps of *Nypa* get washed out, re-establish themselves; rhizomes may branch off and start again.
Avicennia, Rhizophora, Sonneratia—long branches drop down and touch the ground; thigmotropic response—produce roots.
Main apex damaged; buds lateral branches even at the hypocotyl stage; this is common.
Grafting is possible especially at hypocotyl stage.

LEAF

- *Rhizophora mangle*, each leaf stays for 6-12 months, exception 17 months. In Florida, leaves formed in winter stay for a shorter period than those that develop in summer.
- Leaves are produced and also drop off in summer than in winter
- Major components like *Rhizophora* and *Avicennia* are always evergreen, whereas the landward tree forms like *Excoecaria, Terminalia, Xylocarpus* are deciduous. Evergreenness helps to maintain salt balances. If salt accumulation is greater, then there are no mangrove trees in that region.
- *Rhizophora mucronata*—Thailand—ever growing condition—shedding 0.30%, production 0.33%; average life 330 days.
- Unimodal peak (Rainfall)—*Scyphiphora, Lumnitzera* (Thailand),
- Bimodal peak—*R. apiculata, Ceriops tagal, Avicennia marina* (tidal flooding) *Lumnitzera*—9 months *Avicennia marina*—24 months.

Queensland unimodal

Bruguiera gymnorrhiza and *Ceriops tagal*; bimodal—*Rhizophora stylosa, R.* × *lamarckii*, Trimodal—*R. apiculata*; both rainfall and temperature are the influencing factors.

Leaf outline

As good as 18 species of mangroves are ovate, to elliptic in outline; very few species have specific diagnostic characters. Leaves dull, texture fairly smooth, some hairy, e.g., *Avicennia*, cork warts in *Rhizophora*.

Leaf anatomy

Mostly uniform and no diagnostic characters.

Stomata and cuticle

Normal, no unusual features.

Mesophyll

a. Assimilatory; Non-assimilatory tissue ratio is low; water conducting tissue, tannin filled tissue greater in quantity.
b. Leaves both dorsiventral and isolateral, contrasting features in sister species.
c. Sclereids : *Aegiceras, Bruguiera, Rhizophora, Sonneratia, Aegialitis, Pelliciera, Heritiera* : very thick leaves.
d. Oil cells—*Osbornia*; mucilage tissue—*Rhizophora, Sonneratia*; Laticifers—*Excoecaria*. More requires to be studies, available data very scanty.
e. Wood anatomy—no growth rings, exception *Diospyros ferea* (mangrove associate). *Avicennia* and *Aegialitis* have successive anomalous cambial bands.

Vessel size

Range 50-250 μm/150/mM^2. Vessel size/density is proportional to the frequency of inundation. These are high values—High tensions have been measured in xylem of mangrove stems. Perforation plates, simple or scalariform, no uniform characters for all mangroves.

MAIN LEAF CHARACTERS

Leaves Dorsiventral; Leaf characters of various mangroves are as follows :

Aegialitis : Stellate sclereids, salt gland, colourless hypodermis.
Avicennia : Dense capitate hairs on lower epidermis.
Rhizophora : Adaxial hypodermis; 6-7 layers, very prominent, branched sclereids, cork warts.
Aegiceras : Secretary cavities in mesophyll, branches sclereids, salt glands.
Pelliciera : Fibre-like sclereids, thin walled salt glands present.
Ceriops : Terminal sclereids well developed
Kandelia : Mesophyll isodiametric, mesophyll tissue below hypodermis.
Bruguiera : Mesophyll dorsiventral, present only adaxially.
Heritiera : Fiber bundle sheaths present, peltate scales on ventral side.
Excoecaria : Mesophyll bifacial, with palisade on both sides, peltate scales on lower epidermis.
Scyphiphora : Terminal tracheids enlarged bundle sheath not fibrous, not crystalliferous.
Xylocarpus : Bundle sheath fibres prominent with crystals, lower epidermis enlarged.

Leaves isolateral

Osbornia : Lysigenous multicellular oil cavities, more of them towards lower epidemics.
Conocarpus : Mesophyll layer uniform, hairs on both surfaces.
Sonneratia : Sclereids prominent, plenty, hypodermal mucilage cells.
Laguncularia : Salt glands in depressions.

MANGROVES : REPRODUCTION

Sexual reproduction is by flower and seed production. In mangroves reproduction is mostly be seeds since vegetative propagation is very limited or almost unknown.

a. Floral biology, pollination methods and details, breeding mechanisms, isolating mechanisms, sterility barriers, incompatibility mechanisms have broadly been studied in mangroves.

b. Most of them are outbreeders; hermaphrodite flowers. Dioecism is rare, estimated to be 4%, monoecism (flowers on the same plant) is about 16% among the mangroves. *Nypa*, sexual segregation is enforced because it is protogynous. In *Xylocarpus* the difference between male and female flowers slight. In male flowers pollen is sterile, in female ovules are abortive or nonfunctional. Pollen transfer and pollination is carried out by the insects because of Nectar. Protandry in *Avicennia* and *Scyphiphora* weak protandry in *Rhizophora;* heterostyly in *Pemphis.*

POLLINATION BIOLOGY

Transfer of pollen from one plant to the other; pollination is mostly by animals with the exception of *Rhizophora* which is wind pollinated.

a. *Rhizophora*—wind pollinated, self compatible

  stamens dehisce at bud stage, epipetalous hairs help in the dispersal of pollen,

  high pollen/value ratio

  pollen, powdery and light,

  absence of odour or pollinator award like honey, epidermal glands etc.,

  flowers inverted.

  stamens and petals drop off within 12 hours,

  only selected flowers set fruits.

  Rhizophora is self compatible (experimental evidence) flowers covered by fine mesh bags still produce fruits.

b. *Sonneratia*—Self pollinated, flowers open in the evening, stamens drop off in the morning, pollen, powdery, floral disc produces Nectar. Hawk moths are some of the other pollinators.

c. *Ceriops*—Small months are the pollinators, sweet scent produced at anthesis.

d. *Bruguiera*—Flowers are facing down and pollinated by birds. Nectar present in floral cup, calyx red coloured, protandry. Stigma becomes sensitive 2–3 days after anthesis. Pollen is not usually discharged without the disturbance by birds. Pollen scattered on bird's head and is transferred when it visits the next flower. *B. parviflora* is pollinated by butterflies.

e. *Lumnitzera*—*L. littorea* is bird pollinated and *L. racemosa* by ants.

f. *Avicennia, Excoecaria, Aegiceras, Scyphiphora*—These are pollinated by bees and ants.

g. Other aspects

  none of the species are totally dependent on any one pollinator, but some are more frequently visited by certain groups of animals than by other.

  there is no competition among different animals that frequent these flower.

  Bruguiera and *Ceriops* show explosive mechanisms, visited by birds, butterflies and moths.

  in many of the mangrove plants the anthers dehisce in the bud stage.

  pollinators live outside the mangrove community and they are not dependent on mangrove plants. e.g., Bats in Malaysia—they travel upto 40-50 km and pollinate *Sonneratia alba*. Bees and wasps live within the mangrove community.

  Avicennia—4 species in Malaysia, but each one flowers at different times, non-synchrony in flowering but all pollinated by the same group of ants and other small insects. Non-synchrony helps to extend the period of Nectar availability to the insects and avoid *inter-specific* hybridisation.

PALYNOLOGY

Pollen-grains of mangroves are very variable and have been recorded from the tertiary period. e.g. *Pelliciera*

a. *Scyphiphora*—Large pollen-grains.

b. *Nypa*—Sticky pollen-grains, most suitable for animal pollination.

c. *Rhizophora*—Light pollen produced abundantly—suitable for wind pollination.

d. *Bruguiera, Ceriops, Kandelia*—These have pollen like that of Rhizophora, but produced in lesser quantity; not suitable for wind pollination.

e. *Sonneratia*—Pollen sterility indicates the methods of hybridisation.

f. *Nypa* (Fossil pollen)—Late Cretaceous, South America, Africa, India, Borneo; *Sonneratia*—lower Miocene period. Mangroves are more recent as compared to early angiosperms e.g., Chloranthaceae
—Lower Cretaceous period.

g. Pollen structure—

Mangrove Genus	Pollen Structure
Nypa	Monocolpate, annulocolpate, spinose
Xylocarpus	Tetracoloporate
Lumnitzera	Psuedocolpate
Osbornia	Grain with arei, over poles
Sonneratia	Triporate, size 80-90 μ
Excoecaria	Grain with circular operculum covered by a membrane
Aegialitis	Colpi present with wart like sculptures, size 90μ
Aegiceras	Grains tricolporate with annulus
Avicennia	Grains tricolporate, colus intruding

h. Evidence for hybrids

- *Rhizophora* x *lamarckii*—Collapsed and irregular pollen-grains
- *Lumnitzera rosea*—Reduced viability, structure intermediate between the parents.

ECONOMIC IMPORTANCE OF MANGROVES

A.N. RAO

INTRODUCTION

Mangroves form the natural forest wealth of a country. Like any other type of forest, there is biomass increase but in details they differ from the regular conventional forests for the following reasons.

1. It is waterlogged or water dependant community and yet they use the water in a very economic way;
2. Sunlight is used. So also the plant remains are recycled through aquatic medium, lining cellulose and animal remains are part of the nutrient recycling components;
3. Difficult to assign a definite economic value because it is arduous to assess any definite capital value and the annual economic value. In Puerto Rico, a claim was made that it would cost $ 751,400/- per hectare to restore the mangroves to their original condition after they were partly destroyed or damaged by oil pollution;
4. Rural people benefit greatly;
5. Mangroves are the rich bio-productivity centres, encouraging the growth of many types of organisms; and
6. Administration wise; Forest department may want to use it on a suitable basis which would disturb the ecosystem, it is not good for fisheries either. Agriculture department may want to convert the land totally, removing the vegetation which destroys many life forms.

FORESTRY

1. ECONOMICS

Mangrove forests can contribute only 2-3% of the total value of all the forests in the country.

2. PRODUCTION

Production of wood on a sustainable basis—Watson (1928) put up a plan for biomass production on a sustainable basis. Clearfelling is recommended for poles, pulp wood etc. But what is the regeneration rate? How long is the cycle? What is the rate of natural regeneration? What are the plantation methods? Matang reserve is the oldest management project running continuously.

3. TIMBER

Timber produced from mangroves is of great value. Heavy hard wood of excellent quality, especially *Rhizophora*—used mostly for boat building; resistant to termites and sea animals. *Heritiera,* and *Xylocarpus* give valuable timber. Regeneration rate is very low, very difficult to bring back the original vegetation after the timber is harvested.

4. POLES

Extraction of unsawn poles are most common and useful. Short rotation is very important, and must be planned carefully. The data available are limited. Regeneration and growth rates have to be calculated.

5. FUELWOOD OR CHARCOAL

This is an important utilisation in many countries. Short-term rotation cycle has to be worked out.

6. TANNINS AND DYES

Mangroves were the main source of tannin for tannin industry once-now gradually replaced by synthetic tannin. The danger is not that great. *Rhizophora* bark is the main and rich source. A black dye is also produced from some mangroves and used for colouring of Polynesian Tapa Cloth.

7. FOREST PRODUCTS

Minor forest products are sources of irritant gaps. *Cerbera* seeds are poisonous. Fish poisons are extracted from roots of Derris and Barringtonia.

8. ECONOMIC BENEFITS

Nypa – Toddy extraction, ethanol production, sugar production using same method as in *Borassus, Cocos* and *Phoenix*; Leaf for thatching – attap; Cigarette paper from epidermal peel; Jelly from endosperm, etc.

9. FISHERIES

a. Good breeding and nursery ground for a variety of organisms, shell fish, oysters, etc.
b. Provide nutrition for various organisms recycling of plant and animal remains.
c. Protection of coastline; Typhoon proof or minimise the disasters.
d. Fish production with and without mangroves – data available in many countries.

10. AGRICULTURE

a. Very few mangroves are directly edible. *Bruguiera* and *Avicennia* seeds, if cooked, and boiled, can be eaten as famine food.
b. Some epiphytes like *Hydnophytum* provide fruits for birds.
c. Honey production in a limited way.
d. Conversion of mangrove lands rice fields – limited value, because of clayey soil, not worth the effort, becomes wasteland in course of time.
e. Marine aquaculture – practiced in many countries with minimal disturbance to the vegetation or the system.

11. RAW MATERIALS

Wood chips for Rayon, in South-east Asia, very commonly exported to Japan. It is a destructive activity and should be stopped. Very little benefit for local people.

12. CONVERSION TO SALT PRODUCTION

No need to destroy mangroves for conversion to salt production, natural flat beaches can be used. Examples of mangroves destruction are Bahamas, Western Australia.

13. POLLUTION

Sewage treatment in large cities. Long term and excessive usage is harmful to the community though there is a natural recycling system readily available.

14. COASTAL PROTECTION AND USE

Small, thickly populated areas, e.g., island with drive population not feasible, Singapore, Florida, an ethical dilemma. But countries with flat coastlines like the Philippines, and Bangladesh, get protection through mangroves protect against tropical storms.

15. WILDLIFE

Birds, crocodiles, Tigers, Reptiles–natural members or inhabitants of the community, becoming endangered; To be saved.

16. PRODUCTIVITY

Total productivity, Biological productivity of mangroves. Wood production in mangroves is equal or better than in some of the forests : 216 m^3/ha/year. The value varies from place to place. No generalisation possible.

CONCLUSION

"Mangrove Community is a microcosm of the socio-economic complication attendant on the human as a natural resource". What is the real value? To whom/ How much is a given time? These are very subjective questions. We do not know all the facts yet, because studies are limited. With limited use for fuelwood gathering, etc., the community should be allowed to thrive because the uses that mangroves offer are far greater than what we realise at present. More studies are required to assess the detailed value of different components.

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MANGROVES OF BAY ISLANDS

A.K. BANDYOPADHYAY

INTRODUCTION

The Andaman and Nicobar Islands comprise a chain of 572 islands, islets, reefs and isolated rocks spread in the Bay of Bengal at a distance of about 1,200 km from the East coast of mainland India. They extend to a length of 700 km between the lower Burma and the upper Sumatra region of Indonesia (Latitude 6° and 14°N and Longitude 92° and 94°E). The Andaman group forms the Northern part of the chain, while the Nicobar group in the South is separated from the main group by 160 km high seas around 10° channel. The major land mass is occupied by North, Middle and South Andaman Islands which are separated from each other by narrow channels. The coastline is about 1,962 km (one-fourth of the Indian coastline). The irregular and deeply indented coastline of these islands results in innumerable creeks, bays and estuaries which facilitate the development of rich and extensive mangrove forests. The mangrove plants generally prefer clayey soil and areas well protected from high waves and strong winds, usually within the tidal reach. They are also dependent on the regular accretions of silt which is regularly deposited by rain and river water washed down from inland forests. Along with the above basic requirements, the average temperature of the coldest temperature change is only 5°C or less, which is characteristic of humid tropical regions and facilitates the luxuriant growth of mangroves. The mangal formation of these Islands is among the most luxuriant, covering about 115,000 ha (Untawale, 1987); however, estimate varies from survey to survey. The area figures of mangroves of Bay Islands as per the existing working plans of the forest department are as follows:

Name	Area (ha)
North Andamans	29,701
Middle Andamans	23,100
Baratang	8,519
South Andamans	12,870
Little Andamans	1,124
Nicobars	2,455
Total	**77,769**

FLORISTIC COMPOSITION

There are 60 exclusive species of mangroves distributed over 16 families confined to mangrove habitats only and about 23 non-exclusive species in that habitat and elsewhere too. In Andaman and Nicobar Islands the distribution of species per any standard of measurement is very rich and there are 34 exclusive species distributed among 17 genera and 13 families.

VEGETATIONAL CHARACTERISTICS

The mangrove vegetation occurring in the Islands is mostly fringing along the creeks, backwaters and muddy as well as flat rocky shores. The important tidal creeks which harbour mangroves are the Austin Strait, Mayabunder at Mohanpura, Kalighat, Parangara Creeks and Laxmipur (North Andamans); Porlobjig, Bimlungata, Charalungata, Hamphry Strait, Lakdalungata, Yolgig and North Passage (Middle Andamans); Havelock, Wrafters Creek, Baratang, Alexandra, Wandoor (New and Old), Bamboo flat, Burmanalah, Chidiatapu (East and West); Pongibalu, Manjeri Complex, Sipighat, Weight Myo to Shoal Bay, Mile Tilek, Pochang Creek, Rutland, Wood Mason Bay, Ritchie's Archipelago, etc. (South Andamans); Dugong Creek (Little Andaman); Car Nicobar; Katchchhal Island, Nancowry Islands and at the mouth of the Galathea river and tidal creeks of Great Nicobar. For convenience, islands have been divided into seven groups, namely, North Andamans, Middle Andamans, South Andamans, including Tillangchang, Teressa, Camorta, Nancowry, Katchchhal) and South Nicobars (including Little Nicobar and Great Nicobar). Ecological distribution of both, exclusive and non-exclusive species of mangroves in different groups of islands can be seen from Tables 1 and 2.

Rhizophora apiculata, R. mucronata, Bruguiera gymnorrhiza, Heritiera littoralis, Nypa fruticans, Sonneratia caseolaris, and *Excoecaria agallocha* are the most prominent mangroves throughout the islands. Species of *Xylocarpus,* though not forming their own associations, are frequent amongst them. *Avicennia* is a prominent mangrove in Andamans more often in disturbed places but could not be seen in Nicobars. Species of *Acanthus* form thick patches, more frequently in Andamans. However, in Nicobars only *A. ilicifolius* could be seen.

Lumnitzera littorea forms its associations more commonly in Baratang and Manjeri areas where it is a very tall tree. *L. racemosa* is less frequent in Andamans and could be observed at Car Nicobar also. *B. sexangula* though rarely occurs could be separated from *B. gymnorrhiza* only when flowering. However, *B. cylindrica* is rare in Andamans. *Phoenix paludosa* could be seen at restricted sites of Middle and South Andamans bordering mangroves. *Cynometra* occurs only occasionally bordering other mangroves. *Ceriops decandra* is very rare, only seen at Chidiatapu. *Rhizophora stylosa* is not a very common mangrove while *R. × lamarckii* could be seen at Havelock and Ritchie's Archipelago only. *Aegiceras corniculatum* shows very restricted distribution in Middle and South Andamans. *Aegialitis rotundifolia* and *Kandelia candel* reported to occur in these islands are either very rare or have a doubtful distribution.

In the Andaman groups of islands, *Rhizophora apiculata* and *R. mucronata* are the most dominant species towards the sea. In the more protected places, the mangal formation has carried itself right into the sea, so that there is no foreshore and at high tide most of these plants are submerged and it appears like a tree floating on sea. *Avicennia officinalis, A. marina* and *Sonneratia caseolaris* are other species which may be present towards the sea, and these may also be found on rocky shores. *Bruguiera, Ceriops* and *Xylocarpus* are also found in tidal zones at most of the sites in the Andamans. Less frequent or locally abundant species are *Lumnitzera littorea, L. racemosa, Aegiceras corniculatum, Acanthus ilicifolius, Scyphiphora hydrophyllacea, Phoenix paludosa* and *Nypa fruticans.* Most of these occur in large populations fringing all along the tidal creeks.

The tidal creeks of Nicobar group (Car Nicobar, West Katchchhal Bay, harbour of Kamorta and Nancowry Islands, mouths of the rivers, Magarnala and Campbell Bay sites) which harbour in narrow stretches.

Table 1 List of mangrove species in Andaman and Nicobar Islands

Species	Life form	Remarks
Combretaceae		
L. racemosa Willd.	Shrub	gregarious in the muddy or sandy elevated areas in the estuarine
Euphorbiaceae		
Excoecaria agallocha Linn.	Tree	common in the intertidal forests
Fabaceae		
Derris trifoliata Lour.	Scandent shrub to climber	common
Meliaceae		
Aglaia cucullata (Roxb.) Pellegrin	Tree	very rare; reported by Hooker (1875), no further collections are available
Xylocarpus granatum Koenig	Tree	common on sheltered banks in the mangrove forests
X. mekongensis Pierre	Tree	very rare; reported by Parkinson (1934), no further collections are available
X. moluccensis (Lamk.) Roem.	Tree	common
Myrsinaceae		
Aegiceras corniculatum (Linn.) Blanco	Tree	common along the middle zone of the Intertidal banks of the creeks
Plumbaginaceae		
Aegialitis rotundifolia Roxb.	Shrub	very rare; reported by Parkinson (1923), no further collections are available
Rhizophoraceae		
B. gymnorrhiza (Linn.) Savigny	Tree	gregarious on stiff clay behind *Avicennia* spp. on the sea face
B. parviflora (Roxb.) Wt. & Arn. ex Griff	Tree	common in intertidal regions along creeks
B. sexangula (Lour.) Poir.	Tree	very rare; reported by Singh *et al.*, (1987). No further collections are available
Ceriops decandra (Griff.) Ding Hou	Shrub	rare; grows along sheltered parts in the interior of tidal swamps

Table 1 *(contd.)*

Species	Life form	Remarks
C. tagal (Perr.) C.B. Robb.	Shrub	common along the Intertidal bank
B. parviflora (Roxb.) Wt. & Arn. ex Griff	Tree	common in Intertidal regions of estuarine swamps
B. sexangula (Lour.) Poir.	Tree	very rare; reported by Singh *et al.* (1987). No further collections are available
Ceriops decandra (Griff.) Ding Hou	Shrub	rare; grows along sheltered parts in the interior of tidal swamps
C. tagal (Perr.) C.B. Robb.	Shrub	common along the Intertidal bank
Kandelia candel (Linn.) Druce	Shrub	very rare; reported by Parkinson (1923). No further collections are available
Rhizophora apiculata Blume	Tree	gregarious along the Intertidal regions of creeks
R. x lamarckii Montr.	Tree	very rare; reported by Singh *et al.* (1987). No further collections are available
R. mucronata Lamk.	Tree	gregarious
R. stylosa Griff.	Tree	rare, reported only from South Andaman on open coastal areas
Rubiaceae		
Scyphiphora hydrophyllacea Gaertn. f.	Shrub	frequent in swamps along creeks
Sonneratiaceae		
Sonneratia alba J. Smith	Tree	common; grows along the mouth of tidal creeks
S. caseolaris (Linn.) Engl.	Tree	common; thrives well in less salty areas of mangroves for forests
S. griffithii Kurz	Tree	very rare; reported by Parker (1923). No further collections are available
Sterculiaceae		
Heritiera littoralis Dryand	Tree	common on sandy tidal banks

Table 2 List of mangrove associates in Andaman and Nicobar Islands

Species	Life form	Remarks
Acanthaceae		
Acanthus ebracteatus Vahl.	Undershrub	common
A. ilicifolius Linn.	Scandent shrub	gregarious in brackish swamps
A. volubilis Wall.	Twining shrub	rare in tidal forest
Apocynaceae		
Cerbera manghas Linn.	Tree	common
C. odollam Gaertn.	Tree	common
Asclepiadaceae		
Finlaysonia obovata Wall.	Twining shrub	frequent
Tylophora tenuissima (Roxb.) W & A. ex W.	Climber	common
Asteraceae		
Pluchea indica (Linn.) Less.	Undershrub	rare
Caesalpinaceae		
Caesalpinia bonduc (L.) Roxb.	Climber	common
C. crista Linn.	Liana	common
Cyperaceae		
Fimbristylis ferruginea (L.) Vahl.		common
Fabaceae		
Cynometra iripa Kostel.	Tree	frequent
C. ramiflora Linn.	Tree	frequent
Dalbergia candenatensis (Dennst.) Prain	Climber	often found in tidal forests
Flagellariaceae		
Flagellaria indica Linn.	Climber	common
Hippocrataceae		
Salacia chinensis Linn.	Climbing shrub	rare
Lecythidaceae		
Barringtonia racemosa (Linn.) Spreng.	Small tree	common
Lythraceae		
Pemphis acidula J.R. & G. Forst.	Shrub	common
Malvaceae		
Hibiscus tiliaceous Linn.	Tree	common
Myrsinaceae		
Ardisia solanacea Roxb.	Small tree	common
Pandanaceae		
Pandanus odoratissimus Linn.	Di- or trichotomously branched large shrub	common

Table 2 *(contd.)*

Species	Life form	Remarks
Teliaceae		
Brownlowia tersa (Linn.) Kosterm.	Shrub	very rare; no further collections are available
Verbenaceae		
Clerodendrum inerme (L.) Gaertn.	Shrub	common

The dominant species are *Rhizophora mucronata, R. apiculata, Bruguiera gymnorrhiza, Sonneratia caseolaris* and *Excoecaria agallocha. Bruguiera parviflora* is found only in Car Nicobar. A little in the interior, the muddy banks of rivers, nalas (channels) and creeks are fringed with pure stands of *Nypa fruticans* and occasionally with patches of *Acanthus.*

ZONATION PATTERN

In general, three conspicuous zones can be identified of mangroves on these islands.

PROXIMAL ZONE FACING THE SEA

In the areas protected from direct sea waves (in creeks and mouths of rivers where they meet the sea), the mangal formation extends into the sea in such a way that there is no foreshore and a part of the community is inundated for most of time. Species of *Rhizophora* are the major representatives of this zone where they are specially adopted with stilt and prop roots. On rocky flat substratum or coral reefs, species of *Avicennia* and *Sonneratia* are found. These species are equipped with pneumatophores. Sometimes a few trees of Bruguiera may also occur.

MIDDLE ZONE

This zone is represented by a wide range of mangrove species growing on different types of substrata. *Bruguiera gymnorrhiza, B. cylindrica, B. parviflora, B. sexangula* all species of *Rhizophora, Lumnitzera racemosa, C. littoralis, Ceriops tagal, Aegiceras corniculatum* and *Scyphiphora hydrophyllacea* are the main members of this zone. *Nypa fruticans* particularly in muddy substrate is very common in the Nicobars. A few trees of *Xylocarpus granatum, X. moluccensis* and *X. mekongensis* (rare) are also found scattered. Sometimes *Dolichandrone spathacea* comes in this zone or forms its own association.

DISTAL ZONE

This zone is towards the inland forest. Trees such as *Heritiera littoralis, Thespesia populnea, Colubrina asiatica, Pongamia pinnata, Manilkara littoralis, Pandanus tectorius, Hernandia peltata, Licuala spinosa, Cerbera floribunda, Cynometra ramiflora, C. iripa* (rare), *Excoecaria agallocha, Hibiscus tiliaceus, Intsia bijuga, Calophyllum inophyllum, Xylocarpus* sp., *Phoenix paludosa,* etc., form the outer boundary of the mangroves.

PRODUCTIVITY OF THE MANGROVES

The productivity of mangrove trees along the Indian coasts as a whole has not received much attention. Perhaps the major handicap is the estimation of underground biomass. Mall *et al.* (1982) mentioned the density of trees per ha at Wandoor and Chidiatapu to be 2,507 and 1,167 respectively. In one observation 506 trees/ha of *Rhizophora* could produce 6,770 strut roots measuring approximately 11,000 m and in all, producing 25,000 arches, and there were about 5,400 prop roots from the upper branches. Recently, Balachandra (1988) has given the yield/ha in various groups of islands, the average yield from North Andamans, Middle Andamans and South Andamans, being 115 m^3/ha, 120.8 m^3/ha and 59 m^3/ha, respectively. *Bruguiera* contributes more to the yield in North and Middle Andamans and *Rhizophora* in South Andamans. Maximum yield is obtained in the diameter class of 10 to 20 cm. The yield/ha by number of stems (boles) in different diameter class is given in Table 2, and species-wise the number of boles and volume/ha are furnished in Table 3. Extraction figure of mangroves from different divisions of islands from the year 1981–82 to 1984–85 are given in Table 5.

Table 3 Species-wise distribution of number of boles and volume (m^3/ha) of mangroves in various divisions of Andamans

Species	North Andamans		Middle Andamans		South Andamans	
	No.	Vol. (m^3)	No.	Vol.(m^3)	No.	Vol.(m^3)
Rhizophora spp.	800.6	38.4	317.7	28.1	756.0	36.0
Bruguiera spp.	429.0	68.8	308.6	55.3	128.0	6.2
Heritiera littoralis	4.4	0.5	45.7	1.4	156.0	11.6
Others	196.9	7.8	62.8	20.7	100.0	5.0
Grand Total	1430.9	115.5	734.8	105.5	1140.0	58.8

Source : Balachandra (1988)

The primary productivity of phytoplankton has been studied from the mangrove swamps of Bay Islands by Gopinathan and Rajagopalan (1983) and Rajagopalan (1987) in the areas dominated by *Rhizophora, Excoecaria, Bruguiera, Sonneratia* and *Avicennia*. The primary productivity ranged from 0.2 to 0.5 g C/m^2/day at Ariel Bay, Mayabunder, Rangat, Henry, Lawrence and Neil. Slightly higher productivity of 0.5 to 1.0 g C/m^2/day was observed in the mangrove areas at Chidiatapu, Wandoor, Carbyn's Cove, Kimios Bay and Nancowry. Ramachandran Nair and Gopinathan (1983) also observed very high production of 2.0 to 3.6 C/m^2/day in the mangroves adjacent to mud-flats and creeks in Phoenix Bay and Carbyn's Cove. The mangroves and adjacent water-bodies may be considered very productive when compared to the offshore waters of the Bay of Bengal, where the average production is 0.16 g C/m^2/day (Radhakrishna, 1978).

REGENERATION

Natural regeneration of mangroves is found satisfactory in Bay Islands in undisturbed sites. At a less disturbed site, seedlings of *Bruguiera parviflora* were 87 to 119 m^2 while those of *B. gymnorrhiza, Rhizophora apiculata* and *R. stylosa* were 13–43, 2–17 2–7/m^2, respectively. In an average their seedlings had a height of 10 to 28 cm. At one more site the number of seedlings/m^2 of *Rhizophora apiculata, R. mucronata, R. stylosa, Bruguiera gymnorrhiza, xylocarpus* sp. and *Ceriops tagal* were 12–23, 8–12, 6, 12, 12–24, 3–7 and 3–21 m^2, respectively.

Table 4 Yield and number of boles in different diameter class in Andamans

Division	Parameters	Diameter class (cm) 1–10	11–20	21–30	31–40
North Andaman	No. of boles	760.2	512.3	133.4	20.5
	Yield (m^3/ha)	9.7	42.4	41.2	14.3
Middle Andamans	No. of boles	222.9	397.7	88.0	19.4
	Yield (m^3/ha))	2.3	37.5	33.9	15.6
South Andamans	No. of boles	616.0	448.0	36.0	N.A.
	Yield (m^3/ha)	5.6	42.6	9.6	1.1

Table 4 *(contd.)*

Division	Parameters	Diameter class (cm) 41–50	51–60	61–70	71–80	81–90	91–100	Total
North Andaman	No. of boles	3.8	0.4	0.3	0.1	-	-	1431.0
	Yield (m^3/ha)	4.8	0.8	0.7	1.2	-	-	115.1
Middle Andamans	No. of boles	3.4	1.1	-	-	-	2.3	734.8
	Yield (m^3/ha))	9.9	2.6	-	-	-	19.0	120.8
South Andamans	No. of boles	-	-	-	-	-	-	1100.0
	Yield (m^3/ha)	-	-	-	-	-	-	58.9

Source : Balachandra (1988)

MANGROVE MANAGEMENT

A review of mangrove literature and documents issued by the UNDP/UNESCO Regional Mangrove Project for Asia and Pacific outlines the following for managing mangrove resources:

1. Undisturbed and managed mangrove forests are better left in their natural state. In other mangrove areas, particularly those denuded or degraded, other land uses such as paddy cultivation and aquaculture can be introduced based on economic and ecological suitabilities.
2. Decision-makers evaluating the demand for various mangrove resources should consider both the economic and ecological aspects of development, guided by the principles of sustainability of the resource and preservation of ecological balance.
3. Since the mangrove ecosystem is an open system interacting with other systems in the coastal areas, mangrove development can be best pursued by integrating with developmental concerns for other natural systems in the coastal zone, such as beach vegetation, sea grasses, corals and coastal fisheries.
4. There are generally three major developmental alternatives for the management of mangrove areas, namely : (a) conservation of resources exploitation at sustainable level, (b) preservation or ban against exploitation; and (c) conversion to other uses like fish ponds, salt beds, agricultural areas and human settlements.
5. Knowledge of the various mangrove ecosystem processes such as nutrient cycling, detritus, food chain material and energy flow, primary and secondary productivities, is a basic requirement for mangrove management.

Table 5 Extraction figures of mangroves from different divisions

Forest Division	Volume of wood (m^3) by Govt. Agency	Extracted on payment of royalty	Total	Charcoal (tons)
1981–82				
North Andamans	-	472	472	0.96
Middle Andamans	157	4405	4562	7.56
Baratang Division	130	207	337	3.92
South Andamans	-	20586	20586	-
Nicobar Division	-	104	104	-
Total	287	25774	26061	12.44
1982–83				
North Andamans	-	1739	1739	0.71
Middle Andamans	150	567	717	9.55
Baratang Division	100	65	165	3.61
South Andamans	-	15314	15314	-
Nicobar Division	22	-	22	-
Total	272	17685	17957	13.87
1983–84				
North Andamans	-	545	545	-
Middle Andamans	1392	1285	2677	7.12
Baratang Division	127	70	197	4.34
South Andamans	-	12277	12277	-
Nicobar Division	-	-	-	-
Total	1519	14177	15696	11.46
1984–85				
North Andamans	81	2639	2720	1.27
Middle Andamans	8	-	8	8.51
Baratang Division	130	9	149	4.68
South Andamans	-	11059	11059	-
Nicobar Division	-	28	28	-
Total	219	13745	13964	14.47

Source : Balachandra (1988)

6. Various mangrove areas exhibit site-specific, physical-chemical, biological and other ecosystem characteristics depending on existing ecological parameters, for example, soil salinity, vegetation, tidal pattern, climate, temperature, and the degree of human interventions. Management approaches should depend on existing conditions in specific mangrove areas.
7. Due to the dynamic nature of mangroves and their interaction with other adjoining natural systems, the impact assessment of development projects should include both on-site and off-site effects on the whole coastal zone.

8. Mangrove management, even at the national or site specific level, can have regional or international implications as in the case of wildlife and marine migration and the preservation of gene pools.

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SYSTEMATIC NOTES ON MANGROVES OF ANDAMAN AND NICOBAR ISLANDS

H.S. DEBNATH

INTRODUCTION

Mangroves form a rather uniform, evergreen fringe which is most profusely developed in relatively sheltered areas along estuaries, coastal lagoons and backwaters where the periodic ebb and flow of the tides bring along mixing of fresh water from rains and land drainage with marine coastal waters. Thus mangroves are well developed in the East coast of Andaman Islands. Even in some places like Baratang and Austin Strait, the species *Rhizophora apiculata* and *Bruguiera gymnorrhiza* may attain a size of 50 cm in diameter and 50 m in height.

Mangroves are also developed, although in a scattered manner, in sandy or rocky beaches or on old coral-reefs covered with a thin sheet of sand or mud. In these localities the height of the stands is low, the trees are dwarfed and crooked, and the fringe is very narrow and sparse. It is observed in some places of Middle and South Andaman that *Rhizophora mucronata* and *R. apiculata* sometimes grow together on rocks or old coral reefs by making a small isle.

Within the mangrove formation the different species occupy different zones. In places where the shore is steep, *Rhizophora* grows nearest to water and invades it. In places where the shore is not very steep, *Avicennia* and *Lumnitzera* also come to the edge of the formation alongwith *Rhizophora*. Away from the shoreline towards inland where the water stagnates during high tide, other species of *Avicennia, Aegiceras, Bruguiera, Ceriops, Excoecaria* and *Lumnitzera* are found. These species are often intermixed with each other, although in some localities they have a definite zonation. *Bruguiera gymnorrhiza* is found as a dominant in Dugong Creek of Little Andaman. Here there is practically no wave action.

The species distribution also varies depending on the salt concentration of the water. *Avicennia marina* shows a wide tolerance from high salt concentrated zone to near the tidal limit where the salinity is low. The occurrence of *Sonneratia alba* at the seaward edge of the mangrove is due to its preference for near-normal salinity. The species *Rhizophora stylosa* and *R. mucronata* can grow well in more saline conditions than *R. apiculata* which prefers less salinity. Aegiceras corniculatum is found in fresh water on the shores of bays along seepage line and at the junction between fresh water swamp and mangroves. So each species occupies a zone of particular salinity.

EXTENT AND DISTRIBUTION

The total area of the Indian mangroves is estimated at 681,976 hectares, of which nearly 45% occurs in Sunderbans (West Bengal) and the islands in the Bay of Bengal. The 45%, i.e., about 300,000 hectares of mangroves, is one of the most important mangrove areas in the World (Blasco, 1977). The irregular and deeply indented coastline of the Andaman-Nicobar Islands results in innumerable creeks, bays and estuaries which facilitate the development of rich and extensive mangrove forests.

Conservation of Mangrove Forest Genetic Resources : A Training Manual
Edited by Sanjay V. Deshmukh and V. Balaji.

The mangrove stands that grow in the Nicobars are much less extensive and the trees are relatively small. The main factor controlling the growth of mangrove vegetation seems to be the physical condition of the islands. Besides being relatively small, the islands here are mostly rocky, surrounded by deep sea and are influenced by strong wave action. Nearly all of the existing tidal flats are in the form of narrow strips. The absence of big rivers limits the supply of fresh water and suspended matter. All these factors restrict the development of mangrove forests in this region.

It will not be an exaggeration to assume that mangrove formations are found in most of the Andaman islands.

COMMUNITY, STABILITY PROPERTIES

The important role of substrate in determining the dominant species growing on them is well demonstrated by the spatial distribution of the genus *Rhizophora*. Observations of mangrove communities on different islands showed that *Rhizophora mucronata* grows on muddy substrate; *R. stylosa* on sandy coast or reef flat; while *R. apiculata* occupies the transitional area between the two. Thus the type of substrate in combination with other physical factors such as salinity, mineral content and tidal actions are the underlying factors that foster the occurrence of zonation in most mangrove ecosystems. In the entire territory, the common genera recorded are *Rhizophora, Bruguiera,* and *Ceriops*. As stated above, *Rhizophora* is the dominant genus in the area while *Bruguiera* occupies the second position in order of abundance. Species of *Xylocarpus* are relatively poor in occurrence compared to *Ceriops* species. *Avicennia* and *Sonneratia* are poorly represented in the area.

STRUCTURE

On the basis of the height of plants, three categories of forest stratification are observed. The widest trunk with spreading crown is found in the species of *Sonneratia*. The species of *avicennia* have relatively less spreading crown but in height they are close to *Sonneratia*. The species of *Xylocarpus* represent crown structure between *Sonneratia* and *Avicennia*. These three genera together with *Rhizophora apiculata, R. mucronata* and *Bruguiera gymnorrhiza* constitute the top canopy of the forest. The second category is contributed by shrubs and small trees, e.g., *Aegiceras corniculatum, Bruguiera parviflora, B. cylindrica, Excoecaria agallocha,* and species of *Ceriops*. The third one is occupied by small shrubs and ferns such as species of *Acanthus, Nypa fruticans, Aegialitis rotundifolia* and *Acrostichum aureum*.

FLORA AND VEGETATION

Taxonomists often face problems in deciding what is and what is not a mangrove, especially when some of the plant species in coastal forests make their way to the mangrove community. Some genera like *Barringtonia, Salacia,* and *Pemphis* are in this category.

A total of 57 species of mangrove macrophytes has been recorded from Andaman and Nicobar Islands among which some, e.g., *Aegialitis rotundifolia, Aglaia cucullata, Sonneratia griffithii* and *Xylocarpus mekongensis* could not be located further after the first record. This needs confirmation whether those species have been made extinct or identified in some names. The recorded 57 species include plants that occur on land at the limit of salinity influence, i.e., at the transmission between the mangrove forest and the back vegetation, fresh water swamp or peat water swamp forest. On the basis of their habitat, the Andaman - Nicobar mangrove elements can be classified into two groups.

1. Obligate or exclusive group consisting of 35 species in 21 genera, which comprise plants obsoletely bound to salty or brackish water.
2. Facultative or fringe or back mangroves consisting of 22 species in 17 genera, which comprise plants belonging to the littoral vegetation which regularly make their appearance in the back mangroves.

SYSTEMATIC NOTES ON *CERBERA* AND *RHIZOPHORA*

CERBERA MANGHAS AND *C. ODOLLAM*

These two occasional species of coastal forest and back mangal communities are very closely related and have been much confused. As a result, different authors have used the names *manghas* and *odollam* for both entities despite the clear distinction between them, so there are controversies regarding the delimitation and proper status of these two species.

After careful observations of the specimens of *Cerbera manghas*, *C. odollam* of Andaman-Nicobar Islands, it was found that thought the two species are vegetatively somewhat close to each other, yet a few morphological characters show the differentiation between them. These two species may be distinguished as follows:

C. odollam Gaertn.	*C. manghas* Linn.
Leaves apiculate with a fine point	Leaves bluntly pointed
Primary veins perpendicular to mid-rib	Primary veins articulate
Corolla with a yellow eye, throat of the corolla not closed by hairy connective ridges	Corolla with a red eye, throat of the corolla is closed by densely hairy connective ridges
Corolla tube 1.5-2.0 cm long	Corolla tube 2.5-4.0 cm long
Stamens inserted at or shortly above middle of locally widened tube	Stamens inserted in mouth of tube
Fruit with endocarp somewhat transitional to fibres of inner mesocarp	Fruits without clear distinction between mesocarp and endocarp

RHIZOPHORA X LAMARCKII MONTR.

Singh *et al.* (1987) recorded this species in their publication "A new record of some mangrove species from Andaman Islands and their distribution" from Havelock Islands (South Andaman) where they have reported to have seen only some trees of the species amidst *R. mucronata* and *R. apiculata*. They have provided a brief description with a sketch of the plant which indicates this to be *R.* × *lamarckii*. Unfortunately no voucher specimens are indicated. This taxon was first recorded for India from Pichavaram in Tamil Nadu by Lakshmanan (1983).

R. × *lamarckii* was first described from Canada, the North-west of New Caledonia and was considered for long to be endemic to this area. Later its distribution in Queensland, Papua

New Guinea, the Solomon Islands and New Hebrides, i.e., between longitude 150°E and 180°E (Tomlinson 1978 and 1986) was confirmed.

Based on the circumstantial evidence, such as poor representation in the area of occurrence amidst well-recognised species *R. apiculata* and *R. stylosa*, extremely rare or lack of occurrence of seedlings, poor seed formation and aberrations in stamen morphology, all indicating sterility, it is concluded that *R.* × *lamarckii* is a hybrid species (Tomilson, 1978, Muniyandi and Natarajan, 1985; Lakshmanan and Poornima, 1988). Since this species is occurring amidst *R. apiculata* and *R. stylosa* in the type locality and elsewhere, it is reported to be a possible sterile F1 hybrid between them (Tomilson, 1976, 1986).

The rare collection of a seedling of *R.* × *lamarckii* by Muniyandi and Natarajan (1985) and description of seedlings (with emerging hypocotyl) by Singh *et al.* (1987) indicate that sterility is not absolute. Further observations of viable seedlings and cytological studies may throw more light on the genetic status of the species.

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CHARACTERISTICS OF MANGROVE SOILS OF BAY ISLANDS

A.D. MONGIA

INTRODUCTION

The Andaman Nicobar Islands comprise a chain of 572 islands, islets, reefs and isolated rocks spread in a Bay of Bengal at a distance of about 1200 km from the East coast of mainland India. They extend to a length of 700 km between the lower Burma and the upper Sumatra region of Indonesia (latitude 6° and 14°N and longitude 92°E to 94°E. The coast line is about 1962 km. The islands show warm humid climate with mean daily temperatures ranging from 20°C to 33°C. There is a net water deficit between February and April. The mean relative humidity is 79% and the normal annual rainfall is about 3000 mM. The important tidal creeks, which harbour mangroves include the Austin Strait, Mayabunder, Kalighat, and Laxmipura (North Andaman); Porlobjig, Bamlungata, Charulungata, Hamfrey Strait, Lakdalungata, Yoldig and North Passage (Middle Andaman); Baratang, Havelock, Wrafter Creek, Alexandra Island, Red Skin Island, Burmanalah, Chidiatapu, Manjeri, Wandoor, Bambooflat, Wright Myo to Shoal Bay, Sipighat, Mile Tilek, Pochang Creek, Rutland, Wood Mason Bay, Richie's Archipelago (South Andaman); Dugong Creek (little Andaman); creeks of Car Nicobar; Katchchhal, Kamorta (Central Nicobar) and mouths of rivers Galathea, Dugma and Alexandra, etc. (Great Nicobar).

CHARACTERISTICS OF MANGROVE HABITATS

Mangroves colonize in Bay Islands on a variety of substrata that include silty and clayey muds, calcareous muds, quartz sands, calcareous sands or mixtures of these. Occasionally these may colonize coastal coral reef rubble as well as cracks and hallows on rocky substrata. They prefer sediments that have been brought by rainwater or transported or deposited by tidal currents. The mangrove soils are generally slightly acidic due to the presence of pyritic horizon. Carbon dioxide arising from decomposition of organic matter and the connected gas hydrogen may also lower the pH values of the soil. The anaerobic conditions in the soil help sulphate reducing bacteria produce hydrogen sulphide and the emission of this gas gives mangrove soils their pungent odour. The characteristic gray or black colour of these soils is due to reduction of ferric compounds to ferrous sulphides. Atmospheric mean temperature of mangrove habitats varies from 29°C to 32.6°C while surface soil temperature ranges from 31° to 34.5° and temperature of surface water from 30°C to 33°C. The day time surface soil temperature is always higher than the ambient temperatures. Salinity of mangrove waters fluctuates considerably and is 3% to 32% landward and in creek waters while towards the bay it varies from 25% to 35% but approaches that a sea water as initial variations caused by rains disappear. The pH of water fluctuates from 6.5 to 7.5 in the mangrove creeks. The dissolved oxygen contents of mangrove areas is very low usually ranging from 1.7 mg/l to 3.0 mg/l, however sea wards it may approach 17 mg/l.

GEOLOGY

In the mangrove areas the bedrocks, mainly sandstone, occur under unconsolidated mud clays and sand varies little among the creeks apart from their SiO_2 content, which is related to the varying amounts of quartz (Table 1). The muds are relatively poor in Ca, K and trace elements. The clay fraction is composed mainly of Kaolinite and Smectite (Singh and Mongia 1985). The Kaolinite is derived from the upland parent materials while the Smectite has formed under marine influence.

Table 1 Chemical composition of mud samples

	Samples from mangrove flats		Marine deposits not influenced by mangrove vegetation	
Chemical	**Wandoor**	**Pongibalu**	**Wandoor**	**Pongibalu**
MgO	1.32	0.95	0.64	0.73
CaO	0.25	0.27	0.75	2.13
Fe_2O_3	4.56	6.34	3.00	3.19
Na_2O	2.48	1.17	1.15	1.79
K_2O	0.69	0.73	0.50	0.54
SiO_2	47.50	51.90	75.20	68.50
Al_2O_3	14.50	14.00	6.50	7.00
Mn_2O_4	0.03	0.10	0.01	0.01
C	2.67	2.19	1.34	0.98
		ppm		
B	101	80	95	86
Zn	12	14	10	9
Cu	25	27	12	15
S	95	86	95	86

SOIL PROFILE DEVELOPMENT

The parent material consists mainly of peaty, sulfidic mud clay. Total sulphur content usually exceeds 5%. Pure peat layers are common. The peat consists of fibrous root remains of species of Rhizophora community. Profile development is influenced by frequent inundations of saline tides and shallow ground saline water tables within 40 cm depth for a large part of the year. The physical ripening of the parent material mud is incomplete and structural peds are hardly seen. The most conspicuous morphometric differentiation is limited to mottling, decomposition of organic matter, activity of living roots and animals and season fluctuation in salinity and acidity. As tidal influence decreases, profile differentiation extends to greater depths and attains a more permanent character due to increased seasonal fluctuations of the ground water tables caused by precipitation and evapo-transpiration. The above variations in physical setting produce a sequence of soil profiles from creek towards inland with a vegetation sequence which conforms to the gradient of tidal influences.

Table 2 Analytical data of some potentially acid sulphate soils

Depth cm	Composition of mineral fraction			Eh of mud	pH		saturation extract analysis			
	Clay %	Silt %	Sand %	mu	Fresh mud	Air dried	EC DS/m	pH	Fe_2O mg/l	Al_2O_3 mg/l
Chidiatapu, South Andaman (Halic Salfaquents)										
0–20	65.0	25.3	9.7	–170	6.9	3.5	7.0	3.6	–	–
20–40	60.5	28.4	11.1	–190	6.7	2.7	190.0	2.8	–	–
40–80	67.3	28.1	4.6	–180	6.5	2.6	260.0	2.7	2675	180
80–110	70.0	26.0	4.0	–180	6.6	2.5	325.0	2.6	2500	190
Baratang, South Andaman (Halic Salfaquents)										
0–20	63.6	30.2	6.2	–170	6.2	3.7	75.0	3.5	–	–
20–40	64.8	32.2	3.0	–200	6.1	2.6	120.0	2.7	–	–
40–80	66.0	31.9	2.1	–175	6.3	2.7	120.0	2.5	–	–
80–110	65.7	30.5	3.9	–180	6.5	2.3	125.0	2.8	–	–
Great Nicobar (Sulfic Halaquept)										
0–20	28.6	7.5	63.9	–	6.5	3.6	170.0	2.5	–	–
20–60	29.3	10.6	60.1	–	6.4	2.7	120.0	7.2	–	–
60–100	35.0	15.7	49.3	–	6.3	6.5	50.0	7.0	–	–
Chiriatapu, South Andaman (Sulfic Halaquept)										
0–20	–	–	–	80	5.5	5.4	25.0	5.6	–	–
20–40	–	–	–	210	5.1	5.2	32.0	5.4	–	–
40–80	–	–	–	240	4.5	3.2	175.0	3.4	340	800
80–100	–	–	–	–60	4.6	2.9	220.0	2.9	750	2370
Baratang, South Andaman (Sulfic Halaquept)										
0–20	50.6	24.2	25.2	240	5.7	5.5	50.0	7.0	–	–
20–40	58.5	25.1	16.4	270	5.8	5.3	72.0	6.5	–	–
40–80	62.7	28.7	8.6	–20	6.1	2.7	135.0	3.1	260	270
80–120	50.3	30.3	19.4	–200	6.2	2.2	165.0	3.9	245	620
Great Nicobar (Sulfic Halaquept)										
0–20	12.7	10.2	77.1	–	5.9	5.0	140	5.7	–	–
20–40	30.2	15.6	54.2	–	4.5	3.8	210	3.6	–	–
40–80	35.7	13.2	51.1	–	4.3	2.7	250	2.5	–	–
80–120	38.9	10.1	51.0	–	5.4	2.5	340	2.2	–	–

PHYSICAL CHARACTERISTICS

The bulk of the soil material in the creeks of the Andaman and Nicobar Islands consists of heavy clay with frequent inclusions of fibrous roots of *Rhizophora* community alongwith other woody material. The mineral fraction contains more than 50% clay (Tables 2 and 3). The organic matter content is high leading to high lateral and vertical permeability. Consequently the tidal waves penetrate soil bodies upto many meters from the creek banks. The basic colours of the unripe clay are normally dark grey (10 YR 3/1; 4/1) and these turn to brownish grey (10 YR 4/2 - 5/2) in the half ripe and nearly ripe horizons. At the same time brown and yellow and rarely, red mottles appear. Typical is the pale yellow Jarosite, initially associated with the root remains. In some creeks of Great Nicobar, the patchy occurrence of very fine sandy soil material causes irregular pattern of ripening and waste content. Textures vary widely among horizons. Mature surface horizons and sandy sub-soil layers may occur together with half ripe peaty sandy clay horizons. Structure and mottling of top layers in these rather sandy soils are similar to those of heavy clay soils.

CHEMICAL CHARACTERISTICS

Nearly all the soils of the mangrove areas contain potential acid sulphate material within 50 cm of the surface, with total sulphur content exceeding 5% for clay and 2% for sandy mud. In some sandy sub soils, potential acidity (pyrite) is exceeded by potential alkalinity (shell fragments). Except for these sediment layers rich in shells, in soil horizons acidify strongly upon drying. Air dried samples give pH values of 2.5 to 3.5 (Tables 2 and 3). The field pH in soils of bare mangrove land crusted with salts, varies from 3.0 to 3.8 down to 100 cm, except for a temporary rise to pH from 5 to 6 in the surface soil, shortly after rains or spring tide. A plot of the soil pH-($CaCl_2$) against exchangeable Al gives a sigmoid curve, having an inflection at pH 4.2. Below this pH the exchangeable Al content increases steeply and above this starts disappearing. It is evident that the soil pH is buffered by the clay minerals. The pH - ($CaCl_2$2) below 4.2 coupled with presence of yellow mottles are characteristics of acid sulphate soils (Singh *et al.*, 1989).

ORGANIC MATTER

The fibrous root remains of *Rhizophora* and associates are common in the soils under mangrove community and in the reduced sub soils of bare marsh lands. These roots often form the most conspicuous constituent of the soil. Organic matter content is commonly high with low degree of decomposition.

SULPHUR

Sulphur contents of parent materials range from 1 to 4% for mud sands and 3-100% for mud clays. Most of the sulphur comes from microcrystalline clusters of pyrite embedded in the organic matter especially in the fibrous root remains of Rhizophora association. In bare marsh lands, soil horizons with Jarosite mottles have lower sulphur contents. The lowest sulphur contents (0.5%) are found in the half ripe or nearly ripe surface soils without Jarosite mottles. Soils having a water soluble sulphur content of more than 0.5%, may be considered as potentially acid sulphate in nature (Mongia and Ganeshamurthy 1989; Singh *et al.*, 1989).

Table 3 Analysis of some acid sulphate soils from the andaman and nicobar islands

Depth cm	Composition of mineral fraction Clay %	Silt %	Sand %	Eh of mud mu	pH Fresh soil	Air dried soil	Saturation extract analysis EC-DS/m	pH	Fe_2O_3 mg/l	Al_2O_3 mg/l
Chidiatapu, South Andaman (Halic Salfaquents)										
0–15	60.5	32.5	7.0	−370	3.4	4.0	100	4.1	–	30
15–35	58.7	28.0	13.3	−450	3.5	3.7	175	3.4	15	60
35–75	62.0	33.2	4.8	−280	3.8	3.0	240	3.1	450	1590
75–110	64.5	31.2	4.3	−220	4.0	3.4	250	2.9	–	2870
Baratang, South Andaman (Halic Salfaquents)										
0–15	70.4	19.0	10.6	−450	3.7	3.5	85	3.6	30.6	15
15–35	75.6	16.8	7.6	−590	3.5	3.0	80	3.8	49.5	10
35–75	70.5	20.5	9.0	−470	3.6	3.1	140	3.2	290.0	–
75–120	72.0	23.7	4.3	−310	3.5	3.1	240	3.2	–	–
Great Nicobar (Sulfic Halaquept)										
0–15	10.5	5.9	83.6	–	4.0	3.7	290	3.6	–	350
20–40	30.6	10.7	58.7	–	3.6	3.7	280	3.2	390	850
40–60	40.2	16.3	43.5	–	3.7	2.9	370	2.3	650	2370
60–100	25.3	19.2	55.4	–	3.4	2.5	280	2.1	790	2450

Table 4 Electrical conductivity (DS/m) of saturation extract of soil samples at the end of the rainy season

	Mangrove forest		Bare mangrove land	
Soil Depth cm	*Rhizophora* community	*Avicennia* community	Inundated daily	With salt crust
	Chiriatapu, South Andaman			
0–20	45	25	50	105
40–60	160	175	115	180
80–100	170	260	180	270
	Baratang, South Andaman			
0–20	60	40	80	85
40–80	90	70	85	250
	Great Nicobar			
0–20	170	–	150	280
40–60	110	–	210	310
80–110	40	–	320	370

Table 5 Analytical data of creek and ground waters in typical vegetation and soil sequence from South Andaman

Sequence	pH	EC dS/m	Cl^-	SO_4^{2-}	HCO_3	Ca^{2+}	Mg^{2+}	K^{2+}	Na^+
February 1988				Pongibalu site					
1. Creek	7.1	50.3	620	106	2.40	25.0	120.4	10.0	520
2. Rhizophora community	6.2	65.8	900	103	2.15	35.7	195.0	15.9	770
3. Avicennia community	6.4	80.0	1250	130	1.59	40.7	260.5	20.0	1070
4. Bare land daily inundatd	4.2	85.0	1300	125	–	35.5	280.0	20.2	1080
5. Bare land with saline surface crust	3.5	110.3	1700	240	–	37.2	450.0	18.5	1400
March 1988				Wandoor site					
1. Creek	7.3	48.4	360	50.8	1.0	12.3	700	10.0	340
2. Rhizophora community	7.5	45.6	340	42.9	2.1	11.0	690	8.9	300
3. Avicennia community	7.8	49.7	400	58.7	1.3	12.8	127	12.0	340
4. Bare land dail inundated	3.9	75.0	570	85.3	1.6	27.4	–	16.0	380
5. Bare land with saline surface crust	2.9	110.8	830	130.6	–	45.0	224	25.0	790

SOLUBLE SALTS AND SALINITY

All soils of the mangrove areas are more or less saline in the natural state. During the dry season, loss of water by evapo-transpiration is largely balanced by saline tidal water from the creeks. Thus ground water level rarely falls below 50 cm under the surface except in areas far from the creeks where the tidal waves dampen and sub-surface lateral influx of saline ground water only partially compensates the evapo-transpiration losses. The salinity of the ground water increases from the creek banks inwards to a level several times that of sea water (Table 4 and 5). Rainy season is able to desalinate the soil superficially between the vegetation and soil sequence (Table 4). Both highest salinity and acidity occur in the bare mangrove marsh land with salt crusts at the surface i.e. in the zone where during the rainy season, evapo-transpiration exceeds replenishment by tidal water and where the pyritic sub-soil is liable to be exposed to the atmospheric oxygen to a greater depth.

The increase in dissolved sulphate during the formation of hypersaline ground water is less than the increase in chloride, even though considerable amounts of sulphate must be liberated during pyritic oxidation under these conditions (Table 5). Sulphate concentrations are probably kept relatively low by precipitation of gypsum and Jarosite, which are very conspicuous in these soils. Dissolved SiO_2 in the ground water increases away from the creek banks towards the bare mangrove lands. Owing to the presence of silicified Rhizophora community roots in bare mangrove areas, the silica concentration probably exceeds the amorphous silica solubility (2 mMol/l) at times. The dissolution of silicates (clay minerals) is the source of dissolved silica in the bare mangrove areas.

SOIL CLASSIFICATION

The soil sequence between creek banks and bare mangrove areas comprises potential and acid sulphate soils and sometimes para acid sulphate soils that are strongly saline and locally hypersaline. Soil samples from the profile under the mangrove forest and from depths below 40 cm in the bare mangrove areas usually have sulphur contents of 0.75% and a pH of air-dried soil below 3.5. Soils in bare mangrove areas may have Jarosite mottles in the upper horizons. In terms of Soil taxonomy these acid sulphate soils are Halic Sulfaquepts - Tropoquepts (acid sulphate). The potentially acid sulphate soils are may be above 4.0 but decreases with depth 3.5 to 50 cm, below the surface Jarosite mottles are common. These soils are Sulfic Halaquepts.

CHANGES IN SOIL CONDITIONS AS A RESULT OF AIR DRYING

The effect of drying on the changes that occur in the two type of muds under Rhizophora communities was studied by drying the samples of mud for different length of time so as to obtain muds with moisture contents varying from field moisture at low tide to 5% moisture. Absolute dry soil was obtained by oven drying the soil at 110°. The muds were analysed and incubated for 20 days. At the end of 20 days the muds were re-analysed.

The drying of fibrous mud of Rhizophora community and non fibrous mud of Avicennia community to various moisture contents, and changes on incubation at any particular moisture content showed drop in pH of the fibrous mud. A sudden drop in pH occurred when moisture content dropped from 50 to 30% . With further drying to 10% moisture, the pH dropped to a much lower value. However, below 10% moisture no further change in pH was observed.

The change in SO_4 content of *Rhizophora* community fibrous mud on drying folowed the same trend as in case of pH. On the other hand the *Avicennia* community mud did not show any change in SO_4 content during drying except for a small increase when completely oven dried. At this point the pH also dropped to a lower value in Avicennia mud showing the possibility of chemical oxidation of sulphur. Drying did not change acid soluble phosphate in fibrous mud and incubation increased the phosphate content at a stage where pH dropped sharply resulting in the dissolution of Fe and Al phosphates. Drying of non-fibrous mud also behaved similarly. A steady increase in NO_3-N occurred when the fibrous mud was dried and a further increase was noticed during incubation. The non-fibrous mud when dried gave larger increase in NO_3-N than the fibrous mud inspite of the higher organic matter. This is in part due solubleto the acidity in the fibrous mud which inhibits the rate of oxidation. These results explain as to why the lands cleared out of *Rhizophora* community and empoldered for rice cultivation do not retain favourable conditions for rice growth for longtimes while those out of *Avicennia* community can be cleared and empoldered with impunity.

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POPULATION DYNAMICS IN MANGROVES

S.B. CHAPHEKAR

INTRODUCTION

On the West coast of peninsular India, mangroves are distributed along the creeks and a large number of river mouths in fringed state. Most of these West-flowing rivers are short, monsoon-fed, rapidly flowing streams with only a few kilometers of estuarine zone along which mangroves prosper. In the regions where mangroves are left undisturbed, a generalised zonation pattern is perceptible, viz., *Rhizophora* in waters near the low tide area, *Avicennia marina* on the upper side and a sprinkling of *Sonneratia apetala* trees and bushes of *Ceriops tagal* and *Excoecaria agallocha* in the region in between. The back-mangrove region is very short, occupied by grassy patches of *Aeluropus lagopoides, Acanthus ilicifolius,* clusters of Cyperaceae species and some low-growing perennials like *Clerodendrum inerme, Salvadora persica* and a straggler, *Derris scandens* (Figure 1) (Navalkar, 1951; Chaphekar, 1959).

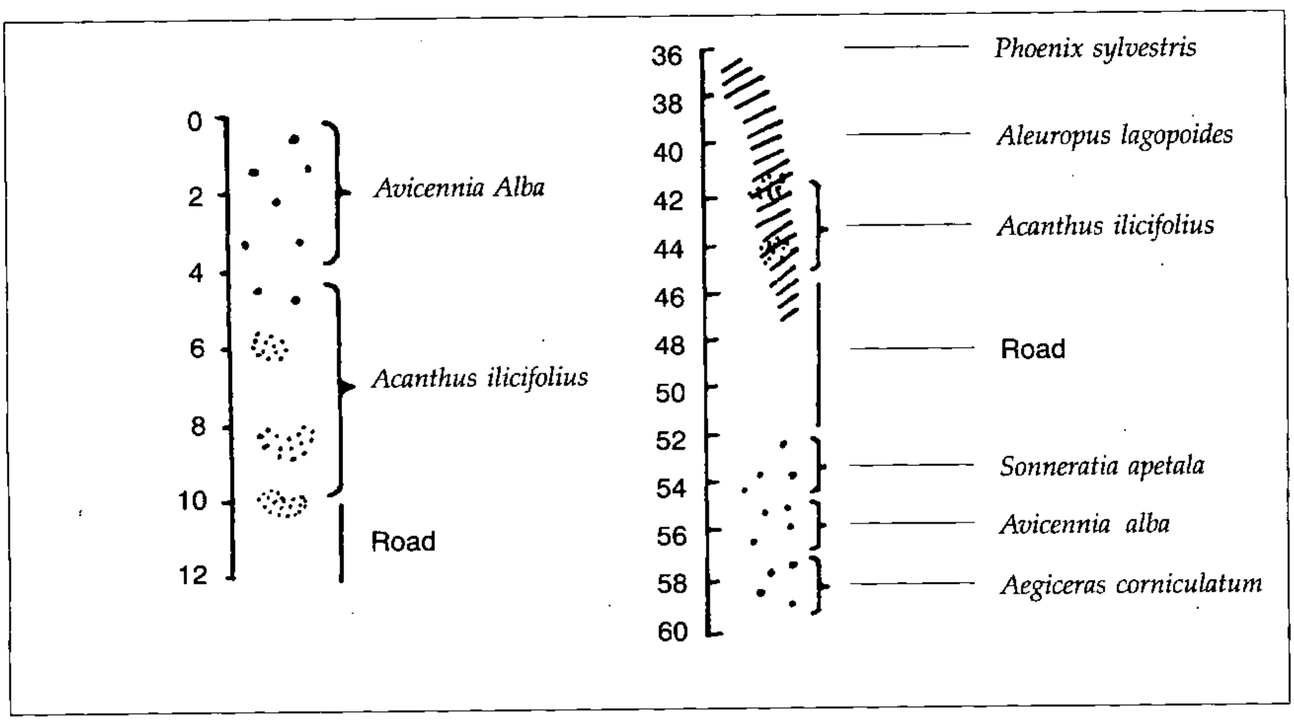

Figure 1. Zonation of mangrove vegetation at Ghodbandal, Thane District (Navalkar, 1951)

Along the East coast of the peninsula where deltaic regions are more spread out on flat lands, all these zones may be more extensive in distribution, but the pattern of zonation is essentially similar (Figure 2) (Blasco and Caratini, 1973).

Along the waterfronts which are disturbed during reclamation for industrial establishment or for human habitat, or due to lopping of wood for fuel, the patterns of zonation are hardly visible. Some species of undisturbed mangrove community come to grow predominantly, even as monocultures, on the banks of chemical polluted estuaries (Mhatre *et al.*, 1980). Reasons for distribution patterns of mangroves and associated species along coastlines, both undisturbed and disturbed are hardly traced, except in a gross fashion. Here is an attempt to list the possible causes of zonation within the mangrove community. Gaps in our knowledge of this subject are spelt out, focusing on the areas that are open for intensive investigations.

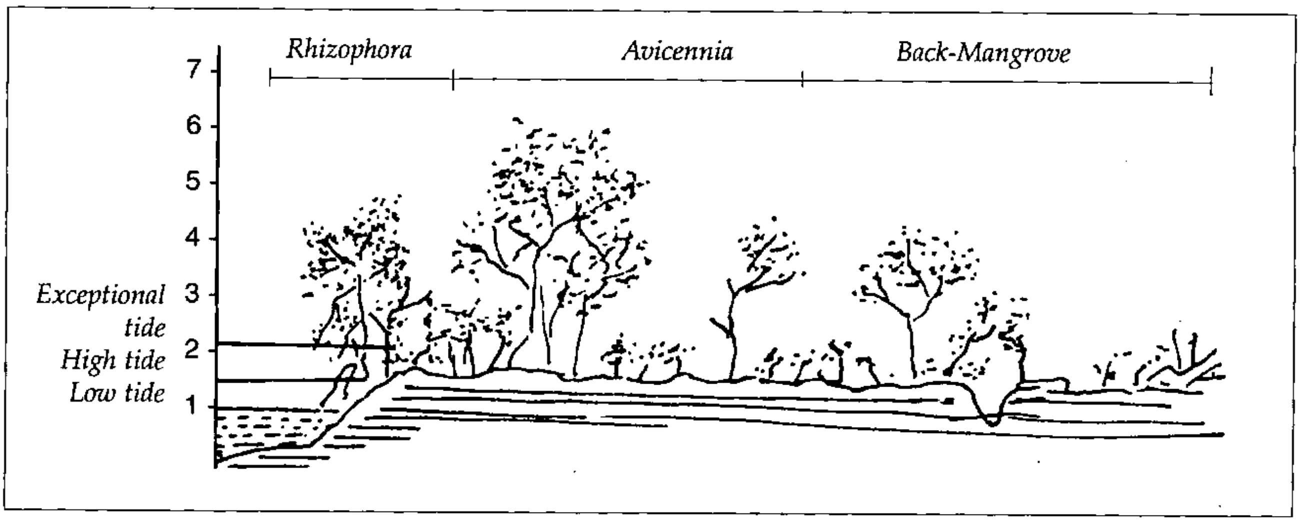

Figure 2. Zonation of the mangrove vegetation in Pichavaram, Cauvery delta, India (Source : Blasco and Caratini, 1973)

PROBABLE FACTORS LEADING TO ZONATION PATTERN

Distribution of plant species may have come into existence due to the finer characteristics of the habitat, growth form of plants and their space requirements, in addition to the major regional characteristics like temperature regimes, salinity levels, flooding, etc. Rates of growth of different species in absolute as well as relative terms also may have contributed to the resultant zonation pattern. Let us take a look at some of these factors more critically, before assessing the impact of human intervention on zonation patterns.

TIDAL ACTION

Distribution of mangroves as seeds or as viviparously formed seedlings, is assisted greatly by tidal action. However, the distribution of disseminules leading to the said zonation pattern is hardly explained by mass transportation of the plant material on tidal swells and ebbs. Seedlings of *Rhizophora, Bruguiera, Ceriops, Avicennia,* etc., are often found associated with the respective parent plant, but when they are carried on water currents, all may be found along the same receding water line, lack of evidence to explain the zonation pattern.

It is common observation that the seedlings of *Rhizophora* keep lying on winds for some time before anchorage in muds. These seedlings are larger than any other seedlings among mangroves. When they germinate, the plumule is raised well above the ground, some 20-30 cm or more. Chances of the delicate plumules remaining unhurt during tidal swells by water or water-borne organisms are good under such raised conditions. Plumules of successfully grown seedlings were often seen adversely affected by predators or other organisms, carried by tidal waters, during our plantation trials on Vikhroli shores of Thane creek. *Cryphalus littoralis* has been identified as a borer of seedling of *Rhizophora mucronata* by Khan *et al.*, (1990). Untawale (1986) recommended plantation of tall seedlings of *Rhizophora* to ensure better survival. It is possible that smaller seedling of other mangroves (*Ceriops, Bruguiera*) may not succeed in their growth, even if planted in deeper waters at low tide line. Stilt roots of *Rhizophora,* virtually lifting the crown a couple of metres above the water level, may also prove an asset for survival to high tides, a facility not provided to other common mangroves. *Avicennia* and *Sonneratia,* with their pneumatophores at ground level, are at a disadvantage for survival at the same tidal level, which would clog the lenticels on pneumatophores.

SALINITY REGIMES

Within the reaches of the tidal waters, salinity levels are not expected to vary to an extent that would determine differentiation of habitat of mangrove species. Soil salinity as well as salinity of pore waters are recorded to be indistinguishable (Chaphekar, 1959; Kanvinde, 1992). Teas *et al.*, (1975) have reported that the type of substrate did not affect establishment of mangrove seedlings. Osmotic pressure of cell sap was found to be low, i.e., nearer the value of osmotic pressure of soil, in the case of *Sonneratia alba, Rhizophora mucronata, Avicennia marina* and *Ceriops decandra* (Chaphekar and Deshmukh, 1987). Whether this contributes to the preference (or survival) of *Rhizophora* at waterfront belts is not known with certainty.

ALLELOPATHY

Dilution effect of tidal waters may also neglect any possibility of allelopathic phenomena within mangrove plants, contributing to zonation. No report in this respect, however, is available in literature.

HORIZONTAL SPACING

Plants like *Bruguiera, Sonneratia, Avicennia,* etc., have their pneumatophores borne on very strong cable roots around the base of their trunks. These may occupy circular areas with 2-5 m radii. Few companions are reported with *Rhizophora* at low tide lines, though different species of the genus are known to be sharing the waterfront to form impenetrable belts (Status Report on Mangroves, 1987). *Avicennia and Sonneratia* have often been noticed to be sharing the ground, forming mixed stands in many places. *Bruguiera* at Chidiatapu in Andamans, however, shows a monoculture and excludes all other species effectively by its powerful knee roots around the tree bases. It appears that in mature stands, the space occupied by pneumatophores proves to be the determinant of the density of individuals in the stand.

GENETIC FACTOR

Virtually nothing is known about the genetic attributes of mangrove species that impart them the ability to survive in their peculiar habitats. As a result, we are unable to answer questions like : a) are there different ploidy levels in a species that determine success or failure of particular individual, by the stress exerted at a particular tidal level within the saline habitat, or (b) is preference within a mangrove habitat by *Rhizophora* made according to its inherent ability to tolerate the worst of the conditions at low tide levels?

COMPETITIVE ABILITY OF MANGROVE SPECIES

Experiments to study the competitive abilities of perennial, woody plants are very few; most of them are confined to herbaceous annuals, for obvious reasons of experimental convenience. As such, not even a guess is possible about the state of competition between mangrove species, so far the most neglected of plants for autoecological studies. For that matter, little is known about the reproductive capacities of mangroves, seed germinability and seedling mortality—the latter is reported to be very high in the case of *Avicennia marina* (Lattoo, 1987)—rates of growth, canopy sizes, etc. A vast array of ignorance prevails in this field, though more scientists and researchers are getting attracted to the coastal ecosystems lately.

HUMAN INTERFERENCE AND ZONATION

Human activity in coastal areas affects the mangrove vegetation and its zonation in a large and sometimes irreversible way. Chaphekar and Deshmukh (1987) have listed thirteen types of activities that affect mangroves. Changes in coastal land-use affect mangroves through alternations in fresh water runoff pattern, increased sedimentation, inundation, frequency changes, oxygen depletion, etc. Activities resulting in eradication of mangroves may be an extreme case. Smaller impacts however, when continued over a period of time affect zonation and patterns of dynamics in mangroves. The effect of two types of human interference that are of a continuing nature, i.e., chopping for fuel and industrial pollution is discussed below.

CHOPPING FOR FUEL

Removal of branches of woody mangroves, especially *Rhizophora, Avicennia and Sonneratia* is very common, as we noticed repeatedly during our studies along the Ulhas river estuarine zone (Aswani Kumar and Chaphekar, 1985). Though no experimental evidence is available, it is safe to assume that repeated chopping of photosynthetic biomass has led to the eradication of several mangrove species, and where *Avicennia* still survives, it is in a highly depauperate form. Where even *Avicennia* got eradicated, vast patches of the spiny bush *Acanthus ilicifolius* were noticeable. Whether establishment and prosperity of *Acanthus* is because of lack of competition from woody mangroves or due to some other reason needs to be investigated. One of the areas studied along the Ulhas river, has been exposed to removal of wood during the last four decades, it presently shows acres and acres of coastal land occupied by monocultures of *Acanthus ilicifolius*.

INDUSTRIAL EFFLUENTS

A relatively better studies example is that of industrial effluents from a number of factories in coastal marshlands, affecting species composition. In this zone, located at the upper limits of the Kalu river estuarine zone, there were hardly ten species of flowering plants, as compared to the unpolluted zone with twenty species (Mhatre *et al.*, 1980). Only two of the species—*Pycreus macrostachyos* and *Cynadon dactylon*—were found to be and abundant while the other species presented reduced, weaker and depauperate forms.

Analysis of the sediment and the plants showed*Pycreus macrostachyos* to be a good accumulator of heavy metal pollutants present in the sediment (Table 1). The species when growing elsewhere was only a minor component of the marshland community, but growing along the polluted banks of the estuary it developed into a vigorous monoculture, since other, more sensitive species had vanished from the region.

Table 1 Heavy metals in sediments and *Pycreus macrostachyos* (Lamarck.) J. Raynal, collected from the banks of the river Kalu at Ambivali and Titwala

Metals	(mg/g dry weight)					
	Pycreus macrostachyos					
	Leaf		Rhizome		Sediment	
	Ambivali	Titwala	Ambivali	Titwala	Ambivali	Titwala
Hg	3.3–110	1.4	6.9–53.3	2.9	1.5–140	39.0–52.0
Pb	100	3.0	100	2.8	5.4–10.6	3.8–4.4
Cd	2.5–10.0	2.5	0.98–0.0	0.1	0.62–12.6	0.42–6.8
Cu	9.0–26.4	23.0	2.03–307	89.0	91.0–864	78.0–89.0

Estimated spectrophotometrically by the dithozone method; other metals were estimated by AAS

It is not easy to understand the reasons for the success of a particular species in pollution loaded sediments, when most others had succumbed to the toxicity of pollutants. Antonovics *et al.* (1971) recognised several strategies of plants for overcoming heavy metal toxicity in the substratum. It appears *Pycreus macrostachyos* has developed strains which accumulate absorbed metals in non-toxic form.

To what extent a similar strategy of evolving pollution-tolerant strains exists among mangrove species is difficult to guess. But this phenomenon, described critically by Bradshaw (1976), is of great significance in the determination of the nature of coastal vegetation of the future, since creeks and estuaries are the most common dumping grounds of industrial effluents and municipal wastes in most countries of the World.

CONCLUSIONS

Mangroves are finally receiving the attention due to them, and the need for conservation of this unique and highly productive ecosystem is no more questioned. The threat of sea level rise in the next century has added a sense of urgency to know more about this ecosystem, already ravaged by the forces of urbanisation, industrialisation and as a source of fuel for the poor. The present state of our ignorance in the matter should urge us to undertake intensive research in several aspects of this vegetation some of which are identified here.

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PLANT REPRODUCTIVE BIOLOGY

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INTRODUCTION

Interest in plant reproductive biology is as ancient as settled agriculture. Farmers have always shown a keen interest in the reproductive biology of plants and mechanism of fruit production. So much of our agricultural production depends upon pollination and pollination systems have long been recognised as a model for understanding the interplay between natural selection and evolution. Charles Darwin wrote several books and papers on pollination systems and plant reproduction, and many of his conclusions are still valid today.

Study of plant reproductive biology includes:

1. Floral morphology floral biology,
2. Pollination biology,
3. Plant-Pollination vector interaction, i.e., pollination ecology,
4. Breeding systems,
5. Phenology of reproductive events,
6. Seed and fruit dispersal,
7. Seed biology (seed physiology, seed generation and seedling ecology),
8. Seed and fruit,
9. Regeneration, and
10. Population genetic structure and genetic variation accompanying the reproductive events.

TERMINOLOGY IN POLLINATION BIOLOGY

Autogamy –	The flower receives its own pollen (self-pollination) and leads to successful fertilisation
Allogamy –	Flower receives pollen from another flower (cross-pollination) and leads to successful fertilisation
Geitonogamy –	Successful fertilisation following cross-pollination between two flowers on the same plant
Xenogamy –	Successful fertilisation following cross-pollination between two flowers of separate plants
Hybridisation –	Between two flowers of separate species
Homogamy –	Stigmas and anthers mature simultaneously. Potentially these flowers can be self-fertilised
Herkogamy –	Bisexual flowers in which self-fertilisation is prevented by the (Herkos-barriers) positioning of stamens and stigma.

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Table 2 Pollination and phenological details and mangroves

Family, genus and species	Distribution	Floral sexuality and morphology (flowering period)	Pollen vector, and vector rewards	Breeding system	Fruit	Dispersal	Germination
Acanthaceae							
1. *Acanthus ilicifolius*	Tropical Asia, Africa	Hermaphroditic	Entomophilous or Ornithophilous pollen	Protandrous and cross-pollinated	Capsule	Explosive release of seeds	
Apocyanaceae							
2. *Cerbera manghas, C. odollam*	Tropical Asia	Hermaphroditic	Animal Pollinated (?) pollen	Cross-pollination favoured as the flower visitor encounter stigmastic disc before it touches pollen mass	2-seeded drupe	Water	Hypogeal
Avicenniaceae							
3. *Avicennia marina*	Pantropical	Hermaphroditic and actinomorphic	Meliottophilous Nectar and pollen	Protandrous	1 seeded capsule	Incipiently viviparous	Epigeal
4. *Avicennia officinalis*	Pantropical	Zygomorphic	-do-	Protandrous	1 seeded capsule	-do-	
Bignoniaceae							
5. *Dolicandrone spathacea*	South Asia to Pacific	Hermaphroditic and zygomorphic cross-pollination favoured. Nectar and pollen fragrant (May-July)	Sphingophily	Hawk-moth (?) capsules. Seeds corky, winged	Semi woody, long		Epigeal
Combretaceae							
6. *Lumnitzera racemosa*	East Africa Western Pacific	Hermaphroditic Actinomorphic	Sun-birds and honey eater ornithophily. Bees and Wasps Meliottophilous	Protandrous		Water	Hypogeal
7. *Terminalia catappa*	Tropical Asia	Zygomorphic Actinomorphic	Meliottophilous	Andromoecious	Drupaceous		Hypogeal
Euphorbiaceae							
8. *Excoecaria agallocha*	East Africa Pacific	Entomophilous. Nectar and pollen. Glands on catkin bracts and leaves	Dioetious				Epigeal
Meliaceae							
9. *Xylocarpus granatum*	East Africa to Indo-Malaya	Meliottophilous. Nectar and pollen	Monoecious and protogynous		Seeds with corky testa	Water	
Myrsinaceae							
10. *Aegiceras corniculatum*	Australia	Hermaphroditic and Zygomorphic	Entomophilic Nectar and fragrant				Epigeal
Palmae							
11. *Nypa fruticans*	Old World tropics		Trigona and flies Meliottophily and Myophily		Monoecious	Water	
Rhizophoraceae							
12. *Rhizophora*	West Africa Pacific, Indo-Malaya		Anemophilous	Protandrous		Water	

NATURE AND PRODUCTION OF ATTRACTANTS

A blossom – visitor relationship is established by means of an attractant. The most important urge that causes animals to visit blossoms is in the search for food, or for feeding the broad. This is the background for an overwhelming majority of blossom visits. Attractants can be divided into two broad groups primary and secondary (Table 3).

