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Original Article

Female biology and early life aspects of the swamp eel (*Monopterus albus*)

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Abstract

The sexual maturity of the female swamp eel (*Monopterus albus*) was studied by determining its fecundity and gonadosomatic index (GSI). The body weight of a sexually mature female swamp eel was 200-250 g. The eggs were non-adhesive demersal and rounded. The maximum fecundity was in June at 701 ova/fish with a gonadosomatic index (GSI) of 3.09%. The minimum recorded fecundity was 181 ova/fish in October with a GSI of 0.57 %. The average diameter of the eggs was 1,784 µm. The fish eggs were classified by diameter into seven groups: 250-750 µm (12.25%) as group 1, 751-1,250 µm (15.62%) as group 2, 1,251-1,750 µm (14.76%) as group 3, 1,751-2,250 µm (31.50%) as group 4, 2,251-2,750 µm (18.87%) as group 5, 2,751-3,250 µm (6%) as group 6, and 3,251-3,750 µm (1%) as group 7. Newly hatched larvae of the swamp eel were produced by the semi-control natural method. Newly hatched larvae had a mean (SD) total length (TL) of 1.76±0.06 cm with a mean (SD) yolk sac volume of 1,279.14±101.50 µm^3. The yolk sacs were completely absorbed within 174 hours after hatching (hAH) at a water temperature of 28,0-30.5 °C. All larvae were able to open their mouths at 108 hAH (2.50±0.17 mm TL), with a mean (SD) height measurement of 785.00±30.83 µm. The digestive tract was straight, and was placed on the yolk sac. The digestive tracts were formed at 116 hAH with a mean (SD) length of 845.00±30.75 µm. The average number of *Moina* sp. in the digestive tract at the start of feeding was 0.83 individuals/larva. The larvae died within 1,092 hAH at water temperatures that ranged 27.0-30.5 °C. It was found that the feeding scheme of the larval swamp eel was as follows: larvae of age 5-15 days (total length 2.81-3.30 cm) consumed *Moina* sp., but at age 12-15 days (average total length 3.2-3.30 cm) the larvae consumed both *Moina* sp. and a commercial pellet known as 'power feed'. Larvae more than 16 days old (average total length 3.20 mm) consumed only 'power feed'.

Keywords: fecundity, gonadosomatic index (GSI), yolk absorption, mouth development, start of feeding, starvation, larviculture, swamp eel, *Monopterus albus*

1. Introduction

The swamp eel (*Monopterus albus*) is a commercially important fish in the Southeast Asia aquaculture industry. To propagate *M. albus* in commercial-scale hatcheries, it is essential to provide fundamental biology information on the early-life yolk absorption, mouth opening, digestive tract development, and the start of feeding time. Complete yolk absorption is recognized as a critical period in larval rearing and survival (Amornsakun, 1999a; Amornsakun, Chiayvareesajja, Hassan, Ambak, & Jee, 1997; Amornsakun & Hassan, 1996; Amornsakun, Sriwatana, &

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Chamnanwech, 2002; Amornsakun, Sriwatana, & Promkaew, 2004a; Amornsakun, Sriwatana, & Promkaew, 2004b; Eda, Fujiwara, & Takita, 1994; Holm, 1986; Kosutaruk & Watanabe, 1984). Survival of fish larvae is determined by the interaction of various environmental factors such as temperature, food supply with a suite of species-specific characteristics, egg and larval size, yolk and oil globule volume, and its resorption rates, time of onset of feeding, and feeding behaviour. Larvae use yolk energy for various activities (Blaxter, 1974; May, 1974). Mouth size at the first feeding stage of various larval fish when they encounter their appropriate prey size has been well documented for a number of cultured fish (Doi & Singhagraiwan, 1993; Eda, Fujiwara, & Takita, 1994; Fukuhara, 1986; Nash, Kuo, & McConnel, 1974; Shirota, 1970).

