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Spawning, Eggs and Larvae of the Hawkfish, *Cirrhitichthys aureus*, in an Aquarium

Yoichi Tanaka and Katsumi Suzuki

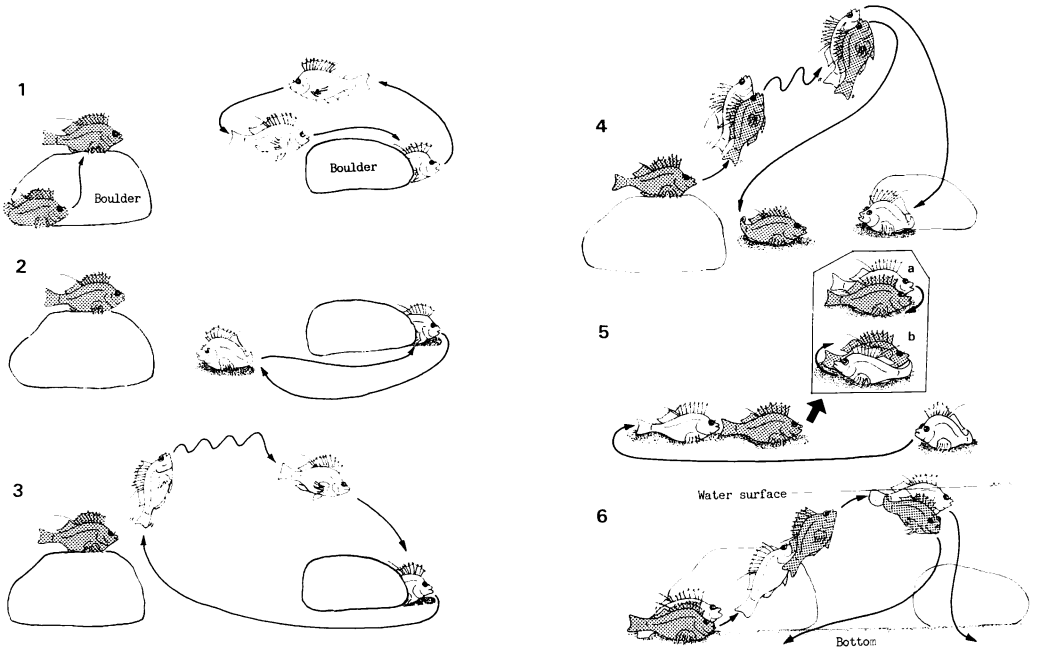
Institute of Oceanic Research and Development, Tokai University, 3-20-1 Orido, Shimizu 424, Japan

Abstract Spawning of the hawkfish, *Cirrhitichthys aureus*, occurred repeatedly between a female and a male in the aquariums of the Marine Science Museum, Tokai University. The pair was collected from Suruga Bay by scuba diving and maintained for 50 days prior to spawning. In early September, 1979, the first successful spawning took place at 17:40 h after several repetitions of a courtship behavior sequence, which was initiated by the male. Spawning continued daily for 104 days between the two fish. Fertilized eggs were spherical, transparent and pelagic, and measured 0.75–0.78 mm in diameter. Hatching took place 19–22.5 hours after fertilization at 26.2–28.4℃. Newly hatched larvae, measuring 2.23–2.28 mm in total length, had a rather slender body with 12+18=30 myotomes and a large ellipsoid yolk sac. The front tip of the yolk sac protruded forward beyond the snout of the larvae. A single oil globule was situated in the front part of the yolk sac. The larvae were maintained for 4 days after fertilization. Larval characteristics of *C. aureus* bore a close resemblance to those of other cirrhitid species especially in melanophore pigmentation along the dorsal and ventral surfaces.