Table 3 Primary and secondary attractants

1. Primary Attractants			
a.	Pollen	-	16-30% Protein, 1-7% Starch, 0-15 Sugar, 3-10% Fat, 1-9% Ashes
b.	Nectar	-	Sugars (Gl., Fr. Suc. – Big three)
	Galactose, Arabinose, Mannose	-	Mono Maltose, Melibiose – Disac. Raffinose Trisac – Amino Acids, Proteins, Lipids, Antioxidants, Alkaloids, Glycosides, Vitamins, Org. Acids, Allantoin, Inorg. Salts.
c.	Oils	-	Fat oils in Elaiophors (In South American Tropics – Common)
d.	Food Tissues	-	Aroids
e.	Protection and brood place	-	*Ficus, Aristolochia, Yucca*
f.	Sexual attraction	-	As Ophrys
2. Secondary Attractants			
a.	Odour	-	Pheromones
b.	Visual		
c.	Temperature	-	Thermogenic respiration volatilisation of odour substances
d.	Motion		
•	Sucr./Gl + Fr (W/W)	< 0.1	- Hexose Dominant 196 spp.
•	Sucr./Gl + Fr (W/W)	0.1-0.49	- Hexose Rich 231 spp.
•	Sucr./Gl + Fr (W/W)	0.5-0.99	- Sucrose Rich 149 spp.
•	Sucr./Gl + Fr (W/W)	> 0.99	- Sucrose Dominant 190 spp.
			Total 766 spp.
e.	Deep-tubed flower produce	Sucrose Rich Nectars and Pollen	Humming Birds, Sphingids Long-tounged Bees – Wasps
f.	Shallow-tubed flower produce	Hexose Rich Nectar and Pollen	Perching birds, Bats, Flies Short-tounged Bees

PRIMARY ATTRACTANTS

POLLEN AS AN ATTRACTANT

Pollen is a rich source of food, especially proteins. 16–30% protein, 1–7% starch and 0–15% sugar, 3–10% fat, and 1–9 percent ashes. Pollen is eaten directly by beetles, and permeative lepidopterans and in a more indirect manner (digestion by diffusion) by other insects.

Insects with broad-management-bees, rocle bees etc. use great quantities of pollen for their larvae. Pollen-grain consists of three concentric layers: exine, intine and protoplast.

Intine – pectin and cellulose membrane – indigestible

Exine – unknown substances, extremely resistant to everything

Protoplast – utilisation by digestion by diffusion

NECTAR AS AN ATTRACTANT

Nectar is peculiar to angiosperms. However, from evolutionary point of view it is not easy to decide whether Nectar production arose in connection with pollinations or whether Nectar-like substances was produced by plants before pollination came into existence. As a matter of fact, even today very much Nectar is secreted extra-nuptillary, i.e. independently of the floral region.

An array of chemical substances have been reported from the Nectars of various flowering plants.

- Sugars (hexose monosaccharide glucose, and fructose, closaccharide, sucrose – big three, galactose, arctinose, mannose, – manosacche maltose and melibrose, - disaccharides melezitose and raffuiose – trisachcheols.
- Amino acids
- Proteins
- Lipids
- Antioxidants (ascorbic acid)
- Alkaloids
- Glycosides
- Thiamine, Riboflavin, Nicotinic acid, Pantolhnic acid, Pyridoxin, Folic acid, mesoinositol
- Organic acids (Sumaric, Succinic, Malic, Oxalic, Citric)
- Allantion and allantoic acid
- Dextrins
- Sulfate

Bees usually forage on Nectar and pollen. Pollen is presented to insects only during certain periods. Pollen presentation must be synchronized with Nectar presentation where Nectar is the chief attractant.

Certain pollen types are reported to contain phytosterols as pollen attractants to insects. Odour may possibly be associated also with the sticky substances on the outer region of the grains.

Where pollen is the sole attractant of a flower, it is frequently produced in great quantities, as much as in anemophiles. *Rosa, Papaver* and *Parkia* (Bat-pollinated) belong to this clan of pollen flowers, can thus be easily recognized by stamens.

However, many stamens are found in flowers that posses Nectar in addition (e.g., *Ranunculus*).

Anemophiles, also producing great quantities of pollen are potential sources of this attractant.

These are exclusive pollen flowers

- Exclusive Nectar flowers – butterfly pollinated
- Pollen or Nectar at any quantitative
- Pollen and Nectar in the same visit. Colour as an attractant - visual attractants

Pollinators are to enticed to visit a flower by colour or any other single attractant not acting in isolation, but rather by a complex syndrome of characters to which the pollinator is intimately attracted or behaviorally entertained.

Natural selection has acted to control the elaboration of numerous floral pigments in several chemicals classes, with absorption-reflection properties over wavelengths to which pollinator visual systems are sensitive and which provide striking visual contrast between floral plants and surrounding background vegetation.

In general visual attractants at over much longer distances than alfactory ones.

In insects however, the visual spectrum is shifted substantially to shorter wavelengths making insects sensitive to near ultraviolet wavelengths but often insensitive to red colouration.

ODOUR AS ATTRACTANT

1. Bees - floral fragrances or dance language of the worker bees.
2. Bats - mostly guided by Nectar but partly by floral fragrance. Diacetyl are chemical compound identified as a bat attractant.
3. Flies - attracted to flowers with the odour and appearance of decaying meat—aminoid compounds. Fruit flies—methyl eugenol.
4. Beetles - Arum likes—The inflorescense produces indole or skatole and the heat produced helps to volatise and disperse the others. The beetles and indigos are attracted by the odour and fall into the floral chamber.

PROTECTION AND BROOD-PLACE AS ATTRACTANTS

In blossoms that are pollinated by egg-laying carrion dipterans, the presence of pollination depends on availability; of a proper substrate for the larvae. Oil palm is said to be at least partly pollinated by beetles hatching in the inflorescense. Ficus (Moraceae)—aganoid weep pollination systems. One of the most advanced systems involving morphological and behavioral adaptations on the part of plants and the insects.

SEXUAL ATTRACTION

Oplyrys speculum—attracts a male by municing a female—pseudo copulation

FOOD BODIES

In trap flowers of some Araceae, the insects are said to eat food bodies. *Amorphophallus* species, which beetle pollinates, have edible substance at the bottom of the spats.

In *Anllumism* and *Arums,* stigma exudes liquid which attracts insects.

Fracynatia have intrusive inflorescences and subtending tracts as food for bats—the pollinators.

The major pigments imparting colouration to flowers are divided among three classes :

(a) flavanoids, (b) carotinoids, and (c) betalains.

Table 4 Colour preferences and qualities pollinator classes

Pollinator		Preferences
a.	Bats	Green, Purple, greenish (drab)
b.	Bees	Yellow, blue (bright)
c.	Beetles	Green, greenish (drab)
d.	Birds	Scarlet (bright)
e.	Butterflies	Red, yellow, blue, pink (bright)
f.	Moths	
	- Nocturnal	White
	- Diurnal	Red, purple, pink (bright)
g.	Flies	
	- Carrion, dung	brown, purple (dull)
	- Others	Green, white
h.	Wasps	Brown (dull)

POLLINATION

Table 5 "Harmonic" relations between pollinators and blossoms

Blossom class	Pollinator	Colour preference
Dish bowl	Wasps	Brown
Bell-beaker	Bats	Drab
	Beetles	White/off-white
Yellow	Flies	Brush
Gullet	Bees	Blue/violet
	Moths	
Flag	Butterflies	Red
Tube	Birds	Green

DISTRIBUTION OF GENETIC VARIATION WITHIN AND AMONG NATURAL PLANT POPULATIONS

Genetic variation in natural populations exist at two basic levels:

1. Genetic differences between individuals within local populations of species, and
2. Genetic differences between local populations.

The population genetic theory, primarily deals with the evolutionary importance of the genetic structure of the species – i.e., the distribution of genetic variation within and between populations. In order to address the first question, population genetics have relied on biochemical techniques primarily electrophoresis to obtain estimated of genetic variation in plant and animal populations. These estimates are usually quantified in terms of the number of polymorphic loci per population, the effective number of allele per locus, or the mean number of loci heterozygous per population. During the last two decades, it has been a practice to describe the extent of distribution of genetic variation in natural populations.

Table 6 Floral biological features of selected mangrove species

Type of feature	*A. ilicifolius*	*A. marina*	*D. spathacea*	*L. racemosa*
Flower colour	Mauve	Yellow Orange	White	White
Symmetry	^	^	*	^
Flower Depth	Mod. Tub.	Mod. Tub.	Deep narrow	Mod.Tub.
Rewards Pollen	Nectar Pollen	Nectar Pollen	Pollen	
Nectar Guides	-	Present	Fragrant	Present
Breeding system	Protandry	Prot. Geito. Geito no. or Xeno.	Auto? or Allo?	Protand. Allo. or Xeno
Syndrome	Melitto.?	Melitto	Sphingo.	Melitto Ornitho?
Flower col.	Pale Green	White	White	Red Calyx
Flower depth	Shallow	Tubular	Shallow	
Rewards Nectar	Nectar and pollen	Nectar and pollen	Pollen	
Nectar Guides	?	Frag.	-	?
Breed. Syst.	Dioec. Xeno.	Allogam.	Auto. or Allo.	Allo.
Synd. Entomo.	Entomo.	Anemo.	Ornitho.	

Recent reviews have demonstrated that allozyme variation within populations are associated with the life history traits of species, e.g.,

1. Geographic range,
2. Effective population size,
3. Mating system and mode of reproduction,
4. Seed dispersal mechanism, and
5. Community type in which the species most commonly occur.

Efforts to preserve genetic resources must take into account the components of genetic variations, both within and between local populations. The latter is of practical importance to the conservation of genetic resources, once it is concerned with the way in which genetic variation in partitioned within and among populations. It is important to know whether the majority of the genetic variation of a species is resident within populations or whether it occurs among populations.

In order to manage the genetic resources of naturally occurring species in a more intelligent and effective manner, we must understand how genetic variation is distributed, and what characteristics of the environs of the species influences its distribution.

In species with small populations, vegetative reproduction and limited pollen and seed dispersal would be expected to have relatively little variation within populations and relatively more variation among populations. Similarly, species with limited distributors or colonising species might also be expected to have relatively high levels of inter-populational variation.

The extent of genetic variation in a species is largely determined by the effect of three fundamental evolutionary forces: (a) genetic drift (b) migration (gene-flow), and (c) natural selection.

The action of these force on the distribution of genetic variation in natural populations analysed using population genetics theory and a series of computer simulations.

GENETIC VARIATION

Tropical species	>	Temperate or cosmopolitan
Habitat generalists	>	Habitat specialists
Mainland populations	>	Island populations

FACTORS CONTRIBUTING TO GENETIC VARIATION

1. Geographic isolation
2. Mode of reproduction
3. Mating systems
   a. Out-breeders —High heterozygosity and high recombination
   b. In-breeders —Low heterozygosity and Low recombination
   c. Asexual —High heterozygosity and no recombination
4. Seed dispersal mechanism
5. Population size (effective)
6. Ploidy level
   a. Diploid —High segregation and rapid response to selection
   b. Polyploid—Low segregation and fixed heterozygosity 30–35% all flowering plants—polyploid

GENETIC DIVERSITY

1. Species diversity
2. Allele diversity (polymorphisms)
3. Allele frequency differences between individuals and between populations

GENETIC VARIATION WITHIN A POPULATION CAN ARISE DUE TO

1. Recurrent mutational changes
2. Migration
3. Stochastic processes such as genetic drift
4. Variation held in the population by some form of selection

BIOLOGICAL CRITERIA FOR SELECTION OF CONSERVATION AREAS

1. Distribution of species (phytogeography) as determined by floristic surveys and inventories (qualitative).
2. Population biology from phytosociological and demographic surveys (quantitative).
3. Genetic variation exhibited by a given species, e.g., *Vitex altissima, Shorea trapezifolia.*
4. Biological features of threatened species, viz., flowering and fruiting phenology, floral sexuality/breeding system, pollinators and dispersal agents, plant-animal interactions.
5. Effect of habitat fragmentation on loss of habitat, species and genetic diversity leading to local and regional extinction of species.

Table 7 Distribution of genetic variation among natural plant populations

Characteristic	Number of Studies	Hr	H_s	G_{st}	A_r	P_A
* Geographic range						
Endemic	10	.275	.208	.200	3.26	.639
Narrow	31	.261	.177	.275	2.96	.609
Regional	38	.238	.154	.312	3.23	.573
Widespread	43	.380	.293	.253	3.70	.702
* Mode of reproduction						
Asexual	1	.172	.159	.080	3.29	.652
Sexual	108	.280	.194	.284	3.17	.620
Both	13	.325	.257	.209	3.30	.732
* Mating system						
Selfed	35	.250	.141	.437	3.02	.559
Mixed-animal	26	.284	.181	.04	2.68	.644
Mixed-wind	3	.712	.560	.189	16.03	.425
Out-crossed-animal	23	.352	.238	.221	3.37	.633
Out-crossed-wind	35	.256	.248	.056	3.29	.737
* Seed dispersal mechanism						
Large	22	.260	.181	.305	3.07	.635
Animal-attached	13	.262	.155	.425	3.77	.504
Small	37	.312	.196	.349	2.81	.846
Winged or plumose	38	.260	.238	.073	3.28	.706
Animal-ingested	12	.344	.210	.310	3.63	.526
* Stage of succession						
Weedy and early	52	.295	.172	.394	3.37	.574
Middle	42	.262	.196	.236	3.15	.613
Late	28	.299	.275	.071	3.14	.786

H_r = total allelic diversity; H_s = mean allelic diversity within populations; G_{st} = the ratio of the allelic diversity among populations to the total allelic diversity; A_r = mean number of alleles per polymorphic locus; P_a = the proportion of the total number of alleles found within each population.

RESEARCH ON REPRODUCTIVE BIOLOGY CRITICAL TO THE MANAGEMENT OF TROPICAL FOREST RESOURCES INCLUDING MANGROVES ON A SUSTAINABLE BASIS

There are three crucial issues that the managers of natural forests must address :

1. Degradation and depletion of forest ecosystems :

   The principal cause of depletion of forest resources is the change in land use patterns, conversion of forest land for agriculture (aquaculture), excessive logging, human habitation, etc.

2. Regeneration and restoration of forest ecosystems :

   Restoration involves improved reforestation of degraded lands through natural and artificial regeneration.

3. Conservation—based research and development :

   Coupled with reforestation, conservation of genetic resources is of high priority. The nature of resources to be conserved and the manner in which they ought to be conserved are serious issues requiring strong scientific input.

DISCUSSION

The contribution of research in reproductive biology to the management of mangrove ecosystems comes from following areas.

PHENOLOGY

The knowledge of leafing, flowering and fruiting periodicity both at community and individual level would reveal considerable information on temporal and spatial variations in phenological patterns. Individual species differ with respect to timing, duration and frequency of flowering and fruiting. Communities differ in terms of overall phenological patterns. (Table 4).

Out understanding of the factors that regulate initiation, periodicity and frequency of flowering of mangrove species is extremely poor. The effects of disturbance including logging on phenological patterns is not known. But it is an area that should be of priority concern to the forest managers.

Logging may change the environmental regime and the spacing patterns of the location-specific trees. Both changes may influence the amount of flowering, fruit and seed set. Altered spacing and phenological patterns may also change the mating relationship with unknown genetic consequences.

Characterisation of phenological patterns at the levels of species—population is of utmost importance to the conservation planner as well as to the tree breeder. In order to identify suitable conservation areas with increased genetic diversity, phenological patterns of different populations need to be studied.

POLLINATION AND SEXUAL SYSTEMS

Some information is already available on the mode of pollination in mangrove species. Pollination ecology at community level and inter-community relationships need to be examined. Further, self-compatibility or self-sterility in mangrove species need to be studied in detail.

Gene flow, effective population size and genetic variation: Information on gene flow and effective population size is of critical importance in designing suitable breeding strategies for tree improvement programmes. Also for conservation of genetic resources, knowledge of breeding structure of population is essential. Central to any breeding programmes, knowledge of the pattern and degree of genetic variability within and between populations is essential. Data on population genetic structure also provide the basis for adequate sampling suitable design of resources *in situ* conservation of forest genetic resources. High levels of out-breeding causes high genetic variability within populations. The patterns of genetic variation in population is largely determined by pollen and seed dispersal patterns. High level of apostasis indicate low genetic variability within population.

RESEARCH PRIORITIES IN MANGROVE ECOSYSTEM

Research priorities in Mangrove Ecosystems towards the conservation and sustainable Management of plant genetic resources can be summarised as follows :

1. Estimation of total extent, rate of it change, and the quality of mangrove ecosystems by a combination of mapping methods using Remote Sensing, aerial photography, field survey for ground truthing and Geographic Information Systems (GIS) are now available. By these methods the information data base can be efficiently built, managed and updated. In most countries today, these methods are increasingly used as identification of specific-species associations, their phenological features, etc.
2. Examination of floristic composition and phytosociology of as many diverse mangrove communities as possible in different climatic and biogeographic regions. This will provide information on species distribution, population sizes of common as well as rare and endangered species. Based on this information, Biodiversity Rating Index could be prepared. In preparing management plans for individual mangrove forest units, the needs of the neighbouring human populations and those of the nation should be taken into account in the correct perspective. Unless these are met, with alternative means, the conservation of biologically rich natural ecosystems may not be achieved. In area where relatively larger mangrove tracts are available, buffer zones surrounding the core mangrove areas should be established to reduce the impact between man and natural forest. The buffer zone should be carefully managed to meet the community needs.
3. Ethnobotanical surveys in different regions to document the traditional users of mangrove plants and bio-cultural interactions associated with mangroves—traditional wisdom into management process makes the participation more effective and would meet the community needs as well, e.g., selection of suitable species for reforestation and their planting know-how.
4. A resource economic survey of all utilities and services rendered by keeping the mangrove ecosystem as opposed to its removal for alternative land use such as aquaculture farm etc. This survey would enable the decision-maker to evaluate all available options based on long-term economic costs and benefit analysis.
5. Based on above surveys, initiation of research into afforestation with appropriate species fulfilling (a) the environmental protection needs, and (b) local community and industrial needs, should be done.
6. A comparative study of population genetic structure, breeding systems, vegetative and reproductive phenology of atleast some key species should be made for conservation of their genetic diversity and also to select suitable genotypes for plant improvement programmes in the case of utility species.

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THE PHYSIOLOGY OF MANGROVES

S.M. KARMARKAR

The consistent efforts of mangrove biologists, aimed at the preservation or restoration of this unique ecosystem, have to some extent been thwarted due to a lack of understanding of the physiology of mangroves; the present discourse thus attempts to highlight some of the fundamental but essential physiological adaptations which enable mangrove species to survive in habitats which, by and large, are hostile to other species.

In spite of the wide diversity in taxonomic and morphological characters exhibited by the mangroves, they share one common feature, namely their ability to survive in areas where salt concentrations often reach toxic level. A basic problem thus confronting these species is that of salt/ion regulation. The need for salt regulation becomes all the more pronounced because of the wide fluctuations in the salt concentration of the environmental water from one season to another. Human interference with the coastal ecosystem compounds this problem. Nature has endowed mangrove species with an inherent ion regulatory mechanism which enables such species to thrive in regions showing wide differences in their levels of salinity.

Since sodium ions constitute the dominant cations in saline soils/waters, these media are characterised by a high exchangeable sodium percentage (E.S.P.) and a high sodium adsorption ratio (S.A.R.). When sodium is adsorbed on 15% or more of the soils total cation adsorption capacity, it alters the physical and chemical properties of the soil, leading to the development of a high pH accompanied by a gradual reduction in soil permeability. As a consequence of the high ESP and SAR of the soil/water the availability of water to the root system is affected; thereby several mangrove species develop mechanisms for the retention of water particularly in their leaf tissues.

Due to the high ionic content of the sea/soil water, and the consequent high osmotic potentials of the external medium, the mangroves exhibit adaptations whereby their internal inorganic content is regulated through periodic adjustments of the osmotica of their tissues. This is achieved through ion transport between roots, stems and leaves or sometimes even by extension of salts from the root tissues (as in *Rhizophora, Kandelia,* etc.) on by excretion of salts in species provided with salt glands (*Avicennia, Acanthus, Aegiceras,* etc.) or even though a dilution of internal salt levels through the retention of water in plant tissues and the development of succulence. (*Sonneratia apetala, Lumnitzera racemosa*). The regulation of internal salt levels may also be accomplished by means of bladders (*Atriplex, Chenopodium*), vesicles (*Atriplex confertifolia*), etc. While the bladders have been shown to possess an active mechanism for salt excretion, vesicles release salts as they burst. In addition, the storage of inorganic ions in the old xylem tissues and the bark and the subsequent shedding of bark, also contributes to salt regulation.

In spite of the fact that the concentration of sodium ion, in the environment as well as within plant tissues, is generally high, the mangroves exhibit a preferential selection for potassium ions. It is now believed that the salt tolerance capacity of mangroves is intimately linked to their efficiency in regulating potassium uptake. Most mangroves are known to possess a well developed mechanism for potassium adsorption. This preferential absorption of potassium ions results in an increase in the concentration of K : Na from approximately 1:40 in sea water to about 1:7 in the plant.

It is now understood that the adenosine triphosphatases (E.C. 3:6:1:3) - ATPases - mediate salt transport across cell membranes. In several species there is a correlation between ion transport and ion stimulated ATPases activity in the roots. It has been suggested that the ATPases function at two sites, namely the plasmalemma and the tonoplast, such that the excess sodium ions can be extruded into the surrounding medium or transported into the vacuole.

In some halophytes, salts of organic acids, such as oxalates, also contribute to the total electrolyte pool and play a significant role in balancing the cation change through substitution for anions such as the chlorides. The more recent discovery of the presence of the amide, proline and the glycine derivative, glycine betaine in the tissues of plants exposed to stress, has introduced a new dimension in the study of plant responses/adaptations to salt/water stress. The accumulation of these organic solutes, besides playing a positive role in osmoregulation, is also believed to concentrate the inhibitory effect of sodium chloride on the activity of several enzymes.

The activities of several enzymes are altered due to the presence of sodium chloride of the cellular environment studies on the long term and short term effect of NaCl on the enzymes from different halophytes, suggest that the altered response is possibly due to conformational changes in the enzyme proteins on due to induction of the synthesis of new proteins.

Studies on various aspects of the mechanism of photosynthesis in halophytes, in general, and the mangroves in particular, have indicated that most species photosynthesise through the C_4, pathway despite the absence of a 'Kranz anatomy, generally believed to be associated with C_4 metabolism. As in C_4 species, in most of the mangroves studied the initial products of autotrophic CO_2 fixation are either aspartate or malase (C_4 products). Further, the activity of the carboxylating enzyme, phosphoenolpyruvate carboxylase (PEPC) is several fold higher than that of ribulose biophosphate carboxylase (RBPC) as expected in C_4 species. Stomatal fluxes during the lights and dark period are also in conformity with those C_4 species. Thus the major evidence supports the operation of the C_4 pathway in most mangrove species. In spite of the above evidence, doubt has been expressed in some quarters regarding the functioning of a C_4 pathway in the mangroves, since the $\delta^{13}C$ ratios for carbon assimilation in most species typically resemble those of C_3 species. As of today this controversy remains unresolved although major evidence is in favour of the C_4 pathway being operational rather than the C_3 pathway.

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THE PHYSIOLOGY OF SALT TOLERANCE

S.M. KARMARKAR

The saline areas of the World comprise the salt marshes of temperate latitudes, the mangrove swamps of the tropics and sub-tropics, interior salt marshes found adjacent to the salt lakes in the U.S.A. and Austria, salt deserts and small areas around small springs. By far the most productive among these saline areas are the mangrove swamps but, paradoxically, they are one among the World's most endangered ecosystems. According to a recent estimate, the mangrove ecosystem constitutes a habitat for more than 2000 species of fish invertebrates and plants. More than 55 species of mangrove trees and shrubs cover approximately 240,000 sq km of coastal land throughout the World (Lean *et al.*, 1990). Unfortunately, World development strategies have ignored nature's gift to mankind and as a consequence of the wanton destruction of these forests, the once serene and bountiful ecosystem has been ravaged almost to the point of no return; in its aftermath, soil erosion and devastation of the coastline have become common features. Thus, deforestation, land reclamation and industrialisation have mainly contributed to the depletion of our natural wealth. It is fortunate that environmental concern, more so during the last decade or so, has led to a revival of human interest in this once neglected ecosystem. Efforts are now on not only for the preservation of the mangrove ecosystem but also for its restoration. Several of the developed as well as developing countries have now drawn up programmes for the management of the ecosystem and its resources. The efforts of the environmental biologists have, to some extent been thwarted owing to their imperfect knowledge regarding the behavioural complexities of the mangrove species and also their responses to environmental stresses. Against this background it was felt necessary to highlight some of the fundamental but essential physiological adaptations which enable mangrove species to survive in habitats which, by and large, are hostile to most plant species.

Essentially, a mangrove swamp constitutes a complex in which the canopy of trees is inhabited by flora and fauna characteristic of a tropical rain forest. The lower parts of the tree trunks of some species are immersed in salt water for various periods of time throughout the day, depending upon the tide cycles (Walsh, 1974). In others, the roots penetrate the substratum which is saturated with salt water. As early as 1883, Warming recognised the adaptive capacity of the mangroves by virtue of which they can survive in a saline habitat. Some of the morphological and anatomical adaptations are :

a. the ability to bring about a mechanical fixing of the plants in loose soil,
b. the development of pneumatophores for overcoming the scarcity of oxygen, caused by a waterlogging of the soil,
c. viviparity,
d. the development of special mechanisms for dispersal, and
e. the development of xeric structures to withstand salinity.

A physiologically noticeable feature of the distribution of mangroves in any area is the characteristic zonation of genera and species related to soil salinity. According to Walter and Steiner (1936), the zonation is related to the capacity of the mangroves to compete and survive in saline soils. Usually *Rhizophora, Avicennia* and *Sonneratia* comprise the outermost zone where salinity is maximum. While the two former genera can withstand variations in salinity, *Sonneratia* requires a more or less constant chloride content. As one proceeds inland from the coast, there is a gradual decrease in soil salinity and, characteristically, the floristic composition also changes.

In spite of the wide diversity in taxonomic and morphological characters exhibited by the mangroves, they exhibit one common feature, namely their ability to survive in areas where salt concentrations not only fluctuate but often reach toxic levels. A basic problem which thus confronts mangrove species is that of salt/ion regulation. The need for salt regulation becomes all the more pronounced because of the wide fluctuations in the salt concentration of the environmental waters from one season to another. Human interference with the coastal ecosystem compounds this problem. However, nature has endowed mangrove species with an inherent ion regulatory mechanism which enables such species to thrive in regions showing wide differences in their levels of salinity. This is very well illustrated in Table 1, which records the mineral composition of sea water, and in five soil samples supporting different mangrove species commonly occurring along the West coast of India. In sea water as well as in different mangrove soils, sodium and chloride are the dominant ions. An interesting feature is the variation in the mineral composition of sea water at three different localities along the West coast of India. In and around Ratnagiri the sea water is rich in salts, representing a natural undisturbed mangrove habitat. At Ganapatipule the sea water is diluted due to the waters of a local river flowing into the creek. At Chiplun, the river Vasishthi flows into the Arabian Sea; in addition, the tail waters of the Koyna Dam are being released into this river. As a consequence of this dual effect, the salinity of the coastal waters is greatly reduced. Relative to the wide differences in the mineral composition of the habitat, the mangrove species also show corresponding changes in their internal salt levels. In short, the mangroves have an in-built adaptive mechanism by virtue of which they are able to regulate ionic uptake; this characteristic enables them to thrive in regions showing wide differences in salinity levels.

Since sodium ions constitute the dominant cations in saline soils, such soils are characterised by a high exchangeable sodium percentage (ESP) and a high sodium adsorption ratio (SAR). When sodium is adsorbed on 15% or more of the soil's total cation adsorption capacity, it affects the chemical and physical properties of the soil (Gardner, 1945; Whitney and Peach, 1952). On account of the high pH that develops and other accompanying changes, soil permeability is reduced; thereby the availability of water to the roots is reduced. Eaton and Horton (1940) have also demonstrated that a gradual increase in the ESP of the root medium reduces the availability of water to the plants, thus affecting the growth of the root system. For most mangrove species, the SAR of the supporting soil exceeds 15% (Table 2).

The mangroves thus face an acute problem of scarcity of water since the available water cannot be absorbed. Thus, like xerophytes, mangroves tend to develop a mechanism for the retention of water in their leaf tissues. This possibly contributes to the induction of leaf succulence in many of the mangroves, viz., *Sonneratia apetala, S. alba, Lumnitzera racemosa, Salvadora persica* etc.

Due to the high ionic content, the soil/sea water develops a high osmotic potential. Correspondingly, the mangroves exhibit osmotic adaptations, thereby facilitating the uptake of water from

Table 1a Major inorganic constituents in mangroves of the West coast of India*

Plant species	Ratnagiri			
	Na	K	Ca	Cl
Water Sample	7.6	0.2	0.285	14.87
Soil sample	0.45	0.056	0.035	0.78
Sonneratia acida	4.4	0.92	0.85	6.8
Rhizophora mucronata	3.36	0.44	1.1	5.09
Aegiceras majus	2.35	0.92	0.42	3.66
Acanthus ilicifolius	2.16	1.56	0.6	2.19
Excoecaria agallocha	2.24	1.32	2.24	4.32

Values expressed as g per litre (sea water), g per 100 g air dry soil (soil sample) and g per 100 g dry tissue (plant sample) *Ratnagiri—seashore mangroves;

Table 1b Major inorganic constituents in mangroves of the West coast of India*

Plant species	Ganapatipule			
	Na	K	Ca	Cl
Water Sample	1.03	0.036	0.03	2.02
Soil sample	0.0296	0.028	0.027	0.44
Sonneratia acida	4.56	0.96	0.82	7.93
Rhizophora mucronata	2.96	0.32	0.87	4.18
Aegiceras majus	0.64	0.76	0.4	1.35
Acanthus ilicifolius	2.68	1.52	0.57	2.19
Excoecaria agallocha	3.0	2.4	1.96	5.81

Values expressed as g per litre (sea water), g per 100 g air dry soil (soil sample) and g per 100 g dry tissue (plant sample) *Ganapatipule—estuarine mangroves;

Table 1c Major inorganic constituents in mangroves of the West coast of India*

Plant species	Chiplun			
	Na	K	Ca	Cl
Water Sample	0.016	0.001	0.001	0.04
Soil sample	0.017	0.03	0.055	0.03
Sonneratia acida	0.96	0.92	1.18	2.41
Rhizophora mucronata	1.6	0.48	0.75	2.9
Aegiceras majus	0.48	0.4	0.27	0.71
Acanthus ilicifolius	0.68	2.4	1.28	3.33
Excoecaria agallocha	0.1	0.58	1.8	0.57

Values expressed as g per litre (sea water), g per 100 g air dry soil (soil sample) and g per 100 g dry tissue (plant sample) *Chiplun—dilution of sea water due to flow of fresh water

Table 2 Sodium adsorption ratios for saline soils

Plant	Soil			S.A.R.
	Na	Ca	Mg	
	(Meq/100g of dry soil)			
Sonneratia apetala	397.0	30.0	12.9	85.74
S. acida	266.0	23.0	14.5	61.43
Salvadora persica	23.9	1.6	1.62	18.9
Acanthus ilicifolius	26.0	2.01	1.99	18.0

Table 3 Osmotic potential of soil/sea water and corresponding osmotic potentials in mangrove species

Species	Leaf	Soils
Sonneratia acida (fresh water)	20	0.3
S. acida (high tide)	27	6.0
Rhizophora conjugata	31	23
Avicennia officianalis	45	23

Source: After Blum (1941)

the environment. Table 3 records the osmotic potential of the sea/soil water and the corresponding osmotic potential developed in *Rhizophora, Avicennia* and *Sonneratia*.

As mentioned earlier, seasonal variations occur in the mineral content of the soil/sea water; obviously, such changes are accompanied by changes in the osmotica of these media. Mangroves are adapted to withstand the environmental fluctuations in osmotica, thus their ability to bring about corresponding changes in the osmotica of their tissues. Such changes are brought about by a periodic ion transport between roots, stems and leaves, or sometimes even by extrusion of salts from their root tissues (as in *Rhizophora, Ceriops, Bruguiera* and *Kandelia*) or by excretion of salts in species provided with salt glands (*Avicennia, Laguncularia, Aegialitis, Aegiceras, Acanthus*). Plant species which have the ability to exclude salts from the water that enters the xylem have an in-built ultrafiltration mechanism. Such a mechanism permits the separation of saline water from fresh water. While Scholander (1968) was able to demonstrate such a mechanism in *Rhizophora,* on the basis of changes in osmotic and hydrostatic pressures in the roots, stems and leaves, Teas (1979) demonstrated a similar mechanism with the use of radiochlorine. According to Scholander (loc. cit.), a very high negative pressure develops in the xylem as a result of which water is rapidly drawn into the xylem; since the salts cannot pass through the cell membrane, more or less pure water enters the xylem. Teas (loc. cit.) confirmed the existence of such a mechanism in *Rhizophora* through experiments in which chlorine was found to be absent in leaf tissues despite the fact that roots of *Rhizophora* seedlings had been dipped in sea water containing radiochlorine for 24-36 hours. On the basis of the observation that radioactivity persisted in the root cells of *Rhizophora,* Teas (loc. cit.) lent support to Scholander's (1955) hypothesis that the separating membrane is probably located in the Casparian strip of the endodermis. It is thus evident that mangroves such as *Rhizophora, Ceriops, Bruguiera* and *Kandelia* are able to withstand the high salt levels in their environmental soils/ waters because of the presence of such an ultrafiltration mechanism in their root tissues.

Mangrove species such as *Avicennia, Laguncularia, Aegialitis, Aegiceras* and *Acanthus* are characterised by the presence of multicellular salt glands through which the salts are secreted. Arisz *et al.* (1955) and Atkinson *et al.* (1967) observed that cyanides and other respiratory inhibitors also inhibit salt secretion through salt glands, thus indicating that salt secretion involves an active mechanism. The regulation of internal salt levels may also be accomplished by means of bladders (*Atriplex henopodium*) or vesicles (*Atriplex confertifolia*). Like the salt glands, the bladders possess an active mechanism for salt excretion. In most species of *Atriplex*, bladders excrete excess Na^+ and Cl^-; however, in *A. facata* they help in the removal of excess K^+. In contract, vesicles release the excess salts as they burst.

In addition to the above two mechanisms developed by mangroves for counteracting the harmful effects of the high salt concentration in their environmental soils/waters, other mangrove species avoid salt toxicity through a dilution of their internal salt levels through the retention of water in the tissues and the development of succulence (*Sonneratia apetala, Salvadora persica, Acanthus ilicifolius*). As is characteristic of halophytic species, these mangroves absorb large quantities of salts from their environment. As a result, higher solute potentials are maintained within their tissues than the solute potentials of the external medium, thereby ensuring a free flow of water from the soil into the plant tissues. In such mangrove species, salts tend to accumulate in the tissues, and therefore to overcome their toxic effects, large volumes of water are stored in their tissues; salt toxicity is thereby avoided through a dilution of the internal salt levels (Table 4). In these accumulator species there is a periodic shedding of leaves or even the bark of stems and roots which act as storehouses of excess salts. Through a shedding of such plant parts, the mangroves are able to regulate their internal salt levels (Table 5).

Table 4 Concentrations of various elements in the leaves and bark of halophytes

	Na	K	Ca	Mg	P	Cl
Rhizophora mucronata[1]	37.4	0.24	0.13	-	-	25.9
Prop Root bark	21.7	6.2	6.5	-	-	10.1
Prop Root xylem	32.6	3.9	6.0	-	-	16.1
Prop Root pith	41.7	4.9	22.5	-	-	42.0
Mature leaf	53.0	3.1	42.0	-	-	38.9
Mature stem	.					
Salvadora persica[2]						
Root Bark	354.52	80.0	43.8	5.17	4.5	259.71
Stem Bark	486.48	75.95	58.0	2.5	2.8	407.43
Root xylem	28.26	1.05	5.1	1.33	10.0	26.29
Senescent leaf	331.65	55.51	300.5	87.5	19.5	280.14

1. Values expressed as meq per 100 g fresh tissue (Joshi, 1976)
2. Values expressed as meq per 100 g dry tissue (Amonkar, 1977)

In spite of the fact that the concentration of Na^+ in the environment as well as in the plant tissues of mangroves is generally high, these species have an efficient mechanism for K^+ uptake.

Table 5 Elemental composition on mature and senescent leaves of halophytes : avoidance of salt toxicity through dilution

Plant		Moisture		Na	K	Ca	Cl
Acanthus ilicifolius[1]	Mature	% dry wt	-	163.50	62.40	108.30	136.60
		% fresh wt	77.45	36.90	14.08	24.44	30.83
	Senescent	% dry wt	-	177.10	65.30	75.00	146.40
		% fresh wt	80.09	35.26	13.00	14.92	29.15
Salvadora persica[2]	Mature	% dry wt	-	310.09	99.05	145.00	215.20
		% fresh wt	68.30	98.27	31.79	45.97	68.19
	Senescent	% dry wt	-	331.65	55.50	88.17	278.64
		% fresh wt	86.10	46.10	7.71	12.26	38.37

Values expressed as meq per 100 g leaf tissue
1. Siddhanti (1977), 2. Amonkar (1977)

It is now believed that the salt tolerance capacity of mangroves is intimately linked with their efficiency in regulating K^+ uptake. Rains and Epstein (1967) demonstrated such an efficient K^+ uptake mechanism in *Avicennia* wherein the Na : K ratio is altered from 40:1 in the sea water to 7:1 within the leaves of the plant. Thus, according to them, the effect of preferential absorption of K^+ was not to exclude Na^+ but, on the other hand, to raise the concentration of K^+ was not to exclude Na^+ but, on the other hand, to raise the concentration of K^+. Table 6 records the Na : K ratios for various mangrove species. It is obvious that these species are well adapted to withstand salinity. Rains and Epstein (loc. cit.) also noted that in *Avicennia* a dual mechanism exists for K^+ uptake, one operating at low concentrations of Na^+ and the other operating at high concentrations of Na^+. Subsequently, studies conducted by Joshi (1976), Jamale and Joshi (1976), Amonkar (1977), Lokhande (1986), Ambike (1986) and Geeta (1988) have confirmed the existence of an efficient K^+ uptake mechanism in various mangroves/halophytes which occur along the West coast of India.

It is now understood that the adenosine triphosphatases (E.C. 3.6 : 1.3) - ATPases - mediate salt transport across cell membranes. Kylin and Gee (1970) have observed that in a number of species there is a correlation between ion transport and ion-simulated ATPases activity in the roots. The effect of NaCl/KCl on the ATPases, *in vivo* and *in vitro*, from the roots of *Acanthus ilicifolius* has been studied by Mukundan (1981). She observed that in the absence of NaCl in the growth medium there was a loss of ATPases activity in the roots of *A. ilicifolius*; however, addition of NaCl to the growth medium resulted in a restoration of ATPases activity. Through studies on the long-term effect (*in vivo*) and short-term effect (*in vitro*) of NaCl on ATPases activity, Mukundan (loc.cit.) was able to demonstrate that ATPases activity was stimulated to a greater extent in the presence of salts, *in vivo*, than when salts were added *in vitro*. The higher enzyme activity in the presence of salts, *in vivo*, gives credence to the view that salts are compartmentalised and therefore the high concentrations of salts in the cellular environment do not interfere with normal metabolic processes. The ATPases are thus believed to play a major role in transporting salts across the membrane. It has been suggested that the ATPases so function at two sites, namely, the plasmalemma and the tonoplast, that the excess sodium ions can be extended into the surrounding medium or transported the vacuole.

Table 6 Sodium : Potassium ratios in the leaves of halophytes

Plant	Na^+	K^+	Na/K	Author
Acanthus ilicifolius	148.0	47.9	3.1	Ambike (1986)
Aegiceras majus	102.2	23.6	4.3	Joshi (1976)
A. corniculatum	78.3	13.8	5.7	Bhosale (1978)
Avicennia alba	135.19	42.3	3.2	Joshi (1975)
A. officinalis	87.0	31.8	2.7	Joshi (1976)
A. marina	200.0	31.7	6.3	Bhosale (1978)
Bruguiera parviflora	19.6	6.2	3.7	Joshi and Bhosale (1982)
Ceriops tagal	68.24	31.28	2.18	Joshi and Bhosale (1982)
Cressa cretica	248.32	98.0	2.5	Amonkar (1977)
Excoecaria agallocha	141.71	34.87	4.1	Joshi (1975)
Kandelia candel	56.2	46.2	1.2	Joshi (1975)
Lumnitzera racemosa	240.9	76.7	3.14	Joshi (1975)
Pentatropis cyñanchoides	255.8	102.2	2.5	Lokhande (1983)
Rhizophora mucronata	146.1	11.3	12.9	Joshi (1976)
Salvadora persica	310.1	99.1	3.1	Amonkar (1971)
Sesuvium portulacastrum	430.4	76.2	5.6	Joshi (1975)
Sonneratia acida	195.9	28.6	6.8	Rao (1974)
Sonneratia apetala	130.9	26.9	4.9	Geeta (1988)

Values expressed as meq per 100 g dry issue

In some halophytes, salts of organic acids, such as oxalates, also contribute to the total electrolyte pool and thereby play a significant role in balancing the cationic change through substitution for anions such as the chlorides. The more recent discovery of the presence of the amide, proline, and the glycine derivative, glycinebetaine, in the tissues of plants exposed to stress has introduced a new dimension in the study of plant responses/adaptations to salt or water stress. According to Measures (1975), the fact that proline accumulates as a response to water stress in a wide variety of living organisms suggests that it is a primitive regulating response. However, what is more significant is that different plant species growing in the same habitat respond differently to water stress as far as proline metabolism is concerned, e.g., while *Carex pachystylis*, a desert plant, shows rapid proline accumulation under conditions of water stress, *Artemisia herba-alba* does not accumulate proline under similar stress conditions. Thus there is a lack of generality of proline accumulation in response to water deficit (Aspinall and Paleg, 1981). Stewart and Lee (1974) have observed that plants such as *Triglochia maritima*, which occur in saline habitats, accumulate proline as a compatible solute. Glycinebetaine, a derivative of glycine, is believed to have a similar role in the cells and tissues of halophytic species. Wyn Jones *et al.* (1977, 1977a) and Storey and Wyn Jones (1978) observed that in various species glycinebetaine concentration runs parallel to the osmotic pressure of the cell sap of leaves; this led them to suggest that glycinebetaine has an osmotic role. On the basis of evidence presented by Flowers *et al.* (1977) that cytoplasmic enzymes of halophytic species are sensitive to high concentrations of inorganic ions, and evidence suggesting that ions are compartmentalised between the cytoplasm and the vacuole (Wyn Jones *et al.*, 1979), glycinebetaine may fulfil the role of cytoplasmic non-toxic osmotica in some plants. In addition to this role, it has also been suggested that glycinebetaine plays a role in preventing inhibition of enzymes in plants exposed to NaCl (Wyn Jones *et al.*, 1977a, Flowers *et al.*, 1978; Pollard and Wyn Jones, 1979).

The activities of several enzymes are altered due to the presence of NaCl in the cellular environment. Studies on the long-term effect (*in vivo* effect) and short-term effect (*in vitro* effect) on malate dehydrogenase (MDH) from the leaves of *Acanthus ilicifolius* (Siddhanti, 1977, Sanglikar, 1982) have indicated that the activity of the enzyme in the leaves of plants raised in a salinated medium is much higher than that of the enzyme obtained from plants raised in an NaCl free growth medium. On the basis of changes in isoenzymes of MDH obtained from the leaves of *A. ilicifolius* subjected to long-term NaCl treatment, Sanglikar (1982) has suggested that salinity, in addition to bringing about conformational changes in the enzyme, also induces the synthesis of new proteins.

Various aspects of the mechanism of photosynthesis in mangroves have been studied. Since the leaves of most mangrove species lack the typical 'Kranz anatomy' generally associated with C_4 photosynthesis, it was presumed that these plants photosynthesised by the C_3 pathway. Treguna and Downton (1967) were the first to report that the halophyte *Salsola kali* photosynthesises by the C_4 pathway. Subsequent studies by Osmond (1966) and Hatch and Slack (1966) revealed that among several halophytic species of *Atriplex*, some fix CO_2 through the C_3 pathway while others do so by the C_4 pathway. Later, Osmond *et al.* (1969) and Hatch and Salck (1966) revealed that among several halophytic species of *Atriplex*, some fix CO_2 through the C_3 pathway while others do so by the C_4 pathway. Later, Osmond *et al.* (1969) demonstrated that in *Atriplex spongiosa*, the initial products of photosynthesis are C_4 compounds, malate and aspartate; and among the carboxylating enzymes, while phosphoenolpyruvate carboxylase (PEPC) showed an enhanced activity, ribulose bisphosphate carboxylase (RBPC) activity was lower than that in C_3 plants. Shomer : Ilan *et al.* (1975) also reported that *Suaeda monoica* photosynthesis by the C_4 pathway even in the absence of 'Kranz anatomy' or dimorphism of chloroplasts.

Intensive studies on photosynthesis in mangroves and other halophytes were conducted in Joshi's laboratory at Kolhapur. The mangrove//halophytic species studied were *Aeluropus lagopoides* (Waghmode and Joshi, 1979), *Rhizophora mucronata, R. apiculata, Avicennia officinalis, A. marina, Acanthus ilicifolius*, (Joshi *et al.*, 1980), *Lumnitzera racemosa* (Joshi and Waghmode, 1981) and *Bruguiera gymnorrhiza* (Bhosale, 1981). In general, these species displayed typical C_4 characteristics such as :

(a) Aspartate or alanine as initial products of CO_2 fixation,
(b) A significantly higher PEPC activity than RBPC activity,
(c) A low CO_2 compensation point,
(d) The presence of pyruvate phosphate dikinase activity, and
(e) A low glycolate oxidase activity.

However, *Bruguiera gymnorrhiza* shows features common to C_3 and C_4 plants. In addition to noting the above features in *Suaeda nudiflora*, Gokhale (1983) also reported that the enzyme RBPC and PEPC in this species displayed thermostability in the presence of aspartate. This apparently is an ecological adaptation. Mangrove and other halophytic species as display a stomatal behaviour similar to C_4 species, i.e., the stomata generally open during the dark period and remain closed for the major pat of the day. All the above characteristics indicate that mangroves photosynthesise essentially by the C_4 pathway. Thus the major evidence supports the operation of the C_4 pathway in most mangrove species. In spite of the above evidence, doubt has been expressed in some quarters regarding the functioning of a C_4 pathway in mangroves, since the $\delta^{13}C$ ratios for carbon assimilation in most species resemble those of C_3 species. (Andrews *et al.*, 1984). As of today, this controversy still remains unresolved, although major evidence is in favour of the C_4 pathway being operational rather than the C_3 pathway.

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MANGROVES : NITROGEN METABOLISM AND SENESCENCE

D.V. AMONKAR

MANGROVES : NITROGEN METABOLISM

Mangroves which constitute typical halophytic plants, exhibit patterns of nitrogen metabolism which are apparently closely related to their adaptation to saline environments. It is well known that growth of higher plants in many ecosystems is limited by nitrogen supply. The occurrence of perennial mangrove species in habitats characterised by a low nitrogen availability suggests that some modifications are taking place in their nitrogen assimilation process which are linked to the efficient conservation and recycling of nitrogen within the plant. The study of nitrogen uptake and its metabolism under saline conditions provides valuable information about the survival strategy of halophytes.

In halophytes, compartmentalisation of nitrogenous compounds and the control of their synthesis are a fundamental part of the adaptive mechanism, and a close relationship exists between N assimilation and adaptation to the saline environment. It has been observed that since salinity does not influence nitrate uptake and there is no competition between external nitrate and chloride, it is the high tissue chloride levels which inhibits nitrate uptake. However, in spite of accumulation of chlorides, halophytes contain appreciable levels of nitrate. This suggests an active inward transport of NO_3 against the electrochemical gradient.

Assimilatory nitrate reduction is catalysed by two enzymes, nitrate reductase (NR) and nitrite reductase (NiR).

$$NO_3^- + NADH + H^+ \xrightarrow{NR} NO_2^- + NAD^+ + H_2O;$$
$$\text{and } NO_2^- + 6H^+ + 6e^- \xrightarrow{NR} NH_3 + H_2O + OH^-$$

In a majority of mangroves, both the root and shoot play a vital role in the assimilation of nitrate. However, the actual contribution of root and shoot tissue to this process is dependent on the external nitrate concentration. At low external levels of nitrate, the root system assisted by the enzymes NR and NiR becomes the major site of assimilation. NR is a substrate inducible enzyme and its activity is a sensitive metabolic marker under stress. Although both the above noted enzymes show a decrease in their activity under the influence of increasing salinity, NiR appears to be much less sensitive than NR. It is now well established that in higher plants the product of NO_3 reduction (NH_4^+) is assimilated via the glutamine synthetase (GS) - glutamate syntheses (GOGAT) pathway.

$$\text{L - Glutamate} + NH_3 + ATP \xrightarrow[Gs]{Me^{2+}} \text{L-glutamine} + ADP + Pi;$$
$$\text{L - Glutamate} + \text{2-oxoglutarate} \xrightarrow[GOGAT]{} \text{2-L-glutamine} + Fd^+.$$

In addition to the above mechanism, ammonia also becomes available under normal conditions through the uptake of ammonium salts or through its release during photorespiration and protein degradation. While salinity does tend to affect the functioning of the GS/GOGAT system in salt-sensitive plants, in halophytes this pathway plays a major role in ammonia assimilation and NaCl is apparently required for sustaining a higher level of enzyme activity.

Glutamate dehydrogenase (GDH) is another enzyme which may contribute to the assimilation of ammonia.

$$\text{2-oxoglutarate} + \text{NAD(P)H} + NH_3 + H^+ \xrightarrow[\text{GDH}]{} \text{Glutamate} + \text{NAD(P)}^+ + H_2O.$$

Compared to GS, GDH has a low affinity for ammonia and thus its aminating role is doubtful under normal conditions. However, under saline conditions, as ammonia tends to accumulate in the cellular environment, GDH plays a significant role in its assimilation. The requirement for ATP in this process may become a rate-limiting factor for the activity of the GS/GOGAT pathway and under certain conditions such as a low rate of photosynthesis and low energy supply, GDH does take over the function of ammonia assimilation.

Through amination and transamination reactions certain keto acids as well as amino acids accumulate and play a protective role. The major aminotransferases which function are aspartate aminotransferase and alanine aminotransferase. Prominent among the amino acids are proline, aspartic, glutamic, alanine, glycine and serine. Cells/tissues of halophytes are thus characterised by a high free amino acid content. In addition to the amino acids, the amides glutamine and asparagine and the ureids function as nitrogen-rich transport compounds. They also act as storage forms of surplus nitrogen.

However, the most noteworthy fact is that halophytes are characterised by the accumulation of high levels of soluble nitrogenous compounds such as glycine-betaine, amino acids, pipecolic acid, proline, sinapic acid, etc. In some halophytes, over 20% of plant nitrogen is present in the form of such compounds which are now known to play a significant role in osmoregulation. It is somewhat paradoxical that in halophytes high levels of nitrogenous compounds are present even when N is often limited in the environment.

SENESCENCE IN MANGROVES – ITS SIGNIFICANCE

Maintenance of a favourable ionic balance by mangroves is accomplished through a variety of mechanisms. These include salt secretion, salt exclusion, succulence, compartmentalisation, water conservation and also abscission of salt-saturated organs. In halophytes, the process of senescence coupled with the abscission of leaves and bark has a great eco-physiological significance, since it is directly influenced by salinity stress. Through shedding of leaves, halophytes are enabled to get rid of excess of salts and thus adapt to a hostile saline environment.

Mangroves have developed a leaf fall strategy whereby leaves are shed continuously throughout the year. With an increase in the salinity stress, the leaf fall increases as it is metabolically less costly to drop the leaves than to overcome the stress. The leaf litter produced by shedding of leaves proves useful not only because it serves as a source of organic carbon but also because it helps to replenish the soils with mineral elements subsequent to its decomposition.

Senescence is a co-ordinated developmental change that leads to the loss of function and ultimately to the death of a cell, organ or organism. It brings about recovery through re-translocation of the bulk of the nutrition from the senescing organs, thereby resulting in the shedding of the ineffective organs. In halophytes, it also serves to achieve a partial desalination of plants.

TRANSLOCATION OF INORGANIC IONS

In ageing leaves, inorganic ion content increases on account of an accumulation of sodium, calcium and chloride ions. In senescent leaves of mangroves, iron and magnesium also contribute to the increased inorganic ion content. The increase is accompanied by a withdrawal of phosphorus and potassium ions from the senescent leaves and then re-translocation to young, developing leaves. This causes a decline in the K:Na ratio in the ageing leaves. The accumulation of chlorides alongwith sodium causes hydration of proteins and induces succulence. Therefore, in mangroves, the senescent leaves are more succulent.

CHANGES IN METABOLISM AND TRANSLOCATION OF METABOLITES

Metabolic changes encountered during the course of ageing are a part of the normal morphogenetic programme, but gradually these changes become increasingly degenerative. With the onset of the ageing of leaves, initiated by hormonal imbalance, there is a loss of chlorophyll accompanied by decline in nucleic acids, proteins and carbohydrates. Increased proteolytic activities cause degradation of soluble proteins, resulting in loss of many enzymes including RubPase. This affects the rate of photosynthesis. With a decrease in protein content there is a concomitant increase in the alpha amino nitrogen and ammonia nitrogen contents. The products of hydrolysis of carbohydrates and proteins are translocated from the senescent leaves to growing vegetative and reproductive centres. The re-translocation of essential metabolites is an effective measure in the original carbon and nitrogen economy of plants. The recovery of nutrients from senescing organs is a positive functional aspect which enables the species to adapt to adverse environmental conditions.

ENZYMES

During ageing, anabolic activities are affected and hence enzymes of photosynthetic pathway and biosynthesis of metabolites show a decrease in their activity. Activities of RubPase, PEPase, catalases, alkaline phosphatases decrease gradually. On the other hand, cellular hydralases, proteases, nuclease, RBPases show an increase in their activity. In mangroves, the accumulated salts in ageing leaves also contribute to the altered activity levels of enzymes.

In the senescent leaves, NR activity is affected more than that of N:R. There is a subdued functioning of the GS/GOGAT system with a simultaneous greater involvement of GDH. Studies on the senescent leaves of mangroves indicate that GDH, coupled with aminotransferases, reduces the toxic level of ammonia caused by increased proteolytic activities. This contributes to the efficient re-translocation of nitrogen reserves to young vegetative and reproductive centres. GDH has a significant role in the process. The enhanced *de novo* synthesis of this enzyme is coupled with the modulatory effect of ammonia on the activity of GDH.

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ASPECTS OF PRODUCTIVITY OF MANGROVES

SAYEEDA WAFAR

The term 'mangroves' refers to an assemblage of different flowering plants which can grow in saline brackish water areas like creeks, backwaters, estuaries and deltas. Mangrove forest cover in the tropical area is about 0.5 million km^2 and this sorts into two distinct geographical assemblages (a) Indo-Pacific region, comprising of South-east Pacific archipelago as far East as Samoa and (b) West Africa - American region comprising of Atlantic coast of tropical America and the Galapagos Islands. The total number of plants that exclusively occur in mangrove habitats is 60 including two genera of palms - *Nypa* and *Phoenix*.

ECOLOGICAL AND ECONOMICAL VALUE OF MANGROVES

The mangroves offer shelter to the juveniles of a wide variety of marine organisms, notable among them being shrimps, so much so that the magnitude of a shrimp fishery of maritime state having mangroves is almost proportional to the aerial coverage of its mangrove forests. The second most important ecological value of mangrove vegetation is its ability to trap and accrete material so that shore erosion in areas bordering mangroves is greatly abated.

Economic values are still several more ranging from production of timber through tannin, wax, fodder, pharmaceuticals to honey. Besides, mangroves are easily available to brackish water fish and shrimp culture, with the natural high productivity of this ecosystem, allowing an enhancement of harvestable yield at low investment, especially of supplementary feeds, which otherwise is a major constraint to aquaculture elsewhere in the World.

ENVIRONMENTAL FACTORS THAT GOVERN MANGROVE DISTRIBUTION

The five most important environmental variables that influence mangroves are temperature, salinity, tides, rainfall and winds, each having a distinct effect. Temperature effects the development and survival of the mangroves in the early stages. Salinity determines the distribution and zonation of the species within a mangrove forest, since each species has a particular salinity preference/tolerance. For example, *Rhizophora* species prefers high saline zones whereas *Sonneratia caseolaris* are found occasionally in the freshwater. Tides act conjointly with salinity in the dispersion and zonation, and the tidal amplitude determines the landward extension of the mangroves. Rainfall is important in the zonation of mangroves on flat coasts, and the productivity of a mangrove ecosystem is related to the frequency and volume of freshwater supply by rainfall. Wind is important in regulating the seasonality of litterfall, which is the major pathway of energy flux from terrestrial to aquatic system.

PRODUCTIVITY

Elements of mangrove productivity are phenology, litter production and litter transformation to aquatic detritus, and aquatic algal production.

PHENOLOGY

This study relates to growth and development of various components of a plant body, and is divisible into vegetative phenology (of leaves, branches) and floral phenology (buds, flowers, fruits). The outcome of phenological studies will indicate the rate of growth of a mangrove tree, leaf formation, growth and fall, flowering and fruiting seasons, etc. Typical results from Indian mangrove show that growth in all mangroves is continuous, leaf formation can vary from unimodal to trimodal pattern according to species, leaf life is between 6 and 12 months, and flowering and fruiting occur within an year.

The fate of bulk of vegetative and floral parts of mangroves is to fall in the mud and decompose there, since direct grazing by herbivores is of limited importance in mangroves. Thus, litterfall is a critical link in energy flux in these ecosystems. Typically, litterfall is seasonal in nature, with a major fraction of its variability accountable for windrum, followed by salinity, rainfall and temperature. Nevertheless, not all of these can account for the total variability of litter production, indicating the involvement of certain physiological factors.

Bulk of litter is leaves with floral parts and fruits assuming importance only at flowering and fruiting peaks. Temporal variations in the quantity of these litter production can also indicate chronology of leaf life, flowing and fruiting, as well as the success rate of these.

LITTER DECOMPOSITION

The litter is not consumed directly by the herbivores, but is broken down to smaller fractions by microbial action, prior to consumption. This renders the litter more suitable for herbivorous feeding and also enhances its nutritive value. The average element ratios of litter are as follows; $C : N = 48 \pm 11$; $C : P = 523 \pm 158$; $N : P = 11 \pm 1$ and the production in terms of these elements in Indian mangroves is about 500 kgC ha^{-1} yr^{-1}, 98 kg N ha^{-1} yr^{-1}, and 7 kg P yr^{-1} 1 yr^{-1}. Decomposition of litter follows a first order kinetics, with decay constants varying from about 20 to 100 depending on the species. Aged (decomposed) litter has a better nutritive value and is easily consumed, well assimilated by herbivores, yielding good growth.

AQUATIC PRODUCTIVITY

This is of little importance in mangroves, being around only 1-2% of the overall productivity. The most important reason for this is the high turbidity zone and rapid light extinction in these waters, reduces considerably the depth of the euphoric zone. Lack of hard substratum prevents the growth of other macroalgae. However, species like *Enteromorpha* can be found in abundance at a few places within the mangroves.

INTERACTION WITH ADJACENT ECOSYSTEMS

Mangrove ecosystem is a major exporter of nutrients and organic matter to adjacent ecosystems, which mostly are the neighbouring estuaries, and occasionally the neuritic waters. This flux is along a concentration gradient and is a function of tidal currents. The net effect of this flux is to enhance the productivity of adjacent ecosystems as well.

CONSTRAINTS IN SUSTAINABILITY

Because of their proximity to human habitations, many mangroves have been adversely affected by human activities. The most important is reclamation of mangrove areas for urban development which causes irreversible damages. The second is unplanned conversion of mangrove areas for farming (agricultural and aquacultural). Ranking in importance successively are : pollution, over-exploitation and unintentional effects that arise from human activities in other areas. Best example for the last case is the construction of dams across rivers in the highlands which reduces freshwater flow into mangrove in the lowlands, affecting productivity and survival of the mangroves.

MANAGEMENT OF MANGROVES

The elements of management follow two paths. The first concern is the mangroves which are practically degraded but yet can be recovered. In this case, suitable steps would be to halt reclamation/conversion, control of discharge of pollutants, rationalisation of resource uses, and development of latest potential of mangroves to maximize the yields. The second case concerns the mangroves which are declared beyond redemption by simple management techniques. The only solution applicable here is afforestation, wherein seedling of mangroves are grown in nurseries and transplanted to areas where once mangroves prevailed. This naturally is time consuming but its success rate is quite high.

APPLICATION OF REMOTE SENSING IN THE STUDY OF MANGROVE ECOSYSTEMS

SHAILESH NAYAK

INTRODUCTION

Mangroves are salt-tolerant plants found mainly in tropical and sub-tropical tidal regions. They not only help in the production of detritus/organic matter and recycling of nutrients thereby enriching the coastal waters to support benthic population of the sea, but also prevent soil erosion and act as a buffer for the mainland from storms to protect the coast from erosion. They provide feed, spawning and nursery grounds to many organisms and a vast range of direct and indirect products, benefits and services to human beings. Above all, they support the most fundamental needs of the coastal population, e.g., food, fuel, shelter and monetary earnings. Important factors which influence this ecosystem are the extent, condition and production potential of mangrove areas, geomorphic processes, viz., erosion, deposition and sediment transport, soil, climate and population in coastal waters. In India, mangroves are under pressure due to increasing population, development of aquaculture, salt pans and ports, location of effluent disposal sites, development of various chemical, petrochemical, fertiliser and allied industries, and petroleum exploration activities in coastal areas. Because of the complexity of data requirement for decision-making, it becomes difficult to manage this ecosystem.

In order to understand various components of the mangrove ecosystem, considerable amount of field data have to be collected. Conventional methods require a lot of time, effort and funds, and present a picture of only a small area. On the other hand, orbital remote sensing gives a synoptic, multispectral and repetitive coverage, which is very useful in the observation of various biotic and abiotic factors and interactions between them. The components that can be observed through remote sensing include spatial distribution of mangrove areas, their status, changes in their conditions through time and space, association of other plant communities, biomass estimation, coastal land forms, shoreline changes, suspended sediment concentration and its dynamics, circulation pattern in estuaries, lagoons and gulfs, coastal currents, pollutants, etc. In addition to this, remote sensing data can also help in delineating meaningful boundaries of the mangrove ecosystem.

Management of mangrove ecosystem, which includes a rational exploitation of resources and / or protection of the environment, needs good knowledge of the above-cited components.

MANGROVE AREAS

The knowledge about aerial extent, condition and destructive uses of mangroves and surrounding wetlands is vital for mangrove ecosystem management programme. Tidal wetlands provide a vital link in the marine energy flow through transfer of solar energy into forms which are readily usable by a wide variety of estuarine organisms (Odum, 1961).

The study of mangroves consists of the following tasks :

a) Mapping or inventory,
b) Change detection,
c) Plant community identification, and
d) Biomass estimation

MANGROVE MAPPING/INVENTORY

Remote sensing data provide information about aerial extent, condition and boundary of wetlands. The potential of Skylab imagery MSS data for mapping major vegetation communities in the coastal areas has been demonstrated (Anderson *et al.*, 1973; Carter and Schubert, 1974; Carter, 1982). Digital and visual analysis of Landsat MSS data have provided information on condition, boundary and areal extent of wetlands (Bartlett and Klemas, 1980). Wetland maps on 1 : 250,000 scale of the Gulf of Kachchh have been prepared through visual interpretation of Landsat MSS data of the 1975, 1982 and 1985 period (Nayak *et al.*, 1986; Pandeya *et al* 1987).

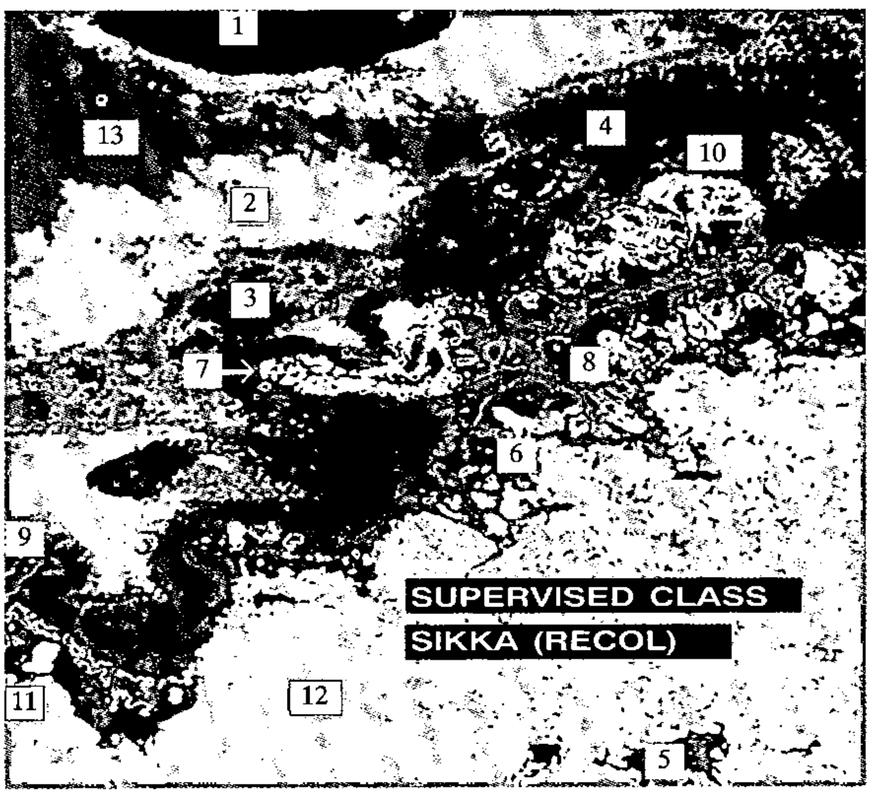

Figure 1. Supervised classification for tidal wetland studies of Sikka area, Gulf of Kachchh, using satellite data.

Legends: 1. Clear water (deep), 2. Clear water (shallow), 3. Turbid water (shallow), 4. Turbid water (deep), 5. Water-bodies (inland), 6. Mud-flat, 7. Coral reef, 8. Mangroves, 9. Algae, 10. Marsh, 11. Salt-affected area, 12. Terrestrial area, 13. Clouds.

Mud-flats, coral reefs, mangroves as well as high and low water line (upper and lower boundaries of wetlands) have been mapped.

In the State of Karnataka, coastal land forms and wetlands such as beach, mud-flat, rocky coast and mangrove could be mapped, however, mangrove areas could not be identified (Rao *et al.*, 1987). Landsat MSS digital data were classified using maximum likelihood classifier around Kandala, Navalakhi and Sikka area (Figure 1).

IRS LISS II/Landsat TM data proved extremely useful for wetland mapping as well as delineating high and low waterline in the Gulf of Kachchh. It was possible to distinguish between mangroves and other plant communities (Pandeya *et al* 1987; Nayak *et al* 1988). These studies helped in standardising classification system, methodology, map-representation scheme and image-interpretation key.

IRS LISS I and Landsat MSS data meet accuracy standards at 1 : 500,000 scale or smaller. The principal limitation of IRS LISS I/Landsat MSS data is the coarse spatial resolution. Wetlands having large species diversity and/or sharp spatial zonation may yield non-specific spectral signature and this is not identifiable with certainty.

NATION-WIDE MAPPING OF MANGROVES

At the instance of the Ministry of Environment and Forests, Government of India, the Department of Space launched a nation-wide mapping/inventory programme for coastal wetlands launched by using Landsat TM/IRS LISS II data on 1 : 250,000 scale. The main objective of this study was to map coastal wetland and associated shoreland features along the entire Indian coast. Information was sought on areal extent, condition and boundaries of wetlands, and mangroves were delineated as one of the categories in this mapping. This project was recently completed with the active participation of various State Government agencies.

BRIEF METHODOLOGY

In this study, false colour composites (FCC) with green, red and infrared bands of IRS 1A LISS II/Landsat TM belonging to low-tide period of December-February were visually analysed on 1 : 250,000 scale. The classification system and legends used are given in Table 1. An image interpretation key indicating tone/colour, size, shape, texture, pattern, location and association for each category (Figure 2) was prepared using ground truth information, topographical maps and aerial photographs (wherever available). Categories less than 25 ha were not mapped. The classification accuracy was tested on a sample basis assuming binomial distribution for the probability of success/failure of sample tests. Sample size was decided using look-up table prepared employing 2x2 mM size. These points were verified in the field. Confusion matrix was then drawn and classification accuracy was estimated.

DISTRIBUTION OF MANGROVES

The distribution of mangroves along the Indian coast can be explained by one representative coastal wetland area.

Table 1 Classification system and legends for coastal mapping

Level I	Level II	Level III	Symbol
• Non-vegetated Wetland	Mud-flat	• High-tide flats	=H=
		• Intertidal	=I=
		• Sub tidal	=S=
	Sand	• Beach	::B::
		• Spit	::S::
		• Shoals	::R::
	Coral reef	• Fringe	^F^
		• Platform	^P^
		• Patch	^T^
		• Atoll	^A^
		• Coral pinnacles	^C^
	Rocky coast		
• Vegetated wetland	Mangroves	• Dense	D
		• Sparse	S
	Marsh vegetation		vvvv
	Algae		++++++
	Mud-flat with vegetation		=V=
	Beach vegetation		::V::
• Water-bodies	Bay		B
	Estuary		E
	Creek		C
	Lagoons		L
	Kayals/backwaters		K
• Shorelands	Saline areas (Salt affected area)		xSx
	Deltaic plain		xDx
	Flood-prone areas		xFx
	Paleo-mud-flats/strand flat		xPx
	Coastal dunes		xDx
	Reclaimed areas		xRx
	Paleo-beachridges		xBx
	Terraces		xTx
• Other Features	Cliff		- - -
	Strand line		= = =
	Highwater line		- - -
	Lowwater line		- - -
	Lineament		L-L
			F-F

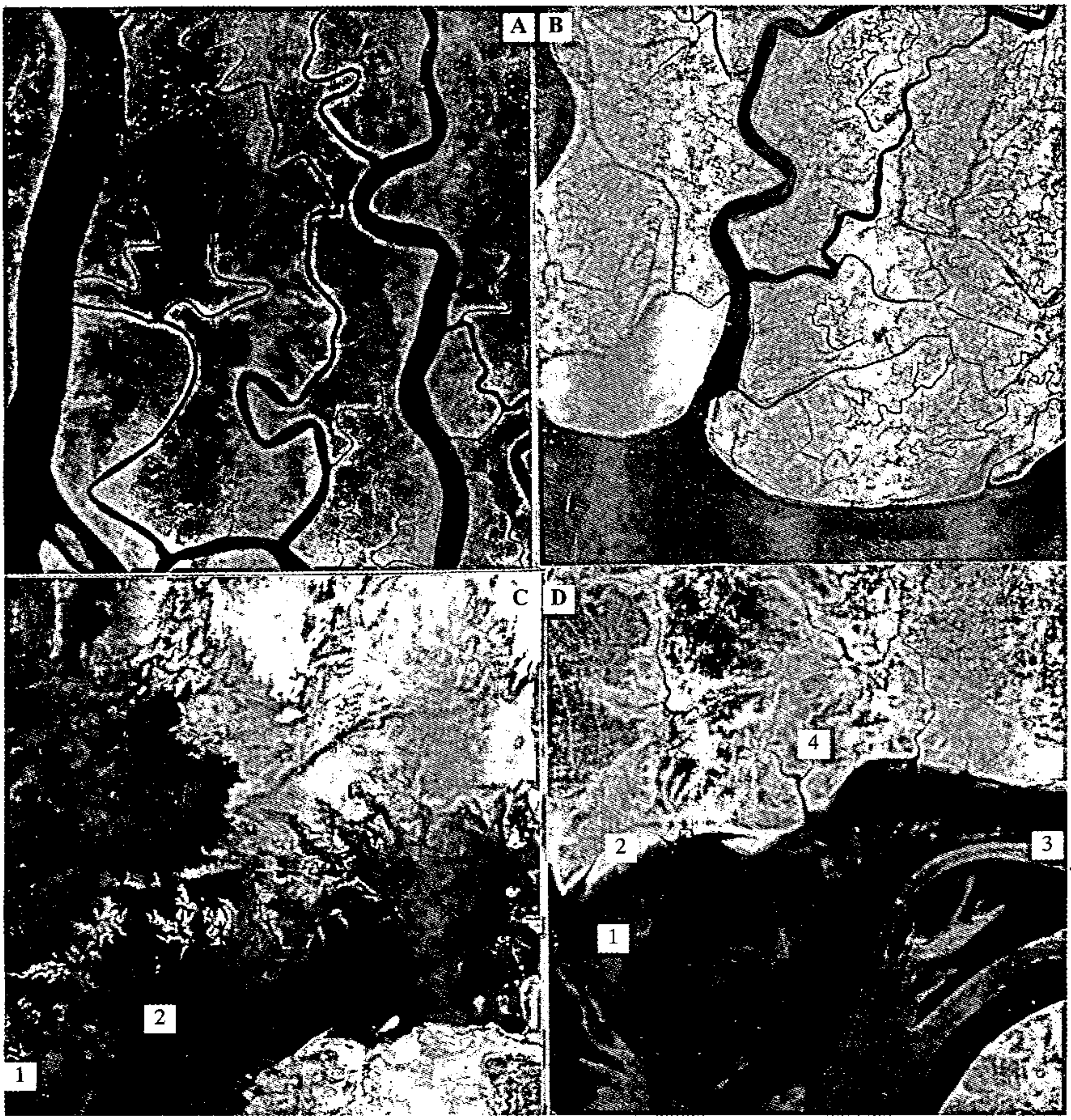

Figure 2. Satellite photographs show (A) dense mangroves with intricate network of creeks, (B) degraded mangroves, (C) salt-marsh vegetation (1) and associated mud-flats (2) of Sunderbans. (D) High tidal (1), Intertidal (2), sub-tidal (3), mud-flats and (4) paleomud-flats in the Gulf of Khambat area.

GUJARAT

Mangroves are found mainly in the Gulf of Kachchh, the Kori creek and as sporadic occurrences at a few places. In the Kori creek, mangrove and saltmarsh vegetation grows on Intertidal slopes and high-tidal flats made up of dark-coloured clayey mud. Marsh vegetation consists of dwarf undershrubs like *Suaeda fruticosa* (quite common), certain members of the Graminae and the Cyperaceae family, e.g., *Aeluropus lagopoides, Cenchrus* spp., *Sporobolus marginatus,* etc. Sparsely distributed mangroves, e.g., *Avicennia marina* and *A. officinalis,* are present along the Kori creek in the form of narrow discontinuous patches. They are bushy with multiple vegetative shoots attaining a height of about 2 m. *Rhizophora* spp. are rare (Blasco, 1977).

Mangroves of the Gulf of Kachchh are of scrubby type with stunted growth, forming narrow discontinuous patches on soft clayey mud. *Avicennia* spp. generally grows as a tree under favourable conditions, but under stress it grows in a scrubby stunted form (Blasco, 1977). *Rhizophora mucronata* grows more towards the seaward side. Condition of mangroves in this area is degrading due to continuous grazing by camel, and their use as fodder and fuel. Due to this indiscriminate use, the area has become barren or with scattered, stunted trees or with only exposed pneumatophores. Such patches of degraded mangroves (*Avicennia* spp.) are observed near Okha, Poshitra, Pindhara, Dhani, Narara, Sikkara, Jindra, Pirotan and the Jakhau port.

Marsh vegetation grows on the Intertidal mud-flats, and sometimes extends as far as supra tidal area. It is found growing in between mangroves or after the mangrove belt towards landward side. This vegetation prefers saline sandy mud as its substrate. In the Gulf of Kachchh, marsh vegetation is found near Balachhadi and from Navlakhi to Kandla. *Suaeda fruticosa, Tamarix dioica,* etc., are some examples of commonly observed species in the Gulf. A rich gregarious growth, e.g., the mat-like growth of *Ulva* spp. and *Saragassum* spp. is found on the edges of the reefs and reef flats of Bural Chank, Ajad, Paga, Munde Narara, Pirotan and other coral pinnacles.

On the Saurashtra coast, sparse patches of mangroves occur along the creeks on the Intertidal mud-flats, near the Jafarabad creek, the Buthrani creek, etc. Sparse *Avicennia* spp. are present near the Ghogha jetty, on the Pipavav bandar, the Narara Bet near Miyani, Porbandar and Diu.

Extensive mud-flats ranging from 6 to 8 km wide are distributed all along the coast of the Gulf of Khambhat except along the Narmada estuary. These mud-flats are generally devoid of mangroves. They are composed of fine-grained silt and clay, and are fluvial marine in nature. Tidal currents play an important role in the formation of these mud-flats. Most of the sediments have been deposited during slack period (Nayak and Sahai, 1985). Mangroves are found growing on the Intertidal mud-flats in the Gulf of Khambhat at a few places. *Avicennia marina,* in stunted and sparse form, is distributed along the coast near the Mahi, the Dhadhar, the Narmada, the Kim and the Sena rivers. A small patch of dense mangroves is observed on the Aliabet island.

The Intertidal mud-flats between the Sabarmati and the Tapi estuaries have a scattered growth of marsh vegetation. It is more prominent between the Mahi and the Dhadhar estuaries. The vegetation comprises of *Suaeda* spp., *Salicornea brachiata, Aeluropus* spp., etc.

On the South coast of Gujarat, a patch of mangrove, mainly consisting of *Avicennia officinalis,* lines the South of the Kolak estuary and a small creek near Umargaum. To the South of Kolak river, a luxuriant growth of *Rhizophora* spp. is seen., attaining a height of about 2 m. Marshy vegetation occurs along the creeks from the Purna estuary to the Daman Ganga estuary.

The area under dense and sparse mangroves is about 160 and 890 sq km, respectively.

MAHARASHTRA-GOA

Mangroves mostly occur along the Intertidal regions of estuaries and creeks. Large patches are noticed along the Mandovi estuary, the Vasishthi estuary, the Savitri estuary, the Kundalika estuary, the Dharamtar creek, the Panvel creek, the Vasai creek and the Vaitarna creek. Small and discontinuous patches were detected along almost 40 estuaries and creeks but were not mapped. The area under mangroves is approximately 150 sq km.

