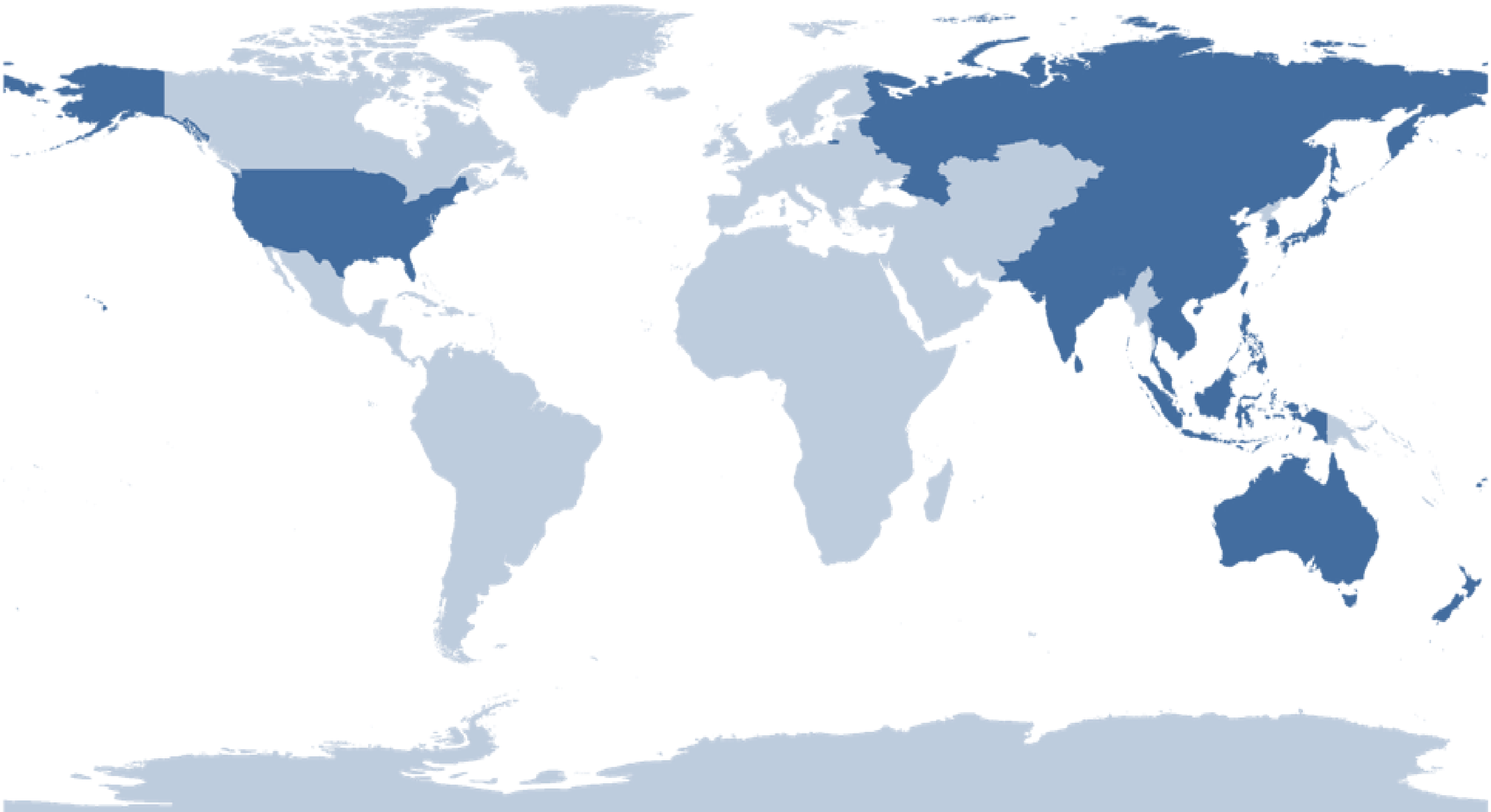
APN
Asia-Pacific Network for Global Change Research

FINAL REPORT for APN PROJECT

Project Reference Number: ARCP2011-10CMY-Lutaenko

"Coastal Marine Biodiversity of Vietnam: Regional and Local Challenges and Coastal Zone Management for Sustainable Development"



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"Coastal Marine Biodiversity of Vietnam: Regional and Local Challenges and Coastal Zone Management for Sustainable Development"

Project Reference Number: ARCP2011-10CMY-Lutaenko
Final Report submitted to APN

OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

The APN Project ARCP2011-10CMY-Lutaenko intended to study marine biological diversity in coastal zones of the South China Sea with emphasis to Vietnam, its modern status, threats, recent and future modifications due to global climate change and human impact, and ways of its conservation. The project involved participants from three countries (Republic of Korea, Russia and Vietnam). The report includes data on the coral reefs, meiobenthos, intertidal ecosystems, biodiversity of economically important bivalve mollusks, rare groups of animals (sipunculans, nemertines). These studies are highly important for the practical purposes of coastal ecosystems management, coral reefs restoration and marine farming. As a part of the project activities, the International Conference *Marine Biodiversity of East Asia Seas: Status, Regional Challenges and Sustainable Development* was held in the Institute of Oceanography, Vietnam Academy of Science and Technology in Nhatrang in 2010, and the workshop *Coastal Marine Biodiversity and Bioresources of Vietnam and Adjacent Areas to the South China Sea* was held in the Research Institute of Aquaculture N 3, Nhatrang, Vietnam. Website of the project is running. The data obtained and summarized and interpretations of the coastal/ecosystem changes would be of use for development of recommendations for local/regional/national decision- and policy-makers and would contribute to current understanding of tropical ecosystem of the South China Sea.

Objectives

The main objectives of the project were:
1, to collect information about overall species diversity and to compile species lists of biota in Vietnam coastal zone as a basis for monitoring of expected changes; **2,** to develop approaches for monitoring of the biodiversity changes in the South China Sea; **3,** to document species diversity in island's ecosystems along the Vietnam coast as a baseline study for conserving coastal and marine biological diversity; **4,** to conduct inter-comparisons of the biodiversity status in the South China Sea and adjacent regions; **5,** to hold joint workshops on biodiversity of the coastal zones between Vietnam, Russia, and Korea; **6,** to prepare and publish the monograph "*Biodiversity and Bioresources of the Vietnam Coastal Waters and their Sustainable Management*" (as a final outcome of the project); **7,** through the project activity, to enhance regional cooperation in global change research of biodiversity, to increase number of joint publications, and to involve as many as possible young scientists in global change community.

Amount received and number years supported

The Grant awarded to this project was:
US$ 40,000 for Year 1: 2010/11
US$ 45,000 for Year 2: 2011/12

Activity undertaken

Activities undertaken in course of implementation of the project included holding of the meetings and workshops, limited field-works in southern Vietnam, synthesis of the available data on biodiversity of Vietnam collected during long-term research by Russian and Vietnamese scientists including preparation of the monograph, website running, and publications in peer-reviewed journals.

As a part of the planned project activities, the International Conference ***Marine Biodiversity of East Asia Seas: Status, Regional Challenges and Sustainable Development*** was held in the Institute of Oceanography, Vietnam Academy of Science and Technology in Nhatrang on December

6-7, 2010. Over 30 participants attended the meeting, and among them there were scientists from five countries (Germany, Japan, Korea, Russia, Vietnam), representatives of some Vietnamese govermental agencies and international organizations; the conference included four sessions and forty-seven full-length papers were published as proceedings of the conference. The APN-funded international workshop ***Coastal Marine Biodiversity and Bioresources of Vietnam and Adjacent Areas to the South China Sea*** was held jointly by the Research Institute for Aquaculture No. 3 and A.V. Zhirmunsky Institute of Marine Biology, FEB Russian Academy of Sciences in Nha Trang City on November 24–25, 2011. Over 40 participants from Vietnam, Russia, Singapore and Republic of Korea attended the workshop and presented their talks on biodiversity, bioresources, marine biology and conservation aspects of the biota of the South China Sea and neigbouring areas. Among topics of the workshop, there were presentations on diversity and taxonomy of marine turtles, echinoderms-ophiuroids, gastropod and bivalve mollusks, nemertean worms, soft corals, sea anemones, marine algae, fish. Other presenters from Vietnam and Russia dealt with biochemical diversity of marine organisms. The workshop was highly successful in terms of a variety of topics, researchers and exchange of the ideas among Vietnamese and foreign participants and showed the need of international efforts to understand regional global change and biodiversity.

Website of the project is running (http://www.imb.dvo.ru/misc/vietnam/); it includes information on the project implementation, publications of the project participants, their CVs, information on two meetings held in Vietnam in 2010 and 2011 and their proceedings.

Limited field-works were undertaken in Nhatrang Bay (southern Vietnam) to collect bivalve mollusks, gastropods, nemerteans, and some other animal groups.

Other activity included preparation of reviews on biodiversity and biogeography of corals and mollusks of Vietnam, and preparation of the summarizing monograph on biodiversity of coastal waters of Vietnam.

Results

Based on various literature data, the survey of coral reefs in Vietnam during the last 15 years shows that the area of coral reefs has been reduced by 15-20%, mainly in coastal waters of the central part of Vietnam from Da Nang to Binh Thuan province. Coal dust has caused the death to large areas of corals in the Ha Long and Bai Tu Long bays (Quang Ninh Province). Along with the coral reef area reduction, the number of species is also reduced. For example, the coverage of coral reefs in Bai Tien area (Nha Trang) was 30% (1984), there was 60 species, and it reduced to 1% by 1998 and the number of species decreased to 30. Other living organisms were also reduced in number significantly. At present, all countries in the South China Sea have degraded reefs, from 95% in Hainan Island to an unknown amount in Vietnam. Sustainable use and protection of the SE Asia coastal reefs are now items which stands in the focus of the international agendas.

In terms of environmental conditions suitable for growth of the reef-building coral species, the coastal areas of western Tonkin Gulf are very far from favorable for reef development. This is largely due to low water temperatures during the winter months, and large contributions of freshwater and sediments to this part of the gulf from adjacent river systems. Corals are mainly observed in areas of Ha Long Bay, Bai Tu Long, the Co To Archipelago, and Long Chau Islands, which are mostly surrounded by shallow and muddy bottoms. The coral reefs that have developed in the western Tonkin Gulf are typically narrow and extend to a depth of only 5-7 m. The reefs of the northern part of the Bai Tu Long Archipelago may be considered a stable ecosystem, adapted to low illumination conditions as a result of heavy water silting and eutrophication. The reef communities in this region are formed by both hermatypic corals, capable of surviving under low illumination conditions, and ahermatypic corals, whose distribution does not depend on the illumination level. These peculiarities make the reefs of the Gulf of Tonkin really unique. The conservation and recovery of the high biodiversity of reef communities in these regions should be considered a first priority task in the framework of creating reserves and conservation areas in the Gulf of Tonkin.

The biota of intertidal zone of the Vietnamese islands from Namzu Islands (9°40' N, 104°22' E) in the Gulf of Siam to Daochao Island (20°50' N, 107°20' E) in the Gulf of Tonkin was studied based on previously taken collections and belt-forming communities of macrobenthos were investigated in five bionomical types of the intertidal zone; these data may serve as a basis for future long-term monitoring of biodiversity changes. In the intertidal zone of studied areas, 101 plant and 268 animal species are found. Biota the Vietnamese Islands' intertidal zone is typical for tropical region of the Pacific Ocean. Tropical and tropical-subtropical species prevail (for the south Vietnam coast – 54 species, or 34%, respectively, for the Central Vietnam one – 61, or 33%, and for the North Vietnam coast – 50, or 39%), faunal elements with wide distribution (from notal to boreal sea waters) is represented as well, but in low proportions. Macrobenthos of hard substrates (the rocky and rocky-blocky-bouldery intertidal zone) is the richest in qualitative and quantitative compositions. Population of crumbly substrates (the silty-stony intertidal zone and sandy beaches) is the poorest. Any macrophytic algae in the upper horizon and the major part of the middle horizon of surf-open sandy beaches are not found. The intertidal zone of dead coral reef has no analogues in temperate waters.

The distribution of the taxonomical composition and the density of meiobenthos depending on some factors of environment has been studied in bottom sediments of the northern estuary part of Ha Long Bay for the first time; a total of sixty six species belonging to 17 families and 52 genera were identified. The estuary part of the Ha Long Bay is exposed constantly as to anthropogenic impact from the sea port (bottom dredging works), and to mainland drain of fresh waters which result in significant changes of salinity within a year. In general, differences in composition and distribution of meiobenthic communities in Ha Long Bay appeared to be connected with changes in granulometric composition of bottom sediments. The silted sediments are characterised by the low species diversity and higher density of the animals than the slightly silted sands. The meiobenthos density at Nha Trang Bay reefs also shows an uneven distribution and depends on the sediment type. The correlation analysis revealed the dependence between the median diameter of sediment particles and the density of meiobenthos. However, taxonomic diversity of meiobenthos in Nha Trang Bay (twenty six groups) was greater than in other areas. Nematodes dominated in bottom sediments both in Nha Trang Bay itself and at its reefs. In total, representatives of four orders, twenty eight families and ninety seven genera were found in Nha Trang Bay. Nematodes made up to more than 90% of the total population density of meiobenthos at stations with high number of silt particles in sediments. Probably, the oxygen deficiency is a limiting factor for the penetration of animals into the depth of sediments in the central part of Nha Trang Bay.

The biodiversity of rare and little-known groups of invertebrates (nemerteans, sipunculids, opistobranch mollusks) of Vietnam was studied for the first time. Twenty species in eleven genera and five families of Sipunculida are recognized from the total 371 individuals collected in southern Vietnam. An analysis of the sipunculan literature has shown that 5 of these species are new records for Nha Trang Bay. 157 species of opistobranch mollusks are recorded in southern Vietnam, about half of them for the first time. About 80 nemertean species belonging to 5 orders: Archinemertea (4 species), Tubulaniformes (2 species), Heteronemertea (32 species), Polystilifera (6 species), and Monostilifera (36 species) were collected in Vietnam, a majority for the first time.

The extensive literature review was prepared with regard of molluscan biodiversity in the Soutrh China Sea. Crame (2000) estimated that about 1211 species of bivalve mollusks inhabit Indonesia-Philippines region excluding both Taiwan and New Guinea, and 1176 species live in the "East China Sea region". This clearly reflects generally accepted concept of high biodiversity in the so-called "East Indies Triangle", or Coral Triangle: the ranges of many tropical marine species overlap in a centre of maximum biodiversity located in the Indo-Malayan region (Malaysia, the Philippines, Indonesia, and Papua New Guinea (Hoeksema, 2007). The Coral Trianle is recognized as a biodiversity hotspot but this centre is located approximately, and its exact boundaries are unknown.

Regional differences in species richness of bivalves in the South China Sea are not clear. They rather reflect sampling efforts than real biogeographical phenomena. Lutaenko (2000b) listed 367 species names of bivalve mollusks from Vietnam based on two largest Russian collections and it was the most complete list at that time. Later on, Hylleberg and Kilburn (2003) compiled updated list of marine bivalves consisting of 815 species, but it is uncritical in many ways. Based on these data, we may assume that the most rich faunas of bivalve mollusks are those of Vietnam (more than 800 species) and Philippines-Indonesia (more than 1200 species). Diversity of bivalves appears to show increase from north (Taiwan and Guangdong Province, 401-463 species) to south (latitudinal gradient of biodiversity widely known in biogeography. Impoverished character of the bivalves faunas of the Tonkin Gulf and the Gulf of Thailand can be explained by significant river discharge which decreases salinity. Problem iin molluscan biodiversity include a lack of taxonomic expertise in many countries surrounding the South China Sea. There are few professional malacologists trained in taxonomy, and there are few well curated research collections/museums with voucher specimens. A few young scientists want to devote themselves to traditional taxonomy due to a limited financial support and low prestige of this field of biology. Other challenges confronting biodiversity specialists in the region include lack of literature, difficulties in disseminating data, and general lack of governmental commitment to develop biodiversity research to its full potential.

Threats to marine biodiversity habitat degradation, fragmentation and loss (especially important are mangrove forest destruction, loss of coral reefs, change in landscape mosaic of wetland, estuary, sand and mud flats); global climate change including sea level rise, storm events, rainfall pattern change, warming of the coastal ocean; effects of fishing and other forms of overexploitation; pollution and marine litter; species introduction/invasions; physical alterations of coasts; tourism.

The 2010 conference and the 2011 workshop held in course of the implementation of the project summarized BD data and information of Vietnamese and Russian researchers to be used in preparation of final APN-sponsored book on the marine BD of Vietnam as one of the outcome of the project. Proceedings of both meetings were published (Dautova and Lutaenko, 2010; Lutaenko, 2011).

Relevance to the APN Goals, Science Agenda and to Policy Processes

The implemented project falls with the APN theme *Ecosystems, Biodiversity and Land Use*. Biodiversity issue is an important aspect of global change, especially in SE Asia - one of the richest regions with respect to biodiversity in the Asia. Enormous human population in Vietnam causes serious impact on coastal zone - extinction of endangered species, biodiversity loss, ecosystem unbalancing. We believe that data obtained in course of the project implementation would serve for more thorough understanding of ecosystems of coastal Vietnam and may be used for assessing overal biodiversity and main threats. Capacity building of young scientists in Vietnam through their participation in this international activity and decision-making process at national/regional level may be improved. The project activities served for raising awareness of global environmental changes in Vietnam.

Self evaluation

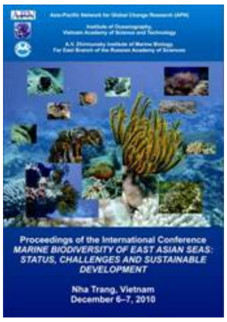
The project implemetation was rather smooth and we accomplished the targets to a satisfactory degree. A bulk of information on biodiversity was collected and summarized in a preliminary level, conference in December 2010 and the workshop in 2011 invloved a number of leading scientists, young researchers and representatives of govermental agencies; limited field-works were conducted. One of the most important outcome of the project, a book on biodiversity of Vietnam, was discussed in details with authors and editors, a plan was designed and some papers are already prepared. However, we definitely need more involvement of young Vietnamese researchers and, in general, more participation from this side, but it is difficult due to a lack of biodiversity/taxonomy expertise in Vietnam. Another weakness is how to present the recommendations and information to coastal managers and regional policy-makers. We believe that through participation of Vietnamese scientists in the international activity such as this APN project, we may expect their involvement in coastal zone management.

Potential for further work

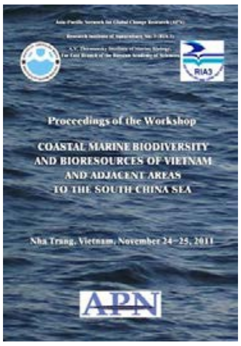
Through implementation of the project, we developed a network of scientists who are interested in future collaboration. Russian biologists traditionally collaborate with a number of institutuions in Vietnam and they would continue joinr researches, field-works and holding joint meetings. A project on biological resources management with a Vietnam leadership and involvement of Russia and Singapore is prepared in the RIA3 to be submitted to the APN in 2012. We plan to publish a book – monograph on biodiversity in 2013 as an outcome of thgis project, jointly with Vietnam.

Publications

Books (Proceedings of conferences/workshops)



T.N. Dautova and K.A. Lutaenko (Eds.). Proceedings of the International Conference *Marine Biodiversity of East Asian Seas: Status, Challenges and Sustainable Development,* Nha Trang, Vietnam, December 6–7, 2010. 202 pp.



K.A. Lutaenko (Ed.). 2011. Proceedings of the Workshop *Coastal Marine Biodiversity and Bioresources of Vietnam and Adjacent Areas to the South China Sea*, Nha Trang, Vietnam, November 24–25, 2011. Vladivostok-Nha Trang: Dalnauka, 2011. 123 pp.

Peer-reviewed papers

Dautova T.N. Pathways for dispersal of the octococorals in the East Asia seas – inter-faunal connectivity and centres of biodiversity. *Bulletin of the Far Eastern Branch, Russian Academy of Sciences.* N 4. P. 31–39. [In Russian with English abstract].

Dgebuadze P.Yu., Fedosov A.E., Kantor Yu.I. Host specificity of parasitic gastropods of the genus Annulobalcis Habe, 1965 (Mollusca, Gastropoda, Eulimidae) from crinoids in Vietnam, with descriptions of four new species. *Zoosystema.* 2012. V. 34, N 1. P. 139–155.

Kantor Yu.I., Fedosov A.E., Marin I.N. An unusually high abundance and diversity of Terebridae (Gastropoda: Conoidea) in the Bay of Nha Trang, Vietnam. *Zoological Studies* (in press).

Pavlyuk O.N., Trebukhova Yu.A. Intertidal meiofauna of the Jeju Island, Korea. *Ocean Science Journal.* 2011. V. 46, N 11. P. 1–11.

Acknowledgments

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TECHNICAL REPORT

Preface

The report includes information and data obtained during implementation of the project ARCP2011-10CMY-Lutaenko *Coastal Marine Biodiversity of Vietnam: Regional and Local Challenges and Coastal Zone Management for Sustainable Development.* Biodiversity of stony and soft corals in the coral reefs' ecosystems of Vietnam, biodiversity and ecology of meiobenthos in northern (Ha Long Bay) and southern (Nhatrang Bay) Vietnam, biodiversity of rare groups (nemertines, sipunculans, opistobranch mollusks), bivalve mollusks, macrobenthic communities of Vietnam's islands are described and analyzed. Programmes of two meetings are presented.

Table of Contents

1.0 Introduction

Biodiversity of the coastal zones of Vietnam is poorly understood and it is experiencing reduction and decline. This APN Project intends to study marine biological diversity in coastal zones of the South China Sea with emphasis to Vietnam, its modern status, threats, recent and future modifications due to global climate change and human impact, and ways of its conservation. The project involves participants from three countries (Republic of Korea, Russia and Vietnam). The main objectives of the project were: 1, to collect information about overall species diversity and to compile species lists of biota in Vietnam coastal zone as a basis for monitoring of expected changes; 2, to develop approaches for monitoring of the biodiversity changes in the South China Sea; 3, to document species diversity in island's ecosystems along the Vietnam coast as a baseline study for conserving coastal and marine biological diversity; 4, to conduct inter-comparisons of the biodiversity status in the South China Sea and adjacent regions; 5, to hold joint workshops on biodiversity of the coastal zones between Vietnam, Russia, and Korea; 6, to prepare and publish the monograph "*Biodiversity and Bioresources of the Vietnam Coastal Waters and their Sustainable Management*" (as a final outcome of the project); 7, through the project activity, to enhance regional cooperation in global change research of biodiversity, to increase number of joint publications, and to involve as many as possible young scientists in global change community.

2.0 Methodology

The project implementation included collection and analysis of relevant data on biodiversity through literature study, original researches on some groups of animals, meiobenthos, and intertidal communities (some data were collected during past decades, but summarized for the first time). As a result, reviews of state and modern knowledge on corals and bivalve mollusks, two important ecologically and economically groups, are prepared for this report. Other methods of field studies are described below.

Study on meobenthic biodiversity and ecology in northern and southern Vietnam

Meiobenthos samples collected between 12th and 13th of March 2007 during the dry season in the northern part of Ha Long Bay (Cua Luc estuary) were used for this research (Fig. 1). The sediment samples were taken with a standart Ponar dredge grab of 150 mm high, 13.7 kg weight and covering a surface area of 230 mm.250 mm. Meiofauna was subsampled using cores of 3.5 cm mouth diameter (10 cm2 surface area) and 30 cm height. The cores were pushed down into the sediment for 5 cm. Per station, four replicates were taken and collected in bottles. The samples were washed through 1mm and 38 im nylon sieves, fixed by hot 10% formaldehyde solution and stained with Rose Bengal. Meiofauna was extracted by flotation with Ludox-TM50 (specific gravity of 1.18). Nematodes were gradually transferred to anhydrous glycerine and ounted onto permanent slides. Meiofauna was identified to higher taxonomical level (order, class) and all animals were taken into account except for foraminiferans. The Shannon-Wiener diversity index (H), the Simpson domination index (C) and Pielou evenness index (e) were used in the characterisation of the nematode community structure:

$$H = -\Sigma ni / N \log ni / N$$
$$C = \Sigma(ni / N)2$$
$$e = H / \log S$$

where ni – is community density of each species,

N – total density of communities,
H – index of Shannon-Wiener,
S – number of species.

The Wieser classification (Wieser 1953), based on the structure of the mouth cavity of animals, was used for the estimation of the trophic structure of the nematode community. According to this classification, four groups of feeders were defined: selective deposit feeders (1A), nonselective deposit-feeders (1B), epistratum feeders (2A) and omnivores (2B). Chemical properties of the bottom layer determined with Water Quality Checker model WQC – 22A. Seven samples from seven stations were selected to analyze the influence of the sediment granulometric composition at the structure of meiobenthos community. Granulometric composition of the sediments was determined by the separation of the sediment samples of natural humidity by two fractions: below 0.1 mm and above 0.1 mm. Even this rough classification allowed us to determine two basic types of the sediments: silted sands (stations HL3, HL5 and HL7) and heterogenous silts with the small admixture of sand (stations HL1, HL2, HL4 and HL6). Spearmen rank correlation coefficient was used to determine the dependence of the quantitative meiobenthic distribution on the silty particles content in sediments. Hierarchical cluster analyses (Ward's method) was used for allocation of nematode taxocenes. Statistica 6.0 software was used for statistical analysis of material.

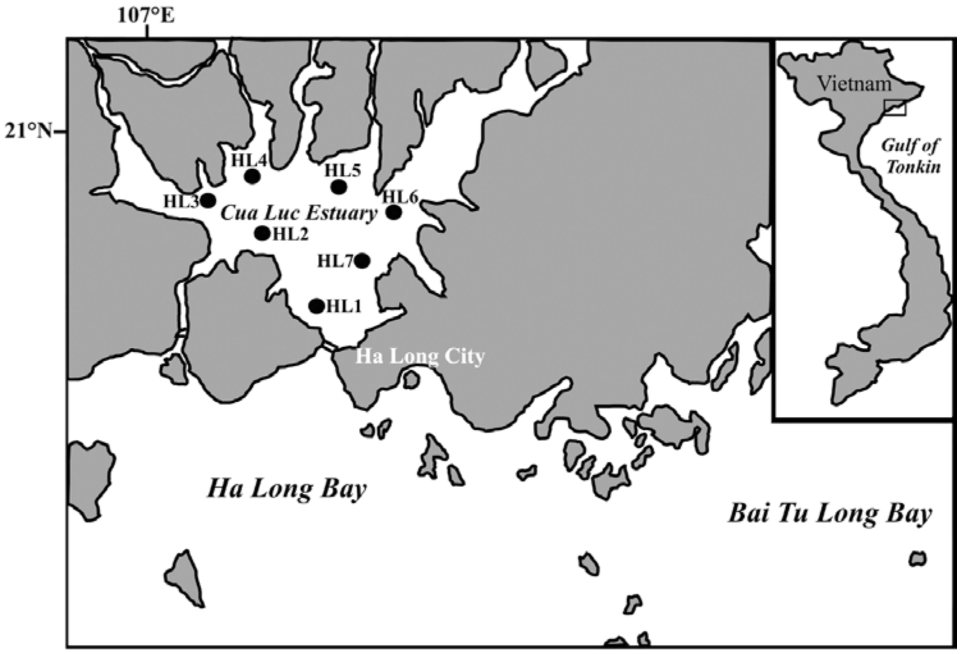

Fig. 1. Map showing the study area in Cua Luc Estuary, with sampling station locations.

Meiobenthos samples from Nha Trang Bay were collected in October 2003 (stations 1-20), and some samples were taken near the islands, on reefs, in bottom sediments between corals (stations 15-20) (Fig. 2). Samples were collected by a SCUBA diver using a 10 cm tube (four samples on every station). In order to investigate the vertical distribution of animals in sediments, a tube of three cm diameter was used (two samples were taken). A sediment column of 10 cm in height was sectioned by five 2 cm levels and each part of each sample was examined separately. In total, ninety two meiobenthos samples were collected and treated. The samples were washed through 1 mm and 63 µm sieves and fixed by 4% formalin and stained with "Rose Bengal". All animals were taken into account, except for foraminifers. During the sampling period the temperature of bottom water varied from 26oC to 29oC, and salinity – from 29 to 32 PSU. The depth of stations varied from 11 to 39 m, on reefs it was from 6 to 10 m. Bottom sediments were classified according to the traditional nomenclature (Parsons et al., 1982). In total, seven ediment types were detected.

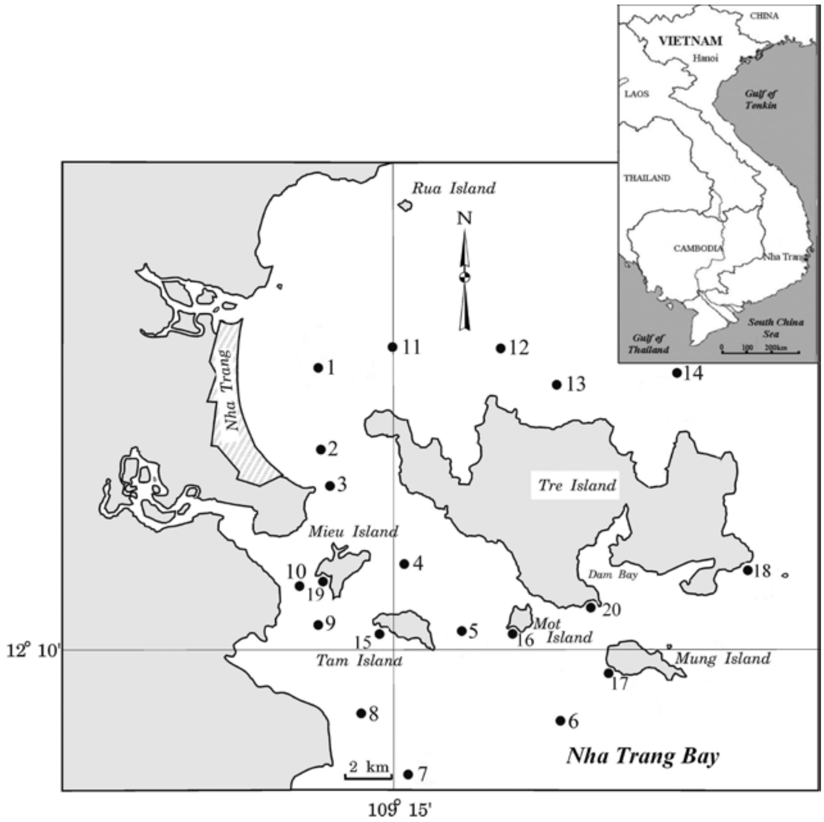

Fig. 2. A schematic map of sampling stations in Nha Trang Bay (South China Sea, Vietnam).

