Summary of Dissertation

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Dissertation Title	Life history, diversity and morphology of symbiotic alpheid shrimps associated with crustacean hosts

Alpheidae is a large family of caridean shrimps and one of the most diverse among the recent decapod crustaceans with over 600 species in 36+ genera. They mainly live in marine shallow tropical and subtropical aquatic habitat while some live in temperate waters. They have been described to perform physical and ecological functions in the marine soft-bottom environments. These functions include bioturbation, nutrient cycling, leaf litter harvesting in sea grass meadows and sediment removal from the coral host.

Burrowing crustaceans are ubiquitous in the tidal flats where they form associations with symbiotic organisms. Several alpheids, especially in the genus *Alpheus*, are known to host symbiotic gobies in their burrows. Some alpheids are symbiotic with crinoids, ophiuroids, echinoids and euchiurans, while still others are associated with burrowing crustaceans such as gebiid and axiid shrimps, stomatopods and other alpheids.

Two alpheids *Stenalpheops anacanthus* and *Athanas japonicus,* with symbiotic relationships with upogebiid and callianassid shrimps, have been investigated in this study to describe the population distribution of the species, sexual dimorphism, and reproductive parameters that includes fecundity, embryo size. Recent studies have suggested that *S. anacanthus* is obligately symbiotic with shrimp burrows, while *A. japonicus* is facultatively symbiotic. Additionally, some morphological aspects of *S. anacanthus* (ontogenetic changes in uropod and cheliped) and *A. japonicus* (chela polymorphism) were clarified on taxonomic problems of the genus and variations on chela patterns respectively.

Stenalpheops in Japan has been proposed to contain two species; "*S. anacanthus*" and "*S. koreanus*" wherein "*S. anacanthus"* have uropod flap in both sexes (no flap in both sexes of "*S. koreanus*") and chela becomes sub-chelae in large males (normal in "*S. koreanus*") by Chinese researchers. The uropod flap and chela of *S. anacanthus* were investigated to clarify that they are sexual characters. It was found out in the study that uropod flap was present only among the largest male shrimp and no male shrimp possessed subchela. Ontogenetic changes in these characters support the view that *S. koreanu* should be synonymized with *S. anacanthus*, and that the male cheliped is normal in *S. anacanthus* (subcheliped in *S. crangonus*), and the uropod flap is found only in the large males of *S. anacanthus* (in both males and females in *S. crangonus*).

Distribution of *S. anacanthus* in Japan was investigated from available literatures and samplings. Two female specimens were collected using a yabby pump from *Neotrypaea japonica* burrows that were approximately 30 cm deep in Kumihama Bay, Kyoto Prefecture, the Sea of Japan. The species was previously recorded in the Seto Inland Sea, Ariake and Yatsushiro Bay, East China Sea, the Pacific coast (Kochi to Tokyo) and the southwestern part of the Sea of Japan. In the coasts of the Yellow Sea, *S. anacanthus* has been documented in Korea and China. The finding of *S. anacanthus* in Kyoto Prefecture extended the distribution of the species to 350 km towards the middle of the Sea of Japan.

Chela pattern was described in detail in *A. japonicus* population in Tokyo Bay, because several patterns were already known to this species, but not qualitatively analyzed. It was found that females with pattern IIB are significantly larger than all female group IIA both in body size (CL) and all morphometric characters of chelae. But both pattern IIA and IIB were different from allometric equation of younger form (pattern I). This is the first case of distinctively accelerated chela growth in females in caridean shrimp. Future experimental and observational studies may be necessary for the use of large chelae in females.

A total of 500 shrimps that comprise 398 and 102 individuals of *S. anacanthu*s and *A. japonicus*, respectively, were collected from a tidal flat in Tokyo Bay. It was revealed that populations of the two species are both female biased. They were present in all months throughout the study, confirming the symbiotic life-style all the year in both species. The mean density ± SE were 1.14 ± 2.56 in *S. anacanthus* and 0.29 ± 0.76 in *A. japonicus*. The maximum number of individuals collected in a sampling effort was 22 in *S. anacanthus* and 6 in *A. japonicus.* Symbiotic incidences of *S. anacanthus* and *A. japonicus* throughout the study pereiod were 36% and 18%, respectively. Burrow sharing was not significant between the two species, indicating interspecific competition between symbiotic species in the host burrows. Reproduction was in summer season, and settlement occurred in summer to autumn in both species.

Sexual dimorphism was detected in the two species (*S. anacanthus* and *A. japonicus*) and weaponry in males, while both males and females are positively allometric in cheliped growth (propodus length, propodus width). Abdomen width has negative allometry in both males of the species as well as females of *S. anacanthus* which suggest efficiency in burrow space mobilization and utilization of *S. anacanthus*, as an obligate symbiotic species. Large frequencies of solitary females were present in ovigerous populations; 57% in *A. japonicus,* 40% in *S. anacanthus*. Further, there was no transitional appendix masculinae in any individual of the two species throughout the study period. Both species exhibited non-monogamous mating system. Nevertheless, mobility of females of *S. anacanthus* inside the burrows was not investigated. Future studies on this aspect are necessary to fully describe their mating tactics and symbiotic lifestyles.

Both species have lower fecundity and egg volume compared to other genera in the family. Strong positive correlation was detected between fecundity and carapace length, abdomen width and pleura width whereas no relationship was found between the growth of egg volume and the three morphometric characters. There was a significant increase of egg volume during embryonic development in both species. Future studies on the degree of symbiosis, frequency of ovigerous females to utilize burrows (at least in the facultative symbiotic species) as well as nature of hosts are necessary to elucidate variations of reproductive biology among symbiotic alpheids.

Population of *S. anacanthus* in Kochi was investigated and compared to Tokyo population to infer host effect on size and distribution. A total of 406 shrimp were collected in Kochi. In Kochi, the host crustacean is primarily *U. yokoyai*, the smaller host, while in Tokyo, the host is primarily *U. major*, the larger host. The body size (CL) of Kochi population was found to be significantly smaller than Tokyo population. The propodus-pollex angle is also significantly different where bending starts at approximately 4.0 mm in Kochi population and about 7.0 mm in Tokyo population. This suggests an early growth and development of morphometric characters in relation to body size. Ovigerous females are also significantly smaller; smallest individuals were 2.74 and 4.34 mm in Kochi and Tokyo populations respectively. Ovigerous females were collected in February-October (Kochi) and June-October (Tokyo) suggesting a longer reproductive season of *S. anacanthus* in Kochi.