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DISPERSAL PATTERNS OF CORALS IN THE INDO-WEST PACIFIC: TOWARDS THE UNDERSTANDING OF THE BIODIVERSITY IN VIETNAMESE WATERS

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Abstract: The Anthozoans are important components of marine ecosystems. Among them the stony corals, Scleractinia, are very remarkable and frame-building animals of coral reefs in tropical zones. The role of Octocorallia, i.e. soft corals, sea fans and sea pens, in the reef-building process is also important andthese corals also deserve attention due to their abundance in marine bottom ecosystems as well as a source of the pharmacologically important compounds. The study ofOctocorallia species richness is substantially in the frame of worldwide and local biodiversity problems. Inrecent years we have found that the contemporary biodiversity of the soft corals in the central area of the Vietnam coastal waters essentially exceeds the same in the Indo-Malayan Centre of Marine Biodiversity (or Coral Triangle). As it was assumedframingthe last decade investigations, solvingcomplex problems of the taxonomy, genetic diversity and species-specific ecology areneeded to trace the possible ways for soft coral dispersal.

Key words:*Coral Reefs, Soft Corals, Marine Biodiversity, Nha Trang Bay, Viet Nam.*

I. INTRODUCTION

High productive ecosystems of coral reefs provide important life support systems to coastal states, especially through food from fisheries for the long-term cultural and social demographic trends in countries having long maritime boundaries. These ecosystems provide the full life cycle for numerous invertebrates and algae that are widely used as food sources, in particular, as a source for cheap protein diets. The high biodiversity of coral reefs is closely related to their environmental complexityand gives these ecosystems the resilience and ability to recover (Wilkinson, 2004). The main drivers leading to global biodiversity change in coral reef ecosystems can be defined as the invasion of the alien species *via* the various pathways of the overseas connectivity, the overexploitation of the bioresources of coral reefs together with the man-made pollution of the coastal seas, and,global climate changeand environmental stress.

Among the reef-inhabiting animals, two main coral groups should be placed infocusfor careful study and monitoring – stony (reef-building) corals and octocorals (soft corals, sea fans, and sea pens). Most coral reefs in the coastal marine waters of South East Asia are located in shallow water.These reefs are affected by complex environmental effects (including the anthropogenic

impact).The overheating of corals in shallow waters can lead to bleaching and their subsequent death. The bleaching, due to loss of micro-algae (zooxanthellae) by corals, leads to their starvation. Mass bleaching of corals has resulted in 60% of coral reef ecosystems dying or being irreversibly destroyed along with the subsequent decrease of coral diversity in the damaged reef complexes. More than 75% of the world's reefs are threatened by human activity ranging from coastal development, marine pollution, sedimentation and eutrophication from inland deforestation and farming (Bryant et al., 1998).There are many reports of coral losses of 30–60% and some as high as 80–90%, with some localized extinctions of prominent corals from the northern part of the South China Sea (Wilkinson, 2004). The species richness of the stony corals was surveyed in the tropical waters and in the South China Sea in particular (Veron, 2000).Octocorallia, especially soft corals, are less well-studied.

