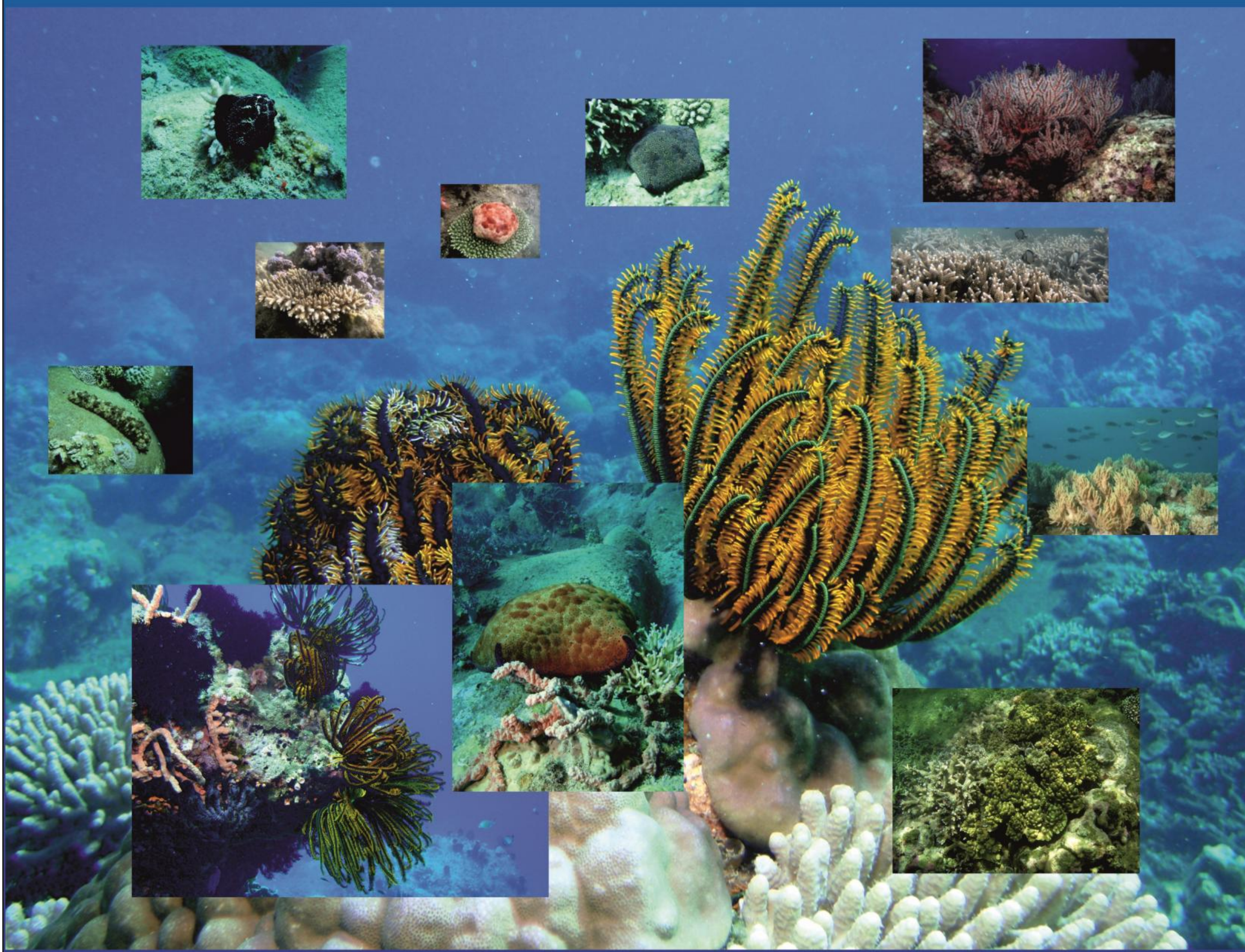
Asia-Pacific Network for Global Change Research (APN)

Institute of Oceanography,
Vietnam Academy of Science and Technology

A.V. Zhirmunsky Institute of Marine Biology,
Far East Branch of the Russian Academy of Sciences



Proceedings of the International Conference *MARINE BIODIVERSITY OF EAST ASIAN SEAS: STATUS, CHALLENGES AND SUSTAINABLE DEVELOPMENT*

Nha Trang, Vietnam
December 6–7, 2010

Asia-Pacific Network for Global Change Research (APN)

Institute of Oceanography,
Vietnam Academy of Science and Technology

A.V. Zhirmunsky Institute of Marine Biology,
Far East Branch of the Russian Academy of Sciences

Proceedings of the International Conference

MARINE BIODIVERSITY OF EAST ASIAN SEAS: STATUS, CHALLENGES AND SUSTAINABLE DEVELOPMENT

Nha Trang, Vietnam, December 6–7, 2010

Nha Trang

2010

Organizing Committee

Mrs. **Do Minh Thu** (Co-Chair)
(Institute of Oceanography VAST, Nha Trang, Vietnam)
Dr. **Tatiana N. Dautova** (Co-Chair)
(A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Russia)
Dr. **Konstantin A. Lutaenko** (Co-Chair)
(A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Russia)

Secretary: **Tatiana V. Lavrova**

EDITORS OF THE PROCEEDINGS:

T.N. Dautova and K.A. Lutaenko

The conference and publication of the proceedings are supported by the Asia-Pacific Network for Global Change Research (APN) and Institute of Oceanography, Vietnam Academy of Science and Technology (ION VAST)

CONTENTS

COMPETITION AND BIODIVERSITY IN CORAL COMMUNITIES: IMPACT OF ENVIRONMENTAL FLUCTUATIONS

Tatiana N. Dautova

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, 690041, Russia

e-mail: tndaut@mail.ru

The main environmental factors affecting biodiversity and condition of coral communities are temperature and salinity fluctuations, sedimentation rate, low tides, water currents, and catastrophic reef destruction (Loya, 1976; Ditlev, 1978; Bradbery, Yonge, 1981; Dollar, 1982; Rogers, 1990). Other substantial factors are related to biotic relationships such as competition for substrate among corals or predator pressure (Sheppard, 1979, 1980; Wellington, 1980; Cope, 1982; Bak et al., 1982; Highsmith, 1982; Logan, 1984). As a result, opportunistic scleractinians such as branched *Acropora* and *Pocillopora* dominate the coral community all over the reef or in some reef zones (Fig. 1). These fast-growing corals are resistant to wave action, low tide, and silting (Geister,

Fig. 1. Colony shape of the main reef-building Scleractinia. From the left – massive *Porites* colonies, from the right – branched *Acropora* and *Pocillopora*, Nha Trang Bay, Vietnam, 2008 (photo by O.V. Savinkin, IEEP RAS).

1975; Ditlev, 1978). Opportunistic corals with massive growth forms such as Faviidae and *Porites* have stronger skeletons but grow slower (Fig. 2). Massive *Porites* may thus be overtopped and shaded by faster growing corals (Done, Potts, 1992). Despite of the above, *Porites* are found in abundance in a range of coral communities such as those in reefs off Barbados or Caño islands or in the Eastern Pacific, of Sri Lanka, Southern India, Philippines, the Great Barrier Reef, and many reefs of the South China Sea (Faustino, 1927; Glynn et al., 1972; Glynn, 1973, 1988; Ditlev, 1978; Chou, Teo, 1985; Potts et al., 1985; Sakai, 1985; Sakai et al., 1986; Thomascik, Sander, 1987; Chou, 1988; Sudara et al., 1988; Guzmán, Cortés, 1989b; Done, Potts, 1992; Dautova et al., 1999). Hence, to understand the peculiarities of *Porites* allowing them to compete successfully with other corals, one needs, first, to compare the data available on the physiology of *Porites* to those on other principal reef builders and, second, to elucidate environmental conditions favoring the abundance and predominance of *Porites* and their in coral communities.

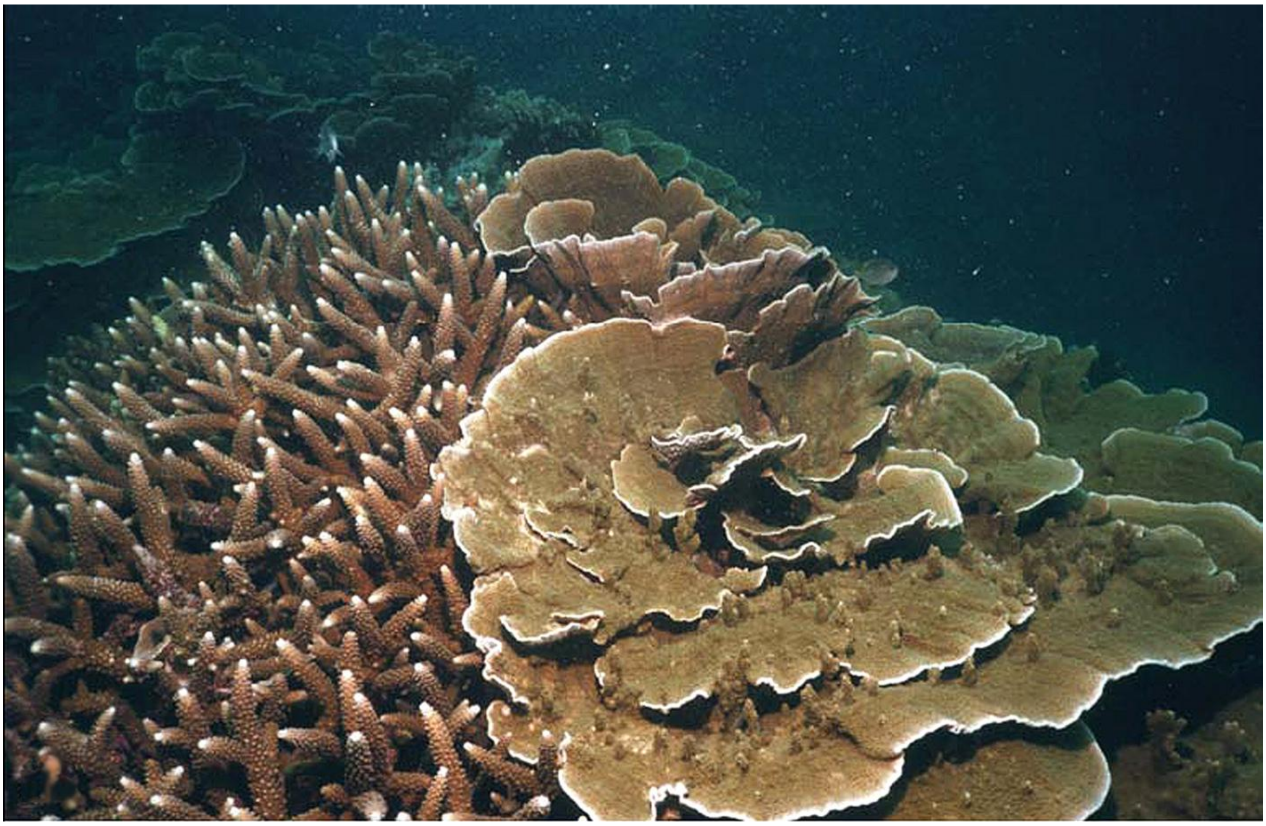


Fig. 2. Coral reef off eastern Tre Island, Nha Trang Bay, Vietnam. From the left – branched colonies *Acropora vaughani*, from the right – foliate colonies of *Montipora* (photo by O.V. Savinkin, IEEP RAS).

Reproduction and recruitment

P. lobata, one of the main Pacific reef-builders, is a presumed broadcast spawner. In good thermal conditions, Eastern Pacific *P. lobata* populations have higher proportion of colonies with gonads (29.9–67.7%) and longer reproductive periods compared to the Western and Central Pacific populations. This species can provide two reproductive cycles per year under warm and stable conditions (Glynn et al., 1994). *P. panamensis* is a brooder, forming small massive or encrusting colonies, 60–85.5% of which produce gonads. This species was reported to release planulae for most of the year at Taboga Island, Panama (Smith, 1991). *P. murrayensis* is sexually active for the whole warm season (5 months) (Kojis, Quinn, 1981). It should be mentioned that the reproductive activity of *Porites lobata* compares well with that of *Pocillopora* spp., the major reef-builders in that region. Thus, in the reefs of the coastal islands of the Eastern Pacific, under stable temperature conditions, gonads were detected in 32–59% and 59.5–89.9% of *Pocillopora damicornis* and *P. elegans* colonies, respectively. At the same time, under more variable temperature and rainfall conditions of the Galapagos Islands, gonads were found in 36 and 39% of *Porites lobata* and *Pocillopora elegans* colonies, respectively, while in *P. damicornis,* as little as 16.2% of colonies had gonads (Glynn et al., 1994). As a rule, spawned gametes have no zooxanthellae, which are acquired by planulae after their settlement and metamorphosis. However, *Porites* spp. are among rare exceptions. Its eggs and/or larvae contain maternal zooxanthellae (Richmond, Hunter, 1990; Glynn et al., 1994). To summarize the above, *Porites* have a high sexual reproductive capacity and produce numerous planulae, which live for a long while because of the presence of the zooxanthellae. The planulae of Caribbean *Porites* spp. are active recruits at areas with high eutrophication level such as the Barbados coastal zone, where new *P. astreoides* colonies are most abundant on artificial substrate, whereas the juveniles of *Montastrea annularis* and *Siderastrea* spp. are absent (Tomascik, 1991). Due to its ability to release brooded planulae, capable of rapid settlement, *Porites astreoides* was the main recruiting species in all surveyed areas of the Bermuda Islands. However, the coral community there was dominated by *Diploria* spp., whose juvenile mortality was lower in comparison with that of *Porites astreoides* (Smith, 1991). Most of juvenile coral colonies, which settled available substrates on the Rasdhoo Atoll (Maldives) during three years after the mass bleaching in 1988, were the members of Faviidae, Poritidae, Pocilloporidae, and Acroporidae. Faviids were most common recruits on solid substrates (78%), and poritids were the next common recruits (11%). Four-year observations of the larvae settlement in the reef off Heron Island, GBR, showed that the recruits were dominated by pocilloporids (80.1%), while acroporids and poritids were in minority, despite their adult colonies were abundant on the reef (Dunstan, Johnson, 1998). If the sexual *Porites* recruitment is hindered by a lack of suitable hard substrates, asexual fragmentation may play the main role in supporting populations of massive broadcast spawners *P. lobata* or *P. lutea* or branching *P. cylindrica*. Planulae recruitment probably plays more essential role for small brooders *P. murrayensis* and *P. panamensis* (Kojis, Quinn, 1981; Glynn et al., 1994). Asexual reproduction is typical of not only massive *Porites* but also of branched *Acropora* (Highsmith, 1980; 1982; DeVantier, Endean, 1989). These corals may reproduce both sexually and by fragmentation. However, their abundance on the reefs seems to be mainly due to the latter (Highsmith, 1982). At Heron Island (GBR) and in the Eastern Pacific, new colonies are presumably formed via fragmentation as a result of storm impacts, bioerosion, and triggerfish activity (Kojis, Quinn, 1981; Glynn et al., 1994). Some 50.4% of a massive *Porites* spp. population dominated by very large colonies may be comprised of clonal colonies (Done, Potts, 1992). Intensive internal bioerosion of massive *Porites* colonies may increase their susceptibility to dislodgement and fragmentation (Sammarco, Risk, 1990).

Competitiveness: growth and interspecific interactions

High linear extension rate of coral colonies results in an increase in the colony surface, occupation of new substrates, and overshadowing neighboring colonies. Branched corals have a higher linear extension rate compared to massive corals. For example, the average annual extension rate in *Acropora palmata* is 60–100 mm, while in *Pocillopora* spp., only 29.8–34.8 mm (Guzmán, Cortés, 1989a). Massive *Porites* colonies show rather low competitiveness. Average skeletal extension rate registered in *Porites lobata* at Clipperton Atoll varies between 13.2–15.1 mm yr^{-1} (Glynn et al., 1996). Linear extension rate and other growth parameters of coral colonies vary with geographical location and in strong correlation with average annual sea surface temperature (Lough, Barnes, 2000).

Porites hold an intermediate position in the hierarchy of interspecific coral interactions via direct contact (Lang, 1973; Cope, 1982). In the reefs of the Southern Taiwan, Dai (1990) distinguished five groups of coral species based on their competitive ability. Massive *P. australiensis*, *P. lutea* and *P. lichen* proved to be intermediate or subordinate, while some *Acropora*, *Montipora*, and Faviidae (*Hydnophora*, *Platygyra*, *Gonyastrea*, *Favia* and *Echinopora*), aggressive to moderately aggressive. From the other hand, Bradbury and Young (1983) examined the significance of coral interactions by paired statistic analysis of both small-scale (neighborhood) and large-scale (reef zonation) coral distribution patterns on the Heron Island reef (GBR) and revealed no strong relations between the distribution patterns and interspecific coral interactions. The competition between corals and benthic algae play an important role in the evolution of reef community, especially at reef deterioration due to excessive exploitation or eutrophication. Studies of direct contacts between filamentous algal turfs and *Porites lobata* showed that the presence of *Porites* suppresses algae growth, while algae do not noticeably effect *Porites* growth. The *Porites* advantage over algae in competition for substrate was greater in areas of the highest terrigenous sediment and organic influx (McCook, 2001). On the contrary, algal turfs were reported to overgrow *Colpophyllia natans* (Faviidae). The growth of this coral is additionally suppressed by increase in terrigenous sediment influx, which furthers competitive success of algae in coastal reefs (Nugues, Roberts, 2003).

Environmental fluctuations

There is some contradiction in the literature concerning relative persistence of *Porites* and opportunistic corals such as Faviidae, *Agariciidae*, *Acroporidae* and *Pocilloporidae* to physical environmental factors. The long-term observations on coral distribution patterns into Kenyan coastal waters showed that *Porites* spp. hold an intermediate position among other corals by their resistance to sediment disposal (McClanahan, Obura, 1997). *Montipora verrucosa* demonstrates higher resistance to sedimentation compared to *Porites lobata* (Hodgson, 1990). The experimentally evoked sedimentation had a profound effect on massive *Porites*, *Acropora* and *Galaxea*. In particular, it caused bleaching, skeleton baring, and the reduction of the amount of healthy tissues to less than 20% of its original value (Wesseling et al., 1999). However there are numerous coral communities dominated by massive *Porites* which phenomenon takes place under combined action of several extreme environmental factors. As a rule, at such reefs the level of the dominance is high and biodiversity is decreased. Thus, in Hawaii, where heavy oceanic surf and predator activity influence the structure of the coral communities, massive *Porites* occupy some 30% of coral settlement area (Grigg, 1983). Off the Costa-Rican Pacific coast, the extreme factors are the predation pressure and warming catastrophes caused by ENSO. Guzmán and Cortés emphasized (1989b) that the structure of the reef community on Caño Island (Costa Rica), dominated by *P. lobata*, is largely determined by the factors influencing this species. The predominance of *P. lobata* in that coral community is probably accounted for not only by its abundant spawning and high capacity to asexual reproduction via fragmentation, but also by its high resistance to predation and drastic environmental changes such as ENSO.

Siltation has a profound adverse effect on coral communities. In particular, intense sedimentation hinders larvae settlement, while high water turbidity restricts the light available, slows down the linear growth of the colonies, and decreases the population density. The species resistant to intense sedimentation gain in many respects. Anthropogenic eutrophication may affect the structure of coral communities as is the case of the fringing reefs off the western coasts of Barbados (Tomascik, Sander, 1985, 1987). The combined action of a number of factors such as biogen content increase, sedimentation rate, water turbidity and toxicity resulted in a decrease in the species diversity and favored predominance of *Porites* on these reefs. *Porites*, together with *Siderastrea radians* and *Agaricia agaricites*, were most abundant in three most contaminated reefs. The average projective coverage of *Porites* species (*P. astreoides* and *P. porites*) varied there from 25.2 to 66.6%. The predominance of *Porites* in the contaminated reefs was attributed to its high resistance to anthropogenic sedimentation due to the production of bacteria-resistant mucus.

The projective coverage of massive *Porites* in scleractinian communities in the north-eastern part of the Gulf of Tonkin (South China Sea) reaches 22% (reefs of the Bai Tu Long Archipelago). These communities suffer abundant terrigenous sediment influx via numerous rivers resulting the exposure of local coral populations to coastal waters with high content of organic and mineral suspended matter. The sediment (originally, finest grain clay) flow in the reef slopes may run up to 10.0–11.9 mg cm^{-1} per day (Dautova et al., 1999). Based on the survey performed off the Cahuita Island (Costa Rica), Cortés and Risk (1985) proposed that sediment flow capable of invoke siltation stress must be not less than 30 mg cm^{-1} per day. This is more than twice as much as the flow rate in the Bai Tu Long reefs. However, coral reefs in the north of the Gulf of Tonkin (South China Sea) grow under extreme climatic conditions. They are situated in the monsoon climate zone characterized by considerable variation in water salinity and wind intensity and direction. In winter, the temperature of superficial waters in this zone drops down to 16–20°C (Yet, 1989), and salinity, to 21–22‰ (Thanh, 1999). It is the combined action of these factors that probably determines the peculiarity of the reefs of the Bai Tu Long Archipelago, where Poritidae and Faviidae are the main reef-builders.

Conclusion

Porites species occur in all coral reefs of the World Ocean. They can survive a wide temperature range and retain high fertility and capacity to both sexual and asexual colonization of substrate. Common inhabitants of the coral reefs, *Porites*, nevertheless, do not exceed other coral opportunists in sediment and temperature resistance and growth rate. *Porites* do not predominate in many reefs growing under favorable conditions, but they are abundant in reef zones or in whole reefs exposed to pronounced adverse environmental effects. *Porites* predominance in scleractinian communities may be accounted for by the suppression of other opportunistic corals such as *Acropora* and *Pocillopora* by environmental disturbances. In such a case, *Porites* occupy both hard and soft substrates and are among predominating species. The unfavorable factors include eutrophication, sedimentation, low tides, desiccation, freshening, wave action, and predation. Massive *Porites* colonies can resist various catastrophes, both natural such as hurricanes, freshening, extreme predation and/or low tides, El Niño disturbances, and others and anthropogenic such as oil spills. *Porites* spp. are noted for their resistance to bleaching and high recovery capacity. Both natural and anthropogenic catastrophes may result in *Porites* predominance, at least as long as the effects induced by a catastrophe continue. In the present time, when the frequency of reef damages and mass bleaching events evoked by anthropogenic catastrophes increases, the structure of coral communities suffering from bleaching or anthropogenic effects can change in a different way. One of the possible ways is an increase in the portion of, and the replacement of less resistant species by, *Porites*.

Acknowledgements

The work presented was supported by FEB RAS Foundation Grant 09-III-A-06-195 and APN Grant ARCP 2010-18NMY.

References

Bak R.P.M., Termaat R.N., Dekker R. 1982. Complexity of coral interactions // Marine Biology. V. 69. P. 215–222.

Bradbery R.H., Young P.C. 1981. The effects of a major forcing function, wave energy, on a coral reef ecosystem // Marine Ecology Progress Series. V. 5. P. 229–241.

Chou L.M. 1988. Community structure of sediment stressed reefs in Singapore // Galaxea. V. 7. P. 101–111.

Chou L.M., Teo Y.H. 1985. An ecological study of the scleractinian corals of Pulau Salu Reef, Singapore // Asian Marine Biology. V. 2. P. 11–20.

Cope M. 1982. Interspecific coral interactions in Hong Kong // Proceedings of the 4th International Symposium on Coral Reefs. V. 2. P. 357–362.

Dai Chang-feng. 1990. Interspecific competition in Taiwanese corals with special reference to interactions between alcyonaceans and scleractinians // Marine Ecology Progress Series. V. 60. P. 291–297.

Dautova T.N., Latypov Yu.Ya., Dautov S.Sh. 1999. Species composition and structure of the coral communities of the Bai Thu Long Archipelago (Gulf of Tongkin, South China Sea) // Russian Journal of Marine Biology. V. 25. P. 111–112.

DeVantier L.M., Endean R. 1989. Observations of colony fission following ledge formation in massive corals of the genus *Porites* // Marine Ecology Progress Series. V. 58. P. 191–195.

Ditlev H. 1978. Zonation of corals on reef flats at Ko-Phuket // Marine Biology. V. 47. P. 29–39.

Dollar S. 1982. Wave stress and coral community structure in Hawaii // Coral Reefs. V. 1. P. 71–81.

Done T.J., Potts D.C. 1992. Influences of habitat and natural disturbances on contributions of massive Porites corals to reef communities // Marine Biology. V. 114. P. 479–493.

Faustino L.A. 1927. Recent Madreporaria of the Philippine Islands // Monographs Burou Scientific, Manila. P. 1–310.

Geister J. 1975. Riffbau und geologische Entwicklungsgeschiche der Insel San Andres (Westliche Karibisches Meer, Kolumbien) // Stuttgarten Beitrage Natuurkunde. Bd. 15. S. 1–204.

Glynn P.W. 1973. Aspects of ecology of coral reefs // Marine Biology. V. 20. P. 297–318.

Glynn P.W. 1988. El NINO–Southern oscillation 1982–1983: nearshore population, community, and ecosystem responses // Annual Review of Ecology and Systematics. V. 19. P. 309–345.

Glynn P.W., Stewart R.H., McClosker J.E. 1972. Pacific coral reefs of Panama // Geologische Rundschau. Bd. 61. S. 483–519.

Glynn P.W., Colley S.B., Eakin C.M., Smith D.B., Cortés J., Gassman N.S., Guzman H.M., Del Rosario H., Feingold J.S. 1994. Reef coral reproduction in the eastern Pacific: Costa Rica, Panama and Galapagos Islands (Equador). II. Poritidae // Marine Biology. V. 148. P. 191–208.

Guzmán H.W., Cortés J. 1989a. Growth rates of eighth species of Scleractinian corals in the Eastern Pacific (Costa Rica) // Bulletin of Marine Science. V. 44. P. 1186–1194.

Guzmán H.W., Cortés J. 1989b. Coral reef community structure at Cano Island, Pacific Costa Rica // Marine Ecology Progress Series. V. 10. P. 23–42.

Highsmith R.C. 1980. Passive colonization and asexual colony multiplication in the massive coral *Porites lutea* Milne Edwards & Haime // Journal of Experimental Marine Biology and Ecology. V. 47. P. 55–67.

Highsmith R.C. 1982. Reproduction by fragmentation in corals // Marine Ecology Progress Series. V. 7. P. 207–226.

Hodgson G. 1990. Tetracycline reduces sedimentation damage to corals // Marine Biology. V. 104. P. 493–496.

Kojis B.L., Quinn N.I. 1981. Reproductive strategies in four species of Porites (Scleractinia) // Proceedings of the 4th International Symposium on Coral Reefs. V. 2. P. 403–408.

Lang J. 1973. Interspecific agression by scleractinian corals // Bulletin of Marine Science. V. 23. P. 260–279.

Logan A. 1984. Interspecific aggression in hermatypic corals from Bermuda // Coral Reefs. V. 3. P. 131–138.

Lough J.M., Barnes D.J. 2000. Environmental controls on growth of the massive coral *Porites* // Journal of Experimental Marine Biology and Ecology. V. 245. P. 225–243.

Loya Y. 1976. Effects of water turbidity and sedimentation on the common structure of Porto Rican corals // Bulletin of Marine Science. V. 26. P. 450–466.

McCook L.J. 2001. Competition between corals and algal turfs along a gradient of terrestrial influence in the near shore central Great Barrier Reef // Coral Reefs. V. 19. P. 419–425.

Nugues M.M., Roberts C.M. 2003. Coral mortality and interaction with algae in relation to sedimentation // Coral Reefs. V. 22. P. 507–516.

Potts D.C., Done T.J., Isdale P.J., Fisk D.A. 1985. Dominance of coral community by the genus *Porites* // Marine Ecology Progress Series. V. 23. P. 79–84.

Richmond R.H., Hunter C.L. 1990. Reproduction and recruitment of corals: Comparisons among the Caribbean, The Tropical Pacific, and the Red Sea // Marine Ecology Progress Series. V. 60. P. 185–203.

Rogers C.S. 1990. Responses of coral reefs and reef organisms to sedimentation // Marine Ecology Progress Series. V. 62. P. 185–202.

Sakai K. 1985. Preliminary observation on coral assemblages in the vicinity of Si Chang Island, the inner part of the Gulf of Thailand // Galaxea. V. 4. P. 53–63.

Sakai K., Yeemin T., Shidvongs A., Yamazato K., Nishishira M. 1986. Distribution and community structures of hermatypic corals in the Sichang Island, inner part of Gulf of Thailand // Galaxea. V. 5. P. 27–74.

Sammarco P.W. 1980. *Diadema* and its relationship to coral spat mortality: grazing competition and biological disturbance // Journal of Experimental Marine Biology and Ecology. V. 48. P. 245–272.

Sammarco P.W., Risk M.J. 1990. Large scale patterns in internal boierosion of *Porites*: cross continental shelf trends on the Great Barrier Reef // Marine Ecology Progress Series. V. 59. P. 145–156.

Smith S.R. 1991. The reproduction and recruitment of *Porites panamensis* (Verrill) at Uva Island, Pacific Panamà. MS thesis, Univ Miami, Florida, 64 p.

Sudara S., Manthachittra V., Thamrongnawasawat T., Natekanjanalarp S. 1988. Change in coral community structure along the West Coast of the Gulf of Thailand // Galaxea. V. 7. P. 234–239.

Thanh T.D. 1999. Change in environment and ecosystems relative to the land–sea interaction in the Vietnam coastal zone // Rep. EALOICZ Workshop, Qingdao. P. 1–10.

Tomascik T. 1991. Settlement patterns of Caribbean Scleractinian corals on artificial substrata along an eutrophication gradient, Barbados, West Indies // Marine Ecology Progress Series. V. 77. P. 261–269.

Tomascik T., Sander F. 1985. Effects of eutrophication on reef–building corals. I. Growth rate of reef building coral *Montastrea annularis* // Marine Biology. V. 87. P. 143–155.

Tomascik T., Sander F. 1987. Effects of eutrophication on reef–building corals. II. Structure of scleractinian coral communities on fringing reefs, Barbados, West Indies // Marine Biology. V. 94. P. 53–76.

Wellington G.M. 1980. Reversal of digestive interactions between Pacific reef corals: mediation by sweeper tentacles // Oecologia (Berl). V. 47. P. 340–343.

Yet N.H. 1989. Research results of corals and coral reefs in western Tonkin Gulf // Tay Nguen va Moy Truong Bien. V. 6. P. 35–36.

THE OPTIMUM ENVIRONMENTAL CRITERIA SET FOR CLAM CULTURE IN MEKONG DELTA

Tong Phuoc Hoang Son

Institute of Oceanography, Vietnam Academy of Science and Technology, Nhatrang, Vietnam

Vietnam's overall mollusk production is estimated at 300,000-350,000 tons per year, of which Clam production is estimated about 60,000 tons. In the Mekong Delta, this species concentrated mainly in six coastal provinces - Ben Tre, Tien Giang, Tra Vinh, Soc Trang, Bac Lieu and Ca Mau.

In October 2009, Ben Tre clam fishery has just received Marine Stewardship Council (MSC) certification, becoming the first fishery in Southeast Asia to meet the Council’s sustainability and management standards. *Meretrix lyrata* - “Ben Tre” clam becomes the famous commercial brand, a highlight spot on fresh aquaculture not only in Vietnam but also in the world.

Statistical analysis based on survey data in 2007–2009 linking with the live assesses server data and processed satellite image data showed the quantitative relationship between environmental parameters and clam yield. The optimum environmental criteria set for the growth of clam life have been found out.

Introduction

By the way of new approaches based on remote sensing techniques, numerical and statistic modeling, this paper tries to explain in detail the quantitative relationship between natural conditions and the formation and development of clam grounds in Mekong Delta (focus in tidal flats of Tien Giang, Ben Tre and Tra vinh provinces).

The main goal of this study is to answer three key questions: when do clam (include breeding and parent grounds) appear; where do they develop well? Which optimum environmental criteria effect to Clam health?

Material and Methodology

Studied scale and objects:

The study region focuses on tidal flats with clam grounds in three provinces Tien Giang, Ben Tre and Tra Vinh and in geographical limit of $106^{o}05'$–$106^{o}50'$ E and $09^{o}30'$– $10^{o}25'$ N (Fig. 1).

Based on the surveyed data and remote sensing processed data (MODIS, TRMM, Landsat, MOSS1-MESSR, JERS-VNIR, ALOS-AVNIR2) the relationship between the natural conditions and the formation and development of clam resource have been found out.

Accumulate rainfall, sea surface temperature (SST), water salinity (Sal), total suspended solid (TSS), chlorophyll-a (instead of food and nutrient source).

Geomorphologic features (topography and bathymetry) in tidal flats, history of evolution (shoreline and morphological changes), grain size of sediment, land use in land base and sea water (include distribution of mangrove forest, aquaculture, human settlement, paddy field, garden tree, relict dunes, ..., formation of underwater relief).

Methodology:

- Analysis of the spatial and temporal variation of rainfall by EOF statistical techniques.

- Analysis of the spatial and temporal variation of SST, TSS, Chlorophyll–a derived from MODIS sensor.

- Application of multi spectral high resolution imagery: for extracting the geomorphologic feature (topography and bathymetry) in tidal flats, history of evolution (shoreline and morphology changes), grain size of sediment, land use in land base and sea water.

- Cluster Analysis has been used for the assessment of the universal relationship between environment parameters and the yield of clam.

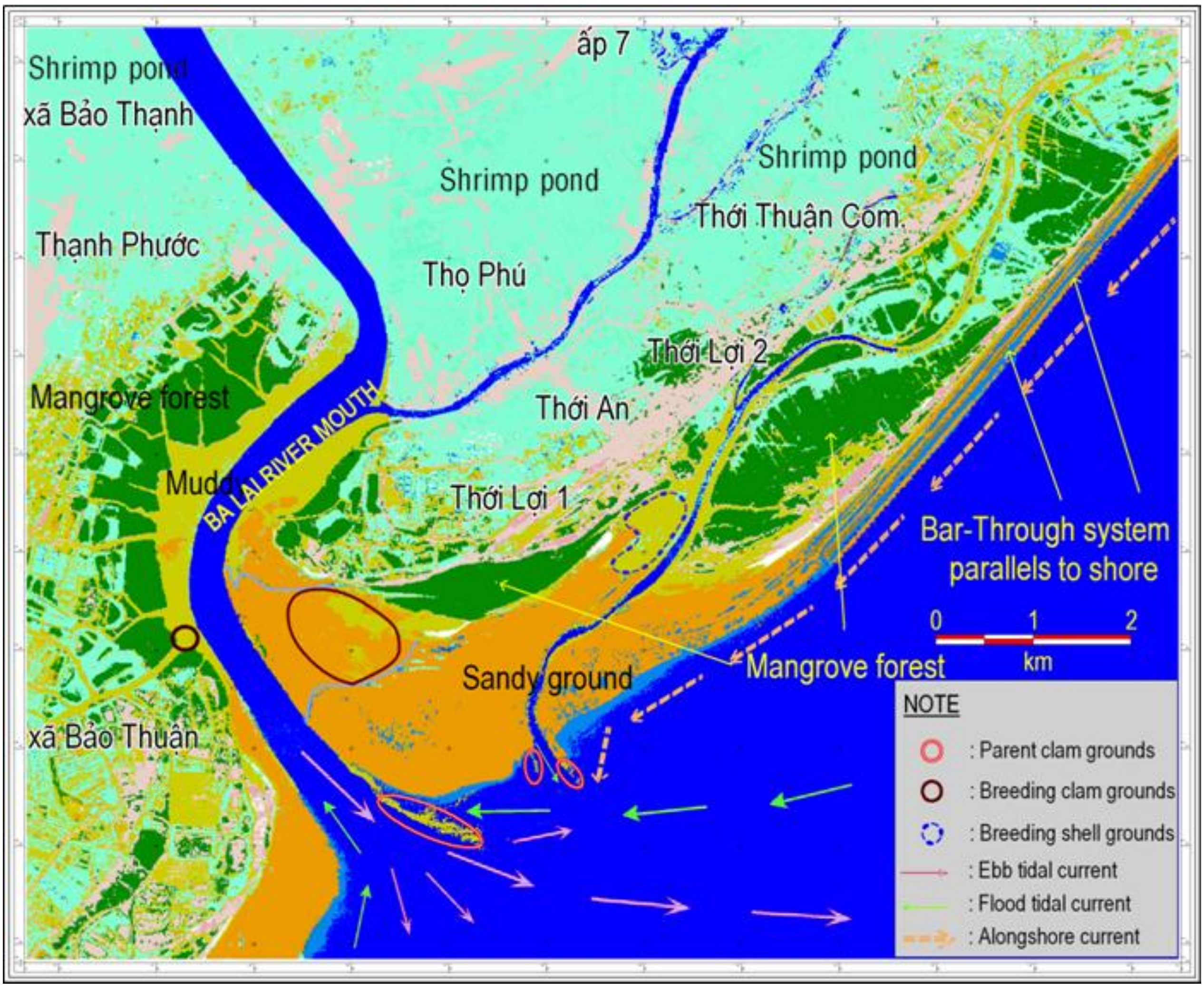


Fig. 1. The location of Potential Clam Grounds in Thoi Thuan commune - Binh Dai district (Ben Tre province) in relationship with geomorphology and dynamic conditions.

Results and Discussion

1) Erosion – accumulation, shore line change processes in Mekong Delta. By mean of band ratio method, the shorelines of Mekong Delta in different periods (1973, 1988, 1998 and 2008) have been extracted. The processed results showed that:

- The erosion–deposition processes of tidal flats occurred alternately. The erosion process occurred in NE of tidal flats, meanwhile the deposition process occurred in SW ones.

- Sand dune moved from NE to SW according to alongshore direction.

- Flood tidal delta laid inside the river, they enlarged toward the sea, attach to the islets and became not only the agriculture land but also clam grounds in outside.

2) Geomorphologic features in relationship with formation and appearance of Clam grounds. In general, the geomorphology of tidal flat in these regions strongly changed in time. The moving trend of sand spit in Binh Dai was alongshore direction (7 km/35years). It narrowed the Ba Lai river mouth and created a large tidal flat in Thoi Thuan village where existed the biggest "Clam's mine" of Mekong Delta.

The process of breaching the sand spit in Cong Be river mouth during period of 1968–1973 formed a second clam ground in Thua Duc Village.

The main remark showed that: the biggest clam ground of Mekong delta laid close to regions where existed small river mouths such as Ba Lai and Cong Be ones.

The parent's grounds usually laid along the channel marginal linear bars at 4-5 m deep. The formation mechanism of these bars related to tidal water circulation as above mentioned. The bottom relief was flatten, the velocity of flood current was medium (60–80cm/s) these created a comfortable area for parent's clam habitat.

On the tidal flat in these areas usually appeared breeding ground with high density and consistency. The position of breeding grounds were close to small channels, near the mangrove forest (mainly *Sonneritia alba*), ground's morphology was lightly hollow, well sheltered by sand dunes. The permanent existence of "slime muddy thin layer" were a typical characteristic of breeding ground in this area.

3) Distribution of rain fall. The rainfall distributed irregularly and slightly increased from Tien Giang, Ben Tre and Tra Vinh. There were two main peaks of rainfall, one occurred during May and other appeared during October of year, between them were dry periods.

Analyzed results of EOF based on series data of rainfall dataset from 2002–2008 determined the main modes of time and spatial EOFs

EOF1 and EOF2 explained the information of two rainfall peaks in May and October in year. On ecological aspect, the medium rainfall is enough to provide food from river water with high organic matter and also from the wetland with mangrove forest. In addition, the warmer water with terrestrial origin stimulated the existing and the development of mature clam during this period.

EOF3, characterized for the distribution of rainfall in January. At that time, in land base the rainfall was minimum, while some thundershower rain with low rate (25–30 mm) happen in inshore water. Their appearance created sudden change of salinity and harmful algae bloom of Dinophyceae and Diatom, under the impact of E wind together with flood tidal current, they landed onto tidal flat and created an additional food source for clam during deficient period of food.

4) Sea Surface Temperature. In general, SST during rainy season was higher in comparison with the value in dry season. Clearly, the affect of warmer terrestrial water plume from in river formed the big difference of SST between two seasons. This warm water plume (especial during immediate season) was important condition that stimulated for the reproduce and development of clam's larvae during July–August.

5) Total suspended solid (TSS). Processed data of Total Suspended Solid derived from MODIS image showed that a general view about coastal current carried a lot of food source for clam in dominant direction from NE to SW. Beside nutrient source from mangrove forest, algae patches landed into coast by waves and also in river mouths of investigated area.

6) Chlorophyll-a content. Changed complexly in time, but in general rule, the content of chlorophyll-a in dry season was higher than that in rainy season. Its peaks have often appeared about one month later in transition period from rainy into dry season (December, January) and also that from dry to rainy season (July).

In this period (December and January), the solar radiation made the sea surface temperature increase and the organic substances decomposited quickly. It made the advance condition for strong development of algae and then created algae patches on surface water. In addition, the affect of NE waves carried materials into the coast, caused muddy deposition of organic substances and food. In general, the coastal water was high nutrient in this period, but not appropriate for the development of clam.

The second peak in July, the content of chlorophyll-a was lower, but it was ecological significance for clam life. The early rains caused the water to be warmer, stimulated the reproduct-ion and growth of clam in this area.

7) Universal relationship between environmental parameters and clam production. Cluster Analysis (CA) method allowed to find out the complex relationship between environment parameters and production of clam. Criteria dataset included: rainfall (mm/day), SST (^oC), the difference of day - night sea surface temperature ΔT (^oC); water salinity (‰), content of chlorophyll–a (mg/m^3) and production of clam (tons/month).

By technique of CA allow me to group the dataset of environmental data in related to production of clam. Result shows as in Fig. 2.

Conclusions

Combining all criteria on biology of clams, geology-geomorphology and environmental conditions, we obtain the optimum data set for clam health.

- Clams inhabit tidal sandy flats nearby small river channel, in which parent clam grounds lie on linear bars in outer edge of river mouth and breed grounds lie on tidal flat where is nearby parent grounds and consequence of larvae dispersion from this locations.
- The clam yield and also breed grounds develop very well during May and October every year. The peaks of rain fall, SST and also safety and "condition" indexes usually occur during these periods, contract the minimum values of yield as well as others happen during drought times (February and June).
- The optimum environmental data set includes:

- accumulated rainfall <10 mm/month;

- range of SST is 29.0–30.5^oC;

- salinity >10‰;

- $\Delta T < 2{,}0^oC$;

- range of chlorophyll–a content is 2–6 mg/m^3.

- During periods when LaNina phenomena happen (SOI <-8) and accompany of extreme flood events occurred, the salinity decrease too low (<5‰) and also water temperature and difference of temperature is too high with values of >30^{o}C and >2^{o}C respectively.

- During periods when ElNino phenomena happen (SOI >+8) as well as the period of mid of dry seasons (February and/or June) the yield usually reach the minimum values and also values of water temperature and difference of temperature is relative high with values of SST >28.5^{o}C and >1.8^{o}C respectively.

- During period of December, January sometimes appear early rain events, they stimulate to develop the patches of algae bloom at that time chlorophyll–a contents also higher (>4 mg/m^3).

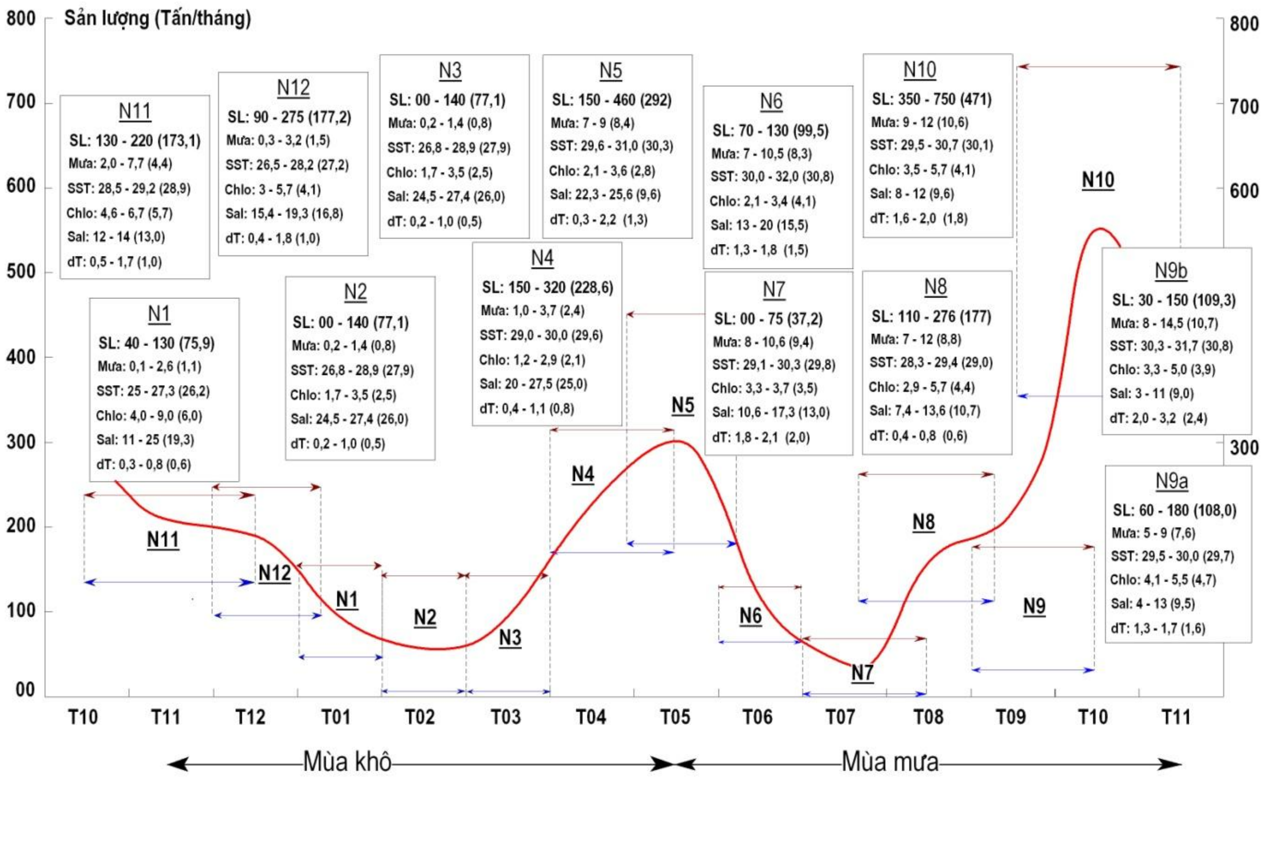


Fig. 2. The temporal variation of clam production in related to environmental data set.

References

Nguyen Tac An, Nga T.T.T. 2001. Scientific basis of solutions for protection and development of clam and blood shell resources in tidal flats in BenTre Province. Institute of Oceanography, Nha Trang: Project Final Report. 216 p. [in Vietnamese].

Boothroyd J.C. 1985. Tidal inlets and tidal deltas // Coastal Sedimentary Environments. R.A. Davis (Ed.). New York: Springer-Verlag. P. 445–532.

Fitzgerald D.M. 1988. Shoreline erosional-depositional processes associated with tidal inlets // Hydrodynamics and Sediment Dynamics of Tidal Inlets. Lecture Notes on Coastal and Estuarine Studies. V. 29. D.G. Aubrey, L. Weishar (Ed.). New York: Springer-Verlag. P. 186–225.

Hung N.D. 2000. Study on ecological and environmental conditions effect to culture procedure in coastal areas of clam *Meretrix lyrata* (Sowerby, 1851) in Tien Giang and Ben Tre. Master Thesis, National Science University, Ho Chi Minh City. 114 p. [in Vietnamese].

Hao N.V. 2001. The characteristics on biology and production of clam (*Meretrix lyrata*) in Mekong Delta // Proceedings of the Scientific Conference "Bien Dong" 2000. P. 219–230. [in Vietnamese].

Oertel G.F. 1988. Processes of sediment exchange between tidal inlets, ebb deltas, and barrier islands // Hydrodynamics and Sediment Dynamics of Tidal Inlets. Lecture Notes on Coastal and Estuarine Studies. V. 29. D.G. Aubrey, L. Weishar (Ed.). New York: Springer-Verlag. P. 297–318.

Tuan V.S. 1999. Investigation on ecological – environmental conditions and developing ability of clam *(Meretrix lyrata)* in Go Cong district – Tien Giang province. Institute of Oceanography, Nha Trang: Project Final Report. 88 p. [in Vietnamese].

REGENERATION IN ECHINODERMS

Igor Yu. Dolmatov

A.V. Zhirmunsky Institute of Marine Biology FEB RAS, Palchevsky 17, Vladivostok 690041, Russia

Every living being on the Earth is capable of some degree of regeneration. The term "regeneration" refers to a set of morphogenetic phenomena, whose common feature is the restoration of lost structures and functions. Regeneration has been investigated over a long period of time; thus, to date, comprehensive descriptive data have accumulated and some concepts of regeneration theory have been worked out (Brockes, Kumar, 2008). Nevertheless, there is as yet no consensus on some theoretical problems. The problems of the origin of regeneration and its mechanisms are under debate. It is not clear how close regenerative mechanisms are to other morphogenetic mechanisms, such as embryogenesis and asexual reproduction. The sources of the cells that are involved in regeneration are still not known for many animals. Moreover, the main concepts of regeneration theory were formulated on the basis of information from only three groups of animals: Cnidaria (*Hydra*), Turbellaria (*Planarians*), and Vertebrata (*Amphibians*). Despite the fact that interesting and important results have been obtained from these model subjects, in our opinion they share one significant weakness: the examined species represent taxa that diverged long ago and thus have little in common in terms of their morphology on the one hand and their embryonic development and regeneration processes on the other.

Echinoderms are uniquely placed to help solve regeneration problems. In terms of phylogeny, echinoderms are deuterostomes and therefore have a near common ancestor with vertebrates. The Echinodermata is one of the few animal groups with extinct Paleozoic members in which the presence of regeneration capability has been demonstrated.

The regenerative responses of recent echinoderms are rather diverse (Candia Carnevali, 2006; Dolmatov, Mashanov, 2007). They can regenerate small body appendages, like tentacles, ambulacral tube-feet, cirri and spines and they show healing of epidermis and body wall lesions. Echinoderms can regenerate almost all internal organs except gonads. Moreover, these animals can regenerate large body regions, like arms or even the whole body after it is cut in two halves. Detailed descriptions of regeneration mechanisms at the cellular level are now available for species in all five classes, which facilitates a comparative analysis of regeneration mechanisms in different echinoderm taxa.

Evolution of regeneration capability

The evolutionary history of echinoderms includes periods during which there were extreme abiotic and biotic changes in the external environment. One such change that could affect regeneration was an increase in the density of large fish and crustaceans in the Middle Paleozoic. In this time the diversity of shell-crushing predators, especially arthropods and fish, increased strikingly and thus initiated the development of protective adaptations in mollusks, brachiopods and crinoids.

Regeneration has limited effectiveness as a means of protection from predators because of the relatively slow rate of the restoration process. Morphogenesis occurring during regeneration includes such biological processes as cell migration, dedifferentiation and proliferation, each with its own time profile. Since the relative rate of these processes is slow, under a high frequency of damage events the individual does not have enough time to recover and dies. Therefore, adaptations that decrease predator impact increase the survival chances of a species. The capacity for movement and autotomy developed in ancient Crinoidea (Baumiller, 2008). After the Permo-Triassic Extinction, those crinoids with structural adaptations that allowed them to move became more numerous. They made up almost one half of the total number of species. This was evidently related to the greater ability of motile crinoids to both resist predation pressure and withstand the arrival of unfavorable abiotic effects, since they could change location. Other echinoderms have developed a hard test and several protective structures, like spines or have a cryptic mode of life.

The ability to autotomise allowed the animals both to avoid predators and to minimize traumatizing effects (Baumiller, 2008). Crinoidea detach distal parts of their arm at special autotomy sites, the syzygies. As a result, the largest soft tissue structures in the arms - the brachial muscles, are not injured and so tissue damage is minimized, thus expediting regeneration. Autotomy mechanisms in echinoderms exploit specific properties of their connective tissue, which can change its mechanical strength under the influence of the nervous system (mutable collagenous tissue) (Wilkie, Emson, 1988). Mutable collagenous tissue and some particular changes in the anatomy of crinoid arms allowed them to shed efficiently any appendages damaged by a predator.

Thus, we can surmise that the augmentation of traumatizing effects did not promote the acquisition or enhancement of regenerative capabilities in echinoderms. During the course of evolution other adaptations arose, which appear to have been more advantageous for the survival of echinoderm species. One of the latter is the ability to avoid predators. Stalked crinoids developed the capacity for locomotion; other echinoderms are also motile. Certain echinoderms (crinoids, holothurians) at present occur at great depths, where the density of predators is lower; others (holothurians, echinoids, and ophiuroids) have a cryptic mode of life. One more adaptation is the development of a hard test and protective structures (echinoids and holothurians). The only adaptation related to regeneration that evolved as a response to predation pressure is autotomy, which involves evisceration in holothurians and the detachment of damaged parts of the body in other echinoderms.

Origin of regeneration mechanisms

The origin of mechanisms of restorative morphogenesis is another unsolved problem of regeneration theory. This problem is of both theoretical and practical interest, since investigation of regeneration mechanisms in invertebrates and lower vertebrates might explain the limited regeneration capabilities of mammals and lead to strategies for promoting human regeneration. It was supposed that regeneration mechanisms originated from embryonic developmental mechanisms. But the problem is more complicated because it is obvious that some manifestations of regeneration and some kinds of asexual reproduction appear to be very similar to each other. Although similarities between the mechanisms of regeneration and asexual reproduction have been recognized, the relationship of these processes to each other or to embryogenesis has not been adequately explained. In my view analysis of restoration mechanisms in echinoderms has thrown light on this problem. Recent data suggest that during regeneration these animals utilize not only mechanisms of embryonic development but also mechanisms of development associated with asexual reproduction.

A characteristic example of the employment of embryonic development mechanisms during echinoderm regeneration is the restoration of muscle systems. In the course of development and regeneration the mesothelium (coelomic epithelium) give rise to two lines, i.e., peritoneal (epithelial) cells and myoepithelial cells. The myoepithelial cells then sink beneath the peritoneocytes, thus losing any connection with the coelomic cavity. Then groups of the myoepithelial cells become isolated from the epithelium, and transform into muscle bundles. Embryogenetic mechanisms are used also during the regeneration of various echinoderm appendages, such as tentacles and arms (Dolmatov, 1999; Candia Carnevali, 2006).

On the other hand, echinoderms have some organs and tissues whose regeneration differs strikingly from their development in the course of embryogenesis. For example, the regeneration of digestive system in crinoids and holothurians after complete ablation occurs as a result of the transformation of the intestinal mesentery and transdifferentiation of cells of the coelomic epithelium (Mashanov et al., 2005; Mozzi et al., 2006). Regeneration of the gut in holothurians after various types of damage (transection, evisceration) can occur in five different ways, none of which resembles its development during ontogenesis (Dolmatov, Mashanov, 2007). Regeneration of such organs depends on other morphogenetic processes, in particular those involved in development in the course of asexual reproduction.

Thus, the regenerating organs of echinoderms fall into two groups distinguished by the origin of their respective regeneration mechanisms. The muscle system and various appendages (tentacles, ambulacral tube-feet) are restored by mechanisms originating from those associated with embryogenesis. The digestive system and some other organs regenerate by mechanisms similar to that of development after fission. Therefore, when investigating different problems of regeneration theory it is necessary to take into consideration the heterogeneity of restoration phenomena. The problem of how and from which source these mechanisms originated needs further investigation involving molecular biology and a wider range of model organisms.

Cellular sources of regeneration

The origin of cells contributing to the regeneration of lost organs remains the major focus of interest in most studies on regeneration. Two sources of cells have been distinguished (Brockes, Kumar, 2008). One of these comprises different types of undifferentiated cells (stem cells). The other source is differentiated cells. The problem of cell sources of regeneration in echinoderms has been discussed for a long time. A number of researchers assume that echinoderm tissues have various totipotent cells, whose supposed characteristics closely resemble those of stem cells (see review of Candia Carnevali, 2006). Despite many papers dealing with this problem, there is as yet no clear evidence for the participation of stem cells in echinoderm regeneration.

To date, the best evidence for the occurrence of stem cells in echinoderms comes from the connective tissue of the body wall and other organs of holothurians, where there is a population of undifferentiated cells (juvenile cells) that have a round shape, a high nucleus/cytoplasm ratio and a centriole that is located in the perinuclear area (Eliseikina et al., 2010). Recently it was shown they help to maintain the coelomocyte population after significant loss of coelomic fluid following, e.g. evisceration or damage to the body wall.

Data derived from electron microscopy and immunocytochemistry indicate that differentiated cells of retained tissues are the main cells on which echinoderm regeneration depends (see reviews of Dolmatov, 1999; Candia Carnevali, 2006). Some echinoderm organs and tissues can regenerate using their own cells. These include the water vascular and nervous systems and the intestine. Another echinoderm organs and tissues regenerate using cells derived from other organ systems. These include the respiratory trees and Cuvierian tubules of holothurians, the muscles of all echinoderms, and the digestive tube in some species of crinoids and holothurians.

Thus, the cell sources of regeneration in echinoderms are specialized cells in retained tissues. The good regenerative capability of these animals is provided by fast dedifferentiation, the ability to enter the mitotic cycle and proliferate, active migration, and redifferentiation or transdifferentiation. Apart from juvenile cells, the presence of stem cells in echinoderms has not been demonstrated yet.

Conclusions

Regeneration is a complex phenomenon. It is obvious that the study of just one phylum cannot supply answers to all the outstanding questions. Nevertheless, the investigation of echinoderm regeneration has given us a wider picture of the processes involved in this phenomenon. During the evolutionary history of the phylum regenerative capability did not improve and new types of regeneration did not appear, despite considerable predation pressure. During evolution many diverse adaptations appeared that helped animals survive potentially damaging factors in their environment. Some of these adaptations, such as autotomy, were related to the pre-existing capacity for regeneration. Furthermore, reparative capabilities appear to be related to other adaptations, in particular to the formation of protective coverings, cryptic ways of life and motility. However, the same adaptations might lead to the loss or diminution of regenerative capabilities, as may have occurred in sea urchins. If there is a high risk of encountering potentially traumatic factors in the environment, regeneration cannot keep pace with the damage load, and therefore a preventative approach, represented by e.g. strong external coverings and spines, becomes a better strategy for survival.

It has been shown that regeneration mechanisms are heterogeneous and fall into two groups, one resembling embryogenesis, the other being closer to the process of development after fission. This implies that regeneration in echinoderms, and perhaps all other animals, is of polyphyletic origin and may be genetically unrelated. This heterogeneity should be taken into consideration when analyzing the origin and evolution of regeneration.

The regeneration processes of echinoderms deserve more attention, since, as well as improving understanding of the theoretical background of regeneration in general, their investigation has biomedical implications. Knowing how to control the dedifferentiation and proliferation of specialized cells would help to solve a wide range of problems in medicine, including the development of methodologies for harvesting the products of differentiated cells, promoting the regeneration of different body parts, and growing artificial organs and tissues.

Acknowledgements

This work was funded by a grant from the Russian Foundation for Basic Research (project N 09–04–98547).

References

Baumiller T.K. 2008. Crinoid ecological morphology // Annual Review of Earth and Planetary Sciences. V. 36. P. 221–249.

Brockes J.P., Kumar A. 2008. Comparative aspects of animal regeneration // Annual Review of Cell and Developmental Biology. V. 24. P. 525–49.

Candia Carnevali M.D. 2006. Regeneration in Echinoderms: repair, regrowth, cloning // Invertebrate Survival Journal. V. 3. P. 64–76.

Dolmatov I.Yu. 1999. Regeneration in echinoderms // Russian Journal of Marine Biology. V. 25. P. 225–233.

Dolmatov I.Yu., Mashanov V.S. 2007. Regeneration in holothurians. Vladivostok: Dalnauka. 212 p.

Eliseikina M.G., Magarlamov T.Yu., Dolmatov I.Yu. 2010. Stem cells of holothuroid coelomocytes // Echinoderms: Durham. L.G. Harris, S.A. Bottger, C.W. Walker, M.P. Lesser (Eds). Boca Raton: CRC Press. P. 504.

Mashanov V.S., Dolmatov I.Yu., Heinzeller T. 2005. Transdifferentiation in holothurian gut regeneration // Biological Bulletin. V. 209. P. 184–193.

Mozzi D., Dolmatov I.Yu., Bonasoro F. et al., 2006. Visceral regeneration in the crinoid *Antedon mediterranea*: basic mechanisms, tissues and cells involved in gut regrowth // Central European Journal of Biology. V. 1. P. 609–635.

Wilkie I.C., Emson R.H. 1988. Mutable collagenous tissue and their significance for echinoderm palaeontology and phylogeny // Echinoderm Phylogeny and Evolutionary Biology. C.R.C. Paul, A.B. Smith (Eds). Oxford, UK: Clarendon Press. P. 311–330.

REPRODUCTIVE BIOLOGY AND SURVIVAL OF ARK SHELL *ARCA NAVICULARIS* AT DIFFERENT SALINITIES

Ngo Thi Thu Thao

College of Aquaculture & Fisheries, Cantho University, Vietnam

e-mail: thuthao@ctu.edu.vn

Ark shells (*Arca navicularis*) were collected to determine the reproductive biology and survival at the beginning and after conditioning in laboratory at College of Aquaculture & Fisheries, Cantho University, Vietnam. Results showed that males of Ark shell in small size class presented high proportion than in large size class. There is synchronized status in gametogenesis development among males and females. There was not hermaphrodite individual in collected samples.

Ark shells were also maintained at different salinities (20, 25, 30, 35‰) in shellfish laboratory to observe the survival and ability to mature after 20 days of maintaining. Results indicated that all of Ark shells were died off after 2 days at salinity of 20‰. However, they presented slightly high survival at 35‰ (58.3%), 30‰ (53%) and 25‰ (41.7%). Histology analysis showed that most of samples reached mature stage and ready for spawning. Our findings suggest that salinity range from 30-35‰ can be applied for broodstock maintaining of Ark shells *Arca navicularis* for scientific researches or seed production purposes.

REPRODUCTIVE BIOLOGY OF MUD CLAM *GELOINA COAXANS* IN MANGROVE FOREST OF CA MAU PROVINCE, MECONG DELTA, VIETNAM

Ngo Thi Thu Thao, Quach Kha Ly

College of Aquaculture & Fisheries, Cantho University, Vietnam

e-mail: *thuthao@ctu.edu.vn*

Materials and Methods

Monthly sampling for this study was conducted in the mangrove system of Ngoc Hien district, Camau Province, Mekong Delta of Vietnam from January to November 2009.

A sample set comprised at least 20 individuals, collected randomly from mangrove system, kept alive and transferred to the laboratory. At the laboratory, after recording the shell height, width and total weight, tissues of clams were weighed and then histological process was applied to determine the reproductive cycle of the population. Transverse cut was made in the middle of body part where digestive glands present, and a 3 mm thick section extracted and fixed in neutral formalin 10%. Tissue samples were then processed and embedded in paraffin. Serial sections, 4 µm thick, were obtained with a rotary microtome and stained with Harris' hematoxylin and eosin Y. Histological slides were observed under microscope to grade the developmental stages of clam gonads. Gonad development of each clam was scored as the following: undifferentiated stage (0); initial development (1); developing stage (2); ripe stage (3) and spawning (4).

Results

Sampling efforts. Biometric data of samples for histological analysis was presented in Table 1. Mean shell height of clams varied from 5.5 to 6.2 cm, total weight from 64.0 to 81.6 g/clam and body mass from 5.3–9.9 g/clam.

Microscopic appearance of gonad development. Photomicrographs of various developmental stages of male and female clams are presented in Fig. 1. A few hermaphrodites were also detected among collected samples with both sexes in one clam body.

Table 1. Biometric data of clams used for histological analysis.

Month	L (cm)	W (cm)	H (cm)	W-total (g)	W-meat (g)	Sex (%)		
						Male	Female	ND
January	5.8±0.8	5.0±0.5	3.2±0.7	65.18±21.28	5.99±2.02	45	35	20
March	6.2±0.5	5.6±0.5	3.3±0.4	81.62±23.39	9.97±3.42	40	55	5
May	5.8±0.4	5.3±0.4	3.2±0.3	79.58±16.33	9.18±2.55	55	45	0
July	5.5±0.5	5.0±0.5	2.9±0.4	64.01±22.36	5.32±2.34	22	61	17
September	5.8±0.4	5.2±0.3	3.1±0.3	74.17±13.88	7.51±2.93	32	63	15
November	5.7±0.4	5.1±0.3	3.1±0.4	73.17±16.95	5.88±1.15	30	65	5

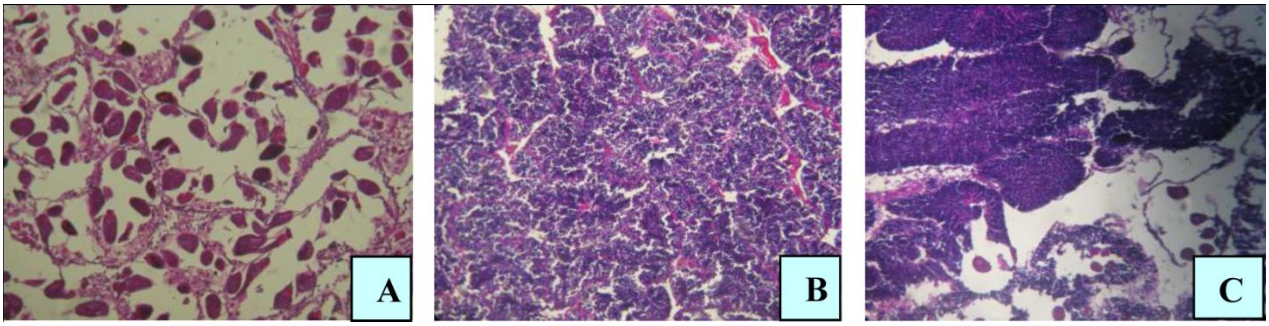


Fig. 1. Microscopic appearance of gonad of *Geloina coaxans*: A) female; B) male; C) hermaphrodite.

Reproductive cycle. Observation of the histological slides indicated that gametogenesis of clams occurred almost year around. However, there were remarkable spawning peaks in May and November (Fig. 2). Gonad index was slightly correlated with condition index of clams in January, March and May but not in other months of the year.

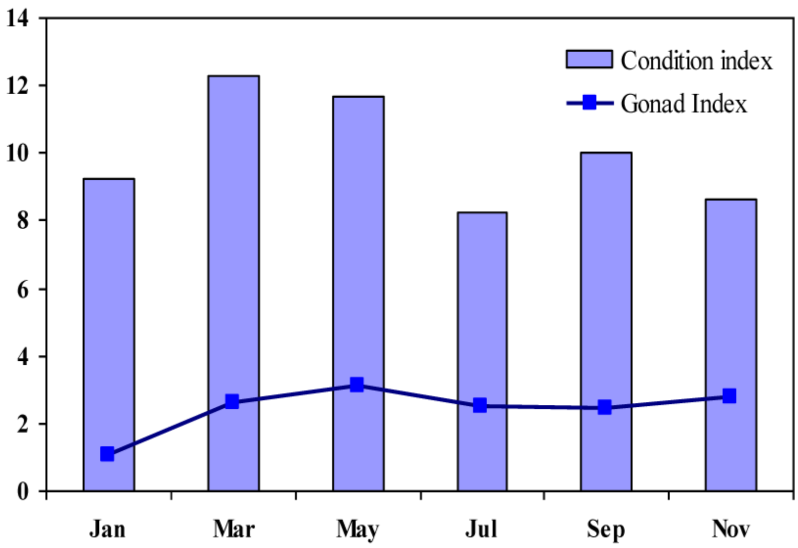


Fig. 2. Condition index and gonad index of *Geloina coaxans* during sampling period.

References

Bachok Z., Mfilinge P. L., Tsuchiya M. 2003. The diet of the mud clam *Geloina coaxans* (Mollusca, Bivalvia) as indicated by fatty acid markers in a subtropical mangrove forest of Okinawa, Japan // Journal of Experimental Marine Biology and Ecology. V. 292, N 2. P. 187–197.

Gimin R., Mohan R., Thinh L.V., Griffiths A.D. 2004. The relationship of shell dimensions and shell volume to live weight and soft tissue weight in the mangrove clam, *Polymesoda erosa* (Solander, 1786) from northern Australia // NAGA, Worldfish Center Quaterly. V. 27, N 3–4. P. 32–35.

Morton B. 1985. The reproductive strategy of mangrove bivalve *Polymesoda* (*Geloina*) *erosa* (Bivalvia: Corbiculoidea) in Hong Kong // Malacological Review. V. 18, N 1-2. P. 83–89.

Natarajan, P. 1976. On the occurrence of *Geloina bengalensis* (Lamarck) (Geloiniidae: Eulamellibranchia) in the Coleroon estuary // Indian Journal of Fisheries. V. 23, N 1-2. P. 278–279.

BIODIVERSITY OF THE ECHINODERMS AND THEIR PELAGIC LARVAE IN NEARSHORE ECOSYSTEMS OF NHATRANG BAY (SOUTH CHINA SEA)

S.Sh. Dautov

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok, 690041, Russia

e-mail: daut49shakir@mail.ru

The sustainability of the ecosystem depends on the biodiversity – the more number of species are in ecosystem, the more it sustains. Nha Trang Bay (South China Sea) demonstrates well preserved up-to-date biodiversity of the many animal taxes. The coral reefs of the Nhatrang Bay have about 200 species of hard-corals (Dautova et al., 2007). They serve themselves as source of the food for many animals and to some sea-stars and sea urchins, they grant asylum for lot of ophiurs and, it indirectly form the conditions for the ophiurs and holothurians which live around, especially, ophiurs, sea stars and holothurians feed on the remnants of the animals and plants, and so, play a role of the decomposers.

Nha Trang Bay – with its straight shore line – is not typical bay. As a haven it is well protected from the storms and typhoons by the near shore islands. Rivers of Nha Trang Bay are not large and they do not affect on the sea water salinity. One large and several small islands notably increase the sea shore line and the size of the littoral and sublittoral zones and therefore essentially increase the productivity of the Bay, establish the diversity of the environmental conditions and therefore the biodiversity. Evidently, that is why the Nha Trang Bay is rate highly by the fishermen and scientists.

Echinoderm fauna of the Vietnam contains of 45 species of crinoids and 66 species of echinoids (Dao, 1994), and South Vietnam has about 53 species of holothurians (Dao, 1991). Some species of the echinoderms of Vietnam became very vanishing and they were added to Red Book of Vietnam (Dao, 2000). All echinoderms have external fertilization, so they have not have the direct contact during mating. But, like the fishes, they need to be as close as possible when spawning.

Generally, many if not all, echinoderms form the spawning assembles. There are some reasons for it. The main reason – when joining they come closer to themselves. Some species have special spawning behavior, in some starfishes males climb on the female, in some holothurians males and females display mating behavior – peculiar mating dances. But in cases when the population density becomes lower the critical – the specimens can't find one another and therefore spawning is impossible. In that cases animals uses asexual reproduction, especially holothurians and sea stars.

In 2006 the check-list of echinoderms of Vietnam was enriches by new species of ophiurs (Dao, 2006). In 2007 was published the check-list of echinoderms of the Nha Trang Bay (Dao, Tam, 2007) and there were enumerate 6 species of crinoids, 11 species of sea stars, 44 species of ophiurs, 16 species of sea urchins, and 20 species of holothurians.

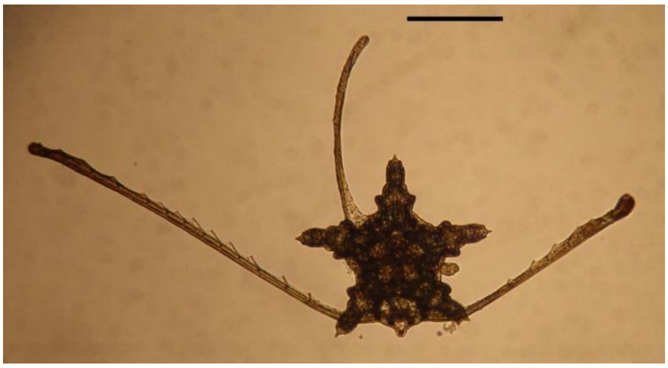


Fig. 1. Late ophiopluteus. Very common at Nha Trang at April-May. Scale bar in all cases: 500 mkm.

The capability for the sexual reproduction is the very important factor. On this point, the Nha Trang Bay was faintly explored. The reproduction of the local feather stars didn't investigate yet. From 11 species of sea stars the larval development was described for 5 only. From 44 species of ophiurs the reproduction was investigated for 4 only. Small better is known about the sea urchins – from 16 species the larval development described for 10. From 20 species holothurians only for 4 species the larvae are known.

