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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：Dharmamony Vijai

## 学位論文題目

SPAWNING ECOLOGY AND EARLY LIFE HISTORY OF THE NEON FLYING SQUID

（アカイカの繁殖生態と初期生活史）

The neon flying squid *Ommastrephes bartramii*, is an oceanic species that is widely distributed in the North Pacific, with the winter-spring cohort spawning around the Hawaiian Islands. Very little is known about its reproduction, development, and early life stages, as it is a true oceanic dweller for which experiments in land-based laboratories are challenging. In the present study I explored the spawning pattern and early life stages of the winter-spring cohort.

I aimed to examine the reproductive characteristics of the winter-spring cohort of *O. bartramii* near the Hawaiian Islands, using individuals collected during 1990 - 2000 and 2013. The findings of this study, combined with the results of previous studies, are expected to clarify whether this species is a single or multiple spawner. Squid were collected aboard the T/S Hokusei Maru and the R/V Kaiyo Maru. Sampling aboard the T/S Hokusei Maru was performed by manual jigging, gillnetting, and trawling on 11 cruises from February to March every year from 1990 to 2000 between 20° and 35°N and 150°W and 180° longitude. Collection aboard the R/V Kaiyo Maru was conducted during December 2013 north of Hawaii, between 24° and 33°N and between 173° and 155°W. A total of 719 (622 males, 97 females) individuals were collected by the T/S Hokusei Maru, in addition to 11 individuals by the R/V Kaiyo Maru. Female spawning status was determined from somatic indices and histological characteristics of the ovaries.

At all developmental stages, the ovaries of spawned females contained oocytes, while oviduct fullness was not correlated with body size. Thus, because the eggs mature asynchronously, with multiple filling and evacuation events, this species is considered an intermittent spawner. Mature males with developed accessory glands were also present within the distribution range of healthy, spawned females, suggesting that mating occurs between spawning events. The data indicate that, the first spawning event occurs at a mantle length of

~520–540 mm. Subsequently, the squid forage and grow, and refill the oviducts, before spawning again.

Studies on the relationships between the early life stages of the *O. bartramii* and oceanographic conditions are essential for understanding the spatial and temporal distribution patterns of this ecologically and economically important species. Eggs of the neon flying squid were artificially fertilized and incubated at temperatures found in the known distribution range of this species (16–26°C). Artificial fertilization was performed on board the R/V Kaiyo Maru using standard techniques. Fresh seawater collected from 500 and 1000 m depth was fortified with antibiotics (25 mg L<sup>-1</sup> each of ampicillin and streptomycin) and used as the experimental medium.

The present study establishes an atlas for the normal development of *O. bartramii* from fertilized eggs to paralarvae. The stages are mainly based on morphological features and can be distinguished clearly under a stereomicroscope. These observations of embryonic development correspond closely with those of two other ommastrephids, *Todarodes pacificus* and *Illex argentinus*. To observe the species-specific effects of the oviducal gland powder on chorion expansion, four batches of *O. bartramii* fertilized eggs (n = 400) were prepared. Two batches were provided with oviducal gland jelly water (OGW) prepared from *T. pacificus*, and the other two batches were provided with OGW prepared from *O. bartramii*. One day after incubation, during the water exchange process, one batch started with *T. pacificus* OGW was changed to *O. bartramii* OGW, and the reverse interchanging procedure was conducted for one batch started with *O. bartramii* OGW. The remaining two batches were provided with the same OGW throughout the experiment. Embryos treated with OGW from a single species throughout the experiment successfully reached the hatching stage. However, the chorion of the embryos for which the OGW provision was switched began to contract and did not survive longer than a day. These results indicate that the overall chemical nature of the oviducal gland was species-specific, although the chorion expansion inducer was the same across species. The addition of oviducal gland jelly also induced partial parthenogenesis in the early stages of embryonic development through the expansion of the perivitelline space and blastodisc formation.

Complete organogenesis with normal successive cleavage and the distinct continuity of morphological features occurred only between 18° and 25°C. Experimental rearing, cruise-

collected specimens, and oceanographic data (sea surface temperature) confirmed that the optimal temperature range for *O. bartramii* paralarval survival around Hawaii is 18–25°C. Embryos reared at 16°C showed abnormal organogenesis; however, normal development resumed when embryos were transferred to 22 or 24°C after blastoderm formation.

Hatchlings showed a variety of swimming behaviors, which may allow squid to regulate their thermal distribution in the wild. Furthermore, ball formation and associated chromatophore expansion might represent an aposematic adaptation to imitate unpalatable prey. Although prey items initially consumed by hatchlings were not identified, I discuss the possible role of the proboscis (fused tentacles) in feeding. This study highlights the flexible strategy of ommastrephid embryo development and illustrates how information on paralarval behavior and oceanographic data (sea surface temperature) may be combined to improve our understanding of the factors that influence survival.