Hawkfishes belonging to the family Cirrhitidae are a minor group of rather small benthic fishes with a wide geographical distribution along the coasts of the tropical Indo-West Pacific, the tropical Atlantic and the eastern Pacific (Randall, 1963; Springer, 1982; Donaldson, 1986a). They are inhabitants of coral and rocky reefs in tropical and warm-temperate waters. They are easily found by scuba divers because of their conspicuous colors and behavior around coral heads or rocky outcrops. *Cirrhitichthys aureus* (Temminck et Schlegel) is one of the northernmost occurring species, ranging from the western Indian Ocean to Sagami and Suruga Bays of central Japan (about 35.0°N). Although reproductive behavior of other hawkfishes has been recently described by Donaldson (1986 b, 1987, 1990) and Donaldson and Colin (1989) based on field observations, nothing has been reported on the reproductive behavior of *C. aureus*. Furthermore, little is known about the early life history of this family (Fourmanoir, 1971, 1973; Leis and Rennis, 1983; Thresher, 1984). This paper describes with the spawning, development of fertilized eggs and early larval stages of *C. aureus* observed in captivity at the Marine Science Museum, Tokai University.

Materials and methods

Two adult fish (a female 99.5 mm and a male 105.0 mm in total length) were individually collected by scuba diving with a small encircling net from a rocky area at depths of 10–20 m along the coast of Uchiura in Suruga Bay. Prior to the first spawning, the two fish were maintained for 50 days with 50 *Dascyllus trimaculatus* (Rüppell) in a cylindrical acrylic resin aquarium tank (60 cm in diameter, 53 cm in depth, 150 *l* in capacity). When a marked swelling of the female's abdomen was observed, the pair were moved into another aquarium (100×30×50 cm) for detailed study. After an initial spawning, however, no further spawnings occurred, and it was thought that the aquarium was too narrow for successful courtship. The pair was then moved into a 100×130×70 cm space partitioned by a plastic net in a larger aquarium (200×130×70 cm). This aquarium was set in a semitransparent acrylic resin house under natural light conditions. The two adult fish were fed cut or chopped horse mackerel, pennaeid prawns, and clams once a day. Water temperature was kept at about 25℃. Fertilized eggs were removed into a receptacle of 30 *l* capacity. Eggs and hatched larvae were then maintained in still water



Figs. 1–6. Diagrammatic view of courtship and spawning behavior of *Cirrhitichthys aureus* in the aquarium. 1: Two hours prior to spawning, the male (white fish) and the female (dotted fish) come out from behind of respective boulders. The male begins to swim actively, while the female rests on another boulder. 2: Forty or fifty minutes prior to spawning, the male stays in front of the female and looks at her. 3: The male approaches in front of the female and pauses with a "standing stroke" showing his back and waving the caudal fin. 4: The two fish swim together upwards in a mutual pause of "standing stroke". 5: The male and the female draw close to each other and stay head to tail in the opposite position (a). They alternate their positions, one with the another and repeated the activity (b). 6: The two fish ascend rapidly and release gametes just below the surface of the water.

with weak aeration in this receptacle, and in a plastic tank of 500*l* in capacity. The water was changed once or twice a day, and water temperature was also kept at about 25℃ for the rearing of eggs and larvae. Larvae were fed the rotifer, *Brachionus plicatilis*, once a day.

Results

Spawning behavior. Spawning of *C. aureus* was first observed on 9 September, 1979, i.e., about two months after the pair was collected. The second spawning was observed on 10 October, one month after the first spawning. Subsequently the pair continued to produce gametes almost every day between 17 : 40 and 19 : 04 h, i.e., about one hour after sunset. About 340–1,800 eggs were spawned each day. About six hours before spawning, the abdomen of the female began to expand obviously. Sex was easily distinguished by body shape during this time period, but they could not be sexed by their appearance prior to or after the spawning season, although Donaldson (1990) reported sexual dimorphism in ten other cirrhitid species.

Daily courtship and spawning behavior of *C. aureus* in captivity is summarized as follows:

1) About two hours prior to spawning, the male, who had stayed still and hidden close to a boulder, came out from behind the boulder and began to swim actively, while the female came out from behind another boulder and rested on top of it in a conspicuous posture (Fig. 1).

2) Forty or fifty minutes prior to spawning, the male swam 2–7 cm above the bottom with an extension of his dorsal fin. The male then approached the female, sat in front of her on the bottom and looked at her. Several seconds after this motion, the male returned to his previous site; the female did not

show a clear reaction to this courtship by the male, which was repeated over ten times (Fig. 2).