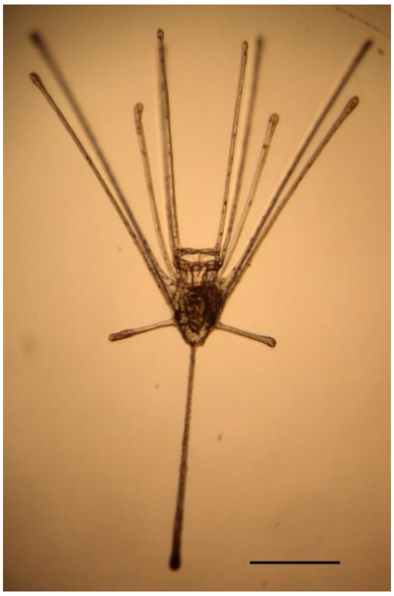


Fig. 2. Echinopluteus of spatangoid, common in pelagic zone of Nha Trang Bay beginning from through late March to May

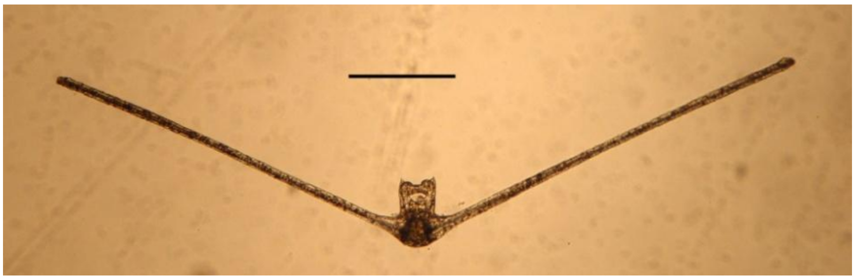


Fig. 3. Diadematoid echinopluteus. Can be very large – up to 3 mm in longetivity

Echinoderm larvae play two roles – spreading and feeding. Spreading maintains the species living space. Feeding gives to echinoderms the possibility of using the unusual trophic source – unicellular algae. Planktotrophic echinoderm larvae spend within sea water from 14 for 90 days, so, they eat a lot of algae.

In early spring (March–May) the reproduction season for echinoderms begins in Nha Trang Bay. One can catch any echinoderm larvae. We can found ophiurs larvae (Fig. 1), sea urchin lar-

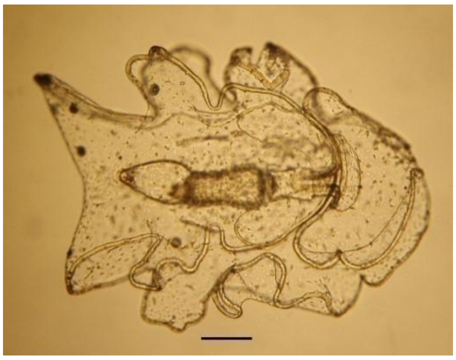


Fig. 4. Giant auricularia. Common from the outer edge of the Nha Trang Bay

vae (Figs. 2, 3) and holothurians larvae (Fig. 4). If the identification the ophiur larvae is very hard and we can only determine them as ophioplutei (Fig. 1), the echioplutei found in Nha Trang Bay are belong to spatangoids (Fig. 2) and diadematoids (Fig. 3). The most peculiar echinoderm larvae are the giant auriculariae (Fig. 4), which belongs to some Apodids.

So, the Nha Trang Bay from point of view of embryologists is the magic area of water which will bring many discoveries in close future.

Acknowledgments

The work presented was supported by FEB RAS Foundation Grant 09-III-A-06-195.

References

Dao Tan Ho. 1991. Holothurians resources in the sea of South Vietnam // Collection of Scientific Presentations: 3rd Symposium of Marine Science, Ha Noi. P. 112–118.

Dao Tan Ho. 1994. Check List of Echinoderms in Vietnam. Vol. I. Crinoidea and Echinoidea. Ha Noi: Science and Technics Publishing House. 112 p.

Dao Tan Ho. 2000. Echinoderms // Vietnam Red data Book. Vol. I. Animals. Ministry of Science, Technology and Environment. Ha Noi: Science and Technics Publishing House. P. 351–355.

Dao Tan Ho. 2006. Description of the additional species of echinoderms to the invertebrate fauna in Vietnamese waters (continued) // Collection of Marine Research Works. V. 15. P. 231–240.

Dao Tan Ho, Nguyen Thi Hong Tham. 2007. The species composition of echinoderms in coral reefs in Nha Trang Bay // Issues of Basic Research in Life Sciences: Proceedings the 2007 National Conference on Life Sciences, Quy Nhon, Vietnam. P. 51–54.

Dautova T.N., Latypov Yu.Ya., Savinkin O.V. 2007. Annotated checklist of scleractinian corals, millepores and Heliopora of Nhatrang Bay // Benthic Fauna of the Bay of Nha Trang, Southern Vietnam. T.A. Britaev, D.S. Pavlov (Eds). Moscow: KMK Scientific Press. P. 13–60.

RESOURCE ASSESSMENT OF THE SEA CUCUMBER POPULATION IN VIETNAM

Nguyen Xuan Truong, Vu Dinh Dap, Nguyen Van Giang

Research Institute for Aquaculture No. 3, Nha Trang, Vietnam

e-mail: xuantruong982@yahoo.com

Sea cucumbers, particularly those from the families Holothuridae have taken an important part of a mixed - species fishery in Vietnam. The sea cucumber fishery has seen a rapid development since 1990s due to the high demand for dried sea cucumber product known as beche-de-mer or trepang on the international market and higher prices offered. However, there are no rules or regulations have adopted for sea cucumbers fishing activities, as well as, no reasonable stock status assessments are available. This implies that the sea cucumber fishery in Vietnam has been faced managerial and technical capacity limitations.

The Ministry of Agriculture and Rural Development (Vietnam) provided funds to the Research Institute for Aquaculture No. 3 for a survey of the status of sea cucumber stocks, exploitation and utilization of sea cucumbers in Vietnam. This paper presents the ecological and biological aspects of Vietnam's sea cucumber fishery by using the belt transect method. The total of 220 sites were surveyed, including 40 sites in the northern fishing ground, 120 sites in the central fishing ground, and 60 sites in the southern fishing ground. Transects are conducted by a pair of divers swimming along a transect line 100 m long and 5 m wide (2.5 m on either side). All sea cucumbers within the belt that are collected, and then they are identified, measured, weighed and photographed. Other information is also recorded during the transect survey, including the substrate type (e.g. coral cover, seagrass, micro-algae beds).

The empirical results show that 30 sea cucumber species have identified and two have recorded as unidentified; in which just 9 species have commercial value with mostly in a low and medium value species such as *Holothuria atra*, *Holothuria edulis*, *Stichopus chloronotus* và *Holothuria leucospilota.* Sea cucumber abundance and species diversity varies among the three fishing grounds and between the habitats preferences (e.g. coral cover, seagrass and algal cover). The relative abundance of sea cucumbers was generally low. The density of individual species was highly variable ranging between 0.56 to 228.25 ind. Ha^{-1}.

Based on this study, some recommendations have also been made with the aim to contribute to develop a sustainable sea cucumber fishery in Vietnam, such as it is necessary to conduct in-depth research on the (reproductive) biology of commercial sea cucumbers and formulating appropriate regulations to protect sea cucumber stocks by precautionary approaches and ecosystem-based management.

DETERMINING OF BACKGROUND CONCENTRATIONS OF METALS IN *SARGASSUM* ALGAE FROM COASTAL WATERS OF THE SEA OF JAPAN AND SOUTH CHINA SEA AS A BASIS FOR BIOMONITORING

E.N. Chernova

Pacific Institute of Geography, Far East Branch, Russian Academy of Sciences, Vladivostok, Russia

e-mail: elena@tig.dvo.ru

The mass and widespread species of hydrobionts are used for biomonitoring of metals in the sea environment. The bivalve Mytilidae and Ostreidae, brown algae of Fucales – Fucaceae and

Sargassaceae order as well as green algae Ulvaceae are most often used. Closely related species under similar environmental conditions accumulate comparable concentrations of microelements (Lobel et al., 1990).

Despite the wide use of hydrobionts for metal biomonitoring only few papers are now known in which the "background" concentrations are determined which can be used to evaluate the metal pollution of the water areas (Scanes, Roach, 1999; Lukashev, 2007).

The purpose of this work is to define the recent total anthropogenic-changed and natural geochemical "background" concentrations of metals in genus *Sargassum* from the Sea of Japan and South China Sea.

Sampling of *Sargassum* algae was taken in the Peter the Great Bay of Sea of Japan (*S. pallidum*) (June–August, 1984–2008) and in bays of Bengoj, Siamese, Nha Trang of the South China Sea (*S. kiellmanianum, S. mcclurey, S. oligocystum, S. polycystum, Sargassum* spp.) (January–February, 1981, 1986, 2003).

Metal concentrations in the samples were determined by flame atomic absorption spectrophotometry using Hitachi-180-70 and Shimadzu-AA-6800 devices.

72 samples of *S. pallidum* from the Sea of Japan and 55 samples of genus *Sargassum* from the South China Sea (Tables 1, 2) were used to determine the statistical parameters of concentrations of metals. A number of definitions of elements Cd and Ni were excluded because the definitions made proved to be overestimated by technical reasons.

The background range was determined by calculation of 85th percentile (P_{85}) as limiting background value (Cantillo, 1997) and also by definition of nonparametric quantity – Me (Mediana)±2MAD (medians of absolute deviations from a median). MAD=Me(|Xi-Me_x|) (Lukashev, 2007). Values of Me±2MAD for 15% of least concentrations in the sampling (Tables 1, 2) were calculated for definition of natural biogeochemical background concentrations in algae.

Table 1. Background concentrations of metals (mkg/g) in *S. pallidum* of the Sea of Japan (Peter the Great Bay and southeastern Primorye)

	Zn	**Fe**	**Mn**	**Cu**	**Cd**	**Ni**
Me±2MAD	14.5±9.3 5.2-23.8	317±355 0-662	168±287 0-455	2.25±1.58 0.67-3.83	1.09±0.54 0.55-1.63	2.01±1.82 0.19-3.83
Min - Max	5.1-40.0	40-4397	5.9-1435	0.88-8.86	0.50-2.14	0.51-4.46
P_{85}	24.1	799	673	4.4	1.69	3.23
P_{15} (n_1)	8.7(11)	120(11)	29.9(11)	1.34(10)	0.75(9)	0.81(10)
Me_{15}±2MAD	7.14±0.86	91.6±31.4	21.4±9.4	1.12±0.24	0.6±0.14	0.63±0.16
N	70	72	72	65	57	57
n_2 (%)	59 (84)	59 (82)	55 (76)	39 (60)	48 (84)	52 (91)
Background*	10-20	20-100	10-50	1-3	1-3	2-3

Note: Background* – Kozhenkova, 2000;
N is the number of specimens in the sampling;
(n_1) is the number of the specimens entering the range P_{15};
n_2 is the quantity of specimens from the total sampling, entering a range of Me±2MAD;
values in parentheses are percent of total number of specimens.

Table 2. Background concentrations of metals in algae of genus *Sargassum* of the South China Sea. Designations are the same as in Table 1.

	Zn	Fe	Mn	Cu	Cd	Ni
Me±2MAD	10.8±10.2 0,6-21	191±177 14-368	27.1±37.8 0-64.9	2.7±1.2 1.5-3.9	0.33±0.38 0-0.71	0.81±0.76 0.05-1.57
Min- Max	4.0-62	24-2557	2.4-388	0.5-5	0.13-2.05	0.22-5.3
P_{85}	23,5	677	118	3.6	1.32	2.0
P_{15} (n_1)	6.1(9)	91.8 (6)	7.5 (9)	1.9 (7)	0.23 (6)	0.46 (4)
Me_{15}±2MAD	5.0±0.8	59±26	6.2±1.2	1.5±0.5	0.23±0.02	0.44±0.06
N	55	53	55	52	26	26
n_2 (%)	51 (93)	37 (70)	38 (69)	48 (87)	14 (54)	15 (58)

The background concentrations of an element in organisms are the sum of physiologically necessary quantity and some nontoxic excess which was accumulated from the life environment with the regional background content of microelements. The background concentration of metals, unlike physiologically necessary concentration, should be in some range of concentrations. Thus, the lower limit of the background concentrations should correspond to minimum physiologically necessary concentration for essential elements (Cu, Zn, Ni, Fe and Mn) and zero concentration for toxic element (Cd). As to the top limit of background concentration of the metal in organisms, its determination involved a certain methodical difficulty.

There is no established procedure of defining the background metal concentrations in organisms in the scientific literature. The method of their definition is not specified in a number of researches (Kavun, 1991; Kozhenkova, 2000) but it is noted that background conditions are observed on the stations located on capes with good water exchange, distant from sources of anthropogenic and technogenic influence. As the background metal concentration, the arithmetic average (under the assumption of normal distribution) or geometrical average (in case of lognormal distribution of concentrations) is taken in geochemistry but it is stated that distribution of concentration of chemical elements in the nature corresponds on rare occasions to both first and second types of distributions (Lukashev, 2007). Based on the database of the National Oceanic and Atmospheric Administration contain data of the microelement composition in mussels and oysters, it was found that, whilst there were no clean indications about what were “natural” concentration, 85th percentiles of all data (i.e. the value below which are the concentrations of 85% of samples) would be indicative of contamination (Cantillo, 1997). This value depends on quantity of abnormal values and varies strongly following sampling average especially in case of small amount of data. It was shown on fresh-water mollusks that the calculation of nonparametric magnitude, median (Me), as average background value for region under consideration is most acceptable method for determining the background range of metal concentration in the living organisms irrespective of the distribution type. For the characteristic of the median variation limits it is suggested to use a double value of median of absolute deviations from median (2MAD) (Lukashev, 2007).

Calculation of Me±2MAD in *Sargassum* of the Sea of Japan and South China Sea covers the most part of the sampled data (from 54% (Cd) to 93% (Zn)) (Tables 1, 2). Based on these quantities, one can judge the element being a specific polluting substance for this water area. So, copper is such element for the Sea of Japan: its concentration in algae exceeds the limiting background value in 40% of stations (a number of stations in Amur, Ussuriisk and Nakhodka bays). Cadmium is specific pollutant for the South China Sea: its limiting background concentration was exceeded in 46% of stations (stations in the Nha Trang bay, round city of Nha Trang). However, if the background ranges of copper concentration in *Sargassum* of both seas are practically equal, the limiting background concentration of cadmium in the Sea of Japan algae was 2 times higher than that in macrophytes of the South China Sea.

As a whole, the recent anthropogenic background concentrations of Zn and Cu in algae *Sargassum* from the Sea of Japan and South China Sea were comparable. The background concentrations of Fe, Cd, Ni in *Sargassum* of the Sea of Japan were 2 times higher, than those of South China Sea. The background concentration Mn in algae of the Sea of Japan was 5 times higher than that in macrophytes of South China Sea.

However, the background concentrations in algae from water reservoir determined by Me±2MAD are a total estimation of the natural and anthropogenic-caused geochemical heterogeneity, characteristic that water area. To allocate from it natural background concentrations, it is necessary to be guided by the minimum values of a background range, as on the physiological needed quantity. It is suggested to use range Me±2MAD from 15% of the least variants to determine minimum value of natural background concentration.

The comparative study of the natural background concentrations in the closely related species of algae of two water areas showed that the natural background concentrations of Zn, Fe, Cu, Ni are comparable in the genus *Sargassum* from the Sea of Japan and the South China Sea. Natural background concentrations of Mn and Cd in organisms of the Sea of Japan are higher.

As to physiologically needed quantity of microelements which as a whole will be approximately identical for the closely related species, median values of 15% of the least concentrations (Me_{15}±2MAD) in the sampling from South China Sea will reflect that magnitude most precisely.

References

Cantillo A.Y. 1997. World Mussel Watch Data. National Oceanic and Athmospheric Administration Technical Memorandum NOS ORCA 109. NOAA, Silver Spring, MD.

Kavun V.Ja. 1991. Microelement concentrations of the Mytilidae mass species from the North-western part of the Pacific Ocean conditioned by environmental conditions. Abstract of PhD Thesis. Russia, Vladivostok. 24 p. [In Russian].

Kozhenkova S.I. 2000. Marine coastal water monitoring in Primorye by using heavy metal content in brown algae. Abstract of PhD Thesis. Russia, Vladivostok. 24 p. [In Russian].

Lukashev D.V. 2007. The method of calculation of background concentrations of trace metals in freshwater mussel tissue for assessment of pollution in Dnieper River // Inland Water Biology. N 4. P. 97–106. [In Russian].

Lobel P.B., Belkhode S.P., Jackson S.E., Longerich H.P. 1990. Recent taxonomic discoveries concerning the mussel *Mytilus*: implications for biomonitoring // Archive of Environmental Contamination and Toxicology. V. 19. P. 508–512.

Scanes P.R., Roach A.C. 1999. Determining natural 'background' concentrations of trace metals in oysters from New South Wales, Australia // Environmental Pollution. V. 105. P. 437–446.

RESTORATION AND MANAGEMENT OF COASTAL CORAL REEF ECOSYSTEMS IN VIETNAM

Nguyen Tac An*[1]*, Vo Si Tuan*[1]*, Phan Minh Thu*[1]*, Hoang Duc Lu*[1]*,

***Nguyen Xuan Hoa*[1]*, Trinh The Hieu*[1]*, Yu.Ya. Latypov*[2]*, E.A. Titlyanov*[2]*, T.N. Dautova*[2]**

[1]*Institute of Oceanography VAST, Nha Trang, Vietnam*

[2]*A.V. Zhirmunsky Institute of Marine Biology of Far East Branch of Russian Academy of Sciences, Vladivostok, 690041, Russia; e-mail: tndaut@mail.ru*

Coastal coral reef ecosystems provide many functions, services and goods to people. The marine products with high economic values such fish, mollusks, crustaceans are rarely found on sampling reefs (Fig. 1). The main amount of the coral reefs in the coastal waters in South East Asia is placed shallow; these reefs are affected by the complex environmental influence (including the anthropogenic impact). The overheating of the corals at shallows can lead to the bleaching and subsequent death of the corals. The bleaching, which process lie in the loss of the micro-algae (zooxanthellae) by corals, leads to the starvation in the corals. The mass bleaching of the corals have leaded 60% of the coral reef ecosystems to the death or hardly reversed destructions along with the sustainable decreasing of the corals diversity at the damaged reef complexes. The survey of the relations between the environmental factors and biodiversity in the reef ecosystems show the very diverse conditions for the bottom animals (the different grounds, seasonal wave activity, the different level of the water exchange) and different levels of the sedimentation influx from the rivers' discharge. The high biodiversity in coral reefs is closely related to this environmental multiformity and possess the ability of the coral ecosystems to the recovery and their resilience. The joint efforts of the ecologists to trace the global and local trends and perspectives in the biodiversity changing in the coral ecosystems have to be focused on the main components of these ecosystems. These components which may be called critical functional

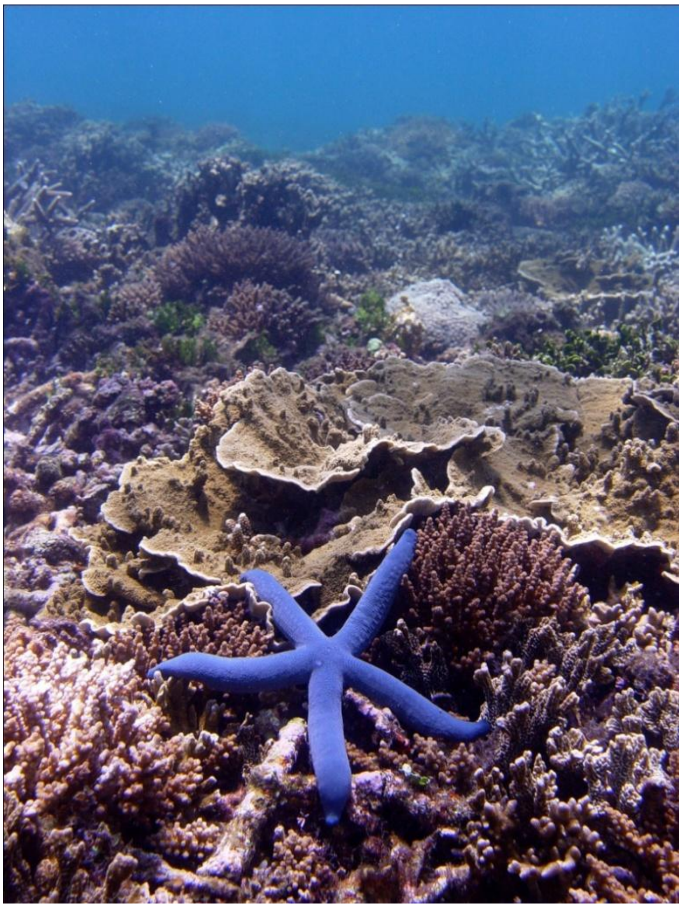


Fig. 1. Large coral reef with well developed coral settlements. South China Sea, Vietnam.

groups (both corals and reef fishes) are fundamental to understanding resilience and avoiding phase shifts from coral dominance to less desirable, degraded ecosystems.

Coral reef ecosystems of the coastal tropical waters being the most productive in the ocean contribute the essential benefit to the Vietnam economics. However, the biological resources of the coral reefs can show the reduction in the abundance and diversity of the bottom fauna in regard to the local and global environmental changing throughout the entire world.

More than 30% of coral reef ecosystems in Vietnam coastal waters have been threaten by human and natural processes. It is important to restore and manage coral reef ecosystems. Initiating adaptive management efforts at each of the national fisheries management councils, by improving monitoring, control and surveillance systems based on an ecosystem framework for management could be a good start for the coral reefs keeping as they are

Fig. 2. Marine farming for the lobsters and shrims. South China Sea, Vietnam, 2005.

he world' heritage. It is with hope and perseverance that the actions at the local levels translate to the broader understanding and shared stewardship of the larger marine tropical ecosystem. The well developed institutional arrangements need to be addressed for an effective monitoring, control and systems. In future, the uneven playing field for sustenance fishers and marine farming can be of great concern with further globalization thrust in the region (Fig. 2). Though much of the ecosystem threats have relatively been less pronounced in this area (e.g. habitat deterioration, destructive fishing and overexploitation) the transboundary concerns both in the living and non-living resources make it a paramount global hotspot in the future. These human induced threats have been suggested to interact with natural threats.

On the occasion of the conference on "*Marine Biodiversity of East Asian Seas: Status, Challenges and Sustainable Development*", we would like to exchange some information concerning the problem on restoration and management of ecosystems of coral reef in coastal waters of Vietnam.

THE ECOLOGICAL-CHEMICAL CHARACTERISTICS OF CORAL REEF WATERS OF VIETNAM COASTAL AREAS

Nguyen Tac An[1], Vo Duy Son[1], I.I. Cherbadgy[2], M.V. Propp[2], V.S. Odintsov[2], L.N. Propp[2]

[1]Institute of Oceanography VAST, 01 Cauda, Nha Trang, Vietnam

[2]A.V. Zhirmunsky Institute of Marine Biology of Far East Branch of Russian Academy of Sciences, Vladivostok, 690041, Russia

The characteristics of primary productive processes and their ecological conditions in coral reef waters of Vietnam coastal areas were studied. The quantification of hydrochemical characteristics: salinity, dissolved oxygen, nutritions such as nitrogen, phosphorus, and silica suspended and dissolved organic substances were in focus.

The gross primary and net primary productions oscillated about 10-124 mgC/m^3day and 1-10 mgC/m^3day, correspondingly. When being added nutrients (nitrogen, phosphorus) the raw primary production power perhaps increased 130%.

The physiological-ecological characteristics of coral species *Pocillopura verrocosa* were studied. The principal characteristics of nitrogen cycle in water of coral reefs were also investigated.

The waters of Vietnam coastal areas belonged to the tropical nutritious form. The fundamental material resource processed relatively high value, perhaps achieved 5 gC/m^2day, and corresponded to 50 $kcal/m^2$day. But the immediate foods of the beings were not much, about only 0.5 gC/m^2day, processed about 10% of energy and total material amount created within a day. Most of the ecological-chemical conditions had local characters, they were relatively identical with tropical coastal regions but the absolute values were relatively higher.

SPECIES COMPOSITION OF SOFT CORAL FAMILY (ALCYONIIDAE) IN CON CO ISLAND, QUANG TRI PROVINCE, VIETNAM

Tran Quoc Hung, Nguyen Huy Yet, Tatiana N. Dautova, Lang Van Ken

Institute of Marine Environment and Resources, Hai Phong City, Vietnam

e-mail: hungimer@gmail.com

Introduction

In Viet Nam, taxonomy studies of soft coral family Alcyoniidae is few and scattered. Up to now, there are only 8 researches related to soft coral family including publications of Serène (1937), Stiasny (1938, 1951), Dawydoff (1952), Tran Ngoc Loi (1967), Tixier-Durivault (1970), Latypov, Malyutin (1991), Nguyen Huy Yet (2005). This study aims to re-examine number of species of soft coral family living in Con Co Island area. Among 20 specimens collected during field survey in Con Co Island on July 2008, 10 new species were identified for this area in comparision with previous studies. They belong to 3 genera *Sinularia, Sarcophyton* and *Lobophytum*. They are mainly distributed in shallow water from 6 to 10 meter depths surrounding Con Co Island.

Soft corals Alcyoniidae belong to Order Alcyonacea, subclass Octocorallia, Class Anthozoa. The Alcyoniidae have 29 genera which have been identified and described worldwide [http://research.calacademy.org/redirect?url=http://researcharchive.calacademy.org/research/izg/orc_home.html]. These genera are distributed worldwide at different depths of all maritime areas. However, they are occured mainly in shallow water of Indo-Pacific area (Fabricius, 2001). In Viet Nam, Alcyoniidae have been studied for 60–70 years. However, the published materials were scattered and few. Most of specimens were kept in French and German museums.

Since 1975, there were only 6 studies that related to soft coral family in Vietnamese sea (Serène, 1937; Stiasny, 1938; 1951; Dawydoff, 1952; Tran Ngoc Loi, 1967; Tixier-Durivault, 1970). Most of publications contain species list report. These studies identified 55 species that belong to 9 genera. Recently, study of soft corals Alcyonacea in West Tonkin Gulf identified 46 species that belong to 10 families and 24 genera (Nguyen Huy Yet, 2005). The predominant family is Alcyoniidae which has 13 species.

To get the update information of species composition of soft coral family for Con Co area, the field survey was carried out on July 2008 in shallow water by SCUBA equipments. About 20 specimens were collected during the survey.

Materials and Methods

Soft coral samples were collected by SCUBA technique during field survey on July 2008 in Con Co Island (Fig. 1). Most of the samples were collected in swallow water ranging from 6 to 10 m depths. All the samples were fixed in 4% formalin in sea water, rinsed by fresh water after 12 hours and transferred to 70% ethyl alcohol. Sclerites were obtained by dissolving the organic

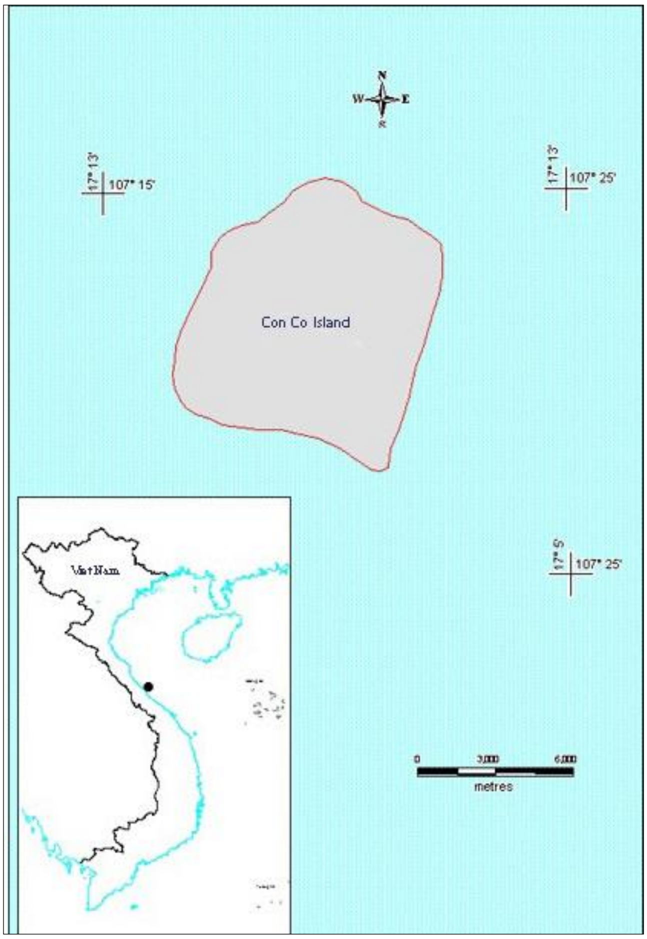


Fig. 1. Map of studied area.

tissues in sodium hypoclorite (NaOCl). They were carefully rinsed with double distilled water and examined by microscope with micrometer and stereo microscope. Sclerites's shapes were recorded using attached camera and Photoshop CS2 software for images editing.

Results and Discussion

Among 20 samples collected during the survey of Con Co Island, there were identified 10 species belonging to 3 genera (*Sinularia*, *Sarcophyton* and *Lobophytum*) of Alcyoniidae family (Table 1). *Sinularia* has 5 species (50%), *Lobophytum* has 4 species (40%) and *Sarcophyton* only 1 species (10%). In comparision with the study of Nguyen Huy Yet (2005) about Order Alcyonacea in West Tonkin Gulf (including Ha Long, Long Chau, Con Co and Hai Van Son Cha) and previous studies, none of these species was described.

These species are mainly distributed in shallows from 6 to 10 m depth. Colonies may be encrusting, massive, mushroom, dish-shaped or digitiform, etc. (Fig. 2). They are occured mainly on hard substrate such as dead stony corals, rocks and other hard subtrates.

In summary, the presented research identifies 10 new species of soft corals in Con Co Island. Together with study of Nguyen Huy Yet, the total species number identified is 23 species of soft co-

Table 1. Species of Alcyoniidae collected in Con Co Island

No	Name of Species
Genus *Lobophytum*	
1	*Lobophytum legitimum* Tixier–Durivault, 1970
2	*Lobophytum durum* Tixier–Durivault, 1956
3	*Lobophytum batarum* Moser, 1919
4	*Lobophytum strictum* Tixier–Durivault, 1957
	Genus *Sarcophyton*
5	*Sarcophyton elegans* Moser, 1919
Genus *Sinularia*	
6	*Sinularia gibberosa* Tixier–Durivault, 1970
7	*Sinularia gyrosa* Klunzinger, 1877
8	*Sinularia* sp.
9	*Sinularia hirta* Pratt, 1903
10	*Sinularia firma* Tixier–Durivault, 1970

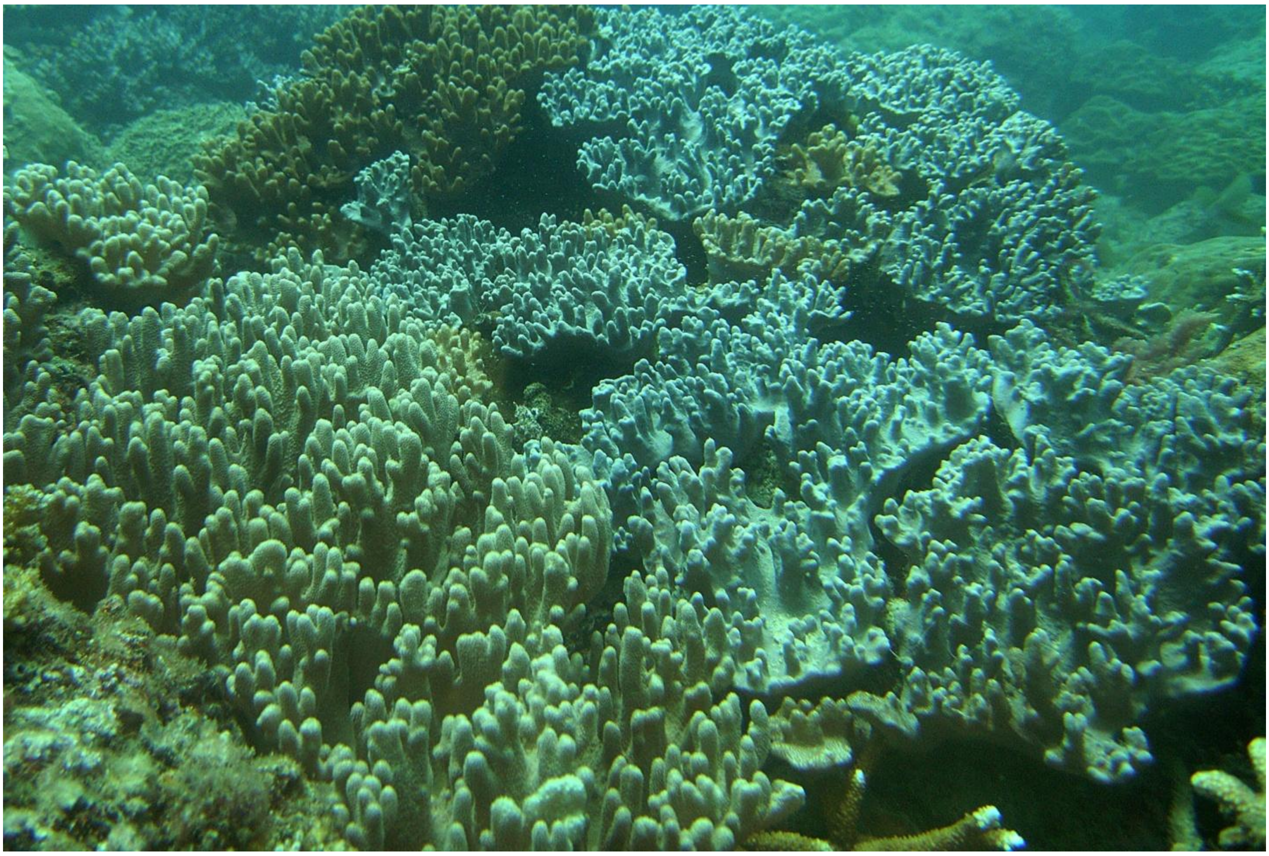


Fig. 2. Colony types of soft coral in Con Co Island.

rals (Nguyen Huy Yet, 2005; Tran Quoc Hung, 2009). They belong to 4 genera - *Sinularia, Sarcophyton, Lobophytum* and *Cladiella*.

Because this study did not use SEM (Scanning Electron Microscope) to analyze shape and size of soft coral sclerites so the accuracy of species identification is limited and needs more closely examination methods (i.e., using SEM images).

References

Bayer F.M., Grasshoff M., Verseveldt J. 1983. Illustrated Trilingual Glossary of Morphological and Anatomical Terms Applied to Octocorallia. Leiden: Brill. 170 p.

Bayer F.M. 1961. The Shallow–Water Octocorallia of the West Indian Region. Martinus Nijhoff. 364 p.

Fabricius K. 2001. Soft Corals and Sea Fans. Townsville: Australian Institute of Marine Science. 263 p.

Latypov Yu.Ya., Malyutin A.N. 1990. New data on the distribution of corals on the reefs in northern Gulf of Tonkin // Biology of the Marine Invertebrates. Vladivostok: FEB, USSR Academy of Sciences. P. 16–24.

Michael P.J., Lee Mei Wah. 2005. Octocoral Taxonomy Laboratory Manual. India, Kerala: University of Kerala. 91 p.

Nguyen Huy Yet. 2005. Order Alcyonacea of west Tonkin Gulf // Fundamental Principles in Living Science. Hanoi: Science and Techonology Publication House. P. 355–358.

Tixier–Durivault A. 1970. Les Octocoralliares de Nhatrang (Vietnam) // Cahiers du Pacifique. N 14. P. 115–236.

Tran Ngoc Loi. 1967. Peuplements animaux et végétaux du substrat des intertidal de la Baie de Nha Trang (Vietnam) // Memoires du Institut Oceanographiques. V. 11. P. 1–236.

Verseveldt J. 1980. A revision of the genus *Sinularia* May (Octocorallia, Alcyonacea) // Zoologische Verhandelingen, Leiden. V. 179. P. 1–128.

Verseveldt J. 1982. A revision of the genus *Sarcophyton* Lesson (Octocorallia, Alcyonacea) // Zoologische Verhandelingen, Leiden. V. 192. P. 1–98.

Verseveldt J. 1983. A revision of the genus *Lobophytum* Von Marenzeller (Octocorallia, Alcyonacea) // Zoologische Verhandelingen, Leiden. V. 200. P. 1–103.

BIODIVERSITY OF COMMERCIALLY VALUABLE MARINE BIVALVE FAUNA OF JEJU ISLAND, REPUBLIC KOREA

Cuong T. Le, Ronald G. Noseworthy, Kwang-Sik Choi

Faculty of Marine Biomedical Sciences (POST BK-21), Jeju National University,

66 Jejudaehakno Jeju 690-756, Republic of Korea

e-mail: skchoi@jejunu.ac.kr

Jeju Island is Korea’s largest and southernmost island, situated about 80 km south of the Korean Peninsula, with a subtropical climate because of the influence of the warm Kuroshio Current. Jeju Island exhibits an abundance of marine benthic communities, especially bivalve populations. Two-hundred twenty-five bivalve species out of 1,015 marine mollusks identified to date are found here in well-developed subtidal and intertidal habitats (Noseworthy et al., 2007).

Over the past decades, a number of field assessment studies on the richness, distribution, and other characteristics of the marine mollusk fauna have been conducted. However, little attention has been paid to basic biological information on the commercially valuable bivalve mollusks which are potential candidates for research as well as a long-term development strategy for the Jeju shellfish industry. Hence, since 1996/98, as a part of this development strategy, island-wide field surveys have been carried out. Their purpose is to supplement the existing information regarding the ecology and biodiversity of commercially exploitable species of marine bivalves in various areas of the island. Results of this research would invariably help to increase knowledge of the true potential of the marine biodiversity of Jeju, and encourage further research and development, especially for village-centered production of these species and their related products.

The level of biodiversity of bivalve species was sampled by collecting specimens at subtidal and intertidal areas along the Jeju coast. Thirty-survey stations were visited. The collections were made by SCUBA diving and through dredge from a research vessel. The samples were either fixed immediately and preserved in a 10% formalin solution at the survey site or kept in seawater and transported to the laboratory for further processing. During the sampling period, information about the characteristics of the sampling sites, such as the composition of bottom sediments and depth, was also recorded.

In the laboratory, biometric measurements were taken before the specimens were dissected and identified under a stereo-microscope. Species identification was done based on a wide variety of publications.

The study reports a list of marine bivalve molluscs consisting of 26 species belonging to 12 families. The species are grouped by family, and comments are made for each species of commercial value. These comments will deal with locality, habitat, and shell and animal morphology. Related to this study, a comprehensive four-year survey was conducted around the coastline of the island to enumerate and study the mollusk fauna (Noseworthy et al., 2007). Additional locality records were obtained to supplement those listed here.

Glycymerididae. Three species of this family are reported from the island, but only one is regarded as having commercial potential.

Glycymeris aspersa (Adams, Reeve, 1850): This species is the most common glycymeridid occurring on the island. Also is known as *Glycymeris vestita* (Dunker, 1877). In this study it was obtained from localities on the south and west coasts, and it has also been reported from the east coast. It is subtidal at a depth of 7–12 m; being collected in sandy deposits at two localities on the south coast, and in fine sand at the remaining locations. It has a rather variable, chestnut-colored pattern and red-colored blood.

Mytilidae. Twenty-one mytilid species are reported from the island but only three of the larger species are considered to be of commercial potential.

Septifer (Mytilisepta) virgatus (Wiegmann, 1837): This is the most common mytilid and is widely distributed around the island, adhering in clumps to intertidal boulders. It has a shell height of about 2–4 cm.

Mytilus galloprovincialis (Lamarck, 1819): This species has been reported from only a few localities around the island. This study obtained specimens from the north coast, and it has also been reported from the east coast. It also occurs at Chujado, a small archipelago to the north which is a part of Jeju Province, and may be more common there because of the somewhat cooler water. It occurs along the shoreline, adhering to rocks.

Mytilus coruscus (Gould, 1861): It was obtained in this study from the east coast, and has also been reported from the south coast. It is rarely found elsewhere on the island but also occurs at Chujado where it may be more common because of the somewhat cooler water. It adheres to intertidal and subtidal boulders. The shell height of adult specimens is from 10–15 cm. The presumed spawning season for this species is from April to June; the female has orange gonads, and the male has beige gonads.

Pinnidae. Two species of this family have been reported from Jeju Island, but only one has any commercial potential.

Atrina pectinata (Linnaeus, 1758): This species is distributed along the south and west coasts of the country where it is abundant. Although it is included in this report, its distribution along the Jeju coastline is poorly known. It has a shell height of about 22 cm, and is found in sandy mud.

Pectinidae. Twelve species have been reported from the island but most are either quite small or not often encountered. Only three species are considered to be of commercial importance.

Amusium japonicum (Gmelin, 1791): This study reports this species from the south coast. It has also been reported from other south coast localities. Its shell height is from 10–12 m. It is found mainly in sandy areas, but also occurs in mud, at a depth of 20–40 m. The presumed spawning season is from April to November. The female has red gonads; the male gonads are milky-white. It is a high quality food, with an excellent taste.

Pecten (Notovola) albicans (Schroter, 1802): This study reports this species from the south coast. It has also been reported from several other localities around the island, predominately on the south and east coasts. It is a subtidal species occurring at a depth of 20–40 m, and is usually found in sandy mud. It has a shell height of about 10 cm.

Chlamys (Azumapecten) farreri farreri (Jones, Preston, 1904): This species was obtained from the south coast, but has subsequently been reported from very few other localities. It occurs in the subtidal area, and has a shell height of 7–10 cm. Some individuals exhibit a variety of shell colors.

Spondylidae. Three species have been reported from the island, but only one is relatively common.

Spondylus barbatus cruentus (Lischke, 1868): This species was obtained from the north and south coasts, and has also been reported from many other localities, mainly along the south and east coasts, at a depth of 2–5 m. It is found adhering to rocks usually in areas with strong wave action. The shell surface is usually covered with coralline algae or other organisms. The female gonads are red in color, and the ripened sexual organs can be observed around July and August.

Ostreidae. Eight species have been reported, and all are presumed edible, but only three occur in numbers large enough to warrant commercial development.

Saccostrea kegaki (Torigoe, Inaba, 1981): This species has been confused with *C. echinata* (Quoy, Gaimard, 1836). Okutani (2000) states that juvenile specimens of *C. echinata* resemble *S. kegaki* but the adult specimens are quite different. Kim et al. (2010) makes reference to this study but refer to this species as *S. kegaki*. Field observations and collections by the second author support this conclusion.

Distributed along the southern Jeju seashore, in this study, but the second author has also obtained specimens from the northern coast. It adheres to rocky surfaces between boulders. The shell length is usually about 5 cm. The shell has a flat shape, and the surface has sharp, well-developed spines.

Crassostrea gigas (Thunberg, 1793): This species occurs at Chujado, and is widely distributed along the coast of Jeju Island. It inhabits intertidal and subtidal rocky areas.

Striostrea circumpicta (Pilsbry, 1904): Obtained in this study from Chujado, and on this island from the north and east coasts. It has also been reported from the south coast, and other localities on the north and east coasts. It adheres to rocks in intertidal rocky areas. The shell is almost circular, and has many folds.

Cardiidae. Nine species have been reported for the island but only two are regarded to be of possible commercial importance.

Acrosterigma (*Vasticardium*) *burchardi* (Dunker, 1877): This species is widely distributed on the island. It was obtained from the south and west coasts. It has also been reported from the east coast. It inhabits subtidal sandy areas, with a shell height of about 10 cm. The animal is very strong and active. The spawning season ranges from approximately April to July; with adult individuals having gonads near the foot area.

Nemocardium bechei (Reeve, 1847): This species is found mainly on the south coast, and has not been reported from elsewhere. It lives in sandy areas at a subtidal depth of 20–40 m. The shell, which has a length of about 7 cm, is orange with one side having sharp, well-developed projections. The mantle cavity and thick foot are also orange.

Psammobiidae. Four species are reported from the island but only one has commercial potential.

Nuttallia olivacea (Jay, 1856): This shell can be easily confused with a related species, *Nuttalia japonica* (Deshayes in Reeve, 1857). They are best separated by an examination of the pallial sinus which is deeper in *Nuttallia olivacea.* Both are edible.

This species was obtained from the north, east, and west coasts, and has also been reported from the south coast. It is particularly common on the east coast. It has a shiny shell which has a length of about 10 cm. It lives in intertidal sandy areas below the surface at a depth of about 20 cm with its long siphons on the surface.

Mactridae. Five species have been reported but only one has commercial potential.

Mactra chinensis (Philippi, 1846): This species is widely distributed all along the coastline in subtidal sandy areas, especially on the west coast. It is a large species with a length of 8–12 cm. The foot is clear orange.

Solecurtidae. Only one species has been reported from the island, and this has commercial potential.

Solecurtus divaricatus (Lischke, 1869): This species was found at localities on the north, east, and west coasts, and has also been reported from other localities in those areas. It lives below the surface in subtidal areas at a depth of 2–30 cm, with siphons branching on the surface. It has a length of 7–10 cm. The animal weighs from 50–100 g.

Solenidae. Only one species has been reported from the island, and this has commercial potential.

Solen strictus (Gould, 1861): This species occurs on the north and east coasts, and has not been reported from elsewhere. It lives in intertidal sandy areas, and has a length of 10–15 cm.

Veneridae. Twenty-eight species of venerids are reported from the island but only eight are regarded as having commercial potential. Several others are relatively large, edible species but have been recorded from only a few localities and probably do not occur in sufficient numbers to warrant commercial development.

Phacosoma japonicum (Reeve, 1850): This species has been recorded only from the east coast, but its presence in beach drift at other localities indicates that living populations may also occur in those areas. It lives in fine sand at a depth of 2–5 m.

Phacosoma troscheli (Lischke, 1873): This species is found mainly on the south coast, and it has also been reported from the east and west coasts. It lives in sandy mud at a depth of 20–40 m. It is a relatively smaller species, with a length of 2–3 cm. The surface of the shell is covered with chestnut-covered spots.

Ruditapes philippinarum (Adams, Reeve, 1850): This is the most common venerid and also one of the most common bivalves on the island, occurring all round the coastline, and is also found on the south and west coasts of the country. It lives in sand in the intertidal area. Some adult specimens are relatively small. The color patterns are very variable among individuals.

Gomphina (Macridiscus) veneriformis (Lamarck, 1818): (*G. aequilatera* (Sowerby, 1825) is a synonym.) This is another common species which is widely distributed on the island. It lives in sand in the intertidal area. The shell is triangular in shape with relatively thick valves, and it exhibits a wide variety of color patterns.

Paphia euglypta (Philippi, 1847): This species has been obtained from the south and east coasts. It lives in sandy areas in the subtidal zone at a depth of 20–40 m. The shell has relatively thick valves with well-developed concentric surface ridges. The mantle cavity and foot are orange.

Paphia schnelliana (Dunker, 1865): This species has been recorded only from the east coast, and has not been reported from elsewhere. It lives in fine sand at a depth of 2–4 m. The shell surface is somewhat shiny with brown concentric ridges.

Saxidomus purpuratus (Sowerby II, I852): This species has been recorded only from the east coast, and has not been reported from elsewhere. It lives in sand in the intertidal and subtidal zones. The shell is oval with relatively thick valves.

Cyclina sinensis (Gmelin, 1791): This species has been recorded only from the east coast, and has not been reported from elsewhere. It lives in fine sand at a depth of 2–4m. The shell is almost circular.

Most of the commercially exploitable species enumerated in this survey occur in the subtidal area. Harvesting the wild populations for commercial purposes would require special techniques and equipment. Much research and experimentation would have to be done to ascertain which species are viable for aquaculture. However, the development of a broad-based aquaculture industry would be of great benefit to the economy of Jeju Island.

Acknowledgments

The authors would like to thank Asia-Pacific Network for Global Change Research for providing all financial support for this study.

References

Bernard F.R., Cai Y.Y., Morton B. 1993. Living Marine Bivalve Mollusks in China., Hong Kong: Hong Kong University Press. 146 p.

Habe T. 1977. Systematics of Mollusca in Japan: Bivalvia and Scaphopoda. Osaka: Hoikusha Publishing Co., 372 p.

Kim B.K., Kang D.H., Ko D.K., Yang H.S., Kim D.K., Kang C.K., Choi K.S. 2010. Annual reproductive cycle of the oyster, *Saccostrea kegaki* (Torigoe & Inaba, 1981) on the southern coast of Jeju island, Korea // Invertebrate Reproduction and Development. V. 54, N 1. P. 19–26.

Noseworthy R.G., Lim N.R., Choi K.S. 2007. A catalogue of the mollusks of Jeju Island, South Korea // Korean Journal of Malacology. V. 23. P. 65-104.

Okutani T. (Ed.). 2000. Marine Mollusks in Japan. Tokyo: Tokai University Press. 1224 p.

ENVIRONMENTAL CONDITIONS AND PRODUCTIVITY CHARACTERISTICS OF *HYDROPUNTIA EUCHEUMATOIDES* (RHODOPHYTA) IN THE WATERS OF VIETNAM

I.I. Cherbadgy, L.N. Propp

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok 690041, Russia

e-mail: icherbadgy@mail.ru

Integrated studies of the environmental conditions of *Hydropuntia eucheumatoides* (Harvey) Gugel et Fredericq, 2004 (Gracilariales, Rhodophyta) in the South China Sea near the north-eastern part of the Re Island were carried out. There were photosynthetically active radiation (PAR), concentrations of oxygen (O_2), ammonium (NH_4), nitrate (NO_3) and phosphate

(PO_4), and also concentrations in algal tissues of carbon (C), nitrogen (N), phosphorus (P), chlorophyll *a* (Chl *a*) and phycoerythrin (PE). Values of its photosynthesis intensity (P_n) and dark respiration (R_d) were measured under *in situ* conditions in May 2007. Rather low values of P_n were registered at *H. eucheumatoides* in comparison with other species of this genus that are caused by its morphological parameters. It is supposed that a basic factor which limits P_n of this alga is low concentration of PO_4 in the medium.

Red seaweeds of the Gracilariaceae have been the main source of agarophytes in the world since the 1960s, due to their euryhaline and eurythermal characteristics, as well as their higher growth ratios and agar contents. Approximately 60 % of all agar is produced from this alga (Tseng, 2001).

Hydropuntia eucheumatoides (Harvey) Gurgel et Fredericq, 2004 (Gracilariales, Rhodophyta); basionym *Gracilaria eucheumoides* Harvey, 1860, grow on a large scale in several countries in South-East Asia, including Vietnam (Hurtado-Ponce et al. 1992). It is known that in this species collected from the coast of 10 islands of the Spermonde (Indonesia) agar content is 27–32%, and the strength of its gel reaches 850 g/sm^2 (Harlim, 1986). However, the influence of environmental conditions on production parameters of *H. eucheumatoides* practically is not studied, and the production of agar on a commercial scale is not being carried out. In this study, we used field and laboratory methods to evaluate the influence of environmental conditions on the intensity of photosynthesis and dark respiration of *H. eucheumatoides* under *in situ* conditions.

Materials and Methods

Integrated studies of the effects of environmental conditions – photo synthetically active radiation (PAR), concentrations of oxygen (O_2), ammonium (NH_4), nitrate (NO_3) and orthophosphate (PO_4) in seawater, as well as concentrations in algal tissues of carbon (C), nitrogen (N), phosphorus (P), chlorophyll *a* (Ch *a*) and phycoerythrin (PE) on the intensity of photosynthesis (P_n) and dark respiration (R_d) *H. eucheumatoides* were conducted in the South China Sea of the north-eastern part of the Re Island under *in situ* conditions in May 2007.

H. eucheumatoides were sampled for analysis from a depth of 12 m. Its thallus are cartilaginous, greenish-brown to purple in color when fresh, forming prostrate clumps and attached to the substratum by hapters originating from the ventral side of the flattened branches. The branching pattern is very irregular and the branches are compressed measuring 2.5–7 mm across, provided with coarse teeth along their margins, attached by discoid holdfast.

The rate of P_n and R_d of *H. eucheumatoides* were measured aboard a research vessel, using a particular flow-through system which imitates the conditions that are characteristic of the habitats of the alga (Cherbadgy et al., 2010). In the evening 8–10 g of the algae in 4 replicates were taken and placed into 800 ml transparent experimental vessels. Every 3 hours during the day period we took water samples from the near-bottom layer and the flow, running through the experimental and control vessels, to determine the concentration of O_2; at the midday and at the midnight we collected additional samples to determine NH_4, NO_3 and PO_4 levels. O_2 concentration in water samples was determined using Winkler test with some modifications; concentrations of NH_4, NO_3 and PO_4 were measured with a spectrophotometer. Contents of C, N and P in algae tissues were estimated with the method of wet burning; Chl concentration was determined spectrophotometrically in 90% acetone extracts of alga. All indices were calculated per gram fresh weight (FW) of the alga. To calculate the daily rate of oxygen exchange (M_{O2}), we used the following modified equation for an unstable regime in a flow-through system (Cherbadgy et al., 2010)

To describe the dependence between net production (P_n) and PAR intensity we used the hyperbolic equation tangent (Henley, 1993):

$$P_n = (P_{max} \times tanh(\alpha \times PAR/ P_{max}))+R_d,$$

where P_n, R_d - the rate of net photosynthesis production and dark respiration, correspondingly, mgO_2 gFW^{-1} h^{-1}; α - the slope of the initial part of light curve; P_{max} - maximum rate of photosynthesis; PAR - photosynthetically active radiation, μE м$^{-2}$ с$^{-1}$.

Results and Discussion

Environmental conditions in research period considerably varied with time that caused corresponding alterations of oxygen exchange of *H. eucheumatoides*. Water temperature within 24 hours changed in the range from 28 to 29.8°C. Maximum PAR on a sea surface at midday reached 1040 μE m^{-2} s^{-1}, and approximately 120 μE m^{-2} s^{-1} penetrated on a bottom (12 m). Environmental conditions in experimental apparatus approximately corresponded to natural (Table 1). Concentrations of NH_4, NO_3

Table 1. Values of environmental factors, content of nutrient in algae tissues and rate of net photosynthesis (Pn) and dark respiration (Rd) *H. eucheumatoides* in the day period.

Variable	Valid N	Mean	Min	Max	SD
T° C	8	28.7	28	29.8	0.75
PAR, μmol m^{-2} s^{-1}	16	36,2	0	114	46,1
O_2, μM	36	199	189	206	5.6
PO_4, μM	12	0,08	0,05	0,13	0,04
NH_4, μM	12	0,29	0,21	0,36	0,06
NO_3, μM	12	0,23	0,15	0,29	0,06
C, mg gFW^{-1}	4	125	67,3	221	64,2
N, mg gDW^{-1}	4	6,28	5,80	6,90	0,45
P, mg gFW^{-1}	4	0,21	0,14	0,27	0,05
Ch *a*, mg gFW^{-1}	4	0.04	0.03	0.07	0.01
PE, mg gFW^{-1}	4	0,15	0,10	0,26	0,07
Pn, mgO2 gFW^{-1} h^{-1}	16	0.14	0.06	0,22	0.04
Rd, mgO2 gFW^{-1} h^{-1}	16	0.03	0.01	0.04	0.01

and PO_4 in water averaged 0.29, 0.23 and 0.08 μM accordingly within 24 hours; molar ratio $(NH_4+NO_3)/PO_4=6.5$. If to compare PO_4 concentration in coastal waters of Re Island (Table 1) to the minimum concentrations limiting growth of macrophytes (0.39 μM PO_4) (Hwang et al., 2004), it is obvious that PO_4 concentration is below limiting level.

By ratio N/P in algae tissues it can be inferred by possible limitation of their photosynthesis or growth rate. So, on several species of green, brown and red algae of subtropical Atlantic the ratio N/P=43 (Lapointe et al., 1992). On the basis of measurements of algae production parameters and the ratio N/P in their tissues, these authors believe that the ratio N/P>11–24 testifies about P limitation, and at N/P<8–16 – about N limitation. Our researches showed that in tissues of *H. eucheumatoides* the molar ratio N/P=64 (Table 2). Such ratio also confirms a strong limitation of *H. eucheumatoides* production in Re Island waters by compounds of mineral phosphorus that is characteristic for tropical waters (Lapointe et al., 1992).

Table 2. Organic carbon (C), nitrogen (N) and phosphorus (P) (μmol gFW^{-1}) in tissues of *H. eucheumatoides* and their rations.

C	N	P	C : N	C : P	N : P	C : N : P
10.4	0.45	0.007	23	1486	64	1486 : 64 : 1

Dependence P_n on PAR intensity at *H. eucheumatoides* (Fig. 1) is well expressed (r=0.96, p<0.001) by the equation of a hyperbolic tangent (Table 3). The P_n rate within daylight hours makes up on the average 0.14 mgO_2 gFW^{-1} h^{-1} or 1.26 mgO_2 gDW^{-1} h^{-1}. The rate of dark respiration (R_d) during the night period makes up on the average 0.03 mgO_2 gFW^{-1} h^{-1} and the ratio $P_n/R_d=4.7$. The compensation point of photosynthesis (Ic) at which the photosynthesis compensates expenses for algae breath, makes up 8.12 μE m^{-2} s^{-1}. The light saturation (I_k) of algae occurs at rather low light intensity - 62.5μE m^{-2} s^{-1}. Photosynthetic parameters of *H. eucheumatoides* basically correspond to algae dwelling at moderate illumination. However P_n has lower values, than other species of *Gracilaria* genus which are being cultivated in coastal waters of Vietnam (Nguyen, 1992; Skriptsova, Nabivailo, 2009).

Table 3. Photosynthesis parameters of light curve (P-I) of *H. eucheumatoides* (the mean±SE, n=16). P_{max} – the greatest level of photosynthesis, mgO_2 gFW^{-1} h^{-1}; R_d – dark respiration, mgO_2 gFW^{-1} h^{-1}; α – the slope of the initial part of light curve; $I_c= R_d/\alpha$ – compensation intensity of PAR, μE m^{-2} s^{-1}; $I_k = P_{Max}/\alpha$ – saturation level of PAR, μE m^{-2} s^{-1}; *r* – correlation coefficient calculated using the Levenberg-Marquardt algorithm for P-I curves; *p* – probability level.

Deep, m	P_{max} ±SE	R_d ± SE	α ± SE	I_c	I_k	*r*	*p*
12	0.20±0.017	0.026±0.007	0.0032±0.0005	8.12	62.5	0.96	<0.000

Thus, the basic factor which limits P_n of *H. eucheumatoides* is possibly the low concentration of PO_4 in the medium that is confirmed also by the molar ratio N/P in algae tissues. Rather low values of P_n at *H. eucheumatoides* apparently are defined by its morphological parame-

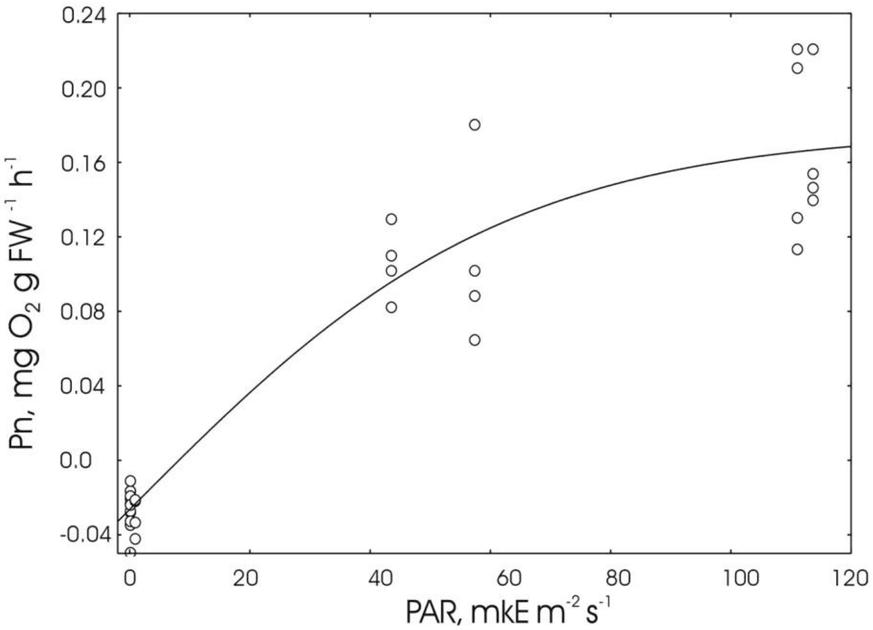


Fig. 1. Dependence between net photosynthesis rate (P_n) in *H. eucheumatoides* and PAR intensity, simulated by hyperbolic tangent on basis of experimentally obtained parameters of light curves. The experiments were performed in habitats of the alga, under natural illumination, for 24 h.

ters. This species has a very massive thallus and its specific surface area (S_{sp}, mm^2/mg) has lower values in comparison with other species of this family, living in moderate and tropical waters. Reduction of S_{sp} means, as it is known, increase in weight of the tissues which are not taking part in assimilation of carbon under unit of assimilation surface. However, considering the great content of agar in the algae and its very high quality (Harlim, 1986) it is possible to breed out and to select forms with higher values of S_{sp} which can be used in mariculture. Additional fertilization of algae by mineral connections of phosphorus, in mariculture conditions, will possibly lead to increase in their primary production in 2-3 times, so also growth rates.

References

Cherbadgy I.I., Sabitova L.I., Parenskiy V.A. 2010. The influence of environmental factors and nutrient concentrations in tissues of the seaweeds *Ahnfeltia tobuchiensis* (Rhodophyta: Ahnfeltiales) on the primary production and dark respiration of its population // Russian Journal of Marine Biology. V. 36, N 4. P. 282–292.

Gurgel C.F.D., Fredericq S. 2004. Systematics of the Gracilariaceae (Gracilariales, Rhodophyta): A critical assessment based on *rbc*L sequence analyses // Journal of Phycology. V. 40. P. 138–159.

Harlim T. 1986. Screening species of brown and red algae collected from the coast of spermonde for active substances // Summary Report of the Workshop on Marine Algae Biotechnology. Washington D.C.: National Academic Press. P. 45–48.

Henley W.J. Measurement and interpretation of photosynthetic light-response curves in algae in the context of photoinhibition and diel changes // Journal of Phycology. 1993. V. 29. P. 729–739.

Hurtado-Ponce A.Q., Luhan Ma R.J., Guanzon N.G. 1992. Gathering of economically important seaweeds in western Visayas, Philippines // Scientist. V. 29. P. 40–47.

Hwang R., Tsai C., Lee T. 2004. Assessment of temperature and nutrient limitation on seasonal dynamics among species of *Sargasssum* from a coral reef in southern Taiwan // Journal of Phycology. V. 40. P. 463–473.

Lapointe B.E., Littler M.M., Littler D.S. 1992. Nutrient availability to marine macroalgae in silici-clastic versus carbonate-rich coastal waters // Estuaries. V. 15, N 1. P. 75–82.

Nguyen H.D. 1992. Vietnamese species of *Gracilaria* and *Gracilariopsis //* Taxonomy of Economic Seaweeds. V. 3. P. 207–210.

Skriptsova A.V., Nabivailo Y.V. 2009. Comparison of three gracilarioids: growth rate, agar content and quality // Journal of Applied Phycology. V.21. P 443–450.

Tseng C.K. 2001. Algal biotechnology industries and research activities in China // Journal of Applied Phycology. V. 13. P. 375–380.

COMMUNITY OF FREE-LIVING MARINE NEMATODES IN INTERTIDAL ZONE OF JEJU ISLAND, KOREA

Yulia A. Trebukhova[1], Olga N. Pavlyuk[2]

[1]Far Eastern State Marine Biosphere Natural Reserve, Far East Branch, Russian Academy of Sciences, Vladivostok, 690041, Russia; e-mail: trebukhova@gmail.com

[2]A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok, 690041, Russia

Introduction

Jeju Island is the largest island in Korea and is located towards southwest of the Korean Зeninsula. The island is on the border of moderate and subtropical zones. It has a humid subtropical climate. The intertidal zone of Jeju Island is well studied. Recently numerous research papers about composition and distribution macrofauna communities were published (Lee et al., 2001; Ko et al., 2008, and others) but there was no data on the meiofauna around Jeju Island until now. There is the only a paper with the description of a new species of nematode *Dracogalerus koreanus* from coastal subtidal zone of Jeju Island (Rho and Kim, 2005).The main goal of this work is to describe composition and density distribution of nematode communities and to compare the data from the different intertidal zones.

Material and Methods

The sampling sites are located on the Jeju Island coast (Fig. 1). Three intertidal zones and 14 stations were sampled in October, 2008. The samples were collected within the intertidal zone at low tide in tide pools and puddles left in the lava rocks on the shore, and on a beach: Geumneung

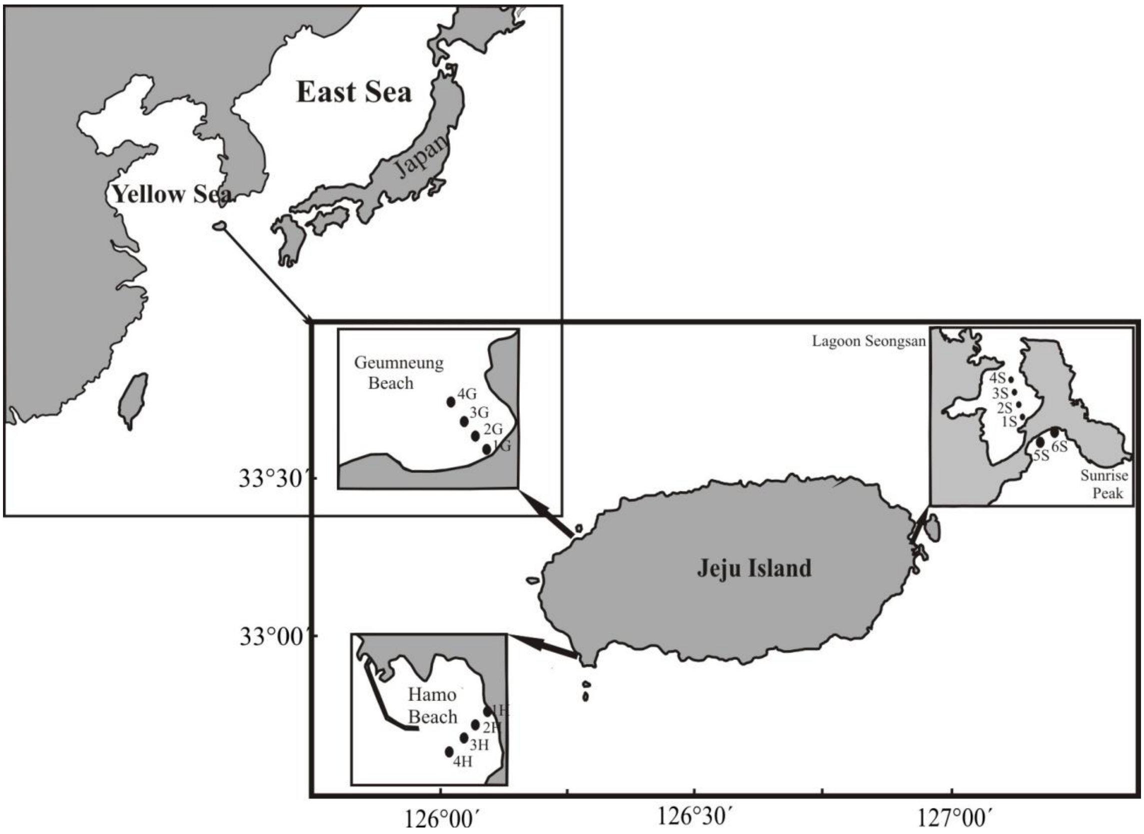


Fig. 1. A schematic map showing the study area with sampling station locations.

Beach (33°23′23.07″ N, 126°13′48.38″ E; stations 1G, 2G, 3G, 4G); Hamo Beach (33°12′34.82″ N, 126°15′45.64″ E; stations 1H, 2H, 3H, 4H); Seongsan lagoon (33°27′27.18″ N, 126°56′00.39″ E; stations 1S, 2S, 3S, 4S) and tide pools in a southern part of peninsula Seongsan near the volcano Sunrise Peak (33°27′30.47″ N, 126°56′05.49″ E; stations 5S, 6S) (Fig. 1). Sediment sample was collected from the top 5 cm of sediment at each station using a tubular bottom sampler with a mouth diameter of 5 cm. Four replicate sediment samples at each station were collected. The samples were washed through 1mm and 32 μm nylon sieves, fixed by 4% formaldehyde solution and then stained with "Rose Bengal".

Samples for granulometric analysis were also taken at each station; sediments were classified based on the domination of particles of different size classes (Parsons et al., 1982). During the sampling period the temperature of the bottom water layer was 20–22°C, salinity – 34.1–34.3 PSU (practical salinity unit).

The Wieser classification (Wieser, 1953), based on the structure of the mouth cavity of animals, was used for the estimation of the trophic structure of the nematode community. According to this classification four groups of feeders were defined: selective deposit feeders (1A), non-selective deposit-feeders (1B), epistratum feeders (2A) and omnivores (2B). The hierarchical analysis was used to estimate similarity between nematode species compositions. The analysis was performed using the Statistica 6.0 software.

Results

A total of sixty eight species belonging to 60 genera and 19 families of nematodes were found in the whole area. The hierarchical analysis clearly separated the four groups of stations (Fig. 2). Stations 1S–4S 5S, 6S clustered into two main groups. Stations from Hamo Beach clustered in a single main group as well as stations from Geumneung Beach. The four clusters interpreted as different nematode taxocenosis, each with its distribution. Nematodes taxocenosis were different in species composition and in structure.

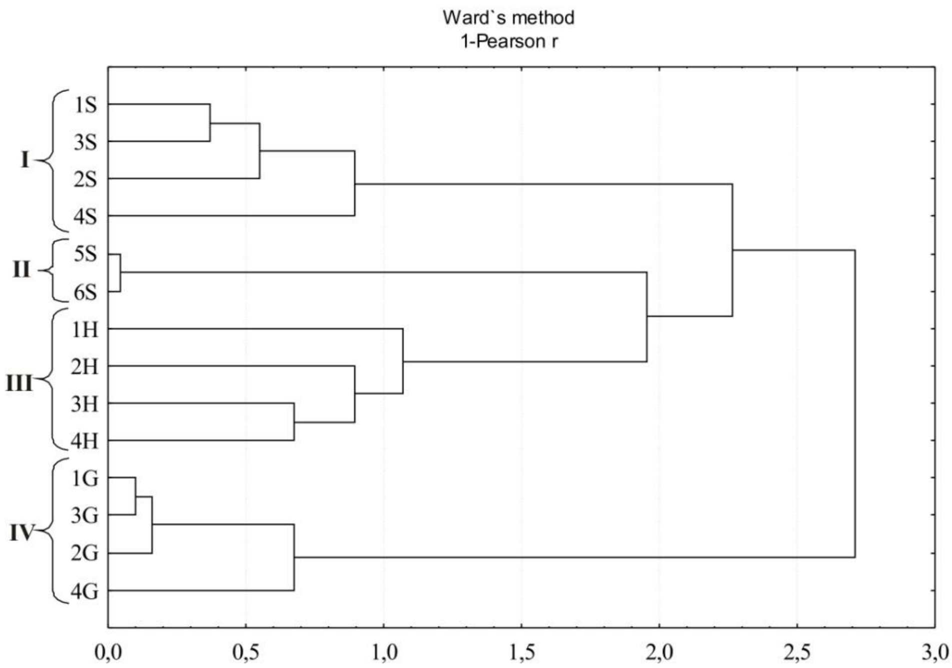


Fig. 2. Hierarchical cluster analysis (Ward method, Pearson correlation coefficient) based on the nematode species composition.

In taxocenosis I, located in the small tidal lagoon, we registered thirty one species of nematodes. The lagoon is situated at eastern side of Jeju Island. Bottom sediments were generally represented by slightly silted sand. In tide puddle (st. 1S) *Axonolaimus* sp. and *Paralinchomoeus* sp. were dominant. In upper tide level (st. 2S) *Halichoanolaimus posseticus* and *Axonolaimus* sp. were dominant, in the mid-tide level (st. 3S) – *Axonolaimus* sp. and in low tide level (st. 4S) – *Paracomesoma* sp. and *Pomponema* sp. The correlation analysis revealed correlation between the density of nematodes and median grain size (Spearmen correlation coefficient is 0.85±0.21, p<0.001). Epistratum-feeders (2A, 55.3%) dominated among nematodes with the different feeding types.

Taxocenosis II occupied the tide pools in Seongsan Sunrise Peak. It is a lava rocky reef with the numerous tide pools, situated on south from Seongsan peninsula, near Sunrise Peak volcano. In two selected tide pools the only bottom sediment was gravelly sand. The species composition of Nematodes counted 8 species, dominated by *Enoplolaimus* sp. Omnivores were generally dominant feeding group (2B).

Taxocenosis III was located in the intertidal zone of Hamo Beach and included 19 species of nematodes. This tiny beach on the southwestern tip of Jeju Island has more rocks than sands. Comparing to other sampling sites, intertidal zone is characterized by various sediments. In the tide pool the sediments were gravelly to slightly silty sand. In the upper-tide and mid-tide level the sediment was slightly silty sands while in the low-tide level only mud was the sediment. In the tide pool (st. 1H) the rare species *Platycoma* sp. was the dominant species. In upper tide level (st. 2H) *Pseudoncholaimus* sp.$_2$ and *Viscosia* sp.$_2$ were dominated, in mid-tide level (st. 3H) – *Calyptronema* sp., and in low-tide level (st. 4H) – *Symplacostoma* sp. and *Euchromadora* sp. The correlation analysis revealed the negative interrelation between the density of nematodes and median grain size (Spearmen correlation coefficient is – 0.50±0.11, $p<0.05$). Omnivores (2B, 55.3%) dominated among nematodes with different feeding types, with an exception at station 1H, where selective deposit-feeders (1A) dominated.

