Final Technical Report
CAF2016–RR08–CMY–Dautova

Developing life–supporting marine ecosystems along the Asia–Pacific coasts – a synthesis of physical and biological data for the science–based management and socio–ecological policy making

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Project Overview

Project Duration	**:**	01.07.2015 – 12.03.2018
Funding Awarded	**:**	US$ 38,000 for Year 1; US$ 38,000 for Year 2
Key organisations involved	**:**	1. A.V. Zhirmunsky Institute of Marine Biology of National Scientific Centre of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences, Vladivostok, Russia; involved persons – Dr. Tatiana N. Dautova, Dr. Igor Dolmatov, Dr Salim Dautov, Prof. Andrey Adrianov, Dr Valery Parensky, Dr Viacheslav Odintsov, Dr.Yaroslav Kamenev, Dr Elena Kostina, Dr Eduard Titlyanov, Dr Tamara Titlyanova, Computing specialist Gennady Dolgov, Diving specialist Konstantin Dudka. 2. Far East Federal University, Vladivostok, Russia; involved persons – MsSci Pavel Kireev, MsSci Alena Moskovtseva, Dr Prof Nadezhda Khristophorova. 3. Racific Institute of Bioorganic Chemistry FEB RAS, Vladivostok, Russia; involved persons –Director Dr Valentin Stonik; Dr Vladimir Kalinin; Dr A. Silchenko. 3. Institute of Oceanography, Vietnamese Academy of Science and Technology (VAST), Nha Trang, Vietnam; involved persons – MsSci Hoang Trung Du, Dr. Vo Si Tuan, Dr Dao Viet Ha, Head General Management Dept Mr. Nguyen Phi Phat, International relation officer Mrs. Bui Thi Minh Ha, Mr. Nguyen Ky, MsSci Thi Thu. 4. Nha Trang Marine Protected Area, Vietnam; involved persons – Mr Truong Kinh, Mr Buong Choi. 5. Long Phu Tourism Corporation, Long Phu, Vietnam. Involved persons – Mr. Nguyen Van Huong. 5. Research Institute of Aquaculture No. 3, Nha Trang, Vietnam; involved persons – Dr Pham Quoc Phung, Dr Minh Du Mai, Dr Minh Nguyen. 6. Government Administration of the Khanh Hoa Province, Vietnam; involved persons – Mr Huynh Ky Han(Department of Science and Technology), Mr Mai Van Thang (Department of Natural Resources), Tran Son Hai (People’s Committee). 7. Khanh Hoa Union of Science and Technology Associations, Nha Trang, Vietnam; involved person - Bui May. 7. San Carlos University, Philippines; involved persons – Dr Fr Louie Punzalan, Dean Dr Fr Miranda, Dr Prof Filipina Sotto, MsSci Antonio Ayop, MsSci Maria Olano. 8. Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China; involved persons – Dr. Xiaoxia Sun, Director Prof. Sun Son, Prof. Li Chaolun, Prof. Xu Kuidong, Prof. Yu Rencheng.

Project Summary

The project addresses the essential questions regarding the global change research – how to identify, explain and predict the changes in the ecosystems of coral reefs in the Asia-Pacific region under the natural and anthropogenic influence forcing? The South China Sea (SCS), the greatest in SE Asia, is a strategic body of water that is surrounded by nations that are currently at the helm of industrialization and rapid economic growth in the region. Our project united the experience and knowledge of the scientists, managers and policy makers to synthesize the data on the physical environments together with the information on the biodiversity and reproductive potential of marine organisms for recognition of the risky changes in their populations and estimate its adaptive capacity under the global climate change. The project has fundamental relevance with APN Focus Activity being intended to promote the regional cooperative global change research via wide discussion and promotion our results and conclusions at public and policy-making levels for developing the social–related policy options for the marine conservation.

Keywords: marine ecosystems, South China Sea, coral reefs, Asia-Pacific region, sustainable exploration

Project outputs and outcomes

Project outputs:

- Output A. The input into the building up strong partnership with managers, policy-makers and researchers concerning with the global change problems.
- Output B. A conceptual framework developed and implanted to assess the sustainability of marine resources in Asian seas.

Project outcomes:

- Outcome A. The integrative assessment of the life-supporting marine ecosystems and their adaptive responses to the global change provided in the targeted regions basing on the arranged partnership with managers, policy-makers and researchers.
- Outcome B. The capacity of the national specialists who are busy with the vulnerable marine ecosystems improved to assess their adaptive responses to the global change in the targeted regions due to a range of meetings for involving all countries parties along with the special training divisions for young eco-managers and scientists.
- Outcome C. Two international workshops and round tables organized with participation of the regional policy makers and the managers of marine coastal area (including Marine Protected areas).
- Outcome D. A website has been uploaded for the project; the content includes data on participating organisations and institutions and workshops data along with the reporting information regarding the elaborated tools and assessments of the status of the life-supporting marine ecosystems in the targeted regions.
- Outcome E. The socio-ecological policy options among the policy-makers elaborated at the provincial and national levels thorough the dissemination of our results and promotion of our achievments due to publication of the books of the workshops proceedings, peer reviewed papers, the handbook on the targeted corals, round tables and TV-interviews, the analytical each-year reports with the strategic environmental assessment.

- Outcome F. The science-based monitoring tools and approaches to the conservation and monitoring of life-supporting marine ecosystems (coral reefs and temperate vulnerable marine ecosystems) elaborated for the Asia Pacific seas.

Key facts/figures

Key numbers from the research:

242 samples of the water and sediment are processed from Nha Trang Bay, South China Sea, for the physical environment study;

64 samples are processed for the stable isotopes composition (δ13Corg and δ15N) from Nha Trang Bay to study the scale of the terrestrial run-off in the bay;

29 and 32 families of the soft corals have been recorded at the studied coral reefs in the central of Vietnam and Philippines respectively; from these 26 families are recorded for the Philippines first time;

59 species of key soft coral genus *Sinularia* have been encountered in the central of Vietnam, 48 from these are identified;

47 species of the *Sinularia* soft corals have been found and identified in Philippines; from these 41 species have been recorded for the region first time;

22 coral reefs have been studied for biodiversity during the reporting period in Nha Trang Bay, Khanh Hoa province, and 12 in Ninh Thuan province;

26 reefs have been studied in northern and central of Philippines for biodiversity;

46 photo-transects have been made during the reporting period in Nha Trang Bay to assess the status and condition of coral reefs;

11 new markers for the sea cucmbers chemotaxonomy have been discovered for the animals from South China Sea.

Key numbers from the dissemination plan:

Two workshops and round tables organized (more than 120 participants in both together);

Twelve young scientists involved to the workshop and publication activity and laboratory experiments;

Five presentations made at international conferences (PICES 2017; WESTPAC 2017; Unique Marine Ecosystems 2016; Unique Marine Ecosystems 2017) in addition to the presentations made at two APN workshops (Nha Trand, Vietnam, and Qingdao, China) and round tables.

Potential for further work

The project implementation has engaged the active participation and support of the local research institutions and universities. The active involvement of the specialists and young scientists will ensure the intensification of the local research directions and projects aimed to study, assess and predict the nearest future of the life-supporting marine ecosystems in the Asia-Pacific. Apart from ongoing efforts to develop the collaborative relations in the Asia-Pacific Region in scientific research, national policymaking and discussions around life-supporting marine ecosystems, the project members have started to make full use of project findings for capacity building and networking. Specifically, the impact evaluation will be done at the different levels and sectors that were involved in these projects either as direct beneficiaries or as implementors as follows:

a) Academic institutions, particularly those who were involved as participants of the conducted workshops, joint field expeditions and joint publications. An impact evaluation of the training on their knowledge, skills and how these were applied in their own respective institutions for their research development.

b) University professors, PhD-students and MsSci students involved as participants of the joint research, lecturers, and discussions during workshops and Round Tables; they would be trainees of the national educational programs on marine ecology, and climate change adaptation strategies.

b) Marine coastal area managers, particularly those who were participated in the workshops and Round Tables organised in the frame of the project; they would be followed up whether they were able to apply their newly elaborated approaches on their levels of responcibility in the managing projects that were established to be more effective in adaptation to the impacts of climate change (particularly - for the Marine Protected areas managing and fishery quotation in the vulnerable marine ecosystems in the region).

c) Policy makers and administrative persons, particularly the local government units, who were trained on site-specific climate change strategies and the assessment of the status of the life-supporting marine ecosystems whether they have mainstreamed climate change and in their local development programs.

As a range of new findings and discoveries have been made in the frame of the project, we suggest that the promicing areas of the joint research would be deloped by the project participants as follows: a) biodiversity of the soft corals and sea fans (Octocorallia) in the South China Sea and adjacent seas of the Asia-Pacific; b) chemotaxonomy of corals and holothurians; c) natural and stimulated reproduction of sea cucmbers and sea urchins for the scien-based methods of farming; d) trainee for the students in the area of taxonomy/biodiversity skills and expertise.

Further, the project collaborators could work towards the establishment of "Marine Scientists Network of the Asia-Pacific Region" (MSN APR), which could be operated jointly for policy and institutional support, for technical support as academic institutions, and for the operative informational support. This MSN APR which would be established with various directions and different marine sciences, will serve as the learning laboratory for the students, marine farmers, practitioners-managers to help promote science-based approache as the key strategy to climate change surveillance. Same time, it serves as one of the income-generating activities of the concerned international research projects planning and performing at the Asia Pacific regional level.

Publications

Journal publications (in peer-reviewed journals)

Dautov, S.Sh. (2018). Towards a science-based approache to sea urchins farming in Asia-Pacific seas. Sent to *APN Science Bulletin*.

Dautov, S.Sh., Dautova, T.N. (2016).The larvae of *Diadema setosum* (Leske, 1778) (Camarodonta: Diadematidae) from South China Sea. Invertebrate Reproduction & Development. *Invertebrate Reproduction & Development*, (60), 290–296.

Dautov, S. Sh., Dautova, T.N. (2018).The embryological and larval Development of *Diadema savignyi* (Audouin, 1829) (Camarodonta: Diadematidae) from South China Sea and some Notes about the Structure of the Diadematoids Pluteus. Invertebrate Reproduction & Development. *Invertebrate Reproduction & Development*, in press.

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Silchenko, A.S., Kalinovsky, A.I., Avilov, S.A., Andryjaschenko, P.V., Dmitrenok, P.S., Yurchenko, E.A., Dolmatov I.Yu., Dautov S.Sh., Stonik V.A. & Kalinin, V.I. (2016). Colochiroside E, an Unusual Non-holostane Triterpene Sulfated Trioside from the Sea Cucumber *Colochirus robustus* and Evidence of the Impossibility of a 7 (8)-Double Bond Migration in Lanostane Derivatives having an 18 (16)-Lactone. *Natural Product Communications*, 11(6), 741–746.

Silchenko, A.S., Kalinovsky, A.I., Avilov, S.A., Kalinin, V.I., Andrijaschenko, P.V., Dmitrenok, P.S., Chingizova, E.A., Ermakova, S.P., Malyarenko, O.S., Dautova, T.N. (2017). Nine New Triterpene Glycosides, Magnumosides A1–A4, B1, B2, C1, C2 and C4, from the Vietnamese Sea Cucumber *Neothyonidium (=Massinium) magnum*: Structures and Activities against Tumor Cells Independently and in Synergy with Radioactive Irradiation. *Marine Drugs*, (15), 256: doi:10.3390/md15080256

Papers in the Books of APN Workshop' Proceedings

Dautov, S. Sh., Dautova, T.N. (2016). Mariculture of holothurians and sea urchins – new trends . In: Dautova T.N. (Ed.). *Developing life-supporting marine ecosystems along with the Asia-Pacific coasts – a synthesis of physical and biological data for the science-based management and socio-ecological policy making. Proceedings Int. APN Workshop 21–22 December 2015, Nha Trang, Vietnam.* Vladivostok, Dalnauka. 120–124.

Dautov, S.S., Vo Si Tuan, Dautova, T.N. (2016). Larval development of Diadema setosum (Leske, 1778) (Camarodonta: Diadematidae) from Nha Trang Bay (South China Sea). In: *Proceeding of "Progress and trends in Science and Technology" commemorating 10 years of partnership between the VAST and the Russian Foundation for Basic Research*. Hanoi, February 2016. Hanoi, The Gioi Publishers, 438–442.

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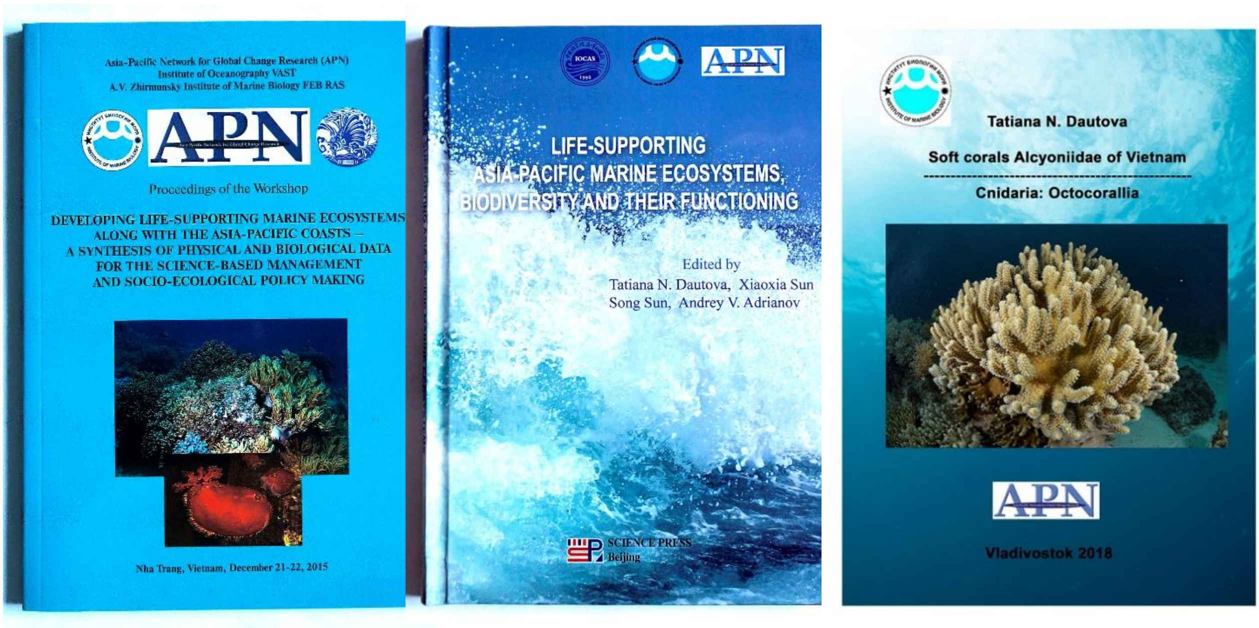
Books

Dautova T.N., Xiaoxia Sun, Adrianov A.V. (Eds). (2017). *Life-supporting Asia-Pacific Marine Ecosystems, Biodiversity and their Functioning.* Science Press, Beijing, 198 p.

Dautova T.N. (Ed.). (2016). *Developing life-supporting marine ecosystems along with the Asia-Pacific coasts – a synthesis of physical and biological data for the science-based management and socio-ecological policy making. Proceedings International APN Workshop 21–22 December 2015, Nha Trang, Vietnam*. Vladivostok, Dalnauka. 180 p.

Dautova T.N. (2018). *Soft corals Alcyoniidae of Vietnam*. Vladivostok, Dalnauka. 284 p.



Awards and honours

No awards or honors.

Pull quote

"I was fortunate to be a member of the CAF2016–RR08–CMY–Dautova project, funded by the Asia-Pacific Network for Global Change Research (APN). Due to this project I had the opportunity to engage with the international collaborative network of marine researchers to propose and design optimal science-based systems and tools for the damaged coral reefs restoration in the Philippines with improved the capacity of ouк universities' students and young scientists"

Filipina Sotto, Professor of San Carlos University, Cebu, Philippines.

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Introduction

The project addresses the urgent problems of the nearest future of coastal marine ecosystems in the Asia-Pacific region, in particular – the capacity of coastal coral reefs to respond and adapt to environmental change. In 2013, the total population of the forty-six countries belonging to the region Asia-Pacific region stood at 4.3 billion, which is 60 per cent of the world's population. Currently, there are 1.8 billion in South and South-West Asia, 1.6 billion in North and North-East Asia, 0.6 billion in South-East Asia, 0.2 billion in North and Central Asia and 38 million in the Pacific. Overall population growth in the region is slowing down with a growth rate of 0.96 per cent per annum. Different speeds of population growth in the subregions will shift the region's composition (Fig. 1). While in 1980, 42 per cent of the region's population was living in East and North-East Asia, by 2050, only 31 per cent of the region's population will live there. Instead, in 2050 almost half of the region's population will live in South and South-West Asia. As the fastest growing subregion, although still small, the share of the Pacific of the region's total population is also growing from 0.8 per cent in 1980 to 1.1 per cent in 2050 (UN ESCAP, 2104).

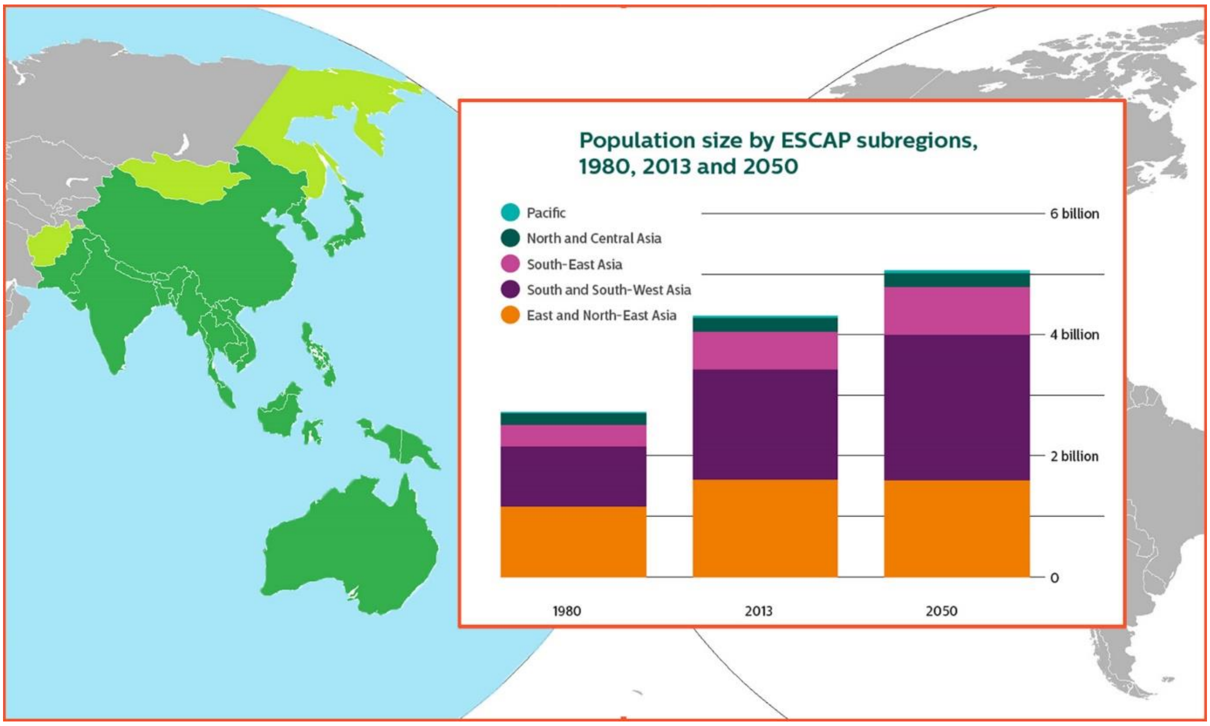


Fig. 1. Asia-Pacific region and its population dynamics (UN Economic and Social Commission for Asia and the Pacific (ESCAP), 2014).

There is growing recognition that the uniting the efforts and experience of the scientists, educators, managers and policy makers with the practitioners is the urgent aim of maintenance to build partner capacity, shared understanding, and networks to enhance stability in the Indo-Asia-Pacific region.

Coastal marine ecosystems in Asia-Pacific regional seas (such as coral reefs and mangroves) provide high natural rates of primary and secondary (protein) production. However, in the last several decades, with their increasing technological capabilities, humans have accelerated the rate of change in these life-supporting ecosystems. Pollution, euthrophication, forced sediment load, coastal urbanization, overfishing, mining and tourism threaten the future of coastal coral reefs and, possibly, increase their adaptive potential under the global climate change. Pollution-related hazards need to be evident in terms of the marine biota decreasing to show its negative consequences and to promote the high-probability policy options leading to sustainable using of marine areas in fast developing SE Asia countries. This crosscutting research includes a range of different sciences – from marine physics/chemistry to biodiversity and reproduction of marine organisms. The dispersal and survival of corals and other key marine organisms depend on currents and other processes that deliver larvae to the settlement site and even concentrate them at certain locations. As Philippines and Central of Vietnam are connected by the branch of Kurioshio current, it can be presumed as the main way to replenish the biota of central Vietnam coral reefs. The comparative studies of the biodiversity (using selected key groups of marine organisms as indicative) provided in these both regions can finalize this question.

The reporting project CAF2016-RR08-CMY-Dautova involved scientists, professors and students, managers and policy makers from Russia, China, Philippines and Vietnam. The uniting of our countries in the frame of the proposed project can provide such wide spectrum of scientists and practitioners to be focused on these multidisciplinary assessments and also support the dissemination of science-based policy options in fast developing East Asia's countries. The project is addressed the policy questions in two main areas: 1) enhancing of the fishing-restriction operation for coral reefs conservation/restoration and Marine Protected Areas designing and 2) national strategy development for the rational using of the coastal marine ecosystems, including the science-based options for sustainable marine farming, quotation of fishing and ecologically oriented coastal tourism developing.

Our project addresses the urgent problem of the nearest future of coastal marine ecosystems in the Asia-Pacific region – the capacity of coastal coral reefs to adapt and survive facing to environmental change. Pollution, forced sediment load, coastal urbanization and overfishing threaten the future of coastal coral reefs and, possibly, increase their adaptive potential under the global climate change. Pollution-related hazards need to be evident in terms of the marine biota decreasing to show its negative consequences and to promote the high-probability policy options for sustainable using of marine areas in fast developing Asia countries. This crosscutting research includes a range of sciences – from marine physics and chemistry to biodiversity and reproduction of marine organisms. The dispersal and survival of corals and other key marine organisms depend on currents and other processes that deliver larvae to the settlement site and even concentrate them at certain locations. As Philippines and Central of Vietnam are connected by the branch of Kurioshio current, it can be presumed as the main way to replenish the biota of central Vietnam coral reefs. The comparative studies of the biodiversity provided in these both regions can finalize this question. The uniting of our countries in the frame of the project provides such wide spectrum of scientists and practitioners to be focused on these multidisciplinary assessments and allows the dissemination of science-based policy options in fast developing Asia's countries. The project is addressed the policy questions in two main areas: 1) enhancing of the fishing-restriction operation for coral reefs conservation/restoration and Marine Protected Areas designing and 2) national strategy development for the rational using of the coastal marine ecosystems, including the science-based options for sustainable marine farming, quotation of fishing and eco-tourism developing.

The main objectives of the project are:

1) to collect and synthesize the existing fragmentary data on the physical environments in the targeted model area in South China Sea (SCS) (with special emphasis on coral reefs in the west and east parts of the South China Sea as model marine ecosystems);

2) to conduct field surveys during contrasting seasonal periods (dry and wet seasons) in the central of Vietnam (Nha Trang Bay) that can contribute to filling data gaps on the physical environments;

3) to analyse these data together with the information on the biodiversity and reproductive potential of key groups of marine organisms for scientifically based recognition of the risky changes in the coastal coral reefs in the west and east parts of the SCS and explain their reasons;

4) to estimate the adaptive capacity and self-restoration potential of the targeted coral reefs under the global climate change;

5) to perform the actions for wide discussion, promotion and dissemination of our ideas and conclusions for developing the social-related policy options for the marine conservation and appropriate responses to global change as well (joint workshop on the status and change of marine ecosystems between Vietnam, Russia, Philippines and China; round table with the policy-makers and business representatives; TV-presentations of our activity);

6) to unite the experience and knowledge both the high-level and early-career scientists, policy-makers and managers from our countries to promote and enhance the regional cooperative global change research of the status and adaptive potential of marine ecosystems in East Asia.

7) to prepare joint publications (including book of proceedings of the workshop, monographs and peer-reviewed papers) along with the detailed reports as a final outcome of the project.

The project CAF2016-RR08-CMY-Dautova aims to enhance understandings of scientists, policy makers and relevant stakeholders in Asia-Pacific and develop their capacity to assess the marine ecosystems management through science-based methods and via various mean such as interdisciplinary "round tables" at the different administrative levels and regional workshops. The project goals correspond well with the goals of DIVERSITAS and its regional initiatives such as DIWPA – International Network for DIVERSITAS in the Western Pacific and Asia. It is also well correlated with the main purpose of the global program CENSUS of MARINE LIFE, and its regional activity under NaGISA. Russian participants collaborated for a long time with START and its Asian branch – TEACOM (Temperate East Asia Committee), conducted research on regional aspects of global change and held 6 regional meeting on global change, including 4 international – APN/START meetings in Vladivostok in 2002 and in Korea in 2008, in Vietnam in 2010, 2011. Institute of Marine Biology (Vladivostok, Russia) was headquarters of the Russian National Committee for IGBP for last four years; this allowed collecting a lot of information to be presented in reports to IGBP, TEACOM and other networks.

Participants of the current project have good experience with APN projects being collaborators of the APN project (ARCP2010–18NMY 2010–2011). In the frame of this project, the wide range of biodiversity data was collected in the Central of Vietnam providing the needed skills to develop the subsequent analysis of the capacity of coastal coral reefs to respond and adapt to environmental change. Two International workshops (6 countries participated) were organized and successfully conducted in Vietnam; two books of proceedings and a range of peer-reviewed papers were published.

The reporting project CAF2016–RR08–CMY–Dautova can set the baseline for knowledge on coral reef ecosystems sustainability under the environmental fluctuations, and this can contribute to increase their adaptive capacity to climate change and other socio-economic changes as well as to mitigate problems associated with excessive use of marine bio-resources. Potential for further long-term impacts will be concerning with a conceptual framework developed and implanted it to assess the sustainability of marine resources in Asian seas. It builds up strong partnership with managers, policy-makers and researchers who have a common interest to solve marine ecosystems' related problems. The project activity would inevitably promote further involvement of regional biodiversity/taxonomy communities in Vietnam, China, Philippines and Russia to networks of global change organizations.

Methodology

2.1. The study region – characters and background

The region targeted in the frame of the project for the survey of environments and status of marine ecosystems is South China Sea (SCS), (Fig. 2). The nearest areas of the Asia-Pacific Region are referred to engage needed comparative data. Two model areas for detailed survey and comparison of environmental data in the frame of the project were outlined – Central of Vietnam (Nha Trang Bay) and Philippine coastal area as these regions are located around the South China Sea and connected by the branch of Kurioshio current (Fig. 3).

Nha Trang Bay is located in Khanh Hoa province with an area of about 507 km^2, including 19 islands (Hon Tre with 3250 ha is the biggest island in the Nha Trang Bay). Nha Trang Bay lies within the administrative boundaries of Nha Trang City, Khánh Hòa Province. The weather of the Bay is characterized by two distinct seasons: the dry season lasting from January until August and the rainy season from September to December. The average annual temperature is 26°C, the highest being 39°C and the lowest 14.4°C. Rainfall is highest during the months of September, October and November, contributing 70–80% of the total annual rainfall. The annual average rainfall is 1285 mm (floods often occurring during the rainy season). The wind direction depends on the monsoon seasons (Northeast monsoon and Southwest monsoon). With regard to the ecosystems in Nha Trang bay, they are the similar to the ecosystems of tropical bays or lagoon, which have mangrove, coral reef, sea grass bed and estuaries ecosystems. The systems of rivers transport all wastes from continental activities to the bay. All of the rivers that input into the bay are not very long and not sloping (average slope is 5%). The Nha Trang Bay is influenced by two rivers, Cai River and Tac River (Fig. 2). Otherwise, it also adjoined with the Nha Phu lagoon in the North. Nha Trang Bay is one of the developed coastal areas in Vietnam with a coastal economic zone in Southern Central Vietnam that includes marine aquaculture, an industrial harbour, tourist and marine services. The flow of Cai River depends on the annual rainfall and two seasons formed: the rainy season and the dry season.

The Philippine coastal zone is typical of tropical coasts, with five major resource units occurring along its shallow coastlines: coral reefs, mangrove ecosystems, beach systems, estuaries and lagoons, and seagrass beds. It is important to note, however, that 'coastal resource management' cannot be limited to the coastal zone, because there are tight linkages between upland and coastal ecosystems and what occurs in one ecosystem inevitably affects the other ecosystems.

The Philippines has a climate dominated by a rainy season and a dry season, although certain locations have no dry season (meaning, all months have an average rainfall of above 60 mm) and certain higher-altitude areas can have a subtropical climate. The summer monsoon brings heavy rains to most of the archipelago during summer, whereas the winter monsoon brings relatively cooler and drier air from December to February. Even at this time, however, temperatures rarely rise above 37°C (98.6°F). Mean annual sea-level temperatures rarely fall below 27°C (80.6°F). Annual rainfall measures as much as 5,000 mm (196.9 in) in the mountainous east coast section of the country, but less than 1,000 mm (39.4 in) in some of the sheltered valleys.

Monsoon rains, although hard and drenching, are not normally associated with high winds and waves. But the Philippines sit astride the typhoon belt, and it suffers an annual onslaught of dangerous storms from July through October. These are especially hazardous for northern and eastern Luzon and the Bicol and Eastern Visayas regions, but Manila gets devastated periodically as well.

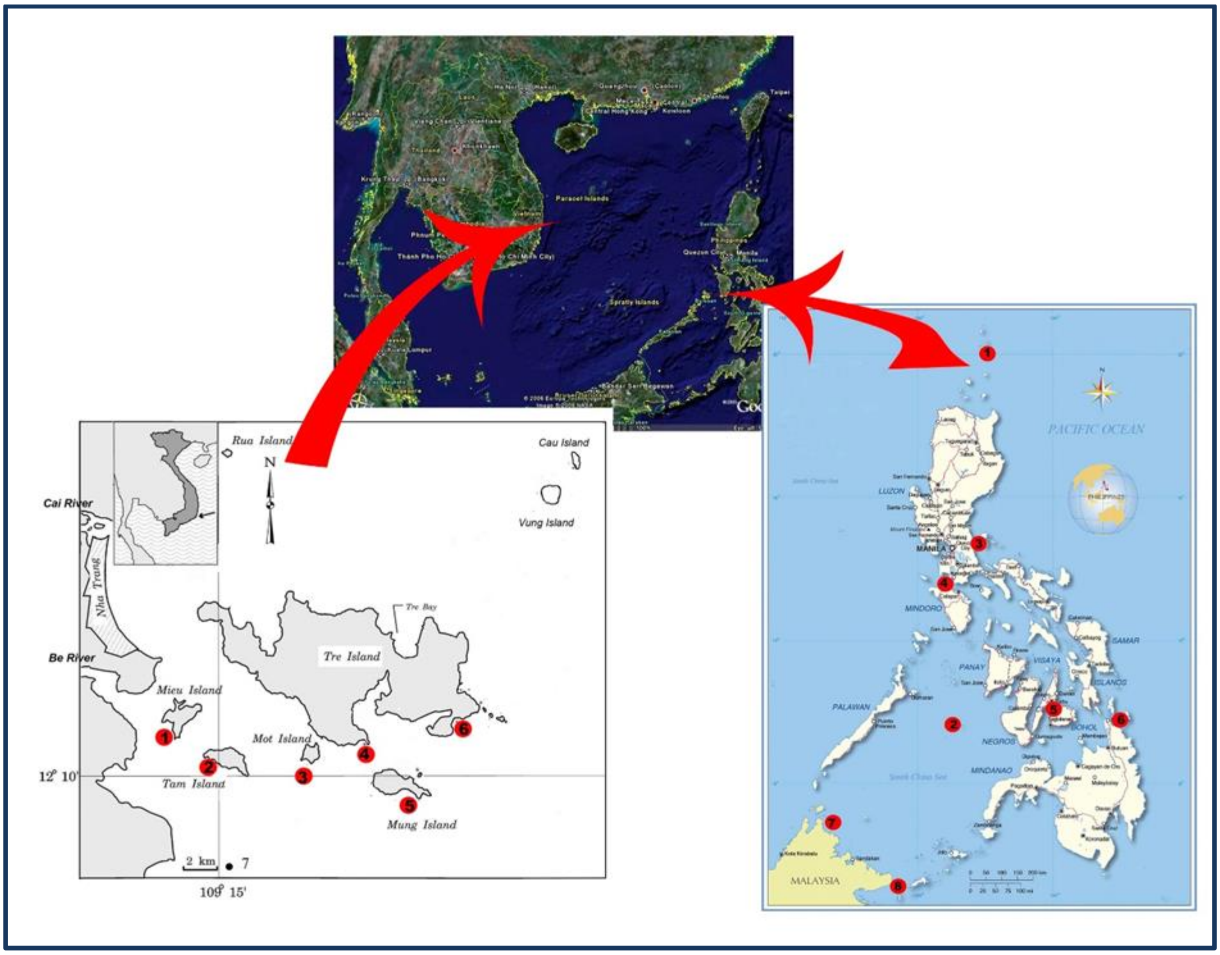


Fig. 2. Two model areas for detailed survey and collecting of the existing data on environmental data in the frame of the reporting project.

With its thousands of islands, the Philippines has one of the longest coastlines in the world estimated at 36,289 kilometers. The coastline extends 2,000 kilometers from north to south, with 25 major cities lying on the coast. It is estimated that more than 60 percent of the nation's total population of 87.8 million (July 2005 estimate) lives in the coastal zone. Most Philippine islands have coral sand beaches, i.e., beaches formed by coral reef growth and erosion. Forming an integral part of the reef communities, these beaches depend on healthy coral reefs for continued supplies of sand, at the same time supporting crustaceans, mollusks and some worms. Unregulated and unplanned development of beaches for tourism and the quarrying of sand for construction and other purposes are two of the most common threats to beaches in the Philippines.

The country depends heavily on its rich coastal and marine resources for the many economic, employment, and biodiversity values and services they provide. Philippine waters contain some of the world's richest ecosystems, characterized by extensive coral reefs, sea-grass beds, and dense mangrove forests. The Philippines lies in the Indo-West Pacific Region, reputedly the world's highest biodiversity marine area, and is part of what is known as the "coral triangle," the center of the most diverse habitat in the marine tropics. The country's coral reefs host about 400 species of corals, 971 species of benthic algae, and a third of the 2,300 fish species known to inhabit Philippine waters. There are 27,000 sq km of coral reef areas in the Philippines. Blessed with a sunny tropical climate, waters enriched with nutrients from the land, and driven by the wind, the country supports an exceptionally high diversity of marine life. Factors that contribute to this exceptional range of biodiversity include:

• A warm climate and stable watertemperatures (rarely below 18° C);

• Abundant sunlight to fuel the photo-synthesis process that supports the growth of algae, coral, and other organisms;

• Relatively low sediment loads, allowing light to pass deep into the water;

• Generally low freshwater inputs that maintain a salinity level between 30 and 36 parts per thousand;

• Currents, clean water, and hard substrates that provide optimal conditions for corals and other aquatic life to thrive (White 2001).

The areas selected for the biodiversity and coral reefs condition study in the frame of the project located in the northern Philippines (Luzon Island coast) and Central of Philippines (Visayas) represent the sufficient geographical range for the survey along with the climate data and socio-economic data.

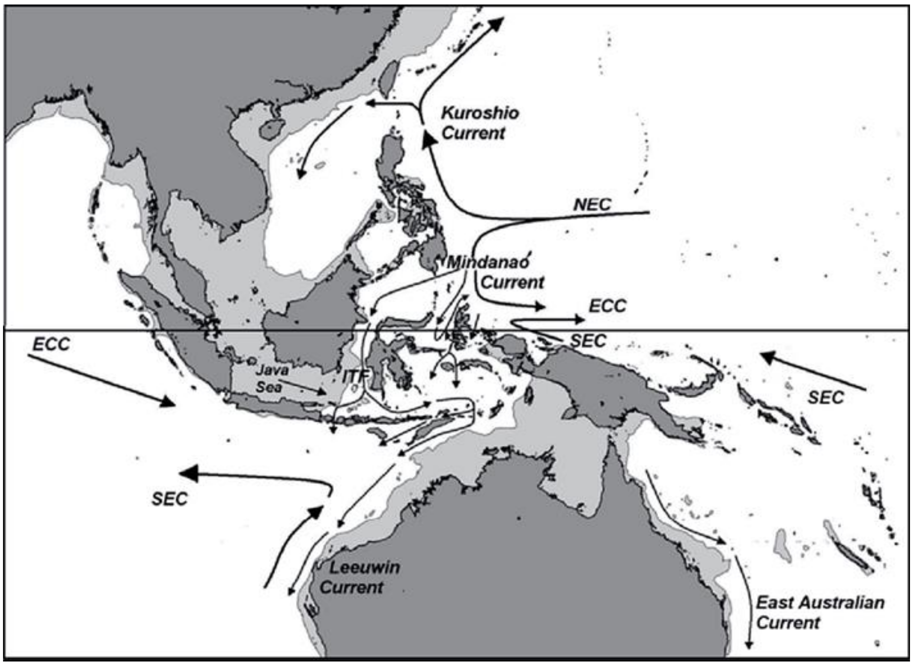


Fig. 3. Main currents connecting the regions inside and around Indo-Malayan Centre of Biodiversity (Hoeksema 2007).

2.2. Collecting of the existing data

Key documents on marine environments, coral reefs status and its change, and economic-social aspects of the two targeted regions have been collected – scientific publication (peer-reviewed papers and books), official reports on the surveys made in the scientific institutions (Institute of Oceanography VAST, Institute of Marine Resources and Environment (Haiphong, Vietnam), Institute of marine Biology (Vladivostok, Russia), San Carlos University (Cebu, Philippines), University of Philippines (Philippines), Institute of Oceanography (Qingdao, China)). The data of the last twenty years are used and some recent projects done by IO, IMER, IMB and IOC have also provided valuable data. These projects related to environmental carrying capacity and environmental protection. The environmental data and information on the status of coral reefs and other coastal ecosystems are included for the comparative analysis for the better understanding of the trends in global change at large-scale level in the Asia-Pacific seas.

Four collections of the key groups of animals processed for the basic producing of the lists of species and genera of stony reef-building corals and octocorals from the targeted regions. These collections are keeping in the Museum of the Institute of Oceanography VAST, Museum of the Institute of Marine Biology NSCMB FEB RAS (Vladivostok, Russia), Zoological Institute RAS (St. Petersburg, Russia), Zoological Museum of the Moscow State University (Moscow, Russia). The cores of these collections were established during the joint research expeditions of the scientists of the involved institutions and countries since 1980th years.

An overview of coastal area and fisheries management policy in the Philippines, where a number of small-scale and community-based coastal area and fisheries initiatives have been documented in recent years. Little is known, however, about coastal resources and fisheries management arrangements in larger marine ecosystems shared by a number of local municipalities. It is a need to contextualize efforts at managing large marine ecosystems in the Philippines by describing the processes involved in building coastal area management systems in Banate Bay, Province of Iloilo, and Batan Bay, Province of Aklan, Panay Island, Western Visayas Region, Philippines. An attempt is also made to determine whether key conditions exist for the successful co-management of the two bays that are surveyed. This study made use of different sources of data, namely, content analysis of project reports, technical papers, and other references; focused group discussions; and interviews of key informants. Content analysis of primary and secondary documents provided information for the creation of an analytical framework in evaluating the possibility of success of fisheries management schemes and composing a socio-economic and demographic profile of the selected case study sites. Focused group discussions and interviews with key informants were undertaken to shed light on how the existing fishery and coastal resource management arrangements have evolved through the years. These deliberations also served as follow–up on some key points that are crucial for the assessment and evaluation of management strategies in the various study sites. Those involved in discussions and interviews were town officials, municipal mayors, officers of the local coastal resource management bodies, and professors and faculty members from the University of the Philippines in the Visayas (UPV) who were involved in coastalresource management activities in the two bays. Discussions and interviews were conducted in a relaxed and comfortable manner by ensuring utmost privacy and confidentiality. The various data sources were reviewed and analyzed together so that findings were based on convergence of information from different origins. The development of converging lines of inquiry through the process of triangulation allowed for the corroboration of evidence. Aside from the use of multiple sources of data, this article was enriched by the different perspectives brought by each of the three authors on the important issues surrounding fisheries and coastal resource management dynamics

2.3. Collecting of the gap-filling data on the environments

Environmental data collecting at the model areas was done using the following methods, documented in the scientific literature and handbooks. The study was carried out in Nha Trang bay in 2015–2017 period with a range field trips in different seasons. The survey results from the dry and rainy seasons reveal very substantial differences in the rainfall recorded for these 2 years. Water samples, suspended matter, and sediments were collected at several stations in the study area in Nha Trang Bay (Fig. 2) with transect stations upstream of the rivers (salinity = 0 ppt), river mouth, nearshore, intermediate and offshore. Water samples for suspended matter were collected from the surface layer and the bottom layer using a 5 L-Niskin sampling bottle (USA). Samples of surface sediment (0–2 cm) were taken with Van Veen grab samplers (size 20 cm × 15 cm). The collected sediment samples were put into cold storage and transferred to the laboratory for analyses. Sediment samples were analysed to determine their grain size distribution as well as organic carbon and nitrogen, chlorophyll a and persistent organic pesticides concentration (POPs). Sediment traps were deployed at each station in the study area and sampled over a period of 24 hours at the river sites, and for 48 hours at the coral stations. These sediment traps (with three replicates) were cylinders with a 1:5 proportion (cylindrical diameter: 90 cm; length: 450 cm) (Gardner 1980; U.S. GOFS Planning 1989) (Fig. 4).

In situ surveys were performed by measuring the parameters of the water column at different layer depths (pH, temperature, salinity, dissolved oxygen, turbidity) with ALEC multiple probes (JPE Advantech-Japan). For analysis of total suspended matter (TSM) the samples were filtered through Whatman GF/F filters (pore size: 0.7 µm; diameter: 47 mm). The paper was then dried and its weight defined (lost and retained weights) with high precision analytical scales (d = 0.0001 g). The size of sediment particles collected in the traps was analyzed by laser diffraction with a Mastersizer 2000 particle analyzer at the Geology lab of Copenhagen University, Denmark (Agrawal et al. 1991). Biogeochemical parameters included the composition of organic C and N both in the sediment and in the suspended matter. Analysis of total nitrogen and organic carbon were conducted for the sediment and total suspended matter samples. Total nitrogen (TN), total carbon (Ctot), and total organic carbon (Corg) were measured with an elemental analyser CHNO-S (EA 1120) described by Grasshoff et al. (1999). For Ntot and Ctot a specific amount (TSM: 5 mg = 1/4 Filter; Sediments: ~25 mg) was weighed in a microbalance (Mettler Toledo-MX5) and transferred into 10 10 mm tin cups. The same amounts for Corg were weighed in the same way, acidified using 1N HCL in order to remove all inorganic carbon, and oven dried (40ºC for 24 h) before testing. After every five samples ~15 mg of LECO standard (C% = 0.91 0.04; N% = 0.016 0.006), with the same treatment as samples, was analyzed for calibration. The analysis of residues of organo-chlorine pesticides in the sediment samples and marine organisms were carried out with the method as described in US EPA (US EPA, 2007). The samples of the solution collected by extraction after the enriched column (vacuum evaporated and made to a final volume of 300 µl) were analysed on the gas chromatography mass spectrometer Shimadzu GC 17A with the automated pump Shimadzu AOC 20S, capillary column SLB-5MS and MS QP 5050A. The temperature program started with 70ºC and a holding time of 2 minutes, which was increased by 15°C per minute up to 180°C with no holding time, and then continued to be increased by 5°C per minute up to 280°C with a holding time of 2 minutes. The internal standard method was used (the substance used for the OCP group was 13C p,p'-DDE included in samples).

List of parameters of water quality measured

sedimentation flux DF-SPM – sediment traps were deployed at each station in the study area and sampled over a period of 24 hours at the river sites, and for 48 hours at the coral stations. These sediment traps (with three replicates) were cylinders with a 1:5 proportion (cylindrical diameter: 90 cm; length: 450 cm; Gardner 1980; U.S. GOFS Planning 1989) (Fig. 4).

suspended matter in the water SPM – samples of the water from the surface layer and the bottom layer using a 5 L-Niskin sampling bottle. The samples were filtered through Whatman GF/F filters (pore size: 0.7 µm; diameter: 47 mm). The paper was then dried and its weight defined (lost and retained weights) with high precision analytical scales (d = 0.0001 g).

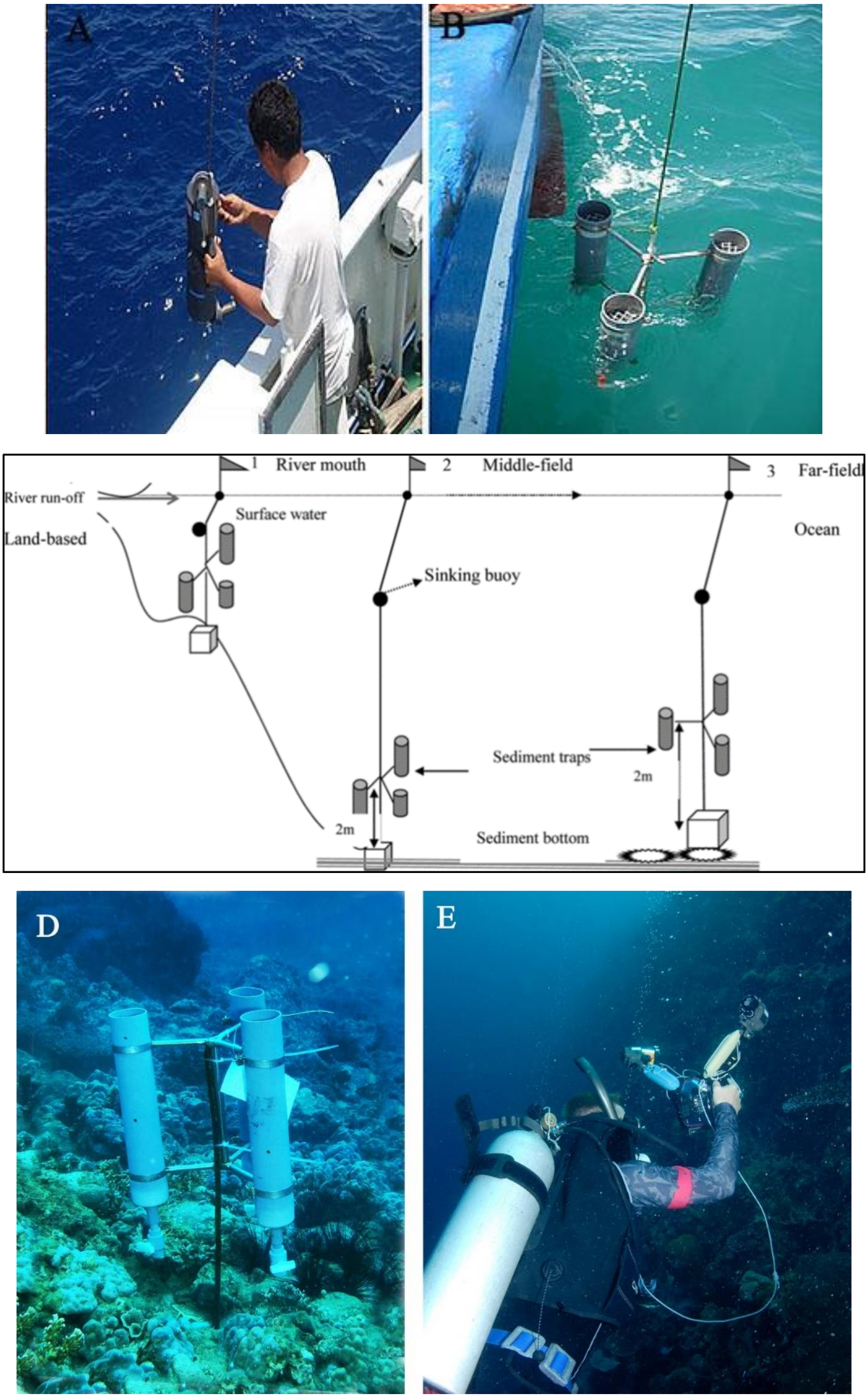


Fig. 4. A, B, C – the process of maintenance and diagram of sediment traps deployed in the transect, Nha Trang Bay, South China Sea (Vietnam). D – the sedimentation traps maintained at the bottom. E – the process of the photographing of the corals using SCUBA.

sediment characteristics – samples of surface sediment (0–2 cm) were taken with Van Veen grab samplers (size 20 cm×15 cm) and kept at cold before to transfer to the laboratory for analyses.

organic carbon and nitrogen, chlorophyll a and persistent organic pesticides concentration (POPs) in sediment and organisms – the method US EPA (SW-846, 2007); the samples of the solution collected by extraction after the enriched column (vacuum evaporated and made to a final volume of 300 μl) were analyzed on the gas chromatography mass spectrometer Shimadzu GC 17A with the automated pump Shimadzu AOC 20S, capillary column SLB-5MS and MS QP 5050A.

the biogeochemical parameters (POC, PN, N and Corg) in sediment/suspended matter – total nitrogen (TN), total carbon (Ctot), and total organic carbon (Corg) were measured with an elemental analyser CHNO-S (EA 1120). For Ntot and Ctot a specific amount (TSM: 5 mg = ¼ Filter; Sediments: ~25 mg) was weighed in a microbalance (Mettler Toledo-MX5) and transferred into 10 10 mm tin cups. The same amounts for Corg were weighed in the same way, acidified using 1N HCL in order to remove all inorganic carbon, and oven dried (40 C for 24 h) before testing.

water parameters – pH, temperature, salinity, dissolved oxygen, turbidity were measured in the water column at different layer depths with ALEC multiple probes (JPE Advantech -Japan).

2.4. Stable isotopes composition (δ^{13}Corg and δ^{15}N). Composition of the natural stable isotopes in living corals was analyzed in the frame of the project as indicator of the terrigenous (anthropogenic) influence on the reefs in Nha Trang Bay. We studied the composition of the stable natural isotopes of nitrogen N and carbon C in tissue of mass reef-building corals Porites in Nha Trang bay as indicator of the terrigenous (anthropogenic) influence on the different reefs. Sediment samples and corals were dried and analysed using CHN analyzer and Isotope Ratio Mass Spectrometer.

2.5. Collecting of the gap-filling data on the status of coral reefs and biodiversity of key groups of reef inhabitants.

The dominance level and the coral community status are assessed as coral coverage (the percentage of the cover of the bottom by living corals, %), *Acropora-Porites* balance, stony corals–soft corals balance, and number of young ones per square m, amount of echinoderms and algae cover area. These data were collected using the underwater photo-registration at the reefs located at different distance from the rivers with SCUBA diving at the 0–30 m depths at 6 model stations in Nha Trang Bay (Vietnam, Fig. 2). For the photo-registration of the above listed parameters of the reef biota, the underwater digital photography was applied using the Nikon D200 camera in the UW housing and two Sea&Sea YS-110 flashlights.

For biodiversity data collecting at the regional level, we applied the digital underwater photography of high resolution using the Nikon D200 and Nikon D800 cameras in the UW housings and two Sea&Sea YS-110 flashlights. The stony corals and octocorals along with the echinoderms (sea urchins and holothurians) were photographed at 22 stations in Nha Trang Bay and 12 stations in Vinh Hy Bay area (Ninh Thuan, Vietnam); 12 stations near northern shore of Luzon Island (Bolinao), 8 stations along with the southern shore of Mactan Island, 12 stations near north-west shore of Cebu Island, 18 stations around Panglao Island (Philippines) (Fig. 5).

Species identifications conducted using the latest knowledge on the phylogeny and modern taxonomy technique (scanning electron microscopy, Fig. 6). The counting of the biodiversity, *Acropora-Porites* balance, coral cover, percentage of young corals and other life forms at the reefs, etc. was conducted along with the transects (3 transects per reef) directed across all reef zones from shore line to the soft-ground pre-reef platform. The information was registered using the digital underwater photography and the SCUBA diving. The photo-sets along with each transect covered the area 2 square metres wide without any interruptions. The collections of the hard corals, soft corals,

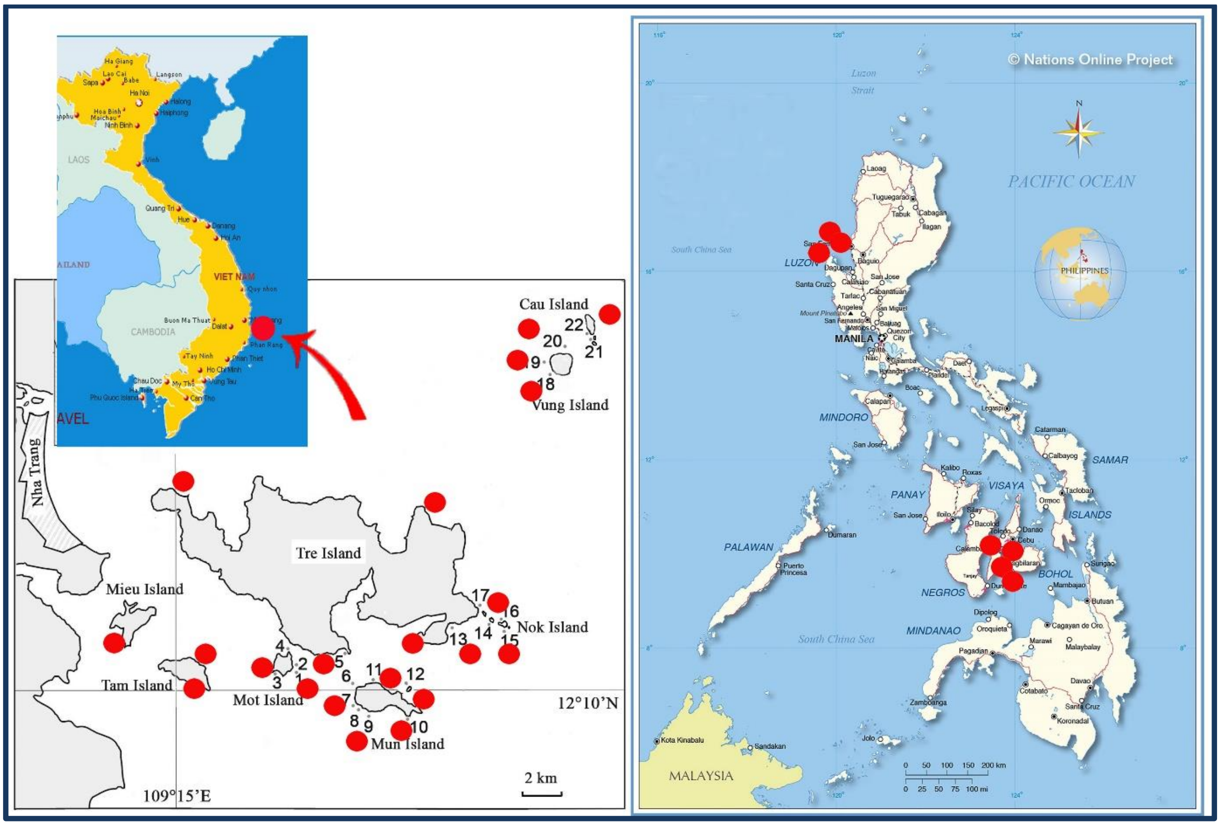


Fig. 5. Stations for the biodiversity observations undertaken in the frame of the reporting project.

marine algae, echinoderms and other reef inhabitants keeping in the scientific museum repositories of the Museums of the Institute Oceanography VAST and Institute of Marine Biology RAS were used for the information on biodiversity and were identified to the species level. Species identifications were conducted using the latest knowledge on the phylogeny and modern taxonomy technique (light and Scanning Electron microscopy for soft corals, Fig. 6).

Biodiversity of echinoderms also have been assessed at above mentioned six model reefs in Nha Trang Bay (SCS). The animals encountered along the photo-transects and registered by digital underwater photography. Extraction and isolation of compounds from the eviscerated internal organs of holothurians provided in laboratory conditions. The organs were minced and extracted twice with refluxing 60% ethanol. The weight of the dry residue was about 23.5 g. The concentrated in vacuo ethanolic extract of *Colochirus robustus* was submitted to chromatography on a Polychrom-1 (powdered Teflon) column eluting the inorganic salts and impurities with H_2O and then the glycosides with 50% ethanol, followed by chromatography on Si gel columns using CHCl3/EtOH/H2O (100:125:25 and 100:100:17) as mobile phases to yield glycosidic subfractions 1–4. Further separation of subfractions and isolation of the individual compounds was achieved by HPLC on a semipreparative reversed phase column Supelco Ascentis RP-Amide (10x250 mm). Colochiroside E (1) (7 mg) was purified by HPLC of this subfraction 3 using MeOH/H2O/NH4OAc (1 M water solution) as mobile phase in the ratio (73:26:1).

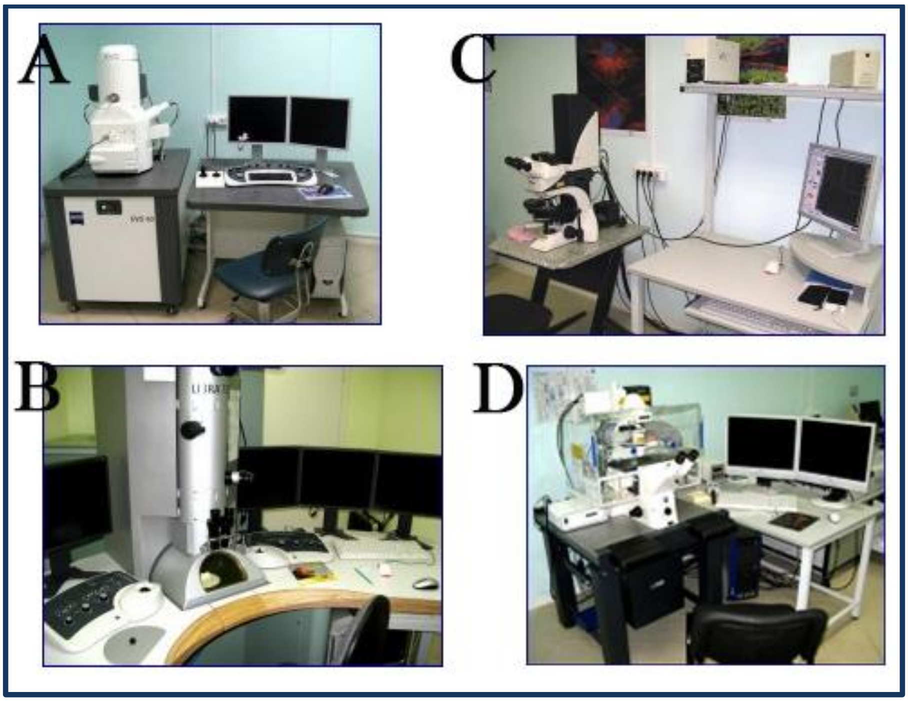


Fig. 6. The microscopy technique used for the reporting project : A – scanning microscope Zeiss EVO 40, B – transmission Zeiss Libra 120, C – laser confocal Leica LSM SPE, D – laser confocal Zeiss LSM Meta.

2.6. Data on the reproduction strategies and recruitment of key animal groups

The study of the reproduction was carried out for the corals and echinoderms (sea urchins and holothurians) included field and laboratory experiments on their reproductive capacity under the different salinity and temperature and under some pollutants; confocal and Transmission Electron microscopy and anti-bodies indications for their sexual and asexual reproduction characteristics.

a. Coral's reproduction data collecting was conducted along with the transects (3 transect per reef) directed across all reef zones from shore line to the soft-ground pre-reef platform. The information was registered using the digital underwater photography and the SCUBA diving. The photo-sets along with each transect covered the area 2 square metres wide without any interruptions.

b. Research of asexual reproduction in holothurians (sea cucumbers).

We studied holothurians of the orders Aspidochirotida and Dendrochirotida collected by SCUBA-divers in April–June of 2015–2017 in different localities of Nha Trang Bay, SCS. Specimens of *H. scabra* were received from the National Center for Marine Seed Production Research and Development in Central Vietnam, from the Research Institute of Aquaculture No. 3. The animals were kept in an aquarium with aerated flowing water with a volume of about 6 m^3. The water temperature during the experiments was 27 to 29°C. Evisceration was induced by injection of distilled water or a 2% KCl solution into the body cavity. Ten to fifteen specimens of each holothurian species were used in our experiments on evisceration and gut regeneration. To study the internal structures, the holothurian's body was dissected along the right ventral radius and examined under a Leica EZ4D binocular microscope.

For the study of *Cladolabes schmeltzii* regeneration, animals regenerating the anterior parts of the body after natural fission were selected. For light microscopy, whole individuals were fixed in

Bouin's solution (Humason, 1962) for 7 to 10 days at 4ºC, embedded in paraffin, and cut into 5- to 6-mm-thick sections. The sections were stained with Ehrlich's hematoxylin and post-stained with eosin (Humason, 1962). For transmission electron microscopy analysis, samples were fixed with 2.5% glutaraldehyde in 0.05 M cacodylate buffer at pH 7.6 for 1–7 days at 48C. After rinsing in the same buffer, the material was postfixed in a 1% solution of OsO_4 in cacodylate buffer for 1 h, dehydrated using increasing concentrations of ethanol and acetone, and embedded in Araldite. Semithin (0.7 mm) sections were stained in a 1% solution of methylene blue in 1% aqueous sodium borate. The sections were then examined and photographed using a Jenamed 2 light microscope (Carl Zeiss Jena) equipped with a Nikon D1x digital camera. Ultrathin (50–70 nm) sections were contrasted with uranyl acetate and lead citrate and examined using a Carl Zeiss Libra 120 transmission electron microscope (Fig. 6).

