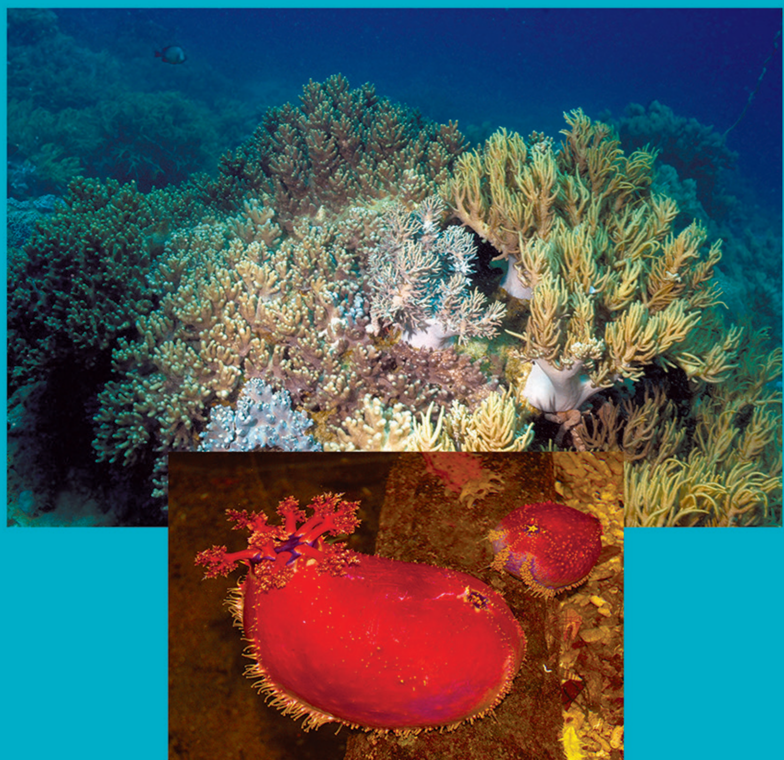
Asia-Pacific Network for Global Change Research (APN)
Institute Oceanography VAST
A.V. Zhirmunsky Institute of Marine Biology FEB RAS

PROCEEDINGS OF THE WORKSHOP

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



Nha Trang, Vietnam, December 21-22, 2015

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Proceedings of the Workshop

“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”

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)

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The book summarizes results of the workshop in the area of biodiversity, marine ecology and biogeography of the South China Sea and adjacent regions held on December 21–22 in Nha Trang, Vietnam. It discusses the synthesis of the biological data concerning the region and surrounding environments, such as marine currents, sedimentation, eutrophication and pollution. The special attention is paid to the policy making for science-based conservation and rational using of the marine ecosystems along with the Asia-pacific coasts.

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PROGRAMME

<u>December 21, 2015</u>

Opening the conference – first day, 21 December 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.

Dr Vo Si Tuan, Director of the Institute of Oceanography VAST (Nha Trang, Vietnam) talks about the workshop goals

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.

1530–16:50. 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.

Maria Jordana A. Olano (University of San Carlos, Cebu, Philippines) with the presentation "Growth and survival of three scleractinian coral species on artificial structures deployed inside and outside a marine sanctuary".

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.
9:50–10:10. Nguyen Chi Cong, Le Dinh Mau *(Institute of Oceanography, VAST, Vietnam)* Numerical simulation of tsunami propagation scenarios to coastal Nha Trang 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.

Nguyen Xuan Vy (Institute of Oceanography, VAST, Vietnam) is discussing his poster "Genetic variations among *Halophila ovalis* and closely related seagrass species from the coast of Tamil Nadu – an AFLP fingerprint approach" with Drs Eduard Titlyanov and Tamara Titlyanova (Institute of Marine Biology FEB RAS, Vladivostok, Russia).

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*

Dr Filipina Sotto (University of San Carlos, Cebu, the Philippines) making the presentations “Restoring Coastal Habitats in the Philippines”.

of Oceanography VAST, Vietnam; [2]Nha Trang University, Vietnam) Effects of densities, tidal zones on the growth and survival of Pacific oyster*, Crassostrea gigas* thũnberg 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.

OPENING SPEECH

Dear colleagues, distinguished participants, fellow scientists and partners, ladies and gentlemen, it is a pleasure to be here today at the APN Conference on the problems of developing life-supporting marine ecosystems along the Asia-Pacific coasts. On behalf of Organizing Committee, I would like to thank all the participants for coming to attend this meeting. Fate decreed that my scientific work and almost 30 years of my life are connected with the marine life, and, in

In the yard of the Institute.

particular, with the sea of Vietnam.

It's a special treat to participate in that APN International Conference here in Nha Trang, in the Central of Vietnam, located at the west part of the South China Sea very close to the Centre of maximal marine biodiversity.

We meet in hope to promote our science regarding the status of East Asia marine ecosystems and unite our efforts for better understanding of their nearest future.

The world, its coral reefs and the millions of people that depend upon them need bolder action - action that is science- and ecosystem-based, action that is embraced locally and nationally, action that values tomorrow as well as today.

And we need bold science – science that is use-inspired: i. e., it is cutting-edge but relevant and focused on solutions.

Since the pre-historical times, coral reefs have been the grocery and pharmacy of people for millennia, their protection against tsunamis and tropical storms, the foundation of cultures, a seemingly infinite source of inspiration, an invaluable library of life's mysteries, and a rich source of resilience against environmental changes.

Approximately 500 million people, or 8% of the global population, depend on goods and services from coral reefs for protein food. Thus, "healthy" reefs have become important for the social development in these areas, especially in the East Asia countries with dense population at their sea shores.

However, under the global change, pollution and overfishing, reef ecosystems are changing rapidly and radically, with profound consequences for people.

Due to it we use all possible ways to find good solutions to protect and rationally use the biological resources of our marine ecosystems!

This meeting is conducting under the aegis of the Vietnam Academy of Sciences, Philippine High-School and Russian Academy of Sciences. We all are greatly thankful to the Asia Pacific Network for the Global Change Research who supported us by the project under the title "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".

MSc Hoang Trung Du (Institute of Oceanography VAST, Vietnam) making the presentation "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".

Dr Filipina Sotto (University of San Carlos, Cebu, the Philippines) commenting the problems of the restoration and developing the coastal marine ecosystems for TV-presentation of the Conference.

That project addresses the essential questions regarding the global change research – how to identify, explain and predict the changes in the coastal marine ecosystems (particularly – coral reefs) under the natural and anthropogenic influence forcing?

The main goals of our meeting are expected to be focused on the problem - how to identify the recent changes in the coastal marine ecosystems and their adaptive capacity under the climate change and human impact in the South China Sea, the largest sea in the Indo Pacific tropical zone.

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.

We intend to unite the experience and knowledge of the scientists, management specialists and policy makers of our countries for the following main goals:

1) to synthesize the data on the physical environments in the sea and their change under the global climate fluctuations and man-made activity;

2) to analyze 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 and explain their reasons;

3) to estimate the adaptive capacity and self-restoration potential of the coral reefs in the South China Sea under the global climate change.

Our project is intended to unite both the high-level and early-career scientists and managers from our countries to promote the regional cooperative global change research. We plan widely discuss and promote at public and policy-making levels all our results and conclusions for developing the social-related policy options for the marine conservation and appropriate responses to global change as well.

As the marine coastal ecosystems, such as coral reefs, contribute the invaluable benefit to the life-support human systems and economics in Asia-Pacific countries, the project is immediately relevant to the APN mission to enable investigations of changes in the Earth's life support systems and their implications for sustainable development in the Asia-Pacific region.

This APN 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. Coastal marine ecosystems in East Asia 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, eutrophication, 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.

Fragment of TV-presentation highlighting the meeting opening.

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 leading to sustainable using of marine areas in fast developing South East Asia countries. This crosscutting survey includes a range of different sciences – from marine physics and chemistry to biodiversity and reproduction of marine organisms.

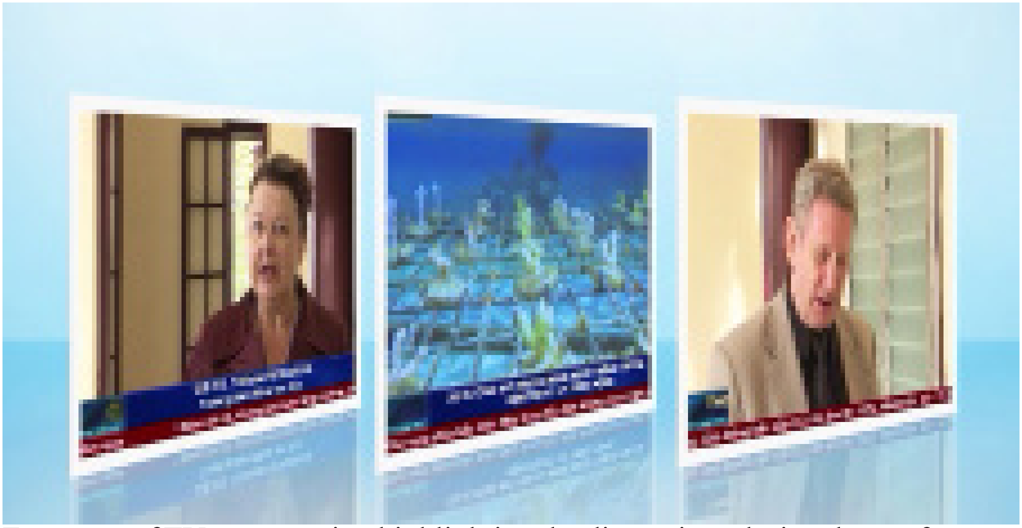
The dispersal and survival of corals and other key marine organisms depend on currents and other processes that deliver larvae to the settlement site and even concentrate them at certain locations.

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.

At the same time, the experience of the scientists and marine managers from the Vietnam, Philippines and Russia shows that we have the very similar problems with the conservation and restoration of our marine ecosystems and resources.

Due to it, the uniting of our efforts can possess the exchange of approaches and ideas and help to synthesize our knowledge to protect our marine heritage for the future generations.

The uniting of our countries can provide 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.



Fragment of TV-prezentation highlighting the discussions during the conference.

The aim of our together discussion is addressed the policy questions in two main areas:

1) enhancing of the operation for coral reefs conservation and restoration 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.

Science is not only vital for providing information, tools, and services for managing coral reefs, but a powerful tool for shaping policy and management of coral reef ecosystems. Science does not tell society what to do, but it should give them the information, tools, understanding of trade-offs of different consequences that facilitate smart decision-making.

This meeting is timely. We need bold science and bold action. There is a vital role for governments to play, but equally importantly is the role of academia, civil society, and industry. Harnessing that collective commitment is underway – but it remains to be seen if changes will be rapid and substantial enough. There is a significant gap between the accelerating pace of degradation and the rate of effective response.

Each of you here can influence the rate of response by activating your science.

You can influence the future of coral reefs for our future generations.

I'm hopeful that the results and ideas discussed here these days will be put to practical use, drawing on the keys to success that I've highlighted.

I invite you to do more to create new knowledge and share it for practical using with partners and a sustained engagement.

Thank you and wish you the interesting discussion at this Conference, and, good prosperity to you and Vietnam!

Dr. Tatyana Dautova
Institute of Marine Biology Far East
Branch Russian Academy of Sciences
Far East Federal University
Vladivostok, Russia

BIOFLOC TECHNOLOGY: NEW TOOL TO IMPROVE *ARTEMIA FRANCISCANA* PRODUCTION FOR COPYING WITH CLIMATE CHANGE IN SOLAR SALT POND OF MEKONG DELTA, VIETNAM

***Pham Quoc Anh Duy*[1], *Nguyen Thi Ngoc Anh*[2],**
***Tran Suong Ngoc*[2], *Nguyen Van Hoa*[2]**

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Introduction

In Vietnam, *Artemia* was firstly introduced in 1984 and successfully cultured along the coastal areas of Mekong Delta and become an important species with high quality of cysts that used in domestic aquaculture and export (Son, 2008). During past time, chicken manure is considered as the traditional fertilizer source with availability and cheap in *Artemia* culture farming in order to stimulate the primary production via photoautotrophic progress of natural algae population in fertilization ponds (Fig. 1). Due to the effects of climate change

Fig. 1. *Artemia* pond.

such as early rain, high temperature, fluctuation in salinity level, etc, during dry season, fermented rice bran and shrimp feed are used as supplemental food for *Artemia* (Truc, 2015). Besides that, “Biofloc technology” by maintaining a high Carbon/Nitrogen (C/N) ratio in water can be stimulate heterotrophic bacterial growth that converts ammonia in to microbial biomass directly, which can be consumed in situ by the cultured animals or harvest, processed as a feed ingredients and improved the culture medium (Avinemelech, 2012).

Materials and Methods

Study was performed to access the effect of different salinities on biofloc development in *Artemia* culture system. In the first experiment, four salinities treatments (30, 60, 80 and 100‰) were conducted in the fertilization ponds for 21 days. Experiment 2 contents 4 treatments, including 2 treatment applied biofloc in the *Artemia* ponds at salinities of 80 and 100‰ were compared with 2 treatments of traditional culture (control) with the same salinity for 6 weeks. Each treatment had 3 replicates. Tapioca powder combined with chicken manure were used as a carbon source and to maintain C: N>10 to stimulate heterotrophic bacteria growth and biofloc formation. Temperature (^{o}C), dissolved oxygen (ppm) and salinity (‰) were measured daily at 7:00 and 14:00. TAN, NO3- and TN in fertilization systems were taken every week, stored under 0 ^{o}C and analyzed using a spectrophotometer according to standard method (APHA et al., 1995).

Total bacteria were analyzed on plates containing Marine Broth Agar. The number of total viable colonies was counted after 24 hours incubation at 29–30 ^{o}C and determined by colony counting method (Baumann et al., 1980). Nutritional values of biofloc were examined at the day of 7th, 14th and 21st by AOAC, 2000.

Results and Discussion

Results of experiment 1 showed that the volume of biofloc in all salinity treatment were highest at at day 9 and day 15 and sharply declined at day 21. Total bacteria were higher at low salinity, they gradually increased and peaked up at day 15 and then tended to decline with time. The proximate composition (crude protein, lipid and ash) of biofloc were not difference among salinities treatments, in which the protein and lipid concentration had the highest values at day 14.

For the experiment 2, survival and growth of *Artemia* after 2 weeks of culture were not significant difference among treatments (p>0.05), varying in the range 65.3–69.7% and 6.7–7.3 mm, respectively. The fecundity and *Artemia* cyst yield in the biofloc treatments was higher than the control treatment but there was no statistical difference. Furthermore, higher cyst yields in the 80‰ treatments were achieved as compared to 100‰ treatments. The concentration of nitrogen compounds (TAN, NO^{3-} and TN) in the biofloc ponds were lower than the control ones. Results revealed that application of biofloc in *Artemia* ponds can enhance the cyst yield and environmental protection.

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GROWTH AND SURVIVAL OF PACIFIC OYSTER *CRASSOSTREA GIGAS* THÜNBERG, 1793 IN NHA PHU LAGOON, KHANH HOA PROVINCE

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Effects of densities, tidal zones on growth and survival rate of Pacific oyster*,* *Crassostrea gigas* Thünberg, 1793, were conducted from June to December of 2014 at Nha Phu lagoon of Khanh Hoa Province. In addition, effects of predators, temperature, chlorophyll-a concentration, total suspended solid on growth and mortality of oyster were examined in two seasons. Oysters were cultured at three different densities: 25, 38 and 50 oysters per m^{-2} at the intertidal and subtidal zone. Results show that Pacific oyster cultured in three different densities at the two tidal zones had fast growth rate. During five months the Pacific oysters reached length of shell average 87±0.95 mm or 67.18±2.48 g at intertidal zone and at subtidal zone they were 85.56±0.95 mm or 64.90±2.58 g. No significant difference was found for specific growth rate between two tidal zones. The average growth rate was faster at density of 25 individuals/m^2 than 38 individuals and 50 individuals/m^2 all treatments. The average growth rate for one month was 13.63±0.51 g equivalent to a shell length of 17.43±0.19 mm/month at the intertidal and at the subtidal (12.98±0.52 g/month, equivalent to a shell length of 17.11±0.19 mm/month). The growth rate difference between dry

season and rainy season was significant at both two tidal zones and positively correlated with concentration of chlorophyll-a, while no significant difference was found for survival rate amongst three densities during 150 days at both tidal zones. At the intertidal, the average survival rate was 56.91±1.92%, and the subtidal zone was 50.36±1.65%. There is significant difference of survival rate between intertidal and subtidal zones with positively correlated predators.

Introduction

The history of oyster culture in Vietnam consists of a succession of development phases with different native species. The oyster *Crassostrea ariakensis (revularis)* cultured at coast in the North as the Chanh river, Bach Dang river from 1960 and still have been continued up to now, while in central of Vietnam the oyster *Crassostrea bilineata (lugubris*) was cultured in Lang Co Lagoon, An Hoa coastal, Thi Nai Lagoon, Nha Phu Lagoon, Nai Lagoon (Cao Van Nguyen et al., 2014) and in South Vietnamese coast it was the culture of oyster *Crassostrea belchery* in the Long Son river of Ba Ria - Vung Tau Province, Can Goi coast of HCM city. From 2007, the Pacific oysters *Crassostrea gigas* were introduced from Taiwan into Vietnam (Fig.1). The Pacific oysters grow fast, being tolerant to a wide range of environmental conditions, replaced native oysters and were first cultured in Bai Tu Long Bay and then spread coastal Centrals and South of Vietnam. We measured the survival and growth rate of the *Crassostrea gigas* oysters at intertidal and subtidal zones in Nha Phu Lagoon and considered water-quality parameters. The study is intended to

Fig. 1. *Crassostrea gigas* Thunberg, 1793 (photo by Cao Van Nguyen).

collect preliminary data about growth and survival rate that can guide future development efforts in the coastal zone of Vietnam.

Materials and methods

1. Site description

Field experiment sites were located in Nha Phu Lagoon, 12 km north of Nha Trang city. It is about 20 km long and 5–6 km wide. The head of the lagoon consists of a shallow area with a maximum depth of 2 m whereas the mouth of the lagoon has 12 m deep. The average depth of lagoon ranges 1.5–2 m, with water surface area at high tide of 5000 ha and at low tide 3000 ha.

2. Experimental Design

Diploid seed Pacific oysters were collected from seed hatchery of Pacific Oyster Company, Nha Trang. After 1 months of being reared on the seed strings in Nha Phu Lagoon, they were separated into individuals, chosen and transferred to cages with size (L x W x H: 20 cm x 20cm x 10cm) in order to continue to monitor the growth and survival rate. With total of 450 Pacific oysters individuals were used with 26.65±0.1mm of shell length and equivalent to 2.33±0.04 g. It was randomly distributed to 30 cages of six treatments on two tidal zones, each treatment was five times replicated according to three densities: 10 oysters/cage, 15 oysters/cage, 20 oysters/cage, equivalent to 25, 38 and 50 oysters per m^{-2}. Each zone tidal includes 15 cages. The cages were hung on rack culture system following two tidal zones on the same string in the intertidal and subtidal zone to compare growth and survival rate of oysters. Intertidal cages were placed where they would receive varying amounts of air exposure during low tide and subtidal cages were placed where they would be continuously submerged (Fig. 2). The cages and oysters were cleaned monthly.

3. Data collection

Oysters measurements. The shell length and the individual weight were measured monthly. The survival rate in each cage was measured using the following formula: $S\% = 100 \times n_t/n_0$, where: S is the survival rate; n_t is the number of oyster at time t and n_0 is the number of oyster at the commencement. The number of oysters in each cage was checked monthly by removing the dead oysters, numbers of flatworms, crabs present at each level of the cages were also recorded.

Water quality parameters. Temperature, salinity and pH, DO (Dissolved Oxygen) were monitored monthly by using Multi-meter water quality criteria. TSS (Total Suspended Solids) and Chlorophyll-a were collected in dry season (August) and rainy season (October) following the techniques described in the Standard Methods for Examination of Water and Wastewater (APHA 1992).

4. Data analysis

Correlations between environmental variables as instant oyster mortality and growth rate in two season were examined using Pearson correlation coefficients with $\alpha < 0.05$. The data were statistically analyzed using statistical analysis program SPSS for Windows version 18. Results were presented as mean ± SE. The normality of data was assessed by the Shapiro – Wilk test, the homogeneity of variance was assessed by Levene test prior to the analysis. Normally distributed data were subjected to one-way analysis of variance (ANOVA) for three densities by using *post hoc* LSD test, to independent samples T-test to compare two zones for data of homogenous variance, and Tamhane's test for data of nonhomogeneous variance. All percentage data were arcsine transformed prior to statistical analysis. All significant tests were at $p < 0.05$.

Results and discussion

1. Growth and survival. The growth and survival rate of the Pacific oysters cultured at three different densities, in the two tidal zones are presented in Fig. 2 and in Table 1.

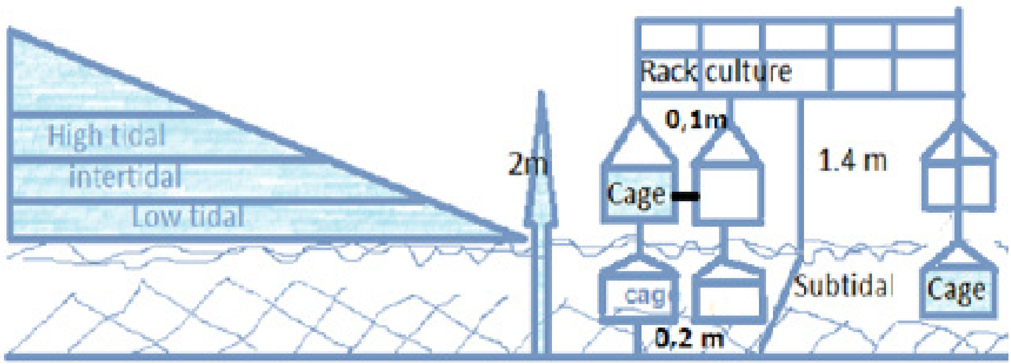

Fig. 2. General experimental set-up of all intertidal and sub-tidal treatments.

2. Discussion. Our studies at Nha Phu Lagoon show that the Pacific oysters, *Crassostrea gigas* for five months reached the average shell length of 87.14±0.95 mm, the weight equivalent to 67.88±2.57 g at intertidal zone and at subtidal zone of 85.56±0.95 mm, the weight equivalent to 64.90±2.58 g. No difference of specific growth rate between two tidal zones was detected (Table 1). This species in European countries in one years reached weight from 40 to 50g, in Israel subtropical fish ponds the young oysters of 4 g reached 80 to 90 g for one year (Héral, Deslous-Paoli, 1991). In China they not excess 75 mm height of shell within two years (Harding, Mann, 2006). Our results indicate that the Pacific oysters at Nha Phu Lagoon grew faster. The specific growth rate was 17.4 mm/month with the chlorophyll-a concentrations in August 2.14 mg m^{-3} and October 5.88 mg m^{-3}; the temperature ranged between 28.8 to 31.4^{0}C; salinity ranged from 34.1 to 34.4‰ during summer and in rainy season fluctuated from 26.4 to 32.7‰. The decline in salinity recorded in rainy season of the study period is caused by a dilution effect as a result of both direct rainfall and land drainage; the pH value in our study ranged from 7.75 to 8.12 in dry season and in rainy season from 7.99 to 8.27. Whereas *Crassostrea virginica* oysters in Chesapeake Bay growth rate of 15.15 mm/month and *Crassostrea lugubris* oysters cultured at Nha Phu Lagoon for one year reaches 50 g, equivalent to 80 mm of shell length (Cao et al, 2014).

Table 1. Survival and specific growth rate of *Crassostrea gigas* during 150 days (mean±SE), n=225

Parameters	Intertidal	Subtidal
Survival (dead) (%)	56.91(43.09)±1.92^{a}	50.36 (49.64)±1.65^{b}
Length (mm)	87.14±0.95^{a}	85.56±0.95^{a}
Weight (g)	67.88±2.57^{a}	64.90±2.58^{a}
SGR (mm/month)	17.4±0.19^{a}	17.11±0.19^{a}
SGR (g/(month)	13.58±0.51^{a}	12.98±0.52^{a}
SGR (g/Rainy season)	19.99±1.27^{a}	18.17±0.21^{a}
SGR (g/Dry season)	5.45±0.10^{a}	5.20±0.12^{a}

Note: SGR - specific growth rate; different superscript letters in the same row indicate significantly different means at $P < 0.05$.

Significant difference in cumulative oyster mortality were found between intertidal and subtidal zone oysters. Cumulative oyster mortality observed at subtidal during the present study was 49.64% higher than at intertidal (6.55%). Instant oyster mortality rates varied at Nha Phu Lagoon throughout the summer with temperature over 31.4^{0}C. ($r = -0.768$, $p=0.026$). The decrease we recorded in the rainy season was possibly linked to lower temperature and lower TSS, total suspended solids in dry season ranged from 39.50 to 56.70 mg/l, and in rainy season, from 15 to 27.80 mg/l. Soletchnik et al. (2006) also described a peak in summer mortalities during June. At intertidal zone, instantaneous oyster mortality was positively correlated with temperature, while at subtidal zone it was negatively correlated with temperature and positively correlated with water turbidities. In the present study, the oyster mortality rate at subtidal during the summer season was higher than during rainy season. Higher mortality rate recorded in subtidal habitat is thought to be results of predation (Menzel et al., 1956; Gosling, 2003). During this study, we recorded blue crabs in the cages, boring sponges, flatworm, other sessile species such as bryozoans at the subtidal more than at the intertidal; these animals can compete with oysters for space and food, contributing to higher subtidal mortality than intertidal.

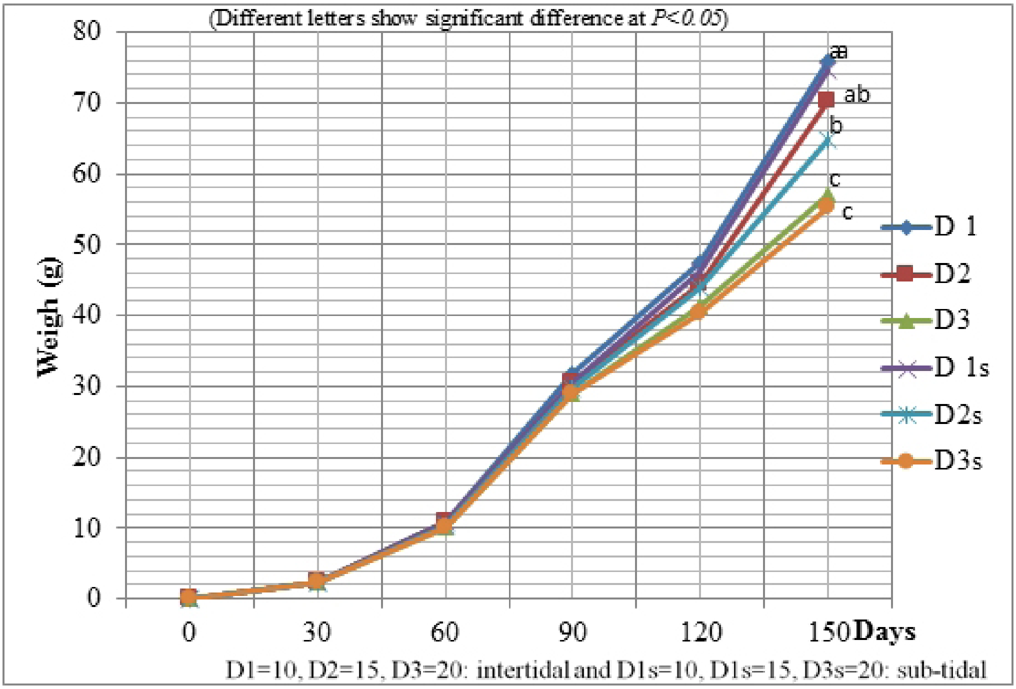

Fig. 3. Growth of *Crassostrea gigas* at three different densities in intertidal and sub-tidal.

Conclusions

Main finding. The average growth for five months the Pacific oysters reached the average shell length of 87.14±0.95 mm or 68.18±2.48 g at intertidal zone and in subtidal zone were 85.58±0.95 mm or 64.90 ±2.58 g.

The average growth rate was faster at density of 20 individuals/m^2 than at density 50 individuals/m^2; there were no significant difference of growth rate for 150 days in all treatments at the places with density of 20 individuals/m^2 and 38 individuals. But biomass of 50 oysters/m^2 resulted in the larger final oyster volumes in comparison with those of densities 20 and 40 oysters/m^2.

The average survival rate of oysters in the intertidal was 56.91±1.92% and in the subtidal zone it was 50.36±1.65 %.

There are significant differences of survival rate between intertidal and subtidal zone with positively correlated amount of predators. But no significant differences were found for survival rate amongst three densities for 150 days in both tidal zones.

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SOFT CORALS IN THE ECOSYSTEMS OF SOUTH CHINA SEA

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The high level of biodiversity is considered as the essential requirement for the resilience of the ecosystems defined as the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a set of different processes. The main goals for the conservation and sustainable use of biological diversity and other natural resources are inseparably linked with distribution of benefits resulting from integrated and participatory approaches to sustainable management of the coupled social-ecological systems.

The marine bottom ecosystems are among the traditional bioresources for the long-term cultures and social demographic trends in countries having long maritime boundaries, such as in the East Asia. The region of the South East Asia seas has been observed to have a high population growth. Around 1.9 billion people have been estimated for this region and 77% live within 100 km of the coast (Burke et al., 2002). Many coastal lands and their adjacent seas, including tropical coasts, are ecologically productive, biologically diverse and climatically and physically attractive. The high productive marine ecosystems, such as coral reefs, provide an important life support system to coastal states especially through food from fisheries. The coral reefs, being the cradle of fish reproduction and fattening, represent a complicated ecosystem. These

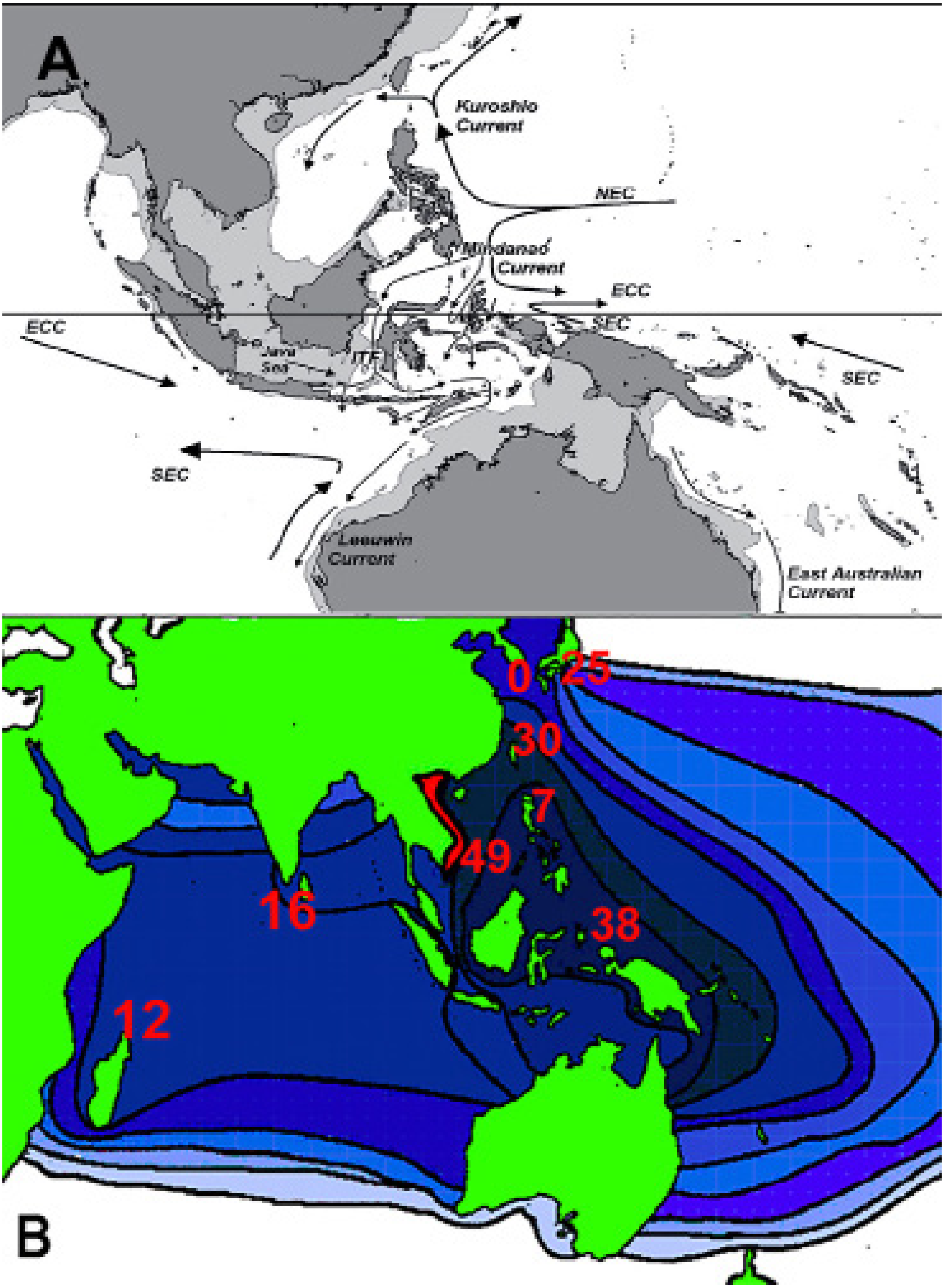

Fig. 1. A. Indo-Malayan Centre of Marine Biodiversity presented as Coral Triangles (Paine 1988, Allen 2002, summarized by Hoeksema 2007). B. Distribution of stony corals species richness (showed by color) and soft coral *Sinularia* species richness (showed by numbers) in the Indo-Pacific.

ecosystems provide the full life cycle for numerous invertebrates and algae that are widely used as food sources, in particular, as a source for chip protein diet.

More than 75% of the world's reefs are threatened by human activity ranging from coastal development, marine pollution, sedimentation and eutrophication from inland deforestation and farming. Most coral reefs in the coastal waters of South East Asia are in shallow water; these reefs are affected by complex environmental effects (including the anthropogenic impact). The overheating of the corals in shallow water can lead to bleaching and subsequent death of the corals. There are many reports of coral losses of 30–60% and some as high as 80–90%, with some localized extinctions of prominent corals from the northern part of the South China Sea. All countries of that region have improved policies concerning coral reefs, but more attention is needed for designating and managing of MPAs and building capacity as reefs in this region come under extreme pressures from overfishing, as well as high levels of sediment and nutrient pollution arising from activities on land.

Among the reef-inhabiting animals, two main coral groups should be placed in a focus of the careful study and monitoring – stony (reef-building) corals and octocorals (soft corals, sea fans, and sea pens). However, Octocorallia, in particular, soft corals Alcyoniidae, are less well-studied in comparison with stony Scleractinia corals. The study of the Octocorallia species richness is essential in the frame of the worldwide and local biodiversity problems. For a competent survey of the trends in the dynamics of soft corals populations, the joint efforts of specialists in the coral taxonomy and ecology are needed together with the analysis of the dispersal ways. The possible dispersal ways by oceanic currents should be analyzed along with the genetic similarity of populations in order to learn how distribution ranges develop and how they are maintained. Solving of the complex problems of the taxonomy and genetics of soft corals with their species-specific ecology is needed both to trace the possible ways for the soft corals dispersal in the ocean and for monitoring purposes. 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 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.

The Vietnam waters, being a part of the South China Sea, are very promising for a detailed survey of the soft corals. Coral reefs of Vietnam are located in the north-eastern part of the greatest region in South East Asia seas in terms of species diversity and are connected with the richest marine region on the Earth – the so-called Coral Triangle located between Indonesia, Malaysia and the Philippines. Octocorallia investigations in Vietnam started in the beginning of the 20th century. Dawydoff (1903, 1929), a pioneer of Vietnam marine biota surveys, worked in the region in 1903 (the Gulf of Thailand) and 1929 (eastern coast of Indochina peninsula and the Gulf of Tonkin). He initiated the collection of marine invertebrates, including soft corals and gorgonians. Based on the results of his scientific expeditions, 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, Central Vietnam collected by staff members of the Oceanography Institute of Indochina. Tixier-Durivault 's publications (1943, 1944, 1956, 1956, 1958, 1970) and a short paper of Stiasny (1951) based on these collections provided some data on the Octocorallia regional fauna diversity and emphasized the insufficient knowledge about Octocorallia. These above mentioned early investigations formed the cornerstone for later biodiversity and taxonomic studies on this group in Vietnam. 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. 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., 1998), 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., 2009). 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. 1). However, most records known before 2000 were for the Red Sea and the Seychelles-Mauritius Plateau (altogether 38 species, Ofwegen, 2002).

By our preliminary data, the soft corals in Nha Trang Bay in the central of Vietnam are founded as important component of the structure of the coral communities (Fig.2). The abundance of soft corals at the Hon Mun and most diving sites near Hon Tre Island is not changed since 2011 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 – at the Hon Mun and Hon Tre islands. At the south of Hon Tre Island, the coral community is suppressed more in comparison with its condition in 2008–2011 years. The soft corals which are common here are mainly *Sinularia*. Their settlements are disposed on the stones and both peninsulas of this small bay at the south shore of Hon Tre. The reefs at the coast of Hon Mieu Island have destroyed population both stony and soft corals. The bottom is occupied by the coral debris; only two soft corals genera are founded here in quite good amount – *Sarcophyton* and *Sinularia*. 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*, among Nephtheidae – to *Paralemnalia*.

The Gulf of Thailand at the south western of South China sea contains only 12 genera – *Sinularia, Dampia, Cladiella, Klyxum, Sarcophyton, Lobophytum, Eleutherobia, Scleronephthya, Dendronephthya, Siphonogorgia Chironephthya*, and *Nepthyigorgia* (Chamentakul et al., 2010). The authors note that there are some differences between Andaman seawaters of Thailand (with 19 genera) and those of Gulf of Thailand due to the differences in habitat environments. The Gulf of Thailand is characterized by low salinity, high turbidity, and a muddy bottom, compared to conditions in the Andaman Sea, which are more oceanic, with more-extensively developed reefs. Based on oceanic circulation models, the source of present-day soft corals in the Gulf of Thailand must have dispersed from the South China Sea (Chamentakul et al., 2010).

The Chinese reefs (mainly on Hainan Island) at the northern part of the South China Sea, 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*, and *Dendronephthya.*

At the same time, we note that the diversity of the region inside the Coral Triangle is just scarcely studied until today, especially – in the Philippines. After the detailed survey of the soft corals of this area, it could be found the more reach fauna of these animals in the eastern and central of Philippines.

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. Being a part of the Coral Triangle Philippines are3 expected to contain the very diverse fauna of soft corals, especially of mass genera – *Sinularia, Sarcophyton* and *Lobopytum*. However, the Philippines *Sinularia*, on the other hand, with only 7 reported species, are poorly known from the scarce publications (Ofwegen 2002). 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, show that the dispersion of the marine species may be directed from Coral Triangle into the Indian Ocean; the Java Sea and the South China Sea 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 warm water of the Kurioshio Current passes east of the Philippines to southern pacific side of the Japan and intrudes into the South China Sea moving along of southern Taiwan. It can influence on the corals richness on the reefs of the central part of Vietnam as well as southern Taiwanese reefs. Really, the stony corals fauna of the reefs of Central Vietnam is quite rich and includes more than 65 genera and, moreover, the several species of the *Porites* genus which were firstly described from Philippines. The same situation can be considered concerning with Octocorallia fauna of the region. The preliminary Alcyonacea list of the soft corals (with *Briareum* genus) of Central Vietnam includes 27 genera; the *Sinularia* species list has 36 “old” species and a range of the new species. The reefs of the southern Taiwan contain 22 genera including *Sinularia* with not numerous species. The coral reefs of Taiwan and Japan are closely linked by the northward flowing Kurioshio Current. The soft coral fauna of both areas shows a close resemblance between their faunas in terms of generic composition and number of species. The finding of *S. higai* and *Sarcophyton nanwanensis* both from Japan and Taiwan anticipate that similar patterns also exist for other important soft coral

Fig. 2. Soft corals in Nha Trang Bay.

genera. 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 be occurred in that region due to the Coral Triangle vicinity. Such studies will contribute to our knowledge on the status of the reefs in this region and should include a temporal scale to provide feedback on reef health for conservation purposes.

The research of the Octocorallia species richness is substantially in the frame of the worldwide and local biodiversity problems. However, 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. Basing on the results of the processing of the museum collections of soft corals, made during the joint projects of the Institute of Marine Biology FEB RAS and Institute of Oceanography VAST, 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.

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EFFECT OF THE DEPTH OF HABITATION ON THE CONTENT OF ORGANIC FORMS OF C, N AND P IN DEEP CORALLINE ALGAE COMMUNITIES IN THE SOUTH CHINA SEA

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Major components of coral reef ecosystems are the red coralline and benthic microalgae. Their communities form a kind of blankets (3–5 mm thick) on the surface of dead corals; they combine autotrophic and heterotrophic organisms and represent a unique microbiocenosis (Sorokin, 1990). Over the past 50 years, coral reef ecosystems have suffered a rapid degradation, which is associated with both the global warming trend and anthropogenic factors. The Great Barrier Reef has lost 25–50% of their coral cover over the last 27 years, while cortical coralline algae have increased their cover by 30.7% (Dean et al., 2015). On the coral reefs of Vietnam, where the gross primary production of the ecosystem is averaging 12.4 g C/m^2 day, the share of coralline and benthic microalgae accounts for up to 48.4% (Nguen Tac-An et al., 2013). The results of the studies of deep-water rhodoliths communities formed by coralline algae, extending from the littoral to a depth of 268 m (Littler et al., 1991; Cherbadgy, Propp, 2008), are of exceptional interest in terms of their adaptation to extremely low light. The recent and ancient biogenic-carbonate structures act as combined traps of oil and gas, in particular on the shelf of the South China Sea (Lukin, 2007). It is assumed that oil and gas fields are mainly byproducts of recent carbon cycling through the surface of the earth. 90–95% of them arise from inflow of meteogenic water to a depth of 1–10 km, and 6–10% is formed at fossilization of organic residues in the crust (Barenbaum, 2004). Determined mainly by the regional character of the climatic cycle, filling of the traps with hydrocarbons occurs within the time of many tens hundreds of years. In the context of the established characteristics of Pliocene–Quaternary and recent carbonate accumulation and reef formation, this discovery is of particular importance. The results of the detailed studies of the organic matter of recent and fossil coralline formations can be used to decipher many obscure issues of the origin of oil and gas. However, little is currently known about the effects of environmental factors such as light and depth in the place of habitation on the biochemical composition of the coralline algal community (CAC), especially those of the deep sea, that are the main components of coral reefs.

The main objective of this study is to determine the total content of organic matter in the community, to establish the proportion of each element and their ratios in the organic substances and the analysis of its distribution in space, i.e. over the water area and vertically through the water column. Information about the elementary composition of the organic matter can be used for calculating the ratio of its basic elements (C/N, C/P, N/P, C/N/P), that gives an indirect characterization of its qualitative composition.

Material and methods

The study of qualitative composition and quantitative content of organic forms of carbon, nitrogen, and phosphorus of the CCA, in terms of the depth of habitation, was carried out in the South China Sea on board the research vessel "Akademik Oparin" from 20 to 29 May 2007 at 4 stations (Table 1). Water samples for the analysis of hydro-chemical characteristics of seawater at shallow stations (St. 1 and 2) were taken with bathometers from the bottom layer in the habitat of algae and at deep-water stations – at a depth of 15 m (Table 1). To determine the hydro chemical parameters, we used internationally accepted methods with some modifications (Management ..., 2003). Determination of the organic forms of N and P in CAC is based on the decomposition of organic compounds to the mineral with sulfuric and perchloric acids. In determination of the C_{org} we applied an indirect method using oxidation of the organic matter with hot solution of chromic acid (Propp et al. 1979).

Table 1. The mean values (± SD) of hydro-chemical parameters of sea water

Region	**Position**	**O2, mg/l**	**PO_4, μM**	**NH_4, μM**	**NO_3, μM**	**NH_4+ NO_3**	**N/P**
Bath Long Isl.	20° 08′ 49 N 107°44′83 E	6.54±0.02	0.07±0.02	0.38±0.00	0.01±0.00	0.39	5.6
Re Island	15° 24′ N 109° 8′ E	6.32±0,11	0.05±0.01	0.27±0.08	0.26±0.00	0.53	10.6
Vanguard Bk	7° 24′ 2 N 109° 33′ 8 E	6.49±0.08	0.07±0.01	0.44±0.11	NM*	NM *	NM*
Ladd Reef	08° 40′ 8 N 111°42′ 7 E	6.29±0.01	0.07±0.01	0.10±0.04	NM*	NM*	NM*

Note: NM * – not measured.

Results and Discussion

Rhodoliths clusters are formed by cortical red coralline algae (*Lithophyllum* sp., *Peyssonelia* sp., *Porolithon sp*.) and covered with overgrowth of brown limestone algae (*Padina* sp.). They are penetrated with boring filamentous green algae (*Ostreobium* sp.) and covered with some species of thalloid green and brown algae (*Halimeda* sp., *Lobophora* sp.). These communities include in their composition benthic diatoms, encrusting foraminifera (*Gypsina* sp.), containing photosymbionts, as well as bacteria, ciliated infusoria, calcareous sponges, etc., thus forming a particular kind of microbiocenosis uniting autotrophs and heterotrophs (Sorokin, 1990).

The limits of fluctuations of orthophosphate concentrations (0.05–0.07 μM) changed insignificantly among reefs located in waters of different productivity (Table 1). The content of ammonium and nitrite varied within 0.1–0.44 μM and 0.01–0.26 μM, respectively, depending on the location of the station. Such values are characteristic of the barrier reef lagoons (Sorokin, 1990).

The content of organic carbon (C), nitrogen (N) and phosphorus (P) in CAC depended on the depth of habitation (ANOVA; $p = <0.00 \div 0.02$) (Fig. 1). With increasing depth, the carbon content of the overgrowths decreased from 78 to 68 g C_{org}/m^2 ($p = <0.00$). The nitrogen content also reduces with depth, from 16 to 11 g N_{org}/m^2 on the average. The maximum values of carbon and nitrogen were observed at a depth of 10 m (78 g of C_{org}/m^2, 16 g N_{org}/m^2, respectively).

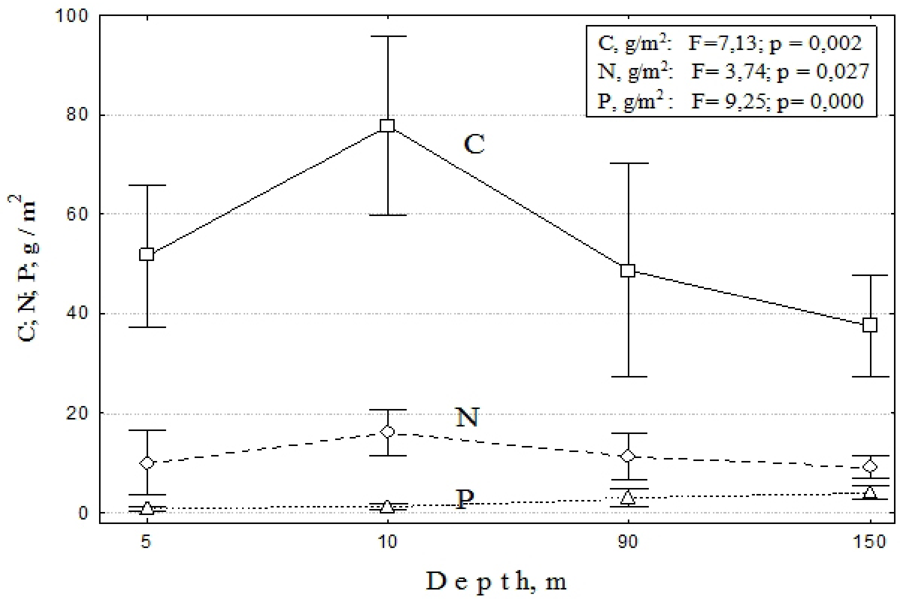

Fig. 1. The content of organic forms of C, N, and P in a coralline algae community in terms of the depth of their habitat.

The phosphorus content in the overgrowths increases with depth linearly, from 0.75 to 4.29 g P_{org}/ m^2.

The atomic ratio of organic carbon, nitrogen and phosphorus in the algal communities is presented in Table 2. The relationships N/P and C/P significantly reduced with increasing depth (ANOVA; p =<0.00), while the ratio C/N decreased statistically insignificantly (p = 0.40). Thus, if the ratio C/P at depths of 5–10 m is on the average about 187, it falls to 24.1 at a depth increase to 150 m. The ratio of C/N/P in CAC at a depth of 5–10 m had similar values and was on the average 187:31:1, which is comparable to the average values obtained for CCA on Phantom Bank (Timor Sea) with a depth of 14 m, which is 192:20:1. It should be noted that the six common species of hermatypic corals of Phantom Bank have the atomic ratio of C/N/P equal on the average 188:19:1 (Propp et al., 1983) and is also comparable with the average for CAC in shallow waters, but differs substantially from the marine macrophytes and weeds, with an average ratio of 550:30:1 (Atkinson, Smith, 1983). The red algae of South Florida living in eutrophic waters have the C/N/P average of 313:29:1 (Lapointe et al., 2005). With further increase in the depth to 150 m, the shares of N and particularly P

Table 2. The atomic ratio of organic forms of carbon (C), nitrogen (N) and phosphorus (P) in a coralline algal community (CAC) (mean ± SD)

Region	Depth, m	C: P	C: N	N: P	C: N: P
Bath Long Island	5	187.6±72.0	6.5±2.5	28.9±3.5	187:29:1
Re Island	10	187.9±70.9	6.2±2.3	32.9±14.1	188:33:1
Vanguard Bk	90	47.7±28.1	5.0±1.8	9.2±2.7	48:9:1
Ladd Reef	150	24.1±6.0	4.7±0.8	5.3±1.5	24:5:1

increase in CAC in comparison to that of C (Table 2).