In taxocenosis IV located in Geumneung Beach we found 34 species of nematodes. Geumneung Beach is beautiful long beach located near the Geumneung-ri on the northwestern tip of Jeju (Fig. 1). The beach is packed with lava rock and bottom sediment is white and very fine sand. In the tide pool (st. 1G) *Oncholaimus* sp.$_2$ predominated. On the beach in upper-tide level (st. 2G) *Oncholaimus* sp.$_2$ and *Epacanthion* sp. were dominant species, in the mid-tide level (st. 3G) – *Oncholaimus* sp.$_2$, and in the low-tide level (st. 4G) – *Enoplus anisospiculus* and *Phanoderma* sp. The correlation analysis revealed the correlation between the density of nematodes and median grain size (Spearmen correlation coefficient is 0.80±0.09, $P<0.001$). Omnivores (2B) dominated among nematodes with different feeding types.

As a result of our research work the correlation was revealed between the densities of nematodes from the type of sediment. Members of two trophic groups – omnivores (2B) and epistratum-feeders (2A) were dominant in the nematodes community. The silt content in of sediments on the littoral was minimal; therefore the portion of deposit-feeders was insignificant. The greatest percentage of non-selective deposit-feeders (1B) is detected on the littoral of Seongsan lagoon, where the benthic sediments were the silted sands. As a result of cluster analysis four taxocenosis of nematodes were defined and they were clearly distinguished by four types of littoral with different granulometric composition of benthic sedimentations. Thus, of the sediment of type is a major factor that determines the structure and distribution of nematode communities of Jeju Island.

References

Ko J.-C., Koo J.-H., Yang M.-H. 2008. Characteristics of ocean environmental factors and community structure of macrobenthos around Munseon, Jeju Island, Korea // Korean Journal of Malacology. V. 24, N 3. P. 215–228.

Lee J.J., Hyun J.M. 2002. Spatial diversity and community structure of macrobenthic invertebrate inhabiting the intertidal zone near Songacksan area, Jeju Islands // Korean Journal of Malacology. V. 18, N 1. P. 41–52.

Lee J.J., Kang K.C., Kim J.C. 2001. Spatial species diversity of macrobenthos in the intertidal zone of Hwasoon, Jeju Islands // Korean Journal of Malacology V. 17, N 1 P. 63–70.

Parsons T.R., Takahashi M., Hargrave B. 1982. Biological Oceanography. Moscow: Legkaya i pishchevaya promyshlennost. 432 p.

Rho H.S., Kim W. 2005. A new free-living marine nematodes species of the genus *Dracogalerus* Allen and Noffsinger (Nematoda: Draconematidae) from shallow subtidal zone of Jeju Island, Korea // Integrative Biosciences. V. 9, N 3. P. 113–122.

Wieser W. 1953. Die Beziehung zwischen Mundhölengestalt, Ernährungswiese und Vorkommen bei freilebenden marinen Nematoden // Arkiv. Zool. V. 4. Bd. 5. P. 439–484.

PSSA - MANAGEMENT TOOL FOR MARINE BIODIVERSITY CONSERVATION IN THE VIETNAM SEA

Du Van Toan

Vietnam Administration of Seas and Islands, (VASI), 83 Nguyen Chi Thanh, Hanoi, Vietnam

e-mail: duvantoan@gmail.com

A PSSA, Particularly Sensitive Sea Area, is important management tool for conserve marine biodiversity at the any marine area. At the time of designation of a PSSA, an associated protective measure, which meets the requirements of the appropriate legal instrument establishing such measure, must have been approved or adopted by IMO to prevent, reduce, or eliminate the threat or identified vulnerability. Information on each of the PSSAs that has been designated by IMO is available at nautical chart. The Marine Vietnam’s coastal zones and Island is an isolated oceanic habitat of extremely rich marine life in very good condition which is important to the maintenance and dispersal of the marine life of the Western Tropical Pacific. Vietnam coastal areas is very high risk areas affected by maritime activities, particularly international shipping, so in the future identification of some PSSA is necessary.

Roughly 80% of international trade is carried by ship. Such traffic carries the risk of groundings, collisions, spills, and other incidents that threaten the ecological health of marine systems. The associated hazards to habitats and wildlife can pose a persistent concern for managers of marine protected areas, particularly those near major ports or shipping routes. In several cases around the world, MPA practitioners have moved to reduce these threats by implementing focused regulatory instruments, such as shipping lanes, areas to be avoided, or discharge restrictions. But abroader, higher-profile tool remains available the international designnation of sites as Particularly Sensitive Sea Areas, or PSSAs - offering managers a comprehensive approach to seeking vigilance and awareness from the international shipping industry. Available since 1991 the PSSA tool has so far been approved for 12 sites, but more are now in the designation pipeline.

Vietnam East Sea has many maritime activities, especially maritime international. Oil tankers to the Vietnam East Sea up to 50% of the world's oil tankers. With the increase in regional economic development in Northeast Asia, leading to an increase in oil consumption and increase the number of ships passing through the South China Sea oil and the risk of oil pollution is very high. Recently happened quite a lot of oil spills from the international maritime activities adversely affecting the environment of coastal areas and islands of Vietnam. As reported by the Vietnam Environment Agency, the 2007 oil spill has affected many of Vietnam's sea areas from Ha Tinh Province to Ca Mau cause great damage to the economy of Vietnam. The cause is mainly due to oil spill from the international maritime routes or other countries of South East, under the action of the east monsoon, ocean dynamics mode vertigo brought oil to the coastal islands of Vietnam.

Identification and application PSSA

The guidelines set out by IMO for an area to gain PSSA status are separated into three categories, which are then subdivided into further criteria. For a PSSA to be designated it must meet any one of the following criteria (Table 1).

Table 1. PSSA categories and criteria

PSSA Categories	Criteria to be met
Ecological	Uniqueness, dependency, representativeness, diversity, productivity, naturalness, integrity and vulnerability
Social, cultural and economic	Economic benefit, recreation and human dependency
Scientific and educational	Research, baselines and monitoring studies, education and historical values

IMO-approved protective measures to accompany a PSSA proposal. IMO tools that could serve as associated protective measures with a PSSA include:

1. Traffic separation schemes - used to separate opposing streams of traffic through the establishment of traffic lanes or separation zones.

2. Areas to be avoided - closure of an area to al ships or to certain sizes or classes of vessels.

3. No anchoring areas - established to protect areas with an unstable anchoring bottom or that may be damaged by anchor weight or slippage.

4. Ship reporting systems - used to determine the intended movement of a ship through a given area.

5. Discharge restrictions – regulating operational discharges from ships.

Applying for PSSA designation. IMO has the competence designate PSSAs on the territorial sea, the 200-mile exclusive economic zone, and into the high seas (Table 2). Only IMO member states can submit proposals for PSSA designation. Governments with a common interest in an area should submit a coordinated proposal. The application itself must contain:

1. A summary of the objectives of the proposed PSSA identification, its location, the need for protection, and a proposal for associated protective measures.

2. A detailed description of the area, together with a chart; an explanation of the significance of the area based on recognized criteria; and an explanation of the vulnerability of the area to damage from international shipping activities.

3. A description of the proposed measures showing how they will provide the needed protection from threats of shipping damage.

4. A review of the possible impact of any proposed measures on the safety and efficiency of navigation.

Table 2. List of adopted PSSAs

TT	PSSA	Year
1	Great Barrier Reef, Australia	1990
2	Sabana-Camagüey Archipelago in Cuba	1997
3	Malpelo Island, Colombia	2002
4	around the Florida Keys, United States	2002
5	Wadden Sea, Denmark, Germany, Netherlands	2002
6	Paracas National Reserve, Peru	2003
7	Western European Waters	2004
8	Extension of the existing Great Barrier Reef PSSA to include the Torres Strait (proposed by Australia and Papua New Guinea)	2005
9	Canary Islands, Spain	2005
10	Galapagos Archipelago, Ecuador	2005
11	Baltic Sea area, Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden	2005
12	Papahānaumokuākea Marine National Monument, United States	2007

Note: PSSA designated in the world.

Benefits of PSSA designation

The International Maritime Organization (IMO) – a United Nations agency focusing on international shipping – is responsible for designating various internationally recognized protective measures, including PSSAs. Member states submit proposals for PSSA designation to the IMO; if approved, the designated PSSA appears on international nautical charts.

The IMO defines a PSSA as "an area that needs special protection through action by IMO because of its significance for recognized ecological, socio-economic or scientific reasons, and which may be vulnerable to damage by international shipping activities."

In short, PSSA designation offers three principal benefits:

1. Providing global recognition of the special significance of a designated area though identification of PSSA status on international nautical charts;

2. Informing mariners of the importance of taking extra care when navigating through a region;

3. Giving coastal states the opportunity to adopt additional protective measures to best address the particular risks associated with international shipping in the area.

The third benefit is a critical part of any PSSA designation because, by itself, PSSA status confers no direct regulatory benefits. Associated measures - such as areas to be avoided (ATBAs) and other regulatory actions - provide the actual legal basis for restrictions on shipping. For this reason, any application made to the IMO for PSSA designation is expected to identify at least one associated protective measure that addresses the risk posed to the area by international shipping activities.

PSSA application for Vietnam sea

Determined by the method of PSSA's indentification, author have some reviews about the direction of Vietnam's PSSA 3 groups (I-III) as follows:

I. Vietnam MPA:

1. Cat Ba (Hai Phong). 2. Son Tra - Hai Van (Thua Thien-Hue). 3. Nha Trang (Khanh Hoa). 4. Con Dao (Ba Ria - Vung Tau). 5. Tran (Quang Ninh). 6. Hon Me (Thanh Hoa). 7. Cu Lao Cham (Quang Nam). 8. Ly Son (Quang Ngai). 9. Co To (Quang Ninh). 10. Phu Quy (Binh Thuan). 11. Bach Long Vy (Hai Phong). 12. Con Co (Quang Tri). 13. Spratly Islands (Khanh Hoa). 14. Phu Quoc (Kien Giang). 15. Hon Cau (Binh Thuan). 16. Nui Chua (Ninh Thuan).

II. Areas with special social and cultural values, such as Ha Long Bay, Bai Tu Long, Cam Ranh, Van Phong, Lang Co, Xuan Dai, Vung Ro.

III. Areas of special ecosystems such as coral reefs in the Spratly Islands, Paracel Islands, Ran Trao, such as mangroves in coastal provinces: Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh, Thanh Hoa, Can Gio, Tien Giang, Ben Tre, Soc Trang, Tra Vinh, Bac Lieu, Ca Mau, Kien Giang.

Discussion and recommendations

Coastal areas of Vietnam are very high risk areas affected by maritime activities, particularly international shipping, so identification of the PSSA for Vietnam is necessary. These are tools to monitor, manage and protect natural resources and the marine environment under the criteria of the International Maritime Organization IMO. If the IMO PSSA is recognized as the international maritime activities will limit pollution to these areas and these areas will become more attractive to developing sustainable maritime economy.

References

IMO (International Maritime Organisation). Revised Guidelines for the identification and designation of Particularly Sensitivity Sea Areas. 2005. Resolution A.982(24) [http://www.gc.noaa.gov/documents/982-1.pdf].

IMO (International Maritime Organisation). Guidelines for designation of special areas under MARPOL 73/78 and guidelines for the identification and designation of Particularly Sensitivity Sea Areas. 2005 [http://www.gc.noaa.gov/documents].

IMO (International Maritime Organisation). Particularly Sensitive Sea Area (PSSA) Wadden Sea Feasibility Study. 2001. Advice to the Trilateral Wadden Sea Cooperation. Final report. Southampton UK SO14 0RD: Southampton Institute. 10 p.

Particularly Sensitive Sea Areas (PSSA). 2007. Compilation of all guidance documents and PSSAs designated by IMO (International Maritime Organisation) since 1990. London: IMO. 150 p.

Nguyễn Chu Hồi. 2005. Basis of Resources and Marine Environment. Ha Noi: VNU Publishing. 306 p. [In Vietnamese].

Nguyễn Huy Yết. 2008. Biological Resources and Ecosystems in the Waters Paracel and Spratly Islands. Ha Noi: Publisher of Natural Sciences and Technology. 256 p. [In Vietnamese].

BARCODING AND PHYLOGENETIC INFERENCES IN NINE MUGILID SPECIES (PISCES, MUGILIFORMES)

Neonila Polyakova

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok 690041, Russia

e-mail: nila.polyakova@gmail.com

Accurate and unambiguous identification of fish and fish products, from eggs to adults, is important in many areas. It would enable retail substitutions of species to be detected, assist in managing fisheries for long-term sustainability, and improve ecosystem research and conservation. Grey mullets of the family Mugilidae are distributed worldwide and inhabit marine, estuarine, and freshwater environments in all tropical and temperate regions. Various mugilid species are commercially important species in fishery and aquaculture of many countries. For the present study we have chosen mitochondrial cytochrome oxidase subunit I (COI). We examined COI diversity within and among 9 mugilid species belonging to 4 genera (*Mugil cephalus* (Sea of Japan and Azov, Mediterranean, Taiwan), *Liza saliens* (Mediterranean), *L. aurata* (Sea of Azov, Mediterranean), *L. ramado* (Mediterranean), *L. macrolepis* (Taiwan), *L. subviridis* (Taiwan), *Chelon labrosus* (Mediterranean), *C. haematocheilus* (Sea of Japan, Taiwan, and introduced to the Sea of Azov), and *Valamugil cunnesius* (Taiwan)), many of which have been examined from multiple specimens, with the goal of determining whether DNA barcoding can achieve unambiguous species recognition of mugilid species. The data obtained showed that information based on COI sequences was diagnostic not only for species-level identification but also for recognition of intraspecific units, e.g. allopatric populations of circumtropical *M. cephalus*, whose pronounced population-genetic structure is well-known, or even native and acclimatized specimens of *C. haematocheilus*. Basing on the data obtained, we conclude that COI sequencing can be used to unambiguously identify fish species.

Despite the lack of informative sites or/and saturation effect, topologies of phylogeny correspond to our previous results based on PCR-RFLPs of extended mtDNA segments. The results of COI analysis have contributed to the long debates over monophyly of the *Liza* genus. It confirmed that *Liza* species were not monophyletic exclusively of *C. labrosus*, which supports the idea of *Liza* and *Chelon* unnatural subdivision into two genera and recommendation of their synonymization with the priority of *Chelon*. Thus, all the *Liza* species should be ascribed to the genus of *Chelon*, hence solving existing disagreement in the taxonomic status of Far Eastern mullet, *C. haematocheilus*.

The unequivocal identification and classification of living organisms to the species level frequently relies on genetic evidence. Specific DNA sequences act as unrepeatable signatures and therefore constitute a unique DNA barcode for each species. Hebert (Hebert et al., 2003) proposed that a single gene sequence would be sufficient to differentiate all, or at least the vast majority of animal species, and proposed the use of the mitochondrial DNA gene cytochrome oxidase subunit I (COI) as a global bioidentification system for animals. Initiatives, such as The Barcode of Life Database [www.barcodinglife.org] including The Fish Barcode of Life [www.fishbol.org], use a DNA-based identification system based on a relatively small fragment of COI.

Here we examine the diversity of mitochondrial cytochrome oxidase subunit I (COI) within and among 9 mugilid species belonging to 4 genera, many of which have been examined from multiple specimens, with the goal of determining whether DNA barcoding can achieve unambiguous species recognition of mugilid species.

Grey mullets of the family Mugilidae (Pisces, Mugiliformes) are distributed worldwide and inhabit marine, estuarine, and freshwater environments in all tropical and temperate regions. Various mugilid species are commercially important species in fishery and aquaculture of many countries. The family includes 14 genera and 64 valid species. Most of them are representatives of *Liza* and *Mugil* genera.

Methods

Samples of striped mullet *M. cephalus* were collected in the Sea of Japan, Azov, Mediterranean Seas and Taiwan waters; redlip mullet *Chelon haematocheilus* – in the Sea of Japan, Azov Sea and Taiwan; golden mullet *Liza aurata* – in the Azov and Tyrrhenian Seas, thinlip mullet *L. ramado*, leaping mullet *L. saliens* and thicklip mullet *C. labrosus* in the Tyrrhenian Sea; largescale mullet *L. macrolepis*, greenback mullet *L. subviridis* and longarm mullet *Valamugil cunnesius* in Taiwan.

DNA extracts were prepared from either muscle or heart tissue or fin clips preserved in 95% ethanol alcohol according to the protocol of (Sambrook et al., 1989). Approximately 652 bp were amplified and sequenced from the 5’ region of the COI gene of mitochondrial DNA using primers designed in [Ward et al., 1994]. Sequences were aligned using Clustal W 1.8 (Thompson et al., 1994). Sequence divergences were calculated using the Hasegawa, Kishino, and Yano (HKY85+G) model (Hasegawa et al., 1985) as the appropriate model of sequence evolution chosen on the basis of hierarchical likelihood ratio tests (LRTs) as implemented in ModelTest version 3.06 (Posada et al., 1998).

Neighbour-joining (NJ) and maximum parsimony (MP) trees were created to provide a graphic representation of the patterning of divergence between species computed in PAUP* (Swofford, 2002). MP analysis was performed using heuristic searches with 50 random stepwise additions and tree bisection-reconnection branch swapping. Bootstrap analyses were used to assess the relative robustness of branches with 1000 replicates.

COI sequences of the following representatives of the family Mugilidae: *Atherinops affinis* (AY290818), *Hypoatherina valenciennei* (EF607407), *Valamugil seheli* (EF609494), *M. cephalus* (AP002930) (Japan), *M. cephalus* (DQ441610) (Argentina) и *M. curema* (DQ441607) were taken in GenBank for comparison.

Sequences have been deposited in GenBank. (Accession numbers EU392233-EU392247).

Results and Discussions

A total of 9 mugilid species were analyzed, giving (because of multiple specimens for most species) a total of 60 sequences. All 9 species can be differentiated by COI.

No insertions, deletions or stop codons were observed in any sequence. The lack of stop codons is consistent with all amplified sequences being functional mitochondrial COI sequences, and that, together with the fact that all amplified sequences were about 628-652 bp in length, suggests that NUMTs (nuclear DNA sequences originating from mitochondrial DNA sequences) were not sequenced (vertebrate NUMTS are typically smaller than 600 bp).

COI sequences of each specimen of each sample proved to be identical. We found no difference within each of *M. cephalus* and *L. aurata* samples from Azov and Meditteranesn Seas. Sequences of geographically remote *C. haematocheilus* (Azov Sea, the Sea of Japan, and Taiwan) and *M. cephalus* (Azov–Mediterranean, the Sea of Japan, and Taiwan) had their own haplotypes, 1–2 nucleotide substitutions being observed between the redlip mullet specimens causing 1 amino acid substitution, while 17–31 nucleotide substitutions being revealed between the striped mullet specimens, which resulted in 4 amino acid substitutions.

198 variables sites were revealed, the most of them (88.9%) were attributable to the the 3rd codon base, 10.1% to the 2nd, and 1% to the 1st codon base. 14 nucleotide substitutions resulted in amino acid replacement.

The GC content of the *Liza–Chelon–Valamugil* species was higher of *M. cephalus* (48.1% versus 45.0%) due to a higher GC content of the first (58% vs. 55%) and, especially, second (54% vs. 43%) and third (44% vs. 32%) codon base in the former. The data obtained indicated that *M.*

cephalus was the most genetically distant from the rest of the species, which conformed to the results of other authors based on mitochondrial and nuclear DNA, allozyme, hemoglobin, and karyologic study (Cataduella et al., 1974, Rizotti, 1993, Rossi et al., 1998).

The HKY85 distance of individuals within *L. haematocheilus* was 0.17% compared to 3.22% within *M. cephalus* specimens. Mean divergence among congeneric species was 12.54%. Mean divergence among species within the family increases to 21.8% *Mugil* vs. *Liza*, and *Mugil* vs. *Chelon*, 20.5% *Mugil* vs. *Valamugil*, 18.2% *Valamugil* vs. *Liza* and *Valamugil* vs. *Chelon*, and only 10.6% *Liza* vs. *Chelon*. Thus, the level of divergence between *Liza* genus, especially its Mediterranean representatives (7%), and *C. labrosus* was obviously congeneric and pointed out their close phylogenetic relationships.

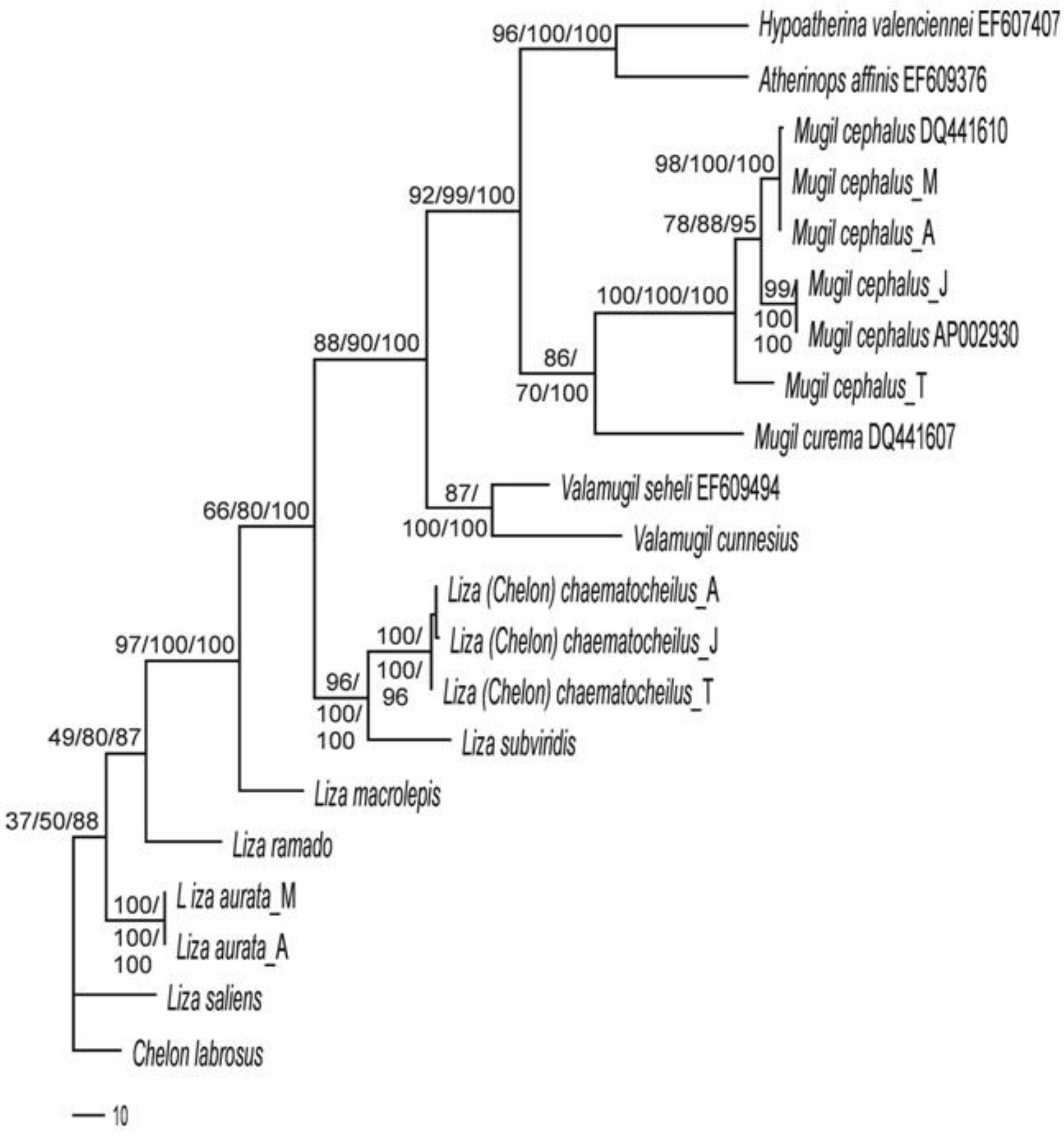


Fig. 1. MP- and NJ- trees based on COI sequences. At nodes – BP-values for MP- and NJ-trees.
A – Azov Sea, M – Mediterranean Sea, J – Sea of Japan, T – Taiwan.
Mugil cephalus DQ441610 – Argentina, AP002930 – Japan.

Although DNA barcoding aims to develop species identification systems, some phylogenetic signal was apparent in the data. The clades revealed after bootstrapping generally corresponded well with expectations. Topologies of MP- and NJ-trees appeared identical and conformed to our previous data based on PCR-RFLP-analysis of extended mtDNA segments, although *L. aurata*, *L. saliens* and *C. labrosus* clade was not resolved, which might be due to the lack of the characters and saturation effect (Semina et al., 2007). The closest relative *L. haematocheius* was *L. subviridis*. *L. macrolepis* was intermediate between Mediterranean mullets and *L. haematocheius – L. subviridis* cluster. *M. cephalus* and *M. curema*, *V. seheli* and *V. cunnesius*, as well as *Atherinops affinis* and *Hypoatherina valenciennei* formed monophyletic clades. M. cephalus from Azov and Mediterranean Seas and Argentina (Atlantic Ocean) clustered together. Azov-Mediterranean-Atlantic, the Sea of Japan and Taiwan striped mullets resolved into three clusters with high bootstrap support (Fig. 1).

Morphologic (pharyngobranchial organ), cytogenetic, genetic (mitochondrial and nuclear DNA), allozyme analyses performed by other authors, revealed no substantial difference between Mediterranean *Liza* species and *C. labrosus* (Papasotiropoulos et al., 2007, Caldara et al., 1996). In our study, *Liza* species also did not form a monophyletic group exclusive of *C. labrosus* (Fig.). Therefore, this fact contributes to a long debate about necessity of *Liza* and *Chelon* genera synonymization with the priority of *Chelon*.

COI short DNA sequence provides sufficient identification labels in terms of nucleotide positions to discriminate even between congeneric fish species despite the intraspecific variation that was especially pronounced between geographically distant *M. cephalus* specimens.

Based on the data obtained, we conclude that COI sequencing can be used to unambiguously identify fish species.

Acknowledgments

The work described in this paper is supported by FEB RAS grant № 09-III-B-268, № 09-1-P22-01 and 09-1-P23-03. We would like to heartily thank Prof. Kwang-Tsao Shao (Academia Sinica, Taiwan), Dr. Anna Rita Rossi (University of Rome "La Sapienza" Italy), Dr. Mikhail Makhotkin (AZNIIRKH, Rostov-on-Don, Russia), Dr. Vladimir Omelchenko, Dr. Vasiliy Radashevsky, Dr. Alexandr Sokolovsky (IMB FEB RAS, Vladivostok, Russia) for their kind help providing samples, thus making this study possible.

References

Caldara F., Bargelloni L., Ostellari L., Penzo E., Colombo L., Patarnello T. 1996. Molecular phylogeny of grey mullets based on mitochondrial DNA sequence analysis: evidence of differential rate of evolution at the intrafamily level // Molecular Phylogenetics and Evolution. V. 6. P. 416–424.

Cataduella S., Civitelli M.V., Capanna E. 1974. Chromosome complements of the Mediterranean mullets (Pisces, Perciformes) // Caryologia. V. 27. P. 93–105.

Hasegawa M., Kishino H., Yano T. 1985. Dating the human-ape split by a molecular clock of mitochondrial DNA // Journal of Molecular Evolution. V. 22. P. 160–174.

Hebert P.D.N., Cywinska A., Ball S.L., de Waard J.R. 2003. Biological identifications through DNA barcodes // Proceeding of the Royal Society B. V. 270, N 1512.P. 313–321.

Papasotiropoulos V., Klossa-Kilia E., Alahiotis S., Kilias G. 2007. Molecular phylogeny of grey mullets (Teleostei: Mugilidae) in Greece: evidence from sequence analysis of mtDNA segments // Biochemical Genetics. V. 45. P. 623–636.

Posada D., Crandall K.A. 1998. Modeltest: testing the model of DNA substitution // Bioinformatics. V. 14. P. 817–818.

Rizotti M. 1993. Fish hemoglobins: the family Mugilidae (Perciformes) // Trends in Comparative Biochemical Physiology. V. 1. P. 385–392.

Rossi A.R., Capula M., Crosetti D., Sola L., Campton D.E. 1998. Allozyme variation in global populations of striped mullet, *M. cephalus* (Pisces: Mugilidae) // Marine Biology. V. 131. P. 203–212.

Sambrook J., Fritsch E.F., Maniatis T. 1989. Molecular Cloning: A Laboratory Manual. NY: Cold Spring Harbor Lab Press. 1626 p.

Semina A.V., Polyakova N.E., Brykov V.A. 2007. Analysis of mitochondrial DNA: taxonomic and phylogenetic relationships in two fish taxa (Pisces: Mugilidae and Cyprinidae) // Biochemistry (Moscow). V. 72. P. 1349–1355.

Swofford D.L. 2002. PAUP*: Phylogenetic Analysis Using Parsimony (*and Other Methods). Version 4.0b10. Sinauer Associates, Sunderland, MA.

Thompson J.D., Higgins D.G.., Gibson T.J. 1994. CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice // Nucleic Acids Research. V. 22. P. 4673–4680.

Ward R.D., Woodwark M., Skibinski D.O.F. 1994. A comparison of genetic diversity Levels in marine, freshwater, and anadromous fishes // Journal of Fish Biology. V. 44. P. 213–232.

IMPACT OF TRACE METAL ACCUMULATION ON PLANKTONIC DIVERSITY OF CHENNAI COAST

R. Ramanibai, J.M. Shanthi

Department of Zoology, University of Madras, Guindy Campus, Chennai-25, India

e-mail: rramani8@hotmail.com

The South Asian seas region includes India, one of the economically important countries where majority of human population resides along the coastal stretch. The rivers and the coastal outlets generally heavily contaminated with municipal sewage, industrial effluent and sediments contribute a significant quantity of pollution load to the coast. Regarding heavy metal's presence in the biota, natural sources account for a background exposure. Among biota, zooplankton may contribute to the transfer of trace metals to higher trophic levels are the recommended groups for the base line studies of trace metals in the marine environment (Rejomon et al., 2008). Zooplankton accumulates metals directly from water by absorption, also by assimilation through food substances. The bioavailable fraction can be assessed only by determining the amount of metals incorporate into organisms which is the main goal in biomonitoring (Kahle, Zauke, 2007).

The Bay of Bengal is the second largest beach in the world, yet its faunal diversity remains relatively little explored in terms of trace metal accumulation. In this context this paper tries to evaluate the current state of knowledge trace metal impact on marine biodiversity.

Environmental issues of Chennai coast have become more prominent recently mainly due to increasing population and intensifying industry. Among the various contaminants, trace metals are of particular concern due to their environmental persistence, available through biogeochemical recycling and encountering ecological risks. Hence, studies on trace metals influenced by seasonal variability and their concentrations in the coastal area are much needed.

One of the objectives of this study was to obtain a dataset of dissolved trace metal concentrations in this region. In order to achieve the objective, surface and sub surface seawater samples were collected from 15 stations representing near shore, 5 and 10 m away from the shore line during pre monsoon (2006) and post monsoon (2007) on Board (CRV SAGAR PASCHIMI) using CTD – SBE 25 (SABIRD ELECTRONICS USA).Common hydrochemical parameters like pH, temperature, salinity, DO; essential trace metals like zinc, copper, cobalt, iron, manganese and nonessential lead, cadmium, nickel and chromium were estimated to know their levels present in the surface sea water.

During pre-monsoon season Fe ranged from 219 µg/l to 551 µg/l. The highest concentrations of Zn (95 µg/l) was observed at Chennai Harbour. Cu, Cr and Co showed low concentration when compared to other metals. The following metal sequence was arrived for pre monsoon Fe>Zn>Ni>Pb>Cu>Cr>CO.

During the post monsoon season the Fe concentration of surface water was 487 µg/l at Ennore station. The sequences of surface water during post monsoon follow as Fe>Zn>Ni>Pb>Co >Cu>Cr.

The subsurface water Fe concentration at Cooum (228 µg/l) during pre monsoon was little lower than that of post monsoon season. The Cr level estimated as 1µg/l at Ennore during pre monsoon season. The metal sequences of subsurface water during pre monsoon was estimated as Fe>Zn>Ni>Pb>Cu>Co>Cr.

The sequence of metal concentration varies with the distance between stations and monsoon seasons.

An overall view of the result indicated that the heavy metals Fe, Zn, Ni, Pb, Cr, Cu, Co concentrations were above the permissible limit prescribed by TNPCB.

The highest metal levels estimated along the shoreline of the Bay of Bengal, reflecting long-term exposure to various activities. Fe is the most abundant metal, whereas cobalt and chromium present in minimum concentration when compared to other metal's concentrations. The range of variation for each metal is unique; their concentration is not restricted only by anthropogenic input. The results suggest that complex combination of factors act on surface water thereby increase the metal concentration. If this valid point consider in future for Bay of Bengal possible influences on metal accumulation in surface waters may be worked out and follow up monitoring programme may be initiated.

The existing data demonstrates that the level of heavy metal concentration is high in the coastal region which acts as an efficient trap for anthropogenic heavy metals.

References

APHA. 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edition. L.S. Clesceri, A.E. Greenberg, A.D. Eaton (Eds). Washington, D.C.: American Public Health Association. 1325 p.

Jayaprakash M., Srinivasalu S., Jonathan M.P, Ram Mohan V. 2005 A baseline study of physico-chemical parameters and trace metals in waters of Ennore Creek, Chennai, India // Marine Pollution Bulletin. V. 42. P. 703–704.

Kahle J., Zauke G.P. 2003. Trace metals in Antarctic copepods from the Weddell Sea (Antaratica) // Chemosphere. V. 51, N 5. P. 409–417.

Rejomon G., Balachandran K.K., Nair M., Joseph T. 2008. Trace metal concentrations in marine zooplankton from the Western Bay of Bengal // Applied Ecology and Environmental Research. V. 6, N 1. P. 107–116.

COMPARATIVE SPERM MORPHOLOGY IN *CRASSOSREA* CF. *RIVULARIS* AND *SACCOSTREA MORDAX* FROM NHA TRANG BAY, VIETNAM

Olga V. Yurchenko

A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch of Russian Academy of Science, Vladivostok, 690041, Russia

e-mail: olyurchenko@yandex.ru

To date a sperm structure has been studied in 5 species among about 50 species of oysters inhabiting the Ocean. In the present spermatology there is the suggestion about absence of two species of bivalve mollusks with the same spermatozoa (Frazèn, 1983). According to published data, there are two points of view on oyster sperm species-specificity. On the one hand, spermatozoa of the studied species are very similar and sometimes it is very difficult to find any difference in their ultramorphology even between two genera (for example, *Crassostera angulata* and *Ostrea edulis*) (Sousa, Oliveira, 1994). On the other hand, sizes and shape of nucleus and acrosome can be accepted as species-specific characters (Gwo et al., 1996). To verify both points of view mentioned above the present work was conducted.

In this paper sperm ultrastructure and dimensional measurements of sperm components in two oyster species *Crassostrea* cf. *rivularis* and *Saccostrea mordax* inhabiting Nha Trang Bay were studied. Oysters were collected by SCUBA equipment and the gonad tissues were treated in

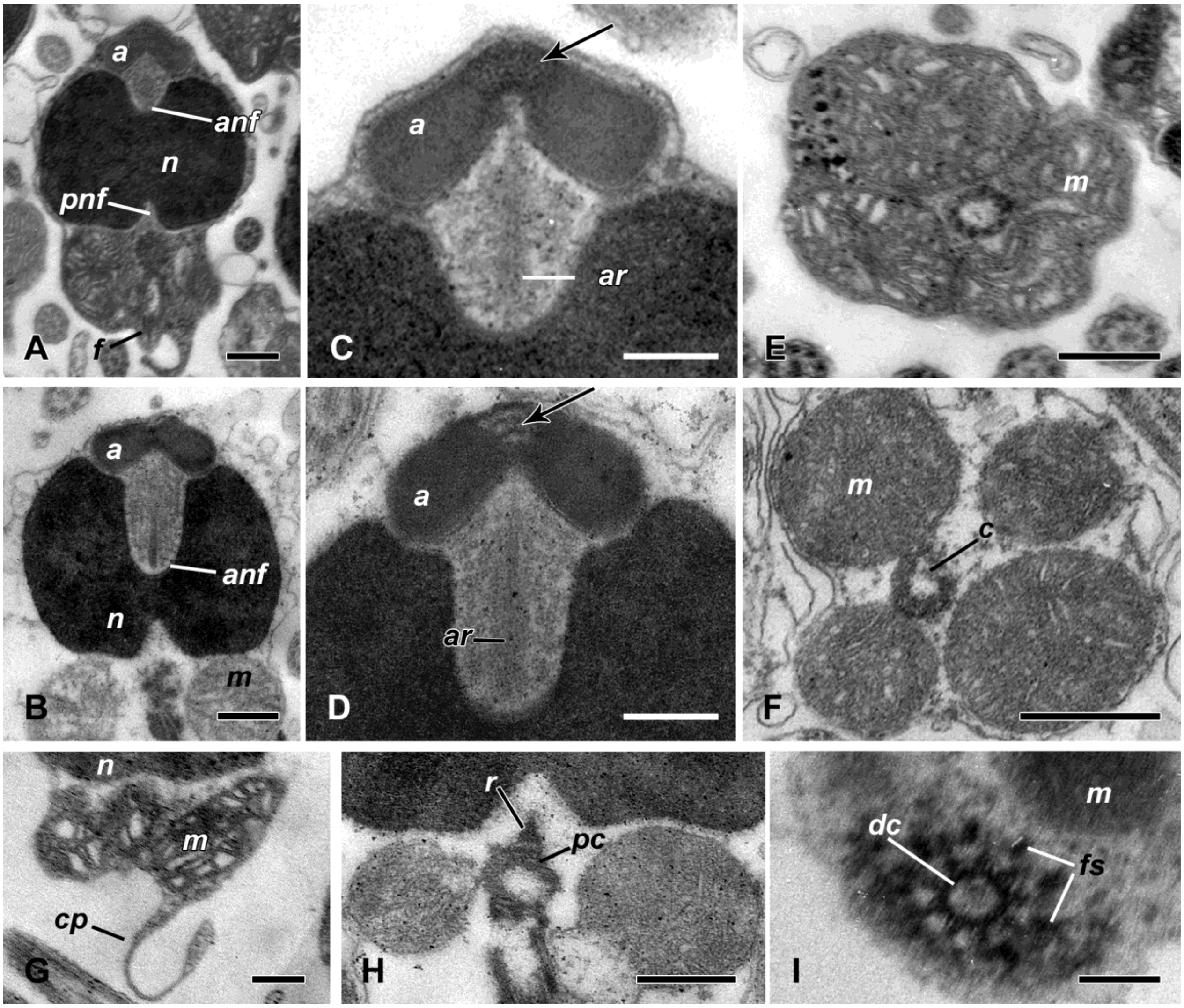


Fig. 1. Sperm ultramorphology in *Crassostrea* cf. *rivularis* (A, C, E, G) and *Saccostrea mordax* (B, D, F, H, I). A, B – longitudinal section through spermatozoa; C, D – longitudinal section through the acrosome and subacrosomal space. Note heterogenous acrosomal material (arrows); E, F – transverse section through the midpiece; G – longitudinal section through the midpiece; H – pericentriolar complex of the proximal centriole; I - section through the pericentriolar complex of the distal centriole. Abbreviations: *a* – acrosome, *anf* – anterior nuclear fossa; *ar* – axial rod; *dc* – distal centriole; *m* – mitochondrion; *n* – nucleus; *pc* – proximal centriole; *pnf* – posterior nuclear fossa; *r* – rootlet; *sf* – satellite fibers. Scale bars: A, B, G, H = 0.5 μm; C,D,I = 0.2 μm; E,F = 1.5 μm.

accordance with standard procedures of material preparation for ultrastructural analysis. Morphometric data were expressed as the mean±SD. The comparison between sampling of two species was done using t-test in Statistica 7.0 program.

Spermatozoa in all studied species consisted of acrosomal complex, nucleus, midpiece and flagellum. Each nucleus with granular electron dense chromatin had barrel shape; two fossae located anteriorly and posteriorly (Fig. 1A, B).

Acrosomal complex included acrosomal granule and subacrosomal space full of flaked substance with moderate electron-density. The acrosome content in both species differentiated into a large and homogeneous basal region and a small heterogeneous apical region with laminar structure (Fig. 1C, D). In the sagittal section overacrosomal electron-lucent knob was present in *C.* cf. *rivularis* and absent in the *Saccosrea mordax*. Anterior nuclear fossae in the studied species had different shapes; in *C.* cf. *rivularis* it looked like a small depression (Fig. 1C), in *S. mordax* the structure was cylindrical (Fig. 1D). Anterior nuclear fossae and invagination of basal part of the acrosome formed a subacrosomal space containing an axial rod (Fig. 1C, D).

Midpiece in spermatozoa consisted of four mitochondria surrounding a centriolar complex (Fig. 1F, E). Proximal and distal centrioles orientated orthogonally to each other had some accessory structures. A short centriolar rootlet presented as a conical mass was connected with proximal centriole and extended into the posterior nuclear fossa (Fig. 1H). The distal centriole had nine radially arranged satellite fibers that attached it to the plasm membrane (Fig. 1I). *C.* cf. *rivularis* spermatozoa in the mitochondria region or/and beneath it (in the flagellum bottom region) rather long cytoplasmic processes about 1 μm at length were situated (Fig. 1G). Flagellums had constant axoneme organization of microtubules 9+2.

Dimensional characters are represented in the Table 1. Despite the rather similar sperm ultramorphology and linear sizes of sperm compartments, spermatozoa from two species differ from each other by depth of anterior nuclear fossa. In *C.* cf. *rivularis* the anterior nuclear fossa occupied about 22% of nucleus extent, while in *S. mordax* the anterior nuclear fossa was almost equal to half of nucleus length (43%).

The comparison of sperm structure of both species shows that they closely resemble one another and those of other investigated ostreids (*Saccostrea commercialis* – Healy and Lester, 1991, *Ostrea edulis* – Sousa, Oliveira, 1994, *Crassostrea virginica* – Eckelbarger, Davis, 1996, *C. angulata* – Sousa, Oliveira, 1994, *C. gigas* – Bozzo et al., 1993; Gwo et al., 1996). However, present study reveals some ultrastructural features that were not described earlier. In *C.* cf. *rivularis* electron-lucent knob is present in the tip of the acrosomal complex beneath the cytoplasm membrane. Such a structure has been earlier noticed in *C. gigas* and interpreted as the “possible species-specific feature” (Yurchenko et al., 2010). But the present wider study indicates that this knob can be found in other oyster species and cannot be accepted as an individual trait of *C. gigas*.

Table 1. Summary of dimensions (μm) of spermatozoa compartments in two species oysters from Nha Trang Bay

Organelles	Acrosome*			Nucleus			Anterior nuclear fossa		
	Length	**Width**	**L/W**	**Length**	**Width**	**L/W**	**Depth**	**Width**	**D/W**
Crassostrea rivularis	0.38 ±0.05	0.74 ±0.08	**0.52** ±0.04	1.09 ±0.11	1.74 ±0.16	**0.62** ±0.07	0.24 ±0.04	0.41 ±0.06	**0.58** ±0.09
Saccostrea mordax	0.39 ±0.05	0.8 ±0.09	**0.49** ±0.04	1.17 ±0.15	1.71 ±0.19	**0.69** ±0.07	0.5 ±0.09	0.39 ±0.05	**1.3** ±0.22

Note: *The size includes the length of electron-dense granule without an electron-lucent knob.

Continue of Table 1.

Organelles	Acrosome length/ Nucleus length	Fossa depth/ Nucleus length	Fossa width/Nucleus width
Crassostrea rivularis	**0.35**±0.04	**0.22**±0.04	**0.24**±0.02
Saccostrea mordax	**0.34**±0.03	**0.43**±0.05	**0.23**±0.02

Species-specific trait is found in *C.* cf. *rivularis* spermatozoa; the midpiece region has the cytoplasm processes. Among the mollusk species the presence of the cytoplasm structures in the midpiece of spermatozoa called “membranous skirts” was noticed in some species of Cephalopoda (Healy, 1996). Their occurrence is likely to be connected with aspects of fertilization process, because spermatozoa with membranous skirt were attributed to species with fertilization within the mantle cavity (Healy, 1996). It is well known that ostreids species may be distinguished on the basis of their breeding habits. Some oysters discharge eggs and sperm directly into the surrounding seawater, while others brood offspring in the inhalant chamber of their mantle cavities (Waller, 1981; Foighil, Taylor, 2000). It is possible that latter once could have sperm with accessory structures that help to penetrate inside female organism and attach and/or anchoring to egg surface under stream condition. Unfortunately, the evidence of *C.* cf. *rivularis* reproductive biology has not been elucidated and kind of fertilization in this species is unclear, therefore the role of the cytoplasmic processes remained the subject of discussion.

In addition to morphological traits the dimensional measurements of sperm components also show the interspecies difference, that confirms suggestion of Gwo and co-authors (1996) about distinctions of linear sizes of acrosome and nucleus in Ostreidae species. The extent of anterior nuclear fossa could also be accepted as a vivid individual character in the studied species. Unfortunately, the size characters were not taken into account in the early descriptions of sperm structure in ostreids. It should be recommended for the future sperm descriptions in Ostreids to present both microscopic data and statistically calculated dimensional characters of the sperm components (acrosome, nucleus and anterior nuclear fossa) and sizing ratios between themselves.

In summary, each of the studied species had its unique sperm organization that was ultrastructurally and morphometrically proved. Therefore the mollusks from the fem. Ostreidae do not refuse but confirm Frazèn (1983) statement about absence of two species of bivalve mollusks with the same spermatozoa.

Acknowledgements

The author sincerely thanks Dr. Alexey Chernishev for the given material, Dr. Konstantin Lutaenko for identification of the oysters species. Financial support was provided by the Russian Foundation for Basic Research (RFBR Project # 09-04-98540) and Far East Branch of the Russian Academy of Sciences (FEB RAS Project # 09-III-A-06-215).

References

Bozzo M.G., Ribes E., Sagrista E., Poquet M., Durfort M. 1993. Fine structure of the spermatozoa of *Crassostrea gigas* (Mollusca, Bivalvia) // Molecular Reproduction and Development. V. 34. P. 206–211.

Eckelbarger K.J., Davis C.V. 1996. Ultrastructure of the gonad and gametogenesis in the eastern oyster, *Crassostrea virginica*. II. Testis and spermatogenesis // Marine Biology. V. 127. P. 89–96.

Foighil D.Ó, Taylor D.J. 2000. Evolution of parental care and ovulation behavior in oysters // Molecular Phylogenetics and Evolution. V. 15. P. 301–313.

Franzèn A. 1983. Ultrastructural studies of spermatozoa in three bivalve species with notes on evolution of elongated sperm nucleus in primitive spermatozoa // Gamete Research. V. 7. P. 199–214.

Gwo J.C., Liou C.H., Cheng C.H. 1996. Ultrastructure of the spermatozoa of the Pacific oyster *Crassostrea gigas* (Mollusca, Bivalvia, Ostreidae) // Journal of Submicroscopic Cytology and Pathology. V. 28. P. 395–400.

Healy J.M. 1996. Molluscan sperm ultrastructure: correlation with taxonomic units within the Gastropoda, Cephalopoda and Bivalvia // Origin and Evolutionary radiation of the Mollusca. Ed. J. Taylor). Oxford: Oxford University Press. P. 99–113.

Healy J.M., Lester R.J.G. 1991. Sperm ultrastructure in the Australian oyster *Saccostrea commercialis* (Iredale & Roughley) (Bivalvia: Osteroidea) // Journal of Molluscan Studies. V. 57. P. 219–224.

Sousa M., Oliveira E. 1994. An ultrastructural study of *Crassostrea angulata* (Mollusca, Bivalvia) spermatogenesis // Marine Biology. V. 120. P. 545–551.

Yurchenko OV, Radashevsky V.I., Reunov A.A. 2010. Ultrastructural study of spermatogenesis in the Pacific oyster *Crassostrea gigas* (Bivalvia, Ostreidae) from the Sea of Japan. Invertebrite Zoology [in press].

Waller T.R. 1981. Functional morphology and development of veliger larvae of the European oyster, *Ostrea edulis* Linné // Smithsonian Contributions to Zoology. № 328. Smithsonian Institution Press. City of Washington.

OBSERVATION/DETECTING CHLOROPHYLL *A* DISTRIBUTION AND HARMFUL ALGAL BLOOMS IN THE VIETNAM COASTAL UPWELLING BY HIGH RESOLUTION MULTISENSOR DATA

***Tong Phuoc Hoang Son*[1]*, Hoang Cong Tin*[2, 3]*, Chun Knee Tan*[4]**

[1]*Nhatrang Oceanography Institute, Vietnam Academy Sciences and Technology, 01 Cau Da, Vinh Nguyen, Khanh Hoa, Vietnam; e-mail: tongphuochoangson@gmail.com*

[2]*Centre for Coastal Management and Development Studies, Hue University of Sciences, 77 Nguyen Hue Street, Hue City, Vietnam*

[3]*NF – POGO Centre of Excellence on Observation Oceanography, Bermuda Institute of Ocean Sciences, 17 Biological Lane, Ferry Reach, St. George GE01, Bermuda*

[4]*Global Environment Information Centre (GEIC), 53-70 Jingumae 5-Chome Shibuya-ku, Tokyo 150-0001 Japan*

Introduction

East Sea (the Vietnamese name that to call the South China Sea) is the largest marginal sea in Pacific Ocean at Southeast Asia region. The East Sea is located in strong activities of East Asia monsoon (Nan-Jung Kuo et al., 2004). In other hand, the climate variation on atmosphere and upper ocean of East Sea is typically controlled by East Asia monsoon, which connect with climate variation in the central of equatorial Pacific (Lui et al., 2002). Upwelling in the Vietnam coast is result of the East Asia monsoon activity. This is a vertical movement of the volume of deep water layer to surface water layer which brings high nutrients optimum to the surface and create environment for phytoplankton photosynthesis. On the other hand, the East Sea has large continental shelves from the northwest to the south, with a volume sediment and runoff from some big rivers such as Mekong River and Pearl River as well as a depth basin in the central with 4700 m deep (Lui et al., 2002). The South of Central Vietnam is a major fishery ground which occur upwelling phenomena in SWM. Therefore, this upwelling area plays an important role in marine fisheries industry as well as marine studies of Vietnam.

In 1959–1960, the research cruise NAGA has been recognized the South of central Vietnam as coastal upwelling area. To date, number of research programs associated with this area has been carried out by various scientists (Wyrtky, 1961; Lafond, 1966; Le Phuoc Trinh, 1981). Nhatrang Institute of Oceanography (1992–1995) had been conducted research investigating meteorological, hydrological dynamics, ecological and some group of important marine resources in this area. The cooperation project between Vietnam and Germany (2002) was implemented aim to research as detail about this phenomenon. In particular, satellite imagery is one of the new approaches for studying hydrodynamic conditions such as sea surface temperature (SST), sea surface height (SSH) and surface winds (Son, 2005). Chl *a* is one of the good indicators for recognizing the upwelling phenomena and harmful algal blooms as well as forecasting the fishery schools. The number of application of satellite oceanography, however, to study on the relationship between hydrodynamic, environments as well as the distribution and phytoplankton biomass in term of Chl *a* as concerned to algal blooms and fisheries resources are limited in Vietnam waters.

The present paper aims to present the distribution of algal blooms through Chl *a* concentrations derived from satellite imagery high resolution in 2007–2008. In particular, the use of high resolution satellite images is an initiate application to observe the coastal marine environment where is covered with clouds frequently that ocean color satellites in the visible wavelengths could not detected. In order to address scientific basic for the strategies management of marine fisheries resources as well as environmental monitoring in this area.

Research Materials

Remote sensing and geographical information system (GIS) techniques have been used as primary tools to determinate the distribution characteristic of Chl *a* in upwelling region.

Software: ENVI v4.4, SeaDAS v5.4 used for processing and analyzing satellite images; Map-*Info* 7.5, Ocean Data View 4.2.*1a* is used to building the maps. Software R and MS. Office Excel integrated with remote sensing and GIS software to analyzing data and algorithms for computation phases.

Types of satellite images: The time-series remote sensing images (including the original image Level 1, 2B and images were processed (Level 3) with different ground resolution were used, as following:

The Moderate Resolution Imaging Spectroradiometer (MODIS) 1.1 km images download from on NASA's Aqua (available at [http://www.oceancolor.gsfc.nasa.gov]) used to distinguish Chl *a* concentration and distribution (Table). The technique emphasis on color composite imagery aim to monthly-averaged Chl *a* concentration was applied.

Landsat ETM^+ images (30 m) consist of 14 scenes and 6 scenes AVNIR2 (10 m) images coverage the period of 2007 to 2008 was used to analyze the distribution characteristic of surface Chl *a* concentration as well as detect the occurrence of HABs in this area in various time.

In addition, time-series averaged data from SeaWiFS imagery also used in the analysis of seasonal variation of Chl *a* concentration in the study area. Data is available at [http://reason. gsfc.nasa.gov/Giovanni/].

In situ data: Chl *a* surface layer concentration at 21 stations surveyed were collected from 17th to 25th with from May to September, 2007 and from April to September, 2008 which used to build standard algorithms in the assessment of the distribution of Chl *a* concentration from high resolution satellite imagery.

Methods

Algorithms. OC3 algorithm was used to determination the distribution Chl *a* surface concentration from MODIS images (O'Reilly et. al., 2000).

Chl *a* (mg m^{-3}) = 10^(0.283 – (2.753 * R) + (1.457 * R^2) + (0.659 *R^3) – (1.403 * R^4)) (1),

where R = $\log_{10}$[max(Rrs(443)/Rrs(551), Rrs(488)/Rrs(551))].

The detail distribution of Chl *a* surface concentration in each specific time and location occurrence of algal bloom has been determined from Landsat ETM^+ (30 m) and AVNIR2 (10 m) images. Chl *a* surface concentration based-on surface reflectance spectrum of blue band and red band of the Landsat ETM^+ and AVNIR2 images (Asif Mumtaz Bhatti et al., 2008). From the results of field Chl *a* surface concentration in Binh Thuan waters was used to build standard algorithms in the assessment of the distribution of Chl *a* concentration for both Landsat ETM^+ and ALOS-AVNIR2, as follow:

Landsat ETM^+ (30 m) imageries.

$$\text{Chl } a = \begin{cases} 3.3887 * R^2 - 10.368 * R + 8.2128 & ;\text{ if Chl } a <= 1 \\ 1287.7 * R^2 - 3431.7 * R + 2289.2 & ;\text{ if Chl } a > 1 \end{cases} \quad (2),$$

where R = $\log(B_3)/\text{Log}(B_1)$; B_3 is surface reflectance spectrum of red band; B_1 is surface reflectance spectrum of blue band. B_1, B_3 is computated by the method of reflect correlation and atmosphere based on original Landsat ETM^+ images including parameters on date, time-image captured, sun-synchronous orbit, reflection indexs and replectance correction at *Top of Atmospheric* (TOA) for each bands.

AVNIR2 (10 m) imageries. The algorithm to detect the distribution of Chl *a* based-on the ratio B3/B1 (3).

Chl *a* (mg m^{-3}) = (48.812 * R^2) + (2.0294 * R) – 6.9266 (3),

where R = B_3/B_1; B_3 is surface water reflectance spectrum of red band; B_1 is surface water reflectance spectrum of blue band. B1, B3 is calculated through the reflect correlation method and atmosphere correlation based on original AVNIR2 images including parameters on date, time-image captured, sun-synchronous orbit, reflection indexs and replectance correction at *Top of Atmospheric* (TOA) for each bands.

Results and Discussion

The concentration of Chl *a* distribution in the upwelling area. Chl *a* concentration is strong varied in temporally and spatially in the study area. Highest Chl *a* concentration along the coastalline and decrease at the offshore as a typically distribution. On the other hand, the variation of the Chl *a* concentration so clear through the period of the years.

Temporally variation of Chl a concentration. Based-on the time-series variation of Chl *a* concentration from 2004 to 2009 showed that Chl *a* concentration varied in the range from 0.1 to 1.513 mg m^{-3}. Chl *a* concentration in the area reached the maximun value 1.917 mg m^{-3} on December 2006 and 1.513 mg m^{-3} on January 2007. In 5 years-averaged, Chl *a* concentration reached the maximum from August to October annual value delivered in range from 0.5 to 0.8 mg m^{-3}.

The spatial distribution of Chl a from MODIS images. Chl *a* concentration generally highest from Ninh Thuan to Ba Ria-Vung Tau coast and the distribution is associated with bottom topography, light intensity, material suspended total discharge from the rivers (Le Phuoc Trinh, 1981). The shallow waters along the coast where are high nutrient content, light intensity and create the optimal environment conditions for phytoplankton grow as resulting in high Chl *a* concentration (Son et. al., 2005). Especially, when upwelling occurs the nutrient is supplied significantly.

In the NEM season (December to February), the Chl *a* concentration usually increased with the average value about 0.88 mg m^{-3}. The spatial distribution also showed that high concentration of Chl *a* in coastal area during the winter and tends to decrease gradually from inshore to offshore but spread Northeast-Southwest. Influence of organic matter discharges from the rivers and waves has increase the concentration of suspended matter and Chl *a* at the coastal area.

In the inter-season (March to May), due to the disturbance flow when wind currents change, Chl *a* only occur a thin range in coastal area, the monthly average value about 0.19-0.25 mg m^{-3}. The NEM started declining and change the direction; in the meantime, the cold current from Northern occur the whole area. Therefore, the concentration of Chl *a* is low during early two month of the season. In May, when sea surface temperature (SST) warm up and wind SWM begun operations, Chl *a* concentration change, the average value from 0.19 mg m^{-3} to 0.25 mg m^{-3} and tend to extend by winds.

At the end of May and early of June are transition season from NEM to SWM completely. Concentration of Chl *a* increased significant with occurring the second high peak of Chl *a* in SWM on July, the average value about 0.72 mg m^{-3}. The concentration of Chl *a* tend to decrease gradually from the inshore to offshore and wide spread towards the SWM wind. This is demonstrated on the spatial map of Chl *a* distribution has a long peak with center in the coastal of Binh Thuan province. This peak spread in mid-season when the strongest winds (July to August).

In inter-season (September to October), Chl *a* concentration is change. The SWM wind began weaken in September, Chl *a* peak is narrow distribution and focused mainly at coastal and to the coastal of Khanh Hoa province. Chl *a* concentration is lowest in October, the averaged value about 0.36 mg m^{-3}. However, this is also the month have widest Chl *a* concentration distribution and at offshore, due to the wind direction change from the SWM to NEM.

Specially, the research area occur the anomalies of Chl *a* concentration higher than surrounding areas such as: *i)* A along the coastal of Ninh Thuan-Binh Thuan which appear on the

SWM and is located in the offshore of Ninh Thuan, often appearing in the NEM; *ii)* The second one is smaller and occur at Phan Thiet's offshore and the Northwest of Phu Quy island. They usually appear on the inter-season period and shallow areas of Phan Thiet.

The first anomaly usually occurs on NEM from September to March next year. The concentration of Chl *a*, however, in this area are not high, only varies from 0.4 to 0.5 mg m^{-3}. The center of high Chl *a* anomaly is not directly related to topography and wind current in the parallel to the coastal but mainly the effect of the mixing of surface water layer and bottom layer in the coastal line. When NEM operation it make a Ekman current from offshore to coastal, the bottom water layer is bring to surface and bring a content of nutrient that to create the optical condition for phytoplankton grow. The interaction of internal wave and offshore cyclone eddy are main cause of this phenomenon.

Another one with high anomaly of Chl *a* occurs in Phan Thiet offshore and is located at the Northwest of Cu Lao Thu. It usually appears in the inter-season period on March to May and sometime appear in September and October ever year. This anomaly is associated with topography change suddenly of shallow water including the system of subsurface island at the Northwest of Cu Lao Thu.

Distribution of Chl *a* concentration and HABs in upwelling region from high resolution imageries. Based on the numerous of optical high resolution satellite imageries (Landsat ETM^+ (30 m) and AVNIR2 (10 m)) and monthly *in situ* data obtained from 21 stations during 2007–2008 in upwelling region, the spatial and temporal variations of Chl *a* and algal blooms have been detected. The detected algorithms of Chl *a* have been presented in methodology part.

Distribution of Chl *a concentration during SWM.* In coastal water of Ninh Thuan province, Chl *a* concentration is lowest at the begin of Spring (March) with average value only about 0.1–0.2 mg m^{-3} and continuously increase during next months, from 0.2 to 0.4 mg m^{-3} in April , from 0.8 to 1.0 mg m^{-3} in May, June and highest during July, August with value about 1.0–1.4 mg m^{-3}. Usually existence of a local anomaly of high Chl *a* concentration in offshore of Phan Ri with maximum value reach 2.5–3.5 mg m^{-3} during July, August (Fig. 1). This anomaly also occurs from March but weakness and small area.

The high anomaly and algal bloom as show above mention locate duplicate with position of center of upwelling region during SWM (from March to August annually) which previous authors (Trinh, 1981; Lanh, 1996; Long, 2004) were recognized.

In coastal water of Binh Thuan province, Chl *a* concentration higher with average value about 0.6–0.7 mg m^{-3} with highest centers lie in southern side of headlands. The first highest area of Chl *a* exists in Ne Cape with value 1.5 mg m^{-3}, another lies in Ke Ga cape with maximum value reach to 10 mg m^{-3}.

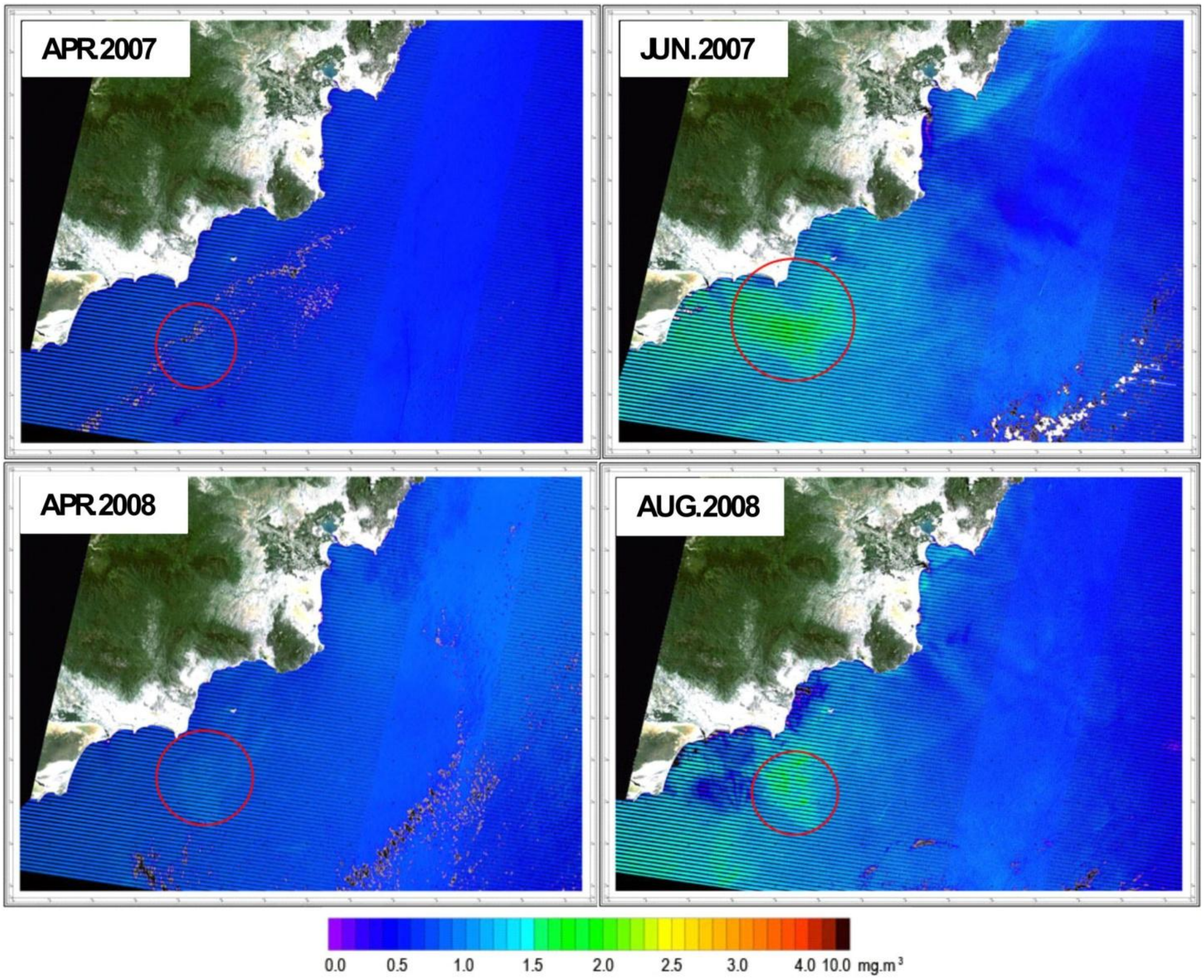


Fig. 1. Chl a distribution in Ninh Thuan during SWM with anomaly of high Chl a ussualy exist in offshore of Phan Ri Bay

Distribution of Chl *a concentration and blooms during NEM.* During NEM, Chl *a* concentration is relative high in offshore waters with average value about 0.6-0.7 mg m^{-3}. In the coastal water exists a high Chl *a* lane with 1 km wide, it lie close to but not attach to the coast with highest value reach to 4.2 mg m^{-3}. This lane strengths from Dinh Cape (Phan Ri) to Ne Cape (Binh Thuan), it have been created by affect of NEM that bring material in coast (Fig. 2a).

In Phan Thiet Bay, usually exist patches of high Chl *a* (maximum value reach to 9–10 mg m^{-3}) usually exist in Phan Thiet Bay (include a patch in the southern of Ke Ga Cape and another lie nearby Mui Ne (Ne Cape). A broad patch of high biomass bloom also happens in offshore of Cu lao Thu during November 2008 (Fig. 2b).

Especial, on 4th December 2008 in coastal water of Vung Tau appears a "silk lane" curl shape, only 200 m wide but Chl *a* concentration is too high (>20 mg m^{-3}) and it only exist in shorter time, this lane disappear during 16th December 2008. The "silk lane" bloom is also recorded in several areas but not clearly. The reason and creating mechanism of this lane in relationship with HAB or non HAB is question that needs to more study.

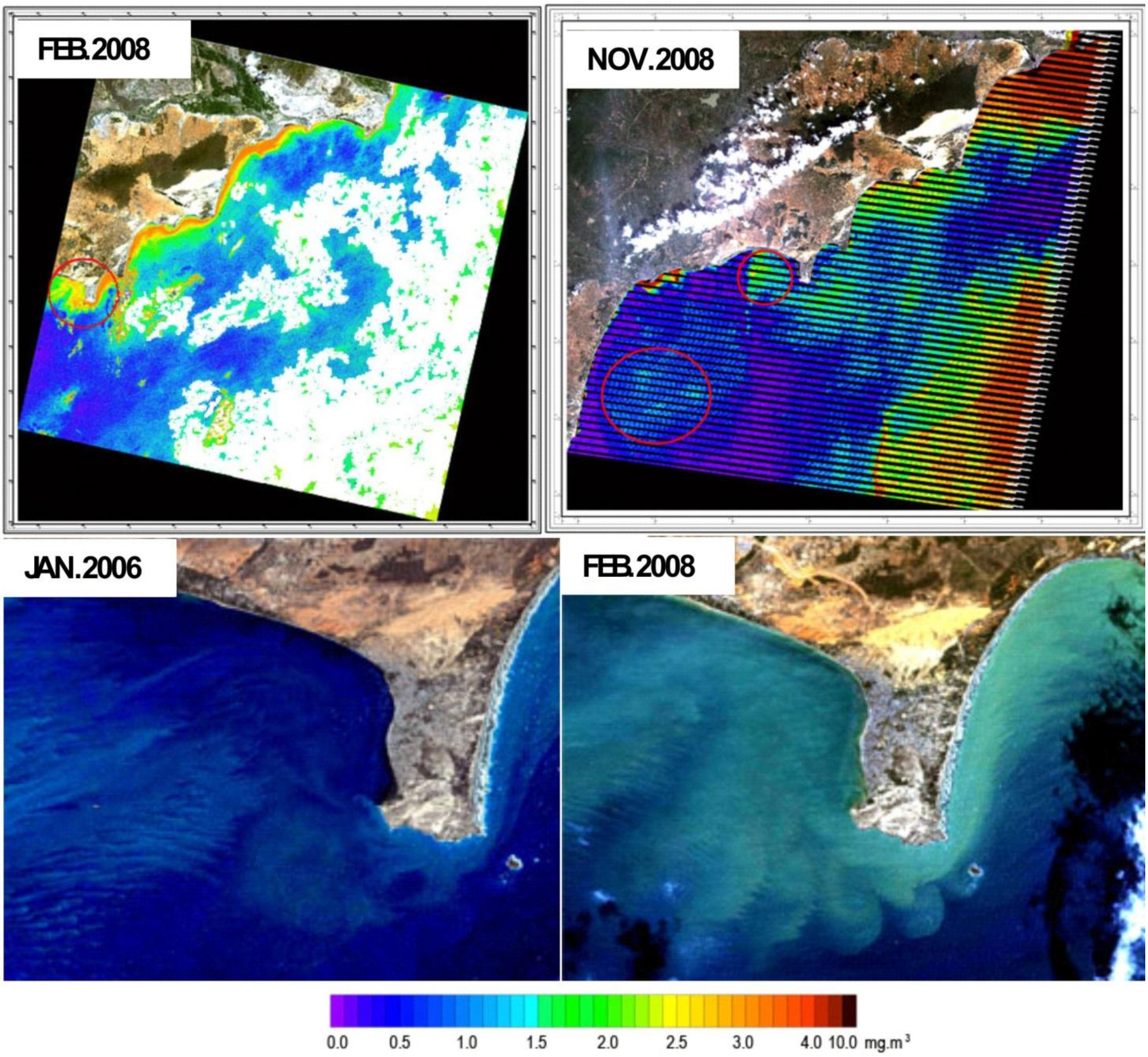


Fig. 2. Chl a distribution in Ninh Thuan-Binh Thuan during NEM with high biomass lane lie close to coast but not attach to coast and also exist in headlands.

On the other hand, from high resolution imagery, we also found out anomalies of higher Chl *a* in offshore of Cu Lao Thu, they lie duplicate with position of shallow bank (8–10m deep compare to 40–50 m deep water in vicinity). From AVNIR2 scene which captured 21st December 2008 show clearly the picture of algal bloom with difference shapes as "patch", "lane" types. From Landsat TM scene, taking 19 June 1988 also recorded this phenomenon. The affect of sediment plume from Mekong river, bathymetry "break" of shallow bank as well as local eddies (anticyclone) creating upwelling vertical current are main reasons that causing high biomass patches as mentioned above. This is one of a main fishery grounds in central Vietnam which be discuss in next part. The general map of algal bloom patches in upwelling region has been shown detail in Fig. 3.

The relationship between algal bloom areas with existence of biological resource grounds. Upwelling area in Central Vietnam is one of regions where have highest biological production of Vietnam sea with diversity resources such as bivalve grounds in coast line as well as pelagic fishery schools in offshore. By this study together with previous ones of Vietnamese authors, we found out:

a) The existence position and development of bivalve grounds (*Chamis nobilis, Anadara antiquata, Modiolus philippinus)* in this region relate strongly to effect of upwelling vertical activities in Summer and permanent current with North-South direction during Winter. These factors created an especial region lie inside edge of advection water circulation where annual-averaged SST is relative low, high nutrient source, concentrated area of high density area of benthos, zooplankton, phytoplankton as well as fish egg and fish larvae. However, previous authors have not explained yet that why sediment distribution in bivalve grounds is coarse sand, terrestrial feed source from short rivers is not enough for creating and developing of bivalve grounds. This study complemented and showed more clearly: the high biomass lane strengths from Dinh Cape (Phan Ri) to Ne Cape (Binh Thuan) that was created by affect of monsoon that bring floating offshore material reach to coast is most important feed source for bivalve live in this region. The high biomass patches in offshore Phan Ri Bay-upwelling center are also indirect feed source of them.

b) The pelagic fishery schools (*Decaterus kuroides*, *D. maruadsi*, *Taius tumifront, Saurida)* mainly concentrate in offshore and lie nearby shallow banks in Cu Lao Thu and another lie in Phan Ri bay on Breda shallow bank in close to coast (Fig. 4). The effect of anti eddy onto shallow banks in offshore creating high biomass-algal bloom as presented in resulted part is main reason using to explain this phenomenon.

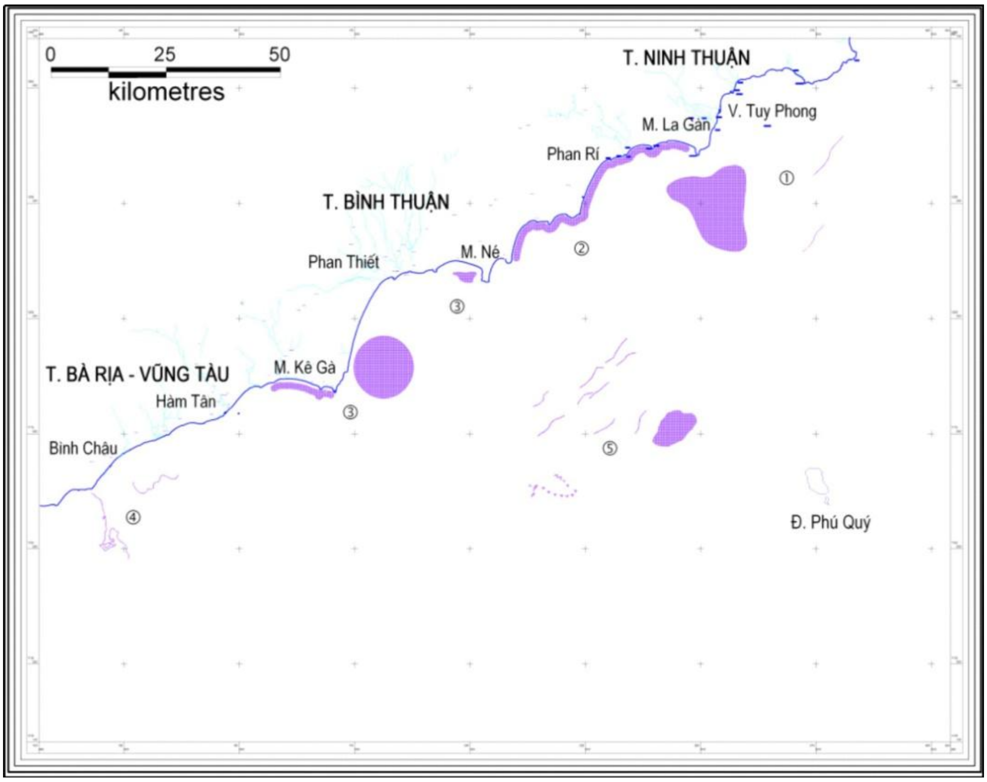


Fig. 3. The distribution of high biomass-algal blooms patches in upwelling regions that has been determined by high resolution imagery.