Taxonomic/faunal study on nemerteans

During the Russian-Vietnamese expeditions in 2005, 2007 and 2010 along the Vietnamese coast we collected about 80 nemertean species, and many of these species appeared to be new for science. Living worms were photographed and sketched out, then anesthetized with $MgCl_2$ and fixed in 4 % formalin or Bouin fluid. Proboscis armature was studied on glycerin preparations. To analyze DNA, fragments of a nemertine body were fixed in 95 % ethanol. Identification of most species requires knowing the colour of the living specimens, which may have a characteristic pattern of spots or bands. Formalin is preferable to preserve the colour, but certainly not for all species. The living nemerteans are compressed between two microscope slides (small specimens can be mounted between a slide and cover glass). The number and distribution of eyes, the length of rhynchocoel, and structure of the proboscis and gut can be determined. Using some experience, the position of the cerebral organs and the structure of the circulatory system can be also determined. Study of the stylet armature in nemerteans requires mounting the dissected proboscis of living specimens under a cover slip in a drop of seawater or mixture of seawater and glycerine (1:1). Dissection is most easily accomplished by cutting the nemertean into two parts with a scalpel or a razor blade; the proboscis usually falls out from the cut. If the proboscis is large, the bulky anterior region must be separated from the stylet bearing middle region with a razor blade, in order to compress the proboscis to a sufficient degree to examine the stylets. Nemerteans can be fixed in Bouin's solution or 4% solution of formaldehyde made up in ambient seawater, with mandatory anaesthesia in isotonic solution of 7.5% magnesium chloride mixed with seawater in the ratio of 1:1. It should be noted that often the head of anesthetized nemerteans loses its characteristic shape and the integument becomes less translucent. Many species undergo severe muscular contraction under the influence of magnesium chloride often resulting in autotomy. Adding 7.5% magnesium chloride diluted with seawater (1:1), followed by 7.5 % magnesium chloride the contraction of the worms can be relaxed. It is often enough to treat small nemerteans with a 7.5% solution of magnesium chloride for 1-2 hours, but sometimes to relax large nemerteans (over several centimeters in length), anesthetic solution in a refrigerator (4°C) may be used for several hours. Cutting the partially narcotized worm into two or more pieces can accelerate the process. Histological preparations of the nemerteans can be prepared after fixation in 4% formaldehyde (1-2 hours for small and up to 8 hours for large nemerteans), post-fixation in Bouin's picric-formal-acetic fixative (for 2-3 days) and subsequent storage in 70% ethanol. Detailed study of nemertean anatomy requires preparing serial paraffin sections of the anterior portion of the body, subsequent staining (Mallory's trichrome and its modifications work best), and mounting in Canada balsam, Permount, or some other mediums suitable for microscopic examination and long term storage.

Study on the intertidal communities

The present paper is based on samples of the macrobenthos taken in the intertidal zone of the Vietnam islands (South China Sea) during a marine expedition aboard the research vessel *Professor Bogorov* of the A.V. Zhirmunsky Institute of Marine Biology of the Far Eastern Branch of the Russian Academy of Sciences (then USSR Academy of Sciences) in August–October 1988. Intertidal zone of Vietnam islands in Katwick Small Island (10° N, 109°09' E), Katwick Big Island (10° N, 108°55 E), Thu Island (10°32' N, 108°56' E), Re Island (15°20' N, 108°40' E), Thiam Island (15°40' N, 108°30' E), Ze Island (17°08' N, 107°20' E), and in Baytylong Arkhipelago, near Zanzola Island (20°40' N, 107°20' E) and Daochao Island (20°50' N, 107°20' E) was studied (Fig. 3).

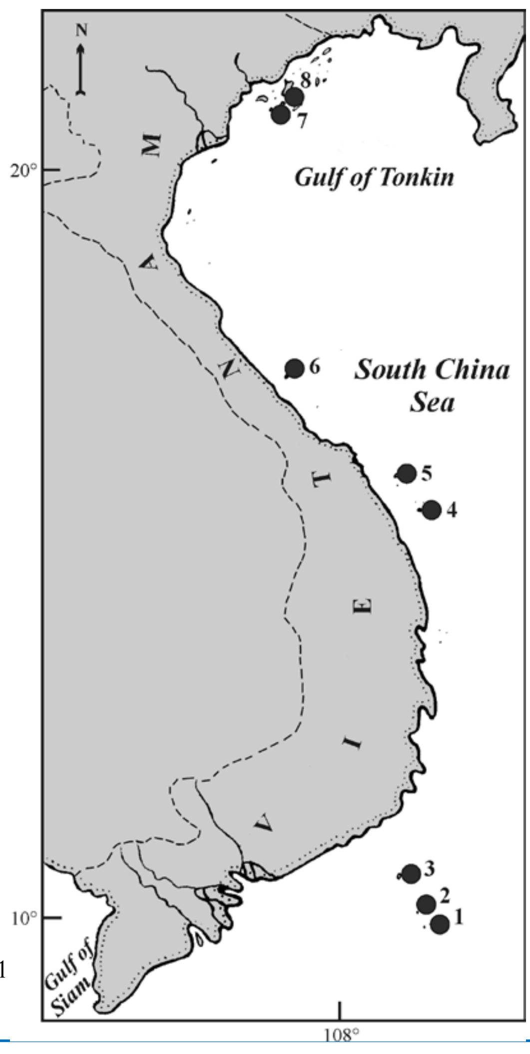

Fig. 3. The schematic map of studied areas. 1 – Katwick Small Island, 2 – Katwick Big Island, 3 – Thu Island, 4 – Re Island, 5 – Thiam Island, 6 – Ze Island, 7 – Zanzola Island, 8 – Daochao Island.

For the identification of intertidal horizons, we used Vaillant's principle of vertical stratification (Vaillant, 1891). The boundaries of the upper, middle, and lower horizons were determined as the highest tide mark; the mean high and mean low water stages, and the lowest possible tide mark respectively. Irregular semi-diurnal tides are characteristic of Katwick Islands (highest tide – 3.3 m); regular diurnal tides are characteristic of Thu Islands and Baytylong Archipelago (highest tide in Thu Island– 2.6 m, Zanzola Island and Daochao Island – 3.9 m); irregular diurnal tides are characteristic for Re, Thiam and Ze islands (highest – 2.4, 2.3 and 3.4 m respectively).

The material was collected according to the method of chorological investigation in the intertidal zone (Kussakin et al., 1974; Kussakin, Kostina, 1996; Ivanova et al., 2001). A hydrobiological transect was performed in the surveyed area of the intertidal zone perpendicularly to the coastline. The distribution of intertidal communities was provisionally estimated visually. The communities were distinguished in this case by dominating (usually belt-forming) species of the macrobenthos. The survey areas were bounded by metal frames 250 and 500 cm^2 in area on loose substrates and 100, 250, and 500 cm^2on the rocky reef. When collecting samples in communities of small evenly distributed objects, we used smaller frames, as opposed (to collection in the communities of relatively large species or species that were randomly distributed and not so common. We took two or three samples in each community. To remove bottom deposits from the macrobenthos samples, we used a set of soil meshes. The collected samples were analyzed, all the organisms were registered and, after drying on a filter paper, weighed using pharmaceutical scales accurate to 10 mg; large plants were weighed on a technical balance accurate to 1 g. The obtained data were extrapolated for 1 m^2. The biomasses presented in the paper including shells, and other skeletal structures are provided as wet weights. The collections were fixed in 75% alcohol or 4% formalin. In total, 12 hydrobiological transects were made in the intertidal zone, 50 quantitative and 75 qualitative samples of macrobenthos were collected.

The collected animals and plants were identified by specialists of A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch, Russian Academy of Sciences (IMB), Institute of Marine Research of National Science Centre of Vietnam (IMR), Pacific Institute of Bioorganic Chemistry, Far Eastern Branch, Russian Academy of Sciences (PIBOC), Pacific Research Fisheries Centre (TINRO-Centre), Far Eastern State Marine Biosphere Natural Reserve, Far Eastern Branch, Russian Academy of Sciences (FESMBNR), Far Eastern Federal University (FEFU), Zoological Museum of Moscow University (ZMMU), Zoological Institute of Russian Academy of Sciences (ZIN), A.O. Kovalevsky Institute of Biology of Southern Seas, National Academy of Sciences of Ukraine (IBSS): plants – by I.S. Gusarova (TINRO-Center) and Nguen Hiu Zin (IMR), Spongia – by V.B. Krasohin (PIBOC), Hydrozoa – by A.V. Moshchenko (IMB), Anthozoa – by Yu.Ya. Latypov (IMB), T.N. Dautova (IMB), A.N. Malyutin (FESMBNR) and – by E.E. Kostina (IMB), Polychaeta – by A.V. Ozolin'sh (IMB), Sipuncula – by V.V. Murina (IBSS), Cirripedia – by A.Yu. Zvyagintsev (IMB), Isopoda – by M.V. Malyutina (IMB), Amphipoda – by V.A. Kudryashov (FEFU), Decapoda and Stomatopoda – by Nguen Thanh Van (IMR), Loricata – B.I. Sirenko (ZIN), Gastropoda (Prosobranchia) – by G.A. Evseev (IMB), V.B. Darkin (IMB) and Yu.M. Yakovlev (IMB), Gastropoda (Opisthobranchia) – by A.V. Martynov (ZMMU) and M.V. Malyutina (IMB), Bivalvia – by G.A. Evseev (IMB), Asteroidea and Echinoidea – by Yu.M. Yakovlev (IMB), G.S. Vasina (FEFU), E.E. Kostina (IMB), Ophiuroidea – by I.S. Smirnov (ZIN) and V.I. Fadeev (IMB), Holothurioidea – by V.S. Levin (IMB), Pisces – by V.E. Gomelyuk (IMB) and V.B. Sakharov (IMB). Classification of zonal-biogeographical terminology is given in details by O.G. Kussakin (1990) and K.A. Lutaenko (1993). Schematic distribution of the macrobenthos in the intertidal zone was drawn by G.S. Vasina (FEFU).

3.0 Results & Discussion

3.1 BIODIVERSITY OF STONY AND SOFT CORALS IN THE CORAL REEFS' ECOSYSTEMS OF VIETNAM

Located within the global centre of marine biodiversity, the South China Sea supports immensely rich corals diversity (Fig. 4). 50 of 70 coral genera, 20 of 50 seagrasses species and 7 of 9 giant clam species are found in the nearshore areas of the South China Sea (Hoeksema, 2007). Such richness in flora and fauna contributes to the area's high natural rates of primary and secondary production. The coral reefs considering as high productive marine ecosystems provide an important life support to the coastal states surrounding the South China Sea especially through food from reef-dependent fisheries and invertebrate species. The value of the products and ecological services provided by the coral reef systems of the South China Sea is estimated at US$ 13,792 million per year (considering one third of coral areas of the South East Asia are located in the South China Sea and have value of US$ 6076 $ha^{-1}year^{-1}$). In addition, coral reefs are important breeding and nursery grounds for many pelagic and demersal fish species found in the open sea. These reefs provide the source of larvae and juveniles of fish and invertebrates that support the capture fisheries in the surrounding ocean. In fact, the future of the coral live-fish trade in the region is still dependent on wild brood stock from the reefs.

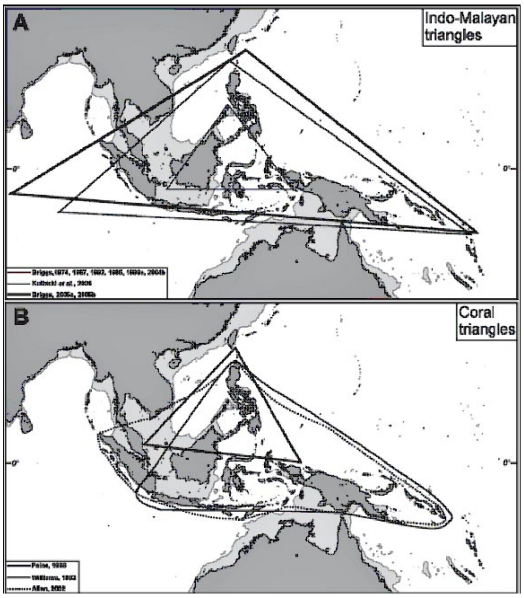

Fig. 4. (**A**) Briggs' (1974) Indo-Malayan centre of marine biodiversity depicted as the "East Indies Triangle" (Briggs, 1987). His later version (Briggs, 2005a) is slightly larger, including all of Sumatra, and therefore more similar to the Coral Triangle indicated by Allen (2002). Kulbicki et al. (2004) refer to a centre of fish diversity, which they call "the Philippines–South China Sea–Indonesia triangle"; (**B**) The centre of maximum diversity presented as coral triangles (Paine, 1988; Allen, 2002). The centre of reef-associated pennatulacean octocorals is also presented as a triangle (Williams, 1993). After: Hoeksema, 2007.

Naturally, the coral reefs condition and biodiversity are influenced by changes of wave and current regimes, climate, morphological processes and fluxes of materials between land, atmosphere and oceans. These processes are causes of high natural variability of the coastal coral reefs which is still imperfectly understood. In the last several decades, with their increasing technological capabilities, humans have accelerated the rate of change and increased their influence on already highly variable ecosystems. Pollution, eutrophication, changing sediment load, urbanisation, land reclamation, overfishing, mining and tourism continuously threaten the future of coastal coral reefs.

The high level of biodiversity is considered as the essential requirement for the resilience of the coral reefs. A resilient coral reef' ecosystem can withstand shocks and restore itself when necessary. Resilience factors extrinsic to the biological characteristics of the community include physical factors, such as current patterns that may favor larval dispersal among sites or physical conditions that enhance coral survivorship and growth. For corals (and for most marine species) dispersal depends on currents and other processes (such as eddies) that deliver larvae to the settlement site and even concentrate them at certain locations (Dayton et al., 2000). Thus, patterns of connectivity should be considered in the design of any MPA network meant to maximize resilience. Besides oceanographic conditions at local or regional scales, other, local physical parameters at a site can also affect resilience. Hence, reefs with effective management in place—such that direct anthropogenic stresses are kept to a minimum in that area—are likely to have a higher resilience after bleaching episodes than reefs that are already suffering from multiple stressors (Salm and Coles, 2001).

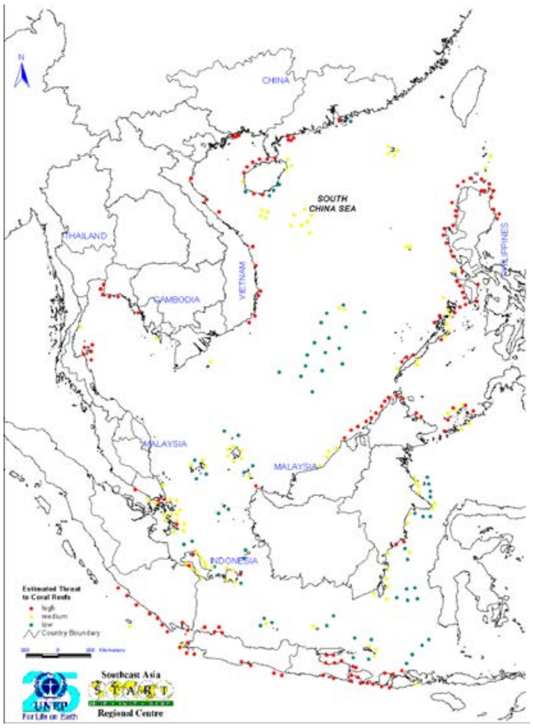

Fig. 5. Distribution of coral reefs in the South China Sea (UNEP SCS/SAP Ver. 3, 1999).

The scientific investigations of the corals and coral reefs of Vietnam are conducted since 20th century beginning. Surveys were carried out from aboard *De Lanessan* vessel at Spratly Islands and Paracel Islands from 1920-30 (Chevey, 1935; Krempf, 1930). Subsequent surveys recorded the species composition of stony corals, and the structure and distribution of several coral reefs in Ha Long Bay, the Gulf of Thailand, Con Dao Island, the and coastal areas of central Vietnam (Serene, 1937; Dawydoff, 1952). Most scientific studies during the first half of the 20th century were conducted by foreign scientists and published in French. During the last decades, a range of government-funded research programs on the coral reefs communities were undertaken in Vietnam due to collaboration between institutions of the Russian Academy of Sciences and Vietnamese Academy of Sciences and Technology. Basic studies on coral reef distribution, structure, and species composition were undertaken as part of these collaborative research initiatives. Documentation of this work published in the scientific literature provide information regarding coral distribution, coral reef communities, reef-building coral species composition, and the status of coral reefs in Vietnam's coastal areas and at the Spratly Islands (Latypov, 1982, 1987, 1990, 1992, 1995, 2003; Nguyen Huy Yet, 1991, 1993, 1994, 1996; Vo Si Tuan and Nguyen Huy Yet, 1995; Vo Si Tuan and Phan Kim Hoang, 1996; Vo Si Tuan, 1998). The survey results during last 15 years show that the area of coral reefs has been reduced in 15-20%, mainly at coastal waters of the central part of Vietnam from Da Nang to Binh Thuan province (KT.03.11 "Special Program on South China Sea"). Coal dust has caused the death to large areas of corals in the Ha Long and Bai Tu Long bays (Quang Ninh Province). Together with the coral reef area reduction the number of species is also reduced. For example, while the coverage of coral reefs in Bai Tien area (Nha Trang) is 30% (1984), there was 60 species and as it reduced to 1% (1988) the number of species became 30. Other living organisms are also reduced in number significantly (UNEP 1998).

At present, all countries in the South China Sea have degraded reefs, from 95% in Hainan Island to an unknown amount in Vietnam (Fig. 5). Sustainable use and protection of the SE Asia coastal reefs are now items which stay in the focus of the international agendas. The several projects were undertaken in the region: ASEAN-Australian Living Resources programme, UNESCO-UNDP mangrove project, ASEAN-USAID coastal management programme, and ADB/ESCAP/UNEP coastal area management programme, etc. The developed international instruments, such as the United Nations Convention on the Law of the Seas (UNCLOS) and the United Nations Strategic Action Programme for the South China Sea (UNEP SCS/SAP, 1999) aimed to provide important mechanisms for understanding of marine coastal ecosystems changing and their management.

Coral reefs and the stony corals of Vietnam - biodiversity and resources under the different level of the press of environmental factors

The coastline of Vietnam extends for some 3,260 km through more than 15 degrees of latitude from 8°30'N to 23°N and shows a variation in climate and biodiversity along this broad N-S cline. The country has more than 3,000 inshore and offshore islands and islets which extend to claims covering the Spratly and Paracel Archipelagos. There are broadly five distinct marine areas that differ according to coral diversity (Fig. 6): (**1**) western Gulf of Tonkin, (**2**) middle central, (**3**) south – central, (**4**) southeastern and (**5**) southwestern (Vo Si Tuan, 1998).

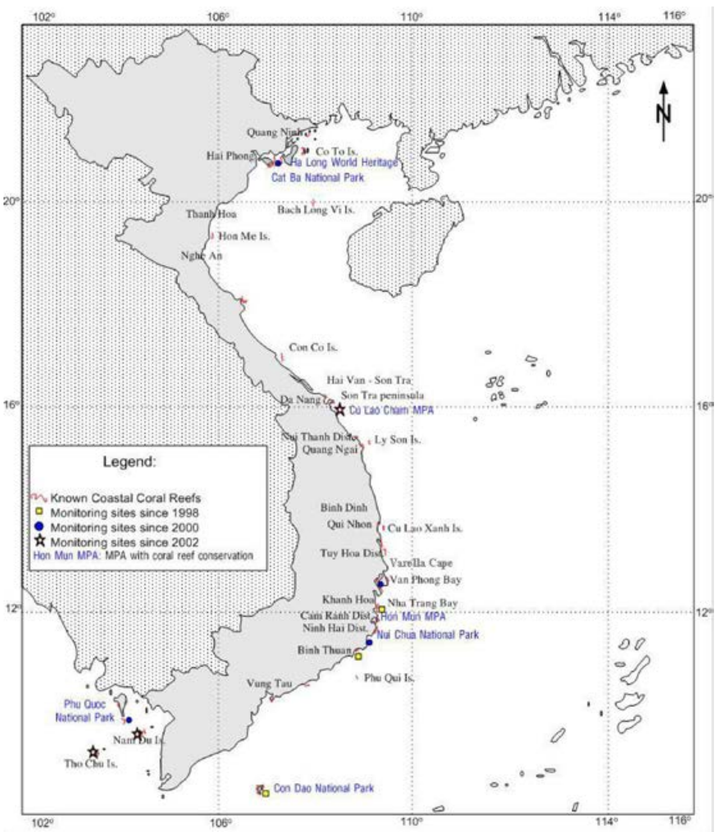

Fig. 6. Coral reefs distribution in the coastal waters of Vietnam including monitoring sites and MPAs (Vo Si Tuan et al., 2006).

The first data on the coral fauna of the **Gulf of Tonkin** with a reference to several scleractinian and gorgonian coral species were obtained by an expedition aboard the R/V *De Lanessan* (Serene, 1937). In the late 1930s, some investigations were undertaken by Dawydoff in Ha Long Bay. The results were included in Dawydoff's list of bottom invertebrates of Indochina (Dawydoff, 1952). The list and general remarks on the distribution of separate animal groups gave one a clear insight into the peculiarities of the Vietnamese fauna. However, Dawydoff's report, as well as that by Serene, contain limited data on the corals of the Gulf of Tonkin, namely, as few as some 20 generic and specific names from different cnidarian groups. In 1958, a joint Chinese-Soviet expedition worked on Hai Nan Island. Mainly focused on studying the reefs in the littoral zone of the northern and southern coasts, the work resulted in new data on the taxonomical composition of reef-building corals and virtually the first data on the reefs of the Gulf of Tonkin (Naumov et al., 1960). There were noted out 37 scleractinian taxa of the generic and specific level and elucidated the peculiarities of their distribution. In 1960-1961, joint Vietnamese-Soviet expeditions were performed with the purpose of a complex study of the Gulf of Tonkin. A hydrobiological survey was conducted all over the gulf at 105 stations at a depth of 5-157 m, as well as several littoral areas of the Bai Tu Long Archipelago and Hai Nan Island (Fig. 7). Based on these studies, a list of some 900 bottom invertebrates was composed. Its analysis, as well as the faunistic characterization of the region, has retained its fundamental importance for the description of the demersal fauna and its environment in the South China Sea to the present time (Gur'yanova, 1959, 1972). Since the survey was mainly restricted to soft ground areas, the reefs and reef corals of the gulf were scarcely studied. The lists of the demersal fauna comprised as few as 12 scleractinian names, most of which were generic ones. This allowed Gurianova to conclude that the sedentary coelenterate fauna of the Gulf of Tonkin cannot be compared to that of the South Vietnam and that "madrepore corals only form reefs off Hai Nan Island" (Gur'yanova, 1972).

Fig. 7. Numerous islands containing fringing reefs, Bai Tu Long Archipelago, Gulf of Tonkin.

In 1984-1990s, eight joint Russian-Vietnamese and independent Vietnamese expeditions occurred in the western part of the Bai TuLong Archipelago. In these expeditions, the reefs of the archipelago's largest island, Cat Ba Island, and the six islands closest to it were studied (Latypov, 1992b; Malyutin and Latypov, 1991; Ken, 1991; Latypov, 1995; Yet, 1989). The studies resulted in a detailed description of the structure and composition of communities of structural and unstructured reefs.

The dependence of the corals biodiversity from the complex of environments in the Gulf of Tonkin showed the significant correlation between number of stony coral species and sedimentation regime at the coral reef (Latypov and Dautova, 2005). On surveyed reefs, the number of species ranged from 62 (Cong Tau Island) to 105 (Cong Do Island). Collecting the data on the both corals biodiversity and local physico-environmental conditions, it becomes possible to analyze the trends in the coral fauna richness in the gulf from the ecology-dependent point of view. Silting significantly hampers the settlement and attachment of coral larvae to substrate, as well as the formation of coral colonies. The mean annual amount of suspended matter equals 5–10 mg/l and is not considered critical for coral settlements located on fringing reefs. However, when sediment is resuspended by tidal currents, this index can exceed 20 mg/l, while under the effects of a storm it may grow further, reaching values an order of magnitude greater. Sedimentation flux in the near-bottom water layer exceeds 30 mg/(cm^2 per day), decreases the species diversity and population density of corals on the reefs, and results in an increasing proportion of scleractinians tolerant against intensive sedimentation. In calm weather, the mean values of sedimentation flux on the reefs of the Bai Tu Long Archipelago do not exceed 6–7 mg/(cm^2 per day). However, the data obtained during a typhoon provided evidence that during storm season the sedimentation flux in open bays can be several times greater. The reefs in the Gulf of Tonkin, significantly differing in the intensity of sedimentation flux, integral water exchange, and sediment resuspension above coral settlements in both open and closed bays, differ respectively in the composition of the stony corals and their diversity. The smallest species diversity was characteristic of reefs on capes and in straits, whereas the greatest one was registered on the reefs in bays.

The most similar in composition (88% of common species) and structure were coral communities of large bays with low sediment loading on the corals (Bo Hung and Cong Do Islands). Bo Hung Bay is larger and open. A community of *Acropora aspera* + *Goniopora columna* has developed there, which is dominated by *A. aspera* in both degree of substrate coverage (40% and more) and the size of colonies (3–7 m in diameter). The corals of the second species formed colonies up to 1.5 x □1.5 m in size
acropores, the aggregations of fungiids (*Fungia fungites, F. scutaria, F. repanda,* and *Sandalolitha robusta*) are occurred with density of settlements to 17 ex/m^2. The diversity of other corals rarely exceeded 10–15 species. In the lower part of the slope, a polyspecific coral community characterized by greater diversity in the number of species and shape of colonies has developed. No domination of any certain species has been registered. The conspicuous large (1.5–3 m in diameter and 1–1.5 m high) colonies of *Lobophyllia hemprichii, Pavona decussata, Merulina ampliata, Micedium elephantotus, Podobacia crustacean, E. echinata, P. lobata, G. columna, and G. fascicularis* live at the reef' slope zone.

Reefs located around capes and in straits are characterized by a greater amount of suspension in both the water column and the near-bottom horizon. On the other hand, probably due to relatively intensive integral water exchange, on these reefs a relatively great degree of sediment resuspension is observed immediately above the coral settlements. The removal of the bulk of precipitating sediment might benefit the development of monospecific scleractinian settlements in large areas, a phenomenon was observed at the Cong Tau and Van Boi Islands. The community of *Acropora aspera* registered in the area of the reef slope on Cong Tau Island stood out because *A. aspera* there provided almost 100% substrate coverage in 2- to 10-m-wide bands. Inside the thickets of *Acropora*, the monosettlements of *G. fascicularis* and *G. columna* occupie 30–70 m^2. At deeper depths (toward the middle part of the reef slope), a zone of *Acropora aspera* + *Goniopora columna* developed, where the *Acropora* occupy no more than 40% of the substrate and *Goniopora* covers up to 15% of the substrate. In this zone, different species of other corals have been registered (*Acropora, Montipora, Pavona, Favia, Favites, Cyphastrea, Leptastrea, Pectinia*, and *Micedium*), as 20 ex/m^2 and isolated alcyonarians of the genus *Cladiella*. In the lower part of the slope, massive and encrusting colonies of the genera *Lobophyllia, Symphyllia, Echinophyllia, Porites, Podobacia, Turbinaria, Merulina,* and *Pectinia* and various faviids were common. The soft corals *Cladiella, Sinularia* and *Sarcophyton* were common at the base of the slope, while the Acropora, dominating the upper part of the slope, was represented only by isolated colonies showing densities of 3 to 7 specimens/m^2 (Latypov and Dautova, 2005).

The important role of massive *Porites* corals is one of the bright peculiarities of the Gulf of Tonkin reefs. As a rule, *Porites* species predominate in the reef flat, especially in its inner part, and in the reef slope, where they often form microatolls **(**Khomenko, 1993; Latypov and Dautova, 1996; Latypov, 1995). The combined action of a number of factors such as biogenic content increase, sedimentation rate, water turbidity and toxicity resulted in a decrease in the species diversity and favored predominance of *Porites* on several studied reefs (Fig. 8). Together with *Siderastrea radians* and *Agaricia agaricites, Porites* corals were most abundant in most contaminated reefs. The average projective coverage of *Porites* species varied there from 25.2 to 66.6%, which can be attributed to their high resistance to the complex environmental stress (Tomascik and Sander 1985, 1987). The similar coral communities structure is observed at the reefs off Singapore and in the Gulf of Thailand, the Great Barrier Reef (Australia), and the eastern coast of Africa, where massive *Porites* predominate and form continuous settlements under similar conditions (Hamilton and Brackel, 1984**,** Chou and Teo, 1985; Potts and Done, 1985; Latypov, 1986; Sakai et al., 1986).

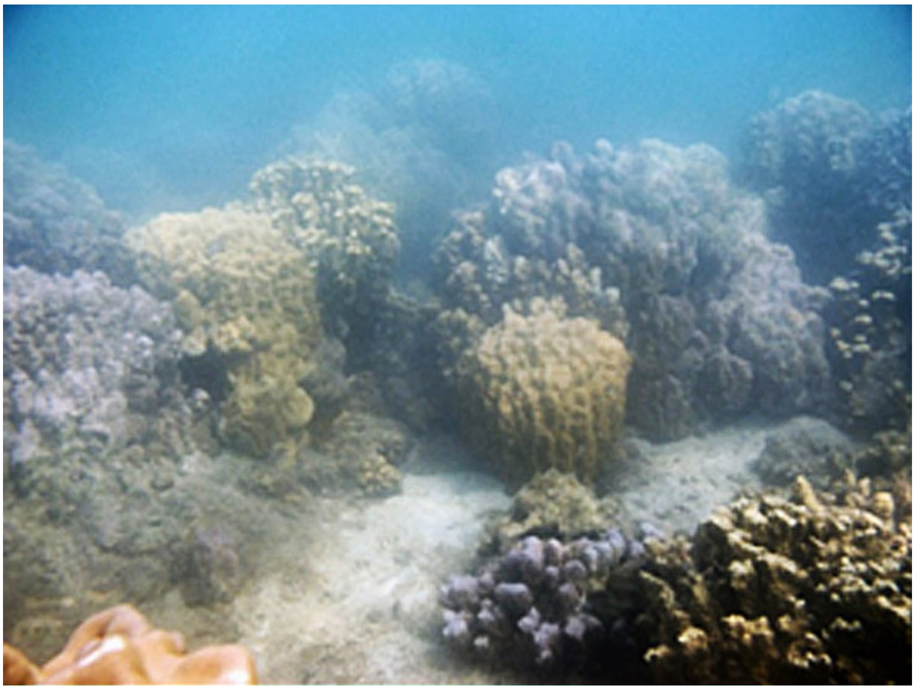

Fig. 8. The stony corals community dominating by massive colonies of the *Porites* corals.

