学位論文内容の要旨

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学 位 論 文 題 目

Spawning behavior, egg masses and paralarval development of the Japanese flying squid, *Todarodes pacificus*
（スルメイカの産卵行動および卵塊とふ化幼生の発育に関する研究）

The Japanese flying squid, *Todarodes pacificus,* is an important oceanic predator of small fishes and invertebrates and prominent prey for large fishes and mammals. This species is also the commercially important target species of fisheries in Japan. Despite its ecological and economical importance, very little is known about its reproduction and early life stages. The annual recruitment of juveniles into the population is the most important process governing population fluctuations in this annual and semelparous species. The factors affecting recruitment, particularly those affecting the survival of the eggs and larvae, are therefore perceived to be of key importance. Understanding the basic reproductive biology is necessary to manage squid population for sustainable fishery.

Observation of the spawning behavior of *T. pacificus* is extremely challenging in the pelagic waters. Females are known to spawn a neutrally buoyant gelatinous egg mass. It was hypothesized that pre-spawning females might rest on the continental shelf or slope before they ascend above the thermocline to spawn, and that the egg masses might settle near the thermocline. Mesocosm experiments were conducted in order to examine this hypothesis and understand the spawning behavior. Embryonic development within the egg mass and development and behavior of hatchlings (paralarvae) were studied in order to understand their early life history. Based on the information acquired by the experiments, I discuss the importance of the thermal gradient on egg mass distribution, role of egg mass for the successful development of embryos and paralarval survival.

A series of experiments were conducted in a large tank (depth, 6 m; length, 10 m; width, 5 m; volume, 300 m^3) to investigate spawning behavior, effect of a thermocline on egg masses, egg-mass properties, and embryonic and paralarval development.

To study the spawning behavior, mature females and males were introduced into the tank and their spawning behaviors were video recorded. A total of 39 egg masses were spawned by 19 females; indicating that females can spawn multiple egg mass. The egg mass sizes varied greatly ranging from 17 cm to 120

cm in diameter. The females spawned smaller (incomplete) egg masses showed higher possibility of spawning again. In nature, a female could possibly spawn all of her eggs in the oviduct at a single spawning. The large variation of egg mass size observed in this study is attributed to interruption by males.

To measure buoyancy of the egg mass, a specially designed net cage was used to hold the egg mass in the tank. The gel from the egg mass was collected to measure its density. The egg mass was found to be 0.26% denser than the sea water (19.5° C) from which it was formed in the tank, indicating that the egg mass would sink in the waters (19-23° C) where it is formed in natural condition, and is retained in the water column of the density 1.0235 g cm^{-3} corresponding to the thermocline (19.5-23° C) which was observed at ~40 - 60 m in the spawning ground of this species in Tsushima strait. Also this temperature range corresponds to the optimum temperature range (19.5-23° C) for embryonic development (Yamamoto *et al.*, 2012).

To study the effect of the thermocline on the distribution of egg masses two mesocosm experiments were conducted. In the first experiment, a thermocline was established in the tank at 2.5-3.5 m depths by creating a thermally stratified (17-22° C) water column. In the second experiment, the temperature was kept uniform (22° C) at all depths. The egg masses remained suspended in the thermocline resulting in the normal development of embryos and successful hatching of paralarvae. But in the unstratified water column, egg masses settled on the bottom of the tank, causing the collapse of egg mass and resulting in abnormal or nonviable embryos. This highlights the importance of the thermal gradient in retaining the egg masses in the water column and facilitating normal development of embryo.

To study the larval development, paralarvae were supplied with natural seawater as a food source in the tank and were collected periodically. They grew from 1.3 mm mantle length (ML) at hatching, to 1.4 mm ML at day 10. The internal yolk reserve in paralarvae was completely exhausted by day 7. Although I didn't get any direct evidence of active feeding, their prolonged survival for another 3 days could be possible by ingestion of food particles such as particle organic matter (POM) with marine bacteria in the natural seawater supplied in the tank.

The mesocosm study presented in this thesis provides a clearer understanding on the spawning behavior, egg mass and early life history of *T. pacificus.* It also confirms the hypothesis that egg masses settle in the thermocline. These findings will provide essential information for detecting the spawning grounds, improving predictive models of recruitment process and allowing fisheries managers to make more informed decisions about commercial squid fisheries.