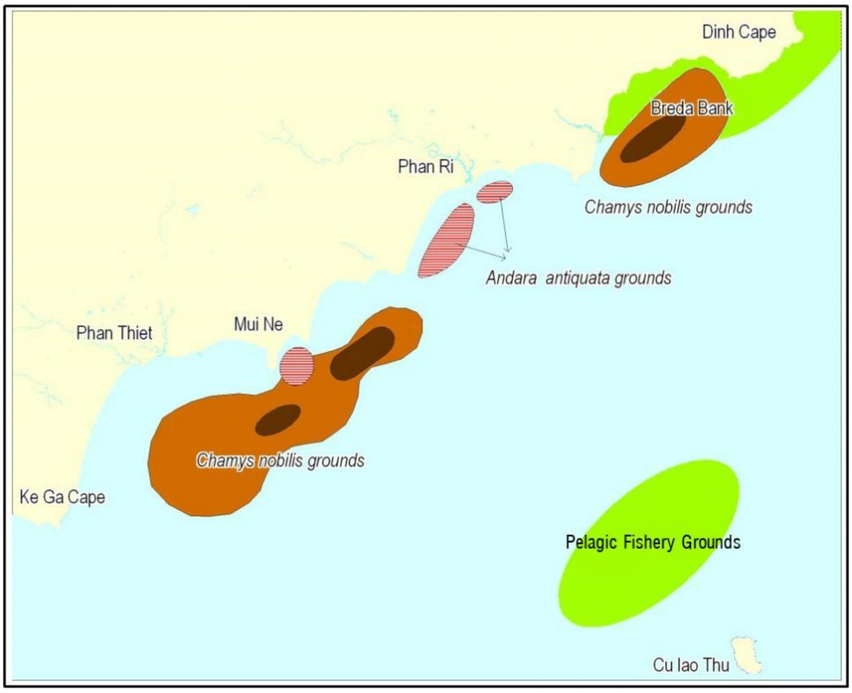


Fig. 4. The position of high chlorophyll-a anomalies relate to strongly with existence of biological resource grounds**.**

Concluding Remarks

Based on the numbers of optical satellite images (include 84 scenes of MODIS images, 14 scenes Landsat ETM$^+$, 6 scenes of AVNIR2) with together monthly *in situ* data obtained from 21 stations during 2007–2008 in upwelling region, the spatial and temporal variations of Chl *a* and algal blooms have been detected (Table 1).

Table 1. 86 scenes of MODIS imagery coverage the study area, the images are taken daily for two years 2007-2008.

Months	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Total**
2007	5	3	4	5	6	3	6	4	4	3	4	5	48
2008	4	3	5	6	2	4	4	3	2	2	1	2	38

The detail distributed map of high biomass-algal bloom areas in both SWM and NEM has been determined. The relationship between algal blooms area with existence ability of biological resource grounds have been more clearance from this study.

Thus, current study on the distribution on Chl *a* using satellite imageries are convinced to imply marine resource management, environmental monitoring and improving fisheries programs. Detailed study on relationship between *in situ* and remote sensing derived dada is essential for ecological changes in the upwelling area where special fishery ground in Vietnam waters.

Need to a synchronized study on fishery oceanography in this region as a key study for forecast model of fishery domain include pelagic fish schools as well as bivalve grounds not only in Vietnam waters but also in the South East Asia.

Acknowledgments

The authors are grateful thank the national project KC 09.03/06-10 study on the processing and ecological of harmful algal species in some typical coastal area and their effect to marine fisheries resources for field study support. We also thank the Japan Aerospace Exploration Agency (JAXA) for support the ALOS-AVNIR2 satellite imagery under ALOS-PI 326 project; the United State Geological Survey (USGS) for LandSat ETM$^+$ imagery and the National Aeronautics and Space Administration (NASA) for the MODIS imagery which distributed for this study.

References

Asif Mumtaz Bhatti, Yoichi Nojiri, Seigo Nasu, Masataka Takagi. 2008. Assessing the Potential of Remotely Sensed Data for Water Quality Monitoring of Coastal and Inland Waters // Proceeding of Kochi University of Technology. V. 5, N 1. P. 201–207.

Investigated Temperate data of VG2, VG3, VG5, VG7 cruises belong to Vietnam-Germany joint project. 2004. Long Bui Hong [Ed.].Technique Report on Vietnam-Germany Project, period 2002–2004. Institute of Oceanography VAST, Nha Trang, Vietnam.

Lui K.-K., Chao S.Y., Shaw P.T., Gong J.C., Chen C.C., Tang T.Y. 2002. Monsoon-forced chlorophyll distribution and primary production in the South China Sea: observations and a numerical study // Deep-Sea Research. V. I (49). P. 1387–1412.

Lafond E.C. 1966. South China Sea // The Encyclopedia of Oceanography. R.W. Fairbridge (Ed.). New York: Reinhold Publishing Corp. P. 829–837.

Le Phuoc Trinh, Nguyen Tien Dung, Tran Van Sam. 1981. A proposal of studies on the upwelling phenomenon in the Southern coastal of Vietnam // Collection of Marine Research Works, Nhatrang, Vietnam. V. 2. P. 15–31 [In Vietnamese].

Nan-Jung Kuo, Quanan Zheng, Chung-Ru Ho. 2004. Response of Vietnam coastal upwelling to the 1997-1998 ENSO event observed by multisensory data // Remote Sensing of Environment. V. 89. P. 106–115.

SeaWiFS Post launches Calibration and Validation Analyses. Part 3. 2000. NASA Technical Memorandum. 2000-206892. O'Reilly [Ed.]. USA: NASA Goddard Space Flight Center. V. 11. 49 p.

The Contribution on coastalstrong upwelling phenomenon in South Central Vietnam. 1997. Vo Van Lanh (Ed.). Institute of Oceanography VAST, Nha Trang, Vietnam. 207 p. [In Vietnamese].

Tong Phuoc Hoang Son, Vo Van Lanh. 2005. Application of empirical orthogonal function (EOF) for studying thermal structure in sea surface water in South China Sea // Proceedings of The 26th Asian Remote Sensing Conference, Hanoi, Vietnam. P. 49–58.

Wyrtki K. 1961. Physical Oceanography of Southern Asian Waters. La Jolla: NAGA report. V. 2.

NEW DATA ON MORPHOLOGY OF BATILLARIID GASTROPODS (CAENOGASTROPODA: CERITHIOIDEA: BATILLARIIDAE)

Larisa A. Prozorova[1], Tatiana Ya. Sitnikova[2], Anna Rasshepkina[1]

[1]Institute of Biology and Soil Science, Far East Branch of Russian Academy of Sciences, Vladivostok, 690022, Russia; e-mail: lprozorova@mail.ru

[2]Limnological Institute of the Siberian Branch of Russian Academy of Sciences, Irkutsk, 664033, Russia; e-mail: sit@lin.irk.ru

The cerithioidean family Batillariidae includes 14–16 living species, grouped in six to eight genera. Batillariids inhabit intertidal zones from tropical to warm-temperate regions, and are sometimes abundant in the sandy or rocky littoral zone. In the Pacific Ocean this family is distributed from Australia to Japan, Korea, and the Southern Russian Far East (southern Sakhalin and Primorye).

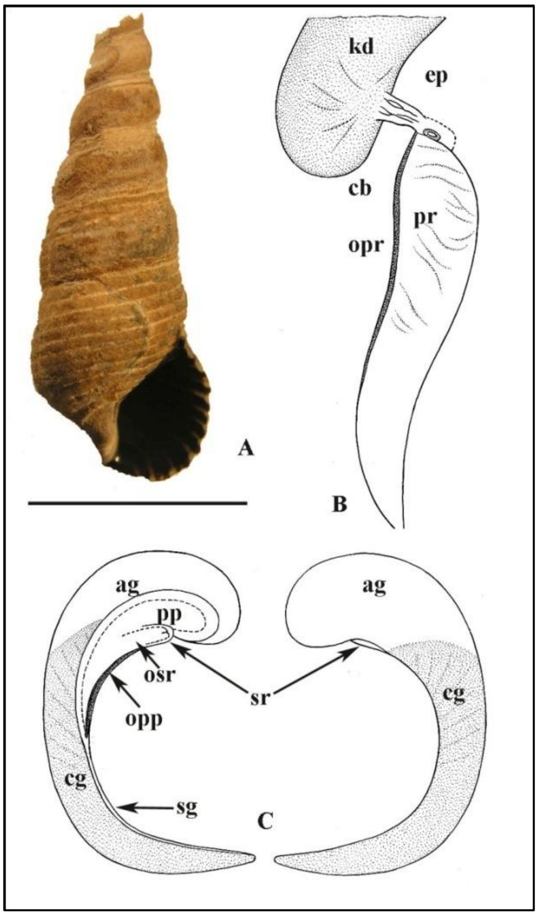


Fig. 1. *Batillaria attramentaria* (G.B. Sowerby, 1855) from Kunashir Island, Southern Kuril Archipelago: A – shell; B – pallial male gonoduct; C – pallial oviduct. Scale bar: 1 cm. srsr. Abbreviations: pr – prostate, opr – opening of prostate, kd – kidney, ep – excretory pore in roof of mantle cavity, cb – connective tissue bands, ag – albumen gland, cg – capsule gland, sr – seminal receptacle, osr – opening of seminal receptacle, pp – pallial pocket or spermatophore bursa, opp – opening of pallial pocket, sg – sperm gutter.

In the Oriental region only one genus, *Batillaria* Thiele, 1931, is known. The genus includes six recent species: *B. attramentaria* (G.B. Sowerby, 1855) (syn.: *B. cumingi* (Crosse, 1862)), *B. flectosiphonata* Ozawa, 1996, *B. multiformis* (Lischke, 1869), *B. zonalis* (Bruguiere, 1792), *B. sordida* (Gmelin, 1791) (syn. *B. bornii* (Sowerby, 1855)), and *Batillaria* sp. The first four species are distributed from Japan and Korea to tropical seas (Higo, Goto, 1993; Noseworthy et al., 2007). The two latter species (*B. sordida; Batillaria* sp.) are recorded in Vietnam as well (Ozawa et al., 2009).

Recently the family was studied phylogenetically and it was revealed that the six oriental *Batillaria* species form a clade with maximum support (Ozawa et al., 2009). In contrast to molecular phylogeny, the morphology of the family Batillariidae has remained insufficiently studied. Taxonomically important anatomical characters of *Batillaria* s. str. were listed by R. Houbrick (1988) without illustration. Some data on radula and shell structure were published as well (Golikov, Starobogatov, 1987 and others). The South Atlantic *Lampanella minima* (Gmelin, 1791) is the only batillariid species examined in detail anatomically (Strong, 2003). Because of the lack of anatomical data on Pacific batillariids, a comprehensive morphological study of *Batillaria attramentaria* from the Southern Russian Far East (Fig. 1A) was conducted using SEM-microscopy and histological methods.

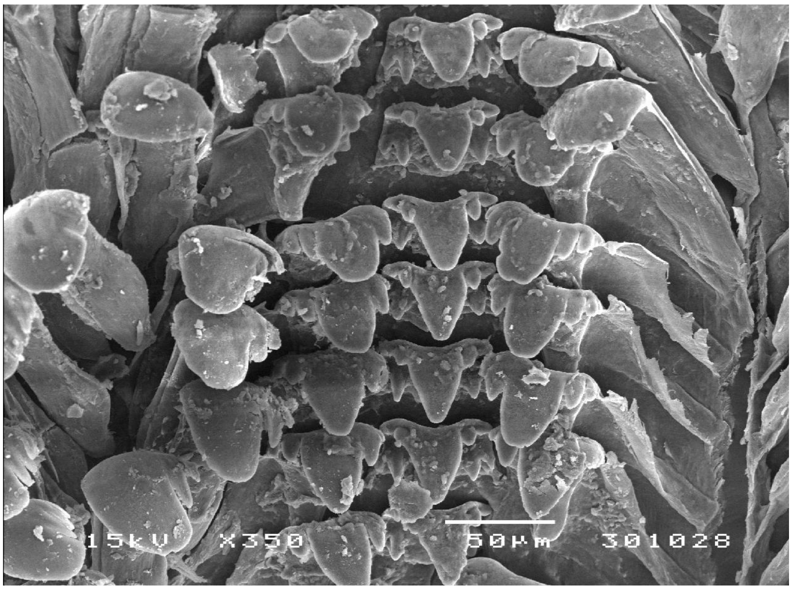


Fig. 2. Radula fragment of *Batillaria attramentaria* (G.B. Sowerby, 1855) from Kunashir Island, Southern Kuril Archipelago.

The morphology of the external body, shell, and radula (Fig. 2) the structure of the reproductive (Fig. 2B, C), alimentary, and nervous systems, and some other anatomical characteristics of *B. attramentaria*, were examined. The characters examined supplemented those cited for *Batillaria* by R. Houbrick (1988). New data was obtained concerning the the radular teeth (Fig. 2) as well as the very long ctenidium and osphradium, which are are nearly the same length, and the pallial gonoviduct of male (Fig. 2B) and female (Fig. 2C) reproductive system was studied in detail.

Using data presented by Strong (2003) for *Lampanella minima,* a comparative morphological analysis of *Batillaria attramentaria* was conducted. The analysis was made more precise because of the unique characters of *Batillaria* and the features shared with *Lampanella,* which are common for Batillariidae.

Acknowledgements

The work was supported by the following Russian Science Foundation grants: Presidium RAS and FEB RAS № 06-1-P-11-023, RFBR № 09–04–98583-r_vostok_a (V.V Bogatov, Principal Investigator).

References

Golikov A.N., Starobogatov Ya.I. 1987. Systematics of the order Cerithiiformes and its position within the subclass Pectinibranchia // Molluscs, Results and Perspectives of Investigation: Abstracts of the Eighth Meeting of the Investigation of Molluscs. Leningrad: Nauka. P. 23–28. [In Russian].

Higo S., Goto Y. 1993. A Systematic List of Molluscan Shells from the Japanese Is. and the Adjacent Area. Osaka: Yuko. 693 p.

Houbrick R.S. 1988. Cerithioidean phylogeny // Malacological Review. Suppl. 4. P. 88–128.

Noseworthy R.G., Lim N.R., Choi K.S. 2007. A cataloque of the mollusks of Jeju Island, South Korea // Korean Journal of Malacology. V. 23, N. 1. P. 65–104.

Ozawa T., Kohler F., Reid D.G., Glaubrecht M. 2009. Tethyan relicts on continental coastlines of the northwestern Pacific Ocean and Australasia: molecular phylogeny and fossil record of batilla-riid gastropods (Caenogstropoda, Cerithioidea) // Zoologica Scripta. V. 38, N 5. P. 503–525.

Strong E.E. 2003. Refining molluscan characters: morphology, character coding and a phylogeny of the Caenogastropoda // Zoological Journal of the Linnean Society. V. 137. P. 447–554.

DIVERSITY OF SOFT CORALS (ALCYONACEA) IN VIETNAM

***Hoang Xuan Ben*[1]*, Tatyana N. Dautova*[2]**

[1]*Institute of Oceanograph, 01 Cauda, Nha Trang, Vietnam; e-mail: hxuanben@yahoo.com*

[2]*Institute of Marine Biology of the Far East Branch of Russian Academy of Sciences, 17 Paltchevsky str., Vladivostok, Russia 690041; e-mail: tndaut@mail.ru*

Vietnam has more than 3.260 km the coastline with thousands of islands where distributed coral reefs and they play an important role in the economic development of the country. Many studies of coral reefs in Vietnam but these results focus on the status of cover and distribution or biodiversity of hard coral. The octocoral fauna of Vietnam has been the subject of several studies. These studies not only scatter somewhere in Vietnam but also lack the information of diversity of soft corals. Based on the previous studies, we will review the status of biodiversity of soft corals, update and arrange the name of species and distribution of soft coral in Vietnam. This result will supply the information about biodiversity of soft corals in Vietnam.

An early collection of soft coral conducted by Hickson in 1919, resulted in the description one new species *Alcyonium krempfi* in the central of Vietnam. Subsequently, Stiasny (1938) determined 18 species of Gorgonians listed for Southern of Vietnam (mainly in Nha Trang and Con Dao). The author described two species *Eunicella dawydoffi* and *Junceella bifurcate* as a new species for science. Dawydoff (1952) gives the list of soft coral in Vietnam with 6 families including Alcyonidae, Fasciculariidae, Xaniidae, Telestaceidae, Tubiporidae and Nephtheidea. In 1970 Tixier-Durivault conducted 94 species of soft coral in Nha Trang bay and this scientific research was considered the most significant for taxomomy of soft coral in Vietnam. The WWF (1994) carried out coral reefs ecology at Cat Ba, Cu Lao Cham, Nha Trang, Cu Lao Cau, Con Dao anh Phu Quoc. This result showed that Cat Ba has 20 species 14 genera and 8 families, Cu Lao Cham 15 species 11 genera and 6 families, Nha Trang 32 species 12 genera and 7 families, Phu

Quoc 19 species 7 genera and 4 families. The diversity of soft corals is not classified at Con Dao in WWF survey team in 1994. The expedition between Vietnam – Philippine (JOMSRE I, 1996) in North of Spratly recorded 17 species belong to 11 genera and 3 families. Nguyen Huy Yet (1998) identified 16 species 8 genera and 2 families of Gorgonians in Spratly. Hoang Xuan Ben and Dautova (2010) published the composition species of soft coral in Ly Son with 59 species belong to 10 genera and 5 families. Malyutin (1991) described two new species *Sinularia mammifera* and *S. laminilobata* in Con Dao islands and Dautova (2009) determined two species *Eleutherobia nezdoliyi* and *Sinularia arctium* in Nha Trang bay. The problem with the previous studies that specimens of soft coral which the authors identified not keep in Vietnam except the studies of Hoang Xuan Ben and Dautova (2010), Dautova and Savinkin (2009) and Malyutin (1990). The overview of studies of biodiversity of soft coral in Vietnam showed in Table 1.

Table 1. The number of species of soft coral in Vietnam

Authors	Area	Families	Genera	Species
Stiasny, 1938	Nha Trang, Con Dao	6	13	18
Dawydoff,1952	Vietnam	6	-	-
Tixier-Durivault, 1970	Nha Trang	5	15	94
Hoàng Xuân Bền, 2009	Nha Trang	9	20	76
Võ Sĩ Tuấn vsc, 1996	North of Spratly	3	11	17
Nguyễn Huy Yết, 1998	Spratly	8	12	16
WWF, 1994	Cat Ba – Hai Phong	8	14	20
WWF, 1994	Cu Lao Cham	6	11	15
WWF, 1994	Cu Lao Cau	3	8	30
WWF, 1994	Phu Quoc	4	7	19
WWF, 1994	Nha Trang	7	12	32
H.X Bền, Dautova, 2009	Ly Son	5	10	59
Nguyễn Huy Yết vcs, 1996	Con Co - Quang Tri	1	4	5
Nguyễn Huy Yết vcs, 2008	Hai Van – Son Cha	6	11	12
Malyutin, 1990	Con Dao	-	-	2*
Dautova, Savinkin, 2009	Nha Trang	-	-	2*
		14	**45**	**200**

Note: *New species for science

The summary of studies of biodiversity of soft coral, we reviewed 200 species belong to 45 genera and 14 families of soft coral which recorded in Vietnam (Appendix). The Alcyoniidae family is the most diverse with 124 species and Nephthaedae 21 species and Plexauridae 18 species. The *Sinularia* genus is the most diverse with 66 species and *Lobophytum* 26 species and *Sarcophyton* 20 species.

References

Dautova T.N., Savinkin O.V. 2009. New data on soft corals (Anthozoa: Octocorallia) from Nha Trang Bay // Zootaxa. V. 2027: 1–27.

Hoang Xuan Ben, Dautova T.N. 2010. Soft corals (Alcyonacea) in Ly Son islands, the central of Vietnam // Journal of Marine Science and Technology. V.10, N 4. P. 39–49.

Nguyen Huy Yet. 1998. The composition and Distribution of Soft corals (Gorgonacea) in Spraty (Vietnam) // The Collection of Research of Resource and Environment. V. 5. P. 175–82.

Stiasny G. 1938. Franzosisch Indochina Gesammelten Gorgornarien // Mémories de Muséum National D'histoire Naturelle. Nouvelle série. V. 6. Fascicule 3. P. 356–68.

Tixier-Durivault A. 1970. Les Octocoralliaires de Nha Trang (Vietnam) // Cahiers du Pacifique. V. 14. P. 115–236.

WWF Vietnam Marine Conservation Southern Survey Team, 1994. Survey report on the Biodiversity, Resource Utilization and Conservation Potential of Cat Ba, Hon Mun, Cu Lao Cau, An Thoi, Co To, Con Dao. Institute of Oceanography (Nha Trang, Hai Phong, Vietnam) and WWF.

APPENDIX. The list of soft coral species in Vietnam.

No	Families	Genera	Species
1.	CLAVULARIIDAE	*Clavularia*	*Clavularia coronata*
2.		*Telesto*	*Telesto arborea*
3.	TUBIPORIDAE	*Tubipora*	*Tubipora musica*
4.	ALCYONIIDAE	*Klyxum*	*Klyxum molle*
5.			*Klyxum flaccidum*
6.		*Cladiella*	*Cladiella australis*
7.			*Cladiella conifera*
8.			*Cladiella foliacea*
9.			*Cladiella hicksoni*
10.			*Cladiella krempfi*
11.			*Cladiella latissima*
12.			*Cladiella parattae*
13.			*Cladiella scabra*
14.			*Cladiella similis*
15.		*Lobophytum*	*Lobophytum angulatum*
16.			*Lobophytum batarum*
17.			*Lobophytum carnatum*
18.			*Lobophytum compactum*
19.			*Lobophytum crassum*
20.			*Lobophytum crassospiculatum*
21.			*Lobophytum cryptocormum*
22.			*Lobophytum delectum*
23.			*Lobophytum durum*
24.			*Lobophytum hirsutum*
25.			*Lobophytum jaeckeli*
26.			*Lobophytum laevigatum*
27.			*Lobophytum lighti*
28.			*Lobophytum oblongum*
29.			*Lobophytum pauciflorum*
30.			*Lobophytum ransoni*
31.			*Lobophytum robustum*
32.			*Lobophytum roxasi*
33.			*Lobophytum salvati*
34.			*Lobophytum schoedei*
35.			*Lobophytum sarcophytoides*
36.			*Lobophytum strictum*
37.			*Lobophytum tenerum*
38.			*Lobophytum undatum*
39.			*Lobophytum variatum*

No	Families	Genera	Species
40.			*Lobophytum varium*
41.		*Sarcophyton*	*Sarcophyton acutum*
42.			*Sarcophyton birkelandi*
43.			*Sarcophyton boletiforme*
44.			*Sarcophyton cherbonnieri*
45.			*Sarcophyton cinereum*
46.			*Sarcophyton crassocaule*
47.			*Sarcophyton crassum*
48.			*Sarcophyton ehrenbergi*
49.			*Sarcophyton elegans*
50.			*Sarcophyton glaucum*
51.			*Sarcophyton mililatensi*
52.			*Sarcophyton molle*
53.			*Sarcophyton poculiforme*
54.			*Sarcophyton pulchellum*
55.			*Sarcophyton roseum*
56.			*Sarcophyton serenei*
57.			*Sarcophyton solidum*
58.			*Sarcophyton tenuispiculatum*
59.			*Sarcophyton tortuosum*
60.			*Sarcophyton trocheliophorum*
61.		*Sinularia*	*Sinularia abhishiktae*
62.			*Sinularia abrupta*
63.			*Sinularia arctium*
64.			*Sinularia brassica*
65.			*Sinularia bremerensis*
66.			*Sinularia capillosa*
67.			*Sinularia capitalis*
68.			*Sinularia ceramensis*
69.			*Sinularia conferta*
70.			*Sinularia compacta*
71.			*Sinularia corpulentissima*
72.			*Sinularia crassa*
73.			*Sinularia cristata*
74.			*Sinularia cruciata*
75.			*Sinularia deformis*
76.			*Sinularia densa*
77.			*Sinularia depressa*
78.			*Sinularia dumosa*
79.			*Sinularia dura*
80.			*Sinularia elongata*
81.			*Sinularia exilis*
82.			*Sinularia erecta*
83.			*Sinularia facile*
84.			*Sinularia fishelsoni*
85.			*Sinularia flexibilis*
86.			*Sinularia flexuosa*
87.			*Sinularia fungoides*
88.			*Sinularia gibberosa*
89.			*Sinularia granosa*
90.			*Sinularia gyrosa*
91.			*Sinularia halversoni*
92.			*Sinularia inelegans*
93.			*Sinularia inexplicita*

No	Families	Genera	Species
94.			*Sinularia intacta*
95.			*Sinularia laminilobata*
96.			*Sinularia leptoclados*
97.			*Sinularia lochmodes*
98.			*Sinularia longula*
99.			*Sinularia macropodia*
100.			*Sinularia mammifera*
101.			*Sinularia marenzelleri*
102.			*Sinularia mayi*
103.			*Sinularia maxima*
104.			*Sinularia microclavata*
105.			*Sinularia minima*
106.			*Sinularia mira*
107.			*Sinularia molesta*
108.			*Sinularia mollis*
109.			*Sinularia nanolobata*
110.			*Sinularia notanda*
111.			*Sinularia numerosa*
112.			*Sinularia ovispiculata*
113.			*Sinularia parva*
114.			*Sinularia pavida*
115.			*Sinularia pedunculata*
116.			*Sinularia polydactyla*
117.			*Sinularia querciformis*
118.			*Sinularia ramosa*
119.			*Sinularia ramulosa*
120.			*Sinularia rigida*
121.			*Sinularia robusta*
122.			*Sinularia rotundata*
123.			*Sinularia scabra*
124.			*Sinularia variabilis*
125.			*Sinularia verrucosa*
126.			*Sinularia whiteleggei*
127.		*Eleutherobia*	*Eleutherobia nezdoliyi*
128.	NEPHTHEIDAE	*Litophyton*	*Litophyton arboreum*
129.			*Litophyton stuhlmanni*
130.		*Morchellana*	*Morchellana anguina*
131.			*Morchellana coronata*
132.			*Morchellana curvata*
133.			*Morchellana dendrophyta*
134.			*Morchellana habereri*
135.		*Nephthea*	*Nephthea chabrolii*
136.			*Nephthea erecta*
137.			*Nephthea brassica*
138.		*Paralemnalia*	*Paralemnalia thyrsoides*
139.			*Paralemnalia eburnea*
140.		*Roxasia*	*Roxasia eburnea*
141.			*Roxasia involuta*
142.		*Dendronephthya*	*Dendronephthya gigantea*
143.			*Dendronephthya aurea*
144.			*Dendronephthya mucronata*
145.			*Dendronephthya roemeri*
146.			*Dendronephthya nipponica*
147.		*Stereonephthya*	*Stereonephthya* sp.

No	Families	Genera	Species
148.		*Lemnalia*	*Lemnalia flava*
149.	XENIIDAE	*Heteroxenia*	*Heteroxenia medioensis*
150.			*Heteroxenia mindorensis*
151.		*Xenia*	*Xenia lillieae*
152.			*Xenia umbellata*
153.	BRIAREIDAE	*Briareum*	*Briareum* sp.
154.	ANTHOTHELIDAE	*Solenocaulon*	*Solenocaulon jedanensis*
155.		*Semperiana*	*Semperiana brunnea*
156.			*Semperiana excavata*
157.			*Semperiana rubra*
158.	SUBERGORGIIDAE	*Subergorgia*	*Subergorgia suberosa*
159.			*Subergorgia thomsoni*
160.			*Subergorgia verriculata*
161.	MELITHAEIDAE	*Acabaria*	*Acabaria bicksoni*
162.			*Acabaria formosa*
163.			*Acabaria ramulosa*
164.		*Melithaea*	*Melithaea ochracea*
165.			*Melithaea variabilis*
166.			*Melithaea esperi*
167.	ACANTHOGORGIIDAE	*Acanthogorgia*	*Acanthogorgia studeri*
168.			*Acanthogorgia* sp.
169.		*Muricella*	*Muricella brunnea*
170.			*Muricella ceylonensis*
171.			*Muricella sinensis*
172.	PLEXAURIDAE	*Psammogorgia*	*Psammogorgoia seurati*
173.			*Psammogorgoia nodosa*
174.		*Swiftia*	*Swiftia studeri*
175.		*Bebryce*	*Bebryce hicksoni*
176.		*Euplexaura*	*Euplexaura curvata*
177.			*Euplexaura pedula*
178.			*Euplexaura recta*
179.		*Menella*	*Menella praelonga*
180.		*Paraplexaura*	*Paraplexaura* sp.
181.		*Echinogorgia*	*Echinogorgia abietina*
182.			*Echinogorgia flabellum*
183.			*Echinogorgia florae*
184.			*Echinogorgia flexilis*
185.		*Echinomuricea*	*Echinomuricea pulchra*
186.			*Echinomuricea indomalaccensis*
187.		*Pracis*	*Pracis* sp.
188.	GORGONIIDAE	*Hicksonella*	*Hicksonella princeps*
189.		*Rumphella*	*Rumphella aggregata*
190.		*Pseudopterogorgia*	*Pseudopterogorgia flava*
191.		*Eunicella*	*Eunicella dawydoffi*
192.	ELLISELLIDAE	*Junceella*	*Junceella bifurcata*
193.			*Junceella fragilis*
194.			*Junceella juncea*
195.			*Junceella gemmacea*
196.		*Verrucella*	*Verrucella umbaculum*
197.		*Ctenocella*	*Ctenocella pectinata*
198.		*Ellisella*	*Ellisella andamanensis*
199.			*Ellisella verrucosa*
200.	ISIDIDAE	*Isis*	*Isis hipperis*

BELT-FORMING COMMUNITIES OF MACROBENTHOS IN THE INTERTIDAL ZONE OF THE VIETNAMESE ISLANDS

Elena E. Kostina

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch,

Russian Academy of Sciences, Vladivostok 690041, Russia

e-mail: cnidopus@mail primorye.ru

The present work is based on samples of the macrobenthos taken in the intertidal zone of the Vietnamese Islands (South China Sea) during a marine expedition aboard the research vessel "Professor Bogorov" of the A.V. Zhirmunsky Institute of Marine Biology of the Far Eastern Branch of the Russian Academy of Sciences in August–October 1988 and literature data. It was investigated intertidal zone of Vietnamese Islands from Namzu Islands (9°40' N, 104°22' E), situated in the Gulf of Siam to Daochao Island (20°50' N, 107°20' E), situated in the Gulf of Tonkin (Fig. 1). The belt-forming communities of macrobenthos were investigated on the five bionomical types of the intertidal zone (Table 1), which were distinguished on the basis of the substrate features, wave action, influence of the water-freshening and also specific factors (pools, ground vegetation).

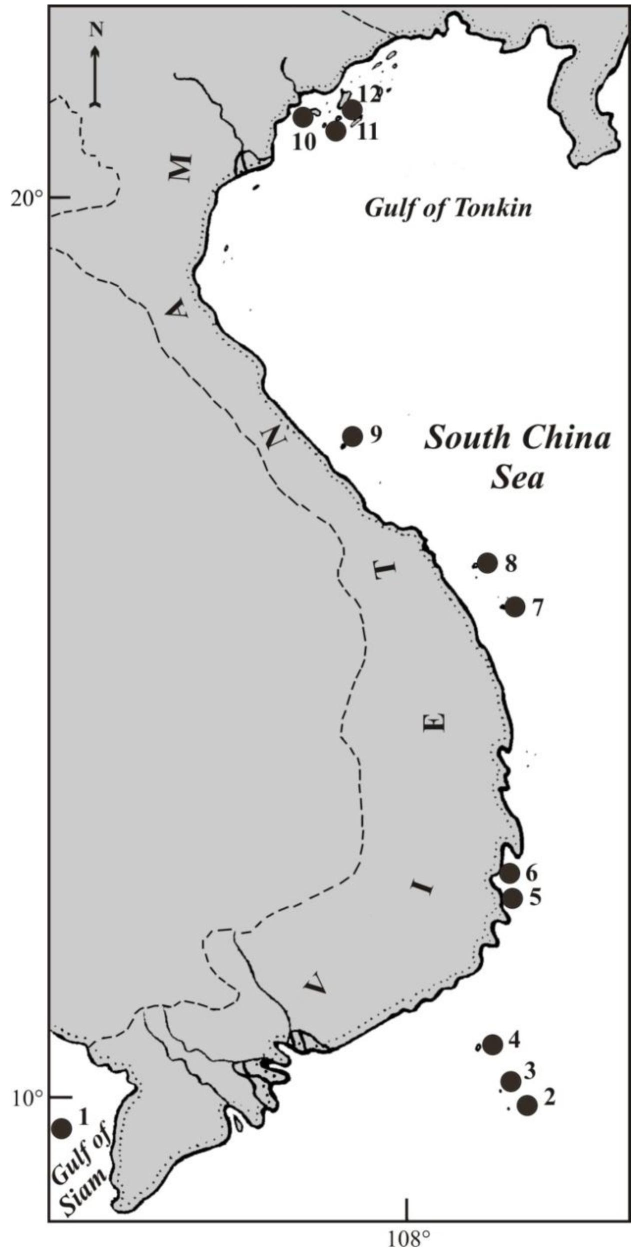


Fig. 1. The schematic map of studied area. 1 – Namzu Islands, 2 – Catwick Small Island, 3 – Catwick Big Island, 4 – Thu Island, 5 – Rua, Mot, Mju Islands, 6 – Lon Island, 7 – Re Island, 8 – Thiam Island, 9 – Ze Island, 10 – Cat Ba Island, 11 – Zanzola Island, 12 – Daochao Island.

Thus, the belt-forming communities inhabit the upper, middle and lower horizons of the rocky intertidal zone. On the rocky-blocky-bouldery, silty-stony intertidal zones and also on the littioral of the dead coral reef the ones were found only in the upper and middle horizons, while in the lower horizon the macrobenthos communities had spotty distribution. The upper horizon of sandy beaches is either wholly devoid macrobenthos or populated only by mobile crustaceans. Macrobenthos of hard substrates was the richest in qualitative and quantitative compositions. Population of crumbly substrates was the poorest.

Table 1. Distribution of the belt-forming intertidal communities in the Vietnamese Islands.

Type of the intertidal zone	**Communities**	**Biomass of macrobenthos, g wet wt m^{-2}**	**Islands**	**References**
Rocky intertidal zone	Bivalve mollusc *Saccostrea mordax* (upper and middle horizons)	7200	Catwick Small Island	Our data
		12000	Catwick Big Island	The same
		10764	Thiam Island	The same
		–	Cat Ba Island	Gurjanova, Phuong Chang Hiu, 1972
		2029	Namzu Islands	Gulbin et al., 1987
		–	Rua, Mot, Mju, Lon Islands	Nguyen Van Chung et al., 1988
	Gastropod *Nodilittorina pyramidalis* (upper horizon)	–	Rua, Mot, Mju, Lon Islands	The same
	Barnacle *Megabalanus tintinnabulum* (middle horizon)	11205	Catwick Small Island	Our data
		5527	Catwick Big Island	The same
	Barnacle *Balanus* sp. (middle horizon)	–	Cat Ba Island	Gurjanova, Phuong Chang Hiu, 1972
	Red algae *Laurencia* sp.+ barnacle *Balanus tintinnabulum* (middle horizon)	3255	Namzu Islands	Gulbin et al., 1987
	Brown algae *Turbinaria decurrens* (middle horizon)	–	Namzu Islands	The same
	Brown algae *Sargassum mcclurei* (middle horizon)	3162	Thu Island	The same
	Barnacle *Tetraclita squamosa squamosa* (middle and lower horizons)	10257	Thiam Island	Our data
	Red algae *Lithothamnium* spp. (lower horizon)	–	Cat Ba Island	Gurjanova, Phuong Chang Hiu, 1972
	Brown algae *Sargassum feldmannium* (lower horizon)	1498	Thu Island	Gulbin et al., 1987
	Brown algae *Sargassum* spp. (lower horizon)	–	Rua, Mot, Mju, Lon Islands	Nguyen Van Chung et al., 1988
Rocky-blocky-bouldery intertidal zone	Barnacle *Tetraclita squamosa squamosa* (upper horizon)	3066	Ze Island	Our data
	Bivalve mollusc *Saccostrea mordax* (upper and middle horizons)	1895	Namzu Islands	Gulbin et al., 1987
		11574	Thiam Island	Our data
		5520	Ze Island	The same

Type of the intertidal zone	Communities	Biomass of macrobenthos, g wet wt m^{-2}	Islands	References
Rocky-blocky-bouldery intertidal zone	Green algae *Halimeda* spp. + *Caulerpa* spp. (middle horizon)	245	Thu Island	The same
	Brown algae *Padina tenuis* (middle horizon)	3308	Thu Island	Gulbin et al., 1987
Dead coral reef	Bivalve mollusc *Saccostrea mordax* (upper horizon)	3442	Re Island	Our data
	Angiosperm *Thalassia hemprichii* (middle horizon)	3240	Re Island	The same
Silty-stony intertidal zone	Bivalve mollusc *Ostrea foliolum* (upper horizon)	2733	Daochao Island	The same
	Bivalve molluscs *Isognomon ephippium*+ *Hormomya mutabilis* (upper horizon)	430	Zanzola Island	The same
	Bivalve mollusc *Saccostrea echinata* (middle horizon)	897	Daochao Island	The same
	Bivalve molluscs *Gafrarium pectinatum* + *Annomalocardia squamosa* (middle horizon)	1263	Zanzola Island	The same
Sandy intertidal zone	Green algae *Cladophora* sp. (middle horizon)	94	Thu Island	Gulbin et al., 1987
	Angiosperm *Cymodocea rotundata*; angiosperm *Thalassia hemprichii*+ brown algae *Sargassum polycystum* (lower horizon)	831	Thu Island	The same

Note: «–» – data are not available.

Acknowledgements

The work was supported by FEB RAS Foundation Grant 09-III-A-06-195.

References

Gulbin V.V., Vinogradova K.L., Nguyen Van Chung. 1987. Quantitative distribution of macrobenthos in the littoral of South Vietnamese Islands // The Soviet Journal of Marine Biology. V. 13, N 3. P. 169–173.

Gurjanova E.F., Phuong Chang Hiu. 1972. Intertidal zone of the Tonking Gulf // Explorations of the Fauna of the Seas. V. 10 (18). P. 179–197.

Nguen Van Chung, Kussakin O.G., Gulbin V.V. 1988. Intertidal survey in Phu Khanh Province // Biology of the coastal waters of Vietnam: Hydrobiologicsal study of intertidal and sublittoral zones of Southern Vietnam. A.V. Zhirmunsky, Le Ghong Fan (Eds). Vladivostok: Far East Branch, Academy of Sciences of the USSR. P. 81–86.

SOME FEATURES OF BIOLOGY OF THE SEA ANEMONES
***NEMANTHUS* CARLGREN, 1940 (ACTINIARIA: ACONTIARIA: NEMANTHIDAE)**

***Elena E. Kostina*[1]*, Irina N. Gladkikh*[2]*, Elena V. Leychenko*[2]**

[1]*A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok 690041, Russia; e-mail: cnidopus@mail primorye.ru*

[2]*Pacific Institute of Bioorganic Chemistry, Far East Branch, Russian Academy of Sciences, Vladivostok 690022, Russia; e-mail: irinagladkikh@gmail.com*

The sea anemone species of the genus *Nemanthus* are widely distributed in the subtropical and tropical regions of Pacific and Indian Oceans. At present there are no less than 3 species of monotypic family Nemanthidae: *Nemanthus nitidus* (Wassilieff, 1908), *N. californicus* Carlgren, 1940 and *N. annamensis* Carlgren, 1943. These acontiarian sea anemones are furnished with acontia-like organs attached at the termination of the filaments and not forming any distinct batteries of nematocysts (Carlgren, 1949). Species *Nemanthus* are distinguished mainly by the coloration of their column, development of muscles of the oral disc, mesenteries, sphincter and the abundance of nematocysts in the acontia-like organs.

Fig. 1. The sea anemones *Nemanthus* on the Gorgonacea from coast of Vietnam (South China Sea). A – *Nemanthus annamensis* with «tiger» coloration from Gulf of Tonkin, Bach Long Vi Island (20°06,071′ N, 107°43,596′ E, 22 m depth); B – *Nemanthus* sp., from coast of Cham Island (15°58,0′ N, 108°29,0′ E, 12 m depth).

Solitary or grouped sea anemones normally live attached to the branches or stems of gorgonians, antipatharians and other invertebrates (Table 1). The individuals so closely packed that the edges of their pedal discs touch each other intimately, forming an elevated border. Pedal disc well developed, much wider than column, up to 3 cm (Fig. 1). Column smooth, normally yellowish to orange, but may be red, olive and even black, as a rule more or less distinctly variegated with dark patches (a «tiger» like pattern). Many individuals keep the typical «tiger» anemone' appearance after preservation. Tentacles with a pale coloration, often white, arranged in three cycles, internal longer than external. *N. annamensis* is known from South China Sea (Vietnam, Cambodia, Malaysia, Indonesia), Mariana Islands. Lavaleye and den Hartog

Table 1. Some habitat of the sea anemones *Nemanthus*.

Species	Locality and depth	Actinian partners	References
Nemanthus annamensis	Kenya; 53 m	Decapoda *Lauridromia intermedia*	Lavaleye, den Hartog, 1995
Nemanthus nitidus	Geojedo Isl., Korea; 30–60 m	Gorgonacea *Acalycigorgia inermis*, *Euplexaura* sp.	Song, Lee, 1998
	Jeju Isl., Korea Strait; 20–40 m	Antipatharia *Antipathes densa*	Moon, Song, 2005
	Izu Peninsula, Honshu Isl., Japan; 20 m	Decapoda *Izucaris masudai*	Marin, 2006
Nemanthus californicus	Archipélago Islas Murciélago, Guanacaste, Costa Rica; 30 m	Antipatharia *Myriopathes panamensis*	Excoffon et al., 2009

(1995) also mentioned it for the coast of Kenya, the Seychelles and the Maldives Islands up to 50 m depth. This sea anemone attaches to colonies of Gorgonacea and Antipatharia. It was described association of crab *Lauridromia intermedia* and *N. annamensis*. Crab uses actinia as cover to provide good camouflage against predators (Lavaleye, den Hartog, 1995). *N. nitidus* also settles on the carapace of crab *Izucaris masudai*, branches of gorgonians and black corals. This species is widely distributed in Japanese and Korean waters. It lives almost up to 500 m depth (Yanagi, 2006).

N. californicus is known from Sea of Cortez, California and Pacific coast of Costa Rica up to 80 m depth. In the area of Archipélago Islas Murciélago (Costa Rica) it was observed *N. californicus* settled on the antipatharian *Myriopathes panamensis* with the pedal disc surrounding the branches in part or totally and showed traces of asexual reproduction by budding. In some colonies live black coral tissue was observed between the anemones, while other sections had anemones and the coral tissue was dead underneath. This type of relationship could be parasitism. (Excoffon et al., 2009).

Acknowledgements

The work was supported by FEB RAS Foundation Grant 09-III-A-06-195.

References

Carlgren O. 1949. A survey of the Ptychodactiaria, Corallimorpharia and Actiniaria // Kungliga Svenska Vetenskapsakademiens Handlingar. Ser. 4, Bd. 1, H. 1. S. 1–121.

Excoffon A.C., Acuña F.H., Cortés J. 2009. The sea anemone *Nemanthus californicus* (Cnidaria: Actiniaria: Nemanthidae) from Costa Rica: re-description and first record outside the type locality // Marine Biodiversity Records. V. 2. P. 1–5.

Lavaleye M.S.S., Hartog J.C., den. 1995. A case of associated occurrence of the crab *Lauridromia intermedia* (Laurie, 1906) (Crustacea: Decapoda: Dromiidae) and the actinian *Nemanthus annamensis* Carlgren, 1943 (Anthozoa: Actiniaria: Nemanthidae) // Zoologische Medelingen. V. 69, N 11. P. 121–130.

Marin I. 2006. Description of *Crinotonia anastasiae*, new genus, new species, a new crinoid associated pontoniine shrimp (Crustacea: Caridea) from Nha Trang Bay, Vietnam, with inclusion of *Periclimenes attenuatus* Bruce, 1971, in the new genus // The Ruffles Bulletin of Zoology. V. 54, N 2. P. 321–340.

Moon H.-W., Song J.-I. 2005. Three new records of Antipatharia (Anthozoa: Ceriantipatharia) from Korea // Korean Journal of Systematic Zoology. V. 21, N 2. P. 259–272.

Song J.-I., Lee I. S. 1998. Fauna of the anthozoans from adjacent waters of Geojedo Island in Korea // Korean Journal of Systematic Zoology. V. 14, N 3. P. 229–242.

Yanagi K. 2006. Sea anemones around the Sagami Sea with list of Japanese species // Memoirs of the National Science Museum, Tokyo. V. 40. P. 113–174.

ON THE COOPERATIVE PROJECT FOR DEVELOPMENT OF FISHERIES *REFUGIA* IN HAM NINH COASTAL AREA OF PHU QUOC ISLANDS, VIETNAM

Vo Si Tuan

Institute of Oceanography, Vitenamese Academy of Science and Technology, Nha Trang, Vietmam

e-mail: vosituan@gmail.com

Fisheries *refugia* in the context of the UNEP/GEF South China Sea Project are defined as *"Spatially and geographically defined, marine or coastal areas in which specific management measures are applied to sustain important species [fisheries resources] during critical stages of their life cycle, for their sustainable use.* The Eighth Meeting of the Regional Working Group on Fisheries of the project in 2006 agreed to establish pilot fisheries *refugia* sites in the region, recorgnising Phu Quoc islands as one among selected site. In February 2007, staff of the Project Coordinating Unit visited the Phu Quoc Island Coral Reef and Seagrass Demonstration Site to review progress in relation to the implementation of project activities at that site. It was identified that a key threat to the longer-term sustainability of project interventions at Phu Quoc Island was a low level of integration of fisheries issues into habitat management and vice versa. In this connection, the fisheries *refugia* concept was introduced to the management board of the Phu Quoc Island Demonstration Site as a means of improving the management of fisheries and critical habitat linkages in the coral reef and seagrass areas of the site. It was agreed that where possible the *refugia* concept should be applied to ensure better management of fisheries issues at the demonstration site.

Kien Giang Province's Department of Science and Technology expressed support for the establishment and management of fisheries *refugia* sites at Phu Quoc Island, including provision of financial support for operational level management activities. The concept was also well received by representatives of the two communes adjacent to the coral reef and seagrass sub-sites, with members of the fishing community indicating strong support for improved fisheries management in areas of these sites critical to the life-cycles of economically important fish species. It was further identified that the institutional setting established as part of the Phu Quoc Island Demonstration Site, as well as the strong support from the site's management board and the local community for the establishment and management of fisheries *refugia* sites at the island, provides a good basis for the establishment of a pilot fisheries *refugia* site in Viet Nam. It was subsequently agreed a joint project involving the fisheries component of the UNEP/GEF South China Sea Project in Viet Nam, the Phu Quoc Island Demonstration Site, Kien Giang Province's Department of Science and Technology, and Department of Fisheries should be developed to establish and manage a pilot fisheries *refugia* site in the Ham Ninh coastal area (seagrass site) of Phu Quoc Island.

The goal of this joint project is to "*Improve the integration of fisheries and habitat management at the Phu Quoc Islans, through the establishment and management of critical fisheries* refugia *(spawning and nursery areas), to improve the longer-term security of sustainable fisheries yields from Phu Quoc Island waters and adjacent areas".* The objectives of this joint project are to:

- prepare an inventory of fisheries *refugia* sites (spawning and nursery areas) for significant fish species in the coastal waters of Phu Quoc Island, including seasonality of spawning and age/size of recruitment from nursery areas for key species;

- develop a fisheries profile (resources, catching sector, post-harvest sector) in relation to the Ham Ninh coastal area of the Phu Quoc Islands, including recommendations for fisheries management measures to be applied in key fisheries *refugia* areas;

- develop a management framework for the participation of community members in the establishment and management of fisheries *refugia* in the Ham Ninh coastal area of the Phu Quoc Islands, and agree at the community-level key fisheries management measures to be applied in relation to fisheries *refugia* in the Ham Ninh coastal area;

- publish and disseminate at the community level, guidelines for the effective management of fisheries *refugia* in the Ham Ninh coastal area of the Phu Quoc Islands;

-establish procedures for the enforcement of fisheries management measures applied to key fisheries *refugia* in the Ham Ninh coastal area of the Phu Quoc Islands, and

- implement long-term operational (day-to-day) management of fisheries *refugia* in the Ham Ninh coastal area with an aim of improving longer-term sustainable yields of target resources, including swimming crab, *Strombus* snail, seahorse, octopus, cuttlefish, and shrimp.

It is noted that a number of "fisheries protection areas" were established in relation with implementation of Ordinance for Fisheries Protection and Development delivered by Viet Nam government. These areas were mainly designed based on information of spawning and/or nursery seasons of some fish and/or invertebrate species group but poor consideration of linkage between habitats and life cycle of resources. Most of these are separated from existing MPA sites in the network. Furthermore, management effectiveness in the fisheries protection areas has been questioned.

Given the fact that MPA concept is legalized in the Law of Fisheries of Viet Nam and the network of MPAs is operational, integration of fisheries *refugia* in management is favorable in lots of existing MPAs. However, the effectiveness of fisheries *refugia* will likely depend on an appropriate consideration of known critical spawning and nursery areas in the selection of sites. It is recommended that MPA managers and scientists work closely with local experienced fishermen to enable use of local knowledge in identifying sites critical to spawning and nursery of target species at the site levels. MPA authorities will also develop and legalize mechanism for fisheries *refugia* management with active participation of local communities.

MARINE MOLLUSKS' SHELLS AS THE OBJECTS OF PREHISTORIC ART (EAST ASIA REGION AS A CASE OF STUDY)

Irina S. Zhushchikhovskaya

Institute of History, Archaeology and Ethnology of Peoples of Far East,

Far East Branch of Russian Academy of Sciences, Vladivostok, Russia

e-mail: irinazh@mail.primorye.ru

The shells of salt-water and fresh-water mollusks were known and used in human culture very widely beginning from oldest times. In particularly, these natural objects have been adopted as ornamental, plastic and painting images in decorative and fine arts from the Prehistory epoch to the modern times. The features attractive for the artists of various times and regions are great diversity of shells' morphology, the geometry and symmetry of shells' structures, "graphical" textural patterns (Yablan, 2007).

The East Asia area presents most early cases of artistic creations inspired by marine mollusks' shells. The paper is considering archaeological records from two regions – Japanese Archipelago and East China - in chronological frames from about 11.000 to 3.000 BP. The materials of archaeological photo-illustrated catalogues and special volumes are used as the database (Yamanouchi, 1964; Kashina, 1977; The Collection of…, 1996; Kaner, 2009).

Japanese Archipelago

During the Neolithic epoch Jomon culture existed in this region from about 13.600 to 900 BC. One of distinctive traits of this culture was the orientation to the exploiting of marine resources in their great diversity. Marine mollusks were used for the nutrition, the production of tools and ornaments (Kobayashi, 2004). Besides this Jomon archaeological assemblages demonstrate interesting cases of the usage of mollusks' shells as the art images.

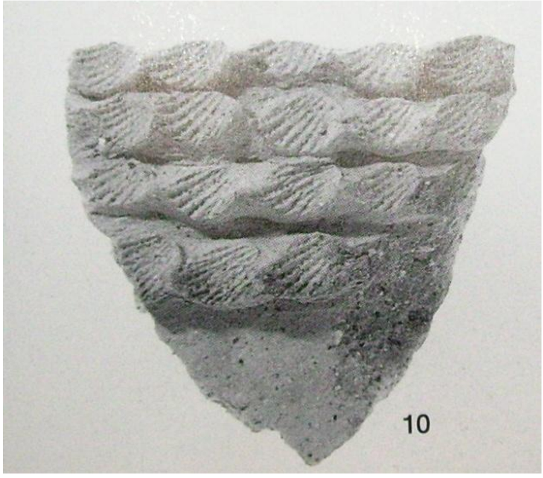


Fig. 1. The fragment of ceramic vessel decorated with the imprints of small-sized shells. Initial Jomon, Sankakuyama site, Kagoshima prefecture, Kyushu island, Japan (The Collection…, 1996:158).

Most early and simple cases are attributed to the Initial stage of Jomon culture, about 9200–5300 BC. These are the imprints of outer shell folds' surfaces on the walls of archaic ceramic vessels. The imprints were made on plastic clay before the vessels were fired. It was primitive manner of ceramic vessels decoration (Fig. 1). On some ceramic samples shell's texture patterns are imprinted clearly to indicate probably the mollusks' species. In all cases the imprints are of extremely small-sized (less than 1cm) shells of Bivalvia class species. The imprints have radial pattern formed by deep grooves. This pattern looks similar to surface texture pattern of *Anadara* family species. All noted cases are fixed in Initial Jomon archaeological sites located on southern, east-southern and west-northern seacoasts of Kyushu Island (The Collection…, 1996). More elaborated three-dimensioned mollusks' shells images are presented in ceramic art of late Middle – Late Jomon stages, about 2500–1200 BC. In some seacoast archaeological sites of Honshu island the marine mollusks' shells models made of clay were discovered. Below some most significant cases of this phenomenon are noted.

Fig. 2. Ceramic shell. Late Jomon, Nakagami site, Iwate prefecture, Honshu Island, Japan (Kaner, 2009: 150).

Ceramic shell from seacoast site Nakagami in Iwate prefecture, north-eastern Honshu, is representing the specie of *Gastropoda* mollusk (Fig. 2). The length of ceramic shell is 24 cm, the color of fired clay is yellow. The outer surface's design imitates spiral structure and thorn-like protrusions that are characteristic features of some *Gastropoda* species. Inner surface of ceramic shell is smoothed carefully (Kaner, 2009).

Ceramic shell from the seacoast site Sampoku in Niigata prefecture, west Honshu, is representing the Gastropoda mollusk (Fig. 3). Its length is 16.6 cm, the surface is covered by red ocher paint (Yamanouchi, 1964: pl. XVI). Another fine ceramic sample was discovered in the shellmound site Edosaki in Ibaraki prefecture, east Honshu (Fig. 4). It is black-polished rounded-shaped bowl of 6 cm high imitating the form of the shell of tropical Gastropoda mollusk *Haliotis* sp. (Yamanouchi, 1964: fig. 191). The researchers suggest that these elegant ceramic artifacts imitating the shells of marine mollusks were served as the kind of table container for special cases (Kaner, 2009).

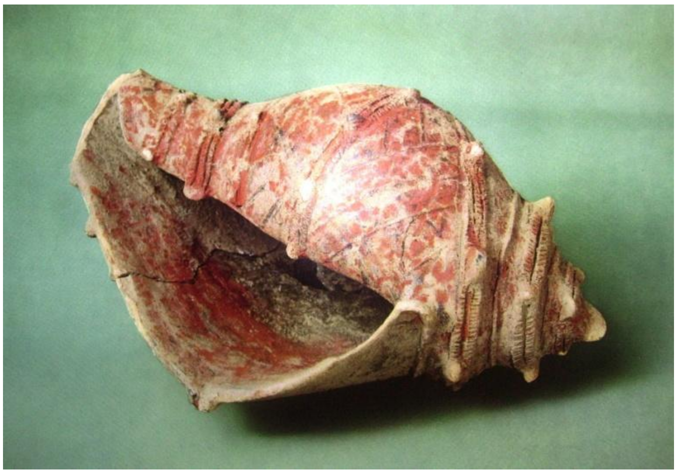


Fig. 3. Ceramic shell. Late Jomon. Sampoku site, Niigata prefecture, Honshu Island, Japan (Yamanouchi, 1964: pl. XVI).

East China

Archaeological records of East China also give us the evidences of the usage of marine mollusks images in decorative art. Ceramic vessels of famous Neolithic Yangshao culture (the late 5th – the late 3rd mil. BC) located in the Huanghe river basin are decorated often with painted pattern which may be interpreted as the image of shell of *Gastropoda* mollusk *Cypraea* sp. (*Kauri*). It is schematic drawing of oval-shaped "toothed" mouth part of the shell. Usually this ornamental motif is combined with various geometrical motifs to form completed decorative composition on ceramic vessel (Kashina, 1977). Tropical *Kauri* shells were imported to Yangshao culture's area from southern latitudes of Indian Ocean and used as exotic and prestige goods in prehistoric community. Obviously, specific social role and fascinating external image of *Kauri* shells were the reasons that they were positioned as the object of artistic creativity.

Fig. 4. Ceramic shell-like bowl. Middle-Late Jomon, Edosaki site, Ibaraki prefecture, Honshu Island, Japan (Yamanouchi, 1964: fig. 191).

As a whole, we fix two forms of the presentation of marine mollusks' shells images in prehistoric art of Japanese archipelago and East China – ornamental motifs of pottery decoration and sculptural models. In all cases the shells of warm-like marine mollusks of Gastropoda and Bivalvia classes were used. Jomon cultural tradition of Japanese archipelago was oriented to naturalistic imitation of mollusks' shells (the imprints and sized models). In Yangshao cultural tradition of East China schematic imaging of the shells was preferred in decorative art (painted pattern).

References

Kaner S. (Ed.). 2009. The Power of Dogu: Ceramic Figures from Ancient Japan. London: British Museum Press.

Kashina T. 1977. Yangshao Culture's Pottery. Novosibirsk: Nauka. [In Russian].

Kobayashi T. 2004. Jomon Reflections. Oxford: Oxbow Books.

The Collection of Data on the Incipient Period of the Jomon Culture. 1996. Yokohama: Yokohama City Museum Press. [In Japanese].

Yablan S. 2007. Symmetry, Ornamental Forms and Modality. Moscow: Institute of Computer Technologies. [In Russian].

Yamanouchi S. (Ed.). 1964. The Primitive Arts of Japan. V. 1. Jomon Pottery. Tokyo: Kodansha Press. [In Japanese].

SPATIAL AND TEMPORAL CHANGES IN THE POPULATION STRUCTURE OF BIVALVE *PINNA FUMATA* AT THE SOUTH VIETNAM

Alla V. Silina

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok 690041, Russia

e-mail: allasilina@mail.ru

The family Pinnidae consists of the single genus *Pinna*, which comprises two subgenera *Atrina* and *Pinna* (Yonge, 1953). The shells of the Pinnidae bivalves are very large and always triangular in outline, tapering to a point anterior. All species have the same mode of life, living vertically embedded in the bottom sediments, usually mud or muddy sand (Yonge, 1953).

At the coasts of South Vietnam two Pinnidae species were found. They were *Atrina vexillum* (Born) and *Pinna fumata* Reeve. It is poorly known in world literature about these species and there is a knowledge gap about their distribution near Vietnam. In the last decades *P. fumata* populations have declined drastically due to increasing anthropogenic pressure. Despite the need for conservation, knowledge of the ecology and monitoring of the main populations of *P. fumata* are limited. The present study is a contribution to the knowledge of the pen shell *P. fumata* distribution, ecology and structures of the populations inhabiting the southern Vietnam coasts (Fig. 1).

The study area was subdivided in 2 sub-areas, near the coasts of (1) Nha Trang city and (2) islands of eastern Siam Bay. Near the coasts of Nha Trang *P. fumata* was collected in 1980, 1984 and 1986 at the depth of 8–10 m. At Siam Bay, in 1986, specimens of *P. fumata* were sampled near the coasts of An Thoi Islands, mainly near Hon Vong Island (depth was 6–7 m) and Hon May Rut Island (3–12 m). A comparison between both sub-areas of individuals was carried out, finding important differences between them.

Fig. 1. Specimen of young (1.5-years old) *Pinna fumata*.

Near the coasts of Nha Trang, *P. fumata* was not numerous in 1980–1986. Usually, the bivalves of the genus *Pinna* live vertically embedded in the ground. However, *P. fumata* was found not only in the ground, but also among the biofouling of the sunken vessel. Now *P. fumata* was not found near the coasts of Nha Trang.

At Nha Trang sub-area, the mean value of shell height of *P. fumata* was 315±22 mm in 1980–1984, but in 1986 it was only 207±20 mm. However, at Siam Bay sub-area, mean and maximum parameters of this bivalve were higher.

At Siam Bay, the wet total weight (W_{total}) varied from 262 to 1590 g (559±118 g on the average), the soft tissue wet weight ($W_{soft\ tissue}$) was 32–132 g (74±10 g) and wet weight of the posterior adductor muscle (W_{muscle}) was 7–25 g (15±2 g) in 1986. The shell height (H) varied from 249 to 377 mm, the length of the shell (L) was 121–172 mm, and shell width (D) was 33–52 mm (43±2 mm). Tissue wet weight was 8.3–20.0% of total wet weight, that is lower than for *Pinna nobilis* (Garcia-March et al., 2007) and the wet weight of the posterior adductor muscle was 1.6–4.6% of total wet weight and 16.8–26.8% of tissue wet weight, that is higher than for *Pinna nobilis* (Garcia-March et al., 2007).

The growth of wet total weight (g) was not isometric, but growth both of the soft tissue wet and shell weights (W_{shell}) were practically isometric with shell height (mm) increase:

$W_{total} = 0.00275H^{3.563}$, R = 0.907;

$W_{soft\ tissues} = 0.00327H^{2.913}$, R= 0.887;

$W_{shell} = 0.00989H^{3.086}$, R = 0.853.

Classical allometric model had no support for other Pinnidae species, too (Rabaoui et al., 2007).

The outer shell layer of the individuals of family Pinnidae is calcitic prismatic that is contribute to appearance of elementary growth layers on the outer surface of the shell. Earlier, it was revealed that the width of these elementary growth layers varied accordingly to seasons (Dorofeeva et al., 1987). It was found that growth rates of *P. fumata* has a seasonal pattern, with an extended period of very slow growth between late autumn and early spring, i.e., during the cold season (water temperature <24°C), another short period of slow growth during August (when water temperatures reached their maximum values exceeding 28°C), and a peak in growth rates during late spring-early summer, probably related to an optimum of temperature (Dorofeeva et al., 1987). The growth rates of *P. fumata* were investigated by the measurement of the portions of the shell height from the shell apex to each winter and summer diminution of the width of the elementary growth layers (Fig. 2). It was revealed that growth rates varied with shell size, with a peak at the first year of *P. fumata* life, followed by a sharp decline.

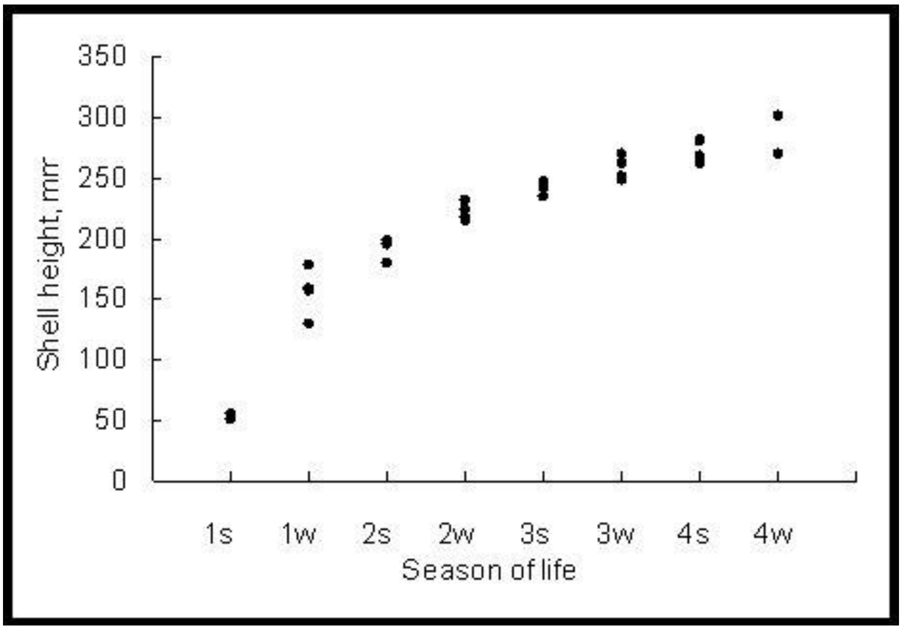


Fig. 2. Growth rates of *Pinna fumata* shell near the coasts of the Southern Vietnam. 1s, 2s, 3s and 4s mean the first, second etc. summers in the life of the mollusk. 1w, 2w, 3w and 4w mean the first, second etc. winters in the life of the mollusk.

The results contribute to increase the knowledge of population ecology of *P. fumata* and to provide useful information for implementing conservation policies.

References

Dorofeeva L.A., Pozdnyakova L.A., Silina A.V. 1987. Dependence of growth rate and calcium-magnium ration in *Pinna fumata* shells on environmental temperature // Bulletin de la Société des Naturalistes de Moscou. Section Géologique. V. 62, N 6. P. 109–115.

Garcia-March J.R., Garcia-Carrascosa A.M., Cantero A.L.P, Wang Y.G. 2007. Population structure, mortality and growth of *Pinna nobilis* Linnaeus, 1758 (Mollusca, Bivalvia) at different depths in Moraira bay (Alicante, Western Mediterranean) // Marine Biology. V. 150, N 5. P. 861–871.

Rabaoui L., Zouari S.T., Katsanevakis S., Ben Hassine O.K. 2007. Comparison of absolute and relative growth patterns among five *Pinna nobilis* populations along the Tunisian coastline: an information theory approach // Marine Biology. V. 152, N 3. P. 537–548.

Yonge C.M. 1953. Form and habit in *Pinna carnea* Gmellin // Phylosophical Transactions of the Royal Society of London. Ser. B. Biological Sciences. V. 237, N 648. P. 335–374.

NITROGEN SOURCES TO MACROALGAL GROWTH AT POLLUTED COASTAL AREAS OF SOUTHERN VIETNAM

***Eduard A. Titlyanov*[1], *Sergey I. Kiyashko*[1], *Tamara V. Titlyanova*[1], *Pham Van Huyen*[2], *Irina M. Yakovleva*[1]**

[1]*A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences, Palchevskogo 17, Vladivostok 690041, Russia; e-mail: etitlyanov@mail.ru*

[2]*Vietnamese Academy of Science and Technology, Nha Trang Institute of Technology Research and Application, 02 Hung Vuong, Nha Trang, Vietnam*

During the last decades, the identification of stable nitrogen isotope (^{15}N and ^{14}N) composition in tissue of macroalgae is widely used for elucidation the main sources of dissolved inorganic nitrogen (DIN) in nutrition of marine plants. This method allows determining the main source of DIN used by algae for growth.

The main sources of DIN for marine plants are (1) ammonium, nitrate and nitrite of tropical oceanic oligotrophic waters; (2) eutrophic waters of closed bays, lagoons and estuaries; (3) water of rivers polluted with agricultural fields runoff (inorganic nutrients); (4) polluted waters from aquacultural animal farms; (5) effluents of urban sewage cleaning systems; (6) effluents of organic and inorganic nitrous matters of polluted agricultural farms and villages; (7) oceanic upwelling, where deep, cooler nutrient-rich waters are brought to the surface. Analysis of nitrogen stable isotopes in algal tissues (characterization of their specific $\delta^{15}N$ signatures) allows tracing both constant and temporal sources of water pollution by nitrogen compounds (Lin, Fong, 2008).

The constitutive essence of the method is a comparative analysis of $\delta^{15}N$ means both in the DIN source and in the tissue of plants (sometimes animals). Close values of the $\delta^{15}N$ signature for DIN source and the tissues indicate the importance of the DIN source in the nutrition of marine plants at the vegetative growth stage.

We analyzed stable nitrogen isotope composition and molar C: N proportion in the tissue of green, brown and red seaweeds from coastal waters of southern Vietnam at the areas of shrimp farming, urban runoff and at clear marine natural reserves of coral reefs.

The aim of the present study was to determine the main sources of pollution in coastal waters of southern Vietnam. The survey of a big amount of macroalgal species allowed a selection of species, genera and groups of macroalgae possessing characteristics of plants-bioindicators of isotopic composition of absorbed DIN.

For the first time, the levels of $\delta^{15}N$ and molar C: N ratios were determined for 73 species of green, brown and red macroalgae at nine sites of differently polluted coastal areas of southern Vietnam for identification of source of dissolved inorganic nitrogen (DIN). The study sites were conditionally divided into three groups according to the pollution influx: “clear” (Con Dao Islands, Anthoi Islands and Ba Lang An Cape), “partially polluted” (the west shore of Phu Quoc Island, O Lan Lagoon and Islands of Nha Trang Bay) and “polluted” (Nha Trang Bay, shore of Nha Trang City). The algae collected at “clear”, “partially polluted” and “polluted” sites had $\delta^{15}N$ signatures of 3.3±0.9‰, 6.7±1.1‰ and 10.6±0.5‰, respectively. Analysis of the present results and literature data allows suggesting direct atmospheric deposition as the dominant DIN source in “clear” water areas. At “partially polluted” and “polluted” sites, the main sources of DIN are waters polluted by feed remnants and excrement from maricultural farms (shrimps, lobsters, and fish) as well as urban and sewage of stock-breeding farms from densely populated areas. The dominance of nitrogen derived from maricultural farms was observed in the central part of Nha Trang Bay and in O Lan Lagoon, while human wastewaters were the main DIN source in front of Nha Trang City. Analysis of the molar C: N ratios in algal tissue showed that macroalgae collected at “clear” sites suffer limitation in nitrogen (on average, the C: N ratios = 21.6±13.3). In most of the polluted areas, macroalgae were also N limited (on average, the C:N ratios = 15.3±8.2). Among macroalgae investigated, plants-bioindicators of both source and concentration of DIN were identified. These plants-indicators are algae from the genera *Ulva, Padina, Turbinaria, Gracilaria, Hydropuntia.*

References

Lin D.T., Fong P. 2008. Macroalgal bioindicators (growth, tissue N, $\delta^{15}N$) detect nutrient enrichment from shrimp farm effluent entering Opunohu Bay, Moorea, French Polynesia // Marine Pollution Bulletin. V. 56, N 2. P. 245–249.

A VIEW OF BIODIVERSITY IN CORAL REEFS THROUGH THE EYES OF CORAL REEF FISHES − SPECIES COMPOSITION OF GASTROPODS FOUND IN THE GUTS OF STRIPED LARGE-EYE BREAM, *GNATHODENTEX AUREOLINEATUS* (PISCES, LETHRINIDAE) IN AMITORI BAY, IRIOMOTE ISLAND, SUBTROPICAL JAPAN

Takeharu Kosuge[1, 2], Hiroyoshi Kohno[1]

[1]*Okinawa Regional Research Center, Tokai University,*

870-277 Uehara, Taketomi, Yaeyama, Okinawa 907-0451, Japan

[2]*Current affiliation: Aquaculture Research for Asian Tropics, TETSUGEN VM, Phuoc The, Tuy Phong, Binh Thuan, Vietnam*

e-mail: tkosuge@tetsugen.co.jp

Coral reefs harbor a variety of fishes. This suggests that a diverse prey items inhabiting coral reefs support populations of fish species. When the feeding habit of fishes was described, higher categories of ‘taxa’ were frequently used, such as benthos, fishes, or mollusks, etc, though the preys consist of substantial number of species. If we could know species composition of the prey for the fish in detail, we may able to obtain more accurate information on predator-prey relationships in coral reefs, which provides further insight on the roles of coral reefs which should provide minute habitats for a variety of the prey-species. However, it is usually difficult to identify prey items to species level by observing gut-contents of fishes. The semi-digested contents would become fragments and most important keys for identification have been already lost.

Fig. 1. A school of *Gnatodentex aureolineatus* underwater in Amitori Bay.

Examining gut-contents of striped large-eye bream, *Gnathodentex aureolineatus*, (Fig. 1) it was revealed that the most important prey for the fish is the gastropods. Moreover, most of the gastropods could be identified to the species level based on characters of shells which remain in partially broken conditions due to week dentation of the fish. As the first step, the species composition of gastropods obtained from the gut-contents is described in this paper.