The five studied holothurian species belonged to three families of Dendrochirotida: *Colochirus robustus* Ostergren, 1898, *C. quadrangularis* Troschel, 1846 (Cucumariidae), *Cladolabes schmeltzii* (Ludwig, 1875), *Ohshimella ehrenbergi* (Selenka, 1867) (Sclerodactylidae) and *Massinium magnum* (Ludwig, 1882) (Phyllophoridae). In 2016–2017, the animals were sampled by SCUBA divers from various areas of the Nha Trang Bay in the South China Sea. The holothurians were kept in aerated tanks with running water at a temperature of 27–30°C during the experiments. To provoke asexual reproduction in *C. robustus*, 30 holothurians were placed in an aquarium with a capacity of about 200 liters. Evisceration in *C. quadrangularis*, *O. ehrenbergi*, and *M. magnum* was induced by adminstration of a 2% solution of KCl or distilled water into the body cavity. In experiments with cross cutting, the holothurians (8–10 ex) were cut with a razor blade in the middle part of their body. The regeneration processes were studied using the transmission electron microscopy (Fig. 6).

2.7. Research of sexual reproduction of sea urchins

Experiments on stimulated sexual reproduction of sea urchins were performed for two most abundant species – *Diadema setosum* and *D. savignyi*. The four series of the stimulated spawning of the two species were undertaken in the laboratory conditions to compare the time characters of their larvae initial development. Sea urchins were collected by scuba diving in Nha Trang Bay in 2015–2017 years. We used the methods of cultivating larvae of the marine invertebrates at laboratory (Strathmann et al., 1992). 11 lines of the larvae of *Diadema savignyi* and 12 lines of *D. setosum* were supported in the laboratory.

Gametes were obtained sea urchins with a test diameter of about 60–70 mm. Spawning was induced by injection of 0.2–0.5 ml of 0.55M KCl solution through the peristome (Iwata & Fukase 1964). Spawning females remained on the glass cups, shedding eggs into filtered sea water. Sperm from males was collected in Petri dishes (dry sperm) and placed in a refrigerator until used. After shedding gametes sea urchins were returned to the sea. Inducing spawning did not kill the sea urchins. The eggs were washed three times in water, placed in a thin layer on the bottom of a 2-liter cup with filtered sea water, and fertilized by adding 5–6 drops of a freshly prepared suspension of spermatozoa (20 µl dry semen diluted in 60 ml of water). Samples of the eggs were taken after insemination to confirm successful fertilization. After appearance of the fertilization envelope, 20–40 minutes post-fertilization, the zygotes were washed three times in FSW and left in the same cup until the swimming blastula stage. The next day, larvae in the stage of swimming blastula were transferred to 4 l glass jars with a density of larvae of 2–3 larvae per cm^3, in which they were cultured according to Strathmann (1987), with permanent agitation of seawater until the larvae had settled and metamorphosed. The temperature in the room was 26–28°C. The larvae were fed the unicellular algae *Nannochloropsis oculata* (with an approximate concentration of 2000–3000 cells/ml). Water was changed twice a day – in the morning at 6:00 and in the evening at 18:00. Preliminary experiments indicated that changing seawater twice a day was required for normal development of larvae at the high temperature of 27–28ºC. Several larval cultures were initiated during our investigation – eight in 2015, and three in 2016.

In the early stages (from 1 to 10 days), several dozens of larvae were taken daily for measurement and photographing. In the later stages, several larvae were taken for analysis, which were examined, photographed and returned to culture dishes. Live embryos and larvae were observed under a compound microscope. Larvae were photographed with a digital camera by putting the camera lens to a microscope eyepiece that had an ocular micrometer. The sizes of eggs, embryos, blastulae and larvae were measured from the photographed images. Sizes are given as mean ± standard deviation (SD). In the late plutei of *Diadema savignyi*, with arm lengths greater than 5 mm, entire larvae did not fit within the field of view even with the lens with the smallest magnification. For measuring the arm length, we therefore used panoramic composite photos with images made under the light microscope Leica MZ125.

2.8. Dissemination of our results and policy-making consultations

Dissemination at public-and-policy level performed via: web-site on the project and its current activity description, the annual work-shops for the exchange by experience, including training for young managers, scientists and policy-makers, "round tables" with the administrative persons at local level, TV-presentations. The scientific results are disseminated via exchange by working visits between our Institutions and laboratories, publication a range of papers in peer-reviewed journals and handbook on the targeted animal group, publication of two books of Proceedings of the annual workshops, annual reports for APN.

3. Results & Discussion

3.1. Physical environments in the targeted model area

3.1.1. Terrestrial run-off and water quality – regional threats, Nha Trang Bay (Vietnam)

Background. The richness and productivity of the South China Sea and associated environments are seriously threatened by high population growth, pollution, overharvest and habitat modification, resulting in high rates of habitat loss and impairment of the regenerative capacities of living resources. The socio-economic impacts of environmental deterioration are significant for the newly developed economies of this region. While gross domestic product (GDP) is newly dominated by the industry and service sectors, food consumption patterns rely heavily on cheap protein derived from fishery resources. Therefore, two key data sets should be surveyed for the initial comparison of the potential for the terrestrial run-off generation by different countries/regions associated with the South China Sea – amount of rivers and intensity of the human socio-economic development including the population density growth in the targeted regions (Table 1).

By data of the UNEP Transboundary Analysis (Talaue-McManus 2000), a total of 270,000,000 people living in the coastal sub-regions of seven countries related to South China Sea are concentrated in 93 cities, each with over 100,000 inhabitants. The weighted mean growth rate in the coastal SCS is 2.17%, which would double the population in 32 years. In Cambodia, Indonesia and Malaysia, growth rates in the South China Sea subregions are 1.5 to 2.0 times the national growth rates. Population densities are highest for the coastal subregions of China and the Philippines at 471 and 472 pers km^{-2}, resp. Malaysia and Cambodia are least dense at 31 and 49 pers km^{-2}. Hinrichsen (1999) notes that in Vietnam, people live at even higher densities of 500-1,000 pers km^{-2} along the northern part of the Gulf of Tonkin. In some parts of Hanoi, densities can reach 35,000 pers km^{-2}. He cites tourism, increasing fisheries efforts and oil exploitation as among the major economic driving forces behind this dramatic increase in coastal populations.

The countries, neighboring with the South China Sea, have different river' activity and sediment loudness (Talaue-McManus 2000). The comparison of the existing data shows that (Table 1.):

1) Vietnam shows the fast growth rate regarding share of Agriculture from annual Gross Domestic Product (GDP)

2) that can be a reason for expecting of the growth of the sedimentation load onto the coastal coral reef ecosystems due to the strengthening of the river run-off.

Sediments are a major pollutant in coastal waters along the densely populated coastal areas due to the terrestrial run-off. Thse have immediate observable impacts including the smothering of coral reefs, and burial of macrophytes like seagrasses and seaweeds. However, very little quantitative data is available in terms of actual sediment load that has entered aquatic systems in the region, and little was obtained from the national reports.

Table 1. Geographic subdivisions of some countries and subregions which interact with the South China Sea (1991 – 1997 years; Talaue-McManus 2000 and https://www.quandl.com).

Country/ Subregion	Major cities amount	Major rivers amount	Watershed area (10^3 km^2)	Area of subregion (10^3 km^2)	Population of subregion (10^3)	Annual population growth rate (%)	% GDP – Agriculture (growth rate/year) (10^6 USD)
Vietnam	26	25	576.09 (1353.09)	137.95	33,057	1.6	19,6 in late 90th (34,2 in 2013 year)
Philippines	16	5	27.43	50.05	23,632	2.1	21 in late 90th (29,9 in 2013)
China	21	11	518.72	138.70	65.354	1.60	16 in late 90th (91 in 2013)
Thailand	14	18	320.51	321.93	37,142	1.4	35 in late 90th (46,4 in 2013)

Note: GDP – gross domestic product.

Under natural processes of erosion, silt load is trapped by mangrove roots in estuarine waters, and then bound by the rhizomes of seagrasses, as they approach the coral reefs. During massive sediment loads, these natural sediment filters break down. For filter feeders like coral polyps, suffocation leads to death as particle removal through tentacular movement is greatly restrained under high silt load. For seagrasses and seaweeds, a reduction in light regimes leads to their demise, and reduced productivities of those plants that can normally deal with relatively higher concentrations of silt and high nutrient regimes of coastal waters. Thus, there is a loss both of biodiversity and productivity of benthic macroflora. In the case of phytoplankton, the massive silt load may not necessarily lead to reduced photosynthesis because cells are suspended in the water column, and shading may be episodic as they are mixed in all directions. The high amount of nutrients associated sometimes with high sediment loads sustains high production.

Much effort was given in understanding Quaternary evolution and paleoceanography of the South China Sea (SCS), but most workers have concentrated on deep-sea sediments (Wang et al. 1999) or on wide shelf areas (Sunda shelf, Hanebut et al. 2000) and off the Chinese coast. Very little sedimentological work has been done in the central part of Vietnam shelf up to recent times. According to Su and Wang (1994) presented basic characteristics of modern sediments in SCS, sand and silty clay are accumulated here that belong to the neritic facies of the inner and outer shelf. Considering the genetic types, they classified sediments on the shelf near Nha Trang city as nearshore terrigenous sands and silts.

Even less is known about contemporary sedimentation rates in SCS. Some calculations based mostly on radiocarbon dating deal with averaged rates for periods of several thousands of years and some experiments with sediment traps have been carried out in deep part of SCS (e.g. Hanebut et al. 2000; Wiesner 1996).

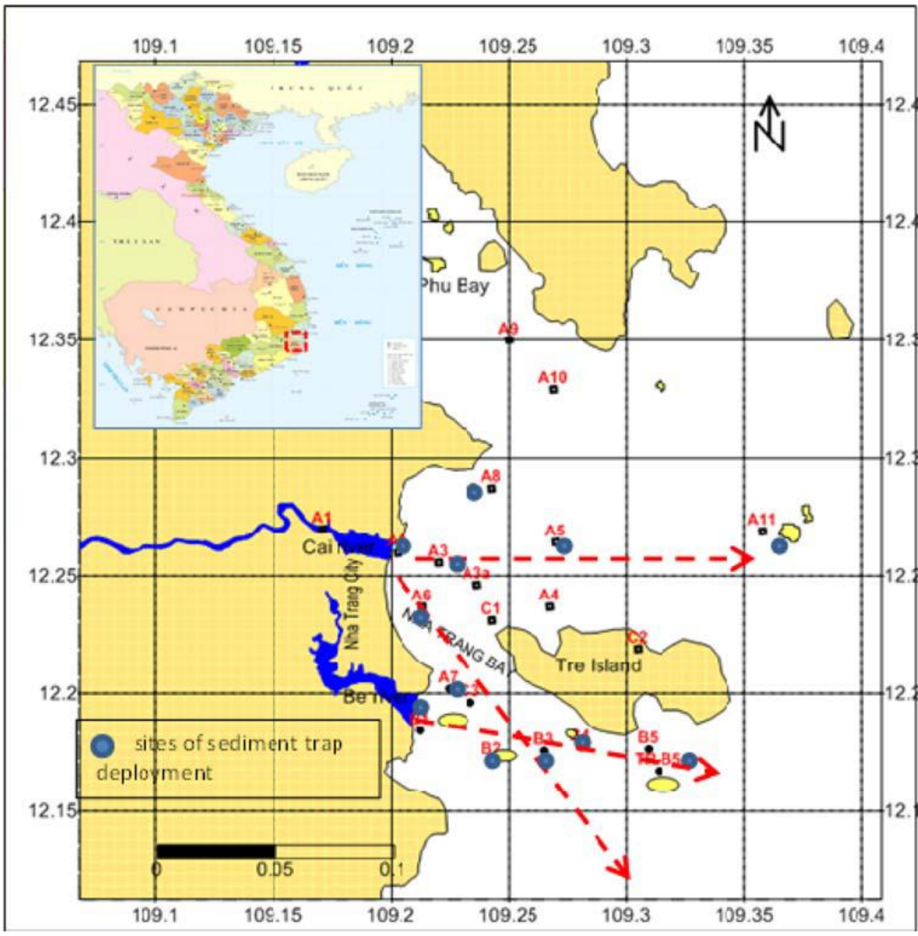


Fig. 7. Sampling stations in Nha Trang Bay, SCS (Vietnam) for environmentals data.

3.1.2. Nha Trang Bay, Central of Vietnam – fluctuation of aquatic environments around coral reefs

Nha Trang Bay is located in Khanh Hoa province, in the central of Vietnam, with an area of about 507 km^2, including 19 islands (Hon Tre with 3250 ha is the biggest island in the Nha Trang Bay, Fig. 7). With regard to the ecosystems in Nha Trang bay, they are the similar to the ecosystems of tropical bays or lagoon, which have mangrove, coral reef, sea grass bed and estuaries ecosystems. Nha Trang Bay is one of the developed coastal areas in Vietnam that includes marine aquaculture, an industrial harbor, tourist and marine services.

Nha Trang Bay is influenced by two rivers, Cai River at north and Be river at south. The systems of rivers transport all wastes from continental activities to the bay. The flow of Cai River depends on the annual rainfall and two seasons are formed: the rainy (wet) season (October–December) and the dry season (summer). The sedimentation and water circulation in the Nha Trang Bay are of low rate in dry season – in a period of lowest river discharge and neap tide. The major hydrological factors during dry season are thermal stratification of the water column and its thorough mixing during short periods of local winds.

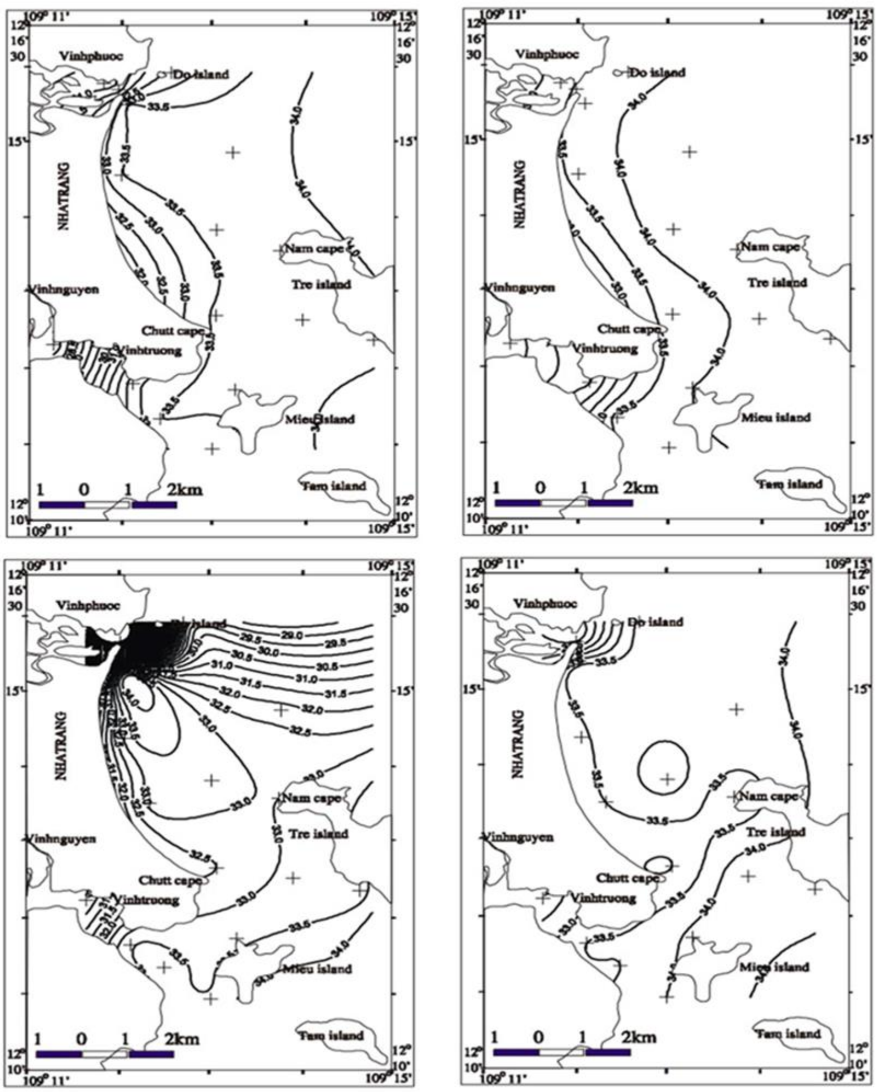


Fig. 8. Distribution of salinity (‰) in Nha Trang Bay (above: February, 1998: left: surface, right: bottom layer; under: August, 1998: left: surface, right: bottom layer).

Salinity in Nha Trang Bay as it is an element sensible to climate and hydrodynamic regime, but it is of strict relation to climate, hydrodynamic regime, formulation of flocculation, and dissolve of chemical elements. During rainy season, the strong gradients of salinity between surface and bottom layer and, also, inside and outside of two river mouths are registering in the bay since 1998 in according with the data recorded by the Ecology Department of the Institute of Oceanography VAST (Fig. 8, Nguyen et al. 2000).

Sedimentation in the Nha Trang Bay was poorly studied before the beginning of the 21 century. For the dry season Szczucinski et al. (2005) reported a few data on the parameters of the terrestrial run-off in the bay. Suspended particulate matter concentrations were very low between 0.03–4.3 mg dm^{-3}, only one sample reached 8.9 mg dm^{-3}. Downward particulate matter flux determined with sediment traps at a station 2.8 km off the river mouth was very low: 0.77 g m^{-2} day^{-1} at 2 m water depth and 5.36 g m^{-2} day^{-1} at 12 m water depth, about 3 m above the bottom. The authors suggested the Cai River water influence as the major freshwater source is limited to less than 2.8 km from its mouth. Along with their sediment trap results, no significant sediment accumulation occurred in the dry season. It was thus evident that fine material, which was expected to be deposited on the bay bottom during the rainy season, as observed in satellite images, must have been reentrained and advected further offshore.

For the wet season, we got the first data on the terrestrial run-off in Nha Trang Bay in 2003–2004 and processed these data to find the gradient decreasing of the terrestrial run-off influence in the bay.

The measurements were made in wet season (Fig. 2) and showed the gradient change of the sedimentation load onto the coral reefs in concerning with their distance from the Cai and Be river's estuaries. It should be specially noted that the wet season in 2003 was characterized by extremely low rainfall. The average sedimentation flux DF-SPM varied from 38,222 g m^{-2} day^{-1} (SE = 2,165) to 20.8 g m^{-2} day^{-1} (SE = 3,669) at Mieu Island (station 1) and Tre Island (station 6, Fig. 2).

Table 2. Physical environments measured in Nha Trang bay (wet season – 2003, September–October). SPM – suspended particulate matter in the surface layer of the water; DF-SPM - sedimentation flux in the water column; SCOL21 – sedimentation flux near bottom considering resuspension; Cai distance – distance from the Cai river; Be distance – distance from the Be river

Station (Island)	Transparency, m	SPM, mg/l	DF-SPM, g m^{-2} day^{-1}	SCOL21, g m^{-2} day^{-1}	Cai distance, km	Be distance, km
1 (Mieu)	7,4	6,04	41,624	5,07	14,36	4,55
			34,2	6,9		
			38,841	7,05		
2 (Tam)	7,8	1,87	–	–	16,73	7,27
			–	–		
			33,58	3,44		
3 (Mot)	8,2	–	33,4	5,256	19,27	12,73
			29,5	4,999		
			28,2	6,513		
4 (Tre, south)	7,6	6,3	30,825	3,782	21,45	16,73
			36,605	4,961		
			43,769	6,807		
5 (Mun)	9	2,8	30,043	3,269	25,64	18,9
			26,731	3,461		
			27,092	4,179		
6 (Tre, east)	10,8	2,1	16,316	2,795	28,28	24,55
			19,928	2,949		
			31,427	3,884		
			15,533	3,141		

Temperature and salinity didn't very significantly along with this gradient (28–29,2º C, 29–30.5‰), but water transparence was coincided with the distance from rivers. Sedimentation flux parameters (DF-SPM, SCOL) also decreased as the distance of the reef from the estuaries (Table. 2). Only the reef at the south of Tre Island (south, station 4, Fig. 2) was the exception.

It was concluded that these rivers input into Nha Trang Bay the significant amount of suspended matter (SPM), so the distance from the estuaries influence the intensity of the sedimentation flux DF–SPM at the surveyed reefs (stations) and can be used as essential factor in analysis.

The resuspension due to the wave activity could be assumed as another essential source of sediment flux at the surveyed area. Reef at station 4 (Fig. 2) probably was under the additional sedimentation load which additional load derives from the Dom Bay. The interconnection between sedimentation flux and distance from the rivers was reliably described by the formula:

$$DF\text{-}SPM_1 = a*\exp(-((dis-b)/c)i),$$

where $DF\text{-}SPM_1$ – sedimentation flux measured at surveyed station excluding st. 4, dis – distance of the stations from the river, a, b and c – coefficients. The regression obtained can explain 72,2% of the dependent parameter' variations. Therefore, the input of sediment into water layer above the surveyed reefs in the above mentioned period (of quite calm weather and small rainfall) was derived more from rivers than from resuspension. The intensive increasing of the sedimentation flux is predicted in the area located not so far from the rivers (10 km and less) due to the thicker layer of the silt at the bottom and stronger wave resuspension in the coastal zone. Indirect indicator of the sedimentation processes – "sedimentation excluding the resuspension" also was well connected with distance from the rivers (Pearson correlation coeff. r = -0.70) indicating that the predominant influence of continental run-off during the survey period.

The sediment flow around the coral reefs increased several times (in comparison with the summer period) during the rainy season and storms and can reach values harmful to coral reefs in Nha Trang Bay. So, the developing of the investigations were assumed prospective and hardly needed for analysis of the composition of the sediment and water quality to know the level of eutrophication/pollution in the bay.

<u>2010 and 2011</u>

Wet season was more pronounced in **<u>2010–2011 years</u>**. The peak rainfall was noted out in October–November with maximal precipitation 940 mm water in 2010 and 350 mm in 2011 (Du and Kunzmann 2015).

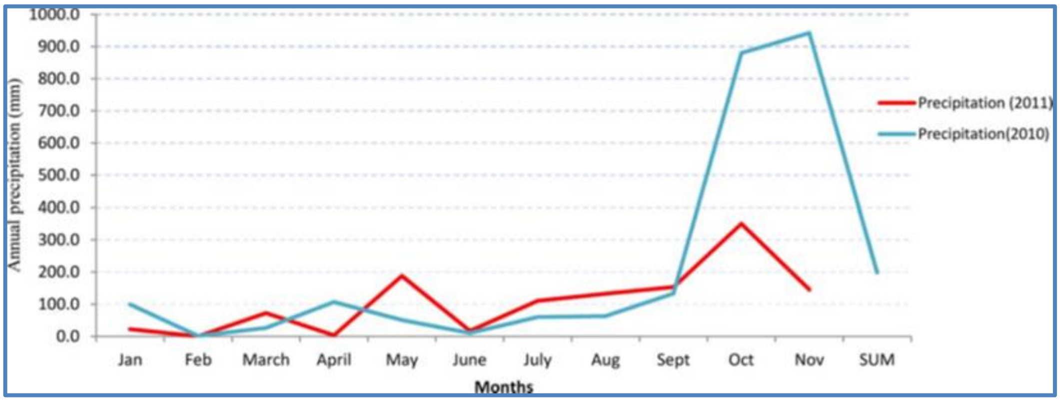
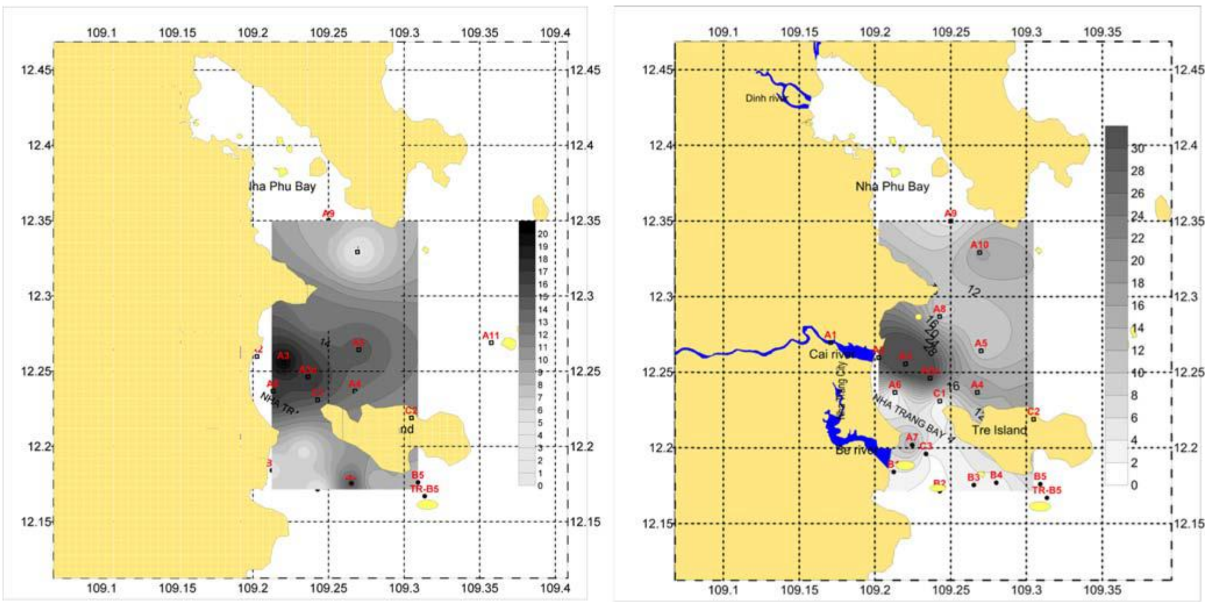


Fig. 9. Monthly rainfall of Nha Trang in 2010 and 2011

Our analysis of the data collected during this period showed large variations in rainfall: the total rainfall in 2010 was 2,568 mm, while that in 2011 was 1,170 mm, and substantial differences can be noticed in each month (Fig. 9). The run-off flow of rivers into the sea also varied much with each year, resulting in considerable variations in the impact on the coastal water volume. As calculated by Duong (2012), the average run-off flow of Cai river (in the north of the bay) was 51.6 $m^3 s^{-1}$ during the southwesterly wind season (the dry season) and 115 $m^3 s^{-1}$ during the northeasterly wind season (the rainy season). The measurements of hydro-physical factors recorded at transects at the same points of time show variations between estuary sites and near-estuary sites, mainly concerning salinity and turbidity in the water column (Fig. 6). In the Cai river transect, the values of hydro-physical factors varied most during the rainy season (when floods occur), at which time salinity and temperatures changed the most: the seawater salinity was 9.0 ppt in the surface layer at the estuary, 26.0 ppt in mid-bay, and 33.0 ppt off shore beyond the bay (Du and Kunzmann 2015). The sedimentation flux DF-SPM reached of the maximum amount 56.2 g m^{-2} day^{-1} during wet season (Fig. 8) and exceeded those recorded in 2003 year (see Table 2).

Distribution of the suspended particulate matter SPM in Nha Trang Bay is very substantial factor as it influence directly not only to the sedimentation flux, but also on the a) physiology/health of corals (via the photosynthesis activity in their symbiotic micro-algae) and b) sexual reproduction of the reef ecosystem inhabitants having the floating larvae. The distribution of the suspended particulate matter (that can be estimated as turbidity in the water column) was unequal between the dry and rainy seasons in 2010–2011. In the rainy season of 2010–2011 years the SPM was distributed farther off shore and reaches high concentrations in the northern area, triggered by massive runoff flows of rivers. In contrast, during the dry season, there is no difference in the SPM distribution at almost all other sites in the bay, which means the whole bay is characterized by a uniform and broad distribution of sediment introduced into the seawater from rivers (Fig. 9).



(A) (B)

Fig. 10. The distribution of TSM (mg L^{-1}) in the surface waters during rainy season: (A) in 2010 and (B) in 2011, Du and Kunzmann, 2015.

The SPM distribution in 2010–2011 had a very substantial influence on the distribution of particulate organic carbon (POC) and particulate nitrogen (PN) in the water environment (Table 3), leading to changes in the balance in biogeochemical cycles. Survey results show huge differences in POC and PN values between the dry seasons and the rainy seasons. At sites at the northern part of the bay during the rainy season, the concentrations of POC increase by 3–14 folds and those of PN increase by 3–21 folds; whereas in the in the middle and southern parts of the bay, the POC and PN values increase by only 1–3 folds.

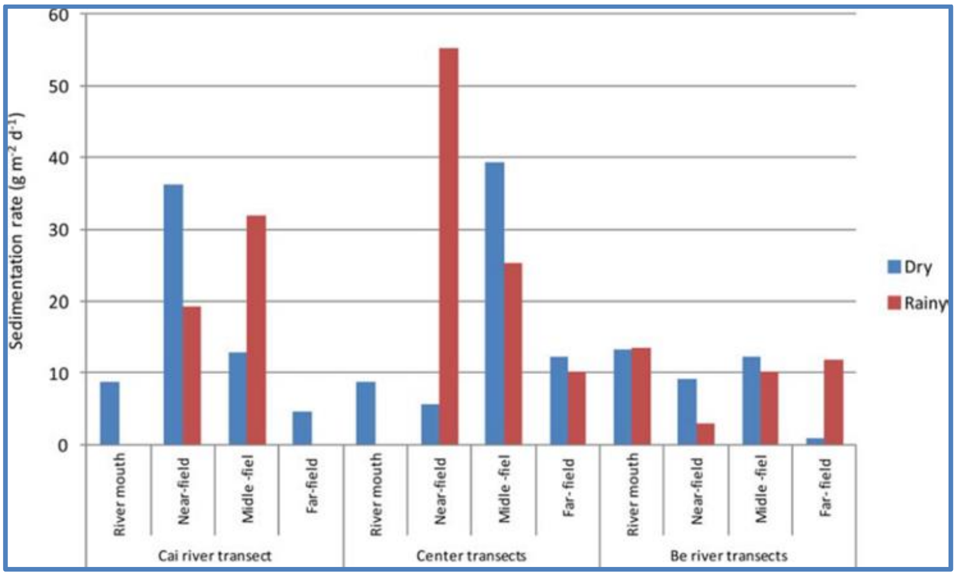


Fig. 11. Sedimentation rates (g m^{-2} d^{-1}) in coastal waters of Nha Trang Bay in 2010–2011.

The results of sediment deposition in Nha Trang Bay show that the sedimentation rate of particles in the bay are different mainly between two areas, with higher rates in the northern and middle parts of the bay and lower rates in the southern part of the bay. The locations with higher deposition rates of sediment particles were highly dependent on the discharge of the Cai River (which was most clearly revealed during the rainy season) (Fig. 10). At the site A3, the deposition rates were 36.1 g m^{-2} day^{-1} during the dry season and 19.4 g m^{-2} day^{-1} during the rainy season; correspondingly, at site A6, the figures are recorded as 12.8 g m^{-2} day^{-1} and 31.9 g m^{-2} day^{-1}. In the meantime, at the transect of Be river (in the south of the bay), the deposition rates are lower and show little change with the seasons, with the highest deposition rate of 9.1 g m^{-2} day^{-1} (dry season) and 9.0 g m^{-2} day^{-1} (rainy season) right at Be river estuary.

At sites marked with high deposition concentrations, there is also a massive accumulation of organic matter: A3 and A6 (Fig. 7) are the two sites with the highest deposition recorded during both the dry and rainy seasons and with high concentrations of organic carbon and nitrogen (Du and Kunzmann 2015). The high percentages of organic carbon and nitrogen in sediment prove that these amounts of sediment originated from agricultural practice, soil erosion and corrosion, and were introduced into rivers and then transported by rivers into coastal waters of the bay (Jennerjahn et al. 2008, Tue et al. 2011, 2012). These organic substances tend to decrease gradually towards the bay.

Pollution rates in Nha Trang Bay were studied regarding the organo-chlorine pollutants (OCPs) in 2010–2011 and these studies were repeated in the 2015 (first year of the Project). The analysis of the samples of the sediment collected in 2010–2011 show that organo-chlorine pesticides (mainly DDTs) contaminated most surveyed sites. High DDT contamination was found at near-estuary sites, and the contamination values at sites of the Cai River transect were always higher than those at the Be river (Table 3). The highest values of DDTs at the transect of Cai River were five time greater than those recorded at Be River. Most often DDTs were highly concentrated in the sediment at near-estuary sites: 20.11 μg kg^{-1} and 5.28 μg kg^{-1} at A3 and A6 stations, respectively in the northern part of the bay; and at B1 site 3.76 μg kg^{-1} at the estuary site in the southern part of the bay. There is a remarkable difference in the residues of pesticides between the two transects (Fig. 7).

The rainfall in the rainy season of 2010 was many times greater than that of 2011, introducing large amounts of sediment particles from river run-off into the bay. Due to it, the total DDTs residues were mainly found in the surface sediment – a very thin layer (0–0.5 cm), and in addition there is the formation of a new sediment layer after the rainy season at sites with high sediment deposition (Du and Lai 2012). This distribution of the contamination of DDT residues is a strong evidence of the significant impacts of river runoffs on the sediment quality in the bay.

Table 3. The average values of SPM, POC and PN in coastal waters of Nha Trang Bay in wet season of 2010 (n = 4).

Station	Latitute	Longitute	Depth(m)	Sampling time	TSM (mg/L)	POC (mg/L)	PN(mg/L)
A1	12.2698	109.1707	0.0	16–Jun–10	12.07	0.195	0.018
A2	12.2598	109.2025	0.0	16–Jun–10	8.47	0.497	0.011
A3	12.2556	109.2201	0.0	16–Jun–10	8.80	0.147	0.018
A5	12.2642	109.2699	0.0	16–Jun–10	2.40	0.022	0.002
A6	12.2367	109.2132	0.0	16–Jun–10	9.80	0.165	0.017
A7	12.2020	109.2245	0.0	16–Jun–10	8.13	0.224	0.016
A9	12.3500	109.2500	0.0	16–Jun–10	10.83	0.293	0.030
A10	12.3292	109.2690	0.0	16–Jun–10	6.60	0.153	0.014
A11	12.2689	109.3576	0.0	16–Jun–10	2.90	0.056	0.006
A11	12.2689	109.3576	0.0	16–Jun–10	3.57	0.053	0.006
B1	12.1842	109.2124	0.0	16–Jun–10	8.13	0.161	0.018
B2	12.1714	109.2427	0.0	16–Jun–10	7.53	0.130	0.019
B3	12.1755	109.2651	0.0	16–Jun–10	8.13	0.099	0.018
B4	12.1770	109.2802	0.0	16–Jun–10	3.65	0.224	0.016
B5	12.1762	109.3091	0.0	16–Jun–10	2.96	0.163	0.017

It was concluded that the residues of organo-chlorine pesticides in the sediment of Nha Trang Bay are relatively high. The DDT pesticide group and their degradation products found in the sediment samples taken at sites of the Cai river transect are much larger in quantity (4–5 times) compared to those from the Be river transect, while other organo-chlorine pesticides levels were very low and far below detection limits. The contamination from DDT pesticides found in sediments should be a matter of serious concern and there need to be warnings about the threats they pose to the coastal ecosystems of Nha Trang Bay. These substances are hard to dispose of and may accumulate in a number of marine organisms, likely to cause harmful impacts on human health. Organo-chlorine pesticides are still used illegally by farmers, and therefore we still find many persistent organic substances in the environment In recent studies carried out by Quoc (2011) on the residues of organo-chlorine pesticides at a number of paddy fields and vegetable fields in Dien Khanh District (in the areas of Cai river upstream) DDTs and derivatives from DDT (DDE, DDD) were found in almost all samples, and p,p'-DDE was found to have the highest concentrations in both vegetable and paddy soils. In other research studies, Cu et al. (2005) revealed the increase in recent years of these substances in sediment samples collected in the coastal waters North Vietnam. Minh et al. (2007) showed fairly high values for these substances in the estuary area of the Mekong River (varying between 0.01 and 110 µg kg^{-1} of dry sediment). A comparison of residues of organo-chlorine pesticides in sediments as it was outlined by Du and Kunzmann (2015) in Nha Trang Bay with those in other inlets and bays in Vietnam such as Ha Long Bay (North of Vietnam), Tam Giang – Cau Hai lagoon (North Center of Vietnam), Thi Nai lagoon (South center of Vietnam), and Mekong estuaries reveals that the values recorded in this research study are slightly higher (Hong et al. 2008, Cu et al. 2005, Du 2009, Minh et al. 2007).

2015–2017

We repeated (during the first year of the project, Fig. 9) the research of the sedimentation processes during wet season in Nha Trang Bay to monitor the possible change of the terrestrial run-off since 2010–2011 years which changes could be expected due to the coastal development. The measurements were done in the December of 2015 year. The sedimentation flux DF-SPM, amount of suspended matter in the water mass SPM were collected using the same methods (see "Methodology" in the present report and Appendix A). The content of the biogeochemicals and the level of the pollution by organo-chlorines and pesticides in the bay also were included into the planned analysis.

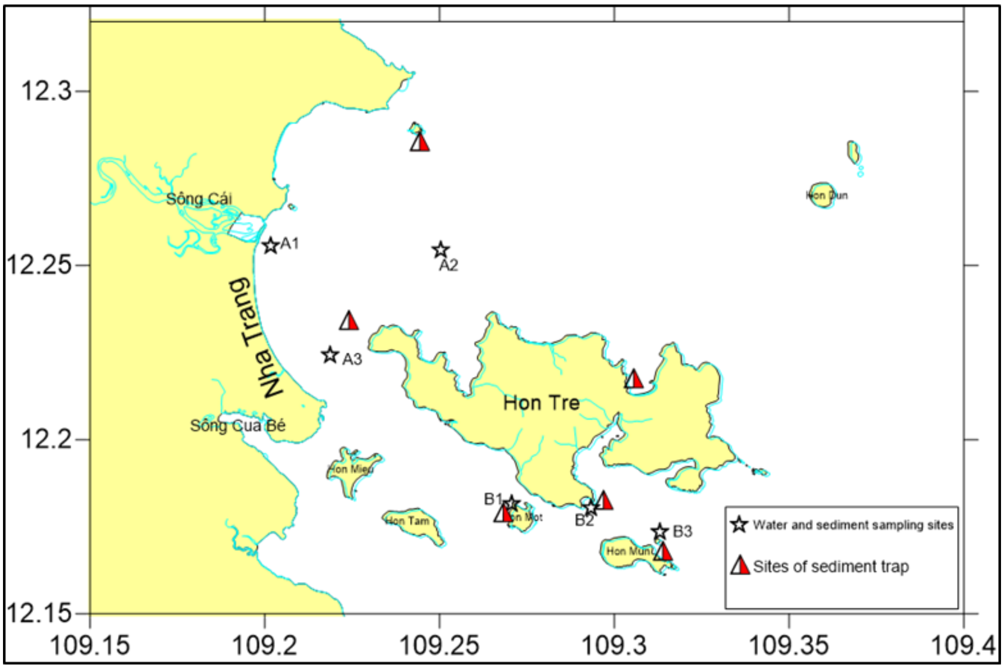


Fig. 12. Map of sampling sites in Nha Trang Bay, Khanh Hoa provinces. Wet season, December 2015.

Results of the collected data processing show the maximal sedimentation flux DF-SPM 28.9 g m^{-2} day^{-1} at the station A2 (Fig. 12, Table 3) which station is located directly before the Cai River mouth. We suggest that the sedimentation load in the Nha Trang Bay in that period was possessed mainly by Cai River and the role of Be River was minor. Also, the additional sedimentation flux from the north (directed from the Nha Phu Bay) also cannot be excluded. Generally, this season of 2015 year is characterizing by twice less sedimentation loan in comparison with those of 2010–2011 years (see Fig. 10). It can be suggested that this seasonal rate of the activity of Cai River may be in concern with the large-scale change due to the strong El Nino event of the year (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.html).

Table 3. The results of water quality analysis in Nha Trang Bay (December, 2015)

Order	Sampling sites	Sed flux DF-SPM (g $m^{-2}.d^{-1}$)	Layer	SPM (mg/l)	TOM(mg/l)
1	A1	21.5	Surface water	2.75	0.85
2			Bottom water	5.85	1.10
3	A2	28.9	Surface water	3.40	0.90
4			Bottom water	4.60	1.05
5	A3	12.3	Surface water	7.53	2.73
6			Bottom water	3.44	0.68
7	B1	17.1	Surface water	6.13	1.27
8			Bottom water	2.20	0.52
9	B2	18.6	Surface water	1.57	0.97
10			Bottom water	2.20	0.90
11	B3	11.2	Surface water	1.57	0.93
12			Bottom water	2.73	0.90

The salinity and temperatures in the studied area were relatively consistent among sites and there were significant differences between the surface layers and bottom layers. The profiles of temperature and Chl-a (Fluorescence) were showed that the vertical distribution in the area of marine farm is a little difference to far station. Salinity varied between 33.6 and 33.7 ppt in the surface layer, and from 33.7 to 33.9ppt in the bottom layers. The temperatures were from 26.4 to 27.1ºC in the surface, and from 24.4 to 25.5ºC in the bottom layers. The contents of dissolved oxygen (DO) in the area showed fairly positive results: 6.49–6.93mgL^{-1} in the surface layer (saturated oxygen: 98.2–105%); 6.60–6.87 mg.L^{-1} in the bottom layer (saturated oxygen: 96.9–101.3%). There are a little differences in the TSM in sites of near cage farm and far-distance sites (far areas). The contents of TSM is distributed high concentrations under cage sites in the bay. Average of TSM contents in near-cage is ranged from 1.92 – 2.09 mgL^{-1}, and md-distances were ranged from 1.52–2.19 mgL^{-1}; and ranged from 1.42–1.69 mgL^{-1} in far-distance areas (Table 4). The DO and chlorophyll a did not change significantly in differ sites.

Table 4. Distance from cages and parameters of water quality.

	In survey 2015 (dry)			In survey 2016 (dry)		
Areas of sites	DO	TSM	Chl-a	DO	TSM	Chl-a
	mg.L^{-1}	mg.L^{-1}	mg.m^{-3}	mg.L^{-1}	mg.L^{-1}	mg.m^{-3}
Nearest the cages	6.71 ±0.11	1.92 ±1.02	0.82 ±0.28	6.32 ±0.10	2.09 ±1.38	0,85 ±0.34
Mid-distance	6.81 ±0.04	1.52 ±0.83	0.73 ±0.25	6.40 ±0.15	2.19 ±0.43	0.73 ±0.24
Far-distances	6.80 ±0.05	1.42 ±0.10	0.63 ±0.17	6.24 ±0.21	1.69 ±0.63	0.86 ±0.22

The data of nutrient concentration: nitrogen (N) and phosphorus (P) in the entire column are presented in Table 5: DIN (dissolved inorganic nitrogen) has a mean value of 177.38 ± 6.01 $\mu g.L^{-1}$ (ranged from 169.88 to 188.88$\mu g.L^{-1}$), in which the contents of NO_2–N showed for the lowest proportion in DIN, with a mean value of 3.94 ± 0,5 $\mu g.L^{-1}$; next is NH_4 –N with 20.45 ± 6.75$\mu g.L^{-1}$and NO_3–N with the highest proportion of 152.99 ± 1.91 $\mu g.L^{-1}$. Unlike DIN, the contents of dissolved inorganic phosphorus varied fairly greatly between 6.16 and 21.97$\mu g.L^{-1}$, at an average of 11.65 ± 4.00 $\mu g.L^{-1}$.

A comparison with the results on nutrient levels obtained in Le Lan Huong et al., 2014 in the lobster cage area at Dam Bay, Nha Trang Bay showed that the average values of inorganic nutrients as NH_4–N, NO_2–N and PO_4–P were relatively similar. However, the contents of NO_3–N and DIN in water column in the studied area were higher than those in Dam Bay at the same time period of the year (about 3–4 times) (Fig. 7). The N:P ratios at almost surveyed sites were greater than the Redfield ratio of 16:1, except for the surface layer at site–NT2 is about 15.62 (in 2015) and for the bottom layer at sites NT4, NT6 are about 11.09 and 15.07 respectively (in 2016). This shows that during the time of the studied survey. Phosphorus might probably be the limitation factor in these waters.

Table 5. The variation of nutrients concentration in coastal waters of Nha Trang bay **(**During dry seasons of 2015 and 2016**)**

Values	$NH_{3,4}$–N	NO_2–N	NO_3–N	DIN	–PO4
	($\mu g.L^{-1}$)	($\mu g.L^{-1}$)	($\mu g.L^{-1}$)	($\mu g.L^{-1}$)	($\mu g.L^{-1}$)
Min	10.9	3.1	148.2	169.9	6.2
Max	30.4	4.9	155.3	188.9	21.9
Mean	20.5	3.9	152.9	177.4	11.7
Stand	6.8	0.5	1.9	6.0	4.0
n	14	14	14	14	14

The results of sediment trap were measured at three sites demonstrated that rates of sediment deposition in surrounding waters of Nha Trang Bay was not truly high. . Whereas the highest sediment rate was determined at site NT2 (under the sea – cages) of 6.81 mg $cm^{-2}.d^{-1}$. The site located above coral reef ecosystem (NT3) showed result of 2.84 mg $cm^{-2}d^{-1}$.

Table 6. Rate of sediment deposition in the study area

Sites	Deployed time (day)	Sedimentation rate (mg $cm^{-2}d^{-1}$)	TOM (%)
Under-cage	2	1.71	16.0
Near-cage farm (coral reef area)	2	2.84	19.9
Far-cage farm	2	1.86	11.3

Considering the nutrients variation in coastal waters of Nha Trang bay, there was little changed in 2005, while the levels of NO3–N and NH4–N in the period 2005 to 2011 have slightly changed. However, from 2011 to 2015 and 2016 there was strongly changes in the concentrations. The average of the two surveys in May, 2015 and 2016 showed that the content of NO3–N increased about 3.6 times; and the NH4–N increased about 5.1 times over the same period in 2011. The distribution of nutrients in the study area shows that DIN and DIP concentrations are mainly concentrated in aquaculture areas, most clearly shown in Table 5.

Table 7. The variation of nutrients in coastal waters of Nha Trang

Years	NO_2–N (µg.L^{-1})	NO_3–N (µg.L^{-1})	NH_4–N (µg.L^{-1})	PO_4–P (µg.L^{-1})	DIN (µg.L^{-1})	DIP (µg.L^{-1})
2005	0.6	47.0	0.0	10.9	47.6	10.9
2006	0.6	33.0	38.3	10.4	71.9	10.4
2007	0.9	36.0	9.8	11.4	46.6	11.4
2008	0.0	35.0	6.0	13.7	41.0	13.7
2009	41.5	212.0	17.3	13.5	270.7	13.5
2010	0.0	31.0	6.5	11.3	37.5	11.3
2011	3.1	28.0	17.8	16.6	48.9	16.6
Apr–11	0.4	30.0	11.3	10.2	41.7	10.2
Jun–11	0.0	31.0	8.0	11.5	39.0	11.5
May–15	3.9	153.0	20.5	11.7	177.4	11.7
Apr–16	1.9	65.7	77.8	16.8	145.4	16.8

A consideration of the relationship of the contents of nutrients and chlorophyll-*a* showed that there was almost no relationship between chlorophyll-*a* and the contents of nutrients (except for NO_2 –N with R^2 = 0.36). The average contents of chlorophyll-a in the surface layer were lower than those of the bottom layers, corresponding to 0.54 ± 0.15mg.m^{-3} and 0.94 ± 0.2 mg.m^{-3}; this proves to be fairly consistent to the variations of nutrients. The N:P ratios at almost surveyed sites were greater than the Redfield ratio of 16:1, except for the surface layer at site – NT2 (15.62). The highest values of the N:P ratio were obtained in the bottom layer at site – NT6 (98.18). This shows that during the time of the research survey (dry season – May, 2015), phosphorus might probably be the limitation factor in these waters, with results nearly contrary to those obtained in cage farm areas in Dam Bay, which had nitrogen as the limiting nutrient factor (Le Lan Huong *et al.*, 2014). A previous study by Le Thi Vinh *et al.*, 2005 also concluded that phosphorus has always played the role of a limiting factor in the coastal waters of Nha Trang Bay in the dry seasons.

The increase of dissolved inorganic nutrient in the waters of the cage farm area is quite closely linked to the eutrophication of a number of coastal waters, especially with the substantial amount of disintegrated and mineralized organic matter from sediments which enter the water column (Mayer *et al.*, 1998). The results of calculating N and P emissions from aquaculture areas showed that lobster cage farming is the most polluted source of nutrients (N) for environmental quality of Nha Trang Bay. In the lobsters cage farming (Fig. 12A), it have strongly emitted nitrogen and phosphorus in the marine environment respectively about 28917 tons of nitrogen per year and 7740 tons of phosphorus per year; Furthermore, in produced ton of commercial lobsters, the amount of nitrogen and phosphorus released into the environment is 261.47 kg per day and 69.98 kg per day. According to Le Anh Tuan (2012), showed that nitrogen load from lobster cages is 257 kg per ton of commercial lobster in Khanh Hoa province in 2010. From the results of cage farming is showed that lobster cages is significantly impacts higher than other sources, due to the lobster feed conversion ratio is so high in nitrogen and phosphorus deposits in Nha Trang bay (Table 7).

This is due to differences in feed conversion ratios (FCR) and N/P contents in the feed used, that the total N and P loads is strongly variable in the calculation (Table 7). This is due to differences in feed conversion ratios (FCR) and N/P contents in the feed used, that total N and P loads will strongly variable in the calculation. From the above results, the cage aquaculture in Nha Trang Bay has contributed to the increase of organic and nutrient contents in water column and bottom sediment in sea-cage farming areas. In addition, in semi-closed bays such as Nha Trang Bay, especially in the southern part of the bay, where most of the lobster cages are located, the area is surrounded by islands. This makes the wastes from the sea-cage farming was difficulty for diffusion, its easy accumulate in the bottom layers.

Fig 12A. Fish and lobster farming in Nha Trang bay, South China Sea.

The waste production of fish farm is depended upon the aquaculture facilities differs from the provinces, there is an additional waste component in uneaten feed that may affect the environment, and the nutrients release rate can be estimate to apply for situation in the areas. The nutrient loading from cage fish farm is point source to influence the surrounding waters and it is depend on the hydrodynamic systems and depth of the sites by current will contribute to water exchange in the cage farm.

3.2. Status of targeted coral reefs in South China Sea – condition of the coral communities and its relation to the environments

3.2.1. Coral reefs of the different regions of Vietnam

Last decades the reef ecosystems of Vietnam coastal waters undergoes of the overexploitation and environmental stresses. Surveys of 142 sites from 15 of the 28 reef areas between 1994 and 1997 show that only 1.4% have live coral cover above 75%. 'Poor' reefs with less than 25% coral cover occurred at 37.3% of the sites. Of the remaining sites, 48.6% had coral cover between 25 and 50%, and 31% between 50 and 75%. There is a distinct correlation between healthier reefs and remoteness from human population centres with the best coral cover on offshore islands or remote coastal locations (Chou and Teo 2000).

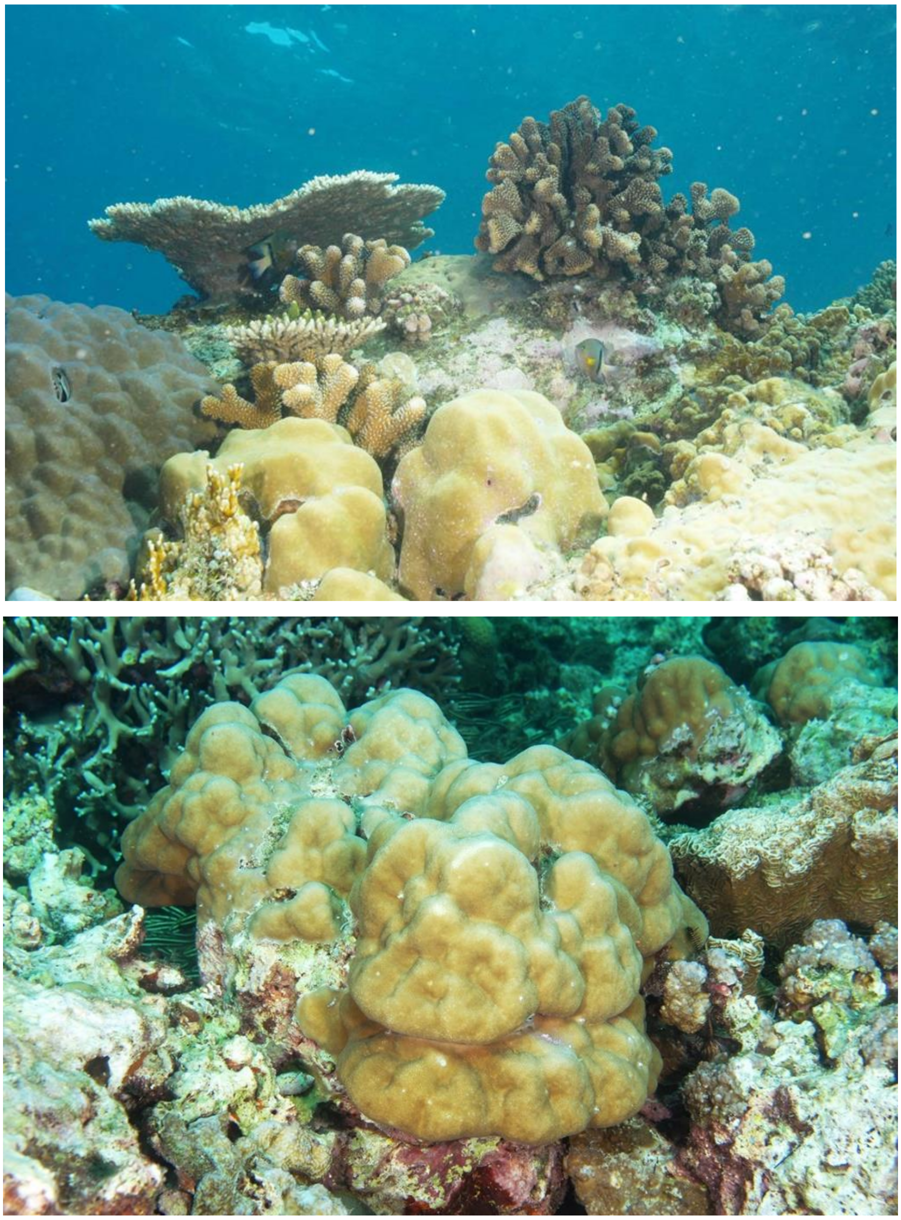


Fig. 13. Typical dominant group of Scleractinian (stony) corals in South China Sea. Above – branched corals *Acropora* and *Pocillopora*. Below – massive colonies of the *Porites* corals. Nha Trang Bay (SCS, Vietnam).

Bleaching also affected the reefs of Con Dao islands, north Binh Thuan province and Nha Trang bay during the summer of 1998. Monitoring in 1999 showed very slow recovery of the Con Dao reefs from the double impacts of typhoon and bleaching. The reefs at north Binh Thuan, Central of Vietnam, however recovered well due to the June–September annual upwelling.

The main physical factors affecting the coral reefs in the inner part of the Tonkin Gulf derive from the intensive terrestrial run-off possessed by Red River – heavy sedimentation flux and high turbidity (Dautova 2010). Mecong River and intense terrestrial run-off influence coral reefs in the Gulf of Siam providing the similar structure of the reef-building corals communities. Coastal waters of southwestern Vietnam in the Gulf of Thailand are also not ideal for coral growth because of muddy bottoms and highly turbid waters. The morphological structure of untypical fringing reefs is highly influenced by coastal hydrodynamics. That hydrodinamics causes the quite heavy-loaded sedimentation regime related to the neighborhood of the Mecong River mouth. Coral reefs have developed in areas adjacent to the offshore islands of Phu Quoc, Nam Du, and Tho Chu. These reefs are normall 50–100m wide and spread to a depth of 10–13m.

The above-mentioned factors cause a similarity in the composition of Scleractinia communities in both gulfs. The stony corals having large polyps and good capability for self-cleaning, such as *Galaxea*, *Echinopora*, *Lobophyllia*, *Echinophyllia*, *Turbinaria*, *Podobacia*, *Lithophyllon*, *Fungia*, and *Goniopora*, – are widespread in both gulfs. The reefs in both gulfs are dominated by many species of these genera (*Galaxea fascicularis*, *Goniopora stokesi*, *Echinopora lamellosa*, and *Lobophyllia hemprichii*), as well as by *Acropora cytherea*, *A. nobilis*, *Montipora hispida*, *Porites lobata*, and *P. cylindrica*, widespread in Indo-Pacific reefs. The very typical massive *Porites* colonies (at least 10 species) forming vast monospecific settlements play dominating role in the coral communities of both gulfs (Fig. 13).

Fig. 14. Well-developed reef with dominating forms – *Acropora* stony corals (branched) and *Montipora* (foliate). Nha Trang Bay, Tre Island (SCS, Vietnam).

At the north-eastern part of the Gulf of Tonkin the share of massive *Porites* in scleractinian population is up to 22% on reefs of Baitylong archipelago (Khomenko 1993). The reefs suffered by sediment flow caused by numerous rivers discharging. The coral population also influenced by high content of organic and mineral resuspended matter in coastal waters. The sediment flow at the reef slopes may run up to 10.0–11.9 mg/cm² per day and sediment consists mainly of fine dispersal clayey material (Moschenko 1990; Latypov 1995; Dautova et al 1999). According to the data obtained from the Cahuita Island (Costa Rica) Cortés and Risk (1985) affirm that sediment flow leading to siltation stress must be no less than 300 g m^{-2} day^{-1}. It is more than twice as much as the value of this flow for Baitylong reefs. However, the coral reefs in the north of the Gulf of Tonkin (South China Sea) exist under extremely hard complex of environmentals. They are located in the monsoon climate zone with significant variations in water salinity, wind intensity and direction. Surface layer of water is considerably cooled down to 16–20ºC (Yet 1989) and desalinated down to 21–22‰ (Thanh 1999) during the winter. Probably, the complex of the factors determines the peculiarity of reefs in the Gulf of Tonkin, where Poritidae and Faviidae are the main reef-builders (Latypov 2003).

Conditions for coral reef development in the central of Vietnam are more favorable regarding the low sedimentation intensity. In particular, in Nha Trang Bay we registered in 2003 and 2004 years the maximal sedimentation flux DF-SPM ≤ 41 g m^{-2} day^{-1} and, later, – 56 g m^{-2} day^{-1} . It is not dangerous for corals. Turbidity surveys indicate that the central area has the highest transparency in both seasons making the region of the Khahn Hoa province (including Nha Trang Bay) very promised for the highest diversity of corals and other reef-related organisms in Vietnam waters (La Van Bai 1991). Due to it, the dominatin position often have *Acropora nobilis* and *Montipora foliata* (Fig. 14).

3.2.2. A case of Nha Trang Bay – coral reefs along with the gradient of river discharge influence

We studied the corals distribution at the 6 coral reefs in Nha Trang Bay along with the data on the environmentals (see the Chapter 3.1.1). The main physical factors affecting the coral reefs in the bay derive from the intensive terrestrial run-off possessed by rivers Cai and Be (Figs. 7, 15).

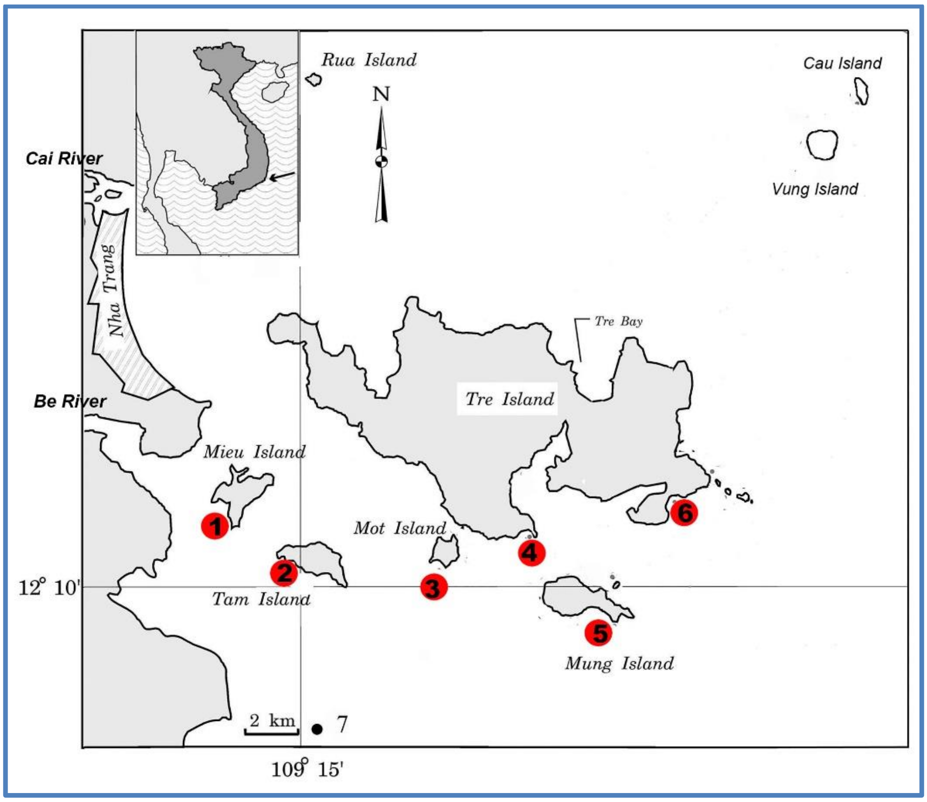


Fig. 15. The map of the stations in Nha Trang Bay (Vietnam) for the research of the status of the coral populations on the reefs.