Thus, with increasing depth, the content of organic forms of C and N in CAC decreases, while the P-content increases. The content of photosynthetic pigments in the community also statistically significantly decreased at greater depths (Cherbadgy et al., in press). Since C_{org} content and photosynthetic pigments are often used as indicators of the community biomass, we can assume that the biomass of both autotrophic and heterotrophic components of the community decreases with the depth. This is connected with the fact that light in the ocean decreases with depth exponentially, and this is one of the most important factors determining distribution and productivity of autotrophic organisms. Previously, it has been shown that in the coastal area of Vietnam, about 15–25% photosynthetically active radiation (PAR) reach a depth of 5–10 m, while, respectively, only 1–0.01% are registered in the open ocean at depths of 90–150 m (Cherbadgy, Propp, 2008). An increase of the share of nitrogen and especially phosphorus, relative to the carbon content in the community with the depth is explained by that coralline community, owing to their high specific surface area of the substrate, adsorb to 98% of an organic and mineral phosphorus; the capacity of the adsorption equilibrium is estimated as 1184 mg

P/kg of substrate (Gray et al., 2000), as well as by an increase of the heterotrophic component of the community, in which the content of nitrogen and phosphorus is higher that the carbon share – in contrast to autotrophic component. Phosphates are partially bound with calcium ions and so transfer from water into sediments.

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ON THE FAUNA OF VIETNAMESE SEA ANEMONES

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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. However, 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 ecological conditions could be mentioned. First 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 condition 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 results in stirring-up in shallow waters, what 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

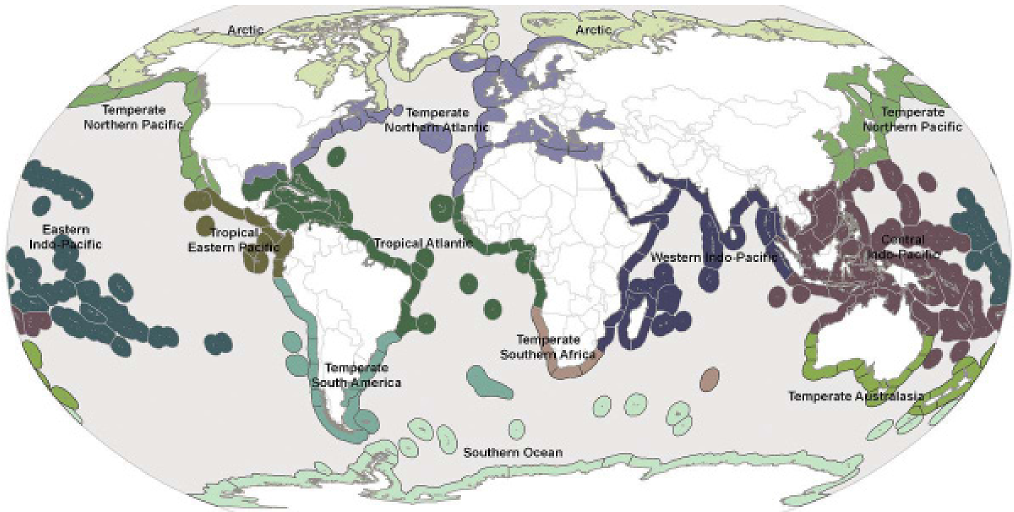

Fig. 1. Basic marine biogeographical subdivisions of the World Ocean (from Spalding *et al.*, 2007).

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

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, the 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 review of 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. Among them though only tree species were 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

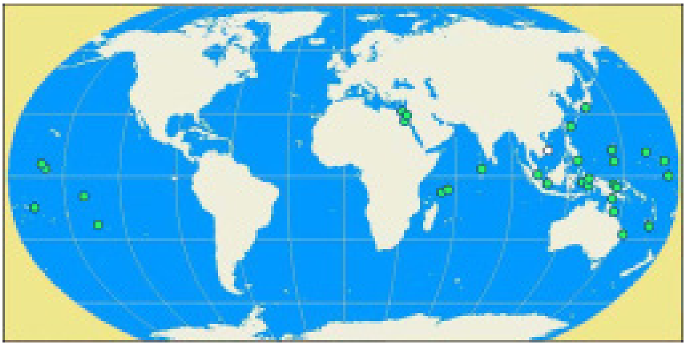

Fig. 2. Geographic range of *Cryptodendrum adhaesivum*, an example of widespread Indo-Pacific species. From Web: (*http://hercules.kgs.ku.edu/hexacoral/anemone2/distribution.cfm?xmlsource*) with addition.

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 Pacific Ocean makes up about 300 species. Amongst the species that we found in waters of Vietnam for the first time, most (7 of 12) belong to forms with very broad geographical 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 Vietnam, 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 remarkable coloration or unusual body form. Between them it is worthwhile to notice first of all corallimorfarians (representatives of order Corallimorpharia, fam. Discosomidae) *Discosoma dawydoffi* and *Amplexidiscus fenestrafer* (Fig. 3), as well as a dangerous actinian *Actinodendron arboretum* (order Actiniaria, fam.

Fig. 3. *Amplexidiscus fenestrafer*. Mui Nam, 25 May 2014. Photo by Oleg Savinkin.

Actinodendridae), which corresponds some hazard for swimmer with its stinging tentacles.

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REGENERATION FOLLOWING FISSION IN HOLOTHURIAN *CLADOLABES SCHMELTZII* (ECHINODERMATA: HOLOTHUROIDEA).

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Asexual reproduction is the oldest mechanism of organismal multiplication and is found in representatives of almost all types of modern animals (Brusca and Brusca, 2003; Ivanova-Kazas, 1977). Because asexual reproduction is closely related to the structure of animals, its types are as diverse as the animals themselves. 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 (Ivanova-Kazas, 1977).

Holothurians are well-known for their regenerating abilities. Some of them can regenerate after transverse cutting. Others are able to autotomize and subsequently regenerate their internal organs. Moreover, some holothurians are capable of asexual reproduction by transverse fission. The capacity for asexual reproduction was previously revealed in 16 holothurians (Dolmatov, 2014). It has recently been shown that the holothurian *Cladolabes schmeltzii* is capable of asexual reproduction through transverse division (Dolmatov, 2014; Dolmatov et al., 2012). This type of reproduction is very common in the populations of the *C. schmeltzii* from Nha Trang Bay of the South China Sea. It is shown that about 21.7% of all animals are at different stages of development after fission during spring season (Dolmatov et al., 2012). Here, we report a brief analysis of regeneration of this species following fission.

Materials and methods

Individuals of *C. schmeltzii* were collected in Nha Trang Bay of the South China Sea. Animals displaying a regenerating anterior or posterior portion of the body following fission were selected for this study. The holothurians were dissected along the right interradius, and according to the degree of development of their internal organs, individuals were sorted into groups corresponding to various regeneration stages. The investigation was undertaken by means of lifetime observation, light microscopy, transmission and scanning electron microscopy.

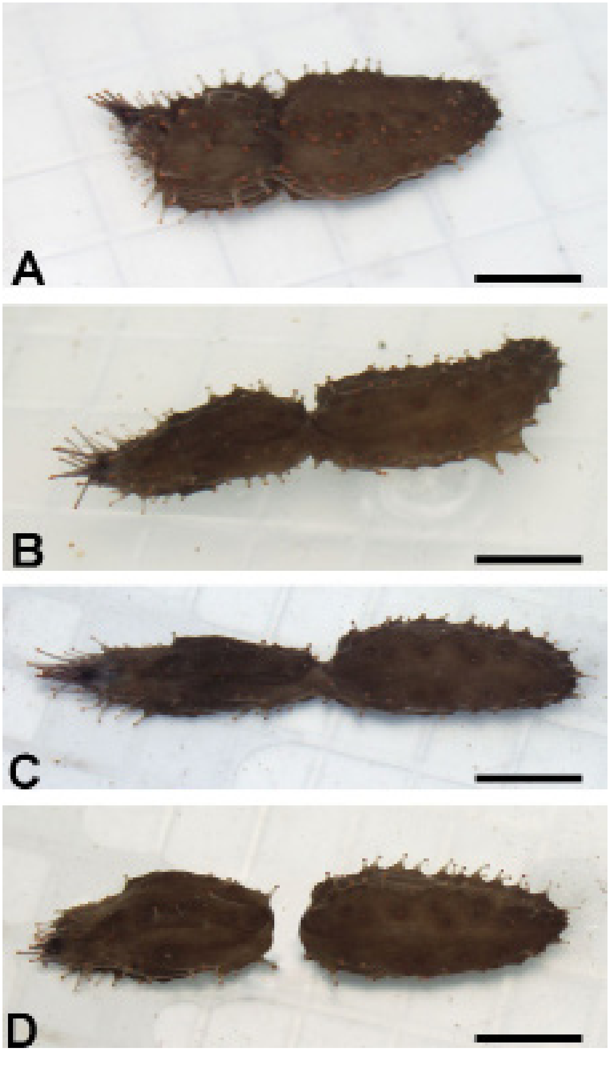

Fig. 1. Consecutive stages of the *Cladolabes schmeltzii* division during asexual reproduction.

Results

Fission. The site of fission is situated at about the middle of the body, so two nearly equal halves are formed as a result of the fission. The fission started from formation of a narrow constriction of the body wall (Fig. 1a). During several hours, the constriction became deeper and broader (Fig. 1b). In the process of fission, the posterior part of the holothurian attached to the substrate by its ambulacral feet and remained motionless, while the anterior part tried to crawl forward, this caused thinning and stretching of the constriction (Fig. 1c). Then, the anterior fragment ceased to move, and both parts of the animal were constricted and approached each other. The animal remained motionless for 30–40 min, and then the anterior part resumed crawling forwards. Several phases of such constrictions and stretchings resulted in dividing the holothurian's body into two halves (Fig. 1d). Under laboratory conditions, the process of fission took about 24 hours.

After the fission the two parts of the holothurian can be designated as the anterior (Ap) (that has a mouth, but is lacking anus) and posterior (Pa) (that has anus, but is lacking mouth) specimens (Fig. 2). Ap specimens had aquapharyngeal complex (AC), gonad, anterior part of intestine and sometimes separated fragment of the gut, which is portion of the anterior intestine loop. In the course of regeneration, they regenerated posteriorly located organs (the posterior part of intestine, cloaca and respiratory trees). Pa specimens retained cloaca, respiratory trees and the posterior part of intestine. In the course of regeneration, the intestine grew anteriorly, coupling with the rudiment of aquapharyngeal complex.

Regeneration. In the Ap specimens, regeneration after fission begins with partial atrophy of the damaged intestine, the length of which is consequently reduced. The isolated fragment of gut, if present, is broken down. At the same time, the wound at the posterior end is repaired. The end of the intestine then begins to grow backward, along the mesentery, and forming the primordium of the intestine. Simultaneously, the cloaca develops at the posterior end of the body. The intestine primordium becomes longer and grows into the cloaca, thus the integrity of the digestive system is restored (Fig. 2c). Animals at this regeneration stage restore the terminal regions of the longitudinal muscle bands (LMB) that were damaged during fission. LMB ends become thinner and grow toward the cloaca. Soon after the intestine and cloaca merge, the primordia of the respiratory trees appear on the dorsal side of the cloaca (Fig. 2d). Body growth also begins at this stage. At the posterior end, a small outgrowth emerges and subsequently becomes longer, thus forming the posterior region of the animal (Fig. 2e). Respiratory trees develop with the growth of the posterior end. The respiratory trees gradually grow and form lateral branches.

The main process in the Pa specimens is the regeneration of the AC. First, a connective tissue thickening, and forming the AC primordium, at the anterior end of the animal between the torn ends of ambulacra (Fig. 2g). Then, the terminal regions of the radial water-vascular canals and radial nerve cords grow into AC primordium. Subsequently, these regions form circular water-vascular canal and the nerve ring, respectively, around the AC. The torn anterior region of the gut is transformed along with the development of the AC. The intestine becomes thinner and begins growing forward up the mesentery (Fig. 2g). Later on, the primordium of the intestine, grows into the AC and the integrity of the digestive system is restored (Fig. 2h). Then the animal begins to grow. At the anterior end, a small outgrowth emerges and gradually grows longer, thus forming the anterior region of the animal (Fig. 2i). ***Microanatomical Features of Regeneration.*** The distinguishing feature of development of the digestive system in both Ap and Pa fragments is the formation of the intestine from two primordia. The entodermal region (intestine) is formed as a result of dedifferentiation and the migration of enterocytes of the remaining portion of the gut. During dedifferentiation, the enterocytes lose many secretory granules and microvilli, and their height decreases. Nevertheless, the enterocytes retain their intercellular junctions. Thus, the luminal epithelium of the intestine is not broken down. After merging with the cloaca (Ap

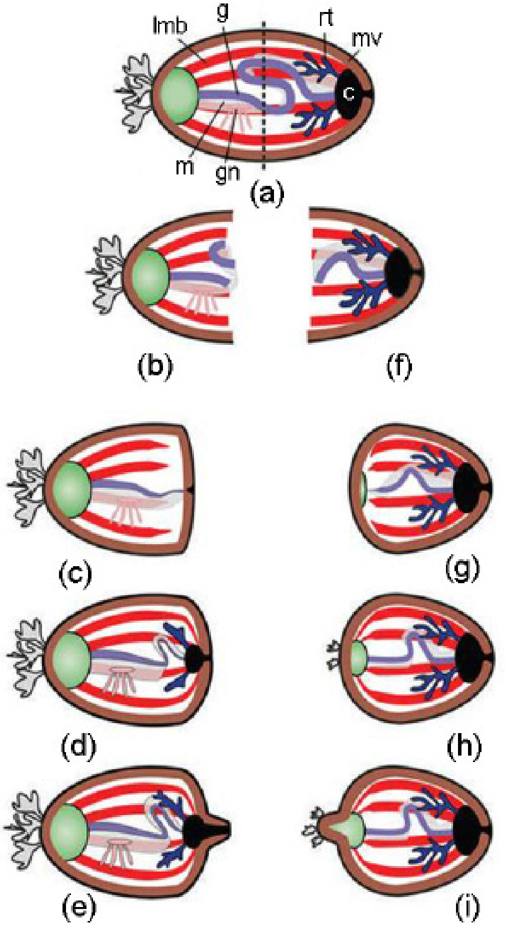

Fig. 2. Scheme of regeneration of internal organs after fission in holothurian *Cladolabes schmeltzii*. (a) Animal before fission. (b) Anterior fragment just after fission. (c) Formation of gut and cloaca in anterior fragment. (d) Formation of respiratory trees in anterior fragment. (e) Growth of the posterior part of the body. (f) Posterior fragment just after fission. (g) Formation of AC and gut rudiments in posterior fragment. (h) Posterior fragment with regenerated internal organs. (i) Growth of the anterior part of the body. ac: aquapharyngeal complex; bw: body wall; c: cloaca; g: gut; gn: gonad; lmb: longitudinal muscle band; m: mesentery; rt: respiratory tree; t: tentacles. Dotted line: site of division of the body during fission (from: Dolmatov, 2014).

specimen) or AC (Pa specimen) and restoring the integrity of the digestive tract, enterocytes become specialized depending on their position along the intestine. Ectodermal sections (the pharynx, esophagus, and posterior end of cloaca) are apparently formed from epidermal cells which migrate from the epidermis of the body wall into the connective tissue of the body wall and AC primordium. In the early stages of gut regeneration, these cells begin synthesizing the cuticle. Subsequently, the ectodermal region merges with the entodermal region; thus, the integrity of the digestive system is restored.

Respiratory trees in the Ap specimens develop through the transformation of the dorsal wall of the anterior region of the cloaca. The main feature of the respiratory system regeneration is the rapid specialization of cells in the luminal epithelium. These cells have lamellae on the apical surface and are connected with one another through a complex of specific intercellular junctions even at the the early stages of formation.

New muscle bundles are formed in the regenerated ends of LMB from the coelomic epithelium, which covers the muscles. First, groups of cells are embedded in the connective tissue. After that these cells transform into myocytes, and myofilaments are observed in their cytoplasm. These groups of cells are then separated from the epithelium and form new muscle bundles.

The regeneration of the AC in the posterior fragment also occurs from cells in the remaining organs. The cells of the terminal segments of the radial water-vascular canals and radial nerve cords are dedifferentiated and migrate down the connective tissue primordium of the AC. Intercellular junctions are not broken during dedifferentiation, and the cells migrate within the epithelium. Therefore, the tubular primordium of the water-vascular canal forms and gradually grows along the AC. The nerve cords apparently grow in a similar manner. Both neurons and glial cells participate in nervous system regeneration.

Conclusion

In summary, *C. schmeltzii* is the first dendrochirotid species of the northern part of the Indo-Pacific Region that is capable for fission. Moreover, it remains so far the only species of the family Sclerodactilidae with registered asexual reproduction. Our data is the first description of the formation of internal organs during asexual reproduction in holothurians. We have shown that regeneration of the body following fission in the holothurian *C. schmeltzii* is realized through morphallactic rearrangements of the remaining parts of organs. Epithelial morphogenesis is the principal mechanism through which the digestive, respiratory, and contractile, nervous and water-vascular systems develop.

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MOLLUSKAN FAUNA DIVERSITY OF THE FAR EASTERN MARINE BIOSPHERE RESERVE, PETER THE GREAT BAY, SEA OF JAPAN

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The preservation of biological diversity of aquatic organisms, which has been reduced due to climate changes and anthropogenic pressure, is a necessity. This is a general problem for the sea coasts of East Asia. In this regard, the aim of the article is to analyze the modern taxonomic composition of mollusks in the Far Eastern Marine Biosphere Reserve, Peter the Great Bay, the Sea of Japan. The list of Mollusca was compiled on the basis of the inventory and monitoring studies carried out between 1978 and 2014. It includes 283 species of mollusks from 4 classes: Cephalopoda – 7, Polyplacophora – 11, Bivalvia – 114 and Gastropoda –151 species.

The corrected list of Polyplacophora inhabiting the reserve and neighboring waters of Peter the Great Bay includes 16 species belonging to 11 genera and 6 families. More elaborate research has revealed 5 species of chitons that were recorded in the 1960s in the western part of the reserve (*Deshayesiella curvata* (Carpenter in Dall, 1879)), *Tonicella squamigera* Thiele, 1909, *T. undocaerulea* Sirenko, 1973, *T. zotini* Jakovleva, 1952 and *Boreochiton beringensis lucida* (Sirenko, 1974)), as well as 4 species inhabiting adjacent waters of Peter the Great Bay: *Leptochiton hakodatensis* (Thiele, 1909), *Placiphorella borealis* Pilsbry, 1893, *Acanthochitona rubrolineata* (Lischke, 1873) and among them one species, *Mopalia middendorffii* (Schrenck, 1861) (Lebedev, Turin, 2015), included in the Red Data Book of Russia.

Cephalopods are represented by 7 species from 6 genera and 5 families (Turin et al., 2004). Four of the seven species of Cephalopoda can breed in the reserve. These are the cuttlefish *Sepiola birostrata* Sasaki, 1918 and *Rossia pacifica* Berry, 1911, as well as the octopus *Octopus dofleini* (Wulker, 1910) and *O. conispadiceus* (Sasaki, 1917). One species of squid, *Todarodes pacificus,* and

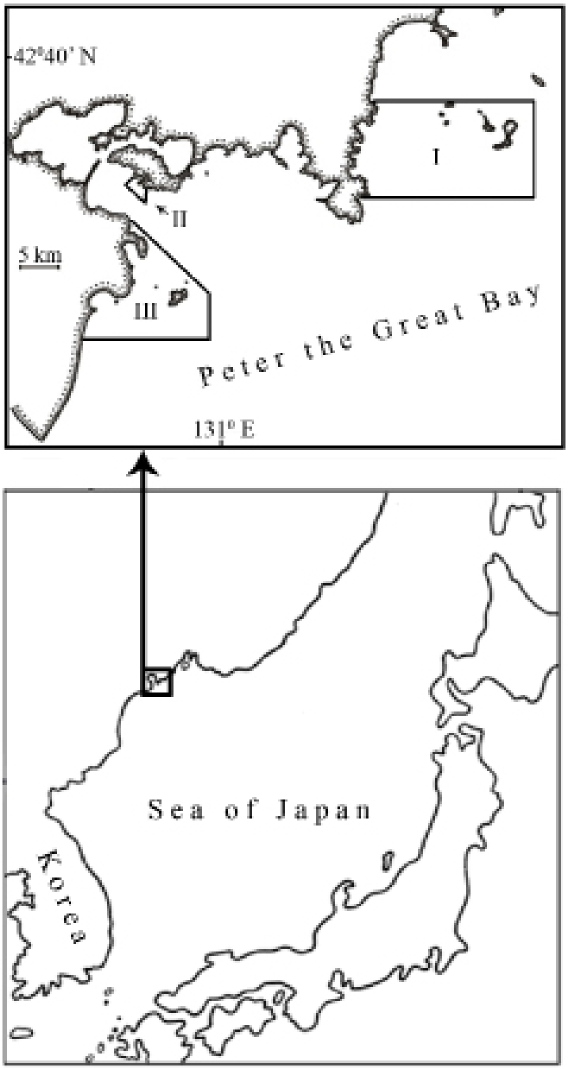

Fig. 1. A schematic map of the Far Eastern Marine Biosphere Reserve: I – eastern part; II – western part; III – southern part.

two species of cuttlefish, *Sepiella japonica* Sasaki, 1929 and *Idiosepius paradoxus* (Ortmann, 1888), are incoming species and do not form populations in Peter the Great Bay. These species enter the bay from the East China Sea through the Korea Strait (Lebedev, Turin, 2015).

The Gastropoda fauna of the reserve includes 1 species of Pulmonata, 122 Prosobranchia belonging to 72 genera, 33 families and 7 clades, as well as 28 species of Opisthobranchia belonging to 23 genera, 16 families and 6 orders. The list of gastropods was supplemented with 11 prosobranchs, 26 opisthobranchs and 1 pulmonate mollusk, *Siphonacmea oblongata* (Yokoyama, 1926) (Turin et al., 2004). The majority of new findings in the reserve were made during the last decade (Lebedev et al., 2015).

Two gastropod species, *Onchidiopsis maculata* Derjugin, 1937 and *Pseudoliomesus canaliculata* (Dall, 1874), that are new records for the reserve fauna were found in the eastern part (Fig. 1). Five species new for the reserve fauna (Erginus *puniceus* Lindberg, 1988, *Lottia tenuisculpta* Sasaki et Okutani, 1994, *Fluviocingula elegantula* (A. Adams, 1861), *Marsenina rhombica* (Dall, 1871) and *Boreoscala rarecostulata* (Dall, 1871)) were found in the southern part (Fig. 1). *Cellana toreuma* (Reeve, 1855) probably living in the reserve was found in storm casts in its southern part too.

The bulk of the Opistobranchia fauna of the reserve is made up of species also known in other parts of Peter the Great Bay. However, a number of taxa are rarely or not found outside the reserve. For example, there are three 1 species of nudibranchs that are endemic to Primorye: *Loy meyeni* Martynov, 1994, *Proloy* *millenae* Martynov, 1994, *Rostanga alisae* Martynov, 2003 and others (Lebedev et al., 2015). Clearly, further studies in this faunistically and biogeographically significant area are necessary.

The modern Bivalvia fauna of the reserve includes 114 species belonging to 74 genera, 35 families and 14 orders. The species recorded as rare for the Russian Far Eastern seas occur in the reserve (*Conchocele bisecta* (Conrad, 1849), *Adonthorina filatovae* (M. Ivanova et Moskaletz, 1984), *Adula falcatoides* Habe, 1955, *Gari kazusensis* (Yokoyama, 1922), *Mytilus coruscus* A.A. Gould, 1861, *Macoma golikovi* Scarlato et Kafanov, 1988 and *M. irus* (Hanley, 1845)), as well as species included in the Red Data Book of Russia, *Corbicula japonica* Prime, 1864 and *Solen krusensterni* Schrenck, 1867 (Turin et al., 2004). Four bivalve species have been added to the check-list of malacofauna of the reserve. Three bivalves (*Borniopsis* sp., *Thracia cf. septentrionalis* and *Gomphina multifaria)* are new records for the fauna of Peter the Great Bay (Lebedev, 2015).

The fauna of cephalopods and gastropods of Peter the Great Bay has been almost completely preserved in the Far Eastern Marine Biosphere Reserve. The taxonomic and biogeographical diversity of the reserve malacofauna is large and comparable to that of Peter the Great Bay in the Sea of Japan (Adrianov, Kusakin, 1998). Northward alongshore currents in the area create favorable conditions for the transfer of molluskan larvae from the coastal waters of Korea. Casual anthropogenic introduction of mollusks from Korea, China and Japan as a consequence of shipping and fishing cannot be ruled out. Due to predominance of sandy bottom substrates in open bays and along coasts, the southern part of the reserve can be colonized by soft bottom mollusks (Lutaenko, Yakovlev, 1999).

The southern part of the reserve and the neighbouring southernmost part of Peter the Great Bay take the lead in terms of the number of mollusks' findings in southern Primorye. Therefore, it is important to protect the malacofauna of the reserve with its unique and diverse habitats. Modern malacofauna has increased in terms of the total species number. This confirms that, significant molluskan diversity, compared to previous studies, has been preserved in the Far Eastern Marine Biosphere Reserve.

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COMPARATIVE CHARACTERISTICS OF BENTHIC COMMUNITIES IN THE WESTERN PART OF THE FAR EASTERN MARINE BIOSPHERE RESERVE, PETER THE GREAT BAY: EVIDENCE FROM HYDROBIOLOGICAL AND REMOTE RESEARCH

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The structure of coastal communities is not constant. It depends on the effect of climatic and anthropogenic factors. This is common for all coastal waters of East Asia. Thus, the goal of our work was to perform a comparative assessment of benthic communities in Minonosok Bay, located in the western part of the Far Eastern Marine Biosphere Reserve (FEMBR), using the data of hydrobiological and remote studies carried out in the 1990s and 2010s.

The hydrobiological studies were conducted at the transects 1 and 2 in September 1997; at the transect 3, in July and September 1998; at the transect 4, in July and August 1999; and at the transect 5, in July, August, and September 2000. The coordinates of the starting points of each transect on shore were determined with a Magellan GPS 3000 satellite navigator. For remote research, an underwater video camera JJ-Connect FishEye was used. The material was collected, processed and analyzed by the standard hydrobiological methods (Lebedev et al., 2004). The basic transects 1, 2, and 4 were set up at the southern rocky shore; the transect 3, at northern rocky shore; and the transect 5, at the apex of the bay (Fig. 1).

At the transect 1, a total of 140 taxa and 9 belts with different values of density and biomass were identified in 1997. Bivalves (*Crenomytilus grayanus* (Dunker, 1853), *Mizuhopecten yessoensis* (Jay, 1857), etc.) and echinoderms dominated in biomass. The snails *Falsicingula* spp. (Gasropoda) and spirorbid polychaetes (Polychaeta) dominated in population density. In 2012, the composition of the bottom sediments at a depth of 0.5–2.5 m was found to have changed. Now the local littoral communities are formed by seston-eaters (the barnacle *Chthamalus dalli* Pilsbry, 1916) and plant- and detritus-eaters such as the gastropod *Tegula rustica* (Gmelin, 1791). Previously, mollusks of various trophic groups – seston-eating Crassostrea (Bivalvia), plant-eating Littorina and predatory Nucella (Gastropoda) – dominated here. *Ch. dalli* was a subdominant species. In the upper part of the sublittoral zone, plant communities were replaced by animal or mixed ones. The mosaic pattern of distribution of benthic communities, co-dominated by 2–3 groups (Gastropoda, calcareous Rhodophyta, and Echinodermata), became more pronounced. The belt of *M. yessoensis* was replaced by the one of *C. grayanus* and *Modiolus kurilensis* Bernard, 1983. In the lower horizons, macroalgae attached to druses of *C. grayanus* rather than to the bottom. Green algae were recorded from a depth of 3–4 m; brown and red ones, from a depth of 6–13 m.

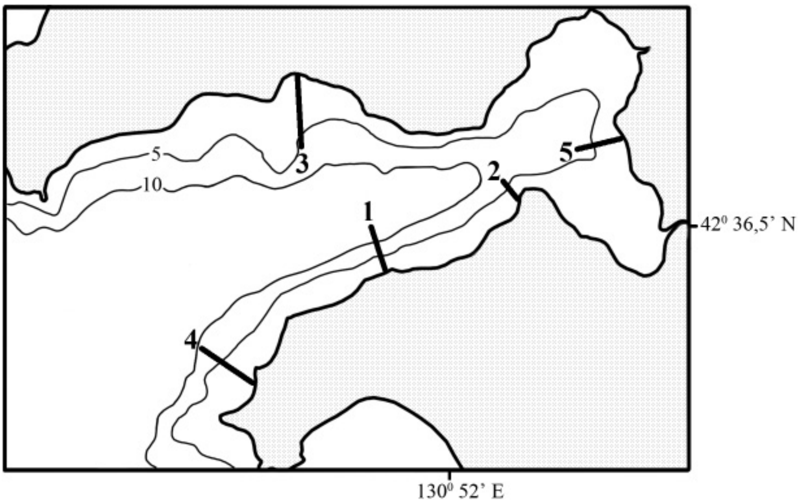

Fig. 1. Arrangement of the basic hydrobiological transects (1–5) in Minonosok Bay (western part of the Far Eastern Marine Biosphere Reserve).

At the transect 2, a total of 77 taxa and 6 belts with different values of density and biomass were identified in 1997. Bivalve mollusks (*C. grayanus*, *M. kurilensis*, *M. yessoensis*) and echinoderms dominated in biomass. Spirorbidae, Cirripedia and Bivalvia dominated in population density. In 2012, changes in the composition of the bottom sediments occurred within depths of 0–7 m, i.e. in most of the belts. Macrobenthos was found only in the lower littoral zone and was represented by spirorbid polychaetes and hermit crabs. In the upper sublittoral horizons, Gastropoda, Spirorbidae, and Echinodermata co-dominated. Presence of kelp attached to large mussel druses became characteristic at the maximum depths.

At the transect 3, a total of 115 taxa and 9 belts with different values of density and biomass were identified in 1998. Bivalves, sea grasses, green and brown algae dominated in biomass, whereas Spirorbidae, Phoronida, and Bivalvia dominated in population density. The distribution of organisms off the northern coast had some specific features: the animal biomass in the supralittoral and littoral zones was low; the mussel *M. kurilensis* dominated the epifauna of stony/pebbly bottom. In 2012, ulvacean and corallinacean algae, being resistant to pollution and eutrophication, became dominant in the upper sublittoral zone at the transect 3 instead of the displaced species of macroalgae (Vinogradova, 1979; Klochkova, 1996). At a depth of 0.9–3.5 m, the role of detritus-eating and predatory species of echinoderms increased significantly.

At the transect 4, a total of 107 taxa and 8 belts with different values of density and biomass were identified in 1999. The algae *Codium fragile* (Suringar) Hariot, 1889 and *Sargassum pallidum* (Turner) C. Agardh, 1820, the echinoderms *Mesocentrotus nudus* (A. Agassiz, 1864) and *Asterina pectinifera* (Muller & Troschel, 1842) dominated in biomass. The distribution of organisms at the transect 4 was quite specific: a low abundance in the upper horizons of the sublittoral zone and a gradual increase in the abundance of calcareous Rhodophyta, Bivalvia, and Echinodermata at a depth of 3–7 m. In 2012, plant communities in the upper horizons were replaced by animal or mixed communities, dominated by seston-eaters, detritus-eaters, and predators.

At the transect 5, a total of 95 taxa and 7 belts with different values of density and biomass were identified in 2000. Distribution of organisms at the apex of Minonosok Bay had some specific features. The biomass of aquatic organisms in the supralittoral and littoral zones was very low; mussels and echinoderms dominated the epifauna locally, at a depth of 1–3 m. In 2012, a change of the bottom sediment was registered at the transect 5 at a depth of 0–1 m. Plant dominants changed also in this horizon. The green alga *Codium* disappeared, and the brown alga *Sargassum* occurred farther off the shore, where it co-dominated along with Gastropoda and Spirorbidae. At depths greater than 1 m, no changes of benthic communities were observed.

Thus, at all the hydrobiolodical transects, set up in Minonosok Bay in the 1990s, mollusks and macroalgae dominated in number of species, frequency of occurrence, and biomass. In 2012, changes occurred in “unstable” zones of the basic transects, in which the bottom substrate composition was transformed. A reduction of the biocenotic role of brown algae and sea grasses was observed also. This phenomenon could be caused by several factors. First, the increasing economic activity results in eutrophication of waters and reduction of the area of sea grass beds in the ocean (Larkum et al., 2006). Second, the long-term warming trend and the complex hydrodynamics in some parts of Peter the Great Bay, including Minonosok Bay (Gaiko, 2005), probably can also contribute to the changes of coastal communities.

The dominant and subdominant species in modern benthic communities in the western part of the FEMBR are ecologically flexible invertebrates. These are the mollusks *Littorina brevicula* (Philippi, 1844), *T. rustica, M. yessoensis, C. grayanus, M. kurilensis*, spirorbid polychaetes, echinoderms *M. nudus, Asterias amurensis* Lutken, 1871, and *A. pectinifera*. They are characterized by a wide food spectrum and natural variability, which is caused by seasonal and local variations in their forage base. Recent studies have shown that the sea urchin *M. nudus* is able to switch from aerobic to anaerobic metabolism in adverse conditions (Drozdov, Drozdov, 2015). Mussels, due to their biochemical characteristics, easily switch from aerobic to anaerobic metabolism also. The sparse mussel druses registered at all the transects in 2012 indicate the stability of the population. However, juvenile mussels cannot survive heavy silting.

Thus, the remote research conducted in 2012 revealed long-term changes in the benthic communities at the basic transects. The changes occurred in "unstable" parts of the littoral zone and in the horizons of the sublittoral zone where the composition of bottom sediments transformed. The biocenotic role of macrophytes decreased, and, as a consequence, the total biomass of macrobenthos declined at all the transects. The mosaic distribution of macrobenthos was increased. Monodominant communities in most cases were replaced by polydominant ones. Due to the heavy silting observed at the transects of the southern shore of the bay, macroalgae in the lower horizons attached to mussel druses, not to the bottom. The trophic structure of communities in the upper horizons of the sublittoral zone changed: seston-eaters, detritus-eaters and predators became dominant instead of producers.

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ZOOGEOGRAPHICAL ASPECTS OF THE WESTERN SOUTH CHINA SEA

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The South China Sea is one of the richest regions of the World Ocean in terms of biodiversity. The biodiversity pattern of the sea clearly reflects the generally accepted concept of high biodiversity in the so-called "East Indies Triangle", or Coral Triangle; the ranges of many tropical marine species overlap in a centre of maximum biodiversity located in the Indo-Malayan region (Malaysia, the Philippines, Indonesia, and Papua New Guinea) (Hoeksema, 2007; Veron et al., 2011). Ekman (1953) called this triangle the *Indo-Malayan Region* and regarded it as a faunal center, from which the other tropical faunas of the Indo-Pacific recruited their species. The Coral Triangle is recognized as a biodiversity hotspot but its centre is only approximately located and its exact boundaries are unknown: some researchers believe that the western angle of the triangle may reach the coast of Vietnam or Peninsular Malaysia, or both; at least, the biodiversity hotspot usually includes the southern half of the South China Sea. Despite containing less than 17% of the reef area as compared to the Coral Triangle, the South China Sea hosts 571 known species of reef corals, a richness comparable to the Coral Triangle's one (Huang et al., 2015).

Biogeographically, the major part of the South China Sea belongs to the tropical **Indo-Polynesian Province** (Briggs, 1974; 1995). This province extends all the way from the entrance to the Persian Gulf to the Tuamotu Archipelago, and from Sandy Cape on the coast of eastern Australia to the Amami Islands in southern Japan; all of Polynesia is included with exception of the Hawaiian Islands, the Marquesas, and Eastern Island. In turn, the Indo-Polynesian Province is a part of the Tropical Indo-West Pacific Region, along with the Western Indian Ocean, Red Sea, Hawaiian, Marquesas, and Easter Island provinces (Briggs, 1995; Briggs, Bowen, 2012). However, the northern mainland part of the South China Sea belongs instead to the *warm-temperate* **Sino-Japanese Province** extending from Cape Inubo on the oceanic side of Japan southwards to, but not including, the Amami Islands, and on the mainland side, it begins at the tip of the Korean Peninsula and at Hamada, Honshu, in the southern part of the Sea of Japan; on the Chinese coast, it begins at about Wenchou and extends southwards to Hong Kong (Briggs, Bowen, 2012). The northwestern coast of Taiwan exhibits an affinity with the warm-temperate mainland coast, while the southeastern coast is purely tropical, being under the influence of the Kuroshio Current (Briggs, Bowen, 2012). This biogeographic unit was known previously as the Japan Warm-Temperate Region (Briggs, 1974; 1995) (Fig. 1).

Based on the distribution of sacoglossan opisthobranchs, Jensen (2007) believes that the vast Indo-Polynesian Province can be subdivided into five sub-provinces including a subprovince of the Andaman Sea, the South China Sea, Indonesia and the Philippines, or the Indo-Malayan Subprovince; this understanding of the Indo-Malayan Province nearly corresponds to one of the variants of the Coral Triangle.

According to our concept, the subtropical Sino-Japanese Province occupies the southern part of the Sea of Japan and extends into the Yellow Sea,

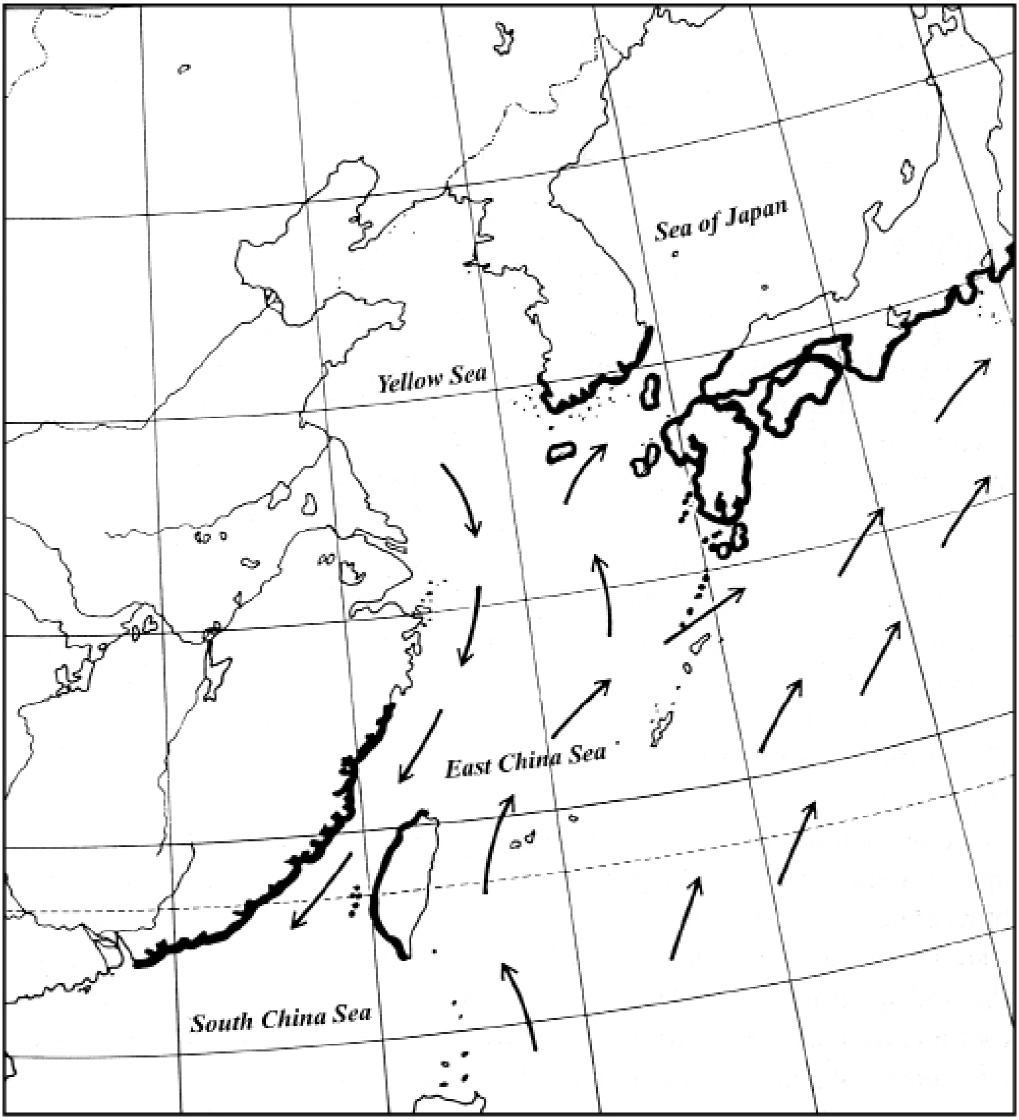

Fig. 1. Japan Warm-Temperate Region (=Sino-Japanese Province) (re-drawn after Briggs, 1995).

including southern Japan, the East China Sea (Lutaenko, Noseworthy, 2014), and, according to Briggs (l.c.), to the northern South China Sea. The Sino-Japanese Province belongs to the tropical Indo-Pacific fauna (Gurjanova, 1972).

According to Liu (2013), the boundary between the tropical-subtropical biotic region and the warm-temperate biotic region extends roughly from the Yangtze River Estuary eastward to Niigata, northern Honshu, Japan, and north to Jeju Island and the Korea Strait. The boundary between the China–Japan

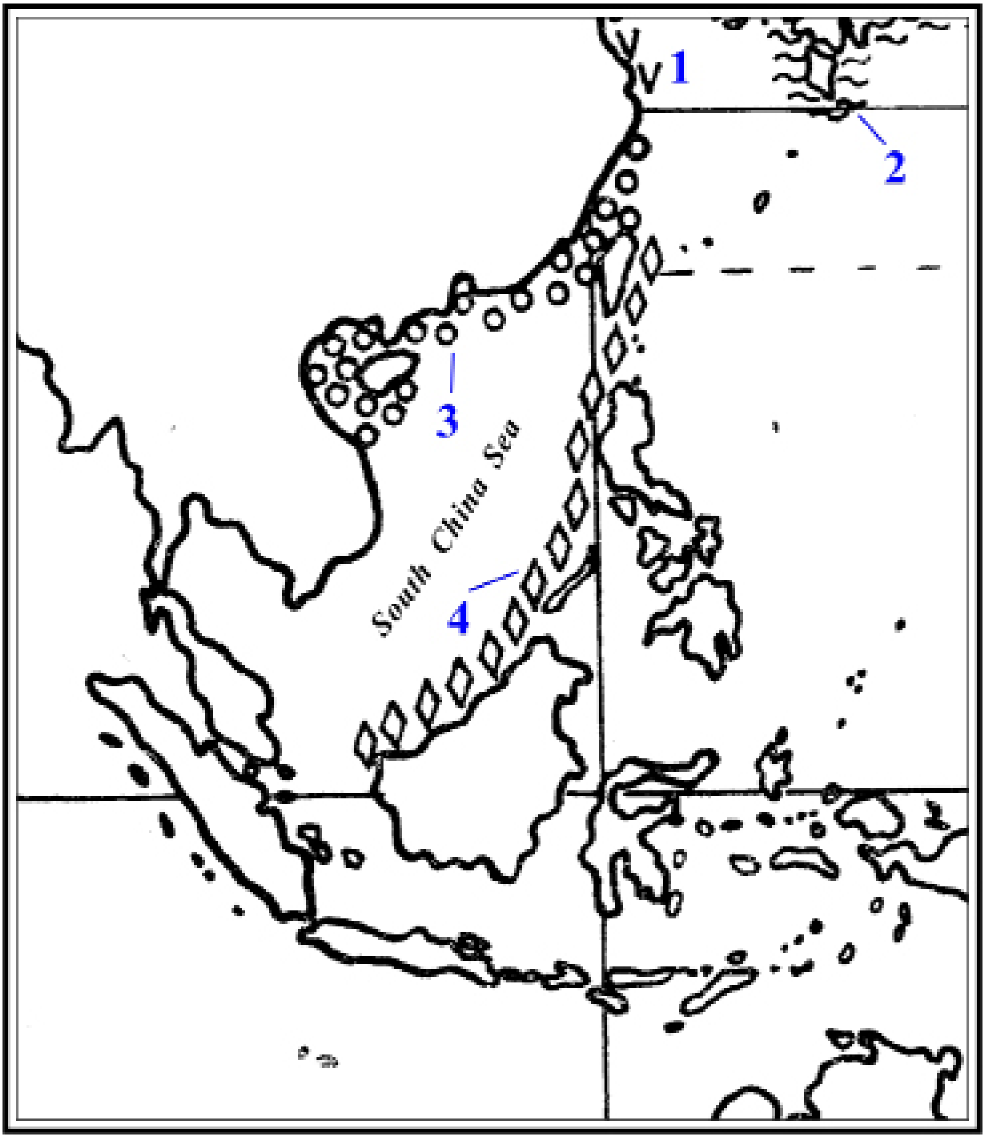

Fig. 2. Biogeographical provinces belonging the the Indo-Pacific tropical region along the Pacific coast of Asia: **1,** Yellow Sea Province; **2,** South-Japanese Province; **3,** Hainan Province; and **4,** Malayan Province (re-drawn after Gurjanova, 1972).

Subtropical Subregion and the Tropical Southern South China Sea Subregion extends roughly from mid- or southern Vietnam to Amami Oshima Island, north of Okinawa, Japan, through the southernmost sea area off Hainan Island and the southeast coast of Taiwan. Liu (l.c.) states that his “China–Japan Subtropical Subregion” (=Sino-Japanese Province) belongs to the Indo-Pacific tropical fauna (“the Indo-West Pacific Warm-Water Biotic Region”), and this view is shared. However, its southern limits lie northward in Guandong Province and not in mid-Vietnam: the Vietnamese biota could hardly be subtropical. Malyutin and Latypov (1991) clearly showed that the coral fauna of Vietnam, including Gulf of Tonkin, is represented solely by tropical species.

Thus, the western part of the South China Sea is divided between two provinces: the truly tropical, vast Indo-Polynesian Province and the subtropical Sino-Japanese Province, and the boundary line lies around Hong Kong. Gurjanova (1972) demarcated the Asian coast into several biogeographic units within the Indo-West Pacific tropical region, from north to south: **1,** Yellow Sea Province; **2,** South-Japanese Province; **3,** Hainan Province; and **4,** Malayan Province (Fig. 2). It is easy to observe that the northern boundary of Hainan Province nearly corresponds to the northern boundary of Briggs’ southern part of the Sino-Japanese Province. However, the meaning and content of provinces in Russian and western literature are different. Briggs’s (1974) provinces were defined on the basis of endemism: a value of 10% was chosen for an area to qualify as a distinct province (Briggs, 1974). According to Gurjanova (1972), the Hainan Province extends south to Tonkin Gulf or even to Cape Varella in Vietnam (Mui Ke Ga, 12° N), and its fauna is close to that of the Malay Archipelago but is much poorer. Malyutin and Latypov (1991), based on the coral fauna, regard the entire Vietnamese coast as biogeographically uniform, and do not support its demarcation into any units and do not recognize any biogeographical lines or boundaries within Vietnam.

The position of the Hong Kong fauna in biogeographical zonation is intermediate. Winter cooling by north-east monsoonal winds, the presence of the winter period from October to mid-March with a minimum air temperature of 15°C in February, and the warm summer with an average July temperature of 28°C allow the climate and the hydrology of Hong Kong to be regarded as subtropical (Morton, Morton, 1983). The waters of Hong Kong are rich in tropical biota but, at the same time in the winter period, temperate algae are found in abundance. Mangroves flourish with near tropical diversity but are dwarfs in comparison with their Malaysian relatives; corals are also well represented but only in the subtidal zone because of the low winter air temperatures (l.c.). The Taiwan Current brings the biota of the subtropical coasts of northern China and southern Japan while the Hainan Current contributes truly tropical species (Morton, Morton, 1983). Adjacent to Hong Kong, the Daya Bay molluscan fauna comprises a mixture of tropical and subtropical species living in both South China and East China seas (Lin et al., 2002).

In general, the fauna of the South China Sea contains, in various proportions in different parts of the region, the following zonal-geographical groups: tropical, tropical-subtropical, tropical-subtropical penetrating to boreal (temperate, or mild-temperate) waters, and subtropical (Lutaenko, 2016). In the north, Taiwan, Fujian and northern Guangdong provinces, the presence of subtropical species is noteworthy. The western part of the South China Sea is divided between two provinces: the truly tropical Indo-Polynesian Province, and the subtropical Sino-Japanese Province; the boundary point lies around Hong Kong.

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EXPOSURE STATE OF SOME HEAVY METALS (HG, PB, CD, FE, ZN AND AS) AT DANANG COASTAL ZONE

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The exposure state of heavy metal in coastal water of Danang during period 2005–2014 was illustrated in this work. There are twelve sites at Bay (04) and Sea (08) that were selected for sampling, for each sampling site was conducted at least four times per year and all the achieved data were also computed of average value. The heavy metals were mentioned in this work as mercury (Hg), lead (Pb), cadmium (Cd), iron (Fe), Zinc (Zn), and metalloid arsenic (As), respectively. The obtained data indicated that almost heavy metal contaminants in coastal water of Danang trend to rising period 2005 to 2012 and reducing in recently. However, some sampling sites are contained significant concentrations, which are highly potential to effect on coastal water quality and endanger toxicology for aqua system such as Cd at B5 and B8 (Phu Loc estuary and Man Thai beach) and Fe content. The iron concentration exposes at all the collected samples and the highest value reaches to 1.9 mg/L exceeding nearly twenty times versus regulation of QCVN 10: 2008/BTNMT (National technical regulation on coastal water quality).

These conducted results show that the improving in environmental water quality takes place in recent period but some toxic heavy metals are still needed preventing and controlled at arising sources.