During the period from May to July 2008, 63 specimens of *G. aurolineatus* were captured using hook-and-line, at Amitori Bay, Iriomote Island, south-western part of the Ryukyu Islands, subtropical Japan. The fishes had empty stomachs while 89% of them contained some prey items in their intestines. Those prey items were benthic invertebrates consisted of molluscs, crustaceans, polychaets, and echinoderms (Figs. 2, 3; Table 1). Among them, molluscs, mostly gastropods and chitons, were the most important preys in terms of both frequency of presence and abundance. The

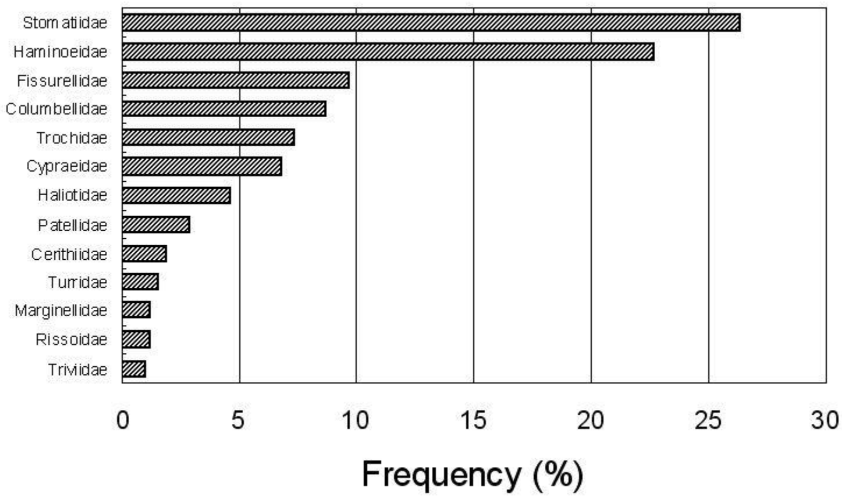


Fig. 2. Gastropod families found as the contents of intestines of the striped large-eye bream, *Gnathodentex aureolineatus.*

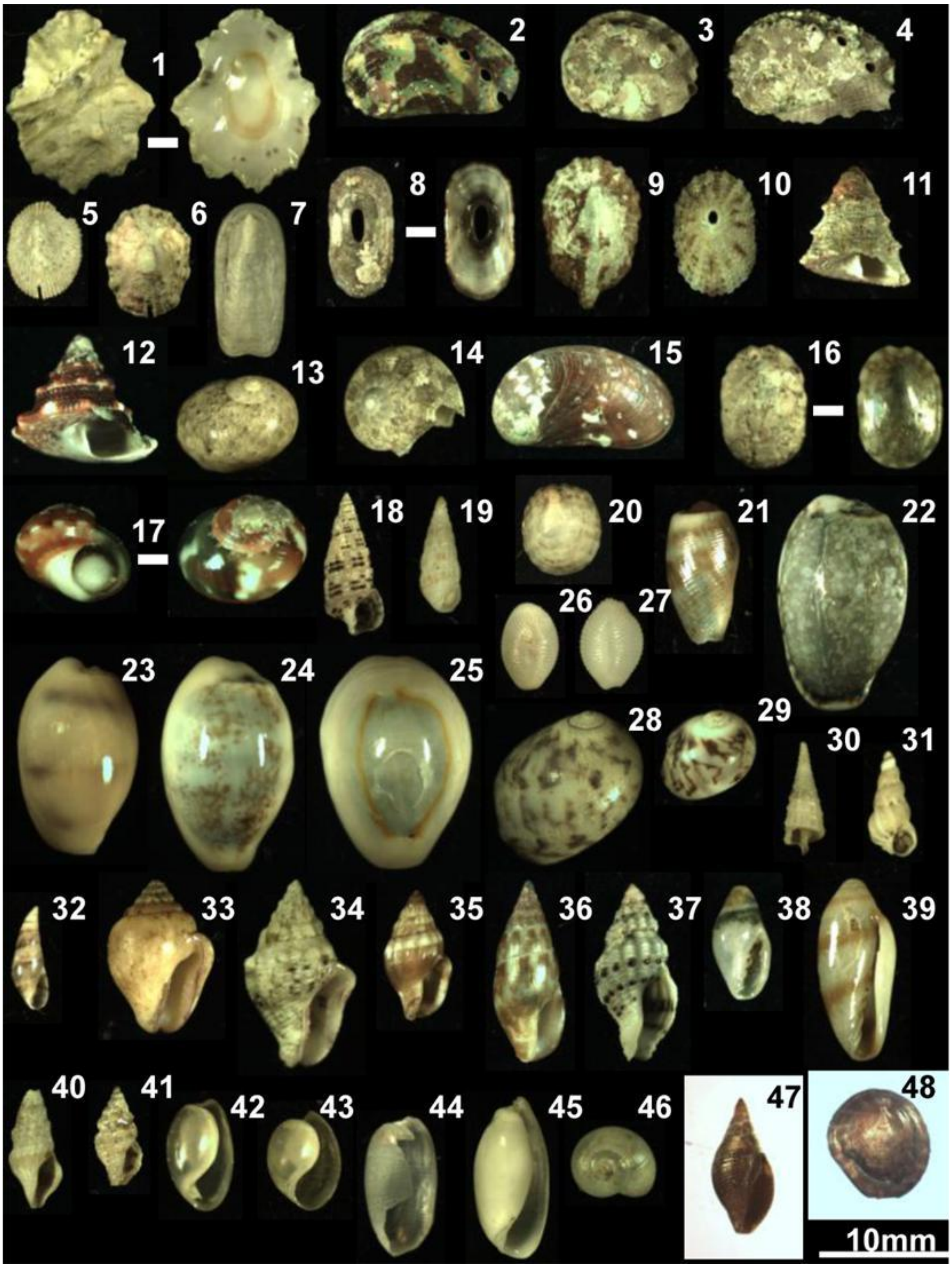


Fig. 3. Gastropods found as the contents of the intestines of the striped large-eye bream, *Gnathodentex aureolineatus*. 1 – *Scutellastra flexuosa*; 2 – *Haliotis asinine*; 3 – *H. ovina*; 4 – *H. jacnensis*; 5 – *Emarginula punctata*; 6 – *E. biangulata*; 7 – *Scutus unguis*; 8 – *Macroshima* sp.; 9 – *Montfortia kirana*; 10 – *Diodora mus*; 11 – *Trochus cumingii*; 12 – *Tectus niloticus*; 13 – *Chrysostoma paradoxum*; 14 – *Talopena vernicosa*; 15 – *Stomatella impertusa*; 16 – *Broderipia iridensis*; 17 – *Turbo petholatus*; 18 – *Cerithium stigmosum*; 19 – *Rissonia* sp.; 20 – *Hipponix* sp.; 21 – *Cypraea fimbriata fimbriata* (immatured specimen); 22 – *C. pallidula pallidula*; 23 – *C. moneta*; 24 – *C. caputserpentis caputserpentis*; 25 – *C. labrolineata*; 26 – *Trivirostra* sp 1.; 27 – *T.* sp 2.; 28 – *Mammilla simiae*; 29 – *Natica* sp.; 30 – *Monophorus*? sp.; 31 – *Epitonium* sp.; 32 – *Hemiliostraca vincta*; 33 – *Euplica borealis*; 34 – *E. varians*; 35 – *Anachis amirantium*; 36 – *Metanachis calliope*; 37 – *Maculotriton serriale*; 38 – *Dentimargo neglecta*; 39, 40 – *Clavus pusilla*; 41 – *Lienardia* sp.; 42 – *Diniatys* sp.; 43 – *Haloa cymbalum*; 44 – *Liola* sp.; 45 – *Aliculastrum cylindricum*; 46 – *Vitrinella*? sp.; 47 – *Nebularia* sp.; 48 – *Willamia radiata.*

gastropods were identified on their shells to the family level, and Stomatiidae, Haminoeidae, Fissurellidae, Collumbellidae and Trochidae were major components. 62% of the gastropods were identified to the species level and *Stomatella impertusa* was the most abundant. Including *S. impertusa*, 45% of the gastropod preys had limpet-formed shells. It is suggested that *G. aureolineatus* prefers to such sedentary molluscs inhabiting the shallow coral reels.

Table 1. List of prey items of 56 striped large-eye bream *Gnathodentex aureolineatus.*

PHYLUM (SUBPHYLUM)	Class	Order (Infraorder)	Superfamily	Number of fishes fed on each item	Frequency of occurrence (%)	Number of preys found in the fish	Composition of the preys (%)
ANNELIDA							
	Polychaeta			13	23,2	15	1,6
MOLLUSCA							
	Polyplacophora			44	78,6	101	10,8
	Gastropoda			53	94,6	408	43,6
	Bivalvia			8	14,3	12	1,3
ARTHROPODA							
(CRUSTACEA)							
	Ostracoda			1	1,8	1	0,1
	Malacostrata						
		Amphipoda		1	1,8	1	0,1
		Decapoda					
		(Caridea)					
			Alpheoidea	5	8,9	5	8,9
		(Anomura)					
			Coenobitoidea	41	73,2	164	17,5
			Galatheoidea	23	41,1	31	3,3
		(Brachyura)		51	91,1	174	18,6
ECHINODERMATA							
	Echinoidea			18	32,1	21	2,2
	Ophiuroidea			2	3,6	2	0,2
Total				-	-	935	100

References

Kosuge T., Kohno H. 2009. Preliminary report on feeding habits of striped large-eye bream, *Gnathodentex aureolineatus* (Pisces, Lethrinidae) in Amitori Bay of Iriomote Island, with notes on species composition of the gastropods found in the guts // Bulletin of Institute of Oceanic Research and Development, Tokai University. V. 30. P. 5–12.

SHRIMP AND CRAB POST LARVAE IN THE XUAN THUY MANGROVE FOREST (VIETNAM)

Tran Manh Ha

Institute of Marine Environment and Resources, Hai Phong City, Vietnam

e-mail: ha@imer.ac.vn

Introduction

Vietnam’s coastal areas are richly endowed with natural resources, such as mangrove forest, fertile soil, minerals, and beautiful scenery. Coastal seas also support coral reefs, sea grass beds and diverse fish stocks. The coastal zone of Vietnam covers an area of about 4200 square kilometers with a total coastal length of about 3444 kilometers. The nothern coast faces the Tonkin guft, while the south coast faces the East Sea.

Xuan Thuy is located on the east coast of Nam Dinh and Thai Binh Province, northeast part of Vietnam. The area is a core zone of Red river delta biosphere reserve and had highly potential both in natural coastal resources and tourist activities.

Since mangrove forests are counted as one of the highly biodiversity and productive ecosystem with a variety of species, life stages and forms. In association with other ecosystems, it provide food sources, shelters, spawning and nursing ground for marine faunna as well as nutrient enrichment sources for all sizes of organisms. Shrimp and crab larvae seem to be one of the active roles in the mangrove ecosystem. They can also be used for fertility indication and toxicity bio-indicator of the areas.

Therefore, the study of shrimp and crab larvae in Xuan Thuy mangrove forest was carried out to determine species assemblages, distribution, and abundace. The results will contribute to baseline information for policy makers as well as conservationists working towards to the sustainable use of marine resources.

Methods

Study area. Xuan Thuy mangrove forest is located between latitude 10°11′ and 10°17′ N and the longtitudes 106°32′ and 106°36′ E, at the Balat estuary (the main mouth of Red river), on the Northeastentern of Vietnam. It has a total area of about 700 km^2. A location map of the study area is shown in Fig. 1.

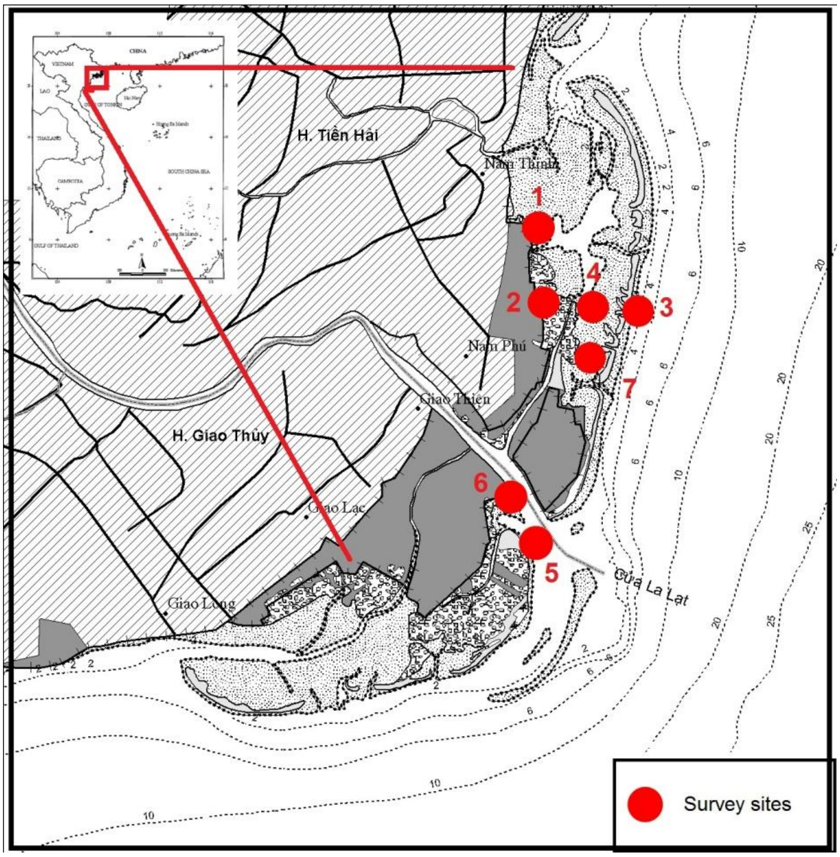


Fig. 1. Sampling stations of mangrove at Xuan Thuy.

The study site has an effected from tropical monsoon climate with two main seasons wet and dry. The wet season is from the end of April to end of October and dry season is from November to March. Mean annual temperature is 23–24°C; annual rainfall is 1750–1800 mm.

Sampling stations. Samples were carried out during field trips of project KC 09-26/06-10 in September, 2009 (Wet season) and March, 2010 (Dry season). A total of 7 stations in the tidal pattern of mangrove forest were selected (Fig. 1), there are three replicate of sample in each station.

Sampling collection. +Post larvae: collected by trawl net with mesh size 500 µm and mouth open was 1 m and the 50 m trawling length. Specimens was stored in plastic jar and fixed by formalin solution 10%.

Statistical analysis. Analysis of variance (ANOVA) was proceeded for statistical test on differences in the abundance and the whole shrimp and crab larvae groups within stations and seasonal variations. Biodiversity index H' (log base e) was conducted by PRIMER v6.0 software.

Results and discussion

Larvae assemblage diversity. Totally 17 species belong to 5 families of shrimp and crab larvae were identified to species level during the study (Table 1). The number of species found in September and March were 15 and 8 species, respectively.

Table 1. List of demersal larvae identified in Xuan Thuy Mangrove

Taxa	Local name	Taxa	Local name
Sergestidae		Penaeidae	
Acetes sp.	Tôm moi	*Metapenaeus ensis*	Tôm rảo
Alpheidae		*Metapenaeus intermedius*	Tôm rảo đuôi xanh
Alpheus sp.	Tôm gõ mõ	*Metapenaeus joyneri*	Tôm vàng
Palaemonidae		*Metapenaeus* sp.	
Leandrites indicus	Tôm gai	*Penaeu monodon*	Tôm sú
Leptocarpus potamiscus		*Penaeus indicus*	Tôm he nhật bản
Macrobrachium mirabile		*Penaeus japonicus*	Tôm he nhật bản
Macrobrachium nipponense	Tôm càng	*Penaeus penicilatus*	
Macrobrachium sp.		Portunidae	
Ocypodidae		Portunus pelagicus	Ghẹ xanh
Uca sp.	Cáy		

The mean abundance of the larvae in Mangrove in in September and March were 40 and 37 ind./100 m^2, respectively.

In the whole collection Sergestidae was the dominant group in dry season with average 55% of total number, while Alpheidae and Penaeidae were following with 25 and 16% rerspectively. In wet season, Penaeidae was the dominant group with average 88%. Palaemonidae follow with 10% and others were less than 1% (Fig. 2).

The diversity index H' (base e) is 1.63 is rather low diversity.

Family Penaeidae has highest number with 8 species – accounting for 47% of the total number of identified species), the following is family Palaemonidae (5 species – 29%), families Sergestidae and Portunidae, Ocypodidae, Alpheidae had 2 species – 6 % (Fig. 3).

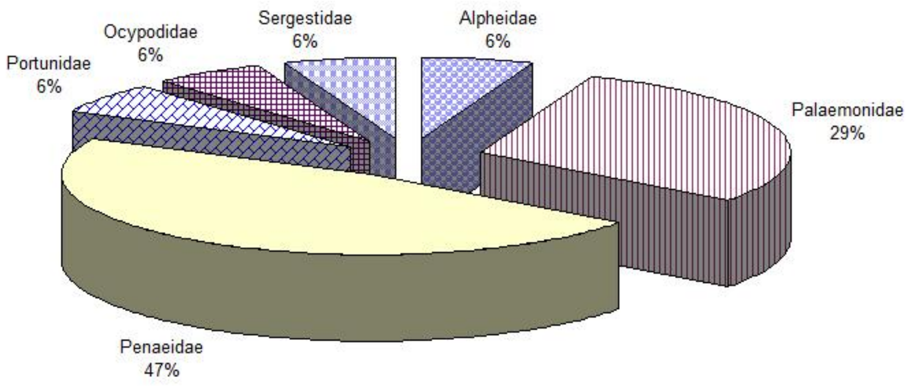


Fig. 2. Percentage of larvae abundance in mangrove forest during dry and wet seasons.

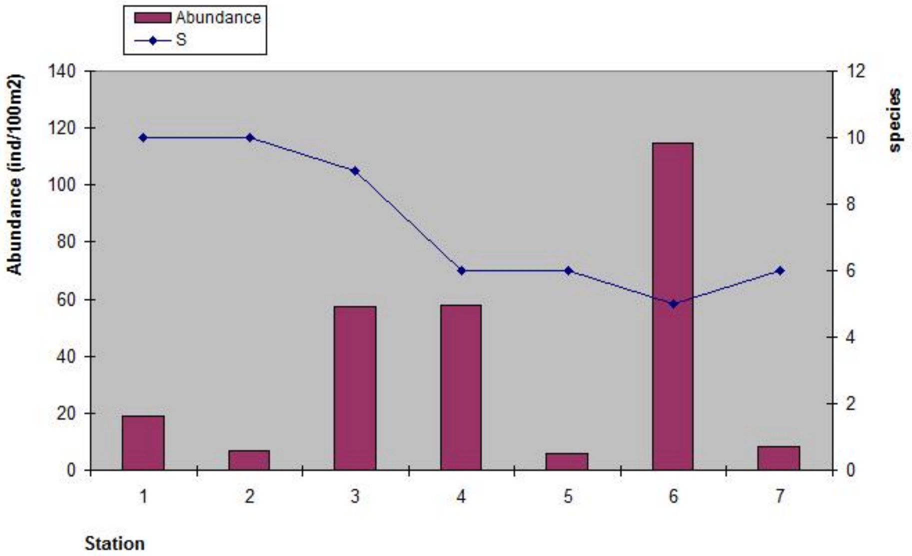


Fig. 3. Percentage of species diversity of larvae in Xuan Thuy mangrove.

Spatial distribution characteristic of larvae assemblage. The distribution of species diversity among the stations was characterized by non-equivalent in the number of species. Station 1 and 2 have 10 species, while station 3 has 9 species, station 4, 5, 7 has 6 species (Fig. 4).

The one-way ANOVA analysis on density and species diversities were indicated significantly different among station ($p<0.05$).

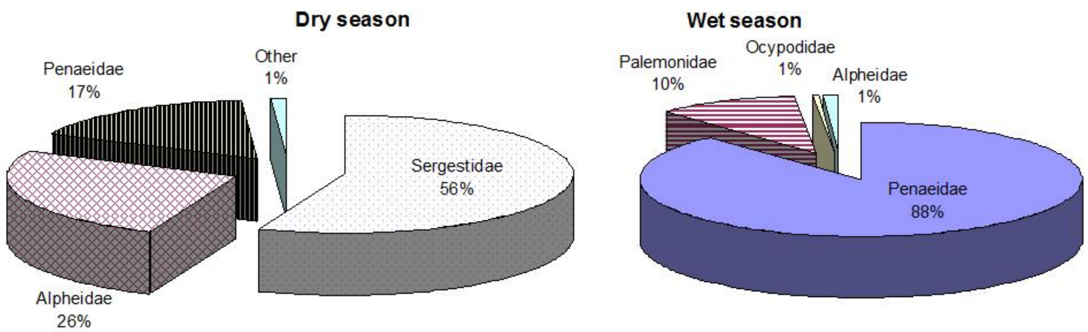


Fig. 4. Variation of larvae abundance and species diversity among stations.

Comparision with studied in adjacent mangrove areas (Hoa et al., 1976; Hoa, 1982; Trong et al., 1985; Ha, 2008; Ha, Thu, 2009; Thu et al., 2009) shown the species diversity and abundace in Xuan Thuy Mangrove forest in average level (Table 2).

Table 2. Comparison of species diversity and abundance with other mangrove areas

Location	Year	Number of species	Abundance (inds/100m^2)
Trang Cat	1976	11	186
Dinh Vu	1985	4	4
Dam nha Mac	1989	10	34
Hoang Tan	1989	10	91
Lach Huyen	2006	29	87
Xuan Thuy	2009	17	37

Seasonal variation of larvae assemblage. Species distribution and average density of macrofauna among stations of the different season were shown in Figure 4, Annex A and Annex B.

Metapenaeus intermedius is dominant species with average abundance is 103 ind./100m^2, following is *Acetes* sp., *Alpheus* sp., *M. ensis* and *M. joyneri* with average abundance is 69, 52, 30, 27 ind./100 m^2 repectively. Among them *Acetes* sp., *Alpheus* sp. is dominant in dry season, while *M. intermedius*, *M. ensis* and *M. joyneri* are dominant in the wet season.

In Dry season H' index is 1.22 and in Wet season H' index is 1,1.

The one-way ANOVA analysis on abundane and species diversities was indicated non-significantly different between seasons (p>0.05).

Conclusion and discussions

The mean abundance of shrimp and crab larvae is generally fluctuated among seasons and stations, ranging from 4–178 ind/100 m^2 in dry season (Annex C), 5–115 ind./100 m^2 in rainy season (Annex B). Penaeidae was the dominant family found in the highest percentage of all stations and wet seasons (51%), while Palaemonidae was the second high density, percentage (10%). In dry season Segestidae was the most dominant group and Alpheidae is second high abundance with 56% and 26%, respectively.

Penaeidae were the most abundance in species diversity in Xuan Thuy mangrove forest, species *M. intermedius* Kishinouye, 1900 and *M. ensis* (De Hann, 1844) seemed to be the common shrimp found in all station and both seasons (Annex B, C).

The studies showed significant different among stations but non-significantly different between seasons.

The present studies, was the preliminary study which do sampling collection only once per season, in order to gain the idea for more research works on this field in the area of Xuan Thuy mangrove forest, which is the very productive area and many activities composed. There are still many parameters that can be identified, such as: mangrove communities structure, predation effect, shoreline development, human activities, physical oceanographic changes and variations and *etc.*, so more studies need to be carried out for all solutions on this subjects. Further works on these field are necessary in order to clarify environmental changes and for some critical warning.

References

Chaitiamvong S., Supongpan M. 1992. A Guide to Penaoid Shrimp found in Thai waters. Australian Institute of Marine Science Townsville, Australia. 177 p.

Chung N.V., Thanh D.N., Du P.T. 2000. Fauna of Viet Nam (Shrimp). Science and Technic Publishing House. 263 pp. [InVietnamese].

Chan T.Y. 1998. The Living Marine Resources of the Western Central Pacific: Vol. 2. Cephalopods, Crustaceans, Holothurians and Sharks.

Ha Tran Manh. 2008. Some note on post-larvae shrimp in Lach Huyen estuary, Haiphong // Marine Environment and Resources. V. 13. P. 204–213. [In Vietnamese].

Ha Tran Manh, Nguyen Thi Thu. 2009. Factors affecting the natural larvae sources in littoral areas of Bach Dang Estuary // Proceeding of 3rd National Scientific Conference on Ecology and Biological Resources. P. 1304–1312. [InVietnamese].

Hoa Tran Quoc, Duc Nguyen Xuan, Trong Pham Dinh, Chung Nguyen Van, Yet Nguyen Huy. 1976. Investigated report of shrimp and fish larvae enter to the Trang Cat brackish pond. Archives in Library of Institute of marine Environment and Resources.

Hoa Tran Quoc. 1982. Planktonic larvae of shrimp in the brackish pond of Hai Phong-Quang Yen. Archives in Library of Institute of marine Environment and Resources.

Holthuis L.B. 1980. FAO species catalogue, Vol. I - Shrimp and Prawns of the World: An Annotated catalogue of species of Interest to Fisheries. FAO Fish. Synopsis, V. 125. 271 pp.

Keiichi Matsuura, O. Kurnaen Sumadhiharga, Katsumi Tsukamoto 2000. Field Guide to Lombok Island: Identification Guide to Marine Organisms in Sea Grass Beds of Lombok Island, Indonesia. Ocean Research Institute, University of Tokyo. 449 p.

Thu Nguyen Thi, Tran Manh Ha. 2009. Shrimp and fish larvae in the Bachdang Estuary, Haiphong // Proceedings of National Scientific Conference on Marine Biology and Sustainable development. P. 311–322.

Trong Pham Dinh, Lang Van Ken. 1985. Larvae of shrimp of Dinh Vu and adjacent water. Archives in Library of Institute of marine Environment and Resources.

Annex A. Species and average abundance of shrimp and crab larvae at Xuan Thuy mangrove forest

Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Acetes sp.	77	10	10	178	8		24	69
Alpheus sp.	24	4	163			4	2	52
Leandrites indicus						4		4
Leptocarpus potamiscus	14	5	24	2	8	8		9

Macrobrachium mirabile	6	4			2			4
Macrobrachium nipponense	4	7	14	12			4	9
Macrobrachium sp.	10			2				6
Metapenaeus ensis	5	2	79	7	2		6	30
Metapenaeus intermedius	20		80		6	297	2	103
Metapenaeus joyneri		26						26
Metapenaeus sp.		4						4
Ocypodidae		6	8		2		12	7
Penaeus monodon				8				8
Penaeus indicus			2					2
Penaeus japonicus		2						2
Penaeus penicilatus	6					2		5
Portunus pelagicus			4					4
Uca sp.	4							4
Average abundance (ind./100m^2)	**19**	**7**	**57**	**58**	**6**	**115**	**8**	**37**
Species diversity	**10**	**10**	**9**	**6**	**6**	**5**	**6**	**17**

Annex B. Species and average density of shrimp and crab larvae at Xuan Thuy mangrove forest during wet season

Taxon	1W	2W	3W	4W	5W	6W	Total
Alpheus sp.		6				4	5
Leandrites indicus						4	4
Leptocarpus potamiscus	14	5	24	2	8	8	9
Macrobrachium mirabile	6	4			2		4
Macrobrachium nipponense	6		22	12			16
Macrobrachium sp.	10			2			6
Metapenaeus ensis	5		101	7	2		29
Metapenaeus intermedius	12		109		6	297	138
Metapenaeus joyneri		26					26
Metapenaeus sp.		4					4
Ocypodidae		6	8		2		5
Penaeus monodon				8			8
Penaeus japonicus		2					2
Penaeus penicilatus	6					2	5
Uca sp.	4						4
Average abundance (ind./100m^2)	**7**	**7**	**67**	**6**	**5**	**115**	**35**
Species diversity	**8**	**8**	**6**	**6**	**6**	**6**	**15**

Annex C. Species and average density of shrimp and crab larvae at Xuan Thuy mangrove forest during Dry season

Taxon	1D	2D	3D	4D	5D	7D	Total
Acetes sp.	77	10	10	178	8	24	69
Alpheus sp.	24	2	163			2	71
Macrobrachium nipponense	2	2	6			4	4
Metapenaeus ensis		2	56			6	30
Metapenaeus intermedius	28		36			2	26
Ocypodidae						12	12
Penaeus indicus			2				2
Portunus pelagicus			4				4
Average abundance (ind./100m^2)	**42**	**4**	**49**	**178**	**8**	**8**	**42**
Species diversity	**5**	**4**	**8**	**1**	**2**	**7**	**8**

DIVERSITY OF SEAGRASS FROM PORT DICKSON, NEGERI SEMBILAN, MALAYSIA

Abu Hena M.K., Japar Sidik B.

Department of Biology, Faculty Science and Environmental Studies,

University Putra Malaysia, 43400 UPM, Serdang, Selangor D.E., Malaysia

e-mail: hena71@yahoo.com

Introduction

Seagrasses are the pastures of the ocean and usually distributed in shallow soft or sandy bottom of estuaries and along the coastal margins of tropical, subtropical and temperate marine water. They are monocotyledon plants, which have numerous important ecological roles in the shallow marine water coasts, especially with regard to marine productivity (Abu Hena, 2000).

Presently there is a recorded of ca. 58 species which are grouped into 12 genera (Kuo, McComb, 1989). The meadows of seagrass are among the most productive of plant communities in marine shallow coastal water (McRoy, McMillan, 1977). They provide habitat and nursery area for many marine commercial species (Orth et al., 1984; Huh, Kittings, 1985). Physically seagrass meadows help to reduce wave and current energy that stabilize sea floor (Fonseca, Fisher, 1986). However, the growth, distribution and abundance of seagrasses are affected by current regime (Fonseca, Kenworth, 1987), nutrient availability (Short, 1987), light intensity (Dennison, Alberte, 1982; Abu Hena et al., 2001), water temperature (Bulthuis, 1987) and salinity ranges (Walker, McComb, 1990) in where they are growing.

Data on Malaysian seagrasses is still scattered. Even-though seagrass is an important habitat for many important coastal fishery resources but without some exception, no direct research on the local seagrass ecosystem has yet been done specially on fishery importance. In recent year, Japar et al. (1999) studied on distribution, ecology and the morphological characteristics of *Halophila spinulosa* in Sabah, and Ethirmannasingam et al., (1996) investigated on temporal variation of the biomass and shoot density of *Enhalus acoroides* at Johor estuary, Malaysia. Therefore, the present study aimed (i) to identify the species of seagrasses occurring in Teluk Kemang, Port Dickson; (ii) to determine the distribution and density of existing species; (iii) to estimate leaf production.

Materials and Methods

The present study was conducted in Teluk Kemang, Port Dickson coastal area in Negeri Sembilan, Malaysia (Fig. 1). It is an inshore tidal area along the Straits of Malacca located at latitude 2°27´ N and longitude 101°51´ E. Shoot density was estimated by using 20x20 cm quadrat. Seagrasses (four species) were sampled in a non-random fashion because of the patchy distribution of plants. Various sizes of seagrass specimens were selected where available. All living plant material in each quadrat was removed and processed in the laboratory. Shoot density was recorded from each quadrat. For identification, fresh samples of seagrasses were collected in plastic bag containing seawater and brought back to the laboratory. Species identification was done following the reference keys described by Den Hartog (1970).

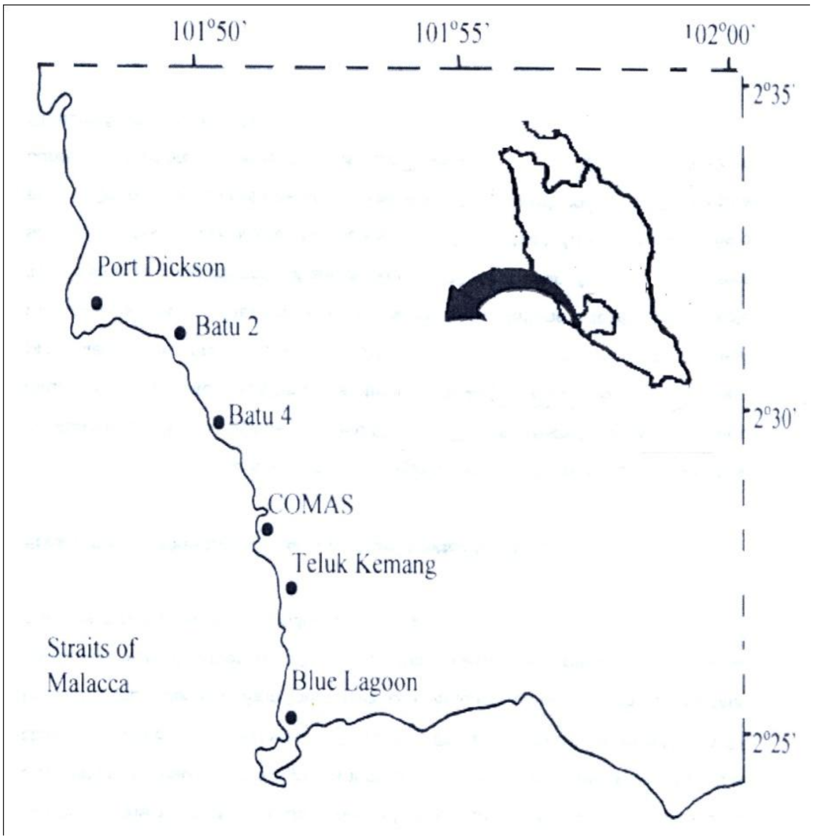


Fig. 1. Study area location at Teluk Kemang in Port Dicksion, Negeri Sembilan, Malaysia.

Leaf production was detected by following the method of Dennison (1990). In this aspect, all leaves base of 10 mature (≥3 leaf) shoots inside the 10x10 cm quadrat were marked with a syringe needle by using the marking method of Zieman (1974) and later modified by Kirkman and Reid (1979). Another four individual quadrat were used as replicates for this detection. At an interval of days, all marked seagrass species were harvested. After collection, all plant samples were carefully scraped and washed with running water to remove adhering silt and epiphytes. The seagrass materials were then dried in the oven at 80°C for 48 h to obtain the Dry Weight (DW) and later on at 500°C at 5 h for Ash Free Dry Weight (AFDW). The data obtain from this study were converted to areal production unit basis (g/m^2).

Results and Discussion

Seagrass identification and distribution. Seven species of seagrass belonging to two families were recorded from this study area. They are *E. acoroides, H. ovalis, H. decipiens* and *T. hemprichii* (Hydrocharitaceae) and *C. serrulata, S. isoetifolium* and *H. pinifolia* (Cymodoceaceae) (Fig. 2).

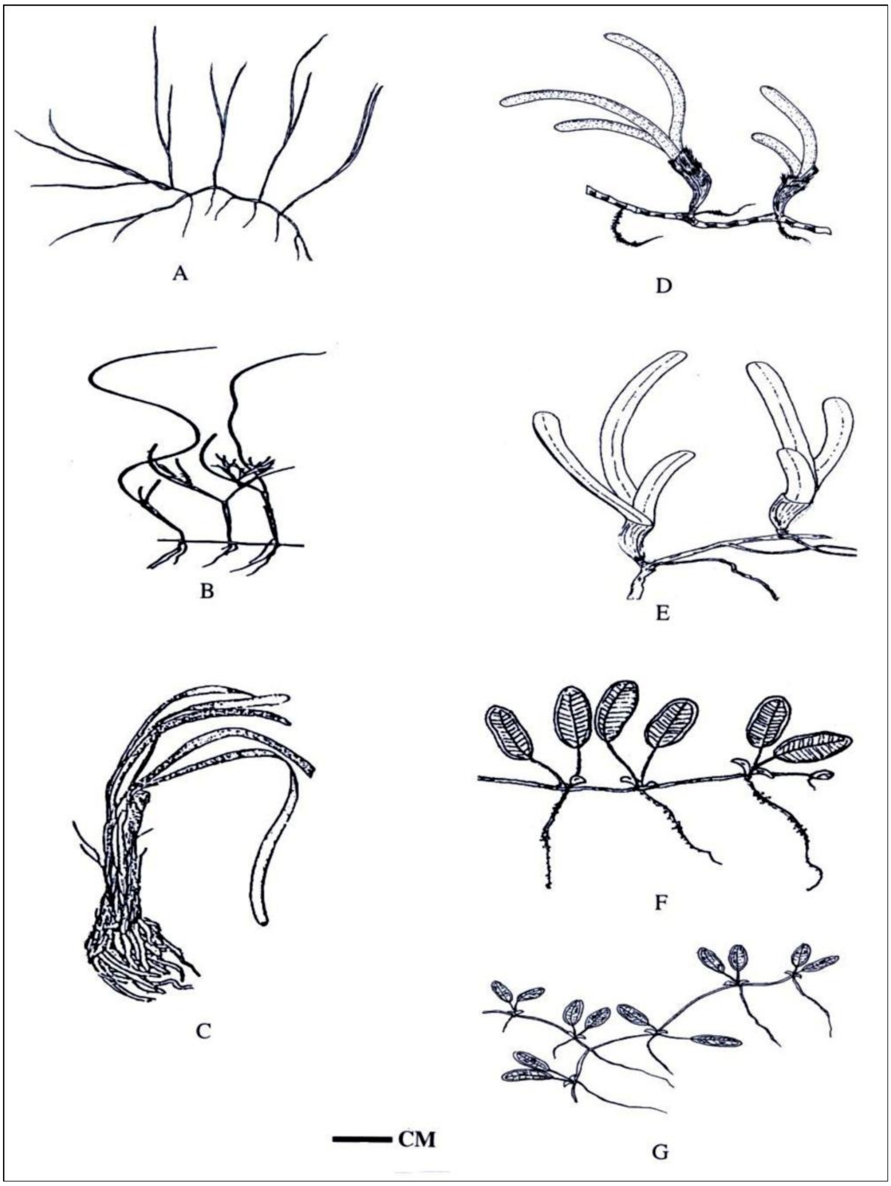


Fig. 2. Seagrasses from Port Dickson, Malaysia: A – *Halodule pinifolia*, B – *Syringodium isoetifolium*, C – *Enhalus acoroides*, D – *Thalassia hemprichii*, E – *Cymodocea serrulata*, F – *Halophila ovalis*, G – *Halophila decipiens*.

The seagrasses *E. acoroides, H. ovalis* (small leaf variety), *H. pinifolia T. hemprichii, C. serrulata* and *S. isoetifolium* were found in the intertidal area co-existing with macroalgae (e.g. *Sargassum*) and scattered sparsely in this seagrass bed. *Cymodocea serrulata, T. hemprichii, H. ovalis* and *H. pinifolia* usually found as pure stands but also found three species association (*E. acoroides – C. serrulata – H. ovalis*), two species association *T. hemprichii – H. ovalis, C. serrulata − H. ovalis and C. serrulata − H. pinifolia*, in the intertidal area. *Halophila decipiens* was found in the subtidal zone either in pure stands or together with big leaf *H. ovalis*. Norhadi (1993) recorded nine seagrass species from intertidal zone down to 2.5 m depths in coastal water of Sabah, Malaysia (Table 1) and they are growing on various type of substrate such as coral rubble, sand to muddy sand. However, only seven of the nine species were found in waters of Port Dickson inhabiting on sandy coarse (90−92% sand) and sandy loamy (80.7% sand) substrate occasionally interrupted by rubbles (Lee, 1999).

Table 1. Seagrasses from Teluk Kemang, Port Dickson, Malaysia

Port Dickson, Malaysia (This study)	**Sabah, Malaysia (Norhadi, 1993)**
Hydrocharitaceae	Hydrocharitaceae
Enhalus acoroides	*Enhalus acoroides*
Halophila ovalis	*Halophila ovalis*
Halophila decipiens	*Halophila minor*
Thalassia hemprichii	*Thalassia hemprichii*
Cymodoceaceae	Cymodoceaceae
Cymodocea serrulata	*Cymodocea serrulata*
Syringodium isoetifolium	*Syringodium isoetifolium*
Halodule pinifolia	*Halodule pinifolia*
	Halodule uninervis
	Cymodocea rotundata

Halodule pinifolia has a relatively higher number of shoots (1300 shoots/m^2), followed by *C. serrulata* (1123 shoots/m^2), *H. ovalis* (1020 shoots/m^2). *T. hemprichii* showed the lowest shoot density of 850 shoots/m^2 for a mono-specific community at Port Dickson. The mean shoot density of *H. pinifolia, C. serrulata, H. ovalis* and *T. hemprichii* were 620.12±108.21 shoots/m^2, 950±136.42 shoots/m^2, 875±102.5 shoots/m^2 and 632.14±113.77 shoots/m^2, respectively. Nienhuis et al. (1989) stated that the shoot number per surface area is species dependent and the range of the number of shoots is extremely variable, which support the present study.

Production. The range of leaf production of *E. acoroides* was recorded 3.20−15.40 mg DW/shoot/day with the mean value of 7.7±3.0 mg DW/shoot, lower than the value recorded at Motupore Island (8.5 mg DW/shoot/day) Papua New Guinea (Brouns, Heijs, 1986). The daily leaf production of *C. serrulata* and *T. hemprichii* ranged from 0.70–1.90 mg DW/shoot/day and 0.60–1.80 mg DW/shoot/day, with the mean value of 1.25±0.02 mg DW/shoot/day and 1.13±0.03 mg DW/shoot/day, respectively. The areal production were estimated as 1.19 ± 0.02 g DW/m^2/day (0.96±0.23 g AFDW/m^2/day) and 0.71±0.02 g DW/m^2/day (0.56±0.17 g AFDW/m^2/day), respectively and both species showed no significant different for leaf production at different quadrats. Leaf production of *C. serrulata* was higher than that of *T. hemprichii*. In ash free dry weight, the mean value of leaf production of *C. serrulata* was lower than the value from Bootless Inlet, Papua New Guinea but higher than the Exmouth Gulf, Australia and Bootless Bay, Papua New Guinea (Table 2). These dissimilarities may be due to morphological variation of seagrasses and environmental condition i.e. geographical location, water quality and circulation, sediment status and nutrient content of seagrass bed.

Table 2. Leaf production of *C. serrulata* and *T. hemprichii* in Teluk Kemang, Port Dickson seagrass bed

Study areas	**Leaf production (g AFDW/m^2/day)**	**Authors**
Port Dickson, Malaysia	0.96±0.23 (*C. serrulata*) 0.56±0.17 (*T. hemprichii*)	This study
Exmouth Gulf, NW Australia	0.24±0.03	Schaffelke, Klumpp, 1996
Bootless Bay, PN Guinea	3.6	Brouns, 1987a
Bootless Bay, PN Guinea	0.42	Brouns, 1987b

Conclusion

In present study, it was found that seven species of seagrass are growing in a sparse, mixed stand and monospecific patches form in this seagrass bed. However, present study revealed that seagrass *E. acoroides* has higher leaf production rate (dry weight/shoot) hierarchically *E. acoroides* (7.70±3.00 mg DW/shoot/day) > *C. serrulata* (1.25±0.02 mg DW/shoot/day) >*T. hemprichii* (1.13±0.03 mg DW/shoot/day).

References

Abu Hena M.K., Misri K., Japar Sidik B., Hishamuddin O., Hidir H. 2001. Photosynthesis of seagrass *Cymodocea serrulata* (Magnoliophyta/Potamogetonales/Cymodoceaceae) in field and laboratory // Indian Journal of Marine Sciences. V. 30, N 4. P. 253–256.

Abu Hena M.K. 2000. Growth and production of seagrass *C. serrulata* (R. Br.) Aschers et Magnus and *T. hemprichii* (Ehrenb) Aschers in Port Dickson, Negeri Sembilan, Malaysia. Published MS Thesis, Universiti Putra Malaysia, 136 p.

Brouns J.J.W.M., Heijs F.M. 1986. Production and biomass of seagrass *E. acoroides* (L. f.) Royle and its epiphytes // Aquatic Botany. V. 25. P. 21−45.

Brouns J.J.W.M. 1987a. Quantitative and dynamic aspects of mixed seagrass meadow in Papua New Guinea // Aquatic Botany. V. 29. P. 33–37.

Brouns J.J.W.M. 1987b. Aspects of production and biomass of four seagrass species (Cymodoceoideae) from Papua New Guinea // Aquatic Botany. V. 27. P. 333–362.

Bulthuis D.A. 1987. Effects of temperature on photosynthesis and growth of seagrass // Aquatic Botany. V. 27. P. 27–40.

Den Hartog C. 1970. The Seagrass of the World. Amsterdam, London: North Holland Publishing Company. 268 p.

Dennison W.C., Alberte R.S. 1982. Photosynthetic responses of *Zostera marina* L. (eelgrass) to in situ manipulations of light intensity // Oecologia. V. 55. P. 137–140.

Dennison W.C. 1990. Leaf production // Seagrass Research Methods. R.C. Phillips, P.C. McRoy (Eds.). UNESCO Publication Series 9. P. 77–80.

Ethirmannasingam S., Phang S.M., Sasekumar A. 1996. A study of some phonological events in a Malaysian *Enhalus acoroides* bed // Proceedings of International Workshop on Seagrass Biology. J. Kuo, D.I. Walker, H. Kirkman (Eds). Rottnest Island, Western Australia, 1996. P. 31–40.

Fonseca M.S., Fisher J.S. 1986. A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration // Marine Ecology Progress Series. V. 29. P. 15–22.

Fonseca M.S., Kenworthy W.J. 1987. Effects of current on photosynthesis and distribution of seagrasses // Aquatic Botany. V. 27. P. 59–78.

Huh S.H., Kitting C.L. 1985. Trophic relationships among concentrated populations of small fishes in seagrass meadows // Journal of Experimental Marine Biology and Ecology. V. 92. P. 29–43.

Japar S.B., Muta Harah Z., Lamri A., Francis L., Josephine G., Fazrullah R.A.R. 1999. *Halophila spinulosa* (R. Br.) Aschers-An unrecorded seagrass in Sabah, Malaysia // Journal of Sabah Parks Nature. V. 2. P. 1–9.

Kirkman H., Reid D.D. 1979. A study of the role of the seagrass *Posidonia australis* in the carbon budget of an estuary // Aquatic Botany. V. 7. P. 173–183.

Kuo J., McComb A.J. 1989. Seagrass taxonomy, structure and development. In Biology of seagrass // A Treatise on the Biology of Seagrass with Special Reference to the Australian Region. A.W.D. Larkum, A.J. McComb, S.A. Shepherd (Eds.). Amsterdam: Elsevier. P. 6–55.

Lee C.N. 1999. Seagrass and macroalgal communities in the intertidal and subtidal waters of Teluk Kemang, 7th mile Port Dickson, BSc Project Paper, Department of Biology, Universiti Putra Malaysia. 146 p.

McRoy C.P., McMillan C. 1977. Production ecology and physiology of seagrass // Seagrass Ecosystems: a Scientific Perspective. C. P. McRoy and C. Helfferich (Eds.). New York, Basel: Marcel Dekker. P. 53–87.

Nienhuis P.H., Coosen J., Kiswara W. 1989. Community structure and biomass distribution of seagrasses and macrofauna in the Flores Sea, Indonesia // Netherlands Journal of Sea Research. V. 23, N 2. P. 197–214.

Norhadi I. 1993. Preliminary study of the seagrass flora of Sabah, Malaysia, Pertanika // Journal of Tropical Agriculture and Science. V. 16, N 2. P. 111–118.

Orth R.J., Heck K.L.J., Montfrans J.V. 1984. Faunal communities in seagrass beds: a review of the influence of plant structure and prey characteristics on predator-prey relationships // Estuaries. V. 7. P. 339–350.

Schaffelke B., Klumpp D.W. 1996. Biomass and productivity of a tropical seagrass comunity in North-West Australia (Exmouth Gulf) // Proceedings of International Workshop on Seagrass Biology. J. Kuo, D.I. Walker, H. Krikman (Eds). Western Australia, Rottnest Island. P. 13–20.

Short F.T. 1987. Effects of sediment nutrients on seagrass: literature review and mesocosm experiment // Aquatic Botany. V. 27. P. 41–57.

Walker D.I., McComb A.J. 1990. Salinity response of the seagrass *Amphibolis antarctica* (Labill.) Sonder ex Aschers: an experimental validation of field results // Aquatic Botany. V. 36. P. 359–366.

Zieman J.C. 1974. Methods for the study of the growth and production of turtle grass *T. testudinum* Konig // Aquaculture. V. 4. 107–130.

THE OPTIMAL TEMPERATURE FOR RAINBOW TROUT (*ONCORHYNCHUS MYKISS*) CULTURE IN LAM DONG PROVINCE

***Nguyen Thi Xuan Thu*[1], *Nguyen Viet Thuy*[2], *Tran Thi Kim Hanh*[2], *Nguyen Anh Tien*[2], *Mai Duy Minh*[2], *Le Trung Ky*[2]**

[1]*Ministry of Agriculture and Rural Development, Hanoi, Vietnam*

[2]*Research Institute for Aquaculture No. 3, Nha Trang, Vietnam; e-mail: trungkyle@yahoo.com*

Introduction

Rainbow trout (*Oncorhynchus mykiss*) is one of the valuable fresh water species and globally cultured in temperate zones. Recently, this species has been cultured in Vietnam. The water temperature is involved in biological processes in fish so the effects of temperature on fish life are of interest. Suitable water temperatures for growth of rainbow trout were from 12 to 18ºC and the optimal temperature for their metabolism was 18ºC (Gamperl et al., 2004; Boughton et al., 2007). They became inactive and stopped eating at 22ºC, and started dying when water temperature increased to 25–27ºC. At high water temperatures fish's biological function and disease resistance decrease. Rainbow trout cultured at 20^{o}C had higher intestine fat content than those reared at 17ºC (Nykanen, 2006). Therefore, if they were cultured at high temperatures, for example at 20ºC, fellet quality may be reduced. Bidgood (1980) stated that rainbow trout could survive at a maximum of 24–26ºC. However, this limit is not consistent and probably depends on fish age. The high temperature threshold for rainbow trout was 29ºC (Rodgers, Griffiths, 1983) and the low threshold was from 1ºC (Finstad et al., 1988) to 2ºC (Belkovskiy et al., 1991). At these low temperatures fish's activities become slowly. In Europe rainbow trout are often cultured at temperatures between 10 and 15ºC. In Vietnam they have been cultured at 12–15ºC in winter and 17–23ºC in summer at reservoirs and streams in Sapa and Lam Dong province. We ask the question which temperature range should be applied for culturing rainbow trout in local conditions of Viet Nam.

The goal of this study was to determine optimal temperature for rainbow trout (*O. mykiss*) of different body weights cultured in flowing water systems in Lam Dong province.

Materials and Methods

The experiment was carried out from May to June 2009 at Freshwater Fish Research Station, Klong Klanh, Da Lat city, Lam Dong province. Experimental tanks had volume of 1 m^3 (2x1x0.5 m) containing 0.8 m^3 water. The culture system was a flowing system set at speed of 1.3–1.9 L/min. and water was supplied from natural streams. Dissolved oxygen in experimental tanks was maintained at more than 6.4 mg/L and pH ranged from 7.5 to 8.0. Air conditioning was used to control water temperatures in experimental tanks.

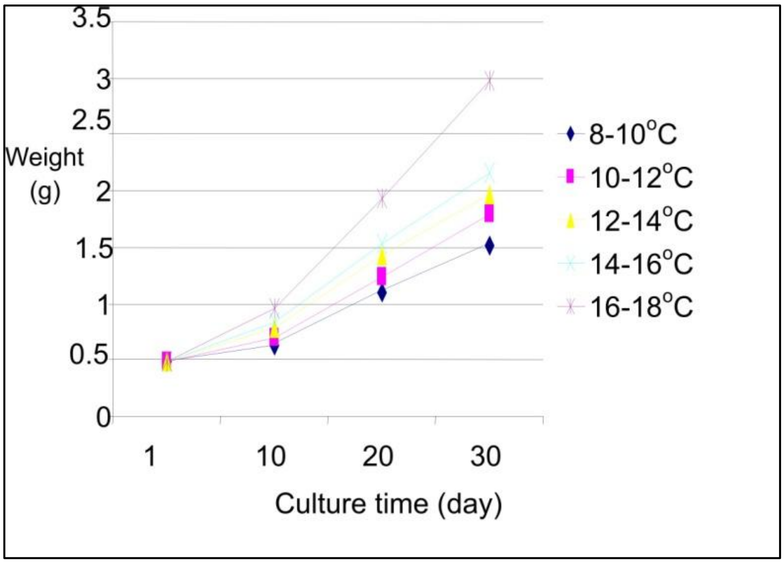


Fig. 1. Body weights of rainbow trout reared at five different temperatures.

Triploid rainbow trout were used. There were two groups of fish i.e. 0.48 g/ind and 7 g/ind and each was cultured in triplicate at five different temperature ranges: 8–10, 10–12, 12–14, 14–16 and 16–18ºC with an initial stocking density of 90 inds/tank for one month.

The fish were fed with formulated diet (Skretting brand, containing 42% protein). When the fish were less than 2 g/ind they were fed 8 times with a feeding rate of 6% body weight per day.When getting bigger 2 g/ind they were fed 6 times with a feeding rate of 5% body weight a day.

In each experimental tank, 30 fish were weighed every ten days. Mean specific growth rate in body weights (SGR, g/day) was estimated as following:

SGR = $(W_t - W_i)/t$;

where W_t is fish weight at time t and W_i is the initial fish weight. Survival rate SR (%) was calculated by:

SR = (number of live fish at the end of the experiment)/(total initial number of fish).

All the statistical analyses were performed using Excel software 2003. Significant differences in fish weight were analyzed using ANOVA.

Results

The growth and survival of fish (0.48 g/ind) nursed at different temperatures. The water temperature affected growth of fish nursed at different temperatures. The mean body weights and SGR of fish nursed at five different temperatures were summarized in Fig. 1 and Table 1. SGR and body weights of fish tended to increase when water temperature increased. Fish cultured at 16–18ºC had significantly faster SGR than those nursed at the other temperatures ($p<0.05$). The

Table 1. SGR (g/day) of rainbow trout (0.48 g/ind.) nursed at five different temperatures. Different superscript letters within a row indicate significantly different means at $p < 0.05$ when the pair-wise comparison between neighboring columns was done.

Culture time (day)	8-10°C	10-12°C	12-14°C	14-16°C	16-18°C
10	0.015	0.021	0.030	0.035	0.047
20	0.046	0.054	0.064	0.071	0.098
30	0.043	0.074	0.054	0.062	0.104
Mean	**0.035^{a}**	**0.0496^{b}**	**0.0493^{b}**	**0.056^{c}**	**0.083^{d}**

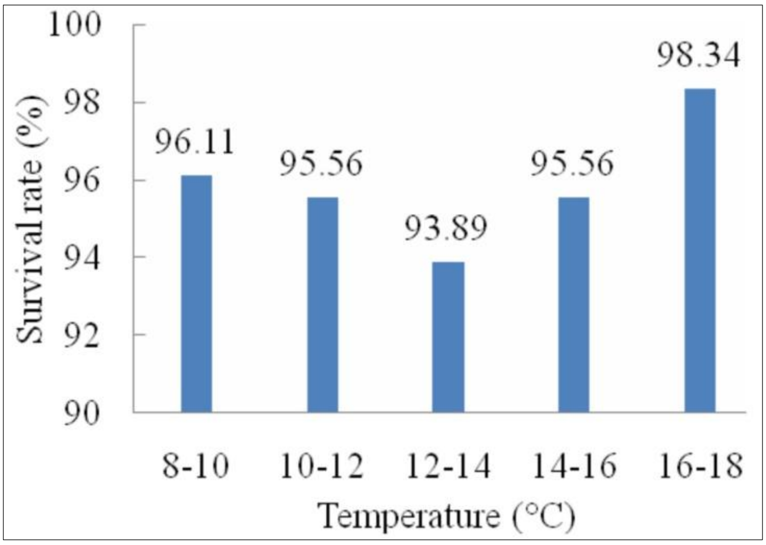


Fig. 2. Survival rate of rainbow trout reared at five different temperatures.

difference in fish weights between fastest growth-group and slowest growth-group was 1.5 g after 30 day experiment. The water temperatures did not clearly affect survival of fish (Fig. 2). The highest survival rate (98.34%) was found in the fish group nursed at 16-18ºC, while the group reared at 12–14ºC had the lowest survival rate (93.89%). However, this difference was not statistically significant ($p>0.05$). The results indicate that in the experimental temperature range of 8–18ºC, the temperature of 16–18ºC was optimal for culturing rainbow trout of from 0.48 g/ind to 3 g/ind.

The growth and survival of fish (7 g/ind) cultured at different temperatures. The water temperature affected growth of rainbow trout cultured at different temperatures. The fish cultured at 16–18ºC grew significantly faster ($p<0.05$) than those cultured at the lower temperatures. The differences in SGR and body weights are illustrated in Table 2 and Fig. 3 respectively. The difference in fish body weights between the group reared at 16–18ºC (highest temperature) and the group reared at 8–10ºC (lowest temperature) was 12.6 g after a 30 day experiment period. Whereas the water temperature affected the fish growth, it did not affect their survival. All fish reared at five different temperatures survived after 30 days. The results indicate that in the experimental temperature range of 8–18ºC, the temperature of 16–18ºC was optimal for culturing rainbow trout of between 7 g/ind and 35 g/ind.

Discussion

The observed results show that temperature affected the growth of rainbow trout at both initial stocking sizes of 0.48 g/ind and 7 g/ind In the temperature ranges from 8 to 18^{o}C, fish's growth increased when temperature increased. This is supported by previous studies (Bidgood,

Table 2. SGR (g/day) of rainbow trout (7 g/ind) cultured at five different temperatures. Different superscript letters within a row indicate significantly different means at $p<0.05$ when the pair-wise comparison between neighboring columns was carried out.

Culture time (day)	8-10ºC	10-12ºC	12-14ºC	14-16ºC	16-18ºC
10	0.179	0.213	0.353	0.335	0.502
20	0.457	0.686	0.663	0.947	1.412
30	0.893	1.129	1.133	1.137	1.259
Mean	**0.510^{a}**	**0.676^{b}**	**0.716^{c}**	**0.806^{d}**	**1.058^{e}**

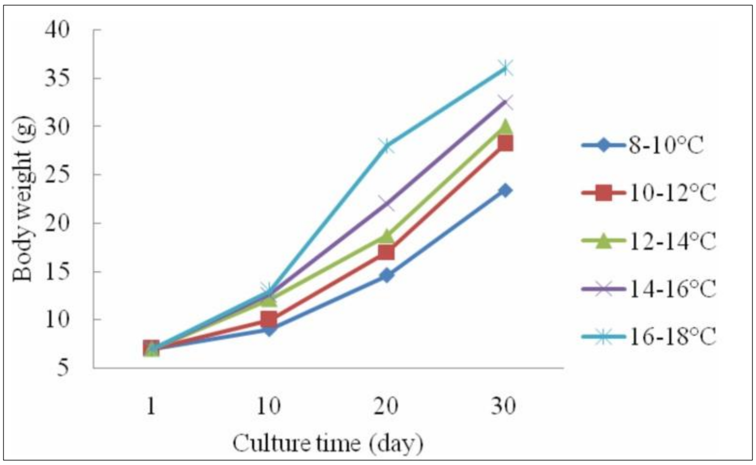


Fig. 3. The body weights of rainbow trout cultured at five different temperatures.

1980; Rodgers, Griffiths, 1983; Alanara et al., 1994). The temperature impacts on fish's metabolism, consequently influences growth of fish. In suitable temperature range, higher temperature makes metabolism faster and fish grow faster.

In two experiments with two different initial sizes, the optimal tem-temperatures for growth of rainbow trout were similar (16–18ºC). The fastest growth was found in the group of fish cultured at temperatures of 16–18^{o}C. It means that the temperature of 16–18ºC is in suitable magnitude for rainbow trout of from 0.48 to 35 g/ind. This optimal temperature for rainbow trout has already been reported by Gamperl et al. (2004) and Boughton at al. (2007). In the present study, survival and growth of fish were rather high in comparison to previous trials (Noble et al., 2007) illustrating high efficiency of the techniques which was applied for the two culture experiments.

Our results are different from those previously reported. Alanara et al. (1994) reported that rainbow trout grew fast at 15ºC, but when temperature went up to 16ºC or higher, fish's growth decreased. Also in European countries, rainbow trout have been cultured at temperature from 10 to 15ºC, and at 15ºC fish consume more food and grow faster (Alanara et al., 1994; Bailey, Alanara, 2006). There are some possible reasons for the conflicting results. First, the different optimal temperature for fish could be explained by the difference in the ambient water temperature in the local places where the fish occur. In the countries such as Finland where the native rainbow trout occur, water temperature is always low and rarely goes over 15ºC. The common ambient temperature should be applied and at that temperature level the fish should have higher growth. However, in the places with higher ambient temperature, the fish should adapted to the higher temperature. Rodgers and Griffiths (1983) stated that the optimal temperature for fish living in areas with high temperature all the year round is higher than that of fish living in colder areas. Other possible explanation is the effect of genetic factors. Until now the quantitative trait loci affecting the fish ability to adapt to higher temperature have been discovered (Jackson et al., 1998) and followed by selective breeding for increasing temperature threshold (Ineno et al., 2005). If this is the case then the rainbow trout we used for our experiments should be from selection programs for higher temperature threshold.

The present results indicate that in the experimental temperatures of 8–18ºC in Lam Dong water, the optimal temperatures for culturing rainbow trout with body weight of from 0.48 to 35 g/ind was 16–18ºC. This is interesting from completing the techniques for culture of the fish.

Acknowledgements

The study was supported by national project No. KC07/06-10.

References

Alanara A. 1994. The effect of temperature, dietary energy content and reward level on the demand feeding activity of rainbow trout (*Oncorhynchus mykiss*) // Aquaculture. V. 126. P. 349–359.

Bailey J., Alarana A. 2006. Effect of feed portion size on growth of rainbow trout, *Oncorhynchus mykiss* (Walbaum), reared at different temperatures // Aquaculture. V. 253. P. 728–730.

Belkovskiy N.M., Lega Yu.V., Chernitskiy A.G. 1991. Disruption of water-salt metabolism in rainbow trout, *Salmo gairdneri,* in seawater at low temperatures // Journal of Ichthology. V. 31. P. 134–141.

Bidgood B.F. 1980. Tolerance of rainbow trout to direct changes in water temperature // Fishery Research Report No. 15. Fish Wildlife Division. Edmonton, Alberta: Department of Recreation, Parks, and Wildlife. 11 p.

Boughton D.A., Gibson M., Yedor R., Kelley E. 2007. Stream temperature and the potential growth and survival of juvenile *Oncorhynchus mykiss* in a Southern California creek // Fresh Water Biology. V. 52, N 7. P. 1353–1364.

Finstad B., Staurnes M., Reite O.B. 1988. Effect of low temperature on sea-water tolerance in rainbow trout, *Salmo gairdneri* // Aquaculture. V. 72. P. 319–328.

Gamperl A.K., Dougher B., Rodnick K.J. 2004. Hypoxia tolerance and preconditioning are not additive in trout (*Oncorhynchus mykiss*) heart // Journal of experimental Biology. V. 207. P. 2497–2505.

Ineno T., Tsuchida S., Kanda M., Watabe S. 2005. Thermal tolerance of a rainbow trout strain selected by high temperature breeding // Fisheries Science. V. 71, N 4. P. 767–775.

Jackson T.R., Ferguson M.M., Danzmann R.G., Fishback A.G., Ihssen P.E., O'Connell M., Crease T.J. 1998. Identification of two QTL influencing of upper temperature tolerance in three rainbow trout *Oncorhynchus mykiss* halfsib families // Heredity. V. 80, N 2. P. 143–151.

Noble C., Suzuki K., Tabata M. 2007. The effect of differing self-feeding regimes on the growth, behaviour and fin damage of rainbow trout *Oncorhynchus mykiss* held in groups // Aquaculture. V. 264. P. 214–222.

Nykanen M. 2006. Effect of temperature and feeding regime on compensatory growth of rainbow trout. University of Jyvaskyla: Master of Science Thesis. 32 p.

Rodgers D.W., Griffiths J.S. 1983. Effects of elevated thermal regimes on survival of rainbow trout (*Salmo gairdneri*) // Journal of Great Lakes Research. V. 9. P. 421–424.

PROSPECTS OF CULTIVATION OF SARGASSACEAE ALGAE IN VIETNAM

***Eduard A. Titlyanov*[1], *Tamara V. Titlyanova*[1], *Pham Van Huyen*[2]**

[1]A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch of the Russian Academy of Sciences, Palchevskogo 17, Vladivostok, 690041, Russia; e-mail: etitlyanov@mail.ru

[2]Vietnamese Academy of Science and Technology, Nha Trang Institute of Technology Research and Application, 02 Hung Vuong, Nha Trang, Vietnam

There were found more than 50 species of *Sargassum* in Vietnam. *S. carpophyllum, S. crassifolium, S. cristaefolium* [=*S. duplicatum*], *S. glaucescens, S. graminifolium, S. henslowianum, S. mcclurei, S. oligocystum, S. polycystum, S. vachellianum* are the most distributed species. The most stocks of Sargassaceae are concentrated in the North Vietnam (Tonkin Bay) and at the southern coast of Vietnam (Thailand Bay). At the end of last century, an annual production of Sargassaceae amounted more than 1500 ton dried mass, and only 300–500 ton of fresh mass was used. Recently, in connection with great demand for Sargassaceae algae (export to China) and with increase in purchase price, all biomass of the algae are collected in sites within reach by local inhabitants. Such irrational use of natural resources led to sharp decrease in total annual production of Sargassaceae algae and 2–3 years later they will be completely destroyed in Vietnam. The destruction of Sargassaceae fields will lead to catastrophic consequences along the open coast of Vietnam: destruction of coral reefs and historically formed ecosystems.

Possibilities of extensive cultivation of Sargassaceae

In connection with the destruction of Sargassaceae fields along the Vietnamese coast, cultivation of Sargassaceae algae has come. In the World, practice of improvement of natural (wild) fields and carrying out extensive cultivation of dominant species on the basis of these natural stocks. The introduction of any species into extensive cultivation need phytocenologic investigations. Phytocenologic investigations of Sargassaceae communities carried out by the Soviet and Vietnamese scientists in 80 of the last century on Thu Island and in Phu Khanh Province showed that on the basis of natural fields of such species as *S. crassifolium, S. feldmannii, S. ilicifolium, S. polycystum* is possible to organize extensive cultivation of these species and to get harvest exceeding natural associations (Titlyanov et al., 1983; Kalugina-Gutnik, Titlyanov, unpublished data of expedition in 1981 on the Research Vessel “Academician Alexander Nesmeyanov”).

In 1980, Sargassum field at western coast of Thu Island occupied 3.5 km^2, where 5 species of *Sargassum* were found: *S. carpophyllum, S. crassifolium, S. feldmannii, S. ilicifolium, S. polycystum.* All these species (except *S. carpophyllum*) formed dominant associations. In frontier area, dominant species of neighboring associations often formed communities of both species almost in equal quantity. In total, there were four associations in the field (according to dominant species).

S. *ilicifolium* association. Phytocenosises are monodominant with high developed plant cover. Bottom coverage by plants amounted 100%. Plants to 230 cm high. Mean size of the population reached 467–81 individuals per m^2.

S. *feldmannii* association. Phytocenosises are oligodominant. Bottom coverage by plants varied from 40 to 100%. Plants to 42 cm high. This species was distributed over the investigated field and sometimes formed monodominant locations. Biomass reached to 7500–1462 g per m^2.

S. *polycystum* association. Phytocenosises are oligodominant with well developed plant cover (from 20 to 80%). Plants up to 51 cm high. Mean size of the population reached 312–424 individuals per m^2 and biomass reached 5296–5591 g per m^2.

S.crassifolium association. This monodominant association was found at depth of 2.5–4 m, with scarce cover. Plants to about 20 cm high and cover by the plants was about 10%. This species formed patches among corals to 4 m depth. Mean biomass amounted to 170 g per m^2.

Spore release was observed in May-June along the south coast of Vietnam, after that plants were gradually destroyed. Thus, phytomass of *Sargassum* spp. grew by the beginning of May (the time of carrying out of the research) may consider as annual production. In May 1980, stocks of the algae reached 1101.2 ton fresh weight that in average amounted to 42.3 ton per ha at the investigated area (total square 26 ha).

Analyses of productional characteristics of *S. polycystum, S. swartzii* и *S. miyabei* [= *S. kjellmanianum*] from Phu Khanh Province showed that these species actively photosynthesing in March and in the first half of April, they had a high level of the ratio of photosynthesis to dark respiration and significant net production (i.e. plants are in the stage of active growth). The most indices of photosynthesis and respiration rates and highest net production had *S. ilicifolium*, which formed dense populations in April. Optimum photosynthetic active radiation (PAR), which is necessary for growth and development of *S. ilicifolium, S. polycystum, S. swartzii* was in the range from от 20×10^5 to 70×10^5 joule x m^{-2} x day^{-1} or from 40 to 200 watt x m^{-2}. The most productive species along the Vietnamese coast were *S. ilicifolium, S. polycystum, S. swartzii*, which could be recommended for extensive cultivation (Titlyanov et al., 1983).

The carried out investigations give the basis to consider that natural fields of *Sargassum* spp. in central and south Vietnam could be reorganized into maricultural plantations with the dominance of *S. ilicifolium* the most productive species. The main managerial measures in the natural Sargassaceae fields could be: (1) the increase of hard substratum surface in sites of *Sargassum* dwelling; (2) settling of free substratum with the most productive species; (3) the regulation of planting density; (4) gradual replacement of less productive species by more productive ones; (5) harvest the algae when useful substances in thalli are the highest; (6) work out the most rational method of harvesting; (7) getting of high productive forms of algae (with high content of useful substances such as alginates, phycoidan and etc.) by selection and crossing; (8) recently all these agro technical measures (when resources are significantly undermined) are possible only in case of complete prohibition of *Sargassum* harvesting from the experimental fields.

References

Titlyanov E.A., Le Nguyen Hieu, Nechai E.G. et al. 1983. Daily changes in physiological parameters of photosynthesis and dark respiration in marine algae of the gene *Sargassum* from South Vietnam // Russian Journal of Marine Biology. N. 3. P. 39–48. [in Russian].

TROPICAL FISH SPECIES IN PETER THE GREAT BAY, SEA OF JAPAN

A.S. Sokolovsky, T.G. Sokolovskaya, I.V. Epur

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok 690041, Russia

e-mail: iraepur@mail.ru

The climatic trends on our planet in the recent decades indicate an increase in global warming. The warmest years during 147 years of instrumental meteorological observations were 1998, 2001, 2002, and 2010. Inertia of the ocean makes it a strong stabilizing factor that smoothes over climatic anomalies. Global warming is therefore less pronounced in the Far East, but the general climatic dynamics is still observed here. One of the indirect evidences of climatic changes is the penetration of subtropical and tropical fishes into northern waters. It is exactly in recent years that the records of typical tropical fishes in the temperate waters of the Sea of Japan and particularly in Peter the Great Bay have become more frequent. Fish migrate to longer distances largely because of temperature rise and changes in sea currents. The main currents in the Sea of Japan bring warm subtropical water through the Korea Strait. The Tsushima and East Korea currents contribute up to 97% of water to the sea. Southern currents are stronger in summer and autumn and in winter they are suppressed by the northwestern monsoon. Peter the Great Bay is an officially established research site for long-term monitoring of marine biodiversity in the Western Pacific under the DIWPA and NaGISA programs, and a full range of observations are carried out in this area. The monitoring of ichthyofauna in the bay presupposes both research of the species composition of resident fishes and registration of all cases when southern migrants, including typical tropical fishes, penetrate into this region.

Materials and Methods

The present work is based on an exhaustive analysis of a wide range of literature sources and on our own extensive material collected in the Far-Eastern Marine Biosphere Natural Reserve and in the Vostok Marine Refuge located in Peter the Great Bay during years of observations (Sokolovskaya, Epur, 2000; Sokolovsky et al., 2009). Records of subtropical and tropical species were grouped by decades starting from 1900 (Fig. 1), allowing us to find out definite trends in the frequency of occurrence of these species. To reveal the prerequisites for the penetration of tropical fishes to the northern borders of their geographical ranges, satellite images were analyzed (Nikitin et al., 1999). Satellite data show that jets and vortex arrays often form along the continental coast in summer, and subtropical waters are transported from the south to the north of the Sea of Japan reaching the western part of Peter the Great Bay in two or three weeks.

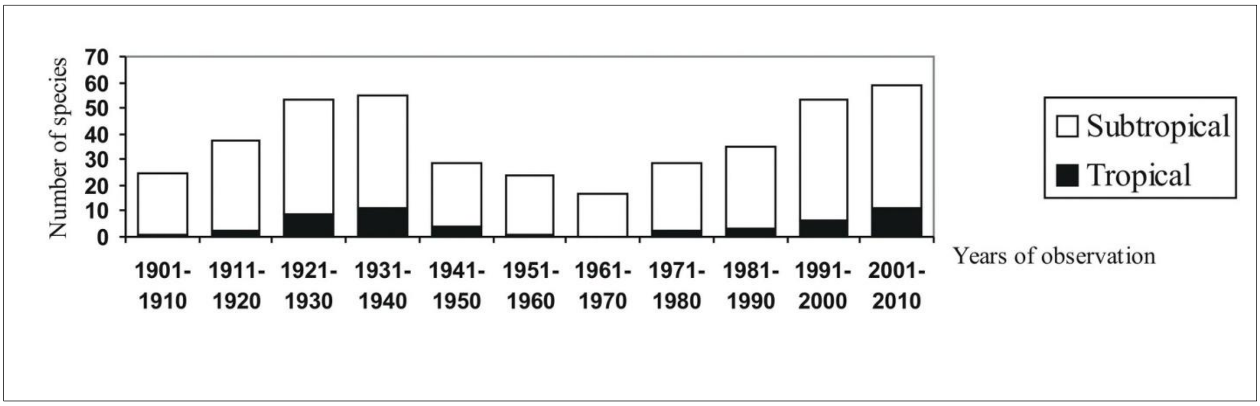


Fig. 1. The number of fish species belonging to tropical and subtropical ichthyofauna recorded in Peter the Great Bay from 1901 to 2010.