Under these conditions, the structure of the model reefs differs between reefs along this gradient. Here we place the list of studied reefs with the illustrations (from photo-transects) and technical notes on the reef-building corals condition, dominance level and recruitment:

Station 1, Fig. 15. Mieu Island, Station 1, south-east side of the island.

2015 year. Three photo-transects, each transect 300 m long.

Visibility 1 m. At 10–11 m depth only silted sand and debris. At 7–9 m depth some holothurians *Holothuria athra* (few) and dead stony corals. At 6–7 m depth – small settlements of stony corals Porites cylindrical and few *Porites lobata*. Very few soft corals *Sarcophyton, Sinularia* and *Alcionium* are occurred between settlements of algae *Sargassum* and others. At 2–4 m depth sea urchins *Diadema setosum* between round stones, a layer of the dead *Acropora* fragments is partly overgrown by algae.

Total coral cover (by stony corals) – 2.3%. Recruitment (stony corals) – 1–11 small colonies *Porites cylindrica*/ m^2

2017 year. Three photo-transects, each transect 300 m long.

Changes: bleaching 12%. Total coral cover (by stony corals) – 1.3%. Recruitment (stony corals) – 0–7 small colonies *Porites cylindrica*/ m^2.

Resume. The coral cover is very low. The dominant stony corals are *Porites cylindrica* (branched) and *Porites lobata* (massive). Soft corals located in the shallow zone of the reef along with the algae settlements. The reef studied is under strong siltatioin/eutrophication stress and can be estimated as dead. Now the only stony corals-opportuniusts presented as small settlements.

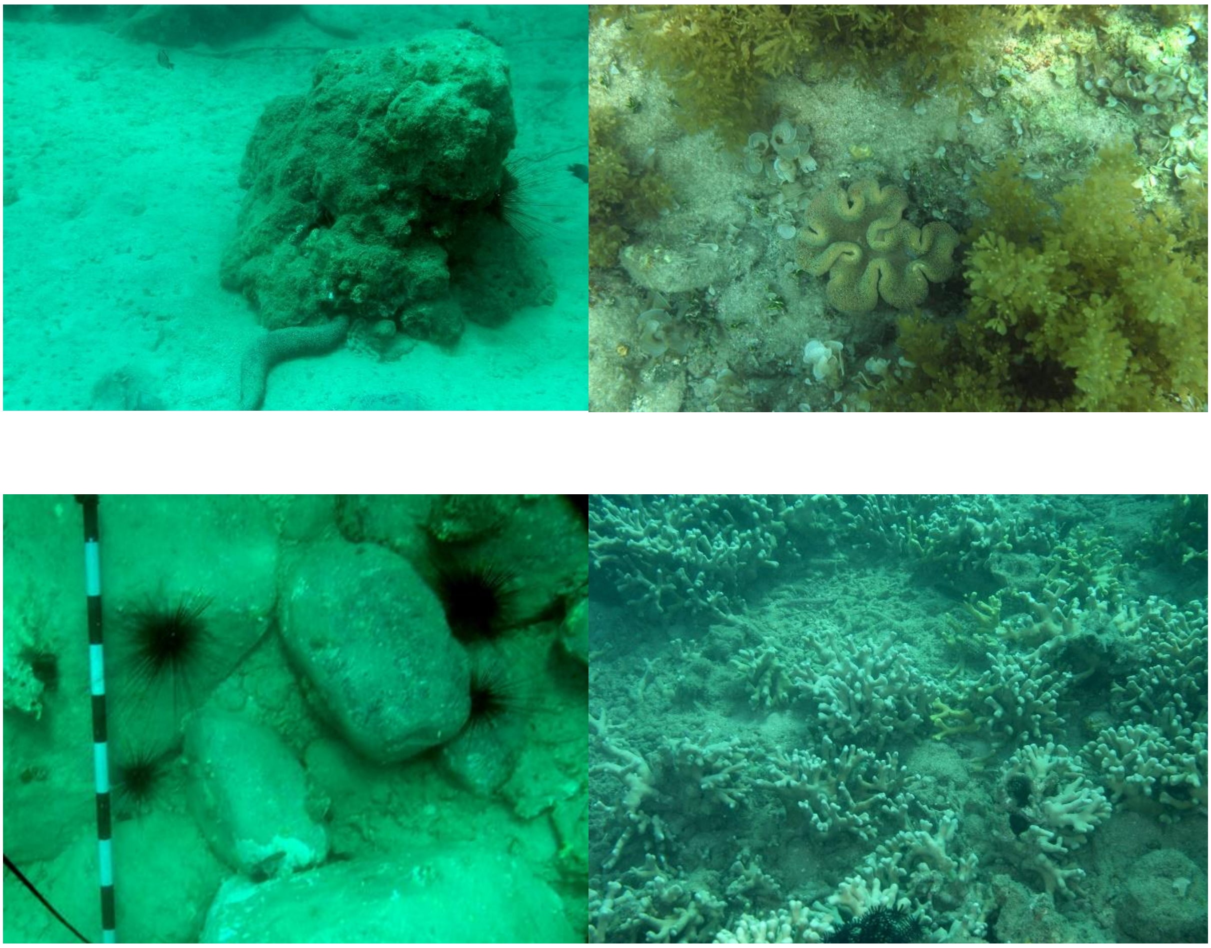


Fig. 16. Typical inhabitants of the reef studied near Mieu Island, 2015–2017.

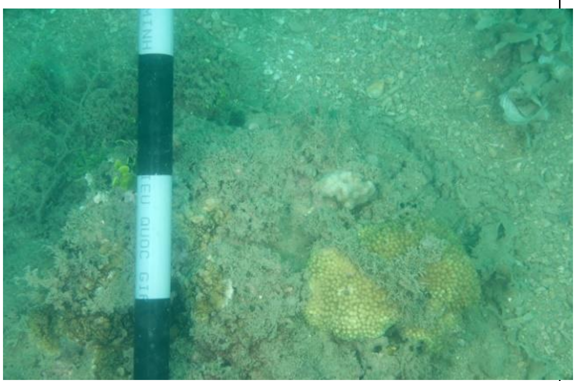
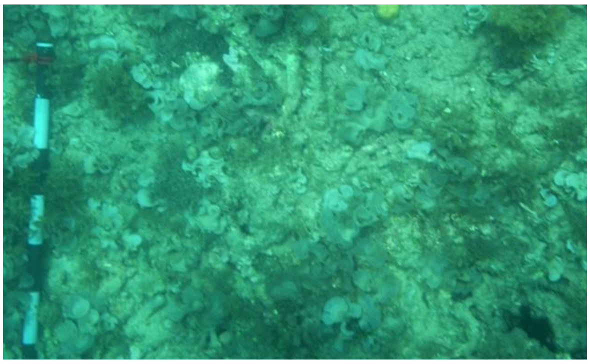
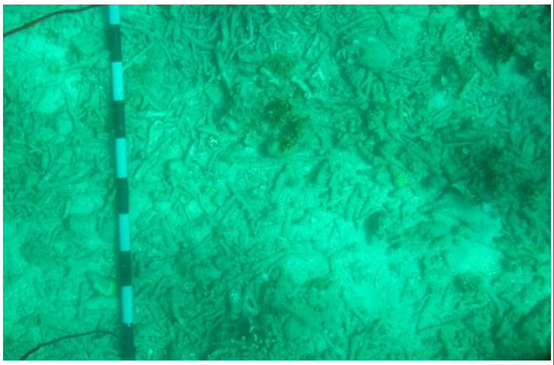
2015 year	2017 year
Depth 7 m	
	
Depth 4 m	
	
Depth 2 m	
	
	

Fig. 17. Typical sites along the transects, Mieu Island

Station 2, Fig. 15. Tam Island, Station 3, south-eastern side of the island.

2015 year. Three photo-transects, each transect 400 m long.

Visibility 1 m. At 9–14 m depth and below only silted sand and rounded stones (0.4–1.2 m across). Only holothurians, dead *Porites* (massive forms) and *Fungia* corals, few soft corals *Sinularia*, few algae. At 7–9 m depth coral cover has 22–38% (mainly *Acropora*). At 5–7 m depth – coral cover 30–42% (mainly *Acropora*+*Millepora*). At 2–4 m depth – 100% coral cover is formed by *Montipora foliata*. Soft corals are distributed at the depth 3–8 m, not abundant. Dead stony corals presented at 2 m depth along with stony coirals Fungiidae population.

Total coral cover (by stony corals) per transect – 19.3%. Recruitment (stony corals) – 1–10 small colonies *Acropora*+ *Millepora*/ m^2

2017 year. Three photo-transects, each transect 300 m long. Changes: bleaching 12%. Total coral cover (by stony corals) – 17.3%. Recruitment (stony corals) – 0–8 small colonies *Acropora*+*Millepora*+Faviidae/ m^2.

Resume. The coral cover is slightly lost after 2015–2016 thermal El Nino event. The dominant stony corals are *Acropora* (branched) and *Porites lobata* (massive). Soft corals distributed in all reef zones including the area of algae settlements. The reef studied is under medium siltatioin/eutrophication stress and can be estimated as having some potential to recovery.

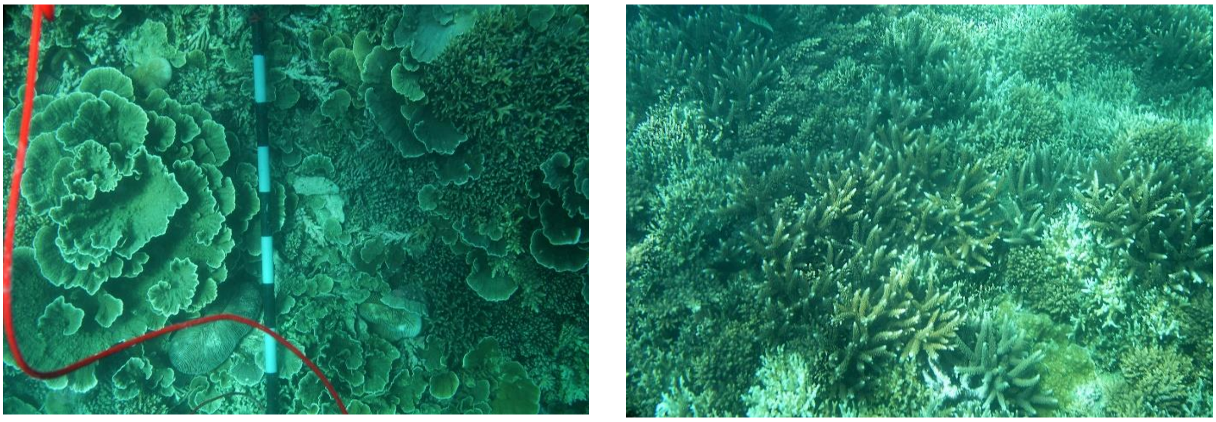
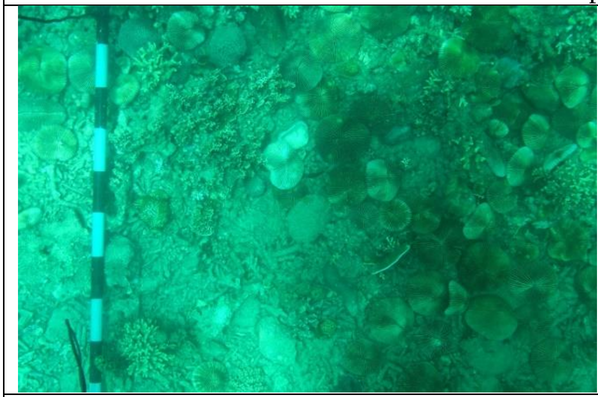
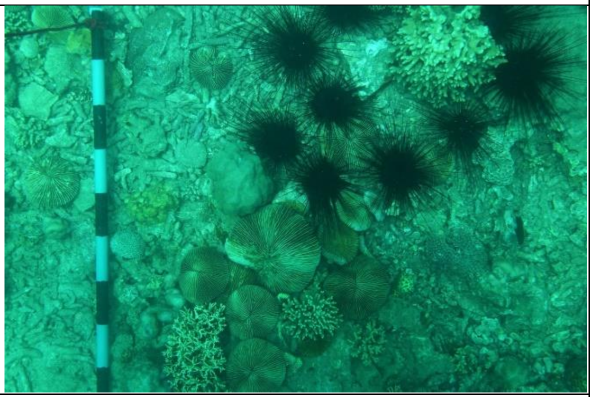
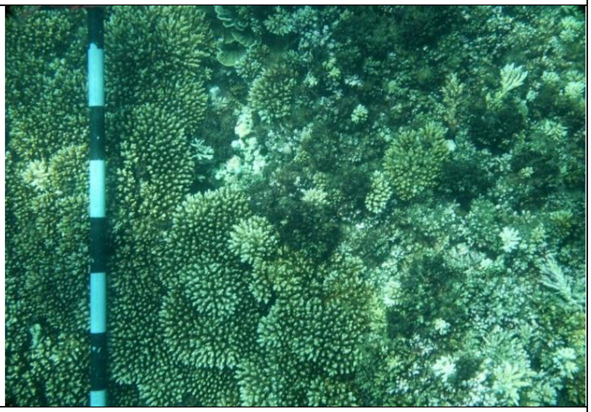
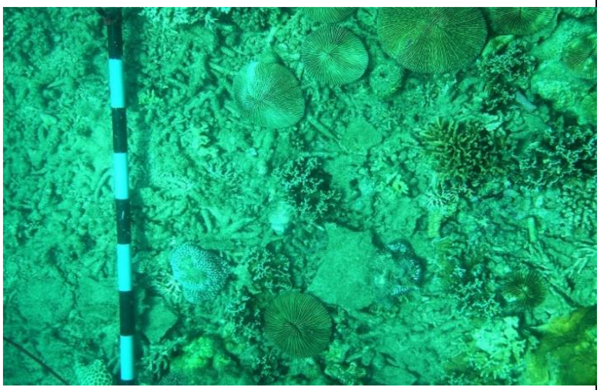


Fig. 18. Typical inhabitants of the Tam Island reef. From the left – stony coral *Montipora foliata*, from the right – branched stony coral *Acropora* sp.

Fig. 19. Typical sites along the transects, Tam Island

May, 2015 year	June, 2017
Depth 12 m	
	
Depth 8 m	
	
Depth 5 m	
	
Depth 2 m	
	

Station 3, Fig. 15. Mot Island, south side of the island.

2015 year. Three photo-transects, each transect 300 m long.

Visibility 3 m. At 12 m depth and below only silted sand and rounded stones (0.7–1.7 m across). At 7–12 m depth coral cover 60–70% (mainly *Porites lobata* and *Millepora dichotoma*). At 2–7 m depth – coral cover 30–42% (mainly *Acropora*). Soft corals are distributed at the depth 3–8 m, not abundant. *Holothuria athra* not found; dead stony corals are few. At 2 m depth – zone of rounded stones, algae *Sargassum* and others are distributed between them.

Total coral cover (by stony corals) – 18.3%. Recruitment (stony corals) – 1–11 small colonies *Porites lobata*+ *Acropora*+ *Millepora*/ m2

2017 year. Three photo–transects, each transect 300 m long.

Changes: bleaching 12%. Total coral cover (by stony corals) – 11.3%. Recruitment (stony corals) – 0–8 small colonies *Porites cylindrica*+ *Pocillopora*+*Acropora*+ *Porites lobata*/ m2.

Resume. The coral cover is slightly lost after 2015–2016 thermal El Nino event. The dominant stony corals are *Acropora* (branched) and *Porites lobata* (massive). Soft corals distributed in all reef zones including the area of algae settlements. The reef studied is under medium siltation/eutrophication stress and can be estimated as having some potential to recovery.

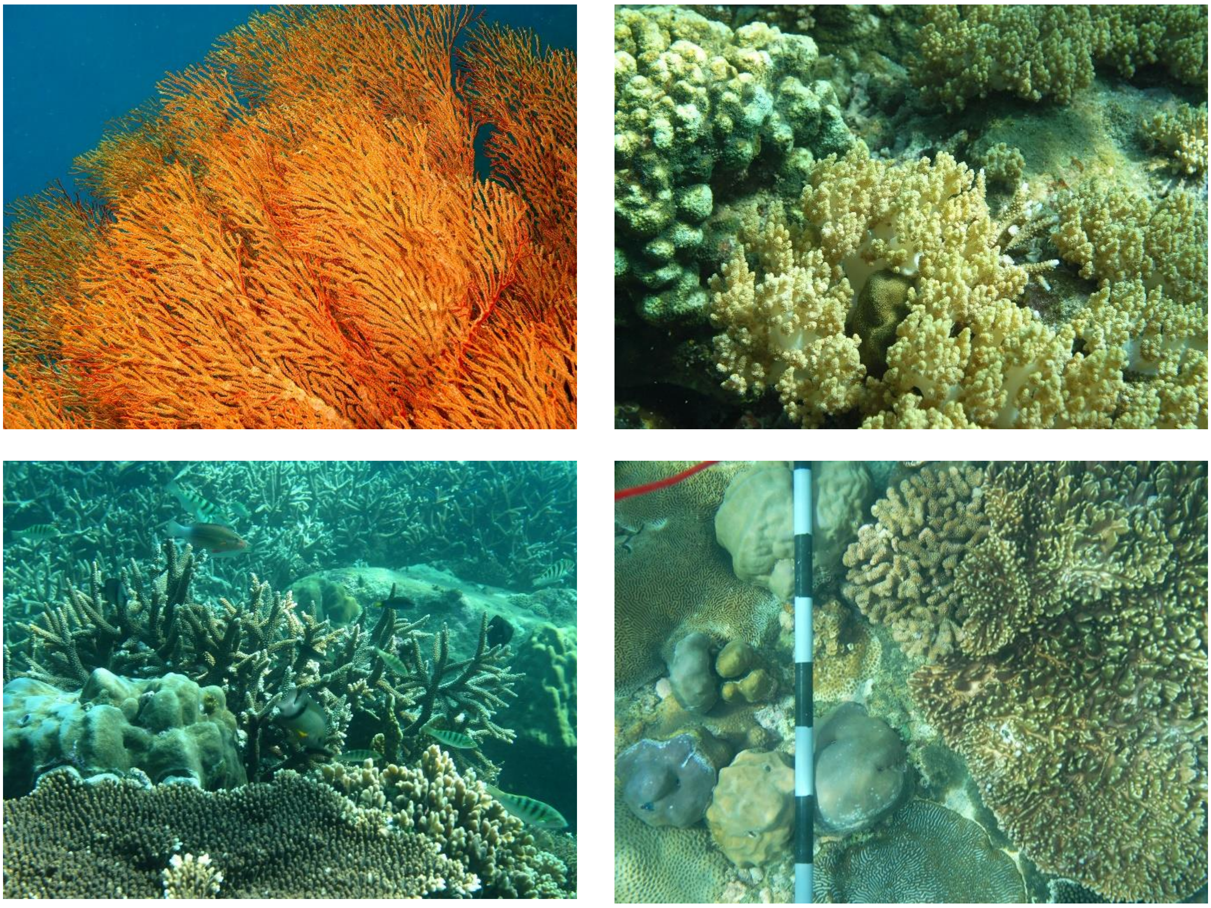
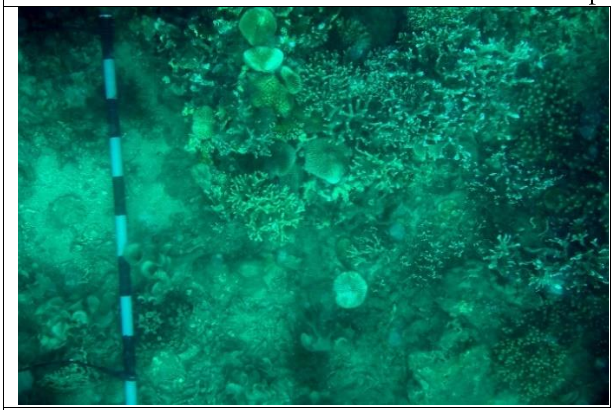
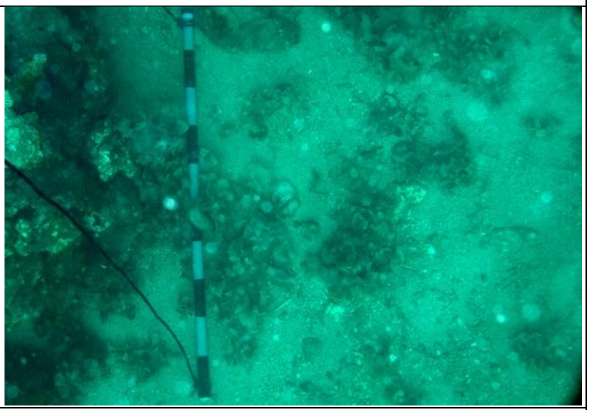
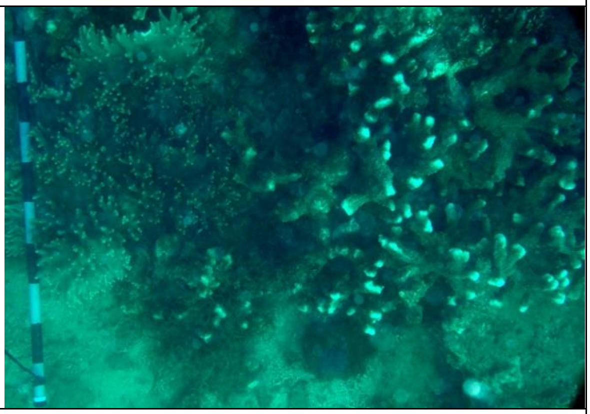
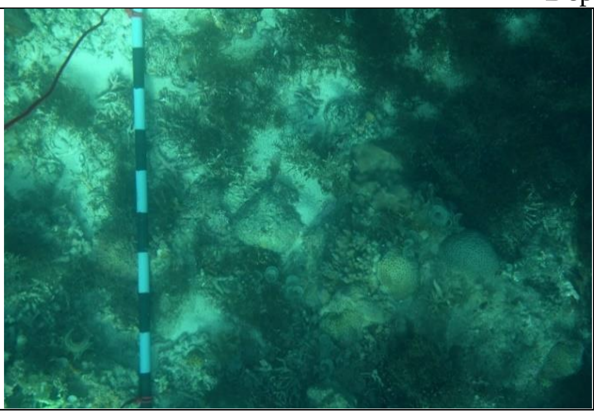
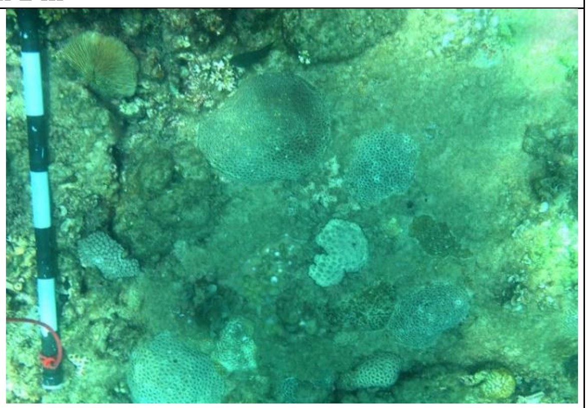


Fig. 20. Typical inhabitants of the reef studied near Mot Island, 2015–2017.

Fig. 21. Typical sites along the transects, Mot Island

May, 2015 year	June, 2017
Depth 12 m	
	
Depth 8 m	
	
Depth 5 m	
	
Depth 2 m	
	

Station 4, Fig. 15. Tre Island, south side of the island.

2015 year. Three photo-transects, each transect 500 m long.

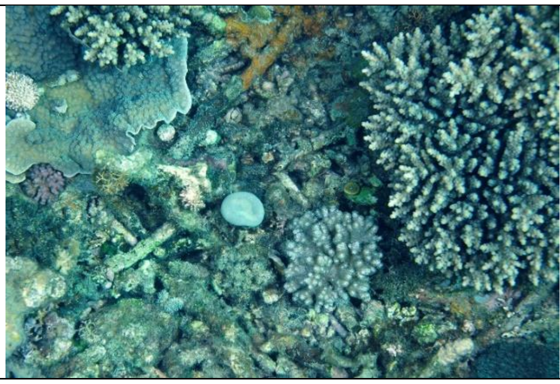
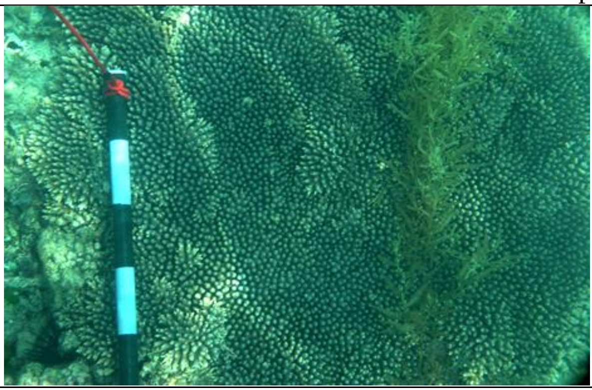
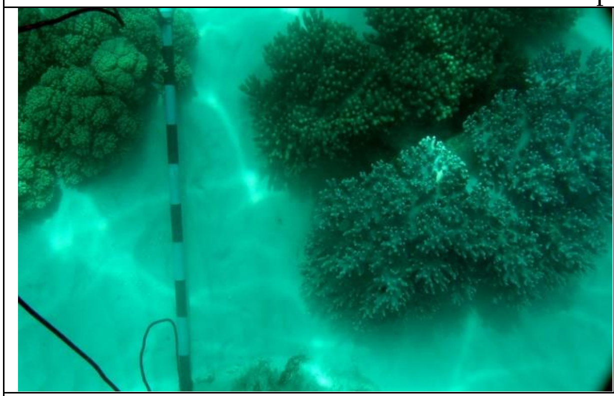
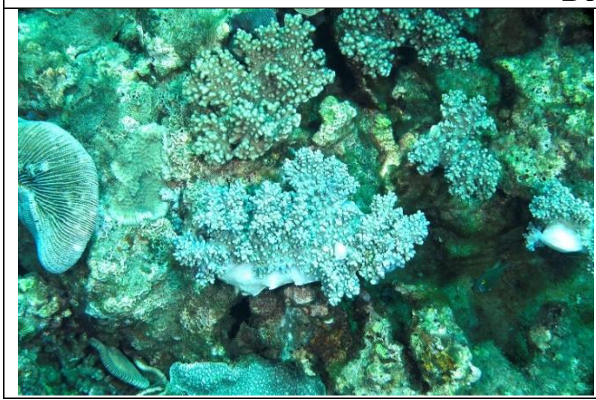
Visibility 3 m. At 11–15 m depth and below only silted sand and rounded stones (0.7–1.7 m across). Only sea urchins *Diadema sertosum*, *Porites* (massive forms) and *Fungia* corals, few soft corals Sinularia, few algae. At 7–11 m depth coral cover becomes 59–68% (mainly *Acropora*). At 5–7 m depth – coral cover 35–44% (mainly *Acropora*+*Millepora*+ *Fungia*). At 3–5 m depth – 60% coral cover is formed by soft corals, mainly Sinularia, branched and lobate forms. Young colonies of stony corals are occurred in the 1–6 m depth, mainly *Acropora*. Total coral cover (by stony corals) per transect – 29.3%. Recruitment (stony corals) – 1–10 small colonies *Acropora* / m^2

2017 year. Three photo-transects, each transect 500 m long.

Changes: bleaching 15%. Total coral cover (by stony corals) – 27.3%. Recruitment (stony corals) – 0–8 small colonies *Acropora*+*Millepora*+Faviidae/ m^2.

Resume. The coral cover is slightly lost after 2015–2016 thermal El Nino event. The dominant stony corals are *Acropora* (branched) and *Porites lobata* (massive). Soft corals distributed in all reef zones including the area of algae settlements. The reef studied is under medium siltation/eutrophication stress and can be estimated as having some potential to recovery.

Fig. 22. Typical corals of the reef community. From the left – soft coral *Sinularia* (red sea lily *Himerometra* settling). From the right – stony coral *Porites lobata*, massive form.

Fig. 23. Typical sites along the transects, Tre Island, station 5	
May, 2015 year	June, 2017
Depth 12 m	
	
Depth 8 m	
	
Depth 5 m	
	
Depth 2 m	
	

Station 6, Fig. 15. Tre Island, eastern shore.

2015 year. Three photo-transects, each transect 700 m long.

Visibility 8 m. At 19–25 m depth and below rounded stones (0.7–2.7 m across) and stony corals *Acropora* and *Porites lobata* (massive form) with coral cover 19%. At the 12–19 m rounded stones (1.7–3.7 m across) and stony corals *Acropora, Pocillopora*, and *Porites lobata* (massive form) with coral cover 69%. Also *Porites cylindrica* (branched forms) and *Fungia* corals, numerous soft corals Sinularia and Lobophytum possess here 70–98% coral cover. Algae are few. At 6–11 m depth coral cover becomes 59–100% (mainly *Acropora* + *Montipora foliata*). At 2–6 m depth – coral cover 35–44% (mainly *Acropora*+*Millepora*+ *Fungia*+*Montipora foliata*). At 3–15 m depth – soft corals are numerous (with coverage of substratrь 8–65%), mainly *Sinularia*, branched and lobate forms. Young colonies of stony corals are occurred in the 1–6 m depth, mainly *Acropora* and branched *Porites*.

Total coral cover (by stony corals) per transect – 49.3%. Recruitment (stony corals) – 1–10 small colonies *Acropora*, *Montipora foliata* and Faviidae/ m^2

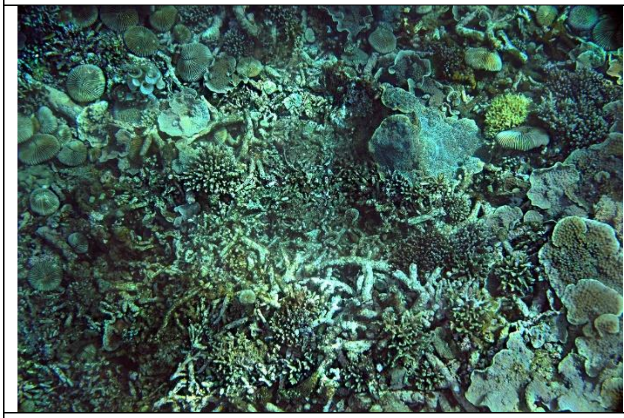
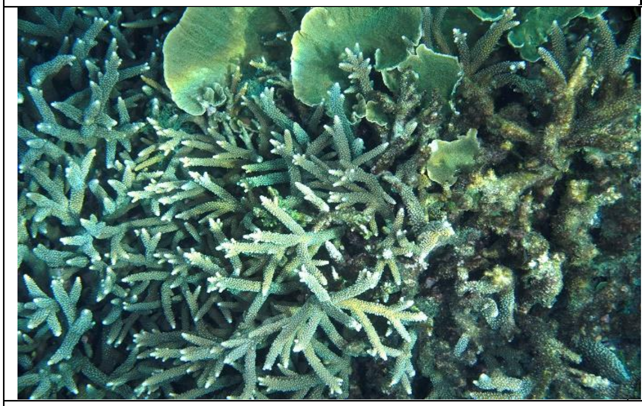
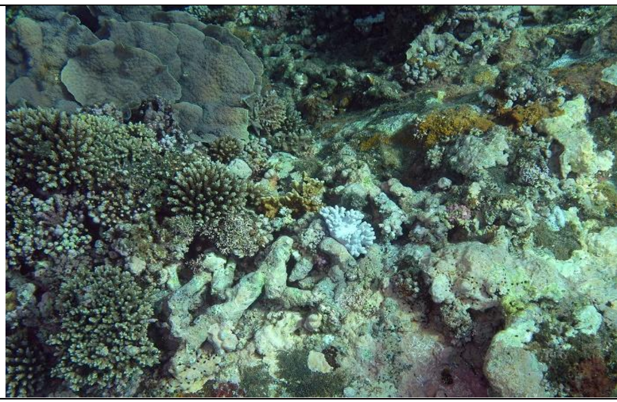
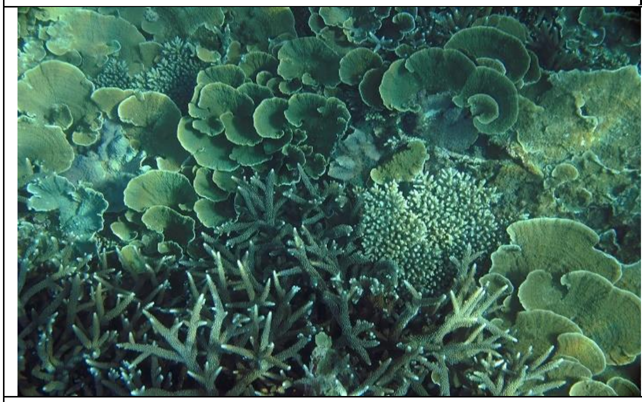
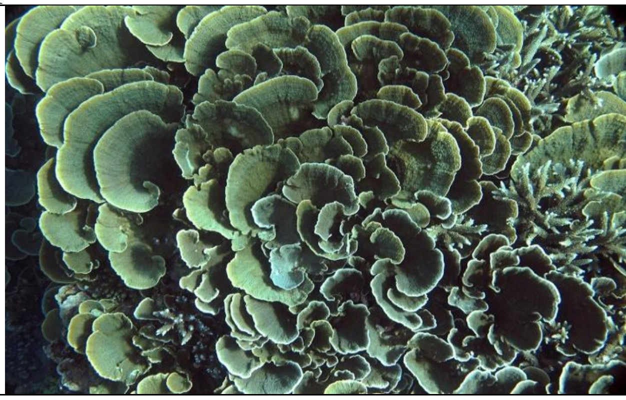
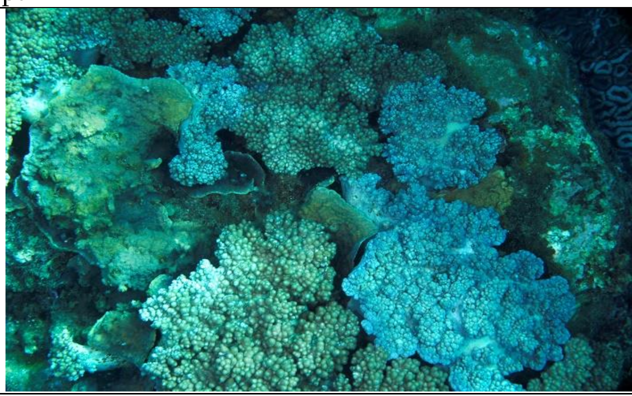
2017 year. Three photo-transects, each transect 700 m long. Changes: bleaching 18%. Total coral cover (by stony corals) – 44.3%. Recruitment (stony corals) – 0–8 small colonies *Acropora*+*Millepora*+Faviidae/ m^2.

Resume. The coral cover is essentually lost after 2015–2016 thermal El Nino event. The dominant stony corals are *Acropora* (branched) and *Montipora foliata*. Soft corals distributed in all reef zones including the area of algae settlements. The reef studied is under medium-to-slight siltation/eutrophication load and can be estimated as having good potential to recovery.

Fig. 26. Young colonies (recruits) of Porites cylindrica.

Fig. 27. Typical corals of the reef community. From the left – soft coral *Sinularia* (lobate form). From the right – stony coral *Acropora*, table form.

Fig. 28. Typical sites along the transects, Tre Island, station 6.

May, 2015 year	June, 2017
Depth 12 m	
	
Depth 8 m	
	
Depth 5 m	
	
Depth 2 m	
	

Composition of the natural stable isotopes in living corals was analyzed in the frame of the project as indicator of the terrigenous (anthropogenic) influence on the coral reefs in Nha Trang Bay. We studied the composition of the stable natural isotopes of nitrogen N and carbon C in mass reef-building corals *Porites* in Nha Trang bay as indicator of the terrigenous (anthropogenic) influence. The anthropogenic influence of the coastal marine ecosystems is often related to the increasing of the man-made nitrogen flux causing eutrophication of the water. The analysis of the balance of the different stable N isotopes in the living tissue of stony corals (if these corals contain symbiotic micro-algae zooxanthellae) can show this man-made influx of nitrogen enriched by the natural isotope ^{15}N (Heikoop et al. 2000a). The isotopic composition was measured in the living tissues of the Porites lobata corals collected in the wet season of 2003 year. The samples were prepared (selected and dried) from the corals of the fringing reefs in the bay which reefs are located along with the gradient of the run-off influence (Fig. 7, 15, Table 8).

Table 8. Isotopic composition in the living tissues of the *Porites lobata* stony corals collected in the wet season of 2003 year, Nha Trang Bay (November). CCOV% – the cover of the reef surface by stony corals.

Island, station	Distance from the Cai mouth, km	CCOV, %	Mean $\delta\ ^{15}N$, % (SD)	Mean $\delta\ ^{13}C$, % (SD)
Mieu, 1	14	27	6.05 (0.40)	-13.68 (0.15)
Mot, 3	19	50	4.98 (0.13)	-12.01 (0.45)
Tre, south, 4	21	30	5.08 (0.08)	-14.31 (1.64)
Mun, 5	26	56	5.46 (0.41)	-13.81 (1.04)

Corals from the Nha Trang Bay presented more high estimations of the δ 15N in comparison with those from the oligotrophic regions of the tropical sea (Heikoop et al. 2000b). It indicates the eutrophication of Nha Trang Bay in general. The $\delta^{13}C$ values are typical for the shallow-living corals and suggest the prevalence of autotrophic nutrition in the studied corals. Corals from the Mieu Island, the closest station to the river mouths, show the essentially higher values of the $\delta^{15}N$ ($p=0.008$, ANOVA statistical processing) in comparison with those located more distantly from the rivers and city. At this period, the reef around Mieu Island undergoes the hardest degradation causing the elimination of the staghorn stony corals Acropora and their replacement by massive corals Porites (resistant to eutrophication). The enrichment of the Porites corals by the ^{15}N isotope indicates the increasing anthropogenic run-off as main reason for the degradation of the coral reefs in Nha Trang Bay.

Conclusion. The impact pattern of sedimentation and eutrophication for the degradation of coral reefs in Nha Trang Bay, Vietnam, is performing as the impacts of sedimentation and pollutants. These factors strongly affect to coral reef ecosystem, and lead to the loss of the coral cover and stability of coral reefs that were located at short distance from the sources of terrestrial run-off (Fig. 7, 15). The coral cover and coral diversity in the bay are increasing along with the decreasing of the rivers Cai and Be influence. Reefs in inner part of the bay (stations 1 and 2, Fig. 15) characterised by a low number of species of mostly massive *Porites* corals and branched *Porites cylindrica*. Reefs rounded Mieu Island survived the destruction of the *Acropora* dense settlements in 1970th years. The most diverse coral settlements are registered in faremost part of the bay (Tre Island, station 6, Fig. 15). 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*, Figs. 13, 14).

The enrichment of the stony corals by the ^{15}N isotope indicates the increasing anthropogenic terrestrial run-off as main reason for the degradation of the coral reefs in Nha Trang Bay. Thermal stress in the period 2015–2017 also affected these reefs and caused bleaching of the reef-building corals. Bleaching with the subsequent elimination of the stony reef-building corals – typical response of the coral reef on the thermal stress caused by climate change or periodical El Nino Southern

Oscillations. The waste production of fish farms is depended upon the aquaculture facilities differs from the provinces, there is an additional waste component in uneaten feed that may affect the environment, and the nutrients release rate can be estimate to apply for situation in the areas. The nutrient loading from cage fish farm is point source to influence the surrounding waters and it is depend on the hydrodynamic systems and depth of the sites by current will contribute to water exchange in the cage farm. And it's strongly the impacts that is known about the distance where impact from the farms can be detected on nearby coral reef.

However, the sedimentation in the bay is not very strong! The sedimentation intensity and SPM in water in Nha Trang Bay are far from those providing siltation stresses for corals. We suggest that eutrophication and pollution play main role in the coral reefs degradation in the bay along with the mechanical destruction (dinamyte fishery, coastal building, etc). The results of studies provide essential data and information which is need to assess the long-term impacts of anthropogenic inputs on the degradation of marine ecosystems in the coastal waters of Nha Trang Bay.

3.3. Philippines – aquatic environments and coral reefs

3.3.1. Data on the aquatic environments around the Philippine's coral reefs

Environmental data available for the Philippine's coral reefs are few. Very little research has been done in other regions of the east part of South China Sea on terrestrial influx discharged by rivers into the sea that will deposit and have a long–term impact on the ecosystem (Hong et al. 2008, Harrington et al. 2005). However, these few existing data relating to the measurements of sedimentation rates and the impacts of sediments from rivers were accompanied by the data on the biodiversity and coral coverage on the reefs (Ken et al. 2004, Thom and Tuan 1997, Tuan et al. 2005, Nguyen and Phan 2008).

First documented surveys of the sedimentation and its influence on the coral reefs in Philippines were undertaken in Philippines in the 1980th years. In the Central Philippines, a study conducted by Aliño (1984) in three areas (Matabang, Bato and Looc) near Toledo, Cebu, using sedimentation traps of 5 cm diameter and 20 cm high, revealed an average sedimentation of 16.2, 10.1 and 33.5 mg/cm^2/day, respectively.

The survey concerning Project of Palawan Integrated Area Development in Bacuit Bay, near the Manlag River, Northern Palawan, Central-Western Philippines showed the similar parameters. The maximal river discharge of SPM was estimated as 13000 metric tons in December 1986 (Hodgson 1989). The natural sediment output from the undisturbed forested coast was 26 g m^{-2} , not dangerous for corals and very close to those in Nha Trang bay. The SPM discharged from the Manlag River also varies at the quite low level in dry periods – from 200 to 580 mg l^{-1}, but was higher during rains (1157 mg l^{-1} in May and 1500 mg l^{-1} in December). Annual sediment discharge from Manlag River 2000 mt km^{-2} is higher when comparing with the some other strong rivers of the World, such as Amason (70 mt km^{-2}). But the SPM was only 110 mg l^{-1} near the Manlag mouth and decreased to 80 mg l–1 around the coral reef at the distance 3 km from the river' mouth during low discharge. However, during the south-west monsoon and high discharge, the SPM was 159 mg l^{-1} and 124 mg l^{-1} at 4 km from the river mouth. The DF-SPM value which value could be considered to be dangerous for corals was registered at only one station (closest to river mouth) in 1986 and valued as 316 g m^{-2} day $^{-1}$ (Hodgson 1989).

The very large-scale research made under the Integrated Protected Areas System (IPAS) Project in the end of 1990s should be suggested as very remarkable as it was carried out at wide range of geographical localities (Uychiaoco et al. 1992). A total of 49 line transects in 8 areas of the Philippines (Fig. 29) were surveyed, the placement of the transects were biased to areas of high coral cover after initially surveying the area by manta-tow (Done et al. 1981). The sites were representative of various conditions of depth, water movement, and sedimentation. Subjective estimates of the latter two ranged from 1 to 5, with 5 denoting greatest water motion or highest sedimentation respectively (Table 9).

Three different types of data matrices were utilized: (1) the lifeform-taxon percentages, (2) the purely lifeform percentages, and (3) the environmental attributes of each site. The environmental attributes considered were: (a) depth in meters, (b) water motion, (c) sedimentation, (d) horizontal visibility in meters, and (e) the North-South and (f) East-West locations of each site relative to the centre of the Philippines (13ºN, 122º E) scaled from –2 to +2 (Table 9).

Fig. 29. Research of the aquatic environments under the Integrated Protected Areas System (IPAS) Project in the end of 1990s in Philippines. Red colour – survey stations, see also Table 5.

After the processing of the matrices using detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) (CANOCO, Ter Braak 1986, 1988), it was found that:

1. there is the strong correlation of the sedimentation and horizontal visibility variables with the water motion variable,

2. due to the above the sedimentation variables could be excluded from the analysis (Uychiaoco et al. 1992).

Thus, the constraining environmental variables used in the latter analysis were depth, water motion and geographic location.

Table 9. Number, lengths and environmental ranges of transects on the eight sample areas (Uychiaoco et al. 1992).

Station/ Geographic Area	Transect			Min-Max Values			
	# sites	min-max length	total length	Depth (m)	Water Motn	Sediment	Horz Visi
1/Batanes Is.	3	22–30 m	89 m	9–12	4–5	1	20–25
2/Cagayan Is.	10	30 m	300 m	6–18	3–4	1–3	10–30
3/Polillo, Quezon	5	30–50 m	190 m	7–10	1–3	2–4	9–30
4/Puerto Galera	6	150 m	900 m	6–13	1–4	1–5	8–25
5/Cebu	6	30–100 m	400 m	7–10	2–4	1–3	10–25
6/Surigao	5	30–100 m	365 m	6–15	2–4	1–4	15–30
7/Turtle Is.	8	30 m	240 m	7–15	2–3	3–5	10–15
8/Sitangkai Is.	6	30 m	180 m	10–15	3	2	15–30

The strong correlation between the coral set (stony and soft coral genera diversity) and environmental data sets (sedimentation-water movement-visibility (transparency?)) was found; the canonical coefficients and the interset correlations suggested the relative roles of the examined environmental variables. The comparison of the correlations confirmed the role of water motion as a major structuring force beyond the confines of bays onto the larger archipelagic scale. This was ascertained despite our not utilizing an onsite gradient and was further supported by the additional information of coral genus identification.

It should be concluded that the use of geographic, environmental, and broad-scale biological characterization as proxies for generic composition of the biotic community to predict community composition has not yet been fully validated. However, there are considerable incentives to be able to use such characterizations to aid in the selection of representative sites for protection (Uychiaoco et al. 1992). However no any exact real data on sedimentation load or SPM in water column were shown in that survey results. The additional effort of genus level identification and more data on the biodiversity are suggested as necessary to provide more potential information into the community dynamics of the area.

The Philippines lies in the Indo-West Pacific Region, reputedly the world's highest biodiversity marine area, and is part of what is known as the "coral triangle," the center of the most diverse habitat in the marine tropics. Reports say the country's coral reefs host about 400 species of corals, 971 species of benthic algae, and a third of the 2,300 fish species known to inhabit Philippine waters. There are 27,000 sq km of coral reef areas in the Philippines, with 60% of them occurring in Palawan.

But Philippine coral reefs are under severe pressure from various human activities, not only from dynamite, cyanide, and other illegal fishing, but also from legitimate activities such as tourism. The degradation is both fast and widespread. A study conducted by the University of the Philippines Marine Science Institute (UP-MSI) between 1976 and 1981 describes the condition of 32% of coral reefs in the Philippines as "poor," 39% as "fair," 24% as "good," and less then 6% "excellent."

Further, for central-western Philippines, the data on the physical and chemical parameters were obtained during the dry season and rainy months in 2003 year at two reef sites near the Bush and Meara islands located in Honda Bay (Becira 2009, Table 10).

Honda Bay is one of the important fishing areas and tourist destinations in Palawan (central-western Philippines). Destructive fishing methods, overexploitation and devastating land-based activities that cause and siltation resulted in the period 1985–1996 (Gomez et al. 1994; Sandalo 1994; ICLARM, 1996). Live cover in coral reefs is currently estimated to be 36.5% (Gonzales, in press). Some authors suggested that one of the causes of coral cover reduction in Palawan is siltation and erosion (Cruz and White 1988 as cited by FRMP, 2001). Six major rivers and numerous small tributaries drain into the bay (Fig. 11).

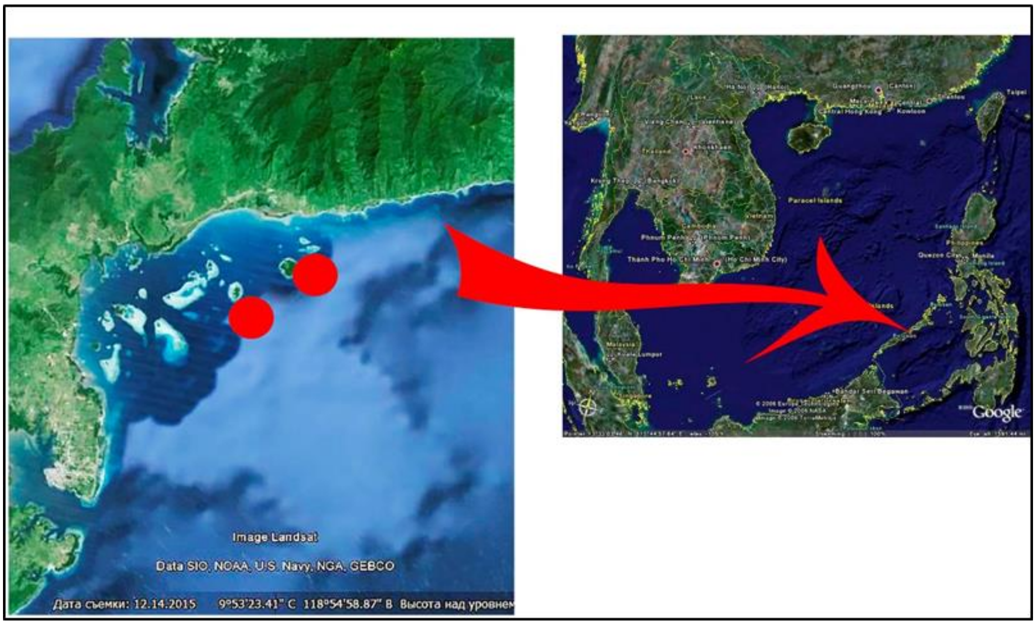


Figure 30. Research stations are shown by red color in Palawan (lower right), the study area and the location of the sampling sites (+) in Honda Bay, Puerto Princesa City provided in Becira 2009.

During rainy season, these rivers carry high amounts of sediments into the bay, so two reef sites selected near the islands of Bush and Meara are affecting of it. The two stations were assessed in terms of sedimentation rate (using sedimentation traps), water temperature, salinity, depth, pH and total dissolved solids. The monthly sedimentation rate in Bush Island ranged from 2.00 to 21.00 mg $cm^{-2}day^{-1}$ while in Meara Island it ranged from 2.00 to 16.00 mg $cm^{-2}day^{-1}$ (Fig. 30). The average sedimentation rates in Honda Bay during dry and wet season were 3.50 and 10.00 mg $cm^{-2}day^{-1}$, respectively. The overall mean sedimentation rate was 7.10 and 6.50 mg $cm^{-2}day^{-1}$ for Bush and Meara Islands, respectively. Between the sites, sedimentation was higher (7.00 mg $cm^{-2}day^{-1}$) in Bush Island than in Meara Island (6.00 mg $cm^{-2}day^{-1}$) (Tab. 10).

Table 10. Environmental parameters and coral cover at sites surveyed by Becira (2009) in Honda bay, 2003 year. Dry season – April–August 2003. Wet season – September–November 2003.

Parameter	Bush		Meara	
	Sampling season		Sampling season	
	Dry	Wet	Dry	Wet
Mean sedimentation flux DF-SPM ($g\ m^{-2}day^{-1}$)	30	110	4.00	9.00
Temperature (C º)	30.57	29.80	29.83	29.03
Salinity (ppt)	32.43	32.80	32.83	32.60
Total dissolved solid (mg/l)	24.75	25.00	25.05	24.90
Soft coral cover, SCCOV	3.80% of benthic cover		3.80% of benthic cover	
Hard coral cover HCCOV	45.83% of benthic cover		43.20% of benthic cover	

Differences in sedimentation rate between sampling events (6 events) and sampling seasons (wet & dry) in Bush Island were not significant. On the other hand, significant differences were detected in Meara Island between sampling events and between sampling seasons. Between the stations in Bush and Meara Islands, no significant differences were established in both sampling events and sampling seasons. The sedimentation rates in the two islands did not show significant difference at 5% level of significance. Total dissolved solids were high in the two island stations (Bush Island, 24.88 ± 0.31 mg/l; Meara Island, 24.98 ± 0.29 mg/l). Salinity readings were relatively stable in the two islands, i.e., Meara Island (32.71 ± 0.41 ppt) and Bush Island (32.61 ±0.41 ppt). Total dissolved solid values during dry and wet season at both islands were almost the same, which shows that freshwater does not influence the water quality of both islands as evidenced by its high and relatively stable salinity (Becira 2009).

3.3.2. Sedimentation/eutrophication influence on Philippine's coral reef ecosystems – a case of Bolinao reef system (Luzon Island)

Sedimentation and nutrient enrichment are supposed to have the strong influence on Philippine's coral reef ecosystems. Heavy sedimentation, nutrient extra-enrichment, heavy metals and plastic pollution has been found to negatively affect marine biodiversity globally. In the Philippines, there have been few studies on effects of nutrient enrichment, sedimentation and heavy metals on different marine species but fewer investigations were found in relation to its effects on marine biodiversity. It was experimentally shown that total mortality of coral nubbins were observed in sites in Bolinao where DF-SPM (193 g m^{-2} d^{-1}) and SPM in water column (~7.2 mg L^{-1}) was high (Villanueva et al. 2005). Possible causes of mortality of these corals, as stated by the authors, can be: (1) increase in nutrients have increased the growth of competitors of coral juveniles; (2) increase in nutrients lowers the dissolved oxygen levels; (3) increased sedimentation increases the turbidity and thus, lessens the amount of light that can be utilized by the zooxanthellae associated with the coral juveniles, leading to lesser nutrition for the coral juveniles and (4) increased sedimentation smothers and buries the coral juveniles which is known to be the major cause of higher mortality and lower abundance of juvenile corals in eutrophic reefs. Increase in sedimentation have also been observed by Wesseling et al. (2001) to increase partial necrosis in *Porites* corals in Philippines and decrease in coral cover. This result was in conjunction to the study conducted by Haapkylä et al. (2011) at Great Barrier reef where they have also suggested, that aside from increased in virulence of pathogens, coral immunity could have been lowered by the increase in stress the coral experienced, possibly from sedimentation.

Intensive fish farming is implicated in the increase of nutrient and sedimentation in the marine environment. Sediment analysis conducted by David et al. (2009) showed that as the volume of fish cages and aquaculture facilities increased, there was also an increase of phosphorous load. In one of the three sites sampled in Bolinao, Pangasinan, where fish cages for milkfish culture are numbered to be more than 1,100 , average phosphorous loading have risen to 204.2 kg/km^2 /yr from a high of 75.7 kg/km^2 /yr observed prior to aquaculture development. This study was corroborated by Villanueva et al. (2005; 2006) in which data showed a very high ammonium (>7 μM) and phosphate (>0.8 μM) loading in sites of aquaculture. With the increasing aquaculture facilities, Philippines will experience an increase in nutrient enrichment and sedimentation in the marine environment.

Another source of sediments with high organic matter content and nutrients in the marine environment are rivers (Woolger 2009; Argente et al. 2013). In a study by Chang et al. (2009) in Manila Bay showed the source of these excessive nutrients are rivers that drain in the Bay. Their data showed that there was higher concentration of nitrates and nitrites (3.04 μM) in an area of Manila Bay located at close proximity to the mouths of rivers than areas away from rivers (0.90 μM and 0.10 μM). This result is in conjunction to a study conducted by Daoji and Daler (2004) in East China Sea where pollutants such as inorganic nitrogen, phosphate, oil hydrocarbons, organic matters and heavy metals were found to be coming from the Yangtze River. Studies on the effects of sedimentation and nutrient enrichment in the Philippines have shown negative impacts to corals, seagrasses and other marine organisms as it was reviewed by Abreo et al. (2015). For example, the June 2010 fish kills in Bolinao and Anda, Pangasinan the fish mass kill coincided with high total inorganic nitrogen (TIN). During the fish kills, TIN was recorded at 12.2 μM, which is almost 3-folds to the ASEAN water quality criterion of 4.40 μM (Escobar et al. 2013). Furthermore, phosphate concentration (2.37 μM) during the fish kill was also observed to be higher than the ASEAN criterion (1.45 μM). Fish kills are often a result of very low dissolved oxygen levels and is connected with high nutrient levels.

Moreover, a study conducted by Sotto et al. (2014) in Manila Bay, have found that areas with higher nutrient concentration have lower near-bottom dissolved oxygen level. They have recorded a dissolved oxygen (DO) level of 0.028 mg/L during the time which total inorganic nutrients have reached 27.8 μM, the highest during the sampling. Nutrient enrichment and sedimentation is shown to reduce habitat heterogeneity by either promoting dominance of a single species or by total eradication of these habitat-forming species as it was shown at Bolinao. As demonstrated by Villanueva (2005, 2006), corals in Bolinao showed very low survivorship in sites where sedimentation and nutrient enrichment was high and the aquaculture reduced water transparency from 80% (in sites farthest from aquaculture sites) to six percent. In Bolinao, Pangasinan, the Philippines, Fortes et al. (2012) have observed that there was a decline in seagrass species in study sites closer to aquaculture structures. The study site closest to aquaculture sites only had two species compared to seven seagrass species found in sites farthest from aquaculture structures. This decrease in species richness shows domination of two seagrass species in areas where eutrophication and sedimentation was highest. Although the study by Fortes et al. (2012) failed to quantify the sedimentation rates or difference in nutrient concentrations in the different study sites.

There is very little information on the levels and distribution of the heavy metals in the Philippines coastal areas (Velasquez et al. 2002). A study in Manila Bay showed that land-based marine pollution has led to an increase in heavy metal concentrations. Results showed that total cadmium concentration was highest at a mean of 56.924 mg L^{-1} , followed by lead (0.743 mg L^{-1}) and chromium (0.368 mg L^{-1}) (Su et al. 2009). In a separate study conducted by Velasquez et al. (2002), higher concentrations of heavy metals were observed in near shore sites and sites that were facing Pampanga river. Heavy metals were also detected in the water column near a jetty port and several beach resorts in Iloilo, Philippines (Sarinas et al. 2013; Sarinas and Alfonsa 2014). Both these studies registered a high concentration of heavy metals that exceeded the allowable value by Philippine Government. The result of the study showed that sea water near a jetty port had average cadmium concentration was 0.69 mg L^{-1}, average chromium concentration was 0.81 mg/L and average lead concentration was 0.34 mg L^{-1}. In a different site in Iloilo, Philippines, average chromium, lead and cadmium concentrations in sea water was 0.55 mg L^{-1}, 0.77 mg/L and 0.02 mg L^{-1}, respectively. Moreover, heavy metal contamination was present in marine sediments in Marinduque, Philippines from a mine tailings spill incident that occurred in 1996 (David 2002). Although several studies have discussed presence of heavy metals in marine environments and organisms in the Philippines (e.g. Su et al. 2009; Solidum et al. 2013), its effects on marine biodiversity is not placed into consideration as it was reviewed by Abreo et al. (2015).

Pollution by pesticides at Philippine aquatic areas ore of the same origin as in Vietnam. The pesticides (common for rice cultivation) were detected in waters around the island of Leyte in the Philippines. Targeted sampling of water was performed in streams, the river mouth, and the municipal drinking-water tap near San Francisco, South Leyte, Philippines. Found levels of at least 0.001 μg/L (λ-cyhalothrin, cypermethrin and deltamethrin) which is exceeded recommended limit values for pesticides in surface water (Elfman et al. 2011). Detectable levels of pesticides λ-cyhalothrin, cypermethrin and deltamethrin (0.0005–1.4 μg/L) were found in representative water samples. In 47% of samples, the detected levels exceeded the recommended limit values for pesticides in surface water according to Swedish agency guidelines (2008). The analysis of samples taken at the river mouth revealed measurable levels of λ-cyhalothrin and cypermethrin, which means that residues of pesticides applied to rice paddy fields, were shown to end up at the river mouth. It may have adverse effects on inhabitants as well as on the aquatic environment, including sensitive coral reefs. This situation is applicable not only to the Philippines, but also to the whole of Southeast Asia, with approximately 70% of their human population living in coastal areas and the need to reduce the impacts of marine pollution in this region is of great importance.