In terms of the environmental conditions suitable for the growth of reef-building coral species, the coastal areas of western Tonkin Gulf are very far from favorable for reef development. This is largely due to low water temperatures during the winter months, and large contributions of freshwater and sediments to this part of the gulf from adjacent river systems. Corals are mainly observed in areas of Ha Long Bay, Bai Tu Long, the Co To Archipelago, and Long Chau Islands, which are mostly surrounded by shallow and muddy bottoms. The coral reefs that have developed in the western Tonkin Gulf are typically narrow and extend to a depth of only 5-7 m. Coral reefs have developed at depths of 10 m in areas adjacent to Bach Long Vi Island (Latypov 2003). The reefs of the Bai Tu Long Archipelago are partly formed by encrusting colonies of *Merulina, Podobacia, Echinophyllia,* and other species, which are present in all reef zones, whereas in most Indo-Pacific reefs, the distribution of these species is limited to the reef slope base. Another peculiarity of the reef community studied is the abundance and diversity of ahermatypic corals of the Dendrophylliidae family, most of which lack symbiotic algae zooxanthellae. These corals make up one-fifth of the entire number of scleractinian species, while in the Indo-Pacific reefs; the proportion of dendrophylliids rarely exceeds 5-10% at a depth of 40 m (Latypov, 1990). Thus, the reefs of the northern part of the Bai Tu Long Archipelago may be considered a stable ecosystem, adapted to low illumination conditions as a result of heavy water silting and eutrophication. The reef communities in this region are formed by both hermatypic corals, capable of surviving under low illumination conditions, and ahermatypic corals, whose distribution does not depend on the illumination level (Latypov and Malyutin, 1990).

These peculiarities make the reefs of the Gulf of Tonkin really unique. Promoted in the conservation of reefs as an integral part of the natural complex, a component of the national wealth of Vietnam, and the property of mankind, the governing body of the National Center for Natural Science and Technology of Vietnam was informed that special attention should be given to the reefs of Bo Hung and Cong Do islands. The conservation and recovery of the high biodiversity of reef communities in these regions should be considered a first priority task in the framework of creating reserves and conservation areas in the Gulf of Tonkin.

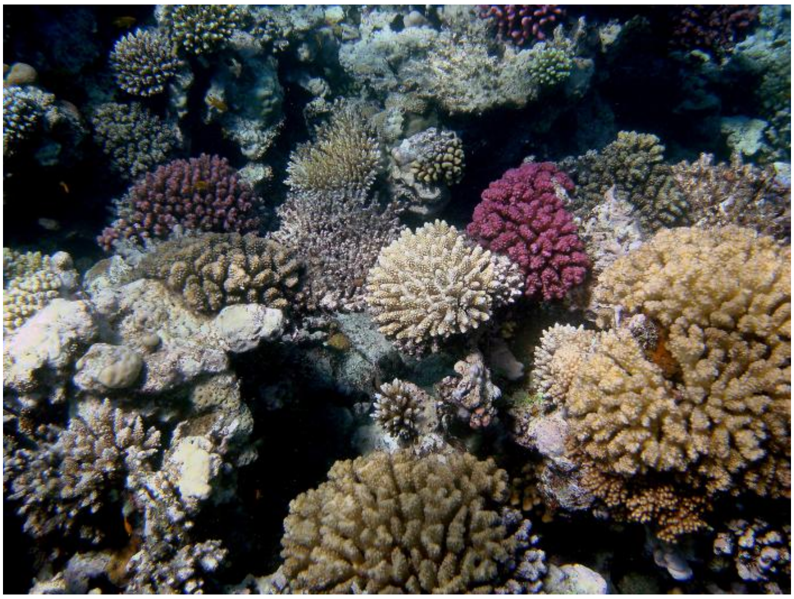

Fig. 9. The settlements of diverse species of branched stony corals *Acropora* and *Pocillopora*.

In the coastal waters of the **central Vietnam, c**onditions for coral reef development are more favourable, as well as adjacent to the **islands offshore southeastern region**. Water temperatures in these areas are normally higher than 25°C, with predomoninantly offshore influences. The coastal areas in the central Vietnam have been known as less impact of waterways system. Turbidity surveys indicate that the central area has the highest transparency in both seasons (La Van Bai, 1991). In particular, in Nha Trang Bay sedimentation flow ≤ 46 g/m^2 per day (registered in 2003 and 2004) is not dangerous for corals (Dautova 2008). The bay is considering as hot spot of stony corals diversity in Vietnam (351 species: Vo Si Tuan, 2002). The relationship between biodiversity and sedimentation regime was preliminary supported using nonlinear multidimensional regression analysis for the reefs of Nha Trang Bay (Dautova and Parensky, 2006). Cai and Be Rivers are sources of the terrigenous influx in the bay. The gradient of the sedimentation was shown for the September-October 2003 and May-June 2004 years (Fig. 10). Coral cover and coral diversity are increasing along with the gradient. The most diverse coral settlements are registered in fare most part of the bay. Level of dominance in the coral communities on these reefs is low. The dominating role is attributed to branched and foliate corals (*Acropora, Montipora, Pocillopora*, Fig. 9).

Near the rivers mouths is suggested the intensive increasing of the suspended matter due to the stronger wave activity and thickness of the soft grounds. Suppressed reefs are observed in the near-shore bays of Vietnam. Low wave energy conditions enable the development of corals to depths of 5-7 metres. Reefs may extend up to a width of 150m, but are usually characterised by a low number of species of mostly massive corals and thin staghorns. Big staghorn and massive *Porites* dominate such reefs in Dam Bay at Mieu Island (Nha Trang Bay) and in other areas such as Co Co Canal between Van Phong and Ben Goi Bays (UNEP, 2004). Reefs rounded Mieu Island survived the destruction of the *Acropora* dense settlements in 1970th years. Then, in 1980th years there were find out new settlements of the corals, mainly massive *Porites.* In 2003-2008 these coral reefs are poorly developed and composed mainly *Porites* and *Montipora digitata* (Dautova, pers. comm.). Because there is typically no reef flat to prevent sedimentation on the reefs, very few coral species are adapted to survive under such conditions (Grigg and Dollar, 1990).

In general, the data indicate higher species diversity at the deeper offshore reefs. Exposed reef exist in areas of high wave energy. Drains normally divide seafloor terrain in such areas, and the substrate is normally rock and some sands, and dead corals in the channels of deep drains. However, studies also showed that the coral reefs at those areas are in danger of sedimentation from the rivers in the rainy season. The coastline in these areas is comprised of a diverse range of small bays and islands, which contributes significantly to the diversity of coral reef areas in these regions. It is highly concerned that high water turbidity has not only locally occurred, but also expanded to a large area, where corals are currently distributing.

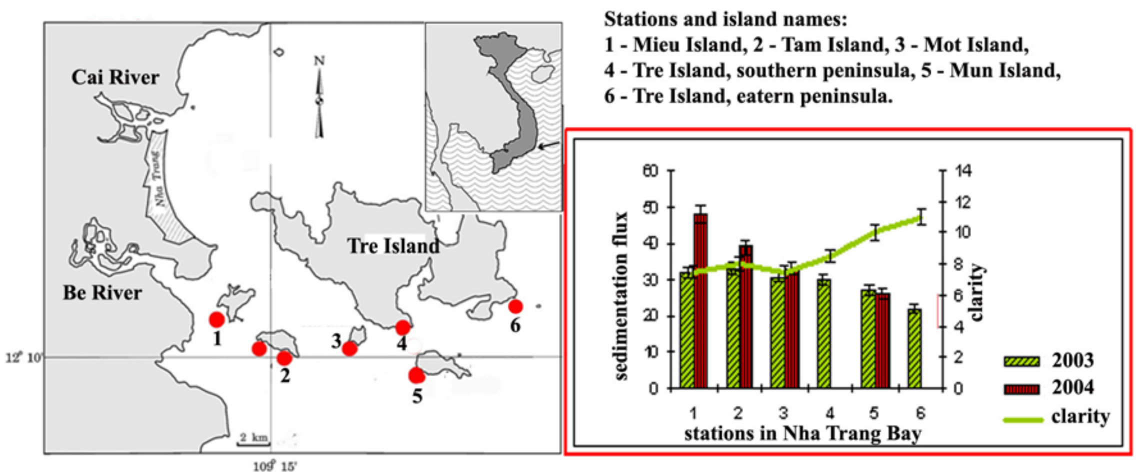

Fig. 10. The gradient of the sedimentation was shown for the September-October 2003 and May-June 2004 years in Nha Trang Bay.

Coral reefs are a main coastal habitat around islands such as Cu Lao Cham to Con Dao, and extend along the coastline from Danang to Binh Thuan Province. Fringing coral reefs are very diverse in their morphology and range in width from 50 to 800 m. Many reefs have developed on submersed banks, which are common on the continental shelf. Reef-building corals may distribute down to 15m deep but account for a small proportion of overall coverage. Zone division at such sites is not obvious, but are typically dominated by *Acropora, Pocillopora*, or soft corals. Staghorn corals are normally observed at the ends of such reefs. Semi-enclosed reefs represent those reefs that are partly encolsed by edges, islands, or submerged rocks. Such sites are usually characterised by well-developed formations of large reef-building corals. They can also be highly diverse in terms of both species composition and colony morphology. Overall coral reef coverage on these reefs is high, and is normally comprised of foliate coral *Montipora* and staghorn corals *Acropora* in the shallow water areas, to massive corals *Porites* and *Diploastrea*, foliate corals *Pachyseris* and *Echinopora*, and cup-sharp *Turbinaria* in deeper waters. The above-analyzed results showed that the untypical fringing reef had much more complicated morphology to compare with typical fringing reef. In qualitative, untypical reef had higher ratio in most of the study areas (Table 1). Typical fringing reef just had relatively high number in Con Dao, Ninh Thuan and northern Binh Thuan province.

Coastal waters of southwestern Vietnam in the Gulf of Thailand are not ideal for coral growth because of muddy bottoms and highly turbid waters. Coral reefs have developed in areas adjacent to the offshore islands of Phu Quoc, Nam Du, and Tho Chu. The reefs of these islands are relatively similar in terms of morphology as there are minimal fluctuations in the hydrological regime and hydrodynamics of the area. These reefs are normall 50-100m wide and spread to a depth of 10-13m. Detailed investigations conducted at the Nam Du Islands indicated that such reefs are normally less affected by wind and waves. Small colonies of staghorn corals *Acropora* and massive *Porites, Goniastrea,* and *Platygyra* are observed in nearshore zones. On the partially developed reef flats, staghorn *Acropora* dominate, often with mono-specific stands several hundreds metres wide. Reef slope are typified by massive corals *Favia, Cyphastrea* and *Physogira*, cup-sharp *Turbinaria* (southern Tho Chu Island), or foliate corals *Pachyseris* (southern Bay Canh Island of the Con Dao Island group) (Latypov, 1986). The morphological structure of untypical fringing reefs is highly influenced by coastal hydrodynamics. That hydrodinamics processes can cause the quite heavy-loaded sedimentation regime related to the neighborhood of the Mecong River mouth.

Similar coral species composition of the Gulf of Tonkin and Gulf of Thailand can be caused by the environmental conditions. On the one hand, the shallowness of both gulfs and high eutrophication and turbidity of their waters, caused by mainly clayey fractions, result in the similarity of their reef communities to one another. From the other hand, the geographical remoteness of the two regions and the difference in their geomorphological conditions cause some differences in the composition of the coral communities of the gulfs. To date, members of the genera *Palauastrea* and *Caulastrea,* as well as *Acropora palifera,* common to most reefs, have been found in neither gulf. Members of the genera *Plerogyra* and *Physogyra* were not encountered in the Gulf of Tonkin, and members of *Pachyseris, Micedium,* and *Pectinia* have not been registered thus far in the innermost and nearshore parts of the Gulf of Thailand. However, some species of the latter three genera, as well as rarely occurring members of *Physogyra* and *Plerogyra* were found in the open parts of both gulfs, off Hai Nan and Tho Chu islands. It is noteworthy that the members of the genera distinguished for large polyp size—*Galaxea, Echinopora, Lobophyllia, Echinophyllia, Turbinaria, Podobacia, Lithophyllon, Fungia,* and *Goniopora*—were widespread in both gulfs. Most reef communities are dominated by numerous species of these genera, in particular, *Galaxea fascicularis, Goniopora stokesi, Echinopora lamellosa,* and *Lobophyllia hemprichii,* as well as by *A. cytherea, A. nobilis, A. hispida, P. lobata,* and *P. cylindrica,* which are widespread in all Indo-Pacific reefs. The former species occupy as great an area as 60-80% of the substrate surface. Another feature shared by the two gulfs is the wide distribution of massive *Porites* colonies, forming vast monospecific settlements and exhibiting a huge diversity (not less than 10 species). As opposed to *Porites,* five to seven *Pocillopora* species forming mass settlements in the majority of the Indo-Pacific reefs are extremely rare in the Gulf of Tonkin and Gulf of Thailand. No more than two Pocillopora species are to be found in the gulfs; the only exception are the reefs off Tho Chu and Hai Nan islands, situated in the open parts of the gulfs, where *Pocillopora* species are common. On the whole, the species compositions of scleractinians of the two gulfs are quite comparable, both qualitatively and quantitatively. The gulfs share 71.7% of their total numbers of scleractinian species. The differences between the gulfs in coral species composition are apparently due to the inequality in the progress of their study. Totally, 61 reefs in different regions of the Gulf of Tonkin were studied. In all coral species were identified and their zonal distribution and structure of their communities were determined along with the level of the predominance of certain coral species. This is not only indicative of the high diversity of coral species in the region studied but also enables their faunistic comparison with the reefs of other parts of the South China Sea. So, it was find out that the coral faunas of the Gulf of Tonkin and the Gulf of Thailand share more than two-thirds of the species. The high diversity of corals in these regions, as well as in the most of the Indo-Pacific reefs, is mainly due to the diversity of acroporids, comprising 28.5% of the coral species composition and forming monospecific settlements, often occupying a considerable proportion of the reef areas. At the same time, the studied reefs in Tonkin Gulf and those of the other regions of Vietnam and the South China Sea have 55-65% common species **(**Latypov 1992, 2003; Veron 1995). To date, the state of the art in the study of reefs of the Gulf of Tonkin is quite comparable with that of the Australian, Indonesian, and Philippine reefs (Best et al. 1989; Veron 1989; Latypov and Dautova 1998).

Soft corals (Octocorallia: Alcyonacea: Alcyoniina) **in Vietnam can** deserve the high interest due to their abundance in marine bottom ecosystems as well as they are source of the pharmacologically important compounds. There are 35 genera of soft corals distributed over 15% of the region (Dai 1990; Fabricius 1997; Fabricius and Déath 2001; Fabricius and Alderslade 2001). However, up to date, information sources on the soft corals fauna for SE Asia are scarce. Surveys carried out in some selected areas of central and southern Vietnam (Tixier-Durivault 1970; Malyutin 1990, Nguyen Huy Yet 1994, 1996; Dautova and Savinkin 2009; Dautova and Ofwegen 2010) show the quite high level of generic diversity of soft corals. The warm water of the Kurioshio Current passes east of the Philippines to southern pacific side of the Japan and intrudes into the South China Sea moving along of southern Taiwan. It can influence on the corals richness on the reefs of the central part of Vietnam as well as southern Taiwanese reefs. Really, the stony corals fauna of the reefs of Central Vietnam is quite rich both at genera and species levels, and, moreover, the several species of the *Porites* genus which were firstly described from Philippines. The same situation can be considered concerning with Octocorallia fauna of the region. The preliminary Alcyonacea list of the soft corals (with *Briareum* genus) of Nha Trang Bay includes 27 genera; the *Sinularia* species list has 36 “old” species and a range of the new species. The reefs of the southern Taiwan contain 22 genera including *Sinularia* (Table 1). The lacking of the genera *Anthelia, Asterospicularia, Cespitularia* and *Heteroxenia* in the list of Vietnamese soft corals is probably because of the missing data and requires more detail study. However the presence in Central Vietnam of the most of Nephtheidae genera as well as longer list of Sinularia species may be considered as a result of the direct connection of the region with Coral Triangle in addition to the Kurioshio influence. The single finding in SCS of the *Sinularia yamazatoi* which species was before recorded only at Southern Ryukyu shows that this species: a) probably has the dispersal from the Indo-Malayan centre; b) may be rare and due to it is not recorded on Taiwanese reefs; c) can pass into the Vietnamese waters both directly from Coral Triangle and by Kurioshio influx. The recent Indonesian finding of the *S. mammifera* which species was described from Vietnam (Manuputti and Ofwegen, 2007) anticipate the same.

Table 1

List of the soft corals genera of the orders Helioporacea Bock, 1938, Alcyonacea Lamouroux, 1816 (soft corals and Briareidae Gray, 1859) for Nha Trang Bay (Tixier-Durivault, 1970; Dautova, 2008) and Taiwan (Benayahu et al., 2004 with comments and list of previous records)

No	Genera	Nha Trang Bay,	Southern

		Central Vietnam	Taiwan
1	*Heliopora* Blainville, 1830	+	+
2	*Cervera* López-González, Ocaña, García-Gómez & Núñez, 1995	+	-
3	*Clavularia* Blainville, 1830	+	+
4	*Pachyclavularia* Roule, 1908	-	-
5	*Sarcodyction* Forbes, 1847	-	-
6	*Cornularia* Lamarck, 1816	-	-
7	*Carijoa* Müller, 1867	+	-
8	*Telesto* Lamouroux, 1812	-	-
9	*Paratelesto* Utinomi, 1958	-	-
10	*Pseudocaladochonus* Versluys, 1907	-	-
11	*Tubipora* Linnaeus, 1758	+	+
12	*Alcyonium* Linnaeus, 1758	-	-
13	*Anthomastus* Verrill, 1878	-	-
14	*Bellonella* Gray, 1862	-	-
15	*Dampia* Alderslade, 1983	+	-
16	*Cladiella* Gray, 1869	+	+
17	*Dampia* Alderslade, 1983	+	-
18	*Eleutherobia* Pütter, 1900	+	+
19	*Klyxum* Alderslade, 2000	+	+
20	*Lobophytum* Marenzeller, 1886	+	+
21	*Paraminabea* Williams & Alderslade, 1999	+	+
22	*Rhytisma* Alderslade, 2000	-	+
23	*Sarcophyton* Lesson, 1834	+	+
24	*Sinularia* May, 1898	+	+
25	*Capnella* Gray, 1869	+	+
26	*Coronephthya* Utinomi, 1966	-	-
27	*Daniela* Koch, 1891	-	-
28	*Dendronephthya* Kükenthal, 1905	+	-
29	*Duva* Koren & Danielssen, 1883		-
30	*Gersemia* Marenzeller, 1878	-	-

31	*Lemnalia* Gray, 1868	+	+
32	*Litophyton* Forckal, 1775	-	-
33	*Nephtea* Audouin, 1826	+	-
34	*Paralemnalia* Kükenthal, 1913	+	+
35	*Scleronephthya* Studer, 1887	+	+
36	*Stereacantha* Thomson & Henderson, 1906	-	-
37	*Stereonephthya* Kükenthal, 1905	-	-
38	*Umbellulifera* Thomson & Dean, 1831	-	-
39	*Chironephthya* Studer, 1887	+	-
40	*Nephthyigorgia* Kükenthal, 1910	+	-
41	*Nidalia* Gray, 1835	-	-
42	*Siphonogorgia* Kölliker, 1874	+	-
43	*Anthelia* Lamarck, 1816	-	+
44	*Asterospicularia* Utinomi, 1951	-	+
45	*Cespitularia* Milne Edwards & Haime, 1857	-	+
46	*Fungulus* Tixier-Durivault, 1987	-	-
47	*Heteroxenia* Kölliker, 1874	-	+
48	*Efflatounaria* Gohar, 1939	+	-
49	*Sansibia* Alderslade, 2000	+	+
50	*Sympodium* Ehrenberg, 1834	-	-
51	*Xenia* Lamarck, 1816	+	+
52	*Studeriotes* Thomson & Simpson, 1909	-	-
53	*Carotalcyon* Utinomi, 1952	-	-
54	*Briareum* Blainville, 1830	+	+
Total:		27	22

Note: "+" **–** the presence of the genus on reefs investigated, "-"– the genus is not recorded.

Fig. 11. Dense settlements of soft corals *Sarcophyton* (Octocorallia: Alcyonacea) on coral reef.

However, the data about the species diversity of the soft corals of Vietnam published in last decades are few (Tixier-Durivault, 1970; Malyutin, 1990; Nguyen Huy Yet, 1994, 1996; Dautova and Savinkin, 2009; Dautova and Ofwegen, 2010). Especially it concerns with the reefs located far from the mainland coast. Ly Son Islands, belonging to Quang Ngai province, are located in central part of Vietnam far 20 km from mainland. The environments in Ly Son could be discussed as differing from those at coastal reefs of Vietnam, whish reefs exist in the turbid, but calm waters. So, the soft corals species composition of Ly Son may be defined by considerably clearer water and strong waves/currents and represent the great interest in comparison with the data on the coastal soft corals of Vietnam. The checking of the soft corals biodiversity of the Ly Son Islands showed that the composition species recorded is 60 species belonging to 10 genera and 5 families recorded in Ly Son Islands. Among them, 33 species were identified as firstly recorded in Vietnam (Table 2).

Among the species identified the *Sinularia* genus has 14 species, *Lobophytum* has 9 species, *Sarcophyton* has 6 species and the each genera *Hicksonella, Paralemnalia, Nephthea, Xenia* have one species recorded in Vietnam firstly (Ben and Dautova, 2010). In that study the species identification was conducted using the information about the type material in concerning with the *Sinularia*, *Lobophytum* and *Sarcophyton* genera. This information concerns with the data on the taxonomy characters of the all existed species of these genera including the data on the skeletal elements (sclerites) which were not shown in the last revisions of the genera (Verseveldt, 1980, 1982, 1983). The information on the native shape of the soft coral colony was obtained using underwater photography, and the living colony shape was compared with preserved specimens. The *Sinularia* genus is the most abundant with 24 species, the subsequent genus *Lobophytum* is 15 species, *Sarcophyton* is 13 species (Fig. 11). The eight specimens were identified only to genus level; these species will discussed as new for science in the further study (Ben and Dautova, 2010).

Table 2

The list of the soft coral species at the stations studied in Ly Son Islands

No	Genera	Species	Stations				New record for Vietnam
			I	II	III	IV	
1	*Sinularia* May, 1898	*Sinularia abhishiktae* Ofwegen & Vennam, 1991	+	+			+
2		*S. arctium* Dautova & Savinkin, 2009	+				
3		*S. capillosa* Tixier-Durivault, 1970	+	+			
4		*S. ceramensis* Verseveldt, 1977		+			+
5		*S.* cf. *corpulentissima* Manuputty & van Ofwegen, 2007	+				+
6		*S. compacta* Tixier-Durivault, 1970				+	+
7		*S. conferta* (Dana,1846)		+			+
8		*S. cristata* Tixier-Durivault, 1969				+	+
9		*S. cruciata* Tixier-Durivault, 1970	+				
10		*S. densa* (Whitelegge, 1897)				+	
11		*S. erecta* Tixier-Durivault, 1945				+	+
12		*S. facile* Tixier-Durivault, 1970				+	
13		*S. fishelsoni* Verseveldt, 1970			+		+
14		*S. flexuosa* Tixier-Durivault, 1945	+				+
15		*S. granosa* Tixier-Durivault, 1970				+	
16		*S. inexplicita* Tixier-Durivault, 1970	+				
17		*S. minima* Verseveldt, 1971		+			+
18		*S. mollis* Kolonko, 1926		+			+
19		*S. nanolobata*, Verseveldt, 1977	+				+
20		*S. numerosa* Tixier- Durivault, 1970		+			+
21		*S. parva* Tixier-Durivault, 1970		+			
22		*S. polydactyla* (Ehrenberg, 1834)		+			
23		*S. querciformis* (Pratt, 1903)		+			
24		*S. cf brassica*, May, 1898	+				+

25	*Lobophytum* Marenzeller, 1886	*Lobophytum batarum* Moser 1919	+	+	+		
26		*L. compactum*, Tixier-Durivault, 1956		+		+	
27		*L. crassum,* Von Marenzeller, 1886		+		+	+
28		*L. delectum* Tixier-Durivault, 1966		+			+
29		*L. jaeckeli* Tixier-Durivault, 1956		+			+
30		*L. lighti* Moser, 1919				+	+
31		*L. pauciflorum* (Ehrenberg, 1834)	+		+	+	
32		*L. salvati*, Tixier-Durivault, 1970				+	+
33		*L. sarcophytoides* Moser 1919	+				+
34		*L. schoedei* Moser, 1919				+	+
35		*L. variatum*, Tixier-Durivault, 1957				+	+
36		*L. varium* Tixier Durivault, 1970				+	+
37		*Lobophytum sp.* 1		+			
38		*Lobophytum sp.* 2				+	
39		*Lobophytum sp.* 3				+	
40	*Sarcophyton* Lesson, 1834	*S.* aff. *boletiforme*, Tixier-Durivault, 1958		+		+	+
41		*S.* aff. *tenuispiculatum* Thomson & Dean, 1931	+				+
42		*S.* aff. *ehrenbergi* Von Marenzeller, 1886	+				
43		*S.* aff. *solidum* Tixier-Durivault, 1958	+				+
44		*S. birkelandi* Verseveldt, 1978		+			+
45		*S. cherbonnieri*, Tixier-Durivault, 1958	+			+	+
46		*S. cinereum* Tixier-Durivault, 1946			+		
47		*S. ehrenbergi* Von Marenzeller, 1886			+		
48		*S. elegans*, Moser, 1919		+			
49		*S. glaucum* (Quoy & Gainmard, 1833)	+			+	
50		*S. pulchellum* (Tixier-Durivault, 1957)		+			+
51		*S. serenei* Tixier-Durivault, 1958		+			
52		*Sarcophyton* sp.			+		

53	*Cladiella* Gray, 1869	*Cladiella* sp.			+		
54	*Xenia* Lamarck, 1816	*Xenia umbellata* Lamarck, 1816		+			+
55	*Tubipora* Linnaeus, 1758	*Tubipora musica* Linnaeus, 1758	+				
56	**Hicksonella* Nutting, 1910	*Hicksonella princeps* Nutting, 1910	+				+
57	*Paralemnalia* Kukenthal, 1913	*Paralemnalia eburnea* Kukenthal, 1913	+		+		+
58	*Nephthea* Audouin, 1826	*Nephthea brassica* Kukenthal, 1903			+		+
59		*Nephthea* sp.	+	+		+	
60	**Briareum* Blainville, 1830	*Briareum* sp.			+		
Total:			21	23	10	20	33

Note: * The genus is newly recorded for Vietnam.

Published data about the soft corals in the southernmost region of Vietnam (part of Gulf of Thailand) are very huge. However, in Thai waters, the Alcyoniidae was found to be widely distributed in all habitat types ranging from reef flats to fore reefs, to over 40 m in depth, covering true reefs and rocky substrates, and found on both inshore and offshore islands. Furthermore, it members often formed patches and covered large areas in monospecific carpets. At most of the inshore islands in the Gulf of Thailand where the Alcyoniidae was dominant, genera (i.e., *Cladiella*, *Sinularia*, *Klyxum*, and *Sarcophyton*) were affected by sedimentation (Chanmethakul et al., 2010). They are able to survive under heavy sediment loads (Schleyer and Celliers 2003). Alcyoniidae produce toxic secondary metabolites and are able to compete with scleractinian corals for space which is an important defense mechanism for surviving on reef habitats (Tursch and Tursch, 1982; Sammarco et al., 1983; Wylie and Paul, 1989; Van Alstyne et al., 1992; Griffith, 1997). It is suggested as a base for the greater probability of Alcyoniidae soft corals to occupy diverse habitats, especially in turbid environments of Thai waters (Chanmethakul et al., 2010). Considering the neighborhood of Thai waters to the Vietnam area in the Gulf of Thailand, it can be supposed the occurrence the similar fauna of the soft corals at the reefs of Phu Quoc and Con Dao Island. Based on oceanic circulation models (Hoeksema, 2007), the source of present-day soft corals in the Gulf of Thailand must have dispersed from the South China Sea/Pacific Ocean. That assumption may give a clear explanation of the boundary of soft coral distribution. Gulf of Thailand, which is situated in a more-oceanic environment in the southern part of the Gulf of Thailand, has the highest genera richness in the gulf. At that position, it may be a sink area for planula from other sources in the South China Sea and served as a "stepping stone" for the dispersal of soft corals within the gulf. The family Alcyoniidae had the highest percentage of occurrence in Thai waters, and *Sinularia*, *Dendronephthya*, *Sarcophyton*, and *Cladiella* were the dominant genera (Fig. 12). In total, 19 genera of soft corals were found in Thai waters, nine of them are newly recorded genera: *Dampia*, *Eleutherobia*, *Stereonepthya*, *Nidalia*, *Siphonogorgia*, *Chironephthya*, *Nepthyigorgia*, *Heteroxenia*, and *Sansibia*. Twelve genera were widely distributed throughout the Gulf of Thailand: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Eleutherobia*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia* , *Chironephthya* , and *Nephthyigorgia*. Some genera occurred in restricted locations and with low populations. The rare genera found in the Gulf of Thailand were *Dendronephthya*, *Scleronephthya*, *Nephthyigorgia*, and *Eleutherobia*. All of above listed genera are found in central of Vietnam already, so the detailed survey in southernmost region can clear the pathways of soft corals dispersal from the South China Sea or surrounded Pacific waters.

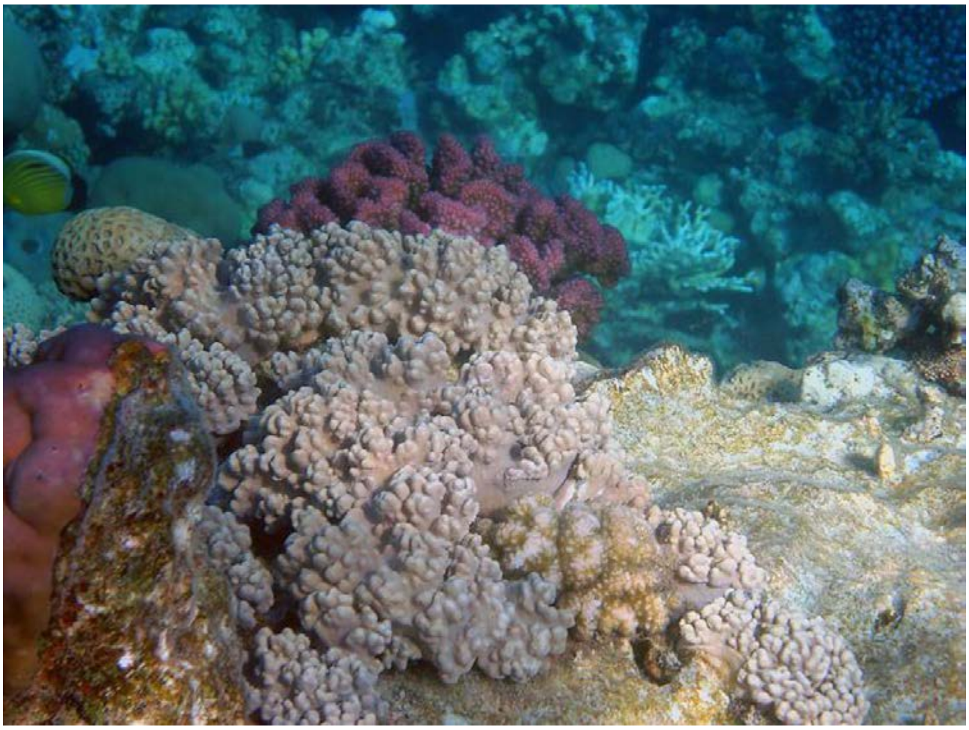

Fig. 12. The settlements of the soft coral *Sinularia* on the coral reefs, South China Sea.

