

## 論文要旨

### 論文題目

Phylogenetic study of orders Zoantharia and Actiniaria (Cnidaria: Anthozoa: Hexacorallia)  
(六放サンゴ亜綱の系統分類学的研究—スナギンチャク目の単系統性の検証—)

In this study, I focused on the intra- and inter-order phylogenetic relationships between orders Zoantharia and Actiniaria. Zoantharia is considered to be the order most possibly ancestral in suborder Hexacorallia, and Actiniaria is phylogenetically closely related to Zoantharia. These two orders are considered to be important taxa to reveal the evolutionary history of not only of the subclass Hexacorallia and class Anthozoa, but also of the phylum Cnidaria.

In chapter 2, taxonomic features and molecular phylogeny of the highly divergent zoanthid family Microzoanthidae are reviewed. This family can be clearly distinguished both morphologically and genetically from other zoanthids by their very small size, reduced or absent stolon, habitat usually on the bottom side of rubble zone rocks, and divergent and distinct DNA (cytochrome oxidase subunit I, mitochondrial 16S ribosomal DNA, internal transcribed spacer region of ribosomal DNA) sequences. My phylogenetic analyses clearly showed Microzoanthidae to be genetically far different from all other hexacorallians at the order level, but the macrocnemic arrangement of mesenteries and other morphological characters (colonial specimens with narrow stolons, two rows of tentacles, sand encrustation) clearly place these specimens within the order Zoantharia.

In chapter 3, the features and molecular phylogeny of the diminutive zooxanthellate zoanthid family Nanozoanthidae are reviewed. Nanozoanthidae polyps occur in 'pools' of sand upon hard substrates in coral reef environments. The results of my molecular phylogenetic analyses of mitochondrial 16S ribosomal DNA and cytochrome oxidase subunit I suggest that Nanozoanthidae is genetically closely related to both family Microzoanthidae and *Isozoanthus sulcatus* at the intrafamily-suborder level. The Nanozoanthidae-Microzoanthidae clade is clearly and highly divergent from all other known zoanthid families and from the order Actiniaria at the suborder level or higher.

In chapter 4, I analysed the molecular phylogeny of order Actiniaria while focusing on the suborder Endocoelantheae, a group that has unusual mesenterial arrangements. The results of my molecular phylogenetic analyses in this study support the theory previously based on morphological features that the Endocoelantheae are highly divergent from other sea anemones that have "exocoel" mesenterial arrangements.

In chapter 5, I analysed the phylogenetic relationships between order Zoantharia and Actiniaria. The relationship between Zoantharia and Actiniaria is poorly known and is still under discussion. The highly divergent zoanthids and actinarians in this thesis (chapters 2-4) formed highly divergent clades within each order although my results suggest the order Zoantharia is monophyletic. The results also suggested order Actiniaria is polyphyletic. Further analyses with poorly known taxa, such as genus *Isozoanthus* in Zoantharia or sub order Gonactinia in Actiniaria, is required to confirm the relationships between Zoantharia and Actiniaria.

This study demonstrated that the genetic diversity within Zoantharia and Actiniaria is much higher than has been previously thought and reported. To understand higher-level (family level or higher) genetic diversity within each order and the phylogenetic relationships between the orders of Hexacorallia, the continued accumulation of taxonomic information, such as from field surveys, is required.

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### 学位（博士）論文審査及び最終試験の終了報告書

学位（博士）の申請に対し、学位論文の審査及び最終試験を終了したので、下記のとおり報告します。

#### 記

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審査要旨 (2000字以内)	The candidate investigated the diversity of two orders within Anthozoa, Zoantharia and Actiniaria, and additionally the phylogenetic relationship between the two groups. Although both of these groups have been shown as ancestral within Anthozoa and as closely related, no research until now has focused on their relationship. While Zoantharia have been well investigated phylogenetically, overall research on this group is lacking, and it is likely much undiscovered remains. On the other hand, Actiniaria has been well investigated historically, but phylogenetic investigations on this group are only just beginning. As well, two of the three suborders in this order have never been examined phylogenetically.	

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## 審査要旨

The candidate pursued research along two main lines. The first line of research was to locate and describe previously undescribed taxonomic groups within Zoantharia, and characterize them phylogenetically. To this end, two new colonial families of zoanths highly divergent from all previously known groups were described, Microzoanthidae and Nanozoanthidae. Microzoanthidae currently consists of 2 species, and is found across the Indo-Pacific. This group is not rare, but occurs on the undersides of coral rubble and in cracks, and has escaped notice until now likely due to its cryptic habitat, small size (oral disk diameter <2 mm) and lack of bright coloration. Nanozoanthidae currently consists of 1 species from Okinawa (and potentially Australia) and is even smaller (oral disk diameter approx. 1 mm), and is found in "pools" of sand on shallow coral reefs. Both new groups were phylogenetically different (COI, 16S sequence data) from zoanths at the order of level, and similarly distant to Actiniaria.

The second line of research was to investigate the phylogeny of an unexamined suborder of Actiniaria, the Endocoelanthaeae. Not unexpectedly, the group was divergent from known anemones in suborder Nyantheae, but also surprisingly formed a weakly supported monophyly with zoanths (COI sequences). Furthermore, results indicate examined Endocoelanthaeae specimens include 1 to 2 undescribed species

Overall, these results show that the two orders Zoantharia and Actiniaria are much closer than previously thought, and higher scale taxonomic revision may be needed. Before any questions on which of these groups is most ancestral within Anthozoa, their relationship and diversity must be clarified. In particular, it is imperative to examine the remaining unexamined suborder in Actiniaria, the suborder Protantheae.

Throughout his study, the candidate has demonstrated a high level of academic achievement, with four publications (including 2 first author papers describing each new family) in high-level international journals, and has been nominated for and won awards. His work has also received attention from local, domestic and international media.

From a scientific standpoint, his work is very significant in anthozoan biology. The discovery of 2 very divergent new families in between all known zoanths and anemones forces researchers to reconsider the definition and relationship of these groups, and of the ancestral position and character of the class Anthozoa. Furthermore, identification and description of these two widely distributed and divergent groups demonstrates how little is known of marine biodiversity for many groups of organisms. Such results show how important it is to search for biodiversity in previously under-examined environments and locations. Finally, alpha taxonomy research is a critical first step towards a more complete understanding of coral reef ecosystems, allowing for more effective and accurate management and conservation. Thus, based on the above reasons, the downstream results of this research will be seen in various fields from basic zoology and biogeography to genomic and developmental studies, and to conservation-related themes.

The candidate's publication history related to this thesis more than meets graduation requirements, with 2 first author papers and 2 more papers as co-author, all in respected international journals. The candidate gave a final thesis presentation (=final examination) on February 13, 2014, in the Science Collaborative Building Room 102, from 14:00 to 15:00 in front of all three members of the Committee. This presentation was open to the public, and attended by many people from both inside and outside the university. In his presentation he discussed his major results, and the implications for future anthozoan research. Overall, the candidate talked for 40 minutes, and then appropriately answered numerous questions related to his thesis and research field for 20 minutes. The Committee then met on February 13, 2014, at 16:45, and discussed and judged the candidate's presentation, as well as answers to questions, as demonstrating his hard work, results, and knowledge. Thus, based on the above results, for these reasons, the Committee unanimously recommended "Pass" for the candidate.