Songklanakarin J. Sci. Technol.
33 (6), 671-677, Nov. - Dec. 2011

SJST SONGKLANAKARIN JOURNAL OF SCIENCE AND TECHNOLOGY
http://www.sjst.psu.ac.th

Original Article

Some aspects in early life stage of snake head fish, *Channa striatus* larvae

Thumronk Amornsakun[1]*, Wasan Sriwatana[2] and Ponpanom Promkaew[2]

[1] *Fisheries Technology Program, Department of Technology and Industries, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus, Mueang, Pattani, 94000 Thailand.*

[2] *Pattani Inland Fisheries Research and Development Center, Yarang, Pattani, Thailand.*

Received 29 October 2010; Accepted 4 October 2011

Abstract

The sexual maturity of female snake head fish, *Channa striatus* was studied by determining fecundity and gonadosomatic index (GSI). It was found that the size at sexual maturity of female snake head fish was 26.45±3.07 cm (mean ± SD, n=10) in total length and 167.4±48.09 g in body weight. The eggs were floating and rounded. The fertilized eggs had a diameter of 588±20.43 μm. The fecundity was 10,279.1±2,527.9 ova/fish and gonadosomatic index (GSI) was 5.07±1.04 %.

Newly hatched larvae of snake head fish were produced by induced spawning using chemical injection (Suprefact and Motilium). The sexually mature fishes were cultured in a fiber-glass tank (water volume 300 liters) with the ratio of male and female brooders 1:1. The fertilization rate, hatching out and hatching rate experiments were carried out using 3 15-liter glass aquaria (water volume 10 liters) each containing 1,000 eggs. It was found that the average fertilization rate was 76.50%, hatching out occurred of 28 hr 40 min and average hatching rate was 60.26 % at a water temperature of 26.5-29.0°C. Sampling of the newly-hatched larvae was done at 2-hour intervals, when 20 of them were randomly taken and preserved in 10% buffered formalin for later determination of yolk absorption time. Observation using a microscope revealed that newly hatched larvae were 3.18±0.11 mm in total length and had yolk sacs of 1,279.71±196.10 μm^3 in volume. The yolk sacs were completely absorbed within 80 hr after hatching at a water temperature of 26.5-29.0°C. Up until full mouth development (start of feeding), 2-hourly samplings of twenty newly hatched larvae were taken from an aquarium for observation of the size of mouth opening. All the larvae had open mouths about 52 hr after hatching (5.48±0.16 mm TL), and measured 324.30±144.60 μm in mouth opening.

The feeding experiments were carried out using a 15-liter glass aquarium (water volume 10 liters) containing 1,000 larvae aged 1.5 days post-hatching (just before the mouth opened). They were fed with *Moina* at a density of 10 individual/ml. Twenty larvae were collected at random from the aquarium at 2-hourly intervals, preserved in 10 % buffered formalin, and then dissected to determine the presence of *Moina* in the digestive tract. The digestive tracts were fixed at 62 hr of hatching at water temperatures of 28.0-30.5°C, and measured 334.87±149.78 μm in mouth opening. The average number of *Moina* in the digestive tract at the start of feeding was 0.56 individual/larva.

Keywords: fecundity, yolk absorption, mouth development, start of feeding, larviculture, snake head fish, *Channa striatus*

1. Introduction

The snake head fish, *Channa srtriatus*, which is considered a first grade fish in Southeast Asia, is a commercially important species for inland fisheries. This fish has become one of the main species being cultured and is in great demand in the aquaculture industry. However commercial scale propagation of this fish in hatcheries is yet to be standardized. Information on the early life history of fish such as yolk absorption, mouth and digestive tract development and started of feeding of the larvae is needed for optimization of large-scale culture and ultimately for the management of the

* Corresponding author.
Email address: thumronk@bunga.pn.psu.ac.th

fish stocks. It is recognized that the critical period of larval rearing begins at the time yolk absorption is completed. If some larvae do not begin to eat during that period, then they become weak and eventually die (Kosutaruk and Watanabe, 1984; Holm, 1986; Eda *et al.*, 1994; Amornsakun and Hassan, 1996; Amornsakun *et al.*, 1997; Amornsakun, 1999b; Amornsakun *et al.*, 2002; Amornsakun *et al.*, 2004a; Amornsakun *et al.*, 2004b). Survival of fish larvae is determined by the interplay of various environmental factors, such as temperature, food supply with a suite of species-specific characteristics, egg and larval size, yolk and oil quantity and resorption rates, and time of onset of feeding and feeding behaviour. Larvae can use a varying part of their yolk sac energy content for various activities (Blaxter, 1974; May, 1974). Mouth size development is very important in the first feeding of larvae to match appropriate prey size. Mouth size at first feeding stage of various larval fish to encounter their prey size has been well documented for a number of cultured fish (Shirota, 1970; Nash *et al.*, 1974; Fukuhara, 1986; Doi and Singhagraiwan, 1993; Eda *et al.*, 1994).