The comparison of the data on the Ly Son soft corals and those from previous surveys in Vietnam showed a rage of new findings. Because of the exact data about the contemporary Octocorallia diversity in Vietnam could be obtained using the above mentioned approach, the perspective way to develop the future investigations could be:

1. The comparison of the soft corals diversity in ecologically different coral reefs and regions of Vietnam.

2. The gap-filling surveys of the diversity and population structure of soft coral in Gulf of Tonkin, the estimation of the present biodiversity in Nha Trang Bay and of southernmost part of Vietnam using morphology/genetic modern approaches.

Coral biodiversity of Vietnam coastal waters and adjacent regions: inter-faunal connectivity

Based on the studies and analysis of natural conditions influencing reef-building coral distribution, it can be assumed to separate four zones of reef-building coral distribution in Vietnam. South central and southeastern waters have similar biomes due to being locating in areas with similar temperature regimes and relative proximity to areas of coral dispersal in the Philippines and Indonesia. Information and data on environmental conditions and the distribution of coral genera in

Vietnamese waters enabled the adjustment of the isopangeneric contours of reef-building corals established by Veron (1993) for the South China Sea (Fig. 2). The isopangeneric contour of 60 genera originates from Con Co Island (17°N). The Tonkin Gulf area is characterized by less than 60 genera of hermatypic corals. Waters of central Vietnam are located to the south of this where the number of genera ranges from 60-70. The isopangeneric contour of 70 genera originates from Varella Cape (approximately 13°N), encompassing the Paracel and Spratly Archipelagos. Studies of population inter-dependence in the South China Sea, based on the genetic structure of fish *Dascyllus trimaculatus* (Ablan et al., 2002), support the establishment of a boundary at Varella Cape. Areas having more than 70 stony corals genera include south central waters, Paracel and Spratly Archipelagous. Although only 61 genera of hermatypic corals have been observed at Con Dao Island, it has been proposed that Con Dao be included within the 70+ genera isopangeneric contour. Southwestern waters of Vietnam belong to the distribution zone with less than 70 genera. The isopangeneric contour of 70 genera covers all the Gulf of Thailand, although does not seem to be compatible with findings of small-scale studies, which indicate that there are fewer genera in this area. Surveys conducted at Phu Quoc Island in Vietnam (WWF-IOC team, 1994) and at Mu Koh Chang in Thailand (Thamasak, unpublished) identified only 34 and 44 genera of hermatypic corals, respectively. It is necessary to undertake additional surveys to enable a better understanding of coral reef fauna in the Gulf of Thailand. Species level analysis suggested establishing contours of 300 species overlapping the 70 genera contour and 200 species overlapping the 60 genera line. Nha Trang Bay, the Ninh Hai coastal reefs, and Con Dao Islands are characterized by a high level of coral species diversity, with more than 300 species recorded.

The study of distribution patterns requires the good understanding both detailed records of the coral fauna throughout the distribution range and high quality oceanographic data to be correlated with these distributions (Veron and Minchin, 1992; Hoeksema, 2007). The warm water of the Kurioshio Current passes east of the Philippines to southern pacific side of the Japan and intrudes into the South China Sea moving along of southern Taiwan. It can influence on the corals richness on the reefs of the central part of Vietnam as well as southern Taiwanese reefs. Really, the stony corals fauna of the reefs of central Vietnam is quite rich and, moreover, the several species of the *Porites* genus which were firstly described from Philippines. The same situation can be considered concerning with Octocorallia fauna of the region. The preliminary Alcyonacea list of the soft corals (with *Briareum* genus) of central Vietnam includes 27 genera; the *Sinularia* species list has 36 "old" species and a range of the new species (Dautova, 2008). The reefs of the southern Taiwan contain 22 genera including *Sinularia* with species (Table 1). The lacking of the genera *Anthelia, Asterospicularia, Cespitularia* and *Heteroxenia* in the list of Vietnamese soft corals is probably because of the missing data. However the presence in central Vietnam of the most of Nephtheidae genera as well as longer list of Sinularia species may be considered as a result of the direct connection of the region with Indo-Malayan Centre of Marine Biodiversity (so-called Coral Triangle) in addition to the Kurioshio influence. The single finding in SCS of the *Sinularia yamazatoi* which species was before recorded only at Southern Ryukyu shows that this species: a) probably has the dispersal from the Indo-Malayan centre; b) may be rare and due to it is not recorded on Taiwanese reefs; c) can pass into the Vietnamese waters both directly from Coral Triangle and by Kurioshio influx. The recent Indonesian finding of the *S. mammifera* which species was described from Vietnam (Manuputti and Ofwegen 2007) anticipate the same.

The studying of the Octocorallia species richness is substantially in the frame of the worldwide and local Vietnam biodiversity problems. The reefs in the Gulf of Tonkin (at least those located far from Red River mouth) at the northern part of the SCS, have links with Coral Triangle due to Kurioshio current. The geographic location of these reefs close to northern margin of the Triangle can allow the quite rich coral fauna existing, but there is lack of taxonomic capacity to confirm this. The solving of the complex problems of capacity building for the taxonomy, diversity and species-specific ecology is hardly needed to develop the soft corals biodiversity study in Vietnam and, finally, trace the possible ways for the soft corals dispersal in Vietnam and adjacent waters.

Status of the coral reefs in Vietnam

Burke et al. (2002) with Reef at Risk in Southeast Asia indicated that most coral reefs in the coastal waters of Vietnam are under threats with 50% of the reefs ranked at high level and 17% at very high level. Destructive fishing was assessed as popular and serious with 85% coral reefs at medium and high levels. This situation has continued with reduction of blast fishing, but popularity of poisoning because of increased demands of live fish trade. Over-fishing was indicated as a serious threat to a half of coral reefs and would occur in forthcoming period to meet requirement of local communities with crowded population. The other potential threats are sedimentation (47% coral reefs), coastal development (40%) and pollution (7%). These threats increased in parallel with rapid economic development of the country. Sedimentation impacts observed in western Tonkin Gulf and eastern Gulf of Thailand will continue to be a serious concern in near future. Rapid developments of new roads, factories, settlement bases, ports in the coast will cause more physical impacts, sedimentation and nutrient inputs. Marine-based pollution will also increase due to more oil and gas exploitation and marine transportation including an oil-transferring base at Van Phong Bay (Vo Si Tuan et al 2006)

Fig. 13. Bleached *Acropora* corals, South China Sea, Vietnam.

With more than 200 coral sites along the Vietnam coast have been surveyed for recent years shows that the coral coverage in the reefs is not in the good status. Based on the scale of English et al (1997), only 1% of coral reefs is in excellent coverage (higher than 75% coral coverage), while there is more than 31% of coral reefs in bad coverage (less than 25%). The coral reefs with fair and good coverage are about 41% and 26%, respectively. The specific inventory data of coral reef areas stated that most of coral reefs have coverage at average level from 25 to 50% (Fig. 2). Only coral reefs located at offshore or far from the communities may maintain relatively good status (Vo Si Tuan, 2000).

Sea temperatures in many tropical regions have increased by almost 1°C over the past 100 years, and are currently increasing at ~1.2°C per century. Coral bleaching occurs when the thermal tolerance of corals and their photosynthetic symbionts (zooxanthellae) is exceeded (Fig. 13). Mass coral bleaching and their subsequent dying has occurred in association with episodes of elevated sea temperatures over the past 20 years (Hoegh-Guldberg, 1999). Although the impacts of human use, both direct and indirect, are generally more severe than impacts resulting from natural events, this is not the case with switches in the El Nino pattern of ocean circulation, which result in warming of the sea surface within the Indo-west Pacific in general and the South China Sea in particular (UNEP 2004). Sea surface temperature in most parts of the South China Sea was raised 2–3°C above the normal seasonal maximum (Wilkinson 1998). By April 1998, anomalous hot water temperatures appeared in the South China Sea. Heating intensified in May and July, and coral bleaching was reported from Philippines, Indonesia, Thailand, Malaysia, Singapore and Vietnam. This coral bleaching was followed by mass mortality of scleractinian coral and other zooxanthellae-bearing reef organisms. Coral mortality reached 70 – 90 % extending from the reef flat down to a depth of 15 meters. Recovery rates varied throughout the region, from full and fast recovery in some reefs of Vietnam located in upwelling areas, to slow, partial recovery in other countries. In 1998, a coral bleaching event affected seriously many coral reefs in Vietnam. Extensive bleaching has not observed in Vietnam since 1999 with no record in the monitoring during 2002–2003 and bleaching index almost being 5, except some records in offshore Tho Chu islands (Fig. 10). The impacts of the event in 1998 have been recognized via evidence of dead corals with unbroken colonies in Cu Lao Cham, Phu Quoc islands by the surveys during 2002 – 2003. Periodical surveys conducted between 1998 and 2002 showed that Con Dao coral reefs recovered very slowly after the combination of two serious natural events, typhoon and coral bleaching (Vo Si Tuan, 2000).

Conclusions

The South China Sea is shared by many countries, and the environmental problems they have are common and of a transboundary nature with similar root causes. In particular, many of the rivers of the South China Sea are heavily laden with suspended solids and some of these rivers have picked up these solids in countries other than that in which the river enters the sea, thus a transboundary problem occurs. The environmental problems they have are common and of a transboundary nature with similar root causes. The richness and productivity of the coastal coral reefs of the South China Sea are seriously threatened by high rate of population growth, pollution, excessive harvesting and habitat modification, resulting in rapid loss of habitat and impairment of the regenerative capacities of living systems.

With along coastal line and diversification of the key habitats, Vietnam has been considered as rich in marine biodiversity both in term of coral diversity and typical tropical marine ecosystems. Marine resources are significant in terms of livelihoods of coastal communities and development of the country. Located in the tropical monsoon area of South East Asia, marine waters of central Vietnam are characterized by high biodiversity of coral fauna high abundance of coral reefs. However, the Vietnam's coral biodiversity and coral reefs status are threatened by human impacts and natural induces by the vision of the global climate changes that tend to reduce of the species diversity and put more rare/endangered species on the status of extinction some days.

The contributor to this chapter is Dr. T.N. Dautova.

3.2 BIODIVERSITY AND ECOLOGY OF MEIOBENTHOS IN NORTHERN (HA LONG BAY) AND SOUTHERN (NHATRANG BAY) VIETNAM

The distribution of the taxonomical composition and the density of meiobenthos depending on some factors of environment has been studied in bottom sediments of the northern estuary part of **Ha Long Bay** (Cua Luc estuary). Ha Long Bay is situated in Northern Vietnam within the Quang Ninh province, approximately 170 kilometres east of Hanoi. The bay is on the western coast of the Bac Bo (Tonkin) Gulf, and it covers an area of approximately 1500 square kilometres. Ha Long Bay is a UNESCO World Heritage Site, and includes some 1,600 islands and islets forming a spectacular seascape. Abundant mainland drain-numerous rivers and streams has a great influence at the bay, especially its northern estuary part (Cua Luc estuary). Salinity regime in Ha Long Bay is very changeable during the year. The Bay is also the scene where a largest deep sea port at Cai Lan is situated with a huge container terminal, a coal transfer complex, and other port facilities. Bottom dredging works are conducted regularly in the bay. There are only a few studies done on meiobenthos in Vietnam coastline of South China Sea, although meiobenthos is an important component of marine ecosystems. In particular, some investigations concerned with the species composition and distribution of free-living marine nematodes, were conducted in the coastal zone of the central Vietnam (Nguyen Vu Thanh et al., 2002). The structure of meiobenthic community of Nha Trang Bay (Pavlyuk and Trebukhova, 2006), and mangrove forests of southern part of the South China Sea (Quang Ngo Xuan et al., 2007) were analyzed as well. So far only one study has investigated the composition and distribution of free-living marine nematodes in Ha Long Bay (Nguyen Vu Thanh and Nguyen Dinh Tu, 2003). Nevertheless, the knowledge about the abundance and ecology of the meiofauna groups of higher taxonomical level (orders or classes) is essential for a better understanding of the structures and functions of benthic communities.

Meiofauna communities in sublittoral sediments of northern part of Ha Long Bay were represented by 11 taxonomical groups and generally dominated by nematodes and harpacticoid copepods (Fig. 14). The average density was low, constituting 180.8±13.1 inds/10 cm^2. The highest density of meiobenthos (295.3±98.4 inds/10 cm^2) is found in heterogenous silt sediments at station HL2, where a depth was 12 m, and a salinity in the benthic layer of water was 33 PSU. Three taxonomic groups were present: Nematoda, Harpacticoida and Polychaeta. Nematodes were dominant at 96.6% of the total meiobenthos density. The lowest density of meiobenthos (110.5±28.1 inds/10 cm^2) is also found in silty sediments at station HL1, where depth was 2 m, and salinity – 30 PSU. The taxonomic composition of meiobenthos included 4 groups: Nematoda, Harpacticoida, Halacarida and Polychaeta. Nematodes dominated at 54.2% of the total meiobenthos density. In the silty sediments the highest number of taxonomic groups – 7 is found at the station HL4.

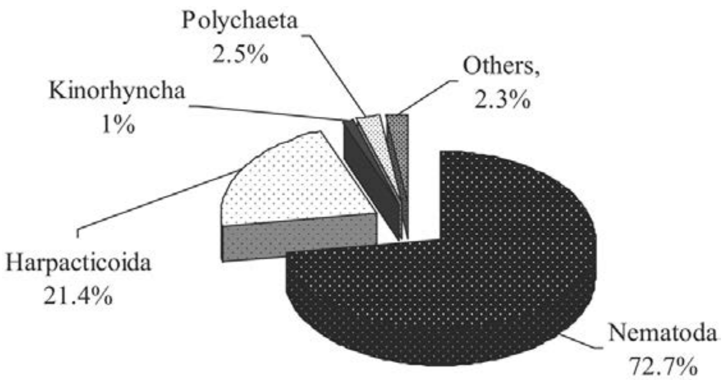

Fig. 14. The percentage of major meiobenthic groups in the bay. "Others" included such groups: Halacarida, Hydrozoa, Oligochaeta, Bivalva, Amphipoda, Cumacea.

The lowest density of meiobenthos (110.5±28.1 inds/10 cm^2) is also found in silty sediments at station HL1, where depth was 2 m, and salinity – 30 PSU. The taxonomic composition of meiobenthos included 4 groups: Nematoda, Harpacticoida, Halacarida and Polychaeta. Nematodes dominated at 54.2% of the total meiobenthos density. In the silty sediments the highest number of taxonomic groups – 7 is found at the station HL4. In silted sand sediments taxonomic composition of meiobenthos varied from 7 to 10 groups. At station HL5, where a depth was 0.5 m, and salinity – 34 PSU, taxonomic composition included 10 groups: Nematoda, Harpacticoida, Halacarida, Hydrozoa, Kinorhyncha, Polychaeta, Oligochaeta, Cumacea, Bivalvia and Amphipoda (Fig. 13). The average density of meiobenthos was determined to be at 227.2±72.8 inds/10cm^2. Nematodes made 66.1% of the total meiobenthos density, besides the highest density of Harpacticoids was recorded (68.7±22.8 inds/10 cm^2) (Fig. 13). The Spearman rank correlation coefficient was computed between density of meiofauna and salinity, and no correlation was found. Thus, nematodes were dominant at all stations in the area of research at more than 70% of the total meiobenthos density. Figs. 12-13 shows that the essential part of meiobenthos was presented by harpacticoid copepods, which comprised from 2.7% to 40% of total density. In temporary meiobenthos, polyhaetes were dominant (2.5%). Fig. 14 demonstrates an abundance of dominated meiobenthic groups (nematodes and harpacticoids) and its relationships with the percentage of sediment particles >0.1 mm and <0.1 mm size. Average density of nematodes was lower in the sediments with the content of silty particles less than 30%, but density of harpacticoids – higher than in the silts (Fig. 15). In the study area taxonomical diversity and densities of meiofauna were generally lower to that reported for another areas of the South China Sea. Comparisons with southern part of South China Sea (Nha Trang Bay) reveal that the density of meiofauna was much more higher in Nha Trang Bay and taxonomical composition was more diverse as a whole (Pavlyuk and Trebukhova, 2006).

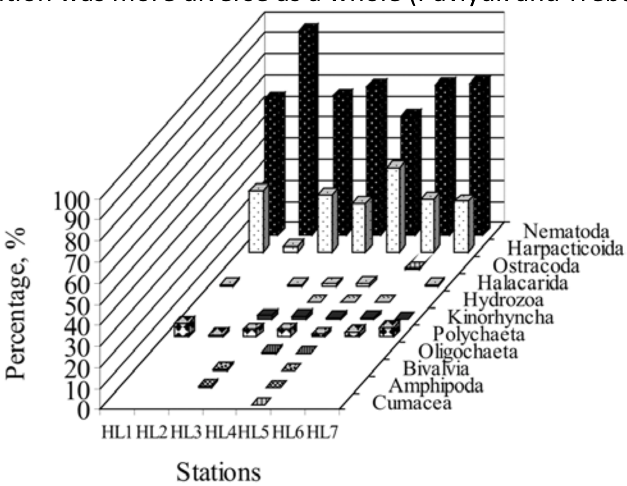

Fig. 15. The percentage of meiobenthic groups at stations.

A total of sixty six species belonging to 17 families and 52 genera were identified in Ha Long Bay. The highest density of nematodes was registered in silty sediments at the station HL2 (285.3±89.8 inds/10 cm^2). Twenty species of nematodes were found, *Sabatieria* sp., *Doliolaimus* sp. and *Terschellingia* sp. dominated. Fig. 15 shows the distribution of nematode species belonging to different trophic groups at the station. Nonselective deposit-feeders generally dominated among nematodes with the different feeding types (1B, 81.3%), while epistratum feeders (2A) were the lowest (Fig. 15). Index of species diversity was at 3.75, Simpson domination index – 0.09 and Pielou evenness index – 1.92, respectively. The lowest density of nematodes (73.9±32.3 inds/10 cm^2) is marked at station HL1. Seventeen species of nematodes were found. *Doliolaimus* sp., *Laimella* sp. and *Sabatieria* sp. dominated. Dominant trophic group was nonselective deposit-feeders (1B, 62.2 %) (Fig. 16). At this station indices of nematode species diversity (3.61) and evenness (1.85) were lower than at the station HL2, domination index was at the same level (0.09). In sandy sediments the highest density of nematodes (150.1±52.3 inds/10 cm^2) is detected at the station HL5. Thirty three species were found, *Mesocanthion* sp., *Paranticoma* sp. and *Dichromadora* sp. dominated. Omnivores (2B, 34.2%) and epistratum feeders (2A, 31%) were the dominant trophic groups (Fig.

15). The Shannon-Wiener index was significantly higher at this station (4.34), domination index (0.05) – lowest. The lowest density of nematodes was found at station HL3 (100±35.2 inds/10 cm^2). Twenty four species detected, dominated by *Parodontophora* sp., *Doliolaimus* sp. and *Daptonema* sp. Omnivores was the dominant trophic group (2B, 38.1%). Indices of species diversity, evenness and domination index were 3.81, 2.0 and 0.06 respectively. Thus, in sandy sediments with low percentage of silty particles indexes of species diversity were higher, and domination index was lower than in the silts. Fig. 15 shows that non-selective deposit-feeders (1B) and omnivores (2B) were generally dominant feeding group at all stations, while selective deposit feeders (1A) were lowest in abundance at most stations, except for station HL5, and ranging from 2% to 7% per station. In the sandy sediments epistratum feeders (2A) and omnivores (2B) generally prevailed among nematodes with different feeding types. In general, as the content of the silty fractions in sediment increases, it leads to increasing of number of deposit-feeding nematodes.

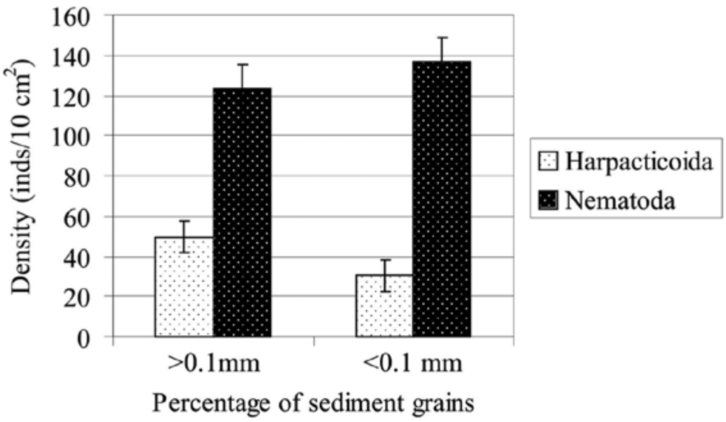

Fig. 16. Relationships between the proportion of sediment particles
> 0.1 mm and < 0.1 mm size and abundance of nematodes and harpacticoids.

The cluster analysis was used to estimate similarity between nematode species composition in the seven stations, and to distinguish nematode taxocenes. Fig. 17 shows that percentage of nematodes belonging to different trophic groups at stations. Trophic groups: (1A) selective depositfeeders; (1B) non-selective deposit-feeders; (2A) epistratum feeders; (2B) omnivores. Fig. 16 shows that stations clustered into two main groups. Stations HL3, HL5 and HL7 with mostly sandy sediments formed taxocene I. The average density of nematodes was determined to be at 123.3±18.2 inds/10 cm^2. Fifty two species of nematodes were found, *Sphaerolaimus* sp., *Mesocanthion* sp., *Parodontophora* sp., *Paranticoma* sp. and *Daptonema* sp. dominated. Stations HL1, HL2, HL4 and HL6 with mostly silty sediment particles formed taxocene II (Fig. 18). The average density of nematodes was determined to be at 137.5±39.3 inds/10 cm^2. Forty one species of nematodes were found, *Doliolaimus* sp., *Sabatieria* sp., *Sabatieria* sp. 1, *Sabatieria* sp. 2, and *Dorylaimopsis* sp. dominated.

The correlation analysis showed the dependence of nematode density on the silty particles content (the Spearman rank correlation coefficient was 0.49±0.21, P=0.035).

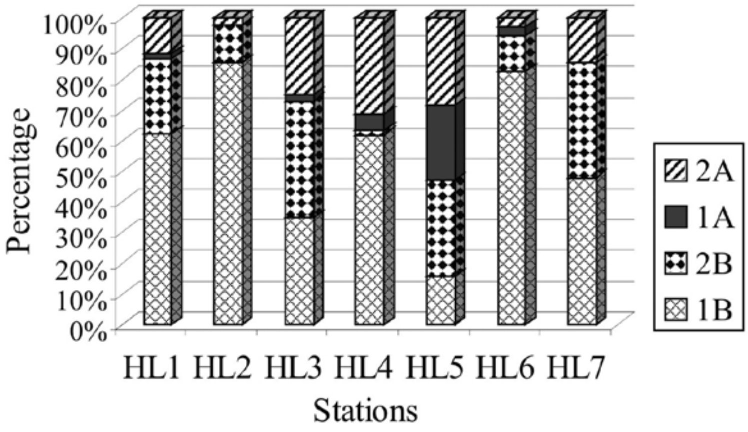

Fig. 17. Percentage of nematodes belonging to different trophic groups at stations. Trophic groups: (1A) selective depositfeeders; (1B) non-selective deposit-feeders; (2A) epistratum feeders; (2B) omnivores.

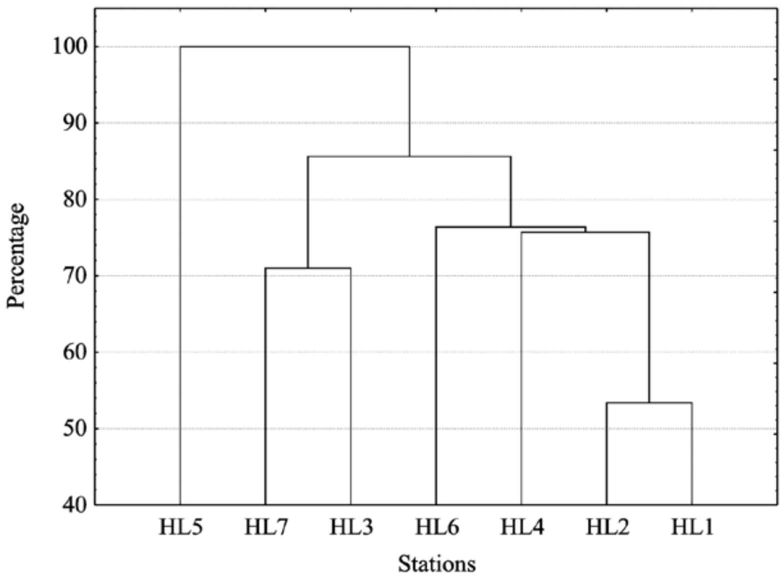

Fig. 18. Hierarchical cluster analysis (Ward method, Euclidean distances) based on the nematode species composition.

Discussion

Several authors stressed the importance of salinity as a key factor that determines the nematodes species diversity and densities in estuaries and coastal lagoons (Gerlach, 1953; Bouwman, 1983). There are two seasons in the Ha Long Bay and its estuary zone – dry and rainy, both depend on the distribution of atmospheric precipitations during the year. Rainy period lasts from April until October; the salinity of surface water during this period is low – from 11.7 to 30.5 PSU. Dry period lasts from October to the end of March. The mainland drain of fresh waters in the estuary part of the Bay is reduced and in certain cases sea water penetrates the numerous rivers and the streams. Salinity during this period varies from 30.0 to 33.4 PSU (Nguyen Vu Thanh and Nguyen Dinh Tu, 2003). Previous study of the nematode species composition done in the Bay during the rainy period showed that a certain tendency is observed in decreasing of the number of nematode species and reduction in the indices of species diversity (Nguyen Vu Thanh and Nguyen Dinh Tu, 2003). It worth noting that sampling for the present study was carried out in March, at the end of the dry season, and nematode species composition consisted exclusively of marine species, but density was low. Probably, changes between dry and rainy period influence on density and taxonomical diversity of meiobenthos. In a study of meiobenthic communities in the estuary of the Chornaya (Black) River (Kandalaksha Bay, White Sea), Udalov et al. (2005) suggested that the distribution of animals in estuaries depends not only on salinity, but on a variety of other factors, specific to that particular estuary. Sediment type was a key factor that determined the distribution of nematode densities (Udalov et al., 2005).

Meiobenthic animals, nematodes in particular, depend not only on the size of the sediment particles but also at the degree of sediment pore space filling. The limiting factor of influence on the density of the animals in the sandy sediments is the minimal size of the capillary passages in which they are able to live (Galtsova, 1991). If there is 7% or more of silt-clay fractions in the sediment, it is enough to fill the slits between the large particles. The sediment with more than 15% small fractions is the homogeneous silty environment (Crisp and Williams, 1971).

Analysis of sediment granulometry showed that practically all sediments of the estuary part of Ha Long Bay contain more than 15% particles with the size less than 0.1 mm and they are homogeneous living environment for meiofaunal organisms. Probably, this is an explanation for low correlation between the content of silty particles and the density of nematodes.

Research of the qualitative and quantitative meiobenthic composition was done depending on the sediments grain size composition in Wrangel Bay located in the eastern part of Nachodka Bay (East/Japan Sea) (Pavlyuk et al., 2003). Nakhodka Bay is the largest deep water port of Russian Far East where bottom dredging works are conducted regularly. The average density of nematodes (92.6±13.1 inds/10 cm^2) was lower compared with that in Ha Long Bay. Nematodes were the dominant group and their density in the silty sediments was somewhat higher than in fine sand sediments. No correlation was found between the density of the meiobenthic animals and the concentration of silt fractions in sediments. Bottom dredging, perfomed in the Bay, has greatly changed meiobenthic communities (Pavlyuk et al., 2003).

The estuary part of the Ha Long Bay is exposed constantly as to anthropogenic impact from the sea port (bottom dredging works), and to mainland drain of fresh waters which result in significant changes of salinity within a year. In general, differences in composition and distribution of meiobenthic communities in Ha Long Bay appeared to be connected with changes in granulometric composition of bottom sediments. The silted sediments are characterised by the low species diversity and higher density of the animals than the slightly silted sands.

* * *

Horisontal distribution and taxonomic composition of meiobenthos in Nha Trang Bay

The density of meiobenthos is distributed non-uniformly in the bay. The highest density of meiobenthos (1406.7±455.6 ind. 10 cm^{-2}) was registered in silted coarse and heterogeneous sand (sediment type II, station 10, depth 11 m). In the northern part of the Bay, in coarse sand (sediment type I, stations 1, 11–14) the depth varied from 15 to 32 m, and the meiobenthos density was 1098.9±359.3 ind. 10 cm^{-2}. In the southern part of the Bay, in the silted fine sand (sediment type III, station 7–9), with a depth range from 13 to 22 m, the meiobenthos density was 1031.4±419.7 ind. 10 cm^{-2}. In the central part of the Bay, sediments consist of silt of different structure (sediment type IV, station 2–6); where the depth ranged from 19 to 39 m, the density of meiobenthos was the lowest –545.3±235.9 ind. 10 cm^{-2}. Negative correlation between the density of meiofauna on different sediment types and vertical depth was only slightly expressed (Pearson's correlation coefficient is - 0.34, p=0.05). Taxonomical composition of meiobenthos was presented by twenty three groups at higher taxonomic levels (class, order). Marine nematodes were the dominant group, accounting for 68.6% of total meiofauna (Fig. 19). Representatives of three orders, twenty three families and ninety one genera were identified. The high taxonomic diversity of meiobenthos was found in coarse sand (sediment type I – II), where twenty one groups of animals were found. Nematodes dominated in eumeiobenthos, and harpacticoids occupied the second place.

Polychaetes dominated in temporary meiobenthos (Fig. 19). In sediment type III, seven meiobenthos groups were found. In eumeiobenthos, nematodes dominated whereas in temporary meiobenthos, polychaetes and oligochaetes. In sediment type IV, the taxonomic composition was poor and included only nematodes (Fig. 5). Thus, one can conclude that, in general, the higher density and taxonomic diversity of meiobenthos in the Bay was marked in coarse sands.