Keywords: heavy metal, contamination, coastal, toxicology.

Introduction

Heavy metal pollution is becoming quite common in industrial areas, mining operations, industrial parks, craft villages, estuaries and coastal zones in many countries in the world. The control and limit the spread of heavy metals are indicating more urgent for the current environmental management (Goksu et al., 2005; Marchand, 2011). Heavy metals are transported by water or wind to coastal area, where they can be deposited as sediment. The presence of heavy metals in coastal zone is evaluated as one of the major factors threating coastal biodiversity, aqua toxicology and human health (Võ Xuân Tiến, Nguyễn Văn Long, 2006; Lê Thị Mùi, 2008; Nguyễn Văn Khánh, Phạm Văn Hiệp, 2009), which are also indicated by a huge of works focusing on toxicity of them (Nguyễn

Văn Khánh, Phạm Văn Hiệp, 2009; Nguyễn Văn Khánh et al., 2009; Franco et al., 2002; Nielsen, Nathan, 1975; Shulkin et al., 2003). The signification toxicity of some heavy metals are concerned as arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb). For example, as enters the body mainly via food, drinking water and air. As drinking water is not visible, odorless, tasteless so it can not be detected without means test. The discovery of arsenic is difficult because people have some symptoms of the disease 5–15 years before detection. Arsenic may cause 19 different diseases such as cancer-causing skin epithelium, bronchi, lungs, sinuses, sinus types (Nguyễn Văn Khánh, Phạm Văn Hiệp, 2009; Nguyễn Văn Khánh et al., 2009). Cd toxicity is very distinct to aquatic invertebrates (shrimp) and fish, human (kidney) and plants. The main cause of toxicities is isomorphic to Zn, hence Cd could be replaced Zn in certain enzyme and causing disorders metabolic process. Depending on the severity of Cd contamination, it can manifest in different levels such as lung cancer, nasal septum perforation, kidney damage, blood endocrine and cardiovascular (Nguyễn Văn Khánh et al., 2009; Franco et al., 2002). Lead is a non-essential element for the organism. Pb is absorbed by plant and contaminates the food chain. Pb is likely to accumulate high in production organisms, even only a negligible amount, which goes through the food chain and will be amplified to become toxic for consuming organisms or production organisms (Franco et al., 2002; Nielsen, Nathan, 1975). Mercury in water can be absorbed into the body of aquatic organisms, especially fish and invertebrate. Fish absorbs mercury and metabolizes into methyl mercury (CH_3Hg^+), this compound is serious toxic to the human body. Methyl mercury dissolves in fat, which localizes in the fatty membrane and human cerebrospinal tissues. Inorganic mercury primarily affects the kidney, while methyl mercury affects the central nervous system (Nguyễn Văn Khánh et al., 2009; Franco, 2002; Nielsen, Nathan, 1975; Shulkin et al., 2003; Maanan, 2007; Silva et al., 2003).

Danang is a coastal city in the Central of Vietnam having many opportunities for economic development and promising tourism from the sea (see Fig. 1). In recent years, economic sector of Danang has improved rapidly versus other municipalities. Along with the high marine economy achievements, this city is coping with the environmental problems as the coastal contamination increasing. The coastal environmental pollution is not only affecting to the healthy coastal communities but also declining of biological diversity and marine resources. According to some assessments of environmental experts, the coastal environment problems of Danang city could be resulted from several different irrational causes as the marine resources exploiting, pollution control at raising sources and integrate coastal management (Võ Xuân Tiến, Nguyễn Văn Long, 2006; Lê Thị Mùi, 2008). Among the above contamination, the heavy metal is one of the contributive factors that are threatening this area. The main sources of dangerous toxins are such activities as industries (industrial parks, particularly shipbuilding industry), mining, infrastructure development, population growth, and services during past years. Facing with the challenges and choices in the new development stage, Danang needs choosing new targets in the short and long term to ensure economic growth and improving environmental quality.

Materials and methods

Danang coastal water was sampled and conducted during period 2005–2014 at 12 points from B1 to B12 (Lien Chieu port – B1; Cu De estuary – B2;

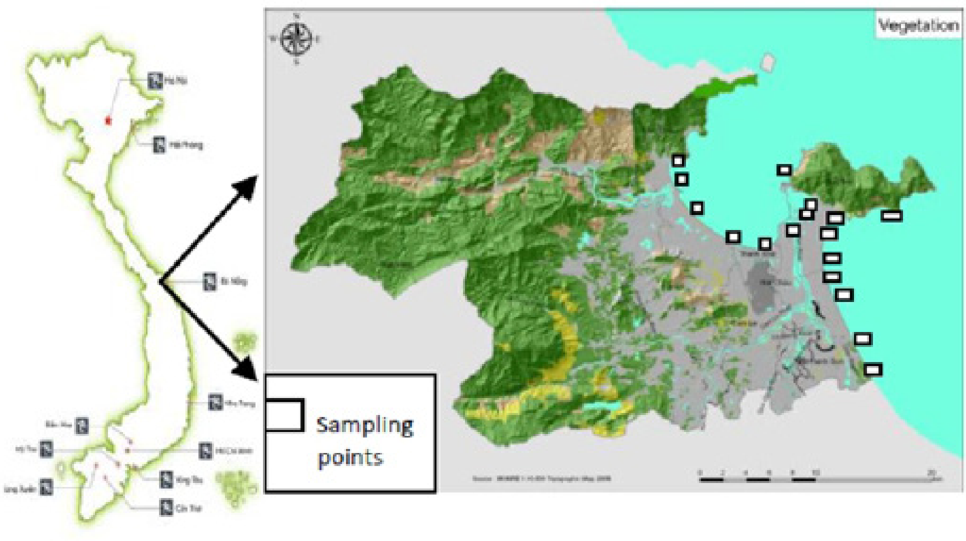

Fig. 1. Sampling points.

Tho Quang dock – B3; Tien Sa port – B4; Phu Loc estuary – B5; Tho Quang beach – B6; Mong Ngua point – B7; Man Thai beach – B8; Pham Van Dong beach – B9; My Khe beach – B10; My An beach – B11 and Ngu Hanh Son beach – B12), where are showed on the Fig 1. The sampling frequency for each point is collected four times per year and entire sampling processing follows the regulations of International Organization for Standardization (ISO) and Vietnam (TCVN) as showing hereafter:

The sampling, store and treatment methods, and marine sampling method follow TCVN 5992:1995 (ISO 5667–2: 1991); TCVN 5993:1995 (ISO 5667–3: 1985) and TCVN 5998:1995 (ISO 5667–9: 1987), respectively.

All the heavy metal (Hg, Pb, Cd, Fe, Zn and As) are conducted following TCVN 6193–1996 (ISO 8288–1986) via atomic absorption spectroscopy method. All the analyses were conducted three times in order to determine the precision and errors of the data.

Results and discussion

1. Exposure of mercury and lead

The variation of Hg concentrations period 2005 – 2014 of Danang coastal zone are indicated in the Fig. 2, the data show that the Hg at high concentration in the initial monitoring time and trend reducing after years. However, the significant concentration at some sampling points (B3, B8, B9 and B10) exceeds more than 0.002 mg/L versus the regulation of National technical regulation on coastal water (QCVN 10: 2008/BTNMT). These higher limitations could be explained that the Hg concentration sources may concern about the local marine and industrial activities.

The variation of lead concentration in the Danang coastal zone is illustrated in Fig. 3. The data in the Fig. 2 show that Pb concentration spurts out at one point for one year (2013). This point (Tho Quang dock–B3) is also considered as highly contaminated. Tho Quang dock is not only the sea harbor using as the settle area for almost of fishing ships of Danang fishermen but also it is the vessel for the wastewater discharge from Tho Quang industrial complex. Thus, there is high risk of lead contamination here.

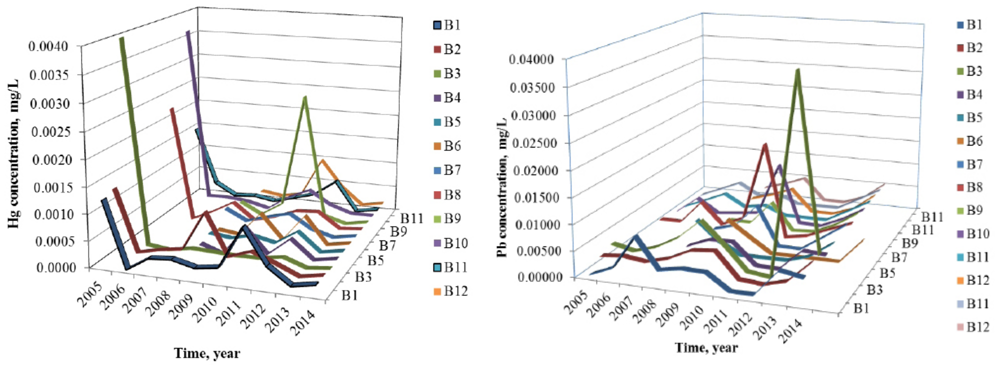

Fig. 2. Variation of Hg and Pb period 2005–2014 at the coastal of Danang.

2. Exposure of Cadmium and Iron

Cd disperse into the environment from waste sources such as plated wastewater, automotive repair industry, shipbuilding, coating plants, decomposed and burn plastics, degradable tires, battery technology, technology of fertilizer production and fertilizer usage especially phosphate (Shulkin et al., 2003; Maanan, 2007). The exposure of Cd of Danang coastal zone is very apprehensive for water environment. Most of monitored points are appearance of Cd (Fig. 3), the significant concentration is twenty times higher than the permitted limit (QCVN 10) at B5 and B8 in period 2010–2013, and others are approximately 10 times higher. The presence of Cd in this area may result from shipbuilding and ship-repair services. The iron concentration exposure of Danang costal zone is showed in the Fig. 3, the presence of Fe is usually totally high at sampling points. The significant concentration is noted at B2–B7 and B12. However, Fig. 5 indicates that there is the trends of decreasing entire Fe recently.

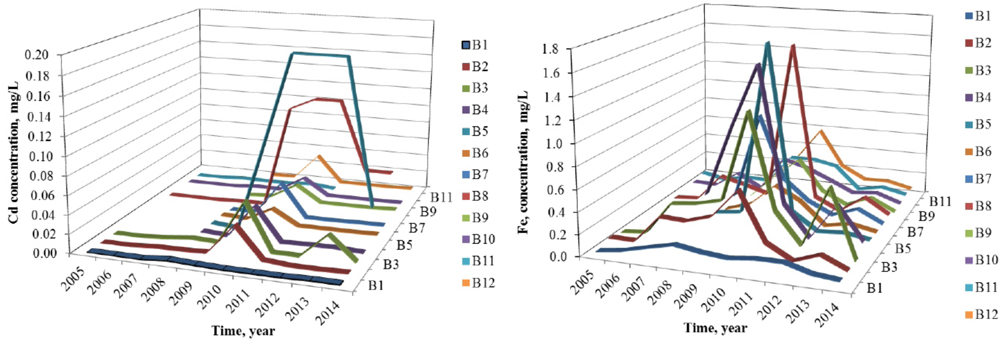

Fig. 3. Variation of Cd and Fe period 2005–2014 at the coastal of Danang.

3. Exposure of Zinc and Arsenic

According to the regulation of QCVN 10: BTNMT/2010 for Zn in coastal water, which is allows 1 mg/L. However, entire the concentration of Zn and As at all the monitored points (Fig. 4) are lower than the allowance for coastal water. As Zn and As values show in the Fig. 4 indicate that both heavy metal concentrations in Danang coastal are not contaminated by any sources from continent or other acitivities.

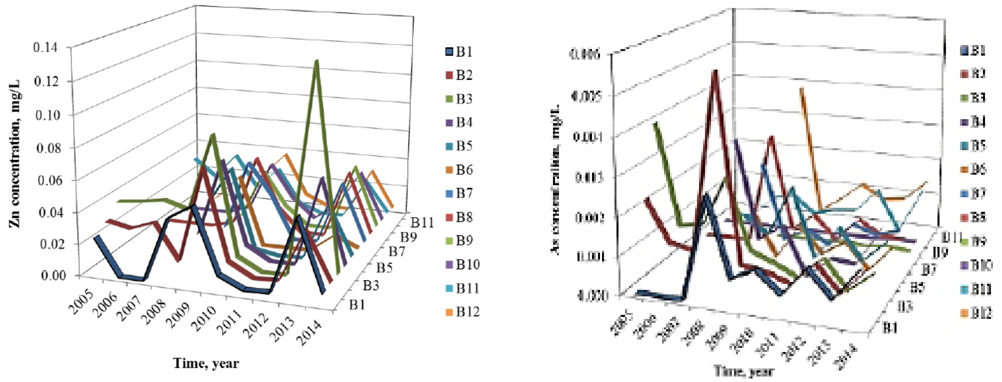

Fig. 4. Variation of Zn and As period 2005–2014 at the coastal of Danang.

Conclusions

The achieved monitoring data of Danang coastal during period 2005–2014 shows some years exceeding versus the QCVN 10: 2008/BTNMT (National technical regulation on coastal water quality) as Hg at B3, B8, B9 and B10 (Vung Thung, Man Thai, My Khe and My An beaches); Cd at B5 and B8 (Phu Loc estuary and Man Thai beach); Pb at B3.

The significant concentration of iron is detected at all the collected samples and the highest value reaches to 1.9 mg/L exceeding nearly twenty times.

Some sampling sites contained significant concentration of elements, which are highly potential to effect on coastal water quality and endanger toxicology for aqua system.

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INTEGRATING CORALS OF OPPORTUNITIES, ARTIFICIAL REEF SYSTEMS, AND MARINE PROTECTED AREAS: POTENTIALS FOR EXPANDING CORAL COVER

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A variety of coral restoration and conservation efforts such as the establishment of marine protected areas (MPAs), deployment of artificial reef structures and coral transplantation have been done both locally and worldwide, in an attempt to mitigate the degradation of reefs and aid in its recovery. MPAs, categorized as a passive form of restoration, is the most commonly

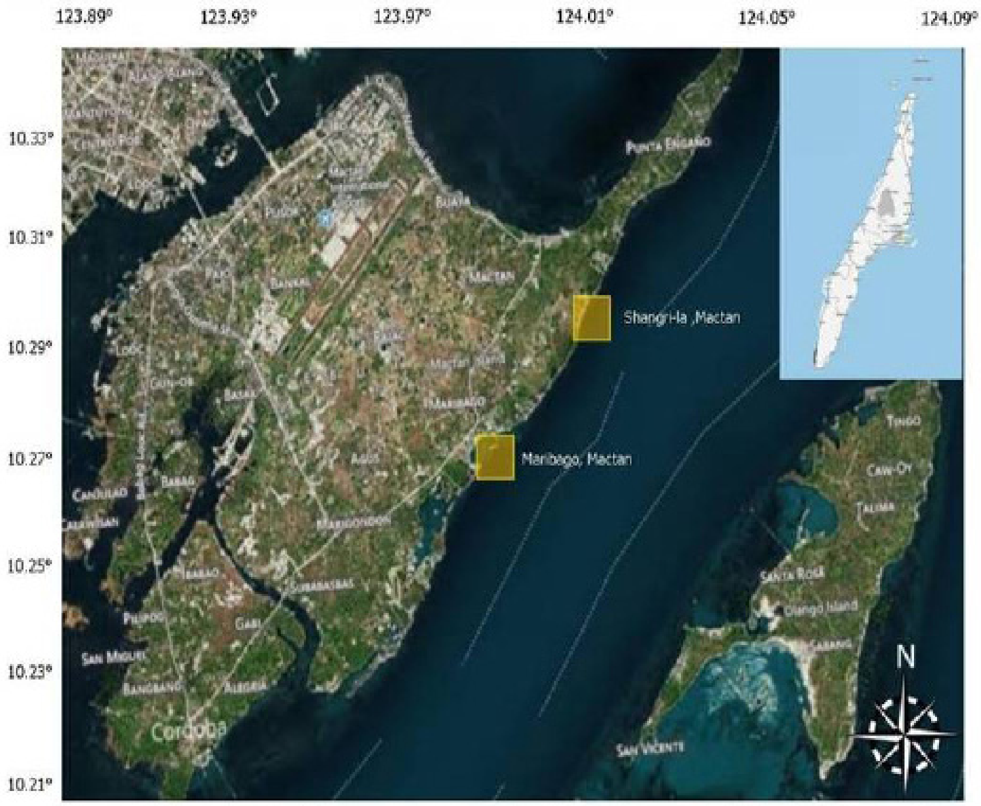

Fig. 1. Map showing the two study sites, the Marine Sanctuary in front of Shangri-La Resort and Spa and the reef area fronting the University of San Carlos Marine Research Station in Maribago, Mactan Island, Cebu Philippines.

implemented among these efforts. Within an MPA is a no-take zone, a defined area to allow natural succession to occur a coral reef ecosystem and restore its resources. However, even with the exponential increase in MPAs worldwide, many fail to proceed from declaration status to implementation. For example, in the Philippines, according to Aliño et al., (2004) the small percent (10%) of MPAs that has been able to achieve its objectives is a question of management, adherence to policy, and lack of community support (Sale, 2008; Rinkevich, 2008). On the other hand, a comprehensive study by Bruno and Selig (2007) compiling 6,001 quantitative surveys of 2,667 sub-tidal coral reefs across the Indo-Pacific which constitutes 75% of the world's coral reefs from 1968 to 2004, revealed that annually about 1% coral cover has been lost over the last 20 years and 2% between 1997 and 2003

Because of this loss, in recent years, 'active' restoration has been gaining popularity and has stirred debates and discussions on various restoration techniques, measures and management options. This has stemmed from the notion that an ecosystem like a coral reef does not often recover naturally from anthropogenic stresses without any form of manipulation (Rinkevich, 2005), stressing the fact that the rate of reef degradation is faster than the restoration efforts. The use of artificial reefs (Munro, Balgos, 1995; Ferse, 2008) coral gardening and transplantation (Rinkevich,1995; Yap, 2009; Hollarsmith et al., 2012;), substrate stabilization (Rojas et al., 2008) and the use of molecular/ biochemical tools (Baums, 2008) are just some of the innovative techniques and approaches developed in the past decade (Rinkevich, 2005). Not employing a variety of restoration measures limits the success of an MPA as a tool for conservation and management of coral reef systems (Rinkevich, 2000). Hence, this study is an attempt to combine local management actions such as the establishment of MPAs, with direct actions such as coral transplantation in an artificial reef structure. According to Abelson (2006), integrating artificial reef structures and coral transplantation to pre-established MPAs may increase coral reef cover and fish communities, larval spillovers from the MPA can also increase yields in fish catch and benefit local fishermen, and may thus encourage them to conserve and protect their local reefs.

This study of growth rate and survival (in percent) of three (3) coral species, *Acropora formosa*, *Porites attenuata* and *Porites cylindrica*, transplanted in a pyramid culvert artificial structure deployed inside and outside a Marine Protected Area (MPA) were determined. Only corals of opportunity (COP's), defined as live scleractinian corals detached from the reef by either natural processes or unknown events which can be repurposed for restoration activities (Monty et al. 2006) were used in this study. Also, the growth and survival of the three (3) coral species were evaluated based on the method of transplantation: *direct* (COPs are transplanted once collected with no recovery or acclimatization) or *indirect* where COPs are allowed to heal, recover, and acclimatize in a coral nursery unit (CNU) for three (3) months.

This study was conducted at two sites along the Hilutungan Channel, Mactan Island, Cebu, Philippines, the Marine Sanctuary fronting the Shangri-La Mactan Resort and Spa (SLMS) at Punta Engano, Lapu-Lapu City, Cebu, Philippines and the reef area fronting the University of San Carlos Marine Research Station (USC-MRS) in Maribago, Mactan Island, Cebu, Philippines (Fig.1). The study was conducted from November 2014 to February 2015.

Growths of the transplanted corals were faster inside the Shangri-La Marine Sanctuary compared to the highly disturbed reef in front of the USC Marine Research Station (Fig 2. Left)

On the other hand, coral fragments that were first allowed to acclimatize and grew in the CNU relatively had higher chances of surviving the transplantation process than those directly planted on the artificial reef structures. The various stressors that a fragment is exposed to coupled with the transplantation process without adaptation contributed to coral mortality.

And finally, of the three coral species, indirectly transplanted (CNU reared) *A. formosa* grew relatively fast (54%) inside and outside the MPA (Fig 2, Left). Healing, attachment and basal growth in all three species were already visible in a span of four months. These stabilize the growing coral fragments which later on becomes important in their growth and survival (Clark and Edwards, 1995). As to the growth between the two poritid species: *P. cylindrica*, and *P. attenuata*, there were no significant differences.

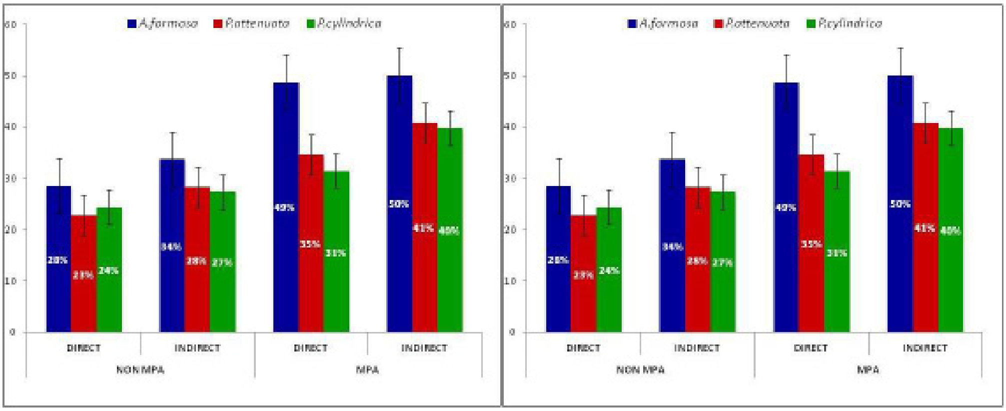

Fig. 2. (Left) Growth rates and (Right) Survival Rate of the three species of corals transplanted directly and indirectly on fish house artificial structures inside and outside the Shangri-La Marine Sanctuary, Punta Engano, Lapu-lapu City, Philippines.

Survival rates of transplanted COP species followed a specific trend, where *A. formosa* had the highest survival rate, followed by *P. cylindrica*, and *P. attenuata* transplanted both inside and outside the MPA (Fig. 2, from the right). Between indirectly and directly transplanted fragments, survival rates were higher in indirectly transplanted fragments of all three species inside the

MPA. And as expected, the highly disturbed area outside the MPA resulted to lower survival rates of all three species.

It can be then concluded that among the three species *A. formosa* is most suitable for transplantation due to rapid growth. This is similar to the findings where acroporids in general are recommended as transplant species for restoration projects. Fragments that went through a 3-month recovery period (indirectly transplanted) in the CNU were able to grow faster and survive better. Acclimatization is essential for healing; because this enables the fragments to withstand the environmental stressors, during the transplantation process. Artificial structures such as the pyramid-culvert have more surface area available for the transplants to grow and for natural recruits to attach to. But still, without regular maintenance, these areas would also provide substrate for turf algae to grow, increasing the likelihood of overgrowth and smothering of transplants.

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GOATFISHES (MULLIDAE) AS INDICATORS OF ENVIRONMENTAL CHANGES: BIOLOGY, POPULATION STRUCTURE, AND MANAGEMENT

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Introduction

Goatfishes from the family Mullidae are regarded as key species in the coastal biotopes due to their special feeding behavior: sediments are mixed by means of a pair of barbels located on the chin of the fish that attracts other fishes to form foraging aggregations. These fishes have a commercial value for fishery and can be used as the indicators of changes registered in biotopes under the influence of different factors including anthropogenic pressure.

Nha Trang Bay (southern Central Vietnam), a well known tourism site, receives thousands of cubic meters of waste water every day from residential quarters. About 90 percents of wastewater from Nha Trang city are discharged directly into the rivers without treatment then make their way to estuaries and Nha Trang bay. Among aquatic pollutants, heavy metals are the most appropriate indicator of pollution, because of their stability in sediments. Sediments are the most concentrated physical pool of metals in aquatic systems.

In fishes, the reproductive system is sensitive to environmental changes. Anomalies in ovarian structure have been studied in three widely distributed goatfish species (*Parupeneus multifasciatus*, *Upeneus tragula*, and *U. margarethae*) from the Marine Protected Area (MPA) of Nha Trang Bay. The

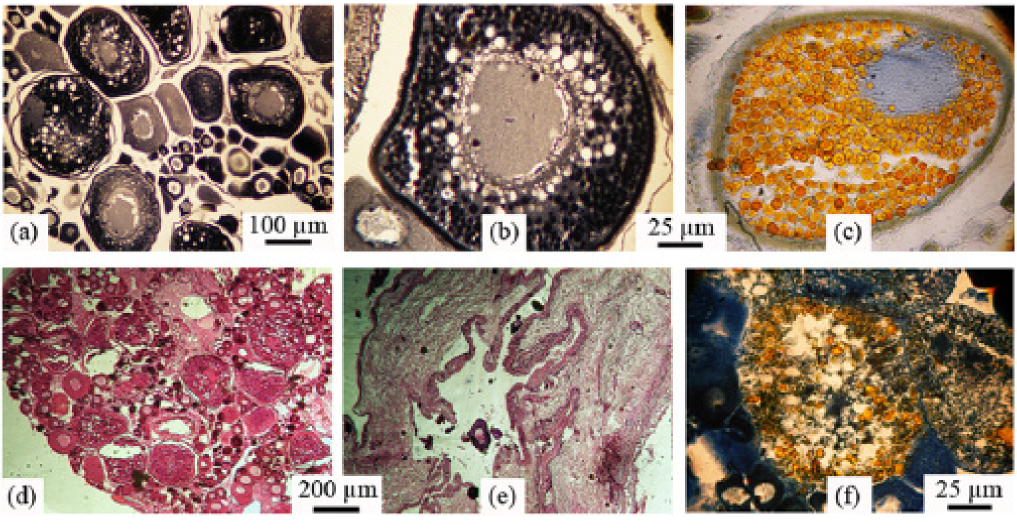

Fig. 1. Normal (a, b, c) and abnormal (d, e, f) condition of sex cells in *Parupeneus multifasciatus* females at the periods of vitellogenesis and maturation: (a) fragment of the ovary at maturity stage IV–V; the oocyte with the nucleus located at the animal pole is seen; (b) oocyte filled with yolk; lipid droplets are located around the nucleus; (c) polarized oocyte at the period of maturation; (d) destruction of oocytes at the period of maturation; (e) sterile fragment of the ovary; (f) oocyte resorption, disintegration of the zona radiata, hypertrophy of follicular cells.

fishes were collected in the buffer zone of the MPA.

Results and discussion

Based on histological analysis, abnormal oocyte structure was observed in ovarian fragments of a large number of females of all three species (Table). The following anomalities are registered in the oocytes at the periods of vitellogenesis and maturation: partial destruction and loosening of the cytoplasm, widening of the zona radiata, decreased size of yolk granules and destruction of some of them, uneven distribution of lipid vacuoles, total destruction of the content of vitellogenous oocytes with the appearance of cellular debris, resorption of oocytes with partial disruption of yolk granules and lipid vacuoles, etc. (Fig. 1). As a rule, abnormal structure of the oocytes at the periods of vitellogenesis and maturation is observed in the majority of cells (>80%) of gonadal fragments.

A probable reason of the destructive changes is the pollution of the bay mainly due to runoff from the Cai and Be rivers. Possible destructive agents are heavy metals distributed in sediments. A sequence of their action can be as follows: accumulation in invertebrates (food objects for goatfishes), dissolving in blood of the fish, and accumulation in the liver and then in vitellogenins (yolk predecessors) and oocytes. Metal ions can interrupt cellular metabolism and enter the nucleus inducing DNA damage.

Other comments

Despite an important role of goatfishes in ecosystems, their life histories are poor studied. We investigated the main biological features and population structure of some species along the coastal zone of Vietnam. These data can be used for sustainable management and conservation of the stocks.

The interspecific and infraspecific interactions of goatfishes are mainly unknown, and genetic studies are limited. A comparative analysis of otolith shapes in different species and forms is a useful tool, for the assessment of taxonomic relationships. The shapes of sagittae are compared in three related species of the genus *Upeneus* (*U. tragula*, *U. margarethae*, and *U. sundaicus*) from North Vietnam (Ha Long Bay). Based on elliptic Fourier analysis and multivariate statistics (principal component and canonical discriminant analyses), *U. sundaicus* differs from *U. tragula* and *U. margarethae*, and the two latter species are closely related to each other (Pavlov, 2016).

The population structure and features of reproduction are described in *U. tragula* from North Vietnam (Ha Long Bay), southern Central Vietnam (Nha Trang Bay), and South Vietnam (Phu Quoc Island). In Nha Trang Bay, the females reach sexual maturity by 10.2 cm fork length (*FL*) (50% of individuals), and the fishes spawn over the entire year. In a part of the population (on average, 23.5% of fishes), the interruptions in spawning not associated with a certain season

Table. Proportion of goatfish females with abnormal oocyte structure in Nha Trang MPA

Species	Females with abnormal oocyte structure, %	Total number of females	Years of observation	References
Parupeneus multifasciatus	20	44	2010	Emel'yanova et al., 2014
Upeneus tragula	15	80	2008–2013	Emel'yanova et al., 2015
Upeneus margarethae	20	20	2012–2013	Pavlov, Emel'yanova (in press)

of the year are registered. In Ha Long Bay, a distinct spawning interruption is observed in all fishes during winter (Pavlov et al., 2014).

A special *U. tragula* population is found off Hon Thom (An Thoi Archipelago, Phu Quoc MPA). The population is represented by two color morphs: "black" and "red". These morphs have different Vietnamese names. The representatives of black morph are smaller, and the female's ovaries are always at maturity stages II or III. The fishes of red morph are larger, and they are always at spawning condition (maturity stage IV–V). We suppose that both morphs belong to the same population, and color change is associated with sexual maturation. In this case, the females (50% of individuals) reach sexual maturity by 15.3 cm *FL* (vs. 10.2 cm *FL* in *U. tragula* from Nha Trang Bay). Thus, this population can be regarded as the unique endemic stock with a limited distribution off Hon Thom. Based on our observations from An Thoi market, the red morph prevailed in January 2012, but it was totally absent in January 2016 (all *U. tragula* was represented by the black morph). Therefore, this population, most likely, has been overfished because of the intensive catch of both most valuable red morph and immature black morph. The fishing restrictions and stronger protection of Phu Quoc MPA are necessary for the conservation of the unique stock.

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THE VARIATION TREND OF SEAWATER QUALITY IN NHA TRANG BAY IN THE PAST TWO DECADES

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The analytical results of seawater samples collected at Nha Trang bay in 2015 showed that although there were contaminations of nitrate (in river mouths), Fe, hydrocarbons (in the entire bay), the seawater quality was relatively good in general. The values of dissolved oxygen, biochemical oxygen demand, nutrients (ammonia, nitrite, nitrate, phosphate) and heavy metals (Zn, Cu, Pb) were in the range of criteria values in the National Technical Regulation on

Fig. 1. Location of sampling stations.

the quality of coastal water in Vietnam (QCVN 10:2008/BTNMT) and ASEAN Marine Water Quality criteria for Aquatic Life Protection. In addition, the data also showed that nitrate was limiting nutrient in Nha Trang bay in both seasons (rainy and dry). There was no big difference in water quality between dry and rainy season.

Data on environmental quality during two decades in Nha Trang bay showed that although the trend variation was not clearly, the concentration of nutrients such as nitrite, nitrate and heavy metals such as Zn, Cu had decreasing trend (in both seasons) and phosphate concentration had increasing trend (dry season).

Introduction

Nha Trang bay is a well known tourism site in the south of the central region. However, due to economic activities (tourism, aquaculture cages), Nha Trang bay has been receiving a large amount of wastewater surrounding. Therefore, seawater quality could be concerned for sustainable development.

From 1996 to present, many studies have been conducted on this bay, typical projects such as SAREC (1996–1999), NUFU (2008–2010), Climate Change (2009–2010), National projects (2004–2009). Based on the historical data of above projects, this report presents changes in water quality of Nha Trang bay.

Documentary and methods

The seawater samples were collected at surface and bottom layers at 15 sites (Fig. 1) in rainy and dry season in 2015; total of 60 samples had been collected. Some environmental basic parameters (dissolved oxygen, biochemical oxygen demand), nutrients (ammonia, nitrite, nitrate, phosphate), heavy metals (Fe, Zn, Cu, Pb), coliform density and hydrocarbons (HC) were analyzed.

The samples were treated and analyzed following APHA (2012); water quality were assessed according to National Technical Regulation (QCVN 10:2008/BTNMT) and ASEAN Marine Water Quality Criteria for Aquatic Life Protection.

The historical data in Nha Trang bay were collected in the period from 1996–2014. Due to topographic characteristics and socio-economic activities, Nha Trang bay is divided into two zones: South (beaches, including Cai river mouth) and Northwest (aquaculture of lobster cages, including Tac river mouth).

Static and linear regression methods, using Microsoft Excel software, were applied to compare and estimate the trend of changes.

Results and discussions

1. Seawater quality situation

The data showed that in dry season the concentration of dissolved oxygen, hydrocarbons were usually higher while concentration of total suspended solid,

Table 1. Values of basic environmental parameters and nutrients in the entire bay in both seasons (dry and rainy) in 2015

Seasons	Value	DO (mg/l)	BOD_5 (mg/l)	HC (µg/l)	$NH_{3,4}$-N (µg/l)	NO_2-N (µg/l)	NO_3-N (µg/l)	PO_4-P (µg/l)
Dry season	Avg.	6.17	1.28	414	4.20	4.59	32.12	7.47
	Min.	5.37	0.46	201	0	1.60	23.40	4.10
	Max.	7.17	2.53	574	77.00	10.80	55.30	13.20
	Count	30	30	15	30	30	30	30
Standard deviation		0.40	0.50	100	14.94	2.60	5.73	2.56
Rainy season	Avg.	5.86	1.15	380	4.09	3.17	37.67	9.24
	Min.	5.26	0.62	330	0.50	0.80	33.10	4.40
	Max.	6.31	3.50	457	20.00	9.00	72.80	15.40
	Count	30	30	15	30	30	30	30
Standard deviation		0.24	0.56	36.94	5.42	1.76	8.27	2.88
Standard		≥5[1]	<4[1]	none[1]	100[1]	55[2]	60[2]	15[2]

Note: (1): National Technical Regulation on the quality of coastal water in Vietnam (QCVN 10:2008/BTNMT); (2): ASEAN Marine Water Quality criteria for Aquatic Life Protection.

nitrate, phosphate and Fe were lower compared to in rainy season. The highest values of nitrate, phosphate, Fe and coliform density always were recorded at river mouths in rainy season (Table. 1, 2).

In general, most of the values of basic parameters (dissolved oxygen, biochemical oxygen demand) and nutrients except nitrate in river mouths were in the range of criteria values in the National Technical Regulation (QCVN 10:2008/BTNMT) and ASEAN Marine Water Quality criteria for Aquatic Life Protection although at few moments, there were partial contaminations of nitrate, phosphate.

For heavy metals, the data shows that heavy metal concentration except Fe were (Table 2) lower than the critical values; concentration of Fe, hydrocarbons and coliform density (in river mouths and Bay lagoon) were always a bit higher than the standard. However, compared to other coastal areas in Vietnam, Fe concentration was not higher.

It could be concluded that, although there were contaminations of nitrate (in river mouths), Fe, hydrocarbons (in the entire bay), the coastal water quality was relatively good in general.

2. The variation trend of seawater quality

Table 2. Values of heavy metals and coliform density in the entire bay in both seasons (dry and rainy) in 2015

Seasons	Value	Fe (µg/l)	Zn (µg/l)	Cu (µg/l)	Pb (µg/l)	Coliform (MPN/100ml)
Dry season	Avg.	134	3.18	2.12	1.71	315
	Min.	44	1.90	1.00	1.00	0
	Max.	247	5.70	2.90	2.70	2400
	Count	15	15	15	15	12
Standard deviation		67.83	1.05	0.73	0.61	707
Rainy season	Avg.	190	3.92	1.77	1.36	407
	Min.	102	1.98	1.10	0.62	0
	Max.	373	6.60	3.40	2.55	4600
	Count	15	15	15	15	12
Standard deviation		85	1.83	0.72	0.45	1321
Standard		*100*[1]	*50*[1]	*30*[1]	*50*[1]	*1000*[1]

Note: (1): National Technical Regulation on the quality of coastal water in Vietnam (QCVN 10:2008/BTNMT)

2.1. In South of Nha Trang bay

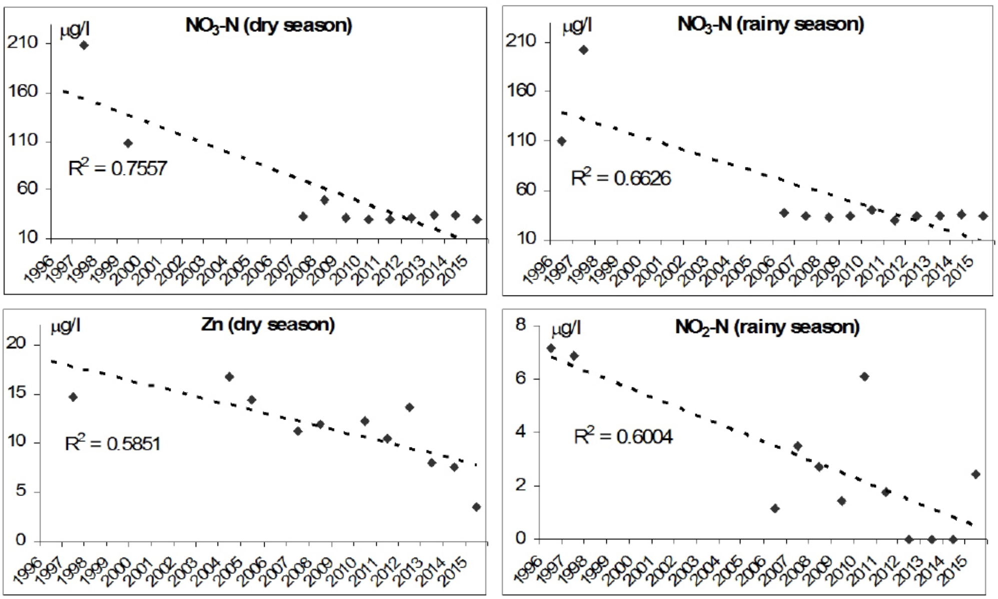

Fig. 2. Changes of some environmental parameters over years.

Concentration of hydrocarbons and Pb had the increasing trend; the trend of environmental parameters such as dissolved oxygen, biochemical oxygen demand and Fe were not clear; concentration of nitrite, nitrate, Zn had decreasing trend in both seasons in South of Nha Trang bay.

2.2. In Northwest of Nha Trang bay

Concentration of nutrients (ammonia, phosphate), hydrocarbons and Pb had increasing trend; the trend of dissolved oxygen, biochemical oxygen

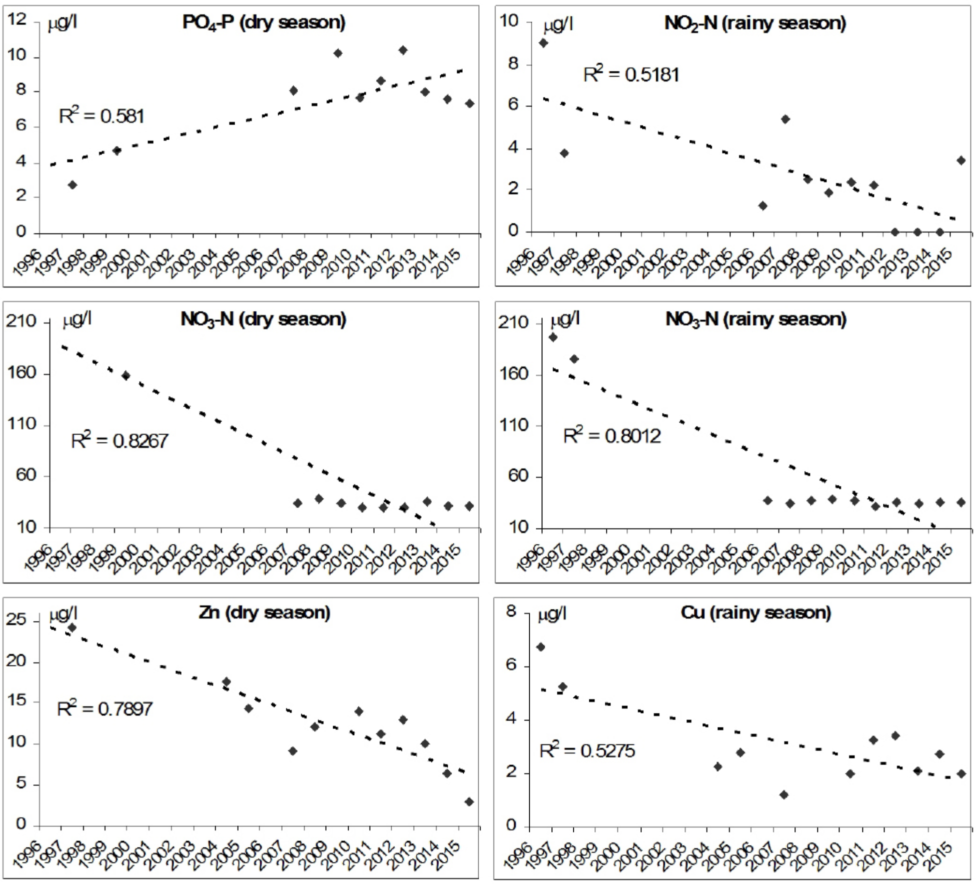

Fig. 3. Changes of some environmental parameters over years.

demand and Fe were not obvious; concentration of nitrite, nitrate, Zn and Pb had decreasing trend in both seasons in Northwest of Nha Trang bay.

Conclusions

Although there were contaminations of nitrate, coliform density (in river mouths, Bay lagoon), Fe, hydrocarbons (in the entire bay), the seawater quality in Nha Trang bay was relatively good in general. The values of dissolved oxygen, biochemical oxygen demand, nutrients (ammonia, nitrite, phosphate) and heavy metals (Zn, Cu, Pb) were in the range of criteria values. In addition, the data also showed that nitrate was limiting nutrient in Nha Trang bay in both seasons (rainy and dry). There was no big difference in water quality between dry and rainy seasons.

Data on environmental quality during two decades in Nha Trang bay showed that although the trend variation was not clearly visible, the concentration of nutrients (such as nitrite, nitrate and heavy metals such as Cu, Zn) had decreasing trend and phosphate concentration had increasing trend.

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NATURAL GASES DISTRIBUTION IN THE BACBO AREA, EAST-VIETNAM SEA, 2013-2015

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Successful development of the Joint Vietnam-Russia Laboratory for Marine Geosciences and Technology, established by Institute of Marine Geology and Geophysics VAST (Hanoi) and V.I. Il'íchev Pacific Oceanological Institute FEB RAS (Vladivostok) during 2010–2015 allow us to get significant scientific and cooperative advances in the field of gasgeochemistry and tectonics and gases anomalies possible influence to the ecology state are discussed.

Results and discussions

The total area for gasgeochemical research includes western part of East-Vietnam Sea (Bien Dong). The discussed sampling area subdivided into 6 sites including profiles and cross profiles and separate sites on islands within the Bacbo Gulf (Fig. 1).

Sediment samples for discussed results were sampled on board and sub-sampled at the 30 stations. Methane was found in the all sediment samples, and ethane was detected in the 95 % of the samples. Ethane concentrations are in 10 times less than methane one, but sometimes can reach the same values, e.x.

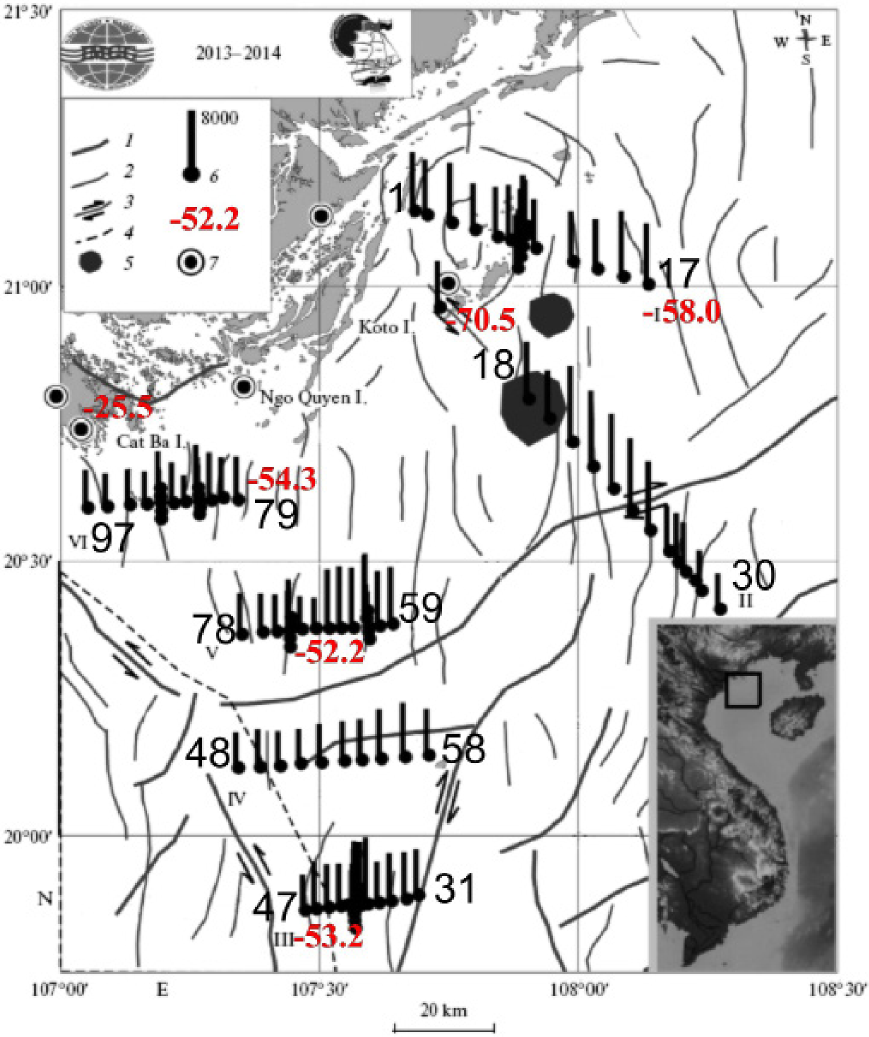

Fig. 1. The area of complex geological–geophysical investigations in the Gulf of Tonkin in 2013. (1–3) Faults: (1) principal, (2) subsidiary, (3) strike slip faults; (4) orientation of the Red River rift; (5) igneous complexes; (6) histograms of methane concentrations (max. 8000 nL/dm^3); (7) sites of water sampling in onshore hydrological sources. (I–VI) numbers of areas and profiles. In the inset, a square corresponds to the study area in the map of Vietnam. $\delta^{13}C$-CH_4 in the sediments marked by ‰ VPDB (-52.2 et cet.) corresponding to the location.

1050 nl/l at the station 73. Propane and butane were found in 75% of the samples. The diagrams below show the typical vertical methane distribution in the sediments of the BacBo Gulf. Methane concentrations in the sediments vary actually from 300 to 8000 nano-liters/dm^3. Such concentrations mark slight methane anomalies in the surface sediments and indicate usually effective lithological cap, trapped possible hydrocarbons and usual for the low seismotectonic environment. Comparably, in the hydrocarbon prone sediment basins of the Sea of Okhotsk methane concentrations in the near bottom water layer reach 10000 nl/l (Shakirov et al., 2005) and up to 15 ml/dm^3 in the sediments. Background methane in the sediments 4 ppm (3.5 mkl/lm^3), He 10.4 ppm, H_2 – 6.4 ppm (He content in the sea water 8.55 ppm, hydrogen in the seawater 4.5 ppm).

Tables below present average gases concentrations for sampling profiles (sites). These results show common features and differences in the study area. Hydrocarbon gases were found: methane, ethane, propane, butane and tracers of pentane. Methane in headspace has similar values in the all profiles is about 4 ppm. It is important that butane has almost similar content and even more (6.7 ppm) at Site V. The significant concentration of i-butane exceeded butane also indicates epigenetic source of hydrocarbon gases. Ethylene and propylene indicates modern oxidizing processes in the sediments (Table 1).

Dissolved gases show steady nearly background methane concentrations usual for the seawater, but hydrocarbon gases exposed abnormal values, especially butane (found at all sites) and pentane (found at Sites II and III). Also, methane distribution in the seawater does not show influence of coastal coal (anthracite) deposits. Also, we are revealed CO_2 content peaks (0.5, 0.6, 2.1 and 3.8 %) along the continental coast of Bacbo Gulf. Helium content in the sediments and seawater has near the normal distribution with slight anomalies. In opposite, we found many hydrogen anomalies, including dissolved (up to 700 ppm, st. 72, Site1 IV) exceeded the background 100 times. These anomalies likely related to the faults, and, probably indicate anthracite coal fields if they are continuing from the coast to offshore. But this assumption is still discussible up to new data. The isotope composition of the dissolved carbon dioxide both at a headspace method and at vacuum degassing demonstrates the similar values characterizing in general the carbon environment in the study area.

It is especially important that water of sources and wells on Cat Ba Island are characterized by very high concentration of carbon dioxide (18–28 ml/l) that can be connected with desalination of carbonate rocks, and also with the intrusions interbedded in carbonate thicknesses. Natives use this water as drinking, but according to the carbon dioxide content it comes nearer to mineral water.