Some studies of this species have been published. Spawning was induced using ovaprim, a synthetic hormone injection (Marimuthu and Haniffa, 2007). Arul (1991) reported the effect of temperature on the duration of embryonic development of this fish. Duration of 56, 48, 36 and 30 hr were found at 20, 24, 28, and 32°C, respectively. Qin and Fast (1997) reported first-feeding snake head fish larvae using *Artemia* nauplii.

The purpose of this study was to investigate fecundity, gonadosomatic index (GSI) of mature female fish, the period of yolk absorption, mouth development and the onset of first feeding. These might provide useful baseline information for optimization of large scale culture and ultimately for the culture management of this fish in future.

2. Materials and Methods

The experiments were carried out at the facilities of the Fisheries Technology Programme, Faculty of Science and Technology, Prince of Songkla University, Pattani campus, Thailand, from October 1, 2003 to September 30, 2004. The sexual maturity of female snake head fish was studied by determining fecundity and gonadosomatic index (GSI). Fecundity estimation was made using a gravimetric method (Tarnchalanukit *et al.*, 1982). Gonadosomatic index (GSI) was calculated by (weight of ovary/ weight of body) x 100 (Tarnchalanukit *et al.*, 1982). Newly hatched larvae of snake head fish were produced by natural method using chemical injection (Suprefact and Motilium) for induced spawning. The injection was done using Suprefact 20 μg/kg and Motilium 5 mg/kg. For male and female brooders, the injection was done once. The sexually mature fish were cultured in fiberglass tank (water volume 300 liters) with the ratio of male and female brooders 1:1.

The fertilization rate, hatching out and hatching rate experiments were carried out using 3 15-liter aquaria (water volume 10 liters) each containing 1,000 eggs, and observation of the amount of fertilized eggs at 5 hr after incubation. In each aquarium the fertilization rate was calculated by (number of fertilization eggs/number of eggs) x 100. The time required for the appearance of the first newly-hatched larvae, which would signal hatching out, was recorded. All newly-hatched larvae were collected using a dropper. The hatching rate was calculated by (number of newly-hatched/number of eggs) x 100 (Tarnchalanukit *et al.*, 1982). The procedure was carried out with three replications.

2.1 Yolk absorption experiment

The time of yolk absorption and the size of yolk-sacs were determined using a profile projector. Twenty newly-hatched larvae were taken at random at 2-hourly intervals from each rearing aquarium until the yolk sacs were fully absorbed. The specimens were fixed in 10% buffered formalin. Yolk volumes were calculated using the formula $4/3 \times \pi (R1/2)2 \times R2/2$ Where R1 = minor axis and R2 = major axis (Fukuhara, 1986).

2.2 Mouth development experiment

Up until full mouth development (start of feeding), samples of twenty newly hatched larvae were taken every 2 hours from the rearing aquarium for observation of the size of mouth opening, and measurement of upper jaw length was done using a profile projector. Specimens were fixed in 10% buffered formalin. The mouth height was calculated by multiplying the upper jaw length by $\sqrt{2}$ (Shirota, 1970).

2.3 Start of feeding experiment

The experiment was carried out using 15-liter aquaria (water volume 10 liters) containing 1,000 larvae aged 1.5 days post hatching (just before the mouth opened). They were fed with *Moina* (207 μm, width) at a density of 10 individual/ml. Twenty larvae were collected at random from each aquarium at 2-hourly intervals and preserved in 10% buffered formalin. They were then dissected to determine the presence of rotifer in the digestive tract which would signal the time of the start of feeding (Pechmanee *et al.*, 1986). The procedure was carried out with three replications.