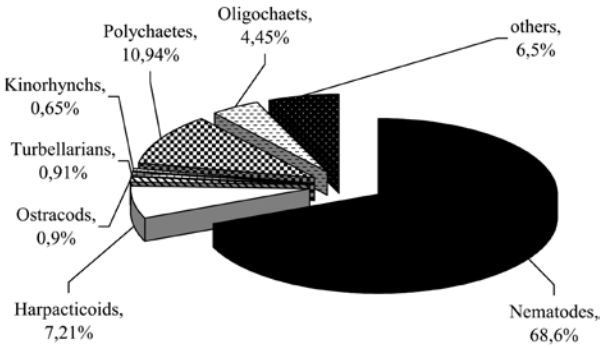

Fig. 19. The percentage of major meiobenthic groups at stations in the bay. "Others" included such groups: Nemertines, Bivalves, Gastropods, Isopodes, Holothurians, Sipunculids, Amphipods, Caprellids, Cumaceans, Pantopods.

Horizontal distribution and taxonomic composition of meiobenthos at the reefs

The density of meiobenthos was uneven near the islands, in the bottom sediments of coral reefs and in the Bay itself (Fig. 20). Sediments on Mieu Island reef (station 19) consist of silted pebble, heterogeneous sand and shell debris (sediment type V). Mieu Island is the closest to the coast. Its reef is in a depressed state as waste discharge and a small river affect the area. Bottom water salinity near the reef was the lowest, and made less than 29 PSU. The density of meiobenthos was 833.1±227.4 ind. 10 cm−2. Sediments of reefs at Tam, Mot, and Mung Islands and to the east of Tre Island (stations 15–18) consist of slightly silted coarse and heterogeneous sand with shell debris and corals (sediment type VI). These reefs are fairly in order. The density of meiobenthos (588.1±152.5 ind. 10 cm−2) was lower than on Mieu Island reef. On a reef located south of Tre Island (station 20), sediments are heavily silted heterogeneous sand (VII sediment type). The reef is depressed, and the majority of the corals are dead. The reef is greatly affected by a lobster culture farm, located behind the nearest cape. The meiobenthos density here was the highest – 1299.8±538.4 ind. 10 cm−2. Twenty six taxonomic groups of meiobenthos were found in bottom sediments of coral reefs. As in the Bay, nematodes dominated in meiobenthos (Fig. 21). There, representatives of three orders, twenty families and forty seven genera of marine nematodes were identified. Taxonomic composition of Mieu Island reef included sixteen meiobenthos groups, where nematodes dominated and harpacticoids and polychaetes occupied the second place. Taxonomic composition of the reefs near four islands – Tam Island, Mot Island, Mung Island and to the east of Tre Island – was presented by the highest number of groups – twenty four, and nematodes were dominant. In temporary meiobenthos, polychaetes, oligochaetes and isopods were dominant groups (Fig. 22).

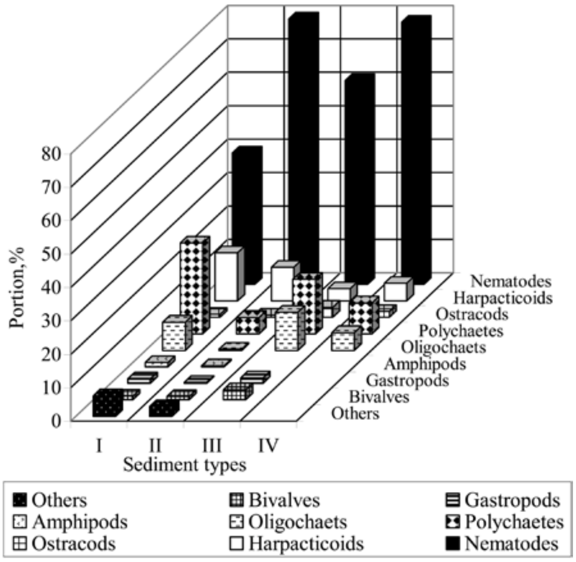

Fig. 20. The proportions (%) of meiobenthic groups at different sediment types in the bay. Others groups: Turbellarians, Halacaroids, Sipunculids, Kinorhynchs, Cumaceans, Nemertines, Pantopods, Isopods, Holothurians.

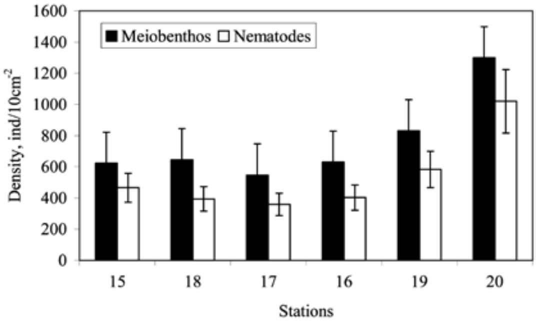

Fig. 21. Abundance of meiobenthos and nematodes at reefs stations.

Taxonomic composition of meiobenthos in reef sediments southward of Tre Island was poor and included only five groups, and nematodes dominated (Fig. 23). Thus, the higher density of meiobenthos was registered in reefs sediments in heavily silted heterogeneous sand, and greatest taxonomic diversity in coarse sands. Vertical distribution of meiobenthos The vertical distribution of meiofauna in the sediments was studied on five sediment types. In sediment type I, the greatest density of nematodes (700 ind. 10 cm−2) was observed in the upper layer (0-2 cm); further, the number of animals gradually declined and in 8-10 cm layer the density was 270 ind. 10 cm−2. In the last layer only six taxonomic groups were found: nematodes, polychaetes, oligochaetes, kinorhynchs, bivalves and ostracods. In sediment types II and III, the distribution of animals was similar. The maximum density of meiobenthos (300 ind. 10 cm−2) was observed in 0-2 cm layer, whereas in the second layer (2-4cm) the meiobenthos density was 150 ind. 10 cm−2. The minimum density (90 ind. 10 cm−2) was registered in 8-10 cm layer, where only polychaetes and nematodes were found (Fig. 10). In the sediment type IV, the greatest number of animals was found in the upper layer (200 ind. 10 cm−2); further, the meiobenthos density sharply declined. The minimum meiobenthos density (25 ind. 10 cm−2) was observed in 8-10 cm layer. In the last two layers, only nematodes were found. At reefs, the maximum number of animals (780 ind. 10 cm−2) was found in the first three layers of sediment type VI. The minimum density (70 ind. 10 cm−2) was registered in 6-8 cm layer. In 8-10 cm layer, harpacticoids were found together with nematodes and polychaetes. Thus, the most number of animals was found only in sandy sediments in the 8-10 cm layer, while in the same layer of silt sediments, only nematodes were found.

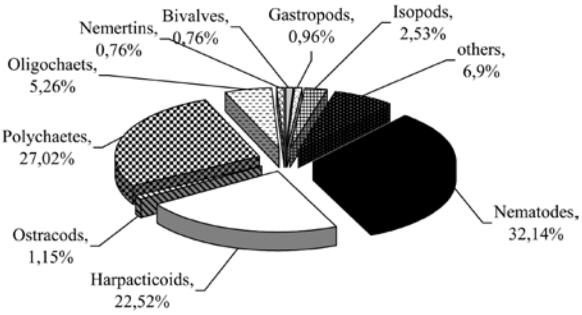

Fig. 22. The percentage of major meiobenthic groups at reefs stations. "Others" included such groups: Turbellarians, Halacaroids, inorhynchs, Gastrotrichs, Holothurias, Sipunculids, Amphipods, Caprellids, Insects, Cumaceans, antopods, Cumaceans.

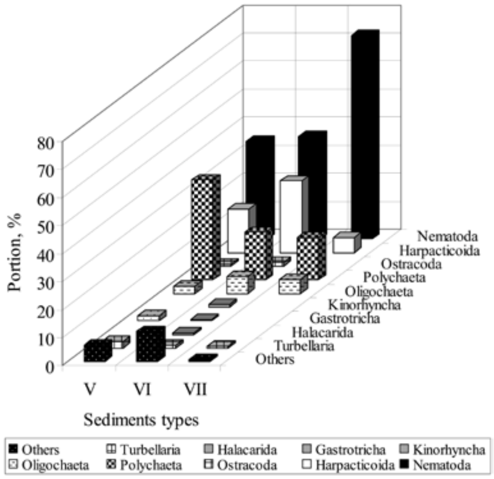

Fig. 23. The proportions (%) of meiobenthic groups from different sediment types on reefs stations. Others: Nemertines, Bivalves, Gastropods, Isopods, Holothurians, Sipunculids, Amphipods, Caprellids, Insects, Cumaceans, Pantopods, Chironomids.

Discussion

Subtidal meiobenthic species assemblages are poorly known in tropical biotopes and few studies give an account of their taxonomic composition and biodiversity (review: Boucher 1997). It is known that one of the key factors affecting distribution of meiofauna is the granulometric composition of sediments. Investigation of meiofaunal density and the taxonomic composition of nematodes in three bottom types in SW lagoon of New Caledonia (SW Pacific) showed that the meiofaunal density was significantly higher in white sand at stations adjacent to the coral reefs than in other biotopes (grey-sand and muddy bottoms). The meiobenthos density at Nha Trang Bay reefs also shows an uneven distribution and depends on the sediment type. The correlation analysis revealed the dependence between the median diameter of sediment particles and the density of meiobenthos (Spearman's correlation coefficient was 0.82, $p<0.05$). A review of existing meiofauna data in tropical areas (Alongi, 1989a, b) shows that meiofaunal densities and species diversity are not greater in the tropics (Boucher 1997). We found that quantitative characteristics of meiobenthos in Nha Trang Bay (944.3±303.7–1034.6±435.8 ind. 10 cm−2) were similar to the data on the other seas: SW lagoon of New Caledonia – 3275±701 ind. 10 cm−2 (Boucher, 1997); the Yellow Sea – 1524–6094 ind. 10 cm−2 (Kim et al. 2000), 0.81–1.51 ind. 106 cm−2 (Zhang et al., 2001, 2002), the East Sea – 517±185.0–2228.2±527.1 ind. 10 cm−2 (Pavlyuk et al., 2001). However, taxonomic diversity of meiobenthos in Nha Trang Bay (twenty six groups) was greater than in other areas. Nematodes dominated in bottom sediments both in Nha Trang Bay itself and at its reefs (Figs. 2, 6). In total, representatives of four orders, twenty eight families and ninety seven genera were found in Nha Trang Bay. Nematodes made up to more than 90% of the total population density of meiobenthos at stations with high number of silt particles in sediments (stations 2-6). Nematodes made 68.6% of the total meiobenthos density in Nha Trang Bay, but at reefs they made only

32.14% (Figs. 18, 21). The highest density of nematodes (1020.8±354.8–1029±547.1 ind. 10 cm-2) was found in silted sands of sediment types II and VII. Statistically significant positive correlation was found between the median diameter of sediment particles and population density of nematodes (Spearman's correlation coefficient was 0.63, $p<0.05$). Representatives of Xyalidae, Chromadoridae and Enchelidiidae families dominated in sandy sediments of the Bay and in silt sediments – representatives of Comesomatidae and Desmodoridae families. In sediments of coral reefs, representatives of Axonolaimidae and Desmodoridae families dominated. Vertical distribution of meiobenthos in soft sediments can be affected by various causes: mechanical properties of sediment, oxygen regime, seasonality and other factors (Janssen, 1967; Fenchel and Riedl, 1970; Skoolmun and Gerlach, 1971; Pavlyuk, 1984; Galtsova, 1991; Kim et al., 2000; Huang et al., 2005). In sandy sediments, where high oxygen concentration is a rule and interstitial space extends to a considerable depth, meiofauna can be found deep in the bottom layers of sediments (Renaud-Debyser, 1963; Bush, 1966). It is quite different in silt sediments where the main number of animals is in the upper sediment layer. In the central part of Nha Trang Bay, the soft silt sediment layer reaches the depth of several tens of centimeters and there is no mechanical barrier to the penetration of animals into the deep layers of sediments. However, bottom oxygen concentration there makes less that 50% of the saturation (Smurov, 2003). Probably, the oxygen deficiency is a limiting factor for the penetration of animals into the depth of sediments in the central part of Nha Trang Bay.

3.3 BIODIVERSITY OF SIPUNCULA FROM NHATRANG BAY (VIETNAM)

Sipunculans from shallow depths ranging from 0 to 25 m, collected during April-June 2008, November 2009 and March 2010 in NhaTrang Bay are recorded. Twenty species in eleven genera and five families are recognized from the total 371 individuals collected. An analysis of the sipunculan literature has shown that 5 of these species are new records for NhaTrang Bay.

The NhaTrang Bay is located in the South China Sea on the coast of Vietnam between the geographical coordinates 11 - 12°N and 109°E approximately. The samples were collected during the April – May 2008, November 2009 and March 2010. The collection, with a total of 371 individuals, presents interesting material in a very good preservational state. The specimens were collected from about 12 sampling localities around the coast line and around islands of NhaTrang Bay, in shallow depths that range between 0 and 25 m.

The species idetifications in the present study were based mainly on the works by Stephen and Edmonds (1972), Murina (1977, 2003) and Cutler (1994). In some cases generic revisions presented by Cutler (1979), Cutler and Cutler (1982, 1983, 1985, 1987, 1988, 1989), Cutler and Murina (1977), Cutler and Cutler (1990) and Cutler, Cutler and Gibbs (1983) were also used. The classification and terminology of Cutler and Gibbs (1985) and Gibbs and Cutler 1987), based on a phylogenetic analysis, have been used here, and all supraspecific categories have been taken from these works. Detailed descriptions and synonymies of the most striking species identified in this report have been omitted.

Family Sipunculidae Rafinesque, 1814

Genus *Sipunculus* Linnaeus, 1766

Subgenus *Sipunculus (Sipunculus)* E. Cutler and Cutler, 1985

Sipunculus (Sipunculus) nudus Linnaeus, 1766

Material. NhaTrang Bay, Mung, sand, 14 m, May 2008, one specimen; NhaTrang fish market, numerous.

Fig. 23. *Sipunculus (Sipunculus) nudus*

Description. Trunk up to 120 mm in length. Introvert is much shorter than trunk length. Longitudinal musculature is split into 27–34 bands, with a predominance of 30 bands for most specimens. The nephridia are 30 – 50% attached to the body wall by mesenteries. An additional helix present. Digitate processes on a bilobulate brain are apparent (Fig. 23).

Discussion. The studied specimens show a wide size range, which is considered normal for this species. All the characteristics accord well with the previous published descriptions, although the length of the attachment surface of the nephridia to the body wall is close to the highest values recorded in the literature (around 50%).

With a cosmopolitan distribution, the species has been recorded the area investigated by Murina (2003) as well as for South China Sea by Pagola-Carte and Saiz-Salinas (2000), Leroy (1936, 1942), Chen and Yen (1958), Chen (1963), Murina (1964, 1989), Li (1985). It is usually found in the intertidal zone, rarely surpassing 30 m of depth. The species shows a preference for sandy bottoms, as exemplified by the specimens of this collection. These were obtained in a local market since this is one of the species that the inhabitants of Vietnam use in their diet.

Genus ***Siphonosoma*** Spengel, 1912

Siphonosoma australe australe (Keferstein, 1865)

Material. NhaTrang, B river estuary, intertidal, June 2008, 50 specimens, November 2009, 30 specimens, March 2010, 15 specimens; NhaTrang Bay, Tre Island, DamBay, intertidal, November 2010, 3 specimens; NhaTrang fish market, numerous.

Description. Trunk up to 150 mm in length. Introvert is equal length of trunk with dark hooks (spines). Longitudinal musculature is split into 15 – 16 bands, which are often visible though the skin. The nephridia are free. Contractile vessel in alive worm looks digiform, after fixation it become more bulbous. Tentacles are numerous and greenish (Fig. 24).

Discussion. The bulbous vesicles of the contractile vessel which do not form villi (sensu Cutler and Cutler, 1982), the hooks rings of the introvert and the absence of rectal caeca are characteristic of this species.

Siphonosoma a. australe shows tropical and subtropical distribution. It is known from the Indian Ocean and from areas of the Pacific Ocean. As the species was collected previously in the area investigated, there are records from Indochina (Leroy, 1942), Hainan (Chen, 1963; Li et al., 1992a, 1993; Pagola-Carte and Saiz-Salinas, 2000) and other parts of South China (Li, 1985a, b). It inhabits muddy sand bottoms of the intertidal zones near the rivers. These were obtained in a local market since this is one of the species that the inhabitants of Vietnam use in their diet.

Fig. 24. *Siphonosoma a. australe.*

Famiy Golfingiidae Stephen and Edmonds, 1972

Genus *Nephasoma*

Nephasoma (Nephasoma) pellucidum pellucidum (Keferstein, 1865)

Material. NhaTrang Bay, Hon Rock, dead coral, 10-12m, May 2008, 10 specimens

Descripton. Trunk up to 25 mm. Introvert some shorter than trunk. The skin in smooth, translucent and of a whitish colour. Small scattered digitiform papillae are brownish. Hooks are scattered, up to 300μm in height. Two retractors are inserted in the middle of the trunk (Fig. 25).

Discussion. The presence ofscattered hooks as well as brownish papilla are especially diagnostic for species. The character of the retractors concerning the insertion point in the body wall, and the ratio introvert/trunk length are also important.

The geographical distribution of the species is mainly shallow waters from Western Atlantic and Caribbean down to Brazil, in the South Pacific (Indonesia and Australia), southern Japan, and one record in Cape Town (Cutler & Cutler, 1986). Cutler (1977) reported with reservation two specimens from bathyal depth.

Fig. 25. *Nephasoma p. pellucidum.*

Fig. 26. *Themiste cymodoceae.*

Family Themistidae E. Cutler and Gibbs, 1985

Genus *Themiste* Gray, 1828

Subgenus *Themiste (Lagenopsis)* Edmonds, 1980

Themiste (Lagenopsis) cymodoceae (Edmonds, 1956)

Material. NhaTrang Bay, Diamond Bay, coral rubbles, 1-2m, June 2008, 1 specimen.

Description. Trunk 6mm long. Introvert 2mm in length. The body, pear-shaped, pale coloration. Small scattered papillae are present all over the trunk. Hooks are absent. Terminal tentacles arise from tentacular branches and stems. No purple pigmented collar-like band is visible around the introvert. The contractile vessel carries villi. Two retractors are inserted in the body wall at a short distance from the posterior trunk end. Spindle muscle does not insert in the body wall posteriorly (Fig. 26).

Discussion. The small size (<35mm) of the specimens, the presence of villi in the contractile vessel, the absence of hooks and the purple pigmented introvert collar must be pointed out as diagnostic characters.

The species resembles *T. (Lagenopsis) minor* (Ikeda, 1904), although it differs from it in the absence of hooks on its introvert. Both species appear as recorded from China, a circumstance which compels us carefully to observe the character of the hooks. None of the specimens, not even the smallest, possesses them.

Themiste cymodoceae was found before in South Australia among roots an intertidal eelgrass beds.

Family Phascolosomatidae Stephen and Edmonds, 1972

Genus *Phascolosoma* Leuckart, 1828

Subgenus *Phascolosoma (Phascolosoma)* Leuckart, 1828

Phascolosoma (Phascolosoma) arcuatum (Gray, 1828)

Material. Mekong delta, mangrove, intertidal, Jun2009, 30specimens.

Description. Trunk 46± 83mm long and 8± 11mm wide. Introvert slightly longer than the trunk. The integument is of a light yellow color with many dark spots at both trunk ends which correspond to papillae. Hooks, 65± 85 mm in height, are arranged in more than 50 rings and curve-shaped without a secondary tooth on the concave side. Internally, the clear streak is simple with a great expansion basally. Longitudinal and circular musculature divided into bands. Retractor uscles are discernible as four short roots split off from a single column. Two nephridia which are shorter than the trunk length.

Discussion. This species is characterized by the simplicity of its hooks, in comparison with those of the remaining species of *Phascolosoma*, and the arrangement in bands of both types of corporal musculature (longitudinal and circular). The external aspect of the worm is also diagnostic at first sight due to its color as well as by the large and outstanding papilllae on both trunk ends.

There are many records from the Indian Ocean and the Western Pacific, having been previously recorded from Haiphong, Gulf of Tonkin (Leroy, 1936), Indochina (Leroy, 1942), Hainan (Chen, 1963), Zhanjiang, South China (Murina, 1964), coasts of South China (Li, 1989) and South China Sea (Li *et al.*, 1992b). The specimens of this collection were purchased in a local market; in fact, a dish which is very appreciated by the inhabitants of the China coasts is made with this species (Chen and Yeh, 1958) (hence the specific name *P. esculenta* used for one of its junior synonyms). The species tolerates long periods out of the water at around the high tide line. They are often found in brackish waters as well as in mangrove estuaries.

Phascolosoma (Phascolosoma) nigrescens Keferstein, 1865

Material. NhaTrang: Dung Is., boring into bivalve *Chama* sp., 10 m, Jun2006, 1 specimen; Tre Is., coral rubbles, 6m, June 2008, 3 specimens; Tam Is., biofouling, intertidal, May 2008; Diamond Bay, coral rubbles, intertidal, June 2008, 4 specimens; Diamond Bay, coral rubbles, intertidal, Nov2009, 3 specimens.

Description. Trunk 11± 50mm long with a maximum width of 12mm. Introvert 8± 55mm long, sometimes shorter or longer than the trunk. Dorsal side of the introvert marked with transverse pigmented bands. Papillae distributed over the entire trunk, larger and more densely packed dorsally and at both trunk ends. Hooks, in more than 50 rings, exceptionally are up to 100 mm (often 50± 60 mm). The hooks are slightly curved with a small secondary tooth, a basal bar and rectangular plates at their base. Internally, there is a distinctly visible streak with an expansion near the midpoint of its length. Anastomosing bands of longitudinal musculature are frequent. Four retractors and two nephridia are at about two-thirds of the trunk length. Their attachment surface to the inner body wall varies strongly between 30 and 90% of the nephridia length, with most specimens exhibiting attachment surfaces around 50% (Fig. 27).

Discussion. The great variability in the shape and structure of the hooks must be taken into account. In spite of this, the character of the clear streak and its expansion near the midpoint of its length are diagnostic in the identification of the species. In some of the present specimens, besides the variability in the hooks, there is a `second clear area' in the form of a crescent on the concave side, which recalls the diagnostic feature of *P. (P.) stephensoni. Phascolosoma (P.) nigrescens* has been reported many times from shallow waters of the Atlantic, Indian and Pacific Oceans, in tropical and subtropical zones. In the area investigated the species has been recorded previously by Leroy (1936, 1942), Li (1982, 1989), Li *et al.* (1992b), Murina (1964, 1989) and Tsuchiya *et al.* (1986).

Phascolosoma (Phascolosoma) scolops (Selenka and de Man, 1883)

Material. NhaTrang: Mung Is., boring into bivalve Pinna sp., 15m, Jun2006, 1 specimen; Mot Is., coral rubbles, 7 m, May 2008, 7 specimens; Tre Is., biofouling, intertidal, Nov. 2009, 6specimens.

Description. Trunk 4± 20mm long with a mean value of 15mm. Introvert 4± 27mm long with a mean value of 12.5mm. Introvert/trunk ratios are variable.

Small spots over the dorsal part of the introvert. Papillae, distributed over the entire trunk, are larger, more pointed and densely packed at both ends. From 12 to 25 rings of hooks which are 25± 75 mm in height. Their shape is variable, sometimes with a hump-like secondary tooth on its concave side. Internally, a distinctly visible triangle in the convex portion and a clear streak are well delimited.

Longitudinal musculature in bands and four retractors which in some contracted specimens appear as only two retractors with one and two basal roots, respectively. Two nephridia, 30± 75% the trunk length, attached to the body wall for about 30± 65% of their length, with most specimens exhibiting mean values of attachment surface (Fig. 28).

Discussion. Despite the observation of the hooks, which helped us in its identification, this species (together with *P. (P.) nigrescens* Keferstein, 1865) has turned out to display great variability with regards to these cuticular structures. Thus, both the width of the clear streak and the height of the hooks are features very variable across all the specimens of this large collection compiled by Cutler (1994) in one large specimen). Its distribution in the Indian Ocean (including the Red Sea) and Western Pacific Ocean includes the coasts of Hainan Island, having been previously recorded from Poulo Condore (Vietnam) by Leroy (1936, 1942), from Hainan by Chen (1963), from the coasts of the South China by Li (1985b, 1989) and Li *et al.* (1992b), from Vietnam by Murina (1989, 2007) and from the Thailand Gulf by Tsuchiya *et al.* (1986). This is a species which shows a preference for shallow and coastal waters, including the intertidal zone where it inhabits soft rocks.

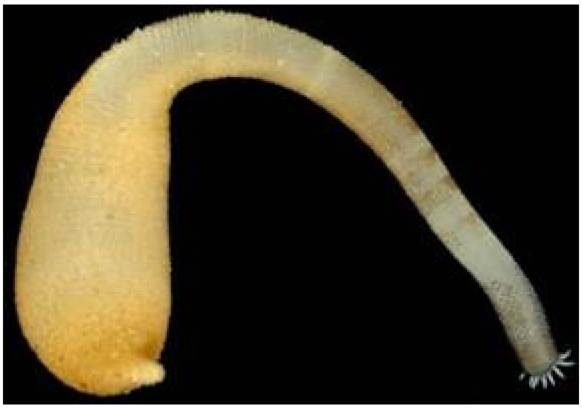

Fig. 27. *Phascolosoma nigrescens*.

Fig. 28. *Phascolosoma scolops.*

Phascolosoma (Phascolosoma) stephensoni (Stephen, 1942)

Material. NhaTrang: Tre Is., sand, boring into *Placuna sella*, 20 m, June 2006, 1 specimen.

Description. Trunk 23mm in length and 4± 6mm in width. Papillae are spread all along the trunk, being conical and larger at both trunk ends. Rings of hooks, with height of about 100 mm. The hooks, which are slightly curved and do not have secondary teeth, show, by contrast, a small elongated basal bar and rectangular plates at their base. Internally, they display a distinctly visible triangle in the convex portion, a clear streak medially, and a region in the form of a crescent on the concave portion. Four retractors and two nephridia. Nephridiopores a little behind the anus (Fig. 29).

Discussion. The papilla and hook shapes are features which characterize this species. The internal structure of the hooks and the conical pre-anal and caudal papillae clearly distinguish this species from other closely related members of the genus. In the present collection, the principal difference between *P.(P.) stephensoni* and *P. (P.) nigrescens* Keferstein, 1865 lies in the internal structure of the hook which lacks enlargements in the clear streak but on the other hand exhibits a clear separated triangle. With regards to *P. (P.) scolops*, the second clear area in the form of a crescent is absent in the latter species.

It is considered a species with a somewhat discontinuous distribution, with records from the eastern Atlantic, the Mediterranean and the western sectors of the Indian and Pacific Oceans. In spite of that, the species has not been previously recorded from the area investigated, therefore, the present specimen represents the first record.

Fig. 29. *P. stephensoni*, bar 10mm.

Fig. 30a, b. *Apionsoma misakianum.*

Genus *Apionsoma* Sluiter, 1902

Subgenus *Apionsoma (Apionsoma)* Sluiter, 1902

Apionsoma (Apionsoma) misakianum (Ikeda, 1904)

Material. NhaTrang Bay; Mung Is., muddy sand, 25 m, June 2006, 1 specimen; Mung Is., muddy sand, 25 m, May 2008, 3 specimens; Mot island, coral rubbles and empty bivalve shells, 10 m, May 2008, 5 specimens; Tre Is., biofouling, intertidal, November 2009, 3 specimens; Diamond Bay, coral rubbles, intertidal, November 2009, 2 specimens.

Description. Trunk 4mm long and 1mm wide. Introvert longer than the trunk, 21mm long and 0.6mm wide. Body wall pale, translucent and covered with small papillae. Rings of hooks, 25± 30 mm tall, with an accesory comb of spinelets at their base. Continuous longitudinal musculature. Bilobed nephridia, four retractors and a spindle muscle attached posteriorly (Fig. 30a, b).

Discussion. The presence of bilobed nephridia and an accessory comb of spinelets at the base of the hooks is characteristic of the genus. The high value of the ratio introvert/trunk is also diagnostic, even though in this case the introvert surpasses the trunk length by five times and a distance of 7± 10 times is indicated in the description of the species, a fact that would lead us to consider this specimen as *A. (A.) murinae* (Cutler, 1969). Nevertheless, the feature of a transparent body wall and autoecological considerations make us identify it as *A. (A.) misakianum* (Ikeda, 1904).

The species is uncommon despite its wide distribution in the Indian, Pacific and Atlantic oceans. Close to the study area, it has been recorded from Japan and French Polynesia. *Apionsoma (A.) misakianum* inhabits coral sands and algae in shallow waters of the tropical and subtropical zones.

Family Aspidosiphonidae Baird, 1868

Genus *Aspidosiphon* Diesing, 1851

Subgenus *Aspidosiphon (Aspidosiphon)* (Diesing, 1851)

Aspidosiphon (Aspidosiphon) elegans (Chamisso and Eysenhardt, 1821)

Material. NhaTrang Bay: Mot Is., coral rubbles, 7 m, May 2008, 8 specimens; Tre Is., coral rubbles, 6 m, June 2008, 11 specimens; Tre is., biofouling, intertidal, November 2009, 7 specimens; Mung Is., coral rubbles, 12 m, May 2008, 6 specimens; Nok Is., coral rubble, 5 m, 2 specimens; Diamond Bay: coral rubble, intertidal, Jun2008, 60 specimens; November 2009, 120 specimens; March 2010, 50 specimens.

Description. Trunk 3.5± 12mm long and 0.8± 3mm wide. Introvert, 2± 9mm long, is shorter than the trunk length. Anal shield without furrows. Caudal shield weakly developed and in some specimens barely visible. Bidentate hooks, 55 mm in height, arranged in rings. The proximal part of the introvert has dark scattered pyramidal hooks of about 60 mm height. There are conspicuous small papillae over the surface of the trunk. Continuous longitudinal musculature. Two retractors originate close to the posterior trunk end. Two nephridia less than 2mm long are attached to the body wall for 85± 90% of their length (Fig. 31).

Discussion. The shape and appearance of the hooks and anal shield help in the identification of this species. Within the subgenus *Aspidosiphon*, there is a group of species characterized by a continuous longitudinal musculature and the presence of hooks arranged in rings. *Aspidosiphon (A.) elegans* can be separated from this group due to its anal shield feature and to the existence of the two types of hooks (compressed bidentate and pyramidal).

An asexual reproduction pattern are known for this species. The worms are capable to form an unequal transverse fission, or budding at the posterior end of trunk, which after a while become a new small individual. This peculiarities were found mostly in intertidal populations than in shallow water.