The major factors defining subvertical migration of gas components (methane, hydrocarbon gases, helium, hydrogen, carbon dioxide) in the study area are: diffusive infiltration and the tectonic mode of the territory. It is expressed

Table 1. Hydrocarbon gases in the sediments (10^{*-4} % vol. (ppm), from headspace, average values for site)

Profile (Site) No	**CH_4**	**C_2H_4**	**C_2H_6**	**C_3H_6**	**C_3H_8**	**i-C_4H_{10}**	**C_4H_{10}**	**neo-C_5H_{12}**	**i-C_5H_{12}**	**He**	**H_2**
I	4.1	0.5	0.1	0.2	0.1	2.8	0.5	tracers	1.1	0.5-13.3/11	0.9-15.7/4
II	5.1	0.5	0.1	0.1	0.1	2.8	0.4	tracers	tracers	7.6-12/10	1.1-20.1/6
III	2.2	0.4	0.4	0.1	0.1	tracers	0	0.3	tracers	8.8-13.1/11	1.9-16.2/6
V	3.8	0.3	0.2	0,1	0.1	6.7	0.3	3.8	tracers	8.7-12.3/11	1.3-20.5/6
VI	4.7	0.32	0.1	0,1	0.1	tracers	0.3	4.7	tracers	4-13.7/10	0.3-101.6/6

in the extrusion structures and intensive folding complicated by polytypic faults forming migratory channels, and also block shifts of geological structures. The increased helium and hydrogen concentrations are connected with the specified geological features of the territory.

Hydrogen distribution in the sediments reveals a number of anomalies to 100 ppm (at the background of 4–6 ppm). It is known that hydrogen in most cases is present in gases of deep faults and is the indicator of seismically active zones. Possibly, in the Bacbo Gulf the lithospheric source associated with the generation center of hydrocarbon gases makes a certain contribution to formation of hydrogen anomalies. The peaks of hydrogen content are distinctly shown over faults; thus the maximum is fixed over faults crossing sea bed (profile VI). Another maximum is placed over "blind" faults. At the same site in the sediments the methane content reached the maximum values for the study area (to 8170 nl/dm^3). 2013 witnessed earthquakes (M 3) in the Bacbo Gulf. These events are an additional factor of hydrocarbon gases and hydrogen intake strengthening from depth to the seabed and water column. It is of prime importance that on the site which is approached to the River Red, biomarkers of hydrocarbon accumulations were found: isoprenoids, pristane and phytane. Thus as a part of organic matter linear alkanes with number of carbon atoms from C_{10} to C_{24} prevailed, and the concentration maximum on the distribution curve n-alkanes was in the area of C_{14}-C_{17}. The correlation pristan/fitan (Pr/Ph) for all samples ranges from 0.8 to 1.1 and points to accumulation of organic matter in redox conditions without oxygen access. The listed features of gases distribution and presence of biomarkers are caused most likely by receipt of slight migratory hydrocarbon fluids by the fault system connected with deep interior zone of permeability of the Red River rift.

Summary

In northwest part of the East-Vietnam Sea the gas-geochemical anomalies caused by a geotectonic structure of the sedimentary Beybuwan basin are marked out and carbon dioxide fluxes are mapped. The faults have low seismic activity, but availability of hydrocarbon and carbon dioxide source in the deep interior of Beybuwan basin expressed in methane anomalies and hydrocarbon gases content. Methane was found in the all sediment samples (in concentration to 9000 nl/dm^3, at the background of 4000 nl/dm^3), ethane is defined in 95% of the all samples. The ethane concentrations in the samples were in 10 times lower, than the methane ones, but sometimes can reach equal values. In 75–80 % of the samples propane and butane were detected. In the hydrological wells and springs on Cat Ba, Co To and Ngoc Vung and Bach Long Vi Islands within the Bacbo Gulf the huge methane abnormal concentrations up to 370000 nl/l and more indicates methane migration by water fluid. Anomalies of migratory methane are found out as in carbonate strata on Cat Ba Island, and in sandstones of ancient Silurian and Devonian periods on Co To Island. The low methane concentration in the sediments could testify also to intensive processes of its oxidation. This opportunity is confirmed by detection of ethylene and propylene and literary data for the geological past (Han et al., 2008).

The obtained data (high concentration of hydrocarbon gases, hydrogen and helium, existence of biomarkers, thermogenic up to metamorphogenic isotope composition of methane carbon) testify to the gas-bearing, possibly gas-condensate potential of the sedimentary basin Beybuvan, thus the contribution of the deep hydrocarbon and hydrogen fluid can be considerable. The hydrocarbon accumulation proves through the hydrological horizons drilled with wells on the island CatBa. The tectonic depressions developed in the study area are the most perspective.

Microbial gases are widespread in fresh-water superficial reservoirs, and confirm earlier revealed tendency to wide range of easy isotope methane (-70 ÷-93 ‰ VPDB) within the small study area.

GCMS data show significant influence of biological activity to the dispersed organic matter (DOM) in the sediments. “Microbiological filter”, probably, decrease methane concentrations in the sediments and sea water of BacBo area. Huge carbon dioxide and methane concentrations in the fresh water wells on the CatBa Island indicate close to mineral and balneal effect of natural gases.

Acknowledgements

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SEVEN–YEAR TAXONOMICAL INVESTIGATION OF CHITONS IN VIETNAM

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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 2016, in press).

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.

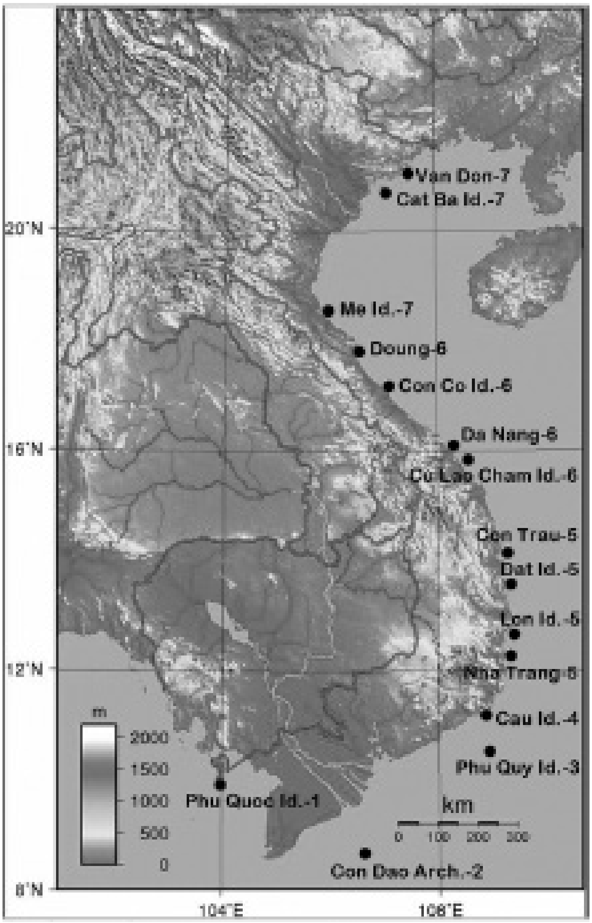

Fig. 1. General localities of sampling of chitons near Vietnam in 2009–2015. The figures correspond to numbers of localities in the Table.

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procedures.

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

№	Species	Localities								
		1	2	3	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9	10	11
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 (10º33´N, 109º43´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)							+		+

1	2	3	4	5	6	7	8	9	10	11
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 (10º26´N; 109º15´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

Note: 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.

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MAPPING SEAGRASS BEDS AND CORAL REEFS IN THE COASTAL WATERS, NINH THUAN PROVINCE OF VIETNAM, USING VNREDSAT1 IMAGE

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Seagrass beds and coral reefs play critical roles on the coastal zone ecosystem. Mapping those habitats is important for management, conservation and protection of coastal zone ecosystem. In Vietnam, researches are normally using traditional methods by go directly to the field and to map them in the laboratory by experience. This method is time consuming, need a lot of manpower and get unstable results. Using remote sensing data for mapping is one of the methods to overcome the problems facing in traditional methods. The objective in this study is using remote sensing data to map seagrass beds and coral reefs: Both DII and BRI methods were used for mapping. The map results show a good overall accuracy of 75.47% and Kappa coefficient of 0.65 for DII method. In while, the BRI method give a lower accuracy level with overall accuracy of 64.05 % and Kappa coefficient of 0.58. Total area of seagrass beds is about 275.22 (ha), located mainly in My Hoa and Thai An communities and the total areas of coral reefs is about 772.45 (ha), located along the coast. This result provides a good sign on underwater habitats mapping for coastal zone management by using the VNREDSAT1 data and promise to be an efficient tool

for management and conservation of underwater ecosystems in Vietnam.
Keywords: Seagrass beds, Coral reefs, Mapping, VNREDSAT1, DII, BRI, Ninh Thuan

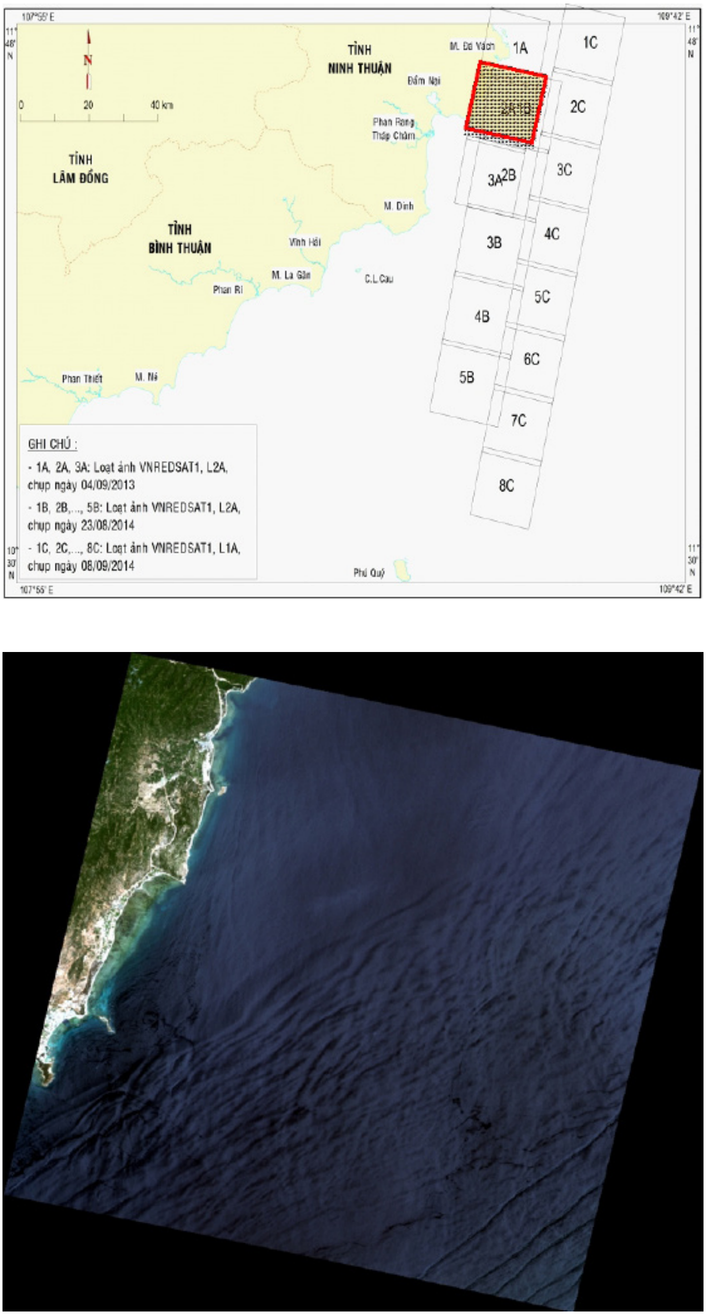

Fig. 1. The studied area scope and 321 color composite VNREDSAT1 image (V130904033142X_2A).

Introduction

Remote sensing technology has proved advantageous in observing the Earth's surface; it supports wide coverage, visits an extensive area repetitively, is low cost and doesn't require a large team of researchers. Within specific techniques, remote sensing can assist us to map underwater benthic habitats. Knowing the importance of remote sensing techniques in environmental observation and monitoring, during 6 May 2013, Vietnam launched VNREDSAT1 satellite. This is the first satellite of Vietnam with studied purposes. The VNREDSat-1 programme, is the result of an initiative by the Vietnamese government to create a space infrastructure enabling the country to better monitor and study the effects of climate change, predict

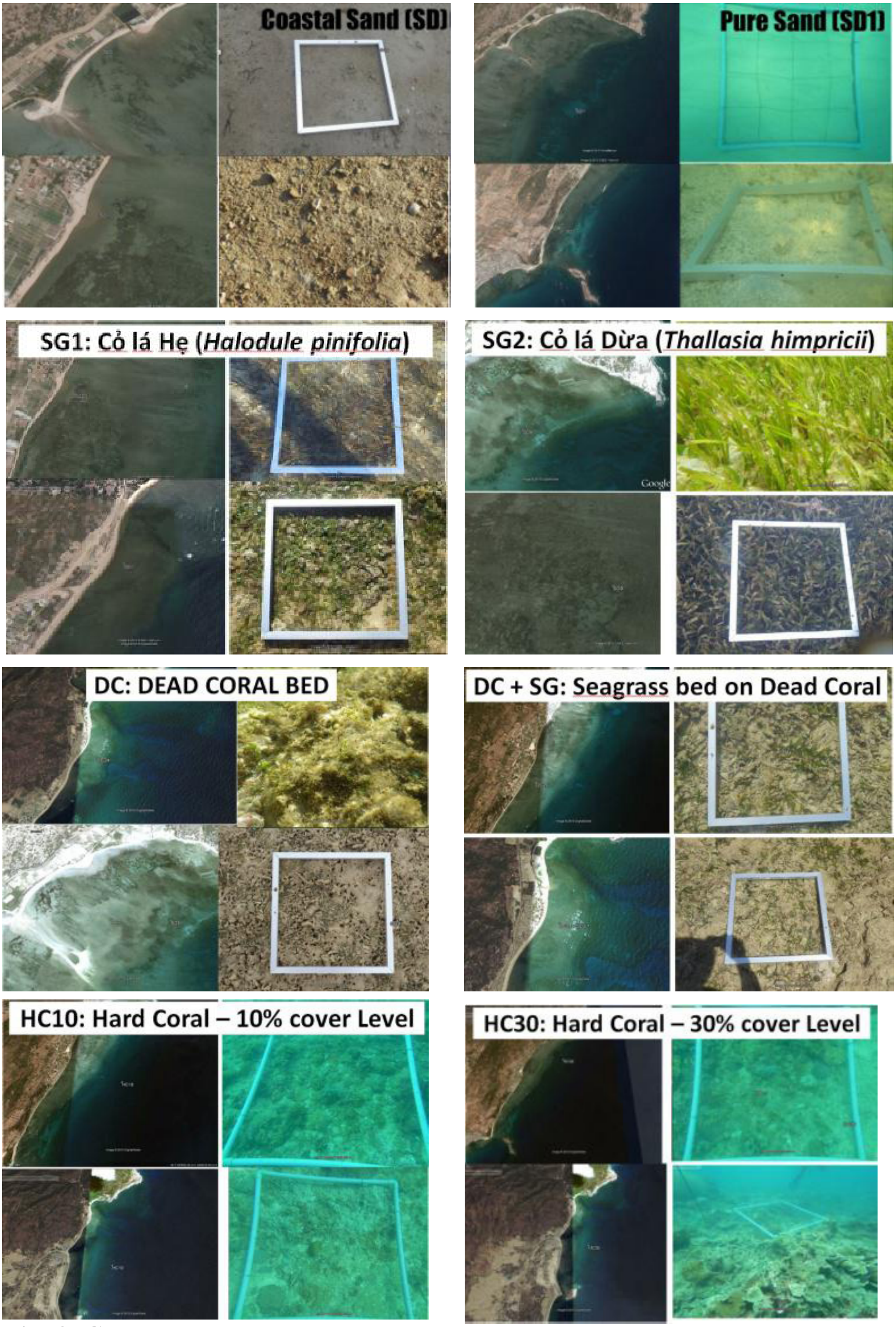

Fig. 2. Cont. next page.

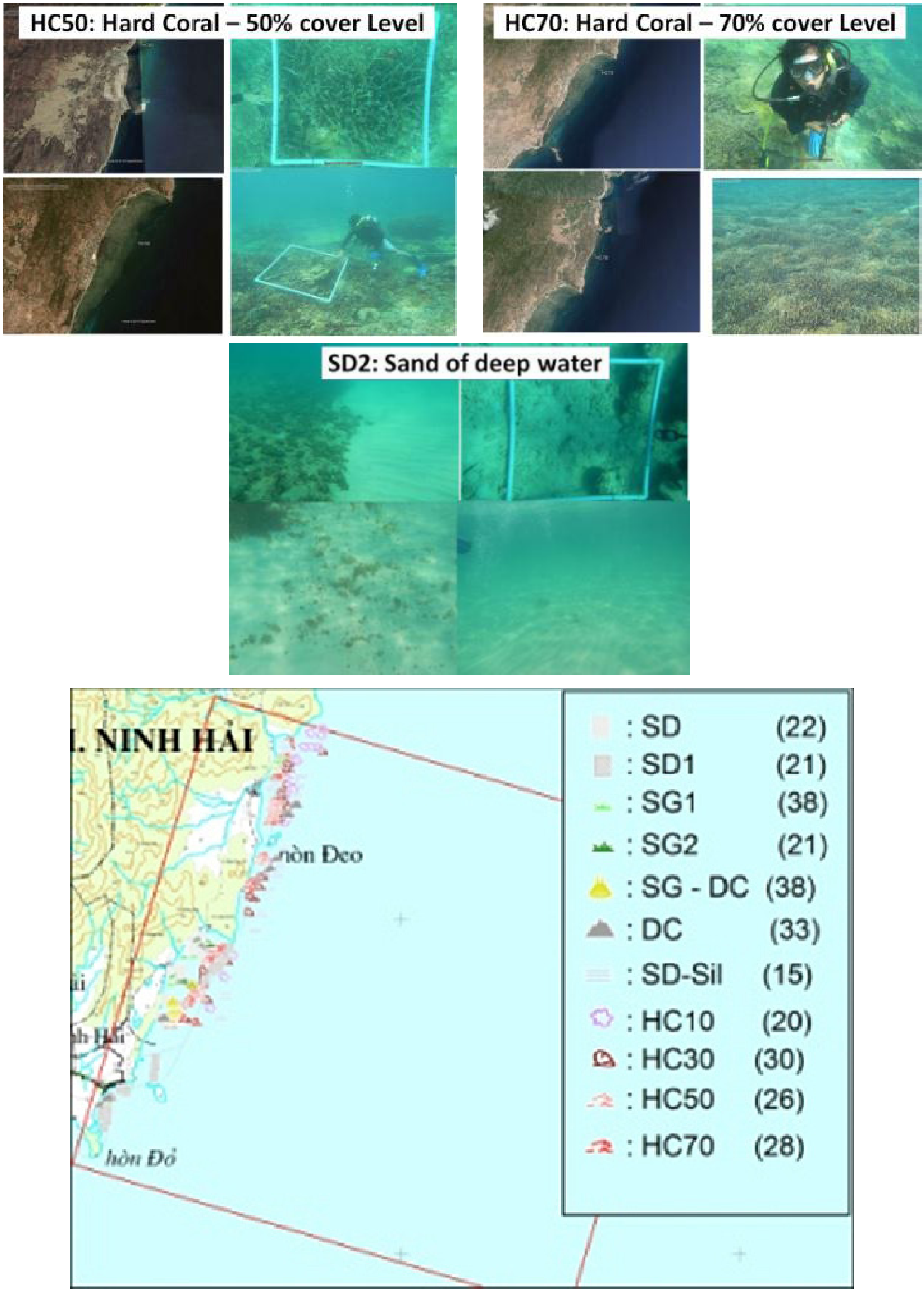

Fig. 2. The ground control points of 11 substrates used for detection of underwater habitats in coastal waters of Ninh Thuan province. (cont. from previous page)

and take measures to prevent natural disasters, and optimise the management of its natural resources. The VNREDSAT 1 system comprises an optical satellite capable of capturing images with a resolution of 2.5 metres for Panchromatic type, 10m resolution for multispectral images.

Adapting with above initiative, Institute of Oceanography participated in Vietnamese space technology program for application of the VNREDSAT1 images in marine studies. A national project "The building a digital database on oceanographic and environmental condition in coastal waters of Binh Thuan – Ninh Thuan provinces derived from VNREDSAT1 and other image sources" with code VT/UD–07/14–15 was formed in Institute of Oceanography and carried out studied issues in two years (2014–2016). The application of remote sensing technology for detecting the marine environmental parameters as well as the underwater habitats is one of the core components of this national project.

In this paper, authors will present some preliminary results of detection seagrass beds and coral reefs derived from VNEDSAT1 image in shallow waters of My Hoa commune – Ninh Hai District, Ninh Thuan province

Study area and data

1. Study Area

The coastal area of Ninh Hai region (Fig. 1) is located in the north of Ninh Thuan province, south-central of Viet Nam belong the Nui Chua national park. Mean sea surface temperature is ranging from 23^{o} to 29^{o} and the mean sea surface salinity is ranging from 30.9‰ to 33.9‰ (were provided by Vietnam Oceanographic Data Center). The coral reefs structured in Ninh Hai are as typical fringing reefs as well as patch reefs. The seagrasses bed is mainly living on a mixing bottom type of sand, death coral and rock algae in the range of 1.5km from the coastline. In recent years, on the requirement of economic developing, a new road along the coast from Phan Rang city was open wide and connected to No. 1 national road to the North. That is increasing the thread to the coastal of Ninh Hai ecosystem, direct and indirect to coral reefs and seagrass beds in this study area.

2. Data

Satellite data:

A scene of VNREDSAT1 (V130904033142X_2A code, level 2A, date 04 Sep 2013) is acquired from (Vietnamese) national remote sensing Agency and used in this study. This image includes 4 spectral bands (Red, Green, Blue and Infrared Red), 10 m spatial resolution, 8-bit radiance resolution, and very good quality (i.e 0% cloud cover level).

In-situ data:

Total 292 ground control points of 11 substrate types were observed using a small boat (diving/snorkeling) as well as walking on tidal ground at low tidal level from 27 to 30 September 2014 (Fig. 1). There are 66 points of low-density seagrass, 61 points high-density seagrass, 31 points hard coral, 48 points of death coral/rock/algae and 51 points of sand/low-density live coral substrates. At each data point, the cover level measured using quadrant frame (50 x 50 cm), took photo by using Pentax Option WG2 digital camera and track location position by Garmin GPSMAP 76CSx with projection of UTM-WGS84 zone 49N. We also divided random surveyed data into two datasets, one includes 146 GCPs for detection and another one of 146 GCPs for error assessment). The ground control points of eleven substrates for detection underwater habitats showed in Fig. 2.

A survey for measurement the depth and taking the sediment samples in coastal waters of Ninh Hai region also is carried out at same time (i.e September 2014).

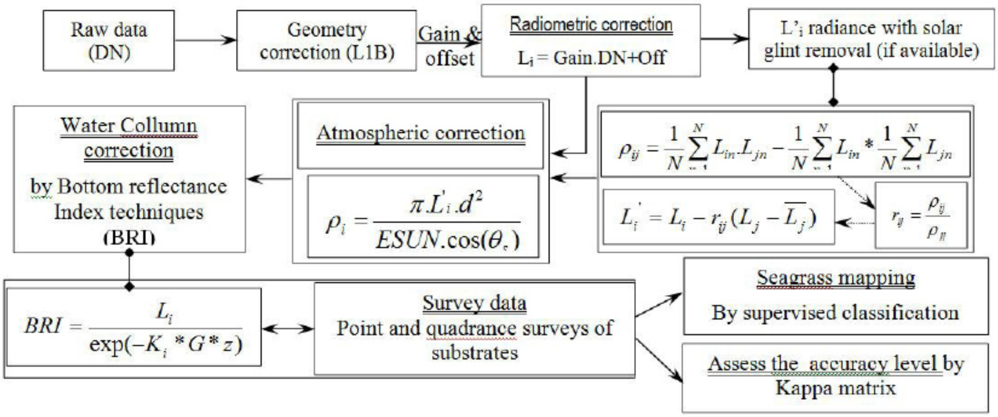

Fig. 3. The flow chart for sea-grass mapping by remote sensing techniques base on BRI and DII methods.

3. Data processing

Several prepossessing steps were applied for underwater habitat mapping in Ninh Hai – Ninh Thuan water, they include radiometric calibration, solar glitter removing, atmospheric correction, water column correction (i.e BRI and DII method), and classification. The Bottom Reflectance Index (BRI) will be estimated base on light attenuation ability in difference depths $BRI = \frac{L_i}{\exp(-K_i * G * z)}$. Whereas, Depth Invariant Index (DII) uses two bands to reduce water depth parameter in equation as $DII_{ij} = \ln(L_i - L_{si}) - \frac{k_i}{k_j}\ln(L_j - L_{sj})$, in which k_i/k_j was indicated by calculate slope of band i and band j in natural logarithm scale in homogenous sandy points in difference depths. A processed procedure is showed in figure 3.

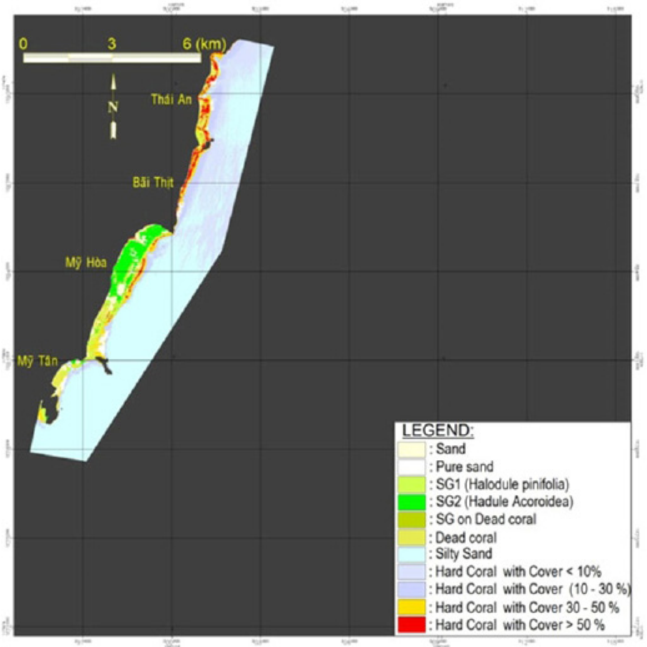

Fig. 4. Coral reef and Seagrass Mapping in shallow waters of Ninh Hai – Ninh Thuan from VNREDSAT1 image base on BRI method.

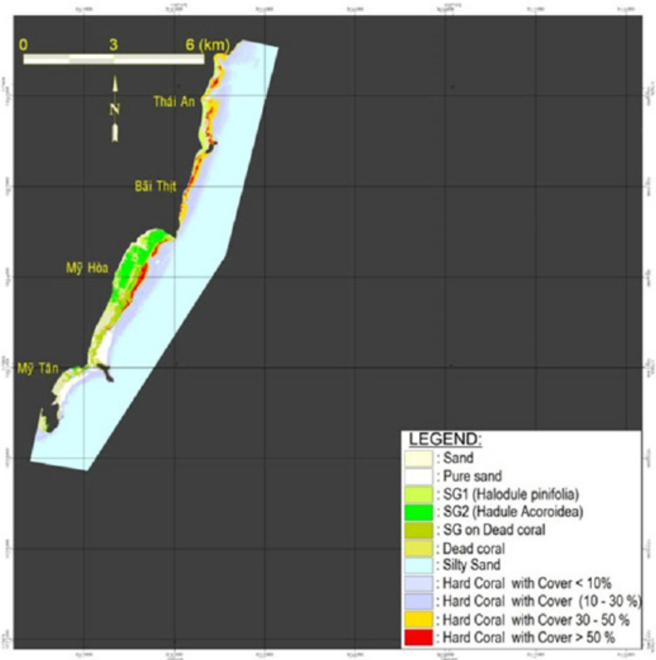

Fig. 5. Coral reef and Seagrass Mapping in shallow waters of Ninh Hai – Ninh Thuan from VNREDSAT1 image base on DII method.

Results and discussion

The classification results for both BRI and DII showed more detail in Fig. 4 and Fig. 5. The BRI method gives relative good accuracy of 64.47% and Kappa coefficient of 0.48. Whereas, the method DII method gave better accuracy of 72.38% and Kappa coefficient of 0.56.

In here, are only preliminary results and testing for habitat mapping in an area of coastal shallow waters of Ninh Thuan province. In next time, we continuously carry out for underwater habitat mapping in others areas of Ninh Thuan – Binh Thuan provinces. The accuracy level of classifications hopes to improve, if we rearrange and reclassify more fitting the ground truth data.

Conclusion

VNREDSAT1 is very good resource for mapping seagrass beds and coral reefs in Ninh Hai coast with a good overall accuracy of

72.38% and Kappa coefficient of 0.56 by DII method promising to be an efficient tool for management and conservation underwater ecosystems in Vietnam. The coastal of My Hoa – Thai An, Ninh Thuan waters have the total areas of sea grass beds of 275.22 (ha), and the total areas of coral reefs is 772.45ha, located along the coast on the outer parts of seagrass areas. How deep the VNREDSAT1 image could be map the coral reefs in Ninh Hai coast need more research to determine.

Acknowledgments

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IDENTIFICATION OF *SYMBIODINIUM* CLADE OF THE BLUE CORAL *HELIOPORA COERULEA* (PALLAS, 1766) (HELIOPORACEA: HELIOPORIDAE) FROM SURROUNDING WATERS IN CENTRAL VISAYAS, PHILIPPINES

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Symbiosis is common among marine invertebrates like corals, sponges, anemones, foraminifera, jellyfish and even in the giant clams. They host a large population of unicellular, photosynthetic zooxanthellae of the genus *Symbiodinium*. For example, symbiotic relationship between the coral and its *Symbiodinium* is significant. *Symbiodinium* provides nutritional benefits and has shown to account 50–95% of the coral's energy needs and in return, coral gives CO_2 and shelter to its *Symbiodinium*. Understanding their unique relationship is of utmost importance in order to gain knowledge on how and when this symbiosis is disrupted due to environmental anomalies such as elevated seawater temperature and anthropogenic causes (e.g. pollution). Stressful environment brought about by elevated seawater temperature could result to the temporary or permanent loss of *Symbiodinium* in a phenomenon known as "coral bleaching".

Understanding the biology of corals and its vulnerability to coral bleaching requires the exploration on the characteristic of its *Symbiodinium*. Different clades of *Symbiodinium* differ in their efficiency to perform photosynthesis, tolerance to environmental stress and their substantial contribution to the energy and nutritional needs of its hosts. To harbor stress and heat-tolerant symbionts could mean higher survival of the coral host under unfavorable environmental conditions.

Among the many host organism is the blue coral, *Heliopora coerulea* (Pallas, 1766), a reef building octocoral made up of massive aragonite skeleton. *H. coerulea* is known to thrive in shallow reefs and is less susceptible to coral bleaching. The heat-resistance capability of *H. coerulea* can indicate that they harbor stress or heat tolerant *Symbiodinium*.

The taxonomy of *Symbiodinium* are problematic due to the dearth of information on its morphology as they appeared to be of no difference especially in their symbiotic state. Genetic analysis revealed that the huge diversity of *Symbiodinium* is distributed non-ramdomly in all coral reefs. To elucidate the genetic diversity within *Symbiodnium*, molecular analysis has been used since the last two decades. With the recent discovery of a new clade in 2010, there are now nine (9) distinct clades (clade A-I) in the genus *Symbiodinium* which are phylogenetically delineated using chloroplast and nuclear ribosomal DNA (*r*DNA).

This study therefore aimed to identify the clades of the symbiont *Symbiodinium* from the blue coral *H. coerulea* collected from seven bodies of water within Central Visayas, located at the core of the Visayas group of islands in the Philippines. The region is surrounded by seven bodies of water, namely: (1) Camotes Sea, (2) Bohol Sea, (3) Visayan Sea, (4) Tañon Strait, (5) Cebu Strait, (6) Danajon Bank and (7) East Sulu Sea. Gratuitous permit no. 03–2013 to collect *H. coerulea* was issued by the Bureau of fisheries and Aquatic Resources – Region 7.

Three fragments of *H. coerulea* were collected from each body of

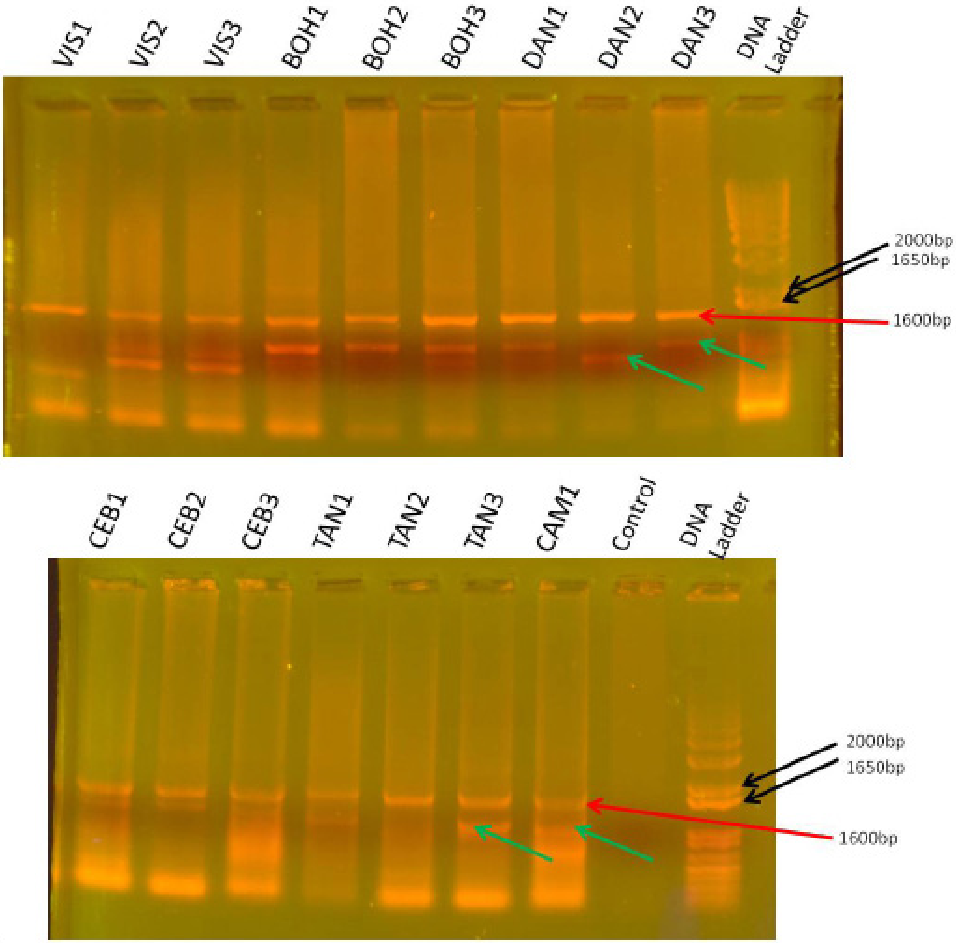

Fig. 1. DNA amplification patterns of the SSU *r*DNA from freshly isolated *Simbiodinium.* (VIS) - Visayan Sea, (BOH) - Bohol Sea, (DAN) - Danajon Bank, (CEB) - Cebu Strait, (TAN) - Tañon Strait, (CAM) - Camotes Sea.

water except in Camotes Sea where there was only one fragment. A total of sixteen coral fragments were collected as no blue coral was found in East Sulu Sea. The sampled fragments were preserved with extraction buffer (1.2µm filtered seawater and 5mM EDTA). *Symbiodinium* were extracted from the *H. coerulea* fragments by air pressure using a modified airgun attached to a SCUBA cylinder. *Symbiodinium* extracts were then centrifuged at 10,000 x g for 5mins and the resulting supernatant was discarded while 25–30 mg of peletted S*ymbiodinium* were extracted with DNA using the Plant Total DNA Purification Kit (Invitrogen™) following manufacturer's protocol. *Symbiodinium* cells were still intact after 15mins incubation at 55°C, hence incubation was extended to an hour. The final eluate was used as DNA template for amplification.

DNA amplification was carried out using the primers designed by Rowan and Powers (1991) under the following thermal profile: an initial denaturing step of 3mins at 94°C followed by 30 cycles at 1min at 94°C, 2 mins at 55°C, and 3 mins at 72°C, and a final extension of 8 mins at 72°C. Amplified DNA

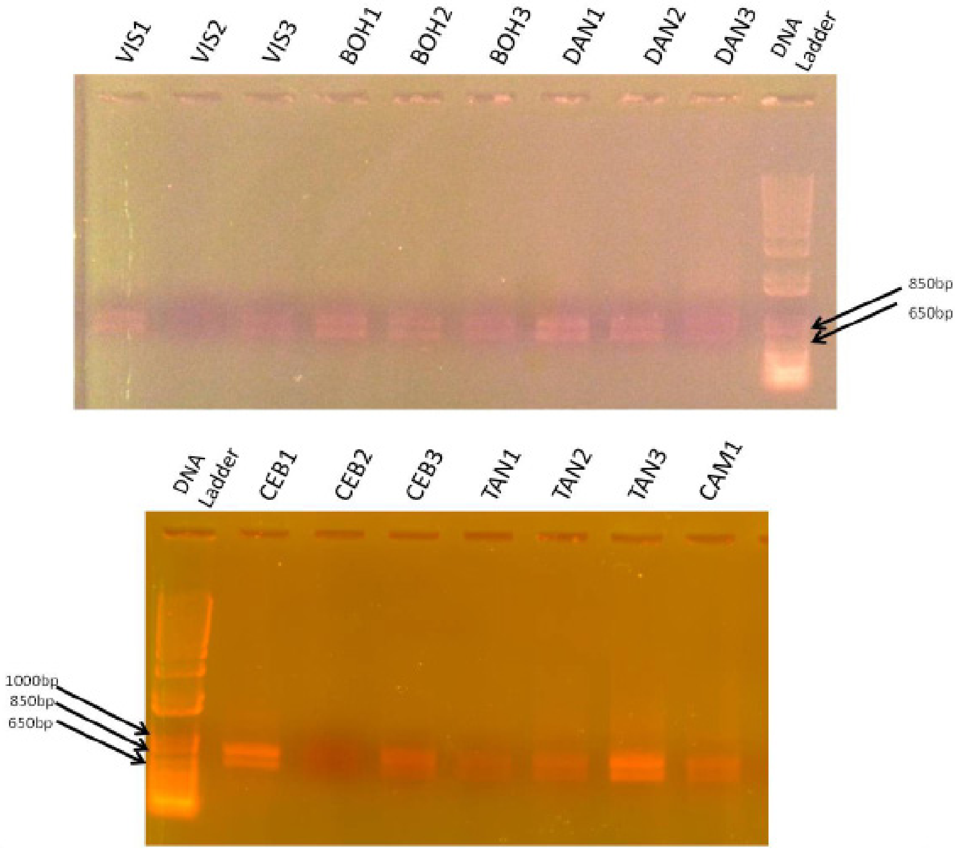

Fig. 2. RFLP patterns derived from *TaqI* digestion of the amplified *Simbiodinium.* (VIS) - Visayan Sea, (BOH) - Bohol Sea, (DAN) - Danajon Bank, (CEB) - Cebu Strait, (TAN) - Tañon Strait, (CAM) - Camotes Sea.

were run in gel electrophoresis along with 1kb Plus DNA ladder (Invitrogen™) at a constant 70V for 45mins using 0.8% agarose gel stained with Ethidium bromide.

Restriction digestion of the amplified products was performed by incubating 20 µl of the purified DNA, 5 µl buffer and 5U of *TaqI* (Vivantis™) for 5hrs. Clades were identified from approximate band sizes through gel electrophoresis, clade A – 700 and 600 bp; clade B – 850 and 500bp; clade C – 880 and 700bp; and clade E – 720 bp (Savage et al., 2002).

Results of DNA amplification of the 16 *Symbiodinium* samples showed bands at approximately 1600 bp (red arrow) as determined by the 1Kb Plus DNA Ladder (Fig. 1). Since the result of the gel electrophoresis showed multiple bands lower than 1600bp (green arrow), gel purification was performed.

Gel electrophoresis of the restriction digested *Symbiodinium* DNA along with the DNA ladder is shown in Fig. 2. Here, two bands were observed from the initial one band as a result of DNA fragmentation. All 16 digested samples showed similar patterns by having band sizes between 880/890 bp and 700 bp scored as *Symbiodinium* clade C. This clade type is consistent with that of *H. coerulea* sampled from the Great Barrier Reef (van Oppen et al., 2005) but not with the samples collected from Andaman Sea, Thailand which harbored *Symbiodinium* clade D (LaJeunesse et al., 2010) and in Enewetak Atoll in the West Pacific which hosted *Symbiodinium* clade A (Banaszak et al., 2000) respectively.

Zooxanthellate octocorals across different geographic regions mostly hosted single *Symbiodinium* clade (102 out of 117 or 87.2%) but the blue coral *H. coerulea* is an exception. Differences in *Symbiodinium* clades harbored by *H. coerulea* across different geographic locations could be a result of taxonomic or geographic differences that will aid in their survival in a wide range of environmental conditions such as elevated seawater temperature during *El Niño* phenomenon In 1982, 1998 and 2002, *El Niño* phenomenon resulted to coral bleaching in many coral reefs such as the Great Barrier Reef (GBR), Caribbean and the islands of Ryukyu in Japan and yet the density of octocorals having *Symbiodinium* clade C was still higher in GBR where the temperature is higher than in the Caribbean (Goulet et al., 2008 and Done et al., 2003).

In the islands of Ryukyu in Japan, extensive coral bleaching was recorded from late July to early October in 1998. Sea surface temperature in this area never exceeded 30°C but reached 35°C during the bleaching event. *Heliopora coerulea* is the most tolerant species in response to the elevated seawater temperature by maintaining almost constant cover before and after the bleaching. This is indicative that *H. coerulea* can withstand thermal stress when subjected to wide fluctuations in seawater temperature (Kayanne et al., 2002).

The result of this study showed that *H. coerulea* in the bodies of water surrounding Central Visayas has the potential to tolerate elevated seawater temperature since it was found to harbor the heat and stress-tolerant *Symbiodinium* clade C. Hence, *H. coerulea* could be included in the list of the coral species recommended for coral reef restoration efforts with a higher survival and success rate. With the degrading status of the Philippine coral reefs, there is an urgent need to make active efforts in coral reef restoration using coral species that can withstand stress caused by natural or anthropogenic activities.

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IMPACTS OF LOBSTERS SEA CAGE CULTURE IN THE SOUTH CENTRAL COAST (VIETNAM) ON THE WATER COLUMN AND THE SEDIMENT

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The lobster aquaculture industry in Vietnam has developed rapidly, especially in the South Central Coast, but spiny lobster aquaculture in sea cages have faced on challenges environmental pollution and break out diseases. This leads to decrease production and incomes of farmers. The paper represented the trend of water quality and sediment at lobster farming during the period from 2010 to 2014. The results showed that water parameters such as dissolved oxygen (DO), chemical oxygen dissolved (COD), ammonia (N-NH_4) and phosphate (P-PO_4) were ranging within acceptable limits of National coastal water quality Standard (QCVN 10:2008/BTNMT). However, total nitrogen (TN) in sediment and total phosphorus (TP) in sediment were nearly exceeded

permitted limit (TCVN 7373:2004 and TCVN 7374:2004)). The Risk quotient index RQtt (overall) values of lobster farming's waters in 2010 and 2012 ranged 0.84 to 1.08 > 0.75, harmful environment in risk, especially Xuan Phuong (Phu Yen) RQtt=1.08 >1 high of environmental harm. The aims of this report were to assess water quality and sediment at lobster farming and proposed sustainable aquaculture zones on further.

Keywords: aquaculture, spiny lobster sea cages, water quality, sediment, and organic contaminations.

Introduction

In Vietnam, sea cage culture of lobsters started in Khanh Hoa province in 1992 and has expanded significantly around the South Central provinces of Vietnam including Phu Yen, Binh Dinh, Ninh Thuan and Binh Thuan. As lobster aquaculture created employments and provided an important source of incomes for communities, the numbers of lobster sea cage increased sharply since 2000. This lead to disease occurred and polluted environment due to its trash fish. Common diseases occurred on lobsters like black gill, red body and milky disease. The "milky disease" appeared firstly in late 2006, lobster production has declined remarkably and continued to fall in following years.

This study reviews environmental quality at lobster sea cage areas in the south central of Vietnam during a period from 2010 to 2014.

Materials and methods

Data used in the report were the results of Ministry of Agriculture and Rural Development programme "Monitoring water quality in aquaculture areas along the South Central Coastline" from 2010 to 2014 (Du, 2010–2012; Thuy, 2013–2014) conducted by Research Institute for Aquaculture No.3.

Collecting samples: samples were collected in March, May, July and August from 2010 to 2014 in lobster sea cages in coastal areas of the South Central provinces, namely Khanh Hoa and Phu Yen. Samples were kept cool 5^0C and transported to the laboratory in order to measure.

Database: data were compared to permitted level of National coastal water quality Standard (QCVN 10:2008/BTNMT). In addition, The Risk Quotient index RQtt (RQ overall) used to assess the quality of the environment in each region was determined using the formula:

$$RQtt = \frac{1}{n} \times \sum_{i=1}^{n} (RQ)i \, \frac{1}{n} \times \sum_{i=1}^{n} (RQ)i$$

RQ is calculated by dividing the estimated environmental concentration by the reference value for toxicity (reference values were taken from the Vietnamese environmental standards).

The environmental quality was assessed through the levels of RQtt as follows:

a. If RQtt <0.25: very low risk of environmental harm
b. If 0.25 <RQtt <0.75: low risk of environmental harm
c. If 0.75 <RQtt <1.0: the risk of environmental harm
d. If RQtt> 1.0: high risk of environmental harm

Table 1. Sample sites locations using Latitude and Longitude Designations

Sample sites	Latitude	Longitude
Dam Mon, Khanh Hoa (KH1)	N 12^o 40.073’	E 109^o 24.239’
Xuan Tu, Khanh Hoa (KH2)	N 12^o 38.183’	E 109^o 12.884’
Xuan Phuong, Phu Yen (PY1)	N 13^o 27.219’	E 109^o 16.024’
Xuan Thanh, Phu Yen (PY2)	N 13^o 25.252’	E 109^o 13.935’

Results and discussion

Variations of environmental parameters

DO concentration. The results showed that dissolved oxygen levels in lobster sea cage areas in 2014 were the highest among other years. In year 2014, DO concentration in all stations were average from 5.50 to 7.14 mg/l, higher than limit level of National QCVN 10:2008/BTNMT (≥ 5 mg/l), while DO concentrations in during a period from 2010 to 2013 were lower or approximately permissible limit in Vietnam environmental standard QCVN 10:2008/BTNMT. In addition, there were no significant differences of DO levels between stations and collecting time in year.

COD concentrations in lobster aquaculture areas of Khanh Hoa and Phu Yen were ranged within acceptable limit of National coastal water quality standard (< 3 mg/l QCVN 10:2008/BTNMT). However, there was a steadily increase concentrations of COD in lobster’s sea cage areas over the study period. COD values in seawater in 2014 were 1.7 times higher than in 2011. A similar trend was found in shrimp farming’s water in Khanh Hoa (Du, 2011; Thuy, 2014), where concentrations of COD were more double between 2011 and 2014. COD level was used to indicate organic matter decomposition in the water. High nutrient concentrations in the water are related to disease, which occurs in lobster.

Ammonia concentration (N-NH_4). The monitoring results of water quality in lobster sea cage areas from 2010 to 2014 showed that most of N-NH_4 levels were lower than the National coastal water quality Standard (< 0.1 mg/l QCVN 10:2008/BTNMT).

Phosphate (P-PO_4). There was a slightly increase the concentrations of phosphate in Khanh Hoa and Phu Yen from 2010 to 2014. P-PO_4 concentrations in 2012 ranged from 0.078 to 0.125 mg/l, nearly exceeded permitted level in dry season (March and May). In Khanh Hoa, the concentrations of P-PO_4 in lobster seacages increased significantly between 2011 and 2012, these figures were 0.067 mg/l and 0.085 mg/l, respectively, was 1.7 times and 2.0 times higher than in 2010. A similar pattern was found in Phu Yen, where P-PO_4 concentration was 0.049 mg/l in 2010, increased doubled in 2012 and 1.5 times in 2014.

Total Nitrogen (TN) in sediment. There was a slightly increase total nitrogen in sediment in lobster sea cage areas over the study period. The total nitrogen (%N) in sediment in lobster sea cage of Phu Yen during 5 years from 2010 to 2014 ranged from 0.099 to 0.195 %N in sediment, exceeded permitted level (TN 0.0 – 0.12%N TCVN 7373:2004), while these values in Khanh Hoa were lower and nearly acceptable limits of National standard, the same results with San (2014). In addition, total nitrogen in sediment in Phu Yen was double higher than in Khanh Hoa.

Total Phosphorus (TP) in sediment. The total phosphorus (TP) in sediment in lobster sea cage areas increased sharply during the period, the %P_2O_5 in sediment in 2012 was 3 times higher than in 2010. In 2013 average concentrations of total phosphorus in sediment in Khanh Hoa and Phu Yen were 0.059 and 0.073%P_2O_5, respectively, exceeded permitted level (TP 0.03 – 0.05%P_2O_5 TCVN 7374:2004), however these numbers fell down under permitted limit in 2014, except for in Xuan Phuong (Phu Yen). The results demonstrated polluted sediment in lobster aquaculture areas would affect water quality and cause disease outbreak as other environmental factors change.

The Risk Quotient (RQ)

The Risk Quotient (RQ) assessed the level of environmental quality in coastal areas where lobster sea cages take place, was based on the Vietnamese environmental standards (QCVN10: 2008/BTNMT). The RQtt values in 2012 ranged from 0.84 to 0.95, environment was risk, and in similarly, in 2010 RQtt of all study stations were from 0.88 to 1.08, especially Xuan Phuong (Phu Yen) 1.08 environment was high risk. There were no significantly differences RQtt values among lobster aquaculture areas in Khanh Hoa and Phu Yen.

