

Incubation Time Required for Hatching, and Ecological Characteristics of the Mode of Life Related with Total Numbers of the Suckers on Each Short Arm of the Hatched Juvenile Larvae of *Octopus ocellatus* (Cephalopoda: Octopodidae), in Western Korea

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ABSTRACT

The incubation time required for hatching of *O. ocellatus* were investigated through the processes of egg and embryonic developments by the dissecting microscopic and visual observations. And differences in ecological characteristics of the plankton mode of life or the benthic mode of life according to total numbers of the suckers on each short arm of the hatched juvenile larvae of *O. ocellatus* were studied by comparisons with other octopodidae species. Compared with the recent a few results reported by other researchers associated with the incubation time required for hatching by female adult mother of *O. minor* (73-90 days after spawning at 20.9-21.5°C ranges), in this study, the incubation time required for hatching by female adult mother of *O. ocellatus* was 56-57 days after spawning at 11.0-20.4°C. Therefore, the incubation time required for hatching by female adult mother varied with Octopodidae species. In this studies, each ovarian egg laid by a female was connected to an egg string attaching to the surface of the wall or bottom of vacunt shell of *Rapana venosa*. Egg and embryonic developments of this species were studied in the indoor aquaria, in the specific gravity ranging 1.024-1.025. the hatched juvenile of *O. ocellatus* is 10.3 mm in the mean total length and 4.5 mm in mantle length, and each of its short arms has 18-20 suckers. The just hatched juvenile larvae of *O. ocellatus* enter the benthic mode of life (benthic larval stage) after hatching. In particular, regarding differences in ecological characteristics of the mode of life according to total numbers of the suckers, *O. vulgaris* may not need to have many suckers because they enter the planktonic mode of life after hatching, however *O. ocellatus* may need to have many suckers, because they should adapt to the benthic mode of life. And also the just hatched juvenile larvae of *O. minor* (bearing many suckers more than *O. ocellatus*) enter the benthic mode of life (benthic larval stage) after hatching. Therefore, the total number of the suckers on each short arm of the hatched juvenile larvae can be used for determining whether an octopus species has planktonic larval stages or benthic larval stage (benthic mode of life). In particular, The intracohort cannibalism phenomena appeared at the hatched juvenile larval stage because the larval stage of *O. ocellatus* and *O. minor* enter into the benthic larval stage in the early stage, unlike entering into the planktonic larval stage in other Octopus species such as *O. vulgaris*: at this time, the early hatched larvae fed the late hatched larvae (they are the same species and almost same ages). Therefore, the intracohort cannibalism phenomena occur in the just hatched juvenile stage of only *O. ocellatus* and *O. minor*.

Key words : *Octopus ocellatus*, Egg and embryonic developments, Time required for hatching, Function of total suckers

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INTRODUCTION

The webfoot octopus, *O. ocellatus* (Neocephalopod: Octopodidae), has been found along the coasts of Korea, China, and Japan etc. In Korea, especially, it lives in sandy gravel or silty sand in the subtidal zone on coasts of the southern and western Korea (Lee,

1956; Kwon *et al.*, 1993; Choe *et al.*, 1999; Kim., 2003; Min *et al.*, 2004), and it is one of the most commercially important edible cephalopods. This species is dioecious and showed a protandry phenomenon. In particular, this species has a life mode showing some special reproductive characteristics of an annual semelparity as shown in the genus *Octopus*. In particular, Intertidal reclamations, reckless over catching, and water quality degradation might be mainly responsible for the recent rapid reduction of its standing stock (Kim *et al.*, 1997, Kim, 2003; Chung *et al.*, 2004). To date, regarding Octopodidae species, there have been several studies on aspects of reproduction, including reproductive ecology (Smale and Buchan, 1981; Boyle and Knoblock, 1983; Forsythe and Hanlon, 1988; Perez & Haimovici, 1991; Cortez *et al.*, 1995), and changes in biochemical components with gonad developmental stage (Chung *et al.*, 2004), besides, on physiology (Taki, 1941; Andrews and Tansey, 1983; Che *et al.*, 1992), on taxonomy and ecology (Boyle and Knobloch, 1982; Takashi, 1984 a,b; Mangold, 1990, Aronson, 1991; McQuaid, 1994; Villanueva, 1995; Nixon and Mangold, 1996; Moltschaniwskyj & Doherty, 1995), and morphology (Bairati *et al.*, 1995).