It is a common species in the Indian Ocean and Western Pacific, which has also been found in the Red Sea, in Israel (Mediterranean coast) and in a wide zone of the Caribbean. In the investigated sector of the China Sea it has been recorded previously from Indochina by Leroy (1942), from Hainan by Chen (1963), from the South China Sea by Murina (1989, 2003) and from by Li *et al.* (1992b). The species is always tropical, it inhabits dead coral and soft rocks in shallow depths.

Aspidosiphon (Aspidosiphon) muelleri Diesing, 1851

Material. NhaTrang: Dung Is., empty gastropods shells on sand, 15m, June 2008, 3 specimens; fish trowl, solid corals, 25m, 40 specimens.

Description. Trunk 7.5± 19mm long and 1.3± 2.5mm wide. Introvert slightly longer than the trunk, 13± 20mm long. Anal shield with a dorsal zone of longitudinal ridges. Caudal shield with radial furrows. Papillae distributed over the entire trunk. Unidentate compressed hooks in 30± 40 rings. Hooks 25± 30 mm in height. The proximal part of the introvert has scattered conical spines. Two retractors have their origins near the caudal shield.

Discussion. The continuous longitudinal musculature and the longitudinal grooves of the anal shield are diagnostic for the species. The morphology of the hooks of *A. (A.) muelleri* has always been a source of confusion. Cutler and Cutler (1989) concluded that each worm has the ability to produce either only unidentate hooks, only bidentate hooks, or some of both. According to Cutler (1994) this species is the most widespread, eurytopic and polymorphic *Aspidosiphon*; thus, comparable with *Golfingia margaritacea* (Sars, 1851), *Phascolion strombus* (Montagu, 1804) or *Sipunculus nudus* Linnaeus, 1766, which are also species with a long list of junior synonyms and a morphology difficult to be defined. It can be found in all oceans and continents, although it is almost non-existent in America. It is frequent in the Western Pacific Ocean, and has been recorded from the Gulf of Tonkin (Murina, 1977), Vietnam (Murina, 1989, 2007), and the South China Sea (Li *et al.*, 1992b).

Subgenus *Aspidosiphon (Paraspidosiphon)* (Stephen, 1964)

Aspidosiphon (Paraspidosiphon) steenstrupii Diesing, 1859

Material. NhaTrang Bay: Mot Is., coral rubbles, 7 m, May 2008, 2 specimens; Tre Is., coral rubbles, 6 m, June 2008, 8 specimens; Tre is., biofouling, intertidal, November 2009, 3 specimens; Mung Is., coral rubbles, 12 m, May 2008, 9 specimens; Diamond Bay: coral rubble, intertidal, June 2008; 4 specimens; November 2009, 3 specimens; March 2010, 5 specimens.

Description. Trunk 17± 37mm long and 2± 4.5mm wide. Introvert shorter than the trunk length, 9± 32mm long. Whitish coloured trunk and brown pre-anal region. Anal shield ungrooved, with calcium carbonate spots. Caudal shield with radiating grooves. Papillae distributed all over the entire trunk. Bidentate hooks (50± 65 mm tall) arranged in several rings at the distal part of the introvert. There are scattered dark pyramidal hooks (40± 50 mm tall) proximal to the rings. Tubular papillae (25± 30 mm tall) are interspersed between both kinds of hooks. Internally, the bidentate hooks exhibit a tongue-like extension on the internal clear streak. Longitudinal musculature in bands with numerous anastomoses. Two retractors have their origins near the caudal shield. Two nephridia of about 80% the trunk length, are attached to the body wall by their anterior halves. Rectal caecum present.

Discussion. The longitudinal musculature in bands, the fact that all compressed hooks are bidentate and arranged in rings, and the ungrooved anal shield are diagnostic characters for the identi® cation of this species. Furthermore, the presence of large tubular papillae over the introvert has been noticed in the specimens of this collection, which has provoked some doubts on whether they are true papillae or something more similar to conical hooks.

The species inhabits coral rocks in shallow waters of tropical seas. It is distributed throughout the Indian Ocean, Western Pacific Ocean and Hawaii, and in areas of the Caribbean sea and the Gulf of Guinea. In the area investigated it has previously been recorded from several localities in Indochina (Leroy, 1942), the Xisha Islands (Li, 1982), and the South China Sea (Murina, 1989; Li *et al.*, 1992b).

Genus *Cloeosiphon* Grube, 1868

Cloeosiphon aspergillus (de Quatrefages, 1865)

Material. NhaTrang Bay: Mot Is., coral rubbles, 7 m, May 2008, 12 specimens; Tre Is., coral rubbles, 6 m, June 2008, 18 specimens; Tre is., biofouling, intertidal, Nov2009, 6 specimens; Mung Is., coral rubbles, 12m, May 2008, 15 specimens; Nok Is., coral rubble, 5m, 8 specimens; Diamond Bay: coral rubble, intertidal, June 2008, 25 specimens; Nov2009, 16 specimens; March 2010, 8 specimens.

Description. Trunk up to 33 mm long and 4mm wide. Introvert shorter than the trunk length (about 15mm long). The anterior end is covered with a white shield of polygonal calcareous units, each of which has a dark central spot. Bidentate hooks in rings, 85 mm tall, exhibit an irregular and complicated internal clear area. Longitudinal musculature continuous; two short retractor muscles present (Fig. 32).

Discussion. This is one of the most distinctive species of sipunculans, as a result of its characteristic white calcified shield. The species exhibits a wide tropical Indo-Pacific distribution with frequent records from numerous places in these oceans, its range reaching as far as the coasts of Africa to the West and the Hawaii Islands to the East. Several localities in Indochina by Leroy (1942), the Xisha Islands by Li (1982), Vietnam by Murina (1989) and the South China Sea by Li *et al.* (1992b).

Conclusions

The collection, which consists of 371 specimens, encompasses a total of 20 species, belonging to eleven genera and five families. Hence, it can be considered to be a relatively rich collection of sipunculan species. Prior to our work, 15 species of sipunculans had been recorded from NhaTrang (Murina, 1989, 2007). Taking into account the 20 species identified in the present study (of which 4 are new records), the NhaTrang sipunculan fauna now includes 24 species. Furthermore, among the new records of sipunculans from NhaTrang Bay, the most striking case is the specimen of *Themiste* (*Lagenopsis*) *cymodoceae*, which represents the first record from the Pacific Ocean, even though its attribution to the species must be taken with care since we only had one specimen at our disposal.

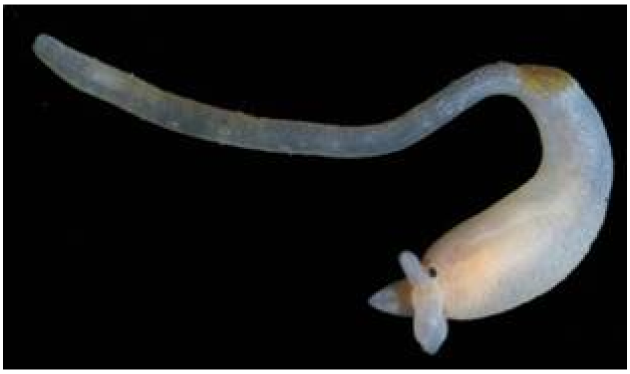

Fig. 31. *Aspidosiphon elegans* with budding juvenile.

Fig. 32. *Cloesiphon aspergillus.*

The fauna of warm water species of sipunculans in the West Pacific is well studied in the East and South China Seas. Thus, around the Taiwan about 29 species has been calculated up-to-date. In South China Sea, about 36 species are found, most of them being described from the Vietnam and China coast line. Thus, in the NhaTrang Bay (Vietnam) we found 20 species of sipunculans. Totally, the fauna of the NhaTrang Bay is estimated as having 24 species of peanut worms.

According to our calculations, about 73 species can be accounted for the West Pacific Seas. This number constitutes about 50 % of the known World fauna of peanut worms.

3.4 BIOVERSITY OF NEMERTINES

Nemertea is a phylum of the invertebrates known as nemerteans, or ribbon worms, which includes about 1300 species. These worms are found on the bottom of different types including silt, sand, algae, sea-grasses, and dead corrals in the regions from the supralittoral to the abyssal zone. About 300 species of ribbon worms are now known in the seas of Northeast and Southeast Asia. The actual number of species, however, must be at least 600. The fact is that the nemertean fauna of this region is investigated rather irregularly. There is almost no information on the nemerteans of the coastal waters of Vietnam. Joubin (1903) described *Cerebratulus velatus* from the Tonkin Bay. Dawydoff (1940) described high diversity of the nemertean larvae in the Nha Trang Bay, but adult worms were not identified. He also listed two heteronemertean species for the Nha Trang Bay: *Beseodiscus unistriatus* and *B. hemprechi*.

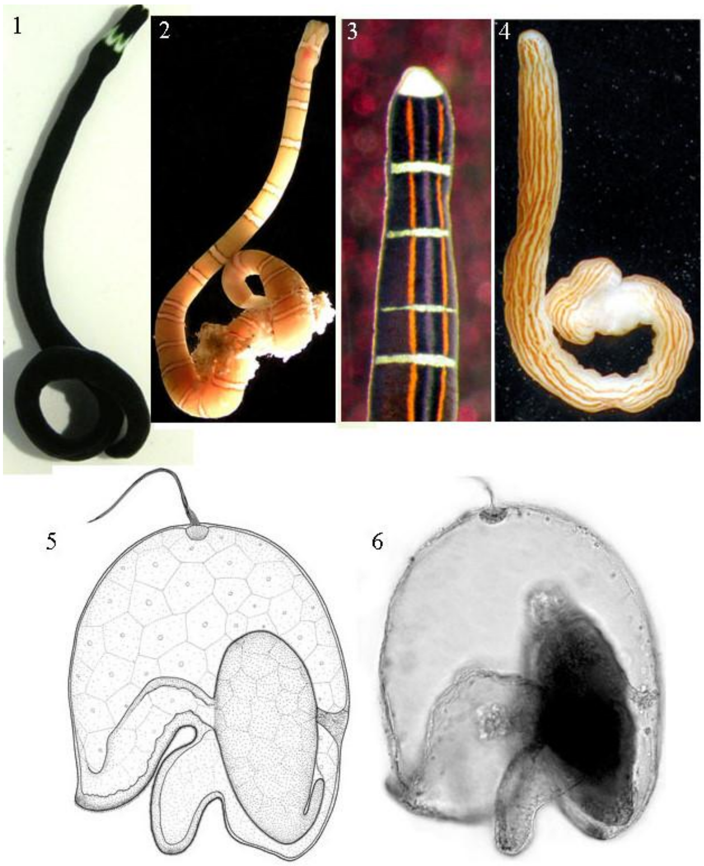

Fig. 33. Nemerteans from Vietnam: 1 – *Notospermus tricuspidatus*, 2 – *N. geniculatus*, 3 – *Micrura callima*, 4 – *Baseodiscus delineatus,* 5, 6 – *pilidium ex. gr. auriculatum*

Preliminary results

1. During the expeditions about 80 nemertean species belonging to 5 orders: Archinemertea (4 species), Tubulaniformes (2 species), Heteronemertea (32 species), Polystilifera (6 species), and Monostilifera (36 species) were collected.
2. 8 species are shown to be new for Vietnamese coastal waters: *Plectonemertes sinensis* Gibson, 1990*, Notospermus tricuspidatus* (Quoy et Gaimard, 1833) (Fig. 33, *1*), *N. geniculatus* (Delle Chiaje, 1825) (Fig. 33, *2*), *Micrura callima* Sundberg et Gibson, 1995 (Fig. 33, *3*)*, Baseodiscus delineatus* (Delle Chiaje, 1825) (Fig. 33, *4*)*, Lineus binigrilinearis* Gibson, 1990*, Cephalotrichella alba* Gibson et Sundberg, 1992*,* and *Tetrastemma verinigrum* sensu Gibson, 1990. *Micrura callima*, described from Australia, is more widely distributed and common species of the nemerteans in Vietnamese coast.

3. Most the collected species are new for science. The greatest number of new species (14) is expected to be discovered in the genus *Tetrastemma*. Most new species of nemertean live among corals, hydrocorals, ant cretaceous algae. New investigations will unquestionably allow us to find and describe many new genera and species of ribbon worms.

4. Four archinemerteans were sequenced and protein-coding gene cytochrome *c* oxidase I (COI) of these species was compared with that of other archinemertean species (Chen et al., 2010).

5. The musculature of 14 nemertean species was studied using phalloidin labeling and confocal laser scanning microscopy. New data is presented on the patterns of the body-wall, proboscis, and gonadal musculature.

6. New form of *pilidium* ex gr. *auriculatum* (larva of the undescribed hubrechtiids nemertean) from Van Phong Bay (South Vietnam) is described (Chernyshev, 2011). Distinguishing feature of this form is presence of short unpaired strand connecting the juvenile to the posterior wall of the pilidial epidermis (Figs. 33, *5, 6*).

3.5 DIVERSITY OF BIVALVE MOLLUSKS IN THE SOUTH CHINA SEA

The South China Sea has an area of some 3.3 million km^2 and depths to 5377 m in the Manila Trench. The sea has also numerous islets, atolls and reefs and it experiences a monsoonal climate being influenced by the Southwest Monsoon in summer and the Northeast Monsoon in winter. The South China Sea is a marginal sea and largely surrounded by land. Countries around the sea include China, Malaysia, the Philippines, Vietnam, Thailand, Indonesia and Taiwan. The coastal fringes of the South China Sea are home to about 270 million people that have had some of the fastest developing and most vibrant economies on the globe and, consequently, anthropogenic impacts, such as over-exploitation of resources and pollution, are anticipated to be huge although, in reality, relatively little is known about them (Morton, Blackmore, 2001). The South China Sea is poorly understood in terms of its marine biota and ecology but it lies in probably the world's most diverse shallow-water marine area. For instance, the fish fauna of the South China Sea includes at least 2321 species belonging to 35 orders, 236 families and 822 genera (among 3048 species of fish occurring in Cnina seas at all) (Ma et al., 2008). The Philippine Islands were called “center of the center” of marine shore fish biodiversity (Carpenter, Springer, 2005). There are many other evidences about the high biodiversity richness of the South China Sea.

A brief history of molluscan research

The bivalve molluscan fauna of the South China Sea - the biggest sea in the World Ocean - is insufficiently studied. Bivalve mollusks of Indo-China and Vietnam itself were studied by French malacologists in the second half of the 19th century and until World War II. They published several key papers which are still a major source of faunal information (Crosse, Fischer, 1889; 1890; Dautzenberg, Fischer, 1905; Fischer, 1891, and others). The French studies of bivalves of Vietnam and Cambodia were then summarized by Fischer (1973; 1987). Russian contribution to study of Vietnamese bivalves in 1970s-1990s was described by Lutaenko (2000a; b). There are some national Vietnamese papers on biodiversity of mollusks (see review in: Hylleberg, Kilburn, 2003). Most important contributions to understanding of biodiversity of mollusks in Vietnam recently published are an inventory by Hylleberg and Kilburn (2003), a check-list of Thach (2002) and two color books by Thach (2005; 2007). Suvatti (1938) summarized for the first time the marine bivalve fauna of Thailand having 153 species but it includes also coast of western Thailand. Two important contributions were recently published for the northern and southern Gulf of Thailand (Swennen et al., 2001; Robba et al., 2002; 2003). The Philippine fauna was reviewed in details in the beginning of the last century (Hidalgo, 1904-1905; Faustino, 1928), and there were some later works including color atlases by amateurs (see: Flessa, Jablonski, 1995). I don’t know special inventories of the entire Indonesian fauna of bivalves; there is a recent book by Dharma (1992). The most comprehensive Chinese monograph by Tchang et al. (1960) on bivalves of the South China Sea is now outdated but recently, two well illustrated guide-books on the entire Chinese fauna were published (Qi, 2004; Xu, Zhang, 2008). Lists of the Chinese bivalve fauna are very useful when dealing with regional distributions (Bernard et al., 1993; Xu, 1997). The Hong Kong bivalve fauna received special attention in past 40 years, and a checklist with full bibliography on all aspects of bivalve biology and ecology in the area was published (Valentich-Scott, 2003). The Taiwan fauna was documented in numerous papers including a list and several books (Wu, 1980; Wu, Lee, 2005; and others). The Chinese authors described many new species including those from the South China Sea (Lutaenko, Xu, 2008). Of course, there are many papers on various groups of bivalves which include records from the South China Sea.

Bivalve molluscan richness in the South China Sea

We still do not know how many species of bivalve mollusks live in the South China Sea. Crame (2000) estimated that about 1211 species inhabit Indonesia-Philippines region excluding both Taiwan and New Guinea, and 1176 species live in the "East China Sea region" (Table 3; Fig. 34). This estimate shows high diversity/richnes of the fauna and can be compared only to eastern Australia – 911 species. However, entire Japanese bivalve fauna is rich too – 1472 (Table 1) being richest molluscan fauna of the world. For comparison, species richnes of marine bivalve mollusks of all Russian seas is only 432 (Kantor, Sysoev, 2005).

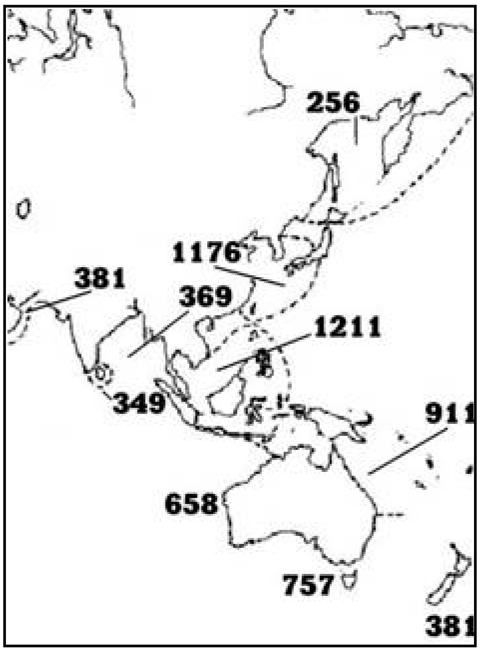

Fig. 34. Species richness (number of species) of bivalve mollusks in the south-east Asia and adjacent some areas (modified after: Crame (2000, p. 190, fig. 1).

This clearly reflects generally accepted concept of high biodiversity in the so-called "East Indies Triangle", or **Coral Triangle**: the ranges of many tropical marine species overlap in a centre of maximum biodiversity located in the Indo-Malayan region (Malaysia, the Philippines, Indonesia, and Papua New Guinea (Hoeksema, 2007). The Coral Trianle is recognized as a biodiversity hotspot but this centre is located approximately, and its exact boundaries are unknown.

Regional differences in species richness of bivalves in the South China Sea are not clear. They rather reflect sampling efforts than real biogeographical phenomena. Lutaenko (2000b) listed 367 species names of bivalve mollusks from Vietnam based on two largest Russian collections from the Zoological Institute (243 species) and the Zoological Museum, Far East Federal University

(Vladivostok) (83 species), and it was the most complete list at that time. Later on, Hylleberg and Kilburn (2003) compiled updated list of marine bivalves consisting of 815 species (Table 3), but it is uncritical in many ways.

Table 3

Species richness of bivalve mollusks in different parts of the South China Sea and some adjacent regions

Region	Number of species	Reference	Comments/notes
Japan	1472	Higo et al. (1999)	
China	1048	Xu (1997)	
Singapore	344	Tan, Woo (2010)	Majority of existing literature records cannot be verified due to a lack of voucher specimens
Vietnam	367	Lutaenko (2000b)	Based mostly on voucher specimens from two largest Russian collections of mollusks
Vietnam	815	Hylleberg, Kilburn (2003)	A compilation of all data available for Vietnam (literature and voucher collections in Vietnam)
Thailand	153	Suvatti (1938)	Including western Thailand; excluding species of Corbiculidae
Southern Gulf of Thailand	229	Swennen et al. (2001)	The area roughly between 6º and 7º N, about 10.000 km²
Northern Gulf of		Robba et al. (2002,	Records include Holocene shells

Thailand	244	2003)	recovered from the Holocene Bangkok Clay
Cambodia	93	Fischer (1973)	Corbiculidae is excluded
Tonkin Gulf	351	Zorina (1978a)	Based on voucher specimens
Guangdong Province, China	401	Cai, Xie (2006)	
Indonesia-Philippines region	1211	Crame (2000)	Excluding Taiwan and Papua New Guinea
Philippines	512	Flessa, Jablonski (1995)	A compilation based on literature data
Taiwan	463	Wu (1980)	

Based on these data, we may assume that the most rich faunas of bivalve mollusks are those of Vietnam (more than 800 species) and Philippines-Indonesia (more than 1200 species). Diversity of bivalves appears to show increase from north (Taiwan and Guangdong Province 401-463 species) to south (latitudinal gradient of biodiversity widely known in biogeography – a negative relationship between latitude and species diversity – Briggs, 1995). Impoverished character of the bivalves faunas of the Tonkin Gulf and the Gulf of Thailand can be explained by significant river discharge which decreases salinity.

Biogeography of bivalve fauna of Vietnam

There is no special analysis of the biodiversity and biogeography published for the entire Vietnamese marine bivalve fauna. Hence we review some older papers in order to raise problems to be dealt with in future based on more comprehensive faunal data.

Gurjanova (1972) showed that the fauna of Tonkin Gulf situated in the tropical zone bears typical tropical features, but it is impoverished due to "subtropical" conditions, i.e., pronounced seasonality and winter cooling of the water masses down to bottom. These "negative features" of the Tonkin Gulf fauna were illustrated by the example of bivalve mollusks (Gurjanova, 1972, pp. 85-86, 89), and can be summarized as follows:

1. *Absence of some common tropical faunal elements in Tonkin Gulf fauna*. *Mytilus smaragdinus* (= *Perna viridis*) (Mytilidae) was not found in expedition samples of the 1960s, while it is commercially important and abundant species in the Gulf of Thailand and southern Vietnam. Typical Indo-West Pacific bivalves of the family Tridacnidae - three species of the genus *Tridacna* - were found only on the southern coast of Hainan Island, but not on the Vietnamese coast, and the genus *Hippopus* is completely absent even in Hainan fauna. Because of weak development of coral reefs, a few species of coral borers were found, and impoverished composition of the genera *Chama* (Chamidae), *Spondylus* (Spondylidae) and Ostreidae was established (for instance, among ostreids only five species occur on the Vietnamese coast, while in Hainan Island there are 17 species). Gurjanova (1972) also noted rare occurence of *Chlamys* and *Pecten* (Pectinidae) on the Vietnamese side of the gulf.

2. *Difference between the fauna of southern Vietnam and Tonkin Gulf.* About 170 species of Bivalvia were recorded for southern Vietnam based on different sources and 101 species - for Tonkin Gulf (Gurjanova, 1972, p. 89; but the list on pp. 78-80 icludes 104 species). The same regularity was established for gastropods. Gurjanova (1972) explained the impoverished character of Tonkin Gulf fauna by the strong variability of hydrological factors and water mass dynamics, complicated and unstable circulation system with strong tidal currents. However, Latypov (2000) found that the reefs of the northern part of the Bai Tu Long Archipelago and Ha Long and Bai Tu Long bays (Tonkin Gulf) show a great degree of similarity in composition and distribution of reef-building corals with other reefs of Vietnam and the whole South China Sea (having from 60 to 72% of the scleractinian species in common) and a rather great species diversity (no less than one third of the common coral species of the Pacific fauna are found here) (Latypov, 2000).

Six types of distributional ranges of bottom fauna species inhabiting Tonkin Gulf were recognized taking into account bivalve species also (Gurjanova, 1972; all species names here are given in original spelling):

1. *Pan-Indo-Pacific species* widely distributed from the eastern coast of Africa eastward to islands of the central part of the Pacific Ocean, northward to southern Japan and southward to Australia (*Paphia lirata, Ostrea echinata, Ostrea mordax, Modiolus watsoni, Arca tortuosa, Amussium pleuronectes, Clausinella thiara, Placuna placenta, Meretrix meretrix, Malleus albus*).

2. *Eastern elements,* or *Philippine-Malayan West-Pacific species* distributed in the western tropical Pacific Ocean; the center of their development - shallow waters of the Malayan Archipelago and Philippine Islands (*Pedalion isognomum, Gomphina aequilatera, Venerupis philippinarum, Clausinella calophyla, Modiola philippinarum, Beguina semiorbiculata*).

3. *Western Atlantic-Indian elements*, or species distributed in the Indian or Indian and Atlantic Oceans and spreading eastward to Indo-China and Malayan Archipelago (*Donax faba, Donax cuneatus*).

4. *Sino-Japanese elements*, or species distributed in southern Japan and along the continental coast of China, southward spreading to the eastern shelf of Indo-China (*Clausinella isabellina, Asaphis dichotoma, Aloidis erythrodon, Sanguinolaria castanea, Sanguinolaria inflata, Abrina magna, Tellinides chinensis, Arca subcrenata, Isocardia vulgaris, Dosinia gibba, Cyclina sinensis, Amussium japonicus, Ostrea rivularis, Gomphina aequilatera*).

5. *Atlantic-Mediterranean elements* are recognized based on polychaete fauna with reference to possible existence of such ranges in mollusks.

6. *Sino-Vietnamese elements*, or species distributed in the north-western part of the South China Sea (southern China - Hainan Island and Guangdong Province) and Tonkin Gulf: the only possible endemic species of Vietnam is known - *Isocardia vulgaris.*

Based on the analysis of distributional ranges of bottom fauna species, Gurjanova (1972), in her biogeographical scheme, placed Tonkin Gulf into the "Hainan Province of the Sino-Japanese

Subregion of the West-Pacific Region of the Indo-West Pacific Superregion".

The study of the Vietnamese and Chinese molluscan collections in Russia was continued by I.P. Zorina, who published three papers dealing with the ecology, distribution and taxonomy of Tonkin Gulf bivalve fauna (Zorina, 1975; 1978a; b). In total, she identified 351 species belonging to 150 genera and 49 families (Zorina, 1978a), but complete species list has never been published except for the enumeration of 140 species from 7 selected families (Zorina, 1975). However, Zorina prepared a card catalogue of the studied collection, and a list of species was later published by Lutaenko (2000b) with some comments and illustrations of type material. Based on mentioned 140 species of the families Donacidae, Veneridae, Mactridae, Psammobiidae, Tellinidae, Solecurtidae and Semelidae, Zorina (1975) subdivided Tonkin Gulf fauna into 10 biogeographical groups (Table 4).

Table 4

Biogeographical analysis of Tonkin Gulf bivalve molluscan fauna based on seven families (Donacidae, Veneridae, Mactridae, Psammobiidae, Tellinidae, Solecurtidae and Semelidae) (after Zorina, 1975)

Biogeographical group	***Number of species***
1. Indo-West Pacific species in the broadest sense	20 (14.3 %)
2. Indo-West Pacific species (without Oceania)	29 (20.7 %)
3. Indo-West Pacific species with disjunct distributional ranges	8 (5.7 %)
4. West-Indian - Western Pacific species	16 (11.5 %)
5. West Pacific (including Oceania) species	3 (2.2 %)
6. Japanese-Malayan species	15 (10.7 %)

7. Philippine-Malayan species	10 (7.1 %)
8. Chinese-Australian species	14 (10 %)
9. Chinese-Japanese species	19 (13.5 %)
10. Conventional endemics of Tonkin Gulf	6 (4.3 %)

Separate analysis of the fauna of the intertidal zone (74 species) and subtidal zone (66 species) showed that species compositions of both zones are close to each other in biogeographical characteristics, however, some differences between these bathymetric areas are found. Among subtidal inhabitants, species widely distributed in the Indo-Pacific in its eastern part or in the western Pacific Ocean are predominant (61 %), while only 49 % of the intertidal fauna has such distributional ranges. Among intertidal species, the share of mollusks whose distribution is limited by coasts of China and Japan is higher (16 %) as compared to subtidal fauna (10 %). Zorina (1975) stated that there is no sharp difference in biogeographical composition of the intertidal and subtidal faunas because of absence of purely intertidal genera and a significant role of planktonic larvae in the dispersal of bivalve mollusks. Biogeographical processing of the entire fauna of Tonkin Gulf and Hainan Island led to the conclusion about predominance of tropical species (132, or 94 %), i.e., distributional ranges of these species lie exclusively in tropical waters. Seven species (5.3 %) reach to southern Japan and the Yellow Sea, and, thus, can be regarded as tropical-subtropical, and one species (0.7 %) - *Mactra quadrangularis* penetrates also into the low-boreal (temperate) area of the Sea of Japan in its north-western part. It was found that 73 species (or 52.1 %) of the Tonkin Gulf bivalve fauna are known from the Indian Ocean.

Comparison of the Tonkin Gulf fauna with those of the Philippine Islands and Japan showed that the former one is 2.5 times poorer than Philippine fauna, but, at least, 1.3 times richer than Japanese fauna. There is a great difference between intertidal faunas of the continental and island (Hainan) coasts of Tonkin Gulf: Hainan Island fauna is two times richer in species. So, Zorina (1975) confirmed the conclusion of Gurjanova (1972) about the impoverished character of Tonkin Gulf fauna caused by the specific hydrological regime (low winter temperatures and high freshening). Chung and Ho (1995) established that the number of zoobenthic species found in Tonkin Gulf is about 20 % of the total Vietnamese fauna, and the diversity of species increases from north to south.

It should be noted that the biogeographical analysis performed on the basis of 351 species identified by Zorina (1978a) yielded different figures (Table 5), especially concerning to the share of typical tropical species (45.9 %), which is much lower as compared to the results of consideration of seven selected families (94 %).

Table 5

Zonal-geographical (a) and biogeographical (b) analyses of Tonkin Gulf fauna of bivalve mollusks based on 351 species (after Zorina, 1978a)

A

Tropical species proper	161 species	45.9 %
Tropical-subtropical species	190 species	54.1 %

B

Circumtropical species	7 species	2.2 %
Widely distributed Indo-West-Pacific species	143 species	40.8 %
Species distributed in the eastern part of the Indo-Pacific and penetrating as far westward as Bengal Bay	144 species	41 %
Species distributed in China and Japan	42 species	11.8 %
Possible endemics of Tonkin Gulf	15 species	4.2 %

Data on the Tonkin Gulf fauna can be updated at present by new list for Cat Ba Isl. and Ha Long Bay (Duc, 2001).

Problems associated with tropical bivalve diversity and its study

One of the great scientific problem in systematic tropical malacology is synonymy. Mollusks are usually large and attaractive animals that have concentrated the most interest from travellers, collectors and scientists, and it is believed that every named species of mollusks had 4 to 5 names, with accumulated load of perhaps 300,000 names (Bouchet, 2006). Old synonyms are copied from one color catalogue or atlas to another without critical examination of existing literature, type materials, etc. In the absence of serious revisions for many groups and decline of taxonomic community of the second half of the 20th century, our biodiversity knowledge seems to be false and impoverished in some ways. Even with modern analytical tools and approaches, synonyms represent at most 10-20% of the new species currently being described each year (Bouchet, 2006). However, the frequent misidentification and underestimation of biodiversity have serious consequences when marine areas need to be studied, assesssed and conserved (Ng, Tan, 2000), and taking into account high diversity and wide distribution of bivalves in the South China Sea, the problem of misidentification/poor taxonomic knowledge is extremely important. Ecological and environmental assessments become useless if we don't know species we deal with in marine ecosystems and communities.

