

Species Diversity of Hexacorallia around the Satsunan Islands, Japan

FUJII Takuma

Research Center for the Pacific Islands, Kagoshima University

Abstract

The Satsunan Islands, in the middle to the north of the Ryukyu Islands, Japan, are located in an important location for biogeography, as there is a shift of marine fauna in this region from subtropical to temperate. However, few have studied about marine biodiversity of this region for many taxa, with exceptions such as fishes. In this report, the biogeographic relations between the Coral Triangle region of highest marine diversity, and the Satsunan Islands, using previous reports related to species diversity of subclass Hexacorallia are reviewed. In the near future, it is strongly needed to more clearly reveal the species diversity of order Hexacorallia within the Satsunan Islands, a region of ecological variety, based on thorough and taxonomical surveys.

Keywords: biogeography, ecological variety, ecozone, Scleractinia, Zoantharia

Suborder Hexacorallia

Class Anthozoa, currently consisting of 3 subclasses; Hexacorallia, Octocorallia and Ceriantharia, is characterized by a lack of the medusa stage in their life cycles. Anthozoans are common organisms that are widely distributed in various marine environments from shallow to deep, from the equator to the polar region. The phylogenetic relationships within Anthozoa are not yet resolved. Compared to the other two suborders, inter-order level phylogeny within the subclass Hexacorallia is still under revision (DALY *et al.* 2007, STAMPAR *et al.* 2014). Octocorallia is characterized by eight plumate tentacles and eight complete mesenteries inside the body cavity. Ceriantharia, recently promoted to subclass from an order within subclass Hexacorallia, is characterized by a nest tube formed utilizing a specialized nematocyst, and unpaired, coupled mesenteries in the body cavity. In contrast to the two easily definable subclasses, Hexacorallia is a less coherent taxon. The morphological and ecological features within the subclass are very varied compared to the other subclasses. The synapomorphys of hexacorallians are considered to be the appearance of spirocysts, a type of nematocyst, and the first six mesenteries in the development of polyps.

Currently, subclass Hexacorallia consists of five orders; Scleractinia, Corallimorpharia, Actiniaria, Zoantharia and Antipatharia. It has been estimated that there are around 4,000 species contained within this subclass in a previous study (DOUMENC and VAN PRAET 1987). However, as well as the other marine invertebrates, the development of the analytical techniques have provided more and more discoveries of new taxa (e.g., studies for order Zoantharia: REIMER and FUJII 2017), and reconstructions of taxonomy have been performed (e.g., studies for order Scleractinia: FUKAMI *et al.* 2008, KITAHARA *et al.* 2010). In the orders Corallimorpharia, Actiniaria and Antipatharia, the accumulation of basal knowledge of species diversity is still required.

The Coral Triangle and the Satsunan Islands

The “Coral Triangle”, an area of Southeast Asia between Malaysia, the Philippines, Indonesia and Papua New Guinea, is considered to be the center of the coral reef region, and the center of maximum marine biodiversity. Recently, the global patterns of biodiversity with various parameters such as species richness, uniqueness, or threats for major marine organisms have been discussed and analyzed for this region. However, further basal studies are required to properly estimate detailed biogeographical patterns. Most previous studies were focused on only major taxa, such as fish, snails, zooxanthellate corals, or lobsters, and the information on the border areas of the Coral Triangle is seriously deficient (e.g., HOEKSEMA 2007, ROBERTS *et al.* 2002).

The Ryukyu Islands are at the northern edge of the Coral Triangle, and are considered as one of the highest centers of marine bio-endemism (ROBERTS *et al.* 2002). Moreover, the Satsunan Islands are an important area to study the gradient of marine biodiversity from subtropical to temperate zones following the Kuroshio Current. The Ryukyu Islands are the southern chain of islands in Japan, from the east side of Taiwan to the Osumi Islands, and spans from the subtropical to temperate zone. The Ryukyu Islands, or even the Nansei Islands, span over two prefectures, Okinawa and Kagoshima. The northern part is called the Satsunan Islands of Kagoshima Prefecture (TOYAMA 2009). From a biogeographical point of view, the Satsunan Islands extend into two regions as well; the Palearctic and Indomalaya ecozones. The border between these two ecozones, designated as Watase line, is crossed on Tokara Strait where is between Kodakarajima Island and Akusekijima Island. The border of the biogeographical ecozones was decided based on the terrestrial organisms, and it's still doubtfully if it can be applied to the marine benthic fauna. For example, the northernmost coral reef region is considered to be around Tanegashima Island (approx. N30° 21' to N 30° 51'), where in the areas where the average sea surface temperature of the coldest month is greater than 18°C (YAMANO 2009). Either way, the Satsunan Islands possibly having high

marine biodiversity from ecological, species to genetic levels. Previously some faunal reports on the major taxa of marine organisms were published only on some part of the islands (e.g., fish: MOTOMURA 2016).