In addition, there have been several studies on culture technology development on the seedling productions of the Korean webfoot octopus (Chu, 1990; Kim *et al.*, 1997; Kim, 2003). However, on the contrary, little information is available on The incubation time required for hatching of *O. ocellatus* and ecological characteristics of the benthic mode of life (the intracohort cannibalism phenomena occur) according to total numbers of the suckers on each short arm of the hatched juvenile larvae of *O. ocellatus*. Therefore, the planktonic or the benthic mode of life were studied by comparisons with other octopodidae species.

According to observations of the hatched process, the hatched juveniles of *O. ocellatus* entered to the benthic mode of life (the benthic stage), as reported in the species of *O. minor* (Kim, 2004). However, they do not enter to planktonic mode of life (the planktonic stage), as seen in *O. vulgaris*. The determination whether

belonging to planktonic mode of life or benthic mode of life may be determined according to the total numbers of the suckers on each short arms of hatching larvae of Octopus. In this study, an ecological confirmation of the processes of the planktonic or benthic larval stages according to total numbers of suckers of hatched juvenile may be one of the most important things. The total numbers of the suckers on each of short arms of in the juvenile stage of *O. vulgaris* are relatively smaller than those of *O. ocellatus*. In case of the morphology and structure of *O. ocellatus*, each of its short arms has 18-20 suckers in the juvenile stage, but each of short arms has approximately 63 suckers in adult individuals. *O. ocellatus* may need to have many suckers because they should adapt to the benthic mode of life (not the planktonic mode of life). However, *O. vulgaris* (only 3 suckers) may not need to have many suckers because they enter the planktonic mode of life after hatching. Therefore, the number of the suckers can be used for determining whether an octopus species has planktonic larval stages or not.

The studies on the reproductive ecology of *O. ocellatus* may be one of the most important tasks in cultural operations for propagation of natural resources. Therefore, the main objectives of the present study is to confirm and describe the incubation time required for hatching for aquaculture. And also the aims of this study are to clarify the functions and roles (cannibalism) by total numbers of suckers on each of small arms in the juvenile stage, and to compare ecological differences (the planktonic mode of life or not) with other octopuses (*O. vulgaris*, etc.). In addition, the goals of this study are to get some information for the basic data of reproductive ecology for aquaculture technology development, in particular, for some problems associated with mutual cannibalism in the juvenile larval stage because their ecological characteristics belong to the benthic mode of life of *O. ocellatus*.

MATERIALS AND METHODS

1. Sampling methodology

To confirm the incubation time required for

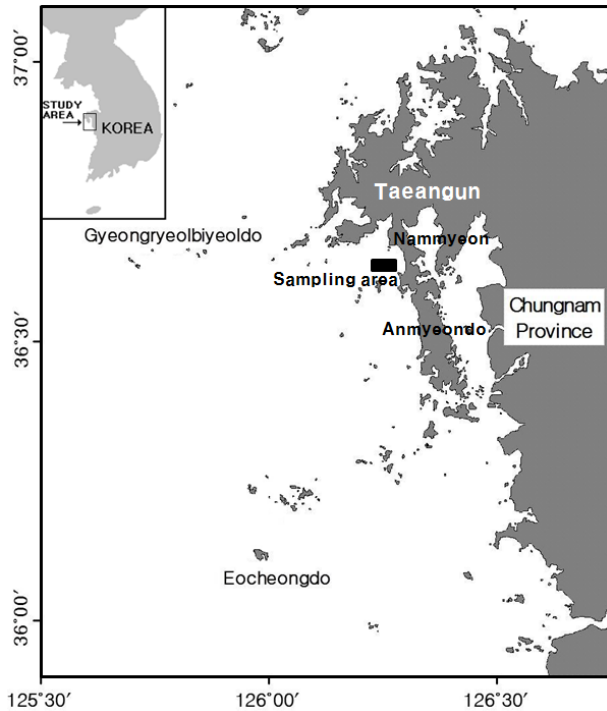


Fig. 1. Map showing the sampling area.

hatching, the adult specimens and larvae (including spawned eggs and developing embryos of *O. ocellatus* during embryonic developments in the octopus spawning pots) were collected during the main spawning period (May) using the octopus spawning pots. In Taeang coastal waters of Korea. After 200 adult webfoot octopuses collected, of them, adult octopuses showing good vitality were selected for the indoor rearing experiment. Above all, we confirmed that in case females finished already copulation with males, we selected female adult octopuses which is assumed not to be spawned, and separated with male adult individuals. In particular, external morphologies and the total numbers of suckers on short arms of female and male adult individuals were confirmed in detail. Investigations of the total numbers of the suckers on each of the short arms of the hatched juvenile were calculated under the dissecting microscope.