KARNATAKA

Mangroves are sparsely distributed in the estuarine areas of Karnataka. The substrate is made up of fine-grained clay particles and is rich in nutrients. The condition of mangroves is good in the Mulki river, the Sita-Swarna river, the Chakra-Haldi-Kollure riverine complex, the Sharavati estuarine region, the Tadri creek, the Aganashani riverine complex and in the Kalinadi estuarine complex. *Rhizophora* spp. *Avicennia* spp. *Sonneratia alba* and *Acanthus ilicifolius* are among the commonly found species.

KERALA

Kerala coast is devoid of extensive or wide mud-flats. The mangrove vegetation in the coastal zone of Kerala is very sparse and thin, ruling out any possibility of mapping it using satellite data, especially on a 1 : 250,000 scale (Nair *et al.*, 1991). The increase in the population density and the developmental activities in the estuarine shores are the main reasons for decline in mangroves of this region.

TAMIL NADU

There are well-developed mangrove forests at Pichavaram, Vedaranyam and Point Calimere. Pichavaram forests occupy 13.6 sq km of mangroves (Venkatesan, 1966). There are about 20 species known to the Tamil Nadu coast. Commonly occurring species are *Excoecaria agallocha, Avicennia alba, A. marina, Rhizophora mucronata, R. apiculata, Ceriops tagal, Bruguiera cylindrica, Sesuvium portulacastrum, Avicennia* spp., etc., dominate where soil is sandy mud. *Excoecaria, Rhizophora* etc., dominate where the soil is clayey mud. Salt-tolerant species grow in between mangroves or on the supra tidal mud-flats. Dominating species on the Tamil Nadu coast are *Suaeda monoica, S. maritima, Salicornia brachiata,* etc. The area under mangroves is about 30 sq km.

ANDHRA PRADESH

On the North Andhra coast, no classical mangrove vegetation is found. A few small pockets of degraded mangroves are observed on Intertidal flats at the mouth of the Sarada river, South of Uppada. Small patches of marsh are seen at the high tide at Bavanapadu (Vaidyanathan *et al.*, 1991).

Mangrove swamps occur in profusion in the Intertidal mud-flats on both sides of the creeks in the Godavari-Krishna deltaic regions. The creeks provide the channel for brackishwater intrusion during high and low tides. Thick vegetation consists of tall, dense, halophytic trees along with other plants species also. It is observed that dense mangrove vegetation is towards the coast rather than upstream region. Dense mangroves are identified on ancient tidal delta at Machilipatnam. These are more widespread on tidal flats on the Western side of the Krishna delta-lobe. Such formations are also seen over recent spits in the Nizampatnam bay. Degraded mangroves are found on the landward side of the Intertidal mud-flats and are also seen on the Eastern side of the Krishna delta. Scattered mangroves are seen over mud-flats, inundated only by exceptionally high tides.

It is observed that in recent years some of the vegetated wetlands are reclaimed for paddy cultivation, artificial fishing ponds and firewood. The area under dense and sparse mangroves is about 235 and 95 sq km respectively.

ORISSA

Mangroves of the Mahanadi delta occur along creeks in fringed manner. The mangrove vegetation possesses tree, shrub and palm species. Important species in this locality include *Avicennia* spp., *Achrosticum* and *Phoenix* spp. The area is also endowed with rich wildlife.

The mangroves of Bhitar Kanika, which are the second largest mangal formations in the Indian sub-continent, harbour high concentration of typical mangrove species and a wide spectrum of genetic diversity. Important mangrove species include *Avicennia alba, A. officinalis, Excoecaria agallocha,Heritiera minor, Sonneratia apetala, Rhizophora mucronata, Ceriops decandra, Xylocarpus, granatum, Phoenix paludosa, Aegiceras Corniculatum, Suaeda maritima, Porteresia coarctata,* etc. (Das *et al.*, 1991).

Mangroves of the Balasore coast are quite different due to the absence of fresh water inflow and the salinity levels remain very high except during the rainy season. The species in this area include *Avicennia alba, A. marina, Ceriops* spp., *Aegialitis rotundifolia* and *Suaeda maritima*. The area under dense and sparse mangroves is 110 and 85 sq km respectively.

WEST BENGAL

The mangroves along the cost of West Bengal mainly colonise in the Sunderban area, which is the largest single block of mangroves in the World. Topographically, the Sunderbans exhibit a number of anastomotic distributories.

The mangroves along river banks and the swampy forests are typical halophytic mangrove types. The major species of the dense mangrove forest include *Heritiera fomes, Rhizophora apiculata, R. mucronata, Bruguiera gymnorrhiza, B. parviflora, Ceriops decandra, Sonneratia apetala, S. caseolaris* and *Avicennia* spp. *Nypa fruticans* is the major species found along the banks of the creek and in the sparse form (Das *et al.*, 1991). *Phoenix paludosa* covers almost all the tidal zones of the Sunderbans, but exploitation of this species in these areas has prevented its rapid growth. Sunderban mangrove forest is famous for the Royal Bengal tiger and crocodiles. The area under dense and sparse mangroves is 580 and 855 sq km respectively. Other marsh vegetation includes *Aeluropus lagopoides, Suaeda nudiflora, S. maritima,* and *Tamarix* sp.

ANDAMAN AND NICOBAR ISLANDS

The mangroves and terrestrial evergreen forests of the Andaman and Nicobar group of islands are gregarious. There are many small tidal estuaries, neritic inlets and lagoons which support dense and diverse mangrove flora. The tidal creeks often form the outlets to the rain-fed stream that flows from the interior and carry silt to the shore to form muddy plains facilitating the spread and regeneration of mangroves (Ananda Rao and Chakraborty, 1987).

The islands alone account for about 18% of the country's total mangrove area. The mangrove flora of the Andaman group of islands comprise 27 species (Jagtap, 1985) and those of the Nicobar group of islands comprise only 10 species (Jagtap, 1991). The dominant mangrove species are *Rhizophora mucronata* and *R. stylosa*, and the co-dominant is *Bruguiera gymnorrhiza*. *Nypa fruticans* occurs in the upstream regions of estuaries and neritic inlets. The area under mangrove is 770 sq km.

CLASSIFICATION ACCURACY

The classification accuracy of the coastal wetland maps achieved is 85-90% at 90% confidence level. The State wise details are given below :

Gujarat	89%	Tamil Nadu	85%
Maharashtra-Goa	84%	Andhra Pradesh	87%
Karnataka	83%	Orissa	85%
Kerala	86%	West Bengal	83%

CHANGE-DETECTION STUDIES

The knowledge about long-term changes in the mangrove vegetation is important to manage this ecosystem. The repeatability of Landsat and IRS data (16 and 22 days, respectively) is suitable for monitoring such changes. However, the length of record for IRS data is too short for monitoring long-term changes. Changes in the wetland conditions can be done before and after classification. The techniques available are given below :

1. Pre-classification changes can be detected using :
   a. Red band (one data) and negative or red band (other date), and
   b. Red band (one date, a ratio of red (two dates) and infra-red bands (one date).
2. Post classification change detection can be accomplished using :
   a. Percentage matrix (listing of each class),
   b. Change matrix (comparison of classes of two dates),
   c. Binary theme prints (changes in map forms), and
   d. Conflict character assignment (map showing changes on pixel basis).

IRS data in conjunction with Landsat data were found to be extremely useful for monitoring degradation of mangroves. In one such study, in the Marine National Park, Jamnagar (Gujarat), significant changes in the mangrove vegetarian and coral reef areas were observed during the period 1975 to 1988. These changes were shown in map form, i.e. binary theme prints. Mangroves were reduced from 140 sq km. to a mere 35 sq km during 1975-1985 (per cent matrix). This reduction was attributed mainly to their use as fodder, fuel, excessive grazing and proliferation of salt pan industries. Coral reef area got reduced from 115 sq km to 55 sq km during the same period. The main cause for this destruction was carbonate sand mining by a cement company, along with dredging, filling and weapon testing. These activities led to a tremendous disturbance on the coast and loose particles were swept along with tidal currents and were ultimately deposited on reefs. The deposition resulted in the death and decay of living corals. Nomination of this area as a marine national park in 1983 to protect and conserve the environment, helped to reverse the trend after 1985 as steps taken by the marine park authorities started showing results, and helped towards restoring the environment. The satellite data of 1988 show that the area under mangroves and coral reef has increased to 50 sq km and 75 sq km. respectively (Pandeya *et al.*, 1989), since then.

PLANT COMMUNITIES DISCRIMINATION

The spectral properties of canopies of different plants are produced by a combination of optical properties of individual vegetative components, effects of plant growth forms, density and height, tidal stage and soil type (Johnson and Munday, 1983). Reflectance of 'leafless' and gramineous canopies is highly dependent upon solar elevation angle whereas 'broad-leaf canopies' reflectance is not. This information is useful for estimating biomass (Gross *et al.*, 1988). Dottavio and Dottavio (1984) concluded that middle IR wavelength region provides a clear separation between brackish low marsh and high marsh communities. Textual pattern observed on the high-resolution space photograph alongwith physiographic conditions can be used to identify different mangrove associations (Panigrahi and Parihar, 1986).

Various digital enhancement techniques were attempted to identify different plant communities using Landsat MSS data in the Navalakhi-Kandla area (1975, 1982 and 1984), Sikka area (1975 and 1982), Aliabet area (1975, 1982 and 1986), Coondapur area (1984 and Karwar area (1984). Band ratio combination of 5/4, 5/7 and 6/5 and principal component analyses were found to be most suitable for studying wetland conditions and classifying vegetation types (Fig. 4). It is seen that various combinations of MSS band 5 and 7, either ratioing or addition/substraction, greatly enhance subtle difference in the reflectance of the vegetation and thus different vegetation types could be distinguished. On the Karnataka coast, edge enhancement FCC (MSS bands 4, 5 and 7) was found to be useful for wetland studies (Shaikh *et al.*, 1989). Seaweeds were detected using digital enhancement of Landsat TM data (Gupta and Nayak, 1989).

The identification of various wetland features using digitally enhanced LISS II and Landsat TM data is quite comparable. However, Landsat TM data give more information about wetland conditions and density of mangroves due to better radiometric and spatial resolution (Nayak *et al.*, 1988).

The combination of colour and colour-infra-red photography provides the best plant community discrimination.

BIOMASS ESTIMATION

Radiance measurements in the near infra-red and red region are used for estimating biomass. Field spectral measurements have confirmed that biomass is related to the canopy reflectance in the near infra-red and red bands. The difference in reflectance at two wavelengths and ratio of two wavelengths are found to correlate with biomass more highly than did reflectance in either band alone (Pearson and Miler, 1972, Bartlett, and Klemas, 1979).

Landsat MSS CCT's were analysed to get some information on standing crops, biomass of selected wetland plans (Bartlett and Klemas, 1979, 1980). An attempt is being made to estimate biomass of seaweeds in the Gulf of Kachchh using Landsat TM/IRS LISS II data. In the study, plant community maps are prepared and converted into productivity maps by assigning productivity value to the plant community.

COASTAL PROCESSES

Coastal processes of erosion, deposition and sediment transport, flooding and sea level changes continuously modify the shoreline. The following parameters are studied to understand coastal processes:

a. Shoreline change,

b. Coastal land form,

c. Tidal boundary, and

d. Offshore bar and underwater features.

The identification of depositional areas proves useful as these areas are likely to be colonised by mangroves. Orbital data have yet to prove their operational use in these studies, mainly because of their limited spatial resolution. However, they are useful for large area sediment transport studies and detecting long-term changes in the entire coastline.

SHORELINE-CHANGE MAPPING OF THE INDIAN COAST

Shoreline-change mapping during the period (1975-80 and 1985-88) for the entire Indian coast using Landsat MSS/TM and IRS LISS II data on 1 : 250,000 scale has been completed, under a project with financial assistance from the Ministry of Environment and Forests, Government of India.

Multidate Landsat MSS/TM and LISS II data period 1975-80 and 1985-88 belonging to the same season and more or less similar tidal conditions were analysed on 1 : 250,000 scale. Infra-red band was found to be suitable for demarcation of shoreline as the contrast between land and water is very sharp (Nayak and Sahai, 1983). The contrast was further enhanced using the negative of infra-red band. The two shorelines were compared using Zoom Transfer Scope and using control points (minimum 4) The topographical maps on 1 : 250,000 scale were used as base maps. The salient findings relevant to mangrove ecosystem are given below :

1. Major shoreline changes were observed in the estuaries and deltaic regions. Most of the estuaries are being silted up, especially the Narmada and the Hoogly estuaries. Das *et al.*, 1991). New mouth bars were noticed in the Hoogly estuary. The configuration of the Sagar island (near Calcutta) has changed on account of erosion and deposition.
2. Complex depositional changes were reported in the Narmada estuary (Nayak and Sahai, 1984, 1985). The size of the Aliabet island was found to be increased considerably between 1891 and 1977. The island had further grown Eastwards and joined the mainland, as a result of which the Southern channel has dried up. Some new islands in the Narmada estuary have been emerging recently and are getting colonised by mangroves. The gradual emergence of these islands may be because of neotectonic activity.

3. The Krishna and the Gautami-Godavari delta are prograding (Vaidyanathan *et al.*,1991). Progradation of the coast is also noticed near Vedaranyam in Tamil Nadu. These areas have a good growth of mangroves.

The mere mapping of shorelines and its rate of change may not be sufficient for understanding the coastal processes operating in an area. Information on near-shore water flow is also required (Johnson and Munday, 1983).

LAND FORMS

The study of land forms gives a clue to the processes operating in an area. They are best studied on aerial photographs in conjunction with topographical maps. In the absence of stereo aerial photography, considerable information on the dynamics of topography may be inferred from sequential satellite data. The recently available stereoscopic data from SPOT are ideal for land form studies.

Coastal land form map of the Gulf of Khambhat on 1 : 250,000 scale using satellite data was prepared. IRS LISS I and II data gave more or less the same information, could replace Landsat MSS and TM data respectively, and compared well with the aerial data (Shaikh *et al.*, 1988, 1989a). However, identification of different vegetation types in LISS II standard products was superior and it helped in identification of certain land forms like reclaimed mud-flats. This was because of use of region-specific look-up tables in the generation of IRS data products.

Land form mapping for the entire Indian coast has been completed on 1 : 250,000 scale using Landsat TM/IRS LISS II data alongwith tidal wetland mapping.

TIDAL BOUNDARY

The average height of the high waters and mean low waters over a 19-year period gives Mean High Water (MHW) and Mean Low Water (LMW). The accurate demarcation of HW and LW is important as they control the boundaries of the mangrove ecosystem.

The high and low water line for the entire Indian coast on 1 : 250,000 scale is being mapped along with tidal wetland mapping. It was possible to demarcate high water line accurately.

COASTAL WATERS

Turbidity/suspended sediments and colour/chlorophyll are indicators of water quality. Chlorophyll indicates trophic status, nutrient load and possibly the presence of manmade pollutants in the coastal waters. Suspended sediments affect navigation, fisheries, aquatic life and recreational potential of sea resorts. They also carry absorbed chemicals and create an environmental problem. Roots of mangrove trap sediment and influence progradation of the coast.

SUSPENDED SEDIMENT DYNAMICS

Suspended sediments are easily observed on the satellite imagery. They help in studying the dynamic relationship between sediment input, transport and deposition. Recent studies have demonstrated the potential of estimating either qualitatively or quantitatively the concentration of suspended sediments in water-bodies. Many authors have suggested the use of a single band, for increasing the sensitivity as well as analytical range, however it is desirable to use all available bands as possible (Nayak, 1983). Shorter wavelength introduces atmosphere noise while longer wavelength suffers from high absorption of water in upper few centimeters and therefore, the best single wavelength used should be between 550-650 mM (Johnson and Munday, 1983). Field measure reflectance indicates that IRS band I (blue), 2 (green) and 3 (red) show high correlation with the Sacchi disc and suspended sediments, respectively (Gupta *et al.*, 1990). Band ratio of IRS bands 3/2 shows high correlation with the Sacchi disc (Chauhan *et al.*, 1990).

With density slicing technique, semi-quantitative maps of suspended sediments in the Gulf of Khambhat were prepared using all four bands (Nayak, 1983). Here, a large tidal range gives rise to strong tidal currents and provides mechanism for transport of suspended sediments. The net transport of sediments was towards land, which was evident from extensive mud-flats (Nayak and Sahai, 1984, 1985).

The currents in the Gulf are observed to be mainly influenced by tides, riverine discharge and shoreline configuration. The slope-induced currents near Aliabet are clearly visible on the satellite imagery (Nayak and Sahai, 1985). As the suspended sediments carry absorbed chemicals and fronts are associated with pollutants, the knowledge about their movement will help in predicting waste effluent transportation paths and their effect on mangroves.

CHLOROPHYLL

Satellite data indicated colour variations which in turn, correlate well with chlorophyll. IRS bands 1 and 3 show a fairly high correlation with chlorophyll 'a' concentration. Recently Landsat MSS, Nimbus-7 CZCS, Ocean Colour Radiometer and aerial photographic data was used to estimate primary productivity in oceanic waters off the Cochin coast. This information helped in estimating the third level productivity, i.e., fish catch.

TEMPERATURE

The temperature distribution can be measured using thermal and microwave spectral ranges. Landsat TM has the capacity to measure temperatures between range 260° - 340°K + 1.5° (Johnson and Harris, 1980). At present, NOAA data are being utilised to generate SST map for the entire EEZ. The low resolution of data has limited use in coastal zone studies.

SALINITY

Obtaining water salinity using remote sensing is one of the most difficult things. This parameter is very useful as pelagic fish such as tuna move along thermal and/or salinity fronts. Salinity distributions can be measured using microwave spectral range. NASA Langley Research Centre (LaRC) has developed a dual-band radiometer operating at L and S band (1.43 and 2.65 GHz) which determines salinity and temperature with 1% salinity and 1°C accuracy.

WASTE OUTFALLS

Waste outfalls in the coastal regions are difficult to detect as nearshore waters are turbid. The combination of colour infrared and colour photography at the scale 1 : 5,000 to 1 : 10,000 is preferred to detect coloured pollutants. The reconnaissance mapping (at 1 : 50,000 scale) and low tide time photography are some of the useful techniques for detecting waste outfalls. The thermal plumes can also be detected using thermal infra-red imagery.

OIL POLLUTION

Oil rises to the surface, spreads across the water body and is thus amenable to remote detection. Dielectric constant. refractive index, absorptivity, fluorescence and emissivity are measured for a variety of petroleum products and naturally occurring biological oils.

Near ultraviolet (UV) is excellent for imaging slick edges and thin regions of various oil slicks. Blue band is next best for mapping slick areas. Green wavelength is useful for mapping thick oil slicks. Oil is about 2.7°-4.0°K cooler than water. As the thickness of slick increases, the temperature decreases. Thus the difference between the temperature of oil and water can be correlated to the thickness of slicks.

Spatial resolution of geosynchronous satellites is too coarse for surveillance while polar orbiting satellites have inadequate repeat cycles. Therefore, satellite detection of oil becomes difficult.

MANGROVE MANAGEMENT PLAN

The management of mangrove areas required data on varied aspects, as discussed earlier. Though the information exists in the form of thematic maps as well as non-spatial format, it is difficult to integrate these data conventionally. It is therefore necessary to develop a computer based information system composed of a comprehensive and integrated set of data designed for decision-making. In this plan, basic input about mangrove areas is derived from remote sensing data. Integration of this thematic data with other secondary data would lead to initial zoning. Preservation or conservation zones could be identified within mangrove areas, depending upon their importance. The preservation zone should be preserved only for ecological use such as biosphere reserve (research), wildlife sanctuary (habitat) and controlled recreation (aesthetic value). There should be a buffer around this zone which should be treated as a conservation zone. It needs to be conserved for sustainable use of fuel, fodder, charcoal, etc. The degraded mangroves and mud-flats, after evaluating sites and studying possible impact of any suggested use, can be designed as utilisation and development zones, respectively. The utilisation zone, after afforestation should be treated as conservation zone. In the development zone, only those activities such as brackish water aquaculture development, salt-pans, ports, harbours, etc. should be allowed. This initial zoning pattern can be finalised after receiving comments from various government and non-governmental organisations, research institutes and the public.

CONCLUSION

The mapping of mangroves at 1 : 250,000 scale has various limitations and constraints. The scale is appropriate only in delineating the mangroves in a broader perspective. Coastal wetland mapping should be carried out at 1 : 50,000 scale for better understanding of the condition of wetlands. At this scale, mangrove areas larger than 1 ha can be mapped. These maps should be used a baseline data and for classifying the coastal zone into preservation, conservation, utilisation and development zones. This will be the first step towards a rational mangrove ecosystem management. Coastal wetland mapping in the scale of 1 : 50,000 scale has been taken up for

Kerala, Tamil Nadu and Karnataka coasts. These maps will provide information up to level III and will be used for planning conservation measures at the district level (Desai *et al.*, 1991).

It is observed that the areal extent of tidal mangrove vegetation is reducing year by year, because of reclamation. This reclamation may be worthwhile in some places, but in a majority of cases it ultimately results in the disturbance of the ecosystem. Moreover, mangroves are threatened by the indiscriminate cutting of the forest for fuelwood and small timbers by the local people. Conversion of mangrove area for agricultural purposes, aquaculture and residential development is also creating loss of important mangrove forest areas.

Heavy grazing by the cattle is another problem encountered near the mangrove areas. Based on the above observations, a concerted and co-ordinated effort is necessary to undertake management plans to conserve the mangroves.

The mangroves are vulnerable to the biodegradable and stable compounds from the land. Point and non-point pollution near the estuarine are due to anthropogenic causes is also another threatening factor to the coastal wetlands.

This dynamic an ever-changing environment of the coast, especially at the delta fronts and mouths of rivers, should be studied through largescale images and aerial photographs on a minimum of 1 : 50,000 scale. This will enable measurements and mapping of small changes occurring in the coastline.

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GENETIC DIVERSITY : CONCEPTS AND MEASUREMENTS

V. ARUNACHALAM

Genetic diversity is the base on which programmes of improvement for desired attributes are planned. It plays an important role in the process of decision- making on the conservation of biodiversity. Unless the concepts of genetic diversity and methods of its measurement are clearly understood, it will be difficult to judge how much to conserve and how often to renew/regenerate biodiversity.

One must define for this purpose, a genetic entity in its qualitative and quantitative characters. The difference between a qualitative and quantitative character is very thin and, for all practical purposes, it would be useful to deal only with quantitative character, flower colour, is qualitative in nature having two states, red or white (corresponding to two alleles of a single gene controlling flower colour). But if it is possible to make measurements more accurately so that the degree of redness or whiteness can be measured with accuracy, then flower colour would be scored as a continuously varying trait so that it now obtains the rank of a quantitative character. with present-day knowledge, more and more characters are being classed quantitative (for example, disease resistance being measured on a continuous scale as disease severity index).

The basic assumption in genetic theory is that all quantitative characters follow a normal distribution with its associated statistical properties.

OTUs can be differentiated, in principle, on a set of quantitative characters. It is difficult a priori to identify characters that are sufficient to bring out the differences between OTUs; however, methods are available for identifying such a minimal set of characters for differentiation. The question of giving weightage to various characters in differentiation has received wide attention. It would seem that it is always beneficial to avoid associating differential weights with characters for the major reasons explained by Sneath and Sokal (1973). In essence:

1. Rational grounds for allotting weights are usually absent,
2. The very existence of variation in the characteristics defining OTUs leads to the logic that it is irrational to associate weights with them,
3. Direct assignment of weights to characters will imply judging taxonomic importance *a priori* which would be questionable,
4. There are no exact rules for allotting weights and, therefore, different investigators are highly likely to arrive at different conclusions on the same set of OTUs,
5. Taxonomists, geneticists, breeders and others would look at characters at different levels of their specialisation leading to arbitrariness in weighting.
6. The weighty reason against weighting is the logic behind the hypothesis—decisions based on a number of characters would eventually even out differences arising out of conceivably differing importance of characters.

However, invariant characters would not be of any use in differentiating between OTUs.

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One must, however, be cautious in the choice of characters for genetic differentiation. No basic ground rules can be set; yet the following broad guidelines will be of use.

So far as genetic differentiation of OTUs is necessarily to be based on phenotypic measurements, it is desirable to use a number of characters measured through the entire growth phase of an OTU. In case the differentiation has to be made before a particular growth stage, it is necessary to identify relevant characters measurable before that stage to attempt an efficient differentiation. Requirements such as evaluation of diversity at juvenile or adult phase should be firmed up before the process of evaluation.

The question of how many characters and how to measure them are relevant to this context. It is useful to avoid characters contributing to redundancy. For example, if yield components are measured, yield, which is a function of those components, should not be included. Discontinuous variables, measured by a few scores like ++, +, –, – –, will not be of much utility in differentiation unless they are transformed for qualifying to be a continuous variable.

The genetic potential is indirectly measured through phenotypic values as genotypes express themselves only in an environment. When there is no *a priori* knowledge on the genetic nature of the OTUs, much less on the genetic values of characters, it is necessary to use field designs to get reliable estimates of environmental variation. Diversity measures which utilise corrections for environmental components would be more efficient than those based on phenotypic variation alone. For example, work on peanuts for more than a decade has suggested that the following characters spread over the entire growth phase of peanut would be useful in efficient genetic differentiation :

SEEDLING PHASE

- Seedling viguour measured as the dry weight of seedlings
- Shoot: root dry weight
- Number of leaves
- Specific leaf weight

FLOWERING PHASE

- Days to first flowering
- Number of primary branches
- Number of secondary branches
- Photosynthetic area

HARVEST PHASE

- Number and weight of mature pods
- Number and weight of mature seeds
- Harvest index
- 100-seed weight
- Weight per unit volume

These characters were found to be useful for the material handled in a project and need not necessarily be unique in differentiating between any set of OTUs in peanut. However, the concepts used to identify such a set of characters are repeatable and can be used for any set of OTUs.

GENETIC DISTANCE

A measure is needed to genetically differentiate any two OTUs on the basis of set of quantitative characters. a large number of measures have been tried, of which Mahalanobis' D^2 distance statistic merits application. This distance statistic is a multivariate analogue of the euclidean distance in two dimensions.

We now explain the concept of distance using two OTUs, G_1 and G_2.

Let two characters, X_1 and X_2, unequivocally define the OTUs. The OTUs have the following values for the two characters:

$$G_1(x_{11}, x_{21})$$
$$G_2(x_{12}, x_{22})$$

In general, x_{ij} denotes the values of the character X_i for the OTU_j.

If the two characters X_1 and X_2, are independent (uncorrelated) then the two OTUs could be represented by the values of the two characters in rectangular axes. (See Arunachalam 1981 for details).

$$\text{Let} \quad d_1 = x_{12} - x_{11}$$
$$d_2 = x_{22} - x_{21}$$

then the distance between the two OTUs, G_1 and G_2, will be given by $d^2 = d_1^2 + d_2^2$.

The generalised distance (D^2) scores over the distance function used in, for example, single linkage clustering leading to dendrograms (Sneath and Sokal, 1973). Let the two OTUs be denoted by L_1 ad L_2 and let measurements on five traits, X_1 to X_5, be made. Let x_{ij} - value of trait j for OTU i (i = 1,2; j = 1,5). Then the distance d between L_1 and L_2 is given by

$$d^2 = \sum_{j=1}^{5}(x_{2j} - x_{1j})^2 = \sum_{j=1}^{5} d_j^2$$

where $d_j = x_{2j} - x_{1j}$.

This distance is just a function of phenotypic values of various traits.

In contrast, the generalised distance takes into account the environmental variation. In the above example.

$$D^2 = \sum_{i=1}^{5}\sum_{j=1}^{5} s^{ij} d_i d_j \quad \text{where}$$

(s^{ij}) is the inverse of the dispersion, matrix (S) = (s_{ij}). An estimate of (S) is provided by the common dispersion matrix corresponding to error variance covariance matrix. Thus, generalised distance is a function of phenotypic values and the inverse of the error dispersion matrix. In effect, therefore, the generalised distance measure would be much closer to genetic divergence than the distance postulated by Sneath and Sokal (1973).

If the distance is to effectively measure genetic divergence between the two OTUs, it must be remembered that the character should completely define the performance potential of the OTUs. This requirement emphasizes again the importance of the proper choice of characters.

In general, a OTU will be defined by a set of characters, say 'n' in number. The genetic divergence between any two OTUs will then be measured by the multivariate distance statistic based on 'n' characters. Procedures of computation are detailed in Rao (1952). Computer algorithms are now available to compute D^2 (Murthy and Arunachalam, 1967).

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METHODS OF STUDYING MANGROVE VEGETATION

SANJAY DESHMUKH

INTRODUCTION

Over the past decade the number of research studies focusing on mangroves and the mangrove environment have significantly increased as a result of public and scientific interest in their role in nature and their value to mankind. although the total number of published reports exceed some 7,000 titles (cf. Rollet, 1982), many major gaps in our scientific understanding persist. Confounding the problem are the difficulties of conducting research in the mangrove environment and the absence of recommended research protocols which would facilitate comparative evaluations, and general synthesis of specific topics. Many research efforts focus on "community structure and description" for the purpose of preparation of general inventories of 'what is there' and in what number (or mass), describing how the components are structured, and making general assessments of the abiotic conditions. We have tried to outline the traditional approach to characterization which might be considered to represent the minimum requirement of any general survey. The taxonomical identification of the mangrove species is in general very poor; most researchers can identify the genera, but species determinations in many areas remain questionable. The basic protocol for quantitatively determining the physiognomic structure of mangrove communities is presented here. This approach places emphasis on relatively simple techniques that yield much useful data and information that have significant value in both, basic ecological studies and the management of forested areas.

MANGROVE VEGETATION

The predominant plants in a mangrove swamp are the trees, and it is these species that are generally listed. However, phanerogamic epiphytes may occur while some phanerogams may appear as ground flora, especially towards the high-tide mark. Any study of a mangrove swamp should take cognizance of all these plants.

An important feature of the major coastal land from is that it frequently provides an optimum habitat for mangrove forest development. this overview demonstrates the fact that the spatial patterns of mangrove development are closely associated with land form types and that local mangrove formations tend to be controlled by the constantly changing coastal geomorphology. Field research that does not take these fundamental, processes into account can lead to erroneous conclusion concerning species zonation, successional status and the causes of differences in regional patterns. It is important to characterise the differences in mangrove species distribution as a function of broad latitudinal gradients in climate. Therefore, in the final account of any swamp, it is recommended that all species be listed and placed in the relevant genera and families.

Where the swamp abuts on elevated land, all species that occur up to the high-water mark of spring tides should be included. In places where the mangroves give may to a riverine forest or swamp, all species should be recorded up to the point where distinctly saline water (1 per

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cent NaCl) ceases to be found in the lower water strata of the main channel at the high water of spring tides. In both cases, it is especially desirable that species occurring in the zone between the mean low-water mark and high-water mark of spring tides should be recorded separately.

COLLECTION AND PRESERVATION

Past workers have generally collected specimens of the higher plants and after drying and pressing, these have been deposited in a local or overseas herbarium. There may be cases where macroalgae have been collected and preserved as herbarium specimens.

In the case of the angiosperms, it is most desirable that samples of leaves, flowers and fruits/seedlings should be collected and preserved. If trees or plants are not in flower, visits should be made at intervals until they can be collected. Twigs with leaves and flowers should be dried between sheets of newspaper or blotting paper, either placed under weights or contained within a plant press. The drying paper needs to be changed frequently.

When the specimens are completely dry they should be mounted on herbarium sheets and properly labelled. In case of small fruits or seedlings, (viviparous can be done mounted) on the herbarium sheet. With large fruits (e.g. *Sonneratia*) and seedlings (e.g. *Rhizophora, Bruguiera*) preservation in bottles is best achieved by using 3 per cent formalin. In the case of herbarium sheets, protection from future damage by insects or fungi can be achieved by exposing the sheets to mercuric chloride.

Any ferns collected can be dried as above and mounted. Wherever possible, sporulating and vegetative fronds should be collected. Lichens, after collection, should be dried and then stored in small packets attached to herbarium sheets and properly labelled. The procedure is to scrape some of the material off on to agar plates in petri-dishes and incubate them. It is worth mentioning here that future studies of mangrove swamps will involve more than just the higher plants; full collections of all plants need to be made.

VEGETATION STUDIES : PLANT COMMUNITY

A study of the analytic and synthetic characters of a piece of vegetation in relation to its environment is the foremost necessity. In nature, individuals of a species are usually grouped into a population, and populations of different species may be intermingled (Hanson, 1958). The ratio of population mixture varies from habitat to habitat, since some plants may be more successful than the others in a particular habitat as compared to other habitats. This is largely governed by phylogenetic and physiological characteristics of the species (Dansereau, 1957). It follows, therefore, that the first fundamental step of an ecologist is to study the structure and composition of the vegetation.

In any region or area, the first step by observation is to establish the association that can be recognized. When this has been done the species present in each association can be established either by observation or by the use of quadrats. In studies such as this, it must be remembered that where one association abuts on to another, there will be a zone, the ecotone, where a mixture of species from both associations can be present. Ecotones should not be included in either associations but treated separately. Species lists should be restricted solely to areas clearly within the association being studied.

It is desirable that all lists should be divided into (a) regular components of the association, and (b) casual components of the association.

The study of the structure and composition of plant communities or associations has been developed largely in Europe. The Zurich-Montpellier school of vegetational analysis led by J. Braun Blanquet has developed detailed methods and this branch of study has been termed "phytosociology".

COMMUNITY STRUCTURE

Plants growing together have mutual relationships among themselves and with the environment. Such a group of plants in one area forms a *stand*. Several similar stands represent a *community*. A community is a part of an ecological system (the ecosystem) in which transformation, accumulation, and flow of energy are involved. The functioning of this system is intimately related with the components of the community. The components vary in quality as well as in quantity and impart a *structure* to the community.

The structure of a community can be studied by taking into consideration a number of characters, which are usually grouped under two heads, viz., analytic and synthetic. Certain analytical character viz., frequency, density, abundance, and dominance can be expressed quantitatively. While others, viz., sociability, vitality, periodicity, and stratification find only qualitative expression. Synthetic characters include presence, constancy and fidelity of components and may be computed through analytical characters of several stands of a community.

The analytic characters of a community are determined through three main sampling units -area, line, and point, as employed in quadrat, transect, and point methods, respectively.

SAMPLING

It is difficult to analyse all members of the entire community and even if it is done the results will not be different from when only an adequate number of samples of the whole are analysed. It, therefore, becomes important to arrive at size, shape and numbers of adequate samples. The next question is to determine where, how, and what is to be sampled. No sampling should be done without a thorough knowledge of the history, physiography and topography, geology, climate and vegetation of the region as a whole. Before starting the preparation of a detailed map, the area or the association is surveyed repeatedly in different parts of its range and more particularly in its local variants. The specific stands to be examined are then chosen keeping in view the obvious variations, extent, limit and transitions of vegetation to contiguous associations.

QUADRAT METHOD

It is actually the sample-plot method of Clements (1998). A quadrat is of many kinds and sizes. Most of the ecologists have used in with slight variation here and there.

Structure of a piece of vegetation is determined in a quadrat which may be plotted at random or on a certain transect run across the local topography or geology.

TYPES OF QUADRATS

a. List quadrat: The list quadrat gives merely a list of the species present in a quadrat. It should include all species botanically identified or otherwise.

b. Count quadrat: In count quadrat, in addition to listing, number of individual plants of each species is also counted. Some difficulty is faced in forests with respect to coppice stumps. The sprouts grow as individuals and those which are taller and thicker, i.e., whose crowns give them chance of suppressing others may be counted as separate individuals.

c. Area quadrat: In area quadrats, the ground covered by every species is evaluated. This can be done by setting up cross strings and counting the number of parts of squares occupied by all the individuals of a species, when put together. In forests also strings may be put. Basal area is taken in forests.

d. Chart quadrat: Chart quadrat is used for details and for the scale recording of growth and distribution of species. Charting is usually done on cross-ruled paper with similar string-cross on the vegetation. A pantograph is generally employed for more accurate work. From these charts actual area of a species can be measured by adding up all the small squares that a species covers, or individuals of the same species occupy separately. A planimeter may be used for direct reading of these areas on the cross-paper. Such studies are done in grasslands.

A chart quadrat may be made a permanent quadrat. Periodic readings are taken. This gives the dynamism of an association as to its structure, pattern, and composition. This also gives successional trends in vegetation, when studied for some years.

e. Experimental quadrat: an Experimental quadrat is a permanent quadrat employed to study such environmental factors as temperature, rainfall, evaporation, light intensity, humidity, etc., in addition to records of growth, survival, invasion and spread of species in time. Such quadrats are generally set up in adjoining situations. When an experimental quadrat is subdivided into smaller squares by cross strings and is used for long term analysis of vegetation, it is called grid pattern quadrat.

f. Point-observation quadrat: A Point-observation quadrat is employed to determine the plant coverage more accurately. The method was designed by Hutchings (1936) for grasslands, but can be profitable used for forests after modification, as given by Gates (1949).

g. Denuded quadrat: In a denuded quadrat, vegetation is first removed by some means like flooding, burning, salting, covering, scrapping or by excavating the top 15 cm of the ground and then studying the details when the quadrat gets regenerated.

h. Clip quadrat: For studying the amount of yield of vegetable matter the vegetation is clipped from a quadrat. This is done at the ground level or at various heights. The clipped matter is determined in terms of fresh weight or dry weight. For studying seasonal variations in a field, periodic clipping is done. These quadrats are generally employed in grasslands and for range management studies.

SHAPE, SIZE AND NUMBER OF QUADRATS

Since the assemblage of plants in a community is largely heterogeneous, the determination of size and number of quadrats necessary for adequate sampling, is a pre-requisite.

SIZE OF QUADRAT

With the help of a string and 3 nails from a L-shaped structure in the field. Thereafter, with the help of another string and a nail differentiate an area 1 × 1m. Note down the species present within this area. Now enlarge the area, to 2 × 2m and note down the additional species coming in. Again increase the area to 3 × 3 m and record new species. Thus go on increasing the area, and recording the additional species till you make up a 15 × 15 m large quadrat. Summarise your data in a table as given below:

Area	Total no. of species
1 × 1 m	
2 × 2 m	
3 × 3 m	
15 × 15 m	

Now on a graph paper, plot the number of species on the Y-axis against the areas on the X-axis. The point at which the curve starts to flatten, represents the minimal area of the quadrat required for sampling that field.

The minimum size of a quadrat in case of mangrove forests is observed to be 10 m × 10 m.

NUMBER OF QUADRATS

When the requisite size of the quadrat has been ascertained, lay 30 to 50 quadrats of that size in a stand under study. Record the species occurring in each quadrat. Tabulate your data as per the procedure mentioned earlier utilising the first column for number of quadrats.

Plot the number of quadrats on the X-axis of a graph sheet against the number of species on the Y-axis. Here also the point at which the curve starts to flatten gives the minimum number of quadrats required for adequate sampling of all the stands of the same community.

TRANSECT METHOD

A transect is a sampling strip extending across a stand or several stands (Oosting, 1958). It is useful where one is concerned with analysis of vegetation changing in composition through an ecotone (transitional zone between any two community) or along the gradient of some environmental factor. Depending upon the objective one may employ "Line transect" (also known as "line intercept") or "belt transect". Size and number of transects vary with the extent of the area to be studied.

Line Transect

A measuring tape or calibrated string is run across the vegetation to be analysed and the plants touching and along the tape are recorded as also the length of the tape to intercepted by the individual plant cover. From these basic data various analytic characters are computed through calculations as will be dealt with in subsequent exercises. This method is useful especially for a bunch or tussock grasses. The construction of a profile or bisect diagram is also possible along a transect.

Belt Transect

In this case instead of the line, a belt of definite width (usually one meter) is studied across the vegetation. This strip is divided into a number of small sections and plant species and number of individuals of each species coming in each section are recorded. In simple words it is laying of quadrats along a line. By mapping the sections on graph paper a useful picture of the vegetation is obtained.

POINT METHOD

The sampling unit in this method is represented by a point. On this basis two main methods for the vegetation analysis have been developed: (a) Point-frame method, and (b) Point-centered quarter method.

Point-Frame Method

A wooden frame in which 10 movable pins are inserted at an angle of 45° is constructed. The usual size of a pin is 50 cm and, the length of the frame is also the same. The height at which this frame is fixed on two folding wooden-crosses is also 50 cm.

This apparatus (known as point-frame) is placed at a number of places in the field, usually in a random way. Each time the plants hit by one or more of the ten pins, when they are lowered, are recorded. From this information, various analytic characters are computed through calculations. This method is useful for extensive grassland surveys, and hence is of no relevance here.

Point-Centered-Quarter Method

In this method of hits as in the case of the previous one, the distance of the nearest plant in each quarter from the base of the pin (needle) and their diameter are recorded. The needle is not mounted in any frame. This method is suited for study of bunched grass and hence is of no relevance here.

TECHNIQUES FOR STUDY

A variety of techniques have been used in plant sociological studies, for example

(a) maps based on aerial photographs;
(b) quadrats as described in the above statements;
(c) belt transects through a homogeneous habitat;
(d) line transects across environmental gradients; and
(e) type maps prepared from aerial photographs together with intensive ground truthing.

Maps of the mangrove vegetation can be prepared, showing different levels of vegetation development or degradation based on height and density of the canopy. To understand the contribution of component species to these different types of vegetation composition and their quantitative aspects, the phytosociological characters of the stands can be studied.

For this purpose transects are laid generally 50 m apart, from the channels of different orders in the estuarine region to the points near the barren or unplaned boundary, i.e., upper Intertidal region. The lengths of the transects and the distances between them may vary according to the Intertidal expanse of the mangrove vegetation.

Each level of identified degradation is given a representation for study with quadrats. This can be achieved by moving in the swampy area, during low tides and in canoe during high tides, when the channels are navigable. Trees, larger than 2.5 cm diameter at the base are recorded in each plot for the following:

1. Number of species of individuals
2. Height of canopy, and
3. Basal area.

Dispersion of plant species in a community (frequency), their numerical strength (density), and dominance can be studied, following the methods given by Misra (1968) and Pandeya *et al.* (1968).

FREQUENCY

Frequency indicates the number of sampling units in which a given species occurs and thus expresses the distribution or dispersion of various species in a community. From this, percentage frequency is calculated as follows:

$$\text{\% Frequency} = \frac{\text{Number of sampling units in which the species occurs}}{\text{Total number of units studied}} \times 100$$

ABUNDANCE AND DENSITY

The terms abundance and density represent the numerical strength of a species in the community. The former, if considered along with frequency, gives an idea of the distribution pattern of the species, while the latter represents number of individuals per unit area. The density and frequency taken together are of prime importance in determining community structure and have a variety of uses far beyond those of other quantitative values (Oosting, 1958).

$$\text{Abundance} = \frac{\text{Total No.of individuals}}{\text{No.of quadrats of occurrence}}$$

$$\text{Density} = \frac{\text{Total No.of individuals}}{\text{Total no.of quadrats studied}}$$

Thus 'Abundance' is described as number of individuals per quadrat of occurrence and 'Density' as number of individuals per square metre.

BASAL AREA

Basal area refers to the ground actually penetrated by the stem and is readily seen when the leaves and stems are clipped at the ground surface (Hanson and Churchill, 1961). It is one of the chief characters determining the dominance and the nature of the community. This is measured either at 2.5 cm above ground or at the ground level. The values obtained in the latter case are less flexible.

The measurement of basal area at ground level was done with the help of Vernier Calipers for every quadrat and the average diameter was calculated.

$$\text{Average basal area} = \pi r^2 \text{ where r (radius)} = \frac{\text{Average diameter.}}{2}$$

Density for each species can be determined in this way and this value is multiplied with that of the respective basal area. The results are expressed as $m^2\ ha^{-1}$.

DOMINANCE

Dominance is the relative prevalence or predominance of individuals of a species that results from their numbers and massiveness. Each species of the community can be assigned some degree (percentage or class) of dominance according to the relative area or volume of the community that is occupied by it. It is also used to express the phenomenon of actual predominance in a community of the individuals of a species (Cain and Castro, 1959).

IMPORTANCE VALUE INDEX (IVI)

In order to express the dominance and ecological success of any species, with a single value, the concept of importance value index has been developed. This index utilises three characteristics, viz., relative frequency, relative density and relative dominance.

All the above-mentioned values could be obtained by evaluating frequency, density and basal area for all the species growing in the study area, using methods already described and the following values are calculated (Phillips, 1959).

1. $\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$
2. $\text{Relative density} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all the species}} \times 100$
3. $\text{Relative dominance} = \frac{\text{Number of occurrences of the species}}{\text{Number of occurrences of all the species}} \times 100$

The above three values are added to get the importance value index (IVI). It is calculated for all the species and for all the levels of degradation.

COMPLEXITY INDEX

It is the numerical expression where the number of species, tree density, height (m), basal area (m^2) and a factor 10^{-3} on 0.1 hectare basis are multiplied (Holdridge, 1967).

COMPARISON OF STANDS

To know whether the stands studied belong to the same community or how far they differ from, or resembled each other, the concept of community coefficient has been developed. Percentage frequencies of all the species found in four different types of stands are determined. All the four stands are compared with each other. Results are calculated by using the formula given by Kulczynski (1937).

$$\text{Community Coefficient (C.C.)} = \frac{2w}{a+b} \times 100$$

where w = sum of lowest frequencies from stand A and B, and
a+b = sum of frequencies of columns A and B. Higher value of coefficient indicates a higher similarity between stands

STEM VOLUME

The total stem volume of each species can be obtained by multiplying the basal area by one half of the total height as suggested by Aksornkoae (1980). The total stem volume is calculated for each type of stands of mangrove vegetation.

SHANNON INDEX (H) FOR SPECIES DIVERSITY

This is determined by the following equation (Curtis and McIntosh, 1951).

$$H = -\frac{(ni)}{N}\log\frac{(ni)}{N} = -pi\log pi$$

where, ni = Importance value of the species
where, N = Total of importance values of all the species, and
where, pi = Importance of probability of each species

PHENOLOGY

For floral phenology, variations are recorded and phenophases are observed every week for each species. Phenophases like budding, blooming, fruiting and seedling development are noted. Observations are generally made for two years, and the data are recorded.

MANGROVE TREE PRODUCTIVITY : BIOMASS STUDIES

The structural aspect of the mangrove community, in addition to phytosociological studies and phenology, also include biomass of trunk, foliage, underground biomass. Such information is essential for assessing the mangrove tree productivity. Weight is a quantitative expression of total mass of structural material that has resulted from the metabolic activities in the net primary production or biomass.

Above-ground biomass

Above-ground biomass is the amount of standing organic matter per unit are at a given time. The amount of standing biomass stored in a forest is a function of the system's productivity, age and organic matter allocation and exportation strategies. Biomass data for mangrove forests are scarce. There are two main approaches for biomass determination: clear-cut and allometric techniques. Clear-cutting is only recommended in young or scrub stands. Allometric measurement is preferred for all forests. The development of regressions of biomass on structural measurements of harvested trees allows estimation of standing biomass from easily measured parameters, such as dbh and height. Allometric biomass estimation is non-destructive, once a samples have been taken and the regression equations calculated.

Stand Biomass

The biomass of an entire stand can be estimated by multiplying the biomass of the stem of the mean basal area by stand density. This estimation technique is reported to give acceptable results (Loetsch *et al.*, 1973). Another technique is to determine the frequency distribution of the diameters in a stand and estimate the biomass of each diameter class separately. The average biomass of a class is multiplied by the number of stems in that class and the results for all the class are summed to obtain total stand biomass. For plots containing a reasonably small number of trees (30–40), it is practical to calculate the biomass of each tree from the allometric relation and sum to obtain the plot's total biomass.

It is worth nothing that the LAI of a stand can be calculated if the foliar biomass is known. Leaf weight must be converted to leaf area by using a leaf-weight leaf-area relationship (remembering that for purposes of LAI, one-area is divided by stand area (in m^2) to obtain forest LAI.

CONCLUSION

The methods discussed in this paper are suggested standard field research methods for mangrove ecosystems. Comparative standardised data from diverse locations and settings are needed to interpret the complex relationships between structure and the major forcing functions. A more complete understanding of the structural responses of mangrove ecosystems to natural variations in the energy signature of the environment will undoubtedly lead to a better understanding of the responses of these systems to stressors and human manipulations.

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SAMPLING DESIGNS FOR SURVEYS, RESOURCE ASSESSMENT AND FOREST INVENTORIES*

FAO FORESTRY PAPER

INTRODUCTION

The objective of sampling is to gather reliable information at low cost. In view of the problems posed by accessibility and working conditions in mangroves, it is strongly recommended, in designing a survey, to incorporate any element that may contribute to increasing the accuracy of forest classification while at the same time making the field enumeration less time consuming. Low altitude aerial reconnaissance, stratification and other sampling procedures such as multi-phase and cluster sampling are some approaches which deserve consideration. The description of these designs and the associated statistical formulas are extensively discussed elsewhere (Lanly, 1973 and others), and are thus only briefly summarised below.

STRATIFIED SAMPLING

Stratified sampling designs are frequently applied in surveys and forest inventories. The object of stratification is to subdivide the forest into more homogenous parts, in order to reduce the variability of the parameter to be estimated.

The allocation of sampling units to strata can be proportional to the strata area or to the variance of the strata. These approaches are discussed in various forest inventory documents. The optimum allocation approach requires advance estimates of the variation in each stratum, which can be provided from pilot surveys or, if available, from past surveys and inventories in similar areas.

MULTI-PHASE SAMPLING

Basically, the procedure involves the selection of large units in the first phase, named primary sampling units. Within each primary, a number of smaller units – secondary units – is drawn. The procedure can have more than two phases and can use varying methods of selecting in each phase.

Its disadvantage however, is that the concentration of the ultimate sampling units results in a larger variance of the estimate compared with a one phase design of the same sampling intensity.

DOUBLE-PHASE SAMPLING

The application of double-phase sampling for stratification in a forest survey results in an improvement in the stand characteristic estimate through a better estimate of strata areas.

In this method, a large number of photo plots are drawn in the first phase, and a sub-sample n′ of the first sample is selected in the second phase to be used in the field. The main objective

*Reproduced from Mangrove Forest Management Guidelines. FAO Forestry Paper No. 117.

of the survey is to provide an estimate of strata proportions in the first phase, based on some stratification rule allowing the first phase sampling units to be classified into land-use classes, vegetation cover classes or other classification criteria. The second phase plots are used to check the photo classification and collect data on forest and tree characteristics.

Advantages of this technique have been found to be substantial in surveys of large areas. The design is more complex than a single stage random sampling but it is more efficient.

The application of this design usually involves aerial photography in the first phase. Satellite imagery can also be used but because of its low resolution, it might be very tedious or even impossible to correctly locate the sub-sample units on the ground.

In non-forest classes and areas where the forest has been so severely disturbed, that no commercially valuable trees exist or the forest is poorly stocked, data collection may be restricted to simple observations on vegetation status.

Areas are estimated from the first large sample of photo plots.

$$P_h = \frac{n_h}{n}$$

where

n_h is the number of photo plots falling in stratum h and

n is the total number of photo plots in the first large sample.

The area A_h of stratum h is estimated by:

$$A_h = P_h * A$$

where A is the total area concerned by the survey, assumed to be known.

The information collected from the ground plots is used to correct biases in area estimates caused by various sources of misinterpretation. The adjustment is applied to strata proportion in the following manner:

The adjusted stratum proportion P_h is obtained by:

$$\text{Adjusted } P_h = \sum^{M} P_h * p_{hj}$$

where,

m is the number of strata and

$$P_{hj} = \frac{n_{hj}}{n_h}$$

withinn_{hj} being the number of ground plots actually falling in stratum j, but classified h on photos and

n_h being the number of photo plots classified in h.

The variance of the adjusted stratum area proportion is computed by the expression:

$$V(Adj.P_h) = \sum^{m} \frac{P_h p_{hj}(1 - p_{hj})}{n_h} + \frac{1}{n} \left[\sum^{m} P_h p_{hj}^2 - \left(\sum^{m} P_h p_{hj} \right)^2 \right]$$

which is a simplified formula for double sampling for stratification with a discrete random variable having attribute 1 or 0, and where the term P_h/n has been dropped being considered negligible.

Data obtained from ground sampling units can also be used to estimate mean values of stand characteristics such as timber volume, stocking, etc. The estimate of the mean value per unit over the whole area concerned by the survey, is given by the expression (Lanly, 1973).

$$\overline{y}_{st} = \sum\sum P_h p_{hj} \overline{y}_{hj}$$

where $\overline{y}_{hj}$ is the mean value per sampling unit of the characteristic y in the part of plots actually in stratum j, classified in stratum h by photo-interpretation.

The mean value per unit in stratum j is estimated by:

$$\overline{y}_j = \frac{\sum P_h p_{hj} yhj}{\sum\limits^{m} P_h phj}$$

The estimate of the total Y over the whole area inventoried is obtained by multiplying the estimate of the overall mean y_{st} by the total area A, and the total in stratum is computed by multiplying the mean of stratum j by the term $A(\Sigma P_h p_h)$ which is the corrected area for stratum j.

Double-phase sampling for regression is another technique which involves two variables, the main (y) and the auxiliary (x). It is a powerful procedure which is frequently used in forest inventory sampling. It is particularly useful when the cost of enumeration of the main character is much higher than the cost of the auxiliary variable, the latter being correlated to the first one. The approach is recommended when the inventory can make use of both aerial photographs and field enumeration. In the first phase, a large sample n of photo plots is drawn from the population N. The stand characteristic of interest (represented by the auxiliary variable (x) is first measured on photo plots. This can be a gross volume estimate for example, based on measurements of the stand height or the crown density on the photos. In the second phase, a sub-sample n' of the first phase large sample is taken and measurements are made on both x and y. y may well in this case be the volume per plot, which is determined in the field through conventional techniques, while x is ground measurements of either stand height or crown density.

Double sampling for regression is also used in inventories on successive occasions. It may involve completely independent samples, or in case of permanent (CFI) plots, it uses sub-samples of the original sample or samples which are partly independent and partly sub-samples. The latter case is termed sampling with partial replacement. In either case, change evaluation is determined through regression analysis between measurements made on successive occasions. The technique involves rather complex computations. Relevant estimators are presented in various forest inventory and statistical textbooks.

THREE-PHASE SAMPLING

The design is similar to that of double-phase sampling for stratification except that more phases are considered. In the first phase a simple random or systematic sample n of large size is drawn from the population concerned by the forest survey or inventory, and sampling units are classified into pre-defined strata. From this first phase stratification, n_1, $n_2, \dots n_h$, sampling units are obtained where n_h in the number of units in stratum h. ($h = 1, \dots L$).

The second phase consists of selecting a sub-sample m_h from n_h. The selected m_h units of phase one are further stratified into the same or different strata as in the first phase one, and m_{nj} second phase sampling units are obtained for each stratum j of second phase in each stratum h of phase one.

In the third phase a sub-sample in each second phase stratum is drawn. The units selected in the third phase noted b_{hj} are then used for measurements of the characteristics of interest. Observations are noted y_{hjk}, where $k = 1, \dots b_{hj}$.

A typical three-phase sampling design incorporates satellite imagery (phase one), aerial photography (phase two) and ground sampling (phase three). A four phase design can as well be employed if both small and largescale aerial photography are used in the second and the third phases respectively.

One question which may be posed concerns the sample sizes in each phase. Theoretically, sample sizes in each level should be determined in such a way that the total survey cost is minimized. The problem becomes one of optimization which is out of the scope of the present discussion. For more details on the question and the computation of the variance of estimates, the papers of Frayer (1979) and Jeyaratnam et al. (1984) are recommended. More simply, sample sizes associated with each phase, can be defined arbitrarily before the first phase selection. It is, however, not recommended to use less than two sampling units per stratum.

In the three-phase sampling case, the estimate of the total value of the population parameter is obtained by:

$$Y = \frac{N}{n} \sum_{h=1}^{L} \frac{n_h}{m_h} \sum_{j=1}^{J_h} \frac{m_{hj}}{b_{hj}} \sum_{k=1}^{b} y_{hjk}$$

The application of a three-phase sampling and the above formula to mangrove forests can be illustrated by the following example: Let N be the total number of sampling units contained in a given area to be inventoried. Let each sampling unit be associated with a pixel from Landsat imagery (say of 1:250 000 scale), used in the survey as the first level of sampling. We consider further that medium scale (1:30 000) aerial photography of the same area is available and could be used in the second phase. The third phase is the sampling in the field where stand characteristic measurements are taken. The sequence of the method is described as follows:

STEP 1

From the total number N of sampling units, say 262 144, a sample n is drawn at random or systematically on satellite images. Out of a total of N units, $n = 13107$ (5% sampling intensity) units are then classified according to defined land-use classes on satellite images. The number of different classes (L) will be a function of the sensor and classification procedure used. The latter can be computer-aided or visual. For sake of simplicity, let us assume that three classes (strata) are defined in this first phase: Forests, non-forest and water.

The results in this first phase may be:

Stratum number	Land cover	Sample size
h = 1	Forest	n_1 = 9 830
h = 2	Non-Forest	n_2 = 1 966
h = L = 3	Water	n_3 = 1 311
		Σn = 13 107

STEP 2

In the second phase, samples are drawn from the first phase samples. Using some pre-defined sampling fraction (1% for instance), these phase two samples which are noted $m_1 = 983$, $m_2 = 197$ and $m_3 = 131$ are located on aerial photographs and stratified according to a more detailed interpretation using photo variables such as crown density, tree height, etc., and other criteria on non-forest areas such as agricultural lands, salt ponds, fish ponds and shrimp farms. We assume in the example that the first phase stratum "forest" is refined into three strata in phase two, namely "dense", "open" and "degraded". The second stratum of phase one is split into three strata also. They are "agriculture", "aquaculture" and "other".

Finally, we consider that the third stratum of phase one which is "water" remained unchanged in the second phase. According to this scheme, the results of classification are:

Stratum number		Land cover	Sample size	
	j = 1	dense	m_{11} = 464	
Forest	j = 2	open	m_{12} = 197	m_1 = 983
	j = 3	degraded	m_{13} = 322	
	j = 1	agriculture	m_{21} = 100	
Non Forest	j = 2	agriculture	m_{22} = 59	m_2 = 197
	j = 3	other	m_{23} = 38	
Water	j = 1	Water	m_{31} = 131	m_3 = 131
				Σm = 1 311

STEP 3

In the third phase, samples are selected from phase two samples to be located in the field. Assuming again a sampling fraction of 1%, the final number of sampling units to be measured in the field will be:

Stratum number	Land cover	Sample size	$\sum_{k=1}^{b_{hj}} y_{hjk}$
j = 1	dense	$b_{11} = 46$	2 760
j = 2	open	$b_{12} = 20$	1 930
j = 3	degraded	$b_{13} = 32$	530
j = 1	agriculture	$b_{21} = 10$	0
j = 2	aquaculture	$b_{22} = 6$	0
j = 3	other	$b_{23} = 4$	0
j = 1	water	$b_{31} = 13$	0

- b_{hj} is the number of third phase samples drawn from the second phase samples m_{hj}
- y_{hjk} is volume measured on the ground plots.

The values in the last column are assumed to be the total values of timber volume in each third phase stratum expressed in m^3. In no-forest classes and areas where the forest has been so severely disturbed, that no commercially valuable tree exists or the forest is poorly stocked, data collection in the field may be restricted to simple observations on vegetation status.

The estimate of the total timber in the whole area concerned by the survey is given by the formula presented above, which yields the following result:

$$
\begin{aligned}
Y &= \frac{2622144}{13107}\frac{9830}{983}\left[\frac{464}{46}(2760)+\frac{197}{20}(1930)+\frac{322}{32}(530)\right] \\
&+ \frac{1966}{197}\left[\frac{100}{10}(0)+\frac{59}{6}(0)\right]+\frac{1311}{131}\left[\frac{131}{13}(0)\right] \\
&= 10436884.25\ m^3
\end{aligned}
$$

Other parameters such as the total forest area may also be estimated using multi-phase sampling techniques. In that case, the variable y_{hjk} takes on the value 1 when the sampling unit falls in the stratum forest and zero otherwise.

In a two-phase sampling design, following the same pattern as above, the estimate of the population total is given by:

$$
Y = \frac{N}{n}\sum_{h=1}^{L}\frac{n_h}{m_h}\sum_{j=1}^{m_h} y_{hj}
$$

CLUSTER SAMPLING

Cluster sampling is also a commonly applied techniques, which has often been used in extensive forest surveys, resource assessments and inventories, particularly in the tropics. With cluster sampling, the elementary units, on which the observations ar to be made, are grouped in clusters of pre-assigned size. When all elementary units of the cluster are included in the sample we have a single phase sampling design. Clusters can be·also of unequal sizes. The cluster size refers to the number of elementary units that compose the cluster.

Like in double-phase sampling, plots which are grouped in clusters, reduce the overall travel distance. However, a cluster sampling design—when compared to simple random sampling—is efficient only if the variance within clusters is large relative to the variable observed. With cluster sampling the variance of estimate is generally larger than that obtained by a simple random sampling of the same intensity. This increase in variance is due to the correlation between units within clusters.

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METHODS OF GERMPLASM SAMPLING

B.R. MURTY

INTRODUCTION

Many theories have been developed to provide background to good and efficient sampling and limiting costs (Cochran, 1963). In statistical terms, sampling is a tool for referring to the 'population'. In fact, any biological event may be regarded as forming an individual of a population of events which might occur under the identical conditions. Series of events is a 'sample' drawn from the population.

The efficiency of a method satisfies the main objective of the conservation allowing for reasonable expenditure of 'effort'. The effort in this context stands for any resource such as time, manual labor, funds, etc. which may be expended for successfully conducting the project (Yonezawa, 1985). Sampling in the field can be carried out according to two main criteria, probability sampling and prepositive sampling.

Probability sampling is a general name given to sampling plans in which every member of the population has a known (and not necessary equal) probability of being included in the sample. The sample is drawn by some methods of random selection consistent with these probabilities. The estimates from the sample are drawn taking account of these selection probabilities.

Conversely, prepositive sampling is a general term used for a sampling plan in which the sample is restricted to units typical of the population or convenient or for a fixed purpose (Jana, 1988).

We shall examine here some of the features offered by probability sampling since it is designed to take advantage of any available information on the structure of the population. This often leads to a desired degree of precision with the minimum expenditure of resources.

PROBABILITY SAMPLING

In order to apply probability sampling, the population must be subdivided into units called "sampling units". These form the basis for selection of the sample. The sample units must be distinct and together they must consist of the entire population. There are various methods for sample selection.

SIMPLE RANDOM SAMPLING

This is a straightforward method and the easiest. It provides every individual member (unit) of the population an equal chance of being included in the sample. In practice, a simple random sample is drawn unit by unit, utilizing one of the many ways to extract random numbers. It is often a satisfactory method when the population is not highly variable.

However, it leaves the selection of the sample to the luck of the draw. This type of sampling suggests a random sample of 49 points. It can then be seen how the points tend to cluster and that two parts of the area, the lower centre and the upper half just right of the centre, are comparatively sparsely sampled.

NON-RANDOM SAMPLING

If the distribution of the sampling units is extremely random, samples of the same number of units is collected. It has the advantage of requiring less time for collecting the sample. When the distribution of the sampling units is patchy, it gives the same precision as using simple random sampling but with a smaller size.

STRATIFIED RANDOM SAMPLING

When the population can be divided into sub-populations or strata that are less variable than the original population, one or more samples can be drawn independently from the same stratum. If a simple random sample is taken in each stratum, the whole procedure is described as stratified random sample.

This method has several advantages. When a heterogenous population is divided into parts, each of which is fairly homogenous a gain in precision is expected. In addition, it allows us to choose the size of the sample that is to be taken from any stratum. This freedom of choice gives the germplasm collector scope to efficiently allocate appropriate resources to the sampling, stratification enables these problems to be handled separately. For example, of during collections in Morocco, several morphotypes of durum wheat were found to possess solid stems. These were collected separately with each morphotype accorded an individual collection number (Damania, 1987). Similarly, on a collection mission, to Tibet the morphological diversity in a single field of wheat and barley was so great that 269 individual morphotypes were separated from 54 population samples (Valkoun and Damania, 1990).

SYSTEMIC SAMPLING

This method allocates the sampling points at regular intervals on a grid. Systematic samples are the easiest to select and if the sampling grid is aligned with the map grid, they are very easily located. There are, however, two drawbacks. The first concerns the periodicity of maturity in the population and possible bias that can be introduced with it. The second disadvantage is that method does not give an entirely valid estimate of the sampling error as the sampling points are not located entirely at random.

UNALIGNED SAMPLING

This method is also known as stratified systematic unaligned sampling. It combines the advantages of a regular grid and randomization. The sample is extracted by dividing the survey area first into sub-areas by means of a coarse grid and then superimposing a fine grid, as a reference system, on each sub-area. The method provides unbiased estimates of means but does not easily estimate the sampling error.

MULTISTAGE SAMPLING

The procedure mentioned above pre-suppose that the sampling unit has to be sub-sampled in each area. The first stage is the sample of primary sampling units. The second stage is the taking of a sub-sample from each selected primary unit. Thus, the sampler can choose both the size of the sample of primary units and the size of the sample that is taken from a primary unit. An added advantage is that it facilitates the task of listing the population.

Often it is relatively easy to obtain a list of primary units but difficult or expensive to list the sub-units. It is usually easy to list the areas in a region and the villages in an area but the problem of making a random selection of the farmers' fields may be difficult. With the multistage sampling the problem arises only in this last stage.

Another advantage of this method is that it permit an estimate to the financial cost of adding an extra primary unit to the sample, relative to that of adding an extra sub-unit in each primary unit; the most economical plan for collection can then be prepared.

PRACTICAL FIELD SAMPLING

The primary objective of a genetic resource collecting mission is to preserve a representative sample, both in nature and in size, of the genetic variability in a target area. This means that there is a need to collect populations representing the smallest aggregate of individuals which are able to continue evolution, if replanted. This ideal objective cannot always be achieved due to advanced genetic erosion (e.g., wheat). The collection of a sample representative of the variability in a target area or one derived from unselected or undisturbed material is very difficult. However, not all species are so seriously eroded. Barley, oats and broad beans, the three crops which have accompanied wheat since the early days of agriculture, have experienced lighter erosion than wheat due to the limited amount of new varieties released to the farmers. Similarly, a number of other species still contain the initial variability as a result of millennia of evolution and cultivation.

On the other hand, the population represents the ideal material allowing largest spectrum of possibilities to the breeder who is aiming at mass selection or extracting a specific gene to be incorporated in his breeding lines.

The methods of sampling require the definition of the following parameters:

1. Selection method and number of plants per site, and
2. Number and distribution of fields in the area.

SELECTION METHODS AND NUMBER OF PLANTS PER SITE

The problems of sampling procedures and the size of samples have been discussed by several scientists. Jana (1988) states that in an out breeding population individual plants do not preserve their genetic integrity in successive generations because genotypes are reshuffled in each generation following random mating. Hence, except for special purposes such as taxonomic or evolutionary studies, single plant samples do not offer much advantage over bulk samples in non self-pollinated species.

The best protection against the loss of within-accession genetic diversity is to collect individual plants, conserve and propagate them separately, without bulking and mass handling (Jana and

Khangura, 1986). For predominantly self-pollinated species such as barley and wheat an optimal number of plants should be collected from each populations and evaluated individually. Marshall and Brown (1975) and Brown (1978) recommended sampling of 50-100 single plants per population. Allard (1970), after considering the results of studies an *Avena fatua*, Malz, recommended random sampling of 200 plants. Multiple target populations were considered in the criterion formula of Oka (1975) which is, however, limited to the situation where a particular allele or genotype is to be collected from a target area composed of many populations. Qualset (1975) found that a minimum number of 500 plants should be collected to get information on the combination of characters evolved under natural and human pressure selection pressures. Yonezawa (1985), on the other hand, recommends the need to collect small samples of only 10 plants per site visited but to increase the number of sites and samples for greater efficiency. Bennett (1970) and Harlan (1975a) emphasized the necessity of random sampling and the opportunity to add rare types separately to that sample.

The decision on the size of the sample is based undoubtedly on the amount of genetic variation existing for some characters. The first step will be to select the most appropriate characters to detect this variation and judged the amount of variation shown by different characters. A judgement on the amount of variation showed by different characters can be obtained through a comparison of standard estimates of coefficient of variation :

$$\frac{S}{\overline{X}} = CV$$

when S = sample standard deviation and
$\overline{X}$ = sample mean

The results obtained by adapting this formula to the data reported by Porceddu (1979) for germplasm collected from Ethiopia, Algeria and Italy, suggest that heading time is the most appropriate character to describe the variability in the analysed populations (Table 1).

Table 1 Values of standard error computed for eight characters observed in wheat from Algeria, Ethiopia and Italy

Characters	Algeria	Ethiopia	Italy
Heading time	0.18	0.29	0.24
Flag leaf senescence	0.06	0.05	0.05
Culm senescence	0.11	0.09	0.09
Plant height	0.08	0.08	0.10
Upper most internode length	0.14	0.11	0.10
Leaf-sheath length	0.13	0.13	0.11
Flag-leaf length	0.16	0.13	0.11
Flag-leaf width	0.25	0.18	0.10

This conclusion is also supported by the evidence that almost all the intra-population variability is concentrated among families, and very little or none within families. The sample size required to conserve the genetic variability found in a population for heading time and according to which the method used for calculation is that proposed by Sokal and Rohlf (1969).

$$n \geq 2(\sigma/\delta)^2[t \propto (v) + t_2(1-P)(v)]^2$$

where n is the desired size of the number of plants per population σ is the true standard deviation (the square root of the variance), d is the smallest truce difference that is desired to detect, v is the degree of freedom for the sample standard deviation, δ is the significance level of t (table value at 0.01 level), and P is the desired probability that the differences to be found are significant (at 95% level) and t (v) and t/2 (1-P) (v) are values from a two-tailed t-table with v degrees of freedom and corresponding to probabilities of and 2(1-P), respectively. The results for the Ethiopian, Algerian and Italian population, utilizing the heading time as a test character, indicate an average sample of 100 plants as optimum i.e., 112 for Ethiopia, 100 for Algeria and 107 for Italy.

Adary (1978) using an identical formula for six characters from the same populations grown at Davis, California, U.S.A. obtained results shown in Table 2.

They indicate that the sample should contain between 6 and 133 plants when heading time is the test character, between 1 and 72 when plant height is used, between 20 and 452 for spike length, between 17 and 192 for the number of caryopsis per spike, between 1 and 60 for seed weight, and between 6 and 40 when the spikelet number is considered. The use of all the six characters simultaneously indicates that the sample size should be between 20 and 133 plants. The result is similar to that obtained by Marshall and Brown (1975) using a different approach.

It should be noted that the analyzed material was collected adopting the methods proposed by Marshall and Brown (1975). In the absence of detailed indications, the collections were made on the hypothesis that all populations had the same variability, which is untrue according to Brown (1978).

The range of 20-130 plants seems advisable also for other valid reasons. These number of plants will account for 95% variability existing in the populations, the size of samples still remaining a workable one. It should, however, be noted that a detailed observation is difficult during a collecting mission, hence the figures reported should be considered only as estimates. In case of large-seeded crops, such as faba beans, the number of reproductive units per individual plant may have to be reduced to sample an adequate amount of variability in a population. Hence, instead of an individual spike, a single pod could be sampled from 20-130 plants. This will not only ensure that an adequate quantity of germplasm is collected, but also that nearly all the variability has been sampled.

NUMBER AND DISTRIBUTION OF SAMPLES TO BE COLLECTED

The variability present in the targeted area of collection can be divided into two parts: (a) a part which is present in the fields, and (b) a part which can be attributed to differences among fields. This subdivision is useful to gather information for efficiently planning surveys of genetic resources.

In statistical terms, if a population is divided into a class and these are subdivided into smaller classes, this classification is called 'nested' or 'hierarchial with two levels'. The smaller classes may still be further subdivided into three or more levels. The important point to understand

Table 2 Sample size required to detect 10% difference from population mean at 95% probability level for six quantitative traits for Ethiopian, Algerian and Sicilian populations

Population	Heading time	Plant height	Spike length	No.of spikelets	Kernel Number	Kernal weight	Mean
E7725	6	1	52	6	17	39	20
E7700	16	72	74	19	67	1	54
E7723	26	55	67	13	73	39	46
E7740	56	20	87	11	45	32	42
E7805	73	41	104	41	101	57	70
Mean	35	38	77	18	61	34	46
A17971	43	20	173	21	192	60	85
A17982	16	17	205	10	114	59	70
A17988	34	21	73	9	65	21	37
A18031	16	4	102	9	52	15	33
A18037	9	5	76	9	37	25	27
Mean	24	13	126	12	92	36	50
S8001	9	7	173	36	106	11	57
S7965	66	43	452	30	153	58	133
S7947	103	55	150	32	59	29	71
S7961	7	7	20	7	104	39	31
S7983	12	15	46	12	96	40	37
S8006	17	13	97	40	143	23	56
Mean	36	23	156	26	110	33	64
Overall mean	32	25	120	19	88	34	53

Modified from Adary (1978).

is that in all cases small groups are within larger groups and that an individual observation belongs to only one group; at each level. Bogyo *et al.* (1980) applied this method while studying strategies for collecting plant genetic resources.

In 1973, the Germplasm Institute in Bari, Italy, organised an exploration and collection mission for wheat in the province of Sicily. For the purpose of the mission, the island was divided into 10 collection areas according to the broad agroecological features of the territory as recommended by Hartley (1963). About 12 samples were collected in each area and each sample consisted of approximately 100 single spikes. The altitude of each site was recorded. On returning to the Institute the seeds from individual spikes were sown in the field and a number of morphological characters were observed on the progenies.

An analysis of variance, carried out on the data from eight different characters, divided the variability into two part, i.e., among areas and among samples within areas.

BENTHIC FAUNA OF MANGROVE ENVIRONMENT

ARUN H. PARULEKAR

INTRODUCTION

Benthos accounts for those biotic entities which dwell in/on/above the substratum. Ecologically, the mangrove environment, bordering tropical and sub-tropical estuaries and open seafront, represents a transitional area between the marine and terrestrial biotopes and thus forms an integral part of the Intertidal or littoral zone. However, depending upon the natural gradient coupled with tidal amplitude, the horizontal expanse may extend either upshore to the infraterrestrial region or downshore to the sublittoral regions.

A general belief that animals are of minor significance in the mangrove environment does exist. It is only recently that the distribution, abundance and importance of the benthic fauna in a mangrove environment has been recognised. The benthic communities of the mangrove ecosystem find themselves in a stressful situation of widely fluctuating ecological parameters. Here the tidal influence is appreciably strong which determines the distribution and zonation of the biota. Due to the lack of vigorous water motion, the fine sediments settling on the bottom give rise to soft substratum, where poor interstitial circulation, high organic content and high microbial populations lead to anoxic conditions.

The effect of thermal gradient in a mangrove benthic environment is three-dimensional. Air temperatures have a telling effect during low tide when mud-flats are exposed whereas soils, due to soft but compact nature of sediments display a temperature range of higher magnitude than the air and water temperatures. Salinity of the interstitial water remains higher than that of the overlying water, by an order of magnitude. Due to the large amount of suspended matter causing oxidation reactions, the oxygen content of both the overlying and the interstitial water is generally low in a mangrove environment.

Typical sediments of mangroves are peaty, soft, sandy (towards land) and clayey mud (seaward). However, the particle size is of great importance, as it controls the ability to retain and circulate water. If the particle size becomes fine, the circulation practically ceases and the result is the formation of anaerobic conditions within the substratum. As a combined effect of weak circulation and high organic inputs mainly from decaying foliage and debris, there is a large amount of organic matter in the sediments. However, the rich organic matter content being highly oxidative in nature, ends up creating difficult living conditions for the benthic communities of the mangrove environment.

TYPES OF BENTHIC FAUNA

The benthic biota in the mangrove environment is a composite of terrestrial, estuarine and marine organisms. As such, the mangrove fauna with its low species diversity but relatively large number of individuals, is highly characteristic and non-specific in nature. It comprises elements from muddy shores as well as the general brackishwater biota. The species that occur in the mangroves

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do not occur in other habitats, though some species may occur in various mangrove ecosystems within the same faunistic region. Following types of benthic fauna are found in the mangrove environment :

Type	Distribution
Terrestrial Species	Upper Littoral and Infraterrestrial Fringe
Aquatic Species	Mid and Lower Littoral; Estuarine
Marsh and Mud-flat Species	Planktonic in Larval Stages; Mangrove Inhabitant throughout the Life

All these types occur in most of the mangroves. However, the distribution characteristics are subjected to variations in the overlapping, which are locality specific. As far as the distribution and abundance are concerned, the benthic fauna of a mangrove ecosystem can broadly be divided into :

1. Those inhabiting the hard substrate offered by mangrove vegetation (trunk, stilt roots, pneumatophores, etc.) :
   a. Wandering or mobile forms, and
   b. Fixed or sessile forms ;
2. The ones inhabiting the muddy substrate :
   a. Infauna or burrowing into substratum, and
   b. Epifauna or forms errant on the substratum.

Qualitative and quantitative distribution of benthic communities in mangrove environment is governed by tidal amplitude, light penetration, nature of substratum and distance from the sea, and accordingly it can best be studied in relation to (a) tidal amplitude, i.e., vertical distribution, and (b) the expanse, i.e., horizontal distribution.

Broadly, the following five zones have been delineated for studying the benthic communities of mangrove ecosystem :

LITTORAL ZONE

Extends upwards of highest high water of spring tide and is comparable with the littoral zone in rocky Intertidal region. Dominant organism is the periwinkle gastropod.

NERITA ZONE

Bounded by mean sea level on lower extent and highest high water of spring tide towards its upper extent. Dominant organism is *Nerita* sp., a gastropod, which varies in extent as per the tidal range.

BARNACLE – OYSTER ZONE

Extends between mean sea level and mean lower low water of spring tide and is populated mainly by *Balanus* and *Crassostrea* species.

UCA ZONE

Lies below mean lower low water of spring tide and extends below lower low water of spring tide. Dominant species are fiddler crabs (*Uca* spp.) and important faunal associates are *Cerithidea* spp. and hermit crabs.

POLYCHAETA ZONE

Narrow vertical delineation but maximum horizontal expanse. Populated by a variety of crabs, mud lobsters, gobiid worms, distributed up to 10 cm within the soft substratum.

Commonest epifaunal species are gastropod molluscs, represented by snails, whelks and top shells; bivalve molluscs like oysters and blood clams; crustaceans represented by crabs, mud lobsters, shrimps and barnacles; fishes, the commonest form being the mud-skipper. In contrast, the infaunal species are few and mainly represented by the polychaete worms. Migrant forms are many, but commercially important ones are the young stages of shrimps and fishes like milk fish, pearl spot and mullets, which use the mangrove ecosystem as shelter and nursery grounds. Quantitative studies on benthic fauna of mangrove environment are rather few, probably because organisms like crabs and those living on mangrove bark or burrowing among pneumatophores are difficult to trap and enumerate. Comparatively, the infauna is slightly better known.

In a comparative study of the benthic fauna in three estuarine mangrove biotopes of Goa, the population density and biomass of infauna was found to vary from 9–1700 m^{-2} and 0.03–33.30 gm^{-2} respectively. The epifauna forming the main bulk was dominated by detritivores as against the infauna which was composed of either omnivores and/or deposit feeders. Suspension of filter/cirral feeders were represented only by oysters and barnacles. Thus, the predominance of detritus-based food web is clearly reflected by the dominance of detritus feeders in the energetics of mangrove environment.

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MICRO-INVERTEBRATE BENTHIC FAUNA OF PICHAVARAM MANGROVES

K. BALASUBRAHMANYAN

Forty-four macro-invertebrates were found as benthic fauna in pichavaram mangroves. Sixteen belonged to crabs and nine to gastropods. Other groups were less represented. Detritus feeders dominated the fauna. Terrestrial gastropods are getting reduced and Pythia plicata is an endangered species in Pichavaram mangroves.

Pichavaram mangrove forest covers an area of about 110 hectares and consists of 51 islands. Pichavaram is connected to Vella estuary by Chinna Vaikkal in the North and to the Coleroon estuary in the South. It receives sea water through Chinna Vaikkal mouth in the North and Coleroon mouth in the South. The region is shallow, having an average depth of 1.5 m and subjected to semi-diurnal tide.