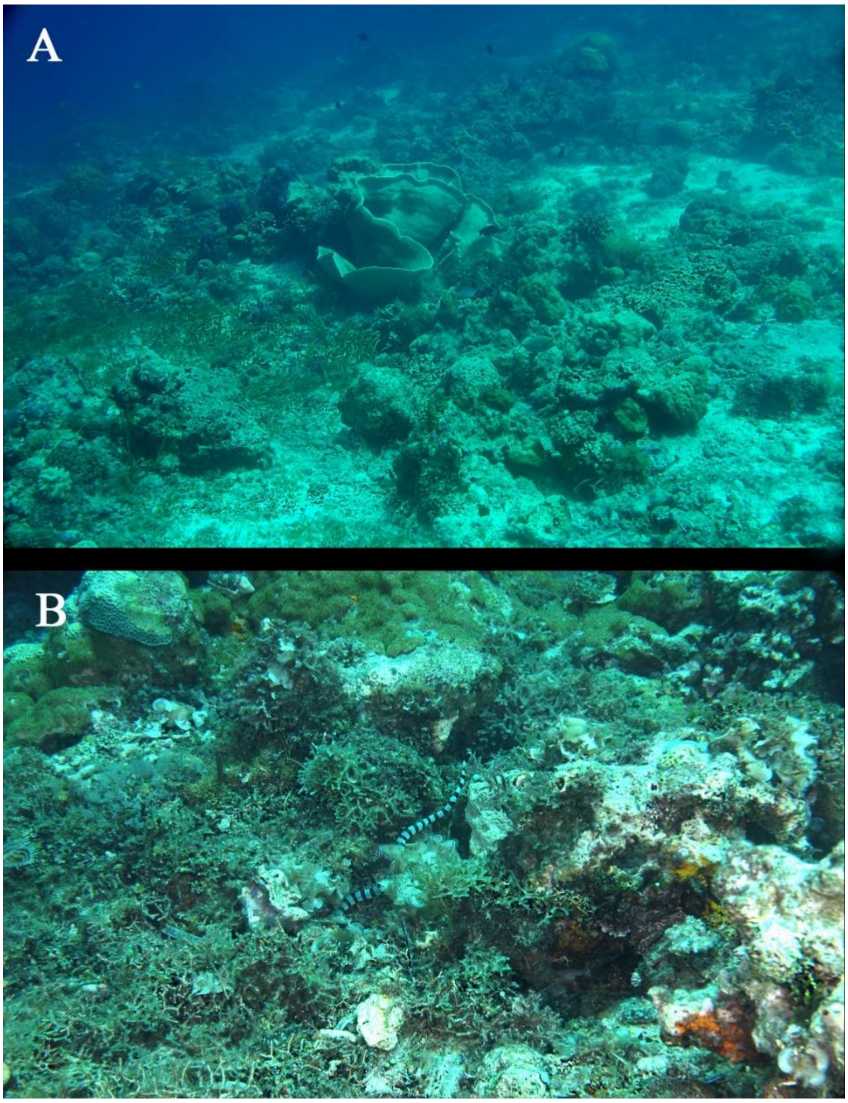


Fig. 31. Destroyed reef-flat along with the south shore of Mactan Island (Philippines), 2015 year, own photo-images. A – behind the Biological station, zone of the reef-flat. B – zone of the reef-crest, same site.

3.3.3. Philippines coral reefs conditions under the environmental fluctuations

Coral cover of the reefs in Philippines has been noted as an average of 25 to 49.90% (White and Trinidad 1998). The pioneering studies (Inventory of the Coral Resources of the Philippines, ICRP) in the 1970s had shown that Philippine reefs had deteriorated, mostly as a result of increasing demands placed on them by human use. Among the most important reasons for the destruction of the ecosystems of the Philippine's coral reefs are notes as overfishing and cyanide fishing (Chou Teo 2000). Gomez et al. (1994a, 1994b) compared the 1982 update with data from the ASEAN-Australia Living Coastal Resources Project (mainly from sites in the NW Philippines) and the ASEAN-US Coastal Resources Management Project (in Lingayen Gulf, NW Philippines). They concluded that methodological problems preclude projection of trends in time, mainly because part of the original inventories in the Visayas region included samples from the reef flat, presumably leading to lower averages. Unfortunately, for scientists, as Licuanan (2000) noted, environmental planners and resource managers, no inventory of comparable scale has been conducted since ICRP, hindering the objective selection of priority reefs for protection and optimal use of others.

Government policy and public opinion remain based on data that urgently need to be updated. Only 5.3% of the reefs had excellent cover in the late 1970s (Gomez 1991). Data from the 1990s report a decline in reef condition, with reefs in the Visayas area most at risk.

An analysis of more than 600 data sets showed that ‘excellent’ reefs (live hard and soft coral cover above 75%) has reduced from 5.3% to 4.3% since the late 1970s. If hard corals alone are considered, only 1.9% of the reefs can be called ‘excellent’, with average hard coral cover on all reefs at 32.3%, whereas it used to be much higher. *Acropora* covered 8.1% of Philippines reefs, and the decline is thought to be due primarily to human impacts, particularly blast fishing, as well as infestations of coral eating crown-of-thorns starfish and drupellids. The 1998 bleaching started at Batangas in June 1998 and other reefs were affected in an almost clockwise sequence around the Philippines. Most reefs in northern Luzon, Palawan, most of the Visayas, northern and eastern Mindanao were affected. The most severe impact occurred at Bolinao, Pangasinan where 80% of the corals were bleached. Most vulnerable were *Acropora* and pocilloporids and even *Porites* corals, faviids, fungiids, caryophilids and hydrocorals were seen to bleach (Chou and Teo 2000). The dominance of stony corals is necessarily for healthy reefs (Mantachitra 1994, Gomez et al. 1994b). However, *Acropora*, the largest genus of corals and one that is considered to be most sensitive to changes in reef conditions and one of the first to return when ideal conditions are reestablished (Wallace 1999), covered only an average of 8.1% of Philippine reefs and reef communities in the 1990s. The Philippines is north of center of *Acropora* species diversity in Sulawesi, Indonesia (which has 76 species, Wallace 1999). The mortality index (the proportion of total hard coral cover, both dead and alive, that was found dead) for the 245 sites that had dead coral cover shows that 20% of the sites had at least half of the corals already dead. In the 1970s, half of the sites studied had at least 50% of their corals already dead (Gomez et al 1994b). In 1997, average hard coral cover was down to 32% with only five sites (2%) in excellent condition based on live coral cover. There is still the decline in average cover in the last four years of the decade. At any rate, it seems we may not have a real comprehensive picture of what is currently occurring in the country. It seems then that the Visayas reefs are most at risk while the better reefs are often less accessible (Licuanan 2000). As such, it is very critical to conduct monitoring of coral cover to verify and confirm the above notion. MPA area may be expanded to include areas with better coral cover.

Some positive changes also were presented in the beginning of the century. Benthic cover of both Bush and Meara in Honda Bay (Palawan, Philippines) was higher in 2003 than in 2000 and the hard coral cover had the largest contribution. In Bush Island, hard corals contributed 45.83% and in Meara Island 43.20% to the benthic community (Tab. 10). In both islands soft coral cover was 3.80%. The abiotic components contributed 35.52% and 48.30% to the total benthic lifeforms of the two islands wherein dead corals covered with algae and rubble contributed most for both islands (Tab. 6). Live coral cover went down at this region after El Niño in 1997 and 1998. In 2000, coral cover in Honda Bay was probably not yet back to its previous state, though there was recovery in 2003. From 2000 to 2003, the biotic component had increased in both sites (Table 10). The quite good homogeneity of the physical environments (sedimentation, temperature, salinity) can be explained by the fact that both sites are located at the roughly similar distance from the shore so there no strong gradient of terrestrial run-off along with the location of these reefs. The fact that coral cover is able to recover despite sedimentation indicates that sedimentation has not yet reached critical levels in Honda Bay. However, Becira (2009) shows the peak intensity of sedimentation flux roughly 21 mg cm $^{-2}$ day^{-1} at the Bush site and, respectively, 16 mg cm $^{-2}$ day^{-1} at Meara (Table 10).

Natural catastrophes – one of suppressing factors influencing marine ecosystems. In the last decade, the Philippines has been hit severely by natural disasters. In 2005 alone, Central Luzon was hit by both a drought, which sharply curtailed hydroelectric power, and by a typhoon that flooded practically all of low-lying Manila's streets. Still more damaging was the 1990 earthquake that devastated a wide area in Luzon, including Baguio and other northern areas. The city of Cebu and nearby areas were struck by a typhoon that killed more than a hundred people, sank vessels, destroyed part of the sugar crop, and cut off water and electricity for several days. The Philippines is prone to about 6–9 storms which make landfall each year, on average. The 1991 Mount Pinatubo eruption also damaged much of Central Luzon, the lahar burying towns and farmland, and the ashes affecting global temperatures.

Building construction is undertaken with natural disasters in mind. Most rural housing has consisted of nipa huts that are easily damaged but are inexpensive and easy to replace. Most urban buildings are steel and concrete structures designed (not always successfully) to resist both typhoons and earthquakes. Damage is still significant, however, and many people are displaced each year by typhoons, earthquakes, and other natural disasters. In 1987 alone the Department of Social Welfare and Development helped 2.4 million victims of natural disasters.

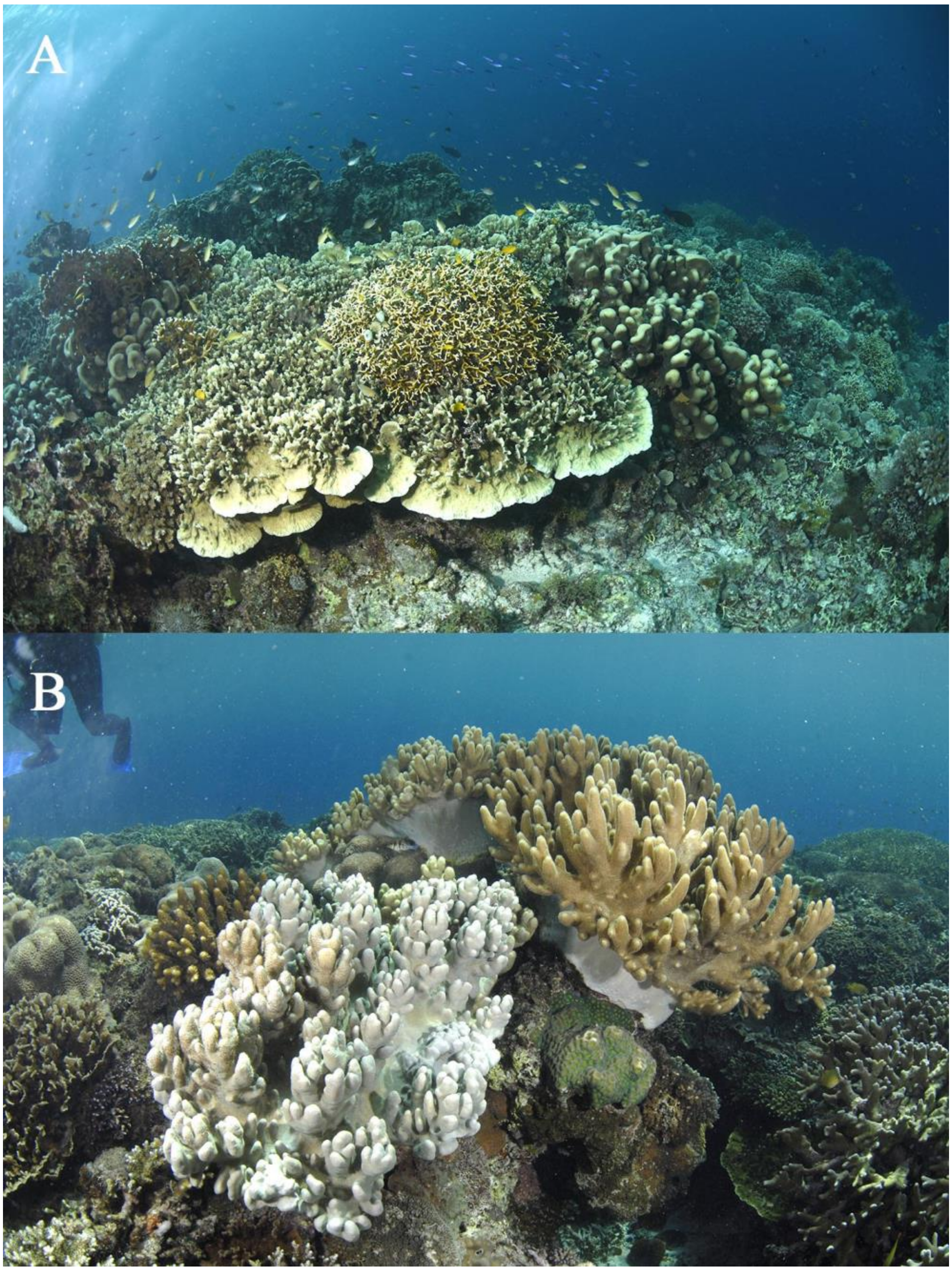


Fig. 32. Dense coral settlements with 100% coverage, Panglao Island, Visayas, Philippines, 2017 year. A – reef-building (stony) corals. B – soft corals (Octocorals) Sinularia among the stony coral settlements, same site.

Conclusion. Sedimentation and nutrient enrichment are supposed to have the strong influence on Philippine's coral reef ecosystems. Heavy sedimentation, nutrient extra-enrichment, heavy metals and plastic pollution has been found to negatively affect marine biodiversity globally. In the Philippines, there have been few studies on effects of nutrient enrichment, sedimentation and heavy metals on different marine species but fewer investigations were found in relation to its effects on marine biodiversity. It was experimentally shown that total mortality of coral nubbins were observed in sites in Bolinao where DF-SPM (193 g m^{-2} d^{-1}) and SPM in water column (~7.2mg L^{-1}) was high (Villanueva et al. 2005).

Possible causes of mortality of these corals, as stated by the authors, can be: (1) increase in nutrients have increased the growth of competitors of coral juveniles; (2) increase in nutrients lowers the dissolved oxygen levels; (3) increased sedimentation increases the turbidity and thus, lessens the amount of light that can be utilized by the zooxanthellae associated with the coral juveniles, leading to lesser nutrition for the coral juveniles and (4) increased sedimentation smothers and buries the coral juveniles which is known to be the major cause of higher mortality and lower abundance of juvenile corals in eutrophic reefs. Nutrient enrichment, heavy metals and plastic pollution has been found to negatively affect marine biodiversity globally. These stressors have lethal and sub-lethal effects on marine organisms, affecting marine biodiversity directly or indirectly. Direct effect includes removal of individuals due to mortality while indirect effects include habitat degradation and alteration, food web simplification, increase alien species invasion and reduction of individual fitness.

3.4. Coral reef conditions along with the Chinese coast of the South China Sea

The Chinese reefs (mainly on Hainan Island) at the northern part of the SCS, have links with reefs of Vietnam and the Spratly Arch. The geographic location of these reefs close to northern margin of Indo-Pacific coral reef centre of high biodiversity can allow the quite rich coral fauna existing, but there is lack of taxonomic capacity to confirm this. Studies are required to assess the possible important role of these reefs in global reef system. Only reefs around Hong Kong are significantly studied. Lam and Morton (2008) showed the full list of Hong Kong's Octocorallia studied since the middle of the 19th century. Besides of the needed studying of some taxa, it is interesting to note the total absence of widely spreaded tropical zooxanthellate genera Sinularia and Sarcophyton along with presence/predominating of azooxanthellate genera, such as Eleutherobia, Paraminabea, Scleronephthya, Nephthyigorgia and Dendronephthya. Fringing reefs are found in the coastal waters around the southern Hengchun Peninsula, Lutao, Lanyu, Hsiao-Liuchiu, and Penghu Islands. Patchy fringing reefs occur along the east and north coasts of Taiwan, where non-reef coral communities are more common. Tungsha Island is an atoll in the northern part of the South China Sea. Taiping Island is a tropical reef island in the Spratlys in the South China Sea. Reef Check data from 8 localities in Taiwan including Northeastern coast, I-lan County, Eastern coast, Hengchun Peninsula, Penghu Islands, Hsiao-Liuchiu, Lutao, and Lanyu from 1997 to 2002 show that coral cover at 5 sites was higher than 50% indicating reefs were in relatively good condition.

Coral cover at 9 other sites was between 25 and 50% indicating reefs under possible stresses. Cover at the remaining 16 sites was below 25% indicating severe damage to these reefs, hence their poor condition. By data of 2000–20001 years, coral cover was highest (50–75%) at Lutao, an offshore island on southeast Taiwan, however, cover on the northeastern coast, Hsiao-Liuchiu Island, and Penghu Islands was below 25%, as a result of localised damage. The low abundance of fishes and indicator invertebrates organisms suggest that most reefs were over-fished. In addition, sediment accumulation was evident and numerous discarded fishing nets were found at most localities indicating that coral reefs in Taiwan were under severe threats from human activities. Most of the reefs remain in a similar condition as that reported in 1998 and 2000, although several reef sites in Nanwan Bay, southern Taiwan and Penghu Islands were heavily damaged by typhoons in 2001. No COTS have been reported during Reef Check surveys of Taiwan's reefs in 2002, and very few cases of predation by gastropods were recorded. Coral predators are not making a significant impact on coral reefs in Taiwan (Dai et al. 2002).

3.5. Biodiversity and interconnections between marine ecosystems in the Asia-Pacific seas

3.5.1. Stony corals of South China Sea

The Indo-West Pacific marine biogeographic province has long been recognized as the global center of marine tropical biodiversity. Forty-five mangrove species out of a global total of 51 (Spalding et al. 1997); 50 of 70 coral genera (Tomascik et al. 1997); 20 of 50 seagrasses species (Sudara et al. 1994); and 7 of 9 giant clam species (Tomascik et al. 1997), are found in the nearshore areas of the South China Sea. Compared to the Atlantic, the tropical Indo-West Pacific is highly diverse. Only 5 mangrove species and some 35 coral species are found in the Atlantic compared with 45 mangrove and over 450 coral species recorded from the Philippines, 200 from the Red Sea, 117 from South East India and 57 from the Persian Gulf. A total of 360–410 reef-building Scleractinia corals pertaining to 70 genera were registered in reefs of Indo-Pacific (Veron 1995). The maximum coral diversity have been observed in the Indo-Malayan Centre of biodiversity, or so called Coral Triangle, with apices in the Philippines, the Malacca Peninsula, and New Guinea (Fig. 33). The same maximal richness can be suggested for other groups of flora and fauna of that region. It explains the key role of the South China Sea for the marine biodiversity of our planet. The coral reefs represent the "hot spots" regarding the marine biodiversity in the SCS.

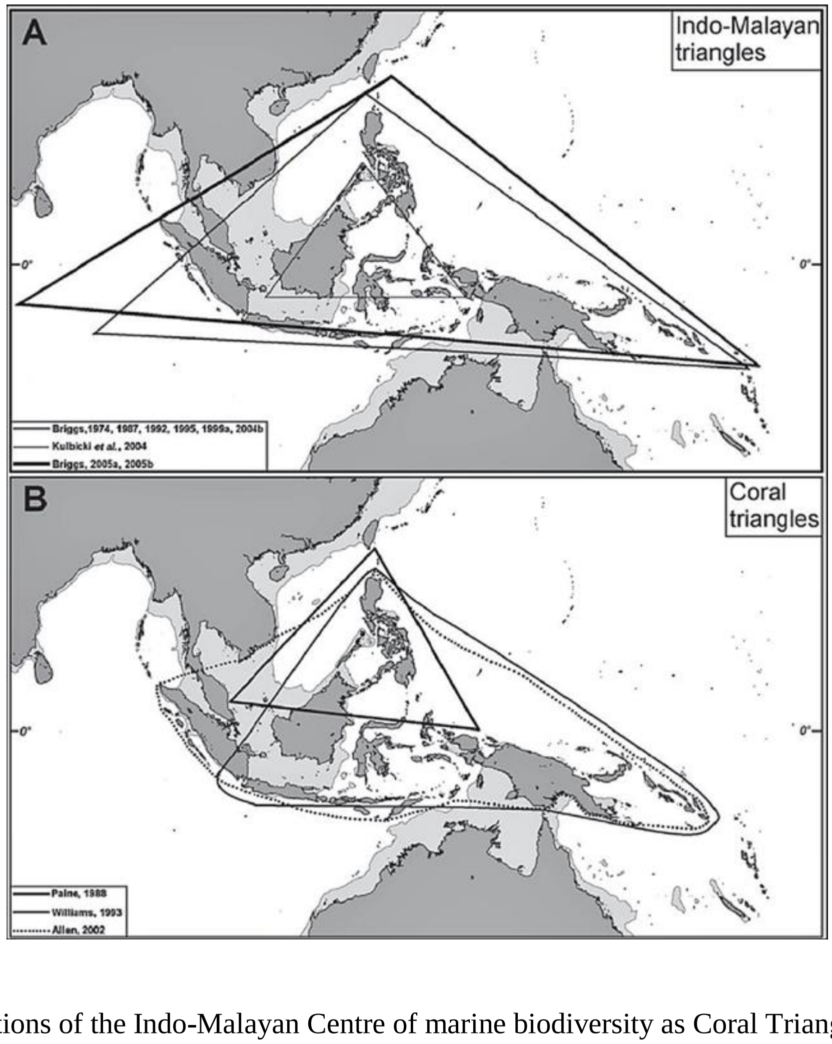


Fig. 33. Delineations of the Indo-Malayan Centre of marine biodiversity as Coral Triangles (Hoeksema 2007).

3.5.2. Coral diversity of the Central and South of Vietnam

Coral reefs of the Central and South of Vietnam are the richest (in faunistic sense) marine habitats, where the reef ecosystems extend along the 3,260 km coastline and on more than 3,000 inshore and offshore islands. Many reefs in Vietnamese waters have developed on submersed banks, which are common on the continental shelf. Reef-building corals may distribute down to 35 m deep but account for a small proportion of overall coverage. According to the studies performed in the last decades of the 20th century, Vietnam's reef-building coral fauna comprises 366 species, belonging to 80 genera. Coral fringing reefs provide main coastal habitats in Vietnam waters around islands such as Cu Lao Cham to Con Dao, and extend along the coastline from Danang to Binh Thuan Province. Nha Trang Bay is considering as "hot spot" of stony corals diversity in Vietnam (351 species, Tuan 2002).

Fringing coral reefs of Vietnam are very diverse in their morphology and range in width from 50 to 800 m possessing the high faunistic richness in that part of South China Sea. Vietnamese reefs have a strong relationship with those of Coral Triangle due to their high similarity in coral species fauna with the reefs of Indonesia, and the Philippines (72.3, and 81.6% of the same species, respectively). The scleractinian species composition of this area exceeds 80% of that of the Pacific (Latypov 1995).

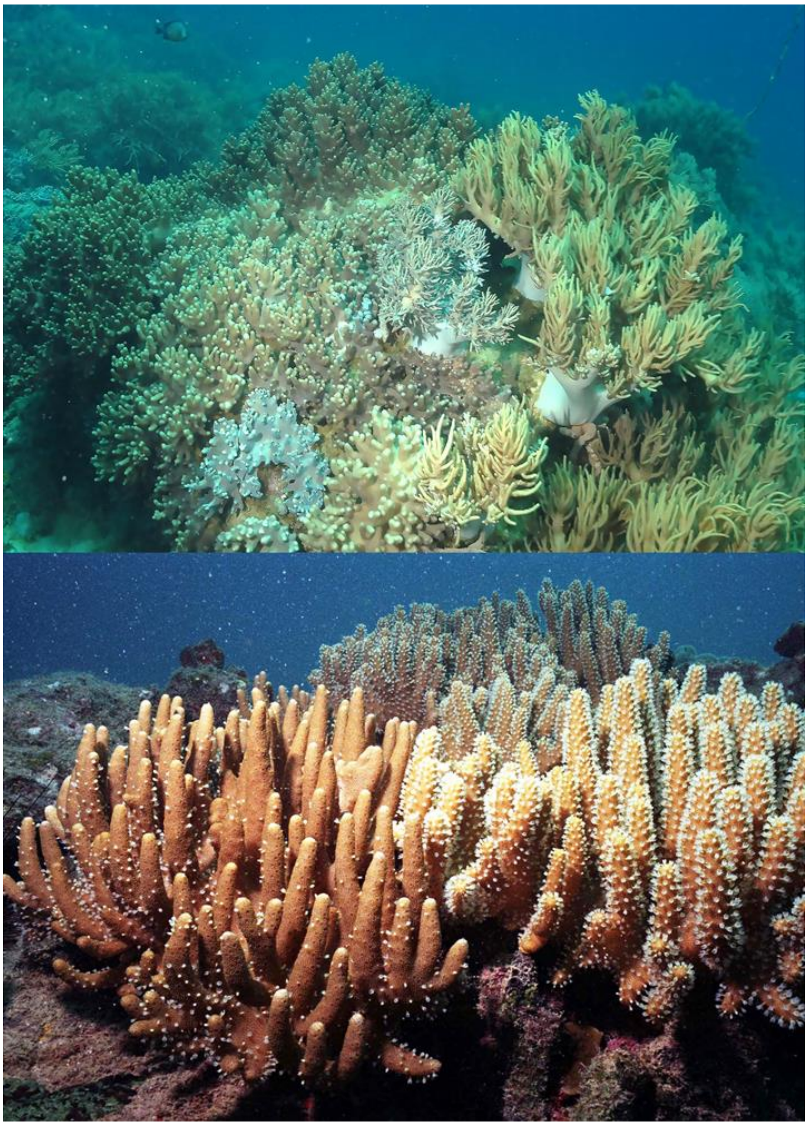


Fig. 34 Typical soft corals of mass genera *Sinularia* (above) and *Lobophytum* (below) , Nha Trang Bay, South China Sea

Zone division at such sites is not obvious, but are typically dominated by scleractinian reef-building corals (hard corals, stony corals) belonging to the *Acropora*, *Pocillopora*, branched or massive *Porites*. Staghorn corals *Acropora* are normally observed at the ends of such reefs and some zones are dominated by soft corals Alcyonacea (mainly *Sinularia*, *Lobophytum* or *Paralemnalia*, Fig. 34). As in most Indo-Pacific reefs, the species diversity of Vietnam's reefs consists mainly of the members of 5 families – Acroporidae (110 species), Faviidae (38 species), Fungiidae (32 species), Poritidae (31 species), and Dendrophylliidae (25 species), making up altogether 64.5% of the total scleractinian species composition. The five genera most diverse and widespread in all reefs comprise *Acropora* (66 species), *Montipora* (35 species), *Porites* (18 species), *Favia* (14 species), and *Fungia* (14 species). In all, some 20 scleractinian species form mono-species settlements with a coverage reaching 60–100% (Latypov 2005).

The peculiarity of the coral faunas of the Siam and Tonkin gulfs was noted out before (see Chapter 3.2.1 of the present report) and explained by the environmental characters of both gulfs (Latypov 2005, Khomenko, 1993). It can be explained by the ecological similarity of these gulfs. Coral reefs have developed in areas adjacent to the offshore islands of Phu Quoc, Nam Du, and Tho Chu. These reefs are normall 50–100m wide and spread to a depth of 10–13m. On the partially developed reef flats, staghorn Acropora dominate, often with mono-species stands several hundreds meters wide. Reef slope are typified by massive corals *Favia, Cyphastrea* and *Physogira*, cup-shape Turbinaria (southern Tho Chu Island), or foliate *Pachyseris* corals (southern Bay Canh Island of the Con Dao Island group) (Latypov 1986). The unfavorable physical factors cause a similarity in the composition of Scleractinia communities in both gulfs. The reef ecosystems in both gulfs lack some Scleractinia corals genera – such as *Palauastrea, Caulastrea*. Members of the *Plerogyra* and *Physogyra* genera are absent in the inner part of the Gulf of Tonkin, and *Pachyseris, Mycedium*, and *Pectinia* are absent in the innermost and coastal areas of the Gulf of Thailand. Another stony corals having large polyps and good capability for self-cleaning, such as *Galaxea, Echinopora, Lobophyllia, Echinophyllia, Turbinaria, Podobacia, Lithophyllon, Fungia,* and *Goniopora*, – are widespread in both gulfs. The reefs in both gulfs are dominated by many species of these genera (*Galaxea fascicularis, Goniopora stokesi, Echinopora lamellosa*, and *Lobophyllia hemprichii*), as well as by *Acropora cytherea, A. nobilis, Montipora hispida, Porites lobata,* and *P. cylindrica*, widespread in Indo-Pacific reefs.

Conclusion. In general, the species composition of Scleractinia corals is determined as similar to that of Australia and Indonesia. Beginning with 1980, systematic studies of Vietnam corals and reefs have been performed due to the joint expeditions of the Institute of Marine Biology FEB RAS (Vladivostok, Russia), Institute of Oceanography VAST (Nha Trang, Vietnam) and Institute of Marine Resources and Environment VAST (Haiphong, Vietnam). The published results are mostly related to scleractinian composition and distribution, with some papers analyzing mass accompanying macrobenthos species and a few publications providing general characteristics of the reefs. Part of the data obtained was presented only in unpublished technical reports. Some findings were published in difficult-to-obtain regional pares collections in Russian and Vietnamese languages.

3.5.3. Reef-building (stony) corals diversity in Philippines

Biodiversity at Philippine's coral reefs is pointed out as some of the highest in the world (Hoeksema 2007, with a literature review; Veron 2000). For example, only in Sogod Bay (South Leyte) the number of stony coral species registered was 276 species and 72 genera of stony corals were found across 7 dive sites, averaging 110 species per site which number represents approximately 59% of all coral species reported for the Philippines (Fenner et al. 2005). Coral species of the Philippines have been studied by several scientists beginning with Faustino (1927). Francisco Nemenzo spent a lifetime studying Philippine corals (Nemenzo 1986), and described a plethora of new species. Gregor Hodgson studied corals with Nemenzo (Nemenzo and Hodgson 1983), and described several new species from the Philippines (Hodgson and Ross 1981, Hodgson 1985). J. E .N. Veron and Hodgson reviewed all new species described by Nemenzo and presented a checklist of 411 species of Philippine corals based on the locations they had studied (Veron and Hodgson 1989). Veron and Fenner (2000) presented a checklist of 305 species that they found in the Calamianes

Islands of northern Palawan, and concluded that 462 species were known from the Philippines. That appears the Philippines to have the world's richest coral fauna at that time, although the fauna of Indonesia is not well enough known. The high coral diversity of Philippines suggests that the reefs of the area are of high conservation importance. However, their status and biodiversity are under the risk and show the degradation in many areas.

3.5.4. Octocorals as a key group to study the ways of corals dispersal in the Asia-Pacific seas

Soft corals often is a dominant group of Octocorallia in the Indo-Pacific as they are able to compete with stony corals for space and have a greater potential than other Octocorallia to occupy diverse habitats. Alcyoniidae corals deserve more interest as a source of pharmacologically important compounds. However, the data on the biodiversity and dispersal of this key soft corals group in tropical waters are scarce and restricted to several local faunas, such as those of Palau, Ambon (Indonesia), Red Sea, and New Guinea.

3.5.5. Soft corals diversity of the Vietnam

The soft corals and gorgonians as well inhabiting the Vietnam coastal area are very promising for a detailed survey of their biodiversity and the ecology-dependent groupings. Coral reefs of Vietnam are located in the north-eastern of the greatest diversity region in South East Asia sea and are connected with the richest marine region on Earth – the so-called Coral Triangle between Indonesia, Malaysia and the Philippines. Soft corals investigations in Vietnam started in the beginning of the 20th century.

Hickson (1919) described one new soft coral species and Stiasny (1938) published the first data on Vietnamese gorgonians. Later on, Dawydoff (1952) published the full list of his findings in the monograph on the fauna and ecology of marine invertebrates of Indochina coastal waters. The next stage of the Octocorallia investigations in Vietnam dealt with the museum collections from Nha Trang Bay. Tixier-Durivault's publications (1943, 1946, 1956, 1957, 1958, 1970) and a short paper of Stiasny (1952) based on these collections provided some data on the Octocorallia regional fauna diversity and emphasized the insufficient knowledge about Octocorallia. Some these old records, mainly of the soft corals, are doubtful and in need of revision. Thus, in the list of Nha Trang Bay octocorals finalized and published by Tixier-Durivault in 1970, she mentioned 38 species of *Sinularia*, the largest zooxanthellate shallow-water genus. Later on, the taxonomic status of several species was changed. *Sinularia dumosa* Tixier-Durivault, 1970, and *S. ramulosa* Tixier-Durivault, 1970, were synonymized with *S. lochmodes* Kolonko, 1926 (Verseveldt, 1980). *Sinularia dura* (Pratt, 1903) was synonymized with *S. brassica* May, 1898 (Benayahu et al., 1997), and *S. gyrosa* sensu Tixier-Durivault, 1970, was recognized as belonging to *S. gravis* (Vennam, Ofwegen, 1996). Recently, seven species new for science were described and three known species were firstly recorded using contemporary collected material from Nha Trang Bay (Dautova et al., 2010).

Some old records, mainly of the soft corals, are doubtful and in need of revision. Thus, in the list of Nha Trang Bay octocorals finalized and published by Tixier-Durivault in 1970, she mentioned 38 species of *Sinularia*, the largest zooxanthellate shallow-water genus. Recently, seven species, new for science, were described and three known species were firstly recorded using contemporary collected material from Nha Trang Bay (Dautova et al. 2010). The distribution of *Sinularia* is somewhat similar to that of other tropical shallow-water animals in the Indo-Pacific, showing a decrease of species number towards the periphery of the Coral Triangle (Fig. 33). However, most records known before 2000 were for the Red Sea and the Seychelles-Mauritius Plateau (altogether 38 species, Ofwegen, 2000).

So, the Octocorallia fauna of the South China Sea, and of Vietnamese waters in particular, clearly needs more research with regard to its octocoral fauna, as much diverse fauna could occurs in that region due to the Coral Triangle vicinity. The study presented is aimed to contribute to our knowledge on the soft corals species richness in the coral reef ecosystems in the Central of Vietnam and to discuss the possible dispersal ways of these animals in the region. The coral reefs of the Nha Trang Bay are located across the north-west edge of the Coral Triangle and as such share many of the species and characteristics of reefs to the south. The survey of the biodiversity in soft corals in the bay can be also helpful for the monitoring purposes to solve the important problem of the tropical marine ecosystems – to predict the nearest future of the damaged and healthy coral reefs.

The study of the soft corals (Octocorallia: Alcyoniidae) species richness is essential in the frame of the worldwide and local biodiversity problems. Alcyoniidae often is a dominant family of soft corals in the Indo-Pacific. They are able to compete with stony corals for space and have a greater potential than other Octocorallia of occupying diverse habitats. Alcyoniidae corals deserve more interest as they are a source of pharmacologically important compounds. However, the data on the biodiversity and dispersal of this key soft corals group in tropical waters are scarce and restricted to several local faunas, such as those of Palau, Ambon (Indonesia), Red Sea, New Guinea.

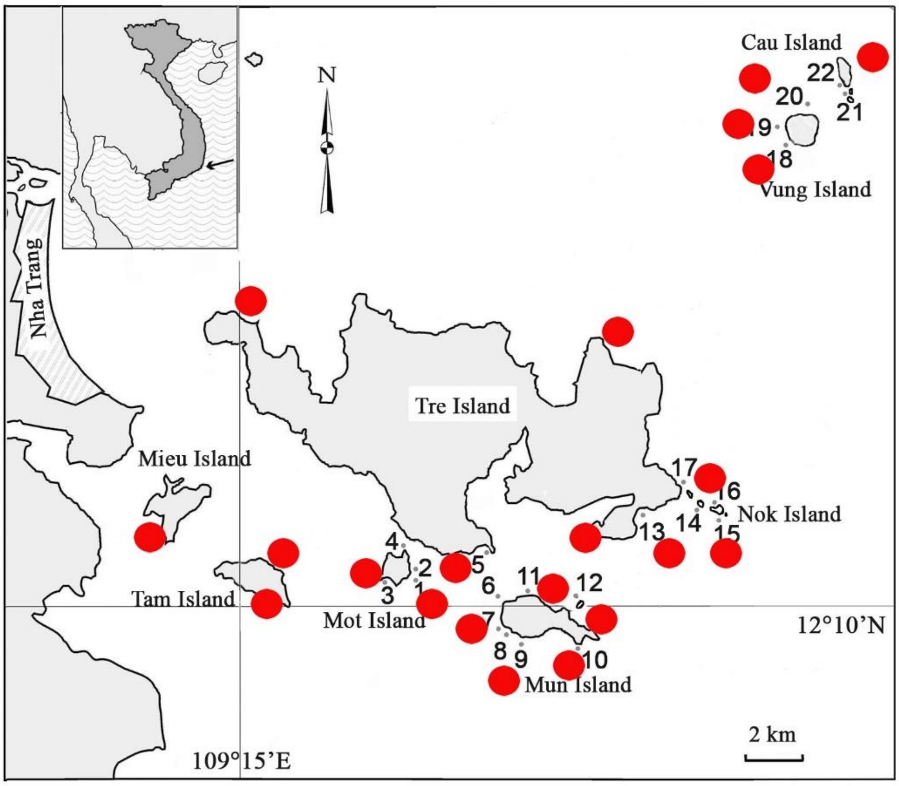


Fig. 36. Sites for biodiversity study in Nha Trang Bay, Central of Vietnam, undertaken in the frame of the reporting project.

The role of soft corals (Octocorallia: Alcyoniidae) in the reef-building process is less obvious comparing with the stony corals Scleractinia. However, soft corals can occupy the large areas on the reef making the biomass up to 35 kg/m2. The skeletal elements of the soft corals, i.e. sclerites (which are limebodies in the soft tissue of these corals), are depositing on the reefs after the coral' dead. 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 tropics (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.

We used the following sources to compose the list of the Octocorallia of Vietnamese waters:

1) collections keeping in the Museum of the Zoological Institute RAS (ZIN RAS, St. Petersburg, Russia) and in the Zoological Museum of the Moscow State University (Moscow, Russia);

2) collection keeping in the Museum of the A.V. Zhirmunsky of the National Scientific Centre of Marine Biology FEB RAS (MIMB, Vladivostok, Russia);

3) collection keeping in the Museum of the Institute Oceanography VAST (Nha Trang, Vietnam);

3) three sets of the underwater photo-images collected in the period 2011–2015; 2015–2016; 2017 years, in the Khanh Hoa Province (Central of Vietnam, Fig.), Vinh Hy (Southern Vietnam).

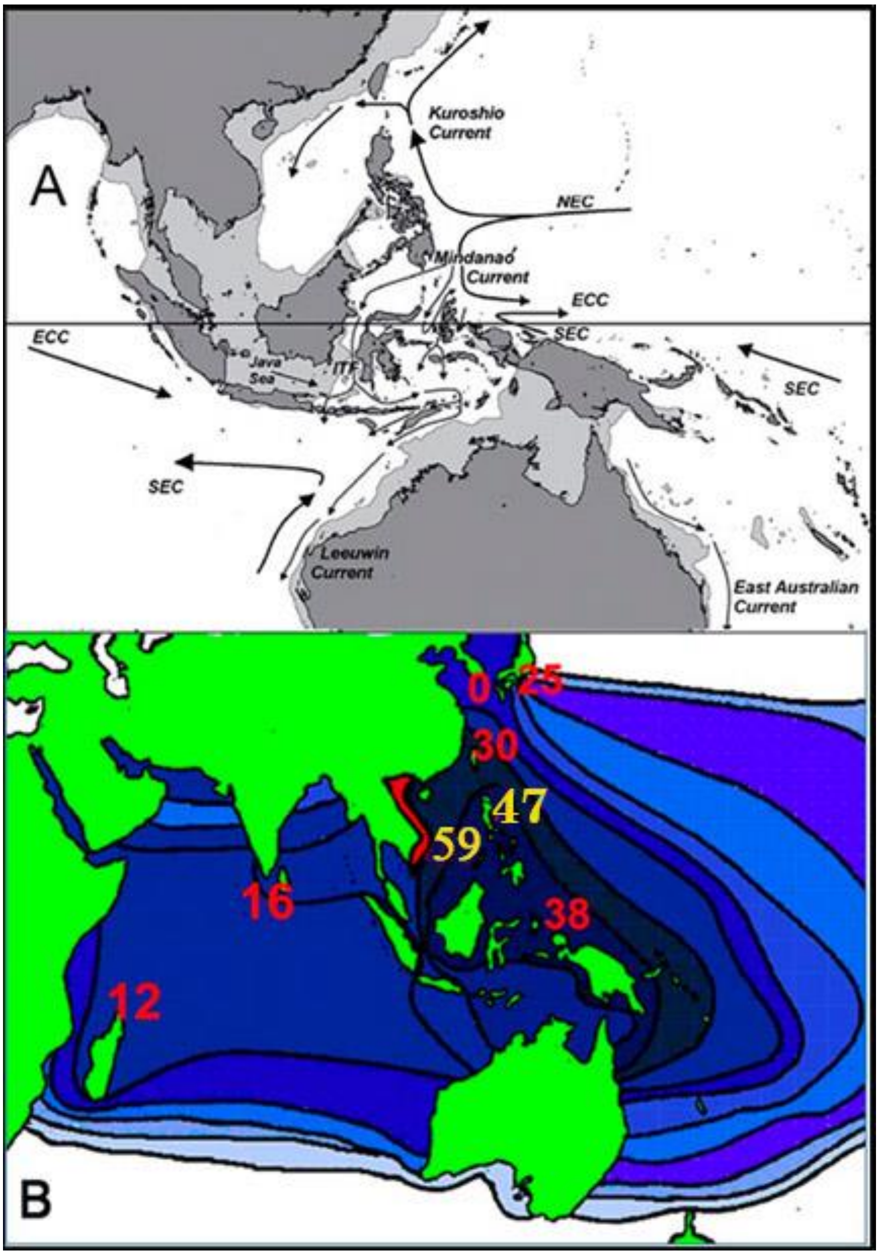


Fig. 37. A. Currents in and around the Indo-Malayan Centre of Marine Biodiversity (Coral Triangle) area (Paine 1988, Allen 2002, summarized by Hoeksema 2007). B. Distribution of stony corals species richness (showed by blue color) and soft coral Sinularia species richness (showed by yellow number for Philippines and red numbers for other regions) in the Indo-Pacific.

By our preliminary data, the soft corals in Nha Trang Bay are founded as important component of the structure of the coral communities. The abundance of soft corals at the Mun Island (stations 7–12, Fog. 36) and most diving sites near Tre Island is not changed since 2015 year. The coverage by soft corals varies in 2015 year between 0.5 and 24% at these sites and remains stabile in the period since 2011 year. The highest diversity of the soft corals was observed at the stations at the middle part of the bay – around the Mun and Tre islands (Fig. 36). At station 5, Tre Island, the coral community in 2017 is suppressed more in comparison with its condition in 2008–2015 years. Most common soft corals here are mainly of *Sinularia* genus. Their settlements are disposed on the stones and both peninsulas of this small bay at the south shore of Tre Island (Fig. 36).

Table 7. List of the Octocorallia taxa of the orders Helioporacea Bock, 1938, Alcyonacea Lamouroux, 1816 (soft corals, gorgonians and Briareidae Gray, 1859) for Central Vietnam (Dautova, personal data), Taiwan (Benayahu et al. 2004 with comments and list of previous records) and Japan (by Imahara 1996), Hong Kong (by Lam and Morton 2008 with list of previous records), South Korea (Song 1976, 1981, 1994, 1995, Song and Lee 1998), and Philippines (Dautova, personal data). "+" – the presence of the genus on reefs investigated, "–"– the genus is not recorded.

Genera	Central Vietnam. Own data	Southern Taiwan	Japan	Hong Kong	Philippines. Own data
Heliopora Blainville, 1830	+	+	–	–	+
Cervera López-González, Ocaña, García-Gómez & Núñez, 1995	+	–	–	–	+
Clavularia Blainville, 1830	+	+	+	–	+
Pachyclavularia Roule, 1908	–	–	+	–	+
Sarcodyction Forbes, 1847	–	–	+	–	
Cornularia Lamarck, 1816	–	–	+	+	
Carijoa Müller, 1867	+	–	+	+	+
Telesto Lamouroux, 1812	–	–	+	–	
Paratelesto Utinomi, 1958	–	–	+	–	
*Pseudocaladochonu*s Versluys, 1907	–	–	+	–	
Tubipora Linnaeus, 1758	+	+	+	–	+
Alcyonium Linnaeus, 1758	+	–	+	–	+
Anthomastus Verrill, 1878	–	–	+	–	–
Bellonella Gray, 1862	–	–	+	–	
Dampia Alderslade, 1983	+	–	–	–	+
Cladiella Gray, 1869	+	+	+	+	+
Eleutherobia Pütter, 1900	+	+	+	+	+

Klyxum Alderslade, 2000	+	+	+	–	+
Lobophytum Marenzeller, 1886	+	+	+	+	+
Paraminabea Williams & Alderslade, 1999	+	+	+	+	+
Rhytisma Alderslade, 2000	–	+	+	–	+
Sarcophyton Lesson, 1834	+	+	+	–	+
Sinularia May, 1898	+	+	+	–	+
Capnella Gray, 1869	+	+	+	–	+
Coronephthya Utinomi, 1966	–	–	+	–	+
Daniela Koch, 1891	–	–	+	–	
Dendronephthya Kükenthal, 1905	+	–	+	+	+
Duva Koren & Danielssen, 1883		–	+	–	
Gersemia Marenzeller, 1878	–	–	+	–	
Lemnalia Gray, 1868	+	+	+	–	+
Litophyton Forckal, 1775	–	–	+	–	
Nephtea Audouin, 1826	+	–	+	+	+
Paralemnalia Kükenthal, 1913	+	+	+	–	+
Scleronephthya Studer, 1887	+	+	+	+	+
Stereacantha Thomson & Henderson, 1906	–	–	+	–	
Stereonephthya Kükenthal, 1905	–	–	+	–	
Umbellulifera Thomson & Dean, 1831	–	–	+	–	
Chironephthya Studer, 1887	+	–	–	–	+
Nephthygorgia Kükenthal, 1910	+	–	–	+	+
Nidalia Gray, 1835	–	–	+	–	+
Siphonogorgia Kölliker, 1874	+	–	+	–	+
Anthelia Lamarck, 1816	–	+	+	+	
Asterospicularia Utinomi, 1951	–	+	+	–	
Cespitularia Milne Edwards & Haime, 1857	–	+	+	–	

Fungulus Tixier–Durivault, 1987	–	–	+	–	
Heteroxenia Kölliker, 1874	+	+	+	–	+
Efflatounaria Gohar, 1939	+	–	–	–	+
Sansibia Alderslade, 2000	+	+	–	+	
Sympodium Ehrenberg, 1834	–	–	+	–	
Xenia Lamarck, 1816	+	+	+	–	+
Studeriotes Thomson & Simpson, 1909	–	–	+	–	
Carotalcyon Utinomi, 1952	–	–	+	–	
Briareum Blainville, 1830	+	+	+	–	+
Total:	29	22	46	12	32

The reefs at the coast of Hon Mieu (Fig. 36) have in 2017 (after 2015 El Nino thermal event) destroyed population both stony and soft corals. The bottom are occupied by the coral debris, and only two soft corals genera are founded here in quite good amount – *Sarcophyton* and *Sinularia*.

The ecology-dependent communities of octocorals are known of the following types:

1) Light-dependent communities, composed by zooxanthellae-containing corals of soft corals of Alcyonacea family (such as *Sinularia, Lobophytum* and *Sarcophyton*) (Fig. 34).

2) Light-non-dependent communities, composed by non-zooxanthellate corals (such as *Paraminabea, Dendronephthya, Lemnalia* and others).

3) Soft-ground inhabitants; the sea pens are the typical representatives of soft bottom having the antler function of the lowermost part of their colonies.

We presume that the communities of the relatively calm-water shallows where the main role can belong to the tidal currents (central part of the small lagoons and semi-closed bays) bring the most input into the high diversity of the soft corals population of Nha Trang Bay. In these communities, the contrasting groups (families of Octocorallia) attract much interest due to their position at the reefs – *Sinularia* (Family Alcyoniidae) and *Paralemnalia* (Family Nephtheidae). Both these families play main role in the coverage of the bottom by soft corals. Among the Alcyoniidae, the main role belongs to the *Sinularia, Sarcophyon* and *Lobophytum*.

3.5.6. *Sinularia* soft corals of Vietnam waters – indicative group for octocorals pathways for dispersal in South China Sea

Many of the Sinularia species are described as widely distributed, both from Ceylon to Vietnam and from Vietnam to Great Barrier reef, but some “old” and the latest described new species are noted to be endemics up to present day (Verseveldt 1974, 1978, 1977a, b, 1980, 1983; Alderslade 1987; Alderslade & Baxter 1987; Alderslade & Shirwaiker 1991; Benayahu 1993, 2002; Li 1982; Malyutin 1990; Ofwegen 1996, 2000 with the full list of the Sinularia species occurrences; Ofwegen & Benayahu 1992; Ofwegen & Vennam 1991, 1994; Vennam & Parulekar 1994). At the same time the modern detailed examination of sclerites using SEM allows to revise and to synonymy some species (Ofwegen & Vennam 1994; Vennam & Ofwegen 1996); the molecular-genetic approaches may support the uniting of some species or discrimination of one species into several. As a result their geographical distribution may be revised too.

Using the above listed museum collections and our own photo-images sets, we counted at the studied reefs 47 known species and 11 new for science (to be published as papers in peer-reviewed journals).

Check-list of the Sinularia species from the Nha Trang Bay

Here the checklist of the *Sinularia* species founded with in Nha Trang Bay in the newest period (1987–2012 years and 2015–2017, reporting period) is provided including the information on the morphology of these corals. The aim of the paper is to present the modern data on the *Sinularia* soft corals of Nha Trang Bay and extend the knowledge on their diversity and distribution in tropical waters as well, with particular emphasis on their morphology and sclerites composition. The species of the *Sinularia* genus can be distinguished based on a set of morphological characters which set includes both growth form of colony and shape of skeletal elements (sclerites). However the data on these characters, in particular – on the polyp sclerites, is lacking or is incorrect in many species descriptions published earlier (McFadden *et al*. 2009). The composition of the sclerites of *Sinularia* polyp is included to the present paper to fill the gap for the species from Nha Trang Bay.

Order Alcyonacea Lamouroux, 1812
Family Alcyoniidae Lamouroux, 1812
Genus *Sinularia* May, 1898

Sinularia abhishiktae Ofwegen & Vennam, 1991

Polyps contain no sclerites. **Distributiion:** Laccadives, Tanzania, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia abrupta Tixier-Durivault, 1970

Polyps contain modified clubs (to 0.1 mm long) and flattened granulated bodies (to 0.11 mm long). **Distributiion:** Eastern and South Africa, Laccadives, South East India, Mauritius Island, Seychelles, Fanning Atoll (Line Island), Mariana Islands, Hawaii Islands, Nha Trang Bay (South China Sea) Japan.

Sinularia arctium Dautova & Savinkin, 2009

The polyp contains modified clubs and curved, slightly flattened, rods arranged as points in the polyps. **Distributiion:** Nha Trang Bay (South China Sea, Vietnam).

Sinularia brassica May, 1898 (Fig. 38A).

Polyps contain flat bodies 0.06–0.09 mm long, often with slightly widened and rounded ends, and modified flattened clubs up to 0.16 mm long. **Distributiion:** Wide spread in the Indo-Pacific including the Great Barrier Reef, Nha Trang Bay (first record for the South China Sea, Vietnam).

Sinularia capillosa Tixier-Durivault, 1970

Polyps have no sclerites. **Distributiion:** Western Australia**,** Nha Trang Bay (South China Sea, Vietnam), Japan.

Sinularia capricornis Dautova, Ofwegen & Savinkin, 2010

The polyps have a collaret and eight points; the tentacles contain flattened rods, up to 0.07 mm long. The points with modified clubs, up to 0.23 mm long. Collaret with bent flattened spindles, which are covered with cones or tubercles; the longer ones are up to 0.58 mm long.
Distributiion: Nha Trang Bay (South China Sea, Vietnam).

Sinularia crebra Ofwegen, 2008

No sclerites in the polyp. **Distributiion:** Palau (Micronesia), Nha Trang.

Sinularia cruciata Tixier-Durivault, 1970

Polyp's sclerites are numerous narrow rods, 0.03–0.07 mm long, and warty clubs, up to 0.19 mm long, with straight or curved warty handles. **Distributiion:** Red Sea, Seychelles, Indonesia, New Guinea**,** Nha Trang Bay (South China Sea, Vietnam).

Sinularia densa (Whitelegge, 1897)

Polyps contain curved spiny rods and modified clubs, up to 0.18 mm long, with straight or slightly curved handles. **Distributiion:** Seychelles, Laccadives, Great Barrier Reef, New Caledonia, Fiji and Tonga Islands, Funning Atoll (Line Island), Funafuti Atoll, Ellice Islands, Hawaii, Taiwan, Nha Trang Bay (a first record for South China Sea, Vietnam).

Sinularia depressa Tixier-Durivault, 1970

Polyps contain modified clubs, up to 0.16 mm long, with straight handles bearing small vesicles in girdles (or unordered). Curved flattened rods, up to 0.2 mm long, with vesicles on the convex side are presented also. Scales, up to 0.07 mm long, occur in the tentacles. **Distributiion:** Indonesia, Nha Trang Bay (South China Sea, Vietnam).

Sinularia exilis Tixier-Durivault, 1970

Polyps contain thin rods and narrow straight clubs, up to 0.11 mm long, and curved spiny spindles up to 0.15 mm long. **Distributiion:** Seychelles, South Eastern India, Mauritius Island, Taiwan, Nha Trang Bay (Vietnam).

Sinularia facilus Tixier-Durivault, 1970

Polyps contain: 1) modified clubs up to 0.1 mm long with narrow spiny heads and straight or curved handles; 2) flattened curved spindles up to 0.08 mm long, sometimes with more developed warts on the convex side. **Distributiion:** Taiwan, Nha Trang Bay (South China Sea, Vietnam).

Sinularia flexibilis (Quoy & Gaimard, 1833) (Fig.38B).

No sclerites in the polyps and in the terminal parts of the lobes and lobules. **Distributiion:** Widespread in the Indo-Pacific tropical zone, including Nha Trang Bay (South China Sea, Vietnam) and Japan.

Sinularia foveolata Verseveldt, 1974

Polyps contain small rods, up to 0.08 mm long, and modified straight or slightly curved clubs up to 0.1 mm long. The surface layer of the polyparium contains: 1) clubs, to 0.08 mm long, with compact plump heads and a distinct central wart or with very calcified heads with an indistinct central wart; 2) clubs, to 0.15 mm long, with the same variations in the shape of the heads; 3) a number of small spindles, to 0.17 mm long, with smooth median part and spinulated ends. **Distributiion:** New Caledonia, Nha Trang Bay (first record for the South China Sea, Vietnam).

Sinularia aff. gibberosa Tixier-Durivault, 1970

Polyp contains modified clubs up to 0.15 mm long; rods up to 0.05 mm long are distributed in the tentacles. **Distributiion:** Nha Trang Bay (South China Sea, Vietnam).

Sinularia grandilobata Verseveldt, 1980

Polyps contain sclerites of crown-and-points; those are: 1) curved flattened spindles, up to 0.15 mm long, with more developed warts on arched side; 2) and spiny spindles, up to 0.33 mm long; some of them are curved, with accumulation of tubercles on one end. **Distributiion:** Eastern Africa**,** Mindoro (Philippines), New Guinea, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia granosa Tixier-Durivault, 1970

Sclerites of the polyps are: 1) thin curved rods up to 0.1 mm long with some knobs; 2) modified clubs 0.1–0.19 mm long, with curved knotty handles; 3) curved flattened spindles, to 0.29 mm long, with knobs more developed on the convex side, sometimes with one irregularly expanded end. **Distributiion:** Indonesia, Taiwan, Nha Trang Bay (South China Sea, Vietnam).

Sinularia gravis Tixier-Durivault, 1970

Polyps contain no sclerites. **Distributiion:** Eastern Africa, Seychelles, Laccadives, Japan, Mariana Islands, GBG, New Caledonia, Tahiti (Tuamotu Archipelago), Cook Islands, Nha Trang Bay (South China Sea, Vietnam), Japan.

Sinularia heterospiculata Verseveldt, 1970

The polyps contain modified clubs, up to 0.15 mm long, with narrow heads and blunt-ended handles, straight or slightly curved. The small flattened rods from the tentacles are up to 0.07 mm long. **Distributiion:** Red Sea**,** Eastern and South Africa, Madagascar, Seychelles, Indonesia, New Guinea, Nha Trang Bay (first record for the South China Sea, Vietnam).

Sinularia inelegans Tixier-Durivault, 1970 (Fig. 38C)

Polyps contain modified clubs, to 0.15 mm long, with slender vesiculated handles and curved flattened spindles, to 0.23 mm long, with expanded vesiculate ends and cones on the convex side. **Distributiion:** Red Sea, Eastern Africa, Laccadives, Nha Trang Bay (South China Sea, Vietnam).

Sinularia inexplicita Tixier-Durivault, 1970

Polyp sclerites are: 1) thin rods up to 0.06 mm long; 2) modified clubs 0.09–0.15 mm long, with narrow knobby heads and flattened knotty handles; 3) spiny spindles up to 0.15 mm long; some of them are slightly flattened with spines more developed on the convex side. **Distributiion:** Great Barrier Reef, Taiwan, Nha Trang Bay (South China Sea, Vietnam).

Sinularia inflata Tixier-Durivault, 1970

Polyps contain no sclerites. **Distributiion:** New Caledonia, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia laminilobata Malyutin, 1990

Polyps contain modified clubs, 0.08 mm long, with narrow small heads and some cones on their weakly bent handles. **Distributiion:** Condor Islands and Nha Trang Bay (South China Sea, Vietnam).

Sinularia aff. leptoclados (Ehrenberg, 1834)

Polyps contain modified *leptoclados*-like clubs, up to 0.1 mm long, and curved flattened spindles with cones on the convex side. **Distributiion:** Nha Trang Bay (South China Sea, Vietnam).

Sinularia lochmodes Kolonko, 1926

Polyps contain: 1) modified clubs, up to 0.15 mm long; 2) flattened rods, up to 0.15 mm long; 3) and curved flattened spindles, up to 0.26 mm long, with cones on the convex side. **Distributiion:** Eastern Africa, Seychelles, Laccadives, Nha Trang Bay (South China Sea, Vietnam), Indonesia, Philippines, Taiwan, Japan, New Guinea, Great Barrier Reef, New Caledonia.

Sinularia manaarensis Verseveldt, 1980

The polyps contain warty flattened rods and club-like rods, up to 0.14 mm long, and flattened curved spindles up to 0.23 mm long. **Distributiion:** Ceylon (Gulf of Manaar), Taiwan, Nha Trang Bay (a new record for the South China Sea, Vietnam).

Sinularia maxima Verseveldt, 1971 (Fig. 38D)

Polyps contain: 1) modified *leptoclados*-like clubs; 2) and club-like spindles with some accumulated cones on one end and flattened expansion of the other end. **Distributiion:** Taiwan, Eastern Africa, New Guinea, Mariana Islands, Gulf of Carpentaria (Australia), Japan, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia microclavata Tixier-Durivault, 1970 (Fig. 38E)

Polyps contain: 1) modified *leptoclados*-like clubs; 2) club-like spindles with some accumulated cones on one end and flattened expansion of the other end. **Distributiion:** New Caledonia, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia microspiculata Tixier-Durivault, 1970

Polyps contain: 1) modified *leptoclados*-like clubs up to 0.09 mm long; 2) club-like spindles with some accumulation of cones on one end; the another end with flattened expansion. **Distributiion:** New Caledonia, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia minima Verseveldt, 1971

Polyps contain: 1) small rods up to 0.06 mm long; 2) and modified clubs up to 0.15 mm long, with slightly flattened handles. **Distributiion:** Madagascar, Marianas, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia cf. mira Tixier-Durivault, 1970

Polyps contain no sclerites. **Distributiion:** Nha Trang Bay (South China Sea, Vietnam).

Sinularia multiflora Dautova, Ofwegen & Savinkin, 2010

The polyps contain modified clubs up to 0.15 mm long. **Distributiion:** Nha Trang Bay, South China Sea.

Sinularia notanda Tixier-Durivault, 1966 (Fig. 38F)

Polyps contain: 1) rods, 0.05–0.12 mm long, covered by short spines; 2) and very few modified clubs, up to 0.143 mm long, with narrow compact heads. **Distributiion:** Red Sea, Eastern and South Africa, Seychelles, Indonesia, Gulf of Carpentaria (Australia), Taiwan, Nha Trang Bay (a first record for the South China Sea, Vietnam), Japan.

Sinularia ovispiculata Tixier-Durivault, 1970

Polyps contain no sclerites. **Distributiion:** Eastern Africa**,** Seychelles, Andaman Sea, Mauritius Island, Indonesia, New Guinea, Taiwan, Nha Trang Bay (South China Sea, Vietnam), Japan.

Sinularia polydactyla (Ehrenberg, 1834) (Fig. 38G)

Polyps contain no sclerites. **Distributiion:** Red Sea, Eastern Africa, Madagascar, Seychelles, South-Eastern India, Andaman Sea, Nha Trang Bay (South China Sea, Vietnam), Indonesia, Taiwan, Japan, W Carol, Mariana Islands, New Guinea, New Caledonia, Marshall Islands, Fiji Islands, Samoa.

Sinularia pumila Dautova, Ofwegen & Savinkin, 2010

The polyps have a collaret, composed with bent flattened spindles, up to 0.32 mm long, and points composed with modified clubs, up to 0.14 mm long. **Distributiion:** Nha Trang Bay (South China Sea, Vietnam).

Sinularia querciformis (Pratt, 1903)

Polyp contains flattened rods in the tentacles, 0.03 mm long, and modified clubs, up to 0.08 mm long. These clubs have thickened handles with tall cones and compact narrow heads. **Distributiion:** Red Sea, Eastern and South Africa, Seychelles, Laccadives, Indonesia, Japan, Marianas, New Guinea, New Caledonia, Nha Trang Bay (first record for South China Sea, Vietnam).

Sinularia rigida (Dana, 1846) (Fig. 38H)

For references see Verseveldt 1977: 32; Manuputty & Ofwegen 2007: 192; Benayahu *et al*. 2004: 551; Dautova, Ofwegen & Savinkin 2009: 51–52, figs. 1f, 20–22, 36f.

There are no sclerites in the polyps.

Sinularia sarmentosa Dautova, Ofwegen & Savinkin, 2010

The polyps have no sclerites. **Distributiion:** Nha Trang Bay (South China Sea, Vietnam).

Sinularia scabra Tixier-Durivault, 1970

Polyps contain no sclerites. **Distributiion:** Nha Trang Bay (South China Sea, Vietnam).