3. Results

The size at sexual maturity of female snake head fish was 26.45±3.07 cm (mean ± SD, n=10) in total length and 167.4±48.09 g in body weight. The fecundity was 10,279.1± 2,527.90 ova/fish and gonadosomatic index (GSI) was 5.07± 1.04%. The eggs were floating and rounded. The fertilized eggs had a diameter of 588±20.43 μm. It was found that the fertilization rate in replicates 1, 2 and 3 were 80.9%, 79.6% and 69.1%, respectively. Thus the average fertilization rate was 76.5%. The hatching out in replicates 1, 2 and 3 were 28

hr 20 min, 29 hr 10 min and 28 hr 30 min, respectively. Thus average hatching out was 28 hr 40 min. The hatching rate in replicates 1, 2 and 3 were 60.9%, 59.9% and 60.0%, respectively. Thus average hatching rate was 60.26% at the water temperature of 26.5-29.0°C.

Newly hatched larvae were 3.18±0.11 mm in total length (mean ± SD, n = 20) with yolk sacs of 1,279.71±196.10 μm^3 in volume (mean ± SD, n = 20). The yolk sacs were completely absorbed within 80 hr (3.3 days) (Figure 1) after hatching at water temperatures of 26.5-29.0°C. All larval mouths were open 52 hr after hatching (5.48±0.16 mm TL) and measured 324.30±144.60 µm in mouth opening (Figure 2). At 62 hr after hatching, the fish started feeding on the *Moina* at which time the remaining yolk sac was 6.42% of its initial volume. The digestive tracts developed fully within 62 hr after hatching at water temperatures of 28.0-30.5°C and measured 334.87±149.78 µm in mouth opening, and contained numbers of *Moina*, indicating that feeding had commenced. Numbers of *Moina* in the digestive tract per larva in replicates 1, 2 and 3 were 0.6, 0.5 and 0.6 individual, respectively. Thus the average number of *Moina* in the digestive tract at the start of feeding was 0.56 individual/larva. The larvae started to feed on the *Moina* at 10 hr after mouth opening, and at 18 hr before yolk absorption (Figure 3).

4. Discussion

Snake head fish is one kind of freshwater fish which has medium fecundity. The size at sexual maturity of female fish was 26.45 cm in average total length and 167.4 g in average body weight. Fecundity was 10,279 ova/fish which is less than that of the climbing perch, *Anabas testudineus* and Siamese gourami, *Trichogaster pectoralis*. Amornsakun *et al.* (2004a) reported the sexual maturity occurred when female climbing perch were 15.2 cm in average total length and 61 g in average body weight, and fecundity was 24,120 ova/fish. Amornsakun *et al.* (2004b) reported that at sexual maturity of female Siamese gourami, *Trichogaster pectoralis*, in average total length was 18.07 cm, in average body weight was 94.20 g and the fecundity was 26,261 ova/fish. The fertilized eggs of the snake head fish (588 µm in a diameter) are smaller than the climbing perch (830 µm in a diameter), Siamese gourami (908.25 µm in a diameter) and red-tail catfish, *Mystus wyckioides* (2,278.80 µm in a diameter) (Amornsakun, 1999b; Amornsakun *et al.*, 2004a; Amornsakun *et al.*, 2004b). The female of snake head fish in this study was mature and gonadosomatic index (GSI) was found to be 5.07%, less than the other fishes. The gonadosomatic index (GSI) of mature freshwater fishes were reported as 8-10 % (Tarnchalanukit *et al.*, 1982). Amornsakun *et al.* (2004a) reported the gonadosomatic index of mature climbing perch is be 10.4%. Amornsakun *et al.* (2004b) reported the gonadosomatic index of mature Siamese gourami is be 10.9%.

The time of hatching out was 28 hr 40 min at the water temperature of 26.5-29.0°C. This is similar to the other fishes, which have hatching-times out about 18-28 hr such as green

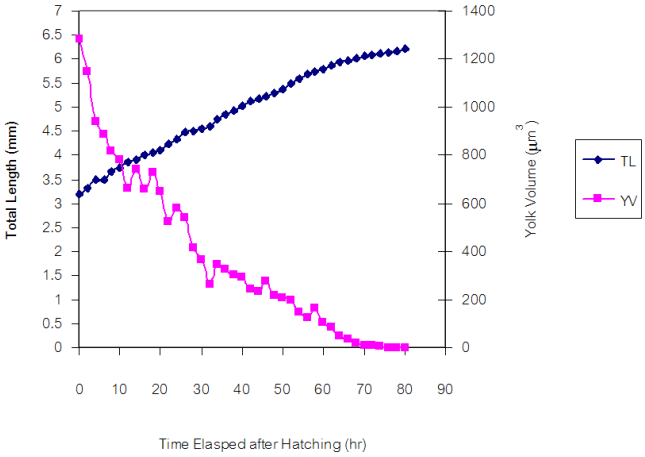

Figure 1. Total length (TL) and yolk absorption of larval snake head fish at elapsed time after hatching YV: Yolk volume