The macro-invertebrate benthic fauna of Pichavaram consists mostly of estuarine fauna present in Vellar and Coleroon estuaries, which includes four polychaetes, one bivalve, nine gastropods, three tanaids, four isopods, four amphipods, one cirripede, sixteen crabs, one shrimp and one hermit crab (Kasinathan and Shanmugam, 1986 and Sethuramalingam and Ajmal Khan, 1991). They are listed in Table 1.

Table 1 Macro-invertebrate fauna recorded from Pichavaram mangroves

Polychaeta	**Tanaidacea**
Heteromastus similis	*Tanais* sp.
Euclymene annandalei	*Apseudes gymnophobia*
Perinereis sp.	*Halmyrapseudes killaiyensis*
Mercierella enigmatica	
Bivalvia	**Isopods**
Dostia (Neritina) credpidularia	*Ligia exotica*
Telescopium telescopium	*Cirolana fluviatilis*
Cerithidea fluviatilis	*Sphaeroma terebrans*
Cerithidea obtusa	*Sphaeroma annandalei*
Littorina scabra	
Assiminera nitida	**Amphipoda**
Pythia plicata	*Paracalliope* sp.
Melampus ceylonicuss	*Grandidierella* sp.
Cassidual nucleus	*Corophium triaenonyx*
	Talorchestia sp.
Cirripedia	*Scylla serrata*
Balanus amphitrite	*Scylla tranguebarica*
	Thalamita crenata

Decapoda – Caridea	**Amphipoda**
Alpheus malabaricus	*Heteropanope indica*
	Ptychognathus altimanus
Decapoda – Anomura	*Neoepisesarma (Neopisesarma) mederi*
Uca (Celuca) lactea annulipes	*N. (Muradium) tetragonum*
Macrophthalmus depressus	*N. (Selatium) brockii*
Macrophthalmus erato	*Parasesarma plicatum*
Metapograspsus maculatus	*Nanosesarma (Beanium) batavicum*
Metapograpsus messor	*N. (Beanium) andersoni*

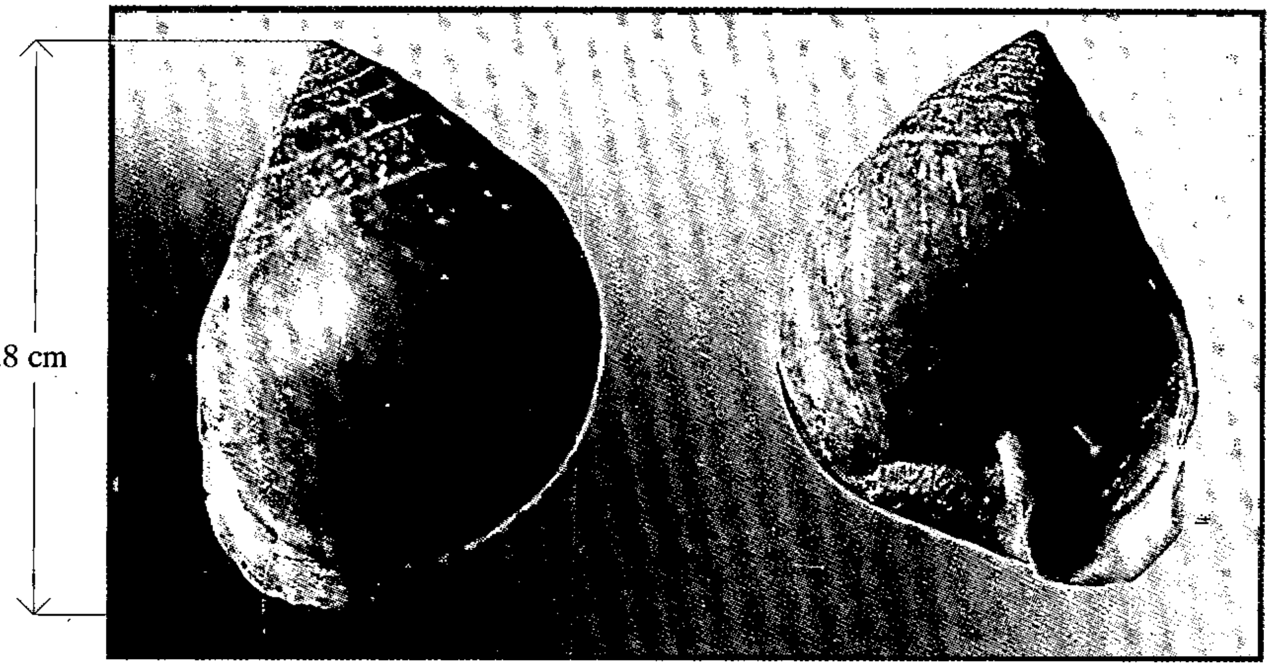

Figure 1. *Pythia plicata*

Perinereis sp., *Tanais* sp., *Cirolana fluviatilis, Grandidierella* sp., *Corophium triaenonyx, heteropanope indica* and *Nanosesarma batavicum* were found associated with oysters while *Mercierella enigmatica, Dostia Crepidularies, Assiminea nitida* and *Balanus amphitrite* occurred on stilt and breathing roots. *Heteromastus similis, Euclymene annandalei, Crassostrea madrasensis, Apseudes gymnophobia, Halmyrapseudes killaiyensis, Paracalliope* sp., *Clibenarius padavensis, Scylla serrata, Scylla tranguebarica, Metapograpsus messor, Thalamita crenata* and *Nanosesarma andersoni* occurred subtidally, and *Cerithidea fluviatilis, Telescopium telescopium, Alpheus malabaricus, Uca annulipes, Macrophthalmus depressus, M. erato, Metapograpsus maculatus,' Ptychognathus altimanus, Neoepisesarma mederi, N. tetragonum* and *N. brockii* occurred intertidally. Most of them lived in burrows. *Parasesarma plicatum* was found concealed among the roots.

Terrestrial gastropods are *Cerithidea obtusa, Littorina scabra, Pythia plicata, Melampus ceylonicus, Cassidual nucleus,* and the isopod *Ligia exotica*. Their members are declining in Pichavaram forests and *Pythia plicata* can be considered as an endangered species in this area. (Figure 1) *Sphaeroma terebrans* and *S. annandalei* are the wood-boring isopods. An amphipod *Talorchestia* sp. occurred among stranded algae.

Out of forty-four animal types recorded in Pichavaram mangroves, sixteen were crabs and nine gastropods. The other groups were represented less. *Uca annulipes* and *Cerithidea fluiatilis* were numerically dominant in the Intertidal area, while amphipods and tanaids were dominant sub-tidally. Most of the animals, viz., crabs and gastropods, are detritus feeders. The mangroves are rich in detritus and hence the detritus feeders are the dominant groups of macro-invertebrates that occur in Pichavaram mangroves.

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REMUNERATIVE ROLE OF FORAMINIFERA IN COASTAL ECOSYSTEM

RAJIV NIGAM

Due to the direct relationship between climate and economy (through agriculture), predictive models for climatic changes are very much needed. Climatic prediction is a delicate task and depends upon how well we know the past climate. Since the direct observational data for climate (temperature and rainfall) is available for only the last 100-150 years, paleoclimatic reconstruction has to be based on indirect evidences (proxy data) of climatic changes. Attempts are made to use fossilised floral evidence to reconstruct the past climate of the Indian region (Singh, 1971; Van Campo, 1986; Caratini *et al.*, 1991) However, credibility of paleoclimatic reconstructions based on floral evidences alone can always be increased by comparing them with parallel records generated through other evidences available in the form of tree rings, coral bands, lake sediments, marine sediments, etc.

Main objectives are :

1. How marine sediments can be used to reconstruct paleoclimate ?
2. In which way such records can be used to supplement information derived through floral evidences ?

TOOLS FOR RECONSTRUCTION OF PALEOCLIMATES

Marine sediments can be explored for paleoclimatic studies by employing temporal variations in textural and mineral characteristics or faunal content as tools. being very sensitive to environmental changes, exclusively marine organisms, foraminifera, have been used extensively.

THE STRATEGY

First, foraminiferal content in surface sediments from the sea bed should be studied. By comparing the distribution pattern with modern environmental parameters (like salinity) the proper techniques can be developed to generate proxy data for paleoclimates. A few such techniques developed so far are : (a) Species distribution, (b) Morpho-groups of benthic foraminifera, (c) Coiling directions, (d) Isotopic (180/160) variations, (e) Dimorphic ratios, etc. Depending upon the requirement, any of the above techniques can be used. For example, freshwater discharge through rivers is one of the crucial limiting factors for proper growth of mangroves. Anyone who is interested to know the history of paleoprecipitation can reconstruct the same by studying the remains of mangrove vegetation and also faunal remains in coastal marine sediments deposited over thousands of years.

CASE STUDY

One integrated approach has been followed to study core samples from the shelf region off Karwar, central West coast of India. The reconstruction of paleoclimate based on variations in mangrove, savanna and foraminifera lead to common conclusion, i.e., about 3500 years B.P., a major climatic boundary exists prior to which relatively higher precipitation is recorded and the intensity of the monsoonal precipitation has deteriorated considerably during the last 3500 years (Nigam *et al.*, 1992).

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MICROBIALLY MEDIATED DETRITAL FOOD WEB : THE LINK BETWEEN MANGROVES AND COASTAL AQUATIC ANIMAL COMMUNITIES

S. RAGHU KUMAR

INTRODUCTION

The importance of mangroves extends far beyond that which is offered by their vegetation. In fact, mangroves constitute the driving force of the food web in coastal waters adjacent to them, in the form of detritus. Detritus, in simple terms, may be defined as any dead organic matter and its associated microbiota. The detrital pathway is the most important one through which the energy of coastal macrophytic primary producers is channelled into the food web of adjacent waters (Pomeroy, 1980). When we consider the enormous amount of coastal macrophytic production, the detrital aspect of tropic web assumes an even greater significance. The salient features of this detrital pathway are the following: (1) Living marine macrophytes are grazed only to a minimal extent. It is only after their death and transformation into detritus in the water that they enter the food web. (2) The detritus is colonised by micro-organisms and is biochemically transformed. (3) Detritus forms an important food source of many marine animals. These aspects are considered in detail here, with particular emphasis on the mangroves.

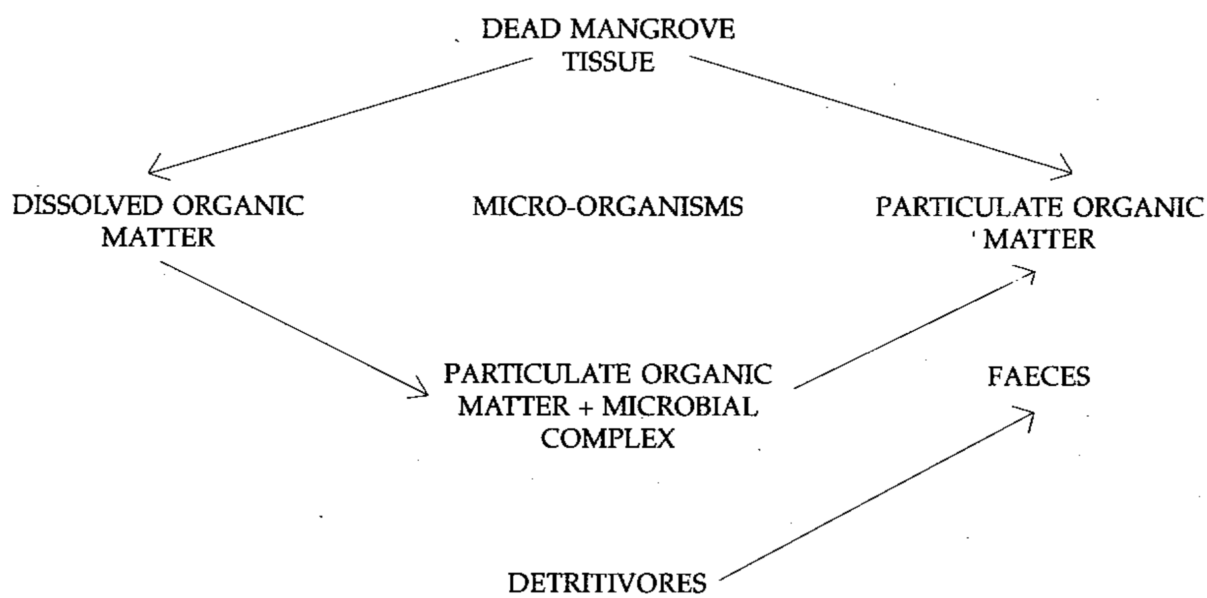

Figure 1: Schematic diagram of the microbially mediated detrital pathway

INPUTS INTO THE DETRITAL FOOD WEB

The above-ground primary productivity of mangroves has been estimated to be (Mann, 1988). A representative value of 730 g $Cm^{-2}yr^{-1}$ has been usually assumed (Benner and Hodson, 1985). A great amount of leaf litter, wood, dead roots and viviparous seedlings fall into the water over any given period of time. Most of the primary production that enters the mangrove waters, however, is in the form of leaves. It has been estimated that in the Chorao mangroves of Goa, an average of 508 g $Cm^{-2}yr^{-1}$ in the form of leaf litter enters the water (Wafar, 1987). Taking into account the area of 2000 ha covered by mangrove vegetation in Goa, this would amount to 10×10^3 tons of leaf litter entering these mangrove waters annually. In addition to this, an unestimated amount of wood and seedlings enter the system. The senescent mangrove plant parts that fall into the water are grazed by animals only to a very limited extent (Benner and Hodson 1985). This has been attributed to several reasons. The high fibre content of vascular plants makes them relatively indigestible to animals (Mann, 1988). Besides, mangrove plants contain high amounts of tannins. Their C:N ratios are also high and are unsuitable as good animal foods, since animals have much less ratios of C:N (Table 1). Dead and fallen mangrove plant parts, therefore, enter the aquatic food web predominantly after decomposition.

Table 1 Tannin contents of leaves of some mangrove species and C:N ratios of their fresh and aged detritus

Species	% Tannins	C:N Ratios	
		Fresh detritus	Aged detritus
Aegiceras corniculatum	-	42 : 1	24 : 1
Avicennia marina	7.0	45 : 1	23 : 1
Bruguiera gymnorrhiza	14.6	-	-
Ceriops tagal	11.0	80 : 1	40 : 1
Kandelia candel	-	23 : 1	24 : 1
Rhizophora mangle	5.2	91 : 1	41 : 1
Rhizophora stylosa	17.0	75 : 1	35 : 1

Data from Robertson, 1988 and Tam *et al.* (1990)

DECOMPOSITION OF MANGROVE PLANT PARTS IN WATER

Phenolic components such as ferulic acid are unpalatable to detritus feeders and negatively affect palatability and growth (Rietsma *et al.*, 1988). Apparently owing to this, native mangrove animals such as the crab *Sesarma erythrodactyla* do not prefer freshly fallen leaves (Camilleri, 1989). It is at this juncture that the micro-organisms play and important role. The decomposition that ensures can be classified mainly into three phases. These are (a) fast leaching phase; (b) a microbial decomposition phase; and (c) the recalcitrant phase (Valiela *et al.*, 1984). Microorganisms play a key role in each of these processes and these have a direct implication on the feeding of detritivorous animals. During decomposition, bacteria and fungi colonising the detritus utilise various nutrients present therein for their growth. While simple organic nutrients like sugars and amino acids are easily assimilated, complex polymers such as lignocellulose are first broken down into simpler ones by extracellular enzymes and only then taken up. Nutrients thus assimilated by microbes are partly mineralised to carbon dioxide through respiration and the rest converted to microbial biomass.

THE LEACHING PHASE AND DISSOLVED ORGANIC CARBON

The first phenomenon that takes place as soon as senescent mangrove plant parts fall into the water is the rapid leaching out of several organic compounds from the detritus, which enter the dissolved organic carbon (DOC) pool in the water. The fate of mangrove DOC has a great variety of obligate mangrove (manglicolous) fungi colonise dead mangrove wood. A great deal of work has been carried out on such mycoflora. Mangrove wood is densely colonised by such fungi.

Among the nutrients present in mangrove detritus, the lignocelluloses are highly recalcitrant to animal digestion and even microbial degradation. The fate of these in the mangrove system, therefore, is of great interest. The breakdown of lignocelluloses in mangrove leaves has been worked out in detail by the group of Benner and co-workers, who have shown the bacteria play an important role in the degradation of mangrove lignocelluloses. The rate of particulate lignocellulose mineralisation, however, is approximately 10 times lower than that of the leachable lignocelluloses (Benner and Hodson, 1985). The rate of degradation is influenced by the quality of the DOC in the environment, leachates from old leaves enhancing the degradation rates.

Microbial biomass in mangrove detritus: The breakdown and incorporation into the cell of various organic detrital components results in an increase in microbial biomass. In view of their potential importance was highly assimilable food for detritivores, a great deal of attention has been paid to this aspect. Examination of mangrove detritus always reveals abundant fungal phase. These penetrate the solid substratum and permeate throughout (Cundell *et al.*, 1979). Microbial biomass gradually builds up as decomposition progress. Loss of tannins from the freshly fallen plant parts through leaching may encourage microbial buildup (Cundell *et al.*, 1979). Robertson (1988) suggested that mangrove as species with a lower C:N ratio and tannin contents, such as *Avicennia*, supported the highest bacterial biomass. Buildup of microbial biomass also encourages microfauna, comprising ciliates and flagellates. These constitute a significant amount of biomass in marine macrophytic detritus, often of the same magnitude as that of bacteria (Mann, 1988). Total microbial biomass is generally about 1.0% or less of the detrital biomass (Table 2) (Blum *et al.*, 1988).

Table 2 Highest values of microbial biomass recorded on detritus of various mangroves and other macrophytes

Species	Biomass	Reference
Avicennia marina	0.25% carbon	Robertson, 1988
Ceriops tagal	0.23% carbon	Robertson, 1988
Rhizophora stylosa	0.25% carbon	Robertson, 1988
Rhizophora mangle	0.08% dry wt.	Blum *et al.*, 1988
Halodule wrightii	0.15% dry wt.	Blum *et al.*, 1988
Syringodium filiforme	0.46% dry wt.	Blum *et al.*, 1988
Thalassia testudinum	0.14% dry wt.	Blum *et al.*, 1988
Thalassia hemprichii	3.1 % dry wt.	Blum *et al.*, 1988

Biochemical changes in detritus are accompanied by numerous, significant biochemical changes (Untawale et al., 1977; Sumitra-Vijayaraghavan *et al.*, 1980; Tam *et al.*, 1990). Biochemical status of detritus may determine the value of detritus as food for detritivores and, therefore, is of great importance. Such changes appear to be caused by the micro-organisms which are present on detritus, by virtue of utilisation of various components of detritus for their nutrition. Thus, the primary saprophytic fungi mentioned earlier appear to be essentially 'sugar fungi', utilising labile components of detritus. The secondary saprophytes may be likened to the 'cellulose degraders', and those in the late stages, probably, could utilise the relatively recalcitrant lignocellulose material (Newell, 1976). Such activities may change the overall composition of detritus. The grazing of bacteria by meiofauna may ensure sustained bacterial been worked out in detail for leaves of *Rhizophora mangle* in Bahamian mangroves sources. (a) The first comprises the non-lignocellulose components consisting of sugars, amino acids, proteins, lipids and tannins. These constitute up to 52% of the dry weight of the leaves. Most of this is leached out very rapidly. These are high-quality substrates for bacteria in the water column and sediments are converted into microbial biomass with efficiencies of 30 to 94% (b) Lignocelluloses (28%) constitute the second components. These are highly recalcitrant to microbial degradation. During after stages of decomposition of the mangrove litter, these are attacked by bacteria and fungi. During this process, some of the broken down, solubilised intermediate products escape into the surrounding water in the form of lignocellulose - DOC. These too are partly mineralised and converted to microbial biomass in the water column.

The DOC-microbial pathway has great relevance to nutrient cycling in mangroves. As much as 71% of total mangrove detrital carbon (51% from non-lignocellulose and 20% from the lignocellulose) was estimated to be processed by bacteria in this manner in a Bahamian mangrove. Bacteria which utilise DOC may form larger, particulate aggregates by production of exudates such as mucus (Mann, 1988)

The DOC may also flocculate by non-microbial means. Various physicochemical processes lead to flocculation and formation of amorphous particles. These too enter the food web. However, micro-organisms may, to some extent, have an indirect role in those too. Fell and Master (1980) demonstrated that fungi present in mangrove leaves promoted flocculation of leached-out DOC as amorphous particles. The relevance of the DOC pathway is that it may enter the food web in the form of particles which are of high nutritive value to detritovores. The leaching process may last a few hours to a few days, depending upon the plant species. Loss of soluble components from the particulate detritus results in a decrease in tits dry weight. While loss in ash-free dry weight (AFDW) in the initial few hours may be attributed entirely to abiotic leaching, that occurring after may at least partly be due to microbial degradation. Loss through leaching can amount up to 50% in 10 to 50 days, depending on various parameters such as the plant species and environment (Benner and Hodson, 1985; Robertson 1988; Tam *et al.*, 1990).

MICROBIAL COLONISATION AND DECOMPOSITION OF THE PARTICULATE DETRITUS

A great deal of attention in mangrove detrital microbiology has been paid to particulate detritus. Bacteria and fungi are universal as the initial consumers of particulate, macrophytic detritus in the sea (Pomeroy, 1980). Three aspects are important in this process, namely, colonisation, biomass buildup and biochemical transformation.

Colonisation: Colonisation of fungi on mangrove leaves and seedlings follows a distinct succession of species (Fell and Master, 1980; Newell, 1976). Several terrestrial species of fungi are present on senescent leaves and healthy seedlings of mangroves, even when they are attached to the plant. These may either occur on the surfaces of the tissue or penetrate the first on or two layers of the cells to exist as 'weak parasites'. Some of these species may persist in the mangrove tissues for several weeks after the latter fall into the water and may have a role to play in the initial stages of decomposition. Within a few hours after mangrove leaves fall into the water, they are colonised by species of *Phytophthora*, which appear to be characteristic of decaying mangrove leaves. Species of this fungus produce motile zoospores, which probably reach the detritus in water by chemotaxis (Newell *et al.*, 1987). By about 36 h, *Phytophthora vesicula* could be isolated wit 100% frequency from such fallen leaves. The zoosporic , fungilike osmoherotrophic protists, the thraustochytrids, are also early colonisers of such leaves (Newell, 1976; Fell and Master, 1980). Besides these, several of the fungal species present on senescent parts also persist for some time in the water. All these forms, together, comprise the first serial stage, or the common primary saprophytes. The second seral stage is characterised by 'secondary saprophytes', which include typical marine species such as *Lulworthia* sp. and *Cirrenalia* spp. in leaves and *Keissleriella blepharospora* and *Cytospora rhizophorae* on seedlings. Very late stages of decomposition harbour species of terrestrial genera, such as *Aspergillus*, *Penicillium* and *Trichoderma* activity. Larger invertebrates are involved in detritus increase available of bacterial colonisation. This also results in enhanced bacteria activity. This process have implications in accelerating changes in the detritus.

One of the major changes brought about in detritus is the reduction in the C:N ratios. The phenomenon of decrease in C:N ratio was earlier explained as follows. Plant detritus has C:N ratios much higher than those of bacteria. In order to utilise the plant organic carbon, but to compensate for the nitrogen deficiency, micro-organisms efficiently take up the inorganic nitrogen from the ambient water and incorporate this into the cell protein, a process termed 'nitrogen immobilisation' (Melillo *et al.* 1984). Presence of micro-organisms in detritus under experimental conditions does indeed lower C:N ratios (Fell and Master, 1980. Reduction in C:N was equated with increase in proteins and this was considered a major indicator of an improvement in detrital quality as animal food. Therefore, this aspect has been studied by many (Fell and Master, 1980); Robertson, 1988; Tam *et al.*, 1984; Robertson, 1988; Crosby *et al.*, 1990). It appears that much of the increase in nitrogen may be ascribed to microbial exudates such as enzymes and mucopolysaccharides, which combine with reactive phenolics in the detritus to form humic, non-protein nitrogen (Wilson *et al.*, 1986; Melillo *et al.*, 1984). The standing stock of bacteriogenic exudates may be several times greater than living bacteria.

As the utilisable components of detritus are gradually used up, particulate detritus becomes increasingly recalcitrant to microbial degradation. Microbial activity on such substrates, and therefore their decomposition, is greatly retarded. Such detritus accumulates in the sediment over a period of time.

IMPLICATIONS IN THE FOOD WEB

Detritus is the major food source for animals in coastal aquatic ecosystems, the production of which far exceeds that of the phytoplankton (Pomeroy, 1980). Many animals in mangrove waters, such as amphipods, isopods and crabs, actively feed on mangrove detritus (Camilleri, 1989); Robertson, 1988). Among economically important animals, juvenile prawns, which are abundant in mangrove waters, are detritus feeders. Because of the presence of microbial biomass on detritus it is necessary to consider their role as food for detritivores. There are two types of detrital from a singe substrate. The first of these comprise DOC, which has flocculated either by abiotic or by microbial means, as detailed earlier (Mann, 1989). Such amorphous detritus is low in C:N, namely < 12, and constitutes food of high nutritional value (Fell and Master, 1980). The other type is derived from the decomposing particulate matter.

From among particulate detritus, detritivores prefer aged to fresh detritus, an example being the crab *Sesarma erythodactyla* feeding on mangrove leaf detritus in Queensland mangroves (Camilleri, 1989). Decomposed black mangrove leaves were reported to be preferred by crabs in Thailand mangroves (Fell and Master, 1980). The prawn *Metapenaeus monoceros* exhibited greater conversion efficiency when fed mangrove detritus in late stages of decomposition in combination with rice bran rather than with fresh detritus (Sumitra-Vijayaraghavan and Ramadhas, 1980). Peak meiofaunal densities in Florida mangrove detritus were reached only three weeks after submergence (Fell and Master, 1980). The crab *Neosarmattium smithii* and the amphipod *Parahyella hawaiiensis* preferred aged mangrove leaves to fresh ones (Robertson, 1988). There are two possible reasons for such a preference, namely (a) the low levels of phenolics and (b) the presence of micro-organisms.

a. Phenolic contents : Total phenolic levels are low in aged detritus. Phenolic contents are reduced due to leaching, and perhaps also by microbial oxidation. The aspect in mangroves has not been sufficiently worked out and the importance of micro-organisms in this process is poorly understood. *Sesarma erythodactyla* preferred not only aged detritus but leaf detritus from *Avicennia marina,* containing less tannins than other species tested (Camilleri, 1989).

b. Role of micro-organisms as food : Microbial biomass increases with age of detritus, upto a particular stage. This may be major factor in determining the palatability of detritus. It is possible that the presence of micro-organisms presents certain clues for detritivores to feed. Suberkropp and Arsuffil (1984) demonstrated that autumn-shed leaves in freshwater streams became more palatable to caddisfly larvae after growth of fungi on them and that different species of fungi evoked different responses in terms of palatability to the detritivores.

However, it is not clear as to the manner in which micro-organisms in detritus are important to animals feeding on them. A very common assumption has been that detritivores ingest detritus and assimilate mostly, if not only, the micro-organisms and digest the rest (Pomeroy, 1980; Crosby *et al.*, 1990). In such a case, micro-organisms would serve as the major or even sole source of carbon and nitrogen contribution from micro-organisms and the non-living part of detritus, as well as the ingestion rates, assimilation and conversion efficiencies of individual animals or the community as a whole.

Animals can derive variable amounts of nutrition directly from the non-living plant component of detritus. This amount may vary from as low as 3% carbon (Crosby *et al.*, 1990) to as high as 72%, depending upon the animal species as well as the detrital source. The total bacterial and fungal biomass present on various macrophytic detritus contributes 0.14 to 25% carbon to animals feeding on the, although the cells of micro-organisms as such can be assimilated with an extremely high conversion efficiency of 40 to 75% by various animals (Stuart *et al.*, 1982; Kofoed, 1975; Crosby *et al.*, 1990). However, animals which carry out multiple repetitive processing by reingesting their faeces recolonised by micro-organisms would derive more microbially derived

C than from the detritus alone (Pomeroy, 1980). More importantly, processing through the 'faeces loop might make microbial contribution very important in terms of supply of N of detritivores, upto 73% of N coming from such a source in the case of kelp bed animals communities in South African coastal waters.

Most studies have only looked into carbon and nitrogen contribution from microbial cells. However, much of microbial production might be released in the form of extracellular enzymes and mucopolysaccharides which may be complexed with reactive phenolics and carbohydrates to produce non-protein, 'humic' nitrogen (Wilson *et al.*, 1986). Detritivores such as the fish *Tilapia* sp. and the freshwater amphipod *Gammarus pseudolimnaeus* are capable of assimilating such nitrogen (Mann, 1988, Barlocher *et al.*, 1989). Microbes of this origin might, therefore, play an important role in the food of detritivores. Apart from carbon from carbon and nitrogen, microorganisms may be extremely important as suppliers of essential nutrients (Phillips, 1984). Bacteria are rich sources of essential amino acids (EAA) and vitamins. Polyunsaturated fatty acids (PUFAs) are now believed to be extremely important in the nutrition of many marine animals. Eucaryotes, including diatoms, are a rich source of the PUFAs. The emphasis on microbial importance in detrial food webs may, indeed, shift to these aspects in future.

Many aspects of detrital food in coastal waters, particularly those supported by mangroves, are poorly understood. Most of these pertain to the role played by micro-organisms in detritus. We do know, however, that dead mangrove plant parts contribute enormously to detritus in coastal aquatic ecosystems, the animal community (including commercially useful ones) is supported largely by these, and that the micro-organisms actively play a role in detrial transformation. The importance of mangrove vegetation to the food web of adjacent waters, therefore, cannot be overemphasised.

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HIGHER MARINE FUNGI FROM MANGROVES (MANGLICOLOUS FUNGI)

S. CHINNA RAJ

INTRODUCTION

The mangrove ecosystem is a typical tropical and coastal vegetation, found in Intertidal regions of river deltas and backwater areas known for high organic matter production (Odum and Heald, 1975), which supports the nearby estuarine and offshore community by detritus transport. Fungi play an important role in the decomposition of organic matter in the mangrove ecosystem (Fell and Master, 1980). Mangrove trees have certain adaptations like prop roots, pneumatophores, knee roots and viviparous germination which facilitate their growth in the aquatic environment (Tomlinson, 1986). The dead and damaged stems, prop roots,seedlings and leaves of the mangroves which fall on the ground are exposed during low tide and submerged in the water during high tide. The period of exposure depends on the tidal amplitude and place where the materials accumulate. This environment creates a unique habitat for a certain group of fungi called "manglicolous fungi" which are well adapted to this type of environment (Kohlmeyer and Kohlmeyer, 1979). The first review on manglicolous fungi recognised 42 species of higher marine fungi which included 23 Ascomycetes, 2 Basidiomycetes and 17 Deuteromycetes (Kohlmeyer and Kohlmeyer, 1979). Hyde (1990a) listed 120 species from 29 mangroves from all over the World this includes 87 Ascomycetes, 2 Basidiomycetes and 31 Deuteromycetes. Later on, the following species were published : *Helicascus nypae* Hyde, *Salsuginea ramicola* Hyde, *Phomopsis mangrovei* Hyde, *Magrovispora pemphii* Hyde et Nakagiri, *Massarina lacertensis* Kohlm. et Volkm-Kohlm., *Bathyascus mangrovei* Ravikumar et Vittal, and *Pedumispora mangrovei* Hyde et Jones. There are still more species awaiting description.

COLLECTION TECHNIQUE

There are two different types of techniques commonly used to study manglicolous fungi: (1) Wood baiting technique, where the terrestrial timber is used to collect the fungi. In this technique wooden logs measuring 6 cm x 3 cm x 2 cm are immersed in the mangrove forests at different tidal levels for a certain period, then retrieved and examined for fungal colonisation. The advantages are: the time of the exposure is known, sporulating stages can be identified, succession of fungi couple with chemical composition and time can be studied; the disadvantages being the substrate does not exactly substitute the natural environment, generally very less species diversity is observed. (2) Direct collection, where the dead and damaged parts of the mangrove trees collected from mangrove forests directly from the natural environment can be examined for fungi colonisation. The advantage is that generally greater species diversity is recognised. The disadvantages are: it is difficult to identify the host and origin of the substrate if the substrate is a driftwood, succession of fungi and change in chemical composition and weight loss of substrate cannot be studied.

Table 1 Frequently collected manglicolous fungi from different mangrove areas

Name of the Species	Bru.	Mal.	Phl.	Sey.	Thi.	Sum.	Mav.	A&N	Ind.
Aligialus grandis Kohlm. et Schatz	–	–	–	–	+	–	–	–	–
Cirrenalia pygema Kohlm	+	–	–	–	–	+	–	–	–
Dactylospora haliotrepha (Kohlm. et Kohlm.) Hafellner	–	–	–	–	+	+	+	–	–
Haloserpheia marina (Cribb et Gribb) Kohlm.	–	–	–	+	–	–	–	–	–
Halosaphaeira quadricornuta Cribb et Cribb	–	–	–	+	–	–	–	–	–
Halocyphina villosa Kohlm. et Johlm.	+	+	–	+	+	–	–	+	+
Hypoxylon oceanicum Schatz	–	+	+	–	–	+	–	+	–
Leptosphaeria australiensis (Cribb et Cribb) Hughes	+	–	–	–	+	–	–	–	–
Lignincola laevis Hohnk	–	–	–	–	–	–	+	–	–
Lophiostoma mangrovei Kohlm	–	–	–	–	–	–	+	+	–
Lulworthia grandispora Meyres	+	–	–	+	+	–	–	+	–
Massarina velatospora Hyde et Borse	–	–	+	–	+	–	–	–	+
Rhizophila marina Hyde et Jones	–	–	–	+	–	+	–	–	–
Savoryella ligcola Jones et Eaton	–	+	+	–	+	–	–	–	–
Trichcladium achrasporum (Meyers at Moore) Dixon	–	+	–	–	–	–	–	–	–
Verruculina enalia (Kohlm.) Kohlm. et Volkm-Kohlm	–	–	–	–	–	–	+	+	+
Zalerion varium Anast.	–	–	+	–	–	–	–	–	–

+ : Indicates frequently collected
– : Indicates not frequently collected
Bru : Brunei (Hyde 1988b)
Mal. : Malaysia (Jones and Kuthbutheen 1989)
Phl. : Philippines (Jones *et al.*, 1988)
Sey. : Seychelles (Hyde and Jones 1988)
Thi. : Thailand (Hyde *et al.*, 1990)
Sum : Sumatra (Hyde 1989b)
Mav : Maldives (Chinna Raj unpublished data)
A&N : Andaman and Nicobar Islands
Ind. : India (Borse 1988)

After collection, the samples can either be studied immediately or after a period of incubation in the moist chamber for about ten to fifteen days which induces the sporulation of fungi. Preliminary identification can be done using the standard keys (Kohlmeyer and Volkm Kohlmeyer, 1991) but for final confirmation the specimen should be referred to the original description. A part of the sample should be dried and preserved as a herbarium and some permanent slides showing

Table 2 Frequently collected manglicolous fungi and its percentage occurrence on different mangrove trees

Name of the Species	Aa*	Ra*	Rm*	Sa*	Xg*	Rm	Ra	Bg	Am	Ao	Sa
Ascomycetes											
Aigialus grandis Kohlm. et Schatz	–	6.0	–	–	–	–	–	–	–	–	–
Aigialus perves Borse	6.0	–	–	–	–	–	–	–	–	–	–
Anoptodera chesapeakensis Shearer et Miller	–	–	–	8.0	–	–	–	–	–	–	–
Aniptodera mangrovei Hyde	–	–	–	7.0	–	–	–	–	–	–	–
Ascorcratera manglicola Kohlm.	–	–	–	–	–	–	–	26.0	–	12.0	–
Biatriospora marina Hyde et Borse	–	–	–	–	–	–	–	–	–	–	11.3
Caryosporella rhizophorae Kohlm.	–	11.0	12.0	–	–	–	–	–	–	–	–
Coronopaphilla mangrovei (Hyde) Kohl. et Volkm – Kohlm.	–	–	–	–	6.0	–	–	–	–	–	–
Dactylospora haliotrepha (Kohlm. et Kohlm.) Hafellner	–	–	–	–	6.0	–	–	20.0	–	–	–
Didymella avicenniae Patil et Borse	–	–	–	13.0	–	–	–	–	–	–	–
Halosarpheia ratnagiriensis Patil et Borse	16.0	–	–	14.0	–	–	–	–	–	–	–
Halosarpheia marina sp.	9.0	8.0	–	8.0	–	–	–	–	–	–	–
Halosphaeria cuculata (Kohlm.) Kohlm.	7.0	–	–	–	–	–	–	–	–	–	–
Helicascus kanoloanus Kohlm.	6.0	–	–	–	–	–	–	–	–	–	–
Hydronectria tethys Kohlm. et Kohlm.	–	–	10.0	–	–	–	–	–	–	–	–
Hypoxylon oceanicum Schatz	20.0	–	12.0	26.0	–	9.9	–	–	–	–	–
Leptoshaeria australiensis (Cribb et Cribb) Hughe	–	16.0	10.0	–	–	–	–	–	–	–	–
Lophiostoma mangrovei Kohlm et. Vittal	–	–	–	–	–	9.2	11.3	21.6	–	12.0	–

the important features should be prepared and preserved using standard methods (Kohlmeyer and Kohlmeyer, 1979) for further references. Table 1 highlights list of manglicolous fungi collected by various scientists throughout the World.

DISCUSSION

Hyde and Jones (1988a) reviewed the occurrence of manglicolous fungi from three major oceanic regions and found that out of ninety species recorded from all the World, 37 species were recorded (e.g., *Halosphaeria quadricornuta, Halosphaeria salina* Kohlm.), on persistent asci *Halosarpheia* ratnagiriensis Patil et Borse, *halosarpheia obonnis* Kohlm. Appendages and a gelatinous sheath may enhance dispersal and attachment to the substrate. In general, most of species release the spores passively; the presence of hyaline, appendaged and sticky ascospores indicates their adaptation to the aquatic habitat. Species having dark-coloured ascospores and an active spore release mechanism which are normally restricted to the upper Intertidal region may be the transition forms between the aquatic and terrestrial species. No experimental data are available indicating whether the spores are released during low tide or high tide; such data would prove very useful for a better understanding of the dispersal mechanism.

This paper is the first ever attempt to study the occurrence and distribution of manglicolous fungi in the Indian region.

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Table 2 *(contd.)*

Name of the Species	Am*	Ra*	Rm*	Sa*	Xg*	Rm	Ra	Bg	Rm	Ao	Sa
Lulworthia grandispora Meyres	–	–	12.0	13.0	–	–	–	–	10.5	17.3	8.0
Lulworthia sp.	18.0	–	–	–	6.0	–	–	–	–	–	–
Marinosphaera mangrovei Hyde	12.0	–	–	–	–	–	11.3	–	–	–	–
Massarina velatopora Hyde et Borse	–	–	–	9.0	–	–	–	–	–	–	–
Passeriniella savoryellopsis Hyde et Mouzouras	–	–	–	–	12.0	–	–	–	–	–	–
Rhizophila marina Hyde et Jones	–	–	–	–	–	11.3	10.1	–	–	–	–
Savoryella lignicola Jones et Eaton	–	9.0	–	–	–	–	–	–	–	–	–
Verruculina enalia (Kohlm.) Kohlm. et Volkm-Kohlm	–	–	7.0	–	–	9.9	18.9	26.6	8.8	12.0	9.5
Basidiomycetes											
Halocyphina villosa Kohlm. et Kohlm.	10.0	–	30.0	10.0	–	10.2	11.3	–	11.4	–	9.5
Deuteromycetes											
Cirrenalia pseudomacrocephla Kohlm.	–	7.0	–	–	–	–	–	–	–	–	–
Cirrenalia pygmea	–	19.0	20.0	–	–	–	–	–	–	–	–
Cirrenalia tropicals	–	–	8.0	–	–	–	–	–	–	–	–
Poma sp.	10.0	–	–	7.0	–	–	–	–	–	–	–
Trichocladium achrasporum (Meyers at Morre) Dixon	–	–	–	–	–	–	–	–	10.5	9.3	–

Am : *Avicennia marina* Ra : *Rhizophora apiculata* Rm : *Rhizophora mucronata*
Sa : *Sonneratia alba* Xg : *Xylocarpus granatum* Bg : *Bruguiera gymnorrhiza*
Ao : *Avicennia officinalis*

*Hyde 1990

Table 3 Number of fungi recorded from mangroves

Name of the mangrove species	Asco.	Basidio.	Deutero.	Total
Acanthus ilicifolius L.	2	1	2	5
Acrosticum speciosum Wild	10	–	8	18
Aegiceras corniculatum Blanco	13	–	13	25
Avicennia africana P. Beauv	4	–	2	6
Avicennia alba Blume	39	1	7	47
Avicennia germinans (L) Stearn	18	–	6	24
Avicennia lanata Ridl	15	1	2	18
Avicennia marina (Forsk) Vierh	33	1	9	43
Avicennia officinalis L.	25	1	10	36
Batis maritima L.	2	–	–	2
Bruguiera gymnorrhiza (L) Lambk.	20	1	5	26
Bruguiera parviflora (Roxb) W. et A. ex Griff	5	1	2	8
Bruguiera cylindrica (L) Bl.	20	1	5	26
Canavalia rosea	2	–	–	2
Ceriops tagal (perr) Rob.	10	1	4	15
Conocarpus erectus L.	10	1	3	13
Excoecaria agallocha L.	14	1	4	19
Hibiscus tiliaceus	13	–	3	16
Kandelia candel (L) Druce	16	1	13	30
Luguncularia racemosa Gaertn	14	1	1	16
Lumnitzera racemosa Gaertn	14	1	1	16
Lumnitzera racemosa Willd	5	–	2	7
Nypa fruticans Wurmb	11	1	–	12
Rhizophora apiculata Blum.	52	1	16	69
Rhizophora mangle L.	36	2	17	55
Rhizophora mucronata Lamk	51	2	15	68
Rhizophora stylosa Griff	9	1	9	19
Sonneratia caseolaris L. Engl.	10	1	2	13
Sonneratia alba j. Smith in Ress	28	1	8	37
Sonneratia apetala Buch - Ham	3	–	–	3
Xylocarpus granatum Konig	30	1	4	35

Asco : Ascomycetes; Basidio: Basidiomycetes; Deutero : Deuteromycetes

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ALGAE ASSOCIATED WITH MANGROVES

V.K. DHARGALKAR

INTRODUCTION

Mangroves are salt-tolerant plants of tropical and sub-tropical Intertidal regions of the World. They play an important role in replenishing the fertility of the coastal regions and support coastal inhabitants socio-economically. Other uses of mangroves for extraction of tannin, timber products, aquaculture, etc., have been recently well organised.

The mangrove ecosystem is a complex and dynamic one. The uniqueness of this ecosystem is that the biota is constantly under physiological stress caused by extreme environmental conditions. Despite such extreme conditions, mangroves have been successfully colonised by developing morphological, reproductive and physiological adaptations (Saenger, 1982; Clough *et al.*, 1982). The mangrove community is not uniform structurally or floristically because of the number of environmental factors that influence on individual mangrove species differently. The various brought about by tide and coastal currents have made organisms of this ecosystem adapt to continuous changing conditions.

The mangrove ecosystems of the World contain about 60 tree species and provide a living support system for dependant biota – about 2000 species of fish, invertebrates and epiphytic plants. (Barth, 1982).

BENTHIC ALGAE

Algae are a primitive group of plants capable of synthesising the complex organic matter. In spite of the considerable diversity in the thallus structure, the important characteristic that distinguishes most algae from other photosynthetic plants is the formation of the reproductive cell and unicellular reproductive organs or multicellular organs.

Algae are classified into a number of systematic groups. They are found in shallow Intertidal and sub-tidal area where 0.1% photosynthetic light is available. Their distribution in the Intertidal areas and geographical regions of the World depends on various environmental factors, the major ones being temperature, light, salinity, nutrient, substrate, etc. In the Intertidal area, algae show distinct zonation on the rocky shores while no zonation occurs in the mangrove area. The rise and fall of the tide is the most important factor in colonisation of the mangrove-associated algae because during low tide algae are subjected to the prevailing salinity conditions, high temperature of the soil and loss of water from thallus due to exposure.

In a mangrove community, number of associated mangrove species are also observed. These plants not only confine to mangrove areas alongwith exclusive mangrove species, but are also found in other coastal ecosystems. This type of association may be considered as casual or intimate which increases the diversity of mangrove community (Saenger *et al.*, 1977), Jagtap (1986) has reported 44 species of algae belonging to 30 genera from Goa coast. (Table 1). This type of variation in the number of algal species perhaps could be attributed to the tolerance capacity of the respective algae in colonising unstable mangrove areas.

Table 1 Algae associated with mangroves

Chlorophyta		**Rhodophyta**	
1.	*Ulva fasciata*	1.	*Gracilaria verrucosa*
2.	*U. lactuca*	2.	*Hypena musciformis*
3.	*U. reticulata*	3.	*Catenalla impudica*
4.	*Enteromorpha clathrata*	4.	*Caloglossa leprieuri*
5.	*E. intestinalis*	5.	*Polysiphonia macrocarpa*
6.	*E. flexuosa*	6.	*P. ianosa*
7.	*Monostroma* sp.	7.	*Bostrychia tenella*
8.	*Cladophora* sp.		
9.	*Chaetomorpha linum*	**Cyanophyta**	
10.	*Rhizoclonium knereri*	1.	*Chlorococcus turgidus*
11.	*R. riparium*	2.	*Aphaniotheca saxicola*
12.	*Codium fragile*	3.	*Oscillatoria earlei*
13.	*Codium elongatum*	4.	*O. limosa*
15.	*Dichotomosiphon salina*	5.	*O. nigrovirdis*
		6.	*O. annae*
Phaeophyta		7.	*O. pinceps*
1.	*Giffordia mitchellae*	8.	*O. marttinii*
2.	*Dictyotta indica*	9.	*Oscillatoria* sp.
3.	*Padina tetrastromatica*	10.	*Phormidium fragile*
4.	*Spatoglossum asperum*	11.	*Phormidium* sp.
5.	*Colpomenia sinuosa*	12.	*Spirulina* sp.
6.	*Sargassum* sp.	13.	*Schizothrix* sp.
		14.	*Macrocoleus echthnoplastes*
		15.	*Anabaena* sp.
		16.	*Calothrix crustacea*

SUBSTRATE

Substrate plays very important role in algal establishment in Intertidal and subtidal areas. Even though substrate is meant only for attachment, it is vital for the algae to get attached to one place without which it can be drifted away by water movements caused by the rise and fall of tides and currents. In the rocky coastal area, algae attach themselves to the substratum with discoidal type of hold-fast, while on the mud and sand or dead shell particles the attachment is with the help of rhizoidal hold-fast. Three microhabitats such as (a) mud surface, (b) surface of tree trunk stilt roots, and upper branches and canopies of the trees, can be identifies based on algal association in mangrove areas.

ALGAL ASSOCIATION

Algae colonising the mud surface are seasonal because of the unstable conditions caused by the erosion and accretion during the season. Mud surface harbours unicellular algae (diatoms) and multicellular algae dominated by blue-green (*Oscillatoria, Macrocoleus* and *Schizothrix* spp.) form a characteristic reddish, bluish or greenish mat on the mud surface.

The benthic algae of the mud surface are represented by the green filamentous *Enteromorpha clathrata, Rhizoclonium* spp. and thalloid *Monostroma* sp., *Ulva fasiata*, etc. These algae are found growing in extreme conditions in the salinity range from 30 to 40% high temperature and nutrients and high light intensity. Enteromorpha spp. shows luxuriant growth and is usually found covering entire mud surface. During the afforestation programme at Jaitapur (Ratnagiri) undertaken by Social Forestry, Government of Maharashtra the canopy of the mangrove seedling of *Rhizophora mucronata* was found covered with *Enteromorpha* sp. In many cases, seedlings were bent due to the weight of this alga. Sometimes due to the strong cyclonic winds, algae growing in the nearby rocky area are uprooted and enter the mangrove area. *Sargassum* spp., *Spatoglossum asperum, Padina teltrastromatica, Ulva lactuca, Ulva fasciata, Gracilaria verrucosa, Hypena musciformis, Acanthophora specifera, Polysiphonia macrocarpa, Codium* spp. are some such examples.

The epiphytic algal flora on mangrove trunks, pneumatophores, stilt roots, upper branches and canopies are comparatively poor. Red algae dominate in these groups and are represented by genus *Bostrychia* spp., *Caloglossa* and *Catenella.* These algae grow in the open, more exposed illuminated area, and form greenish-brown mat-like covering on the tree trunk, pneumatophores and stilt roots. On pneumatophores, *Bostrychia-Catenella-Caloglosa-Catenella* association is seen. The level of settlement on these substrates depends on the tolerance capacity of the algae to the environmental fluctuations. It has been reported that *Bostrychia tenella* can grow above high tide level if it is kept moist and shaded (Almodovar and Biebl, 1962) while Gayral (1966) found that *Bostrychia* spp. can withstand a longer period of desiccation. There is not much information on the tolerance capacity of the algal species under extreme conditions, however, based on broad geographical distribution, most species appear to tolerate a wide range of water and air temperature fluctuation.

BIOTIC FACTORS

With regard to the biotic factors there are a number of animals grazing on mangrove associated algal species. Cribb (1979) recorded traces of *Cladophora* sp. in faecal pellets of gastropod *Littorina* and *Cerithidea* spp. Algae in mangrove habitats generally constitute a significant food resource for various species of mangrove creek fishes and mud-skippers (Beumer 1971, 1978 and Milward, 1974). Odum and Heald (1972) reported that molluscs and crustaceans are the major consumers of diatoms and filamentous algae of the mangrove communities. Competition in respect to space, light and nutrients is another important biotic factor for the survival of the algal species. Green filamentous algae *Enteromorpha* spp. cover other smaller algae of the Intertidal areas, thus depriving the smaller algae from sufficient light, space and nutrients, creating unfavourable conditions for their survival. However, some algae do survive in such conditions by minimising their requirement, perhaps by modifying their metabolic processes. Some pneumatophores and tree trunks were also found covered with *Enteromorpha* spp.

CONCLUSION

In general, mangrove habitat as a whole is unfavourable for the growth of the algal species because of the lack of stable substrate, high turbidity and physiological stress due to the environmental extremes. Algae observed in the Intertidal regions of mangrove areas are very rich and diverse in both quality and quantity. Over the years algae have probably developed resistance to the extreme conditions and adapted to survive in this environment. The literature with regard to algae associated with mangroves is meagre, and whatever information is available does not give sufficient understanding of the mechanism of survival of algae in extreme conditions, their interaction with other biota and genetic changes brought about in such environment over the years. Therefore more in-depth studies in this field area needed to understand their survival strategy for better utilisation and management.

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SEAWEEDS OF THE MANGROVE AND ASSOCIATED ECOSYSTEMS

L. KANNAN

Seaweeds are the valuable, natural marine resources which are renewable. They are useful to mankind in many ways and are used as food, fodder, fertiliser and medicine. Agar and algin extracted from the seaweeds have a variety of industrial applications. Such seaweeds occur not only in the sea but also in various marine environs such as estuaries, backwaters, mangroves and other associated ecosystems. In the mangrove environment, planktonic algae are the primary producers which indicate the pelagic food-chain. But microphytobenthos, mostly diatoms and blue-green algae, macroalgae and seagrasses play a significant role in the benthic food-web process.

In general, the mangrove environment is unfavourable for the growth of many macroalgae because of lack of suitable substratum. The substratum is unsteady and muddy. The mud in suspension will cause more turbidity, thereby reducing light penetration into the water column and affecting the growth of seaweeds. Furthermore, there is always some physiological stress on these algae due to fluctuating salinity, as the mangrove environment is bathed between seawater and freshwater. However, some red algae belonging to the genera *Bostrychia, Caloglossa, Catenella, Murrayella* and *Gracilaria* constitute the unique algal vegetation of this environment. Sometimes thick carpets of green algae like *Caulerpa* and *Cladophorophis* grow on the mangrove mud under the shade provided by the mangrove canopy. But poor growth of such algae is a common feature in the interior mangrove areas because of very heavy shading of the mangrove thickets and relative stagnation of water.

In places of little or brief exposures of the mangrove environment, species of *Bryopsis, Caulerpa, Ceramium* and *Polysiphonia* are present. These are filamentous, richly branched, very finely dissected and delicate. On the roots of mangrove plants, especially the prop roots, a dense mat of algae develop, protected from excess light and desiccation by the overhanging leafy branches. In addition, these algae have water-holding spongy mass of intergrown branches to escape desiccation. In all, the best developed mangrove algal flora are found in the West Indies, in contrast to the poorest development found in tropical Pacific Mexico (Dawson, 1966).

Zonation of algae in the mangrove environment is governed by tides. In the supra-littoral fringe where the tidal influence is negligible, no algae are found. In the mid-littoral zone where the tidal influence is moderate, lesser number of algae (*Chaetomorpha* sp.) are present. In the infra-littoral fringe which is frequented by tides, algal vegetation is rich and is composed of mostly red algae such as *Caloglossa, Catenella, Bostrychia* and *Polysiphonia* (Umamaheswara Rao, 1987).

On the East coast of India, the Pichavaram mangroves represent a heterogenous assemblage of plants with a striking seasonal distribution of algae (Muthukkannu, 1983). During the post monsoon season, when the salinity is low, algae occur abundantly, depicting richness and diversity (*Enteromorpha clathrata, Padina gymnospora, Rosenvingea intricata* and *Hypnea cornuta*).

During the summer season when the salinity is high, these species disappear. Algae such as *Bostrychia radicans* and *Caloglossa leprieuri,* occurring on the roots of *Rhizophora* and *Avicennia,* are found distributed throughout the year during all the seasons by showing tolerance to fluctuating salinities. Scattered distribution of *Cladophora glomerata* is found near the freshwater regions of the mangroves. In the Godavari estuary, green algae (species of *Chaetomorpha, Protoderma* and *Phaeophila*) and red algae (*Caloglossa leprieuri, Bostrychia tenella* and *Catenella impudica*) and common and they show a preferential distribution in low salinity (Umamaheswara Rao, 1987).

On the West cost of India, Nair *et al.* (1982) have studied the macro algal composition of the Ashtamudi estuary with the dominance of greens (*Ulva lactuca, Enteromorpha linza, E. flexuosa* and *Cladophora* spp.) and reds (*Caloglossa leprieuri, Polysiphonia* spp., *Hypnea* spp. and *Gracilaria* spp). Occurring in a salinity range of 10 to 35%. Algae of the mangrove regions of Goa are rich and varied with about 44 species (Jagtap, 1985), dominated by green algae followed by red and brown algae.

Salt marshes lying in the mangrove environment are subjected to partial inundation and the channels of the marshlands serve as a good habitat for many algae such as *Enteromorpha, Ulva* and *Rhizoclonium.* In New Zealand, the marsh fucoid, *Harmosirsa* lives either free in the marsh, rising and falling with the tides or embedded in the mud.

Mangroves are in close association with seagrass and coral reef ecosystems. Coral reefs are the spawning grounds of many fishes, and seagrass beds are important feeding grounds for fishes which seek refuge as juveniles in the mangroves (Rajeshwari, 1991). These ecosystems are interlinked by many important functional processes. Fortes (1990) has established this fact and has found that there is significant energy input from one ecosystem into the other in the form of material exports. He has estimated that the net export of organic matter from the mangroves to the seagrass ecosystems to the nearshore areas is 15g/sq. m. He has also shown that there are many inter-habitat similarities with fish (27 to 52%), crustacean (21-63%) and algal epiphyte (28%) populations between the mangrove and seagrass ecosystems.

The importance of seagrass meadows in the coastal marine environment has been elaborated by Kannan and Veluswamy (1989). Seagrass ecosystems are highly productive and dynamic with more of N_2 fixation. They stabilise the bottom sediments by trapping the sediments. They improve the water clarity and quality to acting as a filter system for various pollutants, including heavy metals. They form the direct source of food for many marine animals, including the economically important ones. In addition, they provide important habitats and shelter to a variety of marine animal species and thus very close to the shore in mangroves and seagrasses. By the transport of organic matter in the form of seagrass detritus, nutrients may be lost, but replenishment takes place in the seagrass ecosystems through capturing nutrients from ambient waters.

One the East coast of India, Rajeshwari (1991) has reported the monospecific and mixed occurrence of seagrasses, viz. species of *Cymodocea, Halophila, Syringodium* and *Thalassia* from the Gulf of Mannar area. Veluswamy (1985) has recorded the occurrence of *Halophila ovalis* and *Halodule pinifolia* in estuarine and mangrove environs of Porto Novo. On the West coast of India, Jagtap (1985) has studied the seagrass distribution in the mangrove areas of Goa. *Halophila baccarii* is rich and distributed throughout the year as compared to *H. ovalis*, and the seagrass populations tend to disappear from monsoon onwards due to erosion, low salinity, low intensity of light and high turbidity.

Seagrass ecosystems are the most critical and linked habitats in the fisheries production as they are sandwiched between the mangroves and coral reefs (Rajeshwari, 1991). Such coral reefs also support a good growth of seaweeds. *Halimeda opuntia* is the predominant calcareous green alga, and species of *Caulerpa, Sargassum, Amphiroa* and *Gracilaria* are the other dominant forms in the coral reef areas (Project document of the Ministry of Environment and Forests, Govt. of India, 1987).

Due to various demographic pressures, the mangroves and their associated ecosystems face a World-wide threat of denudation. When the mangroves such as *Rhizophora* and *Avicennia* are removed, the rich epiphytic growth of *Caloglossa, Bostrychia,* species gets disturbed and they disappear in due course. Thick carpets of algae growing on the mangrove muds under the shade provided by the mangrove canopy also disappear due to excess light and desiccation. When the channels of the mangrove marshlands are disturbed for industrialisation, crop cultivation and human inhabitation, the fine habitat of many important algae (*Ulva, Enteromorpha, Rhizoclonium,* etc.) gets destroyed due to the concomitant loss of natural resource.

However, cultivation of algae in abandoned and discussed mangrove fish ponds can be undertaken, for there is a great demand for seaweed colloids which are used as stabilisers and emulsifiers in the manufacturing industries. Further, there is always an important market for edible seaweeds as they form the basis for many traditional recipes for soups, salads and desserts.

The green weed *Caulerpa* is cultivated in the Philippines in the abandoned mangrove areas for its edible nature. It is highly suitable for cultivation in the clear-felled areas because it can tolerate poor water circulation and low nutrient levels (Fortes, 1979). The red weed *Gracilaria* is cultivated in the disused mangrove fish ponds previously stocked with milkfish in Taiwan for it is a good source of agar and it can tolerate estuarine salinities ranging from 8 to 25% (Chen, 1976).

In recent times, the mangrove environment is also getting polluted with different kinds of contaminants. Heavy metals pose a serious problem due to their environmental persistence and toxicity to marine organisms even at a lower concentration. Hence it is very important to monitor the heavy metal pollution of taking suitable managerial measure to protect the valuable resources. Physical and chemical monitoring will help quantify the pollutants, but the biological monitoring will be rapid and reliable and can detect even the subtle changes taking place in their immediate environment through changes in species composition, diversity and biomass increase. Among the different biological indicators, seaweeds can be employed successfully for monitoring heavy metal pollution in the mangrove environment as they are the 'sentinel' organisms for heavy metals and their bioaccumulation is several thousand times with respect to water concentrations.

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MANGROVE FAUNA OF SUNDERBANS : ECOLOGICAL FEATURES AND UTILISATION

P.V. DEHADRAI

INTRODUCTION

Mangroves are low-lying coastal vegetation, their adaptation alongwith other flora and fauna is very much interesting. Tidal rivers and seawater inundate the flat low lands and lagoons, which are the characteristics of halophytic adaptation. Coastline of India extends over 7,000 km. The states of West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, on the Eastern seaboard whereas Kerala, Karnataka, Goa, Maharashtra and Gujarat occur on the Western Seaboard. The coastal areas are highly variable in relation to soil characteristics, and water resources, but not the least to their typical flora and fauna. Mangroves act as buffer between land and sea prevent the coastal lands from erosion and help in controlling the balance of eco-climatic factors. Besides all these, they also provide fish protein to the urban areas.

The coastal vegetation, especially the mangrove, serve in two ways : (a) fulfilling the energy requirement of the local population and (b) acting as a huge sink of unlimited capacity for absorbing pollutants from air and water which makes the surrounding environment free from pollution. The metropolitan and industrial discharge containing nickel, chromium, chloride and excess nutrients like nitrate and phosphate alongwith high alkalinity act adversely on phytoplanktons and ultimately affect the higher plants and animals.

Ruthless human and other biotic interferences are by and large responsible for decreasing the water flow through the rivers resulting in silting up of the estuarine rivulets and disconnecting the main flow of the rivers. This causes adverse effect on the natural growth of mangrove ecosystems and reduces crop yields, hamper navigation, influence the water circulation and growth of aquatic life. It is felt that the deterioration of these tidal mangrove forests has resulted in frequent natural calamities along the coastal areas, causing enormous damage to life and property.

This paper highlights some of the ecological features of mangrove environment, with particular reference to Sunderbans and efforts taken by both, national and international agencies for preservation of diversity of plants and animals from this unique environment.

MANGROVE FAUNA : ECOLOGICAL FEATURES

Being a very specialised environment, mangroves of Sunderbans support a wide assemblage of animal communities and are the abode of many groups of animals which are endemic to them. In addition to these, several other faunal groups visit this zone to feed and/or breed but live elsewhere and some others use this habital for shelter and/or roosting.

The major faunal components of this ecosystem are of three types, viz. (a) terrestrial, (b) brackish-water, and (c) marine. In other words, three different biomes, namely littoral or supra-littoral forests, Intertidal mud-flats and estuarine regions, are occupied by the mangrove related fauna.

Aerial and arboreal forms, in addition to soil inhabitants form a major component of littoral or supralittoral forest biome which is essentially a terrestrial environment. Arboreal animals and soil dwellers are also categorised as epifauna and infauna respectively. Intertidal mud-flats are essentially semiterrestrial or semiaquatic habitats which mainly support soil forms and the benthos. Aquatic forms such as planktons and nectons form the major elements of estuarine region.

The pattern of distribution of these animals in mangrove ecosystems is influenced by substratum, salinity, tidal amplitude, vegetation, light and temperature, etc. Various species of plants of mangroves form the source of shelter and food for many of these fauna and some of the aspects of these associations in addition to details on the faunal types, are summarised as follows.

COMMON INSECTS

The common honey bees in the Sunderbans tidal forests are *Apis dorsata* (rock bee) and *Apis mellifera* (European bee). *Aegiceras corniculatum, Excoecaria agallocha* and the members of the family Rhizophoraceae, Sonneratiaceae and Avicenniaceae are the important honey producing plants of the Sunderbans. Flower Nectar is an important source of commercial honey, and the *Apis* spp. collect honey from these tidal forests during the main flowering season, i.e., from March to May.

The weaver ants, *Oecophylla* spp., are very common on the mangrove trees belonging to the families Rhizophoraceae and Avicenniaceae. *Anopheles* (*Myzomyia*) *indigo, A. sundericus* and *Culex fatigans* are common mosquitoes found throughout the coastal strip of the Sunderbans. *Aedes butleri* and *A. niveus* are some usual insects of these mangrove forests.

MOLLUSCS, CRUSTACEANS AND ANNELIDS

Several burrowing forms and climbing species - mainly crustaceans, a few bivalves, gastropods, balanus, crabs, worms and small insects are abundant in the tidal mangrove swamps of the Sunderbans including nematodes and small worms. The polychaetes (*Dendronereis* sp. and *Marphysa mossambica*) are widespread throughout the deoxygenated soils of the mangals (Macnae, 1968). The tube-dwelling polychaete is identified as *Dioptera cuprea cuprea* from the river-beds.

The fallen leaves of the mangroves provide shelter to the tiny gastropods like *Melampus* sp. and *Syncera brevicula*. On the sandy shore area, *Cardisoma carnifex* forms burrows. *C. hirtipes* occasionally comes in this estuarine water, where fresh water is also available. Mud lobster *Thalassima anomala* is present in waterlogged areas and on clay soils of the mangrove areas. It burrows in the river-banks, earthen banks or dykes causing soil erosion. The crabs *Sesarma fascinata* and *S. plicata* are found in the brackish water areas. *Uca lactea* is abundant in the landward regions. *Macrophthalmus depressus* takes shelter in wet sand and burrows in the mangals of the Sunderbans. The species *Telescopium telescopium* and *T. meuritsi* are abundant on soft mud, while *Cerithidea alata, C. djadjariensis, C. cingulata, C. obtusa, C. quadrata* and *C. weversi* are the climbing forms. Most of these species climb up and take shelter on trunks of the mangrove trees.

Among these gastropods, members of the families Potamidideae, Ellobiidae, Ochidiidae and Littorinidae are common in the mangrove areas inundated by frequent tides. *Balanus amphitrile* is the most common species in mangrove forests, and is seen colonising on tree trunks, prop-roots and on wooden structures on the riversides, which are very often inundated during high tides.The tiny crabs *Nanosesarma minuta* and the hermit crabs *Clibanarius longitarsus* climb on tree trunks of the mangals. Some of the common mollusc and crustacean orders/ families in the Sunderbans mangrove forests are: Neritidae, Littorinidae, Assimineidae, Rissoidae, Amnicolidae, Potamididae, Nassariidae, Ringiculidae, Ellobiidae, Oncididae, Osteodae, Teredinidae, Pholadidae, Dictocardiae, Taemioglossae, Cerithiidae, Veermetidae, Turritellidae, Strombidae, Lanthimidae, Cypraeedae, Turbinellidae, Mitridae, Olividae, Harpidae and Conidae.

AMPHIBIANS AND REPTILES

The most common and largest reptiles in the Sunderbans are *Crocodilus porosus* and *C. indigo;* these species are the 'top consumers' among the aquatic animals as they live on carnivorous fishes and sharks of the estuarine water. Other reptiles of the Sunderbans are *Varanus salvator, Batagur baska, Lepidochelys olivacea;* the common snakes are *Najas najas, Viper russel, Trimeresurus walgeri, T. purpureomaculatus, Bioga dendrophila, Fordonia leucoballa* and *Cerberus rhynehops.* As the crocodile population was gradually decreasing from the Sunderbans tract, a separate project was been launched at Bhagabatipur on crocodile breeding and rearing. For valuable hide, hunters are very much interested to kill reptiles from the core area. At present, the need for conservation of wildlife is felt and strict rules are enforced.

Among other amphibians, *Rana hexadactylla* (a brackish water species), *Bufo melanostictus* (the common toad), and *Rhacophorus maculatus* (tree frog) are very common. The last two species are found almost all over the Sunderbans during the monsoon season, i.e., from June to September. *R. hexadactylus* is generally found in peripheral zones of the Sunderbans.

BIRDS

Pillay (1954) has reported some fish-eating birds from the Sunderbans mangrove forests which are *Phalacrocorax niger, Anhinga melanogaster, Alcedo atthia, Actitis hypoleucos, Heliaster indus, Bubulcus ibis, Dicurus macrocercus, Ceryle rudis, Lobipluvis malabarica.* These birds prefer mangrove forests for abundant food potentialities and desolateness. Thousands of migratory birds visit the Sunderbans every year during the monsoon and post-monsoon months, and stay till September October. They come from far-away countries, like Siberia. The birds generally take shelter on lofty plants of *Excoecaria agallocha* and *Avicennia* spp. in the Pankhiralay area of the Sunderbans during the evening, and move throughout the forest during day-time for their food, i.e., fishes and other mangrove fauna. During their stay these migratory birds breed and rear their young and fly away to other places with the onset of winter. About 24 migratory birds have been identified from the Sunderbans habitats, so far, viz., *Phalacrocorax niger* (Little Cormorant), *Platalea lenocorodia* (Spoonbill), *Grus antigone* (Sarus Crane), *Sterna aurantia* (River Tern), *Phoenicopterus roseus* (Flamingo), *Netta rufina* (Red Crested Pochard), *Botaurus stellaria* (Bittern), *Ardea cinerea* (Grey Heron), *Nycticorax nycticorax* (Night Heron), *Threskiornia aethiopica* (White Ibis), *Anas strepera* (Gadwall), *Anas poecilorhyncha* (Soft Bill Duck), *Anhinga melanogaster* (Snake Bird), *Alcedo meninting* (Blue eared Kingfisher), *Tringa nebularia* (Green Shank), *Podiceos ruficollis capensis* (Dabchick), *Anas platyrhynchos* (Mallard), *Anaxtomus oscitans* (Open Bill Stork), *Ardeola grayii* (Pond Heron or Paddy Bird), *Porphyrio poliocephalus* (Purple Coot), *Sarkidioruis melanotoa* (Comb Duck), *Anas acuta* (Pintail), *Fulica atra* (Coot) and *Ardea alba* (Large Egret). Their faecal matters enrich the water and soil of the Pankhiralay area shelter of these birds. Cormorants are characteristic species in rivers and estuarine areas of the Sunderbans. The *Anhinga* sp. are abundant in larger rivers and deltas but occasionally enter the pure marine channels of the mangals. Heron and cormorant dwell on the riversides and on fishing grounds. Most of these birds are large-sized and they eat fishes and crabs or molluscs throughout the day and take shelter at night on the branches of mangrove trees.

MAMMALS

Among mammals, the World-famous Royal Bengal Tiger (*Panthera tigris tigris*) is the most dominant here. About 280 tigers dwell in mangrove forests of the Indian Sunderbans (according to the 1986 census); the figure was 264 during 1983. These mangrove-inhabitant tigers solely depend on the Chital deer (*Axis axis*), wild boars (*Sus scrofa*) and water monitors (*Varanus salvator*). These mangrove tigers also eat cat fishes and crabs. According to the scientists of the Tiger Project, development of the Sunderbans mangrove forest solely depends on proper conservation of tigers; being the top consumers, they maintain the ecological balance in the mangrove forests.

Next to the tiger, the most important wild animal in the Sunderbans is Chital deer (*Axis axis*) with an estimated population of 1300. They prefer *Porteresia coarctata*, a wild variety of salt tolerant rice and sometimes graze on the leaves of *Avicennia* spp. and several other mangrove plants. They can run fast and can also swim equally fast across tidal rivers and creeks. *Platenista gangetica* (Dolphin) is also very common in this estuary and this species solely depends on the euryhaline fishes and prawns. The common mangrove monkeys in the Sunderbans are *Macaca mulatta*, which feed on mangrove fruits and leaves and even on rhizomes of riverside grasses and sedges. The other mammals in the Sunderbans are *Felis viverrima* and *Herperstes* sp., which live on birds and fishes. Otters (*Amblonyx cinerea* and *Lutra perspicillata*) are also present which are fish eaters and occasionally feed on smaller animals. With the recent setting up of the Tiger Reserve Project, wildlife of Sunderbans is now kept under strict conservation laws.

UTILISATION OF MANGROVE FAUNA

The tidal creeks, rivers, canals and lagoons of the Sunderbans continuously supply an enormous quantity of fishes and other crustaceans. The fish-fauna either spend all their life-cycle or a part of it in this estuarine environment, as both the marine and freshwater fish species migrate seasonally into or through this estuarine system. In the Sunderbans water, over 120 euryhaline fish species are caught in the commercial catches.

Among the various fishes, Clupeids like *Hilsa hilsa* constitute an important segment in the Sunderbans delta. Other examples are *Hilsa tolley, Harpodon nehereus, Liza* spp., *Mugil* spp., *Lates calcarifer*, cat fishes *Tachysurus, Pangasius* and *Mystus* spp. Smaller clupeids and scianeids are abundant and are caught in considerable quantities, which have a good demand in the local markets. Among them *Penaeus monodon* occupies the attention of most of the fish traders for its high export potentialities. Jumbo shrimp or *P. monodon* has helped in all round economic development of the Sunderbans delta to a great extent in recent years.

Plenty of crabs belonging to different genera and species are available in the Sunderbans region, but economically important ones are *Scylla* and *Neptunus* spp. *Scylla serrata* (Forsk) and *Neptunus pelagicus* (L.) are the two common edible and economically important crabs of the Sunderbans water systems.

CULTURE POTENTIALITIES OF SOME IMPORTANT FISHES AND PRAWNS

Among the culturable fishes, mullets and tiger shrimps are the most important members in the Sunderbans. These are cultured in about 2,500 small to large-sized brackish water fisheries. Some of the most important culture practices are as follows :

Mullet culture

Several species of grey mullets belonging to the family Mugilidae are distributed throughout the mangrove swamps of the Sunderbans. The juveniles of mullets enter these estuaries alongwith the tidal water but adult mullets migrate towards the bay for spawning (Jhingran, 1982). The tropical mullet species belonging to the genera *Liza, Mugil* and *Rhinomugil* are also suitable for culture in the mangrove-associated areas of the Sunderbans (Charkraborty, 1981). Pillay (1954) has mentioned that fishes of *Liza* group are most suitable for culture in the brackish water fisheries because of their intimate association with the mangroves. Possibilities of potential yield from intensive mullet farming in mangrove-associated brackish-water fisheries the Sunderbans were worked out by several cultural trials with *Liza* spp. and *Mugil* spp.

Prawn/shrimp culture

The genera *Penaeus* and *Metapenaeus* are commercially important prawns in the Sunderbans. Adult penaeid prawns migrate towards the sea for maturation and breeding and in their post-larval stage, return to the mangrove forests which serve as nursery beds (Chakraborty *et al.*, 1981). Post-larvae of prawns occur almost throughout the year in the mangrove estuaries, though the abundance fluctuates seasonally.

Predators in the fisheries

Among the marine predator fishes in the Sunderbans the common species are sea-perch (*Lates calcarifer*), nappers (*Lutianus argentimaculatus*), tarpen (*Megalops cyprinoides*), ten pounders (*Elops saurus*), cat fish (*Arus* and *Plotosus* spp.) and Pungas (*Pangasius pangasius*). These predator fishes utilise these mangrove swamp forests for their food and shelter; they have cultural potentiality in addition to supporting important inshore fishing (CMFRI Annual Report, 1978).

Mudskippers

Mudskippers such as *Boleopthalmus* and *Periophthalmus* spp. are very often seen in the mud-flat areas of the Sunderbans mangrove forests. These fishes have not much potential in the Sunderbans as well as other parts of India as these are low-valued fishes.

FISH SEED PROSPECTS IN THE SUNDERBANS

For brackish water prawn and fish culture in the paddy-fields and brackish water fisheries of the Sunderbans delta, demand for prawn and fish seeds is increasing rapidly. The tidal rivers and creeks of the Sunderbans carry a huge quantity of prawn and fish seeds and these are autostocked in the fisheries with the intake of tidal river water during the high tidal flow. But for making more profit, fish seeds are stocked by purchasing from local fish seed markets. To meet this rapid growing demand for prawn and fish seeds, the rural people of the Sunderbans especially from the local fishing communities, are largely engaged in collecting *P. monodon* and *L. parsia* seeds from the estuaries during the tidal flow of lunar phase with the help of self-made nylon nets of different shapes and sizes. After selection of the desired *P. monodon* larvae they destroy the other fish juveniles indiscriminately, which affects the ecology as well as the distribution of natural sources adversely. About 20-50% of the larvae are destroyed during handling and transporting. From the Sunderbans, 10-14 metric tonnes of fishes and crustaceans are captured every year (CMFRI Report, 1984). Therefore, to overcome this casualty, well-managed fish and prawn seed trading, including improved methods of collection, segregation, transport and minimum disturbance to the ecology and to other fish seeds or juveniles, is necessary for this deltaic region.

In recent years brackishwater aquaculture practices are helping one to earn foreign exchange in addition to meeting the local demand for fish protein. These cultural practices have provided employment facilities to the rural people in the Sunderbans delta in addition to utilising available resources where other means of agriculture are not much profitable or not possible.

EFFORTS FOR PRESERVATION

The International Union for Conservation of Nature and Natural Resources (IUCN) expressed the need for conservation of some endangered mangrove fauna like *Batagur baska, Chelonia mydas, Lepidochelys olivacea, Python molurus, Bretmochelys imbricata, Falco peregrinus, Panthera tigris,* and *P. pardus.* After imposing strict rules and with the initiation of 'Tiger Reserve Project', and 'Crocodile Breeding and Rearing Project' in the Indian Sunderbans. The wildlife especially the Royal Bengal Tigers, Chital deer and estuarine crocodiles, are now conserved and protected, as tigers in land and crocodiles in water are the two top consumers of the mangrove ecosystem of Sunderbans. These projects are also looking after the breeding and conservation of many other endangered animal species like large sea-turtles, king crabs, etc. Conservation of these top consumers in the Sunderbans delta is necessary to keep the ecosystem in balance, as the food waves follow some definite pattern and disturbance in the intermediate stages can upset the entire ecosystem. Besides tigers and crocodiles, some other important and endangered fauna like *Carcinoscorpis rotundicauda* and *Tachypleus gigas* are included under the research programme of the Tiger Reserve Project. Several recommendations pertaining to the conservation of the mangrove flora and fauna are based on sound ecological considerations of the Sunderbans delta forests both in the Indian territory and in Bangladesh. (Chakraborty, 1984).

DISCUSSION

With the increase in industrialisation, urbanisation, and modernisation of agriculture most of the coastal ecosystems are facing threat of extinction. Sunderbans the largest of all mangrove forest areas in India, is no exception to it. With the stresses on the environments of this kind and irrational utilisation of natural resources, there is an urgent need to develop a proper, implementable management plan in addition to what is already being done both by national and international agencies for conservation of biodiversity of Sunderbans.

It is therefore felt that this biosphere reserve needs immediate attention for protection, conservation and more importantly, ecologically friendly production intensification of the natural resources.

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FAUNA OF MANGROVES AND ITS MANAGEMENT

AJAI SAXENA

INTRODUCTION

Mangrove forests represent a highly specialised and complex ecosystem occurring in sheltered coastal areas of tropics and sub-tropics. These are highly productive and economically very important. In addition to their role as a buffer between the land and the sea, the mangrove ecosystem contains rich diversity of faunal elements and acts as a nursery for many varieties of economically important fish species and other marine organisms.

Considering their role in checking soil erosion, producing economically important products such as timber, fuel wood, fish and other marine products, proper conservation of mangroves has become very important. There is an urgent need to manage this fragile ecosystem on a sustainable basis. Uncontrolled utilisation may lead to the destruction of mangrove forests, which in turn will lead to manifold damage to the coastal agricultural land as well as fisheries. The impact of such damage will be far greater on small islands such as Andaman & Nicobar, which have limited agricultural land and are exposed on all sides to the sea.

In Andaman and Nicobar, mangrove forests are found in sheltered tidal creeks, channels and bays. They constitute 9.4% of the land area and about 10.95 of the total forest cover of these islands (Bandyopadhyay, 1991), covering about 77,769 ha. In all, 34 mangrove plant species have so far been identified from these islands, out of a total of 46 mangrove species occurring in the Indian subcontinent. This species diversity makes Andaman & Nicobar Islands the richest area of mangrove species in india (Rajpurohit, 1989). The faunal elements of mangroves are still more diverse, and yet to be explored on a full scale.

FAUNA OF MANGROVE

The mangrove ecosystem comprises and Intertidal area having creeks, channels, mud-flats, rock/coral reef flats, estuaries, etc., which provide varied habitats for a variety of animal and plant species. Due to tidal action and mixing of fresh water with saline water, this ecosystem harbours highly specialised fauna and flora.

The faunal communities of a mangrove ecosystem can be broadly divided into the following categories:

a. Aquatic,
b. Semi-aquatic and
c. Terrestrial.

AQUATIC AND SEMI-AQUATIC FAUNA

The Intertidal area and the muddy-sandy floor of bays and creeks provide rich and varied habitats for a host of marine organisms. These aquatic and semi-aquatic marine organisms are called benthos which are broadly sub-divided into the following:

a. Micro-benthos – Organisms of a size smaller than 40 μ, such as planktons.

b. Meio-benthos – Organisms larger than 4 μ, but smaller than 60 μ, such as nematodes, Copepodes, archeannelids, polychaetes, etc.

c. Macro-benthos – Organisms larger that 60 , such as polychaetes, molluscs, crustaceans, echinoderms and fishes.