Results and Discussion

Fig. 1 displays that there were two periods when the migrations of southern fishes to temperate waters intensified: the first in 1920s–1040s, when the number of such species in Peter the Great Bay reached 53–55 (including 9–11 tropical species) and the second in the last two decades. For the first ten years of this century the highest number of southern migrants, 59, has been registered, including 11 tropical species. It should be pointed out that the total number of tropical fishes recorded for the whole period of observations since 1901 in summer and autumn is 20. Three species – small tarpon (*Megalops cyprinoides*), sailor flying fish (*Prognichthys sealei*), and sargassum fish (*Hystrio hystrio*) – have been found in Peter the Great Bay in the last decade (Sokolovsky et al., 2009). Obviously, the dynamics of occurrence of southern species in the bay is in good agreement with global climatic trends. The 1920s–1940s were the warmest period in the northern hemisphere for the last century. It was succeeded by a relative temperature fall in 1950s–1970s (Kaplin et al., 2001), when tropical species were almost absent from the bay. The next rise of temperature began in the 1980s; it continues and enhances at present. Our data on the occurrence of tropical fishes in Peter the Great Bay are consistent with this temperature trend (Fig. 1**)**. In addition to the three above mentioned species, from 2001 to 2010 the following tropical fishes were recorded: blue pointer (*Isurus oxyrinchus*), common hammer-head shark (*Sphyrna zygaena*), common dolphin (*Coryphaena hippurus*), pompano dolphin (*C. equisetis*), brown-banded butterfly fish (*Chaetodon modestus*), ribbon fish (*Trichiurus lepturus*), frigate (*Auxis thazard*), and puffer (*Sphoeroides pachygaster*). The temperature regime of the coastal shallow waters favours the penetration of these species far north. Solar radiation coming to the sea water rises the temperature of the upper water layer over the whole surface of the sea, but in shallow depths the water column warms up at full depth quicker than in deeper areas. It happens due to the low temperature inertia of coastal and shallow-water zones (Nikitin et al., 1999). Water temperature in some semi-closed and closed small bays in Peter the Great Bay warms up to 26–28˚C by the end of summer, and it is very comfortable for tropical species. For the present, the proportion of southern migrants in the ichthyofauna of Peter the Great Bay constitutes 24.7%, and the number of resident species is 180 (Sokolovsky et al., 2009).

We can now assert with confidence that if the positive temperature trend proceeds for the next ten year period from 2011 to 2020, the number of tropical species penetrating to the bay in summer and autumn will increase together with the increase in fish species diversity.

References

Kaplin P.A., Pavlidis Yu.A., Selivanov A.O. 2001. The forecast for the development of the coastal zone of the Russian seas under the conditions of sea level rise and climate warming // Mankind and the Coastal Zone of the World Ocean. Moscow: GEOS. P. 16–28 [In Russian].

Nikitin A.A., Shatilina T.A., Dyomina T.A., Dyakov B.S. 1999. Peculiarities of long-term thermal water variability of the Tatar Strait (Sea of Japan) // TEACOM Publication N 6: Reports of the International Workshop on the Global Change Studies in the Far East. Vladivostok: Dalnauka. P. 97–110 [In Russian].

Sokolovskaya T.G., Epur I.V. 2000. Southern elements of Peter the Great Bay ichthyophauna at the age shear // Global Change Studies in the Far East: Abstracts of Workshop. Vladivostok. P. 42.

Sokolovsky A.S., Sokolovskaya T.G., Yakovlev Yu.M. 2009. Fish of Peter the Great Bay. Vladivostok: Dalnauka. 370 p. [In Russian].

IMPACT OF CLIMATE CHANGE ON HAIPHONG AREA

Nguyen Vu Than, Nguyen Dinh Thuat

North-East Regional Hydro-Meteorological Center, National Hydro-Meteorological Service, MONRE, 01 Tran Tat Van Kienan Dist., Haiphong, Vietnam

e-mail: thangtth@kttvdb.net; dinhthuat@kttvdb.net

In recent years, the problems of climate change and sea level rise have caused special attention to the people, Scientifics, economics as well as managers in the world.

In this article, with the data received from meteorological, hydrological and oceanographically stations in Haiphong area, the changes of climate featured here are made to see the climate change and sea level rise in the 50 years are clearly significant and alarming.

The climate change makes the weather will be more severe, this is also one of the main reasons that cause the changes to the ecological system and affect many areas of economic, social as heavier floods, water blew off dykes occur in the rainy season, in the dry season, water pollution and salty tidal effects more into continents, many infectious disease arising, decreased production of marine products, agriculture.

A. Summary of Haiphong City

Haiphong is located in North-East of Vietnam, is a major city in the coastal areas, with natural area of over 1,500 km^2 with more than 1.8 million people living in 15 districts. Of these, 11 districts are exposed to the 125 km coastline and about 40% of the population lived in coastal area, there are potential economic development in agriculture – forestry – fisheries, services, tourism, shipbuilding industry, Haiphong has many advantages in economic exchange – culture with countries in the region and the world.

B. Climat changes in Haiphong in the recent time. Meteorological features

With research data in about 50 years in the area of Haiphong, may find that the average temperature in the continuous increases (Fig. 1).

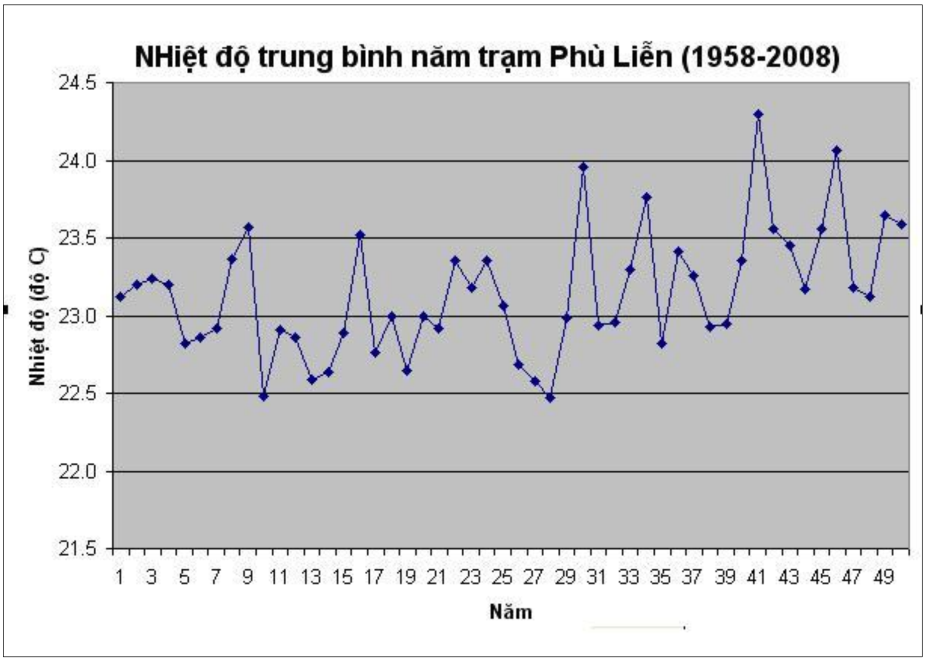


Fig. 1. Evolutions of the average temperature in Haiphong.

Average annual rainfall in the area of Haiphong less stable and is variable in previous years, but during recent fluctuations are not very large and tend to decrease gradually (Fig. 2).

Oceanographic features. In recent years, an average elevation of the sea in Haiphong (Hon Dau station) is also certain changes. Within about 40 years, average water level in here nearly 20 cm (Fig. 3). Simultaneously with the average value of water, the maximum value of the sea here is also constantly increased (Fig. 4).

Storm and storm surges in Haiphong area. Vietnam is usually affected by typhoons and tropical depression, annually the number of them is about 12 to 13 cases. Some time, it can reach to 18 and about 6 of them landed (Vietnam). Haiphong area (17–23 North degree) has nearly half of the total number of storms affecting our country every year. And can say this is one of the areas with high frequency of storms in the world (about 3 per year).

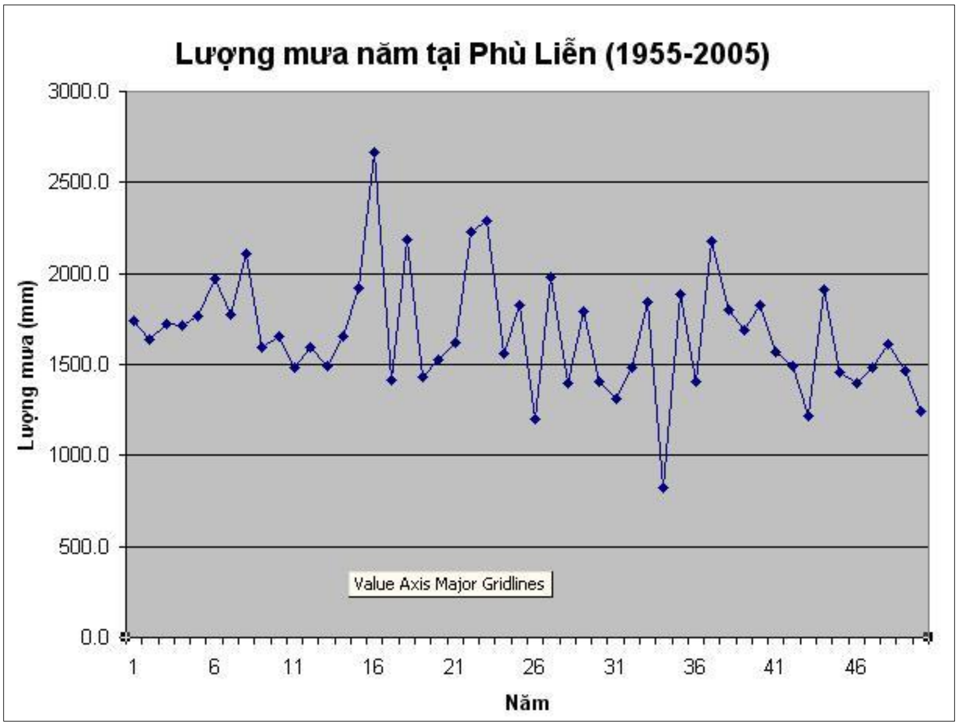


Fig. 2. Evolutions of the annual rainfall in Haiphong.

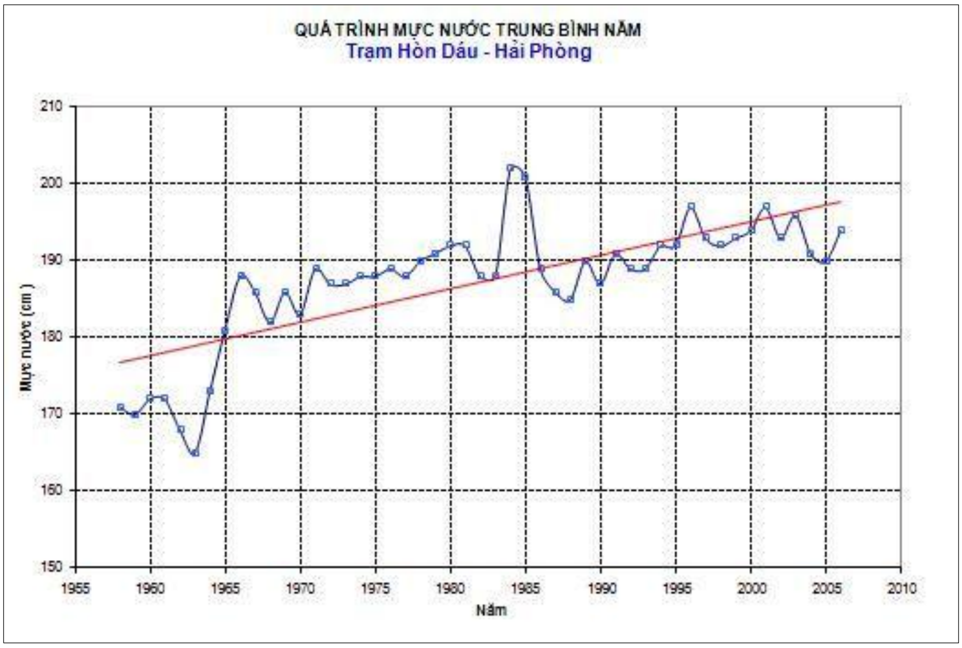


Fig. 3. Evolutions of the annual average sea level at Haiphong.

Storm surges in the particularly dangerous, especially when the tide is on the high period and increased more at risk of flooding. About 40 years, 50% of storm surges is 100 cm or more, 30% from 150 cm upwards and 11% storm surges over 200 cm. Maximum storm surges was observed in this place were 350–356 cm during storm DAN (1989).

Other phenomena. In recent period, the abnormal weather phenomena always occur. Winter cold has lasted longer and longer, mix in the record warm winter, summer storms are stronger, irregular movement make more difficulty for meteorological forecasters. With sea level rise, increasing rainfall events less, causing decline the river flow, so the saltwater intrusion in Haiphong area is becoming more urgent, salty front increasingly penetrate higher to the river, seriously affect agricultural production and fresh water resources.

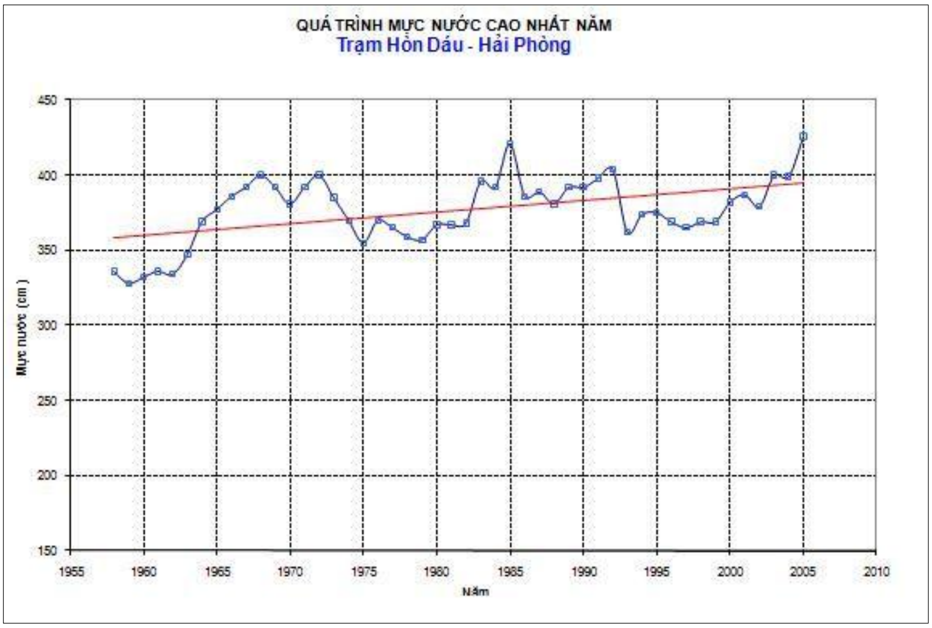


Fig. 4. Evolutions of the highest sea level at Haiphong.

C. Impact of climate change to the area of Haiphong. Urban flooding

Due to the location near the river, when the heavy rains, Haiphong city with the lowest elevation, old drainage system and so often on a large scale flooding, particularly serious in downtown, some time deluges lasted several days. Even when there is no rain, with the high tide also caused severe flooding to many parts of the inner city and coastal areas of some suburban districts of Haiphong. December 2008, the area downtown was flooded by nearly 1 meter influence of tide. Flood situation in Haiphong is increasing frequency and level of flooding.

Population clusters often concentrated in high places from 3 to 3.5 m. Tide in Haiphong averages 3.0 m, maximum 4.2 m. Thus, with conditions normal tide, two-thirds of the land's natural Haiphong will be flooded if the dike system is not surrounded.

Coastal erosion, degrade dike embankment. Erosion phenomenon occurs increasingly clear and intense at the coast of Haiphong, where there are already causing alarm to the loss of many works for coastal cities. Annual Haiphong has invested tens of million USD to reinforced dykes.

The average speed of shoreline erosion in Haiphong coastline of 5.4 m per year, in some places speed reaches 25 m/year. Coastal erosion had wiped many coastal villages. According to documents in the geological past few centuries, the coast of Haiphong are already back on land where the 3–4 km.

Sediment flow. Parallel to the coastal erosion, rising the level of river-bed by the silt, especially for Haiphong port, creeks and streams out of the port and river estuaries obstructing waterway traffic area. Each year Haiphong port has dredged 3-5 million cubic meters of sediment to ensure safe transportation.

Aquatic products. This sector is most affected by climate change due to changes such as rising temperatures, flow regimes, salinity, rainfall change that causes a direct impact to the formation and development of resources structure and quality of food types seafood products, changing their life and reproduction, causing the fluctuation of certain conditions and habitat for aquatic and marine products.

The results of the Haiphong's seafood research institutes has concluded that low quality production tends to increase while production of a species economic value is declining. An impact to our seafood industry to exploit the phenomenon of sea disasters increasingly fierce unpredictable, causing damage to the lives of fishermen, destroying fishing boats offshore. Sea disasters like such as storm, heave northeast monsoon, thunderstorm.

Degraded marine biodiversity. Recently a variety of sea creatures are being serious decline and declining numbers and quality, particularly species of seaweed today almost disappeared from the area of Haiphong. In addition some species are in extinction as he shrimp, prawn, lobster, corals, reptiles and sea mammals live in the sea. Mangroves can protect of dykes and is a habitat for many coastal fishes are in danger of being eradicated due to many reasons, including the causes of sea level rise, much flooding and young trees hard to grow.

Ecosystem characteristics of the city as forest, mangrove forests also affected. Climate change also threatens the sustainability of various economic sectors such as construction, transportation, aviation, industry, commerce and services, especially tourism sector with many major hotels, distributed along the coast.

Changing landscape and coastal islands. Coast of Haiphong will change a lot when sea level rise from half a meter to several meters, can lose most or all of the beaches, causing damages to the tourism and resorts, flooding the limestone islands will make losing original beauty, value natural wonder. Coastal dike system will make losing mangrove forest landscape tropical coastal areas.

Agriculture. Long cold, heavy rains, saltwater intrusion, are the main cause of many influences to productivity as well as plants and animal structure of the port city, in addition to growing pest and widespread, livestock diseases, poultry in many places.

Agriculture sector of Haiphong also faced difficulties due climate change, increase of natural disasters and other extreme phenomena of climate, weather and directly affecting production agriculture – forestry – fisheries and aquatic products.

Salt intrusion and water resources are exhausted. Along with urban flooding, saltwater intrusion go to the upper of the estuary system, changed the quality of irrigation water into the internal. Recently salinity has continually increased and salt water through sewers killing rice. This situation has changed irrigation water quality and living of the people of coastal areas.

At present, the salinity of the rivers constantly improving, the underground water reserves in this increasingly exhausted, low quality should not be large-scale mining. Living water at the same time increasingly pushed upstream, especially in winter little rain, cause difficulties for the service of agriculture and people's life.

Community health. After the first rains, flooding the municipality is the time to increase infectious diseases, the diagnosis and intestinal diseases spread by water from other places to spread. In addition, by crop failures due to climate change will cause hunger, weak resistance, water scarcity will increase diseases caused by poor hygiene, such as diarrhea, sore red eyes, trachoma, skin inflammation, Lao Hac. Flooding residential areas and urban pull as many negative consequences, polluting the living environment, increase disease, damaging roads and other construction work, which raises the complex issues in the planning, renovation of residential and urban areas. Disease of cattle, poultry outbreaks in several neighboring provinces causes psychological fears, reassuring framework for investment and development of production. Prices of materials for production agriculture, fisheries unstable, suddenly rising for months, affecting production of the people.

Future trend and the solutions. Calculations show that sea level will rise to 33–45 cm by 2050 and may be more over so we should prepare of plans for future.

To minimize the risks of climate change caused, Haiphong should have positive measures to actively room, avoiding natural disasters, economic development of sustainable ocean. Haiphong should give a precise forecast of temperature, rainfall, number of days of hot, rising sea levels, in the coming years to the research, evaluate the effects of climate change to localities, thereby could give plan rational exploitation and sustainable environmental conditions and natural resources existing contribution limits the effects of climate change on the city in particular and of Vietnam in general.

Assessment and mapping of partition areas frequently flooded, landslides stone, compromised saline areas, under different levels of sea level rise with scientific basis to prepare plan protect the land.

Construct system of sea dike, construction and development of watershed forests, mangrove forests, planting trees against waves, contribute to reducing damage caused by natural disasters.

In the coming time, the city needs inspection and review the allocation of land within the dyke protection, alluvial rivers, coastal areas. Implementing the withdrawal or change the form of land use in accordance with ecological conditions of each region.

The authority, branches and localities should pay attention for economic development in harmony with the environment, environmental protection, have to calculate about changing the environment, climate and the effects of nature in the future.

Limit deforestation, burning waste products, waste treatment, sanitation focus and develop the use of clean fuel.

Implement a campaign of education information, advocacy to raise awareness about climate change to mobilize all residential city working for the target reduction Minimum and adapt to Climate Change, to ensure sustainable development.

Planting mangroves to protect the coast and the system dikes to avoid erosion by tides and protect lands along rivers.

THE IMPACT OF STOCKING DENSITY ON THE PERFORMANCE OF RAINBOW TROUT (*ONCORYNCHUS MUKISS*) CULTURED IN FLOWING WATER SYSTEM IN LAM DONG PROVINCE

Nguyen Viet Thuy[1], Tran Van Tien[1], Mai Duy Minh[1], Nguyen Thi Xuan Thu[2]

[1] Research Institute for Aquaculture No. 3, Nhatrang, Vietnam

[2] Ministry of Agriculture and Rural Development, Hanoi, Vietnam

e-mail: minhmaiduy@yahoo.com

Introduction

Rainbow trout (*Oncorhynchus mykis*) are one of the economically important species, introduced to Vietnam and their culture has been carried out in several places such as Lai Chau and Lam Dong province. These places have environmental conditions similar to those in temperate areas where native fish occurs. Because they are new, information on suitable stocking densities for a given stage particularly in Vietnam condition is of interest. There are wide discrepancies in stocking densities recommended for rainbow trout. Rainbow trout should be maintained at 30–40 kg/m^3 for getting good welfare (Anon et al., 1996). According to North et al. (2006b), in water flowing system, they should be cultured at less than 50 kg/m^3. Additionally, in water recirculation system, they can be grown out at 80 kg/m^3 (North et al., 2006a) or higher (Lefrancois et al., 2001). However, being cultured at high densities as 80 kg/m^3, the fish are likely to be injured like erosion causing reduction in growth and survival (North et al., 2006a). The stocking density suitable for a species depends on water quality management activities as well as inter-specific competition among fish in a group (Alanärä, Brännäs, 1996; Boujard et al., 2002; Ellis et al., 2002). We asked the question what stocking density is reasonable for rainbow trout cultured in Lam Dong province, Vietnam.

This paper was to identify the suitable stocking densities for culturing rainbow trout with initial average size of 100 g/ind. for completion of technology for growing out in water recirculation system, apart of the project “Research on Technology, Equipment Assembly for Culture of Economically Important Species” No KC.07.15/06-10.

Material and Methods

Rainbow trout (101±14 g; mean±stdev) obtained from Finland were stocked in triplicate into shaded circular tanks of 6.28 m^3 (2 m diameter, 0.5 m depth) at initial stocking densities of 80; 100; 120; 150 inds./m^3 (502; 628; 753 and 942 inds. per tank) equivalent to 21; 26; 32; 40 kg/m^3 respectively. The experiment was run for 10 months (July, 2009 to May, 2010) at Cold Water Fish Station**,** Klong Klanh, Đa Lat, Lam Dong province, Vietnam.

Tanks were supplied with untreated water directly from a stream at ambient temperature of 16-18^o C. Inflow rates were set to 40 L/min in the beginning and increased up to 80 L/min. Water quality parameters in tanks were typically within the following ranges: dissolved oxygen beetwen 6.6 and 7.5 mg/L; pH of 7–8.5; unionized ammonia <0.004 mg/L. Fish were handfed a ration satisfying fish requirement basing on manufacturer's tables (Skretting Aquaculture), which was fed in 4 to 8 meals between 07.00 and 17.00 under ambient lighting. The fish with low health quality expressing erosion and inactively swimming were removed away from the tanks. Each seven days, tanks were cleaned carefully.

Fish weights were measured from monthly sampling of 30 individuals per tank. At the end of the experiment, all fish in each tank were harvested and weighed. The survival rate for each tank was calculated as the number of present fish / total number of initial stocked fish. The significant differences in mean weight of fish among treatments were tested using the excel software.

Results and Discussion

The effects of stocking densities on the performance of fish were not detected in the first seven months but in the last three months. The results of overall mean weight, survival and the standard deviation from mean weight during entire 10 month study period are shown in Figs. 1, 2 and 3, respectively. At the end of 7th month, the overall mean final weight was 575±132; 546±127; 515±110 and 502±87 g for the treatment with the initial stocking densities of 80; 100; 120 and 150 ind./m^3, respectively. These treatments have the maintained densities of 36; 43; 49 and 59 kg/m^3. However, no statistically significant difference in mean fish weight between treatment groups at this study period was detected ($p>0.05$). The survivals of fish in the treatment with the initial stocking densities of 80; 100; 120 and 150 ind./m^3 were 79.18; 78.78; 79.58 and 78.32%, respectively.

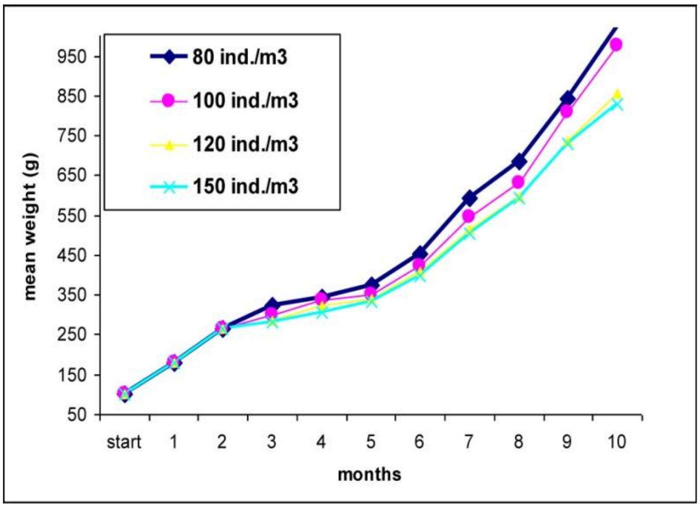


Fig. 1. Mean weight of rainbow trout over ten month culture in four stocking densities.

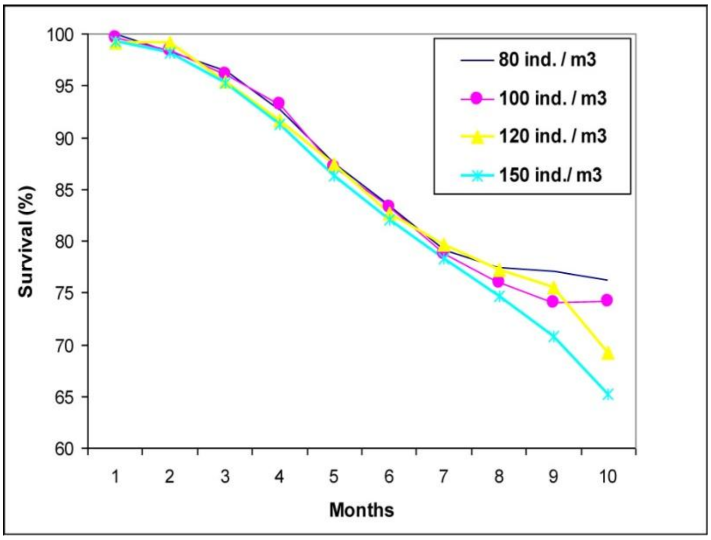


Fig. 2. Survival of rainbow trout over ten month culture in four stocking densities.

The favorable water conditions maintained during the first seven month period could explain for our observations. The performance of fish depends on the water quality and the feed intake. The negative effects of increasing stocking density could be the water quality deterioration (Ellis et al., 2002) caused by higher density and /or the difference in feed intake (Alanärä, Brännäs, 1996; Boujard et al., 2002). In our experiment, the water environmental parameters were maintained at dissolved oxygen of 6.6–7.5 mg/L; pH from 7 to 8.5; unionized ammonia <0.004 mg/L by the use of high rates of water exchange. These are above critical limits for rainbow trout (Wedemeyer, 1996). Also although fish in all treatments were fed a ration satisfying fish requirement, the average feeding rates and feed conversion rates were similar between treatment groups. Feed conversion ratios were not significantly different between the treatment groups (1.43±0.11; 1.41±0.11; 1.39±0.11 and 1.45±0.11, respectively ($p>0.05$). Our results are similar to those reported by several authors (Ellis et al., 2002; North et al., 2006; Good et al., 2009) that increasing stocking density did not affect the performance of rainbow trout. This is because in addition to suitable water conditions, the stocking density did not exceed the maximum level which could cause behavioral routs of welfare infringement. In the present study, at the end of seventh month, the treatment groups with the initial stocking densities of 80; 100; 120 and 150 inds./m^3 respectively were maintained at 36; 43; 49 and 59 kg/m^3. This suggests that the density of 59 kg/m^3 is still in the safe range for culturing rainbow trout from 100 to 500 g/ind.

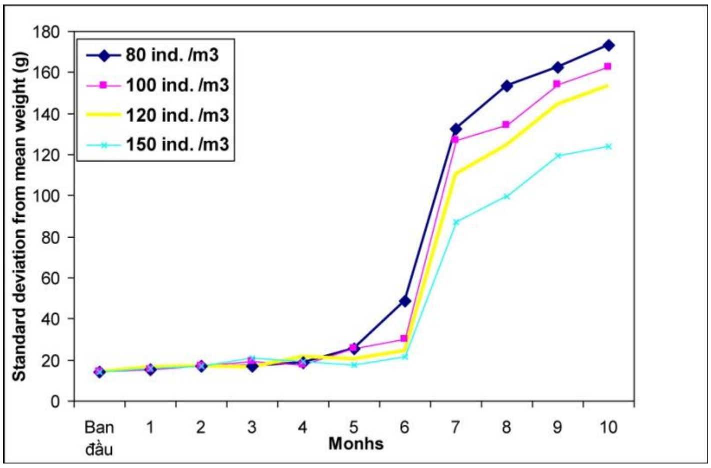


Fig. 3. Standard deviation from mean weight of rainbow trout over ten month culture in four stocking densities.

In the last three month study period, the stocking density affected the survival and growth of fish. The survival rates at the end of the experiment (the end of 10th month) were 76.23; 74.17; 69.18 and 65.27% for treatment groups of 80; 100; 120 and 150 ind./m^3 respectively. The mean weight of fish from those treatment groups were 1022±173; 975±162;

858±153; 830±124 g respectively. No significant differences in mean weights was detected neither between treatment groups with lower stocking densities (80 and 100 ind./m3) nor between the ones with higher densities (120 and 150 ind./m^3) ($p>0.05$). However, the statistically significant difference was detected between the lower and higher treatment groups ($p<0.05$).

The difference in growth and survival of fish between treatment groups in the present study could be explained by the excessive stocking density compared to maximum level in the local water condition. A high stocking densities (ex. of 80 kg/m^3) could have caused fish with more erosive fin (North et al, 2006) and skin and kidney (Good et al., 2009) reducing welfare of fish and consequently reducing the growth even in the favorable water conditions. In the present study, the maintained densities in the treatment groups of 80; 100; 120 and 150 ind./m^3 which, at the end of 7th month, were 36; 43; 49 and 59 kg/m^3 increased to 62; 72; 75 and 85 kg/m^3 respectively at the end of study. During the last three months of the study, in the treatment groups with higher densities, more fish were found with fin erosion, swimming inactively and those fish were removed from the tanks explaining for reduction in growth and survival. The significant differences in growth of fish between lower density groups (initial stocking densities of 80 and 100 ind./m^3 equivalent to 62 and 72 kg/m^3 at the end of study) and higher density groups (initial stocking densites of 120 and 150 ind./m^3 equivalent to 75 and 85 kg/m^3 at the end of study) recommend that the maintained density of 75 to 85 kg/m^3 was not suitable for growing rainbow trout in the present study. Good et al. (2009) found that at the maintained density of 80 kg/m^3, increasing flowing rate of water could reduce fin erosion of fish and increase growth and survival. This should be applied in practical rainbow trout culture.

There appeared to be an increase in weight variation as the stocking densities decreased (Fig. 3). The standard deviations of mean weight from the treatment groups of 80; 100; 120 and 150 ind./m^3 kept similar in the first five months, increased fast and got quite different in the last three months. There are two possible reasons for this observation. The first possible reason is the effect of the social environment within fish populations where inter-individual competition within the fish group increases overtime (Jobling, 1995). Weight variation increased in all treatments as higher level of hierarchies comprising a group of dominant individuals at the top of the hierarchy, followed by a number of subdominants and, thereafter, a number of subordinates with low rank positions (Symons, 1970). Bagley et al. (1994) suggested that the formation and maintenance of hierarchies becomes more difficult at high stoking densities. This could be explained for larger standard deviation in groups with lower compared to higher maintained densities. Additionally, removal of fish with poor welfare that should have low growth rate in the treatment groups with higher densities might narrow the standard deviation of mean weight. The results suggest a minimum stocking density to minimize the variation in fish weight. To obtain high growth but smaller variation in fish weight, stocking density of 100 kg/m^3 shows benefit over the rest ones.

Conclusions

In the culture system where the water environmental parameters are maintained over critical level, the density (ind./m^3 and kg/m^3) still have effects on rainbow trout performance. For growing out fish with initial average weight of approximately 100 up to 1000 g, the initial stocking density should be approximately 100 ind./m^3 and the densities should be maintained less than 70 kg/m^3.

The culturists should be aware of lowering densities (kg/m^3) and increase inflow rates of water to avoid erosion in fish.

Acknowledgments

The study was supported by the national project No. KC.07/06-10.

References

Abbott J.C., Dill L.M. 1985. Patterns of aggressive attack in juvenile steelhead trout *Salmo airdneri* // Canadian Journal of Fisheries and Aquatic Sciences. V. 42. P. 1702–1706.

Alanärä A., Brännäs E. 1996. Dominance in demand-feeding behaviour in Arctic charr and rainbow trout: the effect of stocking density // Journal of Fish Biology. V. 48. P. 242–254.

Anon. 1996. Report on the Welfare of Farmed Fish. Farm Animal Welfare Council, Surbiton. 88 p.

Bagley M.J., Bentley B., Gall G.A.E. 1994. A genetic evaluation of the influence of stocking density on the early growth of rainbow trout (*Oncorhynchus mykiss*) // Aquaculture. V. 121. P. 313–326.

Bosakowski T., Wagner E.J., 1994. Assessment of fin erosion by comparison of the relative fin length in hatchery and wild brown trout in Utah // Canadian Journal of Fisheries and Aquatic Sciences. V. 51. P. 636–641.

Boujard T., Labbé L., Aupérin B. 2002. Feeding behaviour, energy expenditure and growth of rainbow trout in relation to stocking density and food accessibility // Aquaculture Research. V. 33. P. 1233–1242.

Ellis T., North B., Scot A.P., Bromage N.R., Porter M., Gadd, D. 2002. The relationships between stocking density and welfare in farmed rainbow trout // Journal of Fish Biology. V. 61. P. 493–531.

Good C., Davidson J., Welsh C., Brazil B., Snekvik K., Steven P. 2009. The impact of water exchange rate on the health and performance of rainbow trout *Oncorhynchus mykiss* in water recirculation aquaculture systems // Aquaculture. V. 294. P. 80–85.

Jobling M. 1995. Simple indices for the assessment of the influences of social environment on growth performance, exemplified by studies on Arctic charr // Aquaculture International. V. 3. P. 60–65.

Lefrancois C., Claireaux G., Mercier C.e, Aubin J. 2001. Effect of density on the routine metabolic expenditure of farmed rainbow trout *Oncorhynchus mykiss //* Aquaculture. V. 195. P. 269–277.

North B.P., Turnbull J.F., Ellis T., Porter M.J., Migaud H., Bron J., Bromage N.R. 2006a. The impact of stocking density on the welfare of rainbow trout (*Oncorhynchus mykiss*) // Aquaculture. V. 255. P. 466–479.

North B.P., Ellis T., Turnbull J.F., Davis J., Bromage N.R. 2006b. Stocking density practices of commercial UK rainbow trout farms // Aquaculture. V. 259. P. 260–267.

Symons P.E.K. 1970. The possible role of social and territorial behaviour of Atlantic salmon parr in the production of smolts // Technical Reports, Fisheries Research Board of Canada. V. 206. P. 1–25.

Wedemeyer G.A. 1996. Rearing conditions: effects on fish in intensive aquaculture. Fish Stress and Health in Aquaculture // Fish stress and health in aquaculture, Society for Experimental Biology Seminar Series 62. Eds. G.K. Iwama, A.D. Pickering, J.P. Sumpter and C.B. Schreck. Cambridge: Cambridge University Press. P. 38–71.

ON THE MORPHOLOGY AND TAXONOMY OF PACIFIC GASTROPODS IN FAMILIES OF TROPICAL ORIGIN LITIOPIDAE AND DIALIDAE (CAENOGASTROPODA: CERITHIOIDEA)

***Larisa A. Prozorova*[1], *Tatiana Ya. Sitnikova*[2], *Ronald Noseworthy*[3], *Ivan A. Kashin*[4], *Alexander Yu. Zvyagintsev*[4]**

[1]Institute of Biology and Soil Science, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, 690022, Russia; e-mail: lprozorova@mail.ru

[2] Limnological Institute of the Siberian Branch of Russian Academy of Sciences, Irkutsk, 664033, Russia; e-mail: sit@lin.irk.ru

[3]Field Associate, Shellfish Aquaculture and Research Laboratory, Faculty of Marine Biomedical Science, Jeju National University, Korea; e-mail: rgnshells@yahoo.ca

[4]A.V. Zhirmunsky Institute of Marine Biology, Far Eastern Branch of Russian Academy of Sciences, Vladivostok, 690041, Russia; e-mail: ayzvyagin@gmail.com

The gastropod families Dialidae and Litiopidae are of tropical origin, but are distributed in warm-temperate regions. Litiopidae live in shallow-water seagrass environments (*Alaba* H. & A. Adams, 1860) or on floating *Sargassum* mats (*Litiopa* Rang, 1869). Dialidae prefer coralline algae and seaweed, and are also found under rocks, in the intertidal and subtidal zones. These closely related families in the Pacific range northward to Japan and Korea (Dialidae and Litiopidae) or the Southern Russian Far East (Litiopidae ?). A rather diverse litiopid fauna is recorded from Japan and the Korean Peninsula (Higo et al., 1999; Noseworthy et al., 2007, and others).

Diffalaba vladivostokensis (Bartsch, 1929) from Southern Primorye is the only Russian species, and the northernmost record of that mollusk group. The taxonomic position of this species is still in doubt because of the lack of biological data. Sometimes the species is referred to *Alaba,* and *Astrolaba* Laseron, 1956, or cited as a junior synonym of *Diffalaba picta* (A. Adams, 1861) (Higo et al., 1999). To make a more precise taxonomic identification of *D. vladivostokensis* from Vostok Bay, in the northern area of Peter the Great Bay, a morphological study was conducted. An overall examination of shell and animal morphology was made using a MBS-10 binocular microscope with scales. A detailed examination was also carried out using a Philips 525 Scanning Electron Microscope. Juvenile shells of this species, collected in Vostok Bay, were previously described in detail (Prozorova, Sitnikova, 2010). The most taxonomically important characters of *D. vladivostokensis* are listed below.

The shell (Fig. 1) is nearly smooth, without a columellar tooth and umbilicus; body whorls with weak peripheral angle; aperture is drop-like, with thin edge; the operculum (Fig. 2A) is ovate, paucispiral, transparent, with an eccentric nucleus and a fine ridge-like attachment scar below the nucleus; protoconch (Fig. 2B) comprises 3.0–3.5 whorls, the first 3.0 whorls are smooth, glossy, transparent, light brown; teleoconch is dull, yellowish, and sculptured by fine growth lines crossed by slight, strap-like spiral striae (more on the base) (Fig. 1). The radula is taenioglossate; the hourglass-shaped rachidian tooth (Fig. 2C) has a triangular buttress which is wider than long; the cutting edge of the rachidian has a large central cusp and four smaller denticles, a pair on each side. The small head has a short bilobed snout and a pair of long cephalic tentacles; the foot is long and narrow, but extensible, and is supplied by two mucous glands, propodial and mesopodial. The leading edge of the propodium has a pair of tentacles, one on each side; the propodial tentacles are shorter than the cephalic ones; the epipodial tentacles are absent, and the mantle edge is smooth. The ridge-like osphradium is a little shorter than the ctenidium.

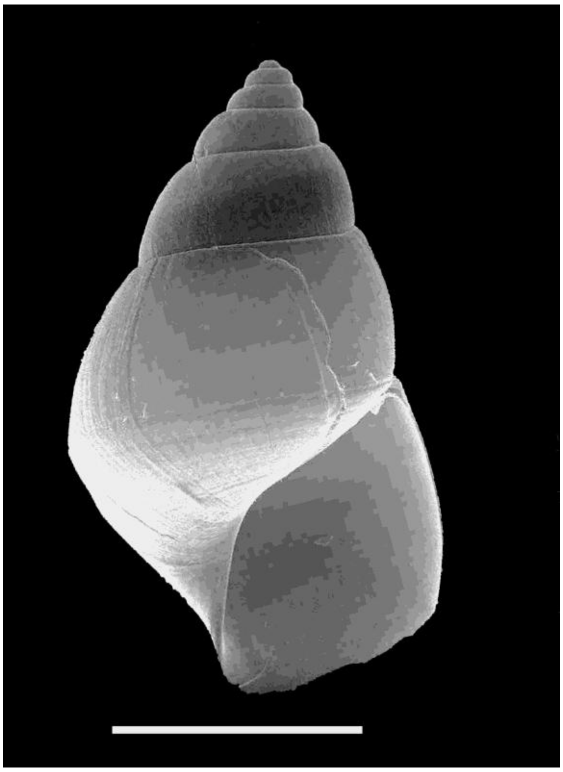


Fig. 1. Juvenile shell of *Diffalaba vladivostokensis* (Bartsch, 1929) from Vostok Bay (Peter the Great Bay, the Sea of Japan). Scale bar – 1 mm.

These mollusks were referred to Litiopidae based on the following characteristics: a long active foot, long cephalic and podial tentacles, large podial mucous glands, an operculum with a narrow spiral ridge on the attached surface, and the shape of the rachidian tooth (Prozorova, Sitnikova, 2010). However, the smooth protoconch (Fig. 2A) and the absence of epipodial tentacles cause the Vostok Bay litiopids to exhibit a distinct morpho-

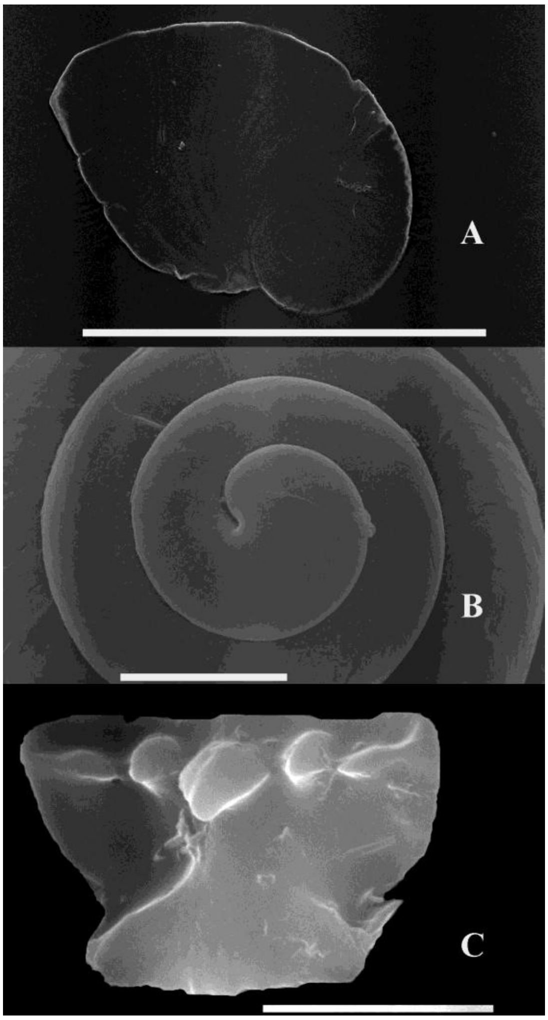


Fig. 2. *Diffalaba vladivostokensis* (Bartsch, 1929) from Vostok Bay: A – operculum, inner view; B – protoconch; C – rachidian tooth. Scale bars: 1 mm (A); 0,1 mm (B); 10 μm (C).

logical difference from two other closely studied recent species of Litiopidae, *Alaba incerta* (Orbigny, 1842) and *Litiopa melanostoma* Rang, 1829 (Houbrick, 1987). These species are characterized by long, retractible, epipodial tentacles along the posterior side of the foot, and protoconchs sculptured with numerous axial riblets and subsutural plaits (Houbrick, 1987). Not only *D. vladivostokensis* but also fossil litiopids of *Litiopella* Bandel et Kiel, 2000 lack the distinct spirals on the protoconch (Bandel, Kiel, 2000). Furthermore, the smooth protoconch and the length of the osphradium (a little shorter than the ctenidium), and some other characters, in accordance with Houbrick (1988), show the possible relationship of *D. vladivostokensis* to the Dialidae known to occur on Japan Sea in Japan and Korea (Higo et al., 1999; Noseworthy et al., 2007). Also, living *Diala* species examined in Australia did not have epipodial tentacles (Houbrick, 1987). The conchological similarity of the se taxa was previously noted (Golikov, Starobogatov, 1976). Thus, *D. vladivostokensis* shares both litiopid and dialid characters.

The generic identification of this Primorye litiopid is also doubtful. The original description of *Diffalaba* Iredale, 1936 is very brief (Iredale, 1936). The animal and larval shell morphology of the type species of the genus, *D. opiniosa* Iredale, 1936 from Australia, is not yet described. Finally, some specialists refer *D. picta* to *Astrolaba* Laseron, 1956 (Dialidae?), while Houbrick (1987) excluded this genus from Litiopidae.

Concerning the specific identification, we should conclude that *D. vladivostokensis,* which was found to be lacking in epipodial tentacles, is not a synonym of *D. picta,* which has four epipodial tentacles, a pair on each side of the foot, and a posterior pair (A. Adams, 1861). Furhermore, there are essential differences in shell morphology between *D. vladivostokensis* and *D. picta* (Golikov, Scarlato, 1967; personal observation).

Therefore, a further comprehensive investigation of the morphology of the Dialidae and Litiopidae is necessary. In order to ascertain the taxonomic position of the litiopids and dialids from the Oriental region, a comparative morphological study of their representatives from South East Russia, Japan, Korea, China, and Vietnam is planned.

Acknowledgements

The work was supported by the following Russian Science Foundation grants: Presidium RAS and FEBRAS № 06-1-П-11-023, RFBR № 09–04–98583-r_vostok_a (V.V. Bogatov, Principal Investigator).

References

Adams A. 1861. On the animal and affinities of the genus *Alaba* with a review of the known species, and description of some new species // Annals and Magazine of Natural History. P. 1–7.

Bandel K., Kiel S. 2000. Earliest known (Campanian) members of the Vermetidae, Provannidae and Litiopidae (Cerithioidea, Gastropoda), and the discussion of their possible relationships // Mitt. Geol.-Palaeont. Inst. Univ. Hamburg. Heft 84. S. 209–218.

Golikov A.N., Scarlato O.A. 1967. Molluscs of the Possjet Bay (the Sea of Japan) and their ecology // Mollusks and their Role in Forming of Faunas. Leningrad: Nauka. P. 5–154.

Higo S., Callomon P., Goto Y. 1999. Catalogue and Bibliography of the Marine Shell-Bearing Mollusca of Japan. Osaka: Elle Scientific Publications. 749 p.

Houbrick R.S. 1987. Anatomy of *Alaba* and *Litiopa* (Prosobranchia: Litopidae): systematic implications // Nautilus. V. 101, N 1. P. 9–18.

Noseworthy R.G., Lim N.R., Choi K.S. 2007. A catalogue of the mollusks of Jeju Island, South Korea // Korean Journal of Malacology. V. 23, N. 1. P. 65–104.

Prozorova L.A., Sitnikova T.Ya. 2010. Morphology and systematic implications of juvenile litiopids (Caenogastropoda: Cerithioidea: Litiopidae) from the Southern Russian Far East // Proceedings of China-Russia Bilateral Symposium on “Comparison on Marine Biodiversity in the North-West Pacific Ocean”, 10–11 October 2010, Qingdao, China. P. 142–145.

THE JOINT IMB FEB RAS AND VAST INSTITUTIONS RESEARCH ACTIVITY: LONG-TERM COLLABORATION HISTORY AND NEW PERSPECTIVES IN MARINE BIODIVERSITY STUDIES

T.N. Dautova[1], Nguyen Tac An[2], T.V. Lavrova[1]

[1]A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of Russian Academy of Sciences, Vladivostok 690041, Russia; e-mail: tndaut@mail.ru

[2]Institute of Oceanography, Vietnam Academy of Sciences and Technology, Nha Trang, Vietnam

There is a growing recognition that reduced diversity makes the world and its inhabitants increasingly vulnerable to natural and human-induced changes. The past decades have seen a rise of interest in biological and cultural dimensions of diversity, the interactions between them and their connection to social and economic development. 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 joint efforts of the ecologists to trace the global and local trends and perspectives in the biodiversity changing in the coral ecosystems have to be focused on the main components of these ecosystems. These components which may be called critical functional groups (corals, fish and sea weeds resources, sea stars *Acanthaster* and others, sea cucumbers, mollusks, shrimps, worms) are fundamental to understanding resilience and avoiding phase shifts from coral dominance to less desirable, degraded ecosystems. The status and biological resources of these animals have to be studied in connection physical environmental factors such as sedimentation and turbidity, eutrophication and water quality, light, salinity and others.

These basic scientific studies in the ecology/physiology of the marine animals are highly promising for the practical purposes such as the coastal marine ecosystems management, coral reefs restoration and marine farming. In addition, the data obtained will assist to solve the present global problem of the tropical zone – clarification the nearest future of the suppressed or destroyed coral reefs.

Fig. 1. First visit of Prof. A.V. Zhirmunsky and Dr. E.A. Titlyanov to Vietnam (1979).

The well developed institutional arrangements need to be addressed for an effective monitoring studies and ecosystems' control. The important task in the frame of the project is – to develop the methods of the monitoring of the status of the coral ecosystems and their biological resources using the basic knowledge about the ecology habits of the main reef-building corals and other animals as biomarkers. It is with hope and perseverance that the actions at the local levels translate to the broader understanding and shared stewardship of the larger marine tropical ecosystem.

Since 1970, the year of foundation of A.V. Zhirmunsky Institute of Marine Biology (hereafter IMB), Far Eastern Branch of the Russian Academy of Sciences, the major research objectives of the IMB are: the study of the flora, fauna, ecology, and production of marine biota in the Far East seas and the Pacific; research and development of the scientific foundations for the conservation, reproduction, and management of biological resources; the study of adaptation, ontogenesis and evolution of marine organisms. Such objectives are the main tasks of some Institutions of the Vietnamese Academy of Science and Technology, in particular, the Institute of Ecology and Biological Resources, Institute of Oceanography, Institute of Marine Environment and Resources, Nha Trang Institute of Technology Research & Application, etc. First visit of IMB specialists to Vietnam was hold in 1979 (Figs. 1, 2).

Fig. 2. In the beginning of the 1980s (Prof. Nguyen Tac An and Prof. A.V. Zhirmunsky – in the center).

Staffs of the Institute of Marine Biology FEB RAS and VAST Institutes have more than 30 years long collaboration experience in the area of the marine ecosystems research. Members of these institutes participated in tens of the marine and coastal expeditions. The original extensive data on the distribution patterns and resources of Vietnamese intertidal animals and plants were achieved. More than 18,000 samples of benthos and phytoplankton which were taken at 78 districts of littoral and coral populations were examined. The lists of the most important marine species of some regions of Vietnam were prepared including reef-building corals, bivalve mollusks, echinoderms, algae. More than 8,000 species of invertebrates were recorded. The searching a biogeography border between the southern and the northern faunas of Vietnam, researches in biotechnology (sea weeds farming and biologically active substances studies) and monitoring of coastal waters and rivers' mouths were conducted in the frame of the joint projects "The South China Sea" and "The World Ocean" (1985–1990).

After the above mentioned period of cooperation 122 scientific papers were published before 2000 year as a result of our collaboration. The range of conferences and 3 Joint Russia-Vietnam Symposiums on marine biology were held in Vietnam and Russia. The successful history of our collaboration can be estimated through long-termed successive periods which history started since 1980 (Nguyen Tac An, Dautova, 2008).

1980–1985. The first agreement of cooperation between IMB FESC AS USSR (IMB, Vladivostok, Russia) and IMR NCSI of Vietnam (IMR, Nha Trang, Vietnam) was signed and a range of joint programs of cooperation were performed, one of them:

"Tropical littoral ecosystems (coral reefs, the littoral: its biodiversity and productivity)" was devoted to some aspects of marine biodiversity**.** It was shown that coral reefs of Vietnam possess great species diversity. These high-productive ecosystems act as an important source of organic substance, which has a great influence on productivity of coastal waters of the South China Sea. The littoral of Vietnam coastal waters has a great productivity – the biomass of marine organisms there is more than 3.3 kg/m ^{2} (Tkhu Island, 1984). Lists of the most important marine species out of some regions of Vietnam were prepared: they included reef-building corals, bivalvians, and algae. An original description was given to bionomic groups of plants and animals found on an extensive territory of Vietnamese littoral, from Khang Khoa province to Gulf of Siam. More than 8000 species of invertebrates were recorded.

There were several cooperative coastal expeditions of IBM FEB RAS and IMR NCSI of Vietnam, and also a scientific-research trip on SRV «Academician Nesmeyanov" (1984).

Two Soviet-Vietnamese scientific symposia on marine biology were held to discuss the research results (the 1st – April 1981, in Ho Chi Minh, the 2nd – March 1984, Nha Trang).

1986–1990. Joint researches were held in the project «The South China Sea» of program «The Worldwide Ocean» (supervisors A.V. Zhirmunsky, E.A. Titlyanov, Le Chong Fan and Nguen Kim Hung). The main cooperative ideas were: search of a biogeographic border which divides the southern and the northern faunas of Vietnam; keeping researches in spheres of biotechnology (mariculture and biologically active substances); biological monitoring of coastal waters and rivers' mouths. Joint programs of cooperation were conducted during that period were:

Consistency, structure and productional characteristics of Vietnamese littoral communities. The research of species diversity of reef building corals and mass marine invertebrates was continued. The change of their communities related to depth changes and substrate types was followed. Types of benthic deposits and main zones of reefs sedimentations were distinguished. A study of species list and quantitative distribution was done, supplies of benthic plants on littoral and sublittoral of Nha Trang bay, Kondao, Anthoi, Thotu islands were valuated. Concentrations of nitrates and nitrites were measured for subterrian waters, population of denitrificating and saprotrophic bacteria, velocity of denitrification, nitrification and nitrium fixation were also found out.

Organisms epibiothic on ships and hydrotechnical constructions. (Species composition and quantitative indexes of epibiothic organisms found on ships, pieres and navigation buoys of southern Vietnam were studied).

The 3rd joint symposium от marine biology was held in March 1986, Nha Trang. There were 70 Vietnamese and 40 Russian scientists, 20 reports were made.

1990–2000. Research of consistency and structure of productive coral reef ecosystems and their conditions for rational use and protection was continued. Biotechnology (mariculture, biologically active substances) and biomonitoring of the South China Sea coastal waters were hold.

Data of the most important factors of physical environment which have great influence on Vietnamese reefs were originally achieved. Intensification of sedimentation and character of water movement at coral reefs were found out for Tonkin Bay and coast of Quang Ninh province.

Fig. 3. A series of monographs by Yu.Ya. Latypov and T.N. Dautova
“Scleractinian Corals of Vietnam».

Species composition and distribution of reef-building scleractinian corals were studied, which was followed by publishing 5-volumed monography with keys: Latypov Yu.Ya., Dautova T.N. “Scleractinian corals of Vietnam» (Fig. 3). It was found out that coral fauna of Vietnam (360 species of scleractinians) is equal to the one in the centre of species diversity (in Indonesia and Philippines). Data of zooplankton biodiversity found in coral reef waters of Tonkin bay were originally obtained.

Information of coral ecosystems diversity distribution and current state of Vietnamese coral reefs in context of intensive economical activities were originally achieved (Latypov, 1995, 2000). Preliminary recommendations were given on coral ecosystems monitoring and choosing coral reefs for setting nature protection terms.

122 scientific papers were published as a result of co-working. Among them, 6 are subject collections and monographs, including keys to reef-building scleractinians of Vietnam.

Co-researches in the 21st century. Joint works are being held due to agreements of cooperation between IMB FEB RAS and scientific organizations of VAST SRV.

Collaboration with the Institute of Oceanography VAST, Nha Trang (2002–2010). The main tasks are: macrophytes and reef-building corals as indicators of anthropogenic pollution; resources of marine algae, grasses and reef-building corals, their realization in nature and cultivation. It was shown that mass death of coral reefs of the southern Vietnam in 1988, 1994 and 1998 led to the increased number and biomass of algae in these regions. Corals of shallow bays were found not to indicate the water polluted with organic wastes. Macrophythic algae act as indicators of organic pollution only in littoral and sublittoral zones of bays and lagoons of the southern Vietnam. After 1981–1983, a second study was performed at Wan Fong and Nha Trang bays. Species of scleractinian corals which provide quick regeneration and growth of their colony fragments and also having great degree of surviving (not less than 90%) were experimentally found. Experiments were also performed to grow corals in natural environment of Vietnamese waters (Titlyanov et al., 2005). The essential task was an exchange of specialists and research of marine plants species consistency in southern and central parts of Vietnam. Writing a book "Marine plants of Vietnam" was as a important result of the long-term cooperation (Fig. 4).

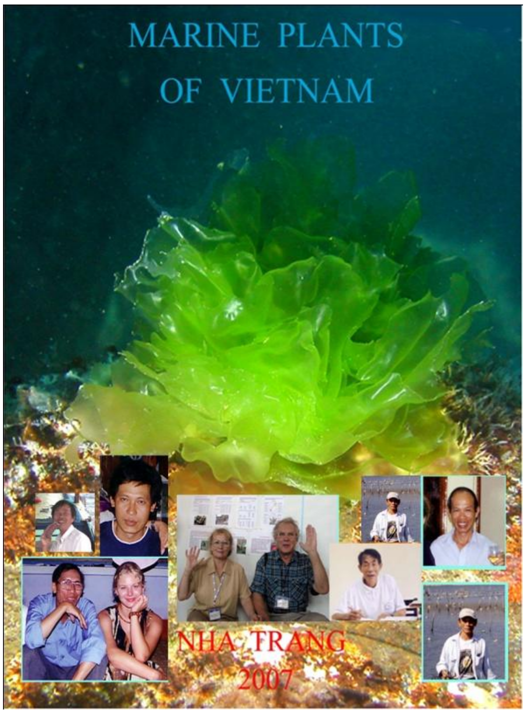


Fig. 4. Russian and Vietnamese colleagues collaboration resulted in publication of the book "Marine Plants of Vietnam".

Co-researches with the Institute of Materials Sciences VAST, Nha Trang (2006–2011). The main tasks are: the study of species diversity and distribution of southern Vietnam marine plants; developing new methods of receiving planting materials of algae; introduction and cultivating of high-productive agarum-posessing *Gracillaria* algae. 200 species of algae were collected in non-polluted aquatories of Nha Trang and identified. 100 algae species were collected in regions of maximum anthropogenic pollution with organic wastes.

Cooperation with the Institute of Marine Environment and Resources, Haiphong (2007–2010). The main tasks are: the study of species diversity and distribution of marine macrophytes of northern Vietnam; introduction of high-productive agarum-having *Gracillaria* alga to the northern part of Vietnam; comparative study of productional characteristics of agarum-posessing algae; developing of the methods of industrial algae cultivation.

Fig. 5. International Vietnam-Russian Research Laboratory of the Marine Biology and Ecology.

Co-researches with the Institute of Ecology and Biological Researches, Ha Noi (2006–2011). The main tasks are: a comparative study of nematodes fauna of marine and salt-watered regions of Vietnam and the Far East of Russia; a research of influence of rivers on marine ecosystems. The valuation of invertebrates' reproductive potential under anthropogenic pressure.

To develop the cooperation between Institute of Marine Biology FEB RAS and VAST institutes the agreement on the establishing of the International Vietnam-Russian Scientific Laboratory of the Marine Biology and Ecology Researches was signed in 2009 year (Fig. 5). The Laboratory (under the aegis of FEB RAS and VAST) is established on the base of Institute of Marine Biology FEB RAS and Institute of Oceanography VAST (Nha Trang). It' main role is to support the further developing of joint practical and basic scientific projects of Russian and Vietnamese scientists and researchers. The establishment of the International Vietnam-Russian Laboratory of the Marine Biology and Ecology Researches as a joint scientific department provides the possibilities for the integration of our efforts in the field of marine sciences and for the developing of our long-term collaborative plans as well. The comprehensive goal of this new Laboratory is the development of our scientific and educational partnership for the:

- joint scientific surveys in the wide range of the marine biology and ecology problems, first of all – marine biodiversity and bioresources;
- mutual exchanging by our knowledge, experience and modern research methods;
- encouraging direct contacts between researchers;
- obtaining new scientific knowledge for the decision making for an effective marine ecosystems' management;
- the promotion of the issue to attract the attention of the governmental and intergovernmental organizations to the hot problems of the marine ecosystems' changing under the environmental fluctuations both at the local and global scales.

Collaborative research programs of the laboratory include the composing of the fauna lists for major groups of animals: reef-building corals, scleractinian corals, octocorals, bivalve mollusks, marine worms, and echinoderms together with survey of physiology and taxonomy of marine animals by modern research methods (morphological and molecular). Based on the data obtained and analyzed by T.N. Dautova and V.A. Parensky, relatively healthy and depressed coral reefs will be chosen as model ecosystems to study the faunal biodiversity.

Successful collaboration will be continued in frames of the APN (Asia-Pacific Network for the Global Change Researches) project "Coastal Marine Biodiversity of Vietnam: Regional and Local Challenges and Coastal Zone Management for Sustainable Development". As a result of such joint researches, a collective monograph "Biodiversity and Bioresources of the Vietnam Coastal Waters" is going to be prepared and published.

References

Latypov Yu.Ya., Dautova T.N. 2005. Species composition of corals in the silty shallows of the Baitylong Archipelago (Gulf of Tonkin, South China Sea) // Russian Journal of Marine Biology. V. 31, 5, P. 311–318. [in Russian].

Latypov Yu.Ya. 1995. Community structure of scleractinian reefs in the Baitylong Archipelago (South China Sea) // Asian Marine Biology. V. 12. P. 27–37.

Latypov Yu.Ya . 2000. Coral communities of the northern part of the Gulf of Tonkin, South China Sea // Russian Journal of Marine Biology. V. 26. P. 250–257.

Nguyen Tac An, Dautova T.N. 2008. Joint Vietnamese-Russian Researches in Marine Biology during 1980-2007 // Journal of Marine Science and Technology. N 4. P. 89–95.

Titlyanov E.A., Titlyanova T.V., Yakovleva I.M. 2005. Regeneration of artificial injuries on scleratinian corals and coral/algal competition for newly formed substrate // Journal of Experimental Marine Biology and Ecology. V. 257. P. 163.

SPECIES OF DEEP-WATER BARNACLES NEW FOR THE FAUNA OF VIETNAM AND COMPARATIVE ANALYSIS OF SOUTH CHINA SEA AND NORTHEAST ATLANTIC BIOLOGICAL DIVERSITY OF DEEP-WATER BARNACLES

Oleg P. Poltarukha

A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences,

Leninsky prospect 33, Moscow, Russia

e-mail: poltarukha@rambler.ru

The fauna of barnacles (Cirripedia, Thoracica) of Vietnam is considered to be well studied. A recently published monograph (Poltarukha, Zvyagintsev, 2008) mentions 86 species of cirripedes inhabiting these waters; most of them are dwellers of intertidal and subtidal zones. However, the information on the fauna of deep-water barnacles of Vietnam still remains scanty, especially in comparison with the data about deep-sea Cirripedia of the adjacent areas, such as the Philippines.

The barnacles, collected in lower subtidal-bathyal zones of Vietnam in 1984 in the course of scientific cruise of the RV «Odissey», and deposited in the collections of Zoological Institute RAS (St.-Petersburg) were studied by author. The brief characteristics of the sampling stations and the names of cirripede barnacles found in the samples follow.

Trawl N 45, 17.09.1984, 11°35´0 N, 109°37´0 E, 120 m deep, rock, on a spine of the sea urchin, *Solidobalanus echinoplacis* (Stubbings, 1936) – 5 specimens;

Trawl N 52, 22.09.1984, 11°09´6 N, 110°02´0 E, 700 m deep, silt, on spines of sea urchin, *Paralepas scutiger* (Broch, 1922) – 10 specimens, *Megalasma minus* Annandale, 1906 – 4 specimens;

Trawl N 55, 23.09.1984, 10°41´8 N, 109°53´8 E, 495-500 m deep, silt, on spicules of sponges, *Scalpellum stearnsii* var. *inerme* (Annandale, 1916) – 2 specimens;

Trawl N 56, 23.09.1984, 10°23´24 N, 109°45´8 E, 490 m deep, silt, on spicules of sponges, *Scalpellum stearnsii* var. *inerme* (Annandale, 1916) – 8 specimens, *Arcoscalpellum sociabile sociabile* (Annandale, 1905) – 2 specimens (sitting on *Scalpellum stearnsii* var. *inerme*), *Rostratoverruca intexta* (Pilsbry, 1912) – 1 specimen (sitting on *Scalpellum stearnsii* var. *inerme*);

Trawl N 60, 24.09.1984, 10°38´4 N, 109°50´5 E, 400 m deep, silt, *Striatobalanus tenuis* (Hoek, 1883) – 4 specimens.

Our study revealed 7 species of barnacles including 6 species (Fig. 1), which appeared new for the fauna of Vietnam: *Arcoscalpellum sociabile sociabile*, *Megalasma minus*, *Paralepas scutiger*, *Rostratoverruca intexta*, *Scalpellum stearnsii* var. *inerme*, *Solidobalanus echinoplacis*. All the revealed species have been reported earlier on from the South China Sea, mostly from areas of the Philippines and Malay Archipelago, which is evidence of similarity between deep-sea faunas of barnacles in these areas and that of Vietnam.

It is interesting that almost all barnacles found in the investigated samples have been attached to other bottom animals. This fact can testify to a wide distribution of obligate symbiotic species of discussed group not only in coastal waters, but also in deep-water communities of a tropical zone. It has been shown earlier by the author that the biological variety and percentage of obligate symbiotic species in the all number of barnacle species in coastal waters of tropics, in particular in Indo-West Pacific, considerably above, than in the moderate and cold waters, and in some cases reaches 50%. The observable phenomenon can be explained by the big complexity of tropical coastal communities that increases quantity of ecological niches accessible to barnacles and promotes increase within this group of a percentage of highly specialized species in relation to a substratum. To these highly specialized species in relation to a substratum, obviously, all obligate symbiotic barnacles will concern (Poltarukha, 2009).

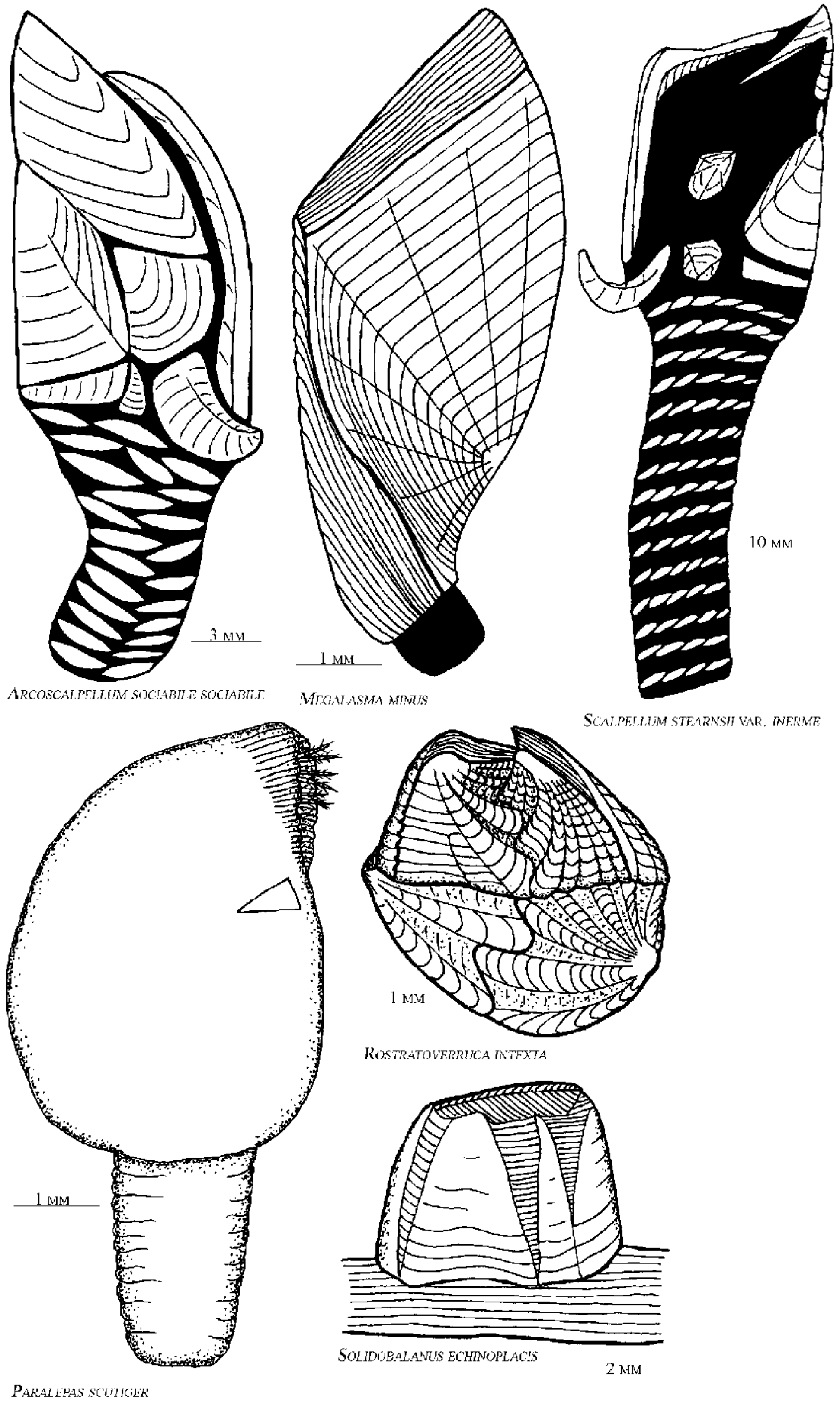


Fig. 1. Some species of barnacles from Vietnam.

In this connection there is a question, whether the specified rule on deep-water barnacles extends or it is limited to littoral-subtidal barnacle fauna. For the answer to this question the author had been carried out the comparative analysis of a biological variety of bathyal-abyssal barnacle fauna of South China Sea and Northeast Atlantic. The choice of these regions is defined by a high variety and a good level of knowledge of their deep-water barnacle fauna. Research has been based on checklists of barnacles of Northeast Atlantic (Young, 2001) and South China Sea (Jones et al., 2004). These checklists have been corrected according to the data about depths of dwelling, and also by results of the subsequent researches (Young, 2002), including with participation of the author (Poltarukha, Zevina, 2006). The species which have been found out on depths of 200 m and more were considered only.

In bathyal zone (200–2000 m) of South China Sea 102 species of barnacles are known. Prevailing group is suborder Scalpellomorpha – 38 species which most part – 30 species, belongs to family Scalpellidae. Also it is a lot of representatives of suborder Lepadomorpha - 26 species which most part belongs to family Poecilasmatidae – 22 species. It is the big variety of Sessilia – 31 species, among them families Archaeobalanidae – 15 species and Verrucidae – 12 species prevail. 45 species of the barnacles living in bathyal zone of South China Sea, are obligate symbionts – more than 44 % of all barnacles species noted to South China Sea bathyal zone. The most part of obligate symbionts belongs to suborder Lepadomorpha – 19 species of which the most part are representatives of family Poecilasmatidae – 15 species. Also a lot of obligate symbionts are Sessilia – 17 species, the majority of them belongs to family Archaeobalanidae – 11 species. The symbiotic barnacles living in bathyal zone of South China Sea are characterized by weak specialization to their hosts. Cases when the same species of symbiotic barnacles attached to the animals of very different taxons are frequent: to echinoid spines and antipatharians, to cirri of crinoids and antipatharians etc. This feature distinguishes them from symbiotic barnacles living in intertidal and subtidal zones which, usually, settle on the specimens of several closely related species or even on the specimens of only one species. Most of all living in bathyal zone species of symbiotic barnacles of South China Sea settle on coelenterates – 21 species, on echinodermats (more often on echinoid spines) – species and on crustaceans (usually on Decapoda) – 13 species, a small number of species are found on sponges and mollusks.

In bathyal zone of Northeast Atlantic 69 species of barnacles are known. Prevalence of Scalpellomorpha in bathyal zone of Northeast Atlantic is even more, than in South China Sea, - 32 species, which most part – 24 species, also belongs to family Scalpellidae. The biological variety of Lepadomorpha are rather insignificant – only 12 species. Sessilia – 20 species are less numerous also, among them Verrucidae – 16 species essentially prevail whereas Archaeobalanidae are almost absent – only 1 species. 11 species of the barnacles living in bathyal zone of Northeast Atlantic are obligate symbionts – less than 16% of all barnacles species noted to Northeast Atlantic bathyal zone. Almost all of obligate symbionts belongs to Lepadomorpha – 10 species, and among them the family Poecilasmatidae – 8 species essentially prevails. The majority of all living in bathyal zone species of symbiotic barnacles of Northeast Atlantic settles on decapods – 8 species, only separate species settle on echinoid spines and antipatharians.