3) The male again approached the female and flashed his body in front of her. Then he swam upwards slowly for a short distance, and paused with a "standing stroke", showing his back to the female and waving his caudal fin. This pause seemed similar to the "tail stand" in *Oxycirrhites typus* described by Donaldson (1990). Finally, the male left the female and returned to his previous site, still keeping up the standing stroke (Fig. 3).

4) The female suddenly ascended with the male, and the two fish swam together 10–20 cm upwards and remained side by side with the standing stroke. Then the pair parted and returned to the substratum, but not to their previous sites (Fig. 4).

5) Ten to fifteen minutes prior to spawning, the male approached the female from behind and the two fish drew close to and paralleled with each other for several minutes (Fig. 5a). Then the male circled in front of the female and paused on her opposite side, in a head to tail position. The male slowly waved his tail, which was close to the female's head (Fig. 5b), before returned to her former side. The female did not move.

6) The pair of fish ascended obliquely and rapidly, and just after nearing the surface of the water, they brushed each other's belly and released gametes simultaneously. After the gametes were released, the pair separately and quickly returned to their initial sites below the boulder (Fig. 6).

Fertilized eggs. Fertilized eggs of *C. aureus* were buoyant, transparent, spherical, colorless, and non-adhesive with a narrow perivitelline space. They measured 0.75–0.78 mm in diameter and contained a single oil globule (about 0.11 mm in diameter). No special structures or appendages were seen on the surface of the egg membrane or yolk sac.

Development of egg (Table 1). Thirty minutes after fertilization, the two-cell stage formed (Fig. 7A). Cleavage occurred at intervals of 10–20 minutes. Two hours after fertilization, at the morula stage, a few granular processes appeared on the surface of the yolk. At 4 hours 15 minutes, the gastrula stage was reached. At 7 hours, the blastoderm covered half of the surface of the yolk and the embryonal body was formed (Fig. 7B). At 8 hours and 30 minutes, the optic vesicles and Kupffer's vesicle were seen, and 3–4 myotomes were counted (Fig. 7C). At 9 hours and 20 minutes, the blastopore was closed, the oil globule was fixed on the opposite side from the embryonal body, and 7 myotomes were seen. At 11 hours, at the 12 myotome stage, several punctate melanophores appeared, aligned along the dorsal axis from head to tail of the embryonal body, and a small part of the oil globule protruded from the surface of the yolk sac. At 12 hours, at the 16 myotome stage, markedly branched melanophores appeared on the surface of the oil globule. At 14 hours and 15 minutes, at the 20 myotome stage, the auditory vesicles and a lens in each of the optic vesicles were formed. Developing branched melano-

Table 1. Developmental process in embryonal stage of *Cirrhitichthys aureus*. *at water temperatures of 26.2–28.4℃.

Stage	Time after spawning*		Code in Fig. 7
2-cell stage		30 min	A
4-cell stage		50	
8-cell stage	1 h	10	
Morula stage	2	00	
Gastrula stage	4	15	
Formation of embryo (blastoderm covers half of the yolk)	7	00	B
3-4-myotome stage; appearance of Kupffer's and optic vesicles	8	30	C
7-myotome stage; closing of blastopore	9	20	
12-myotome stage; appearance of punctate melanophore at the dorsal embryonal body	11	00	
16-myotome stage; appearance of branched melanophore on the surface of the oil globule	12	00	
20-myotome stage; formation of auditory vesicles and lens; developing branched melanophores over ten at the dorsal embryonal body	14	15	D
30-myotome stage; larval tail parted from the surface of the yolk	18	15	E
First hatching	19	00	