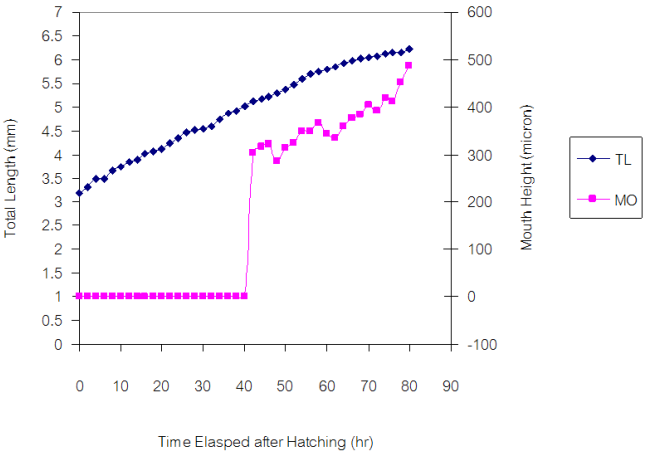

Figure 2. Total length (TL) and development of mouth opening of larval snake head fish at elapsed time after hatching
MO: Mouth Opening

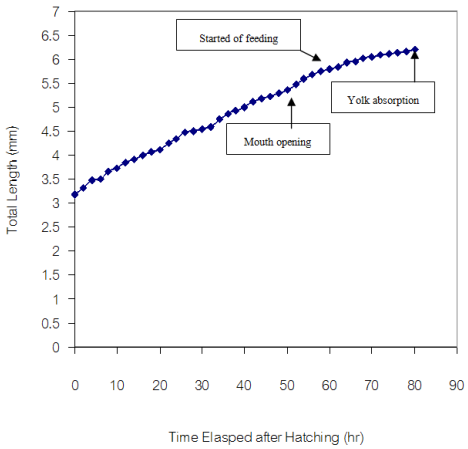

Figure 3. Length of snake head fish larvae at elasped time after hatching
: Mouth opening at 52 hr after hatching
: Started of feeding at 62 hr after hatching
: Yolk absorption at 80 hr after hatching

catfish, red-tail catfish, climbing perch and Siamese gourami with hatching-times out of 18 hr, 23 hr 40 min, 20 hr 30 min and 22 hr 10 min, respectively, at the water temperature 27.0-30.5°C (Amornsakun, 1999a; Amornsakun, 1999b; Amornsakun *et al.*, 2004a; Amornsakun *et al.*, 2004b; Tarnchalanukit *et al.*, 1982).

The yolk absorption period for newly-hatched larval snake head fish (3.3 days after hatching) was found to be similar to that of other fish, both marine and freshwater. Amornsakun *et al.* (1997) reported the yolk absorption of larval green catfish, *Mystus nemurus*, was complete at 3 days after hatching at water temperatures of 25-30°C. Amornsakun (1999c) reported the yolk absorption of larval red-tail catfish was complete at 4.3 days after hatching at water temperatures of 28.0-30.5°C. Amornsakun *et al.* (2002) reported the yolk absorption of larval sand goby, *Oxyeleotris marmoratus*, was complete at 3.4 days after hatching at water temperatures of 27.0-30.5°C. Amornsakun *et al.* (2004a) reported the yolk absorption of larval climbing perch was complete at 3.8 days after hatching at water temperatures of 27.0-30.5°C and at 4.5 days for larval Siamese gourami after hatching at water temperatures of 27.0-30.5°C (Amornsakun *et al.,* 2004b). Houde *et al.* (1976) also reported the yolk absorption of larval white mullet, *Mugil curema* Valenciennes, was complete at 3.5 days after hatching at water temperatures of 26-27°C. The yolk of larval milkfish, *Chanos chanos*, was completely absorbed in about 2.5 day-old larvae at water temperatures of 26.4-29.9°C (Chaudhuri *et al.*, 1978). The yolk absorption of larval freshwater catfish, *Clarias* sp., was completed 3-4 days after hatching (Tarnchalanukit *et al.*, 1982).