Related problem is a lack of taxonomic expertise on mollusks in many countries surrounding the South China Sea. There are few professional malacologists trained in taxonomy, and there are few well curated research collections/museums with voucher specimens. A few young scientists want to devote themselves to traditional taxonomy due to a limited financial support and low prestige of this field of biology. Other challenges confronting biodiversity specialists in the region include lack of literature, difficulties in disseminating data, and general lack of governmental commitment to develop biodiversity research to its full potential (Ng, 2000). Best collections from the South China Sea (besides Europe, the US and Russia) are in the Institute of Oceanology, Chinese Academy of Sciences (Qingdao), Raffles Museum of Biodiversity Research, National University of Singapore (Singapore), Bogor Museum in Indonesia, and National Museum of the Philippines which oversees also the National Museum of Zoology (in recent years, lack of finances, trained manpower, space, equipment and coordination has seriously hindered biodiversity research in the latter one) (Ng, 2000). There are no national museums in Malaysia, Vietnam and Cambodia although regional collections in universities and some research institutes play an important roles. The most effective means of upgrading the value and scientific importance of regional museums is the development of a strong research program, regular publishing, commitment to academic meritocracy and globalisation of biodiversity information (Ng, 2000).

Threats to marine biodiversity including molluscan faunas include habitat degradation, fragmentation and loss (especially important are mangrove forest destruction, loss of coral reefs, change in landscape mosaic of wetland, estuary, sand and mud flats); global climate change including sea level rise, storm events, rainfall pattern change, warming of the coastal ocean; effects of fishing and other forms of overexploitation; pollution and marine litter; species introduction/invasions; physical alterations of coasts; tourism (Gray, 1997). Continued warming through the 21st century is inevitable and will likely have widespread ecological impacts (Serreze, 2009). In Vietnam, the Red (Song Hong) and Mekong rivers discharge into the sea, and the catchments of these two transboundary rivers cover parts of six countries, and their water and sediment discharges greatly influence the coastal seas of Vietnam. The impact of human activities include changes in the quality of the coastal and marine environments due to the increased use and accumulation of pollutants and the loss of habitats. These impacts have resulted in increasing unpredictability and severity of coastal problems such as floods, erosion, sedimentation, and saltwater intrusion; environmental pollution; and the degradation of ecosystems, with accompanying decrease in biodiversity and fishery productivity (Thanh et al., 2004). Bivalve mollusks play an important role in the fishery industry of Vietnam; at least, 15 species (*Anadara granosa, A.* sp. ["*subcrenata*"], *A. antiquata, Arca navicularis, Perna viridis, Modiolus philippinarum, Amussium pleuronectes, Chlamys nobilis, Ostrea rivularis, Cyrenobatissa subsulcata, Dosinia laminata, D. sinensis, Meretrix meretrix, M. lyrata, Potamocorbula laevis*) are regarded as having high economic value (Phung, Tuan, 1996). So, habitat loss, environmental degradation and pollution greatly influence the biodiversity and abundance of mollusks. The same processes take place in other countries of the heavily populated basin of the South China Sea (Chen, Chen, 2002; and others).

3.6 COMPOSITION AND DISTRIBUTION OF MACROBENTHIC COMMUNITIES IN THE INTERTIDAL ZONE OF THE VIETNAM ISLANDS

The intertidal zone, as a more accessible zone of the sea, has traditionally played a key role in the life of maritime population Indo-Pacific region. Many intertidal molluscs, crustaceans, echinoderms and algae are edible, fossil corals are used for building, whereas various articles, decorations and souvenirs are made of sea shells. Investigation of biota of intertidal zone, typically amphibiotic, is one of the aims of marine ecological/environmental studies. Daily and seasonal fluctuations of temperature, salinity and humidity are the most sharply expressed in this zone which results in eurytopic fauna and flora possessing adaptation to unfavorable environment.

The basic publications concerning the intertidal zone of Vietnam are mainly on the northern part of the country (Gurjanova, Phuong Chang Hiu, 1972), although the most studied areas are southern coast (Ho Pham-Hoang, 1961, 1962; Loi Trang-Ngoc, 1967, Gulbin et al., 1987, 1988; Kussakin et al., 1988). In the present work, the species composition and distribution of macrobenthos of the island intertidal zone were studied along the entire Vietnamese coast. Six bionomical categories of the intertidal zone were distinguished on the basis of the substrate features, wave action, influence of the water-freshening and also specific factors (pools, ground vegetation): rocky intertidal zone, rocky-blocky-bouldery intertidal zone, sea pools of the intertidal type, intertidal zone of the dead coral reef, silty-stony intertidal zone and surf-open sandy beaches.

Rocky intertidal zone

The rocky intertidal zone (Katwick Islands and Thiam Island) is represented by the rocky platform with the steep (50–90°) slope of surface exposed to heavy wave action. The intertidal zone is no more than 10–15 m wide. The communities have clearly expressed vertical stratification. The epifauna' biomass is dominated there. The bivalve mollusc *Saccostrea mordax* forms belt in the upper horizon, the barnacles *Megabalanus tintinnabulum* and *Tetraclita squamosa squamosa* – in the middle horizon and in the most part of the lower horizon. In the lower part of the lower horizon the community' composition is liable to alterations in dependence on what algae or coral communities are developed here.

Population of the upper intertidal horizon is uniform. Community *Saccostrea mordax* (Fig. 35) forms belt 0.5–1.5 m wide. Total biomass of macrobenthos is up 12 kgWWm^2, *S. mordax* makes up 99% of the total macrobenthos biomass. Algae form patches 0.01–0.03 m^2 square. There are in the main cyanellae *Calothrix* sp., *Lyngbya* sp., *Oscillatoria* sp., and *Rivularia* sp. The projective covering of the bottom with algae reaches 80–100%. Following animals were found in the community: decapods *Grapsus tenuicristatus*, *Eriphia scabrinscula*, bivalve molluscs *Isognomon ephippium*, *Septifer virgatus*, gastropods *Trochus maculatus*, *Cellana testudinaria*, barnacle *Tetraclita squamosa squamosa*. In Thiam Island in place of belt-forming communitiy *S. mordax* gastropods *C. testudinaria*, *Nodilittorina millegrana*, *Nerita* sp. and other. inhabit upper horizon does not form its own belt (total biomass of macrobenthos is 656.6 gWWm^2.

In the middle intertidal horizon of Katwick Islands community barnacle *Megabalanus tintinnabulum* forms belt 3 m wide. Total biomass of macrobenthos is up 11 kgWWm^2. *M. tintinnabulum* is responsible for a large part of the animal biomass. Red algae *Hypnea pannosa*, *H. esperi*, *Laurencia parvipapillata*, *Liagora* sp., *Gelidiopsis* sp. dominate among plants. Algae sprouts *Polysiphonia* sp., *Gelidiella acerosa*, *Lobophora variegata*, *Liagora* sp., *Gymnogongrus griffithosoae*, *Rhodymenia anastomosans* often inhabit the shells of barnacles and bodies of spongia with the projective covering 60–100%. Sponge *Geodia* sp., *Halichondria* sp., *Suberites* sp., amphipods *Elasmopus* sp., *Ischyrocerus* sp., *Allorchestes* sp., isopods *Dynamenella trachydermata*, *Cirolana* sp., *Clianella brucei*, barnacle *Balanus reticulatus*, polychaeta *Nereis* sp. are the most frequent among animals. In Katwick Big Island community coral *Tubastraea coccinea* (total macrobenthos biomass is 1985.6 gWWm^2) develops in areas where rocky bottom has splits. Biomass of corals *T. coccinea* and *Stylophora pistillata* constitute 95% of the total macrobenthos biomass. In this community algae were not found. Polychaetes *Lysidice collaris*, *Typosyllis variegata*, amphipod *Ischyrocerus* sp., basket star *Ophiactis savigny*, bivalve mollusc *Lithophaga laevigata* are abundant among animals. Belt-forming community of barnacle *Tetraclita squamosa squamosa* is located in the middle intertidal horizon of Thiam Island. In this community algae were not found either. Animal biomass is up 10 kgWWm^2. *T. squamosa squamosa* and *Saccostrea mordax* constitute 90% of the total macrobenthos biomass. Gastropod *Cellana testudinaria*, bivalve mollusc *Septifer virgatus*, decapods *Metapograpsus messor* and *Pachygrapsus minutus*, polychaeta *Perinereis cultrifera* are abundant among animals.

Fig. 35. Scheme of distribution of macrobenthos in the rocky intertidal zones in the Katwick Big Island. 1 – *Saccostrea mordax*, 2 – *Megabalanus tintinnabulum*, 3– Spongia, 4 – Scleractinia, 5 – Polychaeta, 6 – Isopoda, 7 – Amphipoda, 8 – Loricata, 9 – Decapoda, 10 – Gastropoda, 11 – Echinoidea, 12 – Algae. Vertical scale – range over 0 depth.

Communities of barnacles *Megabalanus tintinnabulum* and *Tetraclita squamosa squamosa* spread in the lower intertidal horizon. Total animal biomass is up 10 kgWWm^2 and biomass of algae is up 413.0 gWWm^2. There is abundance of small animals: polychaetes *Syllis gracillis*, *Typosyllis variegata*, *Nereis nichollsi*, amphipod *Ischyrocerus* sp. and sprouts of red algae: *Ceramium gracillimum*, *Polysiphonia* sp., *Jania* sp., *Gelidium crinale*, *Rhodymenia anastomosans*, *Peyssonnelia* sp. Communities of corals *Tubastraea coccinea* and *Pocillopora verrucosa* also are found in the lower horizon.

Rocky-blocky-bouldery intertidal zone

The rocky-blocky-bouldery intertidal zone (Thiam, Thu and Ze Island) is characterized by blocks and boulders in the upper and middle horizons, rocks with a slope up to90°, blocks and boulders with underlying sand in the lower horizon. The intertidal zone can reach 20–30 m wide. There are belt-forming communities in the upper and middle horizons, whereas patching pattern of the distribution of the intertidal communities is observed in the lower horizon. Dominant species of the communities are different in the various areas, but like in the rocky intertidal zone, specimens of the epifauna, sessile and sedentary organisms inhabit here (molluscs *Nodilittorina millegrana*, barnacle *Tetraclita squamosa squamosa* and other).

Population of the upper intertidal horizon is various. There are among algae in the main cyanellae *Calothrix* sp., *Lyngbya* sp., *Oscillatoria* sp., and *Rivularia* sp. on boulders and blocks. In Thiam Island community *Nodilittorina millegrana* forms belt 3–5 m wide with dominating species biomass of 648.0 $gWWm^2$, which makes 99% of the total community biomass. Gastropod *Nerita albicilla*, *Thais mancinella*, *Cellana testudinaria* and other and decapod *Grapsus tenuicristatus* are accompanying species. In Ze Island community barnacle *Tetraclita squamosa squamosa* forms belt with animal biomass of 3066.0 $gWWm^2$. Gastropod *N. albicilla*, *Planaxis sulcatus* and decapod *G. tenuicristatus* are abundant. In the upper intertidal horizon of Thu Island animals inhabit only sea pools.

Communities of green algae *Halimeda opuntia*, *H. discoides*, *Caulerpa serrulata*, *C. racemosa* with dominating species biomass of 245.0 $gWWm^2$ and with rather rich composition of animals and plants are typical for the middle intertidal horizon of Thu Island. In the places of sand accumulation there is angiosperm *Thalassia* sp. There are abundant corals *Heliopora coerulea*, *Pocillopora verrucosa*, *Porites lutea*, *Goniastrea pectinata*, gastropods *Monodonta labio*, *Monetaria moneta*, *Conus ebraeus*, *Morula granulata* and other. In Thiam and Ze Islands community *Saccostrea mordax* forms belt 5–8 m width. Total biomass of macrobenthos is up 11.5 $kgWWm^2$. *S. mordax* makes up 70% of the total animal biomass. In this community algae is absent with the exception of calcareous red alga *Lithothamnion* sp. covering boulders and blocks. Species composition in the community is rather diverse, but gastropods *Nerita albicilla*, *Thais mancinella*, *Conus* sp., *Morula concatenata*, *Planaxis sulcatus* and spongia *Timea* sp. basically prevail.

The mass development of algae and invertebrates are characteristics for the lower intertidal horizon. In Thu and Ze Islands algal biomass is 500–800 and 1500–2000 $gWWm^2$ respectively. In rock splits, in the places of sand accumulation there are frequent red algae *Mastophora rosea*, *Laurencia corymbosa*, green algae *Caulerpa taxifolia*, *C. racemosa*, *Halimeda opuntia*, *H. discoides*, brown algae *Sargassum* sp., *Padina australis*. Algae form patches 0.5–6 m^2 square with the projective covering of the bottom up 100%. There are large diversity stone corals *Montipora digitata*, *M. spongoides*, *Porites australiensis*, polychates *Genetylis castanea*, *Paralentia annamita*, *Typosyllis maculata*, *Eunice antennata*, isopods *Metacirolana sphaeromiformis*, *Paracilicaea asiatica*, *Cervis pravipalma*, decapods *Leptodius exaratus*, *Actaeodes tomentosus*, gastropods *Trochus maculatus*, *Mauritia arabica*, *Scutus elongatus*, *Conus lividus*, *C. ebraeus*, basket stars *Ophiocoma erinaceus*, *Amphipholis squamata*, holothurian *Holothuria atra*, *H. difficilis*.

Marine pools of the intertidal type

Marine pools of the intertidal type were found on the hard substrata (Katwick Small Island, Thu and Ze Islands). They reach 2 m long, 2–3 m wide and up to 0.7 m deep. Their bottom is covered by cyanellae *Calothrix* sp., *Lyngbya* sp., *Oscillatoria* sp., and *Rivularia* sp. The projective covering of the bottom with algae reaches 100%, biomass – up 2000 $gWWm^2$. Sessile organisms (molluscs *Saccostrea mordax*, *Vermetes planorbis*) dwell on the walls of the pools. Such specific feature of the pools as constant presence of the sea water creates favourable conditions for the life of the fishes *Therapon jarbua*, *Abudefduf curacao*, *A. saxatilis*.

In Katwick Small Island community gastropods *Vermetes planorbis+Macrophragma tokyoensis* inhabits perennial depositions of the sedentary polychaetes lime-tubes. The total animal biomass is 5646.4 $gWWm^2$. There are abundance of pisces *Istigobius* sp. and Scorpaenidae gen. sp. In Thu Island bivalve mollusc *Isognomon ephippium* forms settlements on the walls of pools. There are the greatest diversity of pisces (*Therapon jarbua*, *Abudefduf curacao*, *Dascyllus* sp., *Pomacentrus* sp. and other) and basket stars (*Ophiocoma erinaceus*, *Amphipholis squamata* and other). In Ze Island population of intertidal pools is poor. Besides of cyanellae, there was found only pisces *Abudefduf saxatilis*.

Intertidal zone of the dead coral reef

Intertidal zone of the dead coral reef was found in the island lagoon (Re Island) bordered with gently shores with a light wave action. Plateau of the dead coral reef is covered by silty sand with rare boulders. Intertidal zone is about 1 km wide. Communities are characterized by patching pattern of the distribution. Mixed type of the bottom deposits, dismembered of microrelief, presence of passages, clefts inside of the dead corals create favourable conditions for development of cryptofauna.

In upper intertidal horizon community *Saccostrea mordax* (Fig. 36A) with total biomass of macrobenthos 3442.4 $gWWm^2$ is found. It was found no algae here. On the boulders there are also dominating sponge *Suberites* sp. and gastropods *Nerita plicata*, *N. iusculpta*. Colonies of coral polyp *Zoanthus* sp. inhabit the places of sand accumulation among boulders. Animal species composition is rather diverse in upper horizon. Gastropods *Cerithium morus*, *Nodilittorina millegrana*, *Planaxis sulcatus*, decapods *Alpheus* sp., *Calappa hepatica*, *Thalamita admete*, gastropods *Conus ebraeus*, *Monetaria annulus*, *M. moneta*, *Cerithium columna*, bivalve molluscs *Atrina pectinata*, *Isognomon serratula*, basket stars *Ophiocoma scolopendria*, *O. breviceps*, *Ophiactis savigny*, holothurians *Synapta maculata* and *Holothuria leucospilota* frequently occur in the dead corals.

The middle intertidal horizon is covered with community angiosperm *Thalassia hemprichii* (1787.5 $gWWm^2$). There is a large diversity of algae (red algae *Galaxaura fastigiata*, *Ceratodictyon spongiosum*, *Gracilaria* spp., green algae *Ulva* sp., *Halimeda opuntia*, *H. discoides*, *Dictyospaeria cavernosa*, brown algae *Sargassum ilicifolium* and *S. polycystum*). Total algal biomass is up 2000 $gWWm^2$. Total animal biomass is 3240.1 $gWWm^2$. Sponge *Suberites* sp. and holothurian *Holothuria atra* make about 80% of total biomass of animals. Infaunal (coral polyp *Zoanthus* sp., polychaetes *Perinereis cultrifera*, *Cerratulus cirratus*, *Ciratonereis mirabilis*, *Nematonereis unicornis*) and onfaunal decapod *Alpheus* sp. can be found in the rhizomes of *T. hemprichii*.

Species composition of algae the lower intertidal horizon is similar to one of the middle horizon. Algae inhabit in the main boulders and debris of corals with the projective covering 70–100%. There are red algae *Laurencia corymbosa*, *Padina australis*, *Peyssonnelia* sp., *Lobophora variegata*, green algae *Ulva* sp., *Caulerpa racemosa*, *C. lentilifera*, *C. taxifolia*, *C. serrulata*, *C. fastigiata*, brown algae *Turbinaria ornata* and *Sargassum* spp. Colonies of stone corals *Porites lobata* and *P. lutea* form extensive settlements. Big (up 50 cm in diameter) sea anemone *Gyrostoma* sp. and holothurian *Holothuria atra* often meet here. Boulders and corals cover with diversity sponge (*Suberites* sp., *Rhaphidophus erectus*, *Spirastrella* sp., *Geliodes* sp.) and colonial ascidians. Polychaetes *Perinereis cultrifera*, *Cerratulus cirratus*, *Ciratonereis mirabilis*, decapods *Gonodyctylus chiragra*, *Alphes* sp., *Thalamita admete*, gastropods *Conus ebraeus*, *C. flavidus*, *Monetaria annulus*, *M. moneta*, *Cronia margariticola*, *Strombus mutabilis*, bivalve molluscs *Lithophaga laevigata*, *Pinctada margaritifera*, coral fishes and moray are numerous in splits of the stone substrate and corals.

Silty-stony intertidal zone

In the silty-stony intertidal zone, situated in inlets (Zanzola and Daochao Islands), bottom deposits consists of the stony debris, dead coral fragments, shelly ground covered by 15–20 cm silt. A light wave action and little water-freshening are typical here. Intertidal zone reaches 200 m wide. Brushwoods of the ground plant *Aegiceras* sp. and solitary brushes of mangroves, covering by the sea water in the high water, can be observed in the upper horizon. Population of this inteitidal zone is impoverished and the patch pattern of the community' distribution is typical. A presence of the soft ground creates conditions for development of the various infauna (polychaetes *Bhawania cryptocephala*, *Leonnates persica*, *Onuphis eremite*, *Lambrineris shiihoi*, sipunculas *Antilleosoma antillarum*, *Golfingia elongate*, *Thysanocardia catherinae*). Specimens of epifauna inhabit the hard substrata (*Saccostrea echinata*, *Balanus retuculatus*, *Cthamalus malayensis*). *Oystrea foliolum* settles on the stems and branches of *Aegiceras*. Macrophyte algae are almost absent. This is connected with faint transparence of the sea water.

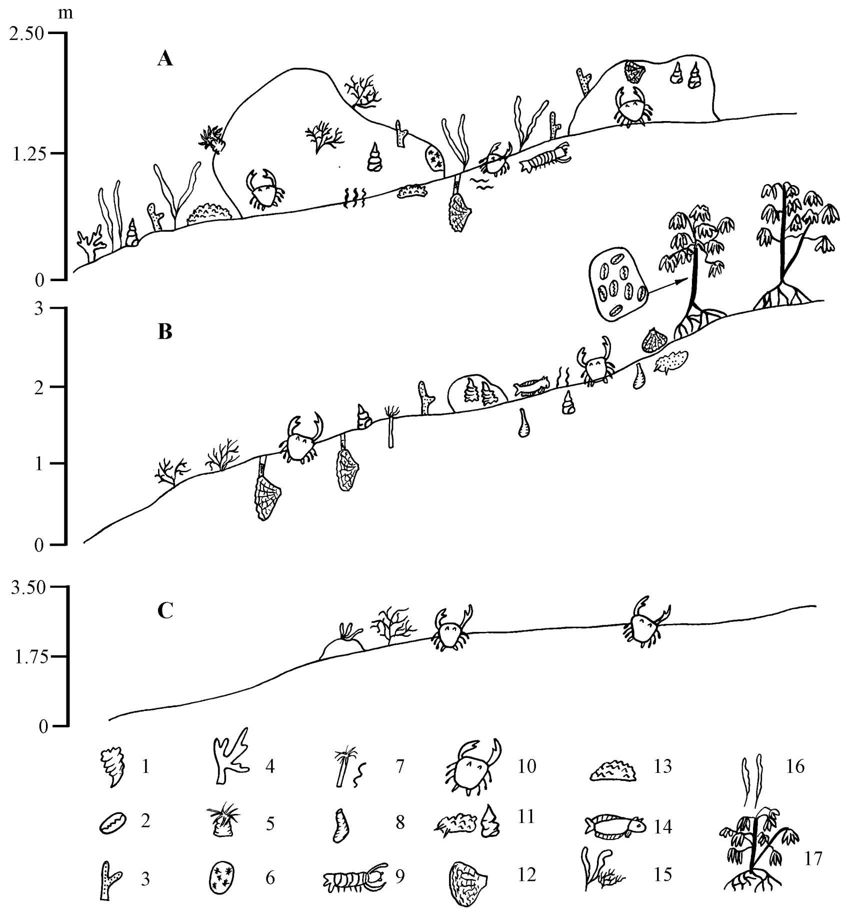

Fig. 36. Schemes of distribution of macrobenthos in the mixed substrates. A – intertidal zone of dead coral reef in Re Island, B – silty-stony intertidal zone in Daochao Island, C – sandy intertidal zone in Ze Island. 1 – *Saccostrea* spp., 2 – *Ostrea foliolum*, 3– Spongia, 4 – Scleractinia, 5 – Actiniaria, 6 – Zoantharia, 7 – Polychaeta, 8 – Sipuncula, 9 – Stomatopoda, 10 – Decapoda, 11 – Gastropoda, 12 – Bivalvia, 13 – Holothurioidea, 14 Pisces, 15 – Algae, 16 – Angiospermae, 17 – *Aegiceros* sp. Vertical scale – range over 0 depth.

In the upper intertidal horizon only animal population is observed. In Daochao Island communitiy *Ostrea foliolum* (Fig. 36B) forms belt on the stems of *Aegiceras* sp. with total biomass 2733.0 gWWm^2. Among of the *Aegiceras* branches there are bivalve molluscs *Gafrarium pectinatum*, *Dicyanthifer manni*, *Kellia* sp. and gastropod *Nerita iusculpta*. The stones are fouled ouster *Saccostrea echinata*, barnacles *Balanus reticulatus* and *Chthamalus malayensis*. There are abundance gastropods (*Nerita albicilla*, *N. signata*, *Lunella granulata*, *Cerithium morus*). Population of the upper horizon of Zanzola Island is poorer, but as the whole species composition is similar to inhabitants of Daochao Island. On the stones there is prevalent community of the bivalve mollusks *Isognomon ephippium*+*Hormomya mutabilis* with the total biomass of macrobenthos 430.0 gWWm^2.

In the middle intertidal horizon of Daochao Island sprouts of algae with total biomass 56.4 gWWm^2 can be obsevered. The total animal biomass is 897.4 gWWm^2. Belt-forming species

Saccostrea echinata makes 80% of the animal biomass. Numerous gastropods *Batillaria zonalis*, *Cerithium morus*, bivalve molluscs *Gafrarium pectinatum*, *Anomalocardia squamosa*, sipuncula *Thysanocardia catherinae* and decapods *Mictyris longicarpus*, *Uca dussumieri*, *Thalamita crenata* are accompanying species. In Zanzola Island community bivalve molluscs *Gafrarium pectinatum+Anomalocardia squamosa* is developed on the stones. Total animal biomass in this community is 1263.4 gWWm^2, dominant species makes more 80% total biomass. Bivalve mollusc *Hormomya mutabilis* and polychaetes *Thyryx mulifilis* and *Leonates persica* frequently occur.

The lower horizon silt-covered, there are rare shell and coral deposits. Macrobenthos is absent, only in Daochao Island sprouts of red algae *Peyssonnelia* sp., *Bastrychia binderi*, *Wurdemannia miniata* and green algae *Cladophora papenfussii* are found.

Surf-open sandy beaches

Surf-open sandy beaches (Re, Thiam and Ze Islands) characterized by clean sand with the rare boulders. The intertidal zone is about 30–40 m wide. Heavy wave action is usual and population is poor here. Vagile animals prevail (decapods *Ocypode ceratophtalma*, *Coenobita* sp.). In some of the studied areas in the lower horizon the species abundance of macrophyte were found.

In the upper and middle intertidal horizons of Re Island animals and plants are not found. Population of the lower horizon is rather rich. On boulders lying on sand there are abundance of species of red algae *Hypnea*, *Laurencia*, *Gracilaria*, *Galaxaura* and green algae *Ulva*, *Caulerpa*, *Dictyosphaeria*. Gastropods *Latirus barclayi*, *Pyrene ocellata*, *Morula granulata*, *Cerithium morus*, *Conus lividus*, *Aplysia* sp. and sea urchins *Diadema setosum*, *Echinothrix diadema*, *Tripeneustes ventricosus* are prevailed among of animals. In Ze Island in the lower horizon bushes of algae *Padina australis* and *Jania* sp. are found on the rare boulders. In the intertidal zone of Ze and Thiam Islands sand is inhabited mobile decapod *Ocypode ceratophthalma* (Fig. 36C).

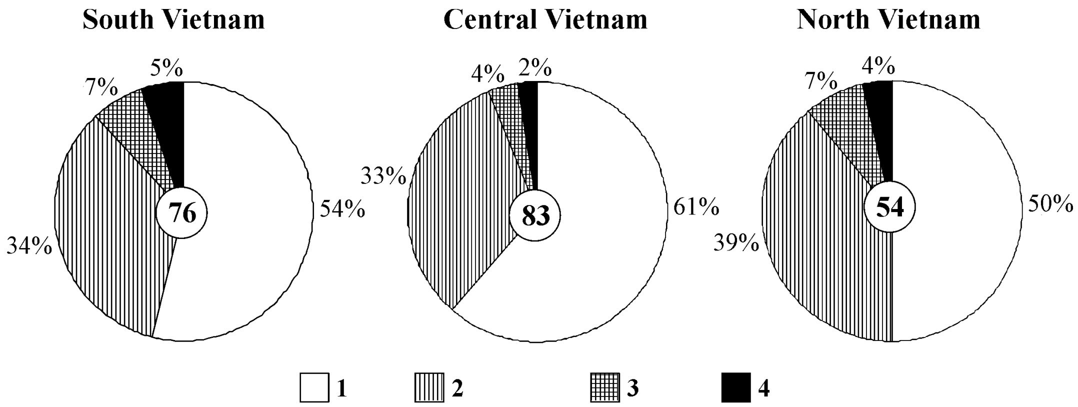

Fig. 37. Zonal-biogeographical structure of the animal macrobenthos in the intertidal zone of the Vietnamese Islands. South Vietnam – Katwick and Thu Islands, Central Vietnam – Re, Thiam and Ze Islands, North Vietnam – Zanzola and Daochao Islands. 1 – tropical; 2 – tropical-subtropical; 3 – notal-tropical-boreal, tropical-boreal, subtropical-tropical-boreal, notal-tropical-subtropical; 4 – cosmopolite species. The number species are shown in the circles centre.

In the intertidal zone of studied areas 101 plant and 268 animal species are found. Zonal-biogeographical composition represents for 173 species of animals. Biota the Vietnamese Islands intertidal zone is typical for tropical region of the Pacific Ocean. Tropical and tropical-subtropical species prevail (for the South Vietnam coast – 54, or 34%, respectively, for the Central Vietnam one – 61, or 33%, and for the North Vietnam coast – 50, or 39%), fauna with wide distribution (from notal to boreal sea waters) is represented as well, but in low proportions (Fig. 37).

Macrobenthos of hard substrates (the rocky and rocky-blocky-bouldery intertidal zone) is the richest in qualitative and quantitative compositions. Population of crumbly substrates (the silty-stony intertidal zone and sandy beaches) is the poorest. It did not find any macrophytic algae in the upper horizon and the major part of the middle horizon of surf-open sandy beaches. The intertidal zone of dead coral reef has no analogues in boreal waters and has a particular place in peculiarity of qualitative and quantitative composition of population.

3.7 FAUNA OF OPISTOBRANCH MOLLUSKS (GASTROPODA) OF NHATRANG BAY

Gastropod opistobranch mollusks of the coastal waters of Vietnam are known insufficiently. The only review paper was published more than 50 years ago and is outdated (Risbec, 1956). During field-works in Nhatrang Bay in 2008, 150 samples were collected in a depth range of 2.5-25 m by SCUBA-diving and intertidally, mostly on hard bottom (rocks, alive and dead corals).

According to Risbec (1956), the opistobranch fauna of the bay consisted of 80. In the present study, we have found 157 species (Table 6). Figs. 38-39 show some typical species.

Table 6

Number of species of opistobranch mollusks in families found in Nhatrang Bay

Families of Opisthobranchia	Number of species found
Diaphanidae	1
Philinidae	1
Aglajidae	6
Gastropteridae	2
Smaragdinellidae	2
Aplysiidae	7
Umbraculidae	1
Limapontiidae	1
Elysiidae	6
Pleurobranchidae	4
Pleurobranchaeidae	2
Chromodorididae	42
Dorididae	15
Hexabranchiae	1

Dendrodorididae	6
Phyllidiidae	22
Polyceridae	4
Gymnodorididae	3
Tritoniidae	1
Tethydidae	3
Bornellidae	3
Dotidae	2
Arminidae	7
Flabellinidae	3
Aeolidiidae	2
Facelinidae	10

Fig. 38. *Hypselodoris bullockii* (Collingwood, 1881).