Faunal Reports on Subclass Hexacorallia from the Satsunan Islands

The order Scleractinia, generally called stony corals, is one of the key taxa in the coral reef region. More than half of the approximately 1,400 species of this order are symbiotic with photosynthetic brown algae and known as reef-building corals or zooxanthellate corals (CAIRNS 1999). Zooxanthellate corals have important ecological roles in shallow warm waters as the primary producers and constructing complex physiological structures on the sea floor that providing various spaces to live for other organisms. Because not only of their ecological but also of the economic importance, recently the scleractinian species have become to be much studied regarding their species diversity for ecological monitoring, particularly by local administrative agencies and civilian organizations (see THE JAPANESE CORAL REEF SOCIETY and MINISTRY OF THE ENVIRONMENT 2004). Unfortunately, it is often difficult to access to details of such reports and to recognize if the surveys were carried out scientifically or not.

A field guidebook edited by VERON (2000) may be the most widely used material to identify zooxanthellate corals in recent years, and currently a beta version of the associated web database has been updated (VERON *et al.* 2016). Based on this database (2016), 369 species of zooxanthellate scleractinian corals have been listed in “Ryukyu Islands North” region (=from Okinawajima Island and the Kerama Islands to the Tokara Islands), and 218 species in the “Kyushu South-east” region (=from the Osumi Islands to the Koshiki Islands, southern Kyushu Island and east coast of Kyushu Island). However, these list contain some uncertain information as the distribution was reported based either or both on specimens or *in situ* photographs clearly identified combined with possibly distributed species in which the distribution was estimated but currently no records exist. Thus, although there are no doubts that this field guide and database are valuable in the preliminary identification and estimation of biogeographical patterns, these data should treat carefully and with caveats for scientific studies.

Within the Satsunan Islands, SUGIHARA *et al.* (2015) reported 161 species of zooxanthellate scleractinian corals from Tanegashima Island in the Osumi Islands. Although this work is an open access electronic field guide book and there is an absence of descriptions of voucher specimens, it can be considered to be a valuable distributional report as the methodology of identification and the traceability of the taxonomy were clarified. YABE and SUGIYAMA (1935) and SUGIYAMA (1937) reported 63 zooxanthellate scleractinian corals species from the Amami Islands and UTINOMI (1956) reported 15 species from the Tokara

Islands based on vouchered specimens in public museums. However, these older reports were simply the results of elementary surveys in each reports, and asides from the Tanegashima Island data, these reports are too old to be treated as information on the current species diversity around the Satsunan Islands region. Thus, there is an overall lack of basal information on coral species diversity in the Satsunan Islands.

The Zoantharia is the other hexacorallian order in which recently the studies on species diversity have been advanced as much as the order Scleractinia. This order, often called colonial sea anemones or sand-encrusting sea anemones, is characterized by a specialized bilateral mesenterial arrangement. This order is as large as Scleractinia, consisting of around 300 species, and the fact that almost all the species have no hard tissues such as a skeleton or sclerites had limited the progress of taxonomy in the past. However, molecular techniques have helped to sort out the taxonomy and advanced biogeographical research. Previously, 13 zoantharian species were recorded from the Satsunan Islands region based on voucher specimens or the descriptions of *in situ* observation, with 9 zooxanthellate species and 4 azooxanthellate species (see REIMER and FUJII 2017). Zooxanthellate zoantharians are considered to occupy a similar niche with zooxanthellate corals and assuming the ecological role as the primarily producer in the coral reef ecosystems, although they have no skeletal tissues to construct the new structures on the sea floor. ONO *et al.* (2008) revealed the distribution patterns of 9 zooxanthellate zoantharian species in the Satsunan Islands, showing decreasing species richness from south to north.

The other hexacorallian orders; Corallimorpharia, Actiniaria and Antipatharia, have been studied little regarding the species diversity around the Ryukyu Islands region. There is no doubt that these orders also have high species diversity around not only the Satsunan Islands but also in the whole Ryukyu Islands, as there are many photographs on field guides (e.g., SHIRAI 1977, UCHIDA and SOYAMA 2001). The preliminary results of this author's informal survey suggest the distribution of 7 species including 2 previously unrecorded species of zoantharians around Takarajima Island, the Tokara Islands (FUJII 2016). Thus, it is easy to estimate that the species diversity of Hexacorallia is higher than has been previously reported within this region, particularly given that Takarajima Island is a comparatively small island and the eco-habitats for hexacorallian species are less varied within the Satsunan Islands.

In the near future, it will be strongly required to more clearly reveal the species diversity of order Hexacorallia not only within the Coral Triangle, the region of highest marine biodiversity, but also within the Satsunan Islands, a region of ecological variety, to report representatively based on the thorough field and taxonomic surveys utilizing identification with voucher specimens.

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