The larvae of rabbitfish, *Siganus guttatus*, have rapid development of the eye, mouth and alimentary tract during the yolk-sac stage which makes it possible for the larvae to feed before the yolk is completely absorbed (Bagarinao, 1986). Morphological investigations of the jaw and the digestive tract showed that larval cod, *Gadus morhua*, is able to absorb ingested food well before exhaustion of the yolk sac (Kjorsvik *et al.*, 1991). In this study, through microscopic observation, it was found that after 52 hr about 15.49% of yolk remained and the mouths (324.30±144.60 μm in mouth opening) of all larval snake head fish had already opened but were not yet functioning. The yolk sac remaining at the time first of feeding of snake head fish was similar to that of sand goby and red-tail catfish but less than that in green catfish, Siamese gourami and climbing perch. The result of the present study reveals that snake head fish larvae start to feed supplied *Moina* at 62 hr after hatching (334.87 μm, mouth opening) with their remaining yolk sacs at 6.42 % of the initial volume. Comparatively, Amornsakun *et al.* (2002) reported that the sand goby started feeding on rotifer at 80 hr after hatching when the yolk sac remained at 6.16% of its initial volume. Amornsakun (1999c) found that the red-tail catfish started feeding on *Moina* at 64 hr after hatching at which time the yolk sac remained at 13.03% of its initial volume. The green catfish started feeding on *Moina* at 52 hr after hatching when the yolk sac remained at 31.20% of its initial volume (Amornsakun *et al.*,1997). The Siamese gourami catfish started feeding on rotifer at 72 hr after hatching when the yolk sac remained at 32.21% of its initial volume (Amornsakun *et al.*, 2004b) and at 32 hr after hatching for larval climbing perch when the yolk sac remained at 52.20% of its initial volume (Amornsakun *et al.*, 2004a). The growth of larval grey mullet, *Mugil cephalus*, increased on the first day, which coincided with rapid yolk absorption (Kuo *et al.*, 1973). Reduction of growth and poor swimming activity of unfed fish larvae after complete yolk absorption led to a critical point for larval survival in association with yolk absorption of the black sea bream (Fukuhara, 1987). The period of time from hatching to first feeding depends upon the nutrients stored in the yolk sac (Hodson and Blunt, 1986 and Ware, 1975) and environmental factors (Houde, 1974). Ishibashi (1974) reported the first feeding of larval *Tilapia sparmanii* started later as the water temperature decreased, i.e. they took food on day 2 at 30°C, on day 3 at 27°C and on day 6 at 24°C.

The size of the first live food, *Moina* (207 mm width), was 61.8% of mouth opening (334.87 μm MO) of the larval snake head fish in this study (5.85±0.15 mm TL). It is more than that in the range 20-40% of the mouth size in various fishes as reported by Ito and Suzuki (1977), Hunter (1980), Amornsakun *et al.* (1997), Amornsakun (1999c), Amornsakun *et al.* (2002), Amornsakun *et al.* (2004a) and Amornsakun *et al.* (2004b). Larval snake head fish is considered to be a fish species easy to rear in early life stages since certain food organisms with appropriate size to larval mouth (61.8% of mouth opening). Qin and Fast (1997) reported first-feeding snake head fish larvae of 6-7 mm total length (TL) with a mouth opening of 0.55 mm selected for *Artemia* nauplii.

The mouth opening at the start of feeding (334.87 μm) of larval snake head fish is similar to that of green catfish, red-tail catfish, sand goby, Siamese gourami and climbing perch, and the time of its first feeding is close to time of green catfish, red-tail catfish, sand goby and Siamese gourami but later than that time of climbing perch. Green catfish started to feed on *Moina* when the mouth opening was 553 μm (40.65% of mouth opening) at 52 hr after hatching. Red-tail catfish started to feed on *Moina* when the mouth opening was 534 μm (45.26% of mouth opening) at 64 hr after hatching. Sand goby started to feed on rotifer when the mouth opening was 549 μm (18.70% of mouth opening) at 80 hr after hatching. Siamese gourami started to feed on rotifer when the mouth opening was 503 μm (19.85% of mouth opening) at 72 hr after hatching and started to feed on rotifer when the mouth opening was 477.63 μm (20.93% of mouth opening) at 32 hr after hatching for larval climbing perch (Amornsakun *et al.*, 1997; Amornsakun, 1999c, Amornsakun *et al.*, 2002; Amornsakun *et al.*, 2004a; Amornsakun *et al.*, 2004b). On the contrary, the mouth opening at first feeding of larval snake head fish is greater than that of rabbitfish and grouper. Juario *et al.* (1985) reported that the mouth of the larval rabbitfish, *Siganus guttatus* (Bloch), was about 125 μm wide when feeding on rotifers started 2 days after hatch-