Sinularia slieringsi Ofwegen & Vennam, 1994

Polyps contain: 1) modified *leptoclados*-like clubs up to 0.1 mm long; 2) curved flattened spindles, up to 0.15 mm long, with cones on the convex side; 3) and flat scales up to 0.07 mm long. **Distributiion:** Indonesia, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia sobolifera Verseveldt & Tursch, 1979

Polyps contain: 1) modified clubs up to 0.15 mm long with bent smooth handles and rounded compact heads; 2) curved flattened spindles, up to 0.14 mm long, with vesicles on convex side. **Distributiion:** Great Barrier Reef, New Guinea, Micronesia, Nha Trang Bay (a first record for the South China Sea, Vietnam).

Sinularia torta Dautova, Ofwegen & Savinkin, 2010

The polyps have eight points with small rods, to 0.15 mm long. **Distributiion:** Nha Trang Bay, Vietnam.

Sinularia uva Dautova, Ofwegen & Savinkin, 2010

The polyps have no sclerites. **Distributiion:** Nha Trang Bay, Vietnam.

Sinularia variabilis Tixier-Durivault, 1965

Polyps contain: 1) modified clubs, to 0.15 mm long, with compact narrow heads and thickened handles ornamented with tall cones; 2) slightly curved and somewhat flattened rods, to 0.16 mm long, covered by scant vesicles. **Distributiion:** Red Sea, Eastern and South Africa, Seychelles, Laccadives, Indonesia, Japan, Western Carolines, Mariana Islands, New Guinea, New Caledonia, Taiwan, Nha Trang Bay (first record for the South China Sea, Vietnam).

Sinularia verseveldti Ofwegen, 1996

Polyp contains: 1) modified *leptoclados*-type clubs, up to 0.16 mm long, with compact narrow heads and slender, sometimes bent, handles ornamented by few tall cones and small vesicles below; 2) slightly curved spindles, up to 0.15 mm long, with higher vesicles on the convex side; 3) flattened spiny rods, up to 0.09 mm long, in the tentacles. **Distributiion:** New Guinea, Nha Trang Bay (first record for the South China Sea, Vietnam).

Sinularia yamazatoi Benayahu, 1995

Polyps contain no sclerites. **Distributiion:** Japan, Nha Trang Bay (first record for the South China Sea, Vietnam).

This is the highest number of *Sinularia* species ever recorded in a particular region, but is also a clear indication of the lack of knowledge of this wide-spread and conspicuous group distribution in the Indo-Pacific. Although the knowledge of soft corals in whole South China Sea is still in its infancy, the data presented and known from previous publications may allow observing some biogeographical circumstances in the composition of the known *Sinularia* fauna.

Many of the *Sinularia* species are described as widely distributed, both from Ceylon to Vietnam and from Vietnam to Great Barrier reef, but some "old" and the latest described new species are noted to be endemics up to present day (Ofwegen 2000) with the full list of the *Sinularia* species occurrences). At the same time the detailed examination of sclerites using SEM allows to revise and to synonymy some species (Vennam & Ofwegen 1996); the molecular-genetic approach may support the uniting of some species or discrimination of one species into several. As a result their geographical distribution may be revised too. Our records of the *S. manaarensis* and *S. abhishiktae* made in Nha Trang Bay extend their known distribution from Indian Ocean to South China Sea and support the point of view (after Ofwegen 2000) that the Indo-Malayan region including New Guinea is the centre of the greatest *Sinularia* diversity. However, the highest number of recorded Sinularia species is not found in the central Indo-Pacific and in the Coral Triangle in particular, until the present day. If the Indonesian Archipelago and New Guinea score rather well, the Philippines *Sinularia*, on the other hand, with only 7 species are poorly known from the scarce publications (Ofwegen 2000). The new data about the true richness of Octocorallia fauna in Indo-Malayan region, and in Coral Triangle in particular, just need more intensive field investigations. As the study of distribution patterns of Octocorallia requires the detailed records of their fauna, the situation with identification of species in the taxa needs to be improved in view of a range of taxonomy problems unsolved until today. The traditional taxonomy tools in Octocorallia and in *Sinularia* in particular, are the coral colony shape and skeletal elements (i.e. sclerites) arrangement.

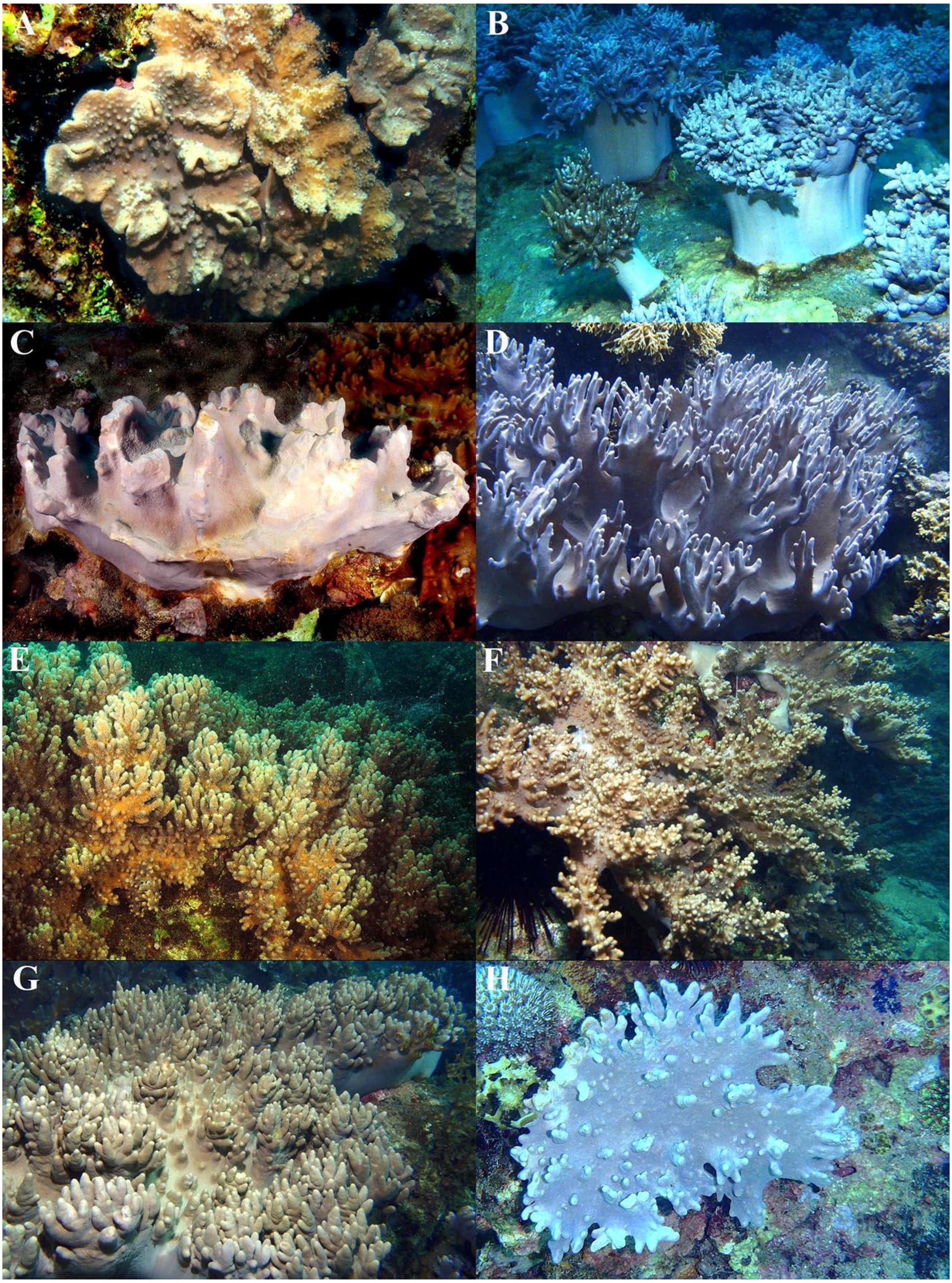


Fig. 38. Common species of soft corals of the *Sinularia* genus from Nha Trang Bay, South China Sea (see species names in the text).

The *Sinularia* species traditionally have been classified into five intrageneric groups – known as five Verseveldt's (1980) identification keys, – based on variation of a single microscopical character, the shape of the clubs from the polypary' surface. Inside of each key, the species should be recognized using shape and size of preserved specimens along with the very few characters of the other sclerites. A molecular phylogeny (constructed using mitochondrial gene msh1 sequences) recovered five well-supported clades, which were not congruent with these traditional intrageneric taxonomic groups (McFadden *et al*., 2009). The morphological characters attributed to each clade include the detailed data on the polyp' armature in addition to the shape of the clubs in the surface tissues. The overall growth form of the colony also distinguishes some clades. However, the previous publications and the latest revision of *Sinularia* (Verseveldt 1980) has incomplete data about the colony body sclerites; moreover, information about polyp sclerites is absent in these literature. It can obscure the identity of samples. Also, the overwhelming majority of publications from the last decades of the 20 century are unusable because of inaccurate hand-made sclerite drawings. Apart from the fact that these drawings very often were made using low microscope magnifications, the opinion that the full sclerite set per specimen/species is necessary for the sample identity was established just towards the end of the 20th century. The detailed examination of the sclerites allowed to re-describe some *Sinularia* species and, therefore, to clarify their distributions (Vennam & Ofwegen 1996; Benayahu *et al*. 1998; Dautova & Savinkin 2009).

For example, *Sinularia manaarensis* was firstly described for a piece of colony from the Gulf of Manaar, Ceylon. Dr. J. Verseveldt pointed out: "According to the enclosed label the specimen was collected by Herdmann in 1902; it was recorded as "type" by Pratt and identified with *S. gardineri* (see Pratt, 1905: 233)". Verseveldt firstly recognized the specimen as distinct from *S. gardineri* (Pratt, 1903), presented sclerite drawings (1980, fig. 43) and placed the species into his *Sinularia* group 4 as having clubs without a central wart. However, his drawings were not a comprehensive representation of all sclerite types in *S. manaarensis*; the information of polyp sclerites was not presented (Verseveldt 1980, fig. 24). The new material of *S. manaarensis* collected by Dautova in 2006 in Nha Trang Bay, South China Sea, shows much more about the sclerite set – the sclerites occurrence in the polyp, more large sclerites in the colony surface layer and the clubs with distinct central wart (Dautova & Savinkin 2009). Such features required attributing the samples to another *Sinularia* species. Verseveldt (1980) noted out the occurrence only of clubs "with a tuberculate head, sometimes with an inconspicuous central wart" in the lobes surface of *S. manaarensis* (Verseveldt 1980: 88, fig. 43a–d). From his drawings it is obvious the central wart exists in all clubs, but indistinct because all head warts are good developed and crowded. The same observed in Vietnamese samples of *S. manaarensis*. Colony shape, described for *S. manaarensis*, is the same as in our material; the sizes of the holotype and Vietnamese colonies are close**.** The investigation of microscope slides of the holotype (made by Verseveldt and stored in the NCB Naturalis) showed the match of the sclerite set for the polyps and other colony parts with the specimens from Nha Trang Bay. The only difference with Verseveldt's description for surface sclerites is the maximal size of the clubs with thickened blunt-ended shafts – 0.4 mm *vs* 0.7 mm long (with wider handles) in the Nha Trang's material. The incompleteness of the single colony described as holotype and the geographical or ecological variability may be a reason for this difference.

Verseveldt, the author of the latest published revision of the genus (1980), who done a lot of work revising all available specimens, described the colony shape for *Sinularia* species using as a rule just small preserved fragments of colonies because these fragments represent the type material. However, colonies in many *Sinularia* can reach quite large size and their morphology differs between the central area of the colony and its edge. Also, the fact that the soft corals can drastically change their shape due to the collecting and preservation is well known now (Fabricius and Alderslade 2001). In addition, species recognition in corals is often hampered by the occasions in which the variability within a species appears high, e.g. the highly variable colony growth morphology. At present, such a wide variation in colonial form among soft corals is best recognized in the genus *Sinularia;* perhaps it is indicative of further species-concept problems to be encountered in this group (Benayahu *et al*. 1998).

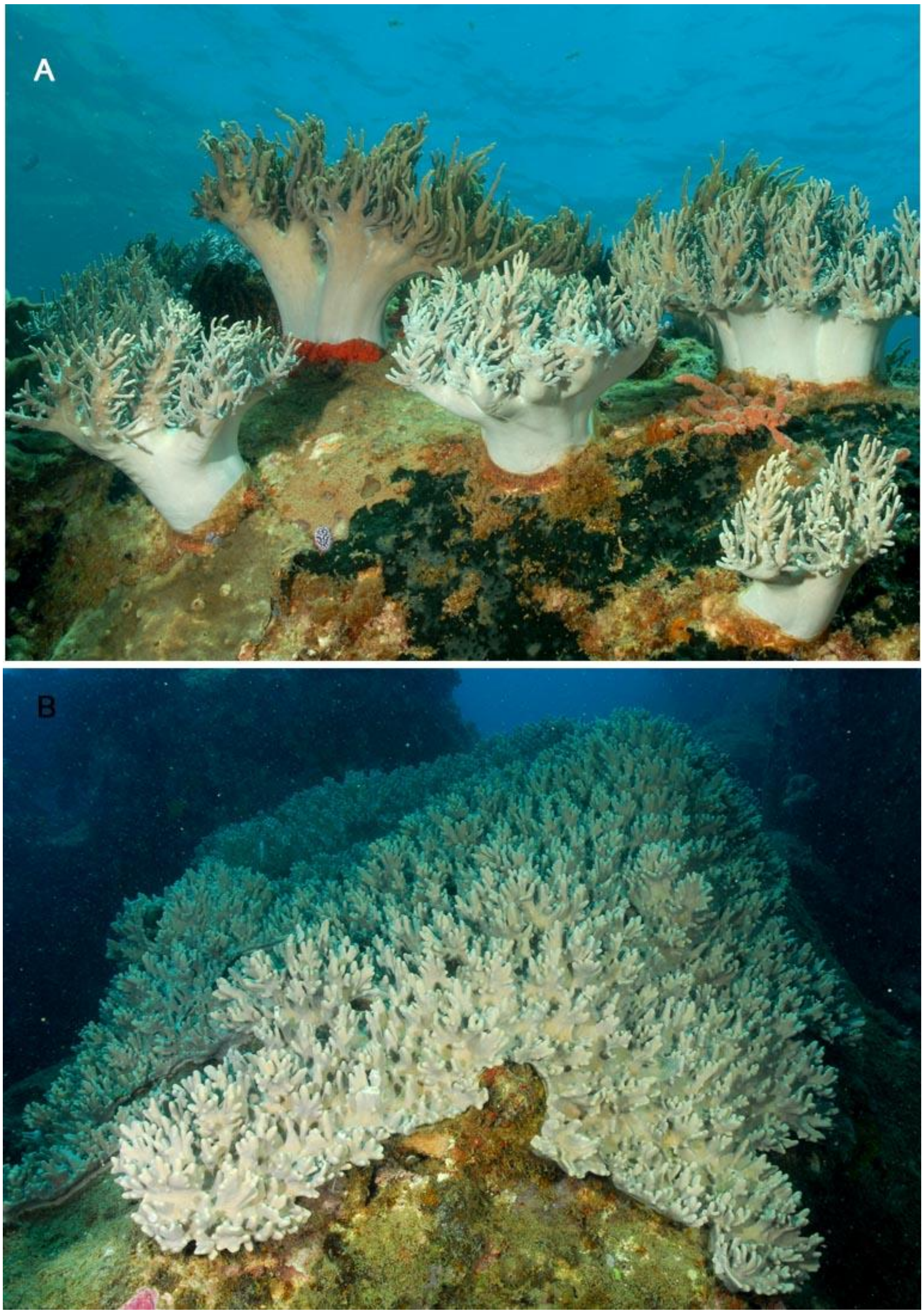


Fig. 39. Types of the *Sinularia* colonies shape from Nha Trang Bay, 2015–2017 years. A – stalked tree-like colonies. B – encrusting colony with branched lobes.

Sinularia species represent highly variable growth forms from encrusting with small surface knobs or ridges to tall tree-like and abundantly branched (Fig. 39, present report). The wide range can be found even in the same species probably due to dependence of the colony shape on ecological factors such as amount of light and wave exposure.

The ecologically-dependent morphology of soft corals should be developed and the underwater images of the living colonies are hardly needed to add the real knowledge on the *Sinularia* morphology and its variability. The investigation of a substantial sampling is needed to understand the intra-species limits of the variation. The result of such work may be that the discontinuous range of the shape variations can be placed between two primary types having the same sclerite composition and architecture; the synonymy of two or three nominal species under the one oldest name can be proposed in such cases (Vennam & Ofwegen 1996; Benayahu *et al*. 1998). The bright and single published example is the case with uniting two known species of *Sinularia* which species were historically distinguished by very different colony shape (*S. brassica* and *S. dura*) into one under the older name basing on the matching of the spiculation and occurrence of the discontinuous range of the intermediate colony' shapes. We have found the same variability in S. brassica as above mentioned authors and have been able to examine a considerable number of specimens covering a large variety of growth forms; the variation within a single resulting species was from a stalked colony with a convoluted capitulum consisting of closely appressed marginal folds to a stalked colony with a capitulum consisting of short lobes (Fig. 40).

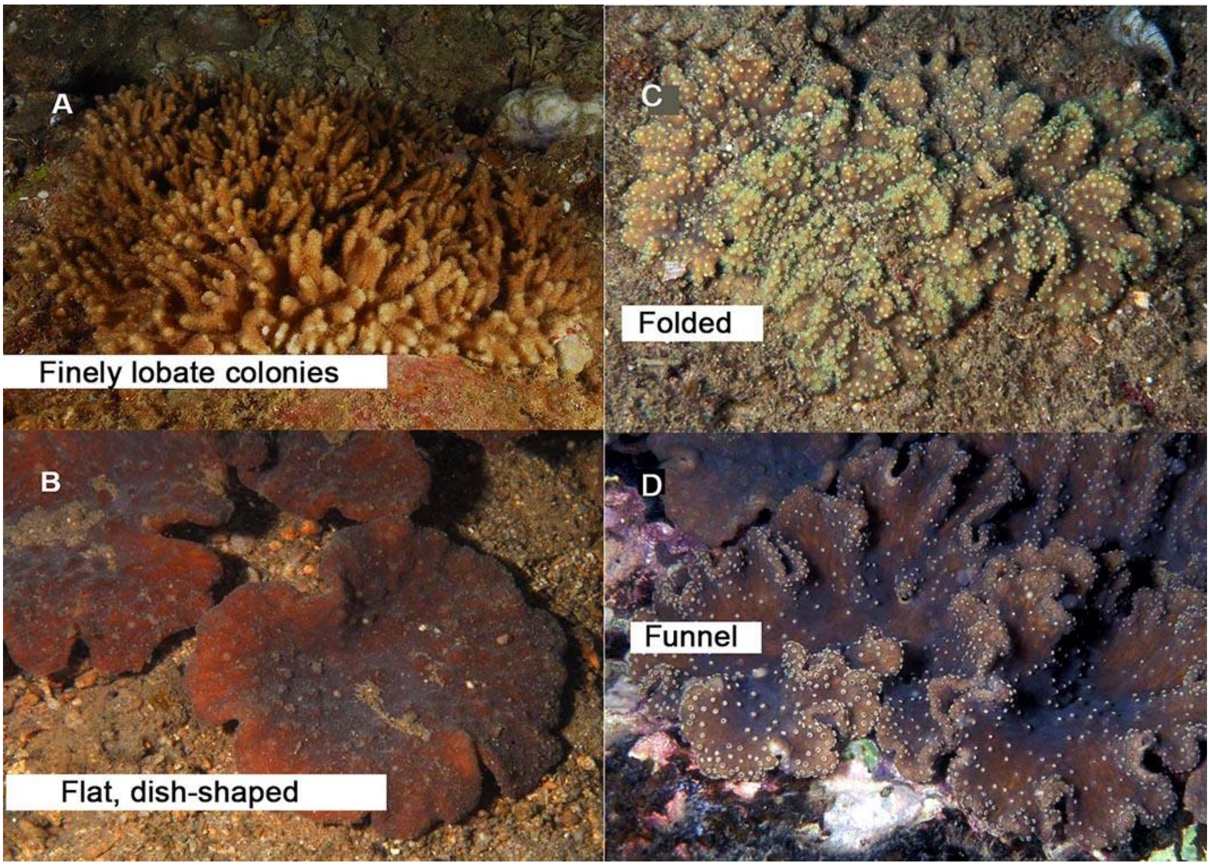


Fig. 40. Variations of the Sinularia brassica colony shape , Nha Trang Bay, South China Sea

A possible explanation for the variation in colony morphology could be that colonies adopt lobe production and a faster growth rate in response to an increase of available light (Benayahu *et al*. 1998). Awareness of such a variation requires examination of series of specimens from the entire distributional range of a given taxa. Not less intriguing is the possibility that part or a whole range of such variations could be the result of cross-fertilization within sibling species or hybridization.

Conclusion. Basing on the results of the processing of above listed collections made during the joint projects of the scientific Russian institutions institutions of VAST, and our own results obtained in the frame of the reporting project in the period 2015–2018 years, we suggest the Central of Vietnam (Nha Trang Bay in particular) can be assumed to play the role of "hot spot" of soft corals biodiversity in the South China Sea. At the same time, we note that the diversity of the region inside the Coral Triangle was poorly studied until today, especially – in the Philippines. After the detailed survey of the Octocorallia of this area, it could be found the more reach fauna of these animals in the eastern and central of Philippines. The establishment of interspecies boundaries requires a molecular/genetic approach along with the examination of a comprehensive specimen collection, which might reveal other possible boundaries than those based on morphological characters only (Benayahu et al. 1998; Fabricius & Alderslade 2001). For the competent tracing of the trends in the status of the stony corals and soft corals populations the joint efforts of the specialists in the coral taxonomy and ecology together with the analysis of the dispersal ways are needed. The possible dispersal ways by oceanic currents should be analyzed along with the genetic similarity of populations in order to learn how distribution ranges are generated and how they are maintained.

The comparison of the data obtained and those from previous literature showed a range of new findings in Nha Trang Bay. These findings are new records of the soft corals species and even genera as new for the Vietnam and north-western part of the South China Sea. Because of the more clear understanding of the contemporary diversity of Octocorallia in Vietnam can be obtained using the above mentioned approach, the perspective aims to develop the future investigations should be stated as:

1 the comparison of the soft corals diversity in ecologically differing coral reefs and regions of Vietnam (i.e. Nha Trang Bay and Gulf of Tonkin);

2 the gap-filling surveys of the diversity and population structure of soft coral in southernmost part of Vietnam waters;

3 the developing of the knowledge on the present biodiversity in Nha Trang Bay and nearest regions of the Central of Vietnam using morphology and genetic modern approaches to estimate the connectivity between the fauna of it and those of the Coral Triangle area.

3.5.7. Soft corals in Philippine's coral reef ecosystems and their ways of dispersal in SCS

The Philippine octocorals are poorly known and, since the early publication by Roxas (1933), there have been no further in-depth taxonomic studies on this fauna.

We have found here a very diverse fauna of soft corals, especially of mass genera – *Sinulari*a, *Sarcophyton* and *Lobopytu*m. The other mass genera of soft corals *Dendronephthya*, *Lemnalia*, different gorgonians also have been recorded here during the reporting period (Fig. 41).

Philippines *Sinularia* were poorly known, with only 7 reported species from the scarce publications (Ofwegen 2000). Nevertheless, the summarizing knowledge about the possible dispersal ways and barriers in Indo-West Pacific, i.e. currents and the areas of river discharge/low salinity in the western part of the Indo-Malayan region, show that the dispersion of the marine species may be directed from Coral Triangle into the Indian Ocean; the Java Sea and the SCS are likely the westernmost part of the border area between the Pacific and the Indian Oceans with very little input from the Indian Ocean (Hoeksema 2007 with a range of references discussed The substantial question is – what ways may be usable for species dispersal from Coral Triangle to periphery.

It is essentially to know how the local and regional marine ecosystems depend on each other for the interchange of organisms. 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 (Fig. 37 A). It can influence on the corals richness on the reefs of the central part of Vietnam as well as southern Taiwanese reefs.

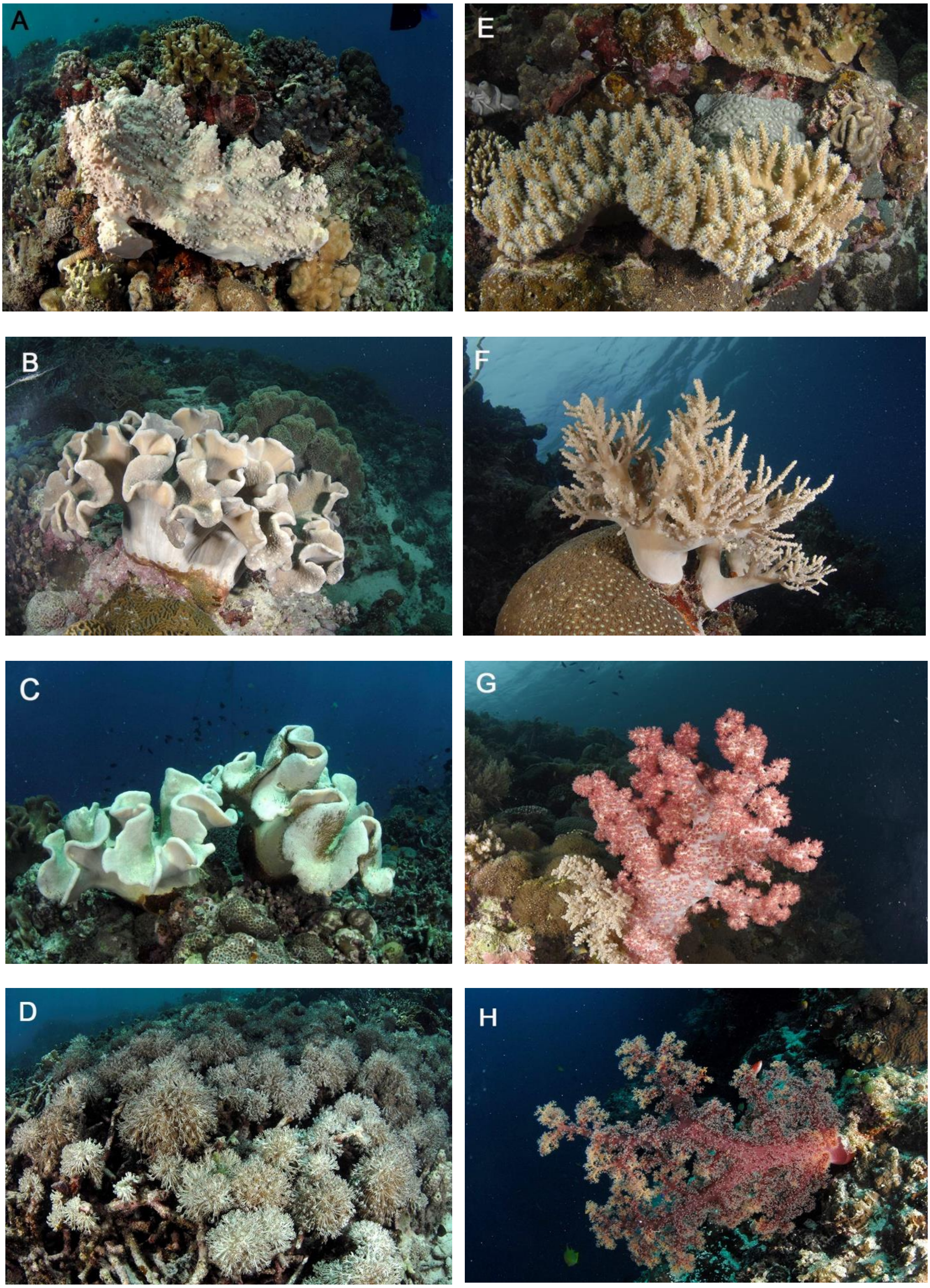


Fig. 41. Common soft corals recorded at the studied sites in Philippines, 2015–2017 : A – *Sinularia*; B, C – *Sarcophyton*; D – *Xenia*; E – *Lobophytum*; F – *Lemnalia*; G, H – *Dendronephthya*.

Really, the stony corals fauna of the reefs of Central Vietnam is quite rich and includes more than 65 genera and, moreover, the several species of the *Porites* genus which were firstly described from Philippines.

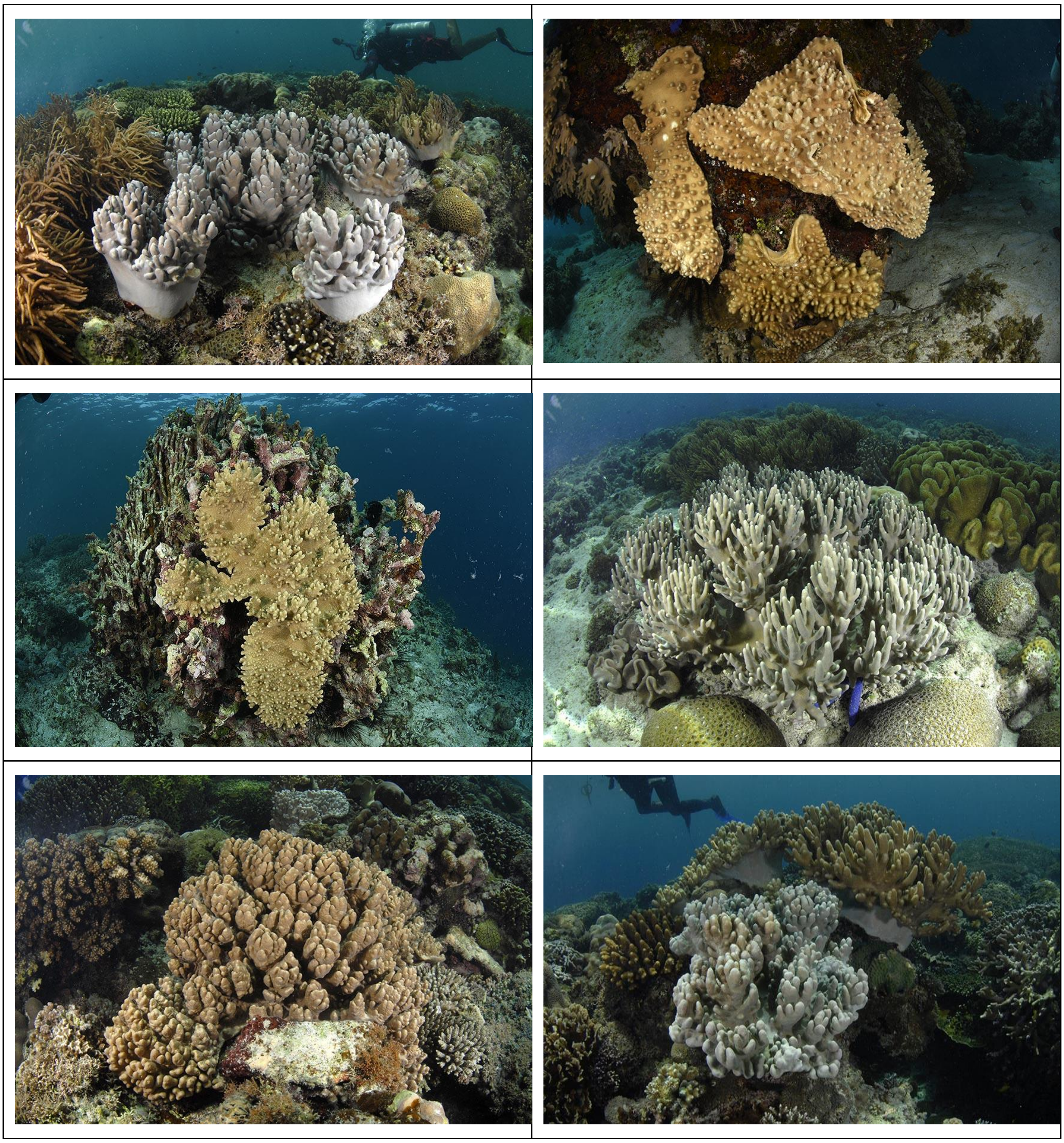


Fig. 42. Typical soft corals of the *Sinularia* genus recorded at the frame of the project 2015–2017 in Philippines area.

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. The reefs of the southern Taiwan contain 22 genera including *Sinularia* with not numerous species (Table 11). The coral reefs of Taiwan and Japan are closely linked by the northward flowing Kurioshio Current (Fijiwara et al. 2000). The soft coral fauna of both areas shows a close resemblance between their faunas in terms of generic composition and number of species (Table 11). The finding of *S. higai* and

Sarcophyton nanwanensis both from Japan and Taiwan anticipate that similar patterns also exist for other important soft coral genera (Benayahu et al. 2004).

Conducting the survey planned in the frame of the current project we studied the following regions of the Philippines Archipelago:

1. at the north – north-western coast of Luzon Island (Bolinao reef system);

2) in the central region – the Visayas area (north-western shore of Cebu Island, south shore reef of Mactan Island, reef around the Olango Island, reefs around the Panglao Island).

Basing on the relative sets of underwater photo–images (made in the reported period 2015–2017), we suggest that the Octocorallia fauna diversity of Philippines reach and includes at least 32 genera of Alcyonacea (Table 11).

We counted 47 species of the most important genus *Sinularia* (Fig. 42) on the reefs of the above listed regions of the archipelago (Fig. 37B). It is 7 times more in comparison with those published before (Stiasny, 1951).

The Chinese reefs (mainly on Hainan Island) at the northern part of the SCS, have links with reefs of Vietnam and the Spratly Archipelago. The geographic location of these reefs close to northern margin of Indo-Pacific coral reef centre of high biodiversity can allow the quite rich coral fauna existing, but there is lack of taxonomic capacity to confirm this. Studies are required to assess the possible important role of these reefs in global reef system. Only reefs around Hong Kong are significantly studied. Lam and Morton (2008) showed the full list of Hong Kong’s Octocorallia studied since the middle of the 19th century. Besides of the needed studying of some taxa, it is interesting to note the total absence of widely spreaded tropical zooxanthellate genera Sinularia and Sarcophyton along with presence/predominating of azooxanthellate genera, such as Eleutherobia, Paraminabea, Scleronephthya, and Dendronephthya.

Conclusion. It can be noted that the research of the Octocorallia species richness is substantially in the frame of the worldwide and local biodiversity problems. The soft corals (Cnidaria: Octocorallia) having the ability to occupy the significant bottom areas belong to the main components of the coral reef ecosystems of the tropics. The survey of the biodiversity of soft corals is needed for the monitoring purposes to solve the important problem of the tropical marine ecosystems – to predict the nearest future of the damaged and healthy coral reefs. However, the existing data about the species composition of the soft corals of South China Sea should be updated and their research should be developed to cover all types of habitats in the South China Sea. Solving of the complex problems of the taxonomy, genetic diversity and species-specific ecology is needed to trace the possible ways for the soft corals dispersal.

3.5.8. Dispersal ways of the Octocorallia in other Asian-Pacific areas and their important role in the vulnerable marine ecosystems

The vulnerable marine ecosystem (VME) concept emerged from discussions at the United Nations General Assembly (UNGA) and gained momentum after UNGA Resolution 61/105. The FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO DSF Guidelines) build on the resolution and provide details on the VME concept for fisheries management. VMEs are now firmly embedded in regimes for the management of deep-sea fisheries in the areas beyond national jurisdiction.

VMEs are groups of species, communities or habitats that may be vulnerable to impacts from fishing activities. The vulnerability of an ecosystem is related to the vulnerability of its constituent population, communities or habitats. Specific criteria are included in the FAO DSF Guidelines to assist States in defining VMEs and how to identify them.

Deep-sea fishing activities sometimes employ types of fishing gears that can, in the normal course of operation, come into contact with the sea floor. This can have a negative effect on both living marine resources and ecosystems and damage can occur, thereby increasing the physical vulnerability of the ecosystem. Another concern is overfishing and the resulting vulnerability of target stocks, associated species and habitats. Selective removal of a species may change the manner in which the ecosystem functions, making the ecosystem functionally vulnerable. Significant adverse impacts (SAIs) to an ecosystem can occur as a result of fishing activities. Once a VME has been designated and potential SAIs assessed, the FAO DSF Guidelines recommend specific conservation and management measures.

Various depth limits have been used to define what constitutes deep-sea fisheries. The Deep-sea Fisheries Guidelines do not define deep-sea fisheries, but characterize deep-sea fisheries as fisheries in which the total catch includes species that can only sustain low exploitation rates and where the gear is likely to contact the sea floor during the normal course of fishing.

FAO in a global review has included for review deep-sea fisheries that target demersal and benthic species and are likely to contact the sea floor during the course of the fishing operation. Fishing depth was not considered a major criterion, but the review generally included fisheries conducted below 200 metres on the continental shelf or isolated typographical features such as seamounts, ridge systems and banks.

There are no tropical taxa of Octocorallia distributed in East Asia seas outside the Japanese reefs. However, numerous Octocorallia occurred below 50 m depth (deep-water) deserve much interest as these possess quite interesting biodiversity data and provide the possibility to trace the ways of their dispersal in the temperate area of East Asian seas. Moreover, Octocorallia are appointed as indicative group for defining of the vulnerable marine ecosystems in all oceans, and in NW Pacific in particular (http://www.fao.org/in-action/vulnerable-marine-ecosystems/definitions/en).

Korea and Japan – boundary between tropical and temperate Octocorallia fauna in the East Asia region. The geographic location of the coral communities existing in Korean waters has produced coral fauna of special biogeographical interest. The tropical and the subtropical marine invertebrates are being distributed together with the temperate ones in the southern part of Cheju Island at south of Korea peninsula, as this place is directly being affected by the Kurioshio Current. As a result, 65% of total Korean Anthozoa species are encountered here including 40 species of gorgonians, 12 Alcyonacea and 4 Pennatulacea species. Approximately 20 soft coral species are being distributed downwards 45m deep in subtidal zones surrounding the island such as Munsom and Boemsom forming soft coral beds (Song 2001). The several species of *Dendronephthya* are presented here as well as “tropical” gorgonians *Menella, Ellisella* and *Acabaria,* but the temperature restricts here zooxanthellate soft corals, such as *Sinularia* or *Lobophytum.* From the other hand, the Tsuishima Current is directed across Korean/Tsusima Straight into the Sea of Japan during summer and winter seasons (Chen et al., 1994). It can limit the dispersal of many temperate Octocorallia to Yellow and East China Seas. By this reason seems to be the temperate gorgonian genus *Primnoa* is not found to the south of Jeodong, Dodong and Sadong Islands in the southern part of the Sea of Japan (Song, 1981).

The Octocorallia fauna of the Japanese waters (mainly Pacific coasts of the archipelago) has been studied in detail and has been recorded in a range of publications. Approximately 29 families (208 species) in the class Octocorallia have been found from the deep littoral to abyssal along the Pacific coast of the Japanese Archipelago (mainly in Sagami Bay and nearest areas) (Table 3). Among these, the Plexauridae and Primnoidae gorgonian families contain 31% of the species recorded, due to highly speciose *Muricella, Plumarella* and *Thouarella* genera (Imahara, 1996; Matsumoto et al., 2007). The high biodiversity of the octocoral fauna in this area can be explained by two factors – convergence of elements of temperate, sub-tropical, and sub-arctic regions and a possible benthic/pelagic transitional zone at 100–200 m depth range. The latter may result in a high degree of biodiversity due to both benthic-pelagic coupling and wide biogeographical extension of the Japanese waters (Matsumoto, 2005; Matsumoto et al., 2007).

Sea of Japan – only temperate Octocorallia fauna. Even though the Octocorallia has been the object of much scientific interest in the last decade, there are vast regions around the world where very little collecting of Alcyonacea and Pennatulacea has been done (Bayer, 1981a). The result is a very low number of published descriptions of species and a general lack of data on deep-water Octocorallia in such biogeographically important areas as the cold temperate Northwest Pacific – from the Sea of Japan to the Kamchatka coast. The scant taxonomic and faunistic literature for the region published before the 21th century includes relevant works by Balss (1909, 1910), Broch (1935), Naumov (1952), Nutting (1908, 1912), Hickson (1915), Kinoshita (1907, 1908), Kükenthal (1906, 1908, 1909, 1919) and Pasternak (1960, 1961, 1970). These focused on the collections made from the deep littoral to the bathyal (and abyssal) depth in that region with trawling as the sampling method.

For instance, the Sea of Japan is yet represented in the literature by no more than 60 recorded species, with few species from deep littoral to deep bathyal. More than 50 species of gorgonians were found by 1919 around the Japanese Archipelago, as reported by Kükenthal (1919). However, the report was based on materials collected only along the Pacific coasts of Japan, mostly in the Sagami, Misaki, and Suruga bays. Nutting (1912) reported finding 54 gorgonian species collected in Japanese waters in 1906, during an expedition aboard the Research Vessel “Albatross”. However, only three species from this collection were found in the Sea of Japan. Broch (1935) examined the materials collected by Deryugin and reported the species *Primnoa resedaeformis* (Gunnerus, 1763) from the northern Sea of Japan (now accepted as *P. pacifica* Kinoshita, 1907 (see Cairns and Bayer, 2005).

Song (1981) provided descriptions of two species of gorgonians found around Jeodong, Dodong, and Sadong islands in the Sea of Japan, to the south off the 38°N latitude, including *P. pacifica* Kinoshita, 1907, but without data on the depth of collecting. Summarizing the long-term studies of Anthozoa fauna in the Korean waters, Song (1981, 2000) noted that the known Korean Octocorallia fauna includes 50 species of Gorgonacea, 16 species of Alcyonacea and 11 Pennatulacea species, but did not mention their vertical distribution. Later, Dautova (2007) added four species to the known gorgonian fauna of the sea. Thus, altogether, the following deep-water species of gorgonians have been reported to date from the Sea of Japan: *Calcigorgia japonica* Dautova, 2007 (Acanthogorgiidae), *Melitodes dichotoma* (Pallas, 1766) (Melithaeidae), *Anthomuricea aberrans* Nutting, 1912, *Elasmogorgia filiformis* Wright and Studer, 1889 and *Euplexaura abietina* Kükenthal, 1908 (Plexauridae), *Thouarella superba* (Nutting, 1912) and *Primnoa pacifica* Kinoshita, 1907 (Primnoidae), *Paragorgia* sp. (Paragorgiidae) (Cairns and Bayer, 2005; Dautova, 2007; Nutting, 1912; Song, 1981).

Sea of Okhotsk and western part of Bering sea – does the temperate-water Center of the Octocorallia diversity exist ?

The composition and distribution of the Octocorallia fauna in the Sea of Okhotsk are also very poorly known. Broch (1935) reported on several gorgonians found at depths between 86 and 836 m in the Sea of Okhotsk and the Gulf of Tartary. These are *Calcigorgia spiculifera* Broch, 1935, *Euplexaura abietina* Kükenthal, 1908, *E. arbuscula* Broch, 1935, *Plumarella longispina* Kinoshita, 1908, *Calyptrophora ijimai* Kinoshita, 1908, *Radicipes verrilli* (Wright and Studer, 1889) and *Primnoa pacifica* Kinoshita, 1907. Broch also described soft corals found in the range 33–3500 m depth (Table 3). These are stoloniferous and Nephtheidae corals: *Clavularia armata* (Broch, 1935) from 3500 m depth, *C. rigida* Broch, 1935 from 1076 m depth, *C.* aff. *peterseni* Kükenthal, 1906 from 1643 m depth, *Sarcodictyon incrustans* (Broch, 1935) from 335 m depth, *Gersemia rubiformis* (Ehrenberg, 1834) and *G. fruticosa* Sars, 1860 from the range of depth 34–235 m. *Anthomastus rylovy* Naumov, 1952 has been recorded at 1430 m depth, to the south of the Shikotan Island of the Kuril

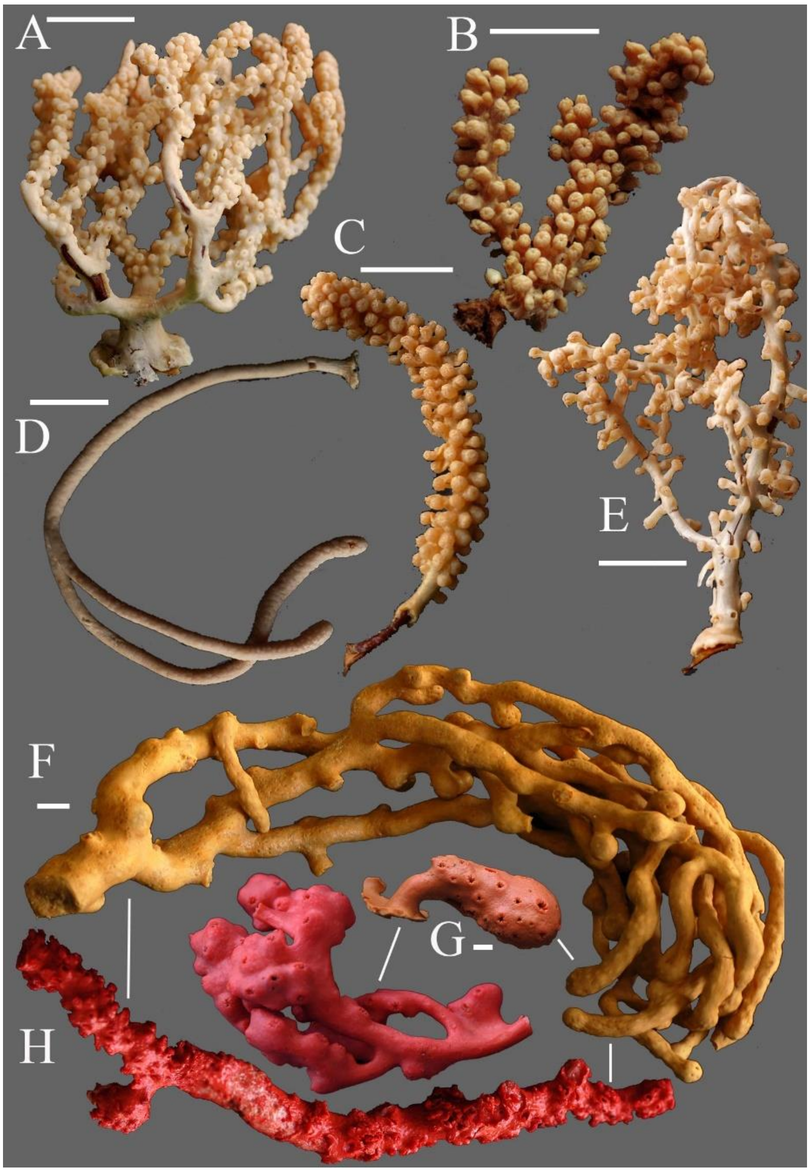


Fig. 43. Common gorgonians from the temperate waters of Asia-Pacific Region: A–E – five species of *Calcigorgia* (Kuril Islands, Sea of Okhotsk); F–H – specimens of the same species, *Paragorgia arborea* (Sakhalin Island, Sea of Okhotsk). Scales: 1 cm.

Islands (Naumov, 1952). The contemporary examination of the materials collected by institutions of the Russian Academy of Sciences in the second half of the 20th century, in progress, extended the above list by three new deep-water species collected in the range 140–900 m (one *Paragorgia* and two new *Calcigorgia* species, Dautova, 2012, 2018, Fig. 43). These findings indicate that the list of deep-water gorgonians and soft corals inhabiting the Sea of Okhotsk and Kuril Islands area is in its initial status and will undoubtedly be enlarged.

The ability to grow to rise above the substratum can be recognized as very beneficial for benthic organisms in the conditions of deep water. Among the soft corals recorded in the temperate Northwest Pacific, only Clavulariidae have been recorded deeper than 3000 m – *Clavularia armata* (Broch, 1935) recorded in the Sea of Okhotsk by Broch (1935), and *Clavularia* sp., the present study. It is possible that Clavulariidae have an advantage compared with Alcyoniidae because stoloniferous octocorals can successfully encrust any hard substrata, e.g. long spicules of hexactinellid sponges, allowing their vertical growth to lift them above the sediment deposited on deep benthic areas. This growth form may also improve food capture and assimilation during periods of sedimentation in the deep sea. Although Octocorallia are generally considered to require hard substrata for larval settlement, sea pens can generate erect colonies that are anchored in soft substrata. This capability allows them to occupy the soft bottom areas that are characteristic for the deep water ecosystems.

The comparison of the richness and structure of faunas shows similarities as well as some peculiar properties among the geographical/zoogeographical areas. Within the temperate waters of the Asia-Pacific, the deep-sea Octocorallia diversity demonstrates inter-regional similarities as follows:

a) everywhere Octocorallia are among the main habitat-forming components of macro-benthic communities as they provide structural habitats and attachment substrate for other benthic animals (Heifetz, 2002; Heifetz et al., 2005; Lundsten et al., 2009; Miyamoto et al., 2017; Stone and Shotwell, 2007).

b) gorgonians are the most common and diverse taxa with wide vertical distribution. Gorgonians occurred at high frequencies and appear to be among major components of macro-benthic communities in many of the studied localities in deep-water in the temperate NW Pacific.

At the same time, some differences should be noted between local deep-water faunas in the NW Pacific that are associated with their geographic position and the character of the bottom. The regional characteristics of the deep-sea coral community in the area of the southern Emperor Seamounts is more similar to that near the northern Hawaiian Islands and off California than those reported from Aleutian, Alaskan and Japanese waters. The Octocorallia from deep-water in areas near the Aleutian Islands, the North American west coast and NW Hawaii (north of the Cancer Tropic), is much better documented than the deep-water Octocorallia from the Sea of Japan, Sea of Okhotsk and Russian waters of the Bering Sea. The summarized data shows the remarkable role of gorgonians in the communities of both the American coast and Hawaii. With approximately 23 families in the class Octocorallia, listed by Cairns (2007, 2017), the Plexauridae and Primnoidae gorgonians contain 28% of the species recorded along the American coast and 46% recorded from NW Hawaii, possibly due to highly diverse *Narella* and *Plumarella* genera (Cairns and Hourigan 2017; Stone and Cairns 2017). In the northern Hawaiian Islands, gorgonians in general are considered among the main components of the cold-water coral fauna whereas Pennatulacea occur at low frequently (Parrish and Baco, 2007).

The remarkable temperate gorgonian genus – *Calcigorgia* – has the very wide range from the Sea of Japan to Alaskan waters. This genus can indicate the possible dispersal way for temperate Octocorallia in the region. Two Calcigorgia species including *C. spiculifera* are occurred in Aleutian Islands area where Octocorallia fauna was studied at 2000 stations (Fig. 44). However, the list of gorgonians of Kurile Islands is richer because of includes five new *Calcigorgia* species in addition to *C. spiculifera* (Fig. 43, Dautova, 2018, the paper supported by the project). The waters of the Oyashio Current form probably the richest fishery in the world owing to the extremely high nutrient content of the cold water. This current circulating counterclockwise in the western North Pacific by Kurile Islands had the intrusion into the Japan Sea across the Tsugaru Strait during the Holocene history (Takei et al. 2002). Does the centre of temperate coral diversity take place in North Pacific as the source of dispersal? It can be the promicing subject of the future investigations using model taxa which are well revised equally with molecular and paleooceanography data.

The contemporary development of sampling methods promises to enlarge knowledge of the deep-sea Octocorallia. Before the present study, twenty five valid Octocorallia species were known from

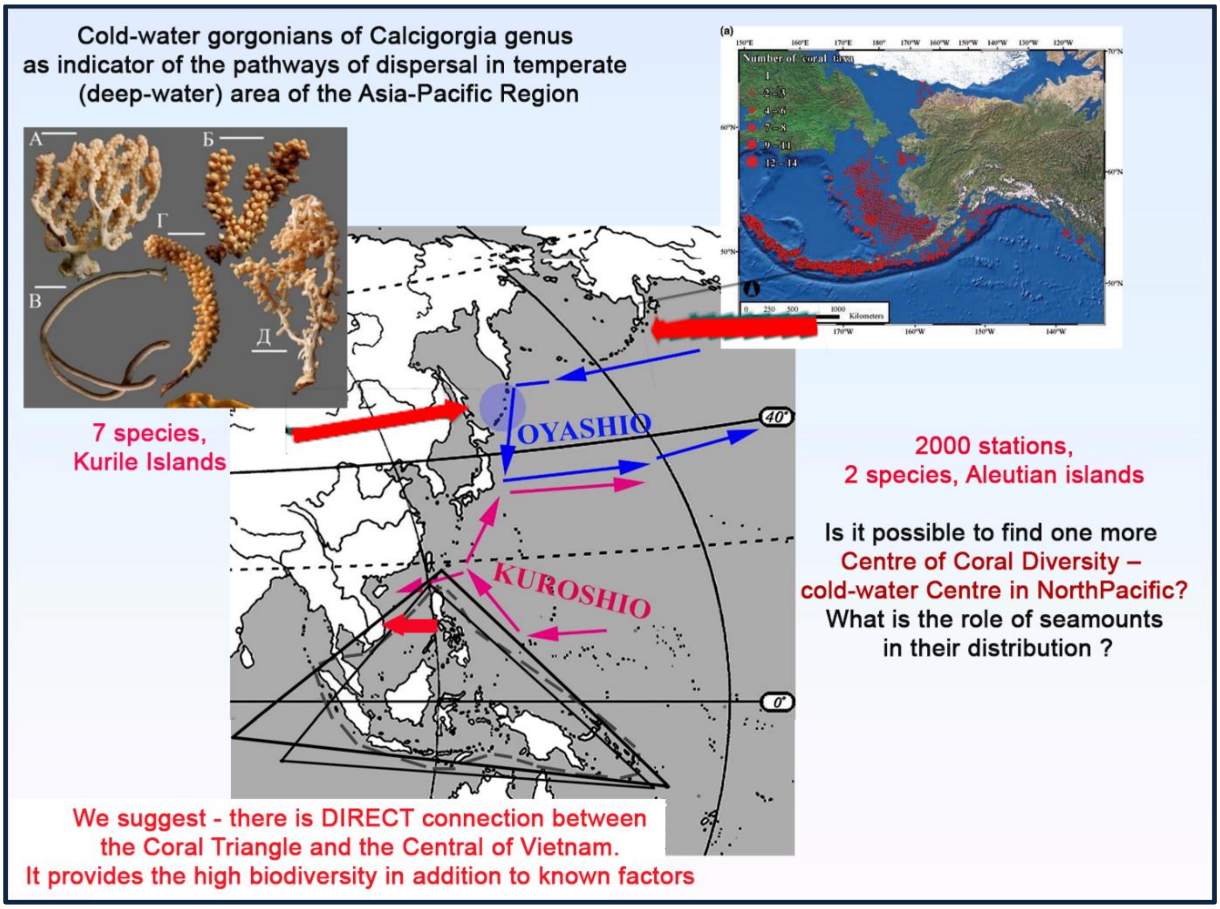


Fig. 44. The outline of the possible pathway of Octocorallia dispersal in the whole region of East Asia seas and adjacent areas.

the Sea of Okhotsk. The present study records 7 founded species, of which three are represented by fewer than five specimens (*Ignis rubeus*, sp. nov., *Halipteris* sp., *Pennatula* sp.), four are represented by 15 to 30 specimens (*Clavularia* sp., *Aspera rosea* sp. nov., *Radicipes sakhalinensis* sp. nov. and *Umbellula* sp.).

Expedition material from SokhoBio 2015 also contains additional species that are insufficiently represented, and which are not described here, with description pending collection of additional morphological or molecular material. Thus, the number of valid deep-water species known from the Sea of Okhotsk is enlarged to 28. However, it is obvious that sampling in the area remains patchy. Undoubtedly, additional species and significant range extensions remain to be discovered and documented with increased exploration in the NW Pacific, especially in the Sea of Okhotsk, the Kuril Islands area and the Kamchatka coasts.

Conclusion. Summarized data on the deep-water Octocorallia distribution now indicate 12 families in the temperate Asia-Pacific waters below 50 m depth (without the record of Melithaeidae off Yakushima Island). All these families are present in both the temperate waters of Asia-Pacific Region (from the Korean waters to the Commander Islands, Bering Sea) and the temperate NE Pacific (from the Alaskan waters to the California coast). This distribution suggests general affinity of the Octocorallia fauna of both regions and, consequently, the prospect of further discoveries from continuing research on deep-water corals in the temperate NW Pacific. However, exploration of deep-water coral fauna in the vulnerable marine ecosystems in NW Pacific, particularly in the Kuril Islands area and the Sea of Okhotsk, along with the Kamchatka Peninsula, can enlarge the database before characteristics of the regional fauna are formulated and its biogeography and the structure of the communities are analyzed.

3.5.9. New markers for echinoderms chemotaxonomy and its Relevance to Biodiversity

Natural compounds continue to provide a diverse and unique source of bioactive lead compounds for drug discovery, but maintaining their continued eminence as source compounds is challenging in the face of the changing nature of biodiversity prospecting brought about by the Convention of Biodiversity. The CBD is an international treaty with the threefold goals of biodiversity conservation, sustainable use of biodiversity, and equitable sharing of benefits from the use of genetic resources. It is a complex and broad-reaching treaty, with provisions covering technical and scientific cooperation, education, impact assessment, technology transfer, and many other related subjects. The basic objectives of the CBD are to promote sustainable use of biodiversity as well as conservation and benefit sharing. Three objectives which are interrelated - "Each Contracting Party shall take legislative, administrative or policy measures, as appropriate….with the aim of sharing in a fair and equitable way the results of research and development and the benefits arising from the commercial and other utilization of genetic resources with the Contracting Party providing such resources. Such sharing shall be upon mutually agreed terms." (Art. 15.7 of the Convention).

These access and benefit-sharing provisions represent an attempt to enhance equity across countries and to provide the means and incentives to use and conserve biodiversity, and they made a way forward for biodiversity-rich countries to reap potential financial benefits from the use of their biodiversity. The future viability of the natural products approach to drug discovery from plants and marine macroorganisms depends not only on continued access to biodiversity through the CBD and agreements derived therefrom, but also on using these bioresources as strategically and efficiently as possible. The ratification of the Convention on Biological Diversity (CBD) marked a turning point in the search for drugs from natural sources. Before the CBD individuals and companies were free to collect and evaluate plant, marine, and microbial sources from around the world as potential drug sources (Kingston 2011).

Marine natural products (MNPs) are acknowledged as the "blue gold," as they hold a vast reservoir of promising leads for drug development. There is still a vast fraction of marine biodiversity yet to be screened, as well as regions in the world's oceans that remain poorly explored.

Fast developing countries are going to continue bioprospecting for the non-destructive commercial use of their biodiversity. For it two key conditions need to be met: 1) it is essential that the search for new drugs from Nature is pursued in a vigorous and enlightened way, using the best available methods and 2) it is important that source countries provide access to their genetic resources in a fair and transparent way, with clear and stable provisions, so that scientists have the assurance that they will have reliable access to the desired biodiversity basing on the CBD points (Kingston 2011). Countries that do adopt such regulations will be in a position to benefit from biodiversity prospecting and all the fringe benefits associated with it.

Some marine animal species that are currently at risk have been shown to be valuable medical models offering windows for greater understanding of human physiology and biochemistry which may lead to successful treatments of diseases that are at present incurable.

The triterpene glycosides from sea cucumbers (class Holothurioidea) have a long history of investigation. These marine natural products are characterized by significant structural diversity (Stonik et al. 1999; Kalinin et al. 2005). Their taxonomic specificity enables their use in resolving some systematic ambiguities (Kalinin et al. 2016). Triterpene glycosides of holothurians (Holothurioidea, Echinodermata) are traditionally used in the systematics of these animals as markers of species, genera, and groups of genera (Kalinin et al., 2015). These substances usually possess a strong membranolytic activity and exhibit a wide spectrum of biological effects, including antifungal effects, cytotoxicity against tumor cells, haemolytic activity, and ichthyotoxicity (Kalinin et al., 2008). Additionally, the triterpene glycosides exhibit a wide spectrum of biological activities, including anticancer effects against different cancer cell lines.

After the processing of regenerative gut and other discarded internal organs of the sea cucumber *Colochirus robustus* (Cucumariidae, Dendrochirotida), the unusual non-holostane triterpene glycoside, colochiroside E was isolated from specimens inhabiting central of Vietnam.

Triterpene glycosides from sea cucumbers are of interest for their structure diversity and biological activities. The presence of so unusual and a rare aglycone in the glycosides of

C. robustus and *P. fabricii*, representatives of two different families of the order Dendrochirotida, namely Cucumariidae and Psolidae, clearly reveals the parallel character of the evolution of triterpene glycosides in different taxonomic groups of sea cucumbers (Kalinin et al. 2016).

Nine new sulfated triterpene glycosides, magnumosides as have been isolated from the tropical Indo-West Pacific sea cucumber *Neothynidium (=Massinium) magnum* (Phyllophoridae, Dendrochirotida) collected in the Vietnamese shallow waters. All the isolated new glycosides were characterized by the non-holostane type lanostane aglycones having 18(16)-lactone and 7(8)-double bond and differed from each other by the side chains and carbohydrate moieties structures. Magnumosides of the group A (1–4) contained disaccharide monosulfated carbohydrate moieties, of the group B (5, 6)—tetrasaccharide monosulfated carbohydrate moieties and, finally, of the group C (7–9)—tetrasaccharide disulfated carbohydrate moieties. The cytotoxic activities of the compounds 1–9 against mouse spleen lymphocytes, the ascites form of mouse Ehrlich carcinoma cells, human colorectal carcinoma DLD-1 cells as well as their hemolytic effects have been studied. Interestingly, the erythrocytes were more sensitive to the glycosides action than spleenocytes and cancer cells tested. Modern mass spectrometric and chromatographymass spectrometric methods make possible elucidation of the qualitative and quantitative composition of triterpene glycosides in the organs and tissues of holothurians and in the seawater that surrounds the animals. Importantly, the isolation of pure glycosides is not necessary and this provides unique opportunities for research into the biological role of triterpene glycosides and various functions of these compounds as dependent on their chemical structure (Kalinin et al. 2016).