2. Facilities in each tank and the induction

Total three rearing tanks were used for this indoor rearing experiments. At this time, vacant large gastropod shells (*Rapana venosa*), which are used as

octopus spawning pots, put into the floor (50 cm in water depth) of each rearing tank. And then, a number of female adult webfoot octopuses, *O. ocellatus* were inducted to enter into the vacant gastropod shells and spawned ovarian eggs in the vacant shells. For the seawater circulation management, natural filtered seawater in each rearing tank were circulated three round per day. In this study, we studied survivals of adult webfoot octopuses and the processes of spawned ovarian egg development and embryonic development up to hatching out in detail.

3. Morphological characteristics of egg and embryonic developments and the study of the incubation time required for hatching

After 100 adults webfoot octopuses (*O. ocellatus*) in the spawning octopus pots were laid in the floor of each tank (6 MTs), *O. ocellatus* were spawned soon in the spawning octopus pots, and then morphological characteristics of egg and embryonic developments were observed and studied by the photomicroscope. After investigation until hatching out, we confirmed the time required for hatching.

RESULTS

1. External morphology of adult individuals

The trunks of adult females and males were oval in shape, many folds were present on the skin, and four longitudinal rows on the dorsal part and two black longitudinal rows on each arm were present. Short arm length was approximately 72.01% of total length, and each arm length was similar, while the third right arm of male was slightly short. The total number of the suckers on the short arms of the body were approximately 63. However, the total numbers of the suckers on each short arm in the hatched juvenile larval stage of *O. ocellatus* were 18-20 suckers.

2. Calculations of incubation time required for hatching according to Egg/embryonic development

The experiment of egg developments carried out in the indoor rearing tank at the seawater temperature of 11.0-20.4°C (cumulative water temperature, 887°C) in

the specific gravity ranging 1.025-1.026. The experiment period was 56-57 days from was 56-57 days from April 18 to June 12-13 2015.

3. The process and sequence of the experiments of *O. ocellatus* in the indoor aquarium

As shown in Fig. 2, four photographs are showing the processes of the experiments in the indoor aquarium at the laboratory. as follows: Fig. 2A shows an external morphology of *O. ocellatus* after collection of the specimens, and an adult female is staying in a vacant shell of *R. venosa* for spawning (Fig. 2B). Thereafter, an adult female of *O. ocellatus* spawned a number of ovarian eggs in a vacant shell in the indoor aquarium (Fig. 2C). A number of hatched larvae after finishing of embryonic development. After hatching, juvenile larvae is living and growing in the aquarium (Fig. 2D).

4. Calculation of the incubation time required for hatching according to the processes of egg / embryonic developments of *O. ocellatus*

Egg/embryonic development can be classified into 12 stages (Fig. 3). A spawned ovarian egg from a female was oval in shape (Fig. 3A), and then it formed the blastodisc, then cell division occurred, 12 days after spawning (Fig. 3B). And the yolk sac at the part of animal pole was covered with the blastodisc 18 days after spawning (Fig. 3C). The site forming eyes and the intestine changed 24 days later (Fig. 3D). The colour of eyes were changed to light pink, and the inner organs began to be differentiated 38 days after spawning (Fig. 3E). The gills observed, the arms became more longer, the yolk became smaller, and the mantle began to move 47 days after spawning. The melanophores were dispersed on the surface of the body, and responded to light intensity. The suckers appeared on the arms, and movement of the arms and body began to occur, Yolk almost absorbed 49 days after spawning (Fig. 3F), the positions of the head and foot were changed, pigment contraction actively occurred in the egg membrane, the egg membrane was expanded because of the body expansion 53 days after spawning (Fig. 3G). The hatching occurred from the