M. albus has an eel-like shape with a yellow ventral and black dorsal body without pectoral fins (Collin, Trexler, Nico, & Rawlings, 2002; Jewham, 2008; Jesoa & Kuanmuang, 1994). *M. albus* is a carnivorous fish that eats shrimp, fish, insects, worms, and detritus (Hill & Watson, 2007). It was reported that *M. albus* consume fish (56%), shrimp (32%), and insects (12%) (Shafland, Gestring, & Sanford, 20 10). The mature age of the fish is over 1 year old, but can be different between male and female fish (Liem, 1963). Sexual dimorphism of this fish can only be classified by gonad observation. The sexually mature females of *M. albus* are known to be about 29-50 cm long at a body weight (BW) of 200-250 g while the males are 60.0-72.5 cm long at a BW of 300-400 g (Kuanmuang, 1994). Spawners were fed daily with fresh fish at about 2% of BW. Fish spawners will make the fish nest before spawning. Cultured *M. albus* larvae were fed a comercial pellet known as 'power feed' that contains 40% protein (Pechcharoon & Uraipradit, 2004).

However, fundamental information on the biological development on the early life and female maturation still remain to be discovered. Therefore, this study was designed to investigate the baseline information for optimization of a large scale culture and ultimately for the culture management of this fish including fecundity, gonadosomatic index (GSI) of the mature female fish, period of yolk absorption, larvae mouth development, and onset of larvae first feeding period.

2. Materials and Methods

The sexual maturity of the *M. albus* was studied by determining its fecundity, egg diameter, and GSI. Fecundity was estimated by a gravimetric method (Tarnchalanukit, Chuapoehuk, Suraniranat, & Na Nakorn, 1982). Egg diameter was measured using an ocular microscope (Amornsakun, Sriwatana, & Promkaew, 2011). GSI was calculated, using the following equation (Tarnchalanukit, Chuapoehuk, Suraniranat, & Na Nakorn, 1982):

$$\mathrm{GSI} = \frac{\text{Weight of ovary}}{\text{Weight of body}} \times 100$$

The semi-control natural method was used to produce newly-hatched larvae in sexually mature male and female brooders at a 1:1 ratio that were cultured in concrete ponds in which soil was placed as the spawning ground and the water depth was kept at 30 cm. The spawners were fed every two days with fresh fish (1% of their BW). Fertilized eggs were routinely checked in the concrete ponds for daily spawning examination. The fertilized eggs were transferred to a fiberglass tank for hatching.

2.1 Yolk absorption

The time of yolk absorption and the size of the yolk-sacs were assessed using a profile projector. Ten newly-hatched larvae were randomly sampled every 2 h from the aquarium until the yolk sacs were fully absorbed. The specimens were fixed in 10% buffered formalin. Yolk volumes were calculated using the following formula (Fukuhara, 19 86):

$$Yolk\ volume = \frac{4}{3} \times \pi \times (\frac{R_1}{2})^2 \times \frac{R_2}{2}$$

where R1 = minor axis and R2 = major axis.

2.2 Mouth height

Samples of 20 newly hatched larvae were taken every 2 h from the aquarium to measure the size of mouth opening and upper jaw length using a profile projector after fixing in 10% buffered formalin. The mouth height was calculated as follows (Shirota, 1970):

$$\text{mouth height} = \text{upper jaw length} \times \sqrt{2}$$

2.3 Start of feeding

Larvae (n=500, aged 1.5 days) were fed with *Moina* sp. (207 μm width) at a density of 10 individuals/mL in a 15-liter aquaria containing 10 L of water. Twenty larvae were randomly sampled every 2 h, fixed in 10% buffered formalin, and dissected to observe the presence of *Moina* sp. in the digestive tract which signaled the start time of feeding (Pechmanee, Pongmaneerat, & Iizawa, 1986). This observation was conducted in triplicate.

2.4 Starvation

Newly-hatched larvae (300) were starved in a 15-liter aquaria of 10 L of water to monitor mortalities every 2 h until completion which was done in triplicate (Fukuhara, 1987).

2.5 Feed and feeding

Larvae (500, aged 2 days) were cultured in a 15-liter aquaria of 10 L of water and were fed in this scheme: those aged 3-15 days with *Moina* sp. at a density of 10 individuals/mL and those aged 12-15 days with *Moina* sp. and commercial pellet (40% crude protein) (in density 1:1) twice a day (Eda, Darwisito, Fujiwara, & Takita, 1993; Kungvankij, Pudadera, Tiro, & Potestas, 1986; Tarnchalanukit, Chuapoehuk, Suraniranat, & Na Nakorn, 1982). Twenty larvae were randomly and daily collected 1 h after feeding, fixed in 10% buffered formalin and their stomach contents were observed.