Conclusion. Marine natural products are acknowledged as the “blue gold,” as they hold a vast reservoir of promising leads for drug development. There is still a vast fraction of marine biodiversity yet to be screened, as well as regions in the world's oceans that remain poorly explored. Chemotaxonomy and chemodiversity oriented research also are fast developing areas of research. As the above mentioned findings in the frame of the project have been made first time, our results suggest that the bioprospecting and chemotaxonomy research is of promising potential for the SCS and adjacent seas of the region.

3.6. Reproductive capabilities and potential of key groups of marine organisms in Nha Trang bay, Central of Vietnam

3.6.1. Coral reproduction in the natural ecosystems can be performed via the sexually derived coral propagules and, also, using the asexual reproduction by fragmentation of their colonies.

Reproduction capabilities of soft and stony corals in Vietnam waters 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).

Surveys carried out in some selected areas of central and southern Vietnam (Tixier-Durivault 1970, Nguyen Huy Yet 1994, 1996, Dautova and Savinkin 2009, Dautova and Ofwegen 2010) show the quite high level of generic diversity of soft corals. However, up to date, information sources on the soft corals reproduction for the region are scarce.

Soft and stony corals belong to the very few organisms in the World Ocean which are capable of reproducing both sexually and asexually. Cloning by somatic division, i.e., budding, fission or fragmentation, occurs among a wide variety of anthozoans, including octocorals. Studies to date indicate that asexual reproduction in octocorals is most common among tropical soft corals, especially in the families Alcyoniidae, Clavulariidae, Nephtheidae, and Xeniidae. Octocorals exhibit a particularly large range of mechanisms of clonal propagation (Lasker 1988). The species capable of this reproduction strategy often exhibit high local abundances and an ability to rapidly recover following disturbance (Highsmith 1982, Dahan and Benayahu 1997). The nature of sexual reproduction among corals varies by species. In most Octocorals and Scleractinians, male and female reproductive organs (gonads) are in separate male and female colonies.

By our data, in stony corals of Nha Trang Bay, the well developed gonads (= i.e. visible under stereo-microscope, magnification x16) were founded only in *Hydnophora* (Scleractinia: Merulinidae) in the period 16 April–12 May. The gonads were shaped as bright-rose spheres 0.3–0.5 mm in diameter. Other mass stony corals, such as *Acropora* spp., *Porites lobata, Porites cylindrica, Pocillopora verrucosa, Pocillopora woodjonesi* had no visible gonads through all the period of our field trips.

The processing of the museum collections of the soft corals keeping in the Museum of the Institute of Marine Biology FEB RAS showed the visibly developed gonads in soft corals collected in the Central of Vietnam during the 2014–2015 years, in the representatives of the following taxa (Table 8):

Table 12. Data of the Octocorallia reproduction observed in the April–May 2015–2017, Nha Trang Bay and Ninh Thuan coral reefs, South China Sea.

Octocorallia taxa checked:		Presence of gonads visible	Occurrence of stolons	Budding	Time of collecting, 2015–2017 years
Family	Genus				
Helioporidae Moseley, 1876	*Heliopora* Blainville, 1830	+		+	18 May – 01 June
Clavulariidae Hickson, 1894	*Cervera* Lopez-Gonzalez, et al. 1995	-			10 May - 11 July
	Carijoa Müller, 1867	-	+		10 May - 11 July
Alcyoniidae Lamouroux, 1812	*Klyxum* Alderslade, 2000	-			10 May – 11 July
	Paraminabea Williams & Alderslade, 1999	+	+	–	10 May – 11 July
	Sarcophyton Lesson, 1834	+	+	+	10 May – 11 July

	Sinularia May, 1898	–	+	+	10 May – 11 July
	Lobophytum Marenzeller, 1886	–	+	+	10 May – 11 July
	Dendronephthya Kükenthal, 1905	+	–	+	
	Lemnalia Gray, 1868		+	+	
	Nephtea Audouin, 1826		+	+	
	Paralemnalia Kükenthal, 1913		+	+	
	Scleronephthya Studer, 1887		–	+	
	Chironephthya Studer, 1887		–	+	
	Heteroxenia Kölliker, 1874			+	
	Efflatounaria Gohar, 1939		+	+	
	Xenia Lamarck, 1816	–	?	+	
	Briareum Blainville, 1830	–	–	+	

The seasonality of reproduction may depend on the geographical location of the soft coral population. Thus, the reproductive season of soft corals in the Red Sea occurs over extended periods and this may lead to temporal reproductive isolation among alcyonaceans (Benayahu 1997). However, in contrast, alcyonaceans in the Great Barrier Reef spawn in multispecific spawning episodes (Aliño and Coll 1989). The mode of reproduction is almost identical within a given genus, except for the genus Alcyonium in which there are both brooding and broadcasting species (Benayahu et al. 1990, McFadden Hochberg 2003). However, the geographic variation in reproductive timing even can be expected in the same species as it was shown for Lobophytum pauciflorum from southern Taiwan and the Great Barrier Reef (Fun et al. 2005).

At this time it is unclear to what degree reproductive strategies in octocorals are influenced by the surrounding environment or is dictated by genetic constraints; however, it is likely that both brooding and broadcast spawning may each confer certain reproductive advantages, especially in different environments.

Cloning by somatic division, i.e., budding, fission or fragmentation, occurs among a wide variety of anthozoans, including octocorals. Studies to date indicate that asexual reproduction in

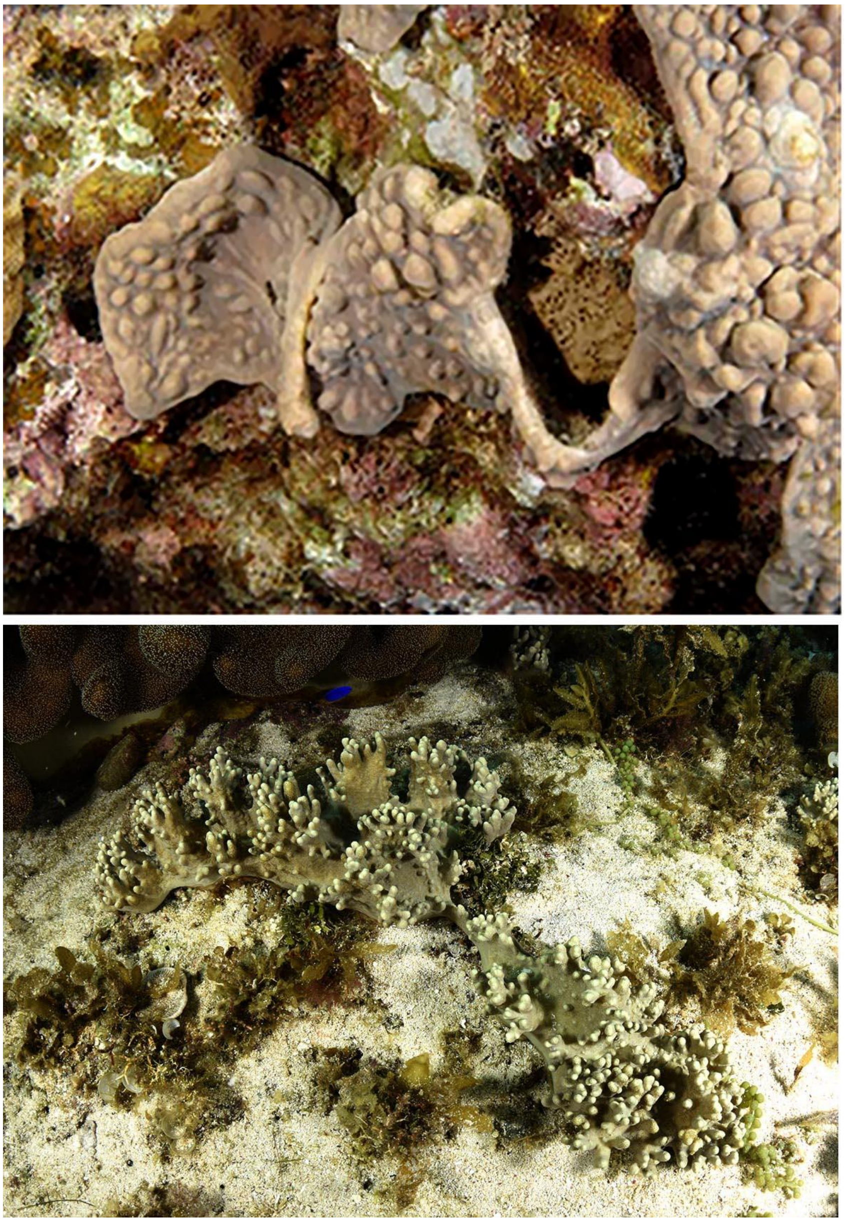


Fig. 18. From the above – *Sinularia exilis* expanding by stolons, Hon Mun Island (Vietnam), 6 m depth. From the below – *Sinularia cruciata* expanding by stolon, Cebu Island (Philippines), 3 m depth.

octocorals is most common among tropical soft corals, especially in the families Alcyoniidae, Clavulariidae, Nephtheidae, and Xeniidae. Octocorals exhibit a particularly large range of mechanisms of clonal propagation (Laske 1988). Among the described mechanisms, for example, budding of daughter colonies is found in *Sarcophyton gemmatum* (Verseveldt and Benayahu 1978), colony fission in *Xenia macrospiculata* (Benayahu and Loya 1985), autotomy of small–sized fragments in *Dendronephthya hemprichi* (Dahan and Benayahu 1997), and the generation of new colonies by stolons in *Efflatounaria* sp. (Lasker 1988). There is evidence that asexual propagation, via vegetative growth, allows for high population growth rates due to the rapid colonization of substrate (Benayahu and Loya 1987). The species capable of this reproduction strategy often exhibit high local abundances and an ability to rapidly recover following disturbance (Highsmith 1982, Dahan and Benayahu 1997). Soft corals (Octocorallia, Alcyonacea) tend to form large monospecific aggregations on coral reefs, composed of numerous colonies and most probably derived by asexual processes (Fig. 18).

Conclusion. Our preliminary data shows the occurrence of the generation of new colonies by different ways of asexual reproduction in the following Octocorallia taxa in Nha Trang Bay (Table 8). Because of the exact data about the contemporary diversity and reproduction modes of Octocorallia in Vietnam could be obtained using the above mentioned approach, the perspective way to develop the future investigations could be:

1. The whole-year monitoring of the reproduction in soft corals to clear the questions of the spawning timing and the cloning capabilities in the different species.

2. The monitoring of the balance between the sexual reproduction and asexual clonal propagation in the soft and stony corals populations is urgently needed to predict and explain the future shift in the biodiversity in the region.

3.6.2. Asexual reproduction in Echinoderms

Asexual reproduction is the most ancient mode of reproduction and is observed in representatives of all phyla of modern Metazoa (Engelstaedter 2008, Ivanova-Kazas, 1977). Because asexual reproduction is closely related to the structure of an animal, its types are as diverse as the animals themselves (Brien 1968). The variety of manifestations of this phenomenon is even greater because asexual reproduction in different species has different biological functions, such as population growth, regulation of body size, colonization of new sites, and survival under adverse conditions. The evolution of multicellular organisms has apparently passed through repeated losses and restorations of various forms of asexual reproduction (Ivanova-Kazas, 1977). Among modern groups of asexually reproducing invertebrates, holothurians deserve special consideration because of their commercial value.

Asexual reproduction occurs in four of the five classes of echinoderms: Asteroidea (sea stars), Ophiuroidea (brittle stars), Echinoidea (sea urchins), and Holothuroidea (holothurians, or sea cucumbers). This type of reproduction can be realized in various ways, including through transverse division (fission), autotomy, parthenogenesis, polyembryony, and budding (Emson and Wilkie 1980, Mladenov 1996). Asexual reproduction has been described in more than 80 species of Echinodermata (Mladenov 1996, Dolmatov 2014a). The most widely observed manner in which it occurs is via fission, which occurs in representatives of the Asteroidea, Ophiuroidea, and Holothuroidea.

Among echinoderms, asexual reproduction has been studied most actively in holothurians, as these animals are of great practical value. Approximately 66 holothurian species are commonly exploited in several regions throughout the world (Conand 2008, Purcell 2010, Uthicke et al. 2010, Purcell et al. 2012). People in these regions consider these species not only as a traditional food product but also as a commercial resource (Taquet et al. 2011). Fission has been shown to be a determining factor in the maintenance of populations of these animals (Uthicke 2001, Thorne et al. 2012). The population dynamics of fissiparous species are being studied actively at present (Conand 1996, Uthicke 2001, Conand 2008, Lee et al. 2008, Thorne et al. 2012). Furthermore, attempts are being made to artificially induce asexual reproduction (Reichenbach and Holloway 1995, Reichenbach et al. 1996, Purwati and Dwiono 2005, Laxminarayana 2006, Razek et al. 2007).

Asexual reproduction in adult holothurians occurs as transverse fission (architomy) and fragmentation. The most detailed description of the fission process is that by Monticelli (1896) who differentiated three fission mechanisms in *O. planci*: by constriction, twisting, or stretching. An analysis of the available fission data on holothurians shows that various holothurian species use different combinations of the methods described by Monticelli (1896). Most holothurians, in which the fission process was observed, began by forming a constriction. Division into fragments proceeds either by the development and deepening of the constriction (Conand et al. 1997) or as a result of stretching and twisting at the fission site. Usually the posterior sections of the body are attached to a substrate by the tube feet whereas the anterior regions move forward or twist (Fig. 46) (Dolmatov et al. 2012; Uthicke 2001). The closure of the wound resulting from fission has not been described but probably results from contraction of circular muscles in the body wall.

However, the available data on the asexual reproduction and post-fission regeneration of internal organs of the sea cucumbers in South China Sea are scant, and they do not provide both a population ecology of this process and time data (seasonal) data of these processes. It has recently been shown that the holothurian *Cladolabes schmeltzii* is capable of asexual reproduction through transverse division (Dolmatov et al. 2012).

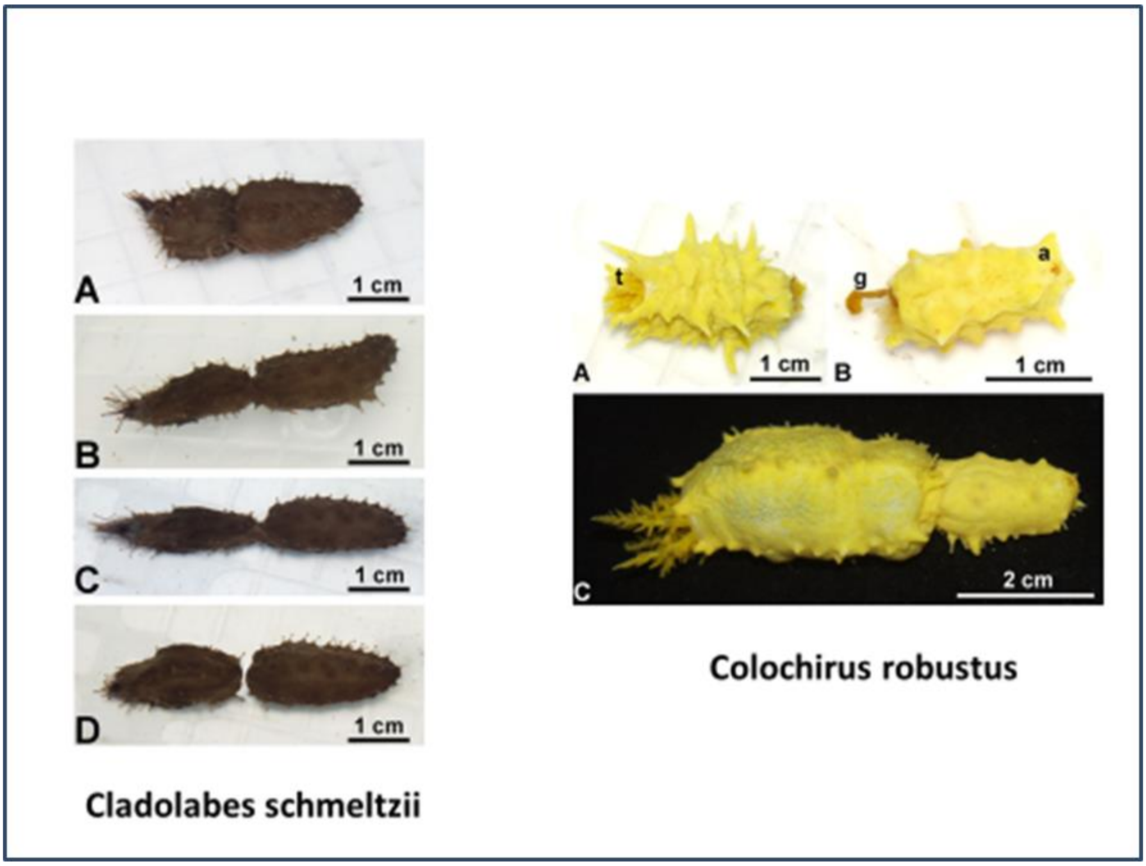


Fig. 46. Stages of fission of the two species of the sea cucumbers from Nha Trang Bay in experiments. Nha Trang, Institute of Oceanography VAST, 2013.

We studied our field data collected in the period 2014–2017 years to find the time and seasonal data of the occurrence of the fission of these animals in Nha Trang Bay. By our data, this type of reproduction was occurred in the natural populations in the bay during spring season 27% of the collected holothurians were regenerating after fission (Fig. 47). Anterior and posterior fragments were regenerating lost body parts, along with normal individuals, were found in each samples set. The fission rate in various samples sets varied sufficiently. The highest fission rate was observed in 2014–2015, with the mean F value amounting to 45.4±2.8%.

Fig. 47. Fission of the *Stychopus* holothurian in natural population. Nha Trang Bay (South China sea), Tam Island, 8 m depth.

The evaluation of fission and regeneration rates is usually based on the external morphology of the holothurians, particularly on the presence of the growing anterior or posterior end of the body. In this case, all animals which do not show a distinct outgrowth at the fission site are combined into one group and consider as recently divided individuals. These holothurians are targeted for the used for the fission intensity assessment in natural populations in the frame of the project to know more on their asexual reproduction capability in the Nha Trang Bay.

The duration of the process varies from a few minutes, as in Stichopus chloronotus (Uthicke 2001), to 1–5 days, as in H. surinamensis and *Cladolabes schmeltzii* (Dolmatov et al. 2012; Crozier, W. J. (1917). The duration of fission most likely depends on the intensity of the transformation of the extracellular matrix of the body wall. For example, the body wall in *S. chloronotus* can quickly soften (J. Lawrence, pers. comm.). Unlike other holothurians, the stimulation of autotomy with potassium chloride in this species causes a rapid softening and rupture of the body wall over a large area and the organs are expelled through the large opening that is formed (Dolmatov et al. 2012).

The location of the constriction is apparently a species-specific characteristic. In most of the studied holothurian species, fission occurs approximately across the middle of the body (Dolmatov 2014, with a review). In *Holothuria atra*, the body is divided into two fragments with an anterior : posterior length ratio of 4 : 5. According to Conand et al. (1997), the location of constriction in *H. leucospilota* is shifted toward the anterior end, and the length of the anterior fragments constitutes approximately 19% of the total body length. In *Colochirus robustus*, the ratio of the divided body sections is 2 : 1; that is, the anterior fragment is twice as long as the posterior fragment (Fig. 46).

Some holothurian species can fragment into several sections of the body simultaneously. This has long been known for species as *Oshimella lactea* and *O. planci*, as described by Dalyell (1851, cited by

Monticelli (1896). The repeated division into fragments, which do not completely regenerate the lost section, a process similar to fragmentation, occurs in the aspidochirotid Holothuria parvula (Emson, Mladenov 1987) and we have found the same in the dendrochirotid *Cladolabes schmeltzii* from Nha Trang bay (South China Sea) (Dolmatov, 2014).

Some internal organs of holothurians such as gut and longitudinal muscle bands (along with body wall) are ruptured during fission. This process is facilitated by muscle contraction. Change in the organs appears to begin from the disruption of the coelomic epithelium. Then the connective tissue is infiltrated by coelomic fluid. It is proposed that the coelomic fluid of holothurians contains evisceration factor which affects connective tissue provoking loss of its tensility (Byrne 1986).

A similar mechanism that alters the connective tissue stiffness of the dermis may also operate during asexual reproduction of holothurians. During fission, a local softening of the dermis because of matrix metalloproteinases activity occurs at a certain site along the anterior-posterior axis of holothurians. This process might be accompanied by contractions of the radial muscles in the body wall, producing additional tensile. A prolonged local effect on the dermis would cause even greater softening, and a constriction in the body wall would be formed. Additional twisting or stretching body movements would accelerate fission. The difference in fission duration between various fissiparous species is most likely determined by differences in extracellular matrix properties and matrix metalloproteinases, tissue inhibitors of metalloproteinases, and other enzymatic activities (Dolmatov 2014).

Regeneration of the internal organs after fission has been described in varying degrees of details for several holothurian species including *C. schmeltzii* (Dolmatov 2014). All descriptions are based only on analyses of fragments collected in nature, and, thus, the duration of regeneration remains unknown. All data assume that the regeneration of the internal organs after fission is similar in all holothurians, at least at the macromorphological level. In general, regeneration of the internal organs after fission in C. schmeltzii is similar to regeneration of these structures after evisceration or artificial damage. Transformation of the remaining sections of organs plays a major role in restoration. The main mechanisms are dedifferentiation and the relocation of epithelial layers (epithelial morphogenesis) (Dolmatov 2014, Kamenev Dolmatov 2016).

Growth of the body begins when the internal organs are formed. Initial signs of regeneration appear at this stage in most holothurians. At the fission site, the dermis is depigmented and a protuberance forms. The growth duration of the body varies broadly and apparently depends on the species. In C. schmeltzii individuals, which were most likely caught soon after fission and did not have visual signs of growth at the end, a 2–3 mm long outgrowth (10–15% of body length) formed within 25 days when the animals were maintained under artificial conditions (Dolmatov, unpublished data). In S. chloronotus, growth of the external region to normal size required up to one month (Conand et al 2002). According to Jaquemet et al. (1999) the regeneration of *H. atra* after fission took about six months.

The intensity of asexual reproduction varies greatly between populations of the same holothurian species (Conand et al 2002). This indicates that the environment plays a major role in triggering and regulating fission. The factors that influence asexual reproduction in holothurian larvae are unknown. Nevertheless, there are experimental data on other echinoderms that serve as the basis for two proposed mechanisms for the stimulation of asexual reproduction. Most likely, the larvae that were under the most suitable habitat conditions were stimulated to asexually reproduce. Growth in a number of individuals living under optimum conditions apparently increases the probability of successful development, metamorphosis, and reaching the juvenile stage that eventually results in the growth of population size.

In adult holothurians, the main factors that influence the asexual reproduction rate are low environmental stability, high mortality, small individual body size, and low sexual reproductive activity (Dolmatov 2014 with a review). Emson and Wilkie (1980) noted that many fissiparous brittle star species inhabit intertidal or shallow waters. In this environment, brittle stars are exposed to greatly varying environmental factors that may trigger asexual reproduction. In *Colochirus robustus*, fission is most likely stimulated by stress when they are maintained under unsuitable conditions.

Internal mechanisms – a case with *Cladolabes* from Nha Trang Bay, South China sea C. schmeltzii specimens were collected in Nha Trang Bay, South China Sea (Dolmatov et al., 2012). For the study, animals regenerating the anterior parts of the body after fission were selected. These individuals lacked tentacles and had a well–developed anal orifice at the posterior end. The holothurians were dissected along the right interradius, and sorted into groups according to the degree of development of their internal organs and corresponding to several regeneration stages (see details on a cellular processes in a paper, supported by the present project, by Dolmatov Kamenev, 2016).

In asexual reproduction, *C. schmeltzii* divides by fission into two nearly equal parts (Fig. 48a) (Dolmatov et al., 2012). Following fission, the posterior portion of the digestive tube, cloaca, and respiratory trees remain in the posterior part of the body, as does a fragment of the intestine corresponding to the transition from the first descending to the ascending part of the intestine in some cases (Fig. 48 b). This blind fragment of the intestine is probably then destroyed in the body cavity.

Regeneration of the internal organs consists in formation of the AB and the anterior portion of the digestive system.

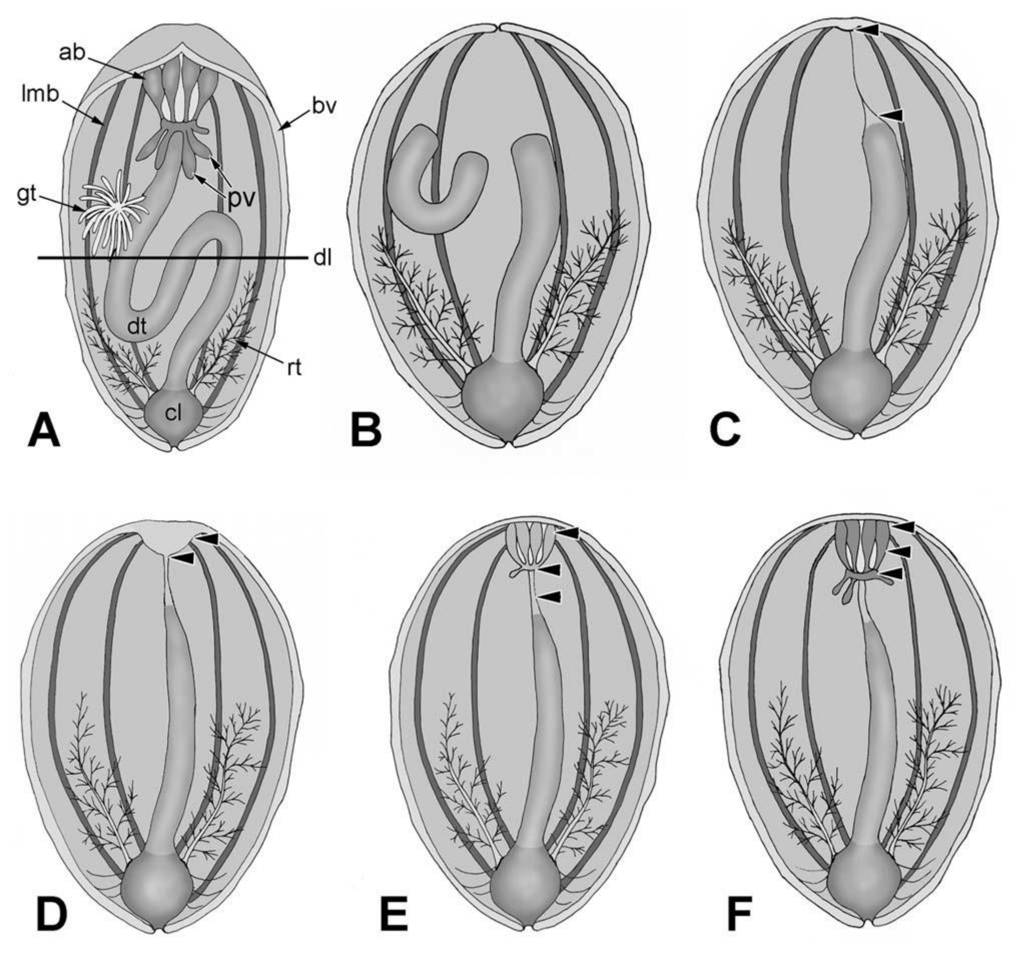


Fig 48. Scheme of the consecutive stages of the regeneration of the anterior portion of the body in the holothurian Cladolabes schmeltzii following fission. (a) Intact animal before fission. (b) Posterior portion of the body just after fission. (c) First stage of regeneration. (d) Second stage of regeneration.

(e) Third stage of regeneration. (f) fifth stage of regeneration. ab, aquapharyngeal bulb anlage; bw, body wall; cl, cloaca; dt, digestive tract; lmb, longitudinal muscle bands; pv, polian vesicles; rt, respiratory trees. Arrowheads indicate the regions that were analyzed.

Stage 1. The anterior end of the body is completely closed. Here, a small connective-tissue thickening (an anlage of the AB) occurs between the torn-off ends of the ambulacra (Figures 48c and 48a). The anterior end of the gut remnant is closed blindly. Degenerative processes take place in the terminal region of the radial nerve cord. The nerve cord disintegrates into individual cells and small bundles of axons. The coelomic epithelium of the anterior part of the gut remnant largely retains its normal structure.

Stage 2. The AB anlage at the anterior body end is clearly visible in animals at this stage (Fig. HHH d). The terminal regions of the radial watervascular canals and the ectoneural parts of the radial nerve cords grow over its surface. The anterior end of the gut remnant grows thinner and passes into the short gut anlage, which is 300 mm in diameter. The gut anlage is located along the edge of the intestinal mesentery and is connected to the AB anlage (Fig. 48d). The terminal regions of growing radial nerve cords are epithelial tubes formed by cells of the ectoneural part of the nerve cord.

Stage 3. The size of the AB increases at this stage, and anlagen of polian vesicles appear on its posterior surface (Fig. 48e). This means that the water-vascular ring has already formed. The mouth orifice is absent, and the gut anlage is 400 mm in diameter. The digestive epithelium of the gut anlage has the same structure as in the previous stage. In this stage, it merges with the lining of the esophagus. In the site of connection the digestive epithelium is composed of flattened enterocytes forming a growing tip.

Stage 4. In this stage, the AB is well developed and features several polian vesicles and stone canals. The integrity of the digestive system is restored. The newly formed anterior segment of the gut is still short, but its diameter has increased compared with the previous stage, reaching 450–500 mm. The coelomic epithelium of the newly formed digestive tube has a uniform structure. It is formed by columnar or irregularly shaped peritoneocytes.

Stage 5. In this stage of regeneration, all the lost organs are formed and their structure is close to the normal with the exception of the gut and gonads (Fig. 48f). The tentacles acquire a treelike shape and can be extended outwards. This suggests that the animal is able to feed. At this stage, the connective tissue of the walls of the radial water-vascular and tentacular canals of the AB proliferates and calcifies, and as a result, the calcareous ring is formed.

Growth of the radial water-vascular canals and nerve cords during the regeneraqtion is the result of migration of the cells of their end parts. In regeneration of the nerve ring, the key role is played by the ectoneural portion of nerve cords. Their growing ends represent epithelial tubes formed by dedifferentiated nerve cells. The formation of epithelial tubes makes the mechanisms of the nerve ring regeneration more similar to those of radial nerve cord regeneration (Mashanov et al., 2008, 2013). The second gut anlage forms at the anterior end of the gut remnant. At the site of the tear, the digestive epithelial cells become dedifferentiated.

Nevertheless, the morphology of cells changes insignificantly: the number of secretory granules and microvilli becomes smaller, the height of the cells decreases, and the basal part of the enterocytes grows thinner. These changes indicate the termination of digestive functions of the cells. At the same time, the epithelium retains its integrity in all regeneration stages, and the enterocytes constituting the epithelium do not divide. The gut in anterior fragments of *C. schmeltzii* regenerates in a similar way (Kamenev and Dolmatov, 2015). However, dedifferentiation is less significant during formation of the gut in the posterior fragments. This is probably due to the relatively small size of the regenerate. After fission, the reproductive system is absent from the posterior fragment of *C. schmeltzii*. In animals that regenerate

AB and gut, the gonad is also not found. In *C. schmeltzii*, the gonad regenerates, as, in spite of the intensity of fission, we have not found asexual individuals (Dolmatov et al., in press). This means that formation of the reproductive system in posterior fragments is much slower relative to development of other internal organs.

Similar data were obtained by Kille (1942) for the holothurian *H. parvula*. In adult individuals of this species, various stages of gonad development are observed only in those animals, the structure of whose other internal organs does not differ from the normal. It is evident that identification of the mechanisms of gonad regeneration will require specific investigation. Stored nutrients play a major role in regeneration, because animals cannot feed when damaged. In echinoderms, these nutrients may accumulate in cells in the form of lipoprotein granules. It has previously been shown that the redistribution of lipoprotein granules from the coelomic epithelium to the anlagen of organs also occurs during the regeneration of posterior structures in *C. schmeltzii* (Kamenev and Dolmatov, 2015).

Environmental influences on intensity of fission have also been demonstrated for *H. atra*. This species was observed to have two size morphs. Small individuals can reproduce both sexually and asexually whereas large individuals reproduce only sexually. Both sizes are observed in the same species and represent phenotypic ecotypes. Small fissiparous individuals inhabit the intertidal zone, which is characterized by significant variations in environmental conditions, whereas large individuals are adapted to the more stable subtidal zone. Moreover, higher food availability, because of decreased population size, stimulates the growth of individuals and stops asexual reproduction.

Assessments of fission and regeneration rates are typically based on the external morphology of the animals, particularly the presence of the growing anterior or posterior end of the body. In this case, all the animals, which did not manifest a distinct outgrowth at the fission site, were combined into one group and considered as just divided individuals. The duration of these stages in nature is unknown, and estimations in holothurians can be only indirect and based on regeneration experiments after artificial cutting. We may assume that the development of organs during asexual reproduction and after artificial cutting progresses at identical rates. In *C. schmeltzii*, the formation of internal organs without the growth of an external region occurs for approximately 30 days (Dolmatov et al 2012).

The size of some populations of fissiparous holothurians, despite a high fission rate, can remain constant for a long time This scenario indicates that some individuals are eliminated from this population because of mortality after asexual reproduction or emigration to other habitats (Lee et al 2008). Undoubtedly, asexual reproduction plays a major role in the life activity of holothurians and supports population size. Fission acquires particular significance for commercially valuable species that are exposed to widespread overfishing (Purcell et al 2012). Active fission enables holothurians to support a large population and mitigate negative external effects. However, although there are some advantages under certain conditions, cloning most likely is only beneficial for the short term. A decline in body size and sexual reproduction activity for a long time may decrease population size and survival of the species.

Unlike other clonal animals, such as Cnidaria, the development of internal organs and further growth in holothurians may be for long term (over several months). The gonad forms only several months after fission. Therefore, intensity of sexual reproduction decreases, and a bias in the sex ratio most likely occurs.It is evident that the adaptive importance and advantages of asexual reproduction in holothurians can be related to its combination with sexual reproduction. The presence of two ecomorphs is a notable adaptation because it enables animals to use completely different habitat conditions. Moreover, asexual reproduction occurs as a mechanism to support large population sizes of Holothuria athra and Stichopus chloronotus, where larval emigration is significant (Uthicke 2001).

Conclusion. Many problems regarding asexual reproduction in holothurians have still to be solved. In particular, there are no studies of the cellular and molecular mechanisms of fission. Currently, which factors (genes) determine the location of the site where the body of a holothurian will divide remains unknown. The matters concerning the restoration of the reproductive system remain unstudied. The source of primary germ cells in fragments that lack gonads is also unclear. Moreover, additional studies of factors that stimulate fission and increase asexual reproduction activity in a population are necessary.

It is evident that the adaptive importance and advantages of asexual reproduction in holothurians can be related to its combination with sexual reproduction. Asexual reproduction occurs as a mechanism to support large population sizes. Asexual reproduction in holothurians is a notable and poorly investigated phenomenon. The study of fission and its associated regeneration is essential for understanding the reproduction of holothurians. It is possible that the development of methods to stimulate asexual reproduction or regeneration after artificial cutting will be helpful to restore holothurian populations and provide additional economic effects (Dolmatov 2014).

3.6.3. Sexual reproduction in Echinoderms, a case with sea urchins

Sexual reproduction is the main way to maintain the area of Echinodermes distribution (Hyman 1955). The sexual reproduction is complex process consisting of sequential stages (gonad development, spawning and fertilization, development of the fertilized egg and the larvae development/metamorphosis); so the detailed investigation of the process requires different methods and approaches. The essential stage of the sexual reproduction in sea urchins (Echinodermata: Echinoidea) is the survey of the timing of their larval development – from the swimming blastula to final metamorphosis (juvenile animal formation). The duration of the larval development, morphology of larvae, range of the temperature and salinity for the optimal larval development – all these questions are vital for the understanding of the mechanisms of the of the marine invertebrates adaptation to the environment.

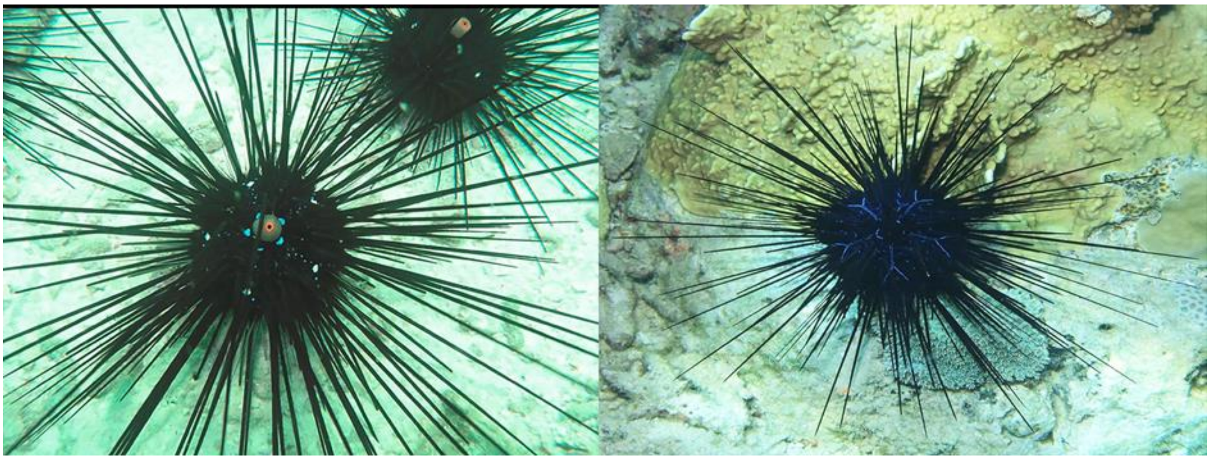


Fig. 49. Sympatric species of sea urchins in Nha Trang Bay. From the left – *Diadema setosum*, from the right – *D. savignyi*. Nha Trang Bay, 2015 year.

Reproduction modes of *Diadema* species, a key group of sea urchins in the South China Sea is poorly studied yet. Echinoid planktotrophic larval forms being pelagic organisms show the wide range of the morphological adaptations (McEdward and Miner 2001, Nakano et al. 2003). Structure of the echinoid larvae of the representatives of various orders demonstrates high level of variability. Sea urchin of the diadematids have very specific larvae (Eckert 1998; Mortensen and Mortensen 1921, Mortensen 1931, 1937), especially *Diadema setosum* which has recently became the very important object for the bioassay and ecological assessment for the control of the aquatic environments. However, the only very early stages of the sexual reproductive processes are quite good known – such as fertilization, egg development and early larvae (pluteus) shape. Our interest in this species was due to the fact that it is an important component of the biological communities of coral reefs of South China Sea and the knowledge on the morphology of the larvae and duration of its full life cycle are necessary for monitoring of larval plankton and the assessment of the restoration ability of the populations (Fig. 21).

***Diadema setosum* –** common in Nha Trang Bay. It is very prominent sea urchin having very spacious aria at Indo-Pacific and recently is discovered in Mediterranean. It has extremely long needles (about 25–30 cm) and inhabits the reefs mainly at the depth 3–10 m. It developed in the experiments through the several stages: blastula, prism, pluteus. Most eggs obtained from the female *D. setosum* have spherical shape except the sporadic oval ones (Fig. 50B).

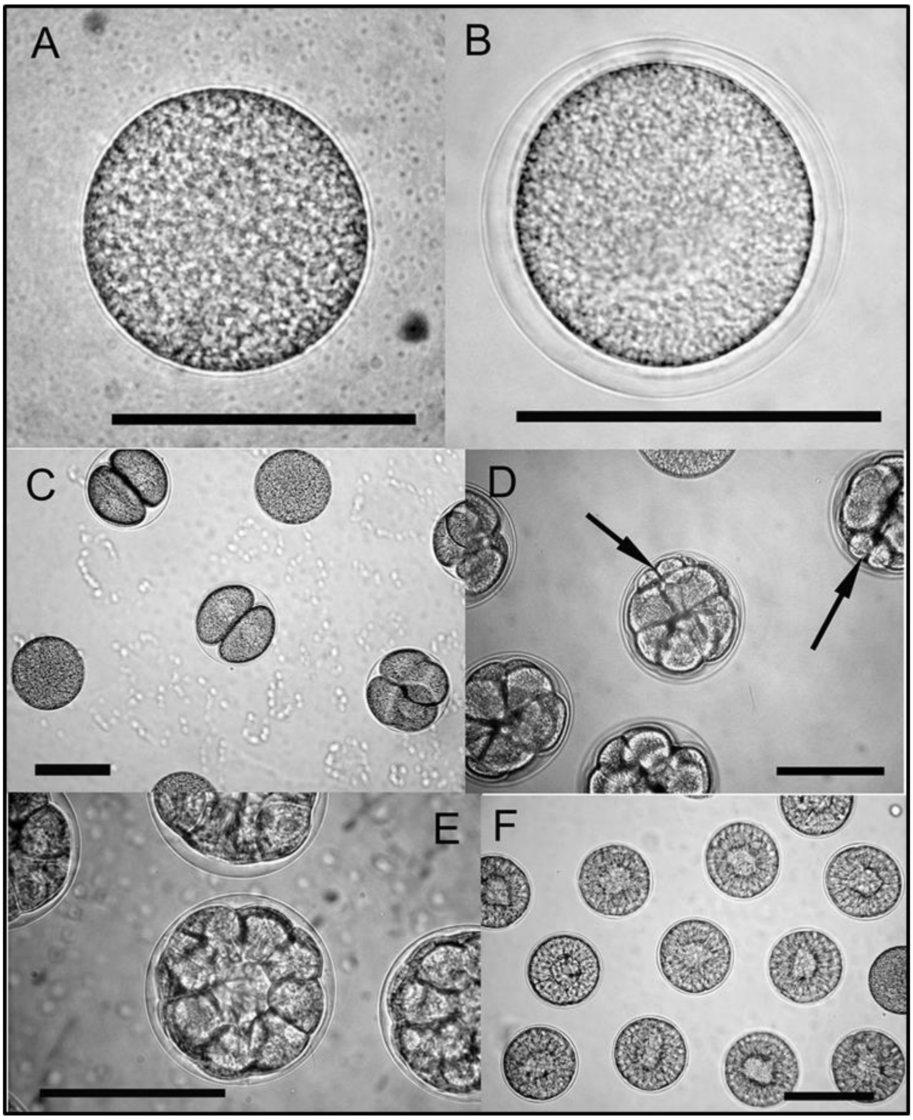


Fig. 50. Early development of the eggs of *Diadema setosum*.

First division of the egg occurs at 30 min after fertilization (a.f.) (Fig. 50C) and the second divisions – at 70 min a.f. The fourth divisions occur at 180 min a.f. those divisions are not uniform –

in the animal hemisphere they give the equal blastomeres whereas in the vegetal hemisphere the macro– and micromeres had appeare (Fig. 50D).

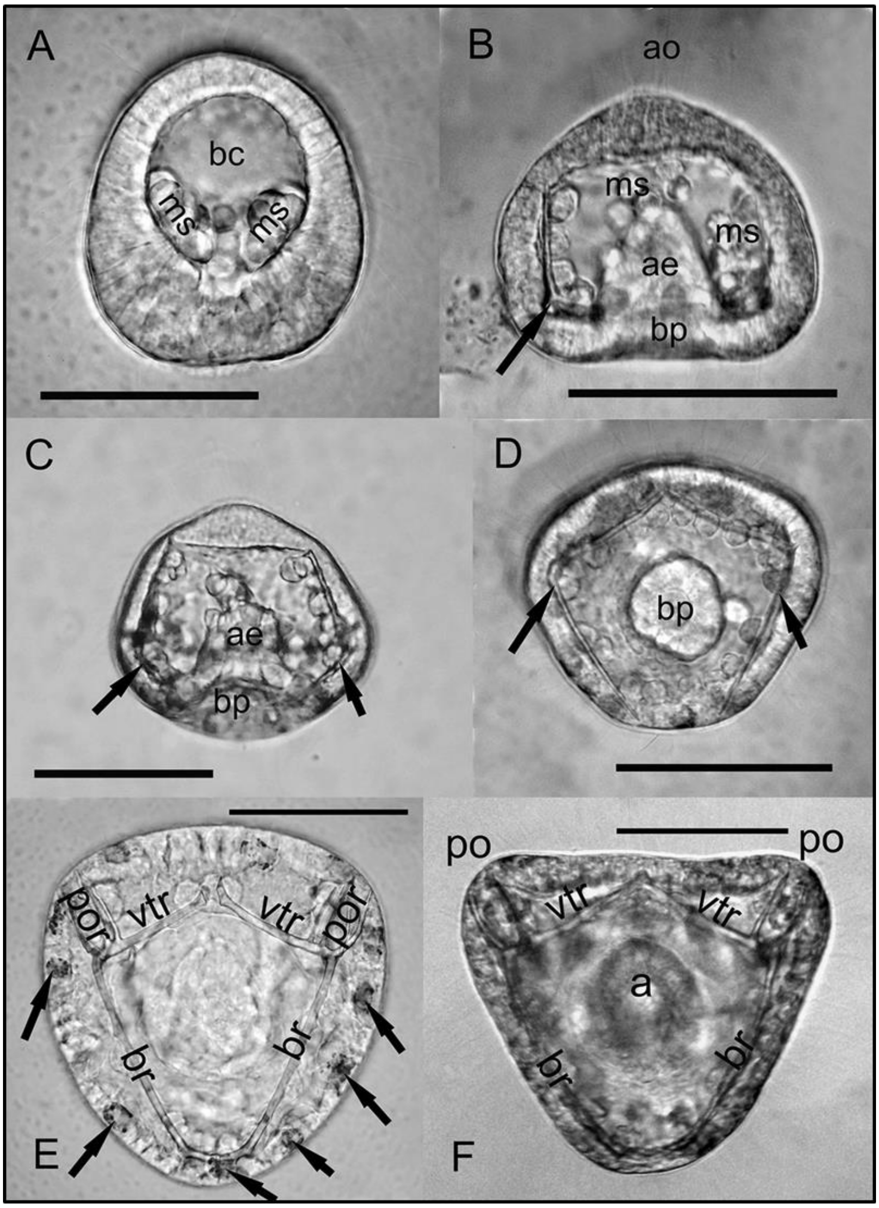


Fig. 51. Prizm development in *D. setosum.*

After two divisions in the developing embryo blastula is formed. Further development at 6.5 h a.f. gives the blastula with the thick and uneven wall and relatively small blastocoele (Fig. 50E, F). At this developmental stage first pigment cells arise in the larvae and during larval development number of pigment cells increases giving the dark red color to the pluteus. Width of the prism of the D. setosum (106.28±2.00 μm) is more than its length (88.16±1.7 μm (n=21)).

Prism is very important stage of larval development of sea urchins. Although this stage is very not-durable, it can be divided into three phases (Fig. 51D, E, F). At first phase the turn of the archenteron to the ventral side of the body and the formation of the sclerenchyma and the rudiments of the skeletal ossicles had occurred (Fig. 51D). At the second phase the body rods and ventral transverse rods have fuse forming basket (Fig. 51D, E). At the third phase the rudiments of the first pair of larval arms – postoral ones – had developed (15–23 hours a.f.) (Fig. 51E). At prism stage the feeding and growing of larvae begin (Fig. 52F).

Development of the pluteus of *D. setosum*. Pluteus I (1 day 22 hours–2 days a.f.) has one pair of arms – postoral ones (Fig. 51F) – but after very short time (at 2 days 8 hours a.f.) larvae become plutei II with two pairs of arms – next ones are the anterolateral (Fig. 52A). Plutei 72 h old have postoral arms 406.23±32.7 μm (n = 23) (Fig. 23B). Mean length of postoral arms of the pluteus 8 days a.f. 931.63±137.4 (n=47) (Fig. 52C).

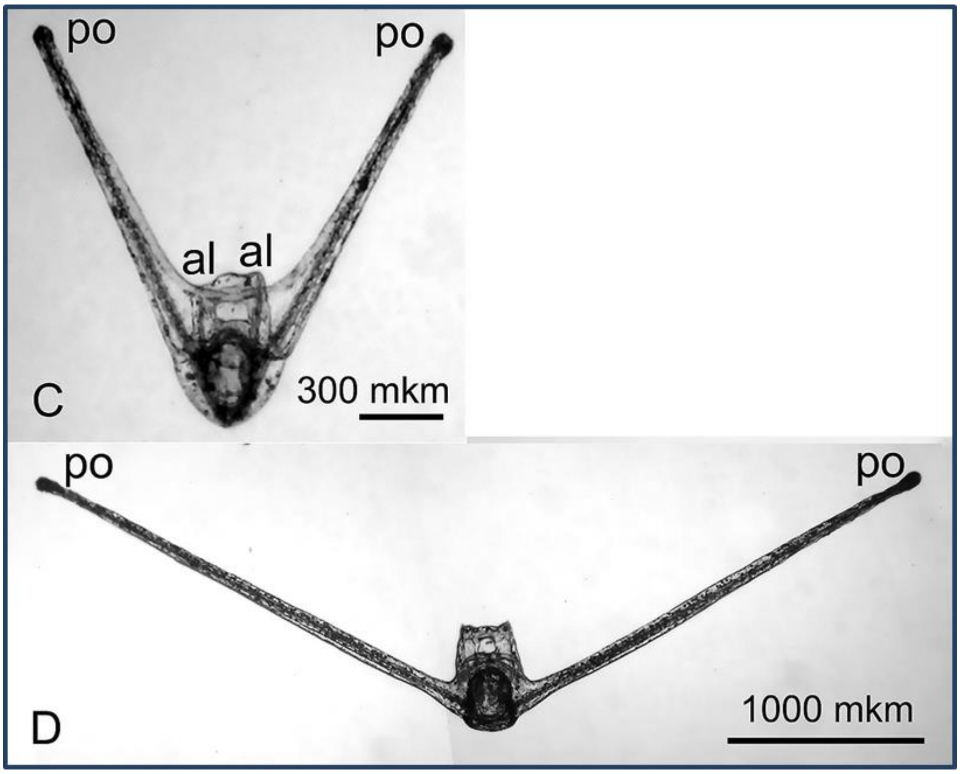


Fig. 52. Pluteus (early stage) of *D. setosum.*

***Diadema savignyi* – closest to *D. cetosum* and another common species on** the coral reefs of the Nha Trang Bay. *D. setosum* has bright white spots at the aboral side around the anal opening, whereas *D. savignyi* is decorated with blue lines at the aboral side (Fig. 49). These both species compose the sympatric aggregations in the Nha Trang Bay and due to it they represent the good model subject to study the mechanisms of the natural inter-species isolation and maintenance of their existence as separate species at the same region.

Embryonic development. The eggs obtained from the females *Diadema savignyi* were spherical and had a slightly yellowish cream color. Approximately 5–7 minutes after insemination, the fertilization envelope lifted with perivitelline space of about (5.1 ± 1.1 μm) (n = 10) (Table 13). First cell division occurred about 25–50 min after fertilization (a.f.) (Fig. 53A), second cell divisions at 50–80 min a.f. (Fig. 53B), and the third cell divisions at 105–115 min a.f., resulting in an embryo with eight equal blastomeres (Fig. 53C).

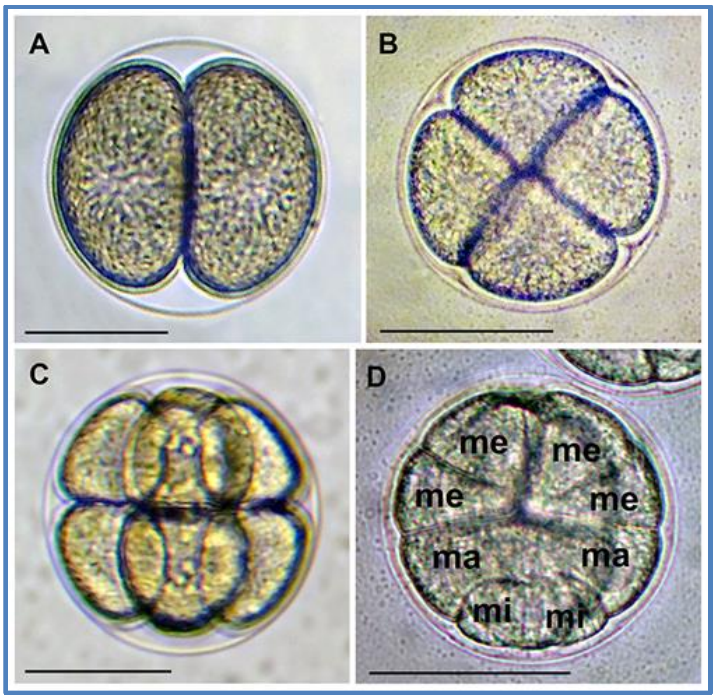


Fig. 53. Fission of the zygote of *Diadema savignyi*. (A) Equal division, 2 blastomeres. (B) Equal divisions, 4 blastomeres. (C) Equal divisions, 8 blastomeres. (D) Fourth unequal divisions, 16 blastomeres. ma – macromeres, me – mesomeres mi – micromeres. Scale bar: 50 µm.

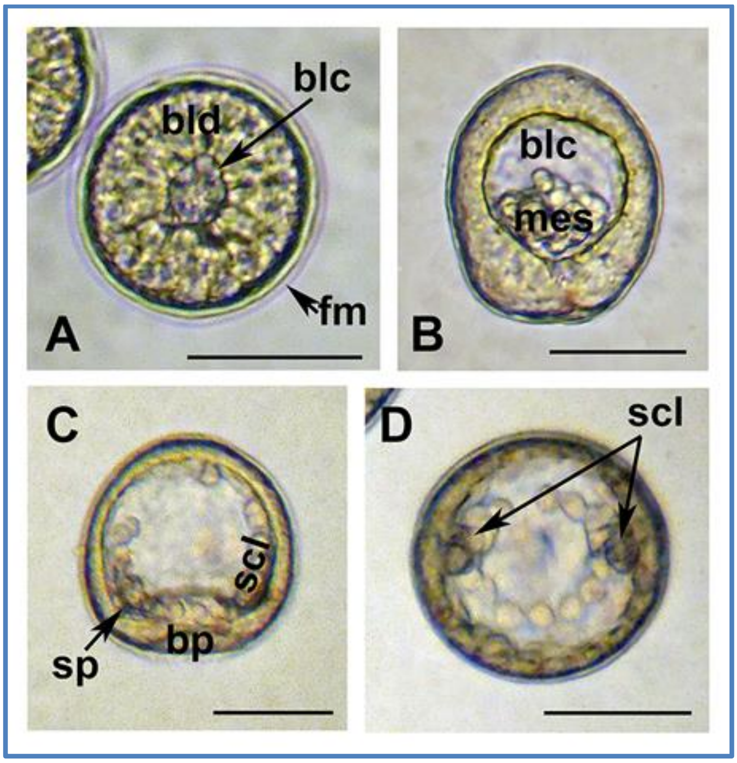


Fig. 54. Early larval development of *Diadema savignyi*. (A) Early spherical blastula shortly before hatching. blc – small blastocoel with diameter about the one-third of the blastula, bld – thick, tight uneven blastoderm, fm – fertilization membrane. (B) Late blastula with the vegetal pole being wider. Note the first pigment cells in vegetal part of the blastula; blc – blastocoel, mes – primary mesenchymal cells. (C) Early gastrula, view from the ventral side, bp – blastopore, scl –

sclerenchyma, sp – spicules. (D) Early gastrula, a view from the animal pole. There are two centers of sclerenchyma (scl) with rudiments of primary spicules. They are shifted to the future ventral side. Note the necklace from the sclerenchyma cells at the vegetative pole (scl). Scale bar: 100 µm.

Fourth cleavage occurred about 120–150 minutes a.f. As in other regular echinoids, in the animal half of the embryo, four cells divide uniformly in the meridional plane, giving a ring of eight mesomeres. In *D. setosum* and in *D. savignyi* this ring is slightly irregular. Four blastomeres in the vegetal hemisphere divide unequally in the equatorial plane giving large macromeres and small micromeres (Figure 53D). After further divisions, at 7–12 h a.f., a spherical blastula forms with a thick and uneven blastoderm and a relatively small blastocoel. The blastula dissolves and leaves the fertilization membrane (Figure 54A) and begins pelagic life.

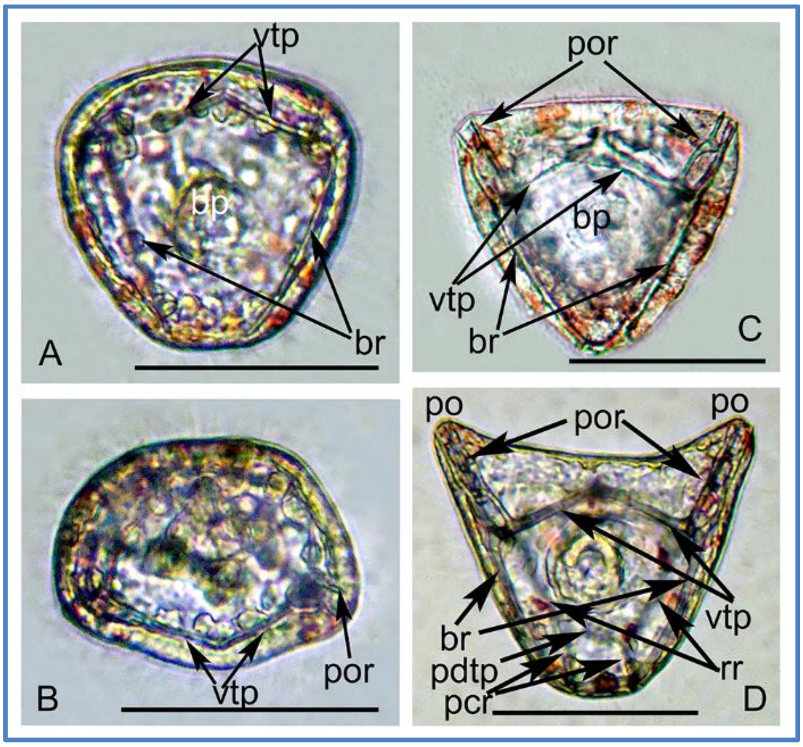


Fig. 55. Early larval development of *D. savignyi*. (A) Young prism. View from the side of the blastopore. bp – blastopore, br – basal rods, vtp – ventral transverse processes. (B). Young prism. View from up. por – the postoral arm rod, vtp – ventral transverse processes. (C) Prism with a larval skeleton being in formation. bp – blastopore, br – basal rods, por – postoral arm rods, vtp – ventral transverse processes. (D) Late prism. an – anus, br – basal rods, pcr – posterior connecting rods, pdtr – posterior dorsal transverse processes, po – postoral arms, por – postoral arm rods, rr – recurrent rods, vtp – ventral transverse processes. Scale bar: 100µm.

Early larval development. Immediately after hatching, the spherical blastulae, 100 µm in diameter, swim and rotate around the longitudinal axis, usually in the upper layer of water, as shown by a video recording. The direction of movement of blastulae is not entirely upward, but results in blastulae in the upper layer of water. By 15–18 hours a.f., the blastulae have become slightly elongated (Fig. 54B). The blastula is slightly narrower at the anterior end, and the vegetal, functionally posterior end of the body becomes slightly enlarged. At this stage, the blastula has a thick blastoderm, and mesenchymal cells fill almost the whole blastocoel (Fig. 54B). Shortly before gastrulation begins, the wall of the blastula's body becomes thinner, the blastocoel becomes more spacious and two groups of mesenchymal cells that will form two primary triaxial spicules are clearly visible (Fig. 54C). The location of mesenchyme and skeletogenic cells marks the future ventral and dorsal sides of the larva (Fig. 54D).

Prism. The blastopore, located at the vegetal pole of the larva, shifts to the ventral side. The spicules, initially each with three axes, become connected by ventral transverse processes (Fig. 55A). Basal processes extend downward (Fig. 55A, B), and approach each other. As the larva develops, the ventral transverse processes and basal rods meet (Fig. 55C forming the larval skeletal basket. Postoral rods begin to grow near the junction of the ventral transverse processes and basal rods. Simultaneously, the dorsal part of the skeletal basket of the pluteus is formed (Fig. 55D), in the same way as in *D. setosum* (Dautov and Dautova 2016). Since the time between the appearance of postoral and anterolateral arms is several hours, the duration of formation of the dorsal part of the larval skeleton can be estimated. The bifurcation of the third axis of each primary larval skeletal spicule to form the recurrent rods and the anterolateral arm rods occurs at the stage of the late prism. The continuations of the recurrent rods are transformed into posterodorsal transverse processes and posterior connecting rods. The rear connecting rods meet the body rods, and the posterodorsal transverse processes meet, and thus the larval skeletal basket is formed (Fig. 55D).