Although micro-benthic organisms of the mangrove of these islands have not been studied fully, extensive studied have been made of meio and macro-benthic fauna of these islands. In all, 53 species of meio-benthos have been reported so far, while the list of macro-benthos includes 8 species of ploychaetes, 100 species of molluscs, 59 species of crustaceans, 6 species of echinoderms and 2 species of sipunculids. Of fishes, 24 species have so far been recorded from mangrove; of these islands. The most noticeable amongst fishes are mud-skippers (*Periophthalmus* and *Boleopthalmus*)

TERRESTRIAL FAUNA

The rich floral diversity of mangrove forests, along with its associated aquatic and semi-aquatic fauna elements, attracts a large number of terrestrial animal life-forms. Many of these terrestrial faunal elements are residents of mangrove forests, while some of them, especially birds and reptiles, come to such area during low tide for feeding on exposed mud-flats and tidal pools. The major terrestrial faunal elements can be grouped as follows:

INSECTS: Many varieties of insects have been found associated with mangroves. Most of them utilises mangroves for food or shelter or both. While for mosquitoes and sand-flies, they provide and ideal breeding ground, many host-specific, gall, causing insects and mites have also been found associated with mangroves. In all, 97 species of insects, mostly coccids, mosquitoes, biting midges, beetles, termites, ants, honey-bees, bugs and bores have been reported form the mangroves of these islands.

AMPHIBIANS: They are poorly represented and only 3 species have been found from mangroves.

REPTILES: They are represented by salt water crocodile (*Crocodilus porosus*) Andaman water monitor lizard (*varanus salvator andamanensis*), *Calotes* sp., dog-faced water snake (*Cerberus rhynehops*) and pit viper (*Trimeresurus* sp.). During low tide, water snakes are seen actively feeding on crabs and fishes, especially at night.

BIRDS: Mangroves provide food, roosting and nesting places for many varieties of birds. During low tide, waders can be seen feeding actively on exposed mud-flats. In all, 53 species of birds have so far been reported from the mangrove areas. These can be broadly grouped into the following:

a. Water birds/waders : Such as herons, egrets, bitterns, sandpipers, plovers, snipes, etc. (13 sp).

b. Kingfishers : These are most noticeable in the mangroves of these islands. All the 8 spp. of kingfishers reported form these islands are associated with mangroves. Ruby kingfisher (*Halcyon*

	coromanda mizorhina) and stork-billed kingfishers (*Pelargopsis capensis osmastoni*) are more closely associated with the mangrove.
c. Fruit-eating/Insectivorous birds :	Pigeons, parakeets, lorikeets, crow-pheasant, swiftlets, woodpecker, orioles, drongos and mangrove whistler frequent mangroves in search of food and shelter.
d. Predatory birds :	sparrow hawks, crested serpent eagles and white-bellied sea eagle also frequent mangroves, of which the most common one is sea eagle, which can be seen fishing in mangrove-fringed creeks.

MAMMALS

These islands are poorly represented by land mammals, due to isolation in the past. But species such as wild pig (*Sus scrofa andamanensis* and *S. s. nicobarica*), crab-eating macaque (*Macaca fasicularis umbrosa*), civet (*Paguma larvata tytleri*), spotted deer (*Axis axis*) and a few species of bats (*Pteropus* and *Cynopterus*) have been found utilising the mangrove habitats.

THE VALUE OF MANGROVE ECOSYSTEM

The varieties of plant and animal life-forms found in the mangrove ecosystem are closely interdependent. Even in the seemingly harsh physical environs, where mangroves and their associates occur, close inter-relationship between the plant and animal life-forms has created one of the most productive ecosystems in the World. This has resulted in a rich biodiversity and highly efficient ecosystem, where every inch of the physical substratum is used and nutrient recycling is done most effectively through closely linked biological and geochemical cycles.

Furthermore, mangroves form, mangroves form varied and critical habitats, which need conservation for the sustainable use of their many valuable products such as fishes, crustaceans, reptiles, insects, timber and other wood products. There are various linked habitats which are critical from the conservation point of view in coastal wetlands including mangroves. Following is one line of action for preserving these unique areas.

MANAGEMENT OF MANGROVES AND COASTAL WETLANDS

Considering various critical habitats and their interdependence, the coastal wetlands must be properly studied and monitored. Effective management of such ecosystems can be done through proper zoning and their utilisation is to be regulated. Following steps are required for designing a mangrove/coastal wetland, or a protected area :

STEP I. Identifying critical habitats to determine core zone.

STEP II. Identifying neighbouring habitats to determine protected area boundary.

STEP III. Identifying linked habitats to determine buffer zone boundaries.

Such protected areas, having well-designated zones for achieving various objectives, such as strict conservation, regulated use etc., will help in conserving mangroves and other coastal wetlands and at the same time will provide the well-needed economical benefits on a sustainable basis. In

Andaman and Nicobar, a Marine National park at Wandoor, Lohabarrack Crocodile Sanctuary and North Reef Sanctuary have been created to protect coastal wetlands, including mangroves and their linked habitats. The Marine National Park is constituted to conserve and protect the fragile reef ecosystem and coastal area. The other secondary but equally important aspect of the Marine National Park is to provide facilities for conducting basic research on various aspects of marine and coastal ecosystem, tourism, education, interpretation and recreation. Habitat improvement works, such as water conservation measures on bigger islands and enrichment planting, especially in deficient mangrove areas, are taken up (Sinha *et al.*, 1991).

MANAGEMENT OBJECTIVES

The following main management objectives can be listed for the mangrove/coastal wetland protected areas (Salm and Clark, 1989):

1. to preserve a sufficiently large representative sample of ecosystem and its linked habitats for conserving its genetic diversity,
2. to main the values of the areas for resident and migratory species,
3. to maintain the value of the area as a nursery and feeding ground for various commercial fishes and other marine species,
4. to check encroachment of valuable and critical habitats,
5. to enrich the deficient areas and depleted species, through better protection and proper management techniques,
6. to conserve the ecological processes and life support systems,
7. to promote research, recreation and educate people about conservation values and related sustainable benefits to the society, and
8. to review and modify periodically the management techniques and objectives as per need, because the system as a whole is dynamic, and it requires various treatments at different stages of management.

CONCLUSION

Through a network of protected areas, conservation of mangrove and coastal wetlands will help in preserving the rich genetic diversity. Checking their further degradation and subsequent recovery, as well as increasing the fisheries and other commercially valuable natural resources. This will lead to regulation and sustainable use of such renewable resources in the long run.

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PROPAGATION OF MANGROVES : SOME CONSIDERATIONS

K. KATHIRESAN

INTRODUCTION

Mangrove forests dominate one-quarter of the World's tropical coastline (Chapman, 1975). These forests are of great ecological and economic importance in protecting the shorelines and boosting the fishery production (Macnae, 1968; Krishnamurthy and Jeyaseelan, 1980). The mangroves are fast disappearing at a time when there are clear indications of potential changes in climate, sea level rise and influence of ultraviolet-β radiation (Swaminathan, 1991). India has lost 40% of its mangrove area over the past hundred years (Status Report, 1987). The mangrove forests will be denuded from most of the shorelines of India by the turn of this century (Roy Choudhury, 1990). The fast depletion of mangrove forests has already caused soil erosion and a significant fall in fishery production (Kathiresan, 1990). Hence there is an urgent need for propagation of mangroves to reforest and protect the coastal economy. This paper describes some methods involved in planning restoration programme.

SELECTION AND PLANTING OF PROPAGULES

Mangrove propagules (fruits and viviparous seedlings) of most of the species are not available throughout the year. The main fruiting or seedling season is from June to September, when plenty of propagules of *Rhizophora* and *Avicennia* can be collected (Muniyandi, 1985; Untawale, 1986). Selection of healthy propagules is an essential step, for which it is necessary to identify the degree of maturity of the stock. Propagules collected from the ground should be checked for their viability, while those from mangrove trees should be checked for maturity.

There are two ways of planting mangrove propagules, either by direct planting or by raising seedlings in the nursery (Untawale, 1986). Any Intertidal area can be selected for direct planting where the substratum is soft clay or mud and is inundated by regular tidal waters. The optimum conditions of the soil for better growth of mangrove seedlings are salinity (15–20 ppt) and pH (around 7) (Kathiresan and Thangam, 1990). Growing mangroves in nursery is a useful technique especially when mangrove species are not available in plenty. Nursery can be developed in the upper part of the Intertidal region (Untawale, 1986). Mangrove nurseries have been established in Goa and Maharashtra, as part of mangrove afforestation projects sponsored by UNDP/UNESCO. Mangrove plantation which was initiated during the year 1982 in the Sunderbans area has been successful with *Avicennia* spp., *Bruguiera gymnorrhiza, Ceriops decandra* and *Sonneratia apetala* (Roy Choudhury, 1990).

VEGETATIVE PROPAGATION

To overcome the problems of non-availability of propagules throughout the year and also the poor germination rate is some mangrove species, it was decided to undertake efforts for propagating mangroves either by vegetative methods or by using micro-propagation techniques. The response of stem cuttings in *Excoecaria agallocha* has been studied in laboratory conditions by using cuttings of different diameter sizes and from different portions (apex, middle portion and base) of the shoot. Application of plant growth promoters such as Indole acetic acid and Indole butyric acid has also been tried for studying the response of shoot cuttings (Patil and Dongre, 1991).

Air-layering involves rooting on the aerial part of a plant after the stem is girdled or slit at an angle and enclosed in a moist rooting medium. This technique has shown potential in *Avicennia marina, Aegiceras corniculatum, Sonneratia apetala, Excoecaria agallocha* and *Acanthus ilicifolius* (Deshmukh *et al.*, 1990). However, limitation in this technique is that large number of plants cannot be produced within a short time because of the availability of a limited number of stock plants in a given forest area. It also requires a lot of physical labour. To overcome this problem, micro-propagation can give desired results.

MICROPROPAGATION

The tissue culture has found wide application in several tree species, and use of this technique would have a great bearing on the propagation of mangroves. The serious constraint in this technique is the phenolic browning of mangrove explants (Kathiresan, 1990). This could be prevented by taking following precautions:

SELECTION OF EXPLANTS

Correct choice of the explant can have a important effect on the success of tissue culture. The explants which can be used for mangroves are shoot tips, axillary buds, leaf bases, leaf, petioles, hypocotyls, cotyledons, stem nodes, etc.

ESTABLISHMENT OF STERILE CULTURE

The explants have to be surface-sterilised with 0.1 % $HgCl_2$, and each of them has to be tested for latent infection of bacteria or fungi by growing them on standard media.

PREVENTION OF PHENOLIC BROWNING

Explants frequently turn brown or black shortly after isolation resulting inhibition of growth and eventual death of tissue. This may be attributed to the oxidation of phenolics. This problem can be overcome by

a. selecting young tissues,
b. soaking explants in running water or sterile water for a given period of time to remove phenolics,
c. soacking explants in antioxidants (ascorbic acid or citric acid),
d. infiltration of tissues using soluble polyvinyl pyrrolidone,
e. reducing sucrose or KNO_3 or Kinetin in the culture medium,
f. incubating cultures initially in the dark
g. culturing in liquid medium, allowing phenolics to leach out in the medium,

h. transferring of explants to fresh medium at very short intervals, and
i. supplementing the culture medium with glucose as carbon source or anti-oxidants like activated charcoal or ascorbic acid or polyvinyl pyrrolidone, (George and Sherrington, 1984).

CULTURE MEDIUM

For a plant part to grow in culture, it needs nutrients and hormones. Suitable media can be prepared for successful tissue culture. MS medium and vitamins of SH medium can be useful for the mangroves. The growth substances used at a range of concentrations from 0.1 to 10 mg/l include (a) Auxins - NAA, IAA, IBA, 2, 4-D, (b) Cytokinins - BAP, Kinetin, (c) Gibberellins - GA3 and coconut milk (10–20%).

ENVIRONMENTAL CONDITIONS OF CULTURE

Temperature, humidity and light conditions have to be standardised for ideal culture conditions.

MULTIPLICATION TECHNIQUES

The shoot tip or axillary buds can be induced to form axillary shoots on multiplication medium. The adventitious shoots can be induced directly on explants or on callus culture. The embryoids can be induced either on the surface of explants or callus tissue in solid or liquid media. Shoots or plantlets derived from the above can be induced for rooting on special medium.

Hardening of Plantlets

The plantlets should be transferred into a medium containing vermiculite and sand, and kept for several days in high humidity and reduced light intensity. After the hardening to exterior environment, the plantlets can be transferred to field conditions.

CONCLUSION

Like most of the other genetic resources connected with agriculture and forestry, the mangrove resources are also dwindling - yielding to population pressure leading to disappearance of many virgin mangrove areas from the coastal regions of India. Efforts related to identification of degraded areas and bringing them under mangrove vegetation are underway and several workers have successfully attempted and implemented largescale afforestation programmes. There is also an endeavour in propagation programmes. There is also an endeavour in propagating mangroves by artificial methods in view of which some suggestions are made.for modification in the techniques which are normally adopted during tissue culture.

Due to high concentrations of phenolic compounds, tannins and salts, the response of most of the mangrove species to tissue culture is very poor. It has therefore been suggested to adopt strategies during various stages of this technique which after success, would help one to undertake largescale eco-redevelopment programmes by using plantlets reproduced from genetically superior varieties by tissue culture.

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REGENERATION OF MANGROVES

P.V. SAVANT

INTRODUCTION

Increasing human pressure for domestic needs and developmental activities has virtually destroyed a sizeable area of virgin mangrove vegetation all over the World. Reclamation of mangroves for agriculture and housing, grazing, removal for fuel and poles, aquaculture, discharge of industrial effluents and excessive release of pesticides in the river systems have threatened most of the mangrove species. These degraded areas need to be restocked and fresh mud-flats need to be afforested with suitable mangroves. To achieve this, proper knowledge of the silviculture of mangrove vegetation, study of potential sites for afforestation vis-a-vis proper regeneration and afforestation techniques would be necessary, as also in-depth knowledge of mangrove ecosystem, in particular rare and endangered species.

The paper deals with the regeneration and nursery techniques of restocking degraded and fresh sites for increasing the area under mangroves.

SILVICULTURAL KNOWLEDGE

Amongst the mangroves, species like *Rhizophora* and *Bruguiera* are dominant with more than 75% of the composition. A sound silvicultural knowledge of dominant, co-dominant and rare species of mangroves is a prerequisite for tackling degraded and freshly formed sites. In addition, adequate knowledge on physiological and ecological aspects of the mangrove species of the area would be necessary. *Rhizophora* generally grows at the outer edge towards water front, where salinity is maximum, and wave action and wind pressure are extremely high. With its dense root system and prop roots, *Rhizophora* checks the soil erosion as well as protects other mangroves in the rear line, besides helping benthic fauna and other micro-organisms from being washed away. *Bruguiera* grows just behind *Rhizophora* line in the middle zone having deep soils where the impact of wave action and wind is at a reduced intensity. While *Bruguiera gymnorrhiza*, the tallest of all the mangroves suppresses the surrounding vegetation, *Bruguiera parviflora* -conspicuous with yellowish green foliage, forms a pure crop amidst the mangroves and reproduces profusely. *B. cylindrica* grows sporadically along with *B. sexangula* and *B. gymnorrhiza*. In the initial years *Bruguiera* needs shade, while *Avicennia* demands light. *Avicennia officinalis* grows gregariously upto ground. It produces seeds profusely; the seeds being light, float in abundance in the incoming tide. *Sonneratia apetala* is a gregarious species, and comes up well on pure patches in the new alluvial land along the river banks and estuaries. *Ceriops* and *Scyphiphora* spring up like a carpet in newly formed openings with deep mud and occasionally along the *Rhizophora* spp. at the outer edge. *Ceriops Sonneratia, Avicennia* and *Scyphiphora* grow in marsh with deep mud extending in upper stretches of tidal forests. *Kandelia candel* occurs upstream on banks of tidal rivers, while *Lumnitzera* occurs in marsh, sporadic in the rear-line. *Acanthus ilicifolius* occurs in dense patches towards landward side in stagnated saline water, which also produces prop roots smaller *Xylocarpus* spp. occur in the outer edges of creeks alongwith *Rhizophora* prominent with

GERMPLASM COLLECTION

To find out the adaptability of species from various mangrove regions, it is better to start with a new species in a mangrovatum. Before introducing new species, their behaviour pattern, growth pattern and tolerance limit to various parameters and complete data on their original habitat, such as light demander or shade bearer, salinity tolerance, tidal submersion limit, etc., should be studied in detail.

REGENERATION OF RARE SPECIES

Regeneration efforts for threatened and rare species need priority. As the availability of seed in case of rare species is scanty, the seedlings should be invariably raised in polybags.

CONCLUSION

Rare and threatened species of mangroves would be safe in virgin and undisturbed areas. In already threatened zone no new species should be introduced as this may disturb the original composition of the forest. Generally, introduction of new species could be tried along with dominant species on fresh site in a mixture. Unless the regeneration technique is perfected, it is dangerous to try threatened species directly in the field. Amongst threatened species, *Nypa, Xylocarpus* and *Heritiera* should be given priority during planting programmes. Some of the mangrove species occurring scantily along the East coast are found in sizeable proportions on the West coast. such deficit areas can be gradually revived by stocking these species. At the global level, conservation of representative germplasm collection of threatened mangrove species needs to be done in the quickest possible time for propagation purposes. Once the gene bank of threatened species is obtained in an adequate quantum, the endangered species could be gradually introduced in the field for maintaining biodiversity which would otherwise lead to the disappearance of endangered mangroves from the gene pool record.

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DEVELOPMENT OF AN INTERTIDAL MANGROVE NURSERY AND AFFORESTATION TECHNIQUES

ARVIND G. UNTAWALE

INTRODUCTION

Indiscriminate over-exploitation of the mangrove resources without any coastal land-use plan, has degraded this fragile Intertidal ecosystem in India (Krishnamurthy *et al*., 1987). Some of the major pressures are abiotic and biotic with special reference to the population pressure. All such activities, aptly called 'human interferences', have denuded the mangrove forests along the East as well as West coasts for the last few centuries (Blasco, 1975, 1977). Some of the impacts are depleting fishery resources, increased coastal erosion and harmful pollution levels (Untawale, 1986).

Silvicultural techniques like regeneration, restoration and afforestation of mangroves can be the only answers to these otherwise serious problems (Hamilton and Snedaker, 1984). Efforts have been made earlier in several countries to use various methods for improving the ecological balance of these degraded areas (Karim *et al*., 1984; Kogo, 1985, 1986; Kogo *et al*., 1986). In India also similar efforts were made but on limited scale and on short term basis (Mathauda, 1959; Untawale, 1986a, 1987; Jagtap, 1985). It has been estimated that approximately 100,000 ha of barren Intertidal mangrove area is available for afforestation programme along the Indian coast (Untawale, 1987a). Recently, Space Application Centre (SAC), Ahmedabad and Forest Survey of India have also studied such areas with remote sensing techniques.

Ecological studies for different mangrove regions along the East and West coasts of India have been made (Krishnamurthy *et al*., 1989; Untawale, 1986; Blasco, 1975, 1977; Wafar, 1987; Jagtap, 1985). Climatology, hydrology, e.g., tidal amplitude and inundation play an important role in the distribution and growth of mangroves. The zonation of species depend mainly on the salinity of the water. These data are of great significance in undertaking afforestation work. Very good case studies have been presented by Dexter, *et al*. (1986) and by Mohmad Nor *et al*. (1986) on the community based mangrove afforestation and the forest management.

MANGROVE NURSERY

Earlier attempts of restoration, regeneration and afforestation have been with direct planting of mangrove propagules or seeds (Kogo, 1985, 1986; Karim *et al*., 1984; Hamilton and Snedaker, 1984). There was, however, no attempt growing the seeds or propagules in an Intertidal nursery. Taking into consideration the non-availability of seedlings, distance of the transplantation sites and also the size of afforestation area, it was thought appropriate to develop an Intertidal mangrove nursery.

Following criteria were used for the site selection of a mangrove nursery:

1. Upper or middle intertidal region with gentle gradient, generally protected from the strong waves as well as currents,

Conservation of Mangrove Forest Genetic Resources : A Training Manual
Edited by Sanjay V. Deshmukh and V. Balaji.

2. Silty-Clayey substratum, and
3. Areas with daily tidal inundation and exposure.

After the site selection, necessary studies on water quality, sediment, tidal amplitude and the biota, etc., were made. This was followed by making a plan of the nursery like footpaths (or the wallboard raised above the water level), laying of beds with bamboo support, and working out other details. The beds were slightly raised with platforms of different sizes and supported with split bamboo on the sides to prevent possible drifting of the polybags. The polybags (20 cm x 10 cm) were kept ready with holes at the base, filled with mangrove soil and kept in upright position close to each other inside the bamboo-supported beds for plantation.

SOURCE OF PLANTING MATERIAL

There are different sources for collecting the mature propagules, seeds, etc. for largescale plantation. For collecting material at proper maturity, studies were undertaken for their distribution and fruiting season. This material was then collected from :

1. Naturally growing young (2 to 3 months old) seedlings. These can be directly transplanted at a permanent site.
2. Fully mature propagules, fruits or seeds from the trees, and
3. Nursery raised seedlings for transplantation.

NURSERY PLANTATION

Once the plantation material was carefully collected and transported to the nursery site,it was further sorted out to avoid injured, infected or tender propagules and seeds. Even the naturally grown seedlings with disturbed or broken root system were discarded. This precaution decreased the mortality rate and increased the survival percentage with good healthy growth. Even seedlings with insect borers' or foulers' attack were be avoided.

Such selected plantation material was taken to the beds. The mature propagules with tapering ends were gently pushed in the polybags up to 1/3rd or 1/4th of their length, while *Avicennia* fruits were pressed in the polybags filled with mud. Separate beds for different mangrove species were used. The number of polybags in each bed varied, depending on the area available and the requirement of the plantation material. A moderate mangrove developed nursery at Chorao Island, Goa had approximately 40,000 to 50,000 seedlings at a time.

Normally, all the seeds and propagules were found germinating with 95 to 100% success. However, different mangrove species showed variable dormancy periods. Rhizophoraceae propagules and *Avicennia* seeds grew quite rapidly, however, seeds of *Sonneratia, Heritiera,* and *Xylocarpus* took long time for germination. Many times it was found economical and time saving to pick up tiny seedlings of such species available in plenty in the mangrove swamps, during low tide, than waiting for their germination, artificially. There was no need for much aftercare of the seedlings in the nursery till they were transplanted.

TRANSPLANTING SEASON

Although the mangrove propagules and the seedlings can be transplanted throughout the year, it has been noticed that the seedlings transplanted during the rainy season, when salinity of water and soil is low, grow better with high survival rate. Attempts of afforestation made in the mesohaline and oligohaline regions with more freshwater influence and low salinity were successful. Use of appropriate species with suitable salinity tolerance range, was found to be the key to this success.

TRANSPLANTATION TECHNIQUE

Transplantation of mature propagules or nursery raised seedlings was comparatively easier in the soft, muddy substratum. However, the entire operation has to be completed during the short period of exposure, i.e., low tide. Before actual transplantation, the site was studied for its profile, tidal inundation levels, and substratum. The plantation pattern was then prepared on the basis of natural zonation and germination according to the tidal inundation. Simultaneously, field workers were taken to the site,and with the suitable low tide, transplantation work was undertaken.

The distance between both, rows and seedlings was maintained at 1 to 1.5 m. Holes were made with bamboo wherein the seedlings or propagules were pushed and the mud was strengthened. After completing about 15 rows, a gap of 10 m was left for future forestry operations or even fishing.

FINANCIAL ESTIMATES

There are different components involved in this programme as indicated below :

1. Research and Development work,
2. Salary of the staff (including labour cost),
3. Material cost,
4. Transportation cost (boat/vehicle), and
5. Maintenance cost.

Since the mangrove research and management is normally handled by the Government agencies, the expenditure can be reduced with long-term planning and the benefits expected. The entire programme can be a part of the Coastal Zone Management.

PROJECT IMPLEMENTATION AND EXTENSION

Once the basic concepts of the model mangrove nursery was planned, it was implemented with the help of the Forest Department of Goa Government at Chorao Island in the Mandovi estuary. Afforestation was with 85 to 90% success. Similar mangrove nurseries and afforestation programmes were extended to other adjacent States like Maharashtra under the social forestry activities.

PROBLEMS

Although there are no major problems envisaged at present, however, some minor problems were found to creep in for which solutions were found. Some of the problems experienced are described below :

MORTALITY DUE TO THE AFFECTED MATERIAL

The mortality was mainly because of selection or collection of injured, infected or tender seeds and seedlings. Needs proper care and training of staff.

ALGAL GROWTH

Dense mats of marine algae prevented growth or chokes the young mangrove seedlings. This can be solved either by manual clearing of algal mat or using 1 or 2 year old nursery raised seedlings, whose foliage would be beyond water column and prevent the seedlings from choking.

EFFECT OF SILTATION

Excessive siltation or turbidity resulted in sediments getting deposited on the foliage of young seedlings and thus prevented photorespiration. Gastropods eventually attacked and destroyed such seedlings. 1 or 2 year old nursery raised seedlings might minimise the problem.

AREAS WITH PROBLEM OF EROSION

On an open mud-flat where heavy erosion was observed, suckers of wild grass *Porteresia coarctata* was tried with great success for stabilisation of mud-flats. This can be followed by planting regular mangrove seedlings.

CATTLE GRAZING

This problem can be solved with regular patrolling by the supervisory staff.

FISHING ACTIVITIES

Operation of fishing nets usually damage the young seedlings. Education to the fisher folks can minimise the problem.

CYCLONES

The storms and cyclones with strong waves and winds can damage the mangrove nursery. It is therefore, advisable to have mangrove nurseries within mangrove forests. More studies are needed on this aspect.

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MANGROVES AND THEIR REHABILITATION FOR CONSERVATION

SUBRATA MAITY

MANGROVE ECOSYSTEM STATUS

An ecosystem, in general, is defined as the sum total of relationship of living and non-living components of a particular environment (Vannucci, 1984). Mangroves form one of the most productive ecosystems in nature. They import nutritional elements from the mainland and export these elements with or without modification to the sea. In spite of its multidirectional uses in various facets of human need, this ecosystem is under threat due to a number of factors, including commercial exploitation for fuelwood and timber, tannin, honey, etc., and also for agriculture, fishery, housing, building, ports, harbours, roads, industry, dams and barrages, sewage outlets, etc. All these factors have affected the mangrove vegetation of India and have reduced the area to a considerable extent (Mathauda, 1957; Waheedkhan, 1957); Sidhu, 1963; Blasco, 1977). The area under mangroves, which in the past was estimated to be 1.4 million hectares, has come down to 0.35 million hectares (Untawale, 1986). Not only the forest coverage but also the richness of Indian mangal species has come down from 63 to 48, and species like *Heritiera minor, H. fomes, Nypa fruticans, Bruguiera gymnorrhiza, Lumnitzera racemosa* and some spp. of *Rhizophora* are threatened due to random deforestation and other biological and environmental factors.

ARTIFICIAL REHABILITATION

An initial study for identification and characterisation of eight species of mangroves for their rehabilitation in the degraded forest land was undertaken. The propagules were collected from the nearby forests and planted on pre-sited soil of the trenches dug earlier. Morphological, anatomical and biochemical parameters during the growth phases were studied to analyse their establishment. The area was a representative zone and was polyhaline in nature and hence supposed to be an ideal habitat of most of the mangrove species (Untawale, 1986).

RESULTS

The species under study showed a clear *inter-specific* variation in their adaptability in the prevalent soil and exhibited differential response regarding growth and other parameters. *Avicennia alba* recorded maximum height (102 cm) at two year growth stage, followed by *A. marina* and *A. officinalis*, but *A. marina* produced maximum biomass due to more number of branches and foliage (Table 1). Maity and Maity (1989) also recorded the superior performance of the same species in a four year study on *Avicennia. Rhizophora mucronata* reached a height of 90 cm with an average of 10 nodes and 30 leaves. *Bruguiera cylindria* also recorded a height of 62 cm with 15 nodes and 29 leaves whereas *Ceriops tagal* recorded 31 cm length, 10 nodes and 15 leaves. Leaving *Avicennia* aside, *Rhizophora* recorded maximum rate of growth, followed by *B. cylindrica, B. sexangula, C. decandra* and *C. tagal*. Variations were also found in the case of nodes and leaves present on the main stem. This differential behaviour in their growth may definitely be accounted for their salt tolerance, and the character of enduring long periods of high salinity with little or no additional growth can be considered as a period of dormancy in growth phase (Greenway and Munns, 1980).

Table 1 Growth parameters of the species at different stages

Species	12 months		15 months		18 months		21 months		23 months	
	Pl.ht. (cm)	Br./ nodes	Pl.ht. (cm)	Br./ nodes	Pl.ht. (cm)	Br./ nodes	Pl.ht. (cm)	Br./ nodes	Pl.ht. (cm)	Br./ nodes
Avicennia alba	24.0	1.0	35.1	2.3	51.0	4.5	73.0	8.0	100.0	13.2
A. marina	25.0	1.0	31.6	2.3	40.9	4.6	65.6	7.5	10.2.0	11.0
A. officinalis	43.8	8.9 (5.8)	51.0	11.4 (7.1)	54.53	16.0 (9.2)	57.7	22.1 (13.1)	62.4	28.6 (15.7)
B. sexangula	25.5	10.8 (7.8)	31.9	13.3 (10.0)	35.8	17.0 (12.0)	39.2	22.3 (16.1)	42.5	25.3 (18.3)
Ceriops decandra	12.5	5.8 (4.6)	17.0	8.1 (6.1)	21.5	11.0 (8.1)	26.1	12.5 (9.0)	27.5	14.0 (10.0)
C. tagal	16.2	6.0 (4.2)	20.0	8.0 (5.9)	23.4	10.8 (7.8)	26.2	12.5 (8.9)	30.7	15.7 (10.8)
R. mucronata	68.1	10.2 (6.0)	75.1	12.5 (7.0)	81.8	14.4 (8.3)	88.1	16.2 (9.2)	90.3	18.1 (10.6)

Figures within brackets : Nodes with leaves

Table 2 Physical characteristics of the leaves of different mangrove species

Species	Mass (g)	Area (cm^2)	Thickness (cm)	Volume (cm^3)	Density (cm^3)	Stomata (no./mm^2)	Moisture (%)	Moisture retention	Surface volume ratio
Avicennia alba	0.361	7.57	0.038	0.287	1.257	295.1	62.5	50.0	26.37
A. marina	0.322	7.01	0.039	0.273	1.179	202.5	70.7	32.3	25.67
A. officinalis	0.758	19.94	0.044	0.877	0.864	242.8	67.1	43.7	22.70
B. sexangula	0.624	12.97	0.045	0.583	1.070	91.1	69.1	35.4	22.24
Ceriops decandra	0.663	10.05	0.047	0.472	1.404	175.1	73.1	77.8	21.29
C. tagal	0.706	12.27	0.048	0.588	1.200	183.0	71.0	61.3	20.88
R. mucronata	1.940	30.30	0.061	1.848	1.049	108.7	67.8	60.1	16.40

Efficient establishment of plant community depends primarily on ecological and physiological means of adaptation. *Rhizophora* exhibited maximum values in respect of mean mass of leaf, leaf area, thickness, volume, moisture content and moisture retention capacity, followed by *B. cylindrica* and *A. officinalis* (Table 2). The stomatal frequency and relative surface areas were high in *Avicennia* species but very low in *Rhizophora*, which indicated their better adaptive potentiality.

The cuticular thickness with the deposition of waxes which is the xerophytic feature of the plant, possesses a great adaptability under salinity. The present study depicted an *inter-specific* variation in this feature. *R. mucronata* recorded 10.6 μ of cuticular thickness and A. marina 6.6 μ (Table 3). In addition to cuticular thickness, succulency, which was determined by the number of cells

Table 3 Thickness of tissue layers (μ) in leaves of some mangrove species

Species	Cuticle (%)	Epidermis (%)	Hypodermis (%)	Pallisade (%)	Spongy (%)	P/S	Total green tissue (%)	Epidermis (%)	Total leaf thickness
Avicennia alba	6.6 (1.7)	19.4 (5.0)	129.9 (64.5)	110.9 (28.8)	94.3 (25.0)	1.18	205.2 (53.8)	18.6 (4.8)	379.7
A. marina	7.4 (1.9)	16.01 (4.0)	90.4 (22.9)	185.5 (41.9)	120.0	1.55	305.5 (69.9)	19.0 (4.3)	441.3
A. officinalis	10.5 (2.3)	19.6 (4.4)	30.4 (6.8)	104.1 (23.4)	262.9 (59.2)	0.39	36.0 (82.6)	17.9 (4.0)	443.5
Bruguiera cylindrica	10.3 (2.3)	1.9 (4.0)	30.4 (6.8)	104.1 (23.4)	262.9 (59.2)	0.39	36.0 (82.6)	17.9 (4.0)	443.5
B. sexangula	9.8 (2.1)	14.4 (3.1)	57.0 (12.2)	10.4.1 (22.3)	262.9 (56.4)	0.39	367.0 (78.9)	17.8 (3.8)	466.0
Ceriops decandra	9.8 (2.1)	14.4 (3.1)	57.0 (12.2)	104.1 (22.3)	262.9 (56.4)	0.39	367.0 (78.9)	17.8 (3.8)	466.0
C. tagal	9.9 (2.1)	17.5 (3.7)	51.0 (10.9)	66.2 (13.9)	313.8 (66.0)	0.21	380.0 (779.9)	16.7 (3.4)	475.8
R. mucronata	10.6 (1.7)	15.6 (2.5)	209.0 (34.0)	152.0 (24.7)	211.2 (34.4)	0.72	363.2 (59.1)	15.5 (2.5)	613.9

Table 4 Phytochemical features of different mangrove species rehabilitated in Sunderbans

Characters	*A.alba*	*A. marina*	*A. officinalis*	*B. cylindrica*	*B. sexangula*	*C. decandra*	*C. tagal*	*R. mucronata*
Chlorophyll a*	9.79×10^{-4}	5.14×10^{-4}	10.65×10^{-4}	4.41×10^{-4}	3.40×10^{-4}	2.82×10^{-4}	4.66×10^{-4}	323×10^{-4}
Chlorophyll b*	6.5×10^{-4}	2.59×10^{-4}	6.23×10^{-4}	2.97×10^{-4}	2.61×10^{-4}	2.71×10^{-4}	2.88×10^{-4}	1.4×10^{-4}
Total chlorophyll*	17.69×10^{-4}	8.76×10^{-4}	19.10×10^{-4}	6.78×10^{-4}	8.25×10^{-4}	6.46×10^{-4}	8.42×10^{-4}	6.14×10^{-4}
Proline**	0.024	0.04	0.0276	0.021	0.048	0.075	0.017	0.041
Protein**	7.497	5.844	6.269	4.575	3.718	3.383	10.868	8.787
Carbohydrate**	1.842	2.354	2.078	2.043	1.989	2.293	3.223	2.983
DNA**	0.013	0.008	0.008	0.014	0.015	0.022	0.018	0.012

* : mg/gm of green tissue; ** : mg/100 mg of dry tissue

in hypodermis and spongy parenchyma, also showed salt-tolerance property. The thickness of hypodermis and spongy parenchyma together recorded about 70% thickness of the leaves of *C. tagal* followed by that of *Rhizophora* and *Bruguiera*. Though succulency is a property of salt-accumulating mangroves, the above species which belong to salt-excluding type also showed some amount of succulence, thereby increasing the adaptability under high salinity.

Chemical constituents of the leaves are considered as factors responsible for salt tolerance. Among them, chlorophyll content was demonstrated to vary with the chloride salinity in halophytes. *Avicennia officinalis* was found to be better (10.65×10^{-4} gm/gm fresh tissue) in this feature whereas *C. decandra* was having the minimum amount (2.82×10^{-4} gm/gm fresh tissue) (Table 4). In addition to this, carbohydrate and total protein content also had an adaptive value in saline environment. Salinity always affects the carbohydrate and protein show definitely higher photosynthetic ability vis-a-vis adaptability. These characters were also found to vary among the species under study. *Ceriops* had comparatively more amount of carbohydrate and protein, which showed their adaptability of the most important amino acids and considered as one of the important parameters for stress tolerance, also varied among the species. *Ceriops* recorded maximum value followed by *Bruguiera, Avicennia,* and *Rhizophora*. Total DNA content also has a relationship with the growth rate of plant species. *Avicennia marina*, which produced maximum biomass during a two-year growth period, recorded minimum amount of DNA (0.05 mg/100 mg dry tissue) followed by *A. officinalis, Rhizophora spp.* and *B. cylindrica* in the degraded forest land in Sunderbans. However, detailed study for a longer duration with more number of species would help to develop a specific management strategy.

In conclusion, the preceding discussion and available literature show that the realm of mangrove physiology and its autogamy is too vast a domain and the implications are too complex to understand. More and more information will be generated in the future which will serve to highlight our knowledge on mangroves. Today mangroves offer a number of interesting problems for study.

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REHABILITATING MANGROVES IN MAHARASHTRA

ARVIND G. RADDI

INTRODUCTION

Maharashtra has a coastline of about 720 km which is cut up by numerous creeks opening into the sea and their deltas. In the past, mangroves were occurring naturally and in abundance in the muddy environs of the creeks, deltas as well as in strips of varying width on the banks of estuaries. Over the years in the past, these areas have suffered on account of biotic attrition. Primarily this was because most of these areas are basically legally non-forest areas. That is to say, their legal status was not that of a reserve forest, nor were they generally in the charge of the Forest Department. Most of these areas were designated as revenue wastelands and were in the charge of the Revenue Department. Consequently, although the Forest Department in the State is over 100 years old, it had no control over these areas for their protection or management. The Revenue Department, which was the custodian of these areas, being constantly under pressure of their multifarious other duties and responsibilities had little time for them and these areas were treated as unproductive coastal wastelands and remained for long in a state of benign neglect.

CHANGING PERCEPTIONS

In the past few years there has been a noticeable change in the situation. With the changing perceptions there has been increasing appreciation of the value of mangroves for coastal fishery and their utility in environmental conservation on the coast as well as in helping to meet some of the needs for fuel and fodder of people residing in coastal hamlets. The Social Forestry wing of the Forest Department which was assigned the role of generating tree culture and promoting tree growth in non-forest areas of the State, initiated rehabilitation of coastal mangrove wastelands from 1986 onwards through plantations of *Rhizophora* and *Avicennia*. This was a pioneering effort in the State and exposed the forestry staff for the first time to the mangrove habitat and mechanics of mangrove rehabilitation. The salient features of this exercise are described in the following pages.

MANGROVE AFFORESTATION

AREA SELECTION

The first step was to identify areas where pilot-scale mangrove planting effort could be tried out. In this context, an initial survey of the creeks in Sindhudurg and Ratnagiri districts was made during 1986 and locations for pilot planting were selected.

STAFF ORIENTATION

The Social Forestry staff, who had no previous experience with mangrove planting, had to be familiarised and educated in this respect through talks, field visits and demonstrations, and motivated to venture into the muddy terrain and participate enthusiastically in the mangrove planting programme in addition to their other work.

SPECIES SELECTION

Considering the locality factors, the existing relict mangrove vegetation, and the needs of the villagers, it was decided to restrict the mangrove planting activity to two species. These were *Rhizophora mucronata* Lam., locally known as 'Kandal', which is a good fuel wood, and *Avicennia* spp. (*A. officinalis* L. and *A. marina* Forsk), locally known as 'Thiwar'. *Avicennia* is good fodder. It is reported that cattle fed on *Avicennia* fodder have very high butter fat content in their milk. *Avicennia* leaves also contain salt, iodine and other trace minerals, which are not naturally present in many other fodders and have to be artificially supplemented. Further, *Avicennia* coppices can withstand periodic lopping. In addition, *Avicennia* flower is also reportedly a good source of honey.

THE PLANTING STOCK

The planting stock tried out was from three sources :

Transplanting naturally occurring saplings

Along the Maharashtra coast there are places where good mangroves are still occurring, particularly species of *Rhizophora* and *Avicennia*. One-year-old or younger saplings of the above species were utilised for transplanting. It was observed that 6 months or 1-year-old saplings if planted during rainy season showed fairly good survival. But the survival rate of those uprooted and transplanted after rains was less. Reduced salinity during rainy season perhaps facilitates better survival of saplings. Care has, however, to be taken to uproot the saplings gently while a few cm of tidal water is still present in the area and the terrain is soft.

Rhizophora/Avicennia propagules

Mature propagules of these mangrove species were collected in May/June. Care was taken to avoid diseased, infected, immature and in other ways poor quality propagules. Only healthy, mature and naturally fallen *Rhizophora* propagules found under mother trees were preferred. Direct collection of propagules by plucking from mother trees was discouraged as the workers often plucked immature propagules which were not suitable for planting. Some isolated *Rhizophora* trees were occasionally found to bear propagules in periods other than the natural season. But such trees were few, far scattered and the bearing of propagules was not profuse and thus they were not considered. Mature *Avicennia* seeds were found in large number in June -July lying below mother trees or free-floating in creek water.

Propagules were transported to the planting site in baskets or sacks. The *Rhizophora* propagules were mostly used for direct planting in the field and the surplus was put in polybags in nurseries. *Avicennia* seeds being small were not planted directly at field site but put in polybags in nurseries.

It has since been learnt that even they can be directly dribbled in the planting areas and give good results.

At present, techniques for long-term storage of viable propagules are not available so as to enable us to take full advantage of propagules' production during the production season and store them for utilisation later in the year. Some attempts made to devise storage techniques were :

1. *Rhizophora* propagules and *Avicennia* seeds were stored in plastic bags in cold storage available at fishing centres on the coast. They did not survive in cold below zero temperature ;
2. It was also observed that in nature *Rhizophora* propagules and *Avicennia* seeds remain free-floating in creek or sea water for a considerable time and on finding suitable soil strata, strike roots and establish themselves at the new site. Thus they retain viability in moving water (under free-floating conditions) for a long time. This needs further study as a means of their storage.

Polybag-raised saplings

Saplings of *Rhizophora* and *Avicennia* were also raised in nurseries in polythene bags. Surplus propagules not planted directly in the field were planted in polythene bags in such nurseries for later use during the year.

Generally the nurseries were located near the planting site to reduce polybag transportation problem. The nurseries consisted of sunken beds 13 × 1.3 m in which 12.5 cm × 25 cm size polybags (250 bags/bed) filled with local creek mud were arranged. The *Rhizophora* propagules and *Avicennia* seeds were planted in these bags. The nursery beds were within the Intertidal zone and consequently the plants were watered daily, naturally, by the incoming tidal waters. The beds, however, needed bamboo supports to ensure that the bags were not disoriented or displaced on account of tidal water flow.

PLANTING WORK

The spacing adopted for planting was 2m × 2m (2500 plants/ha). The planting work was done at low tide, when the area was exposed; *Rhizophora* propagules were planted in crow-bar holes, as this gave them a degree of stability after planting. Only where the mud was very soft (e.g., soft mud-flats) *Rhizophora* propagules were planted by manually pushing them into the soft mud.

For planting *Avicennia* saplings (uprooted from nature) or polythene bag raised *Avicennia* and *Rhizophora* saplings, it was necessary to scoop the earth with a shovel and then plant the saplings.

Taking a realistic view, under existing circumstances it was felt that *Rhizophora* propagules should be planted during the season of their availability, and later as required polybag-raised *Rhizophora* plants could be used for planting in the rest of the year. *Rhizophora* saplings (one-year-old), collected from nature did not stand transplanting well. So far as *Avicennia* was concerned, their propagules being small and liable to be disrupted, got washed away from the planting site. Therefore, planting their propagules in field was not adopted then. It was however, done using seedlings. This could be cost-effective and needs to be tried out in the field. One-year-old naturally found *Avicennia* plants can also withstand transplanting and are advocated for transplanting in the rainy season. For subsequent year-round planting (dry season), if any, stress may be laid on planting nursery-raised polybag *Rhizophora/Avicennia* plants, and if they are not available, one-year-old naturally produced *Avicennia* seedlings may be used for planting.

LABOUR

Labour availability is a problem in Konkan, as able-bodied men migrate to cities (e.g., Bombay) and others work in paddy fields during the monsoon and in mango, cashew, coconut and arecanut orchards during the fair season. Labourers other than fishermen do not prefer to work in the creeks or swampy areas, because of the "skin itching" on account of long exposure to sea water. Under the circumstances, payment of daily wage rate should be high enough, not only to match the prevailing upland rate but also to attract labourers to the work of mangrove planting.

PROTECTION

The mangrove plantations were found to have some protection problems :

1. The planted areas at low tide often appear as open expanses. Buffaloes from the coastal villages love to enter these areas at low tide and browse on the vegetation, e.g., *Avicennia* saplings.
2. At high tide, fishermen fish in the creek waters and while pulling up their nets may dislodge submerged young planted mangrove seedlings.
3. Provision of two-strand barbed wire fence attached to bamboo poles helps identify and protect a mangrove plantation during high tide and low tide in its early vulnerable stage. Also leaving traditional fishing boats a passage for anchoring by leaving some areas unplanted helps avoid conflict with fishermen.
4. An algal form (*Enteromorpha* sp.) has also been observed in the young plantation as well as nursery area. It comes in along with the high tide and envelops young mangrove plants, particularly their leading shoots. This has to be removed manually periodically, otherwise the young seedlings get damaged. The algal menace is observed mostly in the November—January period. After a year or two, when the seedlings grow in height, become sturdy and their shoot portion starts remaining out of water even at high tide, the algal form is not likely to have an adverse effect. In such algal-affected zones, planting tall nursery-raised seedlings may be a solution.
5. At some places insect damage to leaves of mangroves has been observed. The species affected was *Rhizophora*. The insect is a beetle identified as *Monolipta* sp. The leaves develop black spots and the leading shoot also gets damaged. Consequently new shoots are developed by the affected plant from other buds down below, which in turn may also get affected and the sapling, though alive, develops a diseased, scrappy, stunted appearance. In upland areas, a pesticide spray could have got rid of the menace. However, in the case of young mangroves, even if pesticide is sprayed, there is the likelihood of the next tide washing it away.
6. *Rhizophora* propagules have also been at places encrusted with barnacles, i.e., *Balanus* spp. The infection is often heavy, but so far not serious enough to cause mortality in the areas of plantation. This also needs to be studied.

EMERGING SALIENT FEATURES

The exercise of planting mangroves in the coastal areas of Maharashtra has also thrown up in its wake, a number of interesting issues. They are of significance in planning long-term strategies for mangrove planting and merit review.

PLANTING ACTIVITY

Mangrove afforestation differs from other conventional afforestation in that here planting activity can be undertaken on a year-round basis, unlike other forest planting works which are only confined to the rainy season. The nursery costs are also less in the sense that daily watering is done naturally through incoming high tides. The planting activity can provide sustained year-round employment to some of the coastal unemployed. Care, however, has to be taken to ensure that the wages for mangrove activity are higher than those for other activities in the coastal zone. This is to compensate for the mud terrain in which people have to work and the varying times of planting. The latter is so since the mud-flats are exposed only during the low tides, the timing of which changes daily and adds to the variability of the activity. Major planting can only be done where low tide occurs between 10.00 a.m. and 5.00 p.m. since these are the daylight working hours for the labour. Women from coastal hamlets, who traditionally collect fish from the mud-flats when the are exposed during the daylight-hour low tides, were found to be quite effective in mangrove planting. Thus mangrove planting also helps in equitable distribution of the employment potential and facilitates tackling of gender issues.

SOCIAL FORESTRY LINKAGES AND PEOPLE'S PARTICIPATION

Mangrove plantations in Intertidal coastal mud-flats and banks of creeks have generated new fuel and fodder assets for the coastal hamlets. These can be drawn upon in emergency times. Apart from that, these plantations also contribute to sustenance of coastal fisheries, soil conservation, reduction of wind damage and general greening of the coastal wastelands. The planting programme has been confined to *Rhizophora* (fuel and timber value) and *Avicennia* (fodder value) because not only are these species indigenous to the tract but are also of direct relevance to the people. once they are established and protected by the people, other elements of mangrove habitat biodiversity including mangrove associates, can return to the area through planting or naturally in the course of time.

KHARLAND 'BANDHARAS' (DYKES)

This activity consists of construction of long dykes to prevent ingress of sea water into coastal rice fields and is being undertaken on account of the need of the coastal farmers to produce rice for their sustenance as well as for sale. These dykes, however, contribute to the loss of natural mangroves in their hinterland and are thus at cross purposes with conservation of mangroves. This issue needs to be investigated and a *via media* has to be found. It may so emerge that with the recent availability of new strains of salt-tolerant rice varieties, there may be no need to construct such dykes in future, thus facilitating the continued existence of mangroves on the coast.

COMPENSATORY PLANTATION ACTIVITY THROUGH MANGROVE PLANTING

The Forest (Conservation) Act of the Indian Government prohibits non-forest use of forest land unless permitted by the Government. Such permissions now are rarely forthcoming. Consequently, development projects on the coast involving even a very small area of forest land often get held up. The Government of India to the development of the region, may grant the permission to use forest land provided the State Government makes available for compensatory plantation activity, non-forest land equivalent to the forest land being lost in the project and in some cases double of that. Mangrove wastelands, the bulk of which are legally not forest lands, are now being increasingly offered by State authorities to the Forest Department for raising compensatory plantations. With formalisation of mangrove plantation techniques in the State, it has now become possible for the Forest Department to take over such areas for compensatory afforestation works. This is an important change from the past and offers an opportunity to give a boost to mangrove planting in general. It has also contributed in the process to reduction of friction between the Forest Department and some of the other developmental agencies of the State Government.

Whereas one can fully understand the desire to develop prawn exports through aquaculture methods, it must however be developed in the manner where mangroves are not disturbed in the process. Perhaps aquaculture farms can be located in the hinterland just beyond the mangrove belt and water from the creeks pumped in and out of them. In addition, mangroves can also be planted on a systematic basis along aquaculture farm bunds as an activity complementary to aquaculture. This may add a little to the cost of the aquaculture farm but in the process it will contribute greatly to the conservation and development of mangroves in the coastal belt.

RESEARCH

To facilitate continued mangrove conservation and planting activity in the State, it is important that research study be carried out to devise ways and means of tackling the enteromorphic menace to mangrove plantations that is taking place in certain areas, as well as controlling of insect pests through systemic inhibitors. Today, there are no widespread problems but it is important to standardise the methodology to tackle them without waiting for these problems to reach epidemic proportions. It is also important to find out means of extending the viability of *Rhizophora* propagules and *Avicennia* seed in a cheap and effective manner. If this is done, then it may be possible to even bypass the nursery stage altogether and undertake direct planting of propagules and seed sowing on a year-round basis. This will also obviate the need to transport the planting stock in polybags over long distances in boats. The issues of Kharland bandharas (dykes) and aquaculture farms for prawns also need to be thoroughly examined and a *via media* worked out. Over the years many new legislations covering forests, tree-growth, fisheries, pollution and environment, etc., in coastal zone have been enacted. These need to be reviewed vis-a-vis their effect on mangrove welfare, and anomalies, if any, need to be rectified.

ECO-RESTORATION OF MANGROVES : A CASE STUDY

SANJAY DESHMUKH

INTRODUCTION

Mangrove swamps are a prominent component of the coastal vegetation, which occupy the flood plains, margins of bays and tidal rivers in addition to shores. The mangrove ecosystem though open, is quite complex, composed of various inter-related elements in the land-sea interface zone. The mangroves are known to keep to shorelines intact against tidal currents by preventing soil erosion and provide a habitat for several wildlife marine species including birds, shrimps and fishes. In coastal areas, mangroves constitute an important renewable resource for fuelwood and fodder. They control erosion, afford stabilisation and are not only the sources of primary productivity involved in complex detritus food webs (Odum and Heald, 1972), but also provide a habitat and nursery ground for a variety of organisms (Macnae, 1974; Idyll *et al.*, 1967). In view of the ecological and socio-economic importance of these plants, their restoration has become increasingly important, especially in recent years, when land and forest cover of the earth is rapidly on the wane.

Mangroves have been successfully used for soil stabilisation in the tropics. *Rhizophora apiculata* has been planted in Sri Lanka to induce silt deposition and to stabilise the accredited soil (Macnae, 1968). In Java, *Avicennia marina* and *A. officinalis* have been maintained at the mariculture sites to provide protection from the wind and waves (Schuster, 1952). *Rhizophora mangle* from Florida is reported to have been introduced in Molokai, one of the hawaian islands, to control erosion (Mac Caughey, 1917). This introduction resulted in the spread of red mangroves along the banks of many ancient Hawaian fish culture ponds (Teas, 1975). Bowman (1971) and Goforth and Thomas (1979) have reported about planting of mangroves in Florida Keys for reducing the erosive action of the sea. In recent years, mangroves have been planted as landscape plantings in South Florida (Sevage, 1972; Teas, 1975a).

Development of suitable forestry methods for propagation of mangroves has been prompted by the demand for the economically valuable mangroves for production of firewood, charcoal, timber, fishing stakes and tannin (Macnae, 1968). Silvicultural techniques to obtain maximum sustained yield have been developed in the mangrove plantations of South-east Asia (Watson, 1928; Noakes, 1955; Banijbatana, 1957; Macnae, 1968). In Asia it includes hand planting of propagules, controlled harvesting and thinning, control of undesirable species and ditching to improve tidal circulation. Recently, aerial planting technique for afforestation has been tested in parts of the Saigon river delta where large areas of mangrove forests had been killed (Teas, 1972).

MANGROVES OF MAHARASHTRA

With a coastline as long as 720 kilometers, Maharashtra has many coastal villages. These often have sizable wetlands along creeks, which are virtually barren, but suitable for mangrove growth. The most important amongst them are the areas on estuarine fringes and mud-flats which have suffered years of neglect and misuse. Consequently, over the years they have been subject to heavy felling for fuelwood by coastal villagers and other biotic interferences. Reduction of annual freshwater discharge through construction of dams in upstream areas as well as pollution caused by enormous discharge of industrial effluents in the estuary, have also caused adverse effects on mangrove growth and survival at many places. Besides, many mangrove areas are privately owned and exist as wasteland that need rehabilitation.

Bombay could be considered as a region form where mangrove plants have been virtually wiped out, but the habitat conditions are still capable of supporting mangrove growth. Artificial regeneration on newly formed mud-flats through organised planting appears to be the quickest and effective way of rehabilitation of the area. Many of the mangrove regions in Bombay, along the coast fall under this category.

A project for the experimental plantation of mangroves in a swampy region of Vikhroli (Lat. 19°06′N; Long. 72°6′E), Bombay was initiated. The paper highlights the results of a study conducted in this respect.

MATERIALS AND METHODS

In the present study, the emphasis was laid on the effects of size of the propagule, tidal conditions, ground level, soil and water influence and the mode of sowing of the propagules, germination and growth of *Rhizophora mucronata* during pilot plantation and in the nursery.

The studies are broadly classifiable into three categories :

1. Nursery experiments,
2. Pilot plantation of *Rhizophora mucronata* in the field, and
3. Largescale plantation of *R. mucronata* based on the results of pilot plantation.

NURSERY EXPERIMENTS

A mangrove nursery was established near the swampy area of Vikhroli to evaluate the performance of *Rhizophora mucronata,* alongwith the different mangrove species. The need to raise mangrove nurseries was based on the consideration that in nature, propagules of different mangrove species are available only for some part of the year. Therefore, it would be possible to raise propagules into saplings by growing them in the nursery and the planting can be done in the next year subject to planting stock.

Mangroves show different modes of seed germination, namely vivipary, crptovivipary and ovipary. In case of seed germination on soil, the seeds are thrown on the ground in the monsoons when soil salinity is lowest. Germination in halophytes has been reported by many workers (Joshi and Iyengar, 1977). Laboratory investigations of seed germination indicate that seeds of most of the halophytic species reach their maximum germination in distilled water (Seneca, 1969; Dietert and Shontz, 1978) and that specification toxicity occurs when seeds are exposed to various salts (Varshney and Baijal, 1977).

Based on the above observations, the propagules were sown in polybags filled with non-saline soil or garden loam with Farm Yard Manure in the proportion of 3:1 and were irrigated with fresh water. This experiment was conducted to ascertain the relationship between propagule size and seedling performance. The propagules of *Rhizophora mucronata,* collected from the Sindhudurg district of Maharashtra were used for this experiment. They were arbitrarily divided into three groups :

a. Propagules < 30 cm

b. Propagules > 30 < 45 cm, and

c. Propagules > 45 cm.

One hundred propagules of each group were grown in three different sets of polybags containing garden soil and Farm Yard Manure in the proportion of 3:1 and were irrigated with fresh water. The data on their growth performance were recorded when the approximate age of the plants was one year. Growth parameters include the number of internodes, number of leaves per plant, diameter of first internode, net growth in height and mean leaf area per plant. Mean leaf area per plant was calculated by measuring the length and breath of all the leaves of a plant and using the formula Leaf area (A) = Length (L) x Breath (B) x 2/3.

$$\text{Total Leaf area of plant} = \sum_{i=1}^{n} (L \times B \times 0.666)$$

PILOT PLANTATION

A general approach for eco-restoration effort was worked out on the basis of the assessment of the local factors. The observations were based on the following points :

Area Selection

The first step was to identify areas where pilot scale mangrove planting effort could be tried out. In this context, the initial survey and mapping of the vegetation was undertaken. With the help of maps prepared, one mud-flat from the lower shore region was identified for the experimental plantation.

Planting Technique

The propagules of *Rhizophora mucronata* were planted in rows parallel to each other and water level from lower shore to the upper shore. Nearly 1/4 to 1/3 of a propagule was embedded in the soil by direct sowing as the soil was loose and therefore this technique was adopted instead of boring the soil and then planting the propagules.

LARGE SCALE PLANTATION

Based on the results of the pilot plantation, massive afforestation programmes were undertaken, where 8,750 propagules of *Rhizophora mucronata,* collected from the coastal region of Maharashtra, were directly planted in the swampy region of Vikhroli in the monsoon of 1988, and about 16,000 propagules were planted in 1989, alongwith the ones grown in nursery which were used to replace the propagules of the previous years which did not survive. In some areas, the propagules were found infested with barnacles and were therefore replaced by those from nursery. Percentage survival was calculated by measuring the saplings in marked areas representing different zones of the swamp.

OBSERVATIONS

NURSERY EXPERIMENTS

Propagule size and seedling growth

To study the effect of propagule size on its growth, *Rhizophora mucronata*, a species which exhibits variations in its size, was investigated. The experiment was carried out under fresh water conditions. The results of the experiment, 12 months after sowing, are presented in Table 1.

Table 1 Propagule size and seedling performance of *Rhizophora mucronata* under fresh water conditions (Values are mean ± S.E.)

No.	Growth parameter	Height of propagule (cm)		
		< 30 cm	> 30 cm < 45 cm	> 45 cm
1.	Net growth in height (cm)	32.66 ± 1.63	39.12 ± 1.08	47.70 ± 2.60
2.	Number of leaves/plant	8.00 ± 0.58	10.13 ± 1.87	9.97 ± 1.37
3.	Mean area per leaf (cm^2)	16.90 ± 2.40	22.97 ± 1.33	27.33 ± 2.10
4.	Number of lateral branches	—	< 2*	< 2*
5.	Mean diameter of first internode	0.62 ± 0.02	0.77 ± 0.01	0.89 ± 0.03
6.	Total leaf area per plant (cm^2)	179.19 ± 13.86	245.26 ± 7.85	279.61 ± 5.77

* : Observed in few individuals only

It was noted that the performance of the seedlings was directly proportional to their size. Better growth was observed in the longest seedlings amongst the three groups.

PILOT PLANTATIONS

Plantations in relation to edapho-hydrological conditions

The area where these plantations were undertaken on a pilot scale, comprised two types of habitats :

1. Mud-flats in the lower Intertidal regions - from the low water line of spring tides there existed mud-flat upto the range from where actual mangrove vegetation starts. Such mud-flats were utilised for this purpose, and
2. Stand of mangrove vegetation (1-5 m in height) which gradually merged into a barren area with low organic matter content.

Sprouting of *Rhizophora mucronata* propagules, planted from the seaward to the landward side in rows, with a distance of one meter on the mud-flats and five meter between them with the vegetation, was very encouraging (97% survival). This was irrespective of the underlying soil type as, during the rainy season the chloride content of both - sea water and soil was low as compared to the salinity range during non-monsoon periods of the year. However, propagules from the upper shore and the splash zone died with three months of sowing. A belt transect taken from the seaward to the landward side, exhibited a good relationship between survival and mortality (Figure 1). The transect was divided into 20 segments of 5 x 5 m. Table 2 highlights the net growth of seedlings attained 3 and 12 months after sowing.

Table 2 Growth of *Rhizophora mucronata* Propagules (Values are mean ± S.E.)

No.	Growth parameter		Age of propagule	
			3 Months	12 Months
1.	Net growth in height (cm)		27.59 ± 0.55	67.12 ± 3.37
		Range	15.2 to 35.8	40.1 to 97.6
2.	Number of internodes/plant		2.37 ± 0.08	4.36 ± 0.28
		Range	1 to 3	2 to 5
3.	Number of leaves/plant		7.27 ± 0.20	15.97 ± 1.69
		Range	6 to 10	0 to 28
4.	Length of Internodes(base to apex)	i	7.52 ± 0.33	13.5 ±1.27
		Range	4.5 to 9.3	8.1 to 14.6
		ii	5.31 ± 0.57	11.27 ± 0.38
		Range	3.8 to 8.1	7.9 to 13.1
		iii	4.19 ± 0.34	8.07 ± 0.82
		Range	3.8 to 8.1	5.0 to 9.9
		iv	–	3.47 ± 0.82
		Range	–	2.3 to 5.2
		v.	–	1.97 ± 0.09
		Range	–	0.9 to 2.3
5.	Number of lateral branches	i	2 branches of 3.2 cm were seen in only 4 propagules	1.38 ± 0.4
		Range	–	0 to 4

The morphometric parameters were studied for propagules sampled randomly from the plantation area.

The net growth in height of 27.57 ± 0.55 cm was attained by *Rhizophora mucronata* seedlings after 3 months of sowing with average number of internode 2.37 ± 0.08. The number of leaves varied from 6 to 10. After 12 months, the growth attained was found to the 67.12 ± 3.37 cm which was considered good. The number of leaves had almost doubled compared to the previous stage (15.97 ± 1.69) and the number of internodes also increased from 2.37 ± 0.08 to 4.36 ± 0.28 in 12 months. The propagules till this age did not show any infestation. Based on these observations, a largescale plantation/afforestation programmes was undertaken which involved the direct planting of *Rhizophora mucronata* propagates in the areas where they showed maximum survival.

LARGE SCALE PLANTATION

From the observations made for the largescale plantations of 1988 and 1989, it was noted that the survival of the 1988 plantation was 58% and that from the 1989 plantations, 73%. There were some biological factors which affected the growth and survival of *Rhizophora mucronata* saplings.

PHYSICAL PROPERTIES OF SOILS					
Shore type	Coarse sand	Fine sand	Silt	Clay	Soil type
Lower	-	6.25	56.37	33.41	Silt loam
Middle	1.00	27.02	40.49	29.12	Clay loam
Upper	9.28	37.26	43.26	8.20	Loam

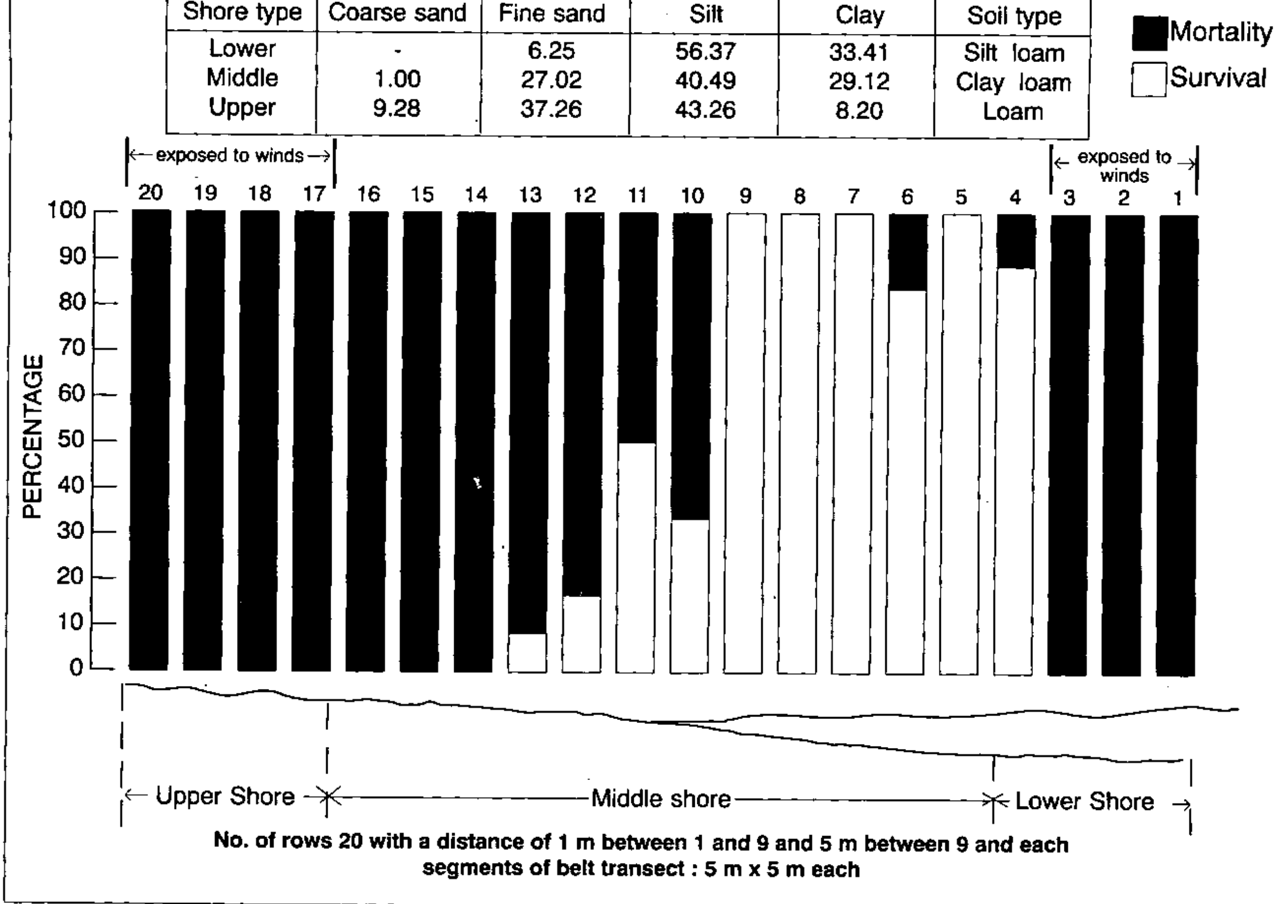

Figure 1. Mortality of *Rhizophora mucronata* along a belt transect 3 months after sowing

PROBLEMS, ISSUES AND THEIR IMPACT ON MANGROVE REHABILITATION

Field observations revealed that there are some biological stresses that influence the success of mangrove plantations to a variable degree.

Infestation by barnacles

The worst marine organisms infesting mangrove plantations in the swampy regions of Vikhroli were the barnacles. The peak season of infestation was during the rainy season and this mostly occurred where the main channel of the creek entered the swampy area. The attack by these cone shaped shells during their larval stage on the newly planted propagules was visually seen only after their growth on the hypocotyl. They were observed in a totally covered state on the hypocotyls and thus resulted in wiping out of plantations. Planting the year old nursery-grown seedlings was observed to be the best remedy over this problem, since the grown portion of the elongated stem remained above the level of the high tide thereby reducing the chances of infestation on the growing shoot.

Infestation by crabs

The plantations in their early stage were found to be infested by the species of *Uca* and *Sesarma*. These crabs often girdled the root collars and fed on the fleshy tissues of the propagules.

Man as a stress factor

The areas near the mid-tide level were most frequently inundated by tidal waters. Due to this, the newly planted propagules were covered by water during high tides and were not visible above water level till a few months. The local fishermen caught shrimps, crabs and mangroves dwelling fish species during high tides in the plantation areas. Plantations near the mouth of the main channel of the creek, as well as near the peripheral areas of the swamp, were badly damaged due to the injury to the hypocotyls caused by impact of small boats passing through the plantations.

Other stress factors like (i) the wood borers which attacked the old plantations, (ii) epiphytic green algae which choke the seedlings to death or clinged on to the hypocotyls thereby giving an additional burden, leading to bending or breakage of stems of propagules, (iii) seaweeds which affected species with smaller hypocotyls, e.g., *Ceriops* and *Bruguiera*, and (iv) the domestic animals which roamed around the plantation areas during low tides and trampled over newly planted seedlings were reported as important factors contributing to the heavy mortality in the plantation areas of coastal Maharashtra.

CONCLUSIONS

Mangroves play an important role in estuarine ecological systems as well as in shoreline protection. Many large areas under mangroves have been lost by dredging, land-filling and other means. It has, therefore, become necessary to develop techniques for restoration of mangrove areas.

From the view-point of eco-restoration of mangroves of the Vikhroli area in Bombay, besides preliminary trials in a nursery, a great deal of emphasis was placed on largescale planting of *Rhizophora mucronata* in the swampy area. Data collected on germination and subsequent growth and mortality indicated that in addition to the method of sowing, soil topography, texture, chloride content and tidal condition appeared to strongly affect the growth performance of the species. The results obtained from the largescale plantations of *Rhizophora mucronata* revealed that the species sprouted equally well in lower and upper shore regions initially, but failed to survive in raised, barren areas of the landward side in the swamp. Here the mortality appeared to be predominantly regulated by substrata level affecting inundation frequency and causing dryness in consequence. The mud-flats which were frequently inundated with tidal water and protected from wave action, were found to facilitate the growth and survival of *Rhizophora mucronata* saplings. The experiment related to comparative growth of the seedlings emerging from smaller or larger propagules of *Rhizophora mucronata* revealed that a correlation between the propagule size and the rate of seedling growth is in favour of bigger propagules.

The practical implication of utlising larger propagules for plantations is that rapid growth would help the juvenile plant to cross the level of mean flooding of tidal water in a short span of time. Moreover, the nursery-grown saplings revealed that the height of saplings reduced the chances and extent of barnacle-infestation in the foliar region of the plant.

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METHODS OF CLASSIFICATION BASED ON GENETIC DIVERGENCE

V. ARUNACHALAM

INTRODUCTION

Genetic divergence measures discussed earlier are mainly used to assess the genetic proximity or otherwise of OTUs. This assessment is usually made by grouping together genetically close OTUs. Such groups, also called 'clusters', help in identifying OTUs that are genetically divergent and making major decisions on conservation of genes using real genetic variants.

They also help in a purposeful choice of parents for hybridisation to obtain heterotic F_1s with a high probability, as would be seen later.

We then need to define a cluster. A cluster has the property that members within it show lesser variation compared to members from different clusters. In other words, members within a cluster are homogeneous while members belonging to different clusters are heterogeneous. This would imply low intra-cluster and high inter-cluster variation.

This principle is mainly used in Tocher's method of clustering described in detail by Rao (1952).

We describe in brief the following methods of grouping and identify the best for genetic clustering :

a. Single linkage clustering : dendrogram,
b. Multiple range test,
c. Principal component analysis, and
d. Tocher's method of clustering.

DENDROGRAM

There are a number of methods of clustering OTUs based on the information of various traits. For a,good description, one may refer to Sneath and Sokal (1973) from which we illustrate a very simple method called 'single linkage clustering'.

Table 1 gives the values of two traits X_1 and X_2 of 8 OTUs. The distance function d^2 has been explained in the earlier paper. Values of d^2 and $d = \surd d^2$ are appended in Table 1.

L.S.D. OR MULTIPLE RANGE TEST

When a group of OTUs requiring classification can be raised in a field design (like a randomised blocks design) and observations on a number of characters important in genetic differentiation can be made, a simple method proposed by Arunachalam and Bandyopadhyay (1984) can be employed.

We consider an example of 8 OTUs in peanut grown in a completely randomised design. Observations were taken on pod yield (PW), test weight (TW) and shelling percentage (SP).

Table 1 Coordinates of 8 OTUs in two-space (X_1 and X_2) and distances

	a	b	f	g	i	j	n	o
X_1	0.00	0.00	2.00	2.00	5.00	6.00	6.00	6.00
X_2	4.00	3.00	2.00	1.00	5.00	5.00	2.00	1.00
a	*	1.00	8.00	13.00	26.00	37.00	40.00	45.00
b	1.00	*	5.00	8.00	29.00	40.00	37.00	40.00
f	2.83	2.24	*	1.00	18.00	25.00	16.00	17.00
g	3.61	2.83	1.00	*	25.00	32.00	17.00	16.00
i	5.10	5.39	4.24	5.00	*	1.00	10.00	17.00
j	6.09	6.32	5.00	5.66	1.00	*	9.00	16.00
n	6.32	6.09	4.00	4.12	3.16	3.00	*	1.00
o	6.71	6.32	4.12	4.00	4.12	4.00	1.00	*

From row 3 onwards : distances below diagonal (marked*), distance values, above diagonal, values of distance squares.

Samples varying in size between 15 and 20 plants per OTU were used for recording observations. The analysis of variance (Table 2) showed significant differences. Using the error m.s., E, the difference in means of populations *i* and *j* was tested using l.s.d. as follows:

$$t = \frac{m_i - m_j}{\sqrt{E\left(\frac{(1}{n_1} + \frac{1}{n_j}\right)}}$$

m_1 and m_1 are the means of the populations *i* and *j* for a trait and n_1 and n_j are the sizes of samples used for recording observations in them. The test statistic '*t*' follows a t-distribution with error d.f.

Table 2 Anova of 3 traits in 8 OTUs of peanut

Source	d.f.	mean squares		
		PW	TW	SP
Between OTUs	7	7984*	465*	732*
Within OTUs	147	428	70	47

The population means were arranged in groups based on t-test (and l.s.d). The topmost group containing populations with the highest mean was given a score 1, the next best a score 2, and so on. If 'k' was the number of groups for a particular character, the populations in group 1 were given a score = 1/k, those in group 2 with a score = 2/k and so on to standardise scores across the characters for each one of which the populations could arrange in varying number of groups. When groups overlap, it is possible for a population to be found in group 1 and also in group 2, for example. The score for that population was then taken to be the average which would be equal to (1+2)/2k = 3/2k. Populations occurring in more than two groups would be treated in a like manner for the allotment of scores. The above points would become clear by a study of Tables 3 and 4.

Table 3 l.s.d. test of significance of differences in OTU means for 3 traits

OTU	n	PW	r	OTU	TW	r	OTU	SP	r
B	9	82.9	–	A	53.0	–	A	73.0	1
A	5	81.1	–	B	52.4	1	B	67.3	–
D	9	78.4	–	E	45.6	–	D	64.4	2
C	7	78.0	1	G	40.1	–	C	64.2	3
E	26	74.2	–	H	38.8	–	E	62.1	–
F	7	40.6	–	C	38.1	2	F	60.1	4
G	36	37.6	2	F	37.7	–	G	58.4	5
H	15	32.6	–	D	36.9	–	H	55.0	–

n = sample size; r = rank.

Table 4 Grouping using l.s.d. test on total scores assigned to OTUs across 3 traits in peanut

OTU	PW	TW	SP	Total score
A	1/2	1/2	1/5	1.2
B	1/2	1/2	3/10	1.3
C	1/2	1/2	5/10	2.0
D	1/2	1/2	5/10	2.0
E	1/2	1/2	5/10	1.5
F	2/2	2/2	7/10	2.7
G	2/2	2/2	9/10	2.9
H	2/2	2/2	5/5	3.0
			Mean	2.08
			Standard error	0.72

The individual scores for each character were added up to provide a total score for each population. The populations were then ranked using the numerical values of total scores.

1.2 1.35 2.08 2.80 3.0

1 A,B m-s C,D,E m F m+s G,H

*Group*1 2 3 4

We note that there were only two groups which were also non-overlapping for PW and TW, and there were five overlapping groups for SP (Table 3). The total scores (Table 4) can be arranged in ascending order. The group with least score was the best and so on (as we attached the score 1 for the topmost group). If, on the other hand, we intend to arrange the OTUs in four groups, one method is to compute the mean (m) and standard error (s) of the total scores. It would then be possible to partition OTUs as follows :

Value of total score (X)	Group
1 < X < or = m-s	1
m-s < X < or = m	2
m < X < or = m+s	3
m+s < X < or = h+	4

where 1 is the lowest value and h the highest value of total score obtained.

By this analogy, the eight OTUs of peanut could be grouped as shown at the bottom of Table 4.

Group	OTUs
1	A, B
2	C, D, E
3	F
4	G, H

A more efficient procedure is to use Duncan's multiple range test in place of l.s.d. test. In principle, the above logic can be extended to obtain any number of groups as desired *a priori*.

Various approaches are in vogue to obtain a preliminary grouping of OTUs. For example, breeders assign a floor value to each character based on their experience and allot a population a core +1 or −1 when it exceeds or falls short of the floor value. The aggregate scores across the characters are used for ranking the populations. Alternatively, an arbitrary weight is associated with each character and a discriminant function is set up. Using the values of discriminant scores, the populations are arranged in their order of merit.

When a number of characters are considered, there is, in general, sequential relationship in biological populations. For example, poor germination affects seedling vigour that affects in turn initial leaf area and hence photosynthesis. Hence decisions based on several important characters spanning the entire growth phase will be fair and precise due to an automatic weighting in the expression of the various characters measured sequentially over the growth period.

Thus the three mechanisms—(scoring process, t-test of differences and decision based on a large number of characters) ensure the superiority of the present method over the one where numerical superiority over floor values of characters is considered. Such a superiority may not be upheld by statistical tests. Though apparently no weight is associated with each character, it is evident the present method takes into adequate account the relative importance of the characters.

On the other hand, discriminant function technique suffers essentially from arbitrary assignment of weights to characters. Since no exact rules of weighting exist, classification by various workers of the same biological populations can differ based on the weights given by them to characters. The problem of character weighting has been considered in great depth by Sneath and Sokal (1973) who defended equal weighting on several independent rounds. When many characters are employed, the statistical analysis of similarity is only inconsequentially affected, if at all, by weighting (unless this weighting is indefensibly extreme).

PRINCIPAL COMPONENT ANALYSIS

The principal component analysis aims to construct linear combinations of variables that could explain the total variation given by 'n' variables. There would be as many linear combinations as the number of variables. The extent of variation accounted for by a linear combination is measured by the proportionate contribution of the canonical root corresponding to the linear combination. The combinations are so constructed as to contribute to the total variation in a descending order of magnitude. However, in many cases, the first two roots (or the first two linear combinations) would account for a large percentage of total variation. These linear combinations, called canonical vectors or principal components, could be used to group OTUs. If the first two roots account for a majority of total variation (normally to the order of 80% or more), the values corresponding to the first two canonical roots are obtained for each OTU by substituting the mean values of characters in the linear combinations. The values of the first two roots of the OTUs could then be plotted in a two-dimensional graph. The OTUs could be grouped taking into account their proximity as judged by the investigator. The method has been illustrated with an example by Rao (1952) (article 9c.3).

The efficiency of principal component analysis will depend on the extent of total variation accounted for by the first two roots. In cases where the first two roots account for less than 50% variation, it would be necessary to use more principal components which will make it difficult to represent the OTUs in a two-dimensional graph and consequently the clustering based on it. Usually this analysis is used to confirm the classification based on distance statistic using Tocher's method. It can, however, be used to construct preliminary groups which would further be grouped using D^2 statistic when the number of OTUs is large, as would be seen later.

TEACHER'S METHOD OF CLUSTERING

As was pointed out earlier, this method of clustering is commonly used to group OTUs on the basis of genetic divergence measured by D^2.

The methodology is explained in detail with a numerical example in Rao (1952) and therefore is not reproduced here. For details refer to art. 9b. in Rao (1952).