3. Results

The female *M. albus* (Figure 1) matured at a BW of 200-250 g and the maximum fecundity was 701 ova/fish with a GSI of 3.09% (Figure 2) in June and the minimum fecundity was 181 ova/fish) with a GSI of 0.57% in October. The eggs were non-adhesive demersal and rounded with an average diameter of 1,784 µm. The eggs were classified into seven groups based on size: 250-750 µm (12.25%), 751-1,250 µm (15.62%), 1,251-1,750 µm (14.76%), 1,751-2,250 µm (31. 50%), 2,251-2,750 µm (18.87%), 2,751-3,250 µm (6%), and 3,251-3,750 µm (1%) (Figure 3).

Newly-hatched larvae (mean±SD, n=10) were 1.76±0.06 cm in length with a mean (SD) yolk sac volume of 1,279.14±101.50 µm^3 (Figure 4). The yolk sacs were completely absorbed within 174 hAH (2.85±0.14 cm) at 28-30.5 °C (Figure 5). The mouths opened at about 108 hAH (2.50 ±0.17 cm) with a mean (SD) mouth size of 785.00±30.83 µm in width (Figure 6). The digestive tract was straight at 845.00 ±30.75 µm in total length with an anus opening at 116 hAH (2.65±0.10 cm) at 27.0-29.5 °C. The average number of *Moina* sp. in the digestive tract at the start of feeding was 0.83 individuals/larval. The larvae started to feed on *Moina* sp. at 8 h after mouth opening and at 58 h before yolk absorption. The starved larvae started to die at 240 h until 1,092 h (45.5 days) at 27.0-30.5 °C (Figure 7),.

Based on the feeding scheme, the numbers of *Moina* sp. consumed by the 5-, 6-, 7-, 8-, 9-, 10-, 11-, 12-, 13-, 14-, and 15-day-old larvae (2.81-3.30 cm in length) were 23.5, 29.9, 32.4, 40.7, 41.5, 52.1, 53.4, 49.8, 26.3, 14.6, and 6 .2 individuals/larva, respectively, at 27.0-30.5 °C. The larvae at age 12-15 days (average total length 3.2-3.30 cm) consumed both the *Moina* sp. and commercial pellet. Larvae aged more than 16 days old (average total length 3.20 mm) consumed exclusively the power feed.

Figure 1. Mature female of the swamp eel.

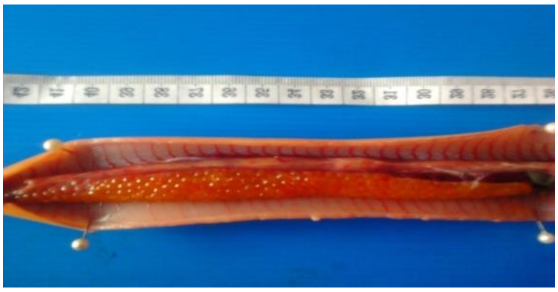

Figure 2. Ovary of the swamp eel.

Figure 3. Eggs of the swamp eel.

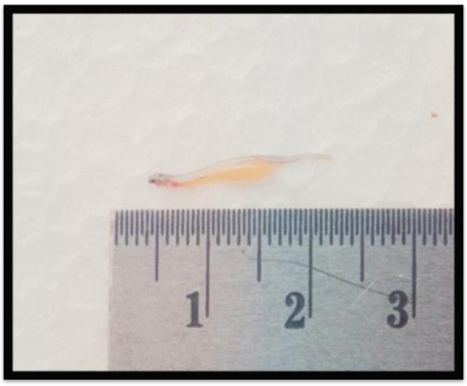

Figure 4. Newly hatched larva of the swamp eel.