Conclusion

DO concentrations in 2014 were the highest levels among other years. The concentrations of DO in 2014 ranged from 5.50–7.14 mg/l, while these numbers in 2010 were average from 3.28 to 4.48 mg/l, lower than Vietnam' water quality standard.

The concentrations of COD and N-NH_4 in seawater in Khanh Hoa and Phu

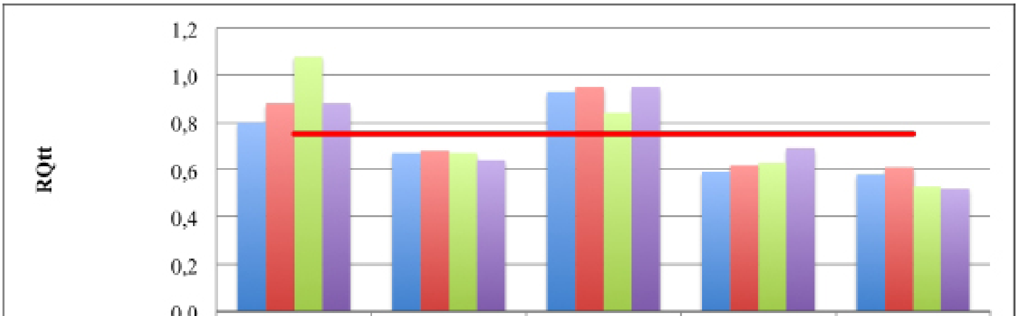
Yen' lobster aquaculture areas were ranged within acceptable limit of National coastal water quality standard.

The concentrations of phosphate in Khanh Hoa and Phu Yen increased slightly from 2010 to 2014. P-PO_4 concentrations in 2012 were nearly permitted level in dry season (March and May) in stations.

During study period, total Nitrogen in sediments in lobster aquaculture in Phu Yen were high and exceeded permitted limit, while these values in Khanh Hoa's lobster sea cage areas were lower than acceptable limit of National standard.

Total phosphorus in sediments increased sharply over 5 years in all stations, in 2013 total phosphorus in stations were exceeded permitted level.

The Risk Quotient overall (RQtt) values at lobster sea cage areas in Khanh Hoa and Phu Yen in 2010 and 2012 were higher 0.75 that means harmful environment was risk; especially Xuan Phuong (Phu Yen) was high risk of environmental harm.



	2010	2011	2012	2013	2014
Dam Mon	0,8	0,67	0,93	0,59	0,58
Xuan Tu	0,88	0,68	0,95	0,62	0,61
Xuan Phuong	1,08	0,67	0,84	0,63	0,53
Xuan Thanh	0,88	0,64	0,95	0,69	0,52
Safe level	0,75	0,75	0,75	0,75	0,75

Fig. 1. Application of the risk quotient at lobster seacage areas a period from 2010–2014.

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Vietnamese National standards: National coastal water quality standard QCVN 10:2008/BTNMT; Total phosphorus in sediment TCVN 7374:2004; Total Nitrogen in sediment TCVN 7373:2004.

HISTORICAL CHANGES IN THE MARINE FLORA OF NHA TRANG BAY BETWEEN 1953 AND 2010

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The first complete checklist of the intertidal and subtidal marine algae (Rhodophyta, Ochrophyta and Chlorophyta) in Nha Trang Bay (Vietnam) was presented earlier (Titlyanov et al., 2015). In this paper, a brief history of the species records in the bay between 1953 and 2010 is documented.

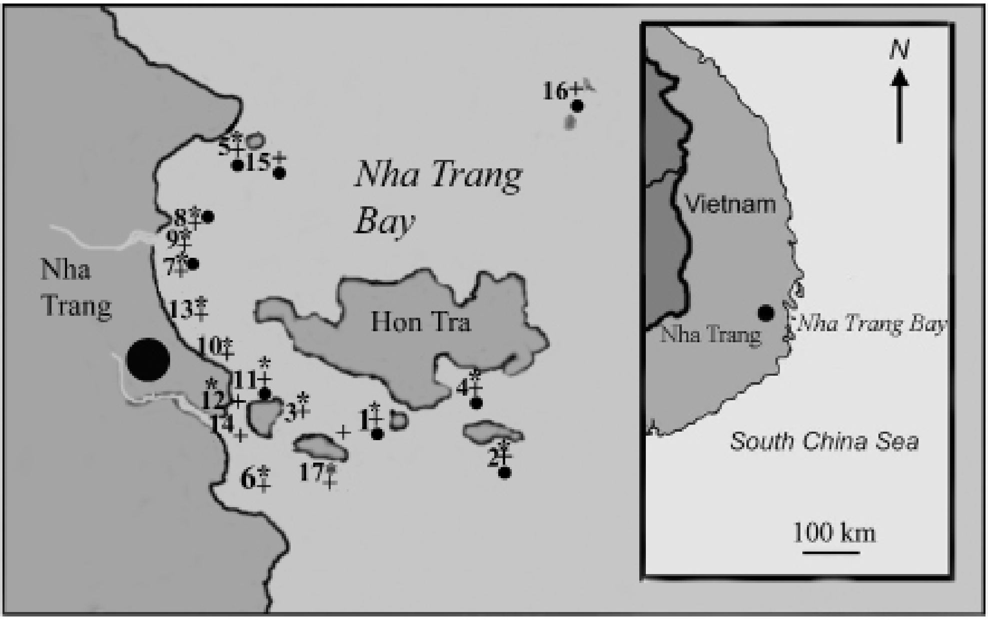

Fig. 1. Schematic map of Nha Trang Bay showing the sites where algae were collected at different periods between 1953 and 2010. 1 – Mot Island, 2 – Mun Island, 3 – Mieu Island, 4 – Tre Island, 5 – Bai Tien, 6 – Diamond Bay, 7 –Xom Con, 8 – Chong Islet, 9 – Cai River Estuary, 10 – Xom Bau, 11 – opposite the Institute of Oceanography, 12 – Bao Dai, 13 – Nha Trang Beach, 14 – Cua Be River Estuary, 15 – Turtle Islet, 16 – Swallow's Island, 17 – Tam Island. Symbols: +, Collection A; •, Collection B; *, Collection D.

Results and Discussion

Samplings. The marine flora in Nha Trang Bay was studied by different research groups from 1953 to 2010 (Fig. 1). The first sampling has been made by E.Y. Dawson in February–March 1953 (Sampling 1)**.** A total of 219 species and taxonomic forms of marine algae were collected. During the period 1958–1969, algal samplings were performed mainly by Pham Hoang Ho. A total of 222 species and taxonomic forms of marine algae were found in this period (Sampling 2). In 1982–1987 algal samplings were performed by T.V. Titlyanova, Ngyuen Huu Dinh, A.A. Kalugina-Gutnik and E.A. Titlyanov during the Soviet-Vietnam expeditions. A total of 223 species and taxonomic forms of marine algae were documented (Sampling 3). Within the period from the 1980s to 1990s, the marine flora was studied mainly by Vietnamese phycologists from the Institute of Oceanography, Vietnamese Academy of Sciences: Nguyen Huu Dinh, Nguyen Huu Dai, Huynh Quang Nang, Pham Huu Tri and Le Nguyen Hau (Sampling 4). In April 1999, marine algae in Nha Trang Bay were collected (within 5 days) and identified by an international team during the 8th Sea Grant Workshop (Sampling 5). A total (Samplings 4 and 5) of 203 species were collected and identified during this time. From January to July 2002 and in

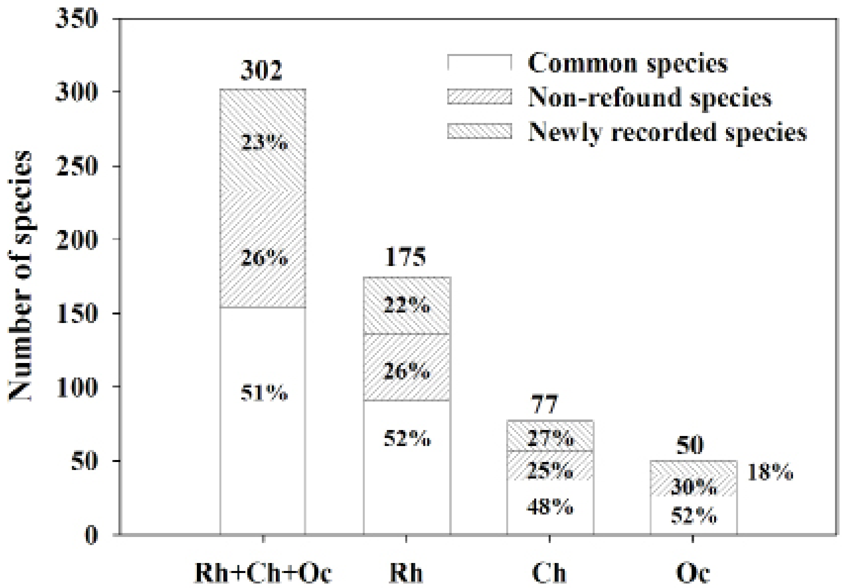

Fig. 2. Total number and taxonomic composition of algal species recorded in Nha Trang Bay in Collections A and B, with percentages of species common to both collections or found only in Collection A (Non re-found species) or only in Collection B (Newly recorded species). Rh, Rhodophyta; Ch, Chlorophyta; Oc, Ochrophyta.

March 2004, Isao Tsutsui, Huynh Quang Nang, Nguyen Huu Dinh studied the marine flora in Nha Trang Bay (Sampling 6, Tsutsui et al. 2005). In parallel, from 2002 to 2010, E.A. Titlyanov, T.V. Titlyanova, O.S. Belous and Pham Van Huyen investigated the marine benthic flora in Nha Trang Bay. In total, 327 taxa were found in the bay from 2002 to 2010 (Sampling 7).

Collections. World practice comparing the diversity and species composition of two or more algal collections in order to clarify the historical (decadal) changes in the marine flora suggests the observance of the following four basic rules (conditions) for making such comparisons (Titlyanova et al., 2014): (1) Collections of algae should be sampled at equal annual or decadal intervals and certainly in all seasons. (2) Algal sampling sites should be the same according to the geographic as well as zonal features. (3) Study of species diversity of the marine flora should be the aim of algal samplings. (4) Algal collections for comparative study should be sampled using the same methods.

In accordance with these terms and conditions, we had the right to compare collections among their taxonomic forms (samplings1, 2, 3,6 and 7) to detect decadal changes in the flora of Nha Trang Bay. Samplings 4 and 5 could not be compared with the other samplings, because it did not satisfy the conditions of the first and third items of above mentioned rules.

To study the historical changes in the marine flora of Nha Trang Bay compared algal collections as follows: collection A (CA, 1953–1959) consisting of sampling 1 and sampling 2; collection B (CB, 1982–1987) consisting of sampling 3; collection C (CC, 1953–1987) consisting of samplings 1, 2 and 3; collection D (CD, 2002–2010) consisting of samplings 6 and 7.

Algal species diversity and taxonomic composition

During the period from 1953 to 2010, totally 481 species of macrophytes and their taxonomic forms were collected in Nha Trang Bay. These consisted of 57% red, 25% green and16% brown algae. The high diversity of the marine flora in Nha Trang Bay is close to that of tropical-subtropical regions such as Hainan Island (South China Sea) with 500 species of macrophytes and Taiwan Island (East China Sea) with more than 450 species of macrophytes (Titlyanova et al., 2014).

Historical changes in the marine flora of Nha Trang Bay between 1953 and 2010

Changes between the 1953–1959 (CA) and 1982–1987 (CB). In total, 302 taxa were documented for CA and CB of which 51% were common to both collections, 23% were recorded only in 1982–1987 (new records) and 26% were not found in 1982–1987 (lost species) (Fig. 2). During this period, changes in species composition occurred in 83% of Rhodophyta families, in 81% of Chlorophyta families and in ~50% of Ochrophyta families. The largest relative number of newly recorded taxa was among green algae (27% of macroalgae from total number of the both collections A and B). The largest percentage of lost species was for brown algae (30%). Thus, the comparison of collections sampled in the 1950s–1960s with those in 1982–1987 did not show substantial differences in either species diversity or relative number of red, brown and green algae, but changes in species composition were detected in the majority of families (more than 50% of all families). The question arises, what are the reasons for such changes? We suppose that the differences found in species composition in the majority of families in these collections probably resulted from periodic (seasonal, annual, perennial) changes in algal population densities.

Comparison of taxonomic diversity and composition of species in collections CC (1953–1987) and CD (2002–2010).

The comparison of species diversity and relative floristic composition of the marine flora in Nha Trang Bay between collections C and D showed substantial decadal (20–30 years) changes (Fig. 3): 1) Changes in species diversity in most families of red, brown and green algae; 2) An increase in species diversity of CD, mainly due to the appearance in the flora of green algae belonging to the

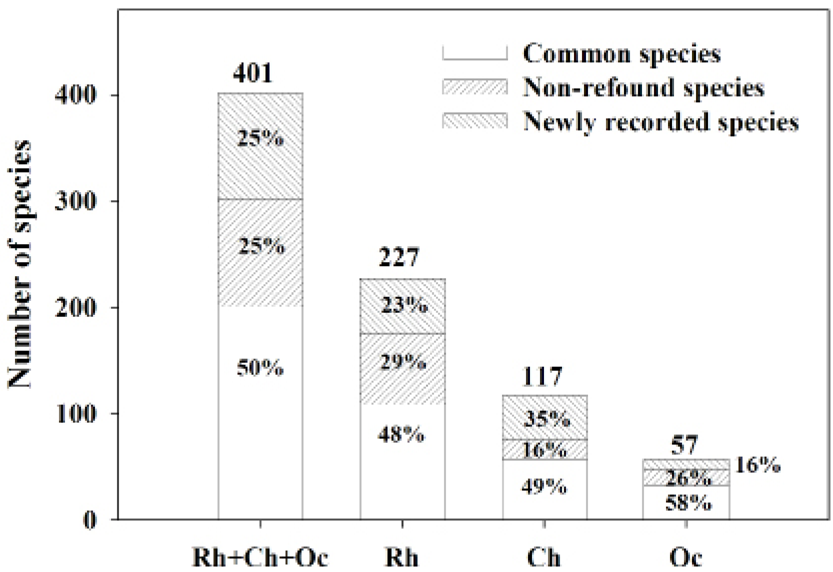

Fig. 3. Total number and taxonomic composition of algal species recorded in Nha Trang Bay in Collections C (1953–1987) and D (2002–2010), with percentages of species common to both collections C and D or found only in collection C (lost species) or only in CD (newly recorded species). Rh, Rhodophyta; Ch, Chlorophyta; Oc, Ochrophyta.

families Caulerpaceae, Ulvaceae and Cladophoraceae, and red algae belonging to the families Rhodomelaceae and Gracilariaceae. Many species found for the first time in Nha Trang Bay had fine filamentous, branched or membranous thalli with a high surface-to-volume ratio and high productivity; 3) The largest number of lost species (i.e. not found again) in the period from 2002 to 2010 belonged to red algae from the Rhodomelaceae and Corallinaceae and brown algae from the Sargassaceae and Dictyotaceae. The majority of lost species were epilithic algae with fleshy, foliose, leathery or calcareous articulated thalli having a low surface-to-volume ratio and low productivity.

An increase in the absolute and relative numbers of species of green algae and a reduction in the numbers of red and brown algae in the collection D may be an indication of seawater pollution by dissolved organic and inorganic compounds of nitrogen and phosphorus between 1987 and 2002. The larger number of green algae in the collection D was due to an increase in frequency of the occurrence of individuals from families such as the Caulerpaceae, Ulvaceae and Cladophoraceae, which are the first to respond to pollution (and known to be sewage indicators) by an increase in biomass and population density.

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DECADAL CHANGES IN THE ALGAL ASSEMBLAGES OF YONAGUNI ISLAND (JAPAN)

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There has been an increasing body of literature indicating long-term changes in shallow-water algal assemblages in different regions of the world, which point to the influence of anthropogenic factors such as pollution of seawater and destruction of coastal environments on the diversity, composition and production of marine algae (Titlyanova et al., 2014). In the present study, we aim to show

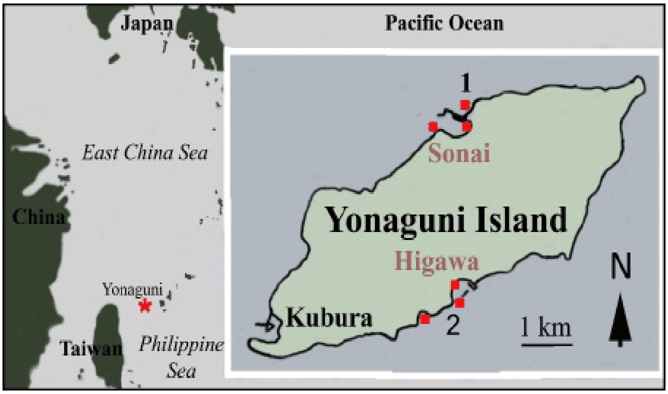

Fig. 1. Collection sites on Yonaguni Island (Japan).

long-term changes in the algal assemblages of the Yonaguni Island in the tropical/subtropical Western-Pacific, which have been relatively free from apparent anthropogenic influences.

Study area

Yonaguni Island (24°27'N, 122°57'E) is located at the tropical northern periphery of the Indo-Pacific Ocean between the East China Sea and the Philippine Sea (Fig. 1). Yonaguni Island is one of the Yaeyama Islands and the last southwest island in the Ryukyu Archipelago chain (Okinawa Prefecture, Japan). The Island of Yonaguni lies 127 km from Taiwan and has an area of 28.88 km^2 and 27.5 km coastline and a population of around 1700. Island is strongly influenced by the Kuroshio Current (North Equatorial Pacific Current).

Between 1935 and 2013 three expeditions were undertaken to investigate the marine flora of Yonaguni. The first collection was performed by Yukio

Fig. 2. Sonai (24°28'25"N; 123°0'13"E), lagoon of coral reef.

Yamada and Takeshi Tanaka in the spring of 1935 at three localities: Sonai, Pinai (Higawa) and Kubura (Yamada and Tanaka, 1938), the second additional sampling was performed in October–November 1959 by Takeshi Tanaka and Hiroshi Itono at seven localities (Tanaka, Itono, 1972). A third collection was performed in March 2013 by Eduard Titlyanov and Tamara Titlyanova at two localities: Sonai (on the north coast of the island, Fig. 2) and Higawa (on the south coast, Fig. 3).

The main aim of our study was to compare the records of shallow-water algal assemblages using sets of comprehensive survey data taken 78 years apart and to highlight the changes in flora with reference to global and local environmental changes.

Results

Two surveys (1935 and 2013) resulted in a total record of 207 taxa of Rhodophyta, Phaeophyceae, Chlorophyta being identified from the intertidal and upper subtidal zones of two localities (Sonai and Higawa) in Yonaguni Island. The algal collection of 1935 comprised 102 species (Yamada and Tanaka, 1938), while the collection of 2013 comprised 172 species. In the 1935 collection, 56% of all taxa were Rhodophyta, 8% Phaeophyceae and 36% Chlorophyta; in the 2013 collection, 55% were Rhodophyta, 11% were Phaeophyceae and 34% were Chlorophyta.

Fig. 3. Higawa (24°26’21”N, 122°59’1”E), lagoon of coral reef.

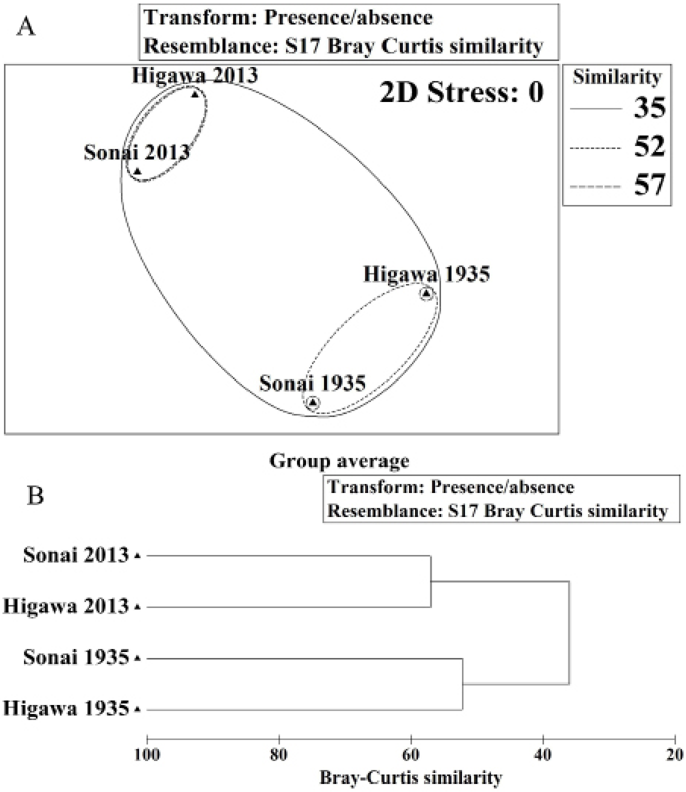

Fig. 4. Patterns of (A) floristic similarity and (B) clustering in non-metric multidimensional scaling ordination (n-MDS) of Sonai and Higawa (Yunaguni Island) samples collected in 1935 and 2013.

Floristic similarity of four assemblages, Sonai 1935, Sonai 2013, Higawa 1935 and Higawa 2013, is shown in a two-dimensional n-MDS plot. The overlay of the MDS plot with the cluster dendrogram similarity lines indicates the respective maximum boundary values for distinct clusters (Fig. 4). The overall similarity of all assemblages (across locality and time) was 35%, while within each of 1935 and 2013 assemblages maximal similarity was >50%, clearly indicating that the temporal variation was larger than the spatial one.

A total of 50% species were newly recorded in 2013, while 33% were common to both 1935 and 2013 collections and 17% occurred only in 1935. Among Rhodophyta newly found in 2013, the Family Rhodomelaceae included 16 species, Coralinaceae 13 species and Ceramiaceae 8 species. Chlorophyta newly found in 2013 included Cladophoraceae (7 species) and Ulvaceae (4 species). Species from the families Acrochaetiaceae, Gelidiaceae, Hapalidiaceae, Cystocloniaceae, Callithamniaceae, Spyridiaceae, (Rh); Acinetosporaceae, Neoralfsiaceae (Ph) and Gomontiaceae, Ulvellaceae, Ostreobiaceae, Polyphysaceae (Ch) were recorded for the first time in the 2013 collection.

Compared with the 1935 collection, major losses in 2013 concern families of red algae: Liagoraceae (50% of species), Rhodomelaceae (25%), Galaxauraceae (33%) and Wrangeliaceae (25%). Among green algae, 42% of Caulerpaceae species and 33% of Boodleaceae recorded in 1935 were not found in 2013.

In terms of habitat preferences, species inhabiting hard substrata accounted for 81% of all species in 1935 and 70% in 2013, while epiphytic algae comprised 15% and 27%, respectively.

In the two collections, species inhabiting tropical and subtropical waters of the world were predominant (49%), followed by those inhabiting tropics and subtropics of the Indo-Pacific (28%). The proportion of tropical species dropped from 93% in 1935 to 80% in 2013, and that of cosmopolitan species (species inhabiting tropical to temperate and Arctic/Antarctic zones) increased from 7 to 20%.

Discussion

The present study confirms that the floristic characteristics of the island Yonaguni are close to those of undisturbed, clear-water coral reefs in the Indo-Pacific where algal assemblages consist of 50–60% Rhodophyta, 20–30% Chlorophyta and 10–20% Phaeophyceae with a R: P index > 4.0 (Titlyanova et al., 2014). Diversity and taxonomic composition clearly varied and the following changes were noted from 1935 to 2013: (1) increase in total species richness; (2) decline in R: P values (i.e. the ratio of red vs brown algal species); (3) appearance/loss of species, but with no noticeable increase of eutrophication-indicating species. Species found in both 1935 and 2013 amounted only to 33% of all recorded species. Addition of new algal species in 2013 concerned Rhodophyta families such as Rhodomelaceae, Corallinaceae and Ceramiaceae, and Chlorophyta families such as Cladophoraceae and Ulvaceae, while losses concerned Liagoraceae, Rhodomelaceae, Galaxauraceae (Rhodophyta), Caulerpaceae and Boodleaceae (Chlorophyta). In addition, epiphytic, opportunistic and cosmopolitan taxa expanded the floristic list of 2013. Analysis involving the multidimensional scaling ordination of similarity values clearly indicated large temporal variation in algal assemblages, which was considered to be associated with natural catastrophes, in particular the coral bleaching event of 1998.

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CENTURIAL, DECADAL ECOLOGICAL AND ENVIRONMENTAL EVOLUTIONS OF HA TIEN CITY AND DONG HO LAGOON

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Since ancient times, the coastal areas around Ha Tien have played a central role in the development of trade and urban settlements in Southeast Asia. Due to colonialism and the wars of the 20th century, textual records such as government documents do not provide a continuous picture of the rapid acceleration in the space of shoreline modification. Neither do they provide a comprehensive view on the impacts of these social processes on natural forces as flooding, sedimentation, storms and erosion. Recently opened collections of soil cores, historic aerial photography, combined with modern satellite imagery and geographic information system (GIS) tools can help fill these gaps. This paper integrates above mention documents to present a more complete historical view of Ha Tien city from the previous centuries to present time.

Keywords: Ha Tien city, Dong Ho lagoon, centurial and decadal environmental changes, soil core sections**,** multiple satellite imageries.

Introduction

One of the challenges, especially for Vietnam, has been managing the long international border with Cambodia that stretches a few hundred kilometers across the Dong Thap and Long Xuyen flood plains. Every year tens of thousands of fishermen, merchants, Theravada Buddhists, Vietnamese, Cambodians as well as Chinese ethnics make pilgrimages to see family in both directions. The permeable nature of this invisible border and the ties that bind people across it have plagued governments intent on controlling smugglers and other who cross it (David, 2010).

By the 1750s, newer Chinese and Vietnamese villages were established close to older, Khmer centers. The delta in the eighteenth and nineteenth centuries remained a violently contested frontier settled by Vietnamese migrants, Chinese émigrés, Khmer inhabitants, and all manner of rebels. In the 1700s, leaders of Ming royalist (Minh Hương) groups received concessions from the Vietnamese and Cambodian kingdoms to operate these ports as semi-independent city states IN Mekong delta. Ha Tien is one of this ancient port

In 1818, the Vietnamese King Gia Long made the first effort to fix this border in the landscape with a massive border canal project. He ordered General

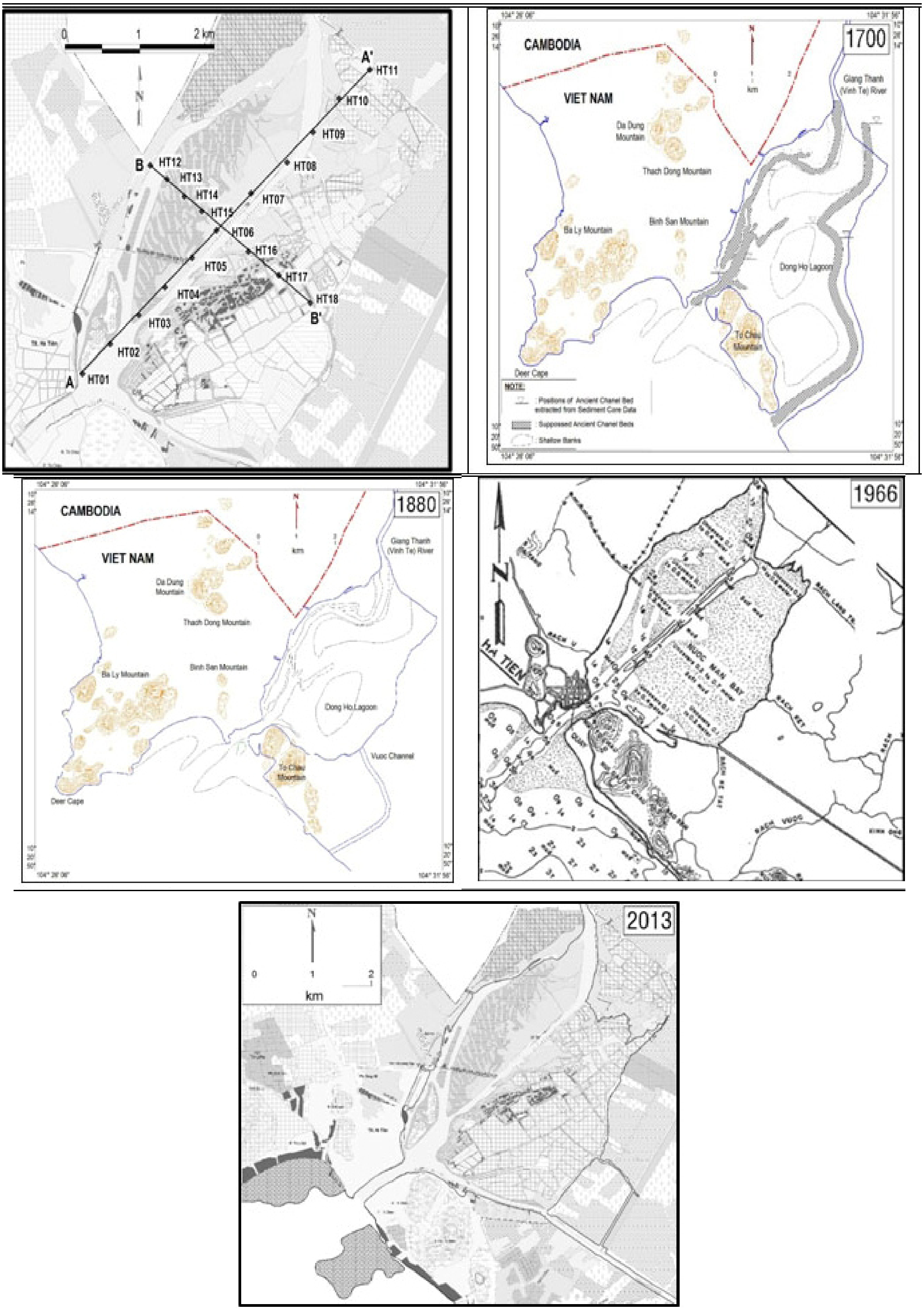

Fig. 1. The historical morphological changes of Dong Ho lagoon in difference centuries base on soil core data in combination with ancient documents.

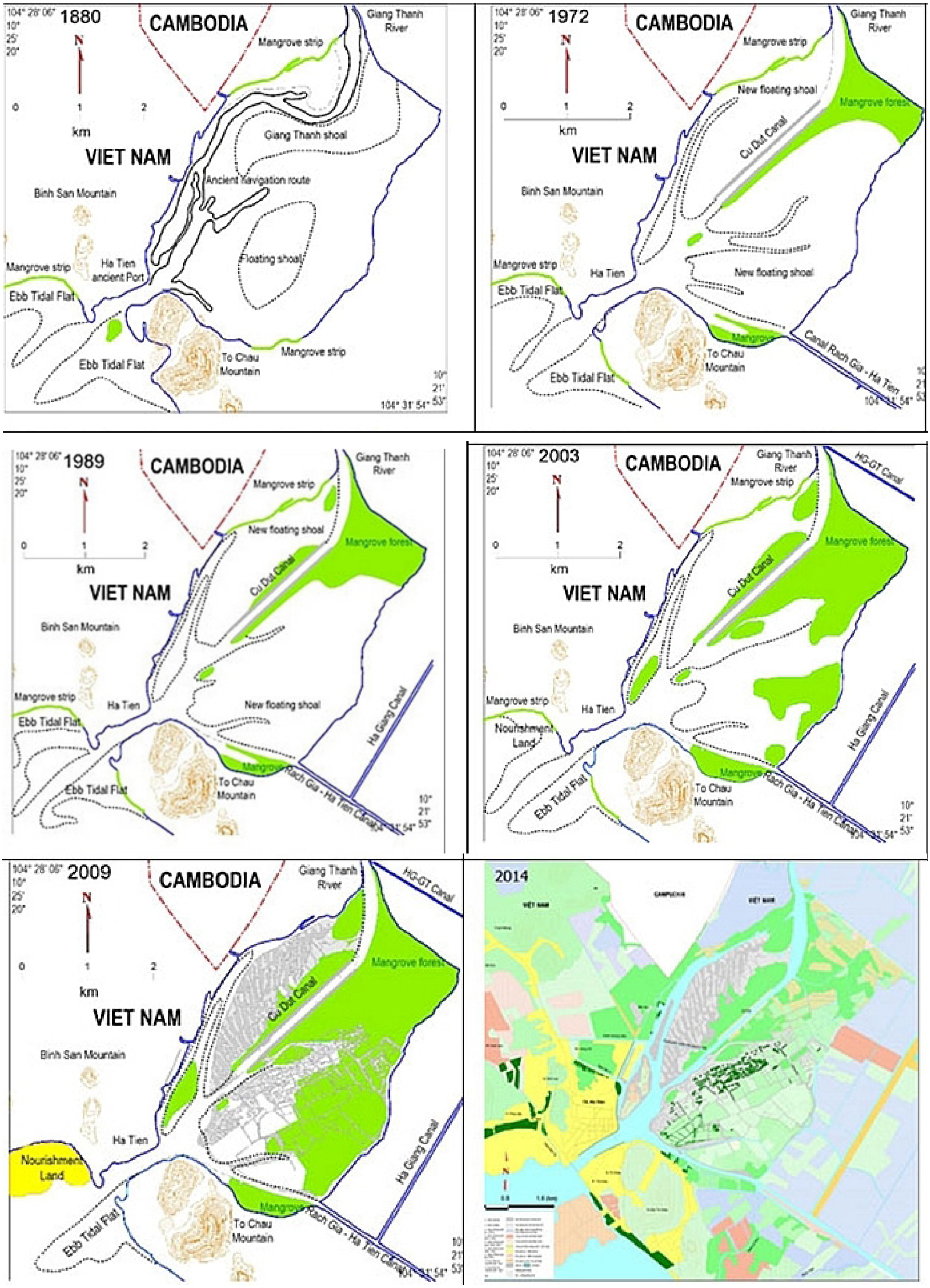

Fig. 2. The decadal land-use changes in Ha Tien town and Dong Ho lagoon (from 1880 – 2014)

Nguyen Van Thoai to build a canal connecting the Hau Giang River with the Gulf of Siam in Ha Tien mouth to move Nguyen forces quickly to the gulf coast if needed and seal the border from potential Siamese incursions.

From the beginning, as a hydraulic and defensive work, the Vinh Te Canal was troubled. Le Van Khoi, the adopted son of the southern Viceroy Le Van Duyet, started a secessionist rebellion in 1832 and invited Siamese forces to help him fight the Nguyen. Siamese naval ships entered Vinh Te Canal from the Gulf and quickly built camps along the Vinh Te Canal. They overtook Vietnamese forces garrisoned at Phnom Penh and much of the western delta region until 1845 (Son Nam, 1988; David, 2010).

Not long after the Siamese left, the French arrived with steam-powered, ironclad gunboats. Their first attacks in the delta commenced in 1860 with major naval battles in the eastern delta in 1862 (Biggs, 2010). By 1868, the western region around Vinh Te Canal had turned into a dangerous harbor for groups organizing raids on French outposts, some led by veterans of the Nguyen Army. (Edwards, 2006; Biggs, 2011).

Since 1867, the Vĩnh Tế Canal had formed part of French Cochinchina's border with Cambodia. In October 1879, a French gunboat Hache entered a deteriorated canal on a survey mission to chart a waterway that once linked river traffic on the Mekong to sea traffic in the Gulf of Siam. Naval hydrographer Jacques Rénaud used soil core drills, depth gauges, and other instruments to measure water flow and bottom features along the seventy-kilometer path of the Vĩnh Tế Canal (Renauld, 1879). He surveyed more detail the canal and made a strong case for dredging it to bring that region of the delta back economically to the region trading center it had been in the late 1700s. According Rénaud 's descriptions (1879), morphology of Dong Ho lagoon at that time, can raise an assumption that in Mac Cuu period (18th century), there was a new renovated canal close to the bank (to replace the channel in mid of lagoon) with purposes, creating a new flow close to the bank to allow small boats of residents from Mang Kham village (in Giang Thanh river banks), from the villages in Bassac and the Cambodia habitants visit Ha Tien port to change the consumable goods. This thing makes siltation in mid of lagoon and formed Giang Thanh and floating Shoals.

Fighting from 1945 to 1954 produced many conflicts on the border as not only the Viet Minh and the French forces clashed, but also over a million followers of a millenarian Buddhist political-religious group, Hoa Hao, organized their zones of control in the border area.

Nicholas Sellers, an American army captain serving in Ha Tien in 1967–1968, notes in the introduction of his historical work the frustration he found in patrolling this porous area sellers (1983). The Vinh Te Canal by 1968 had become another important crossing for land-based and water-based transport of goods through Ha Tien port.

After the American war ended in 1975, violent incidents soon erupted

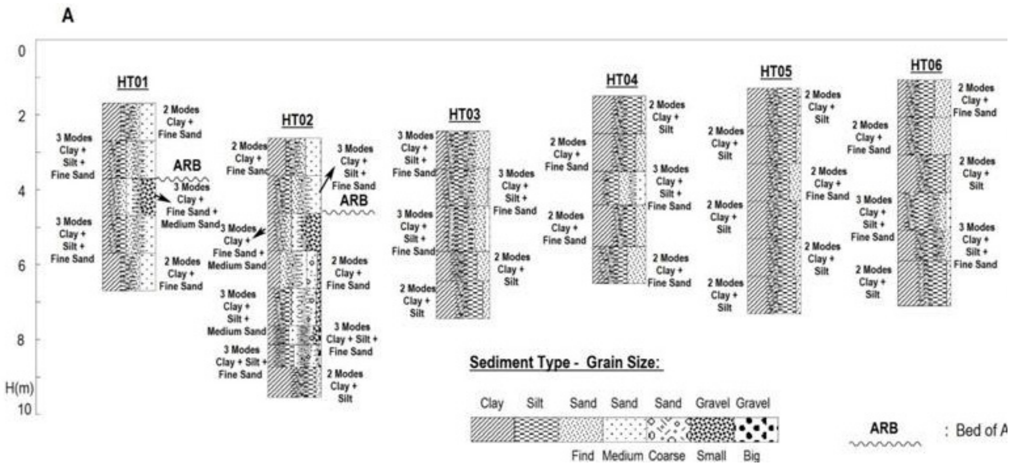

Fig. 3. The linkage of sediment cores according to along direction of Dong Ho lagoon (section A-A’)

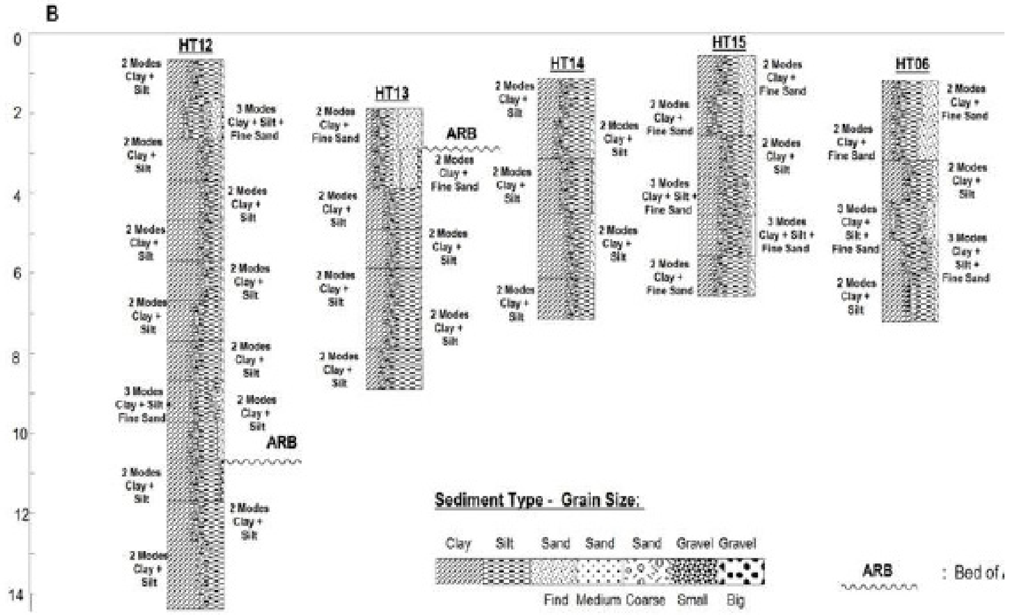

Fig. 4. The linkage of sediment cores according to cross direction of Dong Ho lagoon (section B-B’)

again on the Vinh Te Canal. The Khmer Rouge force in 1977 massacred over 3000 ethnic Vietnamese villagers at Ba Chuc living several kilometers from the canal. That occupation lasted until 1989 with the Paris Agreements commencing in September and concluding in October 1991 (Biggs, 2011).

With sustained peace after 1989 and Vietnam’economic resurgence after the “doi moi” reforms set in 1986, work re-dredging Vinh Te Canal commenced in 1998 as part of the national governments region-wide plan to improve irrigation, transport, and agriculture in the delta.

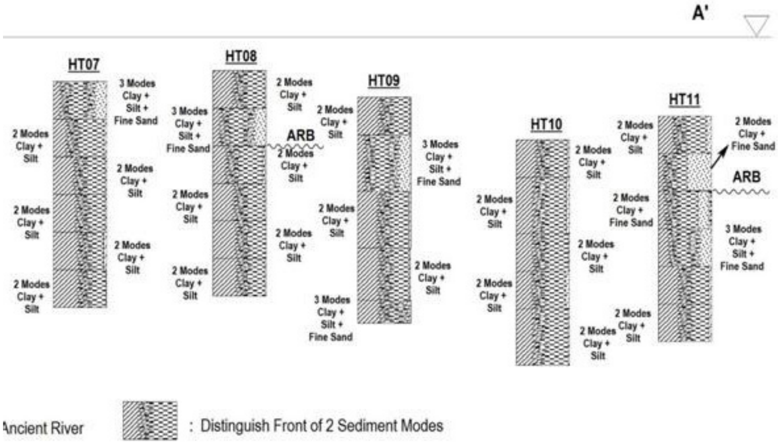

Fig. 3. Cont.

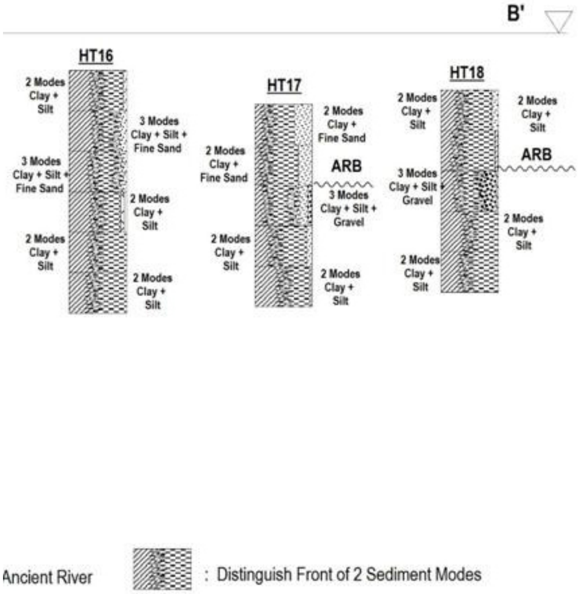

Fig. 4. Cont.

With the roadwork and renewed attention on the border in peacetime. The Southern Institute of Social Sciences and Humanities convened at conference on Vinh Te in 1999 that drew some press attention. Reports and new articles on this gathering of eminent national historians highlighted the canal's important role in nineteenth century for protecting the border.

The conservation of Dong Ho lagoon and Ha Tien town is one of several important objectives that the Kien Giang provincial People's Committee will implement in the following years, in an aim to enhance economic development and deal with climate change. An international seminar held in Ha Tien town at

October 2011 for conservation and sustainable developing of Dong Ho lagoon and Ha Tien city as (Nguyen and Truong, 2011). Scientific activities were carried out to follow of this conference.

In this paper, I try to find new information on centurial, decadal ecological and environmental changes of Ha Tien from synthesizable data.

Data and methodology

Studied area

Ha Tien is a city located in the extreme southwest of Vietnam, which was chosen for this study. Together Dong Ho lagoon and Ha Tien have played a central role in the development of trade and urban settlements in Southeast Asia in 16th – 17th centuries. Their location lies in coordinates from 104°28' – 104°32' E and from 10°20' – 10°25' N.

Used data

The ancient documents:

A series of archived documents (such as Renauld'map 1880, Johnson and Mendenhall's bathymetry map 1966, CORONA aerial photograph 1972, and more than 30 of satelite images of Landsat MSS, TM, ETM+, Landsat OLI (1976 – 2014) for analyzing the environmental evolution of Ha Tien and surrounding areas.

The soil core data

Eighteen (18) soil cores was taken along and cross of Dong Ho lagoon for construction the evolution of ancient Ha Tien (Fig. 1).

Result and discussion

Base on the consideration of 18 sediment cores run along (HT01 ÷ HT11) and cross (HT12 ÷ HT18) (Fig. 1), we found out the signals of the beds of ancient rivers during Mac Cuu period (about 300 years ago). The signal of the bed of ancient rivers existed in cores HT01, HT02, HT08, HT11 (according to along direction in Fig. 3) as well as HT13, HT17, HT18 (according to cross direction in Fig. 4) and lie in depth about 3–3.5m, where exist the layers of coarse size sediment component (size diameter is more than 0.25mm). The linkage of positions where exist of the bed of ancient rivers allow us reconstruction the ancient rivers (channels) in both western and eastern edges of Dong Ho lagoon (Fig. 1). These channels lie under 2.0–2.5m deep and cover on modern sediment layer as in present time. This result also suggests to us an assumption on the existence of the second mouth in Vuoc channel in the past time. More clearly, Dong Ho lagoon during Mac Cuu's period was wider and wider, more open and lead to more saline than today. The question on older name of Dong Ho lagoon that call be "the saline lagoon" as in the archived 1966 map is resolved. The asymmetry property on size of the banks also is explained.

By mean of using the geo data series of Renauld's ancient map, aerial photograph (CORONA image – NASA), satellite images, we also determined in more detail decadal land use changes of Ha Tien town, Dong Ho lagoon and surrounding areas (Fig. 2). These changes occurred in consequent periods.

In the 19th century, the main stream channel at the ancient Ha Tien port pressed close to the western bank of Dong Ho lagoon. Based on geomorphology of lagoon at that time, can raise the hypothesis that during Mac Cuu period (18th century), there was a dredging canal close to the bank (to replace the channel located in mid of lagoon), creating a new navigation route close to the bank. This new navigation route allows small boats of residents from Mang Kham village (on the western bank of Giang Thanh river), from the villages of Bassac river and the residents from Cambodia visit Ha Tien ancient trading port, to change the goods. This created two shallow banks – Giang Thanh and the floating shoals.

Period before 1970. After the survey along Vinh Te Canal during 1879, Renauld has proposed a dredging project the Ha Tien port, but not until over 10 years later, this project have been accepted by the French colonial government at that time. The activities of this project created the new canal – levee system in Cu Dut. Giang Thanh river had been corrected back to response the trade requirements at that time (specially for the marine trade with Thailand). The dredging and construction of Cu Dut levee – canal system, created a new shape of lagoon with two eastern and western shoals, just look like two lobes of a leaf. The local settlements in Cu Dut village just were created after the dredging project and improvement of Ha Tien port, but not formed from Mac Cuu's period in 18 century. Channel Rach Gia – Ha Tien which was built in 1930, is also became a new feature in the 1970 period. Mangrove forests in the northeast of the lagoon are mainly mangrove the forests of Nipa. They grow with thick density with an area of about 140 ha.

After twenty years, the period in 1990, almost the lagoon's shape changed strong, some main changes of this period, those are: a) The formation of Ha Giang canal and canal system connecting channels and international channels Rach Gia Vinh – Ha Tien. This canal system was built in as a part of drainage program of the West Sea by former Prime Minister Vo Van Kiet; b) The mangrove forest patches of Nipa was extended strongly in the northeast side with a total area of approximately 180 ha; c) The western culture Nipa patches in the western side of Cu Dut levee begins to form.

During period of 2000 years, the environmental evolution progressed as follows: a) Nipa forests in northeast continues to expand with an area up to 240 ha; b) Nipa forests in western side of Cu Dut levee started finishing expanded up to a total area of 56 hectares and increasingly tends to shelter and restrict the influence of tidal flow toward the sea and c) During this period, levee – canal system connecting the channel Ha Giang and Giang Thanh river is formed. They served well for aquaculture operations, and waterway traffic in this area.

From 2010 to present, a series of new changes continue to occur, such as: a) Formation of the nourishment land toward the sea, in front of the Tran Hau mouth, including the new Northwest urban region (finished 2004), and another in South east side (just has been finished in 2014). b) The aquaculture system including intensive, semi-intensive and extensive shrimp ponds developed strongly in this period, even a spontaneous tendency of local people in To Chau ward. They grow mangrove forest (mainly, Rhizophora) in the zigzag form. Because of the falling leaves and assimilating a lot of biomass material in the area, only after several years, progressively solid ground, shielding and creating embankments forming pattern of extensive forest shrimp ponds, achieve high yields.

Conclusion

Using of analyzing of synthesizable data of ancient documents, aerial photographs, satellite imageries and soil core datasets the historical ecological and environmental changes of Ha Tien town and Dong Ho lagoon from the past to present time were confirmed more clearly.

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MARICULTURE OF HOLOTHURIANS AND SEA URCHINS - NEW TRENDS

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The representatives only of two classes of Echinoderms are the delicacies for the gourmets – sea urchins and holothurians. Vietnam seashores are the places of the especial biodiversity of these animals. According to the literature in the coastal waters of Vietnam lives 45 species of sea urchins and 36 species of holothurians (Liao, Clark, 1995; personal communication, unpublished).

Holothurians, such as a "trepang", were traditional objects of harvesting and that in the middle of the twentieth century have led to a significant depletion of coastal ecosystems of Vietnam. The most popular for the eating sea cucumbers belong to family Holothuria and include about 15 species. All those are large animals with thick muscular body wall.