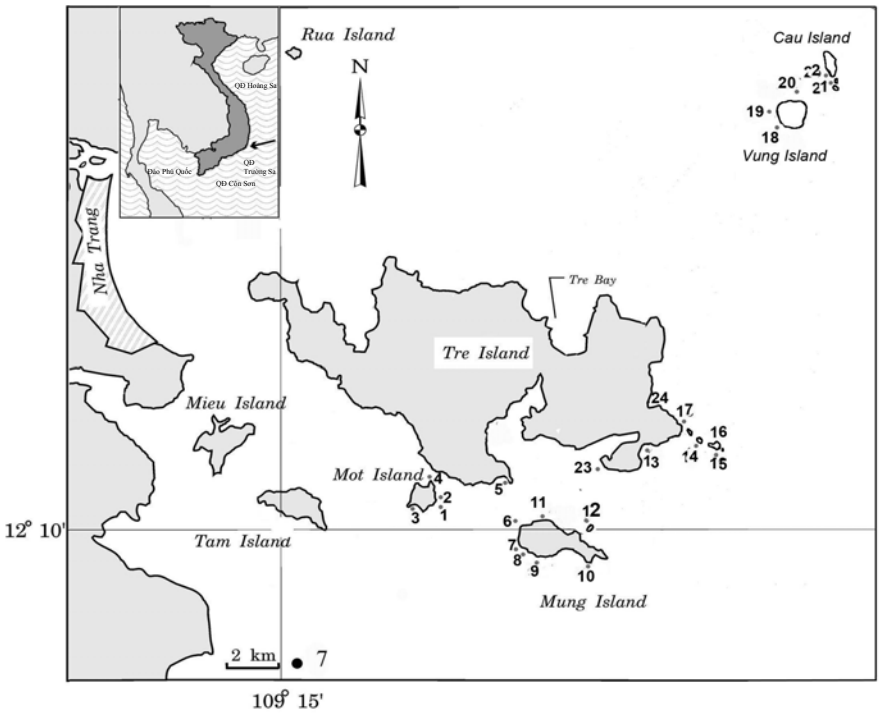

Fig. 1.Collecting stations in Nha Trang Bay (diving sites).

Soft corals are often a dominant group of Octocorallia in the Indo-Pacific as they are able to compete with stony corals for space and have a greater potential than other Octocorallia to occupy diverse habitats. Alcyoniidae corals deserve much interest as a source of pharmacologically important compounds. However, data on the biodiversity and dispersal of this key soft coral group in tropical waters are scarce and restricted to several local faunas, such as those of Palau, Ambon (Indonesia), the Red Sea, and New Guinea. Vietnamese waters, being part of the South China Sea, are very promising for a detailed survey of the soft corals. Coral reefs of Vietnam are located in the north-eastern part of the greatest region in South East Asia seas in terms of species diversity, and, are connected with the

richest marine region on the Earth – the SE Asian Centre of Marine Biodiversity,the so-called Coral Triangle located between Indonesia, Malaysia and the Philippines (see discussion in Hoeksema, 2007).

The coral reefs of the Nha Trang Bay are located across the north-west edge of the Coral Triangle and as such share many of the species and characteristics of reefs to the south. The survey of the biodiversity in soft corals in the Bay can be also helpful for the monitoring purposes to solve the important problem of the tropical marine ecosystems – to predict the near future of damaged and healthy coral reefs.

Octocorallia investigations in Vietnam, and in Nha Trang Bay in particular, started in the beginning of the 20th century. Hickson (1919) described one new soft coral species and Stiasny (1938) published the first data on Vietnamese gorgonians. Later on, Dawydoff (1952) published the full list of his findings in the monograph on the fauna and ecology of marine invertebrates of Indochina coastal waters. The next stage of the Octocorallia investigations in Vietnam dealt with the museum collections from Nha Trang Bay. Tixier-Durivault's publications (1943, 1946, 1956, 1957, 1958, 1970) and a short paper by Stiasny (1952) based on these collections provided some data on the Octocorallia regional fauna diversity and emphasized the insufficient knowledge about Octocorallia. Some of these old records, mainly of the soft corals, are doubtful and in need of revision. Thus, in the list of Nha Trang Bay octocorals finalized and published by Tixier-Durivault in 1970.She mentioned 38 species of *Sinularia*, the largest zooxanthellate shallow-water genus. Later on, the taxonomic status of several species was changed. *Sinularia dumosa* Tixier-Durivault, 1970, and *S. ramulosa* Tixier-Durivault, 1970, were synonymized with *S. lochmodes* Kolonko, 1926 (Verseveldt, 1980). *Sinularia dura* (Pratt, 1903) was synonymized with *S. brassica* May, 1898 (Benayahu et al., 1997), and *S. gyrosa* sensu Tixier-Durivault, 1970, was recognized as belonging to *S. gravis* (Vennam, Ofwegen, 1996). Recently, seven new species have been described and three known species were first recorded using contemporary collected material from Nha Trang Bay (Dautova et al., 2010). The distribution of *Sinularia* is somewhat similar to that of other tropical shallow-water animals in the Indo-Pacific, showing a decrease of species number towards the periphery of the Coral Triangle. However, most records known before 2000 were for the Red Sea and the Seychelles-Mauritius Plateau (altogether 38 species, Ofwegen, 2000). So, the Octocorallia fauna of the South China Sea, and of Vietnamese waters in particular, clearly need more research with regard to its octocoral fauna.The study presented is aimed to contribute to our knowledge of soft corals species richness in coral reef ecosystems in Central of Vietnam and to discuss the possible dispersal ways of these animals.