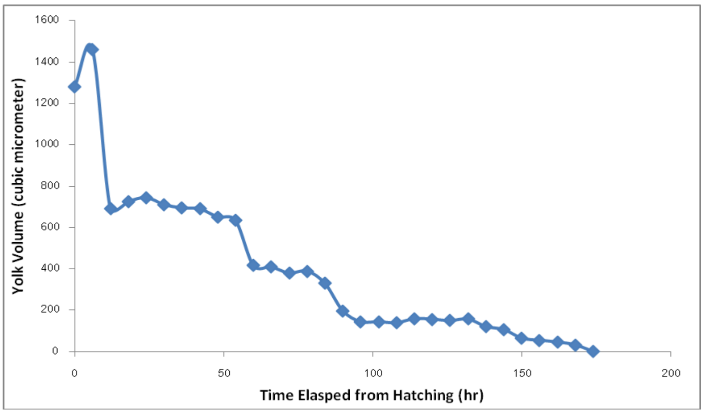

Figure 5. Total length (TL) and yolk absorption by the swamp eel larvae at the elapsed time after hatching. YV: Yolk volume

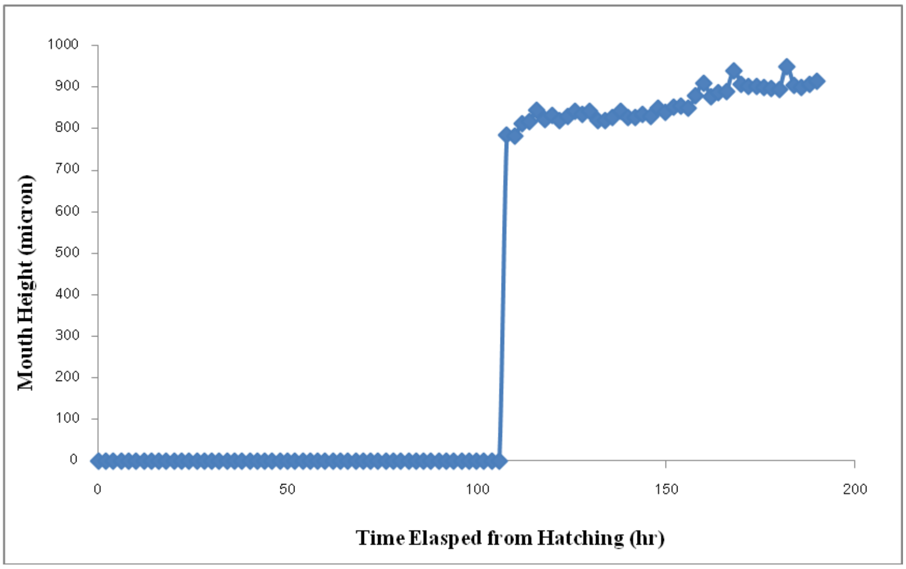

Figure 6. Total length (TL) and development of mouth opening of swamp eel larvae at elapsed time after hatching. MO: Mouth Opening