It may be noted that the intra-cluster distance was set arbitrarily in this method as well. However, Tocher's method scores over others. Any OTU entered into a cluster is judged whether it can form part of the cluster or not by comparing (the average increase in the value of D^2 when the OTU is included + the increase in the number of D^2) with the average D^2 including the OTU. Only when those two quantities agree closely, the OTU is included into the cluster. Otherwise it is taken out of the cluster and tried with another cluster. This computational scheme is described in detail in Rao (1952) (Table 9b.2B).

The intra- and inter-cluster distances would be depicted in a two-dimensional diagram for a visual idea of the clustering pattern. As found from clustering of OTUs in several crop plants, Tocher's method of clustering using D^2 appears to work much better than other methods discussed earlier.

The major criteria for an efficient classification using D^2, as given by Rao (1952), (Chap. 9, art. 9a.2), are : (a) The distance must not decrease when additional characters are considered; (b) The increase in distance by the addition of some characters to a suitably chosen set must be relatively small so that the group constellations arrived at on the basis of the chosen set are not distorted when additional characters are considered; (c) Mahalanobis' generalised D^2 is applicable only when the variables (or measurements) are normally distributed.

While it may be difficult to pinpoint the characters that are to be necessarily included for an efficient classification of plant genotypes, it can be said from earlier experience that component characters that are important to fitness and natural selection provide usually a good choice (Murthy and Arunachalam, 1966, 1967; Chandrasekhariah, Murthy and Arunachalam, 1969; Murthy, Arunachalam and Jain, 1970). By logical argument, it can be observed that functions of direct yield components may not add more value to efficient classification when compared to themselves. A useful method to decide the set of characters to be included, in any particular case, is to compare the average percent contribution of D^2 added by each component character to the total D^2, when all possible D^2 among the genotypes are taken into consideration. Since only quantitative characters that can *a priori* be taken to follow a normal distribution are relevant to the D^2 function, one must be cautious before including discrete variables like intensity of pigment, presence of absence or an attribute like awning, glume covering, etc., or internode position denoted by sequential order from base (say from 1 to 10, etc.), arbitrary scores for disease or insect resistance, quality of grain, etc., for classification. In some cases, appropriate transformations may restore the distribution to normality. But such cases should carefully be scrutinised before inclusion.

When characters are chosen to satisfy the criteria suggested above and when environments (defined in space or time) maintain the relative expression of characters with regard to the genotypes to a great extent, it may be possible to obtain largely identical clustering pattern (as for example, in linseed : Murty, Arunachalam and Anand, 1973). But it is a safe strategy to expect non-repeatability and take adequate corrective steps by working out the divergence pattern afresh before chalking out useful breeding programmes. A compromise may, however, be possible if, for instance, hybridisation between varieties belonging to clusters having the maximum inter-cluster divergence is only to be attempted, since the top and bottom clusters (and most of the varieties included in them) are likely to be largely repeatable unless environment causes a major change in the trend of D^2 values. Such events will, however, be uncommon.

The method of grouping using D^2 will become unwieldy when the OTUs to be grouped are very large in number. For instance, for 200 OTUs the number of D^2 to be scanned would be $200 \times 190/2 = 19{,}000$. Forming preliminary groups based on visual judgement followed by application of Tocher's method will be an arduous exercise. In order to tackle such situations, combination of principal component–Tocher's method has been successfully used in rice (Vairavan *et al.*, 1973) and peanut (Durga Prasad *et al.*, 1985).

The method consists in computing the percentage contribution of the first two principal components and arriving at a preliminary grouping as explained earlier. Such groups would not be expected to be large in principle. For example, 194 rice collections from Assam and North-east Himalayas were grouped on the basis of 10 characters into 42 preliminary groups. The means of the 42 groups were then used to compute the possible D^2 among them followed by Tocher's method of clustering. This exercise resulted in nine final clusters. Three cluster contained 70, 66 and 25 collections in them, two clusters contained 14 and 12, one contained 4, and three a single collection each. A detailed evaluation of those groups would be found in Vairavan *et al.* (1973). A similar analysis using four varietal groups of peanut led to equally interesting information on the genetic diversity present in them (Durga Prasad et al., 1985).

Since the clustering is based on phenotypic values of traits measured for genetic divergence, it is possible that clustering pattern in one environment or season may not agree with that of another. As explained earlier, the basic strategy is to expect such variation and base decisions on grouping made in a specific environment or season.

DISCUSSION

The best character set for genetic differentiation of OTUs is a debatable area. It would, however, be desirable to run a complete assay of genetic, morphological, physiological, pathological and biochemical (and all other known) characters on a known set of genetically divergent OTUs. Using stepwise regression procedures (see for example, Draper and Smith, 1981), it is possible to arrive at an optimal set of traits accounting for a maximum percent of variation in a dependent variable like grain yield, biomass, wood content, etc., depending on the biological entity. Such an exercise coupled with a knowledge of the crop to identify traits essential for survival and fitness, would help to decide on the minimal set of characters to be used in the analysis of genetic diversity.

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ANALYSIS OF DIVERSITY IN MANGROVES USING DATA COLLECTED BY TRAINEES

V. ARUNACHALAM

We attempt a preliminary analysis of variation fundamental to any analysis of genetic divergence and draw feasible inferences from the limited sample of data.

Seven species of mangrove (abbreviated as S) were examined in five gradients (abbreviated as G) ranging up to 50 m from shore for a few characters of which we analyse girth (cm). The observations were collected by two investigators – I 1 (J. Rao) and I 2 (Zulieka). Despite the fact that data were collected on seven species and five gradients, due to missing data in many cases (Table 1), an analysis of variance (ANOVA) cannot be performed using all of them, though some preliminary factual information can be extracted. The amendable data have then been organised in a factorial design with two species (Ao, Bc, Table 2), two gradients (Q2, Q3, Table 1) and the two investigators as factors (Table 2).

Table 1 Details of samples of 7 species of mangroves on which tree girth (cm) was measured

Quadrat Size : 5 m × 5 m

		Ao	Am	Bc	Ct	Ec	Ra	Lr	Total
Q1	I1	3	–	–	–	–	–	–	3
	I2	5	–	–	–	–	–	–	5
Q2	I1	4	–	13	1	2	–	–	20
	I2	5	3	10	–	1	–	1	20
Q3	I1	3	–	9	2	3	3	–	20
	I2	7	–	20	1	–	–	–	28
Q4	I1	–	4	–	–	–	–	–	4
Q5	I1	–	1	–	1	–	–	–	2

SPECIES (S) : Ao = *Avicennia officinalis* ; Ea = *Excoecaria agallocha* ;
Am = *Avicennia marina* ; Ra = *Rhizophora apiculata* ;
Bc = *Bruguiera cylindrica* ; Lr = *Lumnitzera racemosa* ;
Ct = *Ceriops tagal.*

GRADIENTS (G) : Q1 = 25 m from shore ; Q2 = 5 m from shore ; Q3 = shore ; Q4 = 15 m from shore ; Q5 = 50 m from shore.

INVESTIGATORS (I)

1. J. Rao 2. Zuleika

The eight (2 species * 2 gradients * 2 investigators) combinations are denoted as Entities (E) in the ANOVA (Table 3).

In each combination, the number of trees score vary (Table 2), necessitating a completely randomised design analysis using unequal plot sizes. It must be noted that such situations do arise

UTILISATION OF GENETIC DIVERGENCE

V. ARUNACHALAM

INTRODUCTION

Utilisation is as important as measurement of genetic divergence in germplasm. The concepts of utilisation of genetic divergence can help not only in enriching diversity in mangroves but can be used to simultaneously improve its economic traits to enhance the utility of mangrove species.

A number of attributes of economic importance (Table 1) make conservation of mangroves an attractive need.

Table 1 Attributes of economic importance in mangroves

1. Biomass (High CGR, RGR)
2. Timber value (wood content, stem volume and density, plant height)
3. Easy regeneration (from seed, sapling, unsawn poles)
4. Tannins and dyes from bark (biochemical/genetic properties of bark)
5. Resistance of Rhizophoraceae species to herbivores
6. Mangrove sap–source of black dye for manufacture of Polynesian tapa cloth
7. Low floristic diversity (leads to low resource diversity demanding sound genetic basis of breeding)
8. Medicinal value from utilisable poisonous plants
9. Industrial ethanol from *Nypa* palm
10. Mangrove–inshore commercial fishes and shrimps by way of nutrition supply and providing habitat; support of oyster and shellfish (demands study of mangroves as a plant–animal interaction system similar to mulberry – silkworm)
11. Agricultural use through conversion to impounded mangal (notably to grow salt resistant rice varieties, e.g., Sierra Leone)

In addition, mangrove genetics, though yet to be studied in depth, points to several possibilities of further genetic improvement through simple breeding methods. As reported in Tomlinson (1986), the types of possible germination and the associated vivipary (Table 2), the pollination biology in various species conducive to hybridisation (Table 3) and the diversity of breeding mechanisms across species (Table 4) suggest wide possibilities of breeding for purposive genetic improvement. However, no information seems to be available on intra- or *inter-specific* hybridisation in mangroves.

HETEROSIS

Heterosis is defined as the percentage improvement of an F1 hybrid over its mid- or better parent for a particular metric trait. In practical breeding where a breeder is interested in producing a

Table 2 Germination type and seed size in mangroves*

Type	Genus	Propagule	Vivipary (++) or crypto–vivipary (+)	Seed length (cm)
Hypogeal	*Rhizophora*	Seedling	++	70–15
	Kandelia	Seedling	++	40–30
	Bruguiera	Seedling	++	30–15
	Ceriops	Seedling	++	20–15
	Aegiceras	One seeded fruit	+	7–5
	Nypa	One seeded fruit	+	10
	Xylocarpus	Seed	–	7–6
	Avicennia	One seeded fruit and seed	+	3–2
	Osbornia	Seed	–	0.5
	Sonneratia	Seed	–	0.2–0.1

*From Tomlinson (1986)

Table 3 Pollination biology in mangroves

Genus	Mechanisms
Rhizophora	Wind, high pollen/ovule ratio, absence of elaborated stigma to catch wind–borne pollen, flower visitors, (bee, animals), flower exudate (Nectar) after floral organs lost, stigma unreceptive until after pollen release (weak protandry)
Sonneratia	Bats, hawk moths
Ceriops	Moths, small insects (wasp, fly)
Bruguiera	Birds, butterfly
Acanthus	Bees
Avicennia	(Mangrove honey from *Avicennia germinans*)
Xylocarpus	Birds

Table 4 Breeding mechanisms in mangroves

Genus	Breeding mechanism
Rhizophora	Weak protandry, self-compatible
Avicennia	Protandrous
Pemphis	Heterostyly plus self-incompatibility
Scyphiphora	Protandrous
Nypa	Protogynous
Laguncularia	Obligate out-breeding
Excoecaria	Obligate out-breeding

hybrid outperforming parents or commercial checks, heterosis over better parent is the commonly used measure.

In calculating heterosis, it is desirable to keep into account the desired direction of improvement. For instance, if early flowering or dwarf statue is the desired direction of improvement, the F1 hybrid should have lower values for those traits compared to the better parent. Heterosis is calculated as

$$H = \frac{h-p}{p} \times 1000, \text{ where}$$

h = F_1 value and p = better parent value of the metric trait. H is calculated only if (h-p) is significantly different from zero as statistically tested by t-test. When (h-p) is not significant and when h is inferior to p in value (taking direction also into account), H is considered to be absent.

Falconer (1981) defined the genetic basis of heterosis. It is a function of dominance effect for the trait and the gene frequency difference between the populations used in hybridisation. This theory is based on the supposition that the character is governed by a single diallelic gene. Extension of this theory to single multiallelic gene (Cress, 1966) suggested that too high a gene frequency (or genetic divergence) between parents may fail to yield heterosis. The theory for traits governed by two linked loci (Arunachalam, 1977) brought to focus the role of epistatic interactions and suggested that additive X additive interaction alone can bring in heterosis without the need for dominance in the parents. However, from the above theoretical developments, the following points emerge :

a. Parental genetic divergence is needed for realisation of heterosis.
b. Too high a parental divergence may not produce heterosis.

The limits to parental genetic divergence to realise heterosis have been extrapolated from experimental evidence in a wide variety of crop plants (Srivastava and Arunachalam, 1977; Arunachalam *et al.*, 1984; Arunachalam and Bandyopadhyay, 1984). The process consists of the following steps :

a. The D^2 between all possible pairs of genotypes from which parents for hybridisation are to be drawn are computed.
b. The mean (m) and standard deviation (s) of the possible D^2 values are found.
c. Four divergence classes, DC1 to DC4, are set up as under:

Divergence class	D^2 value (x)
DC1	m+s < or = x < or = h
DC2	m < or = x < or = m+s
DC3	m−s < or = x < m
DC4	1 < or = x < m−s

1 - lowest D^2 value; h = highest D^2 value

d. Crosses between parents chosen from the divergence class 3 or 2 (in that order) would give a high frequency of heterotic crosses with high magnitudes of heterosis also.

An example has been provided in Table 5 from a 10 × 10 diallelic crosses in peanut. The range of D^2 values (from 4.9 to 19.6) has been arranged into four divergence classes as described above.

Table 5 Parental genetic divergence and its relationship to F_1 heterosis in peanut

Divergence class (DC)			F_1 heterosis			
			PY		TW	
			n	m	n	m
h	19.6					
		DC1	3	170	1	84
m+s	16.7					
		DC2	7	177	3	71
m	12.9					
		DC3	8	135	7	40
m−s	09.1					
		DC4	1	51	–	–
1	04.9					

n : number of heterotic crosses; m : average heterosis over n; PY : pod yield; TW : 100- kernel weight (Source : Arunachalam *et al.*, 1984).

The frequency (n) and average magnitude of heterosis (m) of heterotic crosses for pod yield (PY) and 100-kernel weight (TW) point out clearly the superiority of DC3 and DC2. The limits for parental divergence to realise heterosis are thus provided by the class DC2 and DC3; in this example, the desired limits D2 values for parental choice were (a) 9.1 to 12.9 (DC3), and (b) 13.0 to 16.7 (DC2).

DISCUSSION

In general, heterosis is pronounced in cross-pollinating species. but in those species, genetic maintenance of parents poses problems as selfing leads to high depression in parental vigour. Pedigree breeding to fix pure lines also suffers due to associated inbreeding depression.

Mangroves appear to have desirable edges for heterosis and pure line breeding. While heterosis can manifest due to outpollination mechanisms (Table 4), parental maintenance or pedigree breeding appear to cause no concern due to reported self-compatibility and self-pollination mechanisms. Granting possibilities for *inter-specific* hybridisation, it should theoretically be possible to enhance genetic diversity through hybridisation. In particular, genetic bridge material appears to be easily generated to fill gaps in plantations through organised hybridisation in or *ex situ*.

As a spin-off, desirable improvement in a number of economic attributes is also likely which will trigger commercial cultivation of mangroves.

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DATA BASE DEVELOPMENT FOR COASTAL ECOSYSTEMS : A MODEL

M.P. TAPASWI

INTRODUCTION

Coastal areas can be regarded as the interface between three habitat media—land, air and sea. These areas contain three obvious habitats namely : (i) maritime zone—a home for many terrestrial animals and plants, (ii) sea itself, and (iii) an intertidal or littoral zone at the sea-land interface with a specialised flora and fauna. In the littoral zones—where marine sediments and soil meets—a specialised community of terrestrial halophytic plants and associated animals develop. Two of the most characteristic coastal communities of this nature are : (i) salt marshes found mainly in temperature to sub-polar climates, and (ii) mangrove swamps—of tropical to sub-tropical occurrence. The term 'mangrove' has been used to describe both an ecological group of flowering halophytic shrubs and trees (upto 30 m high) belonging to several unrelated families, genera, complete community or association of plants which fringe sheltered tropical shores. Such swamps are inhabited by a variety of terrestrial animals including insects, birds, etc. The complex root systems of plants provide suitable habitats for many marine crustaceans, fishes apart from growth of filamentous algae on the substratum giving rise to complex ecosystem. These habitats are studied by specialists from variety of basic disciplines. They collect data pertaining to their interest thereby giving rise to a large amount of information requiring careful, efficient management for future use. This information is mainly available in the form of documents like books, reports, journal articles, etc. and hence called 'documentary sources'. Students, R&D community are the main users of these sources. However, the process does not end here. The generators of such documentary information sources themselves become nondocumentary sources of information having large concern for policy makers and management personnel. Information about various institutions involved in such king of studies, different projects apart from personnel themselves form part of the non-documentary sources of information. These exists other form of equally important information : the resources data itself. Their availability, distribution, ecology, classification, economic importance, social implications, etc., is of interest to both, researchers and policy makers. The contemporary technologies help in archieving this information in the form of data base(s) for their efficient retrieval and use. Several experiments are being carried out in this line.

This paper describes the importance of clubing all pertinent information (documentary, non-documentary sources) about any single aspect system (IIS). While emphasizing on the IIS, it also touches upon the areas of concern like hardware/software and compatibility issues. It also gives an outline of the model of an IIS developed for complex topics like 'mangrove ecosystem'.

INTEGRATED INFORMATION SYSTEMS (IIS)

Any complex, serious human activity, be it research, or management, or executing some task, requires resources such as knowledge and know-how, facilities, materials, human resources and finance. Each of this entity could be collected from specific sources as shown in Table 1.

Table 1 Requirements and availability of information

Resource entity	Source
Knowledge	Documents/Data sheets about specific geographic area
Facilities/Materials, human resources	Corporate entities : Institutions/Projects
Human resources	Specialists/Expertise profiles
Finance	Funding agencies/Project

If all these are put together in one single data base, for a querry—say about a mangrove foliage and its decomposition, then the IIS should be able to retrieve not only the bibliographical citations on this topic but also an information on experts and/or institutions and projects working on it. While the principal objective behind this concept is to provide users a wide range of information as above, IIS also offers other advantages such as:

a. Resource sharing : Multiple use of the same data and of data bases provide for better resource sharing and networking among components of the system.

b. Standardisation : Implementation of norms and standards for information handling and thus ensuring greater compatibility among component systems and data bases. Exchange and merger of data from different data bases become easier.

c. Co-operative efforts : Distributed data processing is facilitated enhancing the possibilities of more optimal use of computing and human as well as computer resources.

OTHER CONSIDERATIONS

HARDWARE AND SOFTWARE

Once the creation and maintenance of IIS is decided upon, one has to select appropriate hardware/software as per the requirements. The Data Base Management Softwares (DBMS) are system (Hardware) dependent. Comparatively lower investment in IBM compatible microcomputers and their increased easy use have made most of the institutions/organisations to have atleast one equipment with them. Large number of DBMS are also available in the market. However, the best known and widely advertised software packages for data management are specialised for numerical and tabulated data. The management of structured text information (such as bibliographic descriptions) demand specific consideration. The size of the length of the data cannot be predefined in the text information (e.g., length of a title or abstract). Similarly, number of occurrences of specific information (e.g., authors of research articles or number of projects in an institution) vary from record to record. The DBMS softwares developed for predetermined length of information (numeric/tabulated data) thus become useless while handling textural data. There are few other softwares available specially for handling structured text information. The comparative evaluations of these (Besmer, *et al.*, 1987) have revealed that the CDS/ISIS (Computerized Documentation Service/Integrated Set of Information System) software used on IBM microcomputers and compatible is relatively powerful. Moreover, the licenced version of the CDS/ISIS can be had by any non-profit organisation from UNESCO (Publishers of the software) or their national distributing agencies in respective countries without any charge.

COMPATIBILITY

Distributed data processing, their sharing among components of the system and utilisation of the products need/pressurise for use of standard machinery, methodology, etc., for their compatibility. The hardware, software, structure and design used by sharing entities within the system should be compatible for easy transfer of such information among themselves. The availability of IBM microcomputers and their clones has considerably reduced the botheration about hardware compatibility issues. The use of CDS/ISIS software has also become a common place in last five years. The data stored on this software can be produced and/or converted to International standard format (ISO-2709) so that even if the entities within the system donot have 100% compatibility and the transfer is possible with little efforts. Thirdly the compatibility issues arise at deciding the structure of the data base. UNESCO - developed Common Communication Format (CCF) provides a detailed structural method for recording a number of mandatory and optional data elements in a computer readable bibliographic record for exchange purposes between two or more computer-based systems.

The proposed model of IIS takes into account these considerations. It uses CCF as a baseline for the structure, CDS/ISIS software for designing IIS on the commonly available hardware – microcomputers.

MODEL

The representation of the model is as shown below.

INTEGRATED INFORMATION SYSTEM

Inputs :	i) Documentary sources	**Outputs** :	i) Displays
	ii) Institute information		ii) Searches
	iii) Project information		iii) Prints
	iv) Personnel information		iv) Export

STRUCTURE

Different sources of information – Bibliographic, Institutional, Project Personnel – can be integrated. The concept of integration is based on the use of a common place (field) for diverse data elements at perceptive level but similar at conceptual level. The authors of a document, associated persons in the entries for institutions, projects, or the head of an institution, project leader and the expert himself, or abstract of a paper, descriptions of institutions, projects etc. are all conceptually similar though they differ at the perceptive level. Placement for such common data elements at similar areas (fields) can be seen in Table 2.

Table 3 Worksheets for data entry

Name of Worksheet	Used for
MGR	Default : having all fields defined Journal articles
JA	Journal articles
BK	Monographs, monographs with series, articles in monographs (conference proceeding articles), etc.
VENDO	Vendors information from whom books/ monographs are purchased
CP	Catalogue of periodical holdings
INST	Institutional information
PROJ	Project information
PERS	Personnel (experts) information

Table 4 Display/print formats

Name of Format	Displays/Prints
MGR	Default : Displays recorded information depending upon data type.
MAIN	Main entry of catalogue card for books
TITL	Title entry of catalogue card for books
AUTH	Author entry of catalogue card for books
SER	Series entry of catalogue card for books
NEWA	Main entry of book with classification numbers
CPERI	Periodical holdings
INST	Institute information
PROJ	Project information
PERS	Personnel information

SEARCH FACILITIES

CDS/ISIS has excellent facilities for indexing the data. It can index on each of the words occurring in any of the fields or even on complete contents. These indexes then provide powerful tool for searching available information in that data base. The software can even search for complex search strategies using boolean operators such as AND, OR, NOT, etc. Within this IIS, one can thus search for an integrated information on any specific aspect, i.e., retrieval from different data types—bibliographic, institutional, project or expertise at single stroke of the key or limit the output by searching on single data type alone.

SORTING/PRINTING

Searched information on any specific aspect can be sorted in a given order for subsequent printing. The print facility has options like : (i) single or multicolumn printing, (ii) page-by-page (by defining number of lines per page) printing and (iii) even in the form of a file for editing or printing using other softwares like DTP. Sample printouts of different data types are appended (Annexure I–IV).

EXPORT/IMPORT

Within a network of any system, sharing of the data bases has become a common practice. The compatibility issues discussed earlier find prime importance at such instance. The software has excellent capability of exporting/importing data to ISO-2709 format.

RESOURCES INFORMATION

While the above discussion in confined to the 'sources of information', a resources data can also be built. One such effort at international level has been noticed (Matthes and Kapetsky, 1988). Similar information can also be put on the CDS/ISIS software. The IIS on 'sources' have been tried and tested but the idea about the data base for resources still remains at conceptual level. The structure of such data base will be based on two main bearings (i) flora/fauna available in the ecosystem and (ii) physico-social conditions of a geographic area/ecosystem. Each of the genus species available/identified in one or other ecosystems will be recorded with relevant parameters such as distribution, ecology, biology, utilisation, conservation measures and management aspects, if any. The physico-social factors of a specific area where such ecosystem is available include information on aspects like : temperature, salinity, humidity, tidal action, climatic conditions, cyclones, rainfall, floods, soil/substratum type, sediment flow, etc. The social aspects may also be highlighted. Examples are industrialisation, educational/economic status of families within/surrounding that area, information from conservation point of view, etc.

These two aspects can be integrated by using flora/fauna code for specific ecosystem in geographic area as well as ecosystem code in specific geographic area having habitation of specific flora and fauna. The information once documented, can be updated after specific periodicity if such machinery exists. This would then eventually give a picture of biotic/abiotic changes in a given ecosystem over a period of time for planners and policy makers. This conceptual design needs to be tested on the data to correct the ideal concept, if any. However, it is felt that this type of IIS could act as an expert system in long run.

CONCLUSION

The concept of IIS has been tried and tested for the sources of information available for one or more types of coastal ecosystems. The model so designed is within the possibility of use in practice. The design is also suitable for network operations so that maximum information can be put-in by participating centres for sharing the same.

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ANNEXURE I

PRINT FORMATS

For Monographic entry

DESHMUKH, S.V. and MAHALINGAM, R. Eds.

A global network of mangrove genetic resources centres. Project formulation workshop, January 15–19, 1991, Madras, India.

India, Madras : Cent. for Res. on Sustainable Agric. and Rural Dev. 1991 : 145 pp.

I95531 N91 21562

For Journal Article entry

00017 Wafar, S.; Untawale, A.G., Bhosle, N.B. (NIO : Bil. Oceanography Div. : Dona Paula, Goa 403 004; India) SEASONAL VARIATION IN THE HEAVY METAL CONCENTRATION OF MANGROVE FOLIAGE. Mahasagar, 13(3) : 1980 : 215–223.

Seasonal variation in the concentration of some heavy metals in the leaves of seven species of mangrove vegetation from Goa, revealed that maximum concentration of iron and manganese occurs during the monsoon season without any significant toxic effect on the foliage of mangroves. Other metals like copper, nickel, cobalt and lead showed somewhat uniform concentration patterns. Copper and nickel were found to be greater (119.41 μg/g) in *Avicennia officianalis,* while *Acanthus ilicifolius* showed high concentration (46.98 μg/g) of cobalt. Nickel was found to be greater in *Bruguiera gymnorrhiza* (113.66 μg/g average and *Rhizophora mucronata* (231.06 μg/g average).

ANNEXURE II

INSTITUTE INFORMATION

Institute Code	: NIO
Institute Name	: National Institute of Oceanography, Dona Paula 403 004, Goa, India.

Tele Address	: Telephone No(s) : 46253, 46254 Telex : 0194-216 NIO IN Fax : 91-(0) 832-44612 e-Mail:
Foundation Year	: 1964-03-12 'Working Language(s): En.
Corporate Name	: Council of Scientific & Industrial Research, Raffi Marg, New Delhi, India.
Associate Entities	: NIO Regional Centre, Sea shell Building, Seven Bungalows, Versova, Bombay 400 061, India. NIO Regional Centre, Kirlampudi Layout, Visakhapatnam 530 023, India.
Principal Person	: Dr. Desai, B.N. Director
Other Persons	: Sastry, J.S., Dr., Dy. Director Sen Gupta, R. Dr., Dy. Director Nayak, B.U., Dr., Dy. Director Desa, E., Dr., Dy. Director
Contact Person	: Kesava Das, V., Mr. Head, Publication & Reprography
Subject Studied	: Physical Oceanography, Chemical Oceanography, Biological Oceanography, Geological Oceanography, Ocean Engineering, Marine Instrumentation.
Projects	: Chemical & environmental studies in the seas around India; Sen Gupta, R. Biological resources of the exclusive economic zone of India; Parulekar, A.H.
Description	: Aimed at the studies of the brackish waters and seas in and around India.
Available Equipment	: R.V. Gaveshani; O.R.V. Sagar Kanya; Atomic Absorption Spectrometer, model 4. Perkin-Elmar.
Services offered	: Consultancy services pertaining to the seas around India and abroad.
Source of Finance	: CSIR, New Delhi, India DOD, New Delhi, India
Annual Budget	: 7,26,00,000.00
Annual Publications	: 150

ANNEXURE III

PROJECT INFORMATION

Title of the Project	: Environmental impact assessment on mangrove ecosystem along the West coast of India.
Institute Affiliation	: National Institute of Oceanography Dona Paula 403 004, Goa, India. Telephone : 46253, 46254 Telex : 0194-216 NIO IN

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Working Language	: English
Principal Person	: Untawale, A.G. (Dr.) Asst. Director
Other Persons	: Wafar, S., Jagtap, T.G.
Subjects Studied	: Mangrove fauna, Mangrove flora, Effects of pollutants
ASFA Code	: 08504, 08482
Description	: Effect of wastes discharged by the industries along the West coast of India on mangrove flora and fauna is surveyed. The control measures are being suggested.
Sponsorer	: Department of Ocean Development, New Delhi, India
Collaborating Institution(s)	: M.S. Swaminathan Research Foundation, Madras Shivaji University, Kolhapur
Infrastructure & Equipment	: Microcomputer IBM PC386, HCL
Services Offered	: Development of Mangrove Ecosystem along West coast.
Budgetory allocations	: Rs.4,00,000.00
Contact Number	: abcd1234
Dates	:
Proposal : 1991-01-14	Approval : 1991-05-10
Start : 1991-06-01	Expected Completion : 1993-01-30

ANNEXURE IV

PERSONNEL INFORMATION

Personal Information About	: Untawale, Arvind G., Dr. Sr.Asst.Director
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Nationality	: Indian
Birth Date	: 1940-06-24
Language(s)	: Working : En. Other Known : Marathi, Hindi
Qualifications	: M.Sc. (Botany), Nagpur University (1966) Ph.D. (Plant Embryology), Nagpur University, (1972)

Work Experience	: Scientist, NIO, Dona Paula, Goa, (1974)
Current Subject Interest	: Resource Evaluation, Mangroves, Biodiversity, Marine Conservation
Present Activities and Plans	: Ecology of different mangroves from West coast of India. Phytogeographical distribution of mangrove species. Seasonal variation in the major metabolites and trace metals in mangrove foliage. Biochemical changes of mangrove foliage during growth and decomposition. Effects of soils on mangrove seedlings. Continuing studies on mangroves related resources, their exploitation and management.
Co-operative programmes with	: CSMCRI, Bhavnagar, India
Visits Abroad	: Meetings: The Philippines (1985), expert, Male (1990); Consultant, Maldives (1991), Papua New Guinea, Cameroon, Senegal.
Activities Financed by	: NIO, Dona Paula, Goa (India), DST, New Delhi (India), Dept. of Environment, New Delhi (India), UNESCO regional office, New Delhi (India), WWF, Indian Chapter, India.
Availability	: Enquire for periodicity

BIOTECHNOLOGICAL STUDIES IN MANGROVES

USHA MUKUNDAN

INTRODUCTION

Mangrove forests are prevalent in the tropics and sub-tropics. They are unique in their structure and function. They are fragile yet one of the most productive ecosystems of the World. Mangroves are useful to mankind in various ways as they yield both direct and indirect products of renewable nature. This fact has greatly contributed in the rapid deterioration of the mangrove environment and biotechnology could greatly contribute to the restoration of this rich environment to its original state.

TISSUE CULTURE STUDIES

One of the main applied areas in which plant biotechnology has begun to manifest its potential in India is micropropagation using tissue culture. The growing realization of the potentialities of plant cell culture for plant propagation has itself provided a substantial impetus for research. It is now apparent that cell culture is the keystone to progress in plant Biotechnology (Evens *et al.*, 1983). Plant tissue culture is a general term used for organ culture, callus, suspension of single cell and protoplast culture.

EXPLANTS

In case of mangroves, choice of explant is an important criteria to be considered since they have a large amount of polyphenols. Juvenile trees would be preferred over mature trees : similarly young growing leaves, apical and axillary buds, anthers, nucellus can serve as explant. Greenhouse grown plants may be advantageous.

SURFACE STERILISATION OF EXPLANTS

This can be carried out by using Ca $(OCl)_2$ solution or by using 0.1% $HgCl_2$, rinsed several times—with sterile distilled water.

MICROPROPAGATION

These are often preferred over conventional practices of asexual propagation in several greenhouse species because of the following potential advantages :

1. Only a small amount of plant tissue is needed as the initial explant for regeneration of millions of clonal plants in one year.
2. The *in vitro* technique provides a method of speedy international exchange of plant materials.
3. The *in vitro* stocks can be quickly proliferated at any time of the year.

There are three possible routes available for *in vitro* propagule multiplication, viz., (a) enhanced release of axillary buds; (b) production of adventitious buds through organogenesis, and (c) somatic embryogenesis.

Murashige (1974), developed the concept of developmental stage, which involves the following three processes:

Stage I : explant establishment
Stage II : multiplication of the propagule and
Stage III : rooting and hardening for planting into the soil.

Compared to herbaceous plants, the micropropagation of woody species has lagged behind. Mangroves fall in this category. The greatest difficulty is experienced at Stage III—the root induction, especially when explants are taken from mature trees. Difficulty during stage I, when the primary culture is established is also frequently encountered. This is partially due to the existence of polyphenolic compounds in the tissue of many woody species and partially due to difficulty of breaking the physiological quiescent state of axillary buds.

CULTURE MEDIA

White's medium (1943) was the most widely used medium during early days. Many improvements have been made since then, the most noticeable of which are the enhancement of the N, P and K levels, the reduction of the Ca level and the prevention of iron precipitation at high pH. There are various media like MS (Murashige and Skoog, 1962) B5 (Gamborg *et al.*, 1968), SH (Shenk and Hilderbrardt, 1972).

STAGE I : CULTURE ESTABLISHMENT

The explants may develop either into single shoots, or into multiple shoots.

GROWTH REGULATORS

Although a small of cytokinin may be synthesised by shoots grown *in vitro*. It is unlikely that the meristem, shoot tip and bud explants have sufficient endogenous cytokinin to support growth and development. Auxin is another hormone required for shoot growth since the young shoot apex is an active site for auxin biosynthesis. However in case of resting buds and small meristems, exogenous auxins are to be added.

INCUBATION CONDITIONS

The incubation temperature is in the range of 20–28°C. The most commonly used photoperiod regime is 16 h day vs 6 h night. The light intensity is usually 1–10 Klx. Since light stimulates tissue browning for explants with high polyphenol content, in case of mangroves it is advisable to incubate in reduced light intensity or even in darkness.

POLYPHENOL OXIDATION

Mangroves are rich in polyphenolic compounds. After tissue injury during dissection, such compounds will be oxidized by polyphenol oxidases and the tissue will turn brown or black. The oxidation products are known to inhibit enzyme activity, kill the explants and darken the tissue and darken the culture media. Some of the procedures used by various workers to combat this problem are :

(1) adding antioxidants like polyvinylpyrrolidone (PVP), dithisthreitol, to the culture medium.
(2) Soaking explants in antioxidant before inoculating into culture medium;
(3) Incubating the initial period of primary cultures in reduced light or darkness;
(4) Frequently transferring explants into fresh medium whenever browning of the medium is observed (Adams *et al.*, 1979; Mc Comb and Newton, 1981, Monaco *et al.*, 1977).

STAGE II : MULTIPLICATION OF THE PROPAGULE

Since multiplication is the major economic criterion for successful commercial tissue culture propagation, the proliferation rate of Stage II determines the feasibility of *in vitro* propagation of a given species. The chemical composition of culture medium and the physiological state of the plant material is of major importance.

STAGE III : ROOT REGENERATION

Adventitious root formation can be induced quite readily in many herbaceous species, but it can be very recalcitrant in most woody species, especially from the mature trees.

JUVENILITY

For hard-to-root species, the age of the plant plays an important role in root regenerating capacity (De Fossard *et al.*, 1974).

TRANSPLANTATION

After rooting, the *in vitro* regenerated plantlets are ready to be transferred from aseptic containers into pots. Factors that should be considered in transplantation are infections and desiccation. In mangroves this would be accompanied by acclimatisation to a saline environment.

GERMPLASM PRESERVATION

Preservation of germplasm is a means to ensure the availability of genetic material as the need arises. Since meristem cells are highly cytoplasmic and non vacuolated, a high percentage of cells could be expected to survive cryopreservation. One strategy used for germplasm preservation is the maintenance of cultures under minimal growth conditions (Morel, 1975). During the past few years, considerable interest has been generated in exploring the possibilities of storing plant meristems or vegetative buds at cryogenic temperatures, i.e., in liquid nitrogen at −196°C.

BIOTECHNOLOGICAL METHODS TO IMPROVE BIODIVERSITY

P. BALAKRISHNA

INTRODUCTION

Genetic diversity occurs in all biological systems, paving the way for the evolution of living World and speciation. Being a natural phenomenon, evolution helps individuals to sustain their existence in the over-growing World of competition and threat of total destruction due to several factors like struggle for space and food and to combat natural calamities. this struggle for existence and successful survival has made all living organisms to adapt themselves by changing according to need and necessity.

The simplest answer that one could give to the question of how an individual can adapt to the situation is by natural selection or by mutations that occur within. Of these, natural selection takes a longer time to bring about the necessary changes, but mutations are spontaneous, changing the characters of the organism rapidly. These mutations may be due to insertions, deletions, translocation, or inversions affecting the basic hereditary material of the DNA, have led to the variations in the biological systems which are presently referred to as biological diversity. biodiversity is not only the variation that occurs between species or genera but also within them.

Though the variations that are present between two different species are well understood, easily distinguished and documented, intra-specific variation is poorly understood as it is difficult to distinguish the variations that occur within a species or a variety. It is therefore important to study the variations that occur within a species, which otherwise may not have morphological manifestations or physiological variations.

Biotechnology has become an integral part of most of the biological programmes, with a network of available techniques and their applications. the techniques that are used in the study, covering they polymorphisms or variations in the species are those of RFLP (Restriction Fragment Length Polymorphism) and RAPD (Rapid Amplification of Polymorphic DNA). This paper aims at explaining the techniques of RFLP and RAPD with details of their application, and use of studying and creating variations at intra-specific levels.

RESTRICTION FRAGMENT LENGTH POLYMORPHISMS (RFLPS)

Natural variation in DNA sequence can be detected in several ways. One way is to directly sequence the DNA and make detailed comparisons. However, this method is time-consuming. Another way of detecting this variation is to use a special class of enzymes called restriction enzymes (nucleases produced by a variety of microorganisms) and have the ability to reorganise target sites (restriction sites) made up of specific base sequences in the DNA. If the required base sequence is present in the target DNA, the restriction enzyme will cleave the DNA at the target size. A large piece of DNA will thus be reduced to a series of smaller fragments of defined size by digestion with a restriction enzyme. The number of fragments produced and the size of each fragment will reflect the distribution of restriction sites in the DNA. The fragments produced will thus be specific for each target DNA/restriction enzyme combination and can be sued as a "fingerprint" specific for a given target DNA (or for the organism containing that DNA).

Relatively small DNAs, such as chloroplast DNA, will usually produce about 40 discrete restriction fragments when digested with a typical restriction enzyme such as EcoRI. The restriction fragments produced by digestion of purified chloroplast DNA can be separated according to size by subjecting the DNA to agarose gel electrophoresis after digestion with a restriction enzyme. After the gel is stained with ethidium bromide, the pattern of restriction fragments can be directly observed or photographed in ultraviolet light. Chloroplast DNAs which differ from on another in base sequence, or have been rearranged by insertions, deletion or inversions, produce restriction fragments of different sizes. Such difference in fragment size, arising from restriction enzyme digestion of DNA, length polymorphisms (RFLP) can be used as a direct measure of genetic variability. Many studies which utilised RFLPs of chloroplast DNA to study phylogeny as systematics in various plant groups, have show that the analysis of RFLP variation in chloroplast DNA is very useful in unravelling systematic relationships in plants. Unfortunately the utility of chloroplast DNA in plant breeding is extremely limited. Most genes of agronomic importance are located on nuclear chromosomes.

RFLP analysis can be applied to chromosomal DNA also, but is more complex because of greater complexity of nuclear DNA. Digestion of the nuclear DNA from a higher plant with a typical restriction enzyme produces millions of discrete DNA fragments in a continuous range of sizes. If digested, DNA is subjected to gel electrophoresis and stained with ethidium bromide so distinct fragments can be visualized. With large number of fragments produced, the DNA appears to run as a continuous smear. However, individual restriction fragments are still well-resolved in the gel, RFLPs can be reorganised between DNAs from different organisms. More complex techniques have to be used to resolve them, which involve the use of cloned DNA probes and DNA hybridisation.

LIBRARIES OF CLONES/PROBES

Since RFLPs of nuclear DNA cannot be directly visualized, the usual procedure is to use small pieces of chromosomal DNA as probes to detect individual restriction fragments. Using the high specificity of DNA - DNA hybridisation, such probes can detect individual fragments in the complex mixture of fragments of nuclear DNA present in a restriction digest.

DNA from the plants to be compared for RFLP difference is isolated, digested with a restriction enzyme, and then fractionated on an agarose gel. As explained above, the DNA will now be in the form of millions of restriction fragments fractionated in the gel by molecular weight. In order to use DNA-DNA hybridisation to detect specific fragments, the probe DNA and the DNA in the gel must be single stranded (denatured). The gel is soaked in a base such as NaOH to denature the DNA and to facilitate hybridisation, the DNA is transferred out of the gel onto a membrane filter by a procedure called "Southern" transfer (or blot). A filter cut to the same size as the gel is placed directly against the gel and the DNA is elated out of the gel onto the filter. Since the filter is in direct contact with the gel; the pattern of restriction fragments in the gel is maintained on the filter. The denature DNA binds very tightly such filters, and the filter can be repeatedly used for hybridisation experiments.

In order to see where the probe is hybridised, it is necessary to label it in some way. The most common way to do this has been to radioactively label the probe with phosphorus-32(32p). The labelled probe is allowed to hybridised with the DNA filter. Excess unhybridised probe is washed off the filter, and the filter is subjected to autobiography to detect the restriction fragments to which the probe has hybridised. In this way, individual restriction fragments can be detected in complex preparations of higher plant DNA. Currently, probe labelling techniques which do not require the use of radioisotopes are being developed.

PROPERTIES OF RFLPs GENETIC MARKERS

Useful, ubiquitous, Mendelian inheritance (Genomic RFLPs), maternal inheritance (organelle RFLPs), stably inherited, co-dominant expression, multiple alleles for each RFLP, devoid of pleiotropic effects on economic characters.

Convenient

Detectable in all tissues, I Detectable at all ages (enabling early detection). Long shelf life of the DNA samples. Informative about the nature of the variation.

Numerous

Virtually unlimited number of probe × enzyme combinations are available. Probes are not restricted to coding sequences (random clones). Probes detect silent variations (introns, spacers), and variations within hybridising and flanking sequences.

RFLPs thus are very useful in many ways — for the construction of genetic maps, for measuring relative gene diversity, in exploring the origin and evolution of crop species, in strain and varietal identification and to measure quantitative trait loci.

RANDOM AMPLIFIED POLYMORPHIC DNA (RAPD)

RAPD is a new type of DNA polymorphism assay developed by Williams *et al.* (1990) based on the amplification of random DNA segments with single short primers of 10 base pair length using the Polymerase Chain Reaction or PCR. This reaction amplifies several regions of the genome under study and the polymorphisms are inherited in a Mendelian fashion as in RFLPs. PCR facilitates the amplification of discrete segments of DNA by annealing the primers to the complementary sequences and the extension of the primers with the enzyme polymerase. As the amplification products are also complementary to the primers, successive cycles of amplification double the DNA synthesised in the previous cycle. There is therefore an exponential increase in the amount of sequence of interest, theoretically giving a maximum of n^2 where 'n' is the number of cycles of amplification performed.

The advantage of RAPDs over the other PCR-base techniques is that RAPD do no require information about the specific sequences of nucleotides. Also RAPDs can be used for analysing variations on all living species as the primers used in this reaction are universal and random. A RAPD reaction is also easier to perform and is very effective over RFLPs as they detect even single base pair changes. It also takes lesser time to carry out a RAPD reaction and the amount of DNA required is also small. RAPD markers are dominant markers and hence detection of homozygotes and heterozygotes is not possible. But the variations can be easily detected like those of a co-dominant marker if the specific bands are used as probes themselves. It has been established that PCR-based assays can have wider applications in varietal identification, in identifying specific and foreign genes in trasgenic or other DNA studies. Effectively RAPDs can replace RFLPs, and are cheaper, easier and efficient.

USING MARKER-BASED VARIATIONS IN GENETIC ENHANCEMENT

Once obvious variations are observed, the individuals are segregated and used for genetic enhancement. Creating variations is easily possibly by using tissue culture, either through wide crossed or by sexual crossing followed by embryo rescue or by hybridisation. But the more easy and definitive way is to obtain somatic hybrids by protoplast fusion of the parental stock.

Once protoplast fusions attempted, it is easier to screen for variations among the fusants (resynthesised plants) and variations occurring out of this can be used in developing new varieties of plants. This has been observed as a better way to broaden the genetic base of plant species. Thus marker-based techniques help in identifying even minute variation that can be tapped for genetic enhancement and are reliable in many breeding applications.

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AQUACULTURE IN MANGROVE ENVIRONMENT

ARUN H. PARULEKAR

Coastal ecosystems, of which mangroves form an integral part, are intricately diverse and equally high productive biotopes, accounting for more than 60% of the World's sea-food production, through capture and culture fisheries. Essentially an Intertidal or littoral space, the mangrove ecosystem is a stressful habitat and is subjected to the lack of vigorous water motion, active sedimentation of fine particles, relatively sheltered location with high decomposing detrital matter, all of which makes the biota adapt to a wide range of environmental variations or evolve strategies to minimise the severity of stress.

No correlation is reported to exist between the phytoplankton biomass, benthic biomass and exploitable fish yield from the mangrove ecosystem. A major part of the primary production enters the mangrove food web as dead organic matter, i.e., detritus, which is either utilised within the mangrove ecosystem or transported into the adjoining water body in a degraded form. Several costly experiences have proven that mangrove environment is not necessarily the optimum location for aquaculture. In spite of being a none-too-ideal aquaculture site, the estuaries and backwaters fringed by mangrove vegetation have long been used for rearing and/or fattening of prawns, bivalves and finfishes.

In India such areas, to name a few, are "bheris" in West Bengal, "Chemmeen Kettu" in Kerala, "Gazani" in Karnataka, "Khazan" in Goa and "Khar lands" in Maharashtra, and they reportedly cover an area of over 45,000 hectares with an annual yield of 15,000 tons of shrimps and 20,000 tons of bivalves, crabs and finfishes. The general consensus based on the analysis of cost factor, pond management efficiency and annual production levels has indicated that the disadvantages of setting up of largescale commercial aquaculture ventures in mangrove areas outweigh the advantages and should be resorted to only in the absence of other options. The scientifically managed aquaculture operations in mangrove ecosystems are relevant to less-developed and developing countries where considerations of minimum use of capital, simplicity of operation, low cost-low price products and a substantial and effective market demand favour it.

In India especially in the last two decades, a number of experimental aquaculture farms have been developed in estuaries and backwaters fringed with mangrove vegetation. A fish farm in the reclaimed mangrove swamp sustained prawn and fish production varying from 1400 to 2200 kg/ha, with prawns alone contributing 550 kg/ha. The culture of "mullets" and "pearl spot" in a fish farm surrounded by mangrove vegetation showed a net increase in fish biomass of 800 kg/ha and a high rate of return of 75% on the investment. Similarly, in the culture of green mussels on a floating raft in a mangrove-lined open estuarine site, a high yield of 4.8t/ha/yr with a rate of return of 180% on the investment has been reported.

The aquaculture in mangroves signifies a case of necessity rather than suitability. In specific cases of aquaculture in the mangrove ecosystem of India as elsewhere, economic and social benefits may outweigh management problems. Experience in Thailand, Indonesia, Ecuador and Panama has shown that salt flats and other spaces on the landward side of mangrove vegetation are suitable for aquaculture. While any substantial increase in marine capture fisheries is thought to be rather uneconomical, other logical course of action for fulfilling the realistic demand for seafood proteins will be from marine and estuarine culture fisheries or aquaculture and towards this, mangrove vegetation as an integral part of most productive and presently underutilised coastal ecosystem, offers immense opportunities for generating food resources through aquaculture.

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UTILISING MANGROVE SWAMPS FOR AQUACULTURE

R. PAUL RAJ

INTRODUCTION

Aquaculture, the farming of aquatic organisms useful to man, is emerging as a successful bio-industry, both in developed and developing nations of the World. the phenomenal growth of human population and the growing threat of depletion of wild stock of commercially important aquatic species due to excessive exploitation and environmental degradation during the past few decades, have prompted governments of draw up plants and execute programmes in a aquaculture to augment natural production by developing higher to unutilised waste lands and water resources. The age-old extensive aquaculture practices are being replaced by improved extensive, semi-intensive and with adequate infrastructure, hatcheries, nurseries, feed plants, processing plants and well-designed grow-out systems added another dimension to the growth of aquaculture and aquaculture-based industries. These hi-tech systems are capital and energy intensive systems with very high production potentials. Planned aquaculture development can generate enormous gainful employment opportunities, both for rural and urban populations, and help improve the socio-economic status of the rural population and the production of exportable commodities, which in turn would help to earn valuable foreign exchange.

Mangrove swamps found to coastal zone of the Indo-Pacific region are favored for the culture of a large variety to finish, crustaceans, molluscs and seaweeds of commercial importance. However, it is essential to judiciously use these unique habitats for a aquaculture purposes, after comprehensive studies on their ecology and by evolving appropriate mangrove-friendly culture techniques. This article highlights the aquaculture practices in the mangrove swamps and their vicinity in the Indo-West Pacific region.

CRAB CULTURE

The mud crab, *Scylla serrata*, is a ubiquitous inhabitant in the sub-tidal and Intertidal regions of mangrove estuaries and creeks in the Indo-West Pacific region. Live mud crab is a gourmet's choice, commands an excellent price and is in great demand. Male crabs with large chelate legs and females with ripe ovaries fetch a premium price in the markets. Extensive farming of the mud crab is practiced in the Philippines, Malaysia, Indonesia, Thailand and Taiwan, using wild juvenile crabs. The non-availability of adequate juveniles (crablings) for stocking is the major constraint since reliable hatchery production technology has not yet been established for the mud crab.

Mud crab flattering is practiced by culturing the young crabs in bamboo cages or in fences earthen ponds in brackish water areas (10 to 30 ppt) for periods ranging from 15 to 30 days to attain additional weight. Animal protein diets such as marine trash fish, prawn heads, bivalve meat, small crabs, etc., are fed to the crabs at the rate of 10% of the body weight initially to 5% of the body weight at harvest. Under-fed animals become increasingly aggressive and restless and cannibalistic. Crabs weighing 200–300 g caught in nearby natural habitats are stocked at a rate of 2 to 4/m^2 and are grown to marketable size and the stage of the moult cycle should be chosen for harvesting to get maximum muscle protein.

Juveniles of the crab weighing 5–10 g can also be cultured in fenced earthen ponds stocked at 3–5 numbers/m^2 and marketable size is reached in 7 to 8 month's time. The dug-out earthen ponds are generally small in size (<1600 sq.m). The central portion of the pond is shallow, often exposed so as to provide a natural habitat for the crabs to be buried and live. Fence structures using bamboo poles are provided all around the ponds so that the crabs do not escape out. Tidal exchange through a simple sluice gate structure is the common method of water supply and drainage in ponds. Although recent studies have shown the potential of using dry pellet feeds based on slaughter-house and shrimp processing plant by-products, calm meat gives better growth. Mud crab culture is also done in milkfish ponds in the Philippines and Taiwan, and in *Gracilaria* culture ponds in Taiwan. Juvenile crabs of 1.5 to 3.0 cm are usually stocked in milkfish or *Gracilaria* culture ponds 0.5–2.0 ha in area. Up to 10,000 crabs/ha are usually stocked and a marketable size of 12 cm (220 g) is reached in five to six months. Waste animal protein is fed and survival over the culture period is 50–70 per cent depending on the size of crabs stocked (Chen, 1976). Post-moult crabs face the highest risk of mortality in culture ponds as these crabs are defenseless against attack from other normal crabs. Provision of shelters in the pond bed for moulting crabs to hide can serve to reduce this source of mortality. Problems of aggression and cannibalism in Scylla culture could be overcome by rearing crabs individually in wire-mesh cages (Bensam, 1986), using cages measuring 24 cm diameter, placed within a coastal pond, reported and overall growth increment of 17 g/crab/month with fresh trash fish and clam meat, and resulted in an overall survival rate of 65.5%. He suggested that survival could be improved by rearing the crabs in larger cages.

PRAWN CULTURE

Prawn culture in mangrove swamps is about a century old, and the trapping and holding system of marine prawn cultivation is still in practice in South-east Asia. However, tremendous advances have taken place in the technology employed in prawn culture, so that today we have an array of technological packages to meet demands from small farmers to industrial entrepreneurs. Although a number of prawn species enter into mangrove ecosystems, the most commonly cultured species are the tiger prawn (*Penaeus monodon*), the banana prawn (*Penaeus merguiensis*) and white prawns (*Penaeus indicus* and *Penaeus penicillatus*).

Based on the pond size, stocking density of seed, technological inputs, management measures, water exchange and production at harvest, prawn farming has been broadly grouped into traditional, extensive, semi-intensive and intensive systems. In the traditional system, ponds are not adequately prepared or managed and there is no control over the quality or quantity of stocking of the prawn seed, and the entire system is tide-dependent. The stocking density depends on seasonal abundance of prawn seed. Shallow water depth and predation by carnivorous fish account for considerable prawn loss from this system, Finish and prawns of low market value often enter into these uncontrolled systems and compete for food and oxygen. The yield from such a system ranges from 100–500 kg/ha/yr, mostly of low-value prawns. The only advantage in this system is that the developmental and operational costs are very low. In India these types of traditional systems are still used for culture 'bheris' of West Bengal and 'pokhali' fields of Kerala. Improvements have been made in these systems.

In the extensive system of prawn culture, ponds are constructed with a systematic layout of the area. Each of the ponds is provided with a separate inlet and an outlet sluice gate to facilitate water intake and flushing out of metabolites through feeder and drainage canals. The ponds are either rectangular or square in shape with 0.5 to 1 ha size and 1.0 to 1.2 m depth. The ponds are dependent on tidal water exchange or are pump-fed. The ponds are prepared by drying the bottom, ploughing liming and fertilising, density ranges from 30,000 to 100,000/ha/crop. Supplementary feeding is done with compounded pelleted feeds, and in some farms fresh clam meat, chopped trash fish and pila meat are given. Production ranging from 1 to 4 tonnes is obtained in two crops in a year.

Ponds for the semi-intensive system require good clayey soil and a large amount of good quality water with minimum fluctuations in the environmental parameters. Salinity, pH, dissolved oxygen and ammonia in the water should be maintained at optimal levels. The size of ponds varies from 0.25 ha to 0.5 ha. In addition to daily water exchange, about 20 to 50% aeration is also provided for maintaining the water quality. Stocking density ranges from 2–3 lakhs/ha of species like *P. monodon* and 3 to 6 lakhs/ha for *P. indicus*. Quality controlled artificial pellet diets with potential feed conversion ratio (FCR) of less than 1.5:1 (feed:prawn) are fed to the prawns. The important characteristics required in the feeds are hydrostability exceeding six hours, balanced nutrients profile, presence of attractants and feeding stimulants, anabolic agents which will not have any residual effect, and preservatives in adequate levels. The feeding strategies employed are very important. The ration offered, feeding schedules and feed dispensing methods are all important factors in achieving maximum efficiency of the feed and in preventing wastage of feed. Paddle-wheel aerators are required to maintain desirable dissolves oxygen levels. Control of plankton blooms and diseases are also important in achieving high production. Removal of waste metabolites, particularly ammonia, in the water is very important aspect of management. Production achievable in this system ranges from 4 to 8 tonnes/ha/crop.

Intensive systems are specially designed tanks with concrete walls and earthen bottom and central drain for the disposal of waste water. Continuous pumping of water, elimination of wastes and aeration are done in this system. Stocking densities range from 100–150 prawns/m^2 and yields 6 to 12 tonnes/ha/crop. Specially compounded feeds containing high protein content, balanced level of fatty acids, vitamins and minerals are fed to the prawns to maintain fast growth.

FINFISH CULTURE

Finfish as a group are abundant in mangrove creeks and estuaries. The milkfish *Chanos chanos*, grey mullets of the genera *Mugil*, *Liza* and *Valamugil*, rabbit fishes, cichlids, mud skippers and predatory fish like groupers, sea-bass, tarpons and catfish are found to be cultivable species. Two systems of fish culture could be adopted in mangrove areas: cage culture in sheltered mangrove lagoons with adequate tidal water exchange, and pond culture in the tidal flats found in the vicinity of mangroves.

MILKFISH CULTURE

The milkfish *Chanos chanos* is a highly euryhaline fish which can tolerate wide fluctuations in salinities and hence can be cultured in fresh water to hypersaline water conditions provided other water characteristics are optimal for the fish. However, low salinities (5–12 ppt) are reburied for fast growth. Despite the breakthrough achieved in the controlled spawning of the fish, milkfish culture is dependent on wild fry collections, and the area to be utilised for culture has to be regulated with reference to the availability of natural seed. Milkfish is the principal species reared in more than 400,00 ha of coastal mangrove ponds in South-east Asia (McIntosh, 1982). In Taiwan, milkfish production as high as 3 tonnes/ha/yr has been achieved in some ponds (Chen, 1976).

Milkfish fry are collected from their nursery ground using sweep nets, scoop nets and shore seines. Kumagi *et al.* (1980) mention that some of the best fry grounds border mangroves and comment on a belief of local fishermen that chanos fry are positively attracted to mangrove environments. Growout ponds for milkfish vary considerably in size depending on location and topography, and intensity of the culture system. Some tambaks in West and central Jawa are only 0.5–2 ha in area; in East Java 3–10 ha (Schuster, 1952). Ponds of 1–6 ha are used in Taiwan (Chen, 1976) whereas in the Philippines ponds as large as 100–500 ha are operated (Ling, 1977).

Milkfish are microparticulate feeders and they graze the benthic organic complex of algae, diatoms, detritus and meiofauna. Milkifish show a strong preference for blue-green algae of the 'lab-lab'type (Blanco, 1973). Lab-lab is made up of a complex mixture of microscopic plants and animals and is considered to be more nutritious than filamentous green algae. The use of organic fertilisers, particularly chicken manure, triggers the growth of lab – lab. In Taiwan, animal manure (500–1000 kg/has) or rice bran (300–500 kg/ha) is applied to pond soils deficient in natural organic matter. ling (1977) has shown that milkfish of mixed size groups utilise the benthic algal crop more efficiently than fish or a single size class. Supplementary feeding is given with rice bran 25 kg/ha/day or soya bean and peanut meal (25 kg/ha/day) together with applications of animal manure. Shallow water depth promotes development of blue-green algae. Water levels are kept low in milkfish ponds, about 12–15 cm in nursery ponds and 20–30 cm in grow-out ponds. Stocking density in grow-out ponds normally varies from 1000–1500/ha and they are grown to a marketable size of 200–350 in 4 to 6 months. Thus two to three crops are obtained in a year, giving a total yield of 100 kg/ha.

MULLET CULTURE

Many species of grey mullets of the family Mugilidae are catedromous, entering estuarine and brackish water environments when young, and as adults returning to the sea for spawning. The mullets are extremely euryhaline finfish and are also cultured along with carbs in freshwater ponds. Like the milkfish they feed on benthic algae, plant detritus and the associated micro-flora and micro-fauna; and their juvenile stages enter mangrove waters in large numbers. The brackish water culturable species belong to the genera *Mugil*, *Liza* and *Valamugil*.

Sivalingam (1975) Surveyed the mangrove areas in the Niger delta and indicated that *L. falcipinnis* could meet the stocking requirements of at least 10,000 ha of mangrove ponds. Mullets of the *Liza* group are ideal candidates for culture in mangrove fish ponds because of their intimate association with mangrove environments (McIntosh, 1982). Up to 239 Kg/ha of mullet were produced in unfertilised experimental mangrove ponds near lagos as a result of natural tidal entry of mullet fry (Sivalingam, 1975), *Liza parsia* fingerlings stocked at 36,000/ha after 180 days gave production of 600 kg/ha and *Liza tade* (196 g) stocked at 6000/ha after 100 days of rearing gave a net production of 87 kg/ha (ICAR, 1978). In polyculture of mullets (*Mugil curema* and *M. brasiliensis*) and various species of Gerridae, in mangrove ponds in Brazil, production figures of 400-1500 kg/ha have been obtained (Cavalcanti *et al.*, 1978).

CULTURE OF SIGNAIDS

The rabbit-fish, *Siganus canaliculatus*, is a herbivore and can be acclimated to withstand salinity down to 5 ppt although it abundantly occurs in waters with 17 to 37 ppt salinity and 23 to 36° C temperature. According too Lam (1974) the fish reaches 150 g at the end of the first year in Singapore water.

CULTURE OF CICHLIDS

Tilapia of the Sarottherodon and the pearl spot, *Etroplus*, are potentially suitable cichlid fishes for mangrove pond culture in estuarine habitats (McIntosh, 1982). *Etroplus suratenis* is a brackish water fish native to India and Sri Lanka and breeds readily in brackish water ponds provided there are stones or other hard substrata present to which spawns can attach their eggs (Hora and Pillay, 1962). Juveniles can also be collected by drag nets during the monsoon season for stocking in ponds (ICAR, 1978), Jayabalan *et al.*, 1980). Experimental culture trials in a fertilised coastal pond of 0.16 ha area have shown that the fish reach a size of 50 g from initial weight of 15 g with a survival rate of 37 per cent (ICAR, 1978). More experimental trials are needed as the fish has high market value. Among the Tilapia, *Sarotherodon mossambicus* is cultured in mangrove tambaks in Java. It is considered as pest in several countries as it breeds prolifically and competes for food with other species. However, techniques to control sex and production of an all-male population have already paved the way for their culture in coastal ponds.

CULTURE OF MUD-SKIPPERS

Mud-skippers are ubiquitous inhabitants of mangrove environments (McIntosh, 1982). In Taiwan, Burma and some countries in South-east Asia, they are highly regarded as a delicacy.*Periphalmodon schlosseri* and *Boleophthalmus chinensis* are two edible species.*B. chinensis* is highest priced among local Taiwanese fishes (Chen, 1976). Mud-skippers are reared in brackish water ponds of 0.1–1.0 ha size. Ponds are prepared with about 600 kg of animal manure and rice bran to encourage development of an algal crop. Juveniles (1 to 1.5 cm) stocked at 50,000/ha grow to marketable size of 24 g in one year with a production of around 600 kg/ha/yr (Chen, 1976).

CULTURE OF PREDATORY FISHES

The sea bass *Lates calcarifer*, and the estuarine grouper *Epinephelus tauvina* are cultured in mangrove ponds and floating cages in brackish water lagoons. All the three species could be grown on a mixture of pellet diets and rash fish. Studies by the Central Inland Fisheries Research Institute (India) at Kakdwip (ICAR, 1978) indicated that y a system of multiple stocking and harvesting, as much as 3350 kg/ha of sea bass could be produced when adequate feed organisms become available.

CULTURE OF MOLLUSCS

Edible species of oysters, clams and gastropods are collected expensively from mangrove habitat for local human consumption, for gelding animals and for compounding feeds. This discarded shells are collected for lime or cement production. Mangrove mollusc culture is being viewed as a means of supplementing natural production to meet local requirements and also supply the developing export markets for molluscs (McIntosh, 1982).

OYSTER CULTURE

Oysters of the genus *Cassostrea* are the most suitable for culture in mangrove ecosystems. The factors that influence distribution and survival of oysters include salinity, current velocity, dissolved oxygen concentration and temperature. *C. madrasensis*, *C. cucullata*, *C. rhizophorae* and *C. gasar* are cultivable mangrove oysters. Moderate tidal and current movements are necessary to provide oyster populations with a steady supply of food and oxygen, and to inhibit settlement of sediments. for *C. rhizophorae*, water currents of 30 cm/second and dissolved oxygen levels of 2–5 ppm are considered optimal (Nikolic *et al.*, 1976). Nikolic *et al.* (1976) have described a low-cost culture system for *C. rhizophorae* developed in Cuba which utilises branches of the red mangrove tree trunks or other inexpensive woods. Collectors are positioned so that the majority of branches penetrate the water over which the greatest natural spat fall occurs. The collectors are raised out of water up to 24 hours once a months to eliminate fouling organisms such as sponges and tunicates. Oysters are harvested as they attain commercial size, beginning 5–6 months after the initial spat settlement. Average yield per collector was about 5.2 kg for 374 oysters. The average life of a collector is about 9 months. Instead of felling the *Rhizophora* trees for use as spat collectors, the combination of the fixed rack and floating raft culture system would help in developing a mangrove-friendly oyster culture operation.

Experimental studies in Taiwan on the suitability of different culture materials have shown that corrugated asbestos sheeting is the most suitable substrate for collecting spat of *C. belchei.* Asbestos strips (10 × 22 cm) are arranged vertically in rows within wooden frames (Chin &n Lim, 1975, 1977). In India spat of *Crassostrea madrasensis* is collected using lime-coated roofing tiles in the oyster spwaning areas. After sufficient numbers of spat have settled, the frames are placed on racks held above the substratum or vertical supports. After four months the oysters are detached from their collectors and transferred to wire trays suspended from floating rafts. After a rearing period of about 12 months, the oysters with an average meat weight of 14–21 g are harvested. The yield is about 18,000 kg per ha. Water temperature, light intensity, food supply and tidal exposure level all influence the meat weight/shell size ratio of oysters.

CLAM CULTURE

The blood clam (cockle) *Anadara granosa* is one of the suitable species for culture in mangrove foreshore, particularly soft mud-flats, wee it lives particularly buried in the surface mud layer. Experiments conducted in Kakinada Bay in India showed a production of 0.39 tonnes/100m 5 months, 2.6 tonnes/625 m 5 1/2 months, and 6.1 tonnes/0.16ha/7 months respectively; the corresponding per hectare production being 39 tonnes, and 38.1 tonnes (Narasimham, 1980). A return of 34.2% on investment was reported by Narasimham (1986). Narasimham (1988) also reported the in Kakinada Bay densities of 75–100 clams/0.25m^2 did no affect the growth ate and suggested that a stocking density of 400m^2 is optimum for maximising the production. A retrieval rate of 41.5% was obtained without whereas a retrieval rate of over 83% was obtained with fencing. In Malaysia this species reaches marketable size in 6–10 months (Bardach *et al.*, 1972) and a production rate of 40 t/ha/yr (Oon *et al.*, 1982). In Thailand, average production of 8.9 tonnes/ha has been reported.

MUSSEL CULTURE

Species which could tolerate muddy estuarine conditions, such as the green mussel *Mytilus smaragdinus*, have been cultivated in Thailand and the Philippines. Groups of wooden stakes are used as sat collectors. Bamboo poles of about 11m length are also used. Stakes cut from mangrove date palms (*Phoenix paludosa*) are preferred in Thailand because they are inexpensive, readily available and Durable. Up to 12.5 kg of mussels can develop in a single meter bamboo (McIntosh, 1982). The annual production of mussels is 40 tonnes/ha in Thailand and 250 tonnes/ha in the Philippines (Chen, 1977).

SEAWEED CULTURE

Edible seaweeds (*Caulerpa* and *Gracilaria* - agar-producing weed) occur in mangrove areas of South-east Asia and are considered to have excellent farming potential in disused mangrove fish ponds. In addition to food and feed value, substances of possible pharmaceutical value also been identified in Caulerpa (Doty, 1977). In seaweed farms in the Calawisan region of the Philippines, *Caulerpa* yields of 35 tonnes fresh weight/ha or more can be produced when conditions are favourable. The alga *Gracilaria* can be grown in estuarine salinities (8–25 ppt) but cannot tolerate hypersaline conditions (Chen, 1976). In Taiwan, *Gracilaria* is cultured in ponds previously stocked with milkfish. Ponds of 1 ha in area are seeded in April with 3000–5000 kg of *Gracilaria* cutting spread evenly over the pond bed. The ware depth is kept at 20-30 cm during the first two months and then increased to 6–80 cm as temperatures rise. The ponds are fertilised with urea (3 kg/ha/applied weekly) or fermented pit manure (120–180 kg/ha every two to three days. During the June to December growing season, the sea weed is harvested a ten-day intervals, cleared of debris and sub-dried. Average yields are 7–12 tonnes of dried sea weed/ha/yr. Although *Gracilaria* culture is possible in the muddy open mangrove areas, grazing the cop by fish and damage by Crabs (CMFRI, 1979) may impede the growth of the alga.

STRATEGIES NEEDED FOR AQUACULTURE DEVELOPMENT IN MANGROVE HABITATS AND THEIR VICINITY

1. Systematic surveys and comprehensive studies are needed to identify areas where aquaculture could be carried out without altering the mangrove habitats and areas that require total protection from any kind of human activity, including aquaculture.
2. Aquaculture practices requiring massive infrastructure development-roads, electrical installations, bridges, ponds, sluice gates and feeder canals, pump houses, farm houses, feed plants, etc., should be banned in mangrove habitats.

3. A reassessment of the extent of coastal areas suitable for land-based coastal aquaculture practices should be made by excluding the mangrove habitats, but covering the mangrove free mud-flats found in the vicinity of mangrove habitats.
4. The conventional view that mangrove swamps and brackish water areas are ideal sites for prawn culture is now being disputed since very high production rates have been achieved in prawn farms located in mangrove-free coastal areas by direct pumping of sea water.
5. The aquaculture practices that could be carried out in mangrove estuaries and lagoons with adequate tidal water exchange are: (i) pen culture of the mud crab, *Scylla serrata*, in the shallow are, (ii) culture of euryhaline clams like *Anadara granosa*, *Villorita cyprinodies* and *Meretrix* sp. in the muddy substratum using suitable enclosures, (iii) tray-culture of edible oysters of the genus *Crassostrea*, (iv) rope culture of mussels which can withstand the ecological conditions prevailing in the mangrove waters, and (v) net cage culture of finish such as mullets (*Mugil* and *Liza*), milkfish (*Chanos chanos*), pearl spot *Etroplus suratensis*) and sea bass (*Lates calcarifer*) could also be done in tide-fed mangrove lagoons and estuaries which are relatively deep (8 m depth). Areas with excessive siltation are not suitable for cage culture. Selection of site for any form of culture practice should consider the problem as accessibility of the culture site without in any way affecting the mangroves.
6. Mangrove habits could support aquaculture in the following way : (a) mangrove swamps, creeks, estuaries and lagoons are some of the best nursery grounds for crabs, prawns, fish, oysters and clams and thus are important as sources of seed of culturable species. (b) Euryhaline clams are abundant in mangrove habitats. Clam growth and maturation of these animals. Sustainable extraction of clams would provide meat for feeding the above animals and the shells have value in the chemical and cement industries. (c) The giant freshwater prawn, Macrobrachium rosenbergii, is known to breed to low-saline waters, including mangrove areas. Brood-stock of the prawn could be collected from mangrove habitats for hatchery production of seed. (d) A variety of polychaetes, nematodes, Copepods, rotifers and diatoms inhabit the mangrove habitats. Some of these are excellent food for feeding larvae and post-larvae of fish and crustaceans. Polychaetes like *Marphysa* spp. have been known to promote maturation when fed to prawns and crabs. These live-food organisms can be collected from mangrove swamps and cultured.
7. Mud-flats in the vicinity of mangroves could be suitably developed for construction of farms for cultivation of prawns, crabs and fish by adopting the monoculture or polyculture techniques. Recent studies in Nellore district in Andhra Pradesh, India, indicated the suitability of low-saline water (< 6 ppt) for the culture of Indian manor carps (*Catla catla* and *Labeo rohita*) along with tiger prawn (*Penaeus monodon*).
8. Experimental studies on the decomposition of the mangrove leaves have shown that the crude fibre and nitrogen-free extract content decrease, but the nitrogen and crude protein contents increase, during decomposition. The detritus thus obtained when included as a component of feed improved the growth of *Penaeus indicus*. Comprehensive microbiological and meiofaunal investigations are needed to identify and isolate organisms which may be useful for bioconversion of fibre-rich plant leaves and grasses, and the detritus obtained could be used in feed or as a substrate to rear live-food organisms.
9. The mangroves also could benefit from aquaculture in their vicinity. By directing the nutrient-rich effluent water from culture systems to mangrove habitats, the growth of mangroves could be improved.

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PENAEID PRAWNS AND THEIR CULTURE IN MANGROVE AREAS

C.T. ACHUTHANKUTTY

INTRODUCTION

The estuaries in the tropics and sub-tropics are fringed with lush green mangrove vegetation and hence are known as mangrove estuaries. The fishery resources of these estuaries are tremendous and provide a major source of income to the majority of the coastal population. However, it is only recently that the importance of mangroves in the development of inland and coastal fisheries is beginning to be understood.

Mangrove estuaries are the nursery for many commercially important marine organisms, and penaeid prawns (marine prawns) are the most important among them. Most species of penaeid prawns spend the early part of their life in the mangrove estuaries and the adult life in the sea. The females mature and spawn in the sea and the larvae - as they develop - are passively brought into the nearby estuaries. They grow in the shallow mangrove zone initially and later move to the deeper areas of the open estuary before migrating back to the sea, thus completing their life-cycle. However, their residing time in the estuary and subsequent size attainment vary with species. In the estuaries of Goa, Metapenaeus dobsoni has a maximum residence period of 6 months; it is 8 months for *M. monoceros* and 7 months for penaeus merguiensis. The actively migrating sizes for prawns to pass from the mangrove areas to the open estuary are 20-30 mM for *M. dobsoni*, 30-40 mM for *M. monoceros* and 40-50 mM for *P. merguiensis*, respectively. However, after a further period of growth in the open estuary and attaining a size of 40-50, 60-70 and 70-80 mM respectively, their active migration to the sea commences.

PENAEID PRAWNS

The mangrove phase of the life-cycle of juvenile of several species of penaeid prawns is well studied. It has also been established that the capture fisher potential of marine prawns is directly related to the existence and expanse of a healthy mangrove ecosystem. Mangrove ecosystem provides the essential nutritional inputs to the estuaries. This ecosystem is rich in particulate organic matter, otherwise known as detritus. Detritus is nutritionally very rich and is the major source of food for the juvenile prawns. They mangrove substratum is also rich in microflora and meiofauna which further enriches the nutritional quality. Other favourable conditions like shallow and calm water, soft bottom for burrowing, protection and shelter provided by the mangrove roots and leaves, less number of predatory animals, etc., make this ecosystem the ideal nursery for the penaeid prawns.

Not only penaeid prawns but several other commercially important marine fishes and crustaceans are also closely associated with the mangrove environment. It is thus apparent that the coastal fishery resources particularly prawn fishery, are dependent on the existence of a healthy mangrove ecosystem and any damage or destruction to this ecosystem will have devastating consequences. Increasing industrialisation, urbanisation and population explosion have put severe pressure on land in coastal areas of the Asia and Pacific regions and mangrove areas have been the hardest hit. Added to this is a the misconception that mangroves are only wastelands. Although it has now been widely accepted and understood that mangroves form the backbone of the estuarine and coastal ecosystems, considerable damage has already been caused on a global scale due to human interference.

AQUACULTURE IN MANGROVE AREAS

Mangrove estuaries are nature's own aquaculture systems. Aquaculture, particularly prawn culture, has tremendous commercial prospects, and at the same time has also the great potential for area expansion. Potential risks of area expansion for aquaculture in mangrove areas have been clearly demonstrated in many countries in South-east Asia. For instance, in the Philippines about 250,000 of precious mangrove forests consisting more than 40% of the total area, were deforested mainly for conversion into prawn culture ponds. In Thailand the destruction it was between 167,000 and 179,000 ha. Other countries like Malaysia, Indonesia and Ecuador have also destroyed the mangrove ecosystem for prawn farming purposes.

CONSTRAINTS

Another question to be addressed in this context is whether mangrove areas are suitable sites for aquaculture. It is a known fact that mangrove solid is not always conductive to construction of aquaculture ponds. The solid mostly acidic, sometimes toxic and show nutritional imbalances.

Development of mangrove land into aqua farms may lead to severe physical constraints during the period of reclamation. Poor accessibility and the danger involved in felling of trees, low load bearing capacity make it impossible for mechanisation of clearing and land preparation. Presence of interwoven pneumatophores make manual tilling extremely difficult and expensive. These are some of the negative aspects of converting mangrove areas for aquaculture.

The micro topography of the mangrove land may also pose problems for aquaculture ventures as the initial investments will be exorbitant for levelling of the land especially on unripened soil for largescale development. Another deterrent is the presence of a large number of burrowing animals, particularly crabs, which would necessitate extra strengthening of bunds. Also, birds can be a nuisance as they prey on the cultured animals, leading to heavy revenue loss.

The general consensus based on cost-benefit ratio and production levels is that disadvantages are more in starting largescale aquaculture ventures in mangrove areas. Scientifically managed aquaculture farms in mangrove areas may be justified in underdeveloped countries only because of the availability of cheap unskilled labour.

SOLUTION

In this context, we should look at alternative plans which would be in the interest of both the mangrove ecosystem and aquaculture. It is evident that aquaculture, whether prawn culture or fish culture, in the mangrove region would not only disturb and destroy this ecosystem but also work out to be very expensive or uneconomical. Hence, it is advisable to select flat land suitable in all other aspects and which is close to the mangrove environment for aqua farms rather than the mangrove area itself. Such lands are plentiful at the middle and upper reaches of our estuaries, with no mangrove vegetation. These are the ideal sites for conversion to aquaculture ponds as this would necessitate minor alterations to the ecosystem and at the same time make use of all conducive conditions prevailing in the adjacent mangrove environment. This would also considerably minimise initial investments in the preparation of sites, resulting in better profits.

Another novel methods is the pen/cage culture method practiced in countries like Malaysia. This method also prevents cutting of mangrove vegetation or major landscaping, although it may be slightly more expensive than the one mentioned above.

AQUACULTURE AND SUSTAINABLE UTILISATION OF MANGROVE FORESTS

K. ALAGARSWAMI

INTRODUCTION

Brackish water aquaculture in the mangrove-rich areas of the coastal zones has been practiced traditionally. These sites were considered suitable for farming due to the tidal flow, freshwater influx and plentiful availability of seed resources of fishes, crustaceans and molluscs. The 'tambak' culture in Indonesia, the 'bheri' culture in India, etc., were developed based on the above factors. Initial success in producing aquaculture crops has helped in the socio-economic development and contributed greatly to nutritional and livelihood security of the coastal poor. The last two decades have seen a great expansion of this activity, with commercial shrimp culture as the most dominant component. Planned conversion of mangrove forest areas to aquaculture farms, is outcome of these efforts. However, intensification of shrimp farming in some countries for achieving higher production has resulted in several changes, leading to environmental degradation. It had deleterious effects on aquaculture production and economy. A balance is now sought to be struck between the environment and production activity, to promote sustainable development.

AQUACULTURE IN MANGROVE AREAS

Mangrove forest is a highly complex ecosystem consisting of biotic and abiotic components which are in dynamic interactive relationship among themselves. From the fishery point of view, the Mangroves play an important role as a nursery ground for the early life history stages of fish and shellfish and give protection to these organisms from adverse conditions in the open waters. Some of the common species associated with mangroves which provide for a sustenance fisher are the grey mullets, signaids, groupers, sea-bass, snappers, catfish, shrimps, crabs, oysters, mussels and cockles. The "capture" fishery does not interfere with the environment, resource and recruitment of the coastal fisheries in any appreciable manner. However, "captive" fishery which was practiced in the tambaks of Indonesia and bheris of West Bengal became the starting point of largescale human interference ultimately led to intensive aquaculture, with consequential effects on the environment, natural resources and recruitment. Today intensive aquaculture in these areas is seen to be a threat to the environment.

There has been considerable expansion of aquaculture in the mangrove areas in some countries (Table 1). The total areas of about 600,000 ha includes mangrove and non-mangrove areas, but 1 million ha of mangrove area or 15% of total mangrove zone is estimated to have been developed for aquaculture. Indonesia and the Philippines have consistently encouraged this transformation. To compensate for the loss in shrimp production due to the imposition of a ban on shrimp trawling in 1980, Indonesia encouraged tambak aquaculture. The Government planned to develop 120,000 ha for tambak intensification and 100,000 ha for tambak extensification in

Kalimantan and Sumatra. In the Philippines, out of the total area of 500,000 ha, 322,154 ha of mangrove forest area has been converted for utilisation, of which 206,525 ha has been brought under aquaculture.