ing. Maneewong *et al.* (1986) reported the mouth size of the larval grouper, *Epinephelus malabaricus* (Bloch and Schneider), was 169.7±16.1 μm when it was first able to consume rotifers with size of 91-100 mm width. Mouth size appears to be the limiting factor in juvenile fish feeding on both natural and pellet diets (Hyatt, 1979). Nash *et al.* (1974) reported the mouth of larval grey mullet was open when the jaws were becoming ossified and eye pigment was sufficiently developed. Larvae with small mouths grew more slowly than those with larger ones (Shirota, 1970; Arumugum and Geddes, 1987). The mouth opening of the larval snake head fish was related to total length. The same relationship between mouth opening and total length was also found in larval perch, *Perca fluviatilis* (Guma, 1978).

Moina could be a good live food for larval snake head fish because of its suitable size and ease of culture. The number of *Moina* in the digestive tract at the start of feeding was 0.56 individual /larva. This is similar to those reported in Siamese gourami and sand goby, but it is less than reported in climbing perch, green catfish, red-tail catfish and milk fish. Amornsakun *et al.* (2004b) reported that the gut of Siamese gourami was first found to contain rotifer 72 hr after hatching with the number of rotifer of 0.57 individual /larva. The gut of sand goby larvae was first found to contain rotifer 80 hr after hatching with the number of rotifer of 0.57 individual /larva (Amornsakun *et al.,* 2002). Amornsakun *et al.* (2004a) reported that the gut of climbing perch larvae was first found to contain rotifer 32 hr after hatching. The number of rotifers in the climbing perch gut was 1.5 individual /larva. Amornsakun *et al.* (1997) reported that the gut of green catfish larvae was first found to contain *Moina* 52 hr after hatching. The number of *Moina* in the green catfish gut was 1.8 individual/larva. Amornsakun(1999c) reported that the gut of red-tail catfish larvae was first found to contain *Moina* 64 hr after hatching. The number of *Moina* in the red-tail catfish gut was 1.3 ind/larva. And the gut of milkfish larvae (3.57-3.81 mm, TL) was first found to contain rotifers 80 hr after hatching. The number of rotifers in the milkfish gut ranged from 1-4 individual /larva (Eda *et al.*, 1990).

It was concluded that the size at sexual maturity of female snake head fish was 26.45±3.07 cm (mean ± SD, n=10) in total length and 167.4±48.09 g in body weight. The eggs were floating and rounded. The fertilized eggs had a diameter of 588±20.43 μm. The fecundity was 10,279.1±2,527.9 ova/fish and gonadosomatic index (GSI) was 5.07±1.04%. The total length of newly hatched larvae of snake head fish was 3.18±0.11 mm and had yolk sacs of 1,279.71±196.10 μm^3 in volume. The yolk sacs were completely absorbed within 80 hr after hatching. All the larvae had open mouths about 52 hr after hatching (5.48±0.16 mm TL), and measured 324.30± 144.60 μm in mouth opening. At 62 hr after hatching (334.87± 149.78 μm in mouth opening), the fish started feeding on *Moina* with the average number of 0.56 individual/larva at water temperatures of 28.0-30.5°C.

Acknowledgements

I am grateful to the National Research Council of Thailand (TEC 47020) for financial support of the field work. I also thank Mr Puriput Yongstar, Miss Piyakorn Songkun and Miss Suchaya Sirivareekun for assistance in research.

References

Amornsakun, T. 1999a. Feeding Biology in Early Life Stages of Green Catfish, *Mystus nemurus* (Cuv. & Val.). Ph.D. Thesis, Faculty of Applied Science and Technology, University Putra Malaysia Terengganu. 199 pp.

Amornsakun, T. 1999b. Preliminary propagation and larval rearing of red-tail catfish, *Mystus wyckioides*. Research report, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus. 46 p. (in Thai with English abstract)

Amornsakun, T. 1999c. Some aspects in early life stages of larval red-tail catfish, *Mystus wyckioides*. Songklanakarin Journal of Science and Technology. 21(4), 401-406.

Amornsakun, T. and Hassan, A. 1996. Aspect in early life stage of larval red snapper, *Lutjanus argentimaculatus* (Forskal). Songklanakarin Journal of Science and Technology. 18(1), 9-15.