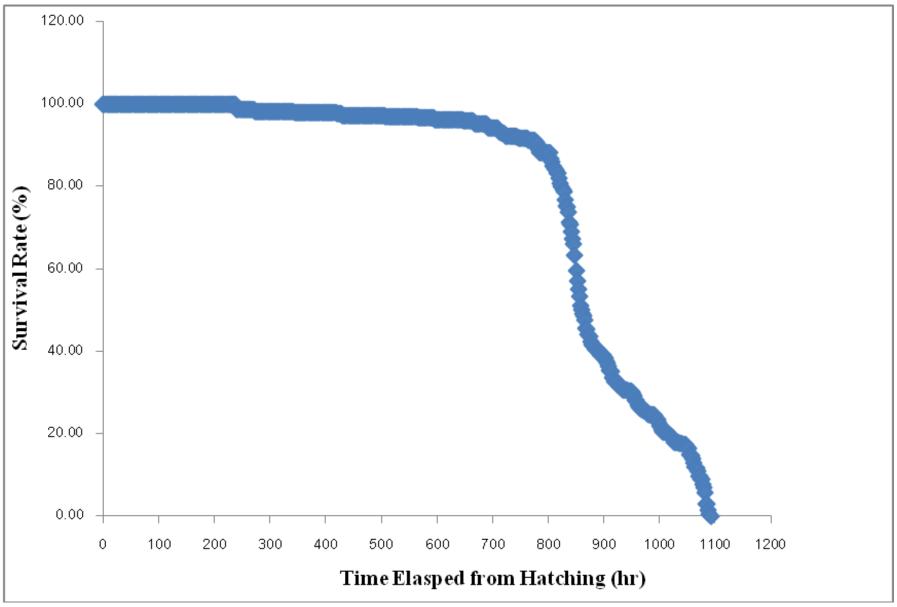

Figure 7. Survival of swamp eel after hatching without feeding at 27.0-30.5 °C

4. Discussion

The fecundity of *M. albus* (701 ova/fish) was comparatively less than *Channa striatus*, *Anabas testudineus*, and *Trichogaster pectoralis*. But the sexually mature female *M. albus* was 200-250 g. The sexually mature female *C. striatus* was reported to have a TL of 26.45 cm, BW of 167.4 g, and fecundity of 10,279 ova/fish (Amornsakun, Sriwatana, & Promkaew, 2011), whereas the TL, BW, and fecundity of the *A. testudineus* were 15.2 cm, 61 g, and 24,120 ova/fish, respectively (Amornsakun, Sriwatana, & Promkaew, 2004a) and the TL, BW, and fecundity of the *T. pectoralis* were 18.07 cm, 94.20 g, and 26,261 ova/fish, respectively (Amornsakun, Sriwatana, & Promkaew, 2004b). The fertilized eggs of *M. albus* (1,784 µm in diameter) were classified as large which were similar to *Mystus wyckioides* (2,278.80 µm) but 2-3 times larger than the fertilized eggs of the *C. striatus*, *A. testudineus*, and *T. pectoralis* (Amornsakun, 1999b; Amornsakun, Sriwatana, & Promkaew, 2004a; Amornsakun, Sriwatana, & Promkaew, 2004b; Amornsakun, Sriwatana, & Promkaew, 2011). The GSI of 3.09% in the mature female *M. albus* was lower than the normal range of 8-10% of *Clarias batrachus* (Tarnchalanukit, Chuapoehuk, Suraniranat, & Na Nakorn, 1982) but similar to *C. striatus* (5.07%) (Amornsakun, Sriwatana, & Promkaew, 2011), and 3.3 and 3.5 times less than *A. testudineus* and *T. pectoralis*, respectively (Amornsakun, Sriwatana, & Promkaew, 2004a; Amornsakun, Sriwatana, & Promkaew, 2004b).

The yolk absorption period for the newly-hatched larvae of *M. albus* was 7.25 days after hatching which was longer than *M. nemurus* (3 days) (Amornsakun, Chiayvareesajja, Hassan, Ambak, & Jee, 1997), *M. wyckioides* (4.3 days) (Amornsakun, 1999b), *Oxyeleotris marmoratus* (3.4 days) (Amornsakun, Sriwatana, & Chamnanwech, 2002), *A. testudineus* (3.8 days) (Amornsakun, Sriwatana, & Promkaew, 2004 a), *T. pectoralis* (4.5 days) (Amornsakun, Sriwatana, & Promkaew, 2004b), *C. striatus* (3.3 days) (Amornsakun, Sriwatana, & Promkaew, 2011), *Mugil curema* (3.5 days) (Houde, Berkeley, Klinovsky, & Schekter, 1976), *Chanos chanos* (2.5 days) (Chaudhuri, Juario, Primavera, Samson, & Mateo, 1978), and *Clarias* sp. (3-4 days) (Tarnchalanukit, Chuapoehuk, Suraniranat, & Na Nakorn, 1982).

The yolk sac volume at the time of the first feeding of *M. albus* was 12.21%, which was greater than *C. striatus* (6.42%) (Amornsakun, Sriwatana, & Promkaew, 2011), *O. marmoratus* (6.16%) (Amornsakun, Sriwatana, & Chamnanwech, 2002), similar with *M. wyckioides* (13.03%) (Amornsakun, 1999c), but less than *M. nemurus* (31.02%) (Amornsakun, Chiayvareesajja, Hassan, Ambak, & Jee, 1997), *T. pectoralis* (32.21%) (Amornsakun, Sriwatana, & Promkaew, 2004b), and *A. testudineus* (52.20%) (Amornsakun, Sriwatana, & Promkaew, 2004a; Kjorsvik, Meerent, Kryvi, Arnfinnson, & Kvenseth, 1991).

