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Author(s)	張, 越
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学位論文内容の要旨

博士の専攻分野の名称：博士（水産科学）　　氏名：張　越

学 位 論 文 題 目

Survival Strategies of the Sea Snail *Nassarius fraterculus* (Dunker, 1860)

(海産巻貝クロスジムシロの生存戦略)

The intertidal zone between high and low tides is subject to the rigors of both the sea and the land, which is a harsh and unforgiving habitat. The physical environment in intertidal zone changes dramatically in moisture, turbulence of tide, temperature and salinity. These factors make the intertidal zone an extreme environment in which to live. Therefore, organisms in the intertidal zone have to adapt to an environment of harsh extremes and have evolved various strategies to cope with and even exploit these conditions.

Nassarius fraterculus is a distinct intertidal snail scavenger that can adapt to the brutal environment living in the tide pool with sand sediment, particularly in sandy patches in intertidal rocky shores. It is widely distributed in the shore area of Japan, China and Korea, especially in Shinori, Hakodate, Hokkaido, Japan.

Previous studies mainly revealed the information on taxonomy and morphology of *N. fraterculus*. Very few researches were detected on basic ecology and behavioral ecology of *N. fraterculus*. Even we know the terminology “the sit-wait foraging model”, but the mechanism in which how *N. fraterculus* to assess food and risk still could not be described very well. Through collecting and analyzing abundant data from field survey and indoor experiment on development, growth, survival and so on of *N. fraterculus*, the present study was investigated on the basic ecology and behavior of *N. fraterculus* to reveal its survival strategy in the intertidal zone.

Primarily, the experiment in first step examined the breeding season in field and indoor early

development of *N. fraterculus.* Field investigations showed that the breeding season of *N. fraterculus* came from June to July in Shinori shore. *N. fraterculus* laid cohesive egg capsules under rocks in tide pools. Each egg capsule contained 1 to 6 fertilized eggs. About 20 days after the eggs were spawned, juveniles left the egg capsule. The results of indoor early development showed that the usual hatchings of *N. fraterculus* developed within the egg capsule, and after leaving the egg capsule the juveniles were benthic. The developmental process could be divided into six stages: cleavage, blastula, gastrula, trochophora, veliger, and juvenile. However, *N. fraterculus* also showed poecilogony, in which they reproduced not only crawling juveniles but also plankton larvae in even the same egg capsule. Significant differences were observed in development time and speed among fertilized eggs in the same capsule. Early and faster developing individuals were observed to kick out slower developing ones from the egg capsule. Having this different development pattern might be a strategy to allow at least some individuals to survive under unfavorable conditions.

Secondly, the population density, growth, sex ratio, life history of *N. fraterculus* in Shinori shore was detected from August 2012 to July 2013. It was reported that there were three or more cohorts living at Shinori shore during study period. Hence the life span of *N. fraterculus* was inferred as 3 years or more. The recruit *N. fraterculus* which occurred in October grew faster than senior, but their shell growth mainly occurred during the warm summer months, slowing down during the colder winter months. And female *N. reticulatus* had a larger shell length than males. *N. fraterculus* showed concentrated distribution in Shinori shore. As we observed, there were many *N. fraterculus* individuals at some tide pools in low-lying land, but in other pools sometimes no snail *N. fraterculus* could be found. In addition, some imposex *N. fraterculus* were found in irregular throughout the survey period. Because the number of imposex individuals was not so many, the fecundity of *N. fraterculus* population for a time was safe.

Finally, the sit-wait foraging strategy was studied more in detail in this step experiment. Starvation tolerance of *N. fraterculus* was detected firstly. Satiety *N. fraterculus* could survive 40 days in the absence of any food. Such formidable starvation tolerance was an effective

characteristic for fluctuant food supply in the intertidal area. The effects of different starvation periods and of crushed conspecifics on the foraging behavior of *N. fraterculus* were examined. The feeding percentage, searching time, eating time, and eating frequency were detected after different starvation periods (3, 6 and 12 days) in two groups: one exposed to chemical cues from crushed mussels (its normal prey) and another exposed to chemical cues from crushed conspecifics. Cues from crushed conspecifics caused a significant decrease in the percentage of *N. fraterculus* that fed and a significant increase in the time spent searching for food. As the starvation periods increased, these two effects subsided. The time spent eating and the eating frequency were affected only slightly by crushed conspecifics in all starvation periods. These results showed that chemical cues from crushed conspecifics inhibited some foraging behaviors. *N. fraterculus* could judge rapidly, locate accurately and rush to the goal as soon as they felt the chemical cue of the food. Meanwhile *N. fraterculus* also sensed the risk cue from predator and crushed conspecies by its siphon, which was helpful to them to avoid risk immediately, and living safely in the intertidal zone.

All the above traits and characteristics of *N. fraterculus*, including spawning habit and development pattern of a unique poecilogony, burrowing habit into the sand sediment to avoid harsh environmental and predation risks, sit-wait foraging strategy, good olfactory senses to detect foods and predation risk, and longer starvation tolerance, might help surviving in the harsh intertidal habitat.