Sea urchin gonads (uni and roe) became very popular in Vietnam last decade and this situation led to the sharp decrease of the density of the population of common species of echinoids. The most delicious are the species of sea urchins with a test diameter larger than 5 cm belonging to families Diadematidae, Temnopleuridae, Toxopneustidae, Cidaridae. Most of them have large gonads with relatively small eggs.

Sexual reproduction of echinoderms in native populations now is not investigated enough to be confident for the result of fertilization. It depends of the seawater quality, presence of the phytoplankton, some external factors – such as disturbing by the wave activity when storms, noise and oil pollution from motor vessels, etc. To population could replicate its density must not be below a critical level. Holothurians and sea urchins are dioecious animal with external fertilization. For many of them the spawning aggregations were described. Moreover, evidently showed that holothurians of some species can find the sexual partners and can spawn synchronously (Pearse, 1908; Colwin, 1948; Nycholm, 1951). The temperature considered the main release factor for spawning in echinoderms in natural conditions. In tropical latitudes, temperature fluctuations are not so clearly expressed as in temperate latitudes.

In several species of sea urchins from the Nha Trang Bay, was found, that at the time of spawning a small percentage of individuals (20–30%), with mature gonads is observed. There was shown that the time of the spawning depends on the phases of the moon – spawning takes place during the full moon or new moon. It is characteristic for the reproductive period of tropical species, which can last several months (Pearse, Cameron, 1991). Most likely that every full or new moon only portion of the population takes a part in spawning. Nevertheless, during the reproductive period every specimen spawns at least ones.

The current state of populations of sea sea urchins and sea cucumbers according to rough estimates suggests significant overfishing. If sea urchins *Diadema* and *Toxopneustes pileolus* still retained their populations, *Tripneustes gratilla* can be found difficult even in protected areas. It requires of various types of regulations in order to recover the density of populations to acceptable values. These values are determined by the peculiarities of reproduction of species and survival parameters of gametes. Such data can be obtained in the laboratory. For

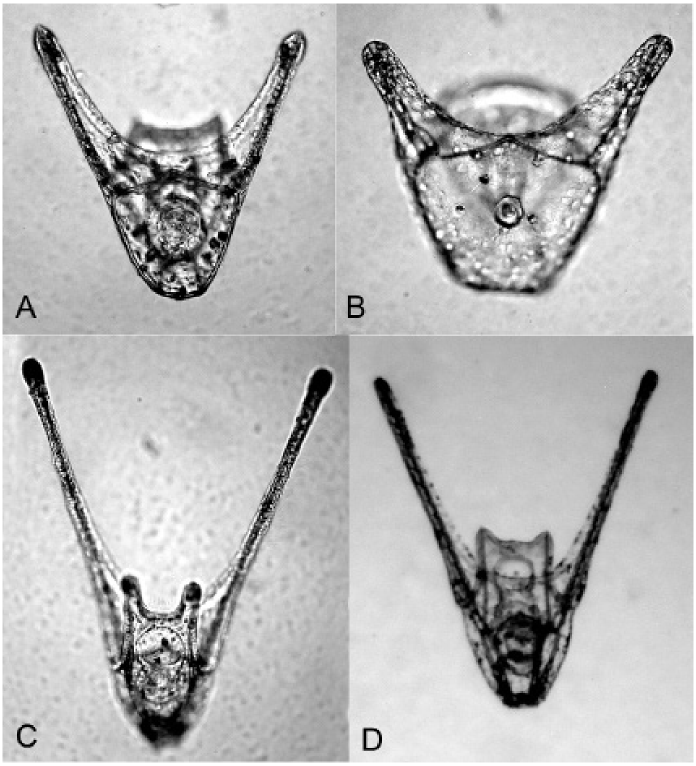

Fig. 1. Larvae of some sea urchins from Nha Trang Bay, obtained in laboratory. A. Young pluteus of *Toxopneustes pileolus*. B. Young pluteus of *Tripneustes gratilla*. C. Pluteus II of *Diadema savignyi*. D. Pluteus II of *Diadema setosum*.

some species such data is probably already known and biological basis of mariculture of sea urchins are already in use.

For many regular sea urchins the biological characteristics of reproduction were studied, as those have been the subject of numerous works on the development and experimental reproduction. Developed and applied technologies of cultivation of sea urchins in order to obtain animals with mature gonads (Yokota, Matranga, Smolenicka, 2000).

To cultivate of the sea urchins one could first of all – obtain seed of the urchin from the laboratory culture of larvae. Then choose the proper water area and put the seed material on it. Then use any methods of controlling of the water area. After three years collect the grown sea urchins.

In our preliminary investigations, we had obtained some data about the morphology of larvae of common species of sea urchins (Fig. 1) from Nha Trang Bay. The general morphology of the echinoplutei of regular sea urchins reflects the systematic position. The pluteus of *Tripneustes gratilla* has straight line at lower part of the body. The body is wider than one of *Toxopneustes pileolus*. Plutei of species of *Diadema* have long thin postoral arms. Plutei when in good conditions swim and ingest unicellular algae or other particles suspended in sea water. Fed larvae grow and during development change their shape. In *Tripneustes gratilla* and *Toxopneustes pileolus* plutei attain third and fourth pairs of arms. In *Diadema setosum* and *Diadema savignyi* plutei grow extremely long arms.

Larval development of the regular sea urchins finishes with metamorphosis after that the young juvenile sea urchin perform its first steps by ambulacral foot. After metamorphosis juvenile sea urchins eat of primary films, grow and reach test diameter up to five millimeters. After that, they are transferred to nursery tanks and grown till reach 15 millimeters in one year. At 15 millimeters the urchins are ready to go to sea for grow out to market size.

If technologies of the sea urchin farming are well developed in world, the biology of holothurians is less investigated. It is known about 35 species of holothurians from the Nha Trang Bay and half of them are the possible edible. However, any information about the larval development, time of spawning, duration of the larval period, how the late larvae choose the substratum for settlement and what is the food for juvenile holothurians is not available for the most species of holothurians from Nha Trang Bay.

The physiology of nutrition and many features of the biology of the adult holothurians are not well known. The larval development is investigated for several commercial species. The auricularia larva of holothurians is planktotrophic and feeds on unicellular algae. It converts to doliolaria and then to pentactula. Pentactula actively swims and sometimes sinks to the bottom and attaches and moves with its primary tentacles. Gradually pentacula transform to juvenile of holothurian. Primary tentacles play role of the feeding arms.

The time from the fertilization to juvenile takes about one month in *Apostichopus japonicus*. The duration of the larval development of many holothurians of genus Holothuria is not known.

There is the practice of the mariculture of the *Holothuria scabra* at Madagascar. There is the farm near Nha Trang for cultivation the same species of holothurians *Holothuria scabra*.

That direction of the holothury farming is very perspective in fast developing Khanh Hoa province due to the following:

1. The presence of the indented coastline with bays and areas for the farming of sea urchins and holothurians in semi-natural conditions.
2. The well developed transportation infrastructure and logistics.
3. The big experience of the population in aquaria building and aquaculture.
4. The presence of the high-experienced scientists and specialist from the Vietnam Academy Institutions, Nha Trang University and Institute of Aquaculture Research No3. It can possess the high-level consultations and expertise at each stage of the farming development.
5. The fast developing of pharmaceutical industry in Vietnam and the other countries of SE Asia who can be the consumers of such mariculture.

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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

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Basing on the survey data and analysis of VAST03.05/15–16 project and the results of experimental tests on the samples of sediment in the sea-cage farming area of Nha Trang bay, we carried out the considering and evaluating the impact of cage farming activities on the eutrophication of the coastal waters. The results obtained show a high level of nitrogen-nutrient (N) in the studied area: the average content of dissolved inorganic nitrogen (DIN) is 177.38±6.01µg/l (ranged from 169.88 to 188.88 µg/l), in which NO_3-N accounts for a high proportion (the average 152.99±1.91µg/l). at most surveyed locations is greater than 16, showing that phosphorus nutrient salt may probably be the limiting nutrient factor in these coastal waters. The TRIX indexes recorded for both the surface and bottom waters are within a range of about 5–6 (at high level of nutritional status); especially, at the sites of under cage and near the cage farming area, and the TRIX indexes at locations close to cage farming areas are higher than those recorded at farther locations.

The coral transition plant of experiments showed significantly difference was detected when the percent of death specimen's coral excretion in the experiment at different sites, and it's strongly the impacts that is known about the distance where impact from the farms can be detected on nearby coral reef (in Hon Mot Island). The increasingly development of human activities are threatened by anthropogenic pollutants. Sea cage farming is one of the stressors negatively impacting coral reefs by being point sources of nutrients and other effluents.

Keywords: eutrophication, TRIX index, nutrients, coral reef, and sea-cage farm.

Introduction

Nha Trang Bay is known for being one of the 29 most beautiful bays worldwide. It is home to most typical ecosystems of tropical marine waters: wetland ecosystem, coral reefs, mangrove forests, seagrass beds, estuary ecosystem, etc., providing favorable conditions for developing economic activities such as tourism, marine transportation, natural resources, and aquaculture activities with substantial potentials. As of 2014, there are about 9.347 sea-cages concentrating in such locations as Vung Ngan, Bich Đam, Đam Bay, and Hon Mot. In Nha Trang bay, coastal sea-cage farming activities are presently taking place in a complicated manner with fairly strong development in scale and diverse farming methods.

In different provinces, sea-cages farm has been developed in an unplanned and non-stable management, the results pushed the coastal zones in the stress pressure and threatening the environment such as degraded ecosystems and increased ecological risk to aquatic organism.

In presently, the environment at many cage farm areas is suffering from a degradation trend marked with complicated developments of epidemics. In addition, as cage farming has been developed too fast without clear-cut planning and without compliance with regulations, the environment of farming areas has been adversely affected, especially the water environment and natural aquatic ecosystems (Nguyen Tac An et al*.,* 2005).

Additionally, environmental pollution has been occured frequent in coastal areas with aquaculture farming operations, with fairly high contents of nutrients and organic matter from un-consumption feed and excrete of raised animals directly discharged into the environment (Sowles et al*.,* 1994; Casabianca et al*.,* 1997; Nordvargr, Johnson, 2002; Hoang Trung Du et al*.,* 2006). According to Islam (2005), the amounts of discharged nitrogen and phosphorus are around 68–86% and 71.4% respectively. The contents of nutrients increased through activities in around aquaculture farming areas are likely to trigger such negative phenomena as eutrophication and algal blooms, adversely affecting coastal waters and reduced the water quality, hence affecting the rates of survival and growth of aquatic life (Beveridge, 1984). The increase of nutrient contents in the water column has created favorable conditions for harmful bacteria and algae to grow, thus negatively affecting the growth of coral reefs and unbalance for marine ecosystems. The assessment of levels of nutrients in aquaculture farming areas is therefore quite necessary, in which the TRIX index (recommended in

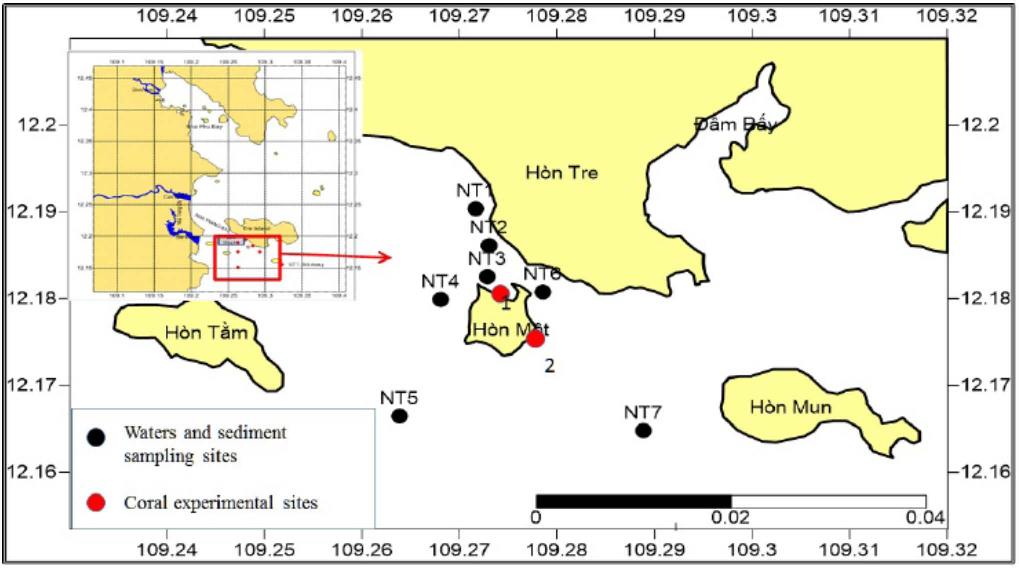

Fig. 1. The Map of sampling stations in Nha Trang bay, Vietnam.

Vollenweider et al*.,* 1998; Giovanardi, Vollenweider, 2004) can be used as an effective factor for researchers to assess the levels of nutrients or environmental status in coastal waters. Many studies have use the TRIX index such as in the studies on European waters (Ioannis Primpas, Michael Karydis, 2011); Marmara waters of Turkey and coastal waters in Southern Mexico (Herrera-Silveira, Morales-Ojeda, 2009).

In the situation and development of sea-cage farm in Nha Trang Bay, this paper will focus on the current status of seawater quality as well as the distribution of dissolved nutrients in waters of the sea-cage farm areas. The TRIX index will be applied in examining and assessing how sea-cage farm activities could possibly influence the increase of nutrients through the degradation and decomposition of organic matters from the sediments in cage farm areas. Hence it can clarify the likely the impacts from sea-cage activities on the eutrophication and the quality of ecological environment, as well as investigating into a number of reasons affecting the present environment of the Nha Trang bay which may cause its degradation.

Materials and Methods

Study Area. Nha Trang – Binh Cang Bay is located in Khanh Hoa province with an area of about 507 km^2, including 19 islands (HonTre 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.

Water and sediment samples were collected at 7 sites of different distances off shore from the cage-breeding area: sites within the breeding area (NT1, NT2, NT3), intermediate sites 1.2 km from the cages (NT4 and NT6), and sites about 3km from the cages (NT5 and NT7) (Fig. 1).

Sampling strategies. The survey results from the dry season of 2015. Water samples, suspended matter, sediments were collected at several stations in the study areas (Fig. 1) with transect stations in the different distances from the cage-farm area: sites within and the nearby the cage, intermediate sites 1.2 km from the cages, and farther sites about 3 km from the cages. Water quality were analysis such as parameters: Dissolved Oxygen, Nutrients, Chlorophyll-a, TSS, TOM).

Samples of surface sediment (0–2cm) were taken with Van Veen grab samplers (size 20 cm x 15 cm). Sediment samples were analyzed to determine their grain size distribution as well as organic carbon and nitrogen.

Measurement and analysis method. In situ surveys were performed by measuring the parameters of the water column at different layer depths (pH, temperature, salinity, dissolved oxygen, turbidity) by 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).

Nutrients parameters was analyzed for dissolved inorganic nitrogen – DIN (NH4-N, NO2-N, NO3-N) and PO4-P by UV-visible spectrophotometer (Parson et al., 1984). 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. (ed) (1999).

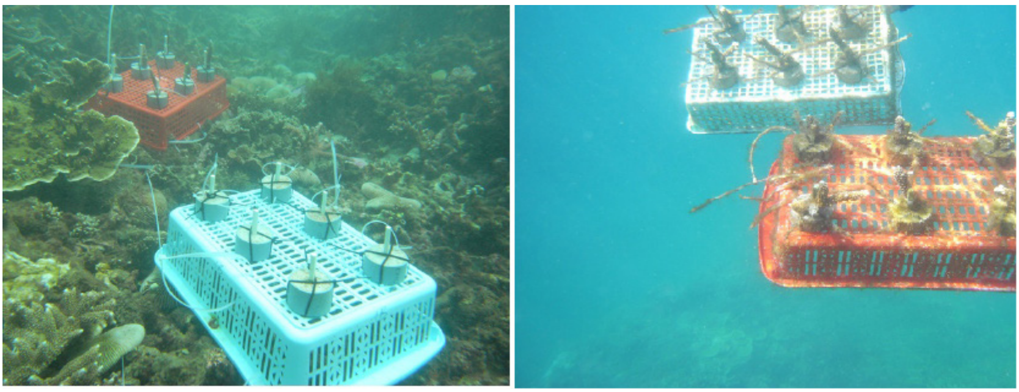

Fig. 2. Pictures of experiments on corals transplanted in Nha Trang bay, 2015.

Day 1 of experiment *After 31 days: in experiment*

Table 1. The variation of nutrients concentration in coastal waters of Nha Trang bay

Values	NH_4-N (µgN/l)	NO_2-N (µgN/l)	NO_3-N (µgN/l)	DIN (µgN/l)	P-PO4 (µgP/l)
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	7	7	7	7	7

Experimental design. A set of *Acropora formosa* corals was simultaneously cross-transplanted between the west and the east side of the Hon Mot island according to the common-garden method of reciprocal transplantation. Polyps (n=10) of corals were transplanted from east side to west, and the opposite (Fig 2.). Additional polyps (n=10) were measured for their mucus production and zooxanthella at site to have a reference value of day 1. After 31 days of experimental time, the coral polyps were brought up and counted for live and dead polyps (white bleaching), measured for their mucus and zooxanthella analyses.

Water Quality Assessment. Using the Trophic Index (TRIX) (first

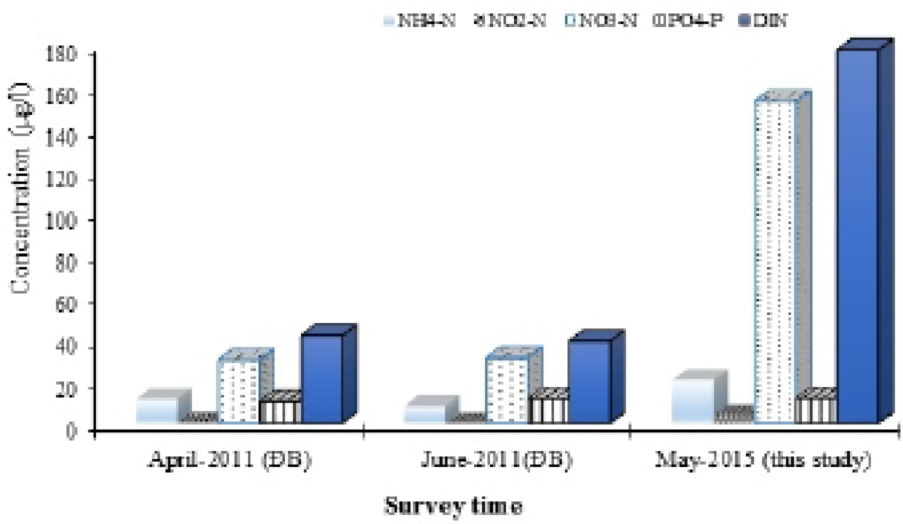

Fig. 3. The comparison of mean values of nutrients between the cage farm areas in Đam Bay (ĐB) and in this study (based on the data of Le Lan Huong et al., 2014).

developed by Vollenweider và cộng sự, 1998) for assessment the water quality, and worldwide application by many researchers (Gilson et al., 2013), equation calcualtion:

$$TRIX = (Log10\ [chl\text{-}a \times |\%O2| \times DIN \times DIP] + k)/m$$

Results and Discussion

Physical characteristics and ecological factors in the research area. The salinity and temperatures in the research area were relatively consistent among sites and there were no major differences between the surface and bottom layers. Salinity varied between 33.6 and 33.7 ppt in the surface layer, and from 33.7 to 33.9 ppt in the bottom layer. The temperatures were from 26.4 to 27.1^{o}C in the surface layer, and from 24.4 to 25.5^{o}C in the bottom layer. The contents of dissolved oxygen (DO) in the research area showed fairly positive results: 6.49–6.93mg/l in the surface layer (saturated oxygen: 98.2–105%); 6.60–6.87 mg/l in the bottom layer (saturated oxygen: 96.9–101.3%).

The data of nutrient concentration: nitrogen (N) and phosphorus (P) in the entire column are presented in Table 1: DIN (dissolved inorganic nitrogen) has a mean value of 177.38±6.01 µg/l (varying between 169.88 and 188.88 µg/l), in which the contents of NO2–N showed for the lowest proportion in DIN, with a mean value of 3.94±0,5 µg/l; next is NH4–N with 20.45±6.75 µg/l and NO3-N with the highest proportion of 152.99±1.91 µg/l. Unlike DIN, the contents of dissolved inorganic phosphorus varied fairly greatly between 6.16 and 21.97 µg/l, at an average of 11.65±4.00 µg/l.

A comparison with the results on nutrient levels obtained from Lê Lan Hương et al. (2014) in the lobster cage area at Đam Bay, Nha Trang Bay, showed that the average values of inorganic nutrients as NH4-N, NO2-N and PO4-P were relatively similar. However, the contents of NO3-N in the studied area were many times higher than those in Đam Bay at the same time period of the year (about 3–4 times) (Fig. 3).

A consideration of the relationship of the contents of nutrients and Chl-a showed that there was almost no relationship between Chl-a and the contents of nutrient (except for NO2–N with R2 = 0.36). The average contents of Chl-a in the surface layer were lower than those of the bottom layers, corresponding to 0.54 ± 0.15 µg/l and 0.94±0.2 µg/l; 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

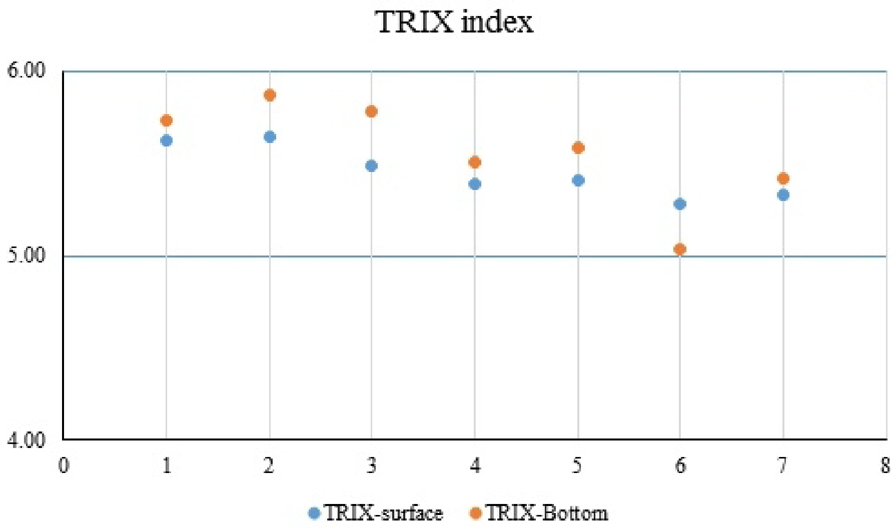

Fig. 4. TRIX index was showed 5–6 at almost the sites of the near and middle-distances from cage farm areas (include surface and bottom waters): State of water quality is bad and levels of eutrophication is high and far-field is lower.

has always played the role of a limiting factor in the coastal waters of Nha Trang Bay in the dry seasons.

Assessment of impacts from cage farm activities on eutrophication of the coastal waters

The use of the TRIX index suggested by Vollenweider et al. (1998) in assessing the nutrient levels, the combination among variables as Chl-a, DIN, PO4-P, and the percentage of saturated oxygen in calculation are bases on which to examine the nutrient level and status of coastal waters, which can be distinguished into 4 scaling levels: 0–4: excellent water quality and low nutrient level; 4–5: good water quality and moderate nutrient level; 5–6: water of average quality and high nutrient level; and: 6–10: degraded water quality and very high nutrient level (Giovanardi, Vollenweider, 2004). From the TRIX indexes calculated with data from this research, it is noticeable that most TRIX indexes in both surface and bottom layers are within a scale of 5–6, i.e. a high nutrient level and seawater of an average quality. It can also be noticed that at such sites NT1, NT2, and NT3 close the cage farm area, the TRIX indexes are higher than those in sites more distant from the cage farm area (NT4, NT5, NT6, and NT7) (Fig. 4). This may show that these waters have been directly impacted by cage farm activities which have triggered the rise of nutrient contents in the coastal waters.

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 *Acropora* spp. coral is highly dependent on the photosynthetically fixed carbon derived from the endosymbiotic algae (Grottoli et al., 2004). The adaptation to the nutrient poor environments has made the symbiosis rather important, providing the coral with excessive carbon. An increase of DIN supply that are the main effluent source from fish farming, leads to:

i) proliferation of zooxanthellae and thereby

ii) an increase in Phosphate demand and in turn an "altered composition of thylakoid membranes and a reduced threshold for light- and heat-induced bleaching" (Fig. 5). Excessive nutrient loads, often combined with elevated levels of sedimentation, turbidity and lack of grazers due to overfishing, affecting the mucus production in two general ways:

i) the mucus excretion elevates due to the exposure the nutrient loading but decreases in time to initial levels probably due to adaptation mechanisms;

ii) the quality of the mucus decreases over time. The coral transition plant of experiments showed significantly difference was detected when the percent of death specimen's coral excretion in the experiment at different sites, and it's strongly the impacts that is known about the distance where impact from the farms can be detected on nearby coral reef (in Hon Mot Island).

When affected by nutrient loads, zooxanthellae accumulate nutrients and proliferates, resulting in lower amounts of mucus produced per algae, but a higher amount of total algae biomass producing DOM. This study confirms the negative impacts that the nutrient loads have upon the coral itself, with lowered growth and calcification rates, but also adds broadens to the scope of impact, suggesting on lowered contribution of ecosystem goods and services.

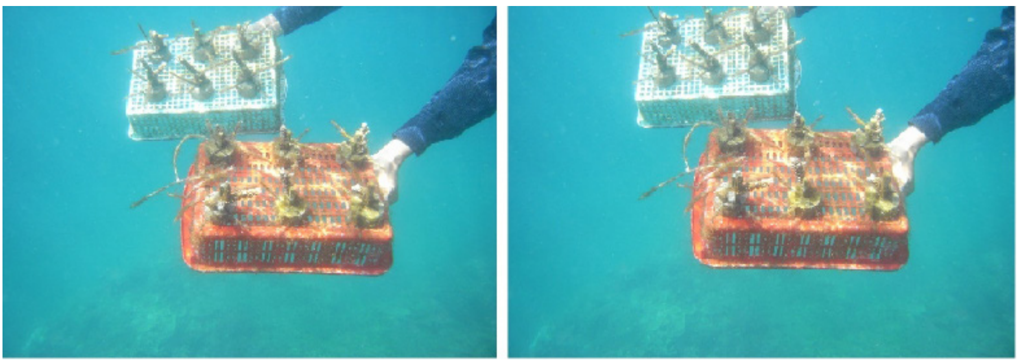

Fig. 5. The different experiment of coral transplantation at clear site (righ) and near-by the fish farm (left) are in Hon Mot Island, Nha Trang bay during 31days.

Acknowledgments

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SLOW RECOVERY OF CORAL REEF FISHES IN NHA TRANG BAY MARINE PROTECTED AREA, SOUTH-CENTRAL VIETNAM

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Assessments of recovery of reef fish communities in the Nha Trang MPA were conducted at 3 sites protected from fishing (the protected zone) and 5 sites heavily fished for over 8 years from 2002 to 2007 and 2010 using visual censuses. The protected zone supported a higher mean value of total species, species richness and total density of fish communities (1.3–1.5 times) than the unprotected zone in all years of study. In both zones, the number of species and the total density and the density at size class of 1–10 cm of fish increased, albeit only slightly. A significant increase was recorded for the density of fish at size class of 11–20 cm (2.8 times higher) and 21–30 cm (2.9 times higher) in the protected zone, whereas this trend was not clear in the unprotected zone. The density of fish at size class of > 30 cm increased both in the protected and unprotected zone, however these increases were not significant due to extremely low density. The fish families which contributed significantly to this increase of the density in the protected zone include damselfishes (2.1 times), angelfishes (1.9 times), parrotfishes (1.7 times), triggerfishes (3.0 times) and leatherjackets (1.6 times). In contrast, the density of most of the above fish families did not increase in the unprotected zone, with a notable exception for rabbitfishes (increase of 4.0 times). However, most target fishes including groupers, snappers, emperors and sweetlips did not increase in density during the 8-year study period.

Keywords: recovery, coral reef fish, marine protected area, Nha Trang, Vietnam.

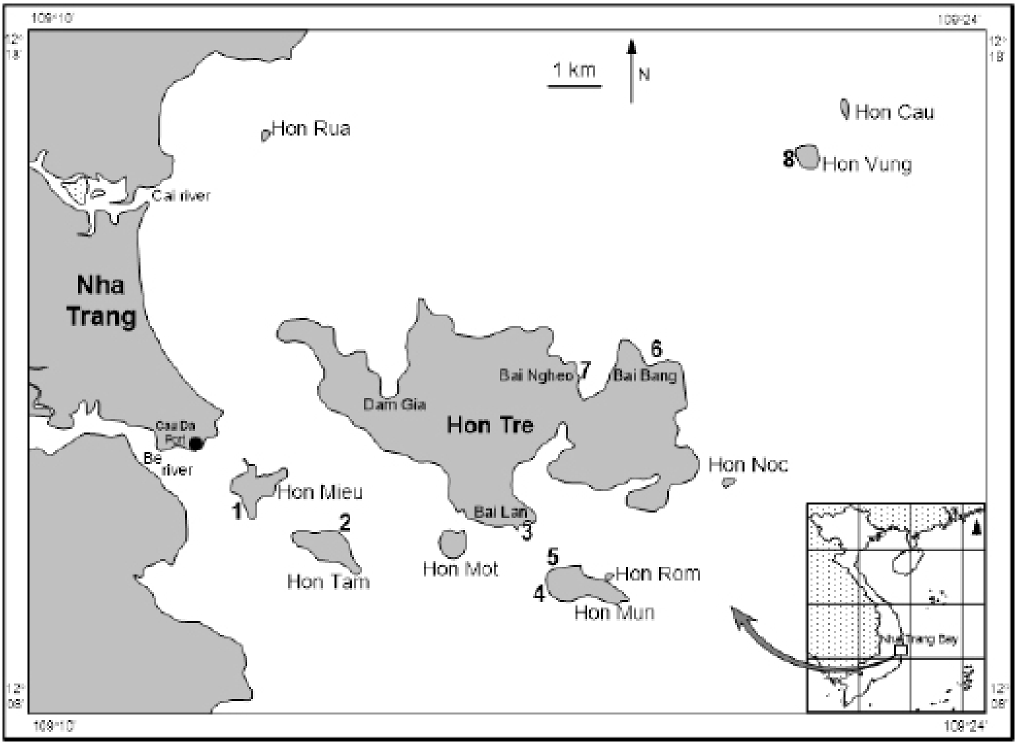

Fig. 1. Approximate location of study sites of coral reefs in Nha Trang Bay MPA monitored in August of each year from 2002 to 2010.

Introduction

In recent decades, establishment of Marine Reserves or Marine Protected Areas (MPAs) has increased and such reserves are considered as effective tools for improving biodiversity and (indirectly) fisheries in many different countries around the world (Salm, 1984; Roberts, Polunin, 1993; Alcala, 1998; Nowlis, Roberts, 1999; Hastings, Botsford, 1999; Roberts et al., 2001; Russ, 2002; Halpern, 2003). Results from previous studies show that MPAs have been playing an important role in protecting diversity and increasing biomass of coral reef fish (Sale, 1980a), maintaining brood stock for spawning and enhancing recruitment through dispersal of larvae (Bohnsack, 1993) and improving fishing effort in adjacent areas through spillover (Rowley, 1994; Alcala, 1998).

Halpern and Warner (2003) reviewed 112 independent studies from 80 MPAs. These studies indicate that density, biomass, size and diversity of coral reef resources in the protected areas are higher than those in comparable unprotected areas after just 1 – 3 years of protection. Increase in species richness of target fish in protected zones is higher than in unprotected zones (Roberts, Polunin, 1991; Polunin, Roberts, 1993; Russ, Alcala, 1996; Russ 2002; Halpern 2003). Some studies indicate that the density, biomass, size and species richness of reef fauna significantly increased in the MPAs over time (Russ, Alcala, 1996; Wantiez et al., 1997; Russ, Alcala, 1998a) whereas other studies found only a slight or no increase (Roberts, 1995; Sale, Cowen, 1998). Alcala (1998) found an increase in abundance and number of species of fish in the no-take zone of Sumilon MPA, Philippines after 5–10 years of protection. The abundance declined in the period of no protection and then gradually increased when protection was enforced. Based on long-term data, Alcala (1998) noted that the recovery for planktivorous fish took about 4 years and spillover of predatory fish between the no-take zone and adjacent areas occurred after 8 – 10 years.

Nha Trang Bay MPA, located in south-central Vietnam is the first dedicated MPA in Vietnam, established in 2002 with three major functional zones including the restricted zone, the buffer zone and the transition zone (Fig. 1). In order to evaluate the effectiveness of the MPA after some years with protection, the present study focused on assessments of recovery of coral reef fish communities. Results from this study should prove useful to scientists, managers and policy makers for development and management of the MPA network in Vietnam.

Materials and methods

Study sites. Data analysed in the present study were collected annually at eight permanent monitoring sites in Nha Trang Bay MPA in August of each year from 2002 to 2007 and 2010. Three sites are located in the protected zone (site 4: SW Hon Mun; site 5: NW Hon Mun; site 8: Hon Vung) and 5 sites are located in the unprotected zone (site 1: Hon Mieu; site 2: Hon Tam; site 3: Bai Lan; site 6: Bai Bang and site 7: Bai Ngheo) (Fig. 1).

Sampling strategy. At each study site, two transects, each 100 m long,

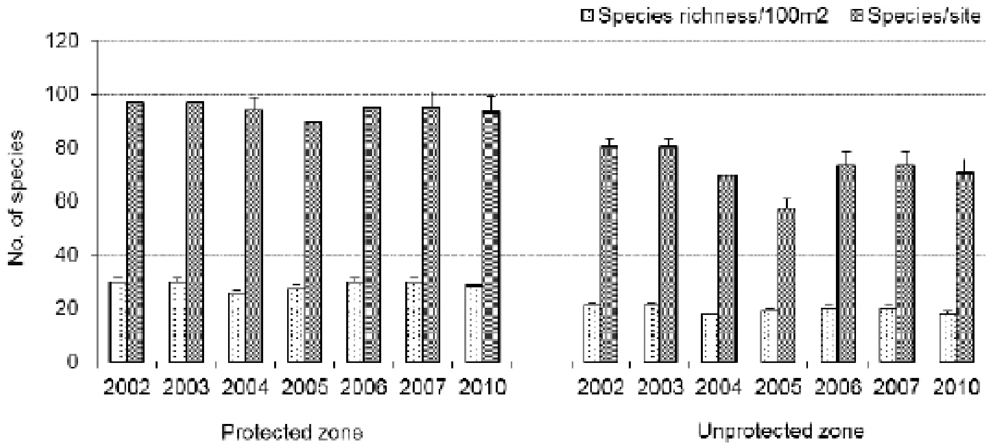

Fig. 2. Temporal change in species richness total species of fish between zones in Nha Trang Bay MPA from 2002 to 2010.

were placed haphazardly at two reef zones (reef flat and reef slope) parallel to the shoreline of the island. The depth was ca. 2–4 m at the reef flat transect (shallow station) and 5–12 m at the reef slope transect (deep station) below low tide level. Each 100 m transect was subdivided into 4 replicate 20 m long x 5 m wide replicate transects. Hence, eight replicate transects were surveyed at each study site.

The fish observer swam slowly along the transect line to identify and count the number of individuals and estimate the size (fork length) of each species of fish by visual estimate (following Hodgson, Waddell 1998; English et al., 1997). Fishes of all families were identified to species level following Randall et al. (1990), Myers (1991), Kuiter (1992) and Allen et al. (2003). Surveyed time at each station was about 50–60 minutes. The surveys were all carried out between 9:00 hr and 14:00 hr local time. This period is considered as the time with maximum light levels penetrating into the water column, when most

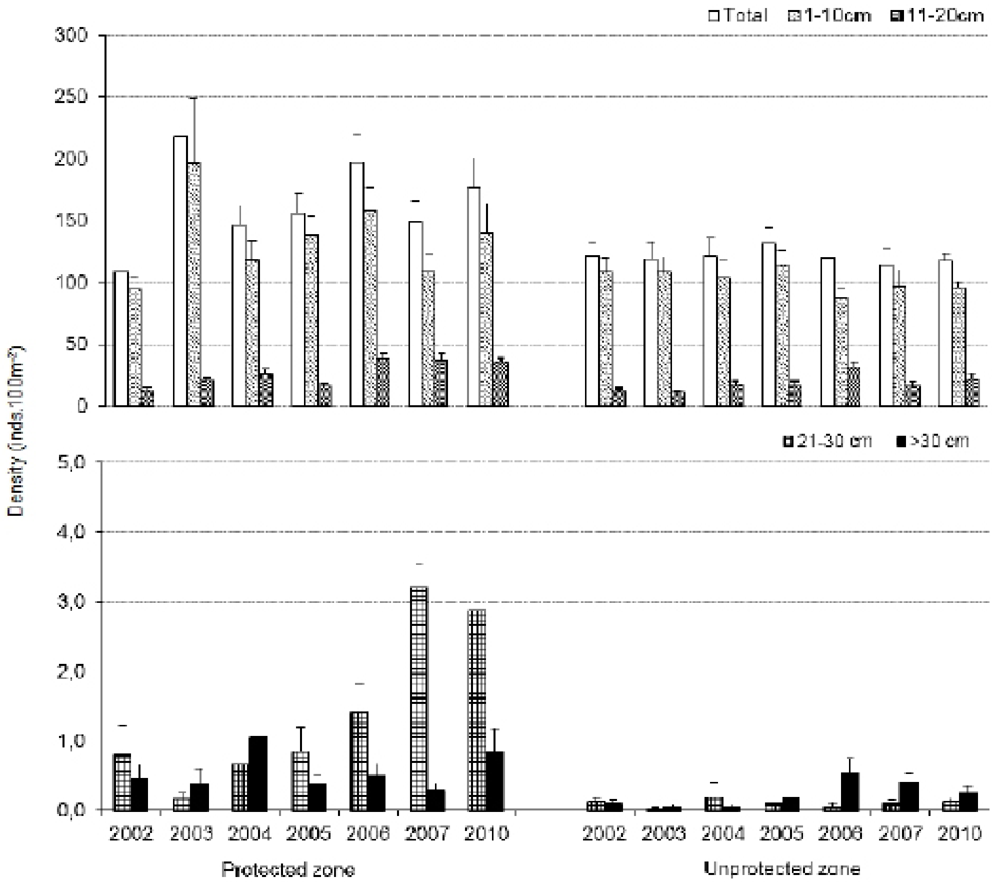

Fig.3. Temporal change in mean density (± s.e.; individuals/100m^2) of fish at different size classes between zones in Nha Trang Bay MPA from 2002 to 2010.

reef-associated fishes are most active (eg. see English et al., 1997). To avoid disturbance from divers, fish surveys were conducted 15 minutes after the first transect was placed.

After completing the work on transects, the observers swam around the study sites to record and take photographs of species that were not found along transects in order to complete as much as possible the list of fish species.

Data storage and analysis. Density of fish at each study site was calculated as the mean value of the eight replicates from the two transects on the reef flat and reef slope. Density was calculated for the total, each of 4 size classes of 1–10 cm, 11–20 cm, 21–30 cm and > 30 cm and fourteen families of target fishes.

A two-way ANOVA was used to compare fish diversity and density between the protected zone and unprotected zone of the MPA. Raw data on diversity and density were $\log_{10}(x + 1)$ transformed prior to analyses to improve the homogeneity of variances (Garpe, Ohman, 2003; McClanahan et al., 2001). When ANOVAs detected significant differences, Tukey's *post hoc* test was used to compare changes between the protected and unprotected zones in each year of the six years from 2002 to 2007 and 2010.

Results

Species richness. Mean total species and species richness in the protected zone were 1.3 and 1.5 times higher than that in the unprotected zone. Although, there was a slight change in the total species and species richness in both the protected and unprotected zones between years of study (Fig. 2), these were not significant ($p > 0.05$).

Density. Comparisons in mean density of fish indicate that the total density in the protected zone was 1.4 times higher than the unprotected zone. The mean densities of fish at size class of 1–10 cm, 11–20 cm, 21–30 cm and > 30 cm in the protected zone were 1.3 times, 1.5 times, 13.7 times and 2.4 times higher than the unprotected zone. There was a slight difference in the total density and the density of fish at size class of 1–10 cm in both protected and unprotected zones from 2002 to 2010 ($p > 0.05$) (Fig. 3). A temporal significant increase was recorded for the density of fish at size class of 11–20 cm (2.8 times higher) and 21–30 cm (2.9 times higher) in the protected zone ($p < 0.01$), whereas this trend was not clear in the unprotected zone ($p > 0.05$) (Fig. 3). The density of fish at size class of > 30 cm increased both in the protected and unprotected zone (Fig. 3), however these increases were not significant due to extremely low density (< 0.6 individual/100 m^2) in both zones ($p > 0.05$).

For the fourteen common and target families of fish, mean densities of most families in the protected zone were higher than the unprotected zone (Table 1). The results of one-way ANOVA show that there was a significant difference in the total density and the density of each size class of fish between the protected

Table 1. Mean density (± s.e.; individuals/100 m^2) and level of temporal increase (times) of density of some common fish families in the protected zone (PZ) and the unprotected zone (UPZ) of Nha Trang Bay MPA between 2002 and 2010

No.	Fish family	Mean density			Level of increase (times)	
		PZ	UPZ	Difference (times)	PZ	UPZ
1	Pomacentridae	92.8±8.2	65.6±3.0	1.4*	2.1*	-1.4
2	Labridae	19.4±2.6	14.5±1.8	1.3	1.4	1.5
3	Chaetodontidae	7.3±0.9	2.1±0.3	3.4**	-1.4	-2.4
4	Pomacanthidae	1.4±0.1	0.3±0.1	4.2**	1.9*	1.2
5	Acanthuridae	12.0±1.0	4.6±0.5	2.6**	1.0	-1.8
6	Scaridae	10.0±0.8	11.9±1.1	-1.1	1.7*	1.3
7	Serranidae	0.9±0.2	0.6±0.2	1.5	2.7	1.6
8	Lutjanidae	0.1±0.02	0.1±0.1	-2.0	1.0	1.0
9	Lethrinidae	0.1±0.01	0.02±0.01	3.5	2.8	1.0
10	Haemulidae	0.03±0.02	0.2±0.1	4.4	1.0	-3.3
11	Balistidae	0.5±0.1	0.1±0.04	3.4**	3.0**	-1.3
12	Monacanthidae	1.0±0.1	0.8±0.1	1.3	1.6*	-1.8
13	Caesionidae	2.0±0.5	1.0±0.1	2.1	-3.8	1.0
14	Siganidae	0.5±0.1	3.0±0.8	-5.8**	1.5	4.0**

Note: * - $p < 0.05$; ** - $p < 0.01$; *** - $p < 0.001$.

and unprotected zones, especially for damselfishes (Pomacentridae: 1.4 times higher; $p < 0.05$), butterflyfishes (Chaetodontidae: 3.4 times; $p < 0.001$), angelfishes (Pomacanthidae: 4.2 times; $p < 0.001$), surgeonfishes (Acanthuridae: 2.6 times higher; $p < 0.001$) and triggerfishes (Balistidae: 3.4 times; $p < 0.01$)

(Table 1). The density of rabbitfishes (Siganidae) in the protected zone was significantly lower (5.8 times) than the unprotected zone ($p < 0.01$) (Table 1).

For each family of fish, there was a significant temporal increase over the course of the study in the density recorded for Pomacenthidae (2.1 times; $p < 0.05$), Pomacanthidae (1.9 times; $p < 0.05$), Scaridae (1.7 times; $p < 0.05$), Balistidae (3.0 times; $p < 0.01$) and Monacanthidae (1.6 times; $p < 0.05$) in the protected zone (Fig. 4 and Table 1). The density of some other families of fish also indicated a slight increase for wrasses (Labridae) and fusiliers (Caesionidae) or remained stable for emperors between years (Fig. 4). In contrast, the density of most of the above families of fish did not increase in the unprotected zone between 2002 and 2010, with a notable exception of rabbitfishes (increase of 4.0 times; $p < 0.01$) (Fig. 4 and Table 1).

Discussion

Subsequent to zoning and protection, the protected area supported higher richness of fish than the unprotected area. This was consistent with results from previous studies indicating that the diversity of reef fish in fully protected areas is higher than in unprotected areas after 1–3 years of protection (reviewed by Halpern and Warner, 2003). The high diversity of species and cover of hard corals in the protected zone of Nha Trang MPA (Vo et al., 2004) may contribute to maintain and increase the diversity of fish communities in this zone compared to that in the unprotected zone.

There were however no temporal significant differences in species richness and total species in both protected and unprotected zones, reflecting a stability of fish diversity after 8 years of protection. This indicates that the recovery of fish communities in the MPA has been very slow compared to that found in many other MPAs around the world (Roberts, Polunin, 1991; Polunin, Roberts, 1993; Russ, Alcala, 1996; Russ, 2002; Halpern, 2003). So, management in the MPA towards stopping fishing has not contributed to increase the diversity of fish in the MPA, even in the protected zone.

The slight temporal increase in the density of total fish and small fish of 1–10 cm in length in the protected zone of the MPA between 2002 and 2010 indicates a slow recovery of fish communities compared to that in other MPAs (reviewed by Halpern and Warner, 2003). The temporal increase in density of large fish (> 20 cm in length) in the protected zone shows that size of fish in this zone have increased after 8 years of protection. These are consistent with the findings from previous studies recorded in the Philippines (Russ, Alcala, 1996; Russ, Alcala, 1998a) and New Caledonia (Wantiez et al., 1997).

The higher density of damselfishes, butterflyfishes, angelfishes, surgeonfishes, groupers, emperors, triggerfishes and leatherjackets in the protected zone than in the unprotected zone of the MPA, especially for the target fish with large sizes, is indicative of the success of zoning, enforcement and

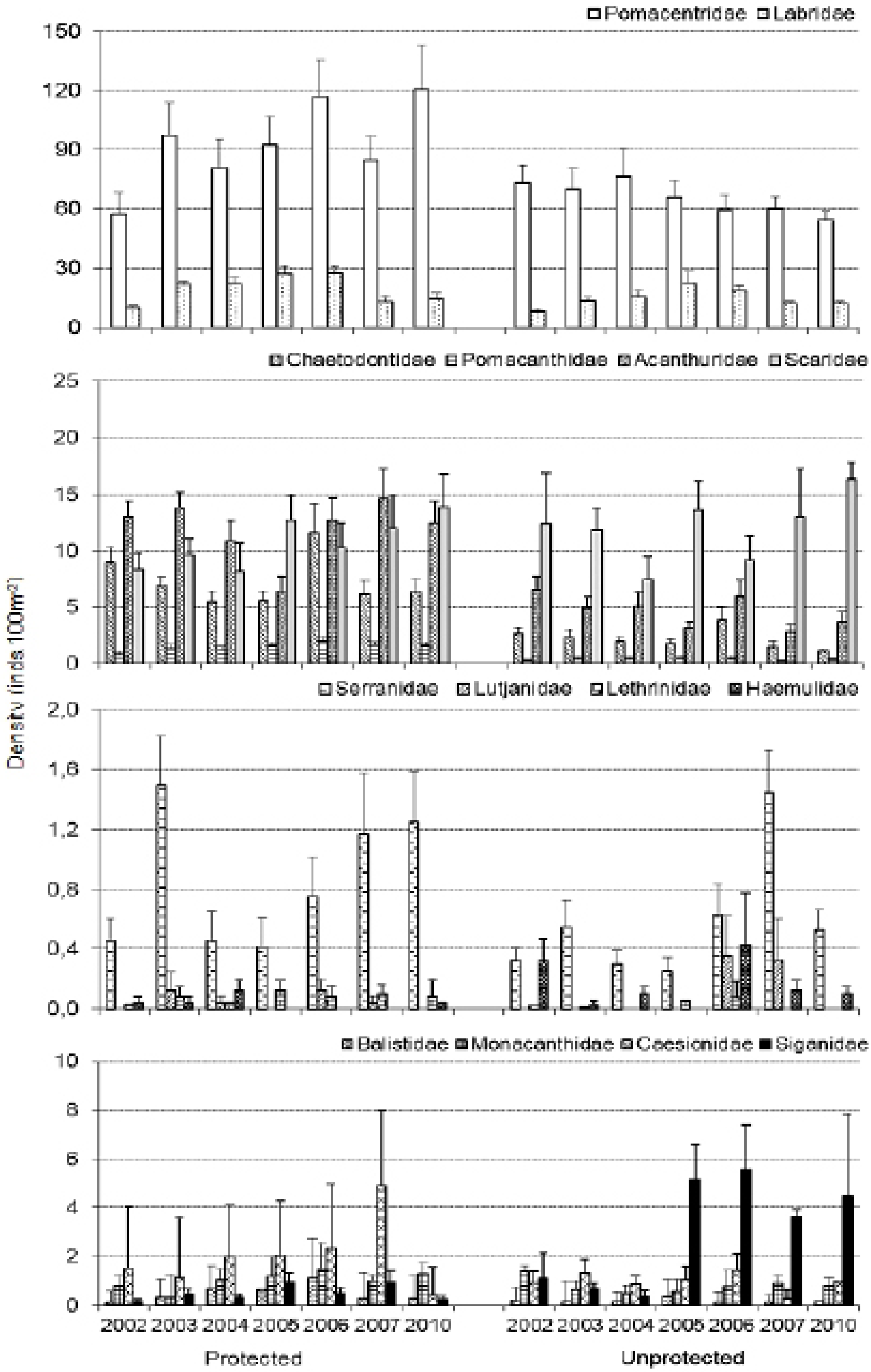

Fig. 4. Temporal change in mean density (± s.e.; individuals/100m^2) of some common families of fish between zones in Nha Trang Bay MPA from 2002 to 2010.

compliance of fishers. These findings are similar to those from other MPAs, including Glovers Reef Atoll, Belize (McClanahan et al., 2001). The higher diversity and abundance of large fish in the protected zone may be important as brood stock in maintaining spawning potential (Bohnsack, 1993) and recruitment or migration of large fish to adjacent areas through spill-over (Rowley, 1994; Alcala, 1998). However, the low density (< 1.0 individual/100 m^2) of target and predatory fish of groupers, snappers, sweetlips and emperors is considered not yet sufficient to ensure successfully spawning (McClanahan, 2000). Indeed, no spawning aggregation sites have yet been identified within the MPA, suggesting that these may have been destroyed by the intense fishing pressure in the period prior to MPA establishment in 2002. This has likely limited the recruitment of fish communities in the protected zone after 8 years of protection in Nha Trang MPA.