II. MATERIALS AND METHODS

This study deals with the available literature on marine biodiversity, in particular – on soft corals of SE Asian seas, andcollections made during several field trips to Nha Trang Bay (Vietnam) in 2005-2012.

Samples of colonial Octocorallia were collected using SCUBA at a range of stations in the Nha Trang Bay (Fig. 1). These stations included all possible types of substratum, different levels of wave activity and lighting. The collection is deposited in the Museum of the Institute of Marine Biology FEB RAS (MIMB, Vladivostok, Russia) and, partly, in the Netherlands Centre for Biodiversity, Naturalis (RMNH, Leiden, the Netherlands).All specimens (fixed in70% ethanol) are registered in MIMB (Museum of the Institute of Marine Biology FEB RAS, Vladivostok). Tissue samples of different colony parts (polyp, top colony surface, top interior, stalk surface, stalk interior) were examined separately through dissolving the organic matter in sodium hypochlorite and observation under optical microscope (200x). Tissue samples from stalks were studied from middle-level and lower stalk parts separately. The sclerites were washed from hypochlorite with distilled water and ethanol (70%), air-dried, mounted for the SEM on carbon double adhesive tape, and coated. Detailed images of the sclerites for identification and species description purposes were obtained with SEM using a Cambridge Instruments Leo 430 and optimum magnification for each sclerite type.

III. RESULTS.

Soft corals in Nha Trang Bay, Central of Vietnam.

As our field investigation of the soft corals of Nha Trang Bay was carried out in different biotopes, all possible types of substratum were surveyed. Due to it an enlarged list of soft corals of Nha Trang Bay was compiled using own materials.There was also comparison of these data with those of the nearest regions of the SE Asia seas is done (Tab. 1).

IV. DISCUSSION

The highest marine biodiversity in the world is found in South East Asia seas. For example, in this area of highest marine diversity, around 2,500 fish species are found (e.g. the Philippines) while in Australia around 1,500 is estimated and only a third of this in the Caribbean (Thresher, 1992). This is consistently seen in other taxa such as for the scleractinian corals with over 400 species registered in the Coral Triangle (Indo-Malayan region), while the Great Barrier Reef would has approximately 400 species and only 100-200 species in the Caribbean (Veron, 1995).

The studying of Octocorallia species richness is substantially in the frame of the worldwide and local biodiversity problems. The mass genera of the soft corals, such as *Sinularia*, *Sarcophyton* and *Lobophytum* can represent the diverse group of Octocorallia in the region. However, the highest number of recorded *Sinularia* species is not found in the central Indo-Pacific or in the Coral Triangle until the present day.

The reason for this is likely that investigation of soft corals diversity in the region are not numerous and very limited to a few local faunas. If the Indonesian Archipelago and New Guinea score rather well (40 Sinularia species for Seram

and Ambon, Indonesia, together, Manuputty and Ofwegen, 2007) , the Philippines *Sinularia*, on the other hand, with only 7 species are poorly known from scarce publications (Ofwegen, 2000). At the same time, the author of the present paper was able to find no less than 46 different *Sinularia* species in Nha Trang Bay (Dautova, *pers obs*). It could mean that the Octocorallia fauna of coastal marine area of the central of Vietnam can be closely connected with those of the Coral Triangle. What direction of the Octocorallia species dispersal may be considered as most important around the Coral Triangle and in the South China Sea in particular?