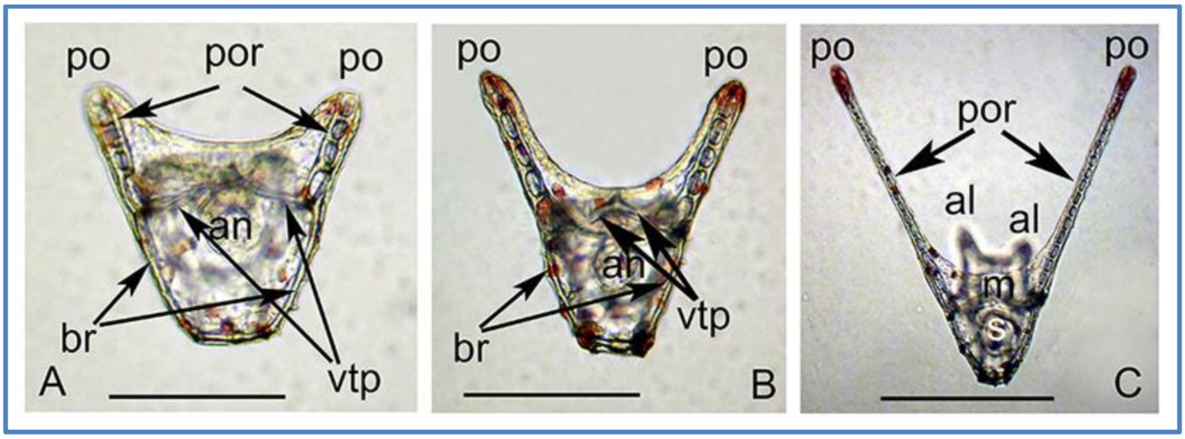


Fig. 56. Development of the pluteus. (A) Early pluteus with one pair of arms. an – anus, br – basal rods, po – postoral arms, por – postoral arm rods, vtp – ventral transverse processes. (B) Pluteus with rudiments of anterolateral arms. an – anus, br – basal rods, po – postoral arms, vtp – ventral transverse processes. (C) 3-day-old pluteus. al – anterolateral arms, m – mouth, po – postoral arms, por – postoral arm rods, s – stomach. Scale bar: A and B 100 μm, C – 200 μm.

Development of the pluteus. The development of the *D. savignyi* pluteus consists of several stages. The first stage, immediately after the prism, is the pluteus stage with one pair of arms (Fig. 56A). At this stage the pluteus already has a complete skeletal basket. A few hours later, the rudiments of the second pair of arms appear (Fig. 56B). On the third day of development, the larva has two pairs of arms (Fig. 56C). The postoral arms grow faster than the anterolateral ones.

The second stage is the transformation of the larval skeletal basket, which begins approximately on the 8–10th day of development (Fig. 57A). This change is indicated by the change in angle between the postoral arms. Postoral arms continue to grow, and towards the end of their growth in late pluteus, the ectoderm is again close to the skeletal rods of postoral arms, as in the young pluteus. (Fig. 58A, B). The length of the postoral arm of the late pluteus reaches more than 5 mm (Fig. 58A, B). Until the metamorphosis, the larvae continue to feed, the oral field extends over the postoral arms, and the ciliary band captures food particles and transfers them to the oral opening.

External structure of the late pluteus and metamorphosis. In addition to elongation of the postoral arms, other changes occur in the proportions of the larval body. It becomes shorter and more oval. The anterolateral arms gradually become so short that they are difficult to see (Figs. 6B, C; 8A, B). Nevertheless, the rods of anterolateral arms are retained in the larvae at latest stages. In the late larva, the larval body becomes wider and shorter; the posterior lobe of the body is clearly distinguished. The mouth moves from the ventral side almost to the anterior end of the body. Rudiments of the juvenile sea urchin, such as primary tube feet, appear. For a short time, only two postoral arms remain from the structures of the larval body, keeping the body of the larva in the water column.

Then the larva settles and metamorphosis is completed. The young sea urchin immediately after metamorphosis is about 486±37 μm (Table 13) in diameter and has five tube feet and fifteen primary spines.

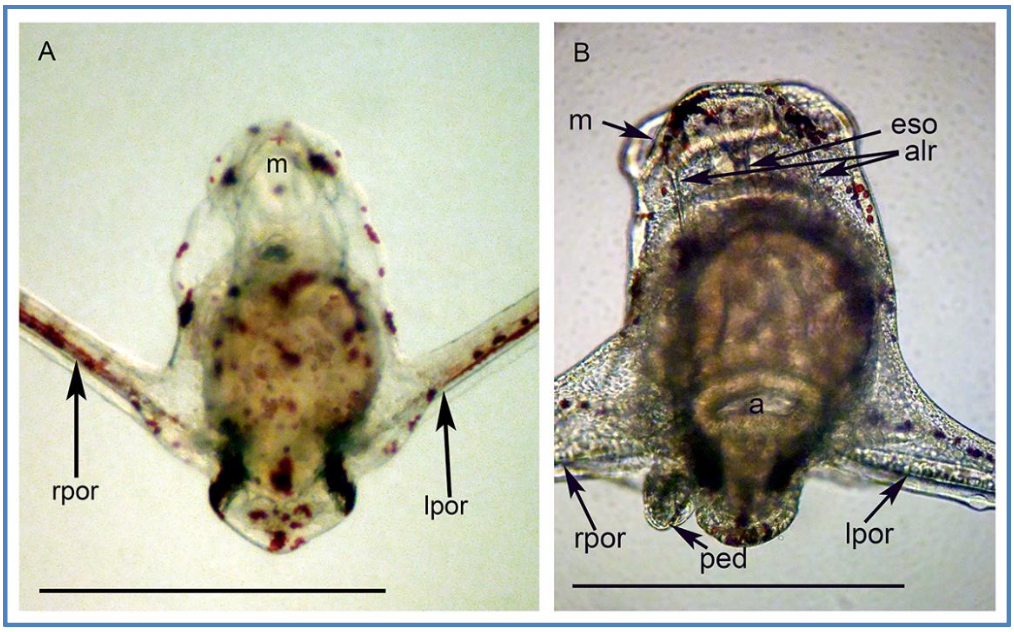


Fig. 57. Common view of the body of the late pluteus. (A) View from the dorsal side. lpor – left postoral arm rod, m – mouth. (B) View from the ventral side. a – anus, alr – anterolateral arms rod, eso – esophagus, lpor – left postoral arm rod, m – mouth, ped – pedicellaria, rpor – right postoral arm rod. Scale bar: 500 μm.

After the study undertaken in the frame of the present project, we can assume that larvae of sea urchins of the Diadematidae are unusual. Two pairs of larval arms only the pair of postoral arms continue to grow in the later stages of development of the plutei. The other pair of arms – anterolateral – lags in growth, although they do not completely disappear until the end of larval development. The skeletal rods of the anterolateral arms persist until the latest larval stages, so that the *Diadema* plutei remain four-armed until the metamorphosis.

In the later pluteus parts of the skeletal basket are resorbed so that the right and left postoral arms lose skeletal connection. Thus, two skeletal complexes are formed, each connected with the right or left postoral arm. In this study, we cannot illustrate these processes but draw conclusions on the basis of observations of the behavior of the larvae. In the pluteus stage, larvae acquire the ability to perform movements with the postoral arms that resemble rowing movements. Mortensen first described the late larvae of *Diadema* but described the larva as Echinopluteus transversus nova forma because he did not know the species. Mortensen suggested that the larva used its arm movements to move in space or avoid unwanted contact with potential predators (Mortensen 1921). As a conscientious researcher, he prepared and sketched several preparations of such larvae. In our previous publication (Dautov & Dautova 2016), we have already mentioned the work of Mortensen (1921), who was devoted to the larvae of *Diadema*. In illustrations from the work of Mortensen (1921), there are indications of the dimensions of the pluteus he sketched. When working with *Diadema savignyi* larvae, we compared them to Mortensen's drawings. In places where Mortensen caught the Echinopluteus transversus (Bay of Bengal and the Maldives), there are only two species from the genus *Diadema – D. setosum* and *D. savignyi*. A comparison of the size of the Echinopluteus transversus with the dimensions described for larvae of *Diadema* suggests that Mortensen caught the pluteus of *D. savignyi*.

Echinopluteus transversus is now a generalized term that designates the plutei of sea urchins from fam. Diadematidae (Soars et al. 2009). We collected data from some works concerning the development of species that have the Echinopluteus transversus type of larvae (Eckert 1999; Huggett et al. 2005; Dautov and Dautova 2016) (Table 13) in order to compare development of plutei within the family Diadematidae.

During their development, plutei of sea urchins of the genus *Diadema* change their behavior. The early pluteus of *Diadema savignyi* with two pairs of arms, has a very rigid skeleton. On about the 8–10th day of development, the angle between postoral arms becomes more than 60 degrees, which coincides with the data obtained for *Diadema setosum.* Then the larvae of *D. savignyi* have a stage of increased primary body cavity. This stage is also noted in *Diadema setosum* (Dautov Dautova 2016, Rahman et al. 2015), but is most pronounced in the larvae of Diadema antillarum (Eckert 1998). From these studies, we can conclude that there is a general schedule of larval development in the genus *Diadema*, which presumably takes place with some modifications in all species of this genus. A similar larva with the same pattern of development occurs in a species of a related genus, *Centrostephanus rodgersii* (Huggett et al. 2005). The pluteus *C. rodgersii* also develops the ability to move its postoral arms through a large angle (Soars and Byrne 2015). The larvae of the species of *Diadema* developed at approximately the same temperature (27 °C) (see more detail in the paper of Dautov and Dautova 2016, supported by the present project).

After the study undertaken in the frame of the present project, we can assume that larvae of sea urchins of the Diadematidae are unusual. The causes of reproductive isolation are not well understood. The distinctive features of *Diadema* adults are obvious, but there was no detailed information on similarities and differences between their larvae. So, our data represent the information which would make the primarily input to the understanding of the mechanism of the interspecies isolation between these species. But from another side, the next series of the experiments are required to obtain the late larval stages of another sea urchins from the same genus (or the same species from another region) and know their longevity and morphology for the purpose of the monitoring of their natural populations.

Table 13. Time-developmental stage (MV±SD) of sea urchins of family Diadematidae. Dimensions are estimated by figures from articles. N – duration of the observation. B – blastula, G – gastrula, J – juvenile, Ov – Ovum, Pl 2 – pluteus with 2–arms, Pl 4 – pluteus 4–arms, Pr – prism.

N	Species (TºC)	
	D. savignyi (27±1)	D. setosum (27±1)
0 hour	Ov (79.24 ± 6.41)	Ov (84.2 ± 3.1)
1 hour	2 cells	2 cells
80 min	4 cells	4 cells
2 hours	8 cells	8 cells
3 hours	16 cells	16 cells
6–7 hours	B (100,2x100.1)	B (98.6±1.7)
42–48 hours	Pl 2 (198.8±16.2)	Pl 2 (344.6±13.1)
3 days	Pl 4 (289.6 ± 55.4)	Pl 4
4 days	Pl 4 (308.3 ± 17.0)	–
5 days	Pl 4 (335.9 ± 49.7)	–
14 days	Pl 4 (567.7 ± 44.4)	–
15 days	–	Pl 4 (615 ± 25)
18 days	Pl 4 (908.4 ± 36.5)	Pl 4 (931.6 ± 137.4)
19 days	Pl 4 (915.0 ± 139.4)	–
43 days	–	Pl 4 (1930.5 ± 98)
44 days	–	J (500)
46 days	Pl 4 (5300 ± 50)	
47 days	J (486 ± 37)	

The ability of the larvae in the Diadematidae to move their arms has been described several times (Mortensen 1921; Eckert 1999; Soars & Byrne 2015; Dautov & Dautova 2016). Movement of postoral arms is widespread among echinoplutei (Wray 1992) but extreme in the Echinopluteus transversus of the Diadematidae. For the emergence of such a behavior, muscles must originate, the larval skeleton must be modified. The elucidation of these behavioral and morphological changes can be a continuation of this study.

Conclusion. The difference in the length of the postoral arms of the plutei of *Diadema savignyi* and D. setosum cannot be the result of differences conditions for growth of the larvae because larvae of both species were kept in the same conditions. The only morphological difference that we observed between larvae of *Diadema setosum* (Dautov and Dautova 2016) and *D. savignyi* was that the larvae of D. savignyi grew longer postoral arms. Larval development of Diadema savignyi lasted a few days longer than that of *D. setosum*. The larvae of *D. setosum* and *D. savignyi* are very similar, while larvae of *D. antillarum* differ in having noticeably broader postoral arms and almost no development of the anterolateral arms (Eckert, 1999).

The experiments in the reported period show that:

1. The percent of the matured animals in the natural populations was the same in both species during the period of our experimental work, but differed in another seasons.

2. The time of the developing of the larval stages was the same in both species. The development of *D. savignyi* begins from fertilization after 20–30 sec, at 40–50 min a.f. the fission begins and the zigotae divides to two blastomeres. At the 1 day the prism stage develops; it begins feed on unicellular algae, very quickly grows and its arms become longer, and after 28–30 hours the prism turns into the pluteus. The early pluteus of *D. savignyi* has the morphological similarity with the same larvae stage of *D. setosum*. The time of the early stage development goes some more quickly, but generally the longevity of the early development of both species is similar.

It means that there is another mechanism of the inter-species isolation for these sympatric species of the same genus. We suggest that the maturity of gonads of these species in different seasons or spawning in different periods can serve as such mechanism. It could be evolutionary developed mechanism to isolate the genetic sets of these species and, via such segregation, – to support the biodiversity in densely populated marine ecosystems in tropics.

4. Conclusions

Status of the coral reefs in South China Sea and the environmental conditions. The impact pattern of sedimentation and eutrophication for the degradation of coral reefs in Nha Trang Bay, Vietnam, is performing as the impacts of mainly eutrophication and pollution. These factors strongly affect to coral reef ecosystem, and lead to the loss of the coral cover and stability of coral reefs that were located at short distance from the sources of terrestrial run-off (Figs. 7, 15). The waste production of fish farms is depended upon the aquaculture facilities differs from the provinces, there is an additional waste component in uneaten feed that may affect the environment, and the nutrients release rate can be estimate to apply for situation in the areas. The nutrient loading from cage fish farm is point source to influence the surrounding waters and it is depend on the hydrodynamic systems and depth of the sites by current will contribute to water exchange in the cage farm.

Finally, it can be concluded that the good amount of exact data on the monitoring of the aquatic environments in Nha Trang Bay (since 2003) give us the possibility to trace their changes and it is promising for indication of the large-scale (global) changes. The distribution of the sedimentation (terrestrial-origin) load in the bay shows the concentration of DF-SPM in the mid-fold of the bay. It is in contradiction with the expected gradiental decreasing of the sedimentation load on the reefs along with the distance from the Cai River and city. However, the analysis of the SPM distribution and isotope analysis show the existing that gradiental decreasing of the sedimentation load. The sedimentation and salinity parameters in the bay until 2017 year did not exceed those dangerous for corals. However, the pollution in the bay can be assessed as risky for the corals health. So, the developing of the investigations is suggested as needed for the nearest years in the frame of the project. The additional data on the influence of the pollutants on the reproduction and other physiology parameters of the corals and coral reefs inhabitants are supposed to be very important to estimate the real condition of the ecosystem in central of Vietnam.

Sedimentation and nutrient enrichment are supposed to have the strong influence on Philippine's coral reef ecosystems. Heavy sedimentation, nutrient extra-enrichment, heavy metals and plastic pollution has been found to negatively affect marine biodiversity globally.

Possible causes of mortality of the corals in Bolinao (Luzon, Philippines) can be: (1) increase in nutrients caused the growth of competitors of coral juveniles; (2) increase in nutrients lowers the dissolved oxygen levels; (3) increased sedimentation restricts the lightening and (4) increased sedimentation smothers and buries the coral juveniles.The additional effort of genus level identification and more data on the biodiversity are suggested as necessary to provide more potential information into the community dynamics of the area (Villanueva et al. 2005). It was experimentally shown that total mortality of coral nubbins were observed in sites in Bolinao where DF-SPM (193 g m^{-2} d^{-1}) and SPM in water column (~7.2mg L^{-1}) was high (Villanueva et al. 2005).

Corals in Bolinao showed very low survivorship in sites where sedimentation and nutrient enrichment was high and the aquaculture reduced water transparency from 80% (in sites farthest from aquaculture sites) to six percent (Villanueva 2005, 2006).

Pollution by pesticides at Philippine aquatic areas ore of the same origin as in Vietnam. The pesticides (common for rice cultivation) were detected in waters around the island of Leyte in the Philippines. The analysis of samples taken at the river mouth revealed measurable levels of λ-cyhalothrin and cypermethrin, which means that residues of pesticides applied to rice paddy fields were shown to end up at the river mouth. It may have adverse effects on inhabitants as well as on the aquatic environment, including sensitive coral reefs. This situation is applicable not only to the Philippines, but also to the whole of Southeast Asia, with approximately 70% of their human population living in coastal areas and the need to reduce the impacts of marine pollution in this region is of great importance.

Unfortunately for scientists, as Licuanan (2000) noted, environmental planners and resource managers, no inventory of comparable scale has been conducted since ICRP, hindering the objective selection of priority reefs for protection and optimal use of others. Government policy and public opinion remain based on data that urgently need to be updated. It seems then that the Visayas reefs are most at risk while the better reefs are often less accessible (Licuanan 2000). In the Philippines, there have been few studies on effects of nutrient enrichment, sedimentation and heavy metals on different marine species but fewer investigations were found in relation to its effects on marine biodiversity. The use of geographic, environmental, and broad-scale biological characterization as proxies for generic composition of the biotic community to predict community composition has not yet been fully validated. However, there are considerable incentives to be able to use such characterizations to aid in the selection of representative sites for protection (Uychiaoco et al. 1992). As such, it is very critical to conduct monitoring of coral cover to verify and confirm the above notion. MPA area may be expanded to include areas with better coral cover.

Stony (reef-building) corals diversity. Coral reefs of the Central and South of Vietnam are the richest (in faunistic sense) marine habitats, where the reef ecosystems extend along the 3,260 km coastline and on more than 3,000 inshore and offshore islands. Many reefs in Vietnamese waters have developed on submersed banks, which are common on the continental shelf. Reef-building corals may distribute down to 35 m deep but account for a small proportion of overall coverage. According to the studies performed in the last decades of the 20th century, Vietnam's reef-building coral fauna comprises 366 species, belonging to 80 genera. Coral fringing reefs provide main coastal habitats in Vietnam waters around islands such as Cu Lao Cham to Con Dao, and extend along the coastline from Danang to Binh Thuan Province. Nha Trang Bay is considering as "hot spot" of stony corals diversity in Vietnam (351 species, Tuan 2002).

It is quite high level of biodiversity comparable whith those of Philippines and Indonesia (Veron 1995). From this fact, we can develop two conclusions – 1) exactly unfavorable environmental conditions (such as heavy sedimentation, eutrophication and anthropogenic pollution) should be pointed out as a reason for the low biodiversity of stony corals on some reefs, not a biodiversity level of the whole region; 2) because the suppressed reefs are often located quite close to "good" reefs (for example in Nha Trang Bay, SCS), even these destroyed reefs have a good capacity for recovering and restoration. These capabilities are expected to be promote in case of the science-based management and conservation tools will be applied.

Biodiversity at Philippine's coral reefs is pointed out as some of the highest in the world (Veron 2000). The high stony corals diversity of Philippines suggests that the reefs of the area are of high conservation importance. However, their status and biodiversity are under the risk and show the degradation in many areas.

Biodiversity of soft corals. The comparison of the data, obtained during the reporting project, and those from previously published literature showes a range of new findings in Nha Trang Bay. We presume that the communities of the relatively calm-water shallows (where the main role can belong to the tidal currents in central part of the small lagoons and semi-closed bays) bring the most input into the high diversity of the soft corals population of Nha Trang Bay. In these communities, the contrasting groups (families of Octocorallia) attract much interest due to their position at the reefs – Sinularia (Family Alcyoniidae) and Paralemnalia (Family Nephtheidae). Both these families play main role in the coverage of the bottom by soft corals. Among the Alcyoniidae, the main role belongs to the Sinularia, Sarcophyon and Lobophytum.

The highest number of Sinularia species ever recorded in a particular region, is a clear peculiarity of Nha Trang Bay but is also a clear indication of the lack of knowledge of this wide-spread and conspicuous group distribution in the Indo-Pacific. These findings are new records of the soft corals species and even genera as new for the Vietnam and north-western part of the South China Sea. Basing on the results of the processing of own data and museum collections processing we suggest the Central of Vietnam (Nha Trang Bay, in particular) can be assumed to play the role of "hot spot" of soft corals biodiversity in the South China Sea.

At the same time, we note that the diversity of the region inside the Coral Triangle have been poorly studied until today, especially – in the Philippines. After the survey of the Octocorallia of Philippines, we assume the more reach fauna of these animals in the north-eastern and central of Philippines. Basing on the relative sets of underwater photo-images (made in the reported period 2015-2017), we suggest that the Octocorallia fauna diversity of Philippines reach and includes at least 32 genera of Alcyonacea (Table 11). We counted 47 species of the most important genus Sinularia (Fig. 42) on the reefs of the above listed regions of the archipelago. It is 7 times more in comparison with those published before (Stiasny, 1951).

It can be noted that the research of the Octocorallia species richness is substantially in the frame of the worldwide and local biodiversity problems. Solving of the complex problems of the taxonomy, genetic diversity and species-specific ecology is needed to trace the possible ways for the soft corals dispersal. The soft corals (Cnidaria: Octocorallia) having the ability to occupy the significant bottom areas belong to the main components of the coral reef ecosystems of the tropics. The survey of the biodiversity of soft corals is needed for the monitoring purposes to solve the important problem of the tropical marine ecosystems – to predict the nearest future of the damaged and healthy coral reefs. However, the existing data about the species composition of the soft corals of South China Sea should be updated and their research should be developed to cover all types of habitats in the South China Sea.

There are no tropical taxa of Octocorallia distributed Asia-Pacific outside the Japanese reefs. However, numerous Octocorallia occurred below 50 m depth (deep-water) deserve much interest as these possess quite interesting biodiversity data and provide the possibility to trace the ways of their dispersal in the temperate area of East Asian seas. Moreover, Octocorallia are appointed as indicative group for defining of the vulnerable marine ecosystems in all oceans, and in temperate Asia-Pacific in particular. Summarized data on the deep-water Octocorallia distribution now indicate 12 families in the temperate (deep-water) area of Asia-Pacific. All these coral families are present in the temperate waters of Asia-Pacific Region (from the Korean waters to the Commander Islands, Bering Sea) and to the eastern Pacific (from the Alaskan waters to the California coast). This distribution suggests general affinity of the Octocorallia faunas and biodiversity in whole North Pacific and, consequently, the prospect of further discoveries from continuing research on deep-water corals in the temperate Asia-Pacific waters. Exploration of deep-water coral fauna in the vulnerable marine ecosystems in temperate Pacific, particularly in the Kuril Islands area and the Sea of Okhotsk, along with the Kamchatka Peninsula, can enlarge the database of characteristics of the regional fauna and formulate its biogeography and the parthways for dispersal.

Reproduction ability of the studied key groups of animals. The asexual reproduction takes place in natural populations both in colonial animals (stony corals and octocorals) and in the holothurians in the region of study. It is evident that the adaptive importance and advantages of asexual reproduction in holothurians can be related to its combination with sexual reproduction. Asexual reproduction occurs as a mechanism to support large population sizes. It serves as mechanism of the stability of their populations and, this way, enlarge the potential of these key groups for recovery after the catastrophes, climate changes and even anthropogenic influense (when stopped).

The distinctive features of *Diadema* adults are obvious, but there was no detailed information on similarities and differences between their larvae. After the study undertaken in the frame of the present project, we can assume that larvae of common sea urchins of the Diadematidae are unusual. Same time, the larvae of sympatric species of *Diadema* are very similar. The experiments in the reported period show that: 1. the percent of the matured urchins in the natural populations was the same in both species during the period of our experimental work, but differed in another seasons; 2. the time of the developing of the larval stages was the same in both species. It means that the another mechanism of the inter-species isolation for these sympatric species should be found. We suggest that the maturity of gonads of these species in different seasons or different periods for spawning can serve as such evolutionary developed mechanism to isolate the genetic sets of these species and, via such segregation, - to support the biodiversity in densely populated marine ecosystems in tropics. Our data represent new information making the primarily input to the understanding of the interspecies isolation in sea urchins. Our new data on the sexual reproduction and larvae development of mass genera of sea urchins input new issue for the science-based approache to the monitoring of their natural populations and farming purpoces.

5. Future Direction

The directions to develop the future investigations of the contemporary diversity of Octocorallia in the Asia-Pacific would prospective be stated as:

1. the comparison of the soft corals diversity in ecologically differing coral reefs and regions of Vietnam (i.e. Nha Trang Bay and Gulf of Tonkin) and the Indonesia along with the getting of new data on the currents in that region; the existing data about the soft corals of South China Sea should be updated to cover all types of habitats in the South China Sea.
2. the gap-filling surveys of the diversity and population structure of soft coral in southernmost part of Vietnam waters and in Indonesia using morphology and genetic modern approaches to estimate the connectivity between the fauna of its and those of the Coral Triangle area;
3. the gap-filling surveys of the octocoral biodiversity and pathway of dispersal in the temperate (deep-sea) waters of the Asia-Pacific; exploration of temperate (deep-water) coral fauna in the local vulnerable marine ecosystems in Asia-Pacific region, particularly in the Kuril Islands area and the Sea of Okhotsk, along with the Kamchatka Peninsula; it can enlarge the database regarding the regional fauna are formulate and its biogeography.
4. the solving of the complex problems of the taxonomy, genetic diversity and species-specific ecology is needed to trace the possible ways for the soft corals dispersal.

The key groups of corals and Echinodermata (sea cucumbers and sea urchins) inhabiting coral reefs in Nha Trang Bay are highly promising for the long-term surveys of their reproduction in natural populations and in the experiments for the follows tasks:

1. the monitoring of the biodiversity and reproduction in the mass species of corals and Echinodermata to explain the influence of the global and local environmental changes on the marine ecosystems of the SCS.

2. the investigation of the seasonality of the reproduction of the mass species of corals and Echinoderms to know their potential for surviving and rehabilitation under the local and global change in the marine ecosystems of the SCS.

In the Philippines, there have been few studies on effects of nutrient enrichment, sedimentation and heavy metals on different marine species but fewer investigations were found in relation to its effects on marine biodiversity. In the case of plastic pollution, no studies were found to have been conducted in the Philippines that shows the effect of this stressor to marine organisms or to marine biodiversity as a whole even though plastic pollution pose a valid threat to marine organisms.

Further studies on effects of marine pollution (nutrient enrichment, sediments, heavy metals and plastic) on marine trophic interactions and biodiversity is prospecting in the Philippine setting.

There is noted the lack of the biodiversity information for the environmental planners and resource managers, no inventory of comparable scale has been conducted since ICRP, hindering the objective selection of priority reefs for protection and optimal use of others. Government policy and public opinion remain based on data that urgently need to be updated.

The detailed survey of the biodiversity of coral reefs populations in key regions of Philippines with a subsequent long-term monitoring are urgently needed. For these purposes, the capacity building programs should be arranged to enhance the national skills in the taxonomy of stony and soft corals, and other key groups – such as algae, echinoderms and bacteria associated (including those causing diseases of corals).

The knowledge on the reproduction (sexual and asexual modes) of the key groups of these marine animals in South China Sea can be developed for the better understanding of the biodiversity sustainability and regulation. The study of fission and its associated regeneration is essential for understanding the reproduction of holothurians. Development of methods to stimulate asexual reproduction or regeneration after artificial cutting will be helpful to restore holothurian populations and provide additional economic effects.

Chemotaxonomy and chemodiversity/biodiversity oriented research also are fast developing areas of knowledge. As there were made findings of a range of new compounds in the sea cucumbers, and these have been made first time, our results suggest that the bioprospecting and chemotaxonomy research is of promising potential in the SCS and adjacent seas of the region.

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7. Appendix

7.1. The initial Workshop was held 21–22 December 2015 year. Nha Trang, Vietnam, venue - Institute Oceanography VAST

Program of the APN International Workshop/Conference

PROGRAMME OF THE
INTERNATIONAL CONFERENCE

"Developing life-supporting marine ecosystems along the Asia-Pacific coasts - a synthesis of physical and biological data for the science-based management and socio-ecological policy making"

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 21-22, 2015

December 21, 2015

8:30-9:00 Registration of the participants and posters placement

9:00-9:30 OPENING SESSION

9:00-9:15: Opening speech by Dr. Vo Si Tuan (*Institute of Oceanography, VAST, Vietnam*)

9:15-9:30: Opening speech by Dr. Tatiana N. Dautova (*Institute of Marine Biology FEB RAS, Russia*)

9:30-9:50 Group photo

9:50-10:10 Coffee break

10:10-12:00. SESSION A. Climate/environmental fluctuations and physical forcing to marine biodiversity (sea water chemistry, water motion, currents, etc.)

Chairman – Dr. Vo Si Tuan *(Institute of Oceanography, VAST, Vietnam*)

10:10-10:30. T. V. Titlyanova, E. A. Titlyanov and O. Belous (*Institute of Marine Biology FEB RAS, Vladivostok, Russia*) Inventory change (1953–2010) in the marine flora of Nha Trang Bay (Vietnam, South China Sea)

10.30-10.50. Pham Xuan Duong *(Institute of Oceanography, VAST, Vietnam*). Model of the water circulation in the Binh Cang-Nha Trang coast

10.50-11.10. Phan Minh Thu, Nguyen Tac An (*Institute of Oceanography, VAST, Vietnam*). Simulation of nitrogen cycle in Vietnamese waters using STELLA tools.

11:10-11:30. Le Dinh Mau, Nguyen Van Tuan *(Institute of Oceanography VAST, Vietnam)* Some circulating features during South-West monsoon in South Vietnam waters

11:30-11:50. Pham Sy Hoan *(Institute of Oceanography, VAST, Vietnam)* Some characteristics of hydro-dynamics in Nha Trang Bay

12:00-13:30. Lunch

13:30-15:50. SESSION B. Marine biodiversity and problems of climate/global environmental changes in East Asia seas

Chairman – Dr. Tatiana N. Dautova *(Institute of Marine Biology FEB RAS, Vladivostok, Russia*)

13:30-13:50. Abadiano Aubrey Jacklynn *(University of San Carlos, Cebu, the Philippines)* Shallow-water soft corals (Order Alcyonacea) off Maribago, Mactan Island, Cebu, the Philippines

13:50-14:10. Cyril A. Taguba *(University of San Carlos-Talamban Campus, Cebu, the Philippines)* Clade identification of the symbiont in the genus Symbiodinium from the blue coral Heliopora coerulea (Pallas, 1766) (Helioporacea: Helioporidae) from selected waters in Central Visayas, the Philippines

14:10-14:30. Truong Thi Oanh *(Institute for Biotechnology and Enviroment, Nha Trang University, Vietnam)* Application of SNPs for population genetics of Redspot Emperor (*Lethrinus lentjan* Lacepède, 1802) in Vietnam

14:30-14:50. Coffee break

14:50-15:10. Tatiana Dautova *(Institute of Marine Biology FEB RAS, Vladivostok, Russia)* Biodiversity studies in the IMB FEB RAS in collaboration with the Institutions of the Asia-Pacific

15:10-15:30. Salim Dautov *(Institute of Marine Biology FEB RAS, Vladivostok, Russia)* Larva of the *Diadema setosum (Leske, 1778)* – long arm echinopluteus from Nha Trang Bay, South China Sea

15:30-16:50. POSTER SESSION

1) Do Van Manh *(Danang Environmental Technology Center, Institute of Environmental Technology,VAST).* State of heavy metal exposure at Da Nang coastal zone

2) Ngo Thi Mai Han *(Universiy of Science, Ho Chi Minh, Vietnam)* The Interannual variations of the Summertime Upwelling Of the Southern Vietnam in the South China Sea

3) Shakirov R.B.[1], Le Duc Anh[2], Syrbu N.S. [1], Nguyen Nhu Trung[2], Duong Quoc Hung[2], Phung Van Phach[2] *([1] V.I. Il'ichev Pacific Oceanological Institute FEB RAS, Vladivostok City (Russia), [2] Institute for Marine Geology and Geophysics, VAST, Viet Nam)* Natural gases distribution in the Bacbo area, East-Vietnam sea, 2013-2015

4) Nguyen Truong Thanh Hoi, Tran Van Chung, To Duy Thai, Ngo Manh Tien *(Institute of Oceanography, VAST, Vietnam)* Temperature and salinity variations in the Bay lagoon currents based

on observation data of project name " Spiny lobster aquaculture development in Indonesia, Vietnam and Australia"

5) Nguyen Truong Thanh Hoi, Tran Van Chung, To Duy Thai, Ngo Manh Tien *(Institute of Oceanography, VAST, Vietnam)* Characteristics of current in Khanh Hoa coastal area from fieldtrips of Vietnam- Russian co-operation during 2010- 2011

6) Pham Huu Tam *(Institute of Oceanography. VAST, Vietnam)* The variation trend of seawater quality in Nha Trang Bay in the two past decades

7) Sergey Grebelnii *(Zoological Institute RAS, Russia)* On Vietnamese fauna of sea anemones anemones (Cnidaria: Actinia)

8) Boris Sirenko *(Zoological Institute RAS, Russia)* Seven-year taxonomical investigation of chitons in Vietnam

9) Phan Tan Luom, Nguyen Ngoc Lam, Doan Nhu Hai *(Institute of Oceanography, VAST, Vietnam)* Taxonomy of the genus *Protoperidinium* (Dinoflagellate) species in the Vietnamese waters. Subgenus *Archaeperidinium*

10) Nguyen Tam Vinh *(Institute of Oceanography, VAST, Vietnam)* Protozoan in Binh Cang bay, Nha Trang

11) Nguyen Thi My Ngan, Bui Quang Nghi *(Institute of Oceanography, VAST, Vietnam)* Holothurians genus *Stichopus* brandt, 1835 in Nha Trang bay with some notes on morphology and ossicles

12) Nguyen Chi Thoi, Doan Nhu Hai, Nguyen Ngoc Lam, Nguyen Thi Mai Anh, Ho Van The, V.L. Tran Thi Le Van *(Institute of Oceanography, VAST, Vietnam)* Regime shift of phytoplankton community structure under tidal forcing at monitoring site in Nha Trang bay, a tropical coastal water of South Central Vietnam

December 22, 2015

8:30-11:50. SESSION C. Marine ecosystems and biological resources - reproduction, conservation, science-based management

Chairman - Dr. Dao Viet Ha *(Institute of Oceanography, VAST, Vietnam)*

8:30-8:50. Tran Dinh Lan *(Istitute of Marine Environments and Resources, VAST, Vietnam)* Approach to assessing total economic value of marine ecosystem: case studies of offshore islands in Vietnam

8:50-9:10. Filipina Sotto *(University of San Carlos, Cebu, the Philippines)* Restoring Coastal Habitats in the Philippines

9:10-9:30. Maria JorDana Olano *(University of San Carlos, Cebu, the Philippines)* Growth and survival of three scleractinian coral species on artificial structures deployed inside and outside a marine sanctuary

9:30-9:50. Nguyen Van Long, Vo Si Tuan *((Institute of Oceanography VAST, Vietnam)* Trends of change in benthic covers of coral reefs in the coastal waters of Vietnam

9:5010:10. Nguyen Chi Cong, Le Dinh Mau *(Institute of Oceanography, VAST, Vietnam)* Numerical simulation of tsunami propagation scenarios to coastal NhaTrang bay.

10:10-10:30. Coffee break

10:30-10:50. Pham Quoc Anh Duy *(Can Tho University, College of Aquaculture and Fisheries)* Biofloc technology: new tool to improve *Artemia Franciscana* production in solar salt ponds of Mekong delta, Vietnam

10:50-11:10. Phan Minh Thu *(Institute of Oceanography, VAST, Vietnam)* Improving quantitative assessment of primary production of tropical coastal waters in Nha Trang Bay, Vietnam using remote sensing analysis

11:10-11:30. Nguyen Ba Cao *(Institute of coastal and offshore engineering, Ho Chi Minh City, Vietnam)* The effect of hydrodynamic regime to coastal development and coastal mangrove forest of Camau cape

11:30-11:50. Phuoc Hoang Son, Nguyen Huu Huan, Lau Va Khin *(Institute of Oceanography, VAST, Vietnam)* Mapping seagrass beds and coral reefs in the coastal waters, Ninh Thuan Province, Vietnam using VNREDSAT1 image

11:50-13:30. Lunch

13:30-15:20 SESSION C (cont.). Marine ecosystems and biological resources - reproduction, conservation, science-based management

Chairman – Dr. Nguyen Van Long *(Institute of Oceanography VAST, Vietnam)*

13:30-13:50 Dao Viet Ha *(Institute of Oceanography, VAST, Vietnam)* Marine toxins responsible for seafood poisoning in Vietnam

13:50-14:10 Nguyen Thi Thanh Thuy, Nguyen Nhat Nhu Thuy, Nguyen Trung Hieu, Nguyen Xuan Hoa *(Institute of Oceanography, VAST, Vietnam)* Some results on rehabilitation and management of multi -species of mangroves at Thuy Trieu lagoon, Khanh Hoa Province, Vietnam

14:10-14:30 Hoang Trung Du, Nguyen Minh Hieu *(Institute of Oceanography, VAST, Vietnam)* The assessment of eutrophication in coastal waters under the influences of sea-cage farm activities for the degradation of surrounding coral reef ecosystem in Nha Trang Bay, Vietnam

14:30-14:50 Cao Van Nguyen[1], Hoàng Trung Du[1], Nguyen Tan Sy[2] *([1]Institute of Oceanography VAST, Vietnam; [2]Nha Trang University, Vietnam)* Effects of densities, tidal zones on the growth and survival of Pacific oyster, *Crassostrea gigas* thữnberg 1973, in Nha Phu lagoon, Khanh Hoa, Vietnam

14:50-15:10. Coffee break

15:10-15:40 POSTER SESSION

1) Dao Thi Thanh Thuy (Research Institute for Aquaculture No.3, Nha Trang, Vietnam) The potential environmental impacts from spiny lobster aquaculture in sea cages in Vietnam
2) Nguyen Xuan Vy[1], Thangaradjou Thirunavukarassu[2] and Jutt a Papenbrock[3] (*[1]Institute of Oceanography, VAST, Vietnam; [2]Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, India; [3]Institute of Botany, Leibniz University-Hannover, Germany*) Genetic variations among *Halophila ovalis* and closely related seagrass species from the coast of Tamil Nadu - an AFLP fingerprint approach
3) Yaroslav Kamenev, Igor Dolmatov (*Institute of Marine Biology FEB RAS, Vladivostok, Russia*) Asexual reproduction in holothurian *Cladolabes schmeltzii* (Echinodermata: Holothuroidea)
4) Nadezda Bobrovskaya, Igor Dolmatov *(Institute of Marine Biology FEB RAS, Vladivostok, Russia)* Autotomy and regeneration digestive system in *Himerometra robustipinna*, Crinoidea, Echinodermata
5) Cherbadgy I.I.[1], Propp L.N.[1], Nguyen Tac An[2] ([1]*Institute of Marine Biology FEB RAS, Vladivostok, Russia;* [2]*Institute of Oceanography, VAST, Vietnam)* The Content of Organic Forms of C, N and P in Deep Coralline Algal Communities of the South China Sea.
6) Obzhirov A.I., Shakirov R.B. *(V.I. Il'ichev Pacific Oceanological Institute FEB RAS, Vladivostok, Russia)* Relationship between methane concentration and content biota in the Okhotsk sea

15:40-16:30. Final discussion: future visions and collaboration perspectives

Chairmen: Dr. Dao Viet Ha and Dr. Tatiana Dautova

7.2. List of participants of the initial workshop 2015.

List of contact persons from participating collectives

International Conference
"Developing life-supporting marine ecosystems along the Asia-Pacific coasts - a synthesis of physical and biological data for the science-based management and socio-ecological policy making"

21 – 23 December 2015, Nha Trang, Viet Nam

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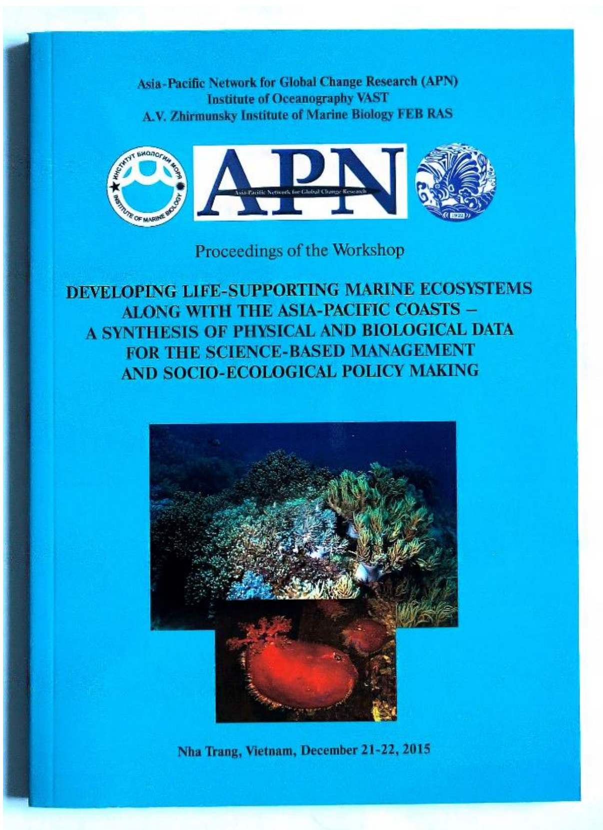
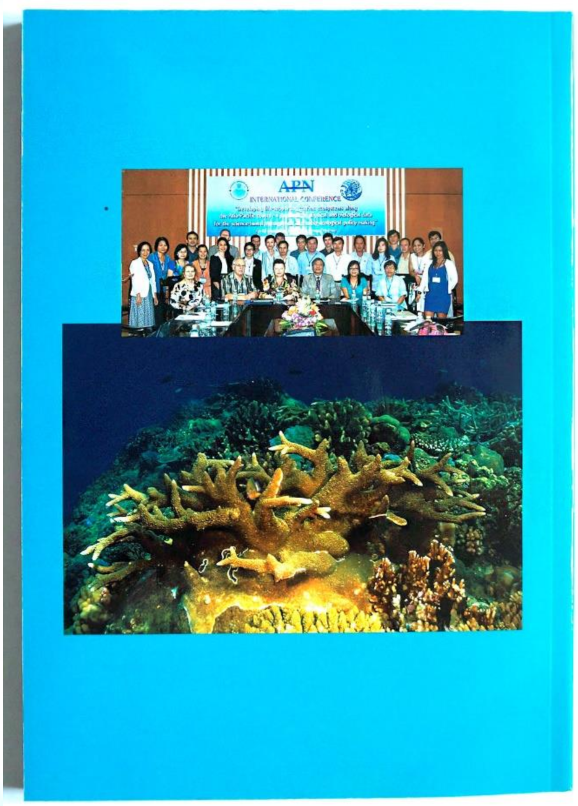
7.3. Cover of the Book of the Workshop 2015 Proceedings published.





7.4. Program of Round Table 2015, Nha Trang, Vietnam, and list of participants.

ROUND TABLE PANEL

"New trends in marine culture – status and perspectives"

under the aegis of

APN, VAST (Vietnam Academy of Sciences and Technology) andRAS (Russian Academy of Sciences)

Venue – Institute of Oceanography VAST, Nha Trang

Language: English (with some translation into Vietnamese)

Goal. The Round Table Panel is aimed to increase the understanding of the policy makers via exchange of the experience of involved parties/countries in two main areas: 1) enhancing of the fishing-restriction operation for coral reefs conservation/restoration and Marine Protected Areas designing and 2) enhancing of national strategy development for the rational using of the coastal marine ecosystems, including the science-based options for sustainable marine farming, quotation of fishing and eco-tourism developing.

Background. The contemporary problemsof the marine ecosystems degradation unite our countries in their need to protect the biopotential/bioresources and enhance understandings of scientists, policy makers and relevant stakeholders in Asia-Pacific. This uniting of the efforts of the acting institutions, administrative persons and business entertainments will develop their capacity to assess the marine ecosystems management through science-based methods and enhanced via interdisciplinary "round tables" at the different administrative levels and regional workshops. The Round Table Panel addresses the urgent problem of the nearest future of coastal marine ecosystems in the Asia-Pacific region,such as the capacity of coastal coral reefs to adapt to environmental change,pollution, forced sediment load, coastal urbanization and overfishing threaten the future of coastal coral reefs and, possibly, increase their adaptive potential under the global climate change. Pollution-related hazards need to be evident in terms of the marine biota decreasing to show its negative consequences and also to promote the high-probability policy options for sustainable using of marine areas in fast developing Asia countries. The Round Table proposed can set the baseline for knowledge on life-supporting shallow marine ecosystems sustainability under the environmental fluctuations, and this can contribute to increase their adaptive capacity to climate change and other socio-economic changes as well as to mitigate problems associated with excessive use of marine bio-resources. Potential for further long-term impacts will be concerning with a conceptual framework developed and implanted it to assess the sustainability of marine resources in Asian seas. It builds up strong partnership with managers, policy-makers and researchers who have a common interest to solve marine ecosystems' related problems. The project activity would inevitably promote further involvement of regional biodiversity/ecologyscientific communities in Vietnam, China, Philippines and Russia to networks of global change organizations.

Moderator: Dr. Vo Si Tuan

Time table: 8:30 – 12:00. Venue. Conference-room of the Institute of Oceanography VAST, Nha Trang Vietnam.

PROGRAM

8:30- 8:45. Welcome speech – Dr Vo Si Tuan, Director of the Institute of Oceanography VAST.

8:45-9:10 Dr Salim Dautov (Institute of Marine Biology FEB RAS, Russia) Sea Urchins in East Asia seas – the world-wide market, new trends and perspectives for their rational aquaculture in Vietnam.

Note: Dr Nguyen Thanh Thuy, IO VAST, will translate presentation of Dr Salim Dautov to Vietnamese.

9:10-9:30 Coffee break.

9:30-10:00 Dr Tatiana Dautova (Institute of Marine Biology FEB RAS, Russia) New ideas and new subjects for marine culture in Russia and Vietnam – food, drugs and education.

Note: Dr Nguyen Thanh Thuy, IO VAST, will translate presentation of Dr Tatiana Dautova to Vietnamese.

10:00-10:20 Questions, Answers and Discussions
10:20-12:00 Final discussion and Conclusion on n**ew trends in marine culture, their status and perspectives for** developing the social-related policy options for the marine conservation and appropriate responses to global change as well.

VIỆN HẢI DƯƠNG HỌC

LIST OF PARTICIPANTS

International Conference

"Developing life-supporting marine ecosystems along the Asia-Pacific coasts - a synthesis of physical and biological data for the science-based management and socio-ecological policy making"

ROUNDTABLE PANEL

"New trends in marine culture – status and perspectives"

23 December 2015, Nha Trang, Viet Nam

No.	Name	Institution	Signature
1	Tatiana Dautova	Institute of Marine Biology, FEB RAS, Russia	
2	Salim Dautov	Institute of Marine Biology, FEB RAS, Russia	
3	Bui Mau	Khanh Hoa Union of Science and Technology Associations, Viet Nam	
4	Nguyen Thi Hoa	Khanh Hoa Union of Science and Technology Associations, Viet Nam	
5	Huynh Ky Hanh	Khanh Hoa Dept. of Science and Technology, Viet Nam	
6	Mai Van Thang	Khanh Hoa Dept. of Natural Resources and Environment, Viet Nam	
7	Pham Quoc Hung,	Inst. of Aquaculture, Nha Trang Univ., Viet Nam	
8	Nguyen Van Huong	Long Phu Tourism Corporation, Viet Nam	
9	Trương Kinh	Nha Trang MPA, Viet Nam	
10	Bui Hong Long	IOC Viet Nam	
11	Vo Si Tuan	Institute of Oceanography, VAST, Viet Nam	
12	Dao Viet Ha	Institute of Oceanography, VAST, Viet Nam	
13	Nguyen Thi Thanh Thuy	Institute of Oceanography, VAST, Viet Nam	
14	Nguyen Van Long	Institute of Oceanography, VAST, Viet Nam	
15	Filipina Sotto	University of San Carlos, Philippines	
16	Abadiano Aubrey Jacklynn	University of San Carlos, Philippines	
17	Maria JorDana Olano	University of San Carlos, Philippines	
18	Cyril A. Taguba	University of San Carlos, Philippines	
19	Huỳnh Bùng Chảo	Nha Trang MPA – Vietnam	

7.5. TV-presentations.

Some screenshots from the TV presentations. See also enclosed files of TV movies enclosed to the Progress Report of the 1st year of the project (in VOB format), these can be open with the "Windows Media Player Classic".

Conference Room – 1st day of Workshop in the IO VAST

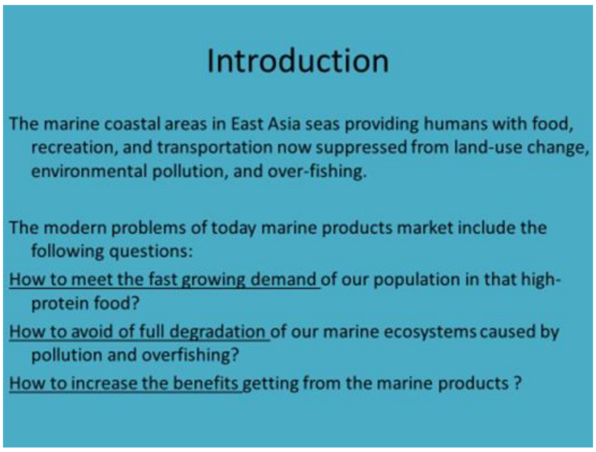
Dr Filipina Sotto, San Carlos University, Cebu, Philippines

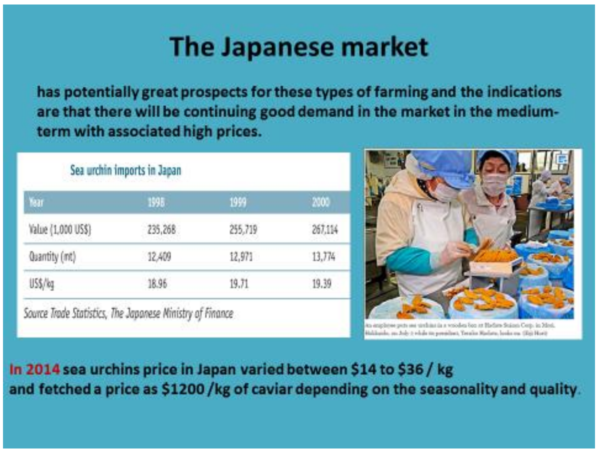
Dr Tatiana Dautova (IMB FEB RAS) and Dr Vo Si Tuan (IO VAST). Discussion at the Round Table

Traditional marine culture in Vietnam waters (fragment from TV presentation)

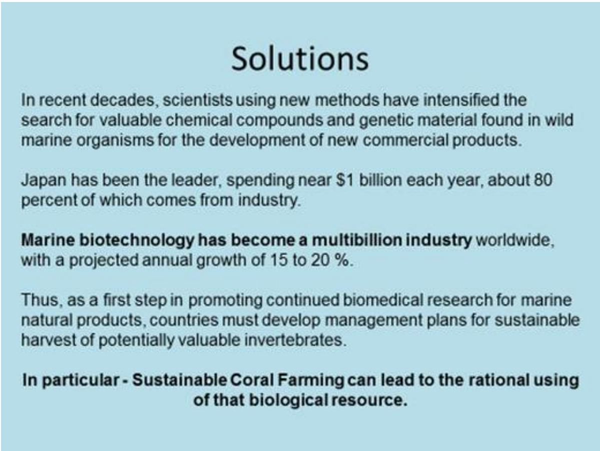
TV-interview with Prof. Filipina Sotto (San Carlos University, Philippines) in the IO VAST, Nha Trang.

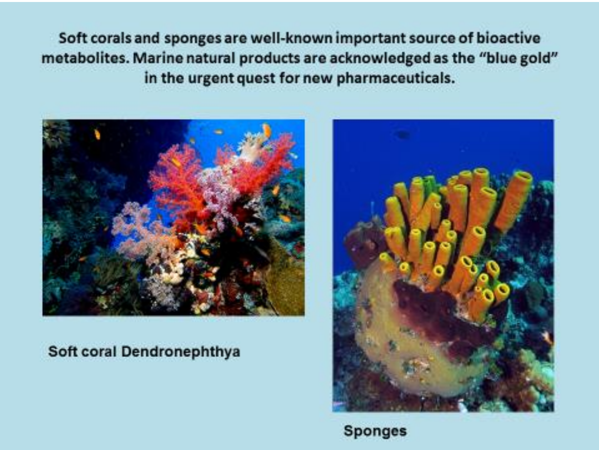
7.6. Presentation of Dr Salim Dautov at the Round Table (some slides)



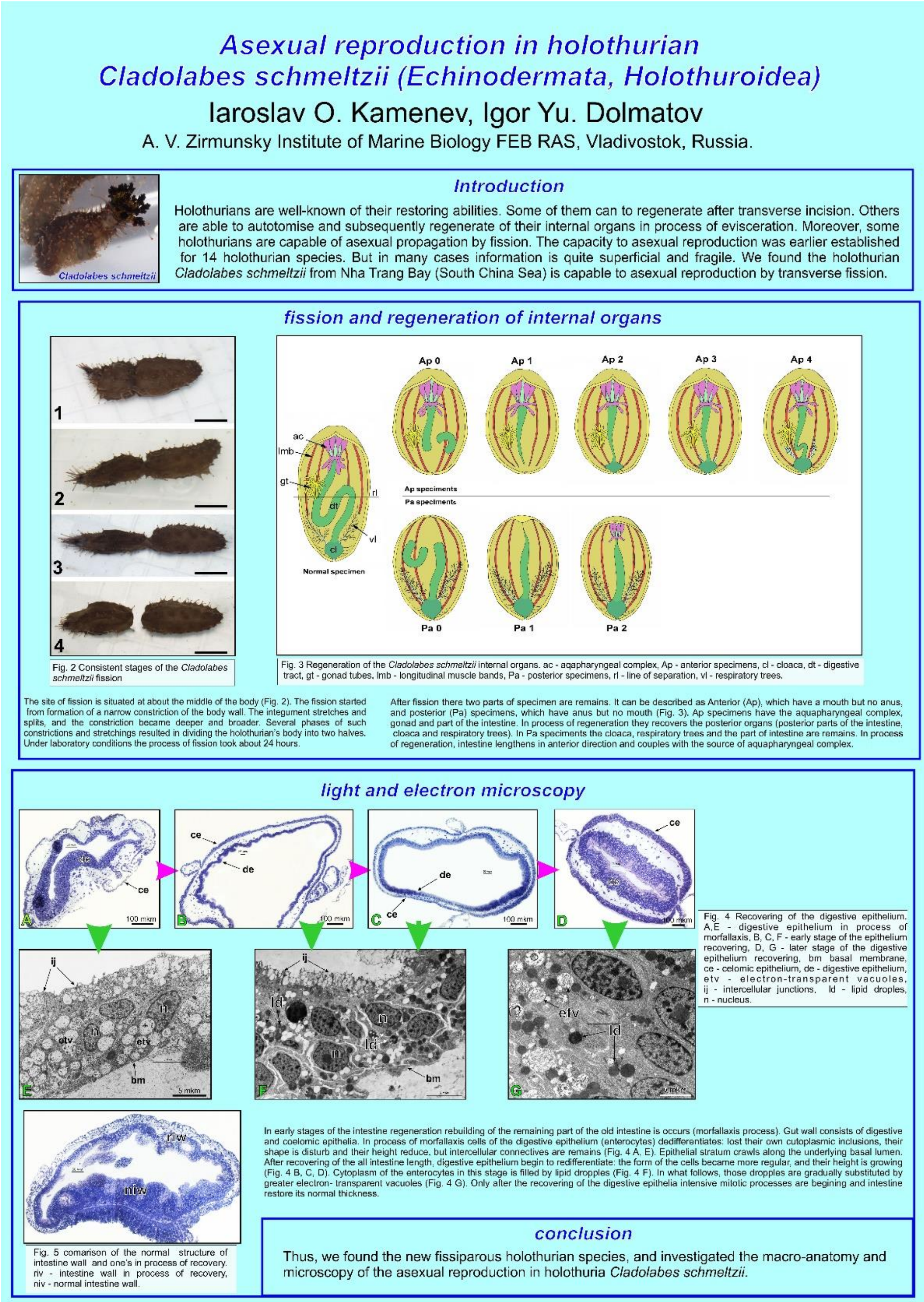


7.7. Presentation of Dr Tatiana Dautova at the Round Table (some slides)





7.8. Some posters presented at initial APN Workshop, 2015.



On the Fauna of Vietnamese Sea Anemones

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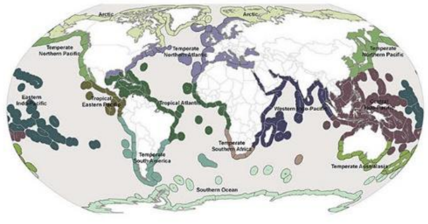

Fig. 1. Basic marine biogeographical subdivisions of the World Ocean (from Spalding *et al.*, 2007).

Coastal waters of Vietnam belong to Central Indo-Pacific Realm, to its South China Sea Province and Sunda Shelf Province (Eckman, 1956; Briggs, 1974; Kafanov and Kudryashov, 2000; Spalding M.D. et al., 2007. Fig. 1). This part of World Ocean is remarkable by high species diversity in many group of shelf marine animals. How-ever, the data gathered in literature about sea anemone fauna of this region don't maintain so far this well-grounded observation.

Not high species richness of sea anemones fauna of region under study could be accounted for a number of reasons. Between them some adverse climatic and eco-logical conditions could be mentioned. Fist of all, we can recall that northern part of Vietnam coast belongs to outskirts of tropical area and during the Quaternary period it more than once undergo considerable fall of temperature. Next, even in recent condi-tion of environment it is not suitable for many tropical species. In addition, in present time the coast of Vietnam is constantly subjected to typhoons coming from east which result in stirring-up in shallow waters, which is less genuine in central Pacific. After all, even more unfavorable influence to coastal strip render a water drain from land, which brings to sea large amount of fresh water and terrigenous material derived from the land by erosion. It is deleterious first of all for reef communities, and consequently for very many tropical sea anemones, which are associated with life of reef.

The last but not the least factor that formally aggravates scarcity of local sea anemones fauna is limited number of articles, published by researchers who could be referred to specialists in this group. In turn, a short number of papers dealing with sea anemones of this region is surely interrelated to violent social, political and military actions that took place here in the course of many years. Except of this materials on sea anemones, collected manly in the beginning of 20th century, are now scattered in zoological depositories of Europe and America and they have never been subjected to monographic description.

The purpose of present communication is to present the first preliminary re-view Vietnamese sea anemones fauna. The review was based on old publications and is now supplemented with our findings made as a result of joint expedition, carried out under the aegis of The Russian-Vietnamese Tropical Center, Hanoi.

Following to valid data, published in the taxonomic papers of specialists in this group (see references in Carlgren, 1949; Fautin, 2003-2014), the species list of Vietnamese sea anemones includes 17 species. In samples of our expedition 12 species had been identified, though only tree species are previously known for Vietnam region in literature. So, entire list includes 26 species belonging to 18 genera, 10 families and 2 orders. Most species that we collected have never been found here before — nine of them should be considered as new for Vietnam, one species is probably new for science.

Total number of sea anemones described from tropical seas of Indian and Pa-cific Ocean makes up about 300 species. Among the species that we found in waters of Vietnam for the first time most (7 of 12) belong to forms with very broad geo-graphical distribution (Fig. 2). It seems to be that considerable part of other species inhabiting this region also appeared to be very widespread ones.

Thus the fist and the simplest conclusion that could be made on the basis of our initial acquaintance with the fauna, is that the shortness of sea anemone list in fact should be explained by our low knowledge of fauna, but not by its proper deficiency.

Among sea anemones found in the course of our work along the coast of Vien-tam, except of Stichodactylidae generally known due to their symbiosis with fishes, there are a lot of other forms that attract attention of researchers and divers by re-markable coloration or unusual body form. Between them it is worthwhile to notice first of all corallimorfarians (representatives of order Corallimorpharia, fam. Dis-cosomidae) Discosoma dawydoffi (fig. 3) and Amplexidiscus fenestrafer (fig. 4), as well as a dangerous actinian Actinodendron arboretum (order Actiniaria, fam. Acti-nodendridae), which correspond some danger for swimmer in contact with its stinging tentacles (fig. 5).

Fig. 3. *Amplexidiscus fenestrafer*. Kon Noi, 16 May 2014. (Photo by Oleg Savinkin.)

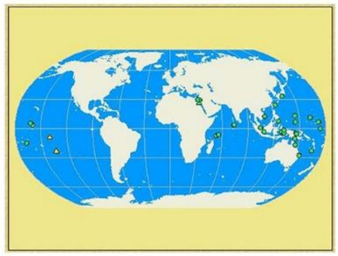

Fig. 2. Geographic range of *Cryptodendrum adhaesivum*, an example of widespread Indo-Pacific species. (From Web: — *http://hercules.kgs.ku.edu/hexacoral/anemone2/distribution.cfm?xmlsource*)
.