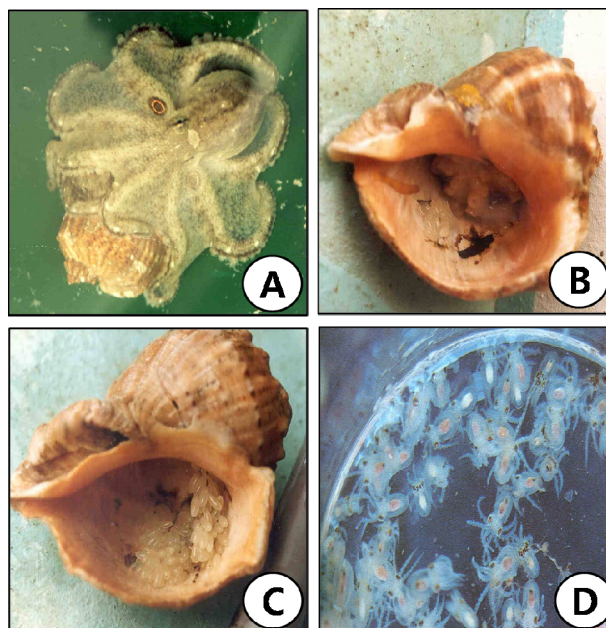


Fig. 2. External morphological characteristics of the webfoot octopus, *Octopus ocellatus* (A-D). **A**, An adult female octopus, *O. ocellatus*, bearing an ovary and 8 arms with approximately 63 suckers on each arm; **B**, An adult female in a large vacant shell of *Rapana venosa* for spawning; **C**, A number of spawned ovarian eggs attaching to the surface of the wall or bottom of vacant shell; **D**, A number of juvenile larvae hatched after finishing of larval development: Each juvenile larva having 8 arms has 18-20 suckers on each arm.

egg membrane. Just hatched juvenile, 56-57 days after spawning (Fig. 3H). is 10.3 mm in the mean total length and 4.5 mm in mantle length, and each of its short arm has 18-20 suckers. After hatching, they immediately started the benthic phase (benthic mode of life) without entering the planktonic phase for a certain period as seen in other octopuses.

After embryonic development finished, just hatched juvenile larvae attached to the surface of the wall or bottom of the experimental rearing tank. In this experiment, we could not find any planktonic phase of just hatched juvenile larvae.

5. Ecological characteristics of the mode of life related with total number of suckers on each short arm of the hatched juvenile larvae of *O. ocellatus*

Regarding ecological characteristics of the mode of life related with the total number of suckers on each short arm of the hatched juvenile larvae, It is

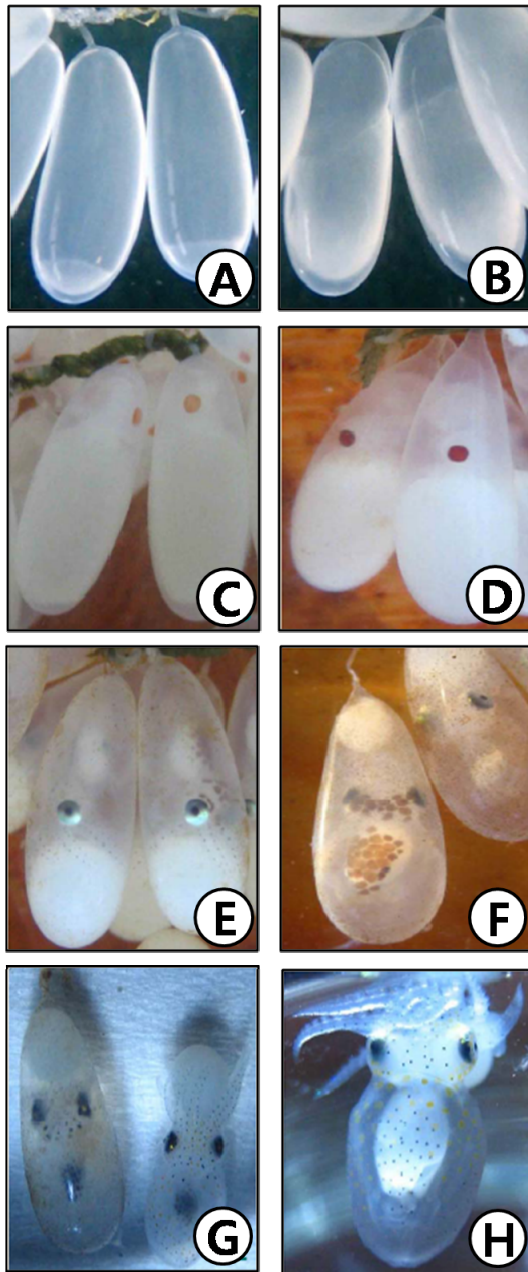


Fig. 3. Egg and embryo developments of *Octopus ocellatus* (A-H). **A**, Fertilized eggs; **B**, A blastodisc formation, 12 days after spawning; **C**, Yolk covered with the blastodisc, 18 days after spawning; **D**, The formation of the heart part and inner organs, 24 days after spawning; **E**, Eye color changed and inner organs differentiated, 38 days after spawning; **F**, Eyes became larger and arms appeared, 47 days after spawning; **G**, Positions of the egg membrane expanded, 53 days, head and arms changed, at the same time, after spawning; **H**, Just before hatching from the egg membrane, 56-57 days.

well-known that, in general, most hatched juvenile larvae of octopus species have some common characteristics of the planktonic phase (planktonic mode of life). However, exceptionally, the hatched larvae of *O. ocellatus* do not have the planktonic phase, this species has the benthic mode of life (= the benthic phase) after hatching. Thus, it immediately starts the benthic phase after hatching because relatively large number of the suckers on each arm. Therefore, ecological characteristics of the mode of life such as planktonic mode of life (= the planktonic phase) or the benthic mode of life (= the benthic phase) are related with the total number of suckers on each short arm of the hatched juvenile larvae.