Table 1. List of Octocorallia taxa of the orders Helioporacea Bock, 1938, and, Alcyonacea Lamouroux, 1816 (soft corals and Briareidae Gray, 1859) for Central Vietnam (Dautova, pers. data), Taiwan (Benayahu et al., 2004 with comments and list of previous records) and Japan (by Imahara 1996), Hong Kong (by Lam and Morton, 2008 with list of previous records), South Korea (Song, 1976; 1981;1994; 1995; Song, Lee 1998). **"+" –** the presence of the genus on reefs investigated, "-"– the genus is not recorded.

Genera	Nha Trang Bay, Central Viet Nam	Southern Taiwan	Japan	Hong Kong
Heliopora Blainville, 1830	+	+	-	-
Cervera López-González, Ocaña, García-Gómez & Núñez, 1995	+	-	-	-
Clavularia Blainville, 1830	+	+	+	-
Pachyclavularia Roule, 1908	-	-	+	-
Sarcodyction Forbes, 1847	-	-	+	-
Cornularia Lamarck, 1816	-	-	+	+
Carijoa Müller, 1867	+	-	+	+
Telesto Lamouroux, 1812	-	-	+	-
Paratelesto Utinomi, 1958	-	-	+	-
*Pseudocaladochonu*s Versluys, 1907	-	-	+	-
Tubipora Linnaeus, 1758	+	+	+	-
Alcyonium Linnaeus, 1758	-	-	+	-
Anthomastus Verrill, 1878	-	-	+	-
Bellonella Gray, 1862	-	-	+	-
Dampia Alderslade, 1983	+	-	-	-
Cladiella Gray, 1869	+	+	+	+
Dampia Alderslade, 1983	+	-	-	-
Eleutherobia Pütter, 1900	+	+	+	+
Klyxum Alderslade, 2000	+	+	+	-
Lobophytum Marenzeller, 1886	+	+	+	+
Paraminabea Williams & Alderslade, 1999	+	+	+	+
Rhytisma Alderslade, 2000	-	+	+	-
Sarcophyton Lesson, 1834	+	+	+	-
Sinularia May, 1898	+	+	+	-
Capnella Gray, 1869	+	+	+	-
Coronephthya Utinomi, 1966	-	-	+	-
Daniela Koch, 1891	-	-	+	-
Dendronephthya Kükenthal, 1905	+	-	+	+
Duva Koren & Danielssen, 1883		-	+	-

Genera	Nha Trang Bay, Central Viet Nam	Southern Taiwan	Japan	Hong Kong
Gersemia Marenzeller, 1878	-	-	+	-
Lemnalia Gray, 1868	+	+	+	-
Litophyton Forckal, 1775	-	-	+	-
Nephtea Audouin, 1826	+	-	+	+
Paralemnalia Kükenthal, 1913	+	+	+	-
Scleronephthya Studer, 1887	+	+	+	+
Stereacantha Thomson & Henderson, 1906	-	-	+	-
Stereonephthya Kükenthal, 1905	-	-	+	-
Umbellulifera Thomson & Dean, 1831	-	-	+	-
Chironephthya Studer, 1887	+	-	-	-
Nephthyigorgia Kükenthal, 1910	+	-	-	+
Nidalia Gray, 1835	-	-	+	-
Siphonogorgia Kölliker, 1874	+	-	+	-
Anthelia Lamarck, 1816	-	+	+	+
Asterospicularia Utinomi, 1951	-	+	+	-
Cespitularia Milne Edwards & Haime, 1857	-	+	+	-
Fungulus Tixier-Durivault, 1987	-	-	+	-
Heteroxenia Kölliker, 1874	-	+	+	-
Efflatounaria Gohar, 1939	+	-	-	-
Sansibia Alderslade, 2000	+	+	-	+
Sympodium Ehrenberg, 1834	-	-	+	-
Xenia Lamarck, 1816	+	+	+	-
Studeriotes Thomson & Simpson, 1909	-	-	+	-
Carotalcyon Utinomi, 1952	-	-	+	-
Briareum Blainville, 1830	+	+	+	-
Total:	**27**	**22**	**46**	**12**