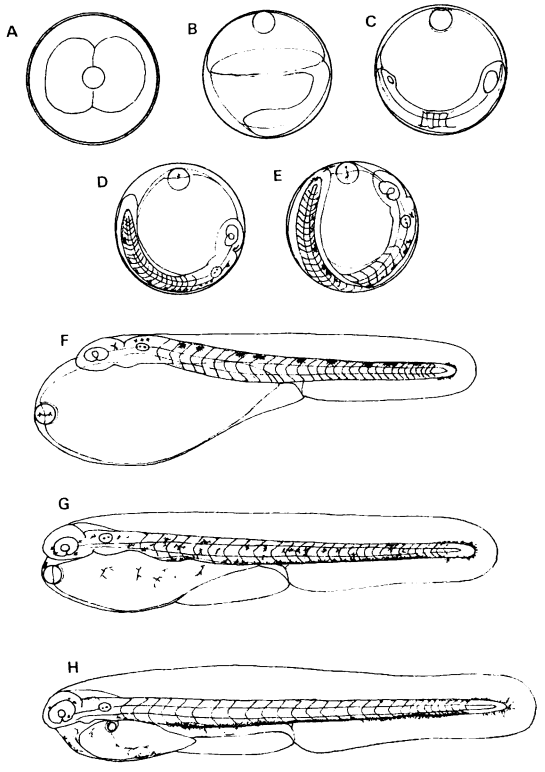


Fig. 7. Developing eggs and larvae of *Cirrhitichthys aureus*. A, 2-cell stage, 30 min after fertilization; B, formation of embryonal body, 7 h; C, 4-myotome stage, 8 h 30 min; D, 20-myotome stage, 14 h 15 min; E, 30-myotome stage, immediately before hatching, 18 h 15 min; F, newly hatched larva, 2.28 mm in total length; G, early larva, 6 h after hatching, 2.38 mm; H, early larva, 12 h, 2.80 mm.

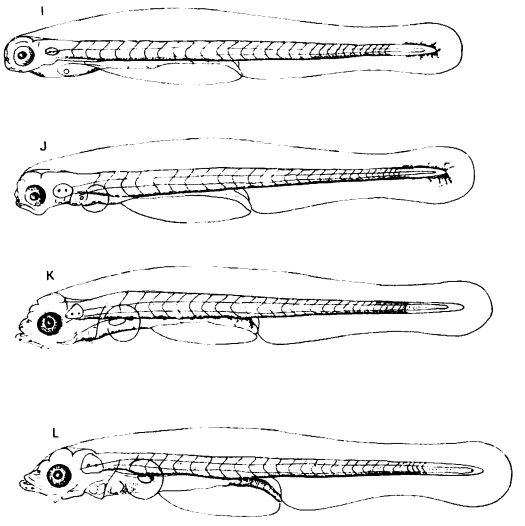


Fig. 8. Early and post-larvae of *Cirrhitichthys aureus*. I, early larva, 24 h after hatching, 2.91 mm in total length; J, early larva, 2 days, 2.93 mm; K, post-larva, 3 days, 2.93 mm; L, post-larva, 4 days, 3.17 mm.

phores numbered over ten at the dorsal embryonal body, and about half of the oil globule protruded from the surface of the yolk (Fig. 7D). At 18 hours and 15 minutes, at the 30 myotome stage, the larval tail clearly parted from the surface of the yolk, and branched melanophores spread over the dorsal embryonal body (Fig. 7E). At 19 hours, hatching began to take place and almost all of the larvae hatched out within 3 hours 30 minutes after the first hatching.

Early larval stages. The newly hatched larvae measured 2.23–2.28 mm in total length, and had an ellipsoid yolk sac (1.20–1.23 mm in largest diameter, 0.28–0.33 mm in smallest diameter). The front tip of the yolk sac extended markedly beyond the snout of the larva. A single oil globule (0.11 mm in diameter) was situated at the front tip of the yolk sac with its front half protruding beyond the front margin of the yolk. The numbers of myotomes were 12+18=30; the anus was located a little posterior to the midpoint of the body length. A single branched melanophore was seen behind the eyes; nine of these were present along the dorsal axis, and several at the rear tip of the caudal part (Fig. 7F). Numerous granular processes were scattered over the whole surface of the larval body such as Suzuki et al. (1980) reported for the larvae of *Chaetodon nippon*.