Generally, the temporal increase in fish density in the protected zone of the MPA was mainly due to small damselfishes, angelfishes, parrotfishes and larger triggerfishes and leatherjackets. These families have a short life cycle and fast growth, so they may recover faster than target and predatory fish such as groupers, sweetlips, emperors with larger size and long life cycles (Russ et al., 1998). The higher increase in the density of surgeonfishes and rabbitfishes in the unprotected zone is consistent with these families being non-target herbivores which can successfully inhabit degraded reefs.

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TEMPERATURE AND SALINITY VARIATIONS IN THE BAY LAGOON CURRENTS BASED ON OBSERVATION DATA OF THE PROJECT “SPINY LOBSTER AQUACULTURE DEVELOPMENT IN INDONESIA, VIETNAM AND AUSTRALIA”.

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The data are measured in Bay lagoon (Nha Trang, Viet Nam). There was a period of small tidal ranges, so the tidal range is only 65 cm. In the measurement period the weather characteristics were: cloudy, weak-rainy (in the evening); the

wind of north and north-eastern directions with the average velocity of 6 m/s. In the Bay lagoon the two layers of the circulation exist. In the upper (surface) layer, the water flows mainly out of the lagoon (to the sea); and in the lower (bottom) layer it flows into the lagoon (from the open area). The daily variability of the sea water temperature at the surface is available ($\Delta T = 0.64^oC$). With the depths (to the depth of 10 m) ΔT decreases. In the layer from 10 m to the bottom, ΔT is very small. The daily variability of the sea water salinity (ΔS) decreases from the surface to the depth of 10 m, and then increases to the bottom, and reaches the highest value at the bottom (ΔS = 0.45‰). There always exist two water layer in the area of the morning station with the border at the depth of about 10 m. This feature is performed by the tidal processes.

Keywords: temperature, salinity, tidal, current, monsoon, Bay lagoon, Nha Trang bay.

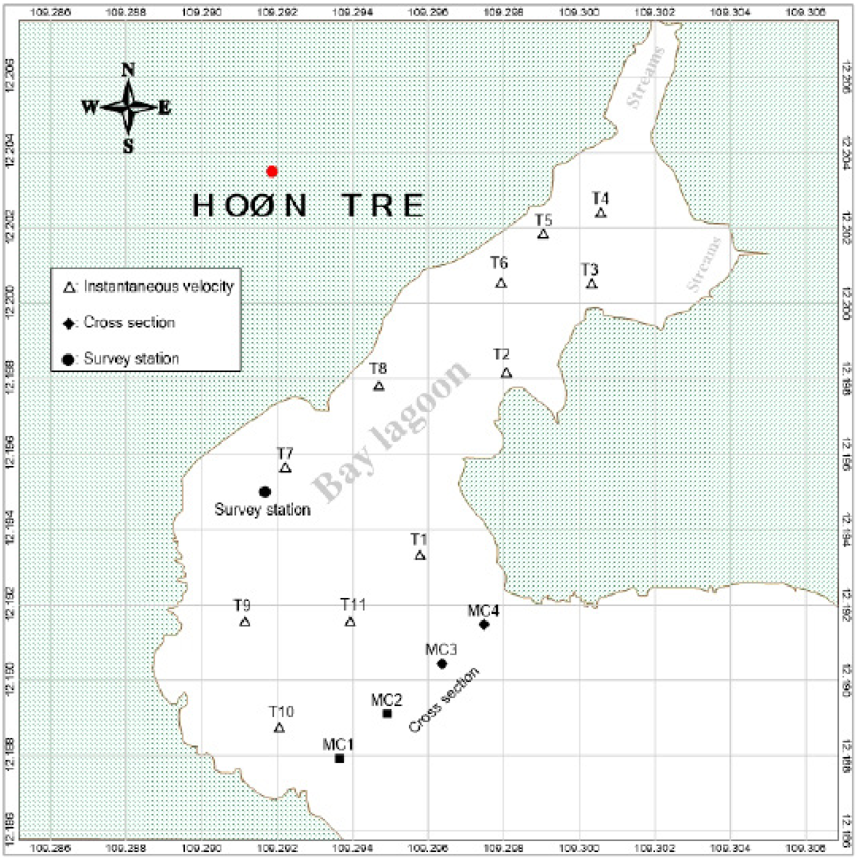

Fig. 1. Survey stations.

Introduction

These interactions between different factors and influences, the geographical structure, the runoff, the rainfall, the evaporation and the circulation result in a highly complicated the distribution of temperature and salinity in these waters and in strong variations. The presentations of the distribution of temperature and salinity are based on the observations of the northeast monsoon and the rainy season in November.

Characteristics of temperature, salinity and currents

Horizontal and vertical distribution of temperature.

At the depth of 1 m the sea water temperature changes from 25.94^{0}C to 27.41^{0}C, the average temperature is 26.67^{0}C, the highest temperature was measured at the lagoon mouth (stations MC1, MC2, MC3, MC4). The temperature change is 1.46^{o}C.

At the depth of 3 m the sea water temperature changes from 25.99^{0}C to 26.98^{0}C, the average temperature is 26.48^{0}C, distribution of temperature slightly decreases from the lagoon mouth to the lagoon top. The temperature change is 0.99^{o}C.

At the depth of 5 m the sea water temperature changes from 26.20^{0}C to 26.78^{0}C, the average temperature is 26.43^{0}C; distribution of temperature slightly decreases from the lagoon mouth to the lagoon top. The temperature change is 0.58^{o}C.

At the depth of 7 m the sea water temperature changes from 26.20^{0}C to 26.65^{0}C, the average temperature is 26.37^{0}C; distribution of temperature slightly decreases from the lagoon mouth to the lagoon top. The temperature change is 0.45^{o}C.

At the depth of 10 m the sea water temperature changes from 26.18^{0}C to 26.51^{0}C, the average temperature is 26.31^{0}C; distribution of temperature slightly decreases from the lagoon mouth to the lagoon top. The temperature change is not large and relatively homogeneous distributed. The temperature change is 0.33^{o}C.

The general distribution of the temperature from a depth 1 m to 10 m is conditioned by local effects of currents and tidal streams. Distribution of temperature slightly decreases from the lagoon mouth to stations T10, T11 and T1.

The vertical distribution of temperature slightly decreases from the surface to the bottom. The difference between depth of 1m and depth of 10m temperatures varies in the different lagoon and has an average of 0.36°C.

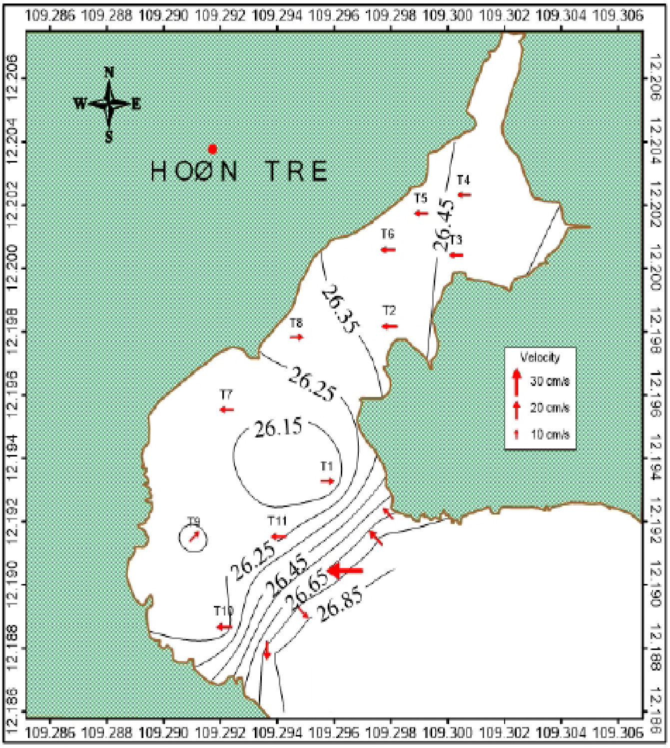

Fig. 2.1. Horizontal distribution of temperature at depth of 1 m.

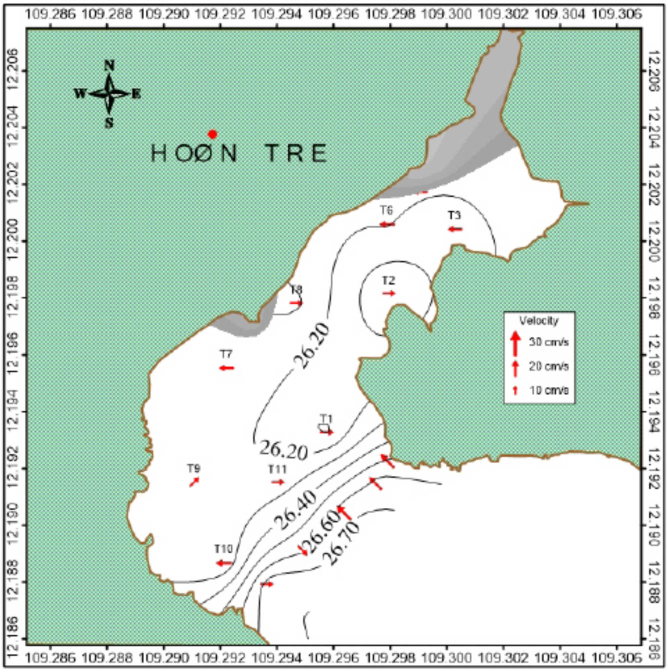

Fig. 2.2. Horizontal distribution of temperature at depth of 3 m.

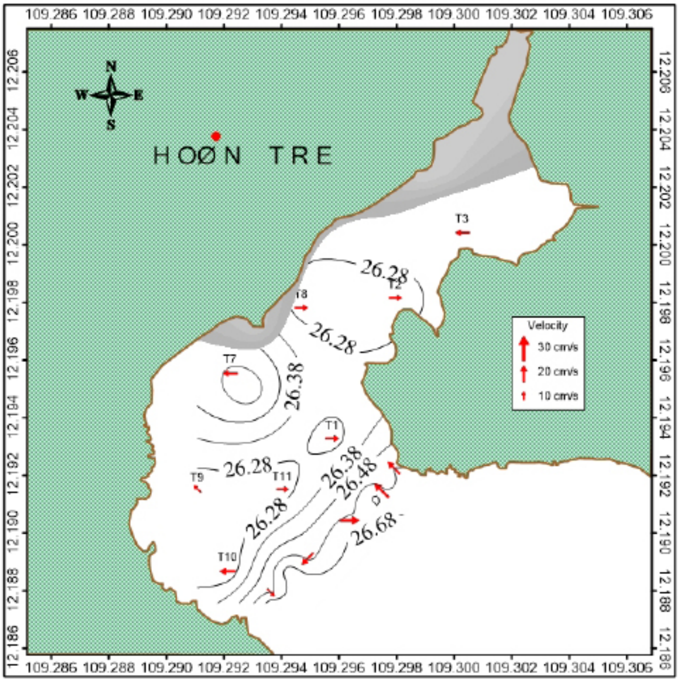

Fig. 2.3. Horizontal distribution of temperature at depth of 5 m.

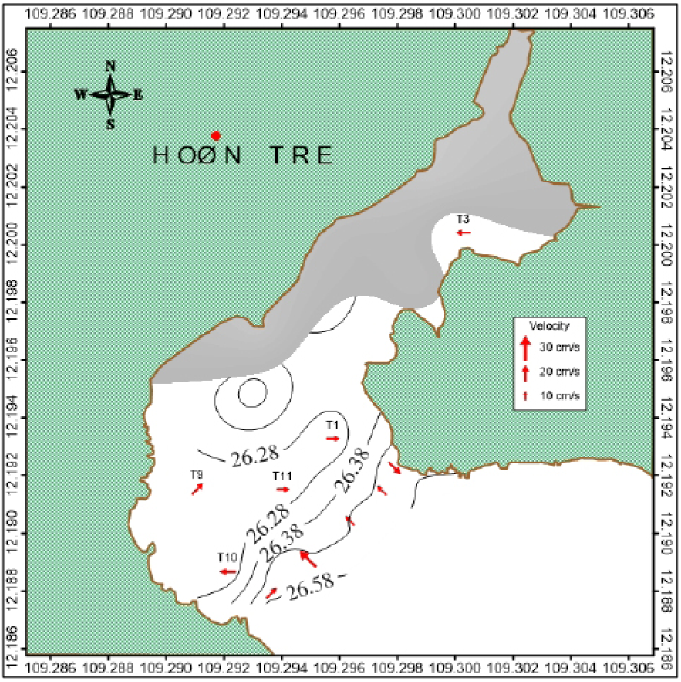

Fig. 2.4. Horizontal distribution of temperature at depth of 7 m.

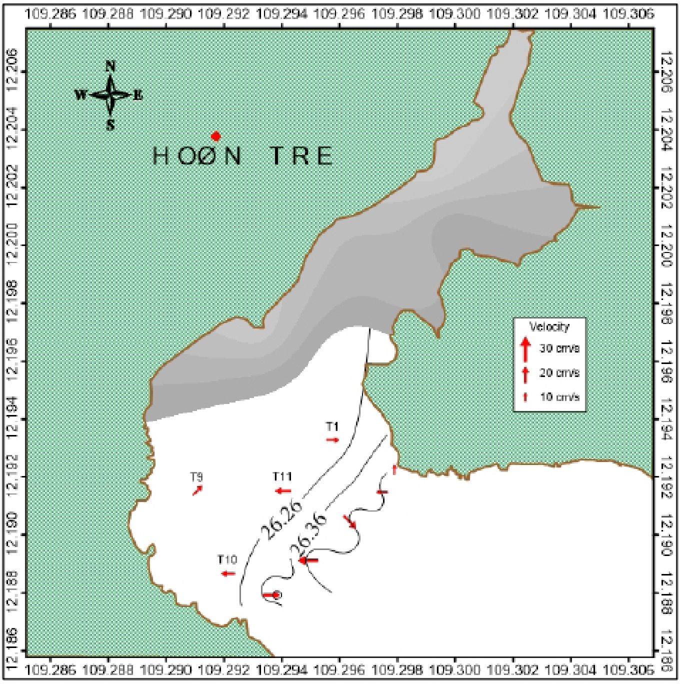

Fig. 2.5. Horizontal distribution of temperature at depth of 10 m.

At the the *tidal rise* and fall, distribution of temperature from the lagoon top to the lagoon mouth varies between 26.50^0C and 26.67^0C. The temperature change is not large.

Horizontal and vertical distribution of salinity.

At the depth of 1 m the sea water salinity changes from 32.01‰ to 32.93‰, the average salinity is 32.30‰. The salinity change is 0.92‰, and salinity increases from the lagoon mouth to stations T11 and T9.

At the depth of 3 m the sea water salinity changes from 32.02‰ to 33.23‰, the average salinity is 32.61‰. The salinity change is 1.59‰, and salinity increases from the lagoon mouth to stations T11 and T9.

At the depth of 5 m the sea water salinity changes from 32.04‰ to 33.27‰, the average salinity is 32.66‰. The salinity change is 1.23‰, and salinity increases from the lagoon mouth to stations T11 and T9. The variation of salinity is smaller than in the stations T7 and T9 and slightly higher than in the the lagoon top (stations T2 and T3).

At the depth of 7 m the sea water salinity changes from 32.07‰ to 33.29‰, the average salinity is 32.74‰. The salinity change is 1.22‰, and salinity increases from the lagoon mouth to stations T11 and T9.

At the depth of 10 m the sea water salinity changes from 32.14‰ to 33.34‰, the average salinity is 32.88‰. The salinity change is 1.20‰, and

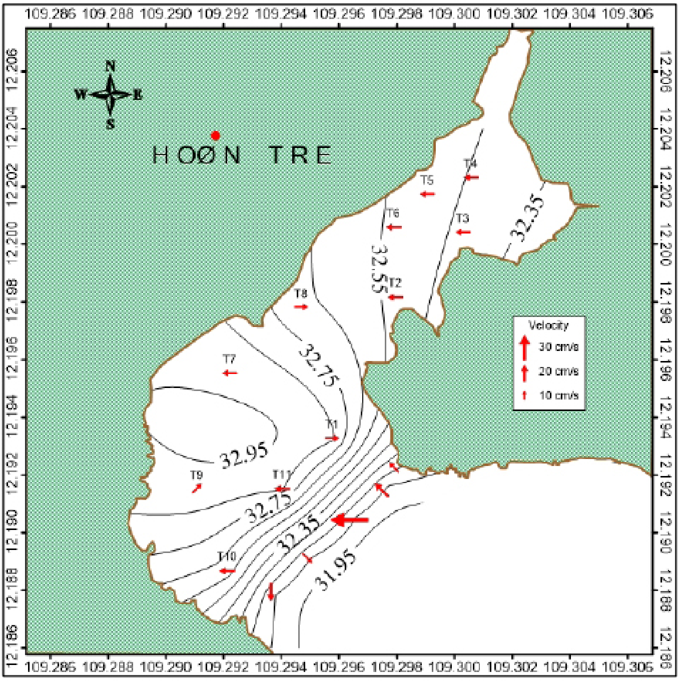

Fig. 2.6. Horizontal distribution of salinity at depth of 1 m.

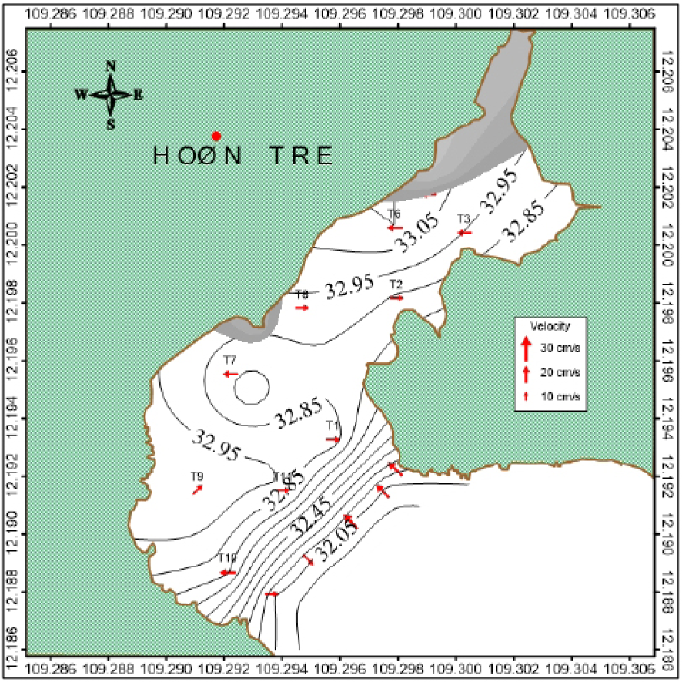

Fig. 2.7. Horizontal distribution of salinity at depth of 3 m.

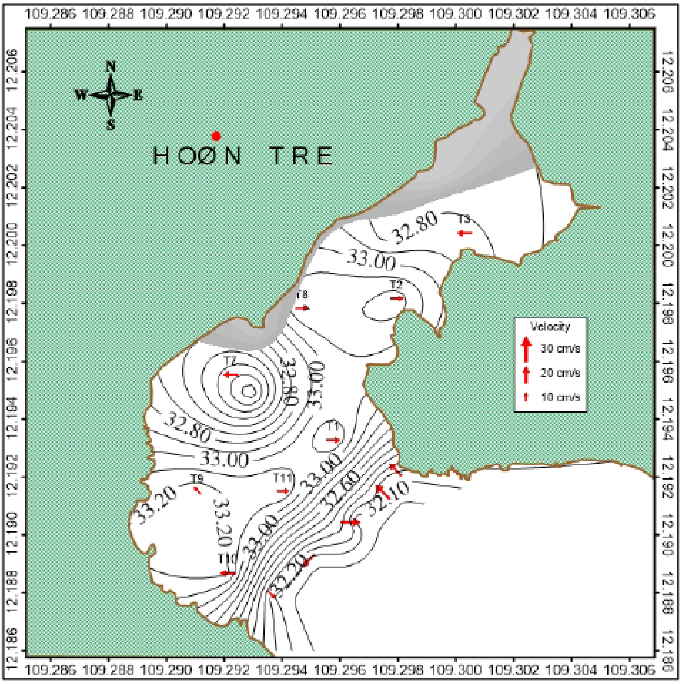

Fig. 2.8. Horizontal distribution of salinity at depth of 5 m.

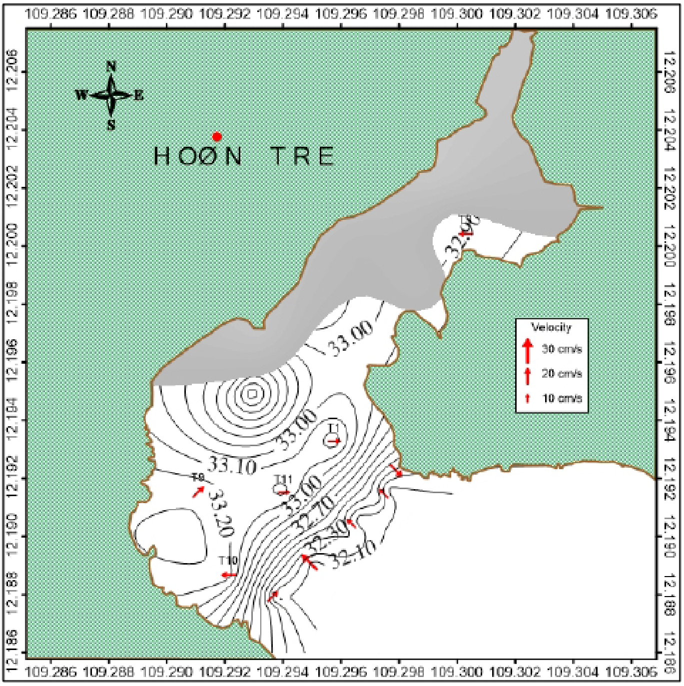

Fig. 2.9. Horizontal distribution of salinity at depth of 7 m.

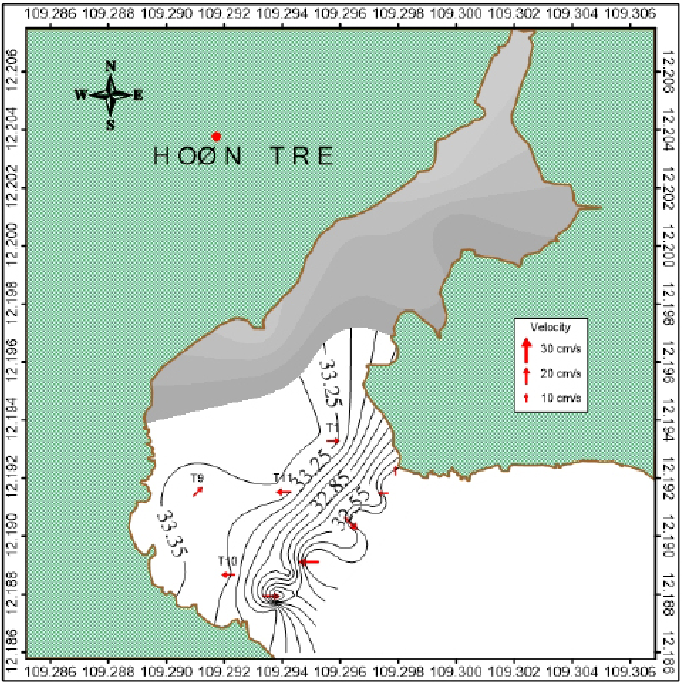

Fig. 2.10. Horizontal distribution of salinity at depth of 10 m.

salinity increases from the lagoon mouth to stations T11 and T9.

The vertical distribution of salinity slightly increases from the surface to the bottom.

In general, the salinity increase and temperature decrease along with depth variation from 1 m to bottom. Almost all these layers are not affected by the fresh water. Transport of water by local effects of currents and tidal streams are a major cause of short term variability in water column properties at Bay lagoon. The increase in water level at the maximum high tide was small over the period, corresponding to a small increase in salinity at maximum high tide.

Discussion

The variation of the temperature and the salinity have to be ascribed to the tidal rise and fall and the relatively small horizontal distribution variations of temperature and salinity are occured. Distribution of temperature slightly decreases from the lagoon mouth to the lagoon top, while salinity increases from the lagoon mouth to the lagoon top. The variation of the depth from 1 m to the bottom coincides with the salinity increasing and temperature decreasing. This is in accordance with the vertical distribution of temperature and salinity. Local effects of currents and tidal streams are a major cause of short term variability in water column properties at Bay lagoon.

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ANATOMY, AUTOTOMY AND REGENERATION OF DIGESTIVE SYSTEM IN *HIMEROMETRA ROBUSTIPINNA* (CRINOIDEA, ECHINODERMATA).

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Many groups of animals are able to discard parts of their bodies in a process, referred in the literature to as autotomy. This process is not taxon-specific and has evolved independently in different groups of animals. Thanks to autotomy animals can avoid death when attacked by predators and reduce the negative effects on their bodies. Usually, the autotomy is followed by complete regeneration of the discarded parts of the body. Autotomy and the subsequent regeneration of various body parts have been found in all classes of echinoderms (Emson, Wilkie, 1980). For instance, crinoids can discard and then regenerate various appendages, such as arms, cirri, pinnules (Candia Carnevali, 2006), as well as the entire calyx with internal organs (Amemiya, Oji, 1992). In several crinoid species, such as *Antedon rosaceus*, the internal organ complex (visceral mass), which located in the calyx, can be easily removed mechanically. Furthermore, individuals of *H. robustipinna* with missing or regenerating visceral masses have frequently been observed in nature (Clark, 1915; Meyer, 1988). According to Wilkie (2001), the easy removal of the visceral mass in several species of crinoids argues in favor of autotomy. The comatulid, *H. robustipinna* (Carpenter, 1881), is widely distributed in the Indian and Pacific Oceans (Clark, Rowe, 1971). The visceral mass in this species is easily separated from the calyx and can be rapidly regenerated (Meyer, 1988).

Anatomy

The body of *H. robustipinna* consists of the calyx, five branching arms, and aboral appendages, the cirri. The latter anchoring the animal on the substrate. The visceral mass is located on the calyx surface (Fig. 1A). Five branching ambulacral grooves descend from the arms, run along the surface of the visceral mass, and unite at the centrally located mouth (Fig. 1B). Numerous modified proximal pinnules occur at the base of the arms. These pinnules are longer and more heavily calcified than those located more distally. The proximal pinnules most likely play an important role in protecting the internal organs (Fig. 1A). When the animal is stimulated (*e.g.,* when the visceral mass is touched), the proximal pinnules descend and cover the oral side of the calyx. Therefore, the visceral mass is completely covered with a dense layer of calcified pinnules.

The visceral mass consists of helically twisted endocyclic digestive tube and centrally located axial organ (Fig. 1C). The slit-like mouth is located at the center of the visceral mass. Within the radii, the digestive tube yields five lateral outgrowths that extend to the base of the arms, thus giving the visceral mass a five-bladed shape. The digestive system ends with anal cone (Fig. 1B). At the tip of the cone, there is eccentrically located anal orifice. The digestive system is surrounded by narrow subintestinal coelom and is held in place by mesenteries (Fig. 1C). The aboral coelom separates the visceral mass from the skeletal elements of the calyx.

Autotomy

The separation of the internal organs in *H. robustipinna* due to mechanical action occurs relatively rapidly. Immediately after the visceral mass is gripped with the forceps, the proximal pinnules descended and form a dense cluster covering the calyx. If the visceral mass is held for 20–30 s, the animal raises its proximal pinnules. At this time, the visceral mass has separated from the calyx and can be easily removed (Fig. 1D, E). When the visceral mass is separated, the tegmen is ruptured at the interradii along the periphery of the calyx and at the base of the arms, where the lateral processes of the digestive system end. Internally, the separation of the visceral mass occurs under the aboral wall of the subintestinal coelom along the aboral coelom septa. Only the ruptured septa of the aboral coelom remain on the surface of the calyx after visceral mass autotomy (Fig. 1F).

Regeneration

Once the visceral mass is removed, coagulated coelomic fluid covers the calyx surface. Six hours after autotomy a loose cellular layer covers the

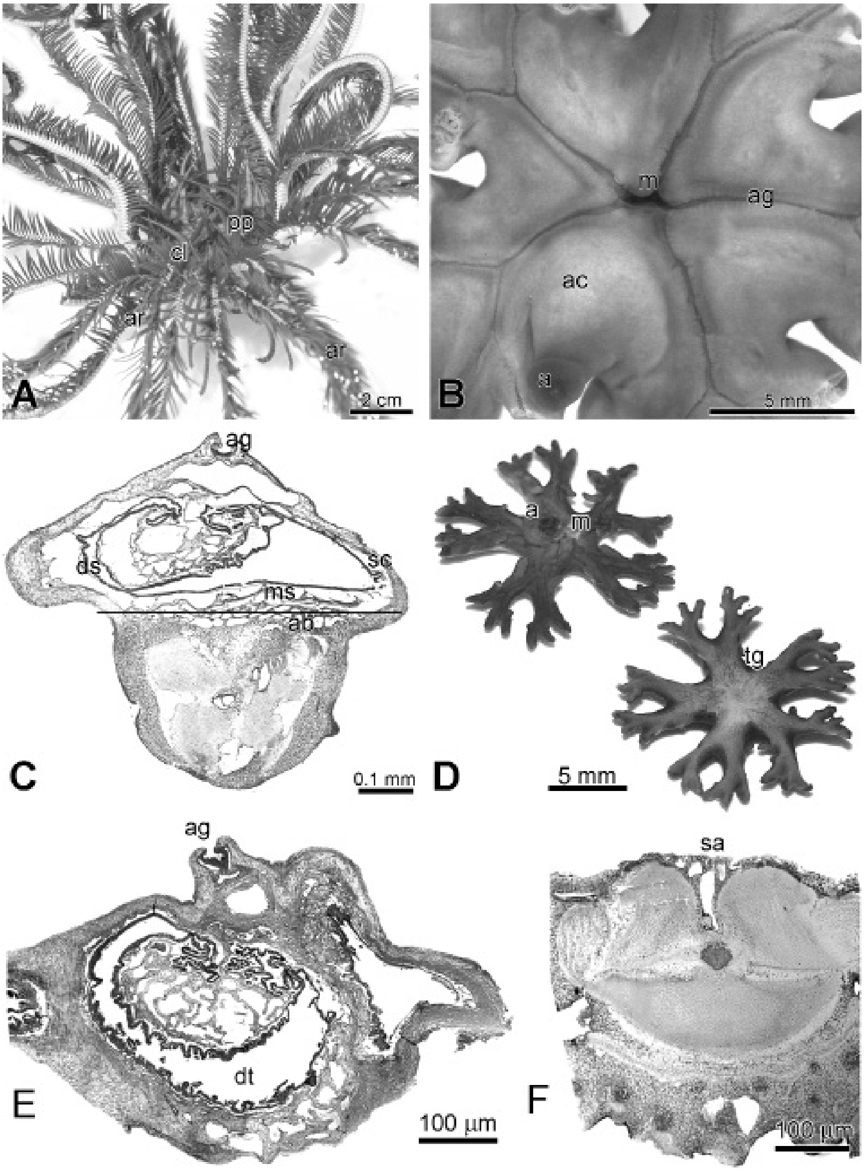

Fig. 1. Anatomy of the visceral mass and its autotomy. (A) A general view of the visceral mass. (B) Oral surface of the visceral mass. (C) A light microscopic section of the calyx and visceral mass. (D) The oral and aboral side of the visceral mass. (E) A light microscopic section of the visceral mass after autotomy. (F) A light microscopic section of the calyx after autotomy. ag – ambulacral grooves, ce – coelomic epithelium, cl – loose cellular layer, ec – enterocyte, ie – intestinal epithelium, in – primordium of the intestine, m – mouth, sa – aboral coelom septa, tg – primordium of the tegmen, uc – undifferentiated cells. The solid line in C indicates the autotomy plane.

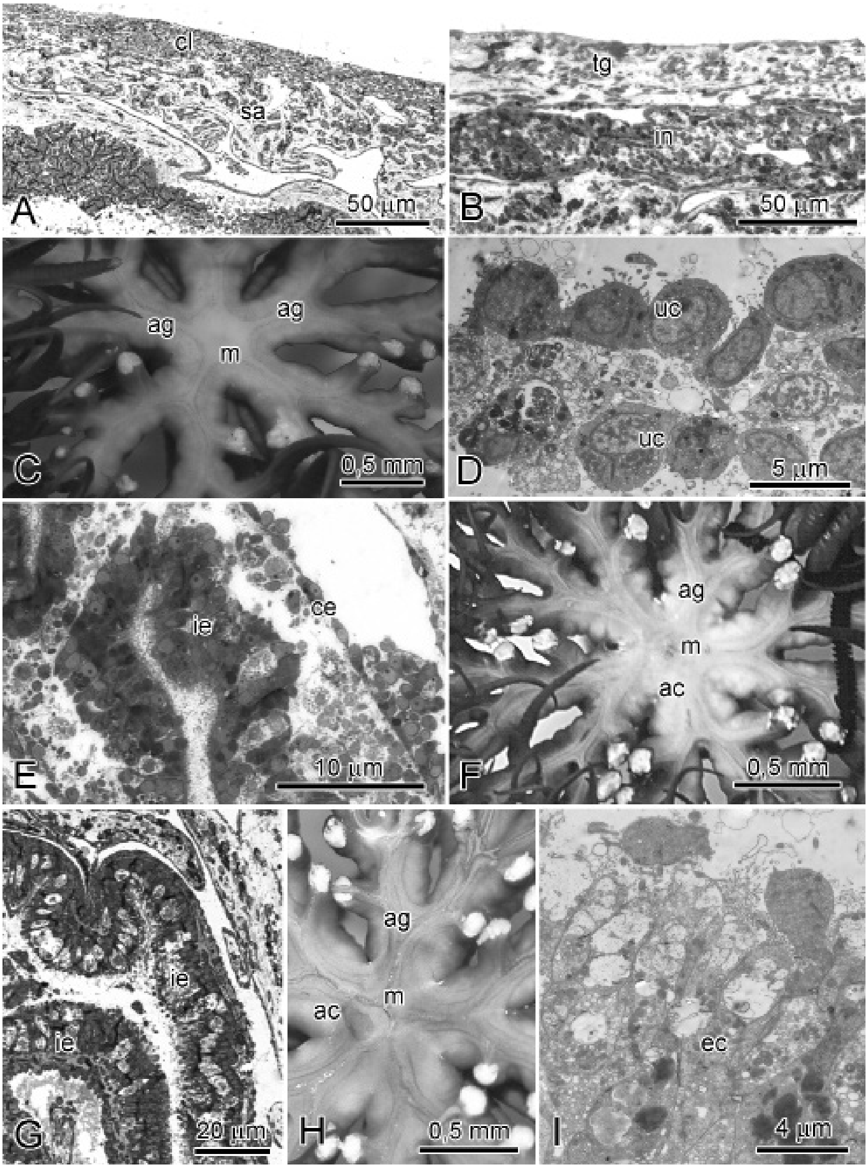

Fig. 2. Digestive system regeneration. (A) Cross-section of the calyx surface six hours after autotomy. (B) Cross-section of the calyx surface 18 hours after autotomy. (C) Oral side of the calyx on 24 hours after autotomy. (D) Groups of undifferentiated cells. (E) Intestinal epithelium on second day after autotomy. (F) Oral side of the calyx on second day after autotomy. (G) Intestinal epithelium on forth day after autotomy. (H) Oral side of the calyx on seventh day after autotomy. (I) Intestinal epithelium on forth day after autotomy. a – anal cone, ab – aboral coelomic cavities, ag – ambulacral grooves, ar – arm, cl – calyx, ds – digestive system, m – mouth, ms – subintestinal coelom, pp – proximal pinnules.

ruptured septa of the aboral coelom (Fig. 2A). This layer gets thicker and in 18 h after autotomy splits into two layers. Of these two layers the outer one is the primordium of the tegmen and the inner one the primordium of the intestine (Fig. 2B). In 24 h after damage, ambulacral grooves appear on the surface of the calyx. These grooves grow from the arms bases toward the center of the calyx (Fig. 2C). Groups of undifferentiated cells occur in the primordium of the intestine (Fig. 2D). Two days after autotomy, the ambulacral grooves reach the center of the calyx where the mouth will appear. In the developing intestine the progenitor cells form the intestinal epithelium (Fig. 2E). Besides, in the vicinity of developing intestine there are many cavities lined with coelomic epithelium. These cavities are developing subintestinal coelom. On the fourth day after damage, the ambulacral grooves unite with the mouth. Small anal cone develops in an interradius. Spiral intestine unites mouth with the anal cone (Fig. 2F). The intestinal epithelium has crypts (Fig. 2G). On the seventh day the animal has well-developed mouth and anal cone; the intenstinal epithelium has all cell types typical for the normal state.

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PROTOZOA IN BINH CANG, NHA TRANG

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Introduction

Protozoa is a group of organisms with size ranging from 5–500 μm in diameter, distributed widely in fresh and marine waters. This group has an important role in aquatic microbial food web as an essential linkage of energy transfer between picoplankton and microplankton (Pierce, Turner, 1992). However, there have been very few studies conducted on protozoa in Viet Nam and most of it was in fresh waters. In 1960, Truong Quoc Hoang has described 110 species with illustration of protozoa in Sai Gon – Cho Lon area. Shirota (1966) had reported a list and illustration of 226 species of protozoa but without description for both marine and fresh waters in South Viet Nam. This present studies are not only providing species composition of protozoa in Nha Trang Bay in different time of a year but also some quantitative data to have better understanding of their role in coastal microbial food web.

Materials and methods

Protozoa samples were collected in June, August and October of 2012 and March of 2013 at 3 stations is 9 (12.2589 ^{o}N, 109.2018 ^{o}E), 11A (12.2643 ^{o}N, 109.2637 ^{o}E) and 1B (12.275 ^{o}N, 109.325 ^{o}E) in Nha Trang bay, Khanh Hoa Province. 5-litter of quantitative samples were taken by Niskin sampling bottle at surface (0.5 m below surface) and near bottom layers at every station, fixed with Lugol solution and stored in cool and dark condition. Quantitative samples were then concentrated to 5 ml by filtering through a sieve with 20 µm meshsize. Individual protozoan was counted under stereomicroscope using Sedgewick Rafter counting chamber. Identification of protozoa was following Lee et al. (2000), Boltovskoy (1999), Shirota (1966), Chihara & Murano (1997).

Results and discussion

38 protozoa species were identified belong to 4 classes. Class Oligotrichea was the most diverse with 28 species, followed by Actinopoda with 8 species, and each class Ganuloreticulosea and Ciliophora had 1 species (Table 1). Number of species increasing from estuarine station (st. 9, 16 species) to middle bay station (st. 11A, 23 species) and to open water station (st. 1B, 26 species).

The average density of protozoa in study area was 30.968±30.194 inds/m^3. There was difference in protozoan densities among stations. The highest protozoan density was 38.563±33.088 inds/m^3 (station 11A) and the lowest was 12.025±4.508 inds/m^3 (station 9) (Fig. 1A). Protozoan density reached peak in March (48.120±25.961 inds/m^3) and the lowest was in September (12.240±15.646 inds/m^3) (Fig. 1B).

Protozoan average density at bottom layer (35.988±34.100 inds/m^3) was not different to the surface (27.622±28.357 inds/m^3) ($p > 0.05$; Kruskal – Wallis test) (Fig. 1C). Protozoan densities were also different in monsoon seasons (Fig. 1D). In northeast monsoon period, the density (47.957±32.279 inds/m^3) was ca. 4 times higher than in southwest monsoon period (13.980±15.536 inds/m^3)

Table 1. List of protozoa species found in Nha Tranf Bay in 2012 - 2013

Group	Species	9	11A	1B
	Actinopoda			
1	Acanthosphaera sp			+
2	Ascosphaera sp			+
3	Acanthospira sp			+
4	Dictyophimus sp	+	+	+
5	Sagenoscena sp			+
6	Sphaerastrum sp	+	+	
7	Sticholonche zanclea		+	
	Ciliophora			
1	Strombidium sp			+
	Granuloreticulosea			
1	Globigerinella sp			+
	Oligotrichea			
1	Acanthostomella sp	+	+	+
2	Amphorellopsis sp	+	+	
3	Codonella aspera		+	
4	Codonella sp		+	
5	Codonellopsis parva			+
6	Codonellopsis sp	+	+	+
7	Cyttarocylis sp	+	+	+
8	Epiplocylis sp			+
9	Eutintinnus sp	+	+	+
10	Favella sp		+	+
11	Rhabdonella spiralis	+		+
12	Rhabdonella amor		+	
13	Rhabdonella sp	+		+
14	Rhabdonellopsis apophysata	+	+	
15	Salpingella sp			+
16	Steestrupiella sp		+	+
17	Stenosemella sp		+	+
18	Stenosemella ventricosa		+	+
19	Tintinnopsis amphora		+	
20	Tintinnopsis complex	+	+	
21	Tintinnopsis cylindrica			+
22	Tintinnopsis mortensenii	+	+	
23	Tintinnopsis nordqvisti	+	+	+
24	Tintinnopsis radix	+	+	+
25	Tintinnopsis sp	+	+	+
26	Tintinnopsis tocantinensis	+	+	+
27	Xystonella treforti f. typica			+
	Total	16	23	26

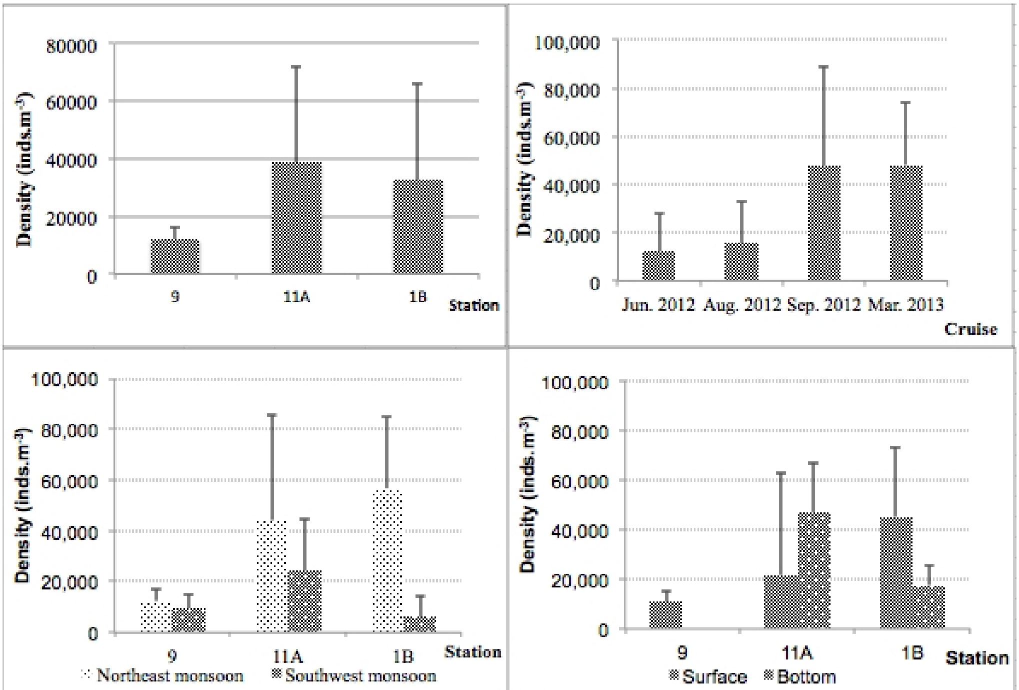

Fig. 1A **Fig. 1B**
Fig. 1C **Fig. 1D**

(z-test, p<0.05).

Acknowledgments

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FAUNA OF THE POLYCHAETA IN THE AMUR ESTUARY

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The Amur River is one of the largest in basin area on the Pacific Asian coast and one of the world's ten longest rivers. As a consequence of the unique geographical position at the junction of the continent and very large Sakhalin Island, the river's flow discharge occurs to the north and south of the river mouth into the Sea of Japan and the Sea of Okhotsk with greatly differing hydrological characteristics Therefore, the Amur estuary influenced by waters that originated from the river and the seas of Japan and Okhotsk has a complex hydrological and hydrochemical regime with high gradients of many parameters. The Amur basin is situated on the territory of three countries – Russia (53% of the basin area), China (45%), and Mongolia (2%). Due to the growth of population and industrial production in the northern provinces of China, the anthropogenic pressure on the Amur River has dramatically increased in the last time. (Lizova, 2007) Nevertheless, despite its important role in estuarine ecosystems, the fauna and distribution of macrobenthic animals, including polychaeta, as one of the dominant groups in benthic communities, are as yet poorly studied in the Amur Estuary. The polychaetes diversity is also useful as bio-indicators of pollutions marine waters.

Macrobenthos was sampled by expeditions in summer from 2005. A total of 35 stations were performed at depths from 1.5 to 54 m.

In the region studied, we found 61 species of polychaetes belonging to 26 families. Most of them were found in Sakhalin Gulf. Relatively many species (19) were recorded in the northern Tatar Strait. During the whole period of study, polychaetes were found at almost all stations in the different areas of the Amur Estuary. The seaward parts of the estuary had a typically marine fauna of polychaetes. The Amursky Liman fauna is markedly impoverished and is mostly represented by only six species *Heteromastus filiformis*, *Eteone bistriata*, *Laonice cirrata*, *Nereis zonata*, *Spiophanes sp.* and *Marencelleria arctia* were found.

The polychaetes of the Amur Estuary belong to two ecological marine animal complexes. The first not numerous group of brackish-water species of the estuarine-lagoonal complex occurs in the strongly freshened and relatively shallow-water central part of the estuary, including almost the entire Amursky Liman. The second ecological group of strictly marine and marine eurytopic species inhabits the deeper northern and southern parts of the estuary, including Sakhalin Gulf and the northern Tatar Strait, where riverine water has a marked effect on superficial water.

Khlebovitch (1986), in his scheme of zoogeographical division of brackish waters of Russia primarily based on the distribution of brackish-water fauna, classified Amursky Liman as a transition area between the Holarctic and Sino-Indian regions. The entire Amursky Liman serves the role of a specific refugium for many warm-water species of bottom animals of the northwestern Pacific (Kamenev, Nekrasov. As is the case with a number of bivalve molluscs, Amursky Liman is the northern distribution limit and frequently an isolated part of the species rage of such warm-water species as the *Chaetozone columbiana*, *Cirriformia tentaculata* and *Heteromastus filiformis*. It appears that anomalously warm water in Amursky Liman, as compared to the rest of this cold region, as a result of intensive warming-up of its shallow-water zone during summer and the input of warm Amur River water from the south of the continent favors the conservation of the remnants of warm-loving fauna.

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SOFT CORALS (OCTOCORALLIA:ALCYONACEA) FROM THE REEF OFF MARIBAGO, MACTAN ISLAND,CEBU, PHILIPPINES

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In the Philippines compared to scleractinian corals and in spite of it being in the Coral Triangle, studies on soft corals particularly on their taxonomy and systematics are limited. The last comprehensive study on soft coral taxonomy was made by Roxas in 1933, hence, the conduct of this study gives newest data on the soft corals of Philippines.

Collections were made on the fringing reef fronting (Fig.1) the University of San Carlos Marine Research Station in Maribago, Mactan Island, Cebu, Philippines by SCUBA and skin diving at depth ranging from 3–15m.

Prior to collection, each species of soft coral colony was photographed *in situ* and from each colony, two 2–3cm fragments were clipped for sclerite examination. The collected fragments were placed in containers with seawater and narcotized by adding magnesium sulfate solution at an interval of 15–20min until the specimens were unresponsive to touch. They were then transferred to glass containers with sea water, fixed with 37% formalin and after 24 h rinsed with freshwater then transferred to 90% ethyl alcohol.

Sclerites were obtained by dissolving the tissues in 5.25% sodium hypochlorite and then added with hydrogen peroxide. Sclerites were pipetted and placed on a slide and examined under a stereoscope. Identification were based on the following morphological features; colony morphology and coloration, number of polyp tentacles and types of sclerites of varying shapes (rosette, curved, corpuscle-like platelet, prickly rods, clubs, spindles, sticks, calicular thorn scales and collarette) and sizes.