Table 1 Brackish water pond areas in some Asian countries with mangroves*
(For the period 1976–1991)

Countries	Area (ha)
Taiwan	11,000
Malaysia	5,240
Singapore	395
The Philippines	206,525
Indonesia	242,000
Vietnam	30,000
Thailand	32,144
Bangladesh	8,345
Sir Lanka	13
India	70,000
Total	605,662

*: data from different sources

In fact, mangroves have not been found to be ideal site for semi-intensive/intensive aquaculture for several reasons. There is heavy sediment load in the canals which interferes with production. the soils are generally acidic which requires constant lime treatment for correction of pH values. Pond construction costs are more in mangrove areas. Hence, there has been a tendency of shifting ponds to high grounds away from mangroves in recent years.

SHRIMP AQUACULTURE PRODUCTION

Production rates in shrimp aquaculture have gone up to 20 t/ha as in Taiwan and also in isolated cases in the Philippines which practice intensive farming techniques. This against an average of 500 kg/ha in the traditional extensive culture practiced in the mangrove regions. The species used in brackish water aquaculture in the World and their production are given in Table 2.

It is seen that *Penaeus chinensis* and *P. Monodon* in the East and *P. vannamei* in the West dominate World shrimp production in aquaculture.

Table 3 presents data on the shrimp culture area, production and production rates in different countries (for 1990). China, Indonesia, Thailand and Ecuador account for 71.6% of total production with different productivity levels and area coverage. Japan has the highest production rate of 7000 kg/ha/year. But the area under culture is only 500 ha and production is controlled without causing environmental degradation. China gets an average production of 1000 kg/ha/year with 150,000 ha under culture, and no environmental damage has been reported.

Table 2 Aquaculture shrimp production by species (1988)

Species	Production (tones)
Penaeus chinensis	175,234
P. monodon	142,653
P. vannamei	79,157
P. merguiensis	31,583
P. japonicus	8,197
P. schmitti	3,000
P. stylirostris	1,692
P. indicus	864
P. penicillatus	745
Penaeus sp.	6,119
M. tapenaeus sp.	18,600

Table 3 Production of shrimp in aquaculture by different countries (For 1990)

Country	Total production (tonnes)	Area under culture (hectares)	Production (kg) per ha
China	150,000	150,000	1,000
Indonesia	120,000	300,000	400
Thailand	110,000	60,000	1,833
Ecuador	73,000	100,000	730
India	32,000	60,000	533
The Philippines	30,000	50,000	600
Vietnam	30,000	160,000	188
Taiwan	30,000	8,000	3,750
Bangladesh	25,000	100,000	250
S.America (Ecuador)	10,000	10,000	1,000
Central America	5,000	5,000	1,000
Honduras	4,500	6,000	750
Mexico	4,000	8,000	500
Japan	3,500	500	7,000
U.S.A.	900	450	2,000
Others	5,000	5,000	1,000
Total	**632,900**	**1,022,950**	**22,534**

Source: World Shrimp Farming (1990)

IMPACT OF INTENSIVE AQUACULTURE

Taiwan, with only 8000 ha land under culture, has the highest production rates for shrimp. The steady, uninterrupted growth of the shrimp industry over two decades has climaxed to a production of 89,622 t in 1987, however, there was a sharp decrease in the production, which dropped to 43,887 t in 1988 (Sheeks, 1989).

The drop was almost entirely due to a sharp drop in the volume of *P. monodon* production from 78,848 t in 1987 to 30,603 t in 1988. The crisis was caused by utter disregard for environmental health which led to serious diseases of epizootic proportions. identifying the causes for the collapse, it was found that viral (MBV), bacterial (*Vibrio* sp.) and protozoan (gill infestation by *Epistylis* and *Acineta* spp.) diseases were rampant. The non-pathogenic factors responsible were the unnatural elevation of temperature for seed production in the hatcheries, cumulative deterioration of ponds over a period of time, extreme stocking densities (as high as $100/m^2$), deficiency in feed quality, indiscriminate use of antibiotics and chemicals, pollution of water, incompetent aquaculture operation and lack of suitable hygiene practices in the ponds. The experience proved that the scale of intensification as practiced in Taiwan was unsustainable. Unscrupulous extraction of groundwater for aquaculture led to subsidence of land and consequent saline water intrusion in many areas.

An impact assessment made in the Philippines (Saclauso, 1989) showed a similar situation with regard to environmental degradation due to intensive aquaculture. The study found that shrimp stocking densities have been raised from $1–2/m^2$ to $50/m^2$. Enormous amount of food, ranging from as low as 0.972 to as high as 19.44 t, are dumped in the pond over 405 months. Since the estimated amount of food converted to shrimp flesh is only 20% on dry weight basis, the remaining 80% takes the form of faeces, urine and gases. These excreta provide the major source of nutrients for both pathogenic and non-pathogenic organisms. It attributed the widespread incidence of disease in shrimp farming to pollution from excessive organic loading in intensive fish farming. The study formed the use of chlorinated hydrocarbons, which are non-biodegradable, in aquaculture as the most alarming. The Philippine fish farmers were found using the chemicals and drugs in their ponds such as Diametin (active ingredient zeolite), complete fertiliser containing NPK and essential trace elements such as Ca, Mg, S, Fe and boron, algaecides, F.G.C. Mycin, endrin, gusathion, brestan, malachite green, copper sulphate, formalin, potassium permanganate, bromosept and fluorine were among the others. All these, while helping to improve production in the ponds, made an adverse impact on the environment.

ACTION PLAN FOR REDUCING ENVIRONMENTAL IMPACTS OF AQUACULTURE

Since the Taiwan experience of 1987, there has been an increasing realisation towards sustainable development of aquaculture. Semi-intensive farming has come to be accepted more than intensive farming. Aquaculture zoning and diversification of species to make use of natural locational advantages and environmental compatibility are being stressed (Alagarswami, 1991).

GESAMP (1991) has recommended the following 14 point action plan for reducing environmental impacts of coastal aquaculture.

1. Formulate coastal aquaculture development and management plans.
2. Formulate integrated coastal zone management plans.
3. Apply the environment impact assessment (EIA) process to all major aquaculture proposals.
4. Select suitable sites for coastal aquaculture.
5. Improve management of aquaculture operations.
6. Assess the capacity of the ecosystem to sustain aquaculture development with minimal ecological change.

7. Establish guidelines governing the use of mangrove wetland for coastal aquaculture.
8. Establish guidelines for the use of bioactive compounds in aquaculture.
9. Assess and evaluate the true consequences of transfers and introductions of exotic organisms.
10. Regular discharges from land-based aquaculture through the enforcement of effluent standards.
11. Establish quality control measures for aquaculture products.
12. Increase public awareness of the safety aspects of consuming seafood.
13. Apply incentives and deterrents to reduce environmental degradation from aquaculture activities.
14. Monitor ecological changes.

The above action plan is a very comprehensive one aimed not only at environmental security but also aquaculture security itself for the present as well as for the future. An aquaculture policy at the national level, strong R&D support and co-operation of the aquaculture industry are some of the factors needed for effective implementation of this action plant.

CONCLUSION

Since the introduction of tambak in the mangrove forests of Indonesia as early as 16th century, aquaculture in the coastal wetlands has made tremendous progress, particularly during he last 2–3 decades with advances in technology for shrimp culture. This has led to largescale destruction of mangroves in some countries for aquaculture purposes. Taking technology to its extreme use in intensive and super-intensive aquaculture has proved that it is not environment-friendly and that it is not sustainable. In many countries, therefore, we see a reversal of the trend towards moderation aiming at semi-intensive culture, a terminology which denotes a scale of operation between the extensive and intensive cultures. In its essence it denotes respect for the aquatic environment of the pond and its carrying capacity with reference to the species cultured. Inputs such as seed and feed, fertilisers and water quality improvement measures should be adjusted in such a way that they are in a state of equilibrium within the pond and also do not adversely affect the environment outside to pond.

Fortunately, the modern trend of coastal aquaculture moves the activity away from mangrove zones to their hinterland and other highland areas might spare the remaining mangrove forests. There are several culture systems which are compatible with the mangrove ecosystems and they can be taken up with advantage, although the yields/value may be low. e.g., cockle, oyster, mussel, seaweed and fish culture in floating cages all *in situ* without altering the mangrove landscape.

Aquaculture with the concept of environment and development will have abetter future for sustainable growth.

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MANGROVE FOREST GENETIC RESOURCES : STRATEGY FOR CONSERVATION AND MANAGEMENT

SANJAY DESHMUKH

INTRODUCTION

International awareness to safeguard global biodiversity has necessitated urgent steps for its conservation and rational or sustainable utilisation at the local, regional and global level. This fringing awareness has come a little but not too late. Disappearance of renewable biological resources from their centres of diversity has occurred at an alarming rate, thanks to over-exploitation of tropical forests and marine ecosystems. There is vast amount of information available on indigenous species which need to be utilised and harnessed for human welfare, both in the developed and developing countries. Moreover, there is no action plan for conservation and utilisation of biological diversity and genetic resources. The preservation as well as ownership of biodiversity and genetic resources has thus become very important. Therefore, it has become apparent to build safe regional centres in homelands of species; for preservation of vanishing biomaterials. At the same time, the importance of physical and cultural environment cannot be ignored for keeping the genetic diversity intact. The establishment of genetic resources centres for these efforts has been one of the major thrust of this project which would eventually serve as building of "field gene banks" (using *in situ* technology) and seed gene banks (using *ex situ* technology).

METHODOLOGY

The work initiated during 1990–91 under a project titled "Genetic Engineering and adaptation to climate change: establishment of a genetic resources centre for identifying and conserving candidate genes for use in the development of transgenetic plants" sponsored by the Department of Biotechnology of the Government of India has helped us to develop guidelines for conservation and management of mangrove forest genetic resources (Table 1).

Table 1 Guidelines for conservation and management of mangrove forests

Project Component	Main Activities		
	Phase I (1 year)	Phase II (1 year)	Future Plan (5 years)
Conservation	• Taxonomic and ecological survey of mangrove forest, zonation studies	• Mapping of mangrove forest including forest inventory (study of associated flora, fauna, phytosociological studies of vegetation, phenology, population dynamics of the faunal elements, etc.)	• Establishment of three more link centres at the national level

Conservation of Mangrove Forest Genetic Resources : A Training Manual
Edited by Sanjay V. Deshmukh and V. Balaji.

Table 1 Guidelines for conservation and management of mangrove forests (contd.)

Project Components	Main Activities		
	Phase I (1 year)	Phase II (1 year)	Future Plan (5 years)
	• Identification of suitable site for establishing mangrove genetic resources centre	• Consolidation of genetic material (mangrove germplasm) at MGRC	• Overall survey of Indian coastline for preparation of state of art on mangroves
	• Collection of genetic material (mangrove germplasm)	• Survey of Indian coastline for identification of sites for conservation	
		• Identification of two sites for establishment of link centres of mangrove genetic resources (at National Level)	
Restoration	• Standardisation of vegetative propagation methods for mangroves	• Standardisation of micropropoagation techniques	• To undertake eco-redevelopment work in the conservation sites identified, based on national and State level surveys, with forest department
	• Identification of sites for eco-redevelopment studies	• Large scale plantations	
	• Nursery experiments		
	• Standardization of plantation techniques		• Activity to be expanded at larger scale and monitored by Department of Forests, Government of Tamil Nadu
	• Pilot scale plantations		
		• Preparation of seed orchard for evaluation of plus material	

Table 1 *(contd)*

Project Components	Main Activities		
	Phase I (1 year)	Phase II (1 year)	Future Plan (5 years)
Evaluation	• Identification of genetic material of "Plus trees" • Selection of species for the study at variation	• Evaluation of different mangrove species based on a. their ability to survive in different environmental conditions b. physiological basis	• Isolation of candidate genes responsible for sea water intrusion and salt water tolerance
Classification	• Study of morphological aspects of classification of mangrove species	• Study of different aspects of classification such as cytogenetical, genetical, biochemical and molecular classification	• Standardising and evolving techniques for multivariate analysis for mangrove species based on population genetics studies
	• Identifying superior genotypes in mangrove species Standardisation of software mechanisms for development of databases, such as (a) mangrove bibliographic database, and (b) mangrove experts database	• Standardization of techniques for RFLP and RAPD work to study intra- and *inter-specific* variation in mangroves • To undertake population genetic studies	• Development of other databases, mangrove genetic variability database, socio-economic database, resources inventory database and audio-visuals database
Utilisation	• Initial of socio-economic surveys in area near mangrove forests of Pichavaram	• Development of eco-matrix based on the principle of socio-economic issues, e.g., ecological security, economic efficiency and social equity.	• Standardisation for recombinant DNA experiments
	Preparation of socio-demographic profile to study human impact on mangroves for better	Developing Sustainable Livelihood Security Index (SLSI)	• Development of concept of transgenic plants

Table 1 *(contd)*

Project Components	Main Activities		
	Phase I (1 year)	Phase II (1 year)	Future Plan (5 years)
	• Understanding of man and mangrove interaction	• Application of techniques e.g., propagation methods by Department of Forests, Government of Tamil Nadu	• Testing superior genotypes (hybrids) in other locations
		• Identification of seedling makers for heterosis and better performance	• Growth characterisation for assessing adult plant performance
Education	• Preparation of documents related to public awareness and collection of material for exhibition on mangrove ecosystems	• Preparation of exhibits, slides for display and brochures highlighting mangroves of the World and their importance Creating public awareness by campaigns involving schools, colleges and universities.	• Preparation of documentary on mangroves.

Detailed work based on the above-mentioned points was carried out in Pichavaram, the details of which are given below :

CONSERVATION

Ministry of Environment and Forests, Government of India identified in 1990, fifteen specific mangrove areas for protection. They are — North Andaman and Nicobar (Andaman and Nicobar group of Islands), Sunderbans (West Bengal), Bhitar Kanika and Mahanadi delta (Orissa), Coringa, Krishna estuary and Godavari delta (Andhra Pradesh), Pichavaram and Point Calimere (Tamil Nadu), Vembanad (Kerala), Coondapur (Karnataka), Chorao island (Goa), Achra (Maharashtra) and Gulf of Kutch (Gujarat). The Government, with the help of different research institutions, initiated environmental and socio-economic research in addition to scientific and applied research on flora, fauna and productivity of these mangrove areas.

With a view to prevent further destruction of mangrove forests, for sustained improvement and utilisation of mangrove forest genetic resources, and to conserve and enhance biological diversity in mangrove ecosystems, it was felt that an integrated approach for the preparation of a 'Global strategy' is required. The consolidation and preservation of mangrove genetic resources is the first step towards this end.

ESTABLISHMENT OF MANGROVE GENETIC RESOURCES CENTRE

Work was initiated to establish a mangrove genetic resources centre for adaptation to sea level rise. An area of about 50 ha of land under mangroves was kindly made available by the Department of Forests, Government of Tamil Nadu, in the mangrove forest of Pichavaram, which is located 240 km South of Madras. Out of 1400 ha of land under mangroves in Pichavaram, this area was selected for *in situ* conservation based on the criteria developed by the CRSARD. In addition to this, a small area within this region was demarcated for consolidation of genetic material collected from different parts of the country.

A nursery was established for this purpose, and the following species were been collected from different parts of the country, for planting and research studies.

In addition to the species mentioned in the table, local mangroves species were also being collected. The success of these species in this type of environmental condition was critically monitored and the data on their performance was thus gathered.

Place	**Name of species collected**
Maharashtra (Ratnagiri, Sindhudurg)	*Bruguiera gymnorrhiza, Ceriops tagal, Rhizophora mucronata, R. apiculata*
Goa	*Kandelia candel, porteresia coarctata*
West Bengal (Sunderbans)	*Heritiera fomes*
Orissa (Bhitar Kanika)	*Xylocarpus* sp., *X. granatum, X. mekongensis*
Andaman and Nicobar Islands	*Bruguiera gymnorrhiza, Ceriops decandra, Rhizophora apiculata, R. mucronata, Xylocarpus granatum*

These species were planted in the mangrove forest of Pichavaram during the rainy season and their ability to survive in different environmental conditions was tested.

ABOUT MANGROVES OF PICHAVARAM

Despite the availability of a large number of descriptions, mangrove areas of Pichavaram still remain to be assessed properly. The total forest area at Pichavaram is getting reduced year after year because of human interference. There is an urgent need for conservation and protection. The work undertaken under this head is highlighted in Table 1.

RESTORATION

The mangrove ecosystem though open, is quite complex, being composed of various inter-related elements in the land-sea interphase zone. The mangroves are known to keep the shoreline intact against tidal currents by preventing soil erosion. In view of the ecological and socio-economic importance of these plants, their restoration has become increasingly important, especially in recent years when land cover of the earth is rapidly on the wane.

Development of suitable forestry methods for propagation and artificial regeneration of mangroves have been prompted by the demand for the economically valuable mangroves; however, not much has been achieved in this respect. The work on experimental plantation of mangroves undertaken at Pichavaram was based on (a) Nursery experiments, and (b) pilot plantations of mangroves.

Emphasis was placed on the germination and growth of some mangrove species in nursery condition and also in field on experimental basis.

EVALUATION

Mangroves are distributed according to three important scales, namely their coastal range, their location with an estuary and their position along the Intertidal profile. Distribution pattern of mangroves in an estuarine region depends on several factors. Influence of freshwater run off and also estuary size is always seen when composition of mangrove flora is observed. In larger estuaries, there is greater range of specilised habitats, and hence the presence of more species as compared to those in smaller estuaries is evident. There is a general trend between genera and distribution, in such a way that genera with greatest number of species, consistently occur in greater number of biogeographic regions. In addition to this, there is also isolation at other scales of distribution, notably in the specilisation of particular mangroves for certain habitats.

When mangroves species are classified, the morphological characters of the species are taken into consideration, and have to be re-assembled for their systematic classification. When such a classification is based on phenotypic character, which may vary their response in different locations, it is also useful to explore intra-specific variation so that inter-relationship of those in larger polymorphic genera might be better understood.

Rhizophora and *Avicennia*, the two major species of mangroves ecosystems, were studied for their botanical systematics/scientific classification. The surveys made also provided interesting information on the distribution of these two as well as other mangrove section of estuaries. This knowledge will be used for evaluating particular distribution pattern of other species of mangroves, which depend on several factors. These studies would also lead to a better understanding of genetic exchange between populations, which is controlled by climatic and geographical conditions.

Surveys undertaken for identification of 'plus trees' of various species of mangroves in different parts of India revealed valuable information on location of such "genetically important" material (Table 2).

The above-mentioned species were collected and are maintained in suitable locations in Pichavaram mangrove forest in Tamil Nadu. Evaluation of these species is being done on physiological basis and also on their ability to survive under different environmental conditions.

CLASSIFICATION

It is common these days to come across ill-defined morphological characters of tropical plants. Mangroves are no exception to this. Considering the limited number of these unique plants

Table 2 Identification of genetic material of plus tree

Name of species	West coast							East coast			
Name of species	GJ	MH	GO	KN	KR	LK	TN	AP	OR	WB	AN
Aegialtis rotundifolia									+	+	+
Aegiceras corniculatum		+		+					+		+
Avicennia alba		+							+		+
Avicennia marina	+	+				+					+
Avicennia officinalis		+									+
Bruguiera cylindrica			+								+
Bruguiera gymnorrhiza					+				+		+
Bruguiera sexangula											+
Cerbera manghas									+		
Ceriops decandra											+
Ceriops tagal			+			+			+		+
Cynometra ramiflora											+
Exoecaria agallocha		+			+		+				+
Heritiera fomes										+	
Heritiera littorlis											+
Intsia bijuga									+		+
Kandelia candel			+								
Lumnitzera littorea											+
Lumnitzera racemosa							+			+	+
Nypa fruitcans											+
Rhizophora apiculata		+		+					+		+
Rhizophora mucronata				+	+						+
Rhizophora (hybrid form)							+				
Scyphiphora hydrophullacea							+		+		+
Sonneratia alba		+	+		+						+
Sonneratia apetala		+							+		
Sonneratia caseolaris									+		
Xylocarpus sp.									+		
Xylocarpus granatum									+		+
Xylocarpus mekongensis									+		+

GJ : Gujarat; MH; Maharastra; GO; Goa; KN; Karnataka; KR; Kerala; LK : Lakshadweep; TN : Tamil Nadu; AP : Andhra Pradesh; OR : Orissa; WB : West Bengal; AN : Andaman and Nicobar.

and the extent of the variation of species level, it is important to sort out these constraint, and therefore, it would be useful to identify genetic differences so as to remove the doubts and subjectivity surrounding the diagnostic character in the systematics of these plants. There are two techniques.

Conventional genetic studies are difficult for mangroves and many forest tree species. In view of the difficulties and delay in conventional genetic analysis, to standardisation of molecular methods of genetic analysis using the molecular variation in DNA was done.

The method is described below :

USE OF RAPD ANALYSIS IN THE STUDY OF GENETIC VARIABILITY IN MANGROVES SPECIES

Base pair changes in DNA can alter sequences that are recognised by restriction enzymes, abolishing sites or creating new sites for particular enzymes. Deletions or transportation of large elements bring about simultaneous changes in the restriction pattern of a number of enzymes. As a result, a given restriction enzymes will not always leave a given DNA molecule at the same position in two individuals. Consequently, fragments of two different lengths will be formed when the DNA of the two individual are digested. The unequal sized fragments will travel at different rates through the gel, and the bands formed, following hybridization and autoradiography, will be located at different locations on the Southern blot. The polymorphisms could be scored on such autoradiographies.

RANDOM AMPLIFIED POLYMORPHIC DNA (RAPD)

The polymorphism assays based on the Polymerase Chain Reaction (PCR) are useful in detecting the variations much more rapidly. But there is a distinct PCR process, based on the amplification of genomic DNA with single primers of arbitrary nucleotides sequences. These primers reveal better polymorphisms and are therefore used as markers. They are called the Random Amplified Polymorphisms DNA (RAPD). Use of RAPD's have several advantages over other markers as

a) A universal set of primers can be used for genomic analysis in a wide variety of species,
b) No preliminary work, in the form of isolation of cloned DNA probes, preparation of filters for hybridisation, or nucleotides sequencing are necessary,
c) each RAPD marker is the equivalent of a Sequence Tagged Site, and
d) the entire process of finding the polymorphism can be automated.

Work based on these lines was undertaken and has helped in understanding the inter- and intra-specific variability in mangrove species.

DESIGNING MANGROVE ECOSYSTEM INFORMATION SYSTEMS (MEIS)

The main purposes of creating this information system is to develop a system with global, regional and national components. At the global level, the data base management system will have to be developed for the dissemination of information on the available mangrove genetic resources. At the regional level, there should be regional genetic resources centres linked with genetic enhancement centres. Finally, at the national level, a policy for the conservation of coastal ecosystems in general, and mangrove ecosystems in particular, could be formulated. In addition to this, research work on genetics, cytogenetics, taxonomy and physiology of mangrove and other associated species e.g., flora and fauna should be promoted at suitable centres.

A need for assimilation and dissemination of critical data with reference to the mangrove ecosystem was felt and therefore, the following data bases were established.

a. Bibliographic data base,

b. Mangrove experts data base,
c. Mangrove genetic variability data base, (on pilot scale),
d. Socio-economic data base,
e. Resources inventory data base, and
f. Audio-visuals data base.

At present MEIS is being functional with the above-mentioned data bases, except 'c' and 'd' from the list.

UTILISATION

In Asia and the Pacific region, nations have managed their mangrove forests on a sustained yield basis. They have considered the production and sustenance of a maximum volume of wood for domestic and export purposes, ecological protection and conservation, preservation of initial coastal mangrove-dependent communities. In case of India, the population pressure in the coastal areas has been more as compared to other countries. Therefore, a multiple use concept was introduced for utilisation of various renewable resources. These would best contribute to the long-term socio-economic development of the country, and would also. This lead to long-term benefits to the greatest number of people.

SOCIO-ECONOMIC SURVEY

Socio-economic activities in the vicinity of mangrove habitats like Pichavaram are very much varied. Poverty seems to have settled together with unwise resource utilisation. The people living within and nearby the mangrove forest depends on this resource for their living. The immediate material benefits they are deriving from these resources and lack of knowledge and understanding on the other mangrove influences, have hindered them from realising the more significant and long-term benefits of this ecosystem. It was therefore decided to understand the behaviour of local people residing within and around the Pichavaram mangrove forest, before attempting to understand their occupational impacts on the coastal ecosystems.

The Mangrove ecosystems of Pichavarm provides enormous goods and services which are vital to the well being of the local population. These goods and services ranged from tangibles as those directly consumed (food, medicine, firewood), trades in market (fishes, prawns, etc.) and non-consumptive service (protection against wind breaks) to more intangible values of knowing that species exist and should continue to exist and also that they were to be conserved and protected for the future. However due to economic requirements, people in many coastal areas over-exploited the mangrove forests. On the other hand, disturbed areas experienced temporary or permanent disruption of water supplies, increased flooding, reduction of water quality and productive decline in faunal species.

Sustainable Livelihood Security Index (SLSI)

The concept of SLSI is described in detail by Dr. R. Maria Saleth in this manual. Efforts were initiated to apply this concept in the Pichavaram area with the following aims:

1. To outline the pathway to sustainable development of our coastal ecosystem with special reference to mangrove ecosystem

2. To discuss the economic issues involved in the utilisation of mangrove resources
3. To develop a mathematical framework useful to capture and analytically show the ecologically-economic interactions in the context of mangrove ecosystems and
4. To indicate certain policy option and action plan essential for the sustainable management of mangrove ecosystem.

Human and mangrove interaction has been evident from the studies undertaken and it is observed that the local people, most frequently act with seeming disregard for the future ecological effects of their action, of exploitation of mangrove resources. It is apparent that occupation exists for their well-being. Therefore a community based approach needs to be brought about for restricting over-exploitation of mangrove forest. At the same time, a detail analysis of social behaviour of such hope of success. Development of sustainable livelihood security index would prove to be one of the pioneering efforts in this field.

EDUCATION

Not every community in the country is endowed with mangroves and swamp lands. However, the areas with mangrove ecosystem are always under stress as the resources are always used by the local population for their livelihood security. For example, the bulk of mangrove resource has been used for firewood, a marginal livelihood activity. In this context , the population residing in the vicinity of such mangrove areas needs to be made aware of how mangrove are important and why they should be conserved. Moreover, it becomes imperative to encourage the local government to focus attention on these mangrove resources in their respective territories.

The major objective of this programme was to create awareness for the conservation of this neglected ecosystem, fragments of which are found scattered in various degraded forms in and around the Pichavarm mangrove forest. The work included preparation of visuals based on interesting features of the ecological importance of the mangrove swamp area from India in general and the Pichavaram mangrove forest in particular. Communication methods included display posters and charts, slides, and transparencies and also arranging lectures and discussions. Target groups benefited by this activity were primarily the people living along the coastal villages and also administrators and decisions makers.

The information collected was also be conveyed to the students, teacher and researchers in colleges and universities in coastal states.

CONCLUSION

The importance of tropical rain-forest as rich reservoirs of biological diversity is widely recognised. Mangrove forest in coastal belts of tropical and sub-tropical regions are equally important natural reservoirs of biological diversity. The mangrove ecosystem constitutes a bridge between terrestrial and aquatic ecosystems and provides numerous benefits to coastal populations. These delicate ecosystems are seriously threatened by human interference. Immediate steps are required to prevent further destruction of mangrove forests, and to restore the partially degraded ones. For sustained improvement and utilisation of mangrove forest resources, it is essential to conserve the existing mangrove species and genetic diversity within them. Like many agricultural and forest species, an integral global strategy is required to conserve and enhance biological diversity in mangrove ecosystems. It is hope that the guidelines mentioned in this paper would be useful for planning a Strategy for the Conservation and Management of Mangrove Genetic Resources anywhere in the World.

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CLONAL FORESTRY : A NEW STRATEGY FOR OBTAINING INCREASED YIELD

S. KEDHARNATH

INTRODUCTION

Customarily seeds are used in artificial regeneration of forest tree species. This is because they are easy to collect and handle and the cost of seeds is not high. The seeds after collection from different areas are bulked, cleaned and graded wherever it is possible to do that, pretreated whenever found necessary and sown in nursery beds. At the appropriate time, they are transplanted to polythene bags or stumped and later transported to the area of planting. For most of the important forest tree species that are used in raising largescale plantations, these operations are well standardised. However, the yield obtained and the quality of wood obtained per hectare at the appropriate rotation age have been highly variable. If one goes through some of these plantations, considerable variation in stocking is also noticed, presumably due to mortality. A few tree species such as the Willows and the Poplars are exceptions to the above method of handling and are propagated normally by cutting only.

Most of the forest tree species are out breeders (naturally cross-pollinated) with various degrees of self-compatibility and so the large plant-to-plant variability noticed is nothing new. Also, some amount of mortality noticed could be due to inbreeding effects. There may be additionally other causes too. In order to reduce this plant variability to a reasonable level and at the same time also to ensure an increase in productivity, it was thought desirable to use the principles of genetics to produce improved planting stock. This involved provenance testing to select the best adapted and most productive provenance, creation of seed production areas, establishing clonal seed orchards using plus trees. This kind of work is in progress in many of our states. When the seed orchards go into large-scale seed production, they will be used for raising the future plantations. This is the internationally followed priority approach in the genetic improvement of forest trees. Later, by controlled crossing using suitable matting designs, new breed populations can be created for practicing advanced generation selections for use in new seed orchards. So goes on the genetic improvement work concerned with population improvement.

Another approach that has in recent times attracted considerable attention is that of using clones in operational forestry as against their use only in research. This approach also exploits the considerable amount of natural variation present in the natural population of the tree species. Most of the forest tree species are represented by wild (undomesticated) population because no conscious efforts had been made in the past for selection. This interest is built upon the expectation that faster gains and greater gains can be obtained by the use of this method. The spectacular results obtained in Aracruz, Brazil with eucalyptus should indeed act as a catalyst for a new, bold and revolutionary approach in forest regeneration. But one must remember that to achieve the goal a lot of inputs as research was necessary so that appropriate methods and techniques, or what we may call protocol, could be developed that are absolutely reliable to give results when taken up in a largescale field-oriented action programmes. The work done already or is being done on Eucalyptus in Aracruz, in Congo and in Israel, and the work on *Gmelina arborea* in Sabah and the results achieved in order to highlight the magnitude of planned efforts that have gone into this type of work are explained.

EUCALYPTUS PLANTATIONS : CASE STUDIES

1. ARACRUZ, BRAZIL

Forest Productivity and Pulpwood Quality (Results from intensive forest management and genetic improvement established by means of rooted cuttings).

Coppicing

This is normally done by cutting the tree at the base, above the soil level at approximately 12 cm height. If kept taller, sprouts arising at points distant from soil root poorly or do not root at all. Best time to harvest juvenile copice shoots at Aracruz was found to be 45 to 55 days after the tree had been cut. Rooting capacity of sprouts obtained from stump exceeded 70%. Selection of tree was made at 7 years, i.e., at harvest age. The following forest and utility characteristics were taken into consideration:

1. The tree had a volume of more than $1m^3$ including bark and was free of disease and insect attack.
2. Tree was straight and had small limbs; this enhanced self-pruning and avoided tension of wood normally associated with thick branches and cooked trees.
3. Tree should have smooth bark, not rough.
4. The crown was well-shaped, having a large leaf volume which provided better and earlier shade over the ground and suppressed weeds and other competitive vegetation.

After felling, the trees selected evaluated for wood properties, such as (a) basic density (500–600 kg/m^3), (b) pulp yield (those exceeding 50% based on the dry weigh of wood), and (c) bark content should be less than 10%.

17000 hectares were brought under plantation each year, with the aim of survival rate which called for skill and inputs. It was planned to undertake replanting after 35 years, i.e., after five harvests.

Recently they have undertaken work to hybridise *E. grandis* with *E. urophylla*, and selected a large number of individual trees from this cross and cloned them. About 5000 clones are in the process of testing.

2. CONGO

In congo, commercial-stage planting programme with clones started in 1978 with 650 ha. Since then 3000 ha are planted annually. By the end of 1984 the total area of clonal planting was 20000 ha. in *Eucalyptus*. Their interest centred around plus trees of *E. alba*, *E. saligna*, *E. tereticornis* and superior genotypes of the species hybrid combination *E. alba* x *E. urophylla* (14 selections) and *E. tereticornis* x *E. saligna* (256 selections). Crosses of the combination *E. urophylla* x *E. grandis* and *E. alba* x *E. grandis* have also been recently taken up.

Two units produce 6 lakh cuttings each per year. Each unit had 20 ha of managed stock plants established at a density of 400/ha. Cuttings were collected from 95 stock plants per day, with a second harvest after six weeks. The annual production was 150–200 cuttings per plant in the season. About 12000 cuttings were set under misting in each nursery every day during the season. Rooting success was around 80% and more. It is claimed that in 1980 the cost per acre worked out to 650 US dollars, which was less than that of plantation establishment from seeds.

3. ISRAEL

In Israel, work is in progress on rooting of stem cuttings for use in clonal forestry in *Eucalyptus camaldulensis*. Grafting of nature scion in young seedlings was tried in order to rejuvenate the mature tissue for producing cuttings to start a clonal line without felling a 'plus tree'. Though the initial grafting was highly successful, the grafts progressively died, with an ultimate survival of only 15% after one year.

Open growing of selected stock plants and repeated pruning (sometimes also referred to in literature as hedging) provided the largest number of cuttings at the least expense. It has been estimated that 1000 stock plants per hectare could produce more than one million cuttings per year yielding 0.5 million rooted cuttings.

4. SABAH (MALAYSIA)

In Sabah in 1981, a clonal approach to improve stem form and branching habits in *Gmelina arborea* was initiated. From a total stand of 1200 ha, a 30 ha block of Philippine seed origin was selected as the best stand, the best 100 trees per hectare (1 10% selection intensity). These trees were coppiced and after propagation 20 ha of stock plants were first established at 1m x 2m spacing. Cutting were harvested at the rate of 20000 per day and when set under mist, rooting was initiated.

A one hundred per cent increase in the number of 2-year-old trees classified as straight was observed and a major reduction in those badly forked were recorded.

Air-Layering

Air-layering is often resorted to obtain clones for experimental work. Some tree species easily respond and produce roots while others do not produce only profuse callus tissue. During the course of an investigation with pines for developing clones at the Forest Research Institute, Dehra Dun, it was found that since stem cuttings did not produce roots, it was thought desirable to take recourse to first grafting and on the grafted plants air layers were tied. A good rooting response was seen in these air-layered branches. *P. roxburghii* and *P. caribaea*, air layers were tried directly on suitable young branches which also gave good rooting and they were very fine. The chances of their survival if directly planted after severance from the mother plants in the field appeared doubtful. So they were (in both the species) planted first in pots with a good mixture of soil-sand-manure medium and kept like that in pots for a year and later they were transplanted with one hundred per cent survival. They grew well and straight.

Similar work was done on Teak, at the Forest Research Institute, Dehra Dun, by my colleagues and I using various rooting harmones did not yield rooted layers but instead they produced profuse callusing. We severed the air layers from the tree, scraped away partially the callus and planted them in the sand-soil-manure rooting medium and they all rooted. Thus some species respond easily and root, while others don't. We had taken care to include a number of trees (genotypes) connected to different periods (seasons) for these experiments. There is thus definite variation in response of species to air layering, and also there are difference amongst the different genotypes within the species.

Grafting (including budding)

This method has been successfully used in many forest tree species to establish clonal seed orchards. In horticulture, particularly in apple, jack, cashew and rubber, such an approach is being employed for establishing large areas of plantations of high-yielding clones. In forestry, however, grafting is not being' used for raising large plantations. It may be mentioned more as of historical importance that in 1820, the Frenchmen Baron de Larminat and Marrier de Boisdhyver undertook the largest forest tree grafting work report. They wanted to better the forests around Paris, particularly the forest of Fontainebleau. For doing this, they grafted scions from *Pinus nigra* var. *poiretiana* on *P. sylvestris* var. *hagunensis* root stocks at the rate of 8000–10,000 grafts per year. In this work, they used terminal cleft graft and field-grown root stocks 308 years of age. The graft unions were about 2–4 feet above the ground and were suitably protected. In 1843, their work had resulted in 104,000 grafts.

Tissue Culture

Tissue culture is a versatile technique and can be employed for a very wide variety of purposes between those who exaggerate its benefits and those who dismiss it as a mere technique. There are moderates who are knowledgeable about the real benefits that can accrue from use of tissue culture. Apart from its use in research for obtaining genetically uniform material (clones) we can integrate it into a plant production system for producing clonal material for field planting in plantation forestry. Micropropagation is highly beneficial for certain species where conventional clonal propagation is not possible or commercially not feasible. Micropropagation through tissue culture has several advantages over conventional methods–i) higher multiplication rates, ii) lower requirement for space, iii) greater degree control over chemical and physical environmental factors, and iv) propagation throughout the year. Tissue culture work has been carried out by many and some of the more important publications are Ahuja (1986), Balaji (1986), Bonga and Durzan (1982), Mohan Ram and Kakkar (1989) and Wilkins and Dodds (1983). Studies on tissue culture carried out in India on forest tree species have been obtained in several cases; viable commercial technologies have been developed only in a few cases.

Shoot organogenesis and somatic embryogenesis are the two main pathways through which plantlets are obtained *in vitro*. The phytoharmones present in the medium are known to control organogenesis. Shoot-inducing medium is relatively low in auxin and high in cytokinin while the root-inducing medium is high in auxin and low in cytokinin.

Regeneration of plants from callus through somatic embryogenesis is reported to be more advantageous than by organogenesis. Somatic embryos are believed to arise from single cells and, therefore, plants derived from them are expected to be genetically alike and stable while plants raised from callus culture through organogenesis may show wide genetic variation. Additionally, somatic embryos are bipolar with well-developed root and shoot apices that can develop into a whole plant. A good tap root system is essential for a tree which has to withstand the ravages of the weather over many years and grow. According to Rangaswamy (1986), who has critically reviewed the literature on somatic embryogenesis in angiosperm cell, tissue and organ cultures, work published up to 1985, only in 102 species somatic embryogenesis has been obtained and subsequent plantlet formation in 51 species. The potential for somatic embryogenesis appears to be genotype specific.

SOMATIC HYBRIDISATION AND TRANSGENIC PLANTS

Incorporating genes for resistance to specific diseases, insect pests, etc., can contribute to greater productivity by decreasing losses. These contributions can take the form of reduced mortality, reduced loss and reduced monetary and environmental costs of chemical counter-measures.

Recent molecular techniques, collectively known as genetic engineering, have been employed for incorporation of foreign material, DNA, into animal and plant cells. The gene transfers are carried out with the help of a plasmid vector system or by direct micro injection of DNA into cells. The successful extension of genetic transformation; procedures from simple micro-organisms to plants has been a landmark of developments in biological sciences. Before attempting gene transfers, specific genes need to be characterised, sequenced, isolated and clones. In the case of forest trees, we know only the chromosome number for many of the species. So what is needed now is using the RFLP technique for mapping of the genes in selected tree species to start with. Also, work should be initiated to work out the protocols of protoplast culture and regeneration of plants from them.

A toxin-producing gene which imparts resistance against a wide spectrum of lepidopteran insects has been transferred form *Bacillus thuringiensis* to a tobacco plant and there this gene has been asked to express itself. While such insertion may prove to be relatively simple and straightforward in a solanaceous plant that normally exhibits a high degree of plasticity in culture, it may be comparatively more difficult. While dealing with woody species for instance, in the case of teak (*Tectona grandis* L.F.), two important insect pests are known to do a lot of damage. They are *Hyblea puera* and *Eutectona machaeralis*. It would be interesting to see whether the toxin producing gene of *B. thuringiensis* could be incorporated into the teak genome. Another approach for incorporating a resistant gene into these two pests of teak is to realise the *inter-specific* hybrid between teak and its allied species *T. hamiltoniana*. Unfortunately the cross does not yield viable seeds. An approach to realise this hybrid would be through somatic hybridisation. There is another example in *Ailanthus triphysa*; here an important insect pest, *Eligma narcissus*, causes considerable damage and frequent chemical spraying becomes necessary to protect the plants. A bacterium *Bacillus firmus*, isolated from the dead larvae of the above insect was very effective in giving a hundred per cent kill when used in water suspension. It is worth speculating that one day we shall identify the gene in this bacterium that enables it to kill the larvae and transfer the gene in the bacterium that enables it to kill the larvae and transfer the same to the genome of *A. triphysa* through genetic engineering techniques.

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CONSERVATION AND MANAGEMENT OF MANGROVES IN ANDAMAN AND NICOBAR ISLANDS

B.P. SINHA

INTRODUCTION

The mangrove vegetation in the Bay Islands plays an important role in minimising the onslaught of devastating cyclonic impact, preventing soil erosion and sedimentation of shores and protecting the terrestrial ecosystem above the high tide level. Besides these providing a safe nursery and breeding ground for a variety of fishes, aquatic forms and avifauna. A coastline of 1962 km of the islands supports a highly productive ecosystem. The bulk of the mangroves are confined fringing innumerable creeks, sheltered muddy shores, and coal substrata, but the presence of patchy mangroves on scattered rocky formation subjected to Intertidal inundation is not uncommon. The mangrove ecosystem existing in the islands is rich in nutrients augmenting the food needs of the sizeable population living in and around these habitats on a sustained basis. The mangroves in Andaman and Nicobar Islands are still rich, luxuriant and in an undisturbed state with a great amount of species diversity.

The paper deals with the mangrove forests of Andamans, various strategies contemplated for effective conservation of the precious ecosystem including linkage of the genetic resources programme to build up a rich gene-pool at the global level.

LOCATION AND AREA

The Andaman and Nicobar Islands, crescent-shaped broken land masses, islets and rocks totally numbering 572, are conspicuous in the Bay of Bengal situated between 6°N and 14°N latitude and 92°E and 94°E longitude. The Southern group of Islands, popularly known as Andaman group, occupies a land area of 6408 sq km. The Southernmost island, the Grate Nicobar, is in the proximity of 150 km from Sumatra (Indonesia) and the Northernmost landfall is within reach of 190 km South of West Burma.

TOPOGRAPHY, CLIMATE, GEOLOGY AND SOIL

The general topography of the islands is hilly, barring Car Nicobar which is undulating to flat. The Andaman islands in the group comprising South, Middle and North Andaman, though contiguous, are separated by several zig-zag creeks. Little Andaman is almost in the center of both groups of islands where the terrain is undulating to flat along the coastal stretch. The Nancowry group of islands in the Nicobar group is hilly, where the Great Nicobar Island is mountainous with tropical zone, the mean maximum temperature is about 29.6°C. and the mean minimum temperature is 23.5°C. The annual precipitation is around 3100 mM, while relative humidity is as high as 81%. Although the temperature is nor very high, the gravity of heat is felt due to proximity to the equator. The benefit of the South-west and North-east monsoons is obtained in the islands and the rainfall is almost spread over a period of eight months, from may to December. A few showers are also received during January to April.

The main rock system found in the islands is of the sedimentary type. Association of igneous intrusions and sporadic volcanic formations are also found. Forest cover plays an important role in the formation of soils. The soils are generally porous and sandy loamy with poor water-holding capacity. The porosity of the soil and varying gradient accelerates the surface and sub-soil run-off and the poor water holding capacity is responsible for scanty perennial water source is these islands. The soils are acidic in nature with pH varying from 4.5 to 6.0.

HYDROLOGY

The temperature in the mangrove habitat varies from 23.4°C to 31°C and that of surface (soil) from 27.8°C to 35.3°C. It is pertinent to note that the surface temperature is always higher than the atmospheric temperature. The burrow temperature recorded in case of some crab-holes at 10 cm depth ranges between 28.1°C and 31.5°C. Salinity ranges between 1.8°C and 31.8°C in the estuaries, and inside the mangroves it varies from 28.6% and 33%. The dissolved oxygen in the mangrove area is between 1.0 mg/l and 5.40 mg/l. The mean sea tide level is 1.21 m while the mean high tide level reach upto 1.85 m and mean low tide level goes upto 0.59 m.

FORESTS

The main forest types occurring in the islands area of the tropical evergreen, semi-evergreen and moist-deciduous types. The forests are largely in virgin state, luxuriant in growth and occupy 86.9% of the land area. The flora of the islands is rich in diversity with about 2200 species, of which 1300 species are not found in other parts of the country; these species are of Malaysian origin and are found in Burma, Indonesia and the Polynesian island. There are about 200 endemic plant species of these islands.

An area of 2929 sq km of forests is reserved and 4242 sq km are protected. For the protection of aboriginal tribes 35.5% of the forest area has been set apart of Tribal Reserves. In all, 94 Wildlife Sanctuaries covering an area of 455.98 sq km and 16 National Parks spread over 361.57 sq km have been established to provide protection to flora and fauna. In addition, 885 sq km of tropical virgin vegetation of Great Nicobar has been declared as Biosphere Reserve and National Park. Thus the protected forest area alone in the Bay Islands is to extent of 59% of the forest cover.

PAST WORKING OF MANGROVE FORESTS

Extraction of a small quantity of mangroves was carried out in the past to meet the domestic requirements of fuelwood around the townships. Besides, this, one power house at Port Blair and three major plywood industries were also consuming mangrove fuelwood for their boilers. Even the departmental steam vessel was using mangrove fuel for generating steam. Although systematic working for mangroves was prescribed in the Working Plans, the extraction of mangrove poles and fuel extraction were not taken up on a largescale commercially due to limited demand for fuelwood and poles. With the growing consciousness for conserving the unique mangrove ecosystem, the Andaman Administration has banned extraction of the mangroves since 1986.

The plywood industries as well as Chatham Power House have since switched over to diesel, and the departmental steam vessel is utilising the sawn fuel in place of mangroves.

As per the prescribed Working Plan for the tidal forests of Andamans, clear felling and selection feelings were to be practiced. *Bruguiera* and *Rhizophora* being the dominant species, a rotation of 99 years with a felling cycle of 33 years was prescribed at a ratio of 120 nos. of poles per ha above 60 cm girth. As *Rhizophora* was giving more of biomass due to branchiness an yield of 86 cm/ha was prescribed, and in spite of *Bruguiera*, being straight growing species, an yield of 31 cm/ha was prescribed. As a precautionary measure a buffer at 20 m width along the main creek and 10 m width along small creeks was left out to prevent the soil wash as also nutrients. In addition, 40 well-formed *Rhizophora* and *Bruguiera* poles per ha were left as standards and seed bearers, uniformly spaced. All the poles above 52 cm in girth were felled, leaving he standards for seed disposal. For holding the mangrove seeds, particularly that of *Rhizophora* and *Bruguiera* from drifting away along with the tidal current, brushwood barriers at various outlets were laid to trap the floating seeds.

Most of the areas in Andamans where the mangrove vegetation is seen is dense stand, were harvested in the past under clear felling and selection system, but mangroves are well stocked by self-sown seeds. Attempts were also made to supplement the natural regeneration by artificial plantation in the past. The feeling coupe area is left intact, alternatively so as to get the mangrove seeds from the adjoining standing strip. As the felled ares have been adequately regenerated under clear felling and selection systems, there has not been any significant damage to the mangrove forests in the islands. But wherever population pressure was heavy near townships, there has been some damage to mangroves due to removal of fuel and poles for domestic need. The Administration is contemplating to impose a ban on felling of mangroves over non-forest land so that a further threat to some rare species of mangroves is minimised.

CONSERVATION AND MANAGEMENT STRATEGY FOR MANGROVE FORESTS

The strategy adopted in the Andaman and Nicobar Islands for conservation and protection of mangrove forests is as follows :

1. Full protection to the mangrove flora and fauna by banning mangrove extraction from Government forests.
2. Identification of potential mangrove areas for declaring as National Parks and Sanctuaries.
3. Afforestation of mangroves in the islands. For this purpose, a few nurseries have been established and efforts are underway to plant suitable areas with mangroves.
4. Awareness amongst the public on the importance of mangroves and the need for its preservation by education of the village folk.
5. Protective measures to keep vigil on possible destruction of mangroves.

LINKAGE OF MANGROVE ECOSYSTEM WITH GENETIC RESOURCE PROGRAMME

Amongst mangrove species occurring in the World, so far 65 species have been reported. The representation of 34 exclusive mangrove species obtained in the Andaman and Nicobar Islands is fairly large and needs thorough study and effective conservation measures. Species like *Kandelia* *candel, Rhizophora × lamarckii, Sonneratia apetala, Bruguiera sexangula, Cerips decandra* and *Cynometra iripa* are threatened ones and they need full protection. Under the Genetic Resource Center activity, studies on adaptability of the trident species of mangroves on various ties will have to be carried out *inter alia*; their ecological status needs in-depth study. One or two sites for the study purpose may not have adequate representation. Hence, several representative sites have to be located under the Genetic Resource Center programme so that threatened species are adequately protected. The existing data on the mangrove ecosystem is scanty and needs further improvement and monitoring. Efforts are required for maintaining species diversity and conserving gene-pool so that the research potential is tapped. Germplasm collection also is necessary to study the adaptability of rare species of mangroves from other parts of the country as well from various mangrove regions of the World.

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SUSTAINABLE MANAGEMENT OF COASTAL ECOSYSTEMS : THE CASE OF MANGROVE RESOURCES

R. MARIA SALETH

INTRODUCTION

Coastal ecosystems are an important part of the natural resource base of our country. Since these ecosystems are a vital ecological bridge between the terrestrial and aquatic ecosystems, their preservation is essential to maintain the ecological balance and biodiversity. Despite their ecological and economic significance, the effects of current resource use practices evident both in the inland and coastal areas have engendered various forms of stresses on the coastal ecosystem. Increasing soil erosion and soil and water pollution caused by the intensive farm practices in the inland areas which get transported through the river and canal systems are also adversely affecting the coastal systems. Moreover, the seawater intrusion and the attendant soil and water quality problems caused by groundwater depletion have already started threatening the very sustainability of the agricultural systems in the Saurashtra region of Gujarat and Tanjavur region of Tamil Nadu. Eventhough the coastal regions are relatively sparsely populated as compared to the inland regions as of now, increasing demographic pressure on the inland resource systems is bound to have a spill-over effect in the form of heightened resource demand in the already fragile coastal resource system. The development of coastal resorts and other coast-based recreational activities prompted by the increasing recreational demand of the affluent section of the population as well as the tourism policy of the Government have also made serious inroads into our coastal resource base. Above all, the prospect of sea level rise, expected to be of the order of 5 to 15 inches due to global warming by 2025 AD, makes the need to take concrete steps to ensure the sustainable management of the coastal ecosystems all the more urgent.

Given the economic and ecological significance of the coastal ecosystem, the need for a careful study to identify the critical issues involved in the sustainable management of our coastal system and their practical and policy implications cannot be over-emphasised. This paper attempts to (a) outline the pathway to sustainable development of our coastal ecosystems by considering the case of the mangrove ecosystem, (b) discuss the economic issues involved in the utilisation of mangrove resources (c) develop a mathematical framework useful to capture and analytically show the ecological-economic-equity interactions in the context of the mangrove ecosystems, and (d) indicate certain policy options and action plans essential for the sustainable management of the mangrove ecosystem.

THE PATHWAY TO SUSTAINABLE DEVELOPMENT

In the use of the natural and environmental capital stock, there exists a fundamental conflict not only between ecological requirements and economic needs but also between the economic needs of different sections of society. The coastal ecosystem is not an exception in this respect. For instance, any attempt at preserving the ecosystem *per se*, will certainly have the corresponding economic cost as the coastal systems support the livelihood security of half the human population World-wide. Similarly, the preoccupation with the satisfaction of our current consumption needs will invariably endanger the future consumption needs as well as the ecological sustainability of the resource system. In this sense, while there is a direct relationship between eco-preservation and the economic interests of future generations, there exists an inverse relationship between eco-preservation and the needs of the current generation. Sustainable use of the ecosystem, therefore, requires the resolution of these inevitable conflicts in an efficient manner. From an ethical point of view, the pathway to sustainable utilisation of our coastal ecosystems will be the 'middle-way path' between the two extremes of complete eco-preservation and the free market approach to resource depletion (Swaminathan, 1989). Such 'middle-way path' can be identified as the path that ensures both the ecological sustainability of the resource system and economic efficiency of the production system dependent on the resource system as well as the social equity in the access to the resource system. From a systems viewpoint, the sustainable development path will be the one that improves the quality of human life while living within the carrying capacity of the supporting ecosystems (IUCN/UNDP/WWF, 1991, p. 10). In an operational context, the programme, project, and policy components of such a sustainable path can be identified using the illustrative methodology suggested by Swaminathan (1991). The methodology is based on three equally important components, i.e., ecological sustainability, economic efficiency, and social equity. It is in this operating sense that the concept of sustainability is used in this paper to evaluate the sustainability of the mangrove ecosystem.

MANGROVE ECOSYSTEM : ECOLOGY, ECONOMICS, AND SOCIAL EQUITY

The coastal ecosystem has four major components, viz., the salt marshes in the temperate zone, mangroves in the tropical zone, estuaries, and coral reefs and seagrasses. Of these four components, the mangrove ecosystem has assumed particular significance in view of its pivotal role both from the ecological and economic point of view. Given the salt-tolerant capacity of the mangrove species and their role as a storehouse of biological diversity akin to the tropical rainforest, they can provide indispensable genetic material for the development of new transgenic species capable of better adapting to salinity caused by the impending sea level rises and the attendant seawater intrusion. Besides, the mangroves also serves as a natural defence against coastal erosion. In fact, in view of the tendency of mangrove species to grow towards the sea, they could regain some land which could otherwise be lost to the sea (Rao, 1986). The economic significance of mangroves is also equally important as they provide both direct benefits in terms of sustainable capture fisheries as the detritus formed from their litter contributes rich food for fish. Despite their ecological and economic significance, the mangrove ecosystems are under various degrees of threat due to the overuse caused by population pressure and land diversion caused by agricultural expansion and urbanisation.

For better understanding of the man-mangrove interaction, it is essential to list various mangrove dependent activities such as the user groups behind these activities, the type of output/products and the degree and nature of stress on the mangrove ecosystem. Table 1 lists this information for impact, economic benefits, and social equity. The ecological impact of a given use can be evaluated in terms of the nature and degree of stress in the mangrove ecosystem. While some activities may lead to the complete destruction of the mangrove forest and hence its other uses such as capture fisheries would undergo both, qualitative and quantitative changes. However, the damaging activities done within the assimilative capacity of the ecosystem or the regenerative growth of the mangrove forest may not cause much concern. These damaging activities where scale of operation is critical are distinguished by a question mark in the Table. Similarly, even those uses requiring the clearance of the mangrove forest need not always lead to the destruction of the ecosystem provided that the uses are well within the limit set by the ecological ground rules.

If the land diverted to other uses forms only a small proportion of the total mangrove area under consideration, then the activity will not cause much disturbance to the mangrove ecosystem. When these destructive activities are well within the limit laid down by the ecological ground rules, they can achieve both economic efficiency and ecological sustainability. These destructive uses whose ecological impact is a function of the scale of operation are distinguished with a star in the Table.

Economic efficiency is concerned with one major issue : can the economic benefit be improved by the maintenance of the mangrove ecosystem or diverting it to other uses? The answer depends on whether we view the problem from the private or social point of view, and also whether the problem is considered on a short-term or long-term basis. It is necessary to recognise that a purely economic approach to any natural ecosystem has some major limitations. Notably, economic analysis relies purely on market mechanisms to signal the economic value of a given resource society. Moreover, the market mechanism can reasonably reflect the value only when property rights in the resource at issue are well defined. Otherwise, there will be a market failure. In view of the inherent difficulties in defining property rights as well as monitoring their strict adherence especially in the case of natural resources like ecosystems, these resources are generally considered as 'open access' resources notwithstanding the fact that they are under the direct control of the State. The absence of any formal property rights system and the attendant lack of any individual economic incentive for resource conservation make these resource systems particularly vulnerable to depletion or species extinction. This is essentially due to the divergence between the private and social values. The price system in a free market condition reflects only the private value. For instance, in the case of a mangrove ecosystem, a timber businessman would resort to timber harvest based only on the price and harvesting cost of immediate timber output, and not the timber output in the future periods. Because, under open access conditions, he does not have the incentive to conserve the resource as the mangrove trees left unharvested by his conservative policy will just be cut by another person due to 'no restriction' on access to the mangrove forest. Moreover, third-party effects would also be ignored. For example, timber harvest reduces detritus production both by a reduction in the number of mangrove trees as well as reduced zooplankton population, affecting the fish catch of fishermen. Thus, the resource use decisions of most of the mangrove users are based not only on a very limited planning horizon but also on a narrow criterion of individual economic benefits. Consequently, the present institutional conditions governing the resource use in the mangrove ecosystem foster a wrong kind of economic behaviour, leading to resource depletion rather than its conservation. Since the price signal from a tree market fails to reflect the non-use values, the divergence between individual and social values become inevitable.

Another important aspect to be noted in the context of Table 1 is the varying degrees of conflict among the four major activities as well as between different users with the same activity. These

Table 1 Man-mangrove interactions : economic benefits and ecological impacts

Activity	Mangrove-dependent groups/sectors	Uses of mangrove ecosystem	Output/products	Stress on mangrove/ ecosystem
Fishing	(a) Fishpond owners	(1) Creating	Fishery products	Cleared area
		(2) Fry collection for stocking	Fishery products	Forested area
	(b) Fishermen	(1) Collection of adult fish, shrimps, etc.	Fishery products	Forested area
		(2) Fish for consumption	Household nutrition security	Forested area
		(3) Tannin collection	Increased durability of Fish	Forested area
Farming	(a) Farmers	(1) Rice cultivation	Higher rice yield	Cleared area
		(2) Manure	Substitute for chemical Fertiliser	Damage (?) (Qty)
		(3) Soil and water pollution	Agricultural output	Damage (Qlty)
		(4) Coastal protection	Land saved from coastal protection	Forested Area
	(b) Other rural	(1) Feed for cattle operation, milk, etc.	Energy for farm groups	Damage (Qty)
		(2) Fuelwood collection	Energy for household use Additional income	Damage (?) (Qty) Forested area
		(3) Honey and income saving	Herbal medicine	
Logging	(a) Businessmen	(1) Commercial wood cutting	Building materials, Charcoal, etc.	Damage (Qty + Qlty)
	(b) Other rural groups	(1)Wood cutting for own household needs	Building materials	Damage (?)
Developmental activities	(a)Industry	(1)Wastage disposal	Industrial products	Damage (Qty)
		(2)Oil spillage	Oil products	Damage (Qlty)
	(b)Urban development	(1)Ports	Enhanced trade	Cleared area*
		(2)Roads	Communication	Cleared area*
		(3)Housing	Houses	Cleared area*
		(4)Sewage disposal	Cost saving	Damage (Qty + Qlty)
	(c) Recreational	(1)Beach hotels and resorts	Foreign exchange Earnings	Cleared area*
		(2) Canoeing, bird watching, etc.	Aesthetic satisfaction, Recreation, etc.	Forested area
	(d)Scientists	(1)Research	Knowledge	Forested area
		(2)Preservation	Biodiversity	Forested area
	(E)Others	(1)Mining	Mineral products	Damage (Qty + Qlty)

conflicts can be discussed better in terms of intra-generational and inter-generational equity. Given the existence of an inequality between different user groups belonging to the current generation in terms of their access to the mangrove resources, there emerges some intra-generational interest conflict having significant welfare implications. For instance, there is a conflict between fishpond owners and rice cultivators in the mangrove area as they vie for the same pieces of land under the mangrove forest. Similarly, there exists an interest conflict between fishpond owners. Obviously, artisanal capture fishery is not only more equitable as it permits a wider group to obtain benefits from the mangrove ecosystem, but also ecologically sustainable as this use does not disturb the ecosystem at all. However, even though fuelwood collection for household consumption is more equitable as this activity supports the livelihood security of the poor groups, it can have serious ecological impact as wood collection involves the destruction of the mangrove forest, especially under conditions of heavy population pressure.

The most interesting is the conflict between the two uses of the fishpond owners themselves. While the creation of fishpond requires the destruction of mangrove forest, the need for the costless collection for stocking the fishpond requires the preservation of the mangrove ecosystem. If one applies the economic criterion alone in this case, it will definitely favour the diversion of mangrove land to fishpond creation as the benefits from the culture fishing activity may very well outweigh the cost saving possible from the natural collection of fry fish. Also, the time dimension also plays an important role in determining the nature and intensity of these inter- and intra-activity conflicts. For instance, while the farmers' use of fertilisers and pesticides increases agricultural output in the short run, they contribute to the long-term qualitative and quantitative changes in the mangrove ecosystem. Consequently, farmers located in the coastal region would subsequently lose their natural defence against coastal erosion leading to loss of farm land. Moreover, the extinction of mangrove species will reduce our ability to develop transgenic species essential to maintain agricultural output in a changed condition resulting from sea level rise. However, the myopic perspective of the present generation will definitely limit the options available to future generations, irrespective of whether it is farmer, businessman or a resort developer. Thus, there is an inherent conflict between the present and future generations. Any effort to resolve this conflict through a purely economic approach will bias resource consumption towards the present generation as the current market conditions do not reflect the options and preferences of future generations.

ECONOMIC APPROACHES FOR MANGROVE ECOSYSTEM MANAGEMENT

Given the inherent difficulty in establishing a property rights system in ecosystems, it is understandable why the market system fails to reflect the true social value of the ecosystem. However, economists try to make the price system amendable to reflect the social value rather than just the private value, using a few economic regulatory mechanisms such as discount rate, taxes and subsidies, and command and control regulations.

DISCOUNT RATE POLICY

The rate can be manipulated to change the economic perception of the decision makers. For instance, the planning horizon can be increased by reducing the discount rate and vice versa. The idea is to make the decision maker take a long-term point of view by increasing the value of the conserved resource. It is essential to recognise that such a discount rate manipulation will work only when a single person or entity owns and manages the resource system. Under open access conditions, this mechanism is not of much use as different individuals will have different time preferences and, hence, discount rates.

TAX-SUBSIDY SYSTEM

With taxes and subsidies, the existing free market price can be modified to reflect the social cost. For instance, a tax can be imposed on the businessman that covers the reduced fish catch and the tax thus collected can be distributed as a subsidy to the affected parties. In the same way, a tax can also be imposed on all depletive users of mangroves to cover the social cost of reduced biodiversity or ecological damage. Such a tax can be used to create an ecological fund usable for the restoration or other perservatory efforts. Apart from the issues such as the calculation of the economic value of the damages and their distribution across the users as well as the costs associated with the administration of such a system, the crucial problem associated with this tax-subsidy system is the assumption of equality between environmental capital, bioproductivity and other man-made capital. The environmental capital and bioproductivity, unlike other capital stocks, cannot be rebuilt to its original status, once exploited beyond a 'safe minimum' point. that is, there are irreversible aspects warranting serious considerations.

COMMAND AND CONTROL SYSTEM

Another approach is that of a 'command and control' system that specifies certain physical limits for the exploitation of the ecosystem. The problem here is the identification of an acceptable physical limit specifying the allowable resource extraction and the creation of a suitable monitoring mechanism to make sure that the specified limit is actually observed. Notwithstanding some operational difficulties associated with this approach, it is the most appropriate one given the uncertainty and irrepressibility associated with and the absence of adequate quantitative information about certain crucial aspects of the ecosystem. By limiting the resources available for extraction and creation thereby an artificial scarcity, the market value is raised to induce the users to follow a policy of resource conservation. The command and control approach is consistent with the 'safe minimum standard' proposed by Toman and Crossan (1991). That is, in view of the inability of the market system to provide the necessary solution for the sustainable management of resources like the mangrove ecosystem where the market fails to reflect the true social value of the resource, it is essential to derive certain solutions based on extra-market criteria such as moral imperatives, ethical considerations and biological parameters.

AN ECONOMIC MODEL OF MANGROVE ECOSYSTEM

It is attempted here to mathematically describe an economic model of a simple mangrove ecosystem depicted in a flow diagram in Rao (1986). The model is aimed to provide a concentrate setting to provide some analytical exposition of the economic approaches and economic issues discussed respectively in sections 3 and 4. To describe the model, the following notations are defined:

t = A time period
T = The planing horizon
$M(.)$ = Mangrove biomass stock in tonnes
M = Time rate or instantaneous change in mangrove biomass stock (dM/dt)
M^* = Initial mangrove biomass stock, i.e., M (0)
$G(.)$ = Annual growth in mangrove biomass stock in tonnes
$Z(.)$ = Zooplankton population
$D(.)$ = Detritus production in tonnes
$F(.)$ = Fish catch in tonnes
E = Mangrove biomass extraction in tonnes
$B(.)$ = Social benefit in rupees
$C(.)$ = Social cost in rupees
$S(.)$ = Net social benefit in rupees
$H(.)$ = Hamiltonian function
δ = Social discount rate, and
μ = Co-state variable or shadow value of an unit of biomass extracted,and
μ^* = Instantaneous change in the co-state variable

With these notations, we can now describe the nature and functional form as well as the economic and ecological significance of a set of functions which together describe the mangrove ecosystem under consideration.

Before proceeding further, it is necessary to state the assumptions under which the model is built. It is assumed that the geographic area covered by the mangrove ecosystem is given. The mangrove ecosystem is also affected very crucially by natural and site-specific factors like temperature, tidal conditions, edaphic factors, species diversity, etc. Eventhough here we are concerned only with few mangrove uses so as to keep the model manageable for the analytical exposition of certain theoretical ideas discussed in sections 3 and 4, the essential elements of a multiple-use mangrove system can be captured in the model by incorporating various uses of not only the mangrove ecosystem but related terrestrial and aquatic ecosystems also.

Since the mangrove forest, the main component of the mangrove ecosystem, is an amalgamation of many mangrove species and mangrove associates each with different wood, leaf, and growth patterns, it is essential to use a common denominator. For modelling purposes, here the mangrove forest is quantified in terms of a common magnitude and measurement unit, i.e., biomass (both wood and leaves) in tonnes. Notably, the control variable, i.e., biomass extraction, is a broader term that includes not only the wood collected either as fuelwood or as building materials but also the extraction of mangrove leaves for feed and manuring purposes. Finally, the model to be described has been developed under simplified conditions just to demonstrate how the economic value of certain ecological process eluding the normal pricing procedure can be depicted at least in an analytical sense.

Within the framework described above, it is postulated that mangrove biomass stock at a given time point, say t, is a function of the level of biomass stock, its annual growth, and biomass extraction all occurring in the previous period, i.e., at t-1. Specifically,

$$M_t = M_{t-1} + G(M_{t-1}, E_{t-1}) - E_{t-1} \tag{1}$$

It can be noted that in equation (1), the annual growth rate of the mangrove biomass stock G(.) at the start of the period t is itself a function of biomass stock and biomass extraction occurring at t-1. The biomass extraction is included to capture its adverse effect on biomass growth. Further, equation (1) also implicitly specifies that the mangrove biomass, at any given point in time, is a function of biomass growth and biomass extraction, i.e.,

$$M = M[G(.), E] \tag{2}$$

Since mangrove biomass growth is a biological process, it is assumed here that the function G(.) takes the logistic growth path. The logistic form of G(.) implies that mangrove biomass increases at a declining rate up to a maximum and then onwards it declines at an increasing rate. This behaviour of mangrove biomass stock can be explained as follows. Recalling the assumption of a fixed geographical area under the mangrove forest, mangrove biomass grows faster in the initial growth phase because mangrove trees are smaller/fewer in number, and hence energy and nutrients per mangrove tree are higher. Also, there is more space for the canopy growth of each tree. Once the maximum possible growth is attained, the mangrove biomass becomes less in view of the increasing competition among the mangrove trees for the available energy and nutrition and reduced space for canopy growth. In other words, given the natural and site-specific conditions, there exists a carrying capacity for the mangrove forest. The system can grow both qualitatively and quantitatively up to the biological limit set by the carrying capacity. But once this limit is crossed, the constraints in the form of lower availability of nutrients and energy limit the growth of the system. Thus, G(.) is concave in M with $G_M > 0$ and $G_{MM} < 0$. On the other hand, G (.) is convex in E with $G_E < 0$ and $G_{EE} > 0$, implying that with every increase in biomass extraction, biomass stock declines at an increasing rate, the reason being that extraction not only reduces the initial biomass stock but also its further growth.

While equation (1) describes the biomass growth in a discrete time frame, equation (3) below describes the instantaneous change in the mangrove biomass on a continuous time frame. That is,

$$\overline{M} = \frac{dM(.)}{dt} = G(M, E) - E \tag{3}$$

Equation (3) implies that the time rate of change in the mangrove biomass stock is just a function of the annual biomass growth and biomass extraction. It is also known as 'the equation of motion' as it describes the instantaneous changes in the resource system caused by its biological parameters as well as the anthropogenic pressure.

Zooplankton is another important component of the mangrove ecosystem comprising very minute life forms representing an important link in the energy cycle of the mangrove ecosystem. While they obtain their nutritional requirements from mangrove biomass, they also convert mangrove litter into detritus capable of providing nutrients for various forms of fish population. Given other natural factors determining their growth and diversity, zooplankton population is viewed as a function of the level of mangrove biomass. That is,

$$Z = Z[M(.)] \tag{4}$$

Z(.) is assumed to be concave in M with $Z_M > 0$ and $Z_{MM} < 0$. Concavity implies that zooplankton increases with mangrove biomass but only at a declining rate as their population is also constantly checked by energy supply as well as predation by fish and other species.

Next, in order to incorporate into the model the interdependence between the mangrove and the aquatic ecosystems, we consider the effect of biomass extraction on fish population in the fish capture area near the mangrove ecosystem. Mangrove ecosystem contributes to the growth of fishery resources in two ways. First, the litter from the mangrove forest converted into detritus by the zooplankton population supplies the essential nutrients for the fish population. And, secondly, mangrove forests provide a nursery ground for various aquatic species. To model the linkages between the mangrove ecosystem and the aquatic ecosystem characterised here by the fishery resources, the following intermediary function relating to the supply of fishery resources to the level of detritus generated by the combined efforts of the mangrove forest and the zooplankton population is defined:

$$D = D[M(.), Z(.)] \tag{5}$$

D(.) is assumed to be concave both in M and Z with $D_M > 0$ and $D_{MM} < 0$, and $D_Z > 0$ and $D_{ZZ} < 0$. The concavity of D(.) follows directly from the concave nature of both M(.) and Z(.) in mangrove biomass.

In addition to the nutrition from detritus, the zooplankton population thriving in the waters of the mangrove ecosystem in itself serves as a direct food material for many carnivorous fish types. Moreover, the reduction in biomass stock caused by increasing biomass extraction activities also affects the level of fishery resources due to the reduction in food supply. In view of these facts, the fish catch is considered as a function of the volume of detritus and the level of zooplankton population. that is:

$$F = F\{D[M(.)., Z(.)], Z(.)\} \tag{6}$$

F(.) is concave both in D and Z with $F_D > 0$ and $F_{DD} < 0$, and $F_Z > 0$ and $F_{ZZ} < 0$.

Having described the ecological aspects of the mangrove and its interrelated ecosystem, let us describe the economic aspects of the resource system. It is postulated that the social value of the mangrove ecosystem is a function of biomass extraction, fish catch, and biomass stock. That is:

$$B = B\{E, F(.)M[G(.), E]\} \tag{7}$$

It is assumed that B(.) is concave in all the three major variables, i.e., biomass extraction, fish catch, and mangrove biomass resource. Notice that the social benefit not only includes the direct material benefits from biomass extraction and fish catch but also the indirect ecological as well as material benefits in the form of mangrove biomass left unextracted. That is, since the mangrove biomass stock has been included in the benefit function, the society derived can include not just the existence value or non-use values reflecting the aesthetic enjoyment, coastal protection, etc., but also cost-saving in biomass extraction and fish catch resulting from higher input productivity due to higher level of biomass stock and fish population.

Regarding the social cost of resources extraction, cost is postulated as a function of biomass extraction, fish catch, and mangrove biomass stock:

$$C = C\{E, F(.), M(.)]\} \tag{8}$$

It is assumed that the cost function is convex in E and F(.) but concave in M(.), that is, $C_E > 0$ and $C_{EE} < 0$; $C_F > 0$ and $C_{FF} < 0$ and $C_{MM} < 0$, while the convexity of C(.) in E and F(.) follows the fact that with increasing resource depletion caused by extraction, input costs increase via lower input productivity. For instance, in a depleted mangrove forest, biomass extraction per day will be lower, and hence the cost of extracting a given amount of biomass will be higher as compared to a well-maintained mangrove forest. Similarly, the concavity of C(.) in M(.) follows from the fact that with improved resource stock, cost-saving will increase but only at a declining rate.

The functions defined in (1) through (8) form the major components of the model of mangrove and its associated ecosystems. It is worth noting again that while equations (1) through (6) depict the ecological aspects, particularly the mangrove and its interdependent ecosystems, equations (7) and (8) depict the economic aspects of the ecosystem. Since the equations (1) and (3) also incorporate the anthropogenic pressure on the ecosystems, the model depicts both the ecological and economic aspects of the mangrove ecosystem.

Given the initial level of biomass stock, the objective of the society is to maximise the discounted net social benefit over an infinite planning horizon within the constraint laid down by the ecological ground rules formalised not only in the equation of motion but also with the inclusion of the non-use values both in the social benefit and cost functions. In this sense, our approach here is to identify an optimum much broader in scope than an anthropocentric optimum, notwithstanding the fact that the ecosystem is still evaluated only in terms of its instrumental value to humans. It is important to note that the approach of viewing the utilisation of the mangrove ecosystem from a social point of view enables us to operationalise the integral or holistic approach to mangrove resource management. It also helps us to internalise the external effects of the action of each mangrove user group on those of their counterparts. The society's problem can be formally stated as follows:

$$MaxS = \int_0^T e^{-\delta t}[B\{E, F[D[M(G,E/),$$
$$Z(M(G,E))], Z(M(G,E))], M(G,E)\} - C\{E, F[D[M(G,E))], Z(M(G,E))], M(G,E)]\}dt \quad (9)$$

Subject to....

$$\overline{M} = G(M,E) - E\{\text{Equation Motion}\} \quad (10)$$

$$M(0) = M^*\{\text{Initial Mangrove Biomass}\} \quad (11)$$

$$E \geq 0 = \{\text{Extraction cannot be negative}\} \quad (12)$$

To characterise the solution to the maximisation problem described above, we form the following Hamiltonian function showing the system's behaviour at an instant:

$$\begin{aligned} H = &[B\{E, F[D[M(G,E), Z(M(G,E))], Z, (M(G,E))].M(G,E)]\} - \\ &C\{E, F[D[M(G,E), Z(M(G,E))], M(G,E)\}] + \\ &\mu\{G(M,E) - E\} \end{aligned} \quad (13)$$

μ in 13 is known as the co-state variable indicating the shadow price or social value of a unit of mangrove biomass extracted. It is also known as the 'rent' or *in situ value* of a unit of biomass stock left unextracted.

Differentiating (13) with respect to E, M, and, we obtain the following necessary conditions to characterise the optimum path for biomass extraction:

$$\frac{dH}{dE} = (B_E + B_F[F_D(D_M M_E + D_Z Z_M M_E) + F_Z Z_M M_E + B_M M_E) - \{C_E + C_F[F_D(D_M M_E + D_Z Z_M M_E)\} + (G_E - 1) = 0 \quad (14)$$

$$\frac{dH}{dM} = \{B_F[F_D(D_M + D_Z Z_M) + F_Z Z_M\} + \{C_F[F_D(D_M + D_Z Z_M) + F_Z Z_M] + C_M\} - (G_m) = - \quad (15)$$

$$\frac{dH}{dy} = M - G(M, E) + E = 0 \quad (16)$$

Equation (14) states the familiar economic condition necessary for an equilibrium, i.e., marginal benefit and marginal cost should be equal. Recall the earlier discussion that biomass extraction at any given point has both direct material costs like extraction costs but also indirect costs, both real and material in nature, such as (i) reduction in fish catch due to lower detritus output caused by lower mangrove litter and zooplankton population (ii) increased future cost of extracting a given amount of mangrove biomass caused by a reduction in biomass stock, (iii) reduction in non-use values, and (iv) reduction in the rate of biomass growth induced by biomass extraction. Therefore, the combined monetary benefit from biomass extraction and fish catch should, at the margin, the equal to the sum of both these direct and indirect costs.

Intuitively speaking, equation (14) also defines the economic relationship between the value of a unit of mangrove biomass extracted and that which is left unextracted. Solving equation (14) for and rearranging terms, we obtain:

$$M = \frac{\{B_E - C_E\} + (B_F - C_F)\{F_D(D_M M_E + D_Z Z_M M_E) + F_Z Z_M M_E\} + M_E(B_M - C)}{(1 - G_E)} \quad (14a)$$

Equation (14a) defines the shadow price of a unit of extracted mangrove biomass as the marginal benefit from biomass extraction net of both direct and indirect costs. While the first part of the numerator in equation (14a) represents the marginal net monetary benefit from biomass extraction, the second part represents the indirect cost (i) valued at the marginal net monetary benefit from fish catch. The third part in the numerator of (14a) captures the indirect costs (ii) and (iii) The denominator in (14a) represents the indirect cost (iv).

Equation (15) states how the shadow value should behave over time. Solving equation (15) for, we obtain the familiar Hotelling condition applicable to a renewable but depletable resource. It specifies that the shadow value or the *in situ* value of a unit of biomass stock should grow at the rate of discount plus the value of the loss in the rates of biomass growth and changes in fish catch value as well as the existence and other non-use values:

$$(-G_M) + (C_F - B_F)\{F_D(D_M + D_Z Z_M) + F_Z Z_M\} + (C_M - B_M) \quad (15a)$$

If the condition specified in equation [15a] is not satisfied, then social benefit can be improved by shifting biomass extraction across time periods. That is, if the *in situ* value of the biomass stock grows at a rate lower than the sum of discount rate plus the growth and value losses, then biomass extraction should be increased and vice versa. Thus, in simple terms, condition (15a) ensures the absence of inter-temporal arbitrage.

Equation (16) simply reproduces the equation of motion stating that the time rate of change in biomass stock should always be equal to the annual biomass growth net of annual biomass extraction. If the biomass extraction is just equal to the annual biomass growth, then the rate of change in the biomass stock will be zero. If this condition holds good for all the time periods, then the resultant biomass extraction is fully consistent with the 'sustainable yield cut' policy as it allows the existence of the initial stock indefinitely into the future. When annual biomass extraction is more than the net annual biomass growth, then the rate of change in the biomass stock will be negative. Note that the sustainable yield cut policy is only a biological equilibrium and hence unrelated to the economic equilibrium. Since the mangrove biomass extraction problem is viewed from the viewpoint of the society, the indirect costs are included in the calculation of an optimal extraction path. Consequently, the amount of biomass extraction will be lower in a social optimum as compared to a private optimum. The divergence between the social and private values in the context of mangrove ecosystem can now be stated in quantitative terms using equation (14a). When the mangrove system is considered as an 'open access' resource, a private wood collector will consider only the first part in the numerator of equation (14a). He considers neither the adverse effects of wood cutting on fish catch and other significant non-use values nor even the increased future extraction costs caused by his current biomass extraction. This means that the private value of a unit of mangrove biomass is far lower than its social value by an amount equal to the sum of second and third term in the numerator plus the terms in the denominator in equation (14a). It goes without saying that such a lower private value leads to a depletive extraction policy. What is interesting is the fact that this socially sub-optimal policy is optimal from the private point of view under an open access condition as the resource conserved by his conservatory policy will be cut by his fellow wood collectors. When the mangrove forest is under the private ownership of the wood collector, then he will consider the effects of his current extraction not only on future extraction cost but also on biomass growth. He will not consider, however, the adverse effects of activities on fish catch and other non-use values. While the wood collector can be made to internalise the adverse effects of fish catch by giving him also the ownership of the adjoining fishery site, the adverse effects of his actions on the non-use values cannot still be internalised. Obviously, there is a limit to the efficacy of property rights approach in view of certain insurmountable difficulties in assigning property rights in the mangrove ecosystems.