Thus, the fauna of barnacles of Northeast Atlantic bathyal zone differs from the corresponding fauna of South China Sea in the smaller biological variety. The smaller number of barnacle species lives in bathyal zone of Northeast Atlantic. The percentage of obligate symbiotic species in the all number of barnacle species in bathyal zone of Northeast Atlantic almost in 3 times is less, than in bathyal zone of South China Sea. Thus obligate symbiotic barnacle species of South China Sea bathyal zone settle on representatives of different animal groups whereas the hosts of obligate symbiotic barnacle of Northeast Atlantic bathyal zone is almost only decapods.

Absolutely other results turn out at the comparative analysis of a biological variety of abyssal barnacle fauna of South China Sea and Northeast Atlantic. In abyssal zone (deeper than 2000 m) of South China Sea 27 species of barnacles are known. Prevailing group is suborder Scalpellomorpha – 18 species, almost all of them – 16 species, belongs to family Scalpellidae. Lepadomorpha are presented only by 4 species, all of them belongs to family Poecilasmatidae. Sessilia also aren't numerous – 4 species, from them Verrucidae – 3 species. Only 2 species are obligate symbionts of echinoids, crinoids and antipatharians. The abyssal barnacle fauna of Northeast Atlantic is richer – 39 species, but they are distributed between the main taxons of this group approximately in the same proportions. Scalpellomorpha – 25 species, from them 23 – Scalpellidae. Lepadomorpha – 4 species, all of them belongs to Poecilasmatidae. Sessilia – 8 species, all of them belongs to Verrucidae. Obligate symbionts are 3 species, they settle on echinoids, bryozoans, ascidians.

In abyssal zone of Northeast Atlantic in comparison with those of South China Sea it is possible to explain the big variety of barnacles, presumably, that abyssal zone of South China sea are substantially isolated from those of adjoining areas of the World Ocean. In favor of this assumption that fact testifies that only 1 from 27 species of the barnacles noted for abyssal zone of South China Sea, is the obligate inhabitant of abyssal zone. Other species are euribathic and occupy also bathyal zone, and some even subtidal zone. From 39 barnacle species of Northeast Atlantic abyssal zone obligate inhabitants of abyssal zone are 18. The small quantity of obligate symbiotic barnacle species in abyssal zones of both studied areas is connected, possibly, with a lack of firm substrata that complicates dwelling of highly specialized species in relation to a substratum which are obligate symbionts.

The done research gives arguments in favor of that the rule revealed earlier for littoral-subtidal barnacle fauna about increase in a direction from midlatitudes to tropics of a biological variety, and also a percentage of obligate symbiotic species, is shown as well in bathyal zone, but not in abyssal zone.

References

Poltarukha O.P. 2009. The main results of Vietnam barnacle (Cirripedia: Thoracica) fauna studying and prospect of the further researches // Hydrobiological Society of the Russian Academy of Sciences, 10th Congress: Abstracts. Vladivostok: Dalnauka. P. 317 [In Russian].

Poltarukha O.P., Zevina G.B. 2006. Barnacles (Cirripedia, Thoracica) of the Northeast Atlantic // Biogeography of the North Atlantic Seamounts. Moscow: KMK Scientific Press Ltd. P. 162–176.

Poltarukha O.P., Zvyagintsev, A.Yu. 2008. The Barnacles (Cirripedia, Thoracica) of Vietnam and their Role in the Fouling Communities. Moscow: KMK Scientific Press Ltd. 335 p. [In Russian].

Jones D.S., Hewitt M.A., Sampley A. 2000. A checklist of the Cirripedia of the South China Sea // The Raffles Bulletin of Zoology. V. 8. P. 233–309.

Young P.S. 2001. Deep-sea Cirripedia Thoracica (Crustacea) from the Northestern Atlantic collected by French expeditions // Zoosystema. V. 23, N 4. P. 705–756.

Young P.S. 2002. Revision of the Verrucidae (Crustacea, Cirripedia) from the Atlantic Ocean studied by Abel Gruvel (Travailleur and Talisman scientific expeditions) // Zoosystema. V. 24, N 4. P. 771–797.

BIODIVESITY OF AMPHIPODS (CRUSTACEA, AMPHIPODA) IN COASTAL ZONE OF NHA TRANG BAY, VIETNAM

V.A. Grintsov[1], O.P. Poltarukha[2]

[1]A.O. Kovalevskii Institute of Biology of the Southern Seas, National Academy of Sciences of Ukraine, Sevastopol, Crimea, Ukraine; e-mail: vgrintsov@gmail.com

[2]A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia; e-mail: poltarukha@rambler.ru

In January–February 2009, the biodiversity of amphipods in a coastal zone of the Bay of Nha Trang and adjoining waters (Vietnam) has been investigated. Amphipods have been collected from friable and firm substrata from depths 0–30 m. The material was gathered by means of net using SCUBA equipment. Net contents were spread in capacity with fresh water and mixed. Within 1-2 minutes amphipods were perished and emerged on a water surface, whence them were took by tweezers and fixed in 70% alcohol. Also amphipods were collected from the samples of fouling from the various metals samples exhibited at the marine test site fixed earlier in 70% alcohol. The collected amphipods belong to 18 families, 23 genera (Table 1). Distribution of amphipod genera on different kinds of substrata and depths is presented in Table 2.

From 32 families of Gammaridea known in South China Sea and in the Bay of Nha Trang (Lowry, 2000), we have found 17 that makes 53% of known diversity. Three families, Anamixidae, Cyproideidae and Haustoriidae, haven't been noted in the article of Lowry (2000). According to this publication, 11 families of Gammaridea are known in the Bay of Nha Trang. It makes 65% of those revealed by us. Thus 6 families (Amphilochidae, Anamixidae, Cyproideidae, Haustoriidae, Hyalidae, Ishyroceridae) haven't been earlier noted for the Bay of Nha Trang (Lowry, 2000).

Table 1. Systematic position of the collected material.

Families	**Genera**
Superfamily Gammaridea	
Ampeliscidae	*Ampelisca* Krøyer, 1842
Amphilochidae	*Gitanopsis* Sars, 1895
Ampithoidae	Gen. sp.
Anamixidae	*Anamixis* Stebbing, 1897, *Paranamixis* Schellenberg, 1938
Aoridae	*Xenocheira* Haswell, 1879; *Globosolembos* Myers; aff. *Dryopoides* Stebbing, 1888
Cyproideidae	*Cyproidea* Haswell, 1880
Haustoriidae	Gen. sp.
Hyalidae	*Hyale* Rathke, 1837
Isaeidae	*Gammaropsis* Liljeborg, 1855; *Photis* Krøyer, 1842
Ishyroceridae	*Ericthonius* Milne Edwards, 1830
Leucothoidae	*Leucothoe* Leach, 1814; *Leucothoella* “subgenera of *Leucothoe*”
Megaluropiidae	Gen. sp.
Melitidae, Hadziidae	*Dulichiella* Stout, 1912*;* *Elasmopus* Costa, 1853
Oedicerotidae	*Synchelidium* Sars, 1895
Podoceridae	*Podocerus* Leach, 1814
Stenothoidae	*Stenothoe* Dana, 1852
Superfamily Caprellidea	
Pariambidae	Gen. sp.
Phtisicidae	Gen. sp.

Table 2. The species of amphipods found in various biotopes of a coastal zone of the Bay of Nha Trang and adjoining waters.

The characteristic of a place of gathering, date	**Taxons, quantity of specimens**
Friable substrata	
The Bay of Nha Trang, south to the Moon Island, 9 m, stones, dead corals, 14.01.2009; Point 1.	*Xenocheira* Haswell, 1879 – 4; *Globosolembos* Myers, 1985 – 2; *Gammaropsis* Liljeborg, 1855 sp. № 2 – 5; *Leucothoe* Leach, 1814 – 1; *Gitanopsis* Sars, 1895 – 3; *Ampelisca* Krøyer, 1842 – 1; *Cyproidea* Haswell, 1880 – 1; *Anamixis* Stebbing, 1897 – 3; Amphipoda gen. sp. – 3.
The Bay of Nha Trang, south to the Moon Island, 12 m, sand, 14.01.2009; Point 2.	(Phtisicidae gen. sp. – 6; *Synchelidium* Sars, 1895 – 1; Megaluropidae gen. sp. – 1; *Gammaropsis* Liljeborg, 1855 sp. № 2 – 4; aff. *Ceradocus* Costa, 1853 – 1; *Ericthonius* Milne Edwards, 1830 – 1; Amphipoda gen. sp. – 1.
The Bay of Nha Trang, north-west to the Moon Island, 12 m, sand, fragments of corals, 19.01.2009; Point 3.	*Ericthonius* Milne Edwards, 1830 – 3; *Ampelisca* Krøyer, 1842 – 1; Haustoriidae gen. sp. – 1; *Synchelidium* Sars, 1895 – 2; *Gitanopsis* Sars, 1895 – 2; *Gammaropsis* Liljeborg, 1855 sp. № 2 – 1; *Cyproidea* Haswell, 1880 – 1; Phtisicidae gen. sp. – 1; aff. *Ceradocus* Costa, 1853 – 1; Amphipoda gen. sp. – 2.
The Bay of Van Phong, Lon Island, sand, 2–2.5 м, 20.01.09; Point 15.	*Synchelidium* Sars, 1895 – 1.
Cam Ranh, sandy beach, 0 m, 19.01.2009; Point 4.	*Ericthonius* Milne Edwards, 1830 – 1.
The Bay of Nha Trang, Tre Island, Dam Bay, around the Marine test site, sand, fragments of corals, 3 m, 17.01.2009; Point 5.	*Synchelidium* Sars, 1895 – 7.
The Bay of Nha Trang, Tre Island, Dam Bay, under the Marine test site, sand, 6 m, 07.02.2009; Point 6.	*Synchelidium* Sars, 1895 – 1.
The Bay of Van Phong, Heo Island, 0 м, sand, dead corals, 20.01.09; Point 16.	Haustoriidae gen. sp. – 2; *Ampelisca* Krøyer, 1842 – 1; Amphipoda gen. sp. – 2.
The Bay of Nha Trang, Tre Island, Dam Bay, sand, 5–6 m, 05.01.2009; Point 7.	Megaluropidae gen. sp. – 3; *Synchelidium* Sars, 1895 – 3; *Ericthonius* Milne Edwards, 1830 – 1.
The Bay of Nha Trang, Tre Island, near the input to the Dam Bay, coral sand and fragments of corals, 14 m, 17.01.2009; Point 8.	aff. *Dryopoides* Stebbing, 1888 – 1; *Gitanopsis* Sars, 1895 – 1; *Ampelisca* Krøyer, 1842 – 1.

The characteristic of a place of gathering, date	Taxons, quantity of specimens
The Bay of Nha Trang, southeast to the Moon Island, sand, stones, fragments of corals, 30 m, 19.01.2009; Point 9.	*Gitanopsis* Sars, 1895 – 2; *Ampelisca* Krøyer, 1842 – 1; *Cyproidea* Haswell, 1880 – 1; Amphipoda gen. sp. – 1.
Firm substrata	
The Bay of Nha Trang, east extremity of Tre Island, the stones covered with filamentous alga, 0–0.5 m, 5.02.2009; Point 10.	*Hyale* Rathke, 1837 – 2; *Gitanopsis* Sars, 1895 – 1.
The Bay of Nha Trang, Meu Island, the stones covered with filamentous alga, 0–0.5 m, 9.02.2009; Point 11.	*Hyale* Rathke, 1837 – 1.
The Bay of Nha Trang, Nha Trang City, Pier, concrete pile; Point 12.	*Dulichiella cotesi* (Giles, 1890) – 1; *Elasmopus* aff. *pseudoaffinis* – 1; Pariambidae gen. sp. – 15; *Podocerus* Leach, 1814 – 13 *Stenothoe* Dana, 1852 – 5
The Bay of Nha Trang, Tre Island, Dam Bay, the fouling of the Marine test site, 0–1 m, 5.01.2009; Point 13.	Ampithoidae gen. sp. – 3.
The Bay of Nha Trang, Tre Island, Dam Bay, the fouling of the samples (different metals) on the Marine test site, 0–1 m, 5.01. –5.02.2009; Point 14.	*Gammaropsis* Liljeborg, 1855 sp. № 1 – 4; *Elasmopus* aff. *pseudoaffinis* – 2; *Leucothoella* “subgenera of *Leucothoe*” – 1; *Paranamixis* Schellenberg, 1938 – 1; Pariambidae gen. sp. – 1; *Podocerus* Leach, 1814 – 7.

From 67 genera of Gammaridea known in South China Sea (Lowry, 2000) we identified 18 that makes 27%. Seven genera (*Anamixis*, *Paranamixis*, *Xenocheira*, *Globosolembos*, *Dryopoides*, *Cyproidea*, *Dulichiella*) haven't been earlier specified for South China Sea (Lowry, 2000). For the Bay of Nha Trang 17 genera of Gammaridea are known (Lowry, 2000); that is 1 genus less than we had found. Thus, among the genera which we have found in the Bay of Nha Trang and adjoining waters, 14 genera haven't been noted for this area earlier (Lowry, 2000) – 7 from above-stated genera for South China Sea and 7 genera (*Gitanopsis*, *Hyale*, *Gammaropsis*, *Leucothoella*, *Elasmopus*, *Podocerus*, *Stenothoe)* for the Bay of Nha Trang.

The obtained data testifies to an insufficient level of scrutiny of amphipods of the Bay of Nha Trang and adjoining waters.

Apparently from the Table 2, the maximum biodiversity is observed at depth from 9 to 12 m on sandy bottom with fragments of corals. The majority of individuals of amphipods belongs to family Phtisicidae (7 specimens), and also to genus *Gammaropsis* Liljeborg, 1855 (sp. 2, 10 specimens) and *Gitanopsis* Sars, 1895 (6 specimens). Friable substrata at depths 0–6, 14 and 30 m are less rich with amphipods. At depth 0-6 m amphipods of the genus *Synchelidium* Sars, 1895 are prevail (12 specimens). At depths 14 and 30 m there are not enough amphipods. Mainly it is representatives of the genera *Gitanopsis* Sars, 1895 and *Ampelisca* Krøyer, 1842.

Biodiversity of amphipods on firm substrata is lower. On stones in littoral zone representatives of the genus *Hyale* Rathke, 1837 prevail. In the fouling of artificial constructers (Marine test site), the prevalence of genus *Podocerus* Leach, 1814 (20 specimens) was obvious and *Gammaropsis* Liljeborg, 1855 (sp. 1, 4 specimens) presence is observed also.

Other genera are presented in separate biotopes (for example in thickets of hydroids, Pariambidae gen. sp. – 15 specimens), or a small number of individuals.

It is interesting that distribution of some genera is the same in different regions of the World Ocean. So, in Black Sea the most usual inhabitants of friable substrata also are representatives of genera *Ampelisca* Krøyer, 1842 and *Synchelidium* Sars, 1895. Both in Vietnam and in Black Sea genera *Stenothoe* Dana, 1852 and *Hyale* Rathke, 1837 live in the same biotope, which is in fouling of firm substrata (Greze, 1977, 1985). A number of genera (*Synchelidium* Sars, 1895; *Stenothoe* Dana, 1852; *Hyale* Rathke, 1837; *Ampelisca* Krøyer, 1842; *Ericthonius* Milne Edwards, 1830; *Leucothoe* Leach, 1814) are known both in Black Sea, and in the Bay of Nha Trang.

References

Greze I.I. 1977. The Amphipods of Black Sea and their Biology. Kiev: Naukova Dumka. 156 p. [In Russian].

Greze I.I. 1985. The amphipods // Ukrainian Fauna. Higher Crustaceans. Vol. 5. Kiev: Naukova Dumka. 172 p. [In Rissian].

Lowry J.K. 2000. Taxonomic status of amphipod crustaceans in the South China Sea with a checklist of known species // The Raffles Bulletin of Zoology. Suppl. 8. P. 309–342.

SHIP'S LASER FLUORIMETER FOR ECOLOGICAL MONITORING OF MARINE ECOSYSTEMS

Yu.N. Kulchin, S.S. Voznesenskiy, E.L. Gamayunov, A.N. Pavlov, A.Yu. Mayor, A.A. Korotenko

Institute of Automation & Control Processes, Far-Eastern Branch of Russian Academy of Science, 5 Radio St., Vladivostok 690041, Russia

Introduction

Ecological monitoring of tropical offshore zones is one of the important means used to ensure biodiversity of earth, the world. The most scientists abandon oneself to the idea, that there is the extinction of kinds provoked by the human factor in our generation. At ocean fishing vessels "plough" a sea-bottom, and the sea agriculture devastates coastal areas. Fishery has decimated up to 80% of a fish biomass. A problem there is also an environmental contamination. Invisible pesticides are extremely dangerous: industrial toxic chemicals make of little avail for a life of the river and sea, destroy food circuits.

The phytoplankton is the first element in a food circuit of all life on the Earth. Sour rains or rise in temperature can bring to ruin some kind's phytoplankton. Reduction of quantity phytoplankton will undermine food base of zooplankton and many kinds of fishes which eat seaweed and fine organisms. On the other hand, phosphorus and the nitrogen flow with water, polluted by fertilizers and sewerage, serve as a meal for development of phytoplankton. Seaweed, having bred because of an abundance of nutrients, perishes and rots, it use a significant part of the oxygen dissolved in water and conducts to increase the concentration of dissolved organic matter (DOM). It will bring to ruin sea organisms. Therefore, monitoring of the phytoplankton contents in sea water allows detecting absence of ecological balance in region.

The phytoplankton cell is the good indicator of an ecological condition of sea water area. Among all methods employed for this purpose the optical ones are considered most widespread. They allow one to estimate concentration of phytoplankton and solutes in sea water. Measurements of fluorescence of phytoplankton and DOM are carried out by method of laser-induced fluorescence (LIF) (Kulchin et al., 2006; Kulchin et al., 2007). In this paper we consider features of practical implementation of this method based upon a mobile fiber-optical system for monitoring of depth and spatial distribution of phytoplankton and DOM in sea water.

General information

The ship's laser fluorimeter consists of a shipborne control system and immersible module connected with the control system by a cable (Onboard…, 2007). The onboard system includes the 532 nm pulse Nd: YAG laser with 6 ns pulse duration and 1.3 mJ pulse energy.

The immersible module includes fiber-optical sensor of fluorescence and electrical pressure and temperature sensors. A water flow through the area of fluorescence excitation is maintained by a small pump.

Laser radiation is guided through an optical fiber to the water to excite fluorescence, which energy is channeled by the other fiber to a high sensitivity broad band (400–780 nm) spectrometer. The spectrometer's signal is processed to obtain its spectrum data used to determine a concentration of phytoplankton and DOM. The distinctive property of the system described is that it has two water devices – a flow-through cell and the immersible module. The flow-through cell being connected with the pump is a part of the onboard equipment. To exercise control over immersible module's electric winch, a special software developed by using the LabView environment is used.One can use the same software to control the measurement process.

Fig. 1. Ship's laser fluorimeter.

Fig. 1 presents the general view of the laser fluorimeter.

A distinctive feature of the fluorimeter is that the measuring and radiating modules, being consisted of the most expensive elements, can be common for flowing water and immersible modifications of fluorimeter, and they are present on ship permanently.

The second distinctive feature is the system of registration of the laser induced fluorescence (LIF) spectrum of sea water, which provides multichannel reception of 640 spectral channels in a 400 A distinctive feature of the fluorimeter is that the measuring and radiating modules, being consisted of the most expensive elements, can be common for flowing water and immersible modifications of fluorimeter, and they are present on ship permanently.

The second distinctive feature is the system of registration of the laser induced fluorescence (LIF) spectrum of sea water, which provides multichannel reception of 640 spectral channels in a 400-780 nm wavelengths range. Broadband registration and high spectral resolution allow us to significantly reduce a systematic error (typical for single-channel fluorimeters) of calculation of the "A" chlorophyll and DOM concentrations in coastal and offshore waters.

780 nm wavelengths range. Broadband registration and high spectral resolution allow us to significantly reduce a systematic error (typical for single-channel fluorimeters) of calculation of the "A" chlorophyll and DOM concentrations in coastal and offshore waters.

During a movement of the ship the outside water is pumped through the flow-through cell which is illuminated by the 532 nm NdYag laser radiation to excite laser-induced fluorescence (LIF) of the sea water. Continuous measurements of LIF spectra of sea water give an information on spatial distribution of "A" chlorophyll along a chosen direction of the ship's movement.

In order to measure a concentration depth gradient of "A" chlorophyll and DOM one has to connect the immersible module to the base module. Interface cable includes two optical fibers and several electric cables. The onboard control system includes a pulse laser and spectrometer linked with a PC, power source and a special interface converter used for interconnection between electronic components in the immersible module.

Immersible module launching is performed by a special electric winch controlled by a PC. To transfer laser radiation from the onboard system to the immersible module we use immersible and onboard optical fibers. They are linked together by using low-loss (<3dB) revolving connectors. Immersible module's weight is 7.5 kg, its diameter is 200 mm, the length is 470 mm.

Data processing is performed during the process of measurement. The sample of data obtained by the control system is shown in Fig. 2. The same plot shows three measured parameters – phytoplankton concentration, salinity and temperature.

Double frequency laser fluorimeter (DLF) based upon 355 nm and 532 nm laser radiation sources was designed, constructed and tested. Both lasers used excite fluorescence in separate flow-through cell. Spectra of either channels are registered by the same channel to avoid a possible drift between signals caused by thermal and temporal instability of registration system's parameters.

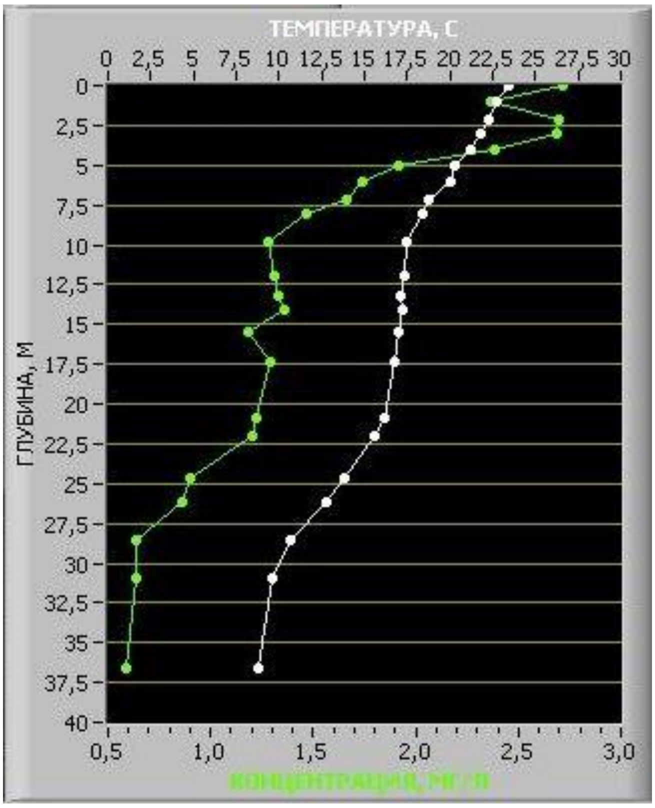


Fig. 2. Measured data sample.

Use of third harmonic of NdYag laser (355 nm) makes it possible to register greater amount of phytoplankton pigments as well as weakly fluorescent pigments when phytoplankton concentration is high. It allows us to observe a change of species composition, stages of population growth etc.

Fluorescence of DOM is excited much more efficiently with the third harmonic (355 nm). Ultraviolet radiation causes fluorescence of DOM caused by natural phenomena (flows, dust storms, terrigen sediments etc) as well as anthropogenic influence. Some hydrocarbons like motor fuel and oil can be identified by typical broad band fluorescence spectra.

Study of these parameters makes it possible to register such ecological calamities like mass seaweed blooming – known as "red tide" (it damages marine ecosystems considerably because of subsequent lack of water oxygen, rise of hydrogen sulfide and ammonia which cause mass fish kill); seaweed blooming which releases poisonous toxins accumulating in fish and mollusks (bivalve – ousters and mussels, especially) bodies.

Moreover, this study gives us an ability to estimate a general condition of seawater, bioproductivity of different areas, degree of coastal discharge of polluting substances and their distribution along the offshore zone. Fig. 2 shows sample map of phytoplankton fluorescence in the Petr Velikiy bay which helps to discover sources of pollution and polluted water propagation.

The fluorimeter developed has the next advantages:

- it allows one to obtain spectral curve of sea water fluorescence near the maximum of "A" chlorophyll concentration which provides an ability to distinguish between DOM and "A" chlorophyll at 680 nm wavelength in waters with high concentration of DOM;

- one can investigate a pigmental composition of phytoplankton cells and DOM components more accurately in comparison with common techniques.

Conclusions

Ship's laser fluorimeter allows registering the big number of phytoplankton pigments, and at large concentration and poorly pigments fluorescing that gives an opportunity to register change of species composition, to study stages of development of populations and to estimate other characteristics. At excitation by ultra-violet radiation fluorescence DOM, caused as by the natural phenomena (sea currents, dust storms, volcanic eruption, etc.), and anthropogenesis influence is registered. For some hydrocarbons (fuels, oils) their identification on characteristic broadband lines of a spectrum is possible.

The given parameters allow to find out such ecological disasters as: the mass flowering of the seaweed which has received the name “red inflow” which cause the big harm sea ecosystems as reduce the contents of oxygen in water, conduct to occurrence in it of hydrogen sulphide and ammonia and by that promote fish kills; flowering of the seaweed allocating toxins which can collect in bodies of fishes and mollusks (especially folding - oysters and mussels), that leads to poisonings and destruction of people and sea animals. These methods allow estimating the common condition of quality of sea water area, to estimate bioefficiency of various areas, to define sources of pollution on coast, to appreciate coastal emissions of polluting substances and their distribution on water area.

The immersed module developed can be used for long-term measurements at any time of the day. The immersion depth of the module is controlled by pressure sensors and can reach 100 meters.

Depending on the task the onboard control system can include the different optical equipment. The availability of loaded module, pump, enables long-term measurements at a certain point of a sea.

Having the wide range of possible obtainable laser radiation power and highly sensitive broadband spectrometer, one can use this system extensively in the very wide range of science and industrial applications.

Due to design features of the equipment developed it is possible to use it onboard any ship. During its testing in the Petr Velikiy bay the equipment was installed onboard the small yacht. Authors used this complex during the time of two month expedition of sailing ship “Nadezhda”. There were two marine expeditions carried out in Okhotsk Sea and one expedition carried out in Japanese sea.

References

Bukin O.A. et al. 2001. On the calibration of laser fluorescence for measuring the concentration of chlorophyll A // Atmospheric and Oceanic Optics. V. 14, N 3. P. 28–32.

Kulchin Y.N., Voznesenskiy S.S., Gamayunov E.L., Gurin A.S., Korotenko A.A., Major A.Y. 2006. System for Monitoring of Phytoplakton in Water // Pacific Science Review. V. 8 (1). P. 5–9.

Kulchin Y.N., Voznesenskiy S.S., Gamayunov E.L., Gurin A.S., Korotenko A.A., Major A.Y. 2007. An Immersible Fiber-Optic Fluorometer// Instruments and Experimental Techniques. V. 50, N 6. P. 828–832.

Onboard measurement system of water parameters: pat. 75042 Russian Federation: IPC7 G01N21/64 / Kulchin Yu.N. et al.; patent IACP. – № 2007148724/22, 24.12.2007.

SEA ECOLOGICAL CONTROL AND ATMOSPHERE CORRECTION PROBLEM

***A.I. Alexanin*[1]*, A.N. Pavlov*[1]*, Nguyen Xuan Anh*[2]**

[1]*Institute of Automation & Control Processes, Far-Eastern Branch of Russian Academy of Science, 5 Radio St., Vladivostok 690041, Russia*

[2]*Institute of Geophysics, Vietnamese Academy of Science and Technology, A8, 18 Hoang Quoc Viet – Cau Giay – Hanoi, Vietnam*

Introduction

Ecological assessment of coastal sea areas is an important task of environmental protection. An impurity substance changes water spectral properties and can be detected with different devices. For example, measurements of water radiance parameters (first of all absorption and scattering coefficients) with a spectroradiometer allow detecting components of water impurity. Sea phytoplankton assessment with satellite remote sensing methods is one of actual tasks of environment control. Such events as red tides and harmful algal blooms damage the coastal area industry valued at some hundred thousand US dollars. Last problem is complicated one and compounds a set of subtasks, and one of the important tasks is atmosphere remote sensing for estimation of vertical distribution of attenuation and scattering coefficients used for a procedure of radiance correction due to atmosphere influence.

Satellite estimations of sea bio-parameters

Automatic means for satellite information reception, processing, and delivery to users have been created in the FEB RAS Satellite Center for every day monitoring. Data of MODIS radiometer and SeaDAS package are used for monitoring of the ocean. It provides near 200 parameters of environment (sea water and atmosphere): diffuse attenuation coefficients; chlorophyll-a concentrations; coefficients of absorption and scattering of both phytoplankton and its dissolve organic matter (DOM); phytoplankton fluorescence; coefficient of photosynthesis effectiveness; sea surface temperature; optical properties of the atmosphere, and others.

Satellite information allows finding the most interesting objects for the investigations. It is used for pointing out the objects for a research vessel. The charts of the follow parameters are used for this goal: chlorophyll-a concentration (chl), fluorescence line height (flh), turbidity (diffuse attenuation coefficient K490), photosynthesis effectiveness, homogeneity of algal species composition, dominant species size (Fig. 1). Photosynthesis capacity F=flh/chl is used as a parameter of photosynthesis effectiveness (the value is inversely proportional to the effectiveness). It allows finding the areas, where phytoplankton concentration will grow. The ratio of phytoplankton scattering coefficient bbp(λ) to absorption one aph(λ) for a selected spectral band is used as a parameter of homogeneity of algal species composition, where λ is the wave length. The ratio may be used for detection of areas with sharp change of the species composition and/or significant chan-

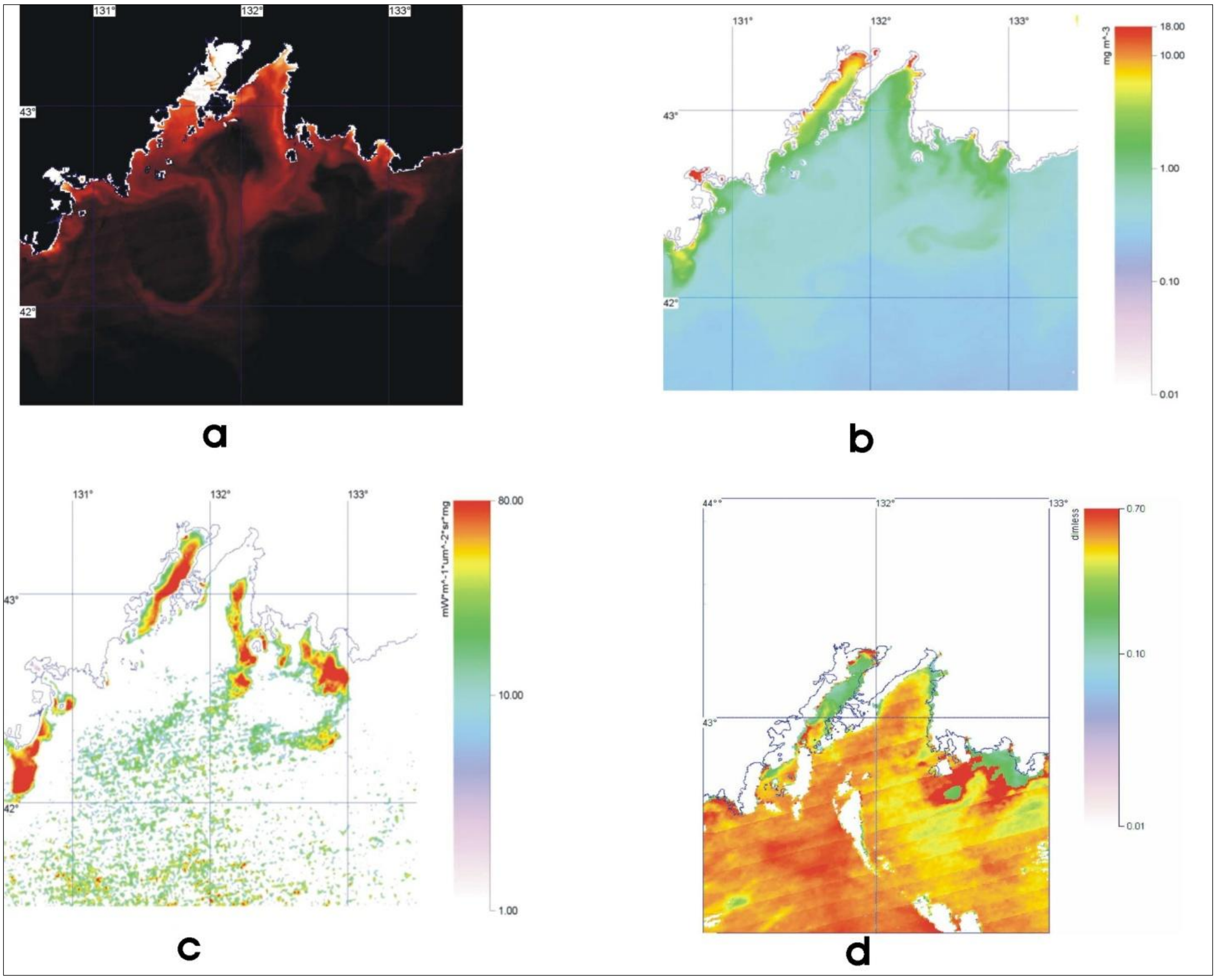


Fig. 1. Bio-optical parameter charts of Peter the Great bay on August 24, 2009. a – diffuse attenuation coefficient K490; b – chlorophyll-a concentration (OC3 algorithm); c – photosynthesis capacity F; d - a parameter of homogeneity of alga species composition (λ=412 ηm, Carder algorithm (Kendall, 2003).

ge of an admixture concentration. The scattering coefficient growth with the growth of spectral band frequency is used as a parameter characterized dominant species size. The growth is inversely proportion to the dominant species size usually. Joint analysis of the parameters mentioned allows looking for interesting sea objects.

Remote sensing of atmosphere

The main problem of atmosphere correction of radiance measured by a satellite radiometer of visual spectral range is inaccuracy of a model used for computation of light absorption and scattering by aerosol. The most effective approach for aerosol parameter estimation is use of atmosphere remote sensing with lasers (Fig. 2). The joint measurements of satellite and mobile lidars are especially effective under heavy conditions of observation.

Ajustment of parameters of water leaving radiance

Direct measurements with spectroradiometers the spectral parameters under and over sea surface allow to control the quality both atmosphere correction procedures and algorithms for dif-

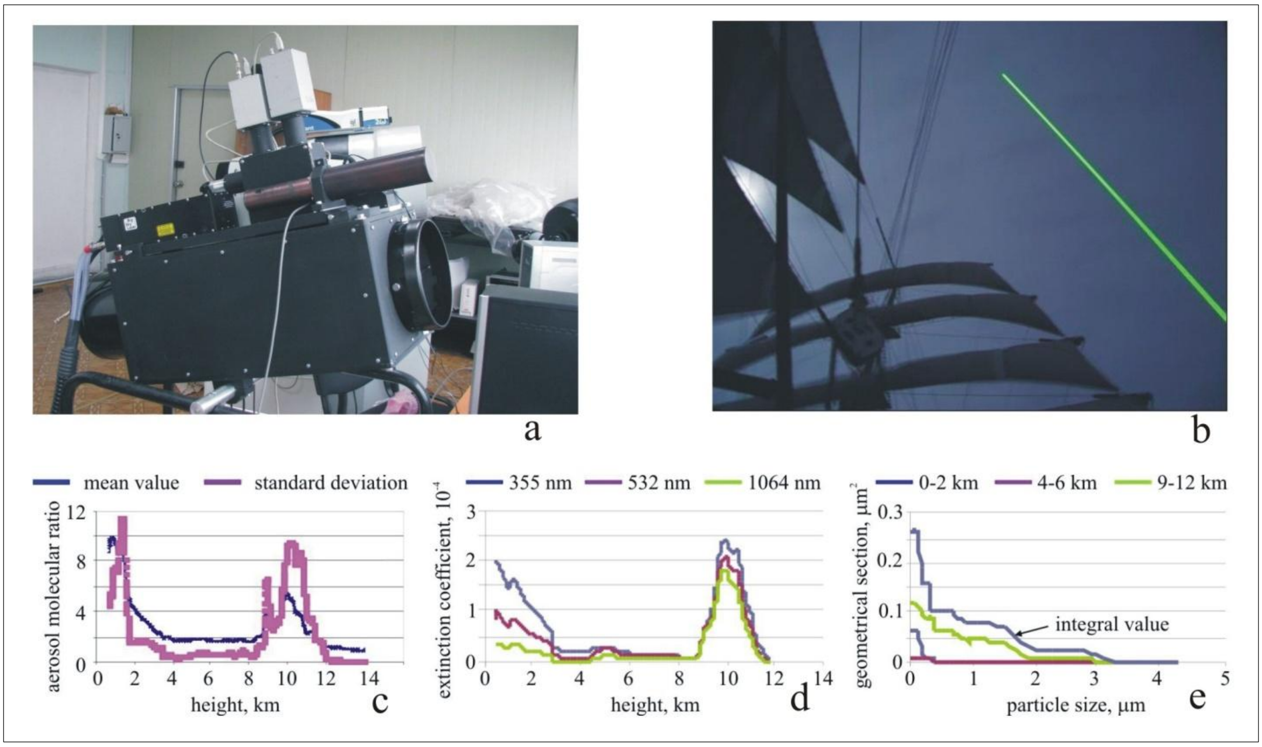


Fig. 2. Mobile three-frequency lidar (a), and Brilliant Ultra lidar (b) used on the "Nadejda" vessel for the expedition works, and lidar estimations of atmosphere aerosol parameters: c – aerosol-molecular ratio for the wave length 532 ηm; d – attenuation coefficient of laser radiance for three wave lengths; e – distribution of aerosol particle sizes for different layers.

different bio-optical parameter computation. An algorithm creation for phytoplankton parameter estimation on spectroradiometer measurements has own significance, because it will be possible to create a mobile equipment for water quality testing, and, for example, for HAB detection. The spectroradiometer measurements allow to calculate accurately the key parameters used in the most bio-optical algorithms – sea reflectance coefficients of different spectral bands:

$$Rrs(\lambda) = \frac{Lw(\lambda)}{Es(\lambda)} ,$$

where Lw(λ) – spectrum of water leaving radiance, Es(λ) – spectrum of sea surface irradiance. The normalization procedure (adjustment of measurements to the same observation conditions) allows to compare in situ data with the satellite estimations.

Detailed measurements of phytoplankton in the upper layer are necessary for verification of different bio-optical algorithms. It's ought to make both common measurements of the sea water components (concentrations of phytoplankton, DOM and mineral suspension), and analysis of pigment of phytoplankton together with species composition. The measurements should have appropriate spatial distribution for comparison the satellite and in situ data.

A regional algorithm for calculation of chlorophyll-a concentration

The facilities and methods presented can be used for creation of accurate regional algorithms for bio-parameter calculation on satellite information. Is was demonstrated the opportunity of a regional algorithm creation for calculation of chlorophyll-a concentration in the Peter the Great bay, which area includes both open sea water (case I) and coastal water (case II) (Salyuk, 2010). An analysis of different SeaDAS algorithms has shown, that the Carder algorithm for computation of chlorophyll-a concentration (Kendall, 2003), DOM concentration, phytoplankton absorption and scattering coefficients demonstrates the most acceptable results if to use MUMM algorithm for atmosphere correction (Ruddick, 2006).

A scheme of an identification procedure of blooming algae

An optical model of light propagation in the upper sea layer (Kendall,2003) may be used for creation of an identification procedure. In according to the model the reflectance coefficients of sea surface are approximated with follow relationship:

$$Rrs(\lambda) = \frac{f * t^2}{Q(\lambda) * n^2} \frac{b_b(\lambda)}{a(\lambda) + b_b(\lambda)},$$

where λ – wave length, a(λ) –water absorption coefficient in the upper layer, bb(λ) – backward scattering coefficient. Other parameters are approximated with the follow formulas:

$$f / Q(\lambda) = 0.02085 + 0.00028796*\lambda + 0.000000289*\lambda^2,$$

$$t2 / n2 \approx 0.54.$$

Knowledge about spectral parameters (a(λ) and bb(λ)) of harmful species allows to estimate often with a good accuracy the reflectance coefficients Rrs for any wave of visual band if we have concentrations of alga species and its DOM. It can be a base of the identification procedure used both satellite and spectroradiometer measurements. Instead of significant variability of species composition in sea, the task of HAB detection is simplified due to the fact that only some species are dominating during a significant alga bloom. Nevertheless, reliable decision of the task is need in a long-term observation for compositions of alga species in a region under investigation. It will allow to detect dominant species and conditions of their blooming. It will increase the probability of correct decision of HAB recognition.

References

Kendall L., Carder F., Chen R., Lee Z., Hawes S.K., Cannizzaro J.P. 2003. Case 2 Chlorophyll-a. MODIS Algorithm Theoretical Basis Document, University of South Florida, 19. 67 p.

Ruddick K.G., Cauwer V.D., Park Y.-J. 2006. Seaborne measurements of near infrared water-leaving reflectance: The similarity spectrum for turbid waters // Limnology and Oceanography. V. 51. P. 1167–1179.

Salyuk P., Bukin O., Alexanin A., Pavlov A., Mayor A., Shmirko K., Akmaykin D. 2010. Optical properties of waters of Peter the Great Bay compares with satellite ocean colour data // International Journal of Remote Sensing [In press].

SOME EXPERIMENTAL CALCULATIONS FOR 3D CURRENTS IN THE STRONG UPWELLING REGION OF SOUTHERN CENTRAL VIET NAM USING FINITE ELEMENT METHOD

Bui Hong Long, Tran Van Chung

Institute of Oceanography VAST, Nhatrang, Viet Nam

Introduction

Studies on currents have been carried out rather early. Prediction models have occurred since the 60s in many research works such as modelling the wind currents of Nguyen Duc Luu (1969), general currents of Hoang Xuan Nhuan (1983), Pohlman (1987), Ping-Tung Shaw, Shenn-Yu Chao (1994), Shenn-Yu Chao et al. (1998), etc. The attained results have contributed to explain the role of wind field in forming and changing water circulation at surface and different depths as well. However, data on thermohaline and wind fields used in these models haven't assurred the needed detaility and accuracy. On the other hand, the grid resolution still can not embrace all the high energy processes. Therefore, the obtained circulation fields only described some fundamental characteristics of the seasonal circulation. The separation of processes lead to inadequate reflection of circulation characteristics which have been obtained through analyses of geodetic current and thermohaline field measurements.

While establishing the National Atlas (1995), in order to meet the scientific and practical needs, but still be faithful to field measurements, the authors have developed maps based on the combination of Wyrtki maps (1961) and research results from coastal waters of Viet Nam, including the maps on current trends from the Report on "General investigations of the Gulf of Tonkin" (1964). Together with these maps, geostrophic current maps from the project 48B 01-01 (1990), which Vo Van Lanh and others have calculated based on temparature and salinity data at 1°x1° coordinate grid stored at the Institute of Oceanography, are also used. The maps in this Atlas have showed the research results on the circulation in the SCS till 1980, and also the need for further investigations on this important issue in the coming years.

In recent years, systematic research oriented modelling method has been developed worldwide. This method has also been applied to investigate the circulation in SCS. In addition to the research works of Metzger, Hurlburt (1996), Le Ngoc Ly, Phu Luong (1997) etc., project KHCN 06-02 "Study on the 3D structure of hydrodynamics in SCS" under the National Marine Research Program (1996–2000) has been carried out to investigate more detailedly the thermo-haline structure and the circulation of Vietnamese waters. Using state-of-the-art mathematical models and modern means of calculation, the analytic results allow us to simulate the spacial distribution characteristics of the circulation and its monsoonal variations more detailedly. With comprehensive and practical input data, the research results from project KHCN 06-02 have shown the possibility of reproducing and predicting real circulation fields in SCS.

However, at the present, research on 3D nonlinear currents hasn't been completely developed, especially the application of finite element method in solving the shallow-water problems is still rather new in Vietnam. To assest the strong upwelling regime in the Vietnamese southern central waters, we have developed a 3D nonlinear model for the calcutions of currents, using finite element method with a triangular mesh. After initial experiments, this method has revealed high flexibility to boundaries and good results, which will open a new prospect in studying the upwelling phenomenon in the southern central waters. The selected computational domain is between 109.244° E –112.386° E and between 10.141° N–10.964° N, with maximum depth of 5485 m (the depth from lowest tidal level). The computational mesh consists of horizontal triangles with total 3248 nodes, total number of element triangles is 6192. In the vertical, we deployed 34 nodes with corresponding depths of 1200 m, 1100 m, 1000 m, 900 m, 800 m, 700 m, 600 m, 500 m, 450 m, 400 m, 350 m, 300 m, 250 m, 200 m, 150 m, 100 m, 80 m, 50 m, 40 m, 30 m, 25 m, 20 m, 15 m, 10 m, 9 m, 8 m, 7 m, 6 m, 5 m, 4 m, 3 m, 2 m, 1 m and the surface. Wind data are forced into 3248 nodes by the interpolation subfunction ***griddata*** in Matlab.

The south-western wind field data in Aug. 2005 and the north-eastern wind field data in Nov. 2005 are selected to use in the model. These data are derived from the web [ftp://ftp.ssmi. com/qscat/bmaps_v03/y2005/]. The processing of wind data and the etstablishment of triangular mesh are carried out using ***Matlab R2006a***., and the model is programmed using ***Fortran PowerStation version 4.0***. The thermo-haline distribution fields are referred to and drawn from the oceanographic database **(VODC)** of our Institute of Oceanography in Nhatrang and from **PHC 3.0** downloaded from [http://psc.apl.washington.edu/POLES/PHC2/Climatology. html].

Literature Review

We have understood rather well the shallow water equations. This is the model that satisfied the diversity of physical phenomena such as currents, surge, long wave transmission etc. From these equations, numerical solution for reality has played a very important role. Therefore, finding a reasonable numerical method to solve these equations and improve it for practical application has always been a challenge for the development.

Together with technological and scientific development, many modern numerical methods have been performed on computer to solve technical-scientific problems, such as finite difference method, finite element method, boundary element method, meshless method of which the finite element method has become more and more popular and is now regarded as the most effective one to solve the problems of continuous environmental mechanics in general and engineering computation in particular. This method has also been applied to solve problems of shallow water wave transmission and obtained good results.

At present, the finite difference method is used worldwide, but for those study areas with complicated geometric structure such as waterways, estuaries, dikes (wharfs, ports, breakwater etc.), this method is impratical because of its poor faculty to represent complex boundary, large computational domain, computational grid is nearly unchangeable while bottom topography is very complex. The finite element method provides solutions to those problems of the finite difference method. It solves the shallow water problems with high geometric flexibility, especially when study on an adapted unstructured grid for areas with complex bottom topography. During the investigation of the upwelling phenomenon in the southern central Vietnam, we have faced great difficulty in solving the problem of shallow water wave transmission by means of finite difference method. The solution is unsteady in areas where depth gradients have been changed strongly, the role of boundary is unclearly represented in the problem, especially for the southwestern wind field where this wind field is important to the assessment of the upwelling. Because of all these reasons, we have used the finite element method for the simulation of the problem of shallow water wave transmission.

In the world. The application of finite element method for studying ocean flows has become more and more popular in the world. Recent related published works are:

- In 1997, Kazuo Kashiyama, Katsuya Saitoh, Marek Behr and Tayfun E. Tezduyar gave a new approach to solve the problem of storm surges and tidal flows in the work “Parallel finite element methods for large-scale computation of storm surges and tidal flows”.

- “Bifurcation analysis of brown tide in tidal flow using finite element method” (Mutsuto Kawahara, Yan Ding, 1998).

- “One-dimensional finite element grids based on a localized truncation error analysis” of S.C. Hagen, J. J. Westerink and R. L. Kolar (2000).

- “Absorbing boundary conditions on elliptic boundary for finite element analysis of water wave diffraction by large elongated bodies” of the authors Subrata Kumar Bhattacharyya, Santhosh Sathyapal and Chiruvai P. Vendhan (2001).

- In 2002, there were two remarkable works: “A comparison of three finite elements to solve the linear shallow water equations” (E. Hanert, V. Legat, E. Dellersnijder) and “A 3D finite-element model of the Adriatic tides” (Benoit Cushman-Roinsin, Christopher E. Naimie).

- “A diagnostic stabilized finite-element ocean circulation model” of D. Nechaev, J. Schroter and M. Yaremchuk published in 2003.

- In 2004, the authors D.A. Greeberg, J.A. Shore, F.H. Page and M. Dowd have writen “A finite element circulation model for embayments with drying intertidal areas and its application to Quoddy region of the By of Fundy” (published in 2005).

The finite element method is a new research orientation in the world and still needs further study and improvement.

In Vietnam. Finite element research for shallow water problems in Vietnam is still very little, scattered and not intensive, especially studies on estuaries and embayments. Published research works could not expressed the strength and possiblity of this modern research technique. Literature on this method is mainly in publications of geomechanics, especially in the Belgen - Vietnam research co-operation program. In the State research program KT03, Dr. Nguyen Trong Dao (Marine Hydrometeorological Centre) had introduced this method for tidal computation in the South China Sea. However, the application of finite elements for calculating 3D currents, with emphasis on the vertical velocity, has been hardly mentioned in research works in Vietnam.

Research Results

Input data. The study domain is selected between 109.244° E–112.386° E and between 10.141° N–10.964° N, with maximum depth of 5485 m (the depth from lowest tidal level). The computational mesh consists of horizontal triangles with total 3248 nodes, total number of element triangles is 6192. In the vertical, we deployed 34 nodes with corresponding depths of 1200 m, 1100 m, 1000 m, 900 m, 800 m, 700 m, 600 m, 500 m, 450 m, 400 m, 350 m, 300 m, 250 m, 200 m, 150 m, 100 m, 80 m, 50 m, 40 m, 30 m, 25 m, 20 m, 15 m, 10 m, 9 m, 8 m, 7 m, 6 m, 5 m, 4 m, 3 m, 2 m, 1 m and 0 m (surface). Wind data are forced into 3248 nodes by the interpolation subfunction ***griddata*** in Matlab. Bathymetric depths are presented in Fig. 1 and computational mesh in Fig. 2.

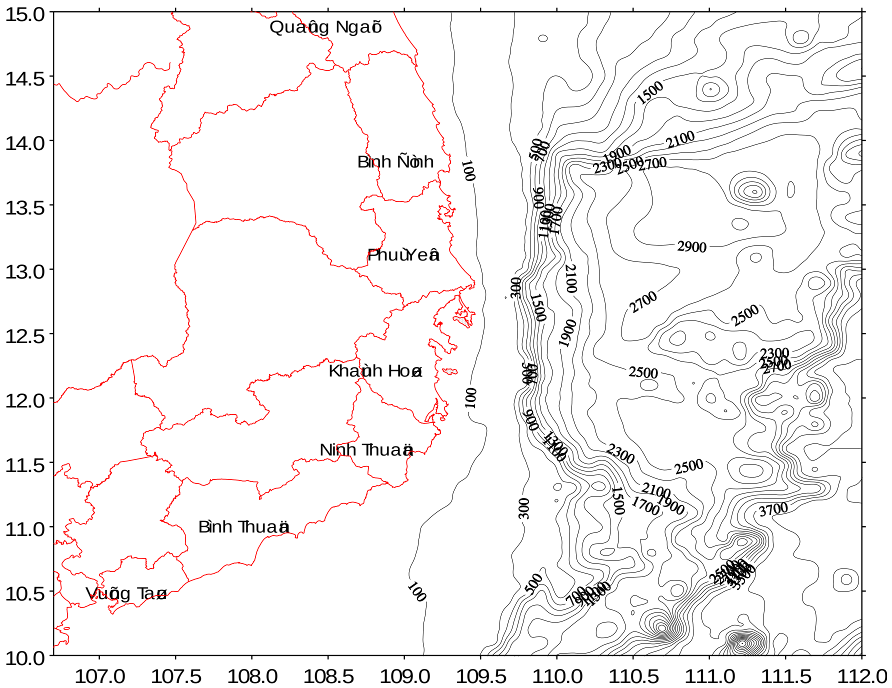


Fig. 1. Depth field (m) used for the computation of currents in the upwelling region in southern central Vietnam.

We selected the wind input data for the model from two main wind fields: the south-western wind field in Aug. 2005 and the north-eastern wind field in Nov. 2005. These data are derived from the web [ftp://ftp.ssmi.com/qscat/bmaps_v03/y2005/]. The processing of wind data and the etstablishment of triangular mesh are carried out using ***Matlab R2006a***, and the model is programmed using ***Fortran PowerStation version 4.0***.

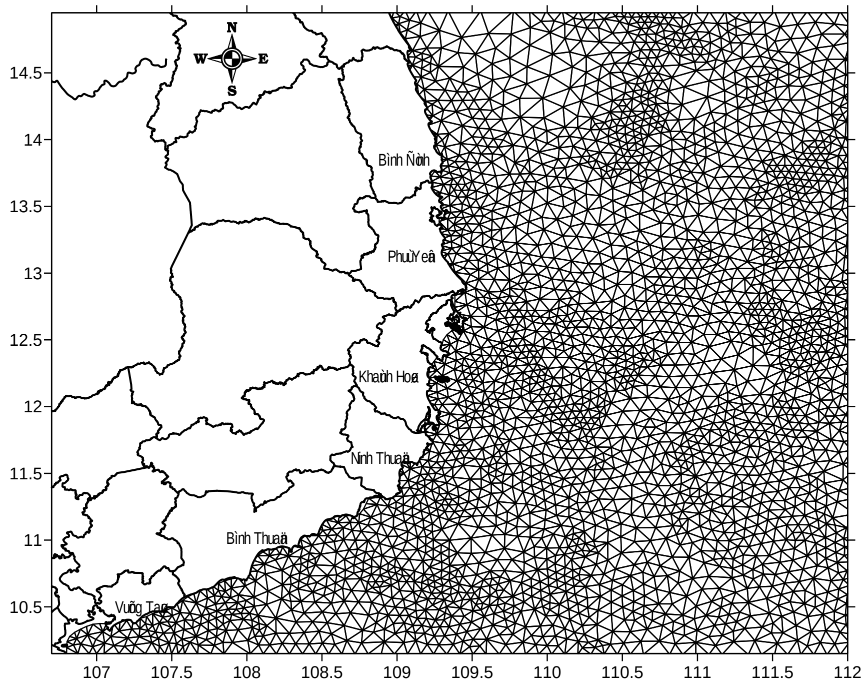


Fig. 2. Triangular mesh used in wind-driven current model for the upwelling region in southern central Vietnam.

The thermo-haline distribution fields are referred to and drawn from the oceanographic database **(VODC)** of our Institute of Oceanography in Nhatrang and from **PHC 3.0** downloaded from [http://psc.apl.washington.edu/POLES/PHC2/ Climatology.html].

At present, the model is in test run under the condition that temparture and salinity are constant at all layers. The heat-salt transport will be completed in the next model version.

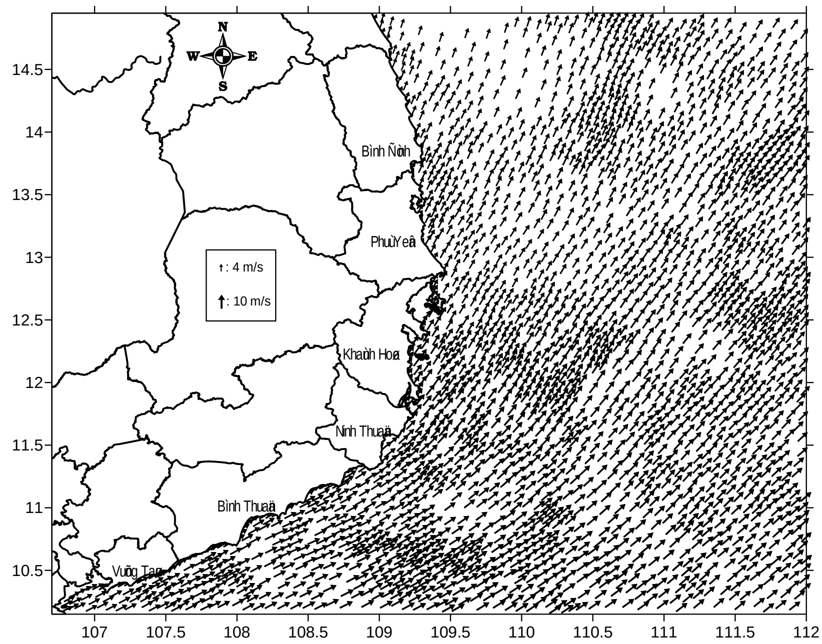


Fig. 3. Distribution of wind pattern in Aug. 2005 in the computional area

Calculation results. The wind-driven current model for the upwelling region in southern central Vietnam is programmed using the software Fortran PowerStation 4.0. Computation results are outputted in the file format **.dat* for each computational hour, including the number of computational nodes, distance x (km), y (km) (in the Cartesian coordinates), longitude and latitude (degree) of computation points, x, y, horizontal and vertical velocities (cm/s), depth layer (m), direction of currents (degree) is clockwise from north axis, direction (degree) represented in *Surfer*, so that it is easily to combine all them to draw maps of distribution, vertical velocity contours and vertical surface stratification in *Surfer*. Computational run time is about 55 minutes, corresponding to real time of 24 hours.

The southwestern wind field (8/2005). During this time, on the computational grid, the highest wind velocity is 9.8m/s, lowest 5.1m/s, and average 8.0 m/s (Fig. 3).

- At 5 m layer, as computed from the linear 3D model, the horizontal velocity may reach its peak value of 41 cm/s, direction 97° at the position (108.85° E–11.2° N). This result is clearly different to the result calculated by non-linear 3D finite element method, which represented a maximum horizontal velocity of only 39cm/s, direction 59° (clockwise from the North axis) at the position 107.455° E–10.149° N. Beside the computed horizontal velocity, we also attained information on vertical profile of the study area. The vertical velocity at the same position (108.85° E–11.2°N) is w=-4.9×10^{-4} cm/s (the sign "– " implies a downward vertical velocity). At the layer of 5 m, the maximum downward vertical velocity is -0.005339 cm/s at the position 110.833° E–10.308° N, and the peak upward vertical velocity is 0.005339 cm/s at 112.386° E–10.52° N (Fig. 4).

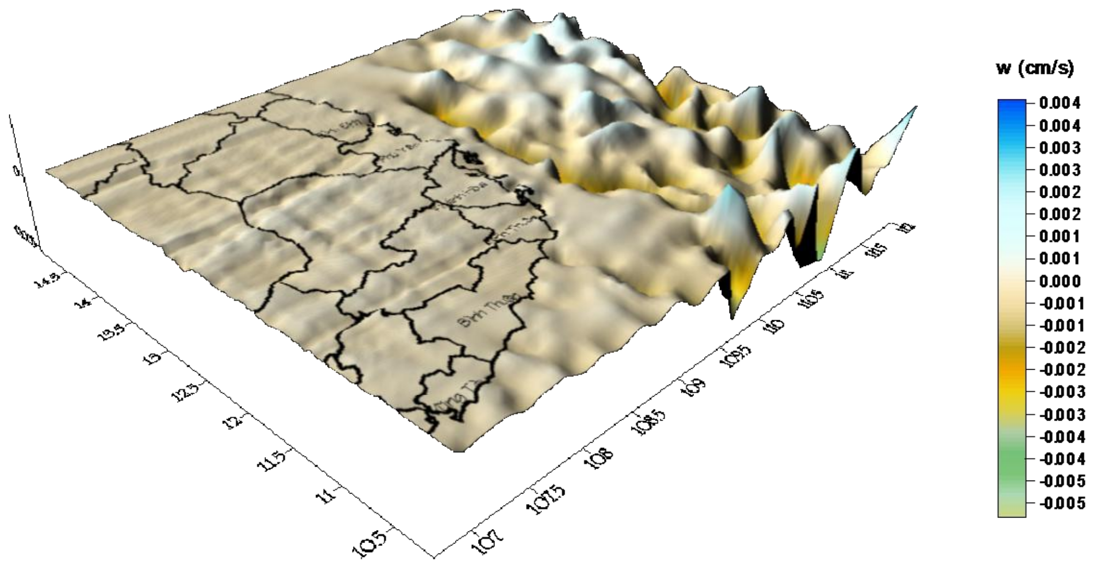


Fig. 4. Distribution of vertical current velocities at 5m layer (averagely computed for the wind field in Aug. 2005).

- At 10 m layer, according to the non-linear 3D finite different method, the peak horizontal velocity is 10.847 cm/s, direction 104.705° at 108.95° E–11.2° N. The velocities decreased rather quickly, because only the linear quantities are taken into account and heat-salt exchange is ignored, and grid is inaccuracy where the depth gradient is great. At deeper layers, the model seems to be irrational because of the decreased surface stress. Meanwhile, according to the non-linear 3D finite element method, at 10 m layer, the maximum horizontal velocity is 38 cm/s, direction 60° at 10.149° N–107.498° E. At this position, the downward vertical velocity w=-0.001461 cm/s. The extreme vertical velocities reached w=-0.03106 (110.815° E–10.143° N) and w=0.02951 cm/s (112.386° E–10.141° N) (Fig. 5).

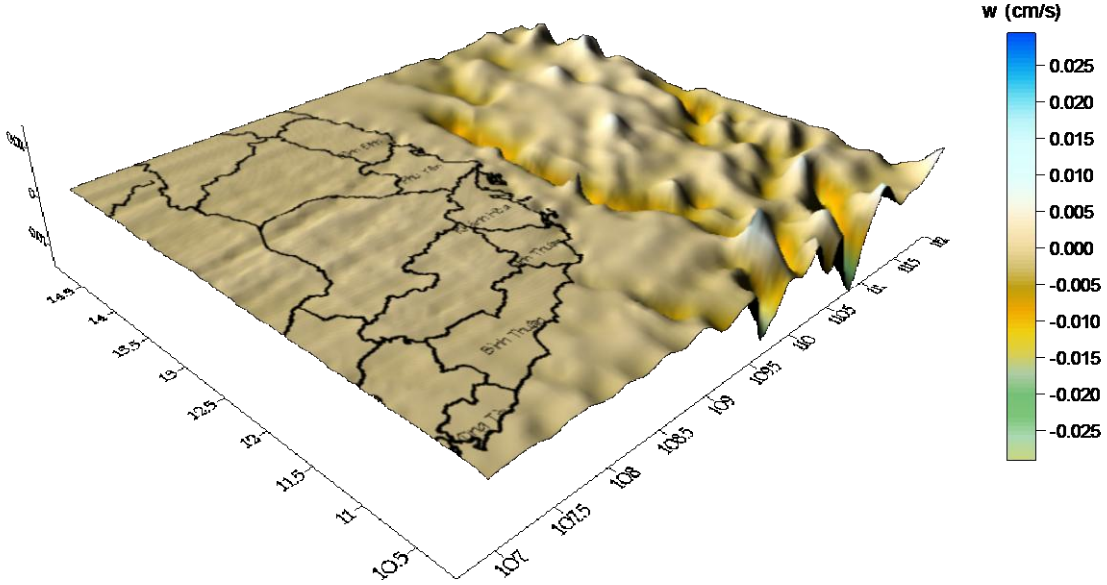


Fig. 5. Distribution of vertical current velocities at 10 m layer
(averagely computed for the wind field in Aug. 2005).

- At 50 m layer, the peak horizontal velocity may reach 23 cm/s, diretion 73° at the position 108.371° E–10.147° N, where the downward vertical velocity is w=-0.004812 cm/s. This position is obviously different to those at 10 m layer. The extreme vertical velocities are w=0.0361 cm/s (109.969° E; 10.503° N) and w=-0.05804 cm/s (109.593° E; 10.145° N) (Fig. 6).

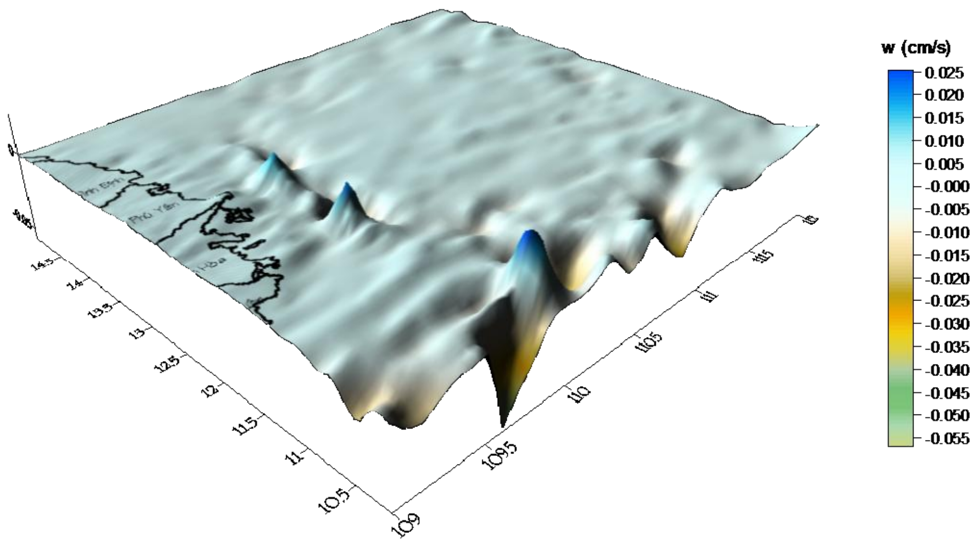


Fig. 6. Distribution of vetical current velocities at the 50 m layer
(averagely computed for the wind field in August 2005).

- At 100 m layer, at the positon 109.125° E–10.247° N, the horizontal velocity is highes with 11cm/s, direction 82°, and vertical velocity here is -0.01843 cm/s. The extreme vertical velocities are w=0.04017 cm/s (109.969° E; 10.503° N), and w=-0.06713 cm/s (109.593° E, 10.145° N) (Fig. 7).

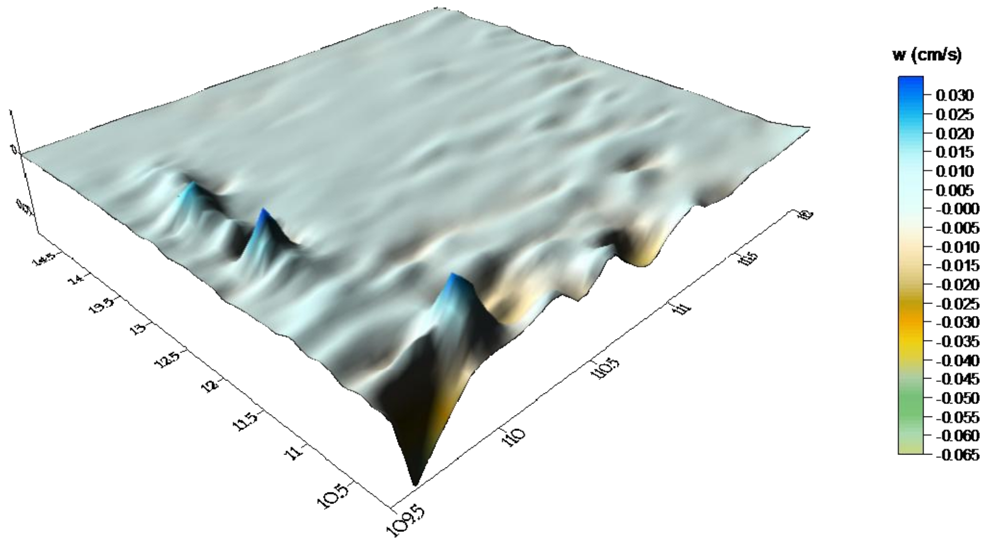


Fig. 7. Distribution of vertical current velocities at 100 m layer (averagely computed for the wind field in Aug. 2005).

- At 150 m layer, the horizontal velocity is maximum at 109.244°E–10.146° N with $|\vec{V}|$ = 8 cm/s, direction 72°, while w=-0.0149 cm/s here. The extreme vertical velocities reached w=0.04641 cm/s (109.76° E; 12.06° N), and w=-0.07096 cm/s (109.593° E; 10.145° N) (Fig. 8).

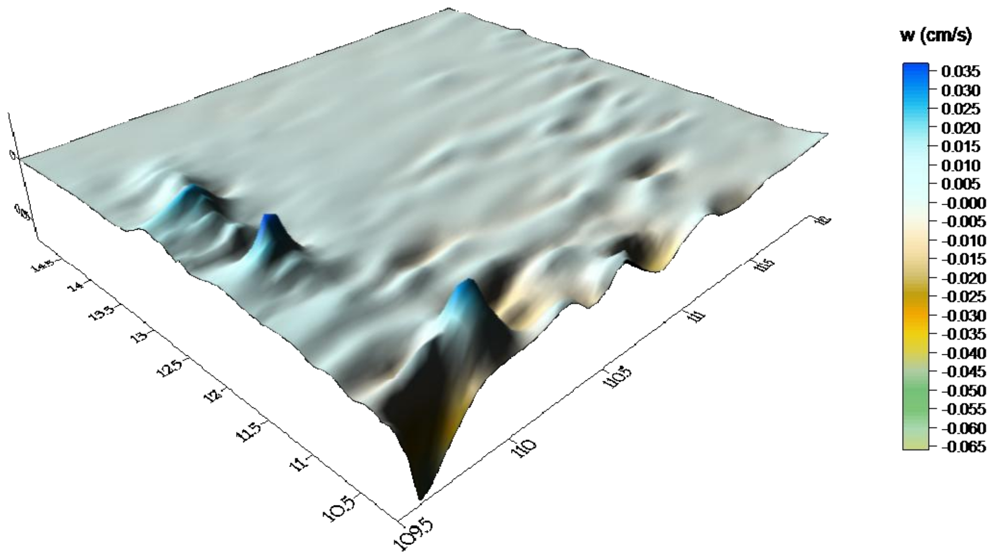


Fig. 8. Distribution of vertical current velocities at 150 m layer (averagely computed for the wind field in Aug. 2005).

- At 200 m layer, peak horizontal velocity is 5 cm/s, with direction 61° at 109.593° E–10.145° N, where the downward vertical velocity also reached its highes value of w=-0.07433 cm/s. The maximum upward vertical velocity is w=0.05226 cm/s (109.76° E; 12.06° N) (Fig. 9).

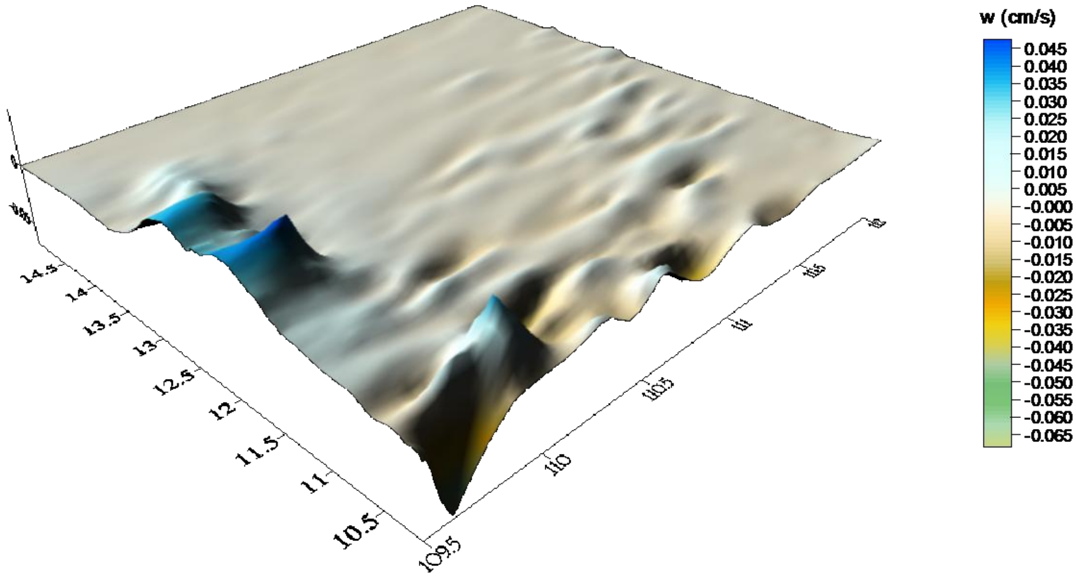


Fig. 9. Distribution of vertical current velocities at 200 m layer (averagely computed for the wind field in Aug. 2005).

The northeastern wind field (11/2005). During this time, on the computational grid, the peak wind velocity is 10.2 m/s, minimum 5.8 m/s, aveage 7.9 m/s.

- At 5 m layer, at the position 107.455° E–10.149° N, the horizontal velocity is highest with $|\vec{V}|$=38 cm/s, direction 239°, where w=0.0004293cm/s (Fig. 14). Peak vertical velocities are 0.005447cm/s (110.833° E; 10.308° N), and -0.003095cm/s (109.969° E; 10.503° N) (Fig. 10).