Amornsakun, T., Sriwatana, W. and Chamnanwech, U. 2002. Some aspects in early life stage of sand goby, *Oxyeleotris marmoratus*. Songklanakarin Journal of Science and Technology. 24(4), 611-619.

Amornsakun, T., Sriwatana, W. and Promkaew, P. 2004a. Biological Breeding and Rearing of Climbing Perch, Anabas testudineus Larvae. Research report, Faculty of Science and Technology, Prince of Songkla University, Pattani Campus. 96 p. (in Thai with English abstract)

Amornsakun, T., Sriwatana, W. and Promkaew, P. 2004b. Some aspects in early life stage of Siamese gourami, *Trichogaster pectoralis* (Regan) larvae. Songklanakarin Journal of Science and Technology. 26(3), 347-356.

Amornsakun, T., Chiayvareesajja, S., Hassan, A., Ambak, A. and Jee, A. K. 1997. Yolk absorption and start of feeding of larval green catfish, *Mystus nemurus* (Cuv. & Val.). Songklanakarin Journal of Science and Technology. 19(1), 117-122.

Arul, V. 1991. Effect of temperature on yolk utilization of *Channa striatus*. Journal of Thermal Biology. 16(1), 1-5.

Arumugum, P. T. and Geddes, M. C. 1987. Feeding and growth of golden perch larvae and fry, *Macquaria ambigua* Richardson. Transactions of The Royal Society of South Australia. 111(1), 59-65.

Bagarinao, T. 1986. Yolk resorption, onset of feeding and survival potential of larvae of three tropical marine

fish species reared in the hatchery. Marine Biology. 91, 449-459.

Blaxter, J. H. S(ed). 1974. The Early Life History of Fish. New York: Springer-Verlag. 765 pp.

Chaudhuri, H., Juario, J. V., Primavera, J. H., Samson, R. and Mateo, R. 1978. Observations on artificial fertilization of eggs and the embryonic and larval development of milkfish, *Chanos chanos* (Forskal). Aquaculture. 13, 95-113.

Doi, M. and Singhagraiwan, T. 1993. Biology and culture of the red snapper, *Lutjanus argentimaculatus*. Thailand: The research project of fisheries resource development in the Kingdom of Thailand, Department of Fisheries. 51 pp.

Eda, H., Fujiwara, T. and Takita, T. 1994. Embryonic, larval and juvenile development in laboratory-reared dragonets, *Repomucenus beniteguri*. Japanese Journal of Ichthyology. 40(4), 465-473.

Eda, H., Darwisito, S., Fujiwara, T. and Takita, T. 1993. Rearing of larval and juvenile dragonets, *Repomucenus* spp. Suisanzoshoku. 41(4), 553-558.

Eda, H., Murashige, R., Eastham, B., Wallace, L., Bass, P., Tamaru, C. S. and Lee, C. S. 1990. Survival and growth of milkfish, *Chanos chanos* larvae in the hatchery. I. feeding. Aquaculture. 89, 233-244.

Fukuhara, O. 1986. Morphological and functional development of Japanese flounder in early life stage. Bulletin of the Japanese Society of Scientific Fisheries. 52(1), 81-91.

Fukuhara, O. 1987. Larval development and behavior in early life stages of black sea bream reared in the laboratory. Nippon Suisan Gakkaishi. 53(3), 371-379.

Guma, S. A. 1978. The food and feeding habits of young perch, *Perca fluviatilis*, in Windermere. Freshwater Biology. 8, 177-187.

Hassan, A. and Amornsakun, T. 1996. The influences of initial delay of feeding on survival and growth of the seabass, *Lates calcarifer*. In the 1996 Annual Meeting of the World Aquaculture Society (January 29 - February 2, 1996), Queen Sirikit National Convention Center, Bangkok, Thailand, p. 17.

Hodson, P. V. and Blunt, B. R. 1986. The effect of time from hatch on the yolk conversion efficiency of rainbow trout, *Salmo gairdneri*. Journal of Fish Biology. 29, 37-46.

Holm, J. C. 1986. Yolk sac absorption and early food selection in Atlantic salmon feeding on live prey. Aquaculture. 54, 173-183.

Houde, E. D. 1974. Effects of temperature and delayed feeding on growth and survival of larvae of three species of subtropical marine fishes. Marine Biology. 26, 271-285.