The works of Fabricius and Alderslade (2001) and Dautova and Savinkin

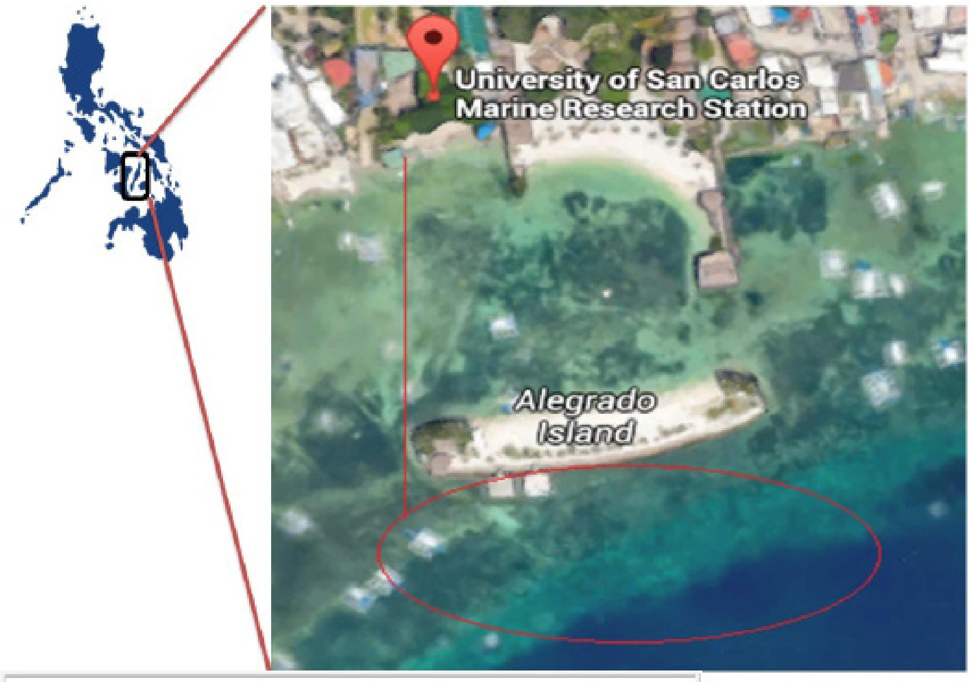

Fig. 1. Sampling site with coordinates 10^{0}17'04.2"N, 124^{0}00'03.7"E to 10^{0}17'04.0"N, 124^{0} 00'09.3"E.

(2013) were referred to in the identification. The examined materials yielded 19 species in eight genera and six families (Table 1).

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Table 1. Synoptic list of the species of soft corals in six families of order Alcyonacea from the fringing reef fronting the University of San Carlos Marine Research Station, Maribago, Mactan Island, Cebu, Philippines
Classification
Family Xeniidae Verrill, 1864
Genus *Xenia* Lamarck, 1816
Xenia sp.1 (Fig.1) Commonly known as “pulse corals”, a thick stalk bears the colony. Tentacles are long, with a non-retractile polyp.
Xenia sp.2 (Fig.1g-h) A small colony having a thick common tissue with slightly contractile polyps that pulsate.
Xenia sp.3 (Fig.1i-j) Colony cylindrical with polyps that do not pulsate. The tentacles are very thin and have a rich brown color.
Xenia sp.4 (Fig.1k-l) A clavate colony with white pulsating polyps and has conspicuous number of pinnules.
Genus *Heteroxenia* Koelliker, 1874

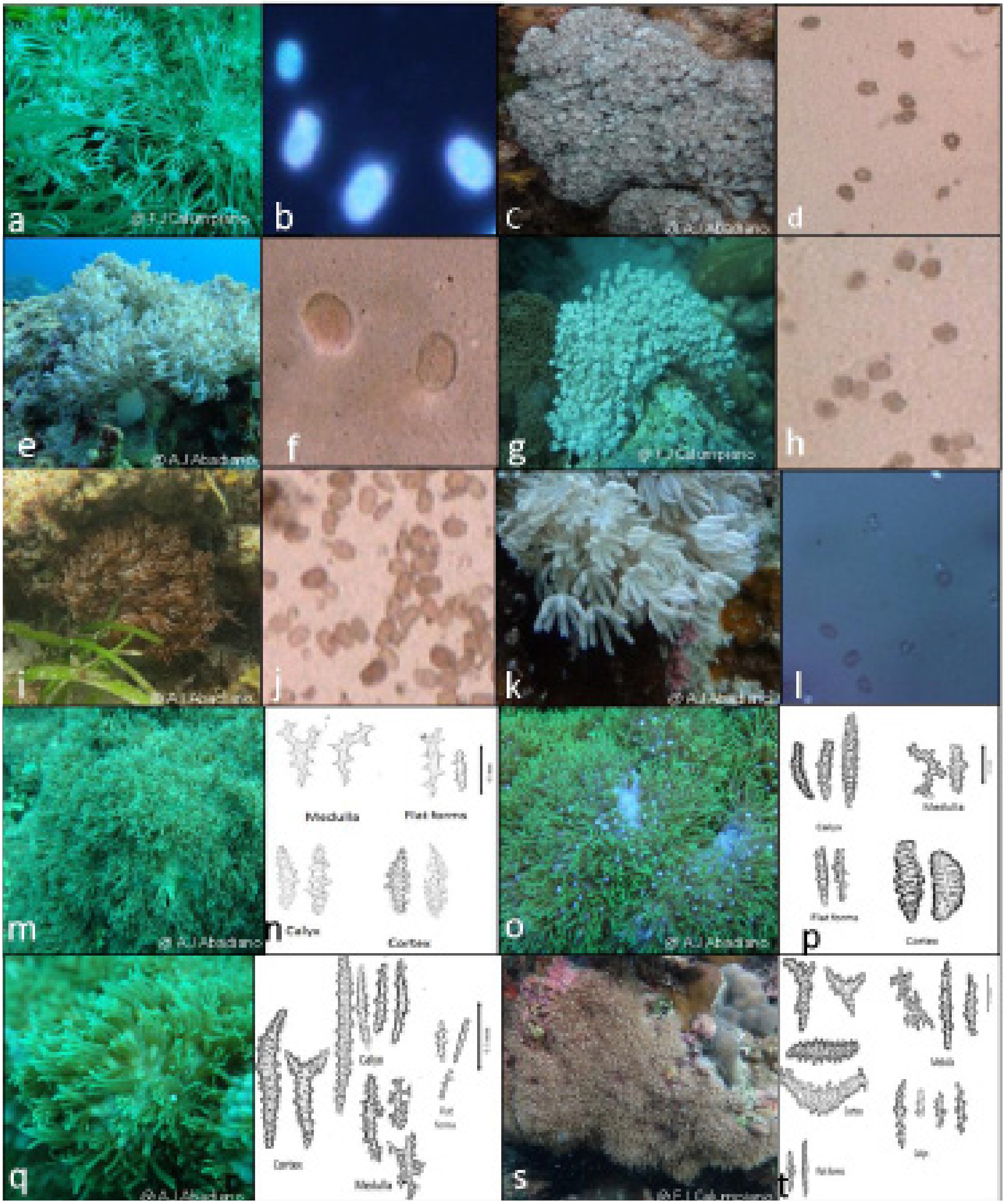
Heteroxenia sp.1 (Fig. 1c-d) The tentacles are relatively long, with short pinnules. Polyps pulsate (Fig.1 a-b).
Heteroxenia sp.2 (Fig.1e-f) The colony is cylindrical with white autozooids that are slightly contractile. Polyps do not pulsate.
Family Briareidae Gray, 1859
Genus *Briareum* Blainville1830
Briareum sp.1 (Fig.1m-n) This species forms thin encrusting membranous sheets. Polyps are brown with relatively long and thin tentacles that have reduced pinnules.
Briareum sp.2 (Figure 1, o-p) Commonly known to aquarists as "green star polyps" because of their small, yellow or green tentacles attached to a red-violet encrusting sheet with small cluster of knobs.
Briareum sp.3 (Fig.1q-r) Membranous sheets are white that have finger like lobes bearing the polyps. Polyps are yellow-brown.
Briareum sp.4 (Fig.1s-t) Species form thick encrusting membranous sheets that bear the pink polyps with protruding white oral disks.
Family Tubiporidae Ehrenberg, 1828
Genus *Tubipora* Linnaeus, 1758

Tubipora musica Linnaeus, 1758 (Fig. 2a-c) Widely known for its vertical, red, and calcareous tubes that are interconnected, each tube bears individual polyps which are monomorphic, retractile, and may vary. Colonies are relatively large and hemispherical. Sclerites are minute corpuscle-like and small, irregular, prickly rods, that either branched or fused into small branching clumps. Commonly known as «organ pipe coral».
Family Nephtheidae Gray, 1862
Genus *Lemnalia* Gray, 1868
Lemnalia sp.1 (Fig. 2 d-e) Slender colonies with conspicuous bare stalks and major branches. Have numerous short minor branches. Contractile polyps shrink to small domes when deflated.
Lemnalia sp.2 (Fig. 2f-g) Colonies are arborescent with smooth slender stalks with relatively long and thin twigs. Contractile polyps shrink into cylinders when deflated.
Family Alcyoniidae Lamouroux, 1812
Genus *Lobophytum* von Marenzeller, 1866
Lobophytum sp. (Fig. 2h-i) Colonies are encrusting and have long, unbranched slender lobes.
Genus *Sinularia* May 1898
Sinularia sp.1 (Fig. 2j-k) Colonies are encrusting and have branching irregular lobes.
Sinularia sp.2 (Fig. 2l-m) Colonies are encrusting; arborescent growth form with lobes having numerous finger-like lobules.

Sinularia sp.3 (Fig. 2n-o) Colonies are encrusting; arborescent, multi-stalked and lobes bear secondary lobules.
Family Plexauridae Gray 1859
Genus *Villogorgia* Duchassaing and Michelotti 1860
Villogorgia sp. (Fig. 2 r-s) Highly branched fan with thin branchlets. Polyps are retractile into prominent calyces.

Fig. 2. (p.167) (**a-b**) *Heteroxenia sp. 1* (**a**) entire colony (**b**)corpuscle-like spheroid from polyp, =0.02–0.3 mm (**c-d**) *Heteroxenia sp. 2* (**c**) entire colony (**d**) Platelets from polyp, =0.02–0.1 mm (**e-f**) *Xenia sp 1* (**e**) entire colony (**f**) Platelets from polyp, =0.01–0.1 mm (**g-h**) *Xenia sp. 2* (**g**) entire colony (**h**) Platelets from polyp, =0.02–0.1 mm (**i-j**) *Xenia sp. 3* (**i**) entire colony (**j**) corpuscle-like spheroid from polyp, =0.02–0.2 mm (**k-l**) *Xenia sp. 4* (**k**) entire colony (**l**) Platelets from polyp, =0.01–0.1 mm (**m-n**) *Briareum sp. 1* (**m**) entire colony (**n**) Sclerites from medulla, calyx and cortex (**o-p**) *Briareum sp. 2* (**o**) entire colony (**p**) Sclerites from medulla, calyx and cortex (**q-r**) *Briareum sp. 3* (**q**) protruding branch of the colony (**r**) Sclerites from medulla, cortex and calyx (**s-t**) *Briareum sp. 4* (**s**) entire colony (**t**) Sclerites from medulla, calyx and cortex.

Fig. 3. (p. 168) (**a-c**) *Tubipora musica* (**a**) entire colony (**b**) Sclerites from the base of polyp (**c**) Platelets from polyp, =0.04–0.06 mm (**d-e**) *Lemnalia sp. 1* (**d**) entire colony (**e**) spindle-shaped sclerites from twigs (**f-g**) *Lemnalia sp.2* (**f**) entire colony (**g**) Sclerites from polyps and stalks (**h-i**) *Lobophytum sp.* (**h**) entire colony (**i**) Sclerites from the lobe and polyp (**j-k**) *Sinularia sp. 1* (**j**) entire colony (**k**) Sclerites from interior and surface (**l-m**) *Sinularia sp. 2* (**l**) entire colony (**m**) sclerites from interior and surface (**n-o**) *Sinularia sp. 3* (**n**) entire colony (**o**) sclerites from interior and surface (**p-q**) *Sinularia sp. 4* (**p**) entire colony (**q**) sclerites from surface and interior (**r-s**) *Villogorgia sp.* (**r**) entire colony (**s**) sclerites from polyp, tentacle, calyx and surface.


a
b
c
d
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l
m
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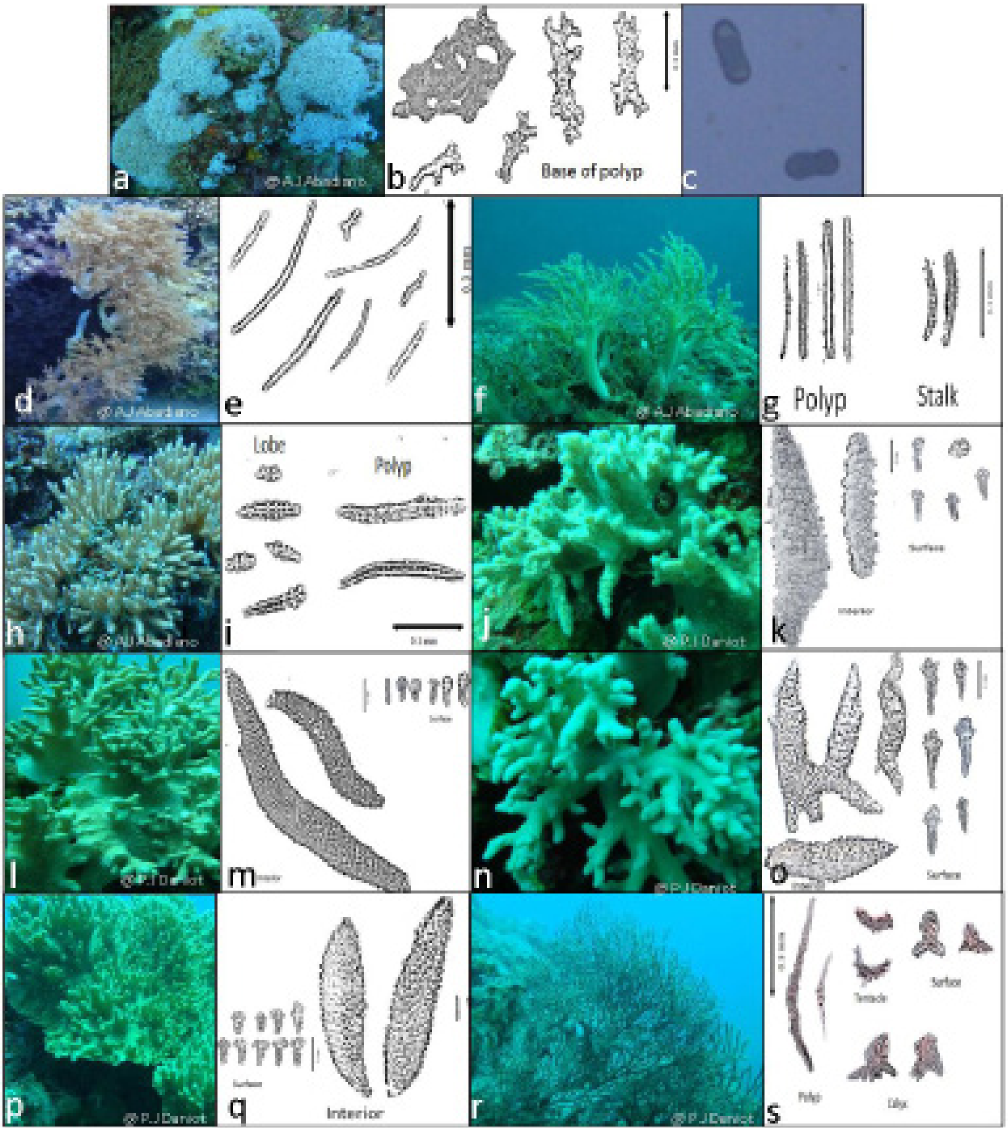
p
q
s
t
Medulla
Calyx
Cortex


a
@ A.J Abadiano
b
Base of polyp
c
d
@ A.J Abadiano
e
f
@ A.J Abadiano
g
Polyp
Stalk
h
@ A.J Abadiano
Lobe
Polyp
i
j
@ P.J Daniot
k
l
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m
n
o
p
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q
Interior
r
@ P.J Daniot
s

MODEL OF THE WATER CIRCULATION IN THE BINH CANG – NHA TRANG COAST

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In this paper, we present the results of using the numerical modeling to input to the solution of the problems of sea dynamic for shallow water of the region. The results obtained show that shallow water flow is one of some essential determining factor defining the speed and direction of flow in the area.

At the flood-tide, the current field vector had been occurred, which was of different direction and speed in the different regions. When flood-tide is following after high tidal, at that times the difference between regions is very clear both by speed and direction – there is region flow according to East – West direction, again there is region flow according to West – North direction, there is region flow according to East – South direction, there is region flow to 30–50 cm/s speed. When tide tends to weakening, then speed of the flow also decreasing and it starts also to change the direction until flood-tide next to low tidal. Then water offshore become lower than water in bay, then the water in bay will go down quickly cross between Hon Do and Hon Tre island section. It shows that at those times, in the study area, vector current field will be also divided into regions by speed and direction very distinctly (the same as flood-tide next to high tidal case but the opposite direction).

Keywords: shallow water, modelling, Binh Cang – Nha Trang coast.

Introduction

In coastal region, sea current is affected by wind, therefore water mass is transporting from nearshore to offshore or opposite. Then, the water level increasing/decreasing will occur in coastal region and the tilt of surface will be caused by gradient pressure which also creates the geostrophic current. Further, the sea current has also affected by spring, river, etc. In addition, sea currents are affected by the external forces like waves, tidal current, alongshore current, high slope or roundabout of bottom topography, etc. Generally, sea current in shallow water appears to be a specific object to surveying and studying, in fact it is very generic. As the overall of sea current' characteristics in shallow water with vertical scale is a much smaller than horizontal scale, so 2-dimensional model has a very important meaning in studied sea current, especially for the study of coastal currents in the shallow water and they can reflect relatively good flow system in this region.

Background theory

1. Governing equations 2-D computational models include conservation momentum equations and continuity equation following:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-fv=-\frac{1}{\rho_0}\frac{\partial p_a}{\partial x}-g\frac{\partial \zeta}{\partial x}+\frac{\left(\tau_x^s-\tau_x^b\right)}{\rho_0(H+\zeta)}+A_\lambda \Delta u \qquad (1)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+fu=-\frac{1}{\rho_0}\frac{\partial p_a}{\partial y}-g\frac{\partial \zeta}{\partial y}+\frac{\left(\tau_y^s-\tau_y^b\right)}{\rho_0(H+\zeta)}+A_\lambda \Delta v \qquad (2)$$

$$\frac{\partial \zeta}{\partial t}+u\frac{\partial (H+\zeta)}{\partial x}+v\frac{\partial (H+\zeta)}{\partial y}=0 \qquad (3)$$

where *u, v* (cm/s) is velocity component in latitude and longitude, respectively; *H* (m) – depth of the average sea level from standard surface go down to the bottom; ζ (m) – fluctuating average sea level from standard surface go up; f – Coriolis parameter with f = $2\Omega\sin\varphi$, (Ω the Earth's rotation and φ is latitude); ρ_0 – Average density ($\rho_0 \approx$ 1026 kg/m^3).; A_ℓ – the coefficient of friction in horizontal (m^2/s $A_\ell \approx$ 11 m^2 / s). τ_x^s, τ_x^b, τ_y^s, τ_y^b (N/cm^2) wind stress components on surface and bottom.

Wind stress components have calculated by the formula:

$$\tau_x^s = C_{10}\,\rho_a|W|W_x, \quad \tau_x^s = C_{10}\,\rho_a|W|W_y; \quad \text{where } |W| = \sqrt{W_x^2+W_y^2}; \qquad (4)$$

C_{10} has calculated by Garrantt formula following:

$$C_{10} = (0.75 + 0.0067 \times 10^{-2}\,W) \times 10^{-3} \qquad (5)$$

Stress friction in bottom determined by flows which used quadratic law

$$\tau_{bx} = \rho k u_b\sqrt{u_b^2+v_b^2},\ \tau_{by} = \rho k v_b\sqrt{u_b^2+v_b^2} \qquad (6)$$

where, u_b and v_b are velocity components in x and y direction, respectively; k is coefficient of friction in bottom, not unit.

2. Initial and boundary conditions

2.1. Initial conditions

Assume, at begin time, still water, therefore:

(x, y, 0) = v (x, y, 0) = ζ (x, y, 0) = 0

2.2. Onshore open boundary conditions

Used formula to calculate fluctuation of sea level at open boundary:

$$\zeta_i = H_0 + \sum_{i=1}^{N} H_i F_i \cos[q_i t + \varphi_i + p_i(t)] \qquad \textit{(7)}$$

where H_0 – average sea level at each measured point; N – wave number components considered; H_i (cm) – harmonic constant value of average amplitude waves, depending on local physic condition; φ_i (degree) harmonious phase value, depending on astronomic condition; q_i (h^{-1}) frequency of i wave components and it's constant; F_i – factor which depends on astronomic conditions; Pi (t) – azimuthal angle of wave, depend on local physic condition.

2.3. Offshore open boundary condition

– at river mouth:

$$V\Big|_{CuaSong} = \frac{Q}{D} \qquad \textit{(8)}$$

where **Q** discharge, D – area of cross-section.

2.4. Hard lateral boundary conditions

At hard boundary (coastline, island, dune, etc.) used non-infiltration condition. Non-infiltration following:

$$\vec{V}.\vec{n}\Big|_{G1} = 0 \qquad \textit{(9)}$$

where $.\vec{n}$ means normal vector.

Methodology

To solution equations ***(1)***, (***2)***, (***3)*** with boundary conditions ***(6)***, ***(7)***, ***(8)***, ***(9)***, we used finite difference method to solution equations and used explicit method which has discretized by upstream and downstream scheme for *u* component:

$$\frac{\partial u}{\partial t} \approx \frac{u(x,y,t+3) - u(x,y,t)}{2\Delta t} \quad ; \qquad \frac{\partial u}{\partial x} \approx \frac{1}{4}\frac{u(x+2,y,t) - u(x-2,y,t)}{\Delta x}$$

$$\frac{\partial u}{\partial y} \approx \frac{1}{4}\frac{u(x,y+2,t) - u(x,y-2,t)}{\Delta y} \quad ; \quad \frac{\partial^2 u}{\partial x^2} \approx \frac{u(x+2,y,t) - 2u(x,y) + u(x-2,y,t)}{16\Delta x^2}$$

$$\frac{\partial^2 u}{\partial y^2} \approx \frac{u(x,y+2,t) - 2u(x,y) + u(x,y-2,t)}{16\Delta y^2} \qquad \textbf{\textit{(10)}}$$

Same way with *v* component (more details in Phan Quang et al., 1998; Pham Xuan Duong, 2001; Dronkers, 1964; Durran, 1999)

Put this approximation into ***(1)***, ***(2)***, we have calculated equations for *u* and *v* u (x, y, t+2), v(x, y, t+2) and the final equations:

For *u* component:

$$u(x,y,t+2) = u(x,y,t) - \frac{1}{2}\frac{\Delta t}{\Delta x}u(x,y,t)[u(x+2,y,t) - u(x-2,y,t)] - \frac{1}{8}\frac{\Delta t}{\Delta y}[v(x+1,y+1,t) +$$

$$v(x+1,y,t) + v(x-1,y+1,t) + v(x-1,y-1,t)][u(x,y+2,t) - u(x,y-2,t)] + \frac{1}{2}f\Delta t[v(x+1,y+1,t) +$$

$$v(x+1,y-1,t) + v(x-1,y+1,t) + v(x-1,y-1,t)] - \frac{1}{\rho_0(x,y)}\frac{\Delta t}{\Delta x}[p_a(x+1,y,t+2) + p_a(x-1,y,t+2)] -$$

$$g\frac{\Delta t}{\Delta x}[\zeta(x+1,y-1,t+1) + \zeta(x-1,y,t+1)] - \frac{\Delta t}{\rho_0(x,y)}\left[\tau_x^s(x,y,t) - \tau_x^b(x,y,t)\right]\left[H(x,y) + \frac{\zeta(x-1,y,t+1)}{2}\right.$$

$$\left. + \frac{\zeta(x+1,y,t+1)}{2}\right]^{-1} + A_\lambda(x,y)\left[\frac{u(x+2,y,t) - 2u(x,y) + u(x-2,y,t)}{16\Delta x^2} +\right.$$

$$\left.\frac{u(x,y+2,t) - 2u(x,y) + u(x,y-2,t)}{16\Delta y^2}\right] \qquad \textbf{\textit{(11)}}$$

For v componet:

$$v(x,y,t+2) = v(x,y,t) - \frac{\Delta t}{\Delta x}u(x,y,t+2)\frac{v(x+2,y,t) - v(x-2,y,t)}{2} - \frac{\Delta t}{\Delta y}\left[\frac{v(x+1,y+1,t)}{8} +\right.$$

$$\left.\frac{v(x+1,y-1,t) + v(x-1,y+1,t) + v(x-1,y-1,t)}{8}\right][v(x,y+2,t) - v(x,y-2,t)] +$$

$$f\Delta t\frac{u(x-1,y-1,t)+u(x-1,y+1,t)+u(x+1,y+1,t)+u(x+1,y-1,t)}{2}-$$

$$\frac{1}{\rho_0(x,y)}\frac{\Delta t}{\Delta x}\left[p_a(x,y+1,t)+p_a(x,y-1,t)\right]-g\frac{\Delta t}{\Delta x}\left[\zeta(x-1,y-1,t+1)+\zeta(x-1,y,t+1)\right]-$$

$$\frac{\Delta t}{\rho_0(x,y)}\left[\tau_x^s(x,y,t)-\tau_x^b(x,y,t)\right]\left[H(x,y)+\frac{\zeta(x-1,y,t+1)+\zeta(x+1,y,t+1)}{2}\right]^{-1}+A_\lambda(x,y)\times$$

$$\left[\frac{v(x+2,y,t)-2v(x,y,t)+v(x-2,y,t)}{16\Delta x^2}+\frac{v(x,y+2,t)-2v(x,y,t)+v(x,y-2,t)}{16\Delta y^2}\right] \qquad \textbf{\textit{(12)}}$$

Calculating ζ , based on continuous equation ***(3)*** and have considered the change in x and y axis following:

$$2\Delta x\left[\frac{\partial}{\partial x}(H+\zeta)u\right]_{(x+1,y,t+1)}=H(x+1,y)\left[u(x+2,y,t+2)-u(x,y,t+2)\right]+\frac{1}{2}\{[\zeta(x+3,y,t+1)+$$

$$\zeta(x+1,y,t+1)]u(x+2,y,t+2)-[\zeta(x+1,y,t+1)+\zeta(x-1,y,t+1)]u(x,y,t+2)\}$$

(13)

With a same way for y axis (more details in [2, 3, and 4]), changing that equality into continuous equation (3), we have received a new equation $\zeta(x+1, y, t+3)$ following:

$$\zeta(x+1,y,t+3)=\zeta(x+1,y,t+1)-\frac{\Delta t}{\Delta x}H(x+1,y)\left[u(x+2,y,t+2)-u(x,y,t+2)\right]+\frac{1}{2}[\zeta(x+3,y,t+1)$$

$$+\zeta(x+1,y,t+1)]u(x+2,y,t+2)-[\zeta(x+1,y,t+1)+\zeta(x-1,y,t+1)]u(x,y,t+2)-\frac{\Delta t}{\Delta x}H(x+1,y)\times$$

$$\left[v(x+1,y+1,t+2)-v(x+1,y-1,t+2)\right]+\frac{1}{2}[\zeta(x+1,y+2,t+1)+\zeta(x+1,y,t+1)]v(x+1,y+1,t+2)$$

$$-[\zeta(x+1,y,t+1)+\zeta(x+1,y-2,t+1)]v(x+1,y-2,t+2)$$

(14)

Limited timestep, have to satisfy the Courant – Fredrichs – Lewy condition:

$$\frac{\sqrt{gH_{Max}}\Delta t}{\sqrt{(\Delta x)^2+(\Delta y)^2}}<1 \qquad \textbf{\textit{(15)}}$$

where, H_{Max} maximum of depth in domain.

Result and discussion

The model has applied to studied area as Binh Cang – Nha Trang shallow water, and located in 12^0 11’ ÷ 12^0 28’N and 109^0 08’ ÷ 109^0 28’E. The bathymetry map received from CAM RANH BAY To CAPE VARELLA map, with resolution 1:150.000.

Table 1. Initial astronomical arguments, multiplier factors, angular velocity and tidal harmonic constants

No.	Wave parameters	Astronomical arguments	Multiplier factors	Angular velocity	**H(cm)**	**G (degree)**
1	M_2	238.1	0.967	28.984	16.76	269.01
2	S_2	0.0	1.000	30.0	5.56	356.96
3	N_2	311.0	0.967	28.44	4.66	165.64
4	K_2	193.5	1.285	30.082	1.52	356.96
5	K_1	6.9	1.104	15.041	35.57	305.61
6	O_1	232.6	1.168	13.943	31.34	247.90
7	P_1	349.6	1.000	14.959	11.89	305.05
8	Q_1	305.4	1.168	12.85	6.65	261.89
9	M_4	116.2	0.935	57.968	0.86	54.65
10	MS_4	238.1	0.967	58.984	0.59	168.33
11	M_6	354.3	0.904	86.952	0.43	40.84

The wind stress at free surface has estimated by friction coefficient C_{10} via wind frequency (wind speed was 5 m/s in Northeast direction).

Domain characteristics include 74 x 104 grid points in x, y direction respectively. Spatial step $\Delta x = \Delta y$ = 315 m (31500 cm), temporal step has to satisfy CFL condition means Δt = 25 s. At open boundary condition, we have considered the number of 11 wave parameter including: diurnal tide K_1, O_1, P_1, Q_1 and semi-diurnal tide M_2, S_2, N_2, K_2, and some short period waves M_4, MS_4, M_6

Average discharge in January at Cai River (Nha Trang) was about 46.8 m^3/s and at Cai River (Ninh Hoa) it was about 2.5 m^3/s.

These calculation results are presented through vector distribution on Fig. 1 to 8, we have some comments in following:

When the wind field is stable, at times of different tidal phases leading to the current field distribution is very different (Fig. 1 to 8).

When the tide starts up, the flow rate is very small (less than 10 cm/s). At mid-tide phase of flood tide (Fig. 1, 2), the distribution of current according to the following areas: The first domain is from the open boundary to the cross-section (Mui Da Chong – Hon Tre island), we can see the current speed is quite small (less than 10 cm/s), mainly direction of current from East to West. The next domain is from cross-section (Mui Da Chong – Hon Tre Island) to Nha

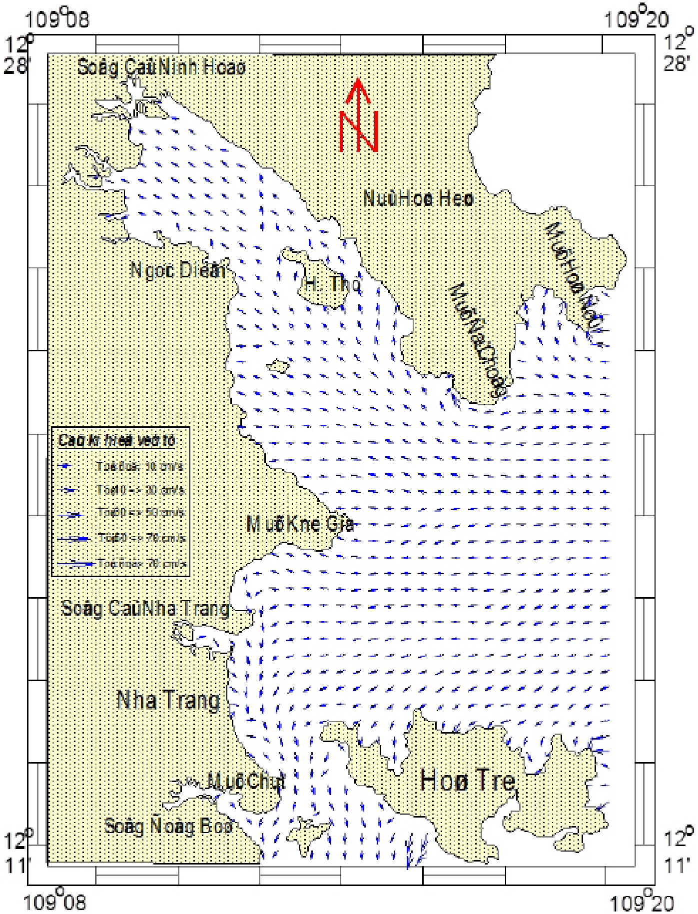

Fig. 1. Distribution of current field in Nha Trang bay, in winter, tide started up.

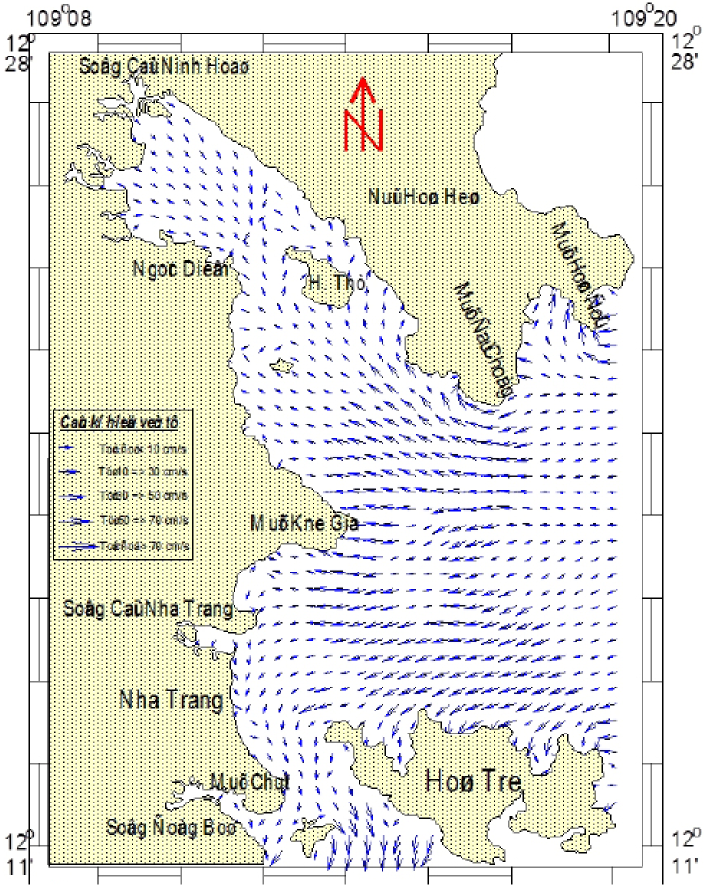

Fig. 2. Distribution of current field in Nha Trang bay, in winter, tide began to strongly.

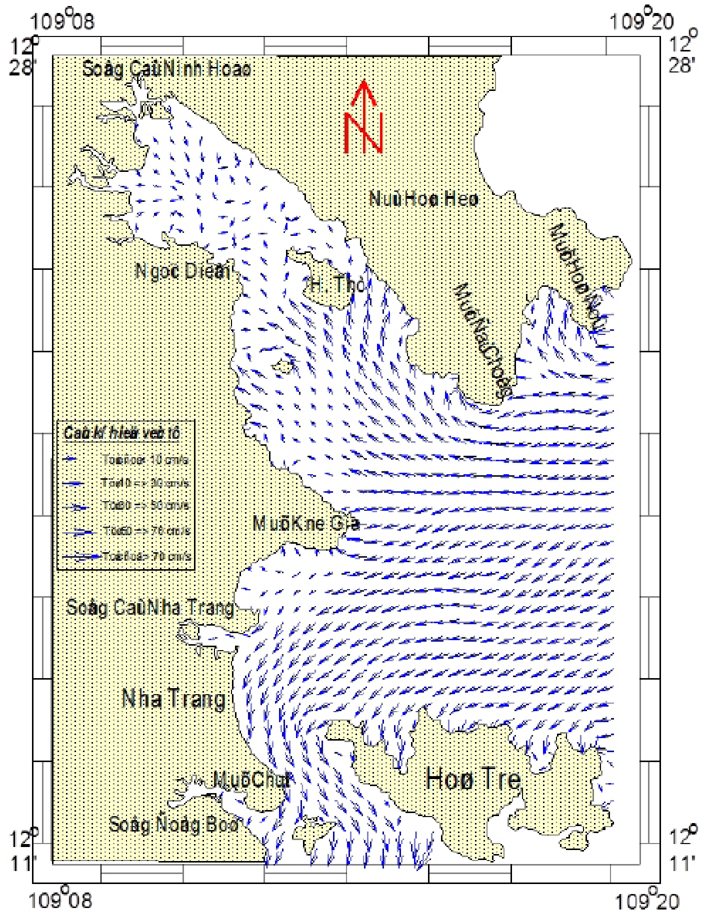

Fig. 3. Distribution of current field in Nha Trang bay, in winter, strongly tide.

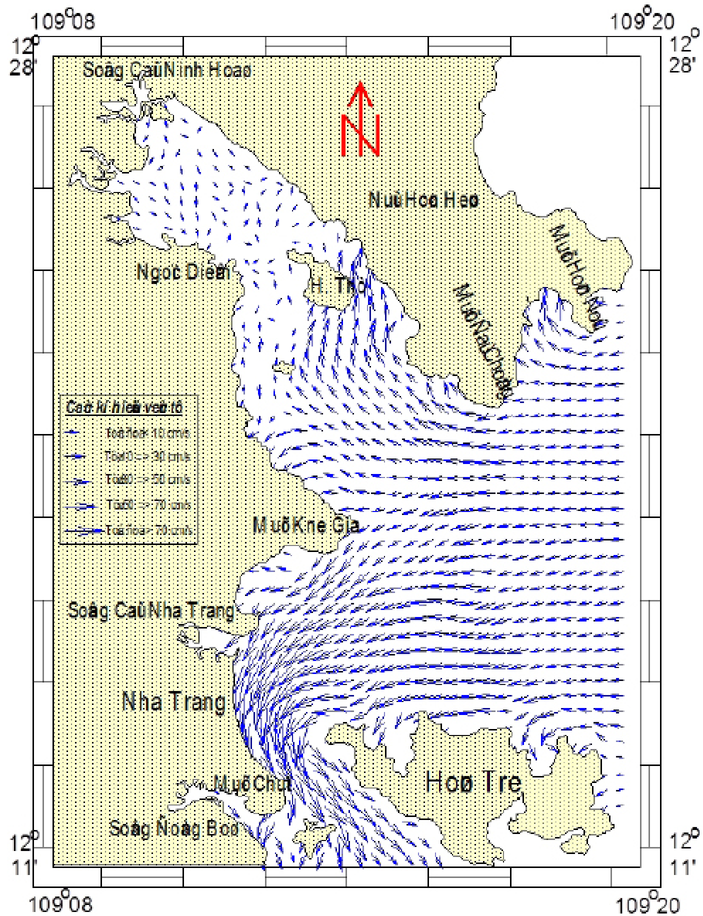

Fig. 4. Distribution of current field in Nha Trang bay, in winter, at the time of tide crest.

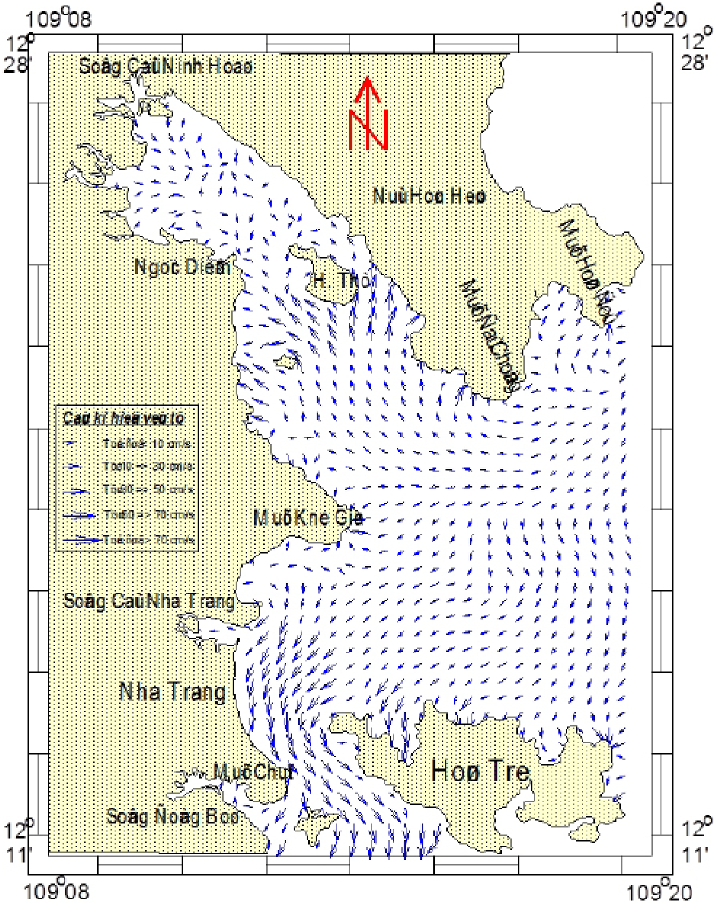

Fig. 5. Distribution of current field in Nha Trang bay, in winter, ebb tide.

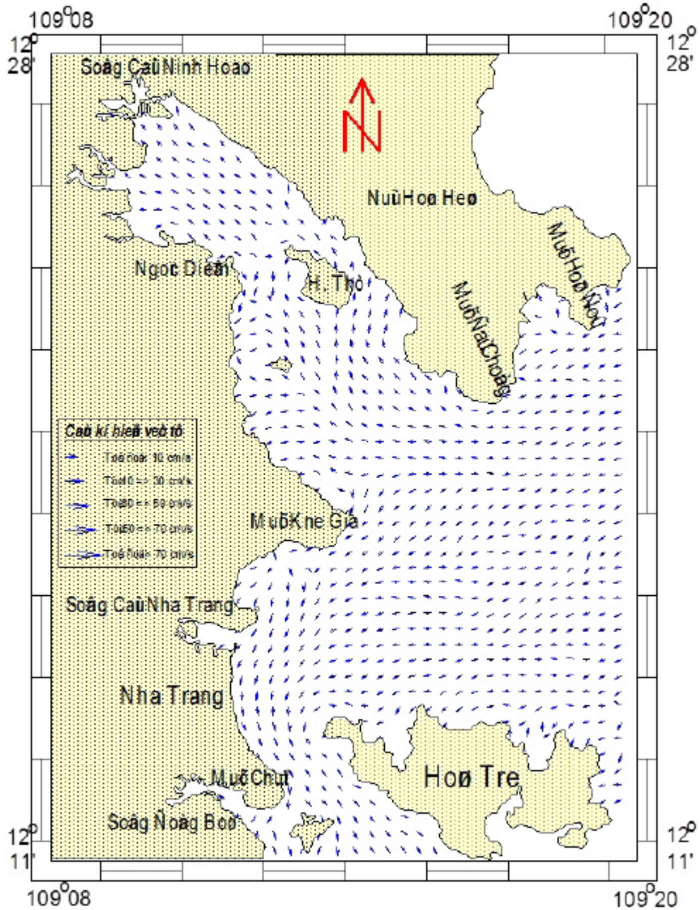

Fig. 6. Distribution current field in of Nha Trang bay, in winter, strongly ebb tide.

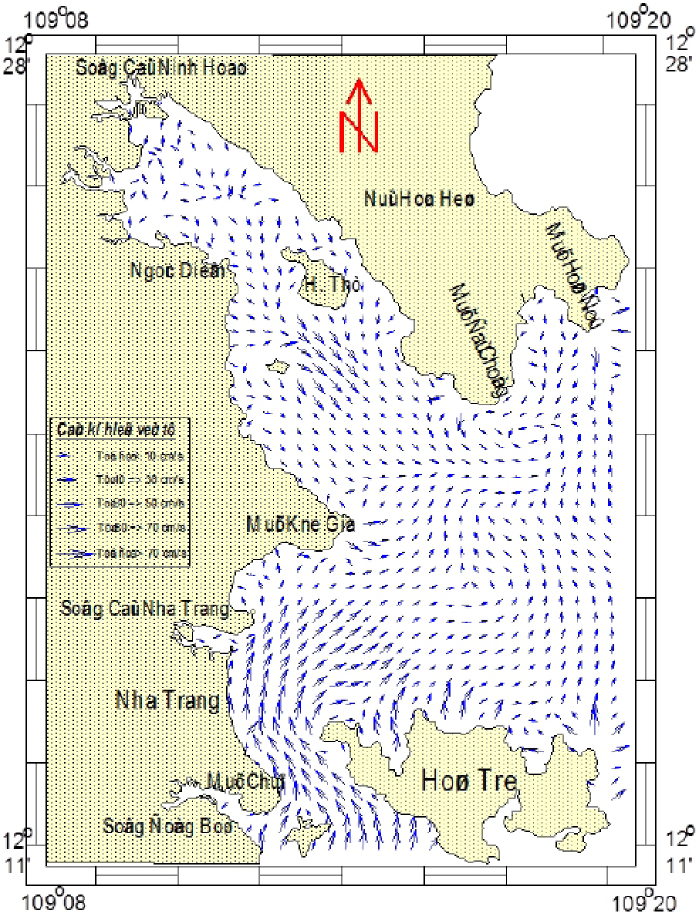

Fig. 7. Distribution of current field in Nha Trang bay, ebb tide, midle tide time.

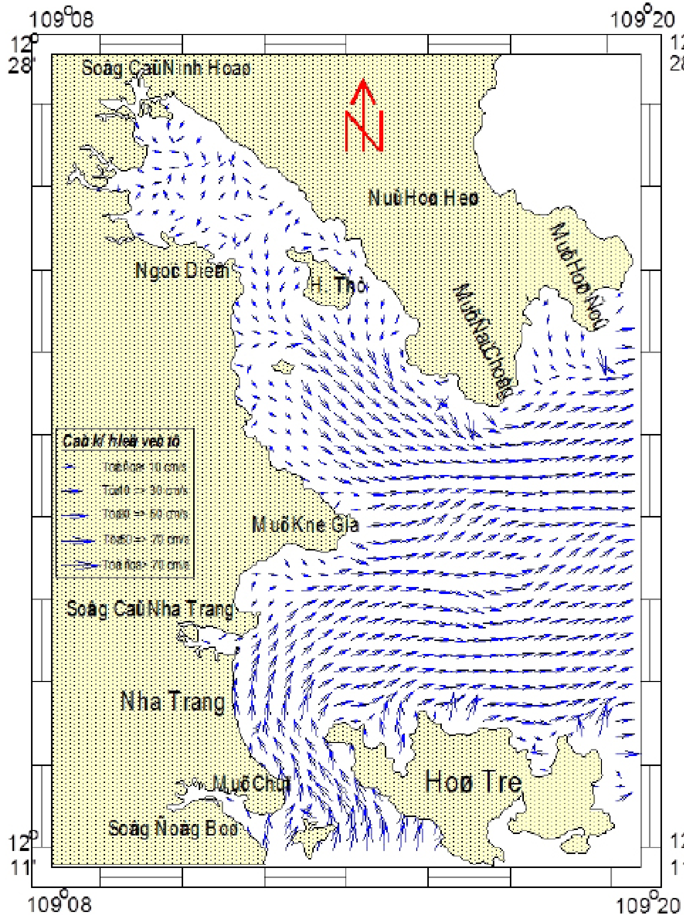

Fig. 8. Distribution of current field in Nha Trang bay, ebb tide, strongh tide time.

Trang – Binh Cang mouth, in this area the current speed is greater than 10 cm/s, however current direction didn't to be homogeneous, it disperses into many different direction and depended on the bottom topography. In the middle area (center of Nha Trang bay), current direction move perpendicular in to coastline from East to West, in center of Binh Cang bay, current came from northwestern. Conversely, in Nha Trang Bay area, current direction is from northeast into Nha Trang Bay with the speed about more than 10 cm/s. In Binh Cang Bay domain, almost all currents have speed relative small, they will decrease a little about speed if they move to the top of bay. Current direction was from northwestern and turbulence occured in near top of bay. The cause of this situation maybe relative to compress of the water mass from open boundary into the bay and the amount of water mass from the Cai Ninh Hoa River. The domain between Nha Trang Bay and Mui Chut – Hon Tre Island canal have complicated direction, they move into the Bay (from East to West) and affected by bathymetry from Hon Tre Island to Mui Chut – Hon Tre Island canal (southeast). At this domain, current speed is about 10 cm/s.

At middle of flood tide phase (Fig. 3, 4). The distribution of current according to the following areas: The domain from open boundary to cross-section (Mui Da Chong – Hon Tre Island) is very separate with the next domain from Mui Da Chong – Hon Tre Island to mouth of Nha Trang – Binh Cang Bay. Both of them have the same about velocity (speed and direction). They have a velocity relative strong about 20–30 cm/s, however, velocity divided into several different directions which have created a lot of eddy and it also depend on bathymetry clearly. In the middle area (center of Nha Trang bay), current direction move perpendicular in to coastline from East to West, in center of Binh Cang bay, current came from northwestern. Conversely, in Nha Trang Bay area, current direction is from northeast into Nha Trang Bay with the speed about more than 20 cm/s. In Binh Cang Bay from mouth bay to Hon Thi Island, the current in this domain have speed relatively greater than current speed from Hon Thi Island to the top of Nha Phu Lagoon, and its speed decrease slowly about 10 cm/s with direction is northwest. In Nha Trang Bay and Mui Chut – Hon Tre Island canal, the current direction is from east to west, moving around Nha Trang Bay and closely to Hon Tre Island and go out to the sea along Mui Chut – Hon Tre Island canal with direction is southeast, in this case, current speed is about 25 cm/s.

At time of high tide, the current increase clearly at some points reached about 30–50 cm/s. Current direction is not stable, such as at some points have direction from east to west, or northwest, or southeast.

When tidal current starts down (in the beginning of ebb tide), speed decreases slowly and change about direction, but tidal current have also a same trend before (Fig. 5, 6).

When water level in the Bay have a balance with water level in onshore, current speed decrease clearly and some points maybe homogeneous about speed (only some cm/s). The direction dispersed to different ways (Fig. 5, 6).

At time of ebb tide when water level in the Bay rapidly decreases, it is higher than water level in onshore, the current go out to Hon Do Island and Nose of Hon Tre Island (onshore side) (Fig. 7, 8). We can see that at this time in studied area, velocity field have divided several regions with direction is stable but it is opposite direction when flood tide occurs strongly.

Conclusion

The using the finite difference method in study of two-dimensional time dependent problem applied to Gulf Binh Cang – Nha Trang leads to positive results reflecting current system in the study area.

Tidal current components (by oscillation of water levels) has the largest contribution among the rest factors such as the wind drift (wind stress), density current (the difference between temperature and salinity), coastal flows (the rise and fall at the coastline), the flow affected by water river (discharge).

Basing on finite difference methods we can continue to develop three-dimensional (3D) modeling to studying and calculating dynamics in coastal areas in more details.

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