Table 1. List of Vietnamese sea anemones

Order Corallimorpharia
Family Discosomidae
○*Amplexidiscus fenestrafer*
●○*Discosoma (Actinodiscus) dawydoffi*
●*Discosoma (Rhodactis) inchoata*
●*Discosoma (Rhodactis) indosinensis*
●*Discosoma (Rhodactis) bryoides*
Order Actiniaria
Suborder Nynantheae
Infraorder Athenaria
Family Haloclavidae
●*Haloclava chinensis*
●*Peachia mira*
Infraorder Thenaria
Superfamily Actinoidea
Family Actiniidae
●*Paracondylactis (Condylactis) hertwigi*
●*Paracondylactis sinensis*
●*Paracondylactis davydoffi*
●○*Macrodactyla doreensis*
Family Actinodendridae
○*Actinodendron arboreum*
Family Thalassianthidae
○*Thalassianthus* sp.
○*Cryptodendrum adhaesivum*
Family Stichodactylidae
○*Stichodactyla tapetum*
○*Stichodactyla gigantea*
●○*Stichodactyla mertensii*
●○*Heteractis magnifica*
●○*Heteractis crispa*
Family Phymanthidae
○*Phymantus sp.*
●*Heteranthus insignis*
Superfamily Metridioidea
Family Hormathiidae
●*Hormathianthus toberculatus*
○*Calliactis sinensis*
●*Sagartianthus indosinensis*
Family Diadumenidae
○*Diadumene lineata*
Family Nemanthidae
●*Nemanthus annamemsis*

● — species recorded in Vietnam in literature
○ — species found in our samples, in 2014

Fig. 4. *Actinodendron arboreum*. Mui Nam, 25 May 2014. (Photo by Oleg Savinkin.)

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Carlgren, O., 1949. A survey of the Ptychodactiaria, Corallimorpharia and Actiniaria. — Kungl. Svenska Vetensk. Akad. Handl., ser. 4, band 1, no.1, s. 1–121.

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Kafanov A. I. and Kudryashov V. A., 2000. Marine Biogeography. Moskow: "Nauka", 176 p.

Spalding M.D. et al., 2007. Marine ecoregions of the world: A bioregionali-zation of coastal and shelf areas. — BioScience, v. 57, no. 7, p. 573–583. — *www.biosciencemag.org*

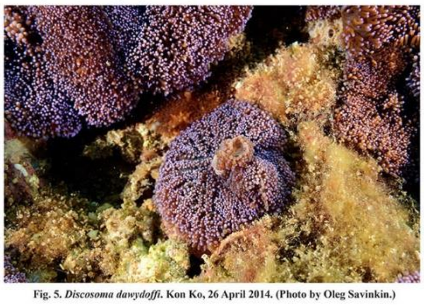

Fig. 5. *Discosoma dawydoffi*. Kon Ko, 26 April 2014. (Photo by Oleg Savinkin.)

Acknowledgements

I would like to thank Temir Britayev (IEE RAS), Oleg Savinkin (IEE RAS), Boris Sirenko (ZISP) and our Vietnamese and Russian col-leagues from the Russian-Vietnamese Tropical Center for support in course of our field teamwork and help in collecting of the material, Tatyana Dautova for maintenance in preparing of this poster.

Seven-year taxonomical investigation of chitons in Vietnam

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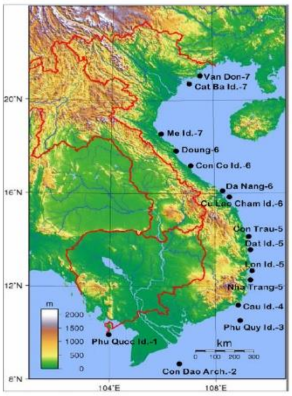

Fig. 1. General localities of sampling of chitons near Vietnam in 2009-2015. The figures correspond to numbers of localities in the Table.

In 2009, the author began collecting polyplacophoran molluscs from the coast of Vietnam. By that time, 40 species of chitons were known from the Siam to Tongking Bays (Strack, 2003). However, as Strack wrote, about half of them needed to be verified. The first revision of the Strack's list showed that only 24 chiton species were really known in Vietnam (Sirenko, 2012). In the last work, 49 species came out from Vietnam. Twenty five of them were found there for the first time. Several new species found in Vietnam were new to science and were described (Sirenko, 2012).

The investigation of the chiton fauna by the author continued for seven years and so far resulted in two articles (Sirenko, 2012, 2014 were published and two articles [Sirenko, in press, Sirenko & Saito in press] will be printed in 2016).

The first article (Sirenko, in press) discusses recent Chitonidae of Vietnam. Seven species of the family are presented in this work. Five of them, Lucilina dilecta Thiele, 1911, Lucilina sp.1, Lucilina sp.2 and two species of genera Lucilina and Onithochiton, are new for Vietnam. The later two are described as new species to science.

The second article (Sirenko & Saito in press) is about the new species of Vietnamese chitons of the superfamily Cryptoplacoidea. Twelve species were found in Vietnam for the first time. Five of them, Acanthochitona achates (Gould, 1859), A. biformis (Nierstrasz, 1905), Leptoplax doederleini (Thiele, 1909), Notoplax cf. richardi (Kaas, 1990) and N. conica Is. et Iw. Taki, 1929, are new for Vietnam. And seven more of them are described as new to science.

Family Chitonidae and superfamily Cryptoplacoidea in Vietnam have the largest species composition (22 and 23 species, correspondingly). Two more families, Ischnochitonidae and Callochitonidae, have a smaller species composition (10 and 5 species, correspondingly). In seven years of field trips to Vietnam, the author collected all 10 species of ischnochitonids and four species of genus Callochiton (except Callochiton longispinosus Leloup, 1952), which inhabits the Macclesfield Bank. Five found species of ischnochitonids, Ischnochiton bouryi Dupuis, 1917, I. comptus (Sowerby, 1859), Lepidozona christiaensi Van Belle, 1982, L. bisculpta (Carpenter in Pilsbry, 1892) and Lepidozona sp., are new to Vietnam, and the latter species is new to science. Also, four species of Callochiton, C. multidentatus (Carpenter in Pilsbry, 1892), C. subsulcatus Kaas et Van Belle, 1985, C. dawydoffi Sirenko, 2012 and Callochiton sp., are new to Vietnam and the latter species is new to science.

The chiton fauna in Vietnam is composed of 68 species. Four of these species, which were mentioned in the Strack (2003) list, Rhyssoplax burmana (Carpenter in Pilsbry, 1893), Rh. speciosa (Nierstrasz, 1905), Acanthochitona bednalli (Pilsbry, 1894) and Leptoplax sp.1, have still not been found, and their presence in Vietnam is questionable.

Thus, in seven years, 43 species of chitons (from a total of 68 species) were found in Vietnam for the first time and 20 of those species are new to science.

Fig. 3. Chitons of the genus Acanthochitona from Vietnam. Five specimens (A, B, C, D, F) belong to new species.

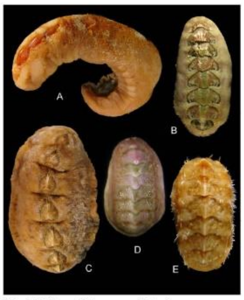

Fig. 4. Chitons of the genera Notoplax, Leptoplax and Cryptoplax from Vietnam. Three specimens (C, D, E) belong to new species.

Table 1. List of Vietnamese chitons. Compiled by B. Sirenko (2015)

№	Species	Localities								
		1	2	3	4	5	6	7	8	9
1	*Leptochiton vietnamensis* Sirenko, 1998 (11 09N, 110 02E, 700 m)			+						+
2	*Leptochiton muelleri* Sirenko et Schwabe, 2011.		+			+		+	+	+
3	*Parachiton politus* Saito, 1996				+				+	+
4	*Nierstraszella lineata* (Nierstrasz,1905) (near South Vietnam, 300-500 m)			+						+
5	*Ferreiraella takii* (Wu et Okutani, 1984) (11 09N, 110 02E, 700 m)									+
6	*Callochiton longispinosus* Leloup, 1952 (Macclesfield Bank)						+			
7	*Callochiton multidentatus* (Carpenter in Pilsbry, 1892)		+			+	+	+	+	+
8	*Callochiton subsulcatus* Kaas et Van Belle, 1985		+	+	+	+		+	+	+
9	*Callochiton dawydoffi* Sirenko, 2012		+	+	+	+			+	+
10	*Callochiton* sp. (16°13 N; 108°12E)						+		+	+
11	*Ischnochiton albinus* Thiele, 1911		+	+		+				+
12	*Ischnochiton boninensis* Bergenhayen, 1933					+		+		+
13	*Ischnochiton bouryi* Dupuis, 1917				+	+			+	+
14	*Ischnochiton comptus* (Sowerby, 1859)							+	+	+
15	*Lepidozona bisculpta* (Carpenter in Pilsbry, 1892)							+	+	+
16	*Lepidozona christiaensi* Van Belle, 1982				+		+		+	+
17	*Lepidozona coreanica* (Reeve, 1847)							+		+
18	*Lepidozona vietnamensis* Strack, 1991			+			+	+		+
19	*Lepidozona* sp.2 (10°33´N, 109°43´E, 310 m)			+					+	+
20	*Stenoplax alata* (Sowerby, 1840)		+	+	+	+				+
21	*Callistochiton granifer* Hull, 1923		+	+	+	+			+	+
22	*Schizochiton incisus* (Sowerby, 1841)		+							
23	*Tegulaplax hululensis* (E.A. Smith, 1903)	+	+	+	+	+				+
24	*Rhyssoplax bullocki* Sirenko, 2012				+	+	+		+	+
25	*?Rhyssoplax burmana* (Carpenter in Pilsbry, 1893)									
26	*Rhyssoplax komaiana* (Is. et Iw. Taki, 1929)			+	+	+	+	+	+	+
27	*Rhyssoplax* cf. *maldivensis* (E.A. Smith, 1903)					+	+		+	+
28	*Rhyssoplax pulcherrima* (Sowerby, 1842)	+	+		+	+				+
29	*?Rhyssoplax speciosa* (Nierstrasz, 1905)									
30	*Rhyssoplax venusta* (Hull, 1923)				+	+	+	+		+
31	*Acanthopleura loochoana* (Broderip & Sowerby, 1829)							+		+
32	*Acanthopleura spinosa* (Bruguiere, 1792)	+								
33	*Acanthopleura tenuispinosa* (Leloup 1939)	+								+
34	*Liolophura japonica* (Lischke, 1873)							+		+
35	*Lucilina carnosa* (Kaas, 1979)		+		+	+			+	+
36	*Lucilina* cf. *dilecta* Thiele, 1911					+			+	+
37	*Lucilina* cf. *tilbrooki* (Milne,1958)		+		+	+			+	+
38	*Lucilina lamellosa* (Quoy & Gaimand, 1835)		+	+		+				+
39	*Lucilina sowerbyi* (Nierstrasz, 1905)				+	+				+
40	*Lucilina* sp.*1*		+		+	+			+	+
41	*Lucilina* sp.*2*		+						+	+
42	*Lucilina* sp.*3*						+	+	+	+
43	*Onithochiton stracki* Sirenko, 2012			+	+	+	+		+	+
44	*Onithochiton* sp. (Danang)						+		+	+
45	*Plaxiphora bucklandnicksi* Sirenko, 2012	+	+	+	+	+	+		+	+
46	*Acanthochitona achates* (Gould, 1859)						+		+	+
47	*?Acanthochitona bednalli* (Pilsbry, 1894)									
48	*Acanthochitona biformis* (Nierstrasz, 1905)				+				+	+
49	*Acanthochitona britayevi* Sirenko, 2012					+	+		+	+
50	*Acanthochitona saitoi* Sirenko, 2012					+			+	+
51	*Acanthochitona savinkini* Sirenko, 2012			+	+	+			+	+
52	*Acanthochitona* sp_1						+	+	+	+
53	*Acanthochitona* sp_3					+	+	+	+	+
54	*Acanthochitona* sp3C							+	+	+
55	*Acanthochitona* sp_4	+	+						+	+
56	*Notoplax conica* Is. et Iw. Taki, 1929					+			+	+
57	*Notoplax* cf. *richardi* Kaas, 1990				+				+	+
58	*Notoplax rosea* Leloup, 1940 (Macclesfield Bank)						+			+
59	*Notoplax* sp_1					+			+	+
60	*Notoplax* sp_2 (10°26´N; 109°15´E, 95 m)			+					+	+
61	*Leptoplax coarctata* (Sowerby, 1841)				+	+			+	+
62	*Leptoplax doederleini* (Thiele, 1909)						+		+	+
63	*?Leptoplax* sp_1 (Halong Bay, coll. H. Strack)									
64	*Leptoplax* sp_2 (Cat Ba Id.)							+	+	+
65	*Craspedochiton laqueatus* (Sowerby, 1842)				+	+			+	+
66	*Cryptoplax* cf. *burrowi* (E.A. Smith, 1884) (Macclesfield Bank)						+			+
67	*Cryptoplax dawydoffi* Leloup, 1937			+	+	+	+		+	+
68	*Cryptoplax oculata* (Quoy et Gaimard, 1835)			+		+			+	+
	Total	6	17	18	23	32	21	17	43	61

1 – Phu Quoc Id.; 2 – Con Dao Arch.; 3 – Phu Quy Id.; 4 – Cau Id.; 5 – Nhatrang Bay, Hon Dat; 6 – Danang, Shon Cha, Cu Lao Cham Id.; 7 – Hon Me, Cat Ba Id., Van Don; 8 – First find for Vietnam; 9 – studied by author.

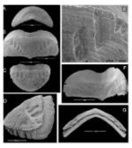

Fig. 7. SEM photographs of valves of *Callochiton* sp. nov. from North Vietnam.

Fig. 8. SEM photographs of perinotum and radula of *Callochiton* sp. nov. from North Vietnam.

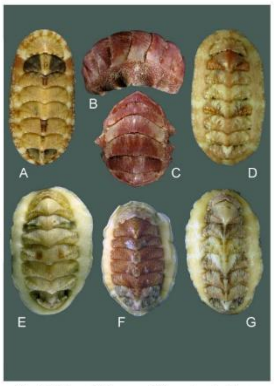

Fig. 2. Chitons of the genera *Rhyssoplax*, *Lucilina* and *Onithochiton* from Vietnam. Three specimens (A, D, G) belong to new species.

Fig. 5. Chitons of the genus Callochiton from Vietnam. All of them are new species.

Fig. 6. Chitons of genus Lepidozona from Vietnam. They are new species.

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Acknowledgements

I would like to thank Temir Britayev (IEE RAS), Oleg Savinkin (IEE RAS), Sergey Grebelny (ZISP) and our Vietnamese and Russian colleagues from the Russian - Vietnamese Tropical Center who help me to collect the material, Mihael Blikshteyn (Portland, Oregon) for the polishing English and Alexey Miroljubov (ZISP) for his technical assistance with SEM procedures.

7.8. <u>Workshop final, 2017</u> <u>(second year of the project). Qingdao, China, (Institute Oceanology CAS).</u>

PROGRAMME OF THE INTERNATIONAL CONFERENCE

“Life-supporting Asia-Pacific Marine Ecosystems, Biodiversity and their Functioning”

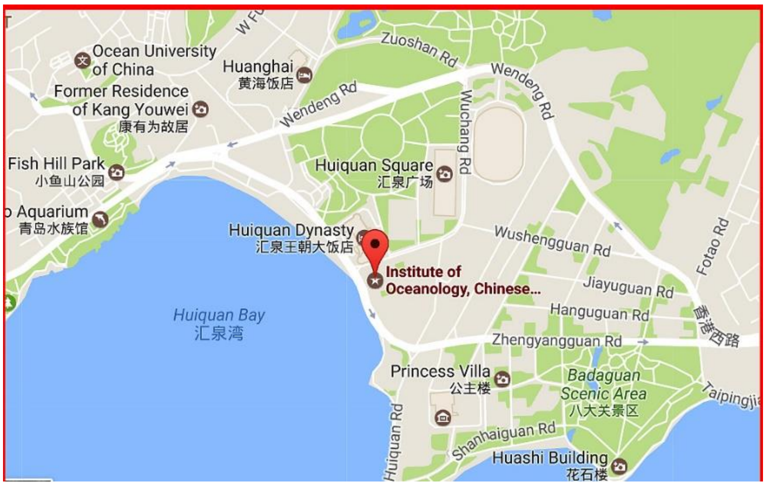
Institute of Oceanology, Chinese Academy of Sciences (IO CAS)

National Scientific Center of Marine Biology FEB RAS (NSCMB FEB RAS)

Asia-Pacific Network for Global Change Research (APN)

Venue: Huanghai Hotel

Qingdao, China, April 26-28, 2017



<u>April 26, 2017</u>

8:30-9:00 Registration of the participants and posters placement
9:00-9:30 OPENING SESSION
Chairman Prof. Li Chaolun
9:00-9:10. Opening speech by Director Wang Fan (Institute of Oceanology CAS)
9:10-9:20. Opening speech by Director Andrey Adrianov (National Scientific Center of Marine Biology FEB RAS)
9:20-09:30. Opening speech by Professor Dr. Tatiana N. Dautova (National Scientific Center of Marine Biology FEB RAS)
9:30-10:00. Plenary talk by Professor Sun Song. Western Pacific Ocean System: Structure, Dynamics and Consequences

10:00-10:30. Plenary talk by Professor Andrey Adrianov

10:00-10:20 Group photo
10:20-10:40 Coffee break

10:40-12:00. SESSION A. Climate/environmental fluctuations and physical forcing to marine biodiversity (sea water chemistry, water motion, currents, etc.)
Chairman –Professor Xu Kuidong (Institute of Oceanology CAS)
10:40-11:00. Hoang Trung Du, Nguyen Minh Hieu, Andreas Kunzmann, Tatiana N Dautova (Institute of Oceanography VAST, Vietnam) The impact pattern of sedimentation and eutrophication for the degradation of coral reefs in Nha Trang Bay, Vietnam
11:00-11:20. Gao Wei, Zhenyan Wang (Institute of Oceanology CAS) Observed thermohaline structure of mesoscale eddies and their controlling effects on the *in situ* chlorophyll distribution in the western North Pacific
11:20-11:40 Shijian Hu, Janet Sprintall (Institute of Oceanology CAS) Observed Strengthening of Inter-basin Exchange via the Indonesian Seas due to Rainfall Intensification
11:40-12:00. Xiaoxia Sun, Junhua Liang, Mingliang Zhu, Tao Liu, Qingjie Li, Shan Zheng (Institute of Oceanology CAS) Impact of microplastics on different zooplankton and fish taxa in Chinese coastal area
12:00-13:30. Lunch

13:30-16:50. SESSION B. Marine ecosystems and biological resources - reproduction, conservation, science-based management

Chairman –Professor Sun Chaomin (Institute of Oceanology CAS)
13:30-13:50. Kuidong Xu, Yang Li, Xuwen Wu, Junlong Zhang (Institute of Oceanology CAS) Benthic Epifaunal Community Structuring in Seamounts along the Yap and Mariana Trenches
13:50-14:10. Meiping Feng, Chaofeng Wang, Guangtao Zhang, Weiding Wang, Henglong Xu, Wuchang Zhang, Tian Xiao (Institute of Oceanology CAS) Annual variation of tintinnid (Ciliophora, Tintinnida) species richness in Jiaozhou Bay, a temperate bay of west Pacific
14:10-14:30. Viacheslav Odintsov (National Scientific Center of Marine Biology FEB RAS) Marine ecosystem management using remotely operated vehicles
14:30-14:50. Antonio N. Ayop, Filipina B Sotto, Ethel C. Wagas (Cebu, the Philippines) Timing of planulation in euphyllid coral, *Euphyllia glabrescens* in the Central Philippines

14:50-15:10. Coffee break
15:10-15:30. Salim Dautov, Tatiana Dautova (National Scientific Center of Marine Biology FEB RAS) Research of the larvae development of Asia-Pacific sea urchins and its importance for science-based aquaculture
15:30-15:50. Tatiana Orlova (National Scientific Center of Marine Biology FEB RAS) Global environmental changes and possible effects on microalgae communities with emphasis on toxic species and HABs on the Russian east coast
15:50-16:10. Tatiana Nikulina, Tatiana Mogilnikova (Federal Scientific Center of the East Asia Terrestrial Biodiversity FEB RAS) Phytoplankton of the coastal zone of Aniva Bay: dominant's seasonal change, quantitative characteristics and phycotoxins (Sakhalin Island, Russia)
16:10-16:30. Jin Zhao, Peng Jiang, Huaxin Chen, Chunhui Wu, Yang Guo (Institute of Oceanology CAS) Have the floating *Ulva prolifera* in the Yellow Sea settled down along Qingdao coastal area after eight-year blooming?

April 27, 2017

9:00-12:00. SESSION C. Marine biodiversity.
Chairman – Professor Dr. Tatiana Dautova
9:00-9:20. Alexandra Romanova, Tatiana Tarasova. (Far East Geological Institute (FEGI FEB RAS), Vladivostok, Russia) Planktonic foraminifera of the Sea of Okhotsk: distribution and preservation in the surface sediments
9:20-9:40. Wen-jie GUO (Institute of Oceanology CAS) Isolation and phylogenetic analyze of epiphytic bacteria from mussels collected from the cold seep
9:40-10:00. Konstantin Lutaenko (National Scientific Center of Marine Biology FEB RAS) Species ricnhess of the bivalve molluscan fauna of the Sea of Japan: toward an inventory
10:00-10:20. Tatiana Dautova (National Scientific Center of Marine Biology FEB RAS) Octocorallia in Asia-Pacific seas – biodiversity and dispersal ways

10:20-10:40. Coffee break
10:40-11:00. Leilei Li (Institute of Oceanology CAS) Metagenomic sequencing of symbiotic methane-oxidizing bacteria of *Bathymodiolus platifrons*
11:00-11:20. Anna V. Raschepkina, Elena M. Sayenko, Ngo X.Q. (Federal Scientific Center of the East Asia Terrestrial Biodiversity FEB RAS) Some new data on Corbicula from estuaries of Vietnam
11:20-11:40. Yuying Zhu, Ning Ma, Weihua Jin, Shimei Wu, Chaomin Sun (Institute of Oceanology CAS) Genomic and transcriptomic insights into the calcium carbonate biomineralization by marine actinobacterium *Brevibacterium* lines BS258
11:40-12:00. Svetlana Tochilina, Lidiya Vasilenko (Pacific Oceanology Institute FEB RAS, Vladivostok, Russia) Importance of biometric analysis for classification of Nasellaria type (Radiolaria)
12:00-13:30. Lunch

13:30-15:20 SESSION B (cont.). Marine biodiversity
Chairman – Dr. Konstantin Lutaenko
13:30-13:50 Minxiao Wang (Institute of Oceanology CAS) Adaptation to the deep-sea, revealed by comparative analysis on the *Bathymodiolus*
13:50-14:10. Filipina B. Sotto, Kurt Bryant B. Bacharo, Antonio N. Ayop, Clyde Kristoffer Ceniza, Nico Brian Uy, Pierre Anthony Gwen Abella (University of San Carlos, Cebu, the Philippines) Black corals of the family Antipathidae (Anthozoa: Antipatharia) from the eastern part of Mactan Island, Cebu, Central Philippines
14:10-14:30. Elena M. Sayenko, Ngo Xuan Quang, Konstantin A. Lutaenko (Federal Scientific Center of the East Asia Terrestrial Biodiversity FEB RAS) Bivalves of the Ba Lai River – one of estuary of the Mekong Delta, Vietnam
14:30-14:50. Junlong Zhang, Olga V. Yurchenko, Konstantin A. Lutaenko, Alexander V. Kalachev, Ivan O. Nekhaev, Robert Aguilar, Zifeng Zhan, Matthew B. Ogburn (Institute of Oceanology CAS) Mya arenaria and Mya japonica (Bivalvia: Myidae) are two distinct species: molecular and spermatozoan ultramorphological evidence

14:50-15:10. Coffee break
15:10-16:10. Final discussion. Future visions and perspectives on collaboration.

7.9. <u>List of participants of the APN Workshop 2017</u>

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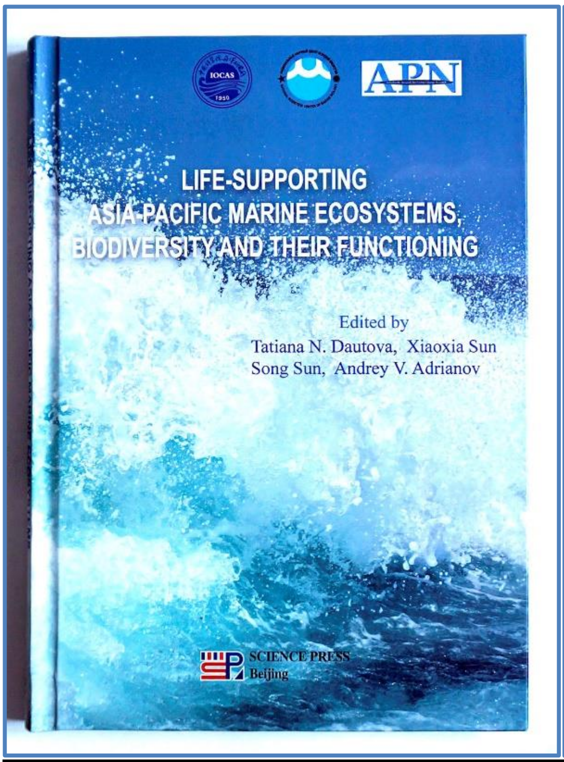
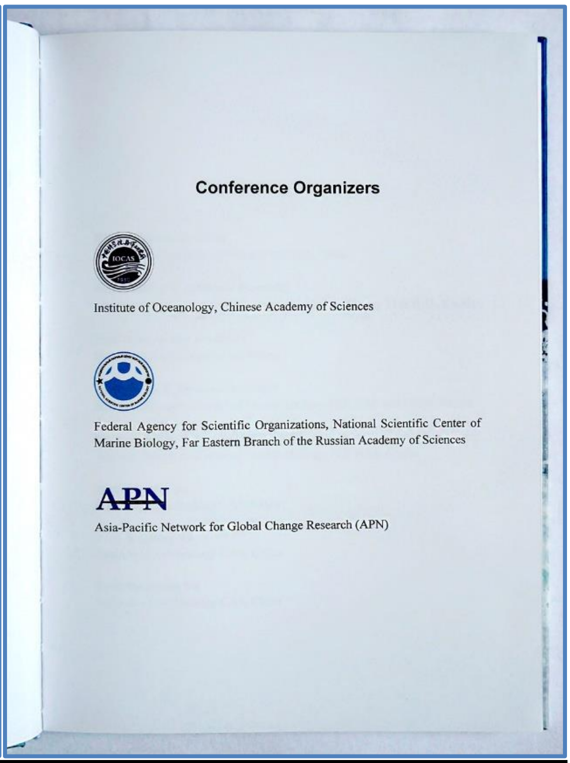
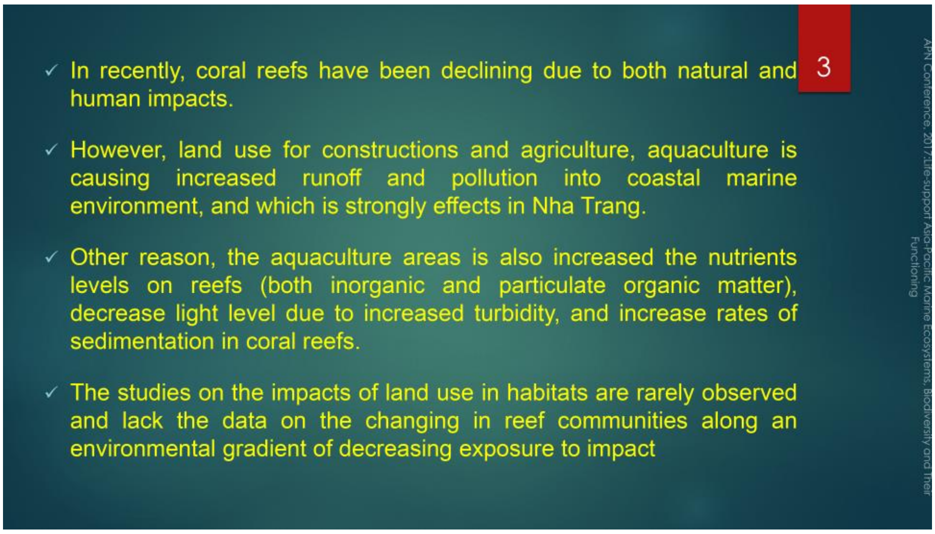
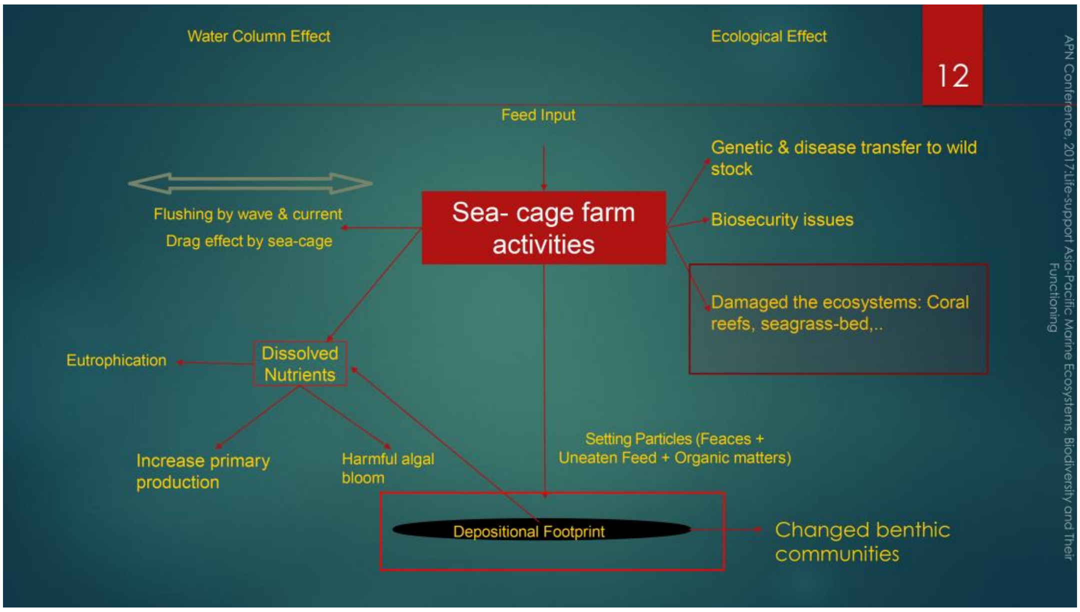
7.10. Cover of the Book of the Workshop 2017 Proceedings

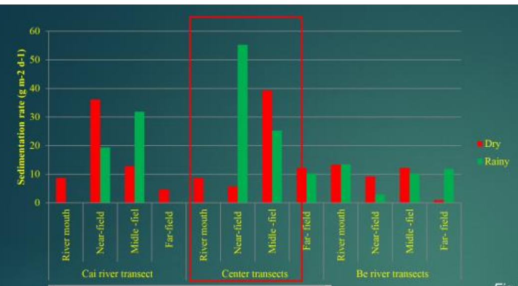




7.11. Some presentations made during the APN Workshop 2017







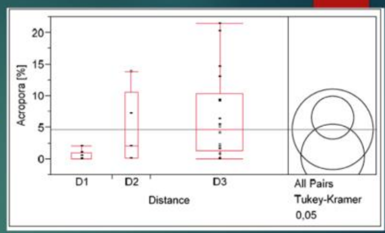
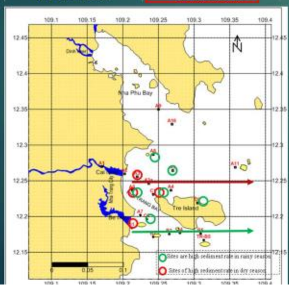


Fig. Acropora coral cover as a function from distance (5, 10, 15 km) to the coast. D1= 0,47% , D2 = 6.43; D3 = 6.25.



- On the coral species level only low to moderate coral cover is found in general.

REMARKS IN CORAL REEF STATUS:

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- The coral reefs at Nha Trang Bay are located in shallow waters around the islands (max. distribution depth 15 m) and are fringing reefs.
- Most frequent are *Acroporids* (wave tolerant) at exposed sites and Poritids/Fungiids (more sediment tolerant) at sheltered sites.
- Coverage of 100% with life corals was never reached at any station. In Northern part of bay, Degraded reefs with high percentages for dead corals, were observed both at 6 m and 10 m depth.
- In addition, the impact of sedimentation also has a directly impact to the coral ecosystem degradation,
- Changes in the coverage and stability of coral reefs in Northern part of the bay: A comparison of the coral stations revealed an increase of *Acropora* coverage with increasing distance from the coast.

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Table: The numbers of cages and FCR (food convert ratio) for differ species in cages

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Species aquaculture		Number of cage in 2015 [3]	Quantity in 2015 (ton) [3]	FCR (trash fish)
	Lobster	2,743	187	27,7[1]
Fish in cages	Cobia	495	120	6-8[2]
	Grouper	183	15	
	Seabass	144	7	
	Other fishes	80	4	

Table: The Nitrogen and Phosphorus released by calculating from cage farm areas in Nha Trang Bay, 2015.

	N (Lobster cage)	P (lobster cage)	N (Fish cage)	P (Fish cage)
Calculate for N and P release from cage (ton)	17.91	4.79	3.33	0.97
Calculate for N and P (kg N/ton of fish)	95.75	25.63	22.82	6.63

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FCR in sea-cage farm in Nha Trang Bay	(%) contents in food	(%) contents in lobster meats	Waste output from lobster cage farm activities (ton/year)
42,785 (b)	Nitơ (e)		124.774
	7,648	6,464	
	Phospho (e)		42.79
	2,6	1,24	
17-30 (c)	Nitơ (e)		48.062 - 86.738
	7,648	6,464	
	Phospho (e)		16.711 - 29.856
	2,6	1,24	
8,335 (b)	Nitơ (b); (e)		21.576
	7,43	6,464	
4,5 (d)	Nitơ (d); (e)		11.220
	7,846	6,464	

Sources of references : (a) Statistical Data of Nha Trang city, 2011; (b) Lê Lan Hương et al 2014; (c) Tuan and Mao, 2005; (d) Lại Văn Hùng, 2010; (e) FAO, 2009.

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Table : sediment quality parameters in cage farming areas

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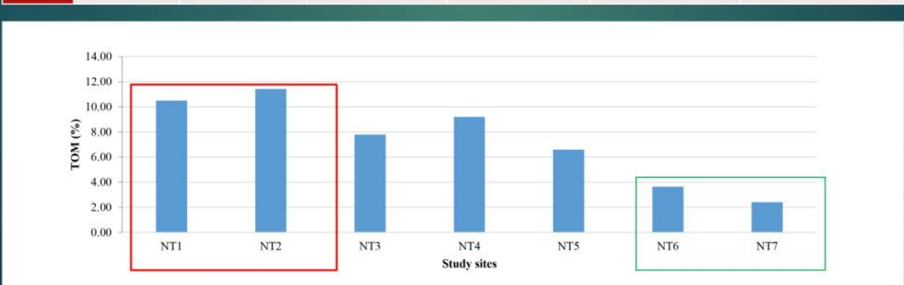
STT	Sites	TOM		TOC	TN	TP
		(%)		(mg/kg)	(mg/kg)	(mg/kg)
1	NT1	10.50		1810.7	217.79	40.436
4	NT4	9.20		1705.9	127.19	64.353
5	NT5	6.59		1668.9	81.47	64.236
6	NT6	3.64		1160.9	48.64	43.363
7	Control	< 2.0				



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Cage farm impacts

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- Using the Trophic Index (TRIX) to assess eutrophication in surrounded waters of coral reef is increasing stressors by activities of sea cage farming
- Remarks: TRIX index was showed 5-6 at almost the sites of the near and middle - distances from cage farm areas (include surface and bottom waters) : State of water quality is bad and levels of eutrophication is high and far-field is lower.
- The results of studies provide essential data and information which is need to assess the long - term impacts of anthropogenic inputs on the degradation of marine ecosystems in the coastal waters of Nha Trang Bay.

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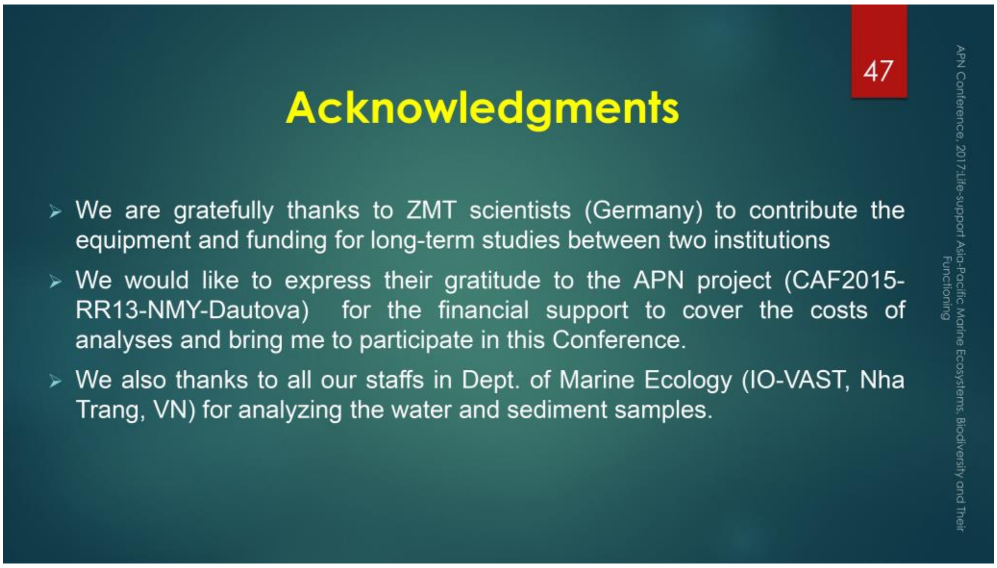


7.5. Other International Meetings and Conferences where results and the project' activity were presented

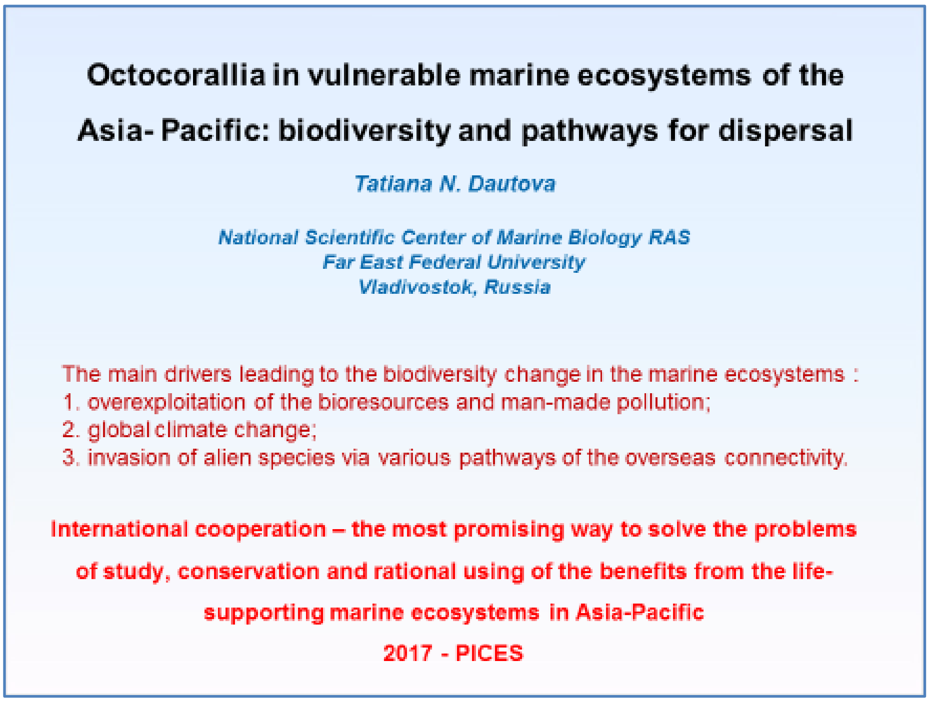
1) WESTPAC, 2017, Qingdao, China. Venue – Sheraton, Qingdao.

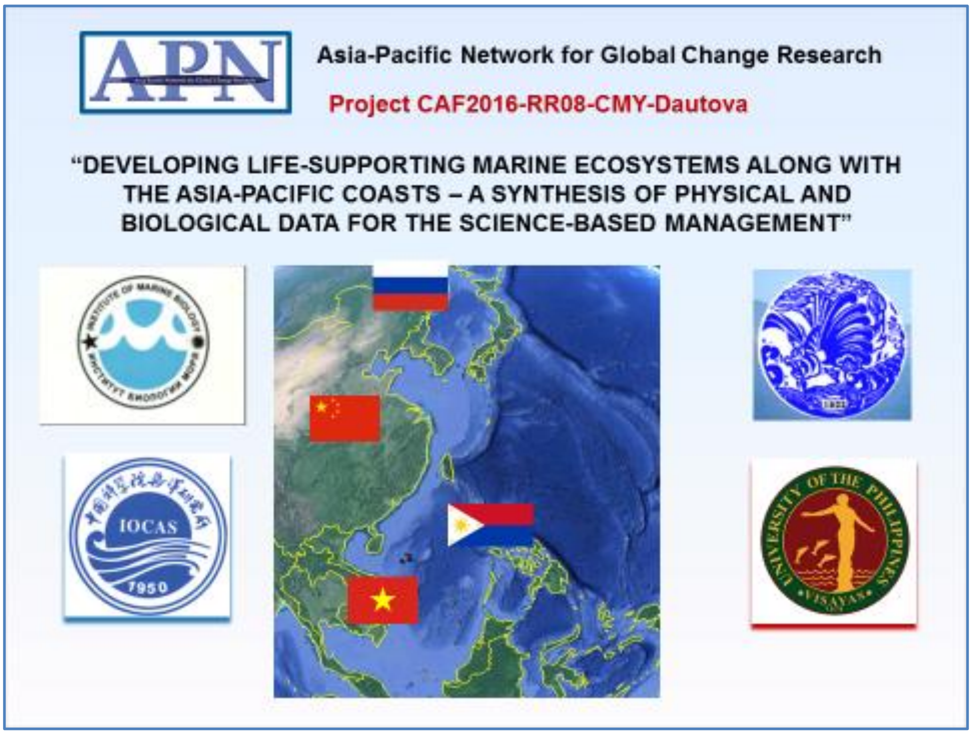
2) PICES, 2017, Vladivostok, Russia. Venue – Federal Far East University.

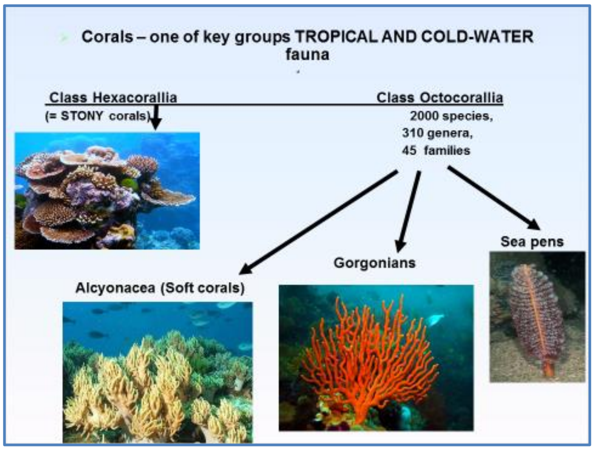
3) Unique marine ecosystems 2016, Vladivostok, Russia. Venue – Federal Far East University.

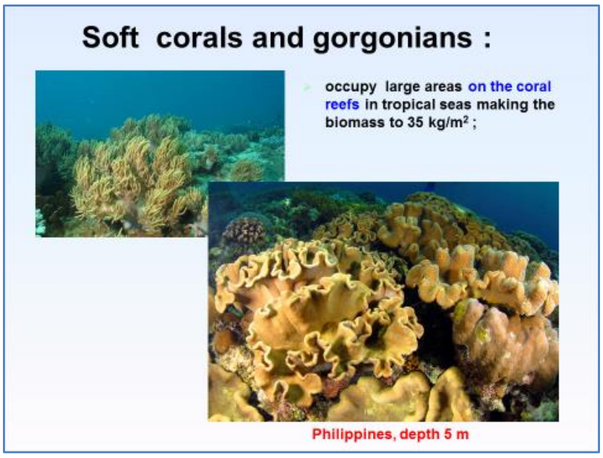
4) Unique marine ecosystems, Vladivostok, Russia. Venue – Federal Far East University.

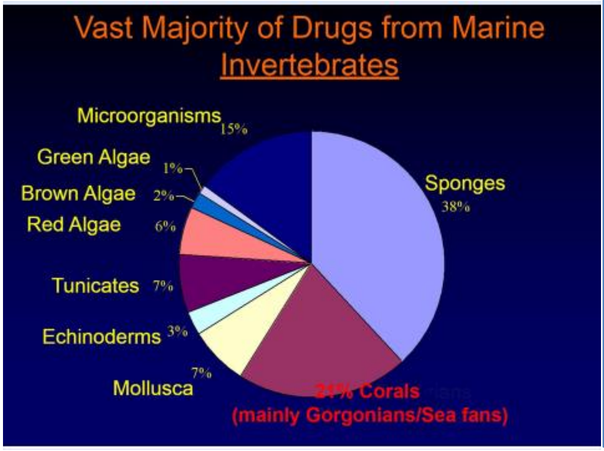
The presentation made by Tatiana Dautova (NSCMB FEB RAS, Vladivostok, Russia) at the International Annual Meeting PICES-2017

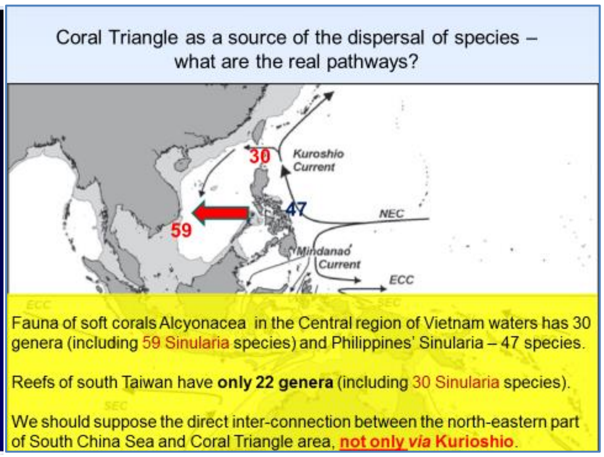


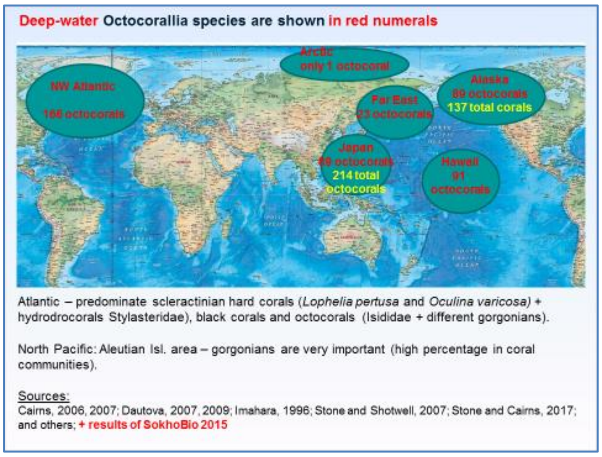

APN
Asia-Pacific Network for Global Change Research
Project CAF2016-RR08-CMY-Dautova
"DEVELOPING LIFE-SUPPORTING MARINE ECOSYSTEMS ALONG WITH THE ASIA-PACIFIC COASTS – A SYNTHESIS OF PHYSICAL AND BIOLOGICAL DATA FOR THE SCIENCE-BASED MANAGEMENT"
IOCAS
1950

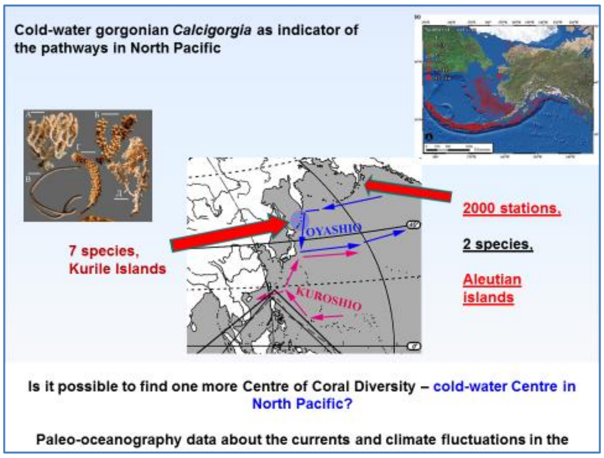

Corals – one of key groups TROPICAL AND COLD-WATER fauna
Class Hexacorallia
(= STONY corals)
Class Octocorallia
2000 species,
310 genera,
45 families
Sea pens
Gorgonians
Alcyonacea (Soft corals)

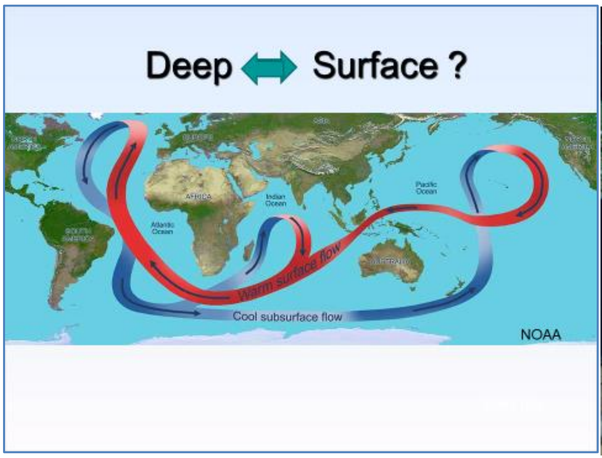

Soft corals and gorgonians :
occupy large areas on the coral reefs in tropical seas making the biomass to 35 kg/m² ;
Philippines, depth 5 m

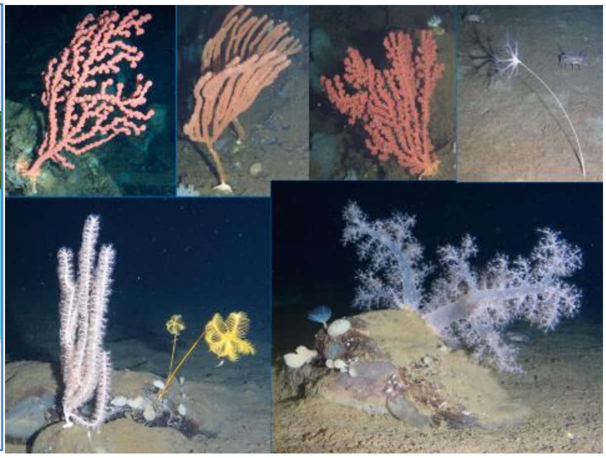

Vast Majority of Drugs from Marine Invertebrates
Microorganisms 15%
Green Algae 1%
Brown Algae 2%
Red Algae 6%
Tunicates 7%
Echinoderms 3%
Mollusca 7%
Sponges 38%
21% Corals
(mainly Gorgonians/Sea fans)


Coral Triangle as a source of the dispersal of species – what are the real pathways?
30
Kuroshio Current
47
NEC
59
Mindanao Current
ECC
Fauna of soft corals Alcyonacea in the Central region of Vietnam waters has 30 genera (including 59 Sinularia species) and Philippines' Sinularia – 47 species.
Reefs of south Taiwan have only 22 genera (including 30 Sinularia species).
We should suppose the direct inter-connection between the north-eastern part of South China Sea and Coral Triangle area, not only via Kurioshio.









7.6. Web–site of the Project is established. It is filling by the data on the project content, participants, project' targets and news on the workshops and publications. The web–site is organized at the base of the web–server of the Institute of marine Biology FEB RAS and is available via link http://wwwimb.dvo.ru/misc/marine_ecosystems/

7.7. Data on the physical parameters (water quality, sedimentation, etc) around coral reefs studied in Nha Trang Bay, South China Sea, Vietnam (see explanation in the text).

Table 1a: The measurement of water parameter in A1 site

Depth (m)	Temp (ºC)	Sal (ppt)	Cond (mS/cm)	Turbidity(NTU)	DO(mg/l)
0	26.28	13.92	23.66	16.51	6.46
1	27.77	31.05	50.32	1.46	5.82
2	27.75	31.55	51.03	2.42	6.20
3	27.68	32.50	52.32	1.14	6.86
4	27.57	33.02	52.97	1.44	7.27
5	27.55	33.06	53.00	2.08	7.26
6	27.53	33.10	53.03	2.66	6.44
7	27.50	33.12	53.03	2.36	6.11
8	27.47	33.14	53.03	1.65	5.82
9	27.42	33.18	53.04	2.08	5.84
10	27.41	33.19	53.05	2.76	5.87
11	27.42	33.21	53.08	3.94	5.89
12	27.42	33.21	53.08	3.99	5.90
13	27.42	33.21	53.09	5.50	5.94

Table 1b: The measurement of water parameter in A2 site

Depth	Temp (ºC)	Sal(ppt)	Cond (mS/cm)	Turbidity(NTU)	DO(mg/l)
0	27.62	31.09	50.24	1.50	6.43
1	27.71	31.49	50.90	1.03	6.75
2	27.71	31.59	51.04	1.20	7.36
3	27.64	32.36	52.08	1.46	6.60
4	27.60	32.76	52.62	1.09	6.30
5	27.51	32.97	52.83	0.94	6.16
6	27.49	33.02	52.88	1.01	6.17
7	27.44	33.11	52.95	1.80	6.22
8	27.42	33.14	52.98	1.95	6.27
9	27.41	33.16	53.00	2.38	6.32
10	27.41	33.16	53.00	3.52	6.37
11	27.41	33.16	53.01	2.85	6.43
12	27.41	33.16	53.01	2.53	6.48
13	27.41	33.17	53.01	3.92	6.53
14	27.41	33.17	53.02	5.81	6.58
15	27.41	33.17	53.01	3.69	6.58
16	27.41	33.17	53.02	11.38	6.59

Table 1c: The measurement of water parameter in A3 site

Depth(m)	Temp (ºC)	Sal (ppt)	Cond (mS/cm)	Turbidity (NTU)	DO(mg/l)
0.00	26.98	24.18	39.60	5.95	7.31

1.00	27.58	31.25	50.43	1.67	6.95
2.00	27.69	32.04	51.67	1.56	6.89
3.00	27.65	32.49	52.28	1.56	6.87
4.00	27.58	32.87	52.76	1.87	6.87
5.00	27.58	32.89	52.78	1.82	7.37
6.00	27.54	32.95	52.83	1.59	6.91
7.00	27.49	33.00	52.85	1.35	6.48
8.00	27.45	33.07	52.92	1.33	6.93
9.00	27.43	33.11	52.94	0.97	6.91
10.00	27.43	33.11	52.95	1.29	6.88
11.00	27.40	33.16	52.99	0.96	6.81
12.00	27.38	33.19	53.01	0.97	6.84
13.00	27.36	33.22	53.03	1.39	6.87
14.00	27.35	33.22	53.03	1.31	6.58
15.00	27.35	33.22	53.03	1.11	6.94
16.00	27.34	33.22	53.02	1.48	6.02
17.00	27.31	33.25	53.03	2.25	6.96
18.00	27.28	33.28	53.04	2.61	5.53
19.00	27.27	33.28	53.04	3.02	6.84
20.00	27.26	33.30	53.05	3.96	6.73
21.00	27.25	33.31	53.05	4.20	6.09
22.00	27.25	33.31	53.05	4.73	6.63
23.00	27.24	33.31	53.05	4.24	6.33

Table 1d: The measurement of water parameter in B1 site

Depth(m)	Temp (ºC)	Sal (ppt)	Cond (mS/cm)	Turbidity (NTU)	DO(mg/l)
0	27.00	23.89	39.19	6.15	6.50
1	27.58	30.86	49.87	1.89	6.20
2	27.68	32.09	51.74	1.39	6.16
3	27.65	32.54	52.36	1.76	6.51
4	27.58	32.84	52.72	1.61	7.12
5	27.55	32.93	52.81	1.72	7.38
6	27.52	32.97	52.84	1.91	7.52
7	27.48	33.02	52.87	1.22	7.34
8	27.44	33.08	52.92	1.26	7.33
9	27.43	33.10	52.94	1.74	7.46
10	27.43	33.10	52.94	1.05	7.55
11	27.43	33.10	52.94	0.82	7.62
12	27.43	33.11	52.95	1.22	7.69
13	27.37	33.21	53.02	1.16	7.69
14	27.34	33.21	53.01	1.37	7.65
15	27.33	33.21	53.00	1.33	7.63
16	27.32	33.23	53.01	1.71	7.60
17	27.28	33.27	53.03	2.66	7.59
18	27.26	33.29	53.04	2.91	7.53
19	27.24	33.31	53.04	3.90	7.49

20	27.24	33.31	53.05	3.45	7.41
21	27.24	33.32	53.05	3.97	7.32
22	27.23	33.33	53.06	3.99	7.19
23	27.22	33.33	53.06	5.03	7.15

Table 1e: The measurement of water parameter in B2 site

Depth(m)	Temp (ºC)	Sal (ppt)	Cond (mS/cm)	Turbidity (NTU)	DO(mg/l)
0	27.45	29.30	47.49	2.36	7.46
1	27.51	31.36	50.53	1.48	6.83
2	27.59	32.13	51.70	1.65	7.51
3	27.57	32.60	52.37	1.57	7.10
4	27.47	33.18	53.08	1.63	7.11
5	27.47	33.19	53.09	1.93	7.16
6	27.46	33.19	53.10	1.65	7.24
7	27.46	33.19	53.10	1.50	7.28
8	27.43	33.20	53.08	1.42	7.18
9	27.42	33.20	53.07	1.26	7.11
10	27.41	33.20	53.06	1.33	6.98
11	27.40	33.21	53.06	1.20	6.65
12	27.39	33.21	53.06	1.11	6.03
13	27.39	33.21	53.06	1.11	7.33
14	27.37	33.22	53.06	1.26	7.29
15	27.27	33.29	53.04	1.24	7.26
16	27.22	33.32	53.04	1.14	7.21
17	27.18	33.36	53.04	1.05	7.17
18	27.09	33.43	53.06	1.82	6.99

Table 1f: The measurement of water parameter in B3 site

Depth(m)	Temp (ºC)	Sal (ppt)	Cond (mS/cm)	Turbidity (NTU)	DO(mg/l)
0	27.40	33.13	52.94	0.81	5.99
1	27.40	33.13	52.94	0.82	6.13
2	27.39	33.13	52.93	0.81	6.35
3	27.39	33.13	52.93	0.88	6.57
4	27.36	33.13	52.90	0.92	6.75
5	27.36	33.13	52.90	0.79	6.63
6	27.36	33.13	52.90	0.82	6.45
7	27.35	33.13	52.89	0.88	6.45
8	27.36	33.13	52.90	1.05	6.51
9	27.35	33.13	52.90	1.07	6.62
10	27.35	33.13	52.90	0.82	6.69
11	27.34	33.13	52.89	0.92	6.76
12	27.30	33.20	52.94	0.94	6.83
13	27.25	33.30	53.03	1.09	6.84

14	27.17	33.39	53.08	1.46	6.81
15	27.15	33.40	53.08	1.57	6.80
16	27.12	33.42	53.07	2.40	6.80
17	27.11	33.42	53.07	2.66	6.82
18	27.10	33.43	53.07	2.76	6.84
19	27.10	33.43	53.08	2.40	6.87
20	27.10	33.37	52.99	33.10	6.91

Table 2: The results of water quality analysis in Nha Trang bay

Order	Sampling sites	Layer	TSS (mg/l)	TOM(mg/l)
1	A1	Surface water	2.75	0.85
2		Bottom water	5.85	1.10
3	A2	Surface water	3.40	0.90
4		Bottom water	4.60	1.05
5	A3	Surface water	7.53	2.73
6		Bottom water	3.44	0.68
7	B1	Surface water	6.13	1.27
8		Bottom water	2.20	0.52
9	B2	Surface water	1.57	0.97
10		Bottom water	2.20	0.90
11	B3	Surface water	1.57	0.93
12		Bottom water	2.73	0.90

Table 5: Sedimentation characters

Sites	Sed rate ($g.m^{-2}.d^{-1}$)	TOM (%) In traps
A1	21.5	7.16
A2	28.9	0.67
A3	12.3	6.22
B1	17.1	4.61
B2	18.6	4.61
B3	11.2	1.67

Funding sources outside the APN

Support Leveraged for the 2nd year from sources other than APN:		In-Kind (US$)	Estimated in Cash (US$)
Budget Secured from Other Sources (Cash and In-kind Contribution)			
Activity	Organisation		
Assessment Tool development	Institute of Marine Biology (Source: research contract fund)	8100	8200
	Institute of Oceanography VAST (Source: Strategic Initiative fund)	8 100	8400
-	Institute of Marine Biology FEB RAS	1 200	2000
Administration Support	Institute of Oceanology CAS	2 000	2400
-	University of the Philippines in Visayas	2 000	2000
Personnel support	Institute of Oceanography VAST	1 000	1000
Total		22 400	24000

List of Young Scientists

No young scientists in the list of initial participants, but we hope that the participation of young scientists from China, Philippines and Vietnam in the undertaken workshops activity and publication activity helped them to develop/build his capacity and the knowledge.

Glossary of Terms

CAS – Chinese Academy of Sciences

CBD – Convention on Biological Diversity

CCOV% – the cover of the reef surface by stony corals.

Ctot - total carbon,

Corg - total organic carbon

DF-SPM – downward flux of the suspended particular matter

FEB RAS – Far East Branch of the Russian Academy of Sciences

GDP – Gross Domestic Product of a country

MIMB – Museum of the Institute of Marine Biology

NW Pacific – North West Pacific

POP persistent organic pesticides

SCS – South China Sea

SCOL – amount of sediment deposited at the bottom

SCUBA - self-contained underwater breathing apparatus

TN - total nitrogen

VAST – Vietnamese Academy of Sciences and Technology

UNEP - United Nations Environment Programme