Summarizing knowledge about the possible dispersal ways and barriers in Indo-West Pacific, i.e. currents and the areas of river discharge/low salinity in the western part of the Indo-Malayan region, show that the dispersion of the marine species may be directed from Coral Triangle into the Indian Ocean; the Java Sea and the South China Sea are likely the westernmost part of the border area between the Pacific and the Indian Oceans with very little input from the Indian Ocean (Hoeksema, 2007, with a range of references discussed). At least, the new records of a range of *Sinularia* species in Nha Trang Bay (made by the author of present paper, *pers comm*) which species previously were noted only in Indonesia (*S. shlieringsi*) and New Guinea (*S. sobolifera, S. verseveldti*) as well as the occurrence in the bay of the species, which were found before close to Eastern Africa (*S. abhishiktae*) or westerly than Strait of Malacca (*S. manaarensis*) are in according with it.

Another substantial question is – what ways may be usable for species dispersal from Coral Triangle to the periphery. It is essential to know how the local and regional marine ecosystems depend on each other for the interchange of organisms. The study of distribution patterns requires good understanding of both

detailed records of the coral fauna throughout the distribution range and high quality oceanographic data to be correlated with these distributions (Veron and Minchin, 1992; Hoeksema, 2007). The warm waters of the Kurioshio Current pass east of the Philippines to southern Pacific side of Japan and intrude into the South China Sea moving along southern Taiwan. It can influence on the corals richness on the reefs of the central of Vietnam as well as southern Taiwanese reefs. The stony coral fauna of the reefs of central Vietnam is quite rich and includes more than 65 genera and, moreover, several species of the *Porites* genus which were firstly described from Philippines. The same situation can be considered concerning the Octocorallia fauna of the region. The preliminary Alcyonacea list of the soft corals (with *Briareum* genus) includes 27 genera (Table 1); the *Sinularia* species list has numerous "old" and new species (Dautova, *pers. obs.*). The reefs of southern Taiwan contain 22 genera including *Sinularia* (Table 1).

The lack of the genera *Anthelia*, *Asterospicularia*, *Cespitularia* and *Heteroxenia* in the list of Vietnamese soft corals is probably becausethe collected material is still in processing. However the presence in Central of Vietnam of the most of Nephtheidae genera as well as a longer list of *Sinularia* species may be considered as a result of the direct connection of the region with Coral Triangle in addition to the Kurioshio influence. The single finding in South China Sea of the *Sinulariayamazatoi* which was before recorded only at Southern Ryukyu shows that this species: a) probably had a dispersal from the Indo-Malayan centre; b) may be rare, due to it not being recorded on Taiwanese reefs; c) can pass into Vietnamese waters both directly from Coral Triangle and by Kurioshio influx. The recent Indonesian finding of the *S. mammifera* (Manuputti and Ofwegen, 2007) which was firstly described from Vietnam anticipates the same.

The coral reefs of Taiwan and Japan are closely linked by the northward flowing Kurioshio Current. The soft coral fauna of both areas shows a close resemblance between their faunas in terms of generic composition and number of species (Table 1). The finding of *Sinularia higai* and *Sarcophyton nanwanensis* (both from Japan and Taiwan) anticipates that similar patterns also exist for other important soft coral genera (Benayahu et al., 2004).

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

V. CONCLUSION

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

1 the comparison of the soft corals diversity in ecologically differing coral reefs and regions of Vietnam (i.e. Nha Trang Bay and Gulf of Tonkin);
2 gap-filling surveys of the diversity and population structure of soft coral insouthernmost part of Vietnam waters;
3 the developmentof knowledge on the present biodiversity in Nha Trang Bay and nearest regions of Central of Vietnam using morphology and genetic approaches to estimate the connectivity between the fauna of it and those of the Coral Triangle area.

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