6. Appearance of Intracohort cannibalism phenomenon related with the benthic mode of life related with the total number of suckers on each short arm of the hatched juvenile larvae of *O. ocellatus*

The intracohort cannibalism phenomena appeared at the hatched juvenile larval stage because the larval stages of *O. ocellatus* and *O. minor* in the Octopodidae species enter into the benthic larval stage in the early stage. Other *Octopus* species such as *O. vulgaris* related with intercohort cannibalism. At the benthic stage, the early hatched larvae fed the late hatched larvae (they are the same species and almost same ages). Therefore, in particular, the intracohort cannibalism phenomena occurred in the just hatched juvenile stage of *O. ocellatus*.

DISCUSSION

This species is dioecious and showed a protandry phenomenon. In particular, this species has a life mode showing some special reproductive characteristics of an annual semelparity.

Regarding spawning after mating and compared this species with other octopuses, in the present study, spawning of *O. ocellatus* began to occur approximately 25-30 days after mating behaviour at $> 11^{\circ}\text{C}$ (effective accumulative water temperature of 887°C), and it took average 56-57 days for hatching after egg laying at $11-20.4^{\circ}\text{C}$, which is longer than that of *O. vulgaris*

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(15-20 days at 23-25°C) (Kume and Tan, 1984). Itami *et al.* (1963) described that spawning of *O. vulgaris* occurred approximately 44 days at 15.3-20.0°C (effective accumulative water temperature of 834 °C). In case of *P. dofleini* (Gabe, 1975) eggs may be laid approximately 42 days after mating. Accordingly, it is assumed that the spawning timing vary with environmental water temperatures (or effective accumulative water temperatures).

Regarding the incubation time required for hatching of *O. minor*, Kim (2004) reported that under the through care by the mother octopus, eggs and larvae hatched took 73 to 90 days after spawning at the water temperatures kept at 20.9°C to 21.5°C ranges.

Except for *O. ocellatus* and *O. minor*, it is well-known that, in general, most *Octopus* species have a common characteristics of the planktonic phase (planktonic mode of life) after hatching for a certain period: *O. vulgaris* spends its first 5-12 weeks after hatching in the planktonic phase and then settles to the benthic mode of life, as all adult Octopodidae do (Itami *et al.*, 1963). However, *O. ocellatus* does not have the planktonic phase after hatching. That is, it immediately starts the benthic phase after hatching.

The total numbers of the suckers on the short arms of the body in adult female *O. ocellatus* were approximately 63. However, the total numbers of suckers on each arm of the female adult *O. minor* were 80-91 pares (Kim, 2004). To date, the total numbers of the suckers on each of short arms in the juvenile stage of *O. minor* have not reported. Henceforth, we have to clarify the total numbers of the suckers on each short arm in the hatched juvenile larval stage of *O. minor*. The just hatched larvae were about 4 cm in length and about 0.2 g in weight. About 2 to 3 hours after sunset, they came out of the mud flat. The larvae prey on one another by cannibalism during the nighttime, which resulted in massive mortality (Kim, 2004).

A Juvenile larva of *O. vulgaris* in a planktonic stage bears only 3 relatively large suckers on each short arm. A hatched *O. vulgaris* is 3 mm in total length and 2 mm in mantle length (Boletzky, 1976, 1977; Boletzky and Hanlon, 1983). However, the hatched

juvenile of *O. ocellatus* is 10.3 mm in the mean total length and 4.5 mm in mantle length, and *O. vulgaris* may not need to have many suckers because they enter the planktonic mode of life after hatching, however *O. ocellatus* and *O. minor* may need to have many suckers, because they should adapt to the benthic mode of life. Therefore, the total number of the suckers can be used for determining whether an octopus species has planktonic larval stages or not. Exceptionally, in particular, we could find special events: "intracohort cannibalism phenomena" between same species and almost same age after hatching on the surface of the wall or bottom of the experimental rearing tank. Perhaps, these phenomena may occur because their life immediately start the benthic phase (benthic mode of life) after hatching. As it were, in case of *O. vulgaris* and *P. dofleini*, their lives start the planktonic phase (the planktonic mode of life). Therefore, it is assumed that "intracohort cannibalism phenomena" may not occur because life modes of these species do not start to the benthic phase. Therefore, hatched juvenile larvae of *O. ocellatus* starts the benthic mode of life (the benthic phase).

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