Another approach noted in section 4 is to levy some kind of tax on the wood collector. In the context of equation (14a), the tax will be equal to the sum of the indirect costs, i.e., the sum of the second and third part of the numerator as well as the denominator in (14a). Thanks to the tax, the wood collector will be made to realise all the indirect costs engendered by his wood extraction activity. The proceeds from the tax can be used to compensate the loss in fish catch as well as create a mangrove fund to be used for reforestation and other related activities. As noted already, apart from the administrative problem associated with the imposition, collection and distribution of the tax, the major hurdle with the tax-subsidy approach is the difficulty in calculating the indirect cost, given the state of current quantitative information on various relationships governing the ecological and economic process in the realm of mangrove ecosystem. However, given all the necessary quantitative information essential for building the model described by equation (1) through (11), it is not difficult to specify the tax-subsidy scheme, if not exactly, at least appropriately.

What effect the discount rate manipulation can have on the extraction path of both biomass extraction and fish can very well be demonstrated utilising equation (15). It can be verified that the lower the discount rate, the lower will be the biomass extraction and fish catch in a bond or security, after the expiry of a certain period, we will get an amount equal to the discount rate as return. If we are not extracting the biomass, the biomass will grow just like any other capital and appreciate in value. Moreover, since the net social value should grow at the rate of discount, which is now lowered by our policy, the social value should also be lower. This will be the case only when the biomass stock is allowed to grow with reduced extraction. Thus, the reduced discount rate will foster conservation and higher discount rate will lead to depletion. Another effect of lower discount rate will be that the planning horizon will be increased,inducing the decision-maker to take a long-term view on the utilisation and management of the ecosystem.

An ideal approach, given the dearth of quantitative information and uncertainty and irreversibility associated with the mangrove ecosystems, is the adoption of a 'command and control' system wherein the extent of allowable biomass extraction could be specified based on the learned judgement of the biological scientists. By limiting the available mangrove biomass supply available for exploitation, the private value of biomass is increased with the artificial scarcity created by the supply restriction. In the context of the above mathematical model, such a supply restriction policy will lead to a change in the resource constraint represented in equation (11). Consequently, the shadow value of the mangrove biomass stock is increased, leading to more efficient and conservative use of the permitted mangrove biomass stock.

STRATEGIES FOR SUSTAINABLE MANAGEMENT OF MANGROVE ECOSYSTEM

It is in a sense of urgency that scientists and policy-makers are resorting to devise plans for the sustainable management and utilisation of our mangrove resources. However, our preoccupation with the ecological and inter-generational equity issues should not lead us to an ignorance of the needs of the present generation and how equitably they are met (i.e., the intra-generational equity). Our strategy is to promote an use pattern of mangroves that produces a minimum stress on the mangrove forest and its ecosystem. Such a use pattern will minimise the direct exploitative use of the mangroves while encouraging indirect and non-exploitative uses of the mangrove forest on a sustainable basis. Moreover, the use pattern will ensure the achievement of some compatibility among the user groups with conflicting objectives.

Among the activities and uses listed in Table 1, there are a number of uses which are neither exploitative nor damaging to the mangrove ecosystem. Uses like the collection of tannin, herbal medicine and honey, culture fisheries, and coastal protection as well as the recreational and scientific uses require the complete preservation of the mangrove ecosystem. It implies that sustainable utilisation of the mangrove ecosystem should have to promote these non-destructive uses and discourage exploitative and damaging activities. This is one of the necessary conditions to be satisfied by any policy for the sustainable management of the mangrove ecosystem. Another condition to be fulfilled by a sustainable policy will be that it should promote a multiple use pattern. Such a use pattern is desirable on two counts. First, multiple use pattern permits an integral or holistic viewpoint of the mangrove ecosystem instead of viewing its components in isolation. And secondly, such a use pattern plays a strategic role in bringing harmony among the conflicting uses. For the identification of a 'sustainable' use pattern, i.e., an use pattern that is ecologically sustainable, economically efficient, and socially equitable, Saleth (1992) has elaborated a mathematical procedure based on the methodology suggested by Swaminathan (1991) and the relativist developed by the UNDP (1990, Appendix-3, p. 109).

It can be noted that some of the user conflicts can be eliminated or minimise by a suitable allocation of mangrove zones in terms of their ecological productivity and locational considerations. For instance, the allocation of a denuded mangrove forest for the creation of fishpond or rice cultivation or the development of a beach resort will minimise not only the interest conflict but also the ecological cost. Such a spatial solution can be sustainable only if the land diverted thus forms only a small proportion of the total mangrove forest area. Otherwise, it is essential to reforest the denuded forest in order to develop the ecosystems to their original status. This also brings us to issue of the present scale of utilisation the scale of utilisation is a function of population growth and economic development.

To advance the sustainable livelihood security of the population, it is not enough to be content with the ecological sustainability of the mangrove ecosystem. It is essential to provide the population, especially the lower starata, with alternative sources for the fuelwood and building material needs.

CONCLUSION

Although grass-root level plans and programmes for the sustainable management of mangrove ecosystem are more effective and immediate in their impact, a national mangrove policy should be evolved urgently to allocate the mangrove regions for various competing uses in accordance with land suitability, mangrove genetic diversity, and economic growth, urban, industrial and recreational needs. Swaminathan (1991) has made a passionate plea for converting important mangrove forests as biosphere reserves in view of their long-term ecological and economic significance. In addition to such preservation needs, there should also be an effective legal and institutional apparatus for both *in situ* and *ex situ* conservation of our mangrove ecosystems. As noted already, even when the mangrove forests are just preserved, they provide valuable economic benefits in addition to the ecological benefits. While *in situ* conservation promotes biodiversity and permits the development of naturally occurring mangrove hybrids due to gene flows, *ex situ* conservation facilitates the development of mangrove gene banks essential to provide ready access of coded and evaluated genetic materials to breeders and scientists for developing multiple resistant transgenic plant species. Given the diversity of mangrove species across the continents, it is also highly desirable to have an international network of genetic resource centres. Such as institutional system can also be instrumental in providing training and information as well as in promoting the exchange of genetic material across nations.

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SUSTAINABLE LIVELIHOOD SECURITY INDEX : AN OPERATIONAL APPROACH

R. MARIA SALETH

INTRODUCTION

Swaminathan (1991) has given a conceptual and methodological basis for identifying a procedure to develop a quantitative measure of sustainable development that can effectively capture three equally important aspects of sustainable development, *viz.*, the ecological security, economic efficiency, and social equity. Ecological security is critical to sustain the economic benefits over a long period. Economic efficiency is important to meet the current developmental needs of the society. Equity is important to ensure a more broad-based distribution of the economic benefits particularly in the form of secured livelihood for the weaker section of the society. Our focus on the weaker section is to create a pro-poor bias so as to effect a more equitable distribution of the economic benefits emerging form the use of natural and environmental resources. To take stock of the full import of the inter-twined nature of ecology, economics, and ethics, the proposed measure of sustainability is called as the Sustainable Livelihood Security Index (SLSI). Thus, the concept of SLSI ensures the integration of both ecological security, economic efficiency, and social equity in a mutually reinforcing and symbiotic manner (M.S. Swaminathan Research Foundation, 1991).

OBJECTIVES AND SCOPE

The major objectives of this paper are : (a) to outline a simple mathematical procedure for developing the SLSI, and (b) to discuss its significance as a tool for resource and ecosystem management and planning. The aim here is to make the index flexible enough to be applicable either at the level of a specific resource (e.g., mangroves, water, soil etc.) or at the level of a given geographic region (e.g., village, watershed, country, etc.). At the same time, the measure should be precise enough to grasp even marginal changes in the sustainability of the resource system(s) under consideration which are induced by technological or other policy interventions such as the introduction of a coastal or agro-forestry programme. Information should be simple and information-efficient so that it can be easily be understood and effectively utilised by policy makers and other agencies involved in the protection and management of the resource system(s).

APPROACH FOR THE OPERATIONALISATION OF THE SLSI

In order to make the SLSI into an operational concept we follow the relativist approach used by the United National Development Programme (UNDP) for developing the Human Development Index (HDI) on an inter-country basis (UNDP, 1990). Briefly, UNDP has viewed human development as affected by three factors : (a) Longevity measured by life expectancy at birth, (b) literacy measured by the percentage of literates, and (c) economic opportunities as reflected by the per capita income (PCI) in constant US Dollars. To develop HDI for a given country, UNDP followed a relativist approach. That is, the performance of each country in the three aspects of human development was evaluated in terms of a common scale that was established based on the maximum and minimum values observed among the countries for each of the three aspects based on the relative performance of the countries in these scales; an index for each of the three aspects influencing human development was established for each country. The HDI which is a composite index of the three variables is considered as a simple arithmetic mean of these indices since UNDP gives equal importance to all the three variables.

Following the same relativist approach, the SLSI is developed here by considering the case of a single resource system, i.e., the mangrove ecosystem. The ecological sustainability of the mangrove system is of concern due to the fact that it is affected by anthropogenic pressure. The, institution may suggest that sustainable utilisation and management bring into focus the nature and degree of impact that each use or user group has on the ecosystem. Given that we have defined all possible mangrove uses, can we evaluate the SLSI for each use in a relative sense?

MATHEMATICAL PROCEDURE

There are three steps involved in the construction of the proposed SLSI, *viz.*, (a) identification of three scales – one each for the evaluation of ecological sustainability, economic efficiency and social equity associated with each use, (b) calculation of three indices – one each to capture the ecological sustainability, economic efficiency, and social equity of each use, and (c) derivation of the SLSI related to each use by combining the three indices mentioned above. Further details can be attain from the another.

IDENTIFICATION OF SCALES

The identification of the scales is essential to evaluate the implication of each use in terms of its psychological sustainability, economic efficiency, and social equity relative to a common standard. These scales can enable us to rank the uses in terms of their ecological, economic, and social significance.

ECOLOGICAL SUSTAINABILITY

To establish such a scale for measuring ecological sustainability, we need to establish the maximum ecological sustainability possible among the uses. The use involving mangrove land diversion such as beach resort development or urban development will clear away the mangrove forest once and for all and hence, ecological sustainability associated with such uses will be the lowest. Even uses involving land diversion for urban development may endanger the whole mangrove forest in view of its scale and speed of forest clearance. Thus, this use produces the minimum ecological sustainability or maximum investment of the ecological capital stock embodied in the mangrove ecosystem. Consider uses like capture fisheries, collection of honey, and recreational activities like bird watching. These uses produce the minimum stress on the ecosystem and hence, assure maximum ecological sustainability which in these cases amounts almost to complete eco-preservation.

To establish the above-noted maximum minimum in a formal sense, let us assume that E1 is the mangrove biomass extraction associated with the use. As it is clear from the previous discussion that in the case of uses involving mangrove forest clearance such as urban development, beach resort development, rice cultivation, etc., the biomass extraction will be equal to the total biomass of the mangrove forest. On the other hand, the use of mangrove forest for recreational purposes may involve no biomass extraction at all. In this case, biomass extraction will be zero or almost zero implying complete preservation of the ecosystem. To identify the use involving minimum ecological sustainability, i.e., maximum ecological degradation, we need to maximize EI across all uses. Formally,

$$ES^{*} = (EI) \quad \text{where } I = 1, 2, \ldots n. \tag{1}$$

Similarly, to find the use involving the maximum ecological sustainability, i.e., the minimum ecological loss, we need to minimize E1 across all uses.

That is,

$$ESS^{**} = \min\ (Ei) \text{ where } \quad i = 1, 2, \ldots n. \tag{2}$$

Thus, the scale for measuring ecological sustainability of different is specified by the range defined by ES* and ES** representing respectively the minimum and maximum ecological sustainability. It can be noted that the 'sustainable yield cut' policy, i.e., biomass extraction always equalling to the regenerative capacity of the mangrove forest, will be within the range ES* and ES**.

ECONOMIC EFFICIENCY

Regarding the economic efficiency of various mangrove uses, first, it is essential to recognise the following facts having significant implication : (a) The economic efficiency of a given use differs depending upon the time horizon or planning period. Some uses appearing to be efficient in the short-run may not be efficient at all in the long-run. Therefore, we need to be sure about the planning horizon for the economic analysis. (b) The economic efficiency is affected by changes in relative prices, general economic conditions, etc., (c) There are a number of uncertainties and irreversibility requiring our careful consideration; (d) The efficiency of uses differs depending on whether we consider it from the individual or social point of view; and (c) Since economic efficiency is evaluated based on the current market conditions which are inherently incapable of adequately reflecting the preferences and options of the generation, it can endanger the interest of the future generation.

Despite these limitations/ Problems associated with the economic efficiency analysis, we can proceed with the relief provided by the fact that since all the use are evaluated in the same price index, even though the absolute values may change the relative values or the ranking of different use can be unaffected by changing market conditions. The interest of the future generation as well as the time preference of the current generation can be accommodated period problem can be solved by considering an uniform planning period, say 20 years, for the calculation of benefit flows associated with each use.

When we evaluate the uses in terms of their economic efficiency, normally uses involving the clearance of mangrove forest like urban development or beach resort development may yield the highest economic return. On the other hand, uses like tannin collection may yield the lowest economic return. This shows that there is a fundamental conflict between long-term ecological sustainability and short-term economic efficiency. It is essential to use a common denominator to measure economic benefits so that uses can be compared in terms of their per hectare of mangrove forest or any other appropriate unit. Let BI be the per hectare economic benefit associated with the use. This benefit will be sum of discounted net benefit flows occurring over an appropriate time period. Then, to find the uses giving the minimum economic benefit per unit of mangrove forest area, we have to minimize BI across all uses. That is, benefit per unit of mangrove forest area, we have to minimize BI across all uses. That is,

$$E^{*} = \min(BI) \text{ where } \quad i = 1, 2 \ldots \tag{3}$$

Similarly, to find the use giving the maximum economic benefit, we need to maximise BI across all uses. That is,

$$EE^{**} = \max(Bi) \text{ where } \quad Ii = 1, 2, \ldots n. \tag{4}$$

Now the range defined by EE* and EE** serves as a scale to measure the economic efficiency associated with various mangroves uses.

SOCIAL EQUITY

In order to evaluate the social equity implications of various mangrove uses, we need to identify the number of persons and their economic and social status, involved in each use. The equity properties of various uses differ as some uses allow wider access to the mangrove ecosystem than other uses. For instance, capture fisheries allow many artisanal fishermen to get direct benefits from the mangrove ecosystem. On the other hand, culture fishery permits only a handful to few and often relatively well to do fishermen or businessmen. Also, there are both direct and indirect beneficiaries. For example while fuelwood collection for home consumption benefits directly the wood collectors, beach development benefits both the developers as well as the tourists. Moreover, beach development also generates some kind of skilled employment opportunities for the youth in neighbouring villages which is very significant from the livelihood security point of view. Similarly, tourism contributes not only the much-needed foreign exchange but also promotes some commercial and business activities that can generate some indirect benefits to the villagers.

Equity is two dimensional concept having both intra- and inter-generation dimensions. The intra-generational equity is as important as the inter-generational equity (Swaminathan, 1989). The issue of inter-generational aspect of equity can be diffused, to a greater extent, in view of the ecological sustainability and intra-generational equity. However, the intra-generational equity should explicitly be included in the SLSI. The major issue here is how to threat the direct equity effects vis-a-vis indirect equity effects such as those emerging form employment creation. One approach will be to take the proportion of direct beneficiaries to indirect beneficiaries. For instance, beach development benefits the investors and tourists more than the village community as indicated by the share of economic benefits, both direct and indirect. Another approach is to consider all the beneficiaries — developers and rural youth, and then use a shifting mechanism by considering a particular income level as a cut-off point? Under this approach, issue is considered more equitable if it benefits large number of person belonging to the poor section of the society.

In this case, the proportion of beneficiaries belonging to the poor section of the society, i.e., those with income below the cut-off-level to the total number of beneficiaries can be a good indicator of intra-generational equity. Let Ni be the proportion of poor beneficiaries to the total beneficiaries associated with the ith use. Then, the least equitable use can be identified by minimising Ni across all uses. That is

$$EQ^{*} = \min(Ni) \text{ where } i = 1, 2, \ldots n \tag{5}$$

Similarly, the most equitable use can be identified by maximising N1 across all uses. That is :

$$EQ^{**} = \max(Ni) \text{ where } i = 1, 2, \ldots n. \tag{6}$$

Now the range defined by EQ* and EQ** serves as a scale for evaluating the equity aspect of each man grove use.

CALCULATION OF THE INDICES FOR THE THREE COMPONENTS OF THE SLSI

Having defined the respective scales for the measurement of the ecological sustainability, economic efficiency, and social equity, let us now specify how each use is faring in these scales. For that let ESi be the ecological sustainability, EEi be the economic efficiency, and EQi be the social equity associated with the i[th] use : We note that these numbers are not comparable in view of the difference in the units of measurement to make them comparable across uses, we need to express these magnitudes on a common measurement unit, i.e., in percentages. Let ESIi, EEIi, and EQIi be the index measuring respectively the ecological sustainability, economic efficiency, and social equity. Now, the indices can be defined as follows:

$$ES_i = 100 - \frac{ES_i}{ES^{**} - ES^{*}} \times 100 \qquad \text{where } i = 1, 2, \ldots, n. \tag{7}$$

$$ES_i = 100 - \frac{EE_i}{EE^{**} - EE^{*}} \times 100 \qquad \text{where } i = 1, 2, \ldots, n. \tag{8}$$

$$EQ_i = 100 - \frac{EQ_i}{EQ^{**} - EQ^{*}} \times 100 \qquad \text{where } i = 1, 2, \ldots, n. \tag{9}$$

Given these indices, the SLSI which is the composite of these three indices scan be easily calculated.

DERIVATION OF THE SLSI

Let SLSI, be the SLSI associated with the i[th] use. This can be calculated form the indices ESLI, EEli and EQli as follows :

$$SLSI = \frac{ESI_i + EEI_i + EQI_i}{3} \text{ where } i = 1, 2, \ldots n \tag{10}$$

Note that in equation (10), the $SLSI_i$ is calculated as an arithmetic average of ESI_i, EEI_i and EQI_i. The averaging technique has profound theoretical and ethical implications as it implies equal weights to all the three inter-related components of sustainable livelihood security. Thus SLSI developed here not only integrate but also balance the three conflicting components, i.e., ecological sustainability, economic efficiency, and social equity. In this sense SLSI finds a middle ground and fosters the quality of life within the capacity of the ecological and life supporting systems.

So far, we have defined only the SLSI of each particular use. Now, what about the SLSI of the whole mangrove ecosystem? The overall SLSI can be found as the average of the SLSI associated with all in n uses :

$$\mathrm{SLSI} = \frac{\sum_{i=1} \mathrm{SLSI}_i}{n} \text{ where } i = 1, 2 \ldots n. \tag{11}$$

The overall SLSI obtained in equation [11] will be of use when a planning agency is interested in the evaluation of the relative sustainability of different mangrove ecosystems located in different parts of the party.

ROBUSTNESS OF SLSI AS A POLICY TOOL

The SLSI can be used as a powerful policy tool. It is robust enough to be applicable to single resource system, or multiple resource system in a given region or even to evaluate independent projects. In the case of a single resource system, the sustainable management policy requires the identification of a set of indices that ensures the SLSI. Such a use pattern can be identified easily by using the SLSI concept. First, the SLSI of various possible uses of the resources system is calculated using the procedure noted earlier. Then, a cut-off point in the SLSI is determined based on the learned judgement of experts as well as the prevailing ecological health of the resource system. For example, if the cut-off is 50 percent, all activities having the SLSI of below 50 percent will be permitted by suitable policies and programmes. But, those activities with an SLSI of more than 50 percent will be well within the assimilative of regenerative capacity of the ecosystem. It can be noted that the determination of the cut-off point involves certain moral and ethical considerations. Moreover, the cut-off point will be closer to 100 when the resource is already degraded seriously but will tend towards 0 if the resource system is ecological healthy and sound. Thus, there is a direct relationship between the cut-off point and the current ecological health of the resource system.

The SLSI can also capture the impact of alternative options and policy interventions aimed to relieve the pressure on the ecosystem. For example, the creation of agro-forestry or social forestry near the mangrove forest area or even eliminate exploitative uses like the cutting of mangrove trees to meet the fuelwood and building material need. Likewise, programmes aiming to avoid soil and water pollution involving the integrated pest management, bio-fertilizers, and bio-pesticides and regulatory policies attempting to limit the exploitative uses within a reasonable limit will have favourable impact on the sustainability of the resources system. Similar will be the effect of a policy declaration of mangrove forest as a biosphere reserve or national park. The impact of these programmes and policies will get reflected in the SLSI either in the form of reduced scale of a given use or with their elimination.

Regarding the generalization of the approach for the evaluation of SLSI in the context of a region/ecosystem, the following steps can be suggested.

Step 1 : List of identify all kinds of uses for a given resource or ecosystem.

Step 2 : Identify the uses that establish respectively the lower and upper bounds for ecological impact, economic benefits, and social equity,

Step 3 : Given these scales, evaluate for each use its ESI, EEI, and EQI.

Step 4 : Find the arithmetic of appropriately weighted mean of these indices and find the SLSI for each use,

Step 5 : Given the preference and requirements of the society, decide on the cut-off point for SLSI, identify the set of uses that are ecologically sustainable, economically efficient and socially equitable, and design policy interventions to promote sustainable uses.

What about the calculation of SLSI in a regional context, say, a village? In these case, all the major natural and ecological resources pertaining to that region like soil, water, air, genetic and plant resources, human resources, etc. are to be identified. Then, each for resource, repeat steps 1 to 5 outlined above and identify the resource specific. Given these resource specific SLSIs find the aggregate SLSI for all uses of a given resource as noted in equation (11). Then, to calculate the SLSI of the region find either simple or weighted arithmetic or weighted mean of all resource-specific composite SLSIs. The weight here can be assigned in proportion to the supply position or scarcity of different resources. If we have regional SLSI for two or more villages or regions, we can rank them in terms of their sustainability and identify the region(s) requiring special programmes for improving the livelihoods, of communities.

CONCLUSION

The simple index developed here can be powerful instrument to measure as well as monitor any policy-induced changes in the sustainable livelihood security both in the context of a single resource system or the resource systems pertaining to a given region. Although the cut-off point used to delineate the set of uses/practices so as to ensure sustainability appears to be arbitrary, its social and economic basis can be strengthened by deciding it on the basis of broad consensus of different partisan groups like economists, environments, and equalitarians.

The most practical and policy significance of the SLSI is that it identifies the set of programmes/activities that are desirable and those which have to be regulated or even eliminated. The major limitation of the index is that since it has been developed on the relative basis, its use can be greatly circumscribed in cases where there are few uses or activities. There is therefore, an urgent need to develop an SLSI based on an absolute approach.

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FOREST TREE IMPROVEMENT IN THE TROPICS : CHALLENGES AND PROSPECTS

C.S. VENKATESH

INTRODUCTION

Deriving from the Latin word "foris", forest refers to a large piece of land covered with trees. Botanically speaking, it is a kind of vegetation in which tree species are the dominant components. In eco-geographical terms, several kinds of forests are recognisable. Examples are :

1. Temperature evergreen coniferous forests (Pines, Spruce, Fir, etc.);
2. Temperate broad-leaved forests (Oaks, Maples, Poplars, Hickory, etc.);
3. Tropical evergreen rain-forests (innumerable tropical species; richest in floristic wealth and biodiversity);
4. Tropical scrub forests (consisting of short or stunted trees and a variety of shrubs);
5. Tidal forests; and
6. Mangrove forests.

From the viewpoint of their origin, two kinds of forests are recognisable, viz., natural forests and man-made forests. Natural forests untouched by man, viz., virgin forests, are almost non-existent today. Natural forests, wherever they occur in remain, are a very valuable biological resource. If not seriously disturbed they are capable of regenerating themselves indefinitely. Man-made forests (forest plantations) are essentially monocultures of single tree species such as Teak, Pine or Eucalyptus established for lumber, pulpwood and other end uses.

By forestry we mean the entire gamut of forest-related activities such as raising, tending, logging, and replanting; and managing forest refers to tending of forests. It bears the same relation to forestry as agronomy does to agriculture. Agroforestry or agri-silviculture refers to raising of agricultural crops and trees together. Deforestation means cutting, clearing or burning down of forests. Reforestation refers to replanting of felled forests. Afforestation is the raising of forests on land not earlier covered with forests, such as for wasteland reclamation.

BENEFITS FROM FORESTS TO MANKIND

Production, protection and recreation are the three principal functions of forests. They check soil erosion, preserve and protect watersheds, regulate flow of water preventing flooding, moderate climate, influence rainfall, serve as a sink for carbon dioxide (one of the gases causing greenhouse effect and global warming) and are useful for wasteland reclamation. Wood is the major forest produce in the form of lumber, pulpwood and firewood (especially important in rural areas of Third World countries; for example, in Africa 90% wood harvested from forests in consumed for fuel, only 10% as timber). Besides wood, forests also yield a variety of minor forest products such as oleoresin, gums, drugs, oils and other silvichemicals. Recreational uses of forests are for picnicking, wildlife watching, hunting (regulated) and fishing.

NATURAL VARIABILITY WITHIN FOREST TREE SPECIES

Since they are essentially wild populations never subjected till recently to either unconscious or conscious selection by man, unlike domesticated crop plants, a good deal of natural variability prevails in forest species populations. Further, although many of them have bisexual flowers or are monoecious (with male and female flowers borne on the same individual tree) still out-crossing in nature is the rule in several of them. For example, Pines which are typically wind-pollinated are out breeders, selfing leading to inbreeding depression (*Pinus resinosa* in Canada is the sole exception, where selfing does not lead to such depression). In *Leucaena leucocephala*, only the tetraploid race is self-fertile; the diploid race and the remaining species are self-incompatible. *Inter-specific* hybridisation among trees is an additional source of variation. Among eucalypts, for instance, species belonging to the same section can intercross. In their native Australia such species are geographically isolated. Where however there is slight overlap in distribution, natural hybrids result. When such species are planted close together as exotics overseas, geographical barriers to interbreeding get removed and hybrids result. I have synthesised artificial inter-specific eucalypt hybrids :

a. *Eucalyptus tereticornis* x *C. camaldulensis* (FRI–4)
b. *Eucalyptus camaldulensis* x *E. tereticornis* (FRI–5)
c. (*E. camaldulensis* x *E. tereticornis*) x *E. grandis*—a trispecific hybrid
d. An example of an inter-generic hybrid among trees is :
   Monterey Cypress (*Cupressus macrocarpa* Hartw.)
   Nootka Cypress (*Chamaecyparis nootkatensis*, Spach)
e. *Cupressocyparis leylandii* Dallim.

This hybrid arose naturally. Propagated by cuttings, it is extensively used as windbreak, hedgrow or ornamental tree. F1 hybrids of eucalypts are very fertile and produce seed sometimes in larger quantities than the parental species. Natural hybridisation is a potent force in the origin of new species. It enables natural introgression of genes from one species into another. One may recall here the fact that hexaploid breed wheat of today originated by natural hybridisation of *Aegilops, Agropyron,* and *Triticum.* Wheat X Rye hybrid, Triticale (Triticosecale) is an artificial hybrid.

DIFFICULTIES IN FOREST TREE IMPROVEMENT

Forest trees are difficult genetic and breeding material :

1. Slow turnover of generations (in annual crop species the plants come to flower within a season of sowing, but in trees there is an intervening juvenile phase of a few to several years before first flowering begins).
2. Grain crops can be harvested and resown within a year; forest trees take anywhere from 5 to a hundred years to reach commercial maturity and harvest age for wood or timber in optimum quantities.

Further, forest trees are stem crops, not fruit or nut yielding trees like Mango or Coconut, which once they reach bearing age keep on yielding year after year without replanting. Rubber tree starts yielding later, 7 years after budding, and continues yielding daily till 30 years. A timber tree can be harvested, but once after a wait of 20–50 or even 100 years.

It usually takes about 7 years to develop, test and release a new crop variety. How much longer will it take to do so with a timber tree? May be 25 years at least.

An eucalypt breeder can realise full fruits of his breeding research within 10 years of starting it. Not so the Teak breeder. He will never be able to do so in his lifetime. This is because eucalypts come to life early in life and grow in short rotations of 7–10 years for pulpwood production because of their fast growth rate.

There is also the problem of great height to which forest trees grow. Because of this, there is difficulty in : (a) harvesting seeds; (b) collection of scion wood for grafting and budding; and (c) carrying out controlled pollination.

Trained monkeys have been deployed for collection of herbarium specimens from the canopies of the tallest trees of tropical rain-forests, and also for plucking coconuts from the palms. To except them to carry out controlled pollinations also will be too much. Tree-climbing ladders and tree bicycles are aids used for seed harvesting and collection of scion wood and also for carrying out controlled pollinations sometimes. Grafting and obtaining flowering and fruiting at low heights is the alternative, most often used for these purposes.

AIMS OF FOREST TREE IMPROVEMENT

Forest trees are stem crops. The principal components are height and diameter of stem because together these determine the volume of wood or timber extractable from a tree. In forestry therefore the choice is clearly for the tall, straight, fast-growing giants and not for dwarf, semi-dwarf varieties (bred of crop plants like wheat for high grain yield). Artificially dwarfed trees (by grafting) are for special use, only for seed production in seed orchards and for carrying out controlled pollinations at safe heights. Miniature bonsai trees serve a purely aesthetic purpose in drawing rooms, but have no place in commercial forestry.

Tree improvement in forestry aims at : (a) Enhancement of growth rate; (b) Producing trees with straighter stems, wider branch angles and smaller branch size and narrower crowns; (c) Improving intrinsic wood properties such as density, fibre length, fibre morphology, grain, figure and cellulose content; (d) Development of inherent resistance to specific pests/diseases.

In short, a good timber tree should show : (a) strong apical dominance; (b) straight, thick, cylindrical stems without forks, flutes and buttresses and with a minimum of taper. In the species so far studied, stem straightness and the tendency to fork or crook have been shown to be highly heritable. They are therefore amenable to improvement by selective breeding.

METHODS OF FOREST TREE IMPROVEMENT

The conventional methods of selection and hybridisation so successfully used in agricultural crop improvement are equally applicable to forest tree improvement also. The modern methods of mutation breeding and polyploidy breeding have only limited applications in forest tree improvement. Biotechnology and molecular genetic techniques have promising potential for forest tree improvement in the future.

As forest tree populations still retain high degrees of natural variability, simple mass selection has proved to be quite effective in giving noticeable improvement. In this method, which is the standard procedure in all general forest tree improvement programmes, natural and more often man-made forests of the species in question are surveyed and individual outstanding trees sorted and designated as plus trees. Multiple phenotypic traits are used for such selection. While doing this, the forest tree breeder is quite aware that as the number of traits sought to be improved increases, the improvement gain per trait will correspondingly diminish. Inverse genetic correlations between different traits selected could further complicated this problem. One would expect these problems to be even more complex in assessing plus phenotypes of multipurpose trees because, by definition, they are planted for multiple benefits derived from their different parts : stems, exudates, bark, leaves, flower, fruit or seed. A simpler practical solution in such cases is to select for improvement only one or two traits at a time.

METHODS EMPLOYED IN FOREST TREE IMPROVEMENT

Forest tree improvement by selection and breeding consists of the following two steps :

1. Phenotypic selection of 'plus trees'; and
2. Establishment of the selected plus trees in seed orchards for the commercial production of improved seed.

The seed orchard method is today the standard procedure adopted in most forest tree improvement programmes throughout the World. Essentially, it consists of selecting superior phenotypes of the species intended to be improved in natural stands, provenance plots and plantations and marshalling these, usually in t he form of grafted clones, into polycross orchard layouts to produce, through open pollination, commercial quantities of improved seed for raising future high-yield plantations. Since, with few exceptions, forest trees are by and large widely variable, undomesticated wild species that have never been subjected to either conscious or unconscious selection, such a simple, unsophisticated way of mass selection has proved to be quite effective in bringing about perceptible genetic improvements even from the very first round of selection.

Usually multiple traits are used in evaluating the selecting plus tree for establishing in the first cycle seed orchards. The whole tree is evaluated using a total score or selection index. Tandem method of selecting for one trait at a time is used only in certain special circumstances, e.g., breeding for disease resistance, oleoresin yield, bole straightness in habitually crooked species. With a view to saving time and in expectation of simultaneous improvements of a complex of several years, if not decades. Further, such first seed orchards should be based on many parents selected at low intensity early in the rotation. Selection should be continuous and increasingly rigorous as plantation area, experience and staff efficiency increase. Although in using multiple traits the selection differential obtainable per individual trait is reduced, the cumulative effect of increase in growth per tree, survival quality of stem and crown, and in some cases resistance to disease or pests, may greatly add to the total growth and yield per hectare of forest.

The second step is the establishment of the selected plus tree material as grafts, cuttings if feasible or sometimes as seedlings in polycross layouts, the seed orchards, where the assembled clones naturally out-cross by wind (in conifers), insects and sometimes birds to produce improved seed. Plus tree material is concurrently also established in clone banks or clone arc hives for preservation of the genotype of the plus trees and forestall their accidental loss by lightning, fire or inadvertent felling. To reduce selfing and encourage panmixy among the assembled clones, the ramets in a seed orchard (not in clone banks and clone archives) are planted in a fully randomised manner. Nowadays, computer-generated designs effectively ensure this. Seed orchards and clone banks facilitate controlled breeding work.

INTER-SPECIFIC HYBRIDISATION

Hybridisation within and between specifics offers one or more of the following possibilities:

a. it is a way of combining the desirable character of different parents, varieties, provenances or species,
b. it may result in hybrid vigour,
c. it offers a means of donating genes for resistance to specific diseases, pests and adverse environmental factors such as drought, swampiness, frost, salinity, etc.,
d. it is a way of increasing variation in populations for subsequent selection in advanced generation (F_2 and later).

Crossability barriers are obstacles to wide hybridisation. But as well shall see later, biotechnology can be helpful in bypassing such barriers.

Pitch pine (*Pinus rigida*) x Loblolly pine (*P. taeda*) artificial hybrid (*P. rigitaeda*), combining in itself the frost hardiness of the former with the greater vigour and better stem form of the latter, has been mass-produced and planted in South Korea. The Euramerican hybrid poplar involving the tetraploid *Populus tremula* and the diploid *P. tremuloides*, happily combines in itself the benefits of both hybridity and polyploidy. It shows hybrid vigour producing 36% more wood than the diploid, its wood fibres are 30% longer, and its heartwood is free from tyloses which improves penetrability for chemical pulping. The triploid hybrid poplar is relatively more resistant to the attack of *Valsa*, a fungus. The European parent and in addition shows hybrid vigour. Of the several *inter-specific* hybrids produced by me at Dehra Dun, Fls of the two crosses FRI–4 (*E. tereticornis*) x *E. camaldulensis*) and FRI–5 (*E. camaldulensis* x *E. tereticornis*) displayed pronounced degree of hybrid vigour even at an early age of 4 years when they were 30% superior in height growth and 80% in diameter growth compared to the parental controls. Such growth superiority was not only maintained but even increased with age, up to 10 years. Further, hybrid vigour (heterosis) was also expressed in earliness to flower, number of flowers, and fruits and seeds produced. The seeds showed higher germinative energy than the mid parent. Slash pine (*Pinus elliottii*) x Caribbean pine (*P. caribaea*) hybrids produced in Queensland, Australia, are promising because they are superior to either parents in economy yield and besides are more tolerant of waterlogging than the Caribbean parent. West Indian Mahogany (*Swietenia mahogoni*) x Honduras Mahogany (*Swietenia macrophylla*) combines the drought resistance and wood quality of the former with the faster growth rate of the latter. By *inter-specific* hybridisation it has been possible to incorporate blister rust resistance into the White pines (*P. strobus, P. lambertiana, P. monticola*, etc.) of N. America from out Himalayan blue or kail pine (*P. wallichiana*) and the Japanse (*P. parviflora*) and Balkan (*P. peuce*) white pines. Armand's pine (*P. armandii*) of China is another possible source of blister rust resistance. In N. America, Jeffrey x Coulter (*P. jeffreyi* x *P. coulteri*) x *P. jeffreyi* backcross hybrids are known to display a degree of resistance to weevil attack.

GAINS FROM TREE BREEDING

Expected benefits from using orchard seed include:

a. rotation age reduction;
b. timber volume gain;
c. timber quality gain; and
d. crop security in the form of disease and pest resistance.

In the Southern Pine improvement programme in the U.S.A., it is estimated that only 2–5% yield improvement at harvest age is sufficient for economic justification. Actually in most tree improvement programmes, gain in yield of merchantable timber is even more, viz., 5–10% even from the first cycle of selection. The seed orchard method has brought down the rotation age of Slash pine (*P. elliotti*) from 40 to 25 years in the U.S.A. In the same pine in Australia, 25% increase in volume production at age 14 years has been obtainable. The gain in loblolly pine (*P. taeda*) in U.S.A has been 18%. In Radiata pine (*P. radiata*) in New Zealand a 12% increase in volume has been reported. In Finland a 40% gain in height and more than that in volume has been attained in Birch (Betula verrucosa). In the Caribbean pine (*P. caribaea*) by selection the percentage of reasonable straight stems has been lifted from 20% to 70%, a gain of 50%. In Douglas fir (*Pseudotsuga douglasii*) after 50 years (1912–1960) the best families had outproduced the poorest by two or even three times in timber volume. Progeny tested or elite seed orchards can give 35–45% additional gain. In Finland, birch cultivars developed from advanced generation seed orchards are expected to yield 100% more timber, the oleoresin yield of Slash pine has been more than doubled in Florida, U.S.A, by only one generation of selective breeding.

ROLE OF CLONE IN FORESTRY

Asexual, vegetative or clonal propagation has a special role in forest genetic research and tree improvement. It has the following advantages over sexual propagation by seed:

a. it enables production and use of genetically identical plants, experimentally for site testing trails and for determining genotype x environment interactions accurately;
b. Operationally it enables raising of very uniform, high-yielding plantations resistant to specific diseases, pests or adverse environmental conditions. For commercial purposes clonal mixtures or mosaics, rather than single clones, are recommended as security against unexpected epidemics or environmental changes.

The clonal option has recently been used to achieve a breakthrough in Eucalyptus wood production in Aracruz Forests in Brazil. Plus trees are selected and simply mass-clones by rooting coppice shoot cutting using commercial hormone and mist. The improved trees grew 20 m tall only 3 years after field planting of the cuttings. Pulpwood yield in 7-year rotations increased from 23–28 m^3/ha/yr to 70–83 m^3/ha/yr. Wood density increased by 25% and cellulose yield 135%.

A limitation of purely clonal selection and multiplication is that it is a 'dead end' method and no changes or further improvements are possible without resorting to sexual breeding. A judicious combination of both sexual and asexual methods therefore is ideal for maintaining genetic diversity and at the same time obtaining rapid genetic improvement.

CONSERVATION OF FOREST GENETIC RESOURCES

In situ conservation is always preferable to *ex situ* conservation because it implies conservation of an entire ecosystem and with it the natural gene pools of its constituent species. In forest trees, clone archives/clone banks offer a good way of *ex situ* collection and preservation of germplasm. There is one advantage in the preservation of forest genetic resources *ex situ*. Being perennials with a long life-span, forest trees can be preserved for very long periods of time unlike agricultural crop varieties which have to be 'rotated' by seed every year to keep them as live plants.

POLLEN/SEED STORAGE, TISSUE CULTURES

Seed storage of mangrove species poses unusual challenges since there is no dormancy at all and the germination occurs within the fruit while the latter is still attached to the parent plant. Germination inhibitors may have to be applied first before cryopreservation can be thought of.

Preserve them as bonsai (suggestion by Antonio from Colombia). Space-saving like tissue culture may be easier to manage, but for multiplication when required tissue culture micropropagation may perforce have to be resorted to because bonsais, inspite of flowering, may not produce a large number of flowers of fruits.

MANGROVE SPECIES CONSERVATION AND IMPROVEMENT

Chromosome numbers in mangrove species range from n = 9 to 32 + 1 in *Avicennia alba, Ceriops tagal* n = 18, *Sonneratia* spp. n = 9 (*S. apetala*), n = 11 in *S. alba, S. caseolaris* and *S. ovata.*

Those species which have bisexual flowers are protogynous or protandrous. However, the occurrence of putative natural hybrids in *Rhizophora, Lumnitzera* and *Sonneratia* are probably outcrossers. Elegant isozyme techniques can be used to estimate the amount of natural selfing outcrossing in different mangrove species. What would be the breeding objectives would depend upon their role in protecting the coastline from eroding or the different end uses for which they are put to. Sundri is the most important firewood in the Sunderbans. Can we selectively breed it for (a) yielding more firewood per tree, which would mean improving growth rate for wood biomass production; and (b) improving caloric value/reduce ash content of sundri firewood?

Could *Rhizophoras* be made to produce longer stilt roots with which they have greater scope for growing lower down in the tidal zone and perhaps colonise deeper waters of the ocean to reclaim more land?

Clone banks/clone archives of *Rhizophora* and other woody species by grafting on to rootstocks of non-mangrove species for *ex situ* conservation.

Methods, classical and modern, used for other forest trees will be applicable to mangroves too for the latter's improvement in future.

JOINT FOREST MANAGEMENT INITIATIVES FOR MAINTAINING BIODIVERSITY

A.V.R.G. KRISHNA MURTHY

INTRODUCTION

Forest Management in India which is more than 150 years old, looked in colonial regime as a custodian-approach with policing and patrolling as main duties of regulatory nature to keep out the people, whose lives depended and sustained on the forests. Forests even though are not truly considered as common property resources, required determination of nature and extent of free access of people on them by regulating use of the available resources. An interface of local communities and state Forest Departments is limited by way of technical inputs and participatory role without any involvement of people and facilitating role of local voluntary organisation, communities, women, NGOs and local democratic institutions. The Forest Management in the past has forgotten the rural poor, especially the tribal and the nature of their dependence on forests for their economy, survival, sustenance, health and prosperity. Over exploitation and deforestation, estimated at an annual rate of 1.3 million ha during 1970–80 period and 4.2 million ha since 1950, caused a stress both on people and nation, adversely affecting their health, economy and prosperity, biological diversity and genetic complexity of plant and animal species characteristic of tropical forests.

The recent Government of India Policy guide lines of 1st June, 1990 on community participation, involvement of local people in protection, regeneration and management of forests, and discontinuing the Tree-Patta schemes aimed at privatisation of forests instead of communalisation is a landmark decision. The need to analyse, review and redraft the priorities in forest management policies is not only emphasised but also the importance of restoring the productivity and sustainability of forests is well recognised. The need to protect reserve/protected forests and lands meant for posterity is in ruins and the solution for restoration and sustainability of resources is recognised to lie in efforts involving community participation to manage, protect and regenerate these resources. Hence is the evolution of Joint Forest Management initiatives.

Due to innovative and willing cooperation of several State Forest Departments and local communities particularly in States like West Bengal, Bihar, Orissa Rajasthan, Gujarat, Haryana, U.P., etc., there is a growing body of experience which can adequately demonstrate that forests can be effectively protected through cooperative action taken by forest-staff and rural communities. India is evolving forest management policies which have been at the centre of an ongoing debate on the environment. Differences in perceptions regarding the goals in forest management often have frustrated attempts to achieve a consensus regarding policies and strategies.

Any forest policy should give priority to improving the livelihood and security of the people, and tribal communities, preserving biological diversity, protecting rivers and watersheds or enhancing economic and industrial growth and ensuring ecological security.

Conservation of Mangrove Forest Genetic Resources : A Training Manual
Edited by Sanjay V. Deshmukh and V. Balaji.

PARTICIPATORY JOINT FOREST MANAGEMENT

During the colonial regime, all the forest areas were in fact, communal lands with unrestricted access to villagers for fuelwood, fodder and non-wood products (NWP). Even after several large chucks of forest areas were left out of Reservation as buffers between village and interior forests to serve the communal purposes of fuelwood, minor forest produce fodder and other non-wood products, collection, grazing of village cattle and as free-access and lung space for community purposes. These buffer forests are generally classified as forest-poramboaks, unreserves and Bancharai areas. With the increase in population pressures both human and cattle, and to a variety of other reasons like land use and assignment policies, these buffers have disappeared and even reserved and protected forests are depleted, degraded and their productivity greatly reduced.

A recent trend that survey and satellite imageries clearly show, nearly 40 million ha of India's Forests are highly degraded and depleted of productivity and this trend is on the increase, resulting in loss in extent and density of forest cover. Most of these degraded forests are nearer to villages and habitations, where the pressure for both wood and non-wood products, fodder, fuelwood and grazing is maximum.

Combining this historical fact of community ownership of forests at one point of time with the open access to villagers and currently prevailing rights to obtain fuelwood, fodder and non-wood products from forests, a case was developed recently for greater right to forest produce to local people, through the JFM initiatives. From this initiative it was a short step to project the need for people to participate in the management of forests, jointly with the Government agency. In operational terms, the JFM involves people as beneficiaries to get together and organise themselves into a user group. The group and the forestry departments jointly conduct a participatory resource appraisal and prepare a resource harvesting scheme. It has to have sustainability, productivity and equitable shares to the users int he group in return for discharging individual and collective responsibility, i.e., to observe and enforce restraint to meet these two goals. By JFM initiatives, the people obtain technically professional guidance on maintaining sustainability and also know about Government's intervention when there is a misunderstanding between the user availing his privilege i.e., harvesting the resource and the user discharging his responsibility, i.e., observe and enforce restraint. The JFM concept visualises motivation of the local community to identify itself with the development and protection of forests from which they derive benefits.

The Joint Forest Management efforts are mainly confined to degraded forests in the vicinity of villages, mainly depending on natural regeneration methods like coppice-growth cutting and helping establishment of advance-growth and naturally regenerated pole crop, supported by supplemental planting, gap planting and enrichment planting. Only degraded natural forests with species diversity and miscellaneous species can be considered for such initiatives. Monocultures and intensive plantations of species like *Eucalyptus* are excluded from Joint Forest Management efforts. Multishoot cutting and singling out coppice for more vigorous growth even in valuable species like Teak, Sal, Rosewood etc. can be successfully brought under JFM. Thus JFM initiatives not only emphasize the need to concentrate on natural regeneration method compatible with environment and affording soil cover and protection but also emphasizes the need to maintain existing biological diversity and species complexity of existing natural forests, coupled with intensive soil and moisture conservation measures, catchment treatment and watershed-protection.

Table 1 Community forest management systems+

State	Type of forest Managed	Name of Protection Group	Total Number of Groups	Status of Organisation	Membership
West Bengal	Reserve and Protected (200,000 ha)	Forest Protection Commiittees (FPCs)	1,684	Certified by West Bengal Forest Dept.	Head of every household
Haryana*	Reserve and Protected (15,000 ha)	Village Forest Protection and Management Committees (VFPMC)	45	Registered Societies	Man and woman from every household
Orissa*	Reserve and Keshra Forest (74,000 ha)	Village Forest Committee/(Jungle Samiti)	1,179	Informal Groups	All village households
Himachal Pradesh	Panchayat Community, and demarcated Forests	Village Development committees/Mahila Mandals	2,000	Unregistered	One man from every household
Gujarat**	Reserve and Protected (10,000 ha)	Forest Protection Committees	200	Recognized by Gujarat Forest Department	All households willing to participate
Uttar Pradesh	Panchayat Forests (220,000 ha)	Van O Panchayat	4,058	Recognised by State Government	All household with ten years of residence
Jammu & Kashmir	Demarcated Forest (5,435 ha)	Village Forest Committees	101	Organised by the Forest Department	All village households
Tamil Nadu	Reserve (5550 ha) ad Revenue	Interface Forestry Project	100	Poor households	Scheduled Caste, tribal, and land

+ Other states in India may have also established Community Forest Management Programs, however no data on these was available at the time this paper was prepared. * Enabling Government Resolution Passed ** Enabling Government Resolution Pending

Table 2 Protection systems: responsibilities and rights

Responsibilities	Protection System	Rights	Important Minor Forest Products
Protection, silvicultural maintenance, micro-planning	–Volunteer patrols (2–10 men) or watcher paid by community–fines	–All MFP –25% timber –Employment	–Sal leaf plates –Tendy –Mushrooms –Sal seeds –Tasar Silk
Protection, social fencing, microplanning, production management	–Community monitoring –Social pressure	–1st auction to buy fodder and bier grass –Leases –All other MFPs	–Bhabbar rope –Bamboo baskets –Fodder grass
Protection, grass distribution, dispute resolution, free labour	–Stick rotation (Thanga Palli) –Fine, seasonal & spatial restrictions –social pressure	–Small timber –Firewood –Leaves –Tendy –Sal seeds	–Sal leaf plates –Fruit
Protection from cutting and grazing, Identify labour for silvicultural work	–Paid watcher –Fines –social pressure	–All MFP –75% Timber	–Leaves for compost –Mushrooms –Medicines
Protection against unauthorised use and encroachment, regulate access, define rules and rights	–Village Patrol Groups –Community monitoring	–ALI MFPS –25% Timber –Employment Rs.100–300/ha for cleaning	–Mahaya flowers and fruit –Dhak leaf plates –Bamboo –Fruits –Gums
Protect against grazing and cutting	–Paid watcher –Community monitoring –Fines	–Grass, dry leaves, twigs, limited timber –Grazing where permitted by Govt.	–Pine resin –Fodder –Medicinal
Participation in micro-planning, forest protection	–Local (paid) watcher –Project, supervised by UCF	–Fodder grass cutting –Fuelwood collection	–Fodder grass –Fuelwood
	–Elimination of Goat population through sale	–Fuel, fodder roof thatch, fruit and other MFP	–Green leaf manure –Fodder –Basket fibers

The benefits and returns from JFM policies, if implemented, will be immense and would include (a) rapid increase in biomass enhancing supplies of fuelwood and fodder, (b) improved vegetation ground cover with improved soil and water conservation, (c) additional employment opportunities for rural people, especially landless and women in forest management, harvesting, processing and marketing, (d) increased income through higher forest-productivity and enhanced marketing and processing systems for minor forest products (MFPs) or other non-wood products, (e) reduced conflicts between foresters and rural communities, and (f) improved capacity and management skills for community resource management.

The new participatory management systems being developed by some of the State forest departments and forest communities point towards a new and promising direction in forest management, not just for India, but rest of the World as well, particularly in South-east Asia, Pacific, African and Latin-American countries. The approach offers hope that natural forests will survive and produce long-term benefits for our children and future generations. In India, Uttar Pradesh (3 lakh ha), West Bengal (2 lakh ha), Orissa (70,000 ha), Haryana (25,000 ha) and Gujarat (15,000 ha) have started practicing Joint Forest Management and participatory community involvement skills.

JFM RELEVANCE TO MANGROVES

In the context of evolving strategies for conservation of Mangrove Genetic Resources, implementation of Joint Forest Management initiatives is not only relevant but also very essential. This most fragile and threatened ecosystem is disappearing at a rapid rate and is on threshold of total extinction. The pressures on mangroves, are three-fold: (a) Pressure of local population for firewood (mangrove species have high calorific value as fuelwood compared to natural forests, mixed hardwoods or Eucalyptus), (b) Land-use policies and reclamation of mud-flats near estuaries for cultivation and salt production and (c) Ecological changes in the forest due to submergence and rise in levels of mud-flats.

Since Mangroves are threatened seriously due to human interference from the above activities, it is possible that a sustainable use and conservation of this important resource can be achieved by involving the people in protection, management and regeneration of Mangrove Resources on a sustainable basis, at the same time maintaining the prevailing biological diversity and species complexity of the mangrove for posterity.

DISCUSSION

People's participatory approach for forest conservation, management, regeneration and productivity increase is not to India. In the past, local people, particularly agricultural labourers were involved through Agri-silvicultural approaches to raise plantations of Teak, Sal and Cashew. The socio-economic conditions of tribals dwelling in the forests gradually improveddue to participatory efforts, involving them in soil and moisture conservation efforts, watershed protection of major river valleys, hydroelectric projects and in coffee cultivation projects over the past three decades. Use of multi-purpose species and multiple land use practices where silviculture, horticulture and sustained agriculture (after terracing and binding hill-streams to divert water for irrigation), have not only been found acceptable to tribals in India but has also contributed to attitudinal changes both in Foresters and Tribals.

It is hoped that while planning conservation measures for mangrove forest areas, the important aspect of "man and mangrove interaction" will be taken into consideration and it will be supplemented with introduction of Joint Forest Management schemes involving coastal communities.

CRITICAL ISSUES IN THE IMPLEMENTATION OF THE CONVENTION ON BIOLOGICAL DIVERSITY*

JEFFREY A. McNEELY

INTRODUCTION

The Earth's genes, species and ecosystems are the product of over 3000 million years of evolution, and are the basis for the survival of our own species. Biological diversity (or "biodiversity") – the measure of the variation in genes, species and ecosystems – is valuable because future practical values are unpredictable, because variety is inherently interesting and more attractive, and because our understanding of ecosystems is insufficient to be certain of the impact of removing any component. Genetic diversity, which provides the variability to enable species to adapt to changing conditions, is important to all species, but genetic variability in cultivated and domesticated species has become a significant socio-economic resource. Without the genetic variability which enables plant breeders to develop new varieties, global food production would be far less than it is at present, and far less able to adapt to the future environmental changes which are certain to come.

Further, biological resources – including genetic resources, organisms or parts of organisms, populations, or any other biotic component of any ecosystem with actual or potential use to humanity – are renewable, and with proper management can support human needs indefinitely. These resources, and the diversity of the systems which support them, are therefore the essential foundation of sustainable development.

The available evidence indicates that human activities are eroding biological resources and greatly reducing the planet's biodiversity. Estimating precise rates of loss, or even the current status of species is challenging, because no systematic monitoring system is in place, and much of the baseline information is lacking, especially in the species-rich tropics. Little data is available to assess which genes or species are particularly important in the functioning of ecosystems, so it is difficult to specify the extent to which people are suffering from the loss of biodiversity.

While the loss of wild species and habitats receives most public attention, the genetic variety of many cultivated species is also being lost, thereby reducing the ability of agriculture to adapt to environmental change. The remaining gene pools in crops such as rice, wheat, maize and many fruits amount to a small fraction of the genetic diversity they harboured only a few decades ago, even though the species themselves may occupy more habitat than ever before. If these trends continue, agriculture will have a far narrower genetic base, and many fewer varieties of fruits and vegetables will reach the market. The available varieties will be less well-adapted to local conditions, requiring larger investments in pesticides and fertilisers to maintain productivity.

The loss of biodiversity is due above all to economic factors, especially the low values given to biodiversity and to the ecological functions – such as watershed protection, nutrient cycling, pollution control, soil formation, photosynthesis, and evolution – upon which human welfare depends. Therefore, virtually all sectors of human society have an interest in the conservation of biodiversity and the sustainable use of biological resources. However, no single sector can, by

*Reproduced from: "*Widening Perspectives on Biodiversity*". IUCN, Switzerland.

itself, ensure that biological resources are managed to provide sustainable supplies of products, rather, co-operation is required between the various sectors, ranging from research to tourism.

The environment is already heavily utilised by people, but given the projected growth in population and economic activity, the rate of loss of biodiversity is far more likely to increase than stabilise. Peter Vitousek and his colleagues at Stanford University have estimated that almost 40% of the Earth's net primary terrestrial photosynthetic productivity is now directly consumed, converted or wasted as a result of human activities. A very considerable body of work in the field of conservation biology over the past several decades has shown that reducing the area of habitat reduces not only the population of each species (and hence its genetic diversity), but also the number of species the habitat can hold. As a broad general rule, reducing the size of the habitat by 90% will reduce the number of species that can be supported in the long run by about 50%. It might be concluded that major habitat changes and associated losses of biodiversity are the inevitable price that people are willing to pay for progress as humans become an ever more dominant species, but society has cause for concern when habitats are degraded to lower productivity, especially when accompanied by species losses, which can have World-wide ramifications.

THE ROLE OF BIOTECHNOLOGY

The emergence of modern biotechnology presents an important potential for a productive link between conservation and sustainable utilisation of genetic diversity. Biotechnology can lead to new and improved methods of preservation of plant and animal genetic resources, and can accelerate the evaluation of germplasm collections for specific traits; it offers new possibilities for increasing the production of food, medicines, energy, speciality chemicals, and other raw materials, and for improving environmental management. Maintenance of a wide genetic base (one of the elements of biodiversity) is essential to the future of biotechnology and the sustainable use of biological resources. The genetic material contained in domesticated varieties of crop plants, trees and animals, their wild relatives, and other wild species which may contain genes useful to the domesticated varieties, is essential for breeding programmes which incorporate genes to improve yields, nutritional quality, flavour, pest and disease resistance, and responsiveness to different soils and climates.

The new biotechnologies may increase the value of the World's biodiversity if they allow increased use of the genetic diversity of both wild and domesticated species, thereby increasing their economic importance. But biotechnology also poses significant ecological and economic risks that could ultimately undermine its potential contribution to the conservation of biodiversity. The introduction of any new organism poses a risk to the environment, and many of the World's known extinctions have been caused primarily by the introduction of exotic species. The release of genetically engineered organisms into the environment thus deserves the most careful oversight and monitoring.

Modern biotechnology reinforces rather than diminishes the need to maintain the richest possible pool of genes. As the field of biotechnology develops further, future needs for germplasm will be far greater than is currently the case. The projected loss of biodiversity could cripple the genetic base required for the continued improvement and maintenance of currently-utilised species, and deprive pharmaceutical firms, agricultural scientists and farmers of the potential to develop new ones.

SUSTAINABLE GOALS FOR BIODIVERSITY

As the Global Biodiversity Strategy has pointed out, the desired future is one where the entire landscape is being managed to conserve biodiversity, and where biological resources are used sustainably for the benefit of current and future citizens. In fact, this is the only sustainable future for our planet; anything less than sustainable use of biological resources will lead inevitably to a decline in productivity and quality of life. Elements in this sustainable future include :

1. A well-informed public, aware of the status and trends of the ecosystems of their own country and of the rest of the World, and conscious of the impact their levels of resource consumption have on biological resources;
2. A system of legislation, economic incentives, and supporting regulations which encourage people to use biological resources sustainably and promote the conservation of biodiversity;
3. A collaborative relationship between governments, scientists, local communities, and the private sector which supports the process of conserving biodiversity;
4. A well-managed system of protected areas established in each country, including representative ecosystems and the widest possible range of a country's biodiversity; and
5. A comprehensive data base on soils, climate, topography, geology, and biodiversity to monitor status and trends of genes, species, and ecosystems, and to predict the impact of future changes.

STRATEGIC LINES OF ACTION TO CONSERVE BIODIVERSITY

Given that sustainable use of biological resources is an essential element in sustainable development, several strategic lines can be followed to bring about the goals outlined above.

Most countries have signed the Convention on Biological Diversity (hereafter the Convention). Thirty governments had ratified the convention by early October 1993, and it entered into force on 29 December 1993. But much remains to be done to actually implement the Convention, and countries should establish mechanisms to determine how the Convention can be most useful to each country, and to the World as a whole. A first step is to prepare national biodiversity strategies and action plans, as called for in Article 6. Strategic issues that must be addressed include means to regulate access to genetic resources, mechanisms for controlling import and possession of materials obtained contrary to the legislation of the originating country, mechanisms to identify the source of material from which any particular benefit is derived, funding mechanisms, intellectual property rights, and technology transfer.

Second, information, research, and data management need to be improved. Decisions for planning conservation measures, identifying priorities, and formulating management policies must be based on a careful analysis of the most complete and up-to-date factual information. Baseline information on the status and distribution of species ecosystems that can serve as a bench mark for monitoring is available only for relatively few parts of the World, indicating a significant shortage of essential information. Biodiversity needs to become a focus of research at national and regional research centres, as a partner (not an alternative) to practical action. Corporations with an interest in biodiversity, including biotechnology, pharmaceuticals, agrochemicals, and many others, should combine forces to support the basic research which is required as a foundation upon which practical, applied research can be built. Countries should collaborate on data management standards for information on biodiversity (such as standard lists of species, inventory methods, etc.), and jointly determine the most efficient way to collect the needed information on a global scale.

Third, in order to build political and public support, more attention needs to be given to the economics of conserving biodiversity and using biological resources sustainably. In addition to the well-known values of agriculture, fisheries and forestry, wild species and the genetic variation within them make contributions to agriculture, medicine and industry worth many billions of dollars per year. Nevertheless, biodiversity tends to be perceived largely in scientific and conservationist terms, rather than in economic and resource terms. This results partly from the inability of specialists to provide sufficient socio-economic insight to quantify the benefits of conserving biodiversity. Economics can help demonstrate the importance of biodiversity to human society by assessing values for the full range of goods and services it provides. At the same time, governments and the public should recognise that economics only provides one of the ways of addressing biodiversity, and that ethical concerns also have a role to play.

Fourth, since the ecological functions of many species or populations are still only partly known, the wisest course is to apply the "precautionary principle" and avoid actions that needlessly reduce biodiversity. Biodiversity needs to become a concern of far more than just protected area and conservation agencies. It is clearly incorrect to assume that biodiversity can only be conserved through the artificial exclusion of economic forces. Rather, in the coming years, improvements in conserving biodiversity will increasingly come from improved management of land and water outside protected areas, and those sites which are given high levels of legal protection will need to be managed as part of wider land-use programmes. These wider programmes will include diversification of agriculture and cropping strategies, encouragement to the spread of new varieties and non-traditional crops, rationalisation of cropping techniques so as to minimise ecological damage, and strategies for the rehabilitation and diversification of damaged habitats. In all cases, greater effort should be made to ensure that local communities are fully involved in the design and implementation of these measures.

ACKNOWLEDGEMENTS

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REFERENCE

Krattiger, A.F., J.A. McNeely, W.H. Lesser, K.R. Miller, Y.St. Hill and R. Senanayake (Ed.s). (1994). *Widening Perspectives on Biodiversity.* IUCN, Gland, Switzerland and International Academy of the Environment, Geneva, Switzerland. 473 p.

CHARTER FOR MANGROVES*

INTERNATIONAL SOCIETY FOR MANGROVE ECOSYSTEMS

The International Society for Mangrove Ecosystems (ISME) has adopted a Charter for Mangroves that complements a World Charter for Nature that the General Assembly of the United Nations proclaimed on 28th October 1982 affirming that nature shall be respected, genetic viability on earth shall not be compromised, conservation shall be practiced, sustainable management shall be utilised by man, and nature shall be secured against degradation.

ISME BEING AWARE THAT

a. Mangrove forests are unique Intertidal ecosystems that occur primarily in tropical regions of the World;

b. The total World-wide mangrove area is estimated at not less than 170,000 km^2 and that there are some sixty species of trees and shrubs that are exclusive to the mangrove habitat;

c. Mangroves support genetically diverse communities of terrestrial and aquatic fauna and flora that are of direct and indirect environmental, economic and social value to human societies throughout the World;

d. Sustainable development of mangrove ecosystems implies the maintenance and rational use of the natural resource to ensure ecological resilience and economic opportunities for present and future generations;

e. Mangroves must be conserved in various parts of the World to prevent the occurrence of degraded coastal lands;

CONVINCED THAT

a. Destruction and degradation of mangrove forests are World-wide phenomena, as a result of activities related to the non-sustainable use and over-exploitation;

b. The value of mangrove lands is consistently under estimated when the areas are converted for non-sustainable purposes;

c. The sustainable use of mangrove ecosystems would provide a better use of the resource;

d. There is an urgent need to restore degraded mangrove ecosystems for economic, social and conservation reasons;

PERSUADED THAT

a. Mangroves are a valuable natural resource with distinctive genetic diversity, high intrinsic natural productivity and unique habitat value;

b. Mangroves sustain important economic and ecological values in adjacent terrestrial and marine systems;

*Reproduced from ISME Newsletter No. 6, September 1992.

c. Mangroves play an important role in the economic and social resources available to subsistence coastal dwellers in the tropics;
d. Mangroves play an important role in coastal protection and in the reduction of coastal erosion;
e. Mangroves buffer coastal waters from undesirable land-based influences, such as sediment, contaminant or nutrient runoff;

Reaffirming that people must acquire the knowledge to use natural resources in a manner which ensures the protection and enhancement of species and ecosystems for their intrinsic values and for the benefit of present and future generations.

Convinced of the need for appropriate measures at individual, collective and national levels to manage, conserve and promote understanding of the mangrove ecosystem.

Convinced also of the need to foster the sharing of information and understanding at an international level, and co-operation in all aspects of management and study of mangrove ecosystems.

Adopts, to these ends, a Charter which proclaims the following principles for the utilisation of mangrove ecosystems by which all human conduct affecting mangrove ecosystems is to be judged.

I. GENERAL PRINCIPLES

1. Mangrove ecosystems shall be respected and their intrinsic characteristics shall be preserved wherever possible.
2. The genetic diversity inherent in mangrove ecosystems shall be safeguarded to this end the necessary habitats must be preserved.
3. Mangrove ecosystems that are utilised by people shall be managed to achieve and maintain sustainable productivity without degrading the integrity of other ecosystems with which they coexist.
4. Mangrove ecosystems shall be secured against indiscriminate destruction, natural hazards, pollution and damage resulting from disturbance of surrounding areas.
5. The sustainable utilisation of mangrove ecosystems by traditional users shall be recognised and provided for to improve the welfare of the indigenous people.
6. The acquisition and dissemination of knowledge with respect to structure, function and management of pristine and disturbed mangrove ecosystems shall be encouraged by all possible means, including international research and technical cooperation.

II. FUNCTIONS

7. The decisions affecting the management of mangrove ecosystems shall be made only in the light of best existing knowledge and an understanding of the specific location.
8. Decisions on how to manage a mangrove ecosystem shall be informed by definition of the following parameters :

   i. the biological components and the physical characteristics of the area under consideration, by means of inventories, maps and the collection of physical and biological data;

ii. the needs of people in relation to sustainable uses of the resource while ensuring adequate reserves for preservation purposes;
iii. the national and international significance of the resource as habitat and as a genetic reservoir;
iv. the national and international significance of the site for coastal stability and fisheries production;
v. the local requirements for education, recreation and aesthetic values;
vi. the requirements that must be satisfied for non-sustainable uses of the resource;
vii. the extent to which rehabilitation and compensation mechanisms can be used to mitigate the impact of non-sustainable use.

9. The information collected in (8) shall be used to define the areas necessary for preservation, to define strategies for the management, restoration and preservation of the resource, or to define areas necessary for sustainable use.
10. Decisions of the use of mangrove ecosystems shall include consideration of the need :

   i. to utilise the mangrove resources so that their natural productivity is preserved;
   ii. to avoid degradation of the mangrove ecosystems;
   iii. to rehabilitate degraded mangrove areas;
   iv. to avoid over-exploitation of the natural resources produced by the mangrove ecosystems;
   v. to avoid negative impacts on neighbouring ecosystems;
   vi. to recognise the social and economic welfare of indigenous mangrove dwellers;
   vii. to control and restrict non-sustainable uses so that long-term productivity and benefits of the mangrove ecosystems are not lost;
   viii. to introduce regulatory measures for the wise use of mangrove ecosystems.

11. Activities which might impact on mangrove ecosystems shall be controlled by appropriate national, regional and international laws and agreements.
12. Activities which are likely to pose a risk to a mangrove ecosystems shall be subjected to an exhaustive examination prior to decisions being made. Only after it has been publicly demonstrated that the potential advantages outweigh the potential damage should the activity be allowed to commence.
13. Mangrove ecosystems degraded by human activities shall be rehabilitated for purposes in accord with their natural potential and compatible with the well-being of the affected people.

III. IMPLEMENTATION

14. The principles set forth in the present Charter should, where possible, be reflected in the law and practice of each state, as well as at the international level.
15. Knowledge of the structure, function and importance of mangrove ecosystems should be communicated by all possible means at local, national and international levels.
16. Knowledge of the structure, function and management of pristine and disturbed mangrove ecosystems should be enhanced.

17. Educational programmes and regional centres should be provided to train scientists, planners, managers and the general public and to encourage an awareness of the importance of mangrove ecosystems.
18. All planning should include the establishment of biological, physical and socio-economic inventories of the mangrove ecosystems under consideration and assessments of the effects on the systems and their surrounds of the proposed activities. All such considerations should be open to public scrutiny and comment prior to any decision.
19. Resources, programmes and administrative structures necessary to achieve the sustainable use of mangrove ecosystems should be provided.
20. The status of mangrove ecosystems should be monitored nationally and internationally to ensure evaluation of current practices and to enable early detection of adverse effects.
21. States should establish specific statutory provisions or regulations for the protection and management of mangroves and mangrove ecosystems.
22. States, other public authorities, international organisations, non-government organisations, individuals, groups and corporations, to the extent that they are able, should;

    i. co-operate in the task of managing mangrove ecosystems for sustainable purposes;
    ii. establish procedures and methodologies for assessing the status of mangrove ecosystems and for managing them;
    iii. ensure that activities within their jurisdiction do not cause unnecessary damage to mangrove ecosystems within or beyond their jurisdiction;
    iv. implement national and international legal provisions for the protection and conservation of mangrove ecosystems.

23. Each state should where possible give effect to the provisions of the present Charter through its competent organs and in cooperation with other states.
24. All persons, in accordance with their national legislation should have the opportunity to participate, individually or collectively, in the formation of decisions of direct concern to the conservation and sustainable use of mangrove ecosystems.
25. Affected people should have means of redress when their mangrove ecosystems have suffered damage.
26. Each member of ISME has the duty to act in accordance with the provisions of the present Charter, acting individually, in association with others, or through participation in a political process. Each member shall strive to ensure that the objectives and requirements of the Charter are met.

INTERNATIONAL TRAINERS' TRAINING PROGRAMME : SCHEDULE

Date	Topic	Faculty
16.3.92	Biological Diversity	M.S. Swaminathan
	Genetics and improvement of forest trees	S. Kedharnath
17.3.92	Reproduction in mangrove plants	A.N. Rao
	Clonal multiplication	S. Kedharnath
	Seed viability	S. Kedharnath
	Genetic diversity : sampling procedures	B.R. Murty
18.3.92	Changes in genetic composition and ecosystems	B.R. Murty
	Assessment of genetic diversity	B.R. Murty
	Conservation genetics/ population genetics	S. Jana
19.3.92	Identification of variables	B.R. Murty
	Biodiversity	M.S. Swaminathan
	Biodiversity/ genetic environment	S. Jana
	Video film on Biodiversity	
	Choice of variables	B.R. Murty
20.3.92	Multivariate analysis of biological data	B.R. Murty
	Tutorials	B.R. Murty
21.3.92	Multivariate analysis (contd.) : clustering procedure	B.R. Murty
22.3.92	Madras city tour	
23.3.92	Ecology of mangroves	A.N. Rao
	Plants of mangrove habitats	A.N. Rao
	Status of mangroves in India	Sanjay Deshmukh
	Plant genetic resources	S. Jana
24.3.92	Biogeography of mangroves	A.N. Rao
	Basic physiological and ecological principles; integration of physiology and ecology into eco-physiology	P.N. Avadhani
	Photosynthetic mechanism, its component systems and limits to the expression of photosynthetic system	P.N.Avadhani
	Silvicultural practices	S. John Joseph
	Sustainable utilisation of natural resources	S. John Joseph
	Carbondioxide fixation and fixtures of C_3, C_4 and CAM plants, light and the photosynthetic process	P.N. Avadhani
25.3.92	Measurement of photosynthesis gas exchange	P.N. Avadhani
	Florescence : methods of apparatus	S. Gunetilleke
	Reproductive biology	S. Gunetilleke
25.3.92	Photosynthetic rates of mangrove plants	P.N. Avadhani
	Effects of light, temperature, salinity and tidal changes on the photosynthetic rates of mangrove plants	P.N. Avadhani

Date	Topic	Faculty
	Floral morphology	S. Gunetilleke
	Phenology in relation to plant breeding	S. Gunetilleke
	Flower varieties and breeding pattern	S. Gunetilleke
	Genetic diversity and biological criteria for selection of genetic conservation areas	I.A.U.N. Gunetilleke
27.3.92	Mangrove propagation, distribution and predators	S. Gunetilleke
	Research priorities in mangrove ecosystems towards conservation and sustainable management of plant genetic resources	I.A.U.N. Gunetilleke
	Understanding the role of physiological factors to identify the mangrove genetic resources	P.N. Avadhani
	Nature of variability within forest tree species	C.S. Venkatesh
	Forest tree improvement	C.S. Venkatesh
28.3.92	Mangrove vegetation of Andaman islands	L.P. Mall
	Stress conditions in mangrove communities	L.P. Mall
	Nutrients, ionic relationships and effects of submergence	L.P. Mall
	Ecological parameters to study mangrove ecosystem	L.P. Mall
29.3.92	Visit to wetlands (Bird Sanctuary) at Pulicat	
30.3.92	Tree improvement/Inter-specific hybridisation	C.S. Venkatesh
	Future improvement in mangrove trees	C.S. Venkatesh
	Root systems in mangroves : structure and function	A.N. Rao
	Threats to mangrove genetic resources	Sanjay Deshmukh
	Methods for studying mangrove ecosystems	Sanjay Deshmukh
	Mangrove genetic resources : strategy for conservation and management	Sanjay Deshmukh
31.3.92	Mangrove tree-shoot systems and leaf structure control of transpiration	A.N. Rao
	Seed production in trees : control mechanisms	A.N. Rao
	Evolution of seed numbers : special characters of	K.N. Ganeshaiah
	mangrove seeds and improved methods to prolong seed viability in mangroves	K.N. Ganeshaiah
	Socio-economic aspects of mangrove ecosystems	R. Maria Saleth
01.4.92	Field Visit to Pichavaram mangrove forest	
02.4.92	Field visit : Pichavaram	Sanjay Deshmukh
	a) Collection and identification of species	
	b) Quadrat measurements–special numbers, frequency	
	c) Biodiversity studies–leaf numbers and other characters	
03.4.92	Lectures at Parangipettai (C.A.S. in Marine Biology)	
	Introduction by The Director	A.L. Paul Pandian
	Video film on mangroves	
	Benthic fauna of Pichavaram mangroves	K. Balasubrahmanian
	Algal association in mangrove communities	L. Kannan

Date	Topic	Faculty
	Vegetative propagation in mangroves and *in vitro* culture studies	K. Kathiresan
	Back to Madras from Pichavaram	
04.4.92	Patenting rights of biological materials: history and development	M.S. Swaminathan
05.4.92	Departure from Madras to Port Blair	
06.4.92	Visits to Long Island mangrove areas	
07.4.92	Mayabunder–Field visits	A.N. Rao
08.4.92	Field studies at Rangat, Middle Andaman	Sanjay Deshmukh
09.4.92	Lectures at Port Blair	
	Mangroves of bay islands	A.K. Bandyopadhyay
	Chemical composition of mangrove soils	A.D. Mongia
	Insects in mangrove community	Veena Kumari
	Mangroves of Andamans	M.K. Vasudeva Rao
	Mangrove systematics and species diversity	H.S. Debnath
	Management of mangroves of Andamans	L. Balachandra
	Succession in mangroves	P.V. Savant
	Fauna of mangroves in Andamans and their management	Ajai Saxena
	Regeneration and propagation of mangroves	P.V. Savant
	Conservation and management of Andaman Mangroves	B.P. Sinha
10.4.92	Field visit to Wandoor National Park	Ajai Saxena
11.4.92	Field studies at Chidiatapu	A.N. Rao
12.4.92	Field studies at Chidiatapu	A.N. Rao
13.4.92	Back to Madras	
	Biodiversity, conservation and utilisation	T.N. Khoshoo
14.4.92	Visit to construction site of M.S. Swaminathan Research Foundation	
	Departure for Goa	
15.4.92	Lectures at National Institute of Oceanography	
	Role of bacteria in nutrient cycling of mangrove soils and water	Chandra Mohan
	Role of micro-organisms in detrital food web of mangroves	S. Raghu Kumar
	Role of zooplankton in mangrove ecosystems	S. Raghu Kumar
	Paleontological observations in relation to coastal ecosystems	Rajiv Nigam
	Specialised tropical marine ecosystems : coral reefs and mangroves	M.V.M. Wafar
	Benthic communities in mangroves	A.H. Parulekar
	Aquaculture in mangrove environment	A.H. Parulekar
16.4.92	Paeneid prawns and their culture in mangroves	C.T. Achuthankutty

Date	Topic	Faculty
	Biofoulers in mangroves	A.B. Wagh
	Estuarine borers with special reference to mangrove ecosystems	L.N. Shanthakumaran
	Higher marine fungi	Chinna Raj
	Aspects of productivity of mangroves	Sayeeda Wafar
	Data base development in relation to coastal ecosystems	M.P. Tapaswi
17.4.92	Visit to Mangrove forest areas in and around Goa	T.G. Jagtap
18.4.92	Visit to Chorao island, Goa	A.N. Rao
19.4.92	Departure for Ratnagiri, Maharashtra	
	Field studies in Ratnagiri : mangrove areas, social forestry sites	S.K. Mahadar
	Film on mangroves—prepared by Forest Department	
	Departure for Bombay	
20.4.92	Visit to Mangrove areas in Vikhroli, Ghodbandar and Thane creek in Bombay	Sanjay Deshmukh
21.4.92	Lectures at IGIDR, Goregaon	
	Population dynamics in mangroves	S.B. Chaphekar
	The physiology of mangroves	S.M. Karmarkar
	Physiology of salt tolerance	S.M. Karmarkar
	Nitrogen metabolism in mangroves	D.V. Amonkar
	Brief work plan for participants	A.N. Rao
22.4.92	Biotechnological methods applicable to mangroves	Usha Mukundan
	Application of remote sensing in the study of mangrove ecosystems	Shailesh Nayak
23.4.92	Field studies at Elephanta island	C.S. Lattoo
24.4.92	Visit to Borivali National Park, Bombay	A.G. Raddi
	Departure for Madras	
25.4.92	*En route*	
27.4.92	Biological rhythm in trees and seed production	A.N. Rao
	Genetic concepts and measurements	V. Arunachalam
	Methods of classification based on genetic divergence	V. Arunachalam
	Soil-plant-atmosphere interactions in mangroves	Barry F. Clough
28.4.92	Selection strategy vis-a-vis genetic divergence	V. Arunachalam
	Gene and genetic conservation	V. Arunachalam
	Palynology applied to mangroves/ Sea level rise	C. Caratini
	Global change and mangrove management implications	Barry F. Clough
29.4.92	Analysis of field data and methods for studying intra-specific variations of mangroves	V. Arunachalam
	Economic importance of mangroves	A.N. Rao
	Pointers for the identification of intra-specific varieties in mangroves	Group Discussion
	Guidelines to write the dissertation	M.S. Swaminathan

Date	Topic	Faculty
30.4.92	An introduction to the RFLP and RAPD techniques	P. Balakrishna
01.5.92	Information resources for Managers of Genetic Resources Centres	T. Viswanathan
	Demonstration and hands-on trial of information retrieval system of INSDOC	T. Viswanathan
	Use of computers in information retrieval	C.R. Muthukrishnan
	Demonstration at Indian Institute of Technology, Madras	C.R. Vengan
02.5.92	Free	
03.5.92	Sunday	
04.5.92	Inaugural session of the Training Programme on Bioindicators at Loyola College, Madras	
	Introduction to the principles of remote sensing	T. Natarajan
	Demonstration : photogrammetry and allied techniques (at Institute of Remote Sensing, Anna University, Madras)	T. Natarajan
05.5.92	Integrated coastal ecosystems	R. Mahalingam
	Mangroves of China	Shao Qiquan
	Biotechnology applications for management of biodiversity	
Shao Qiquan		
06.5.92	Implications of sea level rise and global warming in the management of coastal ecosystems	S.N. Dwivedi
	Mangroves and aquaculture	P.V. Dehadrai
07.5.92	Brackish water aquaculture	K. Alagarswamy
	Aquaculture in mangrove zones	R. Paul Raj
08.5.92	Joint forest management (JFM) with people's involvement	A.V.R.G. Krishna Murthy
	Tissue culture applications for mangrove regeneration	Subrata Maity
09.5.92	JFM—case studies from India	A.V.R.G. Krishna Murthy
11.5.92	Practical work using specimen of mangroves/species characterisation	A.N. Rao
	Abundance and species distribution in gangetic basin with special reference to mangroves	Virendra Kumar
	Discussion on outline of dissertation	M.S. Swaminathan
12.5.92	Report on the field visits in the mangrove areas of Papua New Guinea	Norman C. Duke S. Jana
	Identifying criteria and methods of evaluation of forest areas for establishment of a global network of mangrove genetic resources centres	Sanjay Deshmukh

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