The size of the *Moina* sp. was 26.36% of the mouth opening of the *M. albus* larvae (785.00 µm) which was in the range of 20-40% for the mouth size in various fishes (Amornsakun, 1999c; Amornsakun, Chiayvareesajja, Hassan, Ambak, & Jee, 1997; Amornsakun, Sriwatana, & Chamnanwech, 2002; Amornsakun, Sriwatana, & Promkaew, 2004a; Amornsakun, Sriwatana, & Promkaew, 2004b; Hunter, 1980) but different from *C. striatus* (61.8%) (Amornsakun, Chiayvareesajja, Hassan, Ambak, & Jee, 1997; Amornsakun, 1999c; Amornsakun, Sriwatana, & Promkaew, 2011) *M. wyckioides* (45.26%), *M. nemurus* (40.65%), *O. marmoratus* (18.70%), *T. pectoralis* (19.85%), and *A. testudineus* (20.93%) (Amornsakun, Sriwatana, & Chamnanwech, 2002; Amornsakun, Sriwatana, & Promkaew, 2004a; Amornsakun, Sriwatana, & Promkaew, 2004b).

Moina sp. could be a good live food for *M. albus* larvae because of its suitable size and ease of culture. The number of *Moina* sp. in the digestive tract at the start of feeding was 0.83 individuals/larva, similar to those reported in *T. pectoralis*, *O. marmoratus*, and *C. striatus*, but less than reported in *A. testudineus*, *M. nemurus*, *M. wyckioides*, and *C. chanos*. Gut contents showed 0.57 rotifers/larva of *T. pectoralis* (Amornsakun, Sriwatana, & Promkaew, 2004b), 0.57 rotifers/larva of *O. marmoratus* (Amornsakun, Sriwatana, & Chamnanwech, 2002), 0.56 *Moina*/larva of *C. striatus* (Amornsakun, Sriwatana, & Promkaew, 2011), 1.5 rotifers/ larva of climbing perch (Amornsakun, Sriwatana, & Promkaew, 2004a), 1.8 individuals/larva of green catfish (Amornsakun, Chiayvareesajja, Hassan, Ambak, & Jee, 1997), 1.3 *Moina*/larva of *M. wyckioides* (Amornsakun, 1999c), and 1-4 rotifers/larva of *C. chanos* (Eda *et al.,* 1990).

The starved larvae of *M. albus* become debilitated and eventually died at 240 hAH which indicated less tolerance than *A. testudineus* (348 hours) at 27.0-30.5 ºC (Amornsakun, Sriwatana, & Promkaew, 2004a) and *C. striatus* (326 hours) at 28.0-30.5 ºC (Amornsakun, Sriwatana, & Promkaew, 2011). Larvae can tolerate a feeding delay up to a certain point depending on the amount of yolk, temperature, and other species-specific characteristics (May, 1974; Hunter, 1980; Holm, 1986); for example, 6 days for *Engraulis mordax* (Lasker, Feder, Theilacker, & May, 1970), 7 days for *Mugil cephalus* (Kuo, Shehadeh, & Milisen, 1973), 6 days for *C. chanos* (Chaudhuri, Juario, Primavera, Samson, & Mateo, 1978), 7 days for *Repomucenus* sp. (Eda, Darwisito, Fujiwara, & Takita, 1993), 5 days for *Lates calcarifer* (Hassan & Amornsakun, 1996), and 6 days for *T. pectoralis* (Amornsakun *et al.,* 2004b). Ishibashi (1974) observed that the yolk sac of unfed *Tilapia sparmanii* larvae was absorbed faster than the fed larvae.

Food supply during the larval stage is an important factor in achieving high survival and growth rates. Mass mortality of the larvae and juvenile fish will often occur if the food supply is inadequate (Houde, 1978). Different species require different sequential food during the early stages of life. Most freshwater fish are given rotifers or *Moina* sp. as the first feeding (Tarnchalanukit, Chuapoehuk, Suraniranat, & Na Nakorn, 1982; Tawaratmanikul, Viputanimat, Mewan, & Pokasap, 1988; Vatcharakornyothin, Viputhanumas, Tawaratmanikul, & Pokasap, 1988), and artificial feeds for juveniles are generally in the form of fine crumbs of the appropriate particle size. The larvae of *M. albus* are no exception.