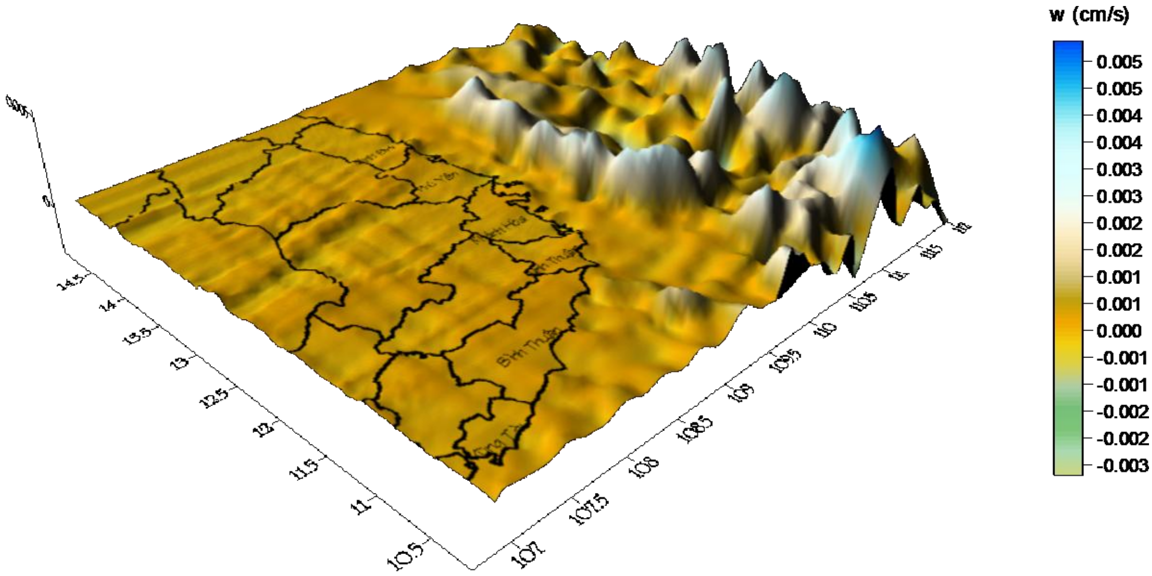


Fig. 10. Distribution of vertical current velocities at the 5 m layer (averagely computed for the wind field in Nov. 2005).

- At 10 m layer, peak horizontal velocity $|\vec{V}|$=37 cm/s, direction 242° at 108.022° E–10.148° N, and here w=0.001891 cm/s. Peak vertical velocities are 0.02305 cm/s (110.815° E; 10.143° N), and -0.01653 cm/s (109.969° E; 10.503° N) (Fig. 11).

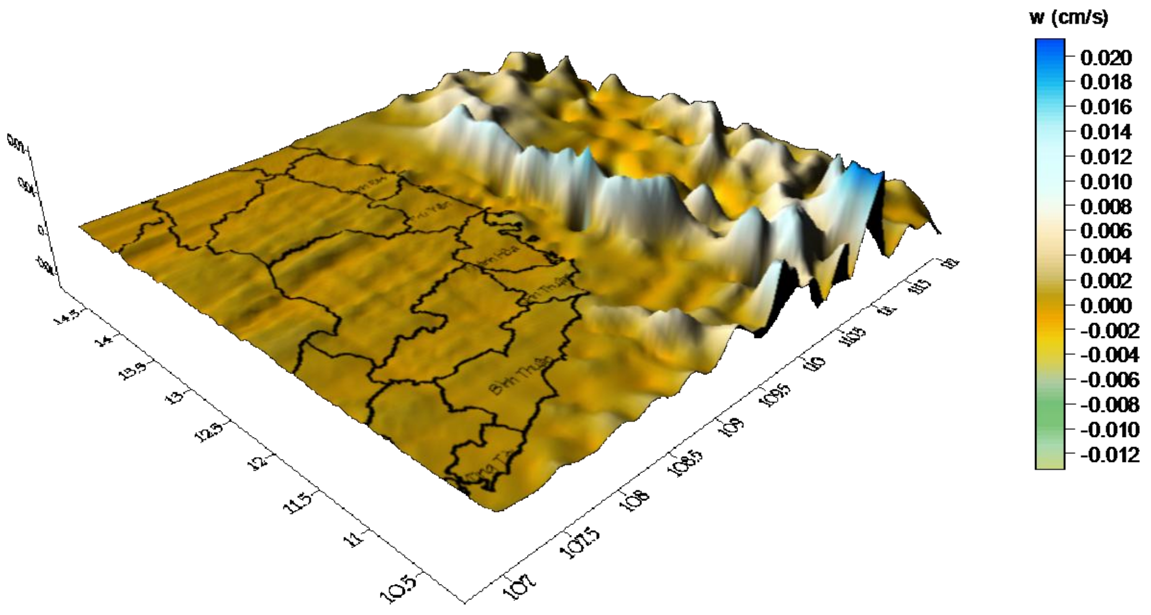


Fig. 11. Distribution of vertical current velocities at the 10 m layer (averagely computed for the wind field in Nov. 2005).

- At 50 m layer, peak horizontal velocity is 27 cm/s, direction 249° at 108.371 °E–10.147° N, where w=0.00508 cm/s. Peak verical velocities are 0.04061 cm/s (109.593° E–10.145° N), and -0.02882 cm/s (109.969° E–10.503° N) (Fig. 12).

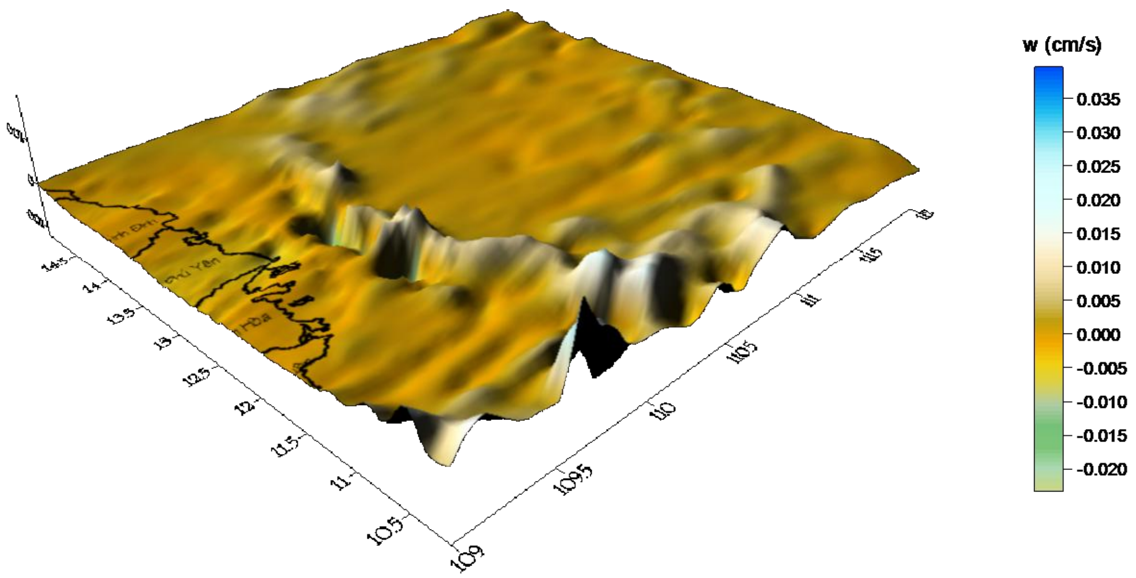


Fig. 12. Distribution of vertical current velocities at the 50 m layer (averagely computed for the wind field in Nov. 2005).

- At 100 m, at the position 109.157° E-10.146° N, horizontal velocity is highes with 12 cm/s, direction 249°, and here w=0.02225 cm/s. Highest vertical velocities reached w=0.04511 cm/s (109.593° E; 10.145° N), w=-0.03963 cm/s (109.76° E; 12.06° N) (Fig. 13).

- At 150 m layer, at the position 109.244° E; 10.146° N, peak horizontal velocity is 8 cm/s, direction 249° at 109.244° E–10.146° N, and here w=0.01464 cm/s. Extreme vertical velocities reached 0.04639 cm/s (109.593° E; 10.145° N), and -0.04627 cm/s (109.76° E; 12.06° N) (Fig. 14).

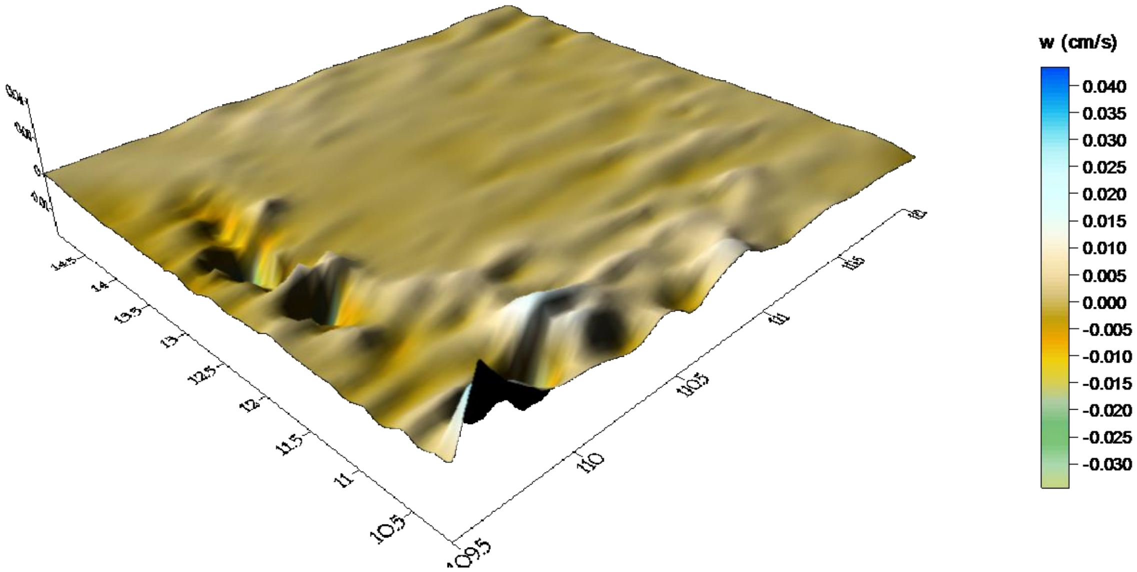


Fig. 13. Distribution of vertical current velocities at the 100 m layer
(averagely computed for the wind field in Nov. 2005)

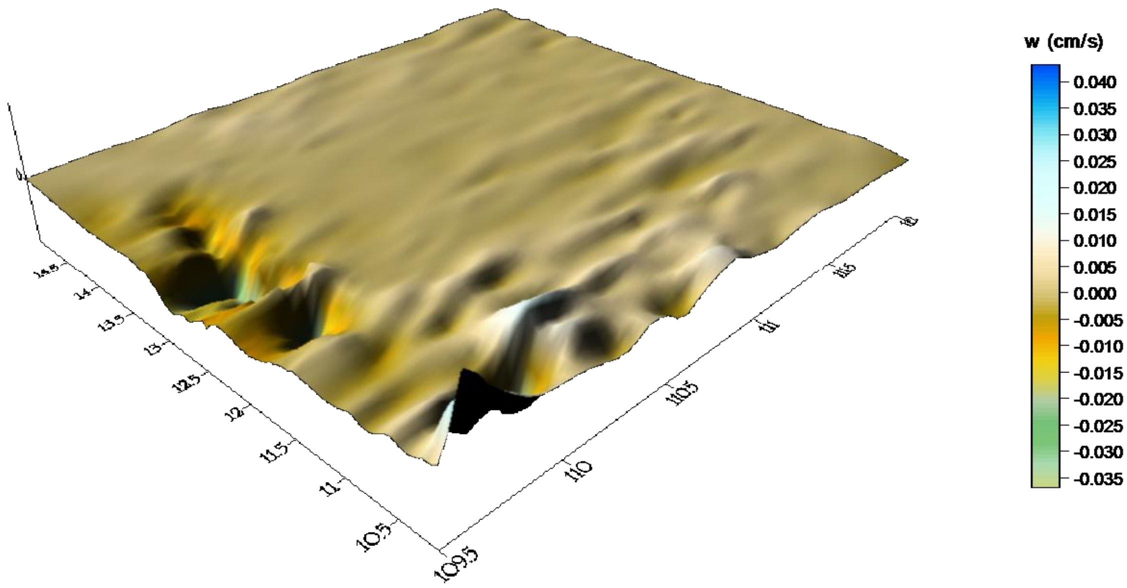


Fig. 14. Distribution of vertical current velocities at the 150 m layer
(averagely computed for the wind field in Nov. 2005)

- At 200 m layer, maximum horizontal velocity is 5 cm/s, direction 255° (109.418° E; 10.146° N), and here w=0.006646 cm/s. Extreme veritical velocities are 0.04471 cm/s (109.593° E; 10.145° N), and -0.05197 cm/s (109.76° E; 12.06° N) (Fig. 15).

Conclusion

The southwestern and northeastern wind-driven currents (in August and Nov. 2005) are computed in a 3D nonlinear model. The computation is performed based on the nonlinear 3D shallow water wave equation using the finite element method. The initial results are good, especially the high flexibility to hard boundaries, the stability of the problem (due to the empolyment of iteration in implicit time difference). The computational mesh is flexible according

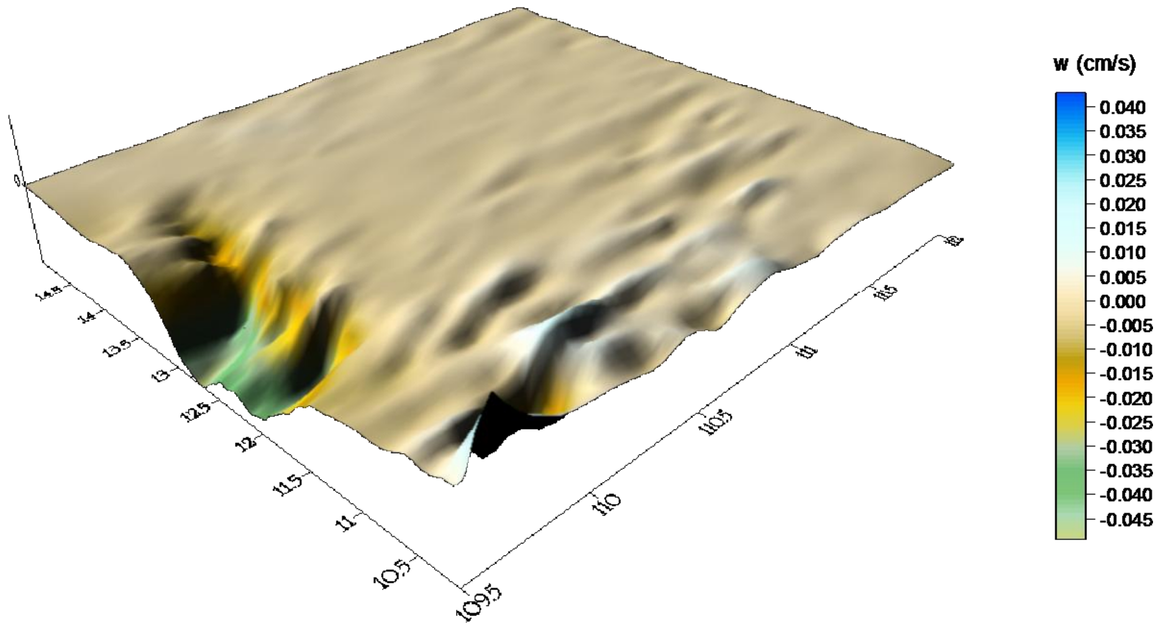


Fig. 15. Distribution of vertical current velocities at the 200 m layer (averagely computed for the wind field in Nov. 2005).

to the topographic changes. However, this result is only the initial result of the whole development process of the model. In order to evaluate more accurately the centre of the upwelling in southern central waters, this model need improvement and check with field data, which will be dealt with in the coming time for better sastifaction of future upwelling research.

References

Cushman-Roisin B., Naimie C.E. 2002. A 3D finite-element model of the Adriatic tides // Journal of Marine Systems. V. 37. P. 279–297.

Greenberg D.A., Shore J.A., Page F.H., Dowd M. 2004. A finite element circulation model for embayments with drying intertidal areas and its application to the Quoddy region of the Bay of Fundy // Ocean Modelling. V. 10. P. 211–231.

Hagen S.C., Westerink J.J., Kolar R.L. 2000. One-demensional finite element grids based on a localized truncation error analysis // International Journal for Numerical Methods in Fluids. V. 32. P. 241–261.

Hanert E., Legat V., Deleersnijder E. 2002. A comparison of three finite elements to solve the linear shallow water equations. Ocean Modelling. V. 5. P. 17–35.

National Marine Research Program KHCN-06. Pham Van Ninh (Ed.) (1996-2000). 2003. “South China Sea” (Part: Marine Hydrometeorology and Dynamics). Vol. 2. Ha Noi: National Univ. Publishing House. 565 p.

Nechaev D., Schrůter J., Yaremchuk M. 2003. A diagnostic stabilized finite-element ocean circulation model // Ocean Modelling. V. 5. P. 37–63.

Kashiyama K., Saitoh K., Behr M., Tezduyar T.E. 1997. Parallel finite element methods for large-scale computation of storm surges and tidal flows // International Journal for Numerical Methods in Fluids. V. 24. P. 1371–1389.

Kawahara M., Ding Y. 1998. Bifurcation analysis of brown tide in tidal flow using finite element method // Computer Methods in Applied Mechanics and Engineering. V. 151. P. 195–213.

Subrata Kumar Bhattacharyya, Santhosh Sathyapal, Chiruvai P. Vandhan. 2001. Absorbing boundary condition on elliptic boundary for finite element analysis of water wave diffraction by large elongated bodies // International Journal for Numerical Methods in Fluids. V. 37. P. 249–277.

AN OVERVIEW OF THREATS TO ECOSYSTEM SERVICES OF TROPICAL PEATLANDS AND MANGROVES IN SOUTHEAST ASIA

Nguyen Chu Hoi

Chairman of ASEAN Working Group on Coastal and Marine Environment,

Vietnam Administration of Seas and Islands

e-mail: nchoi52@gmail.com

Introduction

The Southeast Asia (SEA) includes 11 countries in which 10 are ASEAN members, except Timor-Leste and 10 are maritime countries and island states, except Lao PDR. The SEA region lies within the waters of the Pacific Ocean, Indian Ocean, Andaman Sea and South China Sea (Bien Dong Sea) and borders China to the north, India and Bangladesh to the northwest, and Papua New Guinea to the southeast. The ASEAN has combined land area of about 4.46 million square kilometers, accounting for 3% of the world's total area.

About 35% of mangrove (52.000 square kilometers) and 60% of the global tropical peatland (25 millions hectares) – ecosystems that support the highest coastal and marine biodiversity of the world can be found associated with 173,000 kilometers of coastline in the marine environs of the ASEAN region. The coastal and marine components are a resource base for key industries in the region, including fisheries, aquaculture, tourism and shipping, and for some 580 million people which equal 8.7% of the world's total (mid-2008), it is the lifeline for a secure source of food and income.

Mangrove and peat forest ecosystems fulfill a number of important functions and provide a wide range of services at the local and national levels. Fishermen, farmers and other rural people depend on them as a source of wood (timber, poles, osts, fuelwood, charcoal, and non-wood forest products (food, alcohol, sugar, medicine and honey, especially from nipa palm), production of tannin for leather work.

However, these ecosystems and their services are regionally threatened by human activities and natural impacts including agricultural, aquacultural and urbanization expansion, land-based sources of pollution, climate change and its associated consequences. These threats cause the coastal and marine biodiversity resources of the region, and may reduce their capacity to continuously provide for the livelihoods, health and food security of its people.

Facing the challenges, many countries of the region have taken initiatives to conserve and protect their ecosystems including establishment of Ramsar sites, coastal protected areas (CPA), national parks and the degradated ecosystems restoration, etc. Especially, the regional ASEAN Peatland Management Strategy has also been adopted to address the above mentioned challenges on sustainable base. The countries of the region have also various conservation efforts which have been mobilized, funded and have resulted to successful improvement of local human and institutional capacities in management, governance and enforcement of mangrove and peatland protected areas.

The paper presents an overview of the state of mangrove and peatland ecosystems in the region, focusing coastal areas, which not only is a regional common concern, but also of globally benefits; about the pressures, threats to the ecosystem services and the management responses to address the above threats. The main sources of information for the paper's preparation were the ASEAN Center for Biodiversity (ACB), FAO/RAP, MFF, ASEAN's publications from which the paper's author extracted and presented as the references.

Status of Mangroves and Peatlands in the Region

Mangroves. Mangroves are unique in that they an eco-tone between land and sea. They are a type of wetlands characterized by coastal salt-tolerant tidal forests in tropical and subtropical zones. Mangroves play an integral role in the ecology of watersheds, including protection against coastal erosion and natural hazards (including climate change); protection of coral reefs, seagrass beds and shipping lanes against siltation; support conservation of biodiversity by providing habitats, spawning grounds, nurseries and nutrients to support a marine food web, for a number of animals, as well as for many commercial species of fish and shellfish, including a number of endangered species (FAO, 2007).

According to Dan Laffoley (2009), half the world's carbon stocks are held in plankton, mangroves, salt marshes and other marine life. So it is at least as important to preserve this ocean life as it is to preserve forests, to secure its role in helping us adapt to and mitigate climate change. The case for better management of oceans and coasts is twofold. These healthy plant habitats help meet the needs of people adapting to climate change, and they also reduce greenhouse gases by storing carbon dioxide.

The mangroves are widely distributed along the SEA region's coastline, particularly at sheltered estuaries, coastal deltas, along river banks and lagoons. In the SEA region, there are over 5,243,830 hectares (over 35% of the world total in 2005), a reduction of about 18% since 1980. Presently, the region has the largest extent of mangroves in the world with Indonesia accounting for more than half of ASEAN's mangrove areas, and together with Malaysia and Myanmar account for more than 80% of total mangroves in Southeast Asia.

The report by FAO (2007) showed that 20% (or 36,000 km^2) of the global mangrove areas have been lost since 1980. The greatest extent of mangroves is found in the East Asia of Seas (EAS) region, where mangrove loss between 1980 and 2005 ranges from 14% in Thailand and Viet Nam some 45% to over 60% in Singapore. The reduction of mangroves between 1980 and 2005 is presents in Table 1.

Table 1. Mangrove areas in SE Asia (1980–2005)

Country	Hectares		% of total ASEAN mangrove area	
	1980	2005	1980	2005
Brunei Darussalam	18,400	18,400	0.29	0.35
Cambodia	91,200	69,200 (loss 22,000 ha)	1.43	1.32
Indonesia	4,200,000	3,443,830 (756,170 ha)	65.78	65.71
Malaysia	674,000	565,000 (109,000 ha)	10.56	10.78
Myanmar	555,500	507,000 (48,500 ha)	8.70	9.67
Philippines	295,000	240,000 (55,000 ha)	4.62	4.58
Singapore	1,790	400 (1,390 ha)	0.03	0.01
Thailand	280,000	240,000 (40,000 ha)	4.39	4.58
Timor - Leste	na	3,000	na	na
Viet Nam	269,150	157,000 (112,150 ha)	4.22	3.00
Total	**6,385,040**	**5,243,830**	**100**	**100**

Note: Source: FAO updated by ASEAN member state (AMS), RAP publication 2006/200;
na – not available.

The edaphic and coastal features of the SEA's countries, together with the high rainfall and significant reverie inputs, are particularly favorable to the development of well-structured mangrove forests. Along the coasts, trees may grow to a height of 20-30m in Malaysia, Thailand, Viet Nam, or even to 50m in Indonesia (ASEAN, 2009). This country harbors the highest biodiversity in the region - and in the world – with 43 different true mangrove species, followed by Malaysia, Thailand and Viet Nam.

Peatland. Peat is one of the important soil types which much have a very high organic matter content (more than 65% organic matter) in a soil layer at least 50cm deep. An area where peat soil has naturally accumulated is called a peatland (ACB, 2009). Peatlands are primarily water-logged areas containing centuries-old decayed vegetative matter up to several metres deep. Peatlands are mainly found in the coastal lowlands in ASEAN region as a natural peat swamp forest ecosystems (for example in Indonesia, Malaysia, Thailand and Viet Nam). In ASEAN, peatland is usually found in low altitude, sub-coastal areas extending inland for distances upto 300 kilometres and with depths varying from 0.5 metre to more than 10 metres (ASEAN, 2009).

The ASEAN region has more than 30 million hectares of peatland, comprising 60% of the global tropical peatland and roughly one tenth of the entire extent global peatland. A majority of

ASEAN peatland occurs in Indonesia, which has over 70% of total peatland area in SEA. Remaining peatland areas are found in Malaysia (2.6 million ha), Thailand, Viet Nam, Brunei Darussalam and the Philippines (ASEAN, 2009; ACB, 2009).

Peatlands contribute to the economy and ecology in the region in terms of providing timber and non-timber forest products, land for agriculture development, water supply, food control, educational and recreational values and many other benefits. These peatlands have not only significant importance for socio-economic development, but also support for the livelihoods of local communities. In Malaysia, there are at least 120 timber species of commercial value found in peat swamp forests, and fish species are main source of protein for local people and for ornamental fish trade. The peat has function of water regulation as a sponge absorbing water during the wet season and releasing it gradually during dry periods. Peatlands also maintain dry season river flow and reduce incursion of tidal waters, so they can prevent the saline water intrusion (ACB, 2009).

Peatland ecosystems have globally and regionally significant roles in storing and sinking carbon and acting as repositories for unique and important biodiversity (ASEAN, 2009; ACB, 2009). Peat swamp forests in the SEA region store an average of 2000 tons of carbon per hectare (ACB, 2009). If disturbed by drainage and burning, the carbon is released into the atmosphere, contributing to greenhouse effects. In 1997-1998, forest and peatland fires in the region had caused an estimated $ 9 billion worth of damage. Peatland fires are now major problems of regional and global significance releasing carbon emissions and causing transboundary smoke haze pollution (ASEAN, 2009).

The Table 2 presents the state and distribution of peatland in some AMSs.

Table 2. The state and distribution of peatland in some AMSs.

Indonesia	Total peatland was estimated (in 1987) about 17 million hectares, down from original peatland area of about 20 million hectares (in 2000). The loss of 3 million hectares of peatlands between 1987 and 2000. The major peatland areas in Indonesia are: Sumatra (4.6 million ha), Kalimantan (3.5 million ha) and Papua (8.7 million ha).
Malaysia	The total of peat swamps is 2.5 million ha; mainly distribution in Peninsular Malaysia (0.9 million ha), in Sabah and Sarawak (peat swamps – about 1.5 million ha).
Thailand	The total of peat swamps is 64,000 ha; mainly distribution in Narathiwat province of Southeast Thailand (45,000 ha); the most important site is Pru Toh Daeng.
Brunei Darussalam	The main peat deposits are in Belait Peat Swamp in the South and peat swamp forest in the Tasek Merimbun Park in Central Brunei.
Philippines	The main peat areas are in the Southern Island of Mindanao, primarily in Agusan Marsh and Liguasan Marsh.
Viet Nam	The main peat areas are located in the Mekong Delta, especially in Dong Thap Muoi area.

Note: Source: Fourth ASEAN State of the Environment Report 2009 (ASEAN, 2009).

Pressures and Threats to the Mangroves and Peatlands in the Region

As the above mentions, the mangrove and peatland ecosystems of the SEA region are among the richest and most productive in the world and of enormous social and economic importance to the region's counties. Historically, the coastal zones where disributed the mangrove and peatland, have been the site of, and often the drive for the region's most dynamic economic development and population growth. Despite the undeniable economic gain from coastal development, tremendous pressures and threats to the coastal managrove and peatland ecosystems increasingly compromise their sustainable use. Worldwide, coastal habitats like these mangroves and peatlands are being lost because of human activity. Extensive areas have been altered by land reclamation and fish farming, while coastal pollution and overfishing have further damaged habitats and reduced the variety of species. It is now clear that such degradation has not only affected the livelihoods and well-being of more than millions people dependent on these ecosystems for food, it has also reduced the capacity of these ecosystems to store carbon (Polidoro, 2010).

The loss of mangroves in the SEA region is being pertained to coastal development activities and traditionally used mangroves of the rural people as a source of wood and non-wood forest products for the production of charcoal, fuel wood, timber, and poles for houses, boats and fish-traps, even for national and international markets (Indonesia, Malaysia, Viet Nam, Brunei Darussalam and The Philippines) (ACB, 2009).

Several fishing and rural communities depend on the fish and shellfish in mangroves as a source of income and food security, when mangroves are destroyed, a significant decrease in local fish catches has been resulted. Many rural communities have used mangroves to produce honey, tannins, and traditional medicines. All of the above mangrove uses have led to reduction of the mangrove area, mangrove growth and density, stunting trees and degrading stand quality (FAO, 2007).

One of the biggest threats to mangrove forests in the region is the expansion of aquaculture, most shrimp farms. Due to its high economic return, the farming has been promoted to boost national economies, as a potential source of income for local communities and as a means of poverty alleviation. However, the extensive aquaculture production has led to widespread mangrove destruction, to loss of habitat, of ecosystem services provided by mangroves. The environmental impacts of this "blue revolution" are enormous: accidental escapes of non-native species, invasion of pathogens to wild stocks, discharge of waste, and destruction of coastal habitats makes current aquaculture practices largely unsustainable (Seto, Fragkias, 2007).

The delta of the Ayeyarwady river, Myanmar, is large mangrove forest which has, however, been degraded over time owing to overexploitation of the resource and to the conversion of land for rice-fields, an activity promoted by the government as a way to ensure self-sufficiency in food production. The main causes of mangrove loss in Indonesia, Malaysia, Viet Nam, Philippines, Singapore are conversion of land for shrimp farms, excessive logging, and to a lesser extent, conversion of land to agriculture, urban development and human settlements or salt production and coastal tourism, fewer by oil spill and pollution, even during the war (Viet Nam 1962–72) (ASEAN, 2009; FAO, 2007).

Among the current threats to mangrove ecosystem, the ever-increasing human pressure on coastal areas is one of the most serious. Besides that, the natural hazards such as cyclones, storms and floods frequently occur in the region, threatening several coastal ecosystems, including mangroves. Trees in the front lines are often uprooted and damaged during the events (FAO, 2007).

While being significantly important for development, livelihood, environment and biodiversity, unsustainable practices and adverse climate conditions have severely degraded the peatlands, making them the primary source of fires and smoke haze that affects the region regularly. Degraded peatlands are also a major source of greenhouse gases contributing to global warming (ASEAN, 2009).

The loss of 3 million hectares of peatlands in Indonesia as above mentioned (Table 2) were converted or destroyed between 1987 and 2000 mainly for the cultivation of perennial or plantation crops such as oil palm, and more and more increasingly up to now. And the peat swamp forests in Malaysia have been cleared for agriculture, and are under plantation crops of oil palm (ASEAN, 2009). In Viet Nam the peat forests in Mekong delta have been lost by dried up and fired which damaged the benefits from the peatland for local community and economic development. The forest fire in general and peat forest fire in particular in ASEAN is considered as a transboundary haze issue.

Recently, the climate change impact to coastal ecosystems in general and to managrove and peatland ecosystems in particular is being more and more interested by not only relevant scientists, managers but also by entire society, and at all levels. As a results of climate change, the warming of water-bodies can result in significant biological changes, degradation of peatlands and mangroves, and affects species in many ways: by rising sea levels faster than most biomes can adapt; by stressing temperature-sensitive organisms which are living in and around these ecosystems; by changing current patterns and other ecological conditions in the water-bodies; by increasing temperature in the water-bodies influences on species with narrow temperature tolerances (Geisen, 2006; UNEP/COBSEA, 2010).

The Regional Management Efforts of the Mangroves and Peatlands

It is vitally important that the above mentioned pressures and threats be better monitored, understood and managed, and translated into a more effective and integrated management system that achieves the necessary balance between current social and economic needs, and conservation for future needs (MFF, 2009).

A series of international principles for responsible shrimp farming have been prepared by the FAO, Network of Aquaculture Centers in Asia-pacific, UNEP, WB, WWF, with the main aim of offering guidance on reducing the sector’s environmental impacts while boosting its contribution to poverty alleviation. The international organizations have also supports to the region’s countries in development of more eco-friendly shrimp production (FAO, 2007).

At regional level, the ASEAN Summit has approved and endorsed a number of policy, institutional framework for mangrove, peatland management, governance and reached to the relatively achievements. The countries of the region have also various concrete efforts which have been mobilized, funded and have resulted to successful improvement of local human and institutional capacities in management, governnance and enforcement of mangrove and peatland protected areas.

A number of ASEAN's wetlands have been disignated as Wetlands of International Importance or Ramsar sites which identified based on the criteria (09) listed by the Convention of Wetlands of International Importance (Ramsar Convention). The Ramsar sites established to promote the wise use of the important wetland ecosystems, to maintain their ecological function and character within the context of sustainable development based on ecosystem-based approaches. In 2009 (ASEAN, 2009), some 29 ASEAN's Ramsar sites have been established in 07 AMSs by different time (Combodia, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Viet Nam) with a total area of 1,320,391 hectares, increased by 63% from 811,000 hectares in 2006. Among them, Thailand has the most Ramsar sites (10 sites), followed by Malaysia (6), the Philippines (4), Cambodia (3), Indonesia (3) and has the largest area of the Ramsar sites, covering a total of 656,510 hectares (or 50% of the regional total), Viet Nam (02) and Myanmar (01).

This is an important contribution of AMSs to the global efforts as the region hosts some of the most important peatlands and mangrove forests in the world, and hopefully more wetlands in the region will be designated as Ramsar sites in the future.

The ASEAN's commitment to a more sustainable path to development was expressed as early as 1997 in the ASEAN Vision 2020 which called for: "*A clean and green ASEAN with fully established mechanisms for sustainable development so as to ensure the environmental protection of the region, the sustainability of its natural resources, and the preservation of its cultural heritage and the high quality of life of its peoples"*.

In November 2006, ASEAN Environment Ministers endorsed the ASEAN Peatland Management Strategy (2006–2020) (APMS) to provide a framework for the sustainable management of peatland. The APMS was prepared due to the pressing need for wise use and sustainable management of peatlands as well as the emerging threat of peatland fire and its associated haze to the economy and health of the region, and its contribution to addressing global climate change. The goal of the strategy is to promote sustainable management of peatland in the ASEAN region through collective action and enhanced cooperation to support and sustain local livelihoods, reduce risk of fire and associated haze and contribute to global environmental management. The strategy includes 25 operational objectives and 97 actions in 13 focal areas ranging from integrated management to climate change and inventory.

The APMS focuses on the following 4 objectives:

- enhance awareness and knowledge on peatlands;
- address transboundary haze pollution and environmental degradation;
- promote sustainable management of peatlands;
- enhance and promote collective regional cooperation on peatland management.

The APMS contains operational actions in the following focal areas:

- inventory and assessment;
- research;
- awareness and capacity building;
- information sharing;
- policies and legislation;
- fire prevention, control and monitoring;
- conservation of peatland biodiversity;
- integrated management of peatlands;
- promotion of demonstration sites for peatlands;
- restoration nand rehabilitation;
- peatland and climate change;
- regional cooperation;
- financing of the implementation of Strategy.

The AMSs have been developed the National Action Plans (NAPs) on Peatlands and are in the process of implementing these action plans. At regional level, ASEAN Centre of Biodiversity (ACB) plays an important role in coordinating and collaborating mechanism to implement the Strategy. The AADCP-RPS project on "Capacity building to improve peatland management and reduce land and forest fires and associated transboundary haze pollution in the ASEAN region" has been completed in April 2008. During 2008–2009, the project on "Conservation of peatland of biodiversity in the South East Asia" supported by the ACB in partnership with the Global Environment Centre has been undertaken. The project focused on practical actions and identfication of the gaps to support the implementation of the APMS and NAPs and also follow through specific items to address management issues of peatlands in the region and in-country (ACB, 2009).

Except from that, the AMSs have undertake the joint efforts in monitoring, preventing and mitigating transboundary haze pollution based on the Regional Haze Action Plan and the ASEAN Agreement on Transboundary Haze Pollution (ASEAN Haze Agreement) which entered into force on the 25th November, 2003. The Agreement includes also the establishment of the ASEAN Transboundary Haze Pollution Control Fund. One of the actions is control and monitor land and forest fire occurrence in the region and promote the sustainable management of peatlands in the ASEAN region to reduce risk of fire and associated transboundary haze pollution through the implementation of the ASEAN Peatland Management Initiative by the year 2015. A US$ 15 million peatland project (US$ 4.3 million from GEF) is being implemented to undertake measures to prevent peatland fires, the major source of smoke haze in the region.

On the 15th December 2008, the ASEAN Charter has been entried into force and the Charter represents a significant development in the long history of ASEAN which transformed the coalition of nations born out of the Bangkok Declaration of 1967 into a legal and rules-based entity. The Charter has emphasized that the ASEAN shall promote and vigorously pursue its sustainable development framework as embodied in the Roadmap for an ASEAN Community 2009–2015 while a market-based economy still have to focus on economic growth and social development.

Beside the regional policy and institutional framework to conserve and protect the mangroves and peatlands, the activities at community level were to be also encouraged. Many examples of the community participation in mangrove conservation and rehabilitation of the AMSs such as in Kok Kong province, Cambodia and etc. have been successfully undertaken and synthesized as the regional case study. The Belait Peat Swamp in Brunei Darussalam is a good example of a well-kept peat swamp forest in the region. Malaysia and Viet Nam have very long traditions of sustainable management, plantation and afforestation programmes of mangroves, even Viet Nam has an on-going progrmme at national level on mangrove plantation and conservation towards year 2020 funded by its government. Many countries in the region have been increasingly promoting establishment and maintenance of mangrove greenbelts as protection against natural hazards such as Philippines, Viet Nam. Many countries in the region have also promulgated laws and regulations to protect remaining mangrove areas and mitigate widespread loss. However, effective enforcement of this legislation is often hampered by a lack of financial and human resources (MFF, 2009).

Countries should be encouraged to establish coastal and marine protected areas – that is, set aside parts of the coast and sea where nature is allowed to thrive without undue human interference – and do what they can to restore habitats like mangrove, tidal marshes and sea-grass meadows. Managing these habitats is far less expensive than trying to shore up coastlines after the damage has been done. Maintaining healthy stands of mangroves in the region through careful management, for example, has proved to cost only one-seventh of what it would cost to erect manmade coastal defenses against storms, waves and tidal surges (Laffoley, 2009).

Recommendations

To effectively conserve and sustainable use of the peatland and mangrove ecosystems in new climatic regime to address the threats to them, the following actions should be implemented together with the above mentions:

- encouraging the actions at national and local level with technical assistance from the international and regional programs such as MFF, PEMSEA, ACB etc;

- networking the coastal ecosystems, including the peatland and mangrove among ASEAN and between ASEAN and dialogue countries;

- improve the regional policy and institutional framework of coastal and marine biodiversity management in new climatic regime with the key role of the ACB;

- investment for coastal ecosystems means invest in coastal infrastructure like the MFF's statement;

- increasing exchange of experiences and lessons learnt from both sides of ASEAN and dialogue countries, especially Europe;

- developing and implementing a Asia-Europe joint program on peatland and mangrove sustainable use to mobilize the implementation of the APMS;

- development of coastal green corridors in the member states to capture carbon and protect the coastal areas.

References

ACB. 2009. Conservation of Peatland Biodiversity in South East Asia (phase II). Copletation report, Manila, The Philippines.

FAO. 2007. The World's Mangroves 1980-2005. FAO Forestry Paper 153, Rome, Italy.

Fourth ASEAN State of the Environment Report. 2009. Published by the ASEAN Secretariat under sponsor of Japan-ASEAN Cooperation (JAIF) and Hanns Seidel Foundation (HSF), Jakarta, Indonesia.

Geisen W. et al. 2006. Mangrove Guidebook for Southeast Asia. FAO and Wetland International, RAP Publication 2006/2007, Rome, Italy.

MFF (Mangrove For Future) Initiative. 2009. Rapid Assessment: Opportunities for a Sustainable Regional Mechanism for Governmental and Civil Society Collaboration on Integrated Coastal Management. Published by MFF Secretariat, Bangkok, Thailand.

Laffoley D. 2009. To Save the Planet, Save the Seas. Op-Ed Contributor in COP15, Copenhagen, Denmak.

Polidoro B.A. et al. 2010. The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern. PloS ONE 5(4): e10095. doi: 10.1371/journal.pone.001 0095.

Seto K.C., Fragkias M. 2007. Mangrove Conservation and Aquaculture Development in Viet Nam: A Remote Sensing-based Approach for Evaluating the Ramsar Convention on Wetlands // Global Environmental Change. V. 17. P. 486–500.

UNEP/COBSEA. 2010. State of the Marine Environment Report for the East Asian Seas 2009**.** Ed. Chou L.M., COBSEA (Coordinating Body on The Seas of East Asia) Secretariat, Bangkok, Thailand.

DIVERSITY OF BIVALVE MOLLUSKS IN THE SOUTH CHINA SEA

Konstantin A. Lutaenko

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch of the Russian Academy of Sciences, Vladivostok 690041, Russia

e-mail: lutaenko@mail.primorye.ru

Introduction

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

A Brief History of Molluscan Research

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

Bivalve molluscan richness in the South China Sea

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

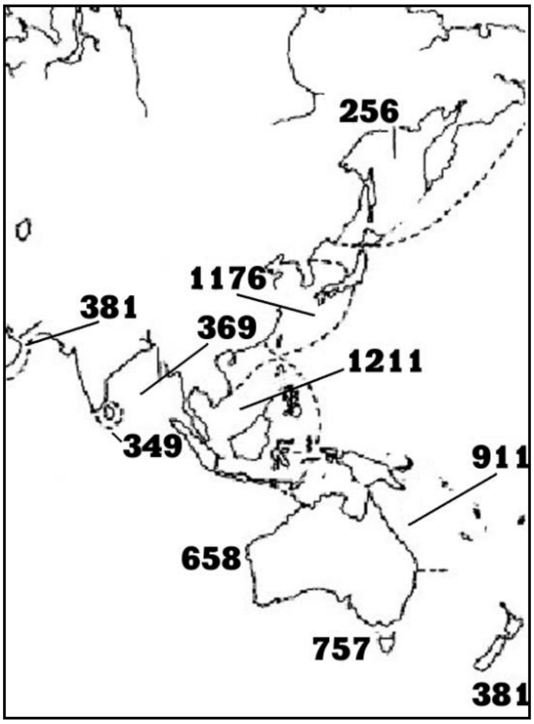


Fig. 1. Species richness (number of species) of bivalve mollusks in the south-east Asia and adjacent some areas (modified after: Crame (2000, p. 190, fig. 1).

This clearly reflects generally accepted concept of high biodiversity in the so-called "East Indies Triangle", or **Coral Triangle**: the ranges of many tropical marine species overlap in a centre of maximum biodiversity located in the Indo-Malayan region (Malaysia, the Philippines, Indonesia, and Papua New Guinea (Hoeksema, 2007). The Coral Trianle is recognized as a biodiversity hotspot but this centre is located approximately, and its exact boundaries are unknown (Fig. 2).

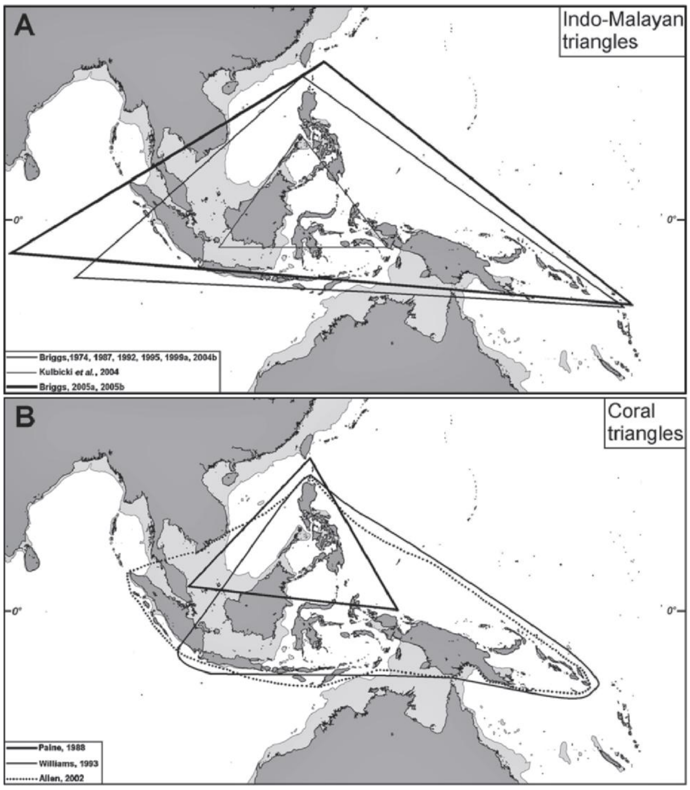


Fig. 2. Various versions of boundaries of the Coral Triangle (Indo-Malayan centre of marine biodiversity) (after Hoeksema, 2007, p. 124, fig. 1).

Regional differences in species richness of bivalves in the South China Sea are not clear. They rather reflect sampling efforts than real biogeographical phenomena. Lutaenko (2000b) listed 367 species names of bivalve mollusks from Vietnam based on two largest Russian collections from the Zoological Institute (243 species) and the Zoological Museum, Far East Federal University (Vladivostok) (83 species), and it was the most complete list at that time. Later on, Hylleberg and Kilburn (2003) compiled updated list of marine bivalves consisting of 815 species (Table 1), but it is uncritical in many ways.

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

Biogeography of Bivalve Fauna of Vietnam

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

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

1. *Absence of some common tropical faunal elements in Tonkin Gulf fauna*. *Mytilus smaragdinus* (= *Perna viridis*) (Mytilidae) was not found in expedition samples of the 1960s, while

Table 1. Species richness of bivalve mollusks in different parts of the South China Sea and some adjacent regions

Region	Number of species	Reference	Comments/notes
Japan	1472	Higo et al. (1999)	
China	1048	Xu (1997)	
Singapore	344	Tan, Woo (2010)	Majority of existing literature records cannot be verified due to a lack of voucher specimens
Vietnam	367	Lutaenko (2000b)	Based mostly on voucher specimens from two largest Russian collections of mollusks
Vietnam	815	Hylleberg, Kilburn (2003)	A compilation of all data available for Vietnam (literature and voucher collections in Vietnam)
Thailand	153	Suvatti (1938)	Including western Thailand; excluding species of Corbiculidae
Southern Gulf of Thailand	229	Swennen et al. (2001)	The area roughly between 6º and 7º N, about 10.000 km²
Northern Gulf of Thailand	244	Robba et al. (2002, 2003)	Records include Holocene shells recovered from the Holocene Bangkok Clay
Cambodia	93	Fischer (1973)	Corbiculidae is excluded
Tonkin Gulf	351	Zorina (1978a)	Based on voucher specimens
Guangdong Province, China	401	Cai, Xie (2006)	
Indonesia-Philippines region	1211	Crame (2000)	Excluding Taiwan and Papua New Guinea
Philippines	512	Flessa, Jablonski (1995)	A compilation based on literature data
Taiwan	463	Wu (1980)	

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

2. *Difference between the fauna of southern Vietnam and Tonkin Gulf.* About 170 species of Bivalvia were recorded for southern Vietnam based on different sources and 101 species – for Tonkin Gulf (Gurjanova, 1972, p. 89; but the list on pp. 78–80 icludes 104 species). The same regularity was established for gastropods. Gurjanova (1972) explained the impoverished character of Tonkin Gulf fauna by the strong variability of hydrological factors and water mass dynamics, complicated and unstable circulation system with strong tidal currents. However, Latypov (2000) found that the reefs of the northern part of the Bai Tu Long Archipelago and Ha Long and Bai Tu Long bays (Tonkin Gulf) show a great degree of similarity in composition and distribution of reef-building corals with other reefs of Vietnam and the whole South China Sea (having from 60

to 72% of the scleractinian species in common) and a rather great species diversity (no less than one third of the common coral species of the Pacific fauna are found here) (Latypov, 2000).

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

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

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

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

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

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

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

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

The study of the Vietnamese and Chinese molluscan collections in Russia was continued by I.P. Zorina, who published three papers dealing with the ecology, distribution and taxonomy of Tonkin Gulf bivalve fauna (Zorina, 1975; 1978a; b). In total, she identified 351 species belonging to 150 genera and 49 families (Zorina, 1978a), but complete species list has never been published except for the enumeration of 140 species from 7 selected families (Zorina, 1975). However, Zorina prepared a card catalogue of the studied collection, and a list of species was later published by Lutaenko (2000b) with some comments and illustrations of type material. Based on mentioned 140 species of the families Donacidae, Veneridae, Mactridae, Psammobiidae, Tellinidae, Solecurtidae and Semelidae, Zorina (1975) subdivided Tonkin Gulf fauna into 10 biogeographical groups (Table 2).

Table 2. Biogeographical analysis of Tonkin Gulf bivalve molluscan fauna based on seven families (Donacidae, Veneridae, Mactridae, Psammobiidae, Tellinidae, Solecurtidae and Semelidae) (after Zorina, 1975)

Biogeographical group	***Number of species***
1. Indo-West Pacific species in the broadest sense	20 (14.3%)
2. Indo-West Pacific species (without Oceania)	29 (20.7%)
3. Indo-West Pacific species with disjunct distributional ranges	8 (5.7%)
4. West-Indian - Western Pacific species	16 (11.5%)
5. West Pacific (including Oceania) species	3 (2.2%)
6. Japanese-Malayan species	15 (10.7%)
7. Philippine-Malayan species	10 (7.1%)
8. Chinese-Australian species	14 (10%)
9. Chinese-Japanese species	19 (13.5%)
10. Conventional endemics of Tonkin Gulf	6 (4.3%)

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

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

It should be noted that the biogeographical analysis performed on the basis of 351 species identified by Zorina (1978a) yielded different figures (Table 3), especially concerning to the share of typical tropical species (45.9%), which is much lower as compared to the results of consideration of seven selected families (94%).

Table 3. Zonal-geographical (**A**) and biogeographical (**B**) analyses of Tonkin Gulf fauna of bivalve mollusks based on 351 species (after Zorina, 1978a)

A

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

B

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

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

Problems Associated with Tropical Bivalve Diversity and its Study

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

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

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

Acknowledgments

I would like to thank Dr. Tatyana Dautova (A.V. Zhirmunsky Institute of Marine Biology FEB RAS) for discussions of problems of biodiversity of the South China Sea and Vietnam. This work was supported by grants FEB RAS 09-III-A-06-195 (Dr. T.N. Dautova, Principal Investigator) and ARCP2010-18NMY.

References

Bernard F.R., Cai Y.-Y., Morton B. 1993. Catalogue of the Living Marine Bivalve Molluscs of China. Hong Kong: Hong Kong University Press. 146 p.

Bouchet P. 2006. The magnitude of marine biodiversity // C.M. Duarte (ed.). The Exploration of Marine Biodiversity. Scientific and Technological Challenges. Fundación BBVA. P. 33–64.

Briggs J.C. 1995. Global Biogeography. Amsterdam, etc.: Elsevier. 452 p.

Cai Y., Xie S. 2006. Seashells of Guangdong. China. 430 p.

Carpenter K.E., Springer V.G. 2005. The center of the center of marine shore fish biodiversity: the Philippine Islands // Environmental Biology of Fishes. V. 72. P. 467–480.

Chen J.-Y., Chen S.-L. 2002. Estuarine and coastal challenges in China // Chinese Journal of Oceanology and Limnology. V. 20, N 2. P. 174–181.

Crame J.A. 2000. Evolution of taxonomic diversity gradients in the marine realm: evidence from the composition of Recent bivalve faunas. *Paleobiology.* V. 26, N 2. P. 188–214.

Crosse H., Fischer P. 1889. Note sur la faune conchyliologique marine de l'Annam // Journal de Conchyliologie. V. 37. P. 281–296.

Crosse H., Fischer P. 1890. Mollusques marins de la Baie d'Halong (Tonkin) // Journal de Conchyliologie. V. 38. P. 14–19.

Chung N.V., Ho D.T. 1995. Zoobenthos fauna in the sea waters of Vietnam // Collection of Marine Research Works. V. 6. P. 91–100.

Dautzenberg P., Fischer H. 1905. Liste des mollusques recoltes par M. le Capitaine de Fregate Blais au Tonkin, et description d'especes nouvelles // Journal de Conchyliologie. V. 53. P. 85–234.

Dharma B. 1992. Indonesian Shells II. Wiesbaden: Verlag Christa Hemmen. 135 p.

Duc N.X. 2001. The molluscan fauna from the coast of Cat Ba Islands and Ha Long Bay // Proceedings of the First National Workshop on Marine Molluscs, Research Institute of Aquaculture No. 3, Nha Trang, March 25–27, 1999. Ho Chi Minh. P. 87–102.

Faustino L.A. 1928. Summary of Philippine marine and fresh-water Mollusks // Monographs of the Bureau of Science, Manila. V. 25. P. 1–384.

Fischer P. 1891. Catalogue et distribution géographique des mollusques terrestres, fluviatiles et marins d'une partie de l'Indo-Chine (Siam, Laos, Cambodge, Cochinchine, Annam, Tonkin) // Bulletin de la Societe d'Histoire Naturelle d'Autun. V. 4. P. 87–276.

Fischer P.-H. 1973. Les mollusques testaces du Cambodge. Seconde partie: gasteropodes pulmones, bivalves et bibliographie (1) // Journal de Conchyliologie. V. 110, N 3. P. 89–113.

Fischer P.-H. 1987. Liste des Mollusques Testacés Marins des Côtes du Vietnam. Chipping Norton (Australia): Surrey Beauty & Sons Pty Ltd. 23 p.

Flessa K.W., Jablonski D. 1995. Biogeography of Recent marine bivalve molluscs and its implications for paleobiogeography and the geography of extinction: a progress report // Historical Biology. V. 10. P. 25–47.

Gray J.S. 1997. Marine biodiversity: patterns, threats and conservation needs // Biodiversity and Conservation. V. 6. P. 153–175.

Gurjanova E.F. 1972. Fauna of the Tonkin Gulf and its environmental conditions // Explorations of the Fauna of the Seas (Leningrad). V. 10 (18). P. 22–146.

Higo S., Callomon P., Goto Y. 1999. Catalogue and Bibliography of the Marine Shell-bearing Mollusca of Japan. Osaka: Elle Scientific Publications. 749 p.

Hoeksema B.W. 2007. Delineation of the Indo-Malayan centre of maximum marine biodiversity: the Coral Triangle // W. Renema (Ed.). Biogeography, Time, and Place: Distributions, Barriers, and Islands. Heidelberg, etc.: Springer. P. 117–178.

Hylleberg J., Kilburn R.N. 2003. Marine molluscs of Vietnam. Annotations, voucher material, and species in need of verification // Phuket Marine Biological Center Special Publication. V. 28. P. 1–300.

Kantor Yu.I., Sysoev A.V. 2005. A preliminary analysis of biodiversity of molluscs of Russia and adjacent territories // Ruthenica (Russian Malacological Journal). V. 14, N 2. P. 107–118.

Latypov Yu.Ya. 2000. Coral communities in the northern part of the Gulf of Tonkin, South China Sea // Russian Journal of Marine Biology. V. 26, N 4. P. 250–257.

Lutaenko K.A. 2000a. Russian contributions to studies of Vietnamese bivalve molluscs. Part 1. Historical and bibliographical review with emphasis on faunal studies // Phuket Marine Biological Center Special Publication. V. 21, N 2. P. 347–360.

Lutaenko K.A. 2000b. Russian contributions to studies of Vietnamese bivalves. Part 2. List of species recorded by Russian authors or stored in museums // Phuket Marine Biological Center Special Publication. V. 21, N 2. P. 361–390.

Lutaenko K.A., Xu F. 2008. A catalogue of types of bivalve mollusks in the Marine Biological Museum, Chinese Academy of Sciences (Qingdao) // Bulletin of the Russian Far East Malacological Society. V. 12. P. 42–70.

Ma C., You K., Zhang M., Li F., Chen D. 2008. A preliminary study on the diversity of fish species and marine fish faunas of the South China Sea // Journal of the Ocean University of China (Oceanic and Coastal Sea Research). V. 7, N 2. P. 210–214.

Morton B., Blackmore G. 2001. South China Sea // Marine Pollution Bulletin. V. 42, N 12. P. 1236–1263.

Ng P.K.L. 2000. Biodiversity challenges for Southeast Asia in the new millennium and the role of the Raffles Museum // National Science Museum Monographs, Tokyo. N 18. P. 3–23.

Ng P.K.L., Tan K.S. 2000. The state of marine biodiversity in the South China Sea // Raffles Bulletin of Zoology. Suppl. 8. P. 3–7.

Phung N.H., Tuan V.S. 1996. Some main resources of bivalves (Bivalvia – Mollusca) in marine waters of Vietnam // Collection of Marine Research Works. V. 7. P. 9–15.

Qi Z. (ed.). 2004. Seashells of China. Beijing: China Ocean Press. 418 p.

Robba E., Di Geronimo I., Chaimanee N., Negri M.P., Sanfilippo R. 2002. Holocene and Recent shallow soft-bottom mollusks from the northern Gulf of Thailand area: Bivalvia // Bollettino Malacologico. V. 38, N 5–8. P. 49–131.

Robba E., Di Geronimo I., Chaimanee N., Negri M.P., Sanfilippo R. 2003. Holocene and Recent shallow soft-bottom mollusks from the northern Gulf of Thailand area: Scaphopoda, Gastropoda, additions to Bivalvia // La Conchiglia. Suppl. to N 309. P. 5–288.

Serreze M.C. 2009. Understanding recent climate change // Conservation Biology. V. 24, N 1. P. 10–17.

Suvatti C. 1938. Molluscs of Siam. Bangkok: Bureau of Fisheries. 91 p.

Swennen C., Moolenbeek R.G., Ruttanadakul N., Hobbelink H., Dekker H., Hajisamae S. 2001. The molluscs of the southern Gulf of Thailand // Thai Studies in Biodiversity. N 4. P. 1–210.

Tan S.K., Woo H.P.M. 2010. A Preliminary Checklist of the Molluscs of Singapore. Singapore: Raffles Museum of Biodiversity Research. 78 p.

Thach N.N. 2005. Shells of Vietnam. Hackenheim: ConchBooks. 338 p.

Thach N.N. 2007. Recently Collected Shells of Vietnam. Ancona: L'Informatore Piceno. 384 p.

Tchang S., Tsi C.Y., Li K.M., Ma S.T., Wang Z., Hwang H.M., Zhuang Q.Q. 1960. Bivalves of Nanhai (South China Sea). Beijing: Science Press. 272 p.

Thanh T.D., Saito Y., Huy D.V., Nguyen V.L., Ta T.K.O., Tateishi M. 2004. Regimes of human and climate impacts on coastal changes in Vietnam // Regional Environmental Change. V. 4. P. 49–62.

Valentich-Scott P. 2003. A taxonomic, distributional and bibliographic checklist of Hong Kong marine bivalve molluscs and research published on them from 1971–2000 // Perspectives on Marine Environment Change in Hong Kong and Southern China, 1977–2001: Proceedings of an International Workshop Reunion Conference, Hong Kong, 21–26 October 2001. B. Morton (Ed.). Hong Kong: Hong Kong University Press. P. 259–310.

Wu W.-L. 1980. The list of Taiwan Bivalvia fauna // Quaterly Journal of the Taiwan Museum. V. 33, N 1–2. P. 55–208.

Wu W.-L., Lee Y.-C. 2005. The Taiwan Mollusks in Color. Taipei: Research Center for Biodiversity, Academia Sinica. 294 p.

Xu F. 1997. Bivalve Mollusca of China Seas. Beijing: Science Press. 333 p.

Xu F., Zhang S. 2008. An Illustrated Bivalvia Mollusca Fauna of China Seas. Beijing: Science Press. 336 p.

Zorina I.P. 1975. The fauna of Bivalvia of the Tonkin Gulf // Zoologichesky Zhurnal [Zoological Journal, Moscow]. V. 54, N 3. P. 455–458.

Zorina I.P. 1978a. Some peculiarities of ecology of bivalve mollusks of Tonkin Gulf // Morphology, Systematics and Evolution of Animals. L.Ya. Borkin (Ed.). Leningrad: Zoological Institute, USSR Academy of Sciences. P. 65–66.

Zorina I.P. 1978b. New species of bivalve mollusks (Bivalvia) of Tonkin Gulf (South China Sea) // Proceedings of the Zoological Institute, USSR Academy of Sciences. V. 61. P. 193–203.

BIOLOGY AND DIVERSITY OF ABERRANT RHIZOCEPHALA – SUCCESSFUL FRESWATER INTRUDERS IN EXCLUSIVELY MARINE GROUP (CRUSTACEA: CIRRIPEDIA)

Alexey V. Rybakov

A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok 690041, Russia

e-mail: avrybakov@mail.ru

Rhizocephala is a marine group of exclusively parasitic Cirripedia closely related to free-living barnacles and infesting other crustaceans, mostly decapods. Adult parasites are extremely reduced consisting of a sac-like external reproductive part (or “externa”) located on the abdomen of the host and root-like branching internal trophic system (or “interna”) located inside the host and taking nutrition from its hemolymph. The morphophysiological degeneration in these animals is extreme resulting in the loss of all major characters of the arthropod Bauplan. All Rhizocephala are colonial animals and have very complicated life cycles with numerous morphologically different larval instars and alternating sexual and asexual reproduction (metagenesis).

The free-living Cirripedia occur in all marine habitats, from supratidal zone to deep-sea hydrothermal vents, but, unlike many other crustacean groups, none of them could penetrate into fresh waters. However, a few of their parasitic relatives could do that piggyback on their crustacean hosts. To date, four freshwater species (all belonging to the family Sacculinidae) have been described so far inhabiting different tropical and subtropical areas throughout the world (Fig. 1):

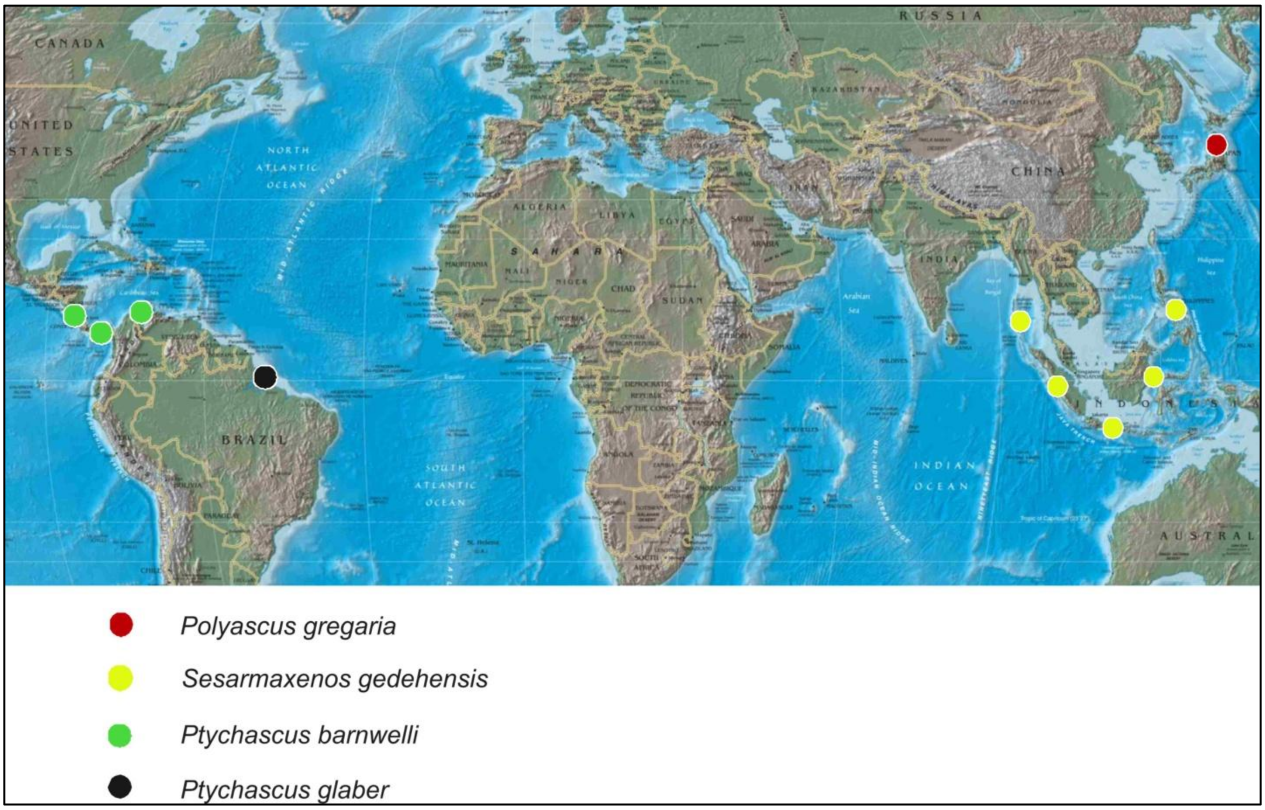


Fig. 1. Worldwide distribution of freshwater Rhizocephala.

- *Polyascus gregaria* (Fig. 2, *1*) – on the catadromous Japanese mitten crab, *Eriocheir japonicus*. This rhizocephalan is a local Japanese endemic species inhabiting a very small area in the valleys of Yura and Maruyama rivers (Okada, Miyashita, 1935).
- *Sesarmaxenos gedehensis* (Fig. 2, *2*) – on crabs of the family Sesarmidae inhabiting mountain streams of the Philippines, Indonesia and Andaman Islands (Annadale, 1911; Boschma, 1933a).
- *Ptychascus glaber* (Fig. 2, *3*) – on semi-terrestrial crabs of the family Sesarmidae inhabiting mangrove forests at the coast of Brasilia (Boschma, 1933b).
- *Ptychascus barnwelli* – on crabs of families Ocypodidae and Grapsidae in Costa-Rica, Panama and Columbia (Andersen et al., 1990).

Despite inhabiting localities remote far from each other, all these species are closely related making up a solid cluster; moreover, their hosts are also closely related to each other. Their supposed ancestors should have been similar to colonial sacculinid rhizocephalans that are distributed worldwide and are very common on marine intertidal grapsoid crabs. The transition to freshwater mode of life induced profound changes in the morphology of adult externae and larval stages, life cycle and the general pattern of reproductive strategy of the parasites.

P. gregaria is, like its crustacean host, a catadromous species; it is the only catadromous rhizocephalan and one of a few known catadromous parasites. Its life cycle is similar to that of the marine relatives and comprises four free-living naupliar instars and a stage of cypris larva. The larval development takes about 2 days. Adult parasites could withstand fresh water for several

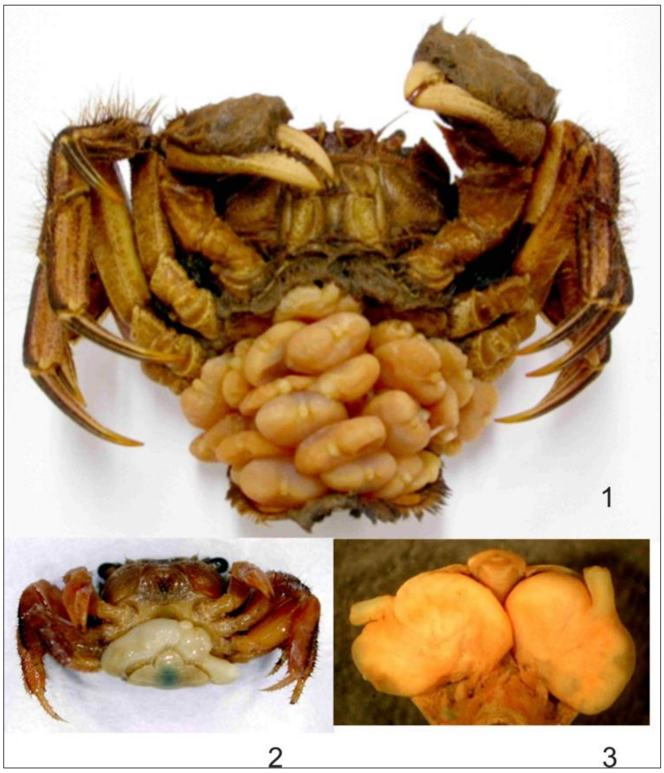


Fig. 2. Some freshwater rhizocephala.
1) *Polyascus gregaria;* 2) *Sesarmaxenos gedehensis;* 3) *Ptychascus glaber*.

months, travelling along the rivers with their host crabs. However, their free-living larvae (nauplii and cyprids) are dying in both fresh water and the water of the normal ocean salinity. The life cycle of the parasite is intimately synchronized with the cycle of its host. The latter in early autumn migrates to the lower river reaches for spawning and this is also the spawning period for the parasite. The Yura and Maruyama rivers are unique for being extremely quiet, so the tidal waves penetrate high enough along the riverbed, and the river, in the lower reaches, represents a sandwich, with more light fresh water atop and heavier saline water at the bottom. The salinity in the bottom layer equals 18–24‰, i.e., the optimum value for *P. gregaria* nauplii. After being released from the externa, the nauplii sank down to the brackish-water layer (unlike other rhizocephalan larvae they demonstrate negative phototaxis) and slowly drift to estuarine zone. The drift takes about 2 days, i.e., exactly the time needed for the larval development. Arriving to the estuarine zones are cyprids, more resistant to high salinity and ready to infest their respective crab hosts (late zoeae or megalopae of *E. japonicus*). Despite these ecological adaptations, the mortality among the free-living larvae appears high enough and the reproductive capacity of the parasite is just amazing. *P. gregaria* is highly gregarious; one crab can host several tens of externae, which together can release 1.5–2.5 millions larvae. The larval development is synchronous and nauplii are released over a very short period. In general, this reproduction pattern might be considered as a variant of r-strategy.

The other three species are true freshwater animals and their reproduction also takes place in the fresh water. In *S. gedehensis* the habitats of crab hosts could sometimes be entirely isolated from the sea. The current is very fast, so releasing larvae could be transferred far away of their respective habitats in just a few minutes. In the species of the genus *Ptychascus* the hosts are semi-terrestrial and can leave water for long enough. Thus, adult morphology, life cycle pattern and reproductive strategy of these animals are heavily modified.

Adult morphology. In of *Phychascus* the externae do not shed molting skins, so adult animals are covered with several skin layers making up a rigid sheath protecting the animal from desiccation. The mantle opening is located atop of a tube-like structure provided with strong circular musculature. Contraction of these muscles could safely isolate the mantle cavity of the animal from environment, thus preventing the water from pouring out, when the host crab leaves its riverine habitat. The internal space of the mantle cavity underwent compartmentalization due to development of either numerous extended mesenterial folds (in *Sesarmaxenos*) or radial septa on the inner mantle wall (in *Ptychascus*). The compartmentalization, on the one hand, helps to retain developing embryos inside the mantle cavity and, on the other hand, allows the larvae to be released through extended time periods, thus increasing their survival rate.

Life cycle and larval morphology. The number of free life stages is reduced and free nauplii are absent. They are embryonized and pass inside the egg sheath. Cypris larva lacks frontal filaments and frontal horn glands (the structures considered as needed for free-leaving nauplius larvae. Developing embryos are not stack in plates or tubes, like it is the case in free-living Cirripedia and in the "classical" Rhizocephala. Development of embryos is asynchronous and in mantle cavity the larvae in different stages of development could be observed, from non-differentiated embryo to advanced larvae almost ready for hatching.

Reproductive strategy. The reproductive capacity of these species is much smaller than in the "standard" rhizocephalans. The fecundity of a single externa ranges from several hundred to several thousand larvae, i.e., being about 3 orders of magnitude smaller than that in *P. gregaria.* Life cycle is abbreviated; the free-living nauplii are embryonized and hatching cyprids are ready to settle onto the host immediately after hatching. The reproduction period is much extended, actually the fertilized embryo come to the mantle cavity almost continually. The hatching period of the larvae is also much extended, which should be important to increase the survival rate in unstable environment with rapidly fluctuating conditions. In general, this reproduction pattern might be considered as a variant of K-strategy.

The revealed facts provide evidence that the freshwater Rhizocephala is a recently appeared, but evolutionarily successive group of closely related species. Their origin and evolution is a brilliant example of parallel evolution in a host-parasite system after penetration into an entirely new alien habitat. The occurrence of certain phylogenetically different hosts (Ocypodidae) should be considered as an example of the well-known phenomenon of "horizontal transfer". Amazingly enough, the same evolutionary target (the adaptation to freshwater habitats) had been attained, in closely related species, involving entirely different reproductive strategies.

References

Andersen M.L., Bohn M., Høeg J.T., Jensen P.G. 1990. Cypris ultrastructure and adult morphology in *Ptychascus glaber* and *P. barnwelli* n.sp. (Crustacea: Cirripedia: Rhizocephala) parasites on semiterrestrial crabs // Journal of Crustacean Biology. V. 10, N 1. P. 20–28.

Annandale N. 1911. Note on a rhizocephalous crustacean from fresh water, and on some specimens of the order from Indian Seas // Records of Indian Museum. V. 6. P. 1–4.

Boschma H. 1933a. New species of Sacculinidae in the collection of the United States National Museum // Tijdschrift der Nederlandsche Dierkundige Vereenining. V. 3, N 4. P. 219–241.

Boschma H. 1933b. The Rhizocephala in the collection of the British Museum // Journal of the Linnaean Society of London. Ser. Zool. V. 38. P. 473–552.

Okada Y.K., Miyashita Y. 1935. Sacculinization in *Eriocheir japonicus* de Haan, with remarks on the occurrence of complete sex-reversal in parasitized male crabs // Memoirs of the College of Science, Kyoto Imperial University. V. 10, N 3. P. 169–208.