Houde, E. D., Berkeley, S. A., Klinovsky, J. J. and Schekter, R. C. 1976. Culture of larvae the white mullet, *Mugil curema* Valenciennes. Aquaculture. 8, 365-370.

Hunter, J. R. 1980. The feeding and ecology of marine fish larvae. In Bardach, J. E., Magnuson, J. J., May, R. C. and Reinhart, J. M. (Editors) Fish Behaviour and Its Use in Capture and Culture of Fishes. ICLARM Conf. Proc., Manila, Philippine, pp. 287-330.

Hyatt, K. D. 1979. Feeding strategy. In Hoar, W. S., Randall, D. J. and Brett, J. R. (eds) Fish Physiology, Vol. VIII. London: Academic Press. pp. 71-119.

Ishibashi, N. 1974. Feeding, starvation and weight changes of early fish larvae. In Blaxter, J. H. S. (ed) The Early Life History of Fish. New York: Springer-Verlag. pp. 339-344.

Ito, T. and Suzuki, R. 1977. Feeding habits of a cyprinid loach in the early stages. Bullatin Freshwater Research Laboratory. 27, 85-94.

Juario, J. V., Duray, M. N., Nacario, J. F. and Almendras, J. M. E. 1985. Breeding and larvae rearing of the rabbitfish, *Siganus guttatus* (Bloch). Aquaculture. 44, 91-101.

Kjorsvik, E., Meerent, T., Kryvi, H., Arnfinnson, J. and Kvenseth, P. G. 1991. Early development of the digestive tract of cod larvae, *Gadus morhua* L., during start-feeding and starvation. Journal of Fish Biology. 38, 1-15.

Kosutaruk, P. and Watanabe, T. 1984. Growth and survival of newly hatched larvae of seabass, *Lates calcarifer* in starved condition. Report of Thailand and Japan Joint Coastal Aquaculture Research Project (April 1981-March 1984) No.1, September 1984. Thailand: National Institute of Coastal Aquaculture. pp. 81-82.

Kuo, C. M., Shehadeh, Z. H. and Milisen, K. K. 1973. A preliminary report on the development, growth and survival of laboratory reared larvae of the grey mullet, *Mugil cephalus* L. Journal of Fish Biology. 5, 459-470.

Lasker, R., Feder., H. M., Theilacker, C. H. and May, R. C. 1970. Feeding, growth and survival of *Engraulis mordax* larvae reared in the laboratory. Marine Biology. 5, 345-353.

Maneewong, S., Akkayanont, P., Pongmaneerat, J. and Iizawa, M. 1986. Larval rearing and development of grouper, *Epinephelus malabaricus* (Bloch and Schneider). Report of Thailand and Japan Join Coastal Aquaculture Research Project (April 1984-January 1986) No. 2, April 1986. Thailand: National Institute of Coastal Aquaculture, pp. 39-52.

Marimuthu, K. and Haniffa, M.A. 2007. Embryonic and larval development of the striped snakehead, *Channa striatus*. Taiwania. 52(1), 84-92.

May, R. C. 1974. Larval mortality in marine fishes and the critical period concept. In Blaxter, J. H. S. (ed.) The Early Life History of Fish. New York: Springer-Verlag, pp. 3-19.

Nash, C. E., Kuo, C. M. and McConnel, S. C. 1974. Operational procedures for rearing larvae of the grey mullet, *Mugil cephalus* Linnaeus. Aquaculture. 3, 15-24.

Pechmanee, T., Pongmaneerat, J. and Iizawa, M. 1986. Effect of food density on food comsumption for larval seabass, *Lates calcarifer*. In Report of Thailand and Japan Join Coastal Aquaculture Research Project (April 1984 - January 1986) No. 2, April 1986. Thailand: National Institute of Coastal Aquaculture, pp. 1-11.

Qin, J. and Fast, A.W. 1997. Food selection and growth of young snake head fish, *Channa striatus*. Journal of Applied Ichthyology. 13, 21-25.

Shirota, A. 1970. Studies on the mouth size of fish larvae. Bulletin of the Japanese Society of Scientific Fisheries. 36(4), 353-368. (in Japanese with English abstract)

Tarnchalanukit, W., Chuapoehuk, W., Suraniranat, P. and Na Nakorn, U. 1982. Pla Duk Dan Culture. Thailand: Faculty of Fisheries, Kasetsart University. 58 pp. (in Thai)

Ware, D. M. 1975. Relation between egg size, growth and natural mortality of larval fish. Journal of the Fisheries Research Board of Canada. 32, 2503-2512.