Fig. 39. *Discodoris boholiensis* Bergh, 1877.

4.0 Conclusions

The APN Project ARCP2011-10CMY-Lutaenko intended to study marine biological diversity in coastal zones of the South China Sea with emphasis to Vietnam, its modern status, threats, recent and future modifications due to global climate change and human impact, and ways of its conservation. The project involved participants from three countries (Republic of Korea, Russia and Vietnam).

Based on various literature data, the survey of coral reefs in Vietnam during the last 15 years shows that the area of coral reefs has been reduced by 15-20%, mainly in coastal waters of the central part of Vietnam from Da Nang to Binh Thuan province. Coal dust has caused the death to large areas of corals in the Ha Long and Bai Tu Long bays (Quang Ninh Province). Along with the coral reef area reduction, the number of species is also reduced. For example, the coverage of coral reefs in Bai Tien area (Nha Trang) was 30% (1984), there was 60 species, and it reduced to 1% by 1998 and the number of species decreased to 30. Other living organisms were also reduced in number significantly. At present, all countries in the South China Sea have degraded reefs, from 95% in Hainan Island to an unknown amount in Vietnam. Sustainable use and protection of the SE Asia coastal reefs are now items which stands in the focus of the international agendas.

In terms of environmental conditions suitable for growth of the reef-building coral species, the coastal areas of western Tonkin Gulf are very far from favorable for reef development. This is largely due to low water temperatures during the winter months, and large contributions of freshwater and sediments to this part of the gulf from adjacent river systems. Corals are mainly observed in areas of Ha Long Bay, Bai Tu Long, the Co To Archipelago, and Long Chau Islands, which are mostly surrounded by shallow and muddy bottoms. The coral reefs that have developed in the western Tonkin Gulf are typically narrow and extend to a depth of only 5-7 m. The reefs of the northern part of the Bai Tu Long Archipelago may be considered a stable ecosystem, adapted to low illumination conditions as a result of heavy water silting and eutrophication. The reef communities in this region are formed by both hermatypic corals, capable of surviving under low illumination conditions, and ahermatypic corals, whose distribution does not depend on the illumination level. These peculiarities make the reefs of the Gulf of Tonkin really unique. The conservation and recovery of the high biodiversity of reef communities in these regions should be considered a first priority task in the framework of creating reserves and conservation areas in the Gulf of Tonkin.

The biota of intertidal zone of the Vietnamese islands from Namzu Islands (9°40' N, 104°22' E) in the Gulf of Siam to Daochao Island (20°50' N, 107°20' E) in the Gulf of Tonkin was studied based on previously taken collections and belt-forming communities of macrobenthos were investigated in five bionomical types of the intertidal zone; these data may serve as a basis for future long-term monitoring of biodiversity changes. In the intertidal zone of studied areas, 101 plant and 268 animal species are found. Biota the Vietnamese Islands' intertidal zone is typical for tropical region of the Pacific Ocean. Tropical and tropical-subtropical species prevail (for the south Vietnam coast – 54 species, or 34%, respectively, for the Central Vietnam one – 61, or 33%, and for the North Vietnam coast – 50, or 39%), faunal elements with wide distribution (from notal to boreal sea waters) is represented as well, but in low proportions. Macrobenthos of hard substrates (the rocky and rocky-blocky-bouldery intertidal zone) is the richest in qualitative and quantitative compositions. Population of crumbly substrates (the silty-stony intertidal zone and sandy beaches) is the poorest. Any macrophytic algae in the upper horizon and the major part of the middle horizon of surf-open sandy beaches are not found. The intertidal zone of dead coral reef has no analogues in temperate waters.

The distribution of the taxonomical composition and the density of meiobenthos depending on some factors of environment has been studied in bottom sediments of the northern estuary part of Ha Long Bay for the first time; a total of sixty six species belonging to 17 families and 52 genera were identified. The estuary part of the Ha Long Bay is exposed constantly as to anthropogenic impact from the sea port (bottom dredging works), and to mainland drain of fresh waters which result in significant changes of salinity within a year. In general, differences in composition and distribution of meiobenthic communities in Ha Long Bay appeared to be connected with changes in granulometric composition of bottom sediments. The silted sediments are characterised by the low species diversity and higher density of the animals than the slightly silted sands. The meiobenthos density at Nha Trang Bay reefs also shows an uneven distribution and depends on the sediment type. The correlation analysis revealed the dependence between the median diameter of sediment particles and the density of meiobenthos. However, taxonomic diversity of meiobenthos in Nha Trang Bay (twenty six groups) was greater than in other areas. Nematodes dominated in bottom sediments both in Nha Trang Bay itself and at its reefs. In total, representatives of four orders, twenty eight families and ninety seven genera were found in Nha Trang Bay. Nematodes made up to more than 90% of the total population density of meiobenthos at stations with high number of silt particles in sediments. Probably, the oxygen deficiency is a limiting factor for the penetration of animals into the depth of sediments in the central part of Nha Trang Bay.

The biodiversity of rare and little-known groups of invertebrates (nemerteans, sipunculids, opistobranch mollusks) of Vietnam was studied for the first time. Twenty species in eleven genera and five families of Sipunculida are recognized from the total 371 individuals collected in southern Vietnam. An analysis of the sipunculan literature has shown that 5 of these species are new records for Nha Trang Bay. 157 species of opistobranch mollusks are recorded in southern Vietnam, about half of them for the first time. About 80 nemertean species belonging to 5 orders: Archinemertea (4 species), Tubulaniformes (2 species), Heteronemertea (32 species), Polystilifera (6 species), and Monostilifera (36 species) were collected in Vietnam, a majority for the first time.

The extensive literature review was prepared with regard of molluscan biodiversity in the Soutrh China Sea. Crame (2000) estimated that about 1211 species of bivalve mollusks inhabit Indonesia-Philippines region excluding both Taiwan and New Guinea, and 1176 species live in the “East China Sea region”. This clearly reflects generally accepted concept of high biodiversity in the so-called “East Indies Triangle”, or Coral Triangle: the ranges of many tropical marine species overlap in a centre of maximum biodiversity located in the Indo-Malayan region (Malaysia, the Philippines, Indonesia, and Papua New Guinea (Hoeksema, 2007). The Coral Trianle is recognized as a biodiversity hotspot but this centre is located approximately, and its exact boundaries are unknown. Regional differences in species richness of bivalves in the South China Sea are not clear. They rather reflect sampling efforts than real biogeographical phenomena. Lutaenko (2000b) listed 367 species names of bivalve mollusks from Vietnam based on two largest Russian collections and it was the most complete list at that time. Later on, Hylleberg and Kilburn (2003) compiled updated list of marine bivalves consisting of 815 species, but it is uncritical in many ways. Based on these data, we may assume that the most rich faunas of bivalve mollusks are those of Vietnam (more than 800 species) and Philippines-Indonesia (more than 1200 species). Diversity of bivalves appears to show increase from north (Taiwan and Guangdong Province, 401-463 species) to south (latitudinal gradient of biodiversity widely known in biogeography. Impoverished character of the bivalves faunas of the Tonkin Gulf and the Gulf of Thailand can be explained by significant river discharge which decreases salinity. Problem iin molluscan biodiversity include a lack of taxonomic expertise in many countries surrounding the South China Sea. There are few professional malacologists trained in taxonomy, and there are few well curated research collections/museums with voucher specimens. A few young scientists want to devote themselves to traditional taxonomy due to a limited financial support and low prestige of this field of biology. Other challenges confronting biodiversity specialists in the region include lack of literature, difficulties in disseminating data, and general lack of governmental commitment to develop biodiversity research to its full potential.

Threats to marine biodiversity habitat degradation, fragmentation and loss (especially important are mangrove forest destruction, loss of coral reefs, change in landscape mosaic of wetland, estuary, sand and mud flats); global climate change including sea level rise, storm events, rainfall pattern change, warming of the coastal ocean; effects of fishing and other forms of overexploitation; pollution and marine litter; species introduction/invasions; physical alterations of coasts; tourism.

The 2010 conference and the 2011 workshop held in course of the implementation of the project summarized BD data and information of Vietnamese and Russian researchers to be used in preparation of final APN-sponsored book on the marine BD of Vietnam as one of the outcome of the project. Proceedings of both meetings were published (Dautova and Lutaenko, 2010; Lutaenko, 2011).

The data obtained and summarized and interpretations of the coastal/ecosystem changes would be of use for development of recommendations for local/regional/national decision- and policy-makers and would contribute to current understanding of tropical ecosystem of the South China Sea.

5.0 Future Directions

Through implementation of the project, we developed a network of scientists who are interested in future collaboration. We hope to work together in frames of other projects. A project on biological resources management with a Vietnam leadership and involvement of Russia and Singapore would be prepared in the RIA3 to be submitted to the APN in 2012, and a joint book would be published in 2013.

Appendix

PROGRAMME OF THE INTERNATIONAL CONFERENCE

"MARINE BIODIVERSITY OF EAST ASIA: STATUS, REGIONAL CHALLENGES AND SUSTAINABLE DEVELOPMENT"

under the aegis of the APN (Asia-Pacific Network for Global Change Research), VAST (Vietnam Academy of Sciences and Technology) and RAS (Russian Academy of Sciences)

Venue:

Institute of Oceanography VAST,

Nha Trang, Vietnam, December 6-7, 2010

December 6 (Venue – Conference Hall of the IO VAST)

8:30 – 9:00

Registration of the participants and posters placement.

9:00 - 9:40 Opening address

9:00-9:15

Opening speech by **Mrs Do Minh Thu**, Co-Chair of the Organizing Committee

9:15-9:30

Opening speech by **Dr. Tatiana N. Dautova**, Institute of Marine Biology FEB RAS, Vladivostok, Russia

9:30-9:40

Opening speech by **Dr. Konstantin A. Lutaenko**, Institute of Marine Biology FEB RAS, Vladivostok, Russia

9:40 – 10:00 Group photo

10:00 – 10:10 Coffee break.

10:10 – 12:00

Session A**. Physical forcing to marine biodiversity: sea water chemistry, water motion, currents, etc.**

10:10-10:30. Bui Hong Long *(Institute of Oceanography VAST, Nha Trang, Vietnam*) SOME EXPERIMENTAL CALCULATIONS FOR 3D CURRENTS IN THE STRONG UPWELLING REGION OF SOUTHERN CENTRAL VIET NAM, USING FINITE ELEMENT METHOD

10.30-10.50. Tong Phuoc Hoang Son[a], Hoang Cong Tin[b,c], Chun Knee Tan[d]

([a]Institute of Oceanography VAST, Nha Trang, Vietnam; [b]Centre for Coastal Management and Development Studies, Hue University of Sciences, Vietnam; [c]NF – POGO Centre of Excellence on Observation Oceanography, Bermuda Institute of Ocean Sciences, Bermuda; [d]Global Environment Information Centre (GEIC), Tokyo, Japan) OBSERVATION/DETECTING CHLOROPHYLL A DISTRIBUTION AND HARMFUL ALGAL BLOOMS IN THE VIETNAM COASTAL UPWELLING BY HIGH RESOLUTION MULTISENSOR DATA

10.50-11.10. Nguyen Tac An *, Vo Duy Son *. Cherbadzhi I.I.**, Propp M.V.**, Odintsov V.S.**; Propp L.** **(***Institute of Oceanography VAST, Nha Trang, Vietnam, ** A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, Russia)* THE ECOLOGICAL-CHEMICAL CHARACTERISTICS OF CORAL REEF WATERS OF VIETNAM COASTAL AREAS

11.10-11.30. Tong Phuoc Hoang Son *(Institute of Oceanography VAST, Nha Trang, Vietnam)* THE OPTIMUM ENVIRONMENTAL CRITERIA SET FOR CLAM CULTURE IN MEKONG DELTA

12:00 – 13:30. Lunch break.

13:30 – 15:20. Session B. Climate/global environmental changes and possible effects on the marine biodiversity in East Asia.

13:30-13:50. Nguyen Vu Than, Nguyen Dinh Thuat (*North-East regional Hydro-meteorological center, National Hydro-meteorological service, MONRE Vietnam*) IMPACT OF CLIMATE CHANGE ON HAIPHONG AREA

13:50-14:10. Nguyen Thi Xuan Thu [1], Nguyen Viet Thuy[2], Tran Thi Kim Hanh[2] , Nguyen Anh Tien[2], Mai Duy Minh[2], Le Trung Ky[2] *(-[1]Ministry of Agriculture and Rural Development, [2]Research Institute for Aquaculture No. 3)* THE OPTIMAL TEMPERATURE FOR RAINBOW TROUT (ONCORHYNCHUS MYKISS) CULTURE IN LAM DONG PROVINCE

14:10-14.30. Eduard A. Titlyanov[a], Sergey I. Kiyashko[a], Tamara V. Titlyanova[a], Pham Van Huyen[b], Irina M. Yakovleva[a] (*[a]A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, Russia; [b]Nha Trang Institute of Technology Research and Application VAST)* NITROGEN SOURCES TO MACROALGAL GROWTH AT POLLUTED COASTAL AREAS OF SOUTHERN VIETNAM

15:00 – 15.30. Coffee break.

15:30 – 17:10. Session C. Marine biodiversity 1.

15:30-15:50. Cuong T.Le, Ronald G. Noseworthy, Kwang-Sik Choi (*Jeju National University, Republic of Korea)* BIODIVERSITY OF COMMERCIALLY VALUABLE MARINE BIVALVE FAUNA OF JEJU ISLAND, REPUBLIC KOREA

15:50-16:10. Larisa A. Prozorova[1], Tatiana Ya. Sitnikova[2], Anna Rasshepkina[1] *([1,]Institute of Biology and Soil Science FEB RAS, Vladivostok, Russia; Limnological Institute of the SB RAS, Irkutsk, Russia)* NEW DATA ON MORPHOLOGY OF BATILLARIID GASTROPODS (CAENOGASTROPODA: CERITHIOIDEA: BATILLARIIDAE)

16:10-16:30. Alexey V. Rybakov (*A.V. Zhirmunsky Institute of Marine Biology FEB RAS)* BIOLOGY AND DIVERSITY OF ABERRANT RHIZOCEPHALA – SUCCESSFUL FRESWATER INTRUDERS IN EXCLUSIVELY MARINE GROUP (CRUSTACEA: CIRRIPEDIA)

16:30-16:50. Larisa A. Prozorova[1], Tatiana Ya. Sitnikova[2], Ronald Noseworthy[3] ([1]Institute of Biology and Soil Science FEB RAS, Vladivostok, Russia; Limnological Institute SB RAS, Irkutsk, Russia; [3]Faculty of Marine Biomedical Science, Jeju National University, Republic of Korea) ON THE MORPHOLOGY AND TAXONOMY OF PACIFIC GASTROPODS IN FAMILIES OF TROPICAL ORIGIN LITIOPIDAE AND DIALIDAE (CAENOGASTROPODA: CERITHIOIDEA)

16:50-17:10. [1]Tran Quoc Hung, [1]Nguyen Huy Yet, [2]Tatiana N. Dautova, [1]Lang Van Ken *([1]Institute of Marine Environment and ResourcesVAST, Hai Phong, Vietnam; [2]A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, Russia)* SPECIES COMPOSITION OF SOFT CORAL FAMILY ALCYONIIDAE IN CON CO ISLAND, QUANG TRI PROVINCE, VIETNAM

December 7 (Venue – Conference Hall of the IO VAST)

8:00 – 10:00. Session D. Marine biodiversity 2.

8:00-8:20. Konstantin A. Lutaenko *(A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, Russia)* DIVERSITY OF BIVALVE MOLLUSKS IN THE SOUTH CHINA SEA

8:20-8:40. Tatiana N. Dautova *(A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, Russia)* COMPETITION AND BIODIVERSITY IN CORAL COMMUNITIES: IMPACT OF ENVIRONMENTAL

FLUCTUATIONS

8:40-9:10. *Takeharu KOSUGE[1,2], Hiroyoshi KOHNO[1]* (*[1]Okinawa Regional Research Center, Tokai University, Okinawa, Japan; [2]Aquaculture Research for Asian Tropics, TETSUGEN VM, Phuoc The, Tuy Phong, Binh Thuan, Vietnam).* A VIEW OF BIODIVERSITY IN CORAL REEFS THROUGH THE EYES OF CORAL REEF FISHES -SPECIES COMPOSITION OF GASTROPODS FOUND IN THE GUTS OF STRIPED LARGE-EYE BREAM, GNATHODENTEX AUREOLINEATUS (PISCES, LETHRINIDAE) IN AMITORI BAY, IRIOMOTE ISLAND, SUBTROPICAL JAPAN

9:10:9:30. Nguyen Viet Thuy[1], Tran Van Tien[1], Mai Duy Minh[1], Nguyen Thi Xuan Thu[2]*([1] Research Institute for Aquaculture No3; [2] Ministry of Agriculture and Rural Development)* THE IMPACT OF STOCKING DENSITY ON THE PERFORMANCE OF RAINBOW TRAUT (*ONCORHYNCHUS MYKISS*) CULTURED IN FLOWING WATER SYSTEM IN LAM DONG PROVINCE

9:30-9:50. T.N. Dautova[1] , Nguyen Tac An[2], T.V. Lavrova[1] *([1]A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, Russia; [2]Institute of Oceanography VAST, Nha Trang, Vietnam*) THE JOINT IMB FEB RAS AND VAST INSTITUTIONS RESEARCH ACTIVITY: LONG-TERM COLLABORATION HISTORY AND NEW PERSPECTIVES IN MARINE BIODIVERSITY STUDIES

9:50 - 10:10. Coffee break.

10:10 – 12:00. Session E. Physiology and reproduction of the marine organisms.

10:10-10:30. Ngo Thi Thu Thao *(College of Aquaculture & Fisheries, Cantho University, Vietnam).* REPRODUCTIVE BIOLOGY AND SURVIVAL OF ARK SHELL *ARCA NAVICULARIS* AT DIFFERENT SALINITIES

10:30-10:50. *Salim Sh. Dautov (Institute of Marine Biology FEB RAS, Vladivostok, Russia).* BIODIVERSITY OF THE ECHINODERMS AND THEIR PELAGIC LARVAE IN NEAR SHORE ECOSYSTEMS OF NHATRANG BAY

10:50-11:10. *Ngo* Thi Thu Thao, Quach Kha Ly *(College of Aquaculture & Fisheries, Cantho University, Vietnam)* REPRODUCTIVE BIOLOGY OF MUD CLAM GELOINA COAXANS IN MANGROVE FOREST OF CA MAU PROVINCE, MECONG DELTA, VIETNAM

11:10-11:30. Tran Manh Ha *(Institute of Marine Environment and Resources VAST, Hai Phong, Vietnam)* SHRIMP AND CRAB POST LARVAE IN THE XUAN THUY MANGROVE FOREST (VIETNAM)

11:30-11:50. Salim Sh. Dautov (*A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok, Russia*). BIODIVERSITY OF THE ECHINODERMS AND THEIR PELAGIC LARVAE IN NEAR SHORE ECOSYSTEMS OF NHATRANG BAY

11:50 – 13:30. Lunch break.

13:30 – 15:10 Session F. Conservation and sustainable exploitation of the marine living resources.

13:30-13:50. Eduard A. Titlyanov[a], Tamara V. Titlyanova[a], Pham Van Huyen[b] ([a]A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Vladivostok,Russia; [b]Nha Trang Institute of Technology Research and Application VAST, Nha Trang, Vietnam) PROSPECTS OF CULTIVATION OF SARGASSACEAE ALGAE IN VIETNAM

13:50-14:10. Si Tuan Vo *(Institute of Oceanography VAST, Nha Trang, Vietnam)* ON THE COOPERATIVE PROJECT FOR DEVELOPMENT OF FISHERIES *REFUGIA* IN HAM NINH COASTAL AREA OF PHU QUOC ISLANDS, VIETNAM

14:10-14:30. Nguyen Chu Hoi *(ASEAN Working Group on Coastal and Marine Environment, Vietnam Administration of Seas and Islands, IOC Vietnam)* AN OVERVIEW OF THREATS TO ECOSYSTEM SERVICES OF TROPICAL PEATLANDS AND MANGROVES IN SOUTHEAST ASIA

14:30-14:50. Nguyen Xuan Truong, Vu Dinh Dap, Nguyen Van Giang *(Research Institute for Aquaculture No. 3, Nha Trang, Vietnam)* RESOURCE ASSESSMENT OF THE SEA CUCUMBER POPULATION IN VIETNAM

14:50-15:10. Si Tuan Vo *(Institute of Oceanography VAST, Nha Trang, Vietnam)* THE PLANNED ACTIVITIES FOR CORAL REEF REHABILITATION IN VIETNAM

15:10 – 15.20. Coffee break.

15:20 – 17:00. Final discussion: future visions and collaboration perspectives.

PROGRAMME OF THE INTERNATIONAL WORKSHOP

COASTAL MARINE BIODIVERSITY AND BIORESOURCES OF VIETNAM AND ADJACENT AREAS TO THE SOUTH CHINA SEA

under the aegis of the APN (Asia-Pacific Network for Global Change Research), Research Institute for Aquaculture No. 3 and the A.V. Zhirmunsky Institute of Marine Biology, Russian Academy of Sciences

November 24–25, 2011

Venue:

Research Institute for Aquaculture No. 3,

33 Dang Tat, Nha Trang, Khanh Hoa Province, Vietnam

November 24 (Venue – Conference Hall of the RIA3)

9:00 – 9:30 Registration

9:30 – 10:00 Opening of the workshop

9:30 – 9:40 Welcome speech by **Dr. Dao Van Tri**, Director of RIA3

9:40 – 9:50 Opening speech by **Dr. Thai Ngoc Chien**, Co-Chair of the Organizing Committee (RIA3)

9:50 – 10:00 Welcome speech by **Dr. Konstantin A. Lutaenko**, Co-Chair of the Organizing Committee (APN & IMB)

10:00 – 10:15 Group photo

SESSION 1

10:15 – 10:30

Thai Ngoc Chien, Nguyen Huu Khanh (*Research Institute for Aquaculture No. 3, Vietnam*)

Species composition, density and distribution of two classes Asteroidea and Echinoidea in coral reefs in Van Phong Bay, Khanh Hoa Province, Vietnam

10.30 – 10:45

Nguyen Anh Dung, Hoang Vinh Phu (*Department of Biology, Vinh University, Vietnam*)

The composition of plant species in Song Ngu Island, Cua Lo Town, Nghe An Province, Vietnam

10:45 – 11:15 Coffee break

11:15 – 11:30

Nguyen Thi Khanh Dung, Tan Koh Siang *(Tropical Marine Science Institute, National University of Singapore, Singapore)*

Biology of the Caribbean bivalve *Mytilopsis sallei* (Dreissenidae) In Southeast Asia

11:30 – 11:45

Binh Thuy Dang, Quyen Ha Dang Vu *(Institute for Biotechnology and Environment, Nha Trang University, Vietnam; Faculty of Aquaculture, Nha Trang University, Vietnam)*

Molecular phylogenetic relationship of Vietnamese groupers (*Epinephelus* and *Plectropomus*) based on sequences of 16S mtDNA

11:45 – 12:00

Alla V. Silina *(A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Russia)*

The Indo-Pacific Pen shell *Atrina vexillum* in south-eastern Siam Bay (South China Sea)

12:00 – 13:30 Lunch

SESSION 2

13:30 – 13:45

Dam Duc Tien *(Institute of Marine Environment and Resources, Vietnam)*

The study on the change of species composition and distribution of marine algae from Cat Ba and Ha Long Bay

13:45 – 14:00

Konstantin A. Lutaenko *(A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Russia)*

Status of the knowledge of the Indo-Pacific Anadarinae (Mollusca: Bivalvia)

14:00 – 14:15

Nguyen Van Chung, Ton That Chat *(Institute of Oceanography, VAST; Hue College of Agriculture and Forestry, Vietnam)*

Introduction of Calappidae Dana, 1852 in Thuan An, Phu Vang District, Thua Thien Hue Province

14:15 – 14:30

Alexei V. Chernyshev (*A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Russia)*

Nemertean worms (Nemertea) of the Vietnamese coastal waters

14:30 – 15:00 Coffee break

15:00 – 15:15

Hyun-Sung Yang *(East Sea Branch of Korea Ocean Research & Development Institute (KORDI), Republic of Korea)*

Annual variation of *Perkinsus olseni* infection and reproductive effort in Manila clam, *Ruditapes philippinarum*, in Hwangdo off the west coast of Korea

15:15 – 15:30

Anna V. Rasshepkina, Larisa A. Prozorova *(Institute of Biology and Soil Science, Far Eastern Branch, Russian Academy of Sciences, Russia)*

Patterns of pallial gonoduct structure of mud snails in the genus *Batillaria* (Caenogastropoda, Cerithioidea, Batillariidae)

15:30 – 15:45

Le Xuan Sinh *(Institute of Marine Environment anh Resources, VietNam)*

Study on growth's rule of hard clam (*Meretrix lyrata*) in Bach Dang's estuary, Vietnam

15:45 – 16:30 Discussion

November 25 (Venue – Conference Hall of the RIA3)

SESSION 3

9:00 – 9:15

Nguyen Thi Anh Thu (*Department of Biotechnology, Institute of Biotechnology and* Environment, University of Nha Trang, Vietnam).

Production and characterization of monoclonal antibodies against white spot syndrome virus and host shrimp proteins

9:15 – 9:30

Natalia V. Zhukova *(A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Russia)*

Molecular diversity of fatty acids in marine Opisthobranchia

9:30 – 9:45

T.H. Lai, T.Y. Nguyen, K. Thumanu, V.T. Hoang, H.H. Le, T.T.H. Nguyen (*Institute of Biotechnology,* *Vietnam Academy of Science and Technology, Vietnam; Synchrotron Light Research Institute, Thailand; Institute of Ocenography, Vietnam Academy of Science and Technology, Vietnam)*

Characterization of biosurfactant producing bacteria *Pseudomonas* sp. Hp55, *Acinetobacter haemolyticus* Qn15 and *Rhodococcus ruber* Td2 isolated from Vietnam coastal zones

9:45 – 10:00

Le Thi Bich Thao, Bui Thi Huyen, Bui Quang Nghi, Doan Viet Binh,Nguyen Bich Nh, Phan Van Chi *(Institute of Biotechnology; Institute of Oceanography VAST, Vietnam)*

Study on the conopeptides from cone snails collected from Nha Trang, Vietnam

10:00 – 10:15

Le Thi Anh Tuyet, Nguyen Thi Giang An, Dang Diem Hong, Sabine Mundt (*University of Hong Duc; University of Vinh, Vietnam; Institute of Biotechnology, Vietnam Academy of Science and Technology,Vietnam)*

Debromoaplysiatoxin, a cytotoxic metabolite from the marine cyanobacterium *Lyngbya majuscula* from Vietnam

10:15 – 10:45 Coffee break

10:45 – 11:00

T.Yu. Magarlamov, A.V. Chernyshev, J.M. Turbeville *(A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Russia; Virginia Commonwealth University, USA)*

Morphology of the proboscis of some nemerteans from Vietnamese and Russian coastal waters

11:00 – 11:15

Le Xuan Sinh, Do Minh Chung, Le Tan Thoi *(College of Aquaculture and Fisheries, Cantho University; Department of Agriculture and Rural Development, Travinh Province, Vietnam)*

Management of wild hard clam (M*eretrix lyrata*) resources in the southern coast of Vietnam

11:15 – 11:30

Larisa A. Prozorova, Tatiana Ya. Sitnikova, Ivan A. Kashin, Alexander Yu. Zvyagintsev *(Institute of Biology and Soil Science, Far Eastern Branch, Russian Academy of Sciences; Limnological Institute, Siberian Branch, Russian Academy of Sciences; A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch, Russian Academy of Sciences, Russia)*

Review of the morphology and distribution of microgastropods of the genus *Diffalaba* (Caenogastropoda: Cerithioidea: Litiopidae)

11:30 – 11:45

Nguyen Anh, Nguyen Duy Huy, Nguyen Hung Thanh, Nguyen Thi Bich Nga, Do Van Thu, Le Thanh Hoa *(Institute of Biotechnology, Vietnam)*

Taxonomic identification and phylogenetic relationships of the groupers (*Epinephelus* spp.) collected along the coastal zone of Vietnam

11:45 – 12:00

Anna V. Rasshepkina, Larisa A. Prozorova *(Institute of Biology and Soil Science, Far Eastern Branch, Russian Academy of Sciences, Russia)*

Pallial gonoduct histology of two species of medically important genus *Parafossarulus* (Caenogastropoda, Rissooidea, Bythiniidae) from Vietnam and the southern Russian Far East

12:00 – 12:15

Le Thi Thu Huong, Phan Ngoc Hoa, Nguyen Hoang Dung, Phan Dinh Tuan, Ngo Kim Chi (Lac Hong University, Hochiminh City University of Technology, Institute of Natural Products Chemistry, VAST, Vietnam)

Characteristics and application capability of the *Pangasius hypophthalmus* skin collagen

12:15 – 12:30

Yu.Ya. Latypov (to be presented by K. Lutaenko on behalf of Dr. Yu.Ya. Latypov)

(A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok 690059, Russia)

Spratly Archipelago as a potential recovery reserve of biodiversity of coastal and island reefs of Vietnam

12:30 – 12:45 Concluding remarks

19:00 – 21:00 Farewell party (to be announced)

POSTERS

(to be displayed throughout the workshop; there will be no special poster session)

Truong Van Dan, Ho Thi Thu Hoai, Ngo Thi Huong Giang, Vo Dieu

Studies in Hai Van – Son Cha benthos regional fauna serves the building Son Cha – Hai Van marine protection areas

Kieu Thi Huyen, Ha Thi Hue, Nguyen Quang Linh

Anguilla marmorata in Quang Binh's estuaries and resvervation techniques

Ho Thi Thu Hoai, Ngo Thi Huong Giang, Tran Dinh Minh, Vo Dieu

Species composition (Sargassaceae) of butter zone of Hai Van - Son Cha marine protected areas

Funding sources outside the APN

The financial support for this project was additionally provided by three institutions –A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok, Russia; Institute of Biology and Soil Science, Far East Branch of the Russian Academy of Sciences, Vladivostok, Russia; Iinstitute of Oceanography, VietnamAcademy of Science and Technology, Nhatrang, Vietnam; and Research Institute for Aquaculture No. 3, Nhatrang, Vietnam. The IMB paid for travel and accomodation expenses of part of the Russian participants; IO and RIA3 provided facilities for field-works, conferences and partial in-cash contribution for meetings (meals, stationary, etc.). The estimate amount of the three institutions is about 20,000 USD.

Glossary of Terms (main acronyms)

APN – Asia-Pacific Network for Global Change Research
IMB – A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok, Russia
IO – Institute of Oceanography, Vietnam Academy of Science and Technology, Nhatrang, Vietnam
RIA3 – Research Institute for Aquaculture No. 3, Nhatrang, Vietnam