The type of feed for the *M. albus* larvae, such as the *Moina* sp. and commercial pellet, is similar with other fishes but the time for feeding may be different. It was found that the *M. albus* larvae age 5-15 days (average total length 2.81-3.30 cm) consumed *Moina* sp. The larvae at 12-15 days of age (average total length 3.2-3.30 cm) consumed both *Moina* sp. and power feed. Larvae aged more than 16 days were able to feed completely on power feed. Watanabe, Kitajima, and Fujita (1983) described the food regimes used most extensively in the larvae of various fish productions in Japan. In newly hatched fish greater than 2.3 mm of body length, rotifers were exclusively given as an initial feed. When the fish reached 7 mm or more, marine copepods, such as *Tigriopus*, *Acartia*, *Oithona*, and *Paracalanus*, were given. Brine shrimp (*Artemia salina*) were commonly used for the larvae of many species during shortages of marine copepods. Larvae larger than 10 to 11 mm were fed minced fish, shellfish and shrimp or an artificial diet. Tsukashima and Kitajima (1981) reported the rearing of larvae and juvenile filefish (*Stephanolepis cirrhifer*) up to the stage of young fish. They were fed rotifers, *Tigriopus japonicus, Artemia*, and subsequently fish meat. Tarnchalanukit, Chuapoehuk, Suraniranat, and Na Nakorn (1982) reported that *C. batrachus* of age 2-15 days were fed on *Moina* sp. and fed with a commercial catfish pellet when they reached 10 days-old. Chawpaknam, Vorasayan, and Poungin (1990) reported that fry nursing of two-spot glass catfish, *Ompok bimaculatus*, age 3-15 days fed on *Moina* sp. showed better growth and higher survival rates than those fed with egg custard.

The *M. albus* larvae age 5-15 days (average total length 2.81-3.30 cm) consumed zooplankton such as *Moina* sp. At 16 days the larvae consumed only power feed. This age is regarded as the juvenile stage. The time for juvenile stage development was similar with the *M. nemurus* and *A. testudineus*, but it was earlier than *O. marmoratus* and *T. pectoralis*. As reported previously, the larval stages for *M. nemurus* and *A. testudineus* were reported at ages 2-10 and 3-15 days and fed on rotifers and *Moina* as the main diets, respectively. At 16 days old onward, both species developed in the juvenile stage and were able to feed on a commercial artificial diet (Amornsakun, Chiayvareesajja, Hassan, Ambak, & Jee, 1997; Amornsakun, Hassan, Ambak, & Chiayvareesajja, 1998; Amornsakun, Sriwatana, & Promkaew, 2004a). However, *O. marmoratus* have a longer larval period at about 2-27 days which was fed only on rotifers and *Artemia* before they reached the juvenile stage at 30-45 days old and then fed with either *Moina* sp. or ground fish (Amornsakun, Sriwatana, & Chamnanwech, 2003a; Amornsakun, Sriwatana, & Chamnanwech, 2003b). Despite *T. pectoralis* having a larval stage reported as 3-25 days old, the first diet for the *T. pectoralis* was rotifers at the early stage followed by *Moina* sp. Nevertheless, at the age of 25-30 days old *T. pectoralis* were able to feed on an artificial diet (Amornsakun, Sriwatana, & Promkaew, 2004b).

5. Conclusions

We concluded that the size at sexual maturity of the female *M. albus* was 200-250 g in BW. The eggs were non-adhesive demersal and rounded type. Fecundity was maximum (701 ova/fish) in June with a GSI of 3.09%. The average egg diameter was 1,784 µm. The newly hatched larvae were 1.76±0.06 cm in total length and had yolk sacs of 1,279. 14±101.50 μm^3 in volume. The yolk sacs were completely absorbed within 174 hours after hatching at a water temperature of 28.0-30.5 °C. All the larvae had open mouths at about 108 hours after hatching (2.50±0.17 mm), with a mouth size of 785.00±30.83 µm that opened at 116 hAH. The average number of *Moina* sp. in the digestive tract at the start of feeding was 0.83 individuals/larva. The food deficient larvae started to die at 240 h. The feeding scheme of the *M. albus* larvae was as follows: larvae at age 5-15 days (average total length 2.81-3.30 cm) consumed *Moina* sp., but at 12-15 days of age (average total length 3.2-3.30 cm) the larvae were able to feed on *Moina* sp. and the commercial pellet known as 'power feed'.

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