Six hours after hatching, the larvae measured 2.38–2.50 mm in total length and had 10+18=28 myotomes. The yolk sac became about half the size of that in the previous stage. The front tip of the yolk was situated in the same level with the snout. Several branched melanophores appeared on the surface of the yolk. Melanophores along the dorsal axis began to move toward the lateral axis and the ventral surface of the larval body. Small branched melanophores developed on the rear part of the caudal membranous fin (Fig. 7G).

Twelve hours after hatching, the larvae measured 2.66–2.80 mm in total length and had 11+17=28 myotomes. The yolk sac markedly reduced in size to about 1/5 of its original size, while the reduced oil

globule became movable. The melanophores on the dorsal axis moved to and aligned along the ventral axis behind the fourth myotome (Fig. 7H).

Twenty-four hours after hatching, the larvae measured 2.78–2.90 mm in total length and had 12+16=28 myotomes. The yolk sac was markedly degenerated and measured 0.25 mm in diameter. The digestive organ was formed. A group of melanophores was seen in a linear pattern along the ventral axis. Numerous punctate melanophores appeared in the eyes (Fig. 8I).

Two days after hatching, the larvae measured 2.88–2.93 mm in total length and had 10+17=27 myotomes. The yolk sac was scarcely retained. The mouth was open on the underside of the head. Rudimentary pectoral fins were formed behind the auditory vesicles (Fig. 8J).

Early post-larval stage. Three days after hatching, the larvae measured about 3.07 mm in total length and had 10+17=27 myotomes. The yolk and the oil globule were entirely absorbed. The eyes became completely black. The anus was open at the midpoint of the larval body (Fig. 8K).

Four days after hatching, the larvae measured 3.07–3.17 mm in total length and had 10+17=27 myotomes. Numerous punctate melanophores were seen around the rectum (Fig. 8L).

Maintenance of larvae. The larvae were fed the rotifer, *Brachionus plicatilis*. However, almost all of the larvae did not take this food and they gradually decreased in number day by day. The last one died 10 days after hatching, with no marked changes in size or shape from 4 days after hatching.

Discussion

Donaldson (1990) described and arranged the courtship and spawning motor patterns of cirrhitid fishes into three types, i.e., "assessment and synchronization," "stimulation," and "spawning." Twenty-eight motion patterns were identified based on field observations. The mode of courtship and spawing behavior of *C. aureus* in captivity generally agreed with those of other cirrhitid fishes in field. Lobel (1974, cited by Thresher, 1984) described unfertilized "adhesive eggs" for *Oxycirrhites typus*, which spawned, unobserved, in an aquarium. The fertilized eggs of *C. aureus* were undoubtedly non-adhesive and pelagic, as Donaldson (1986b, 1987, 1990) and Donaldson and Colin (1989) reported for *Cirrhitichthys falco*, *O. typus* and others in this family.

The characteristics, especially in melanophore pigmentations along the dorsal and ventral surfaces, of the newly hatched larvae of *C. aureus* bore a close resemblance to those of *O. typus* and *Cirrhitops hubbardi* (Tanaka and Ohyama, 1991) and an unknown species of cirrhitid collected from the Great Barrier Reef, Australia (Leis and Rennis, 1983). Fourmanoir (1971, 1973) described the characteristics of late post-larvae or early juveniles of *Oxycirrhites* sp. and *Cyprinocirrhites polyactis*, collected from ichthyoplankton. These larvae measured 30 and 31 mm in standard length. No common characteristics were found between these late post-larvae and the early post-larvae of *C. aureus*.

The overall larval characteristics of *C. aureus* bore certain resemblances to those of the anthiines, viz., *Sacura margaritacea* (Szuzuki et al., 1974) and *Franzia squamipinnis* (Suzuki et al., 1978) belonging to the family Serranidae, as well as to those of the wrasses, *Stethojulis kalosoma* (Mito, 1962) and *Cirrhilabrus temmincki* (Suzuki et al., 1981) belonging to the family Labridae. There was, however, a sharp contrast in the size of newly hatched larvae between those fishes, i.e., 1.22–1.63 mm in total length in the anthiine and labrid fishes as compared with 2.23–2.28 mm in total length in *C. aureus*.

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水槽内におけるオキゴンベの産卵と卵・仔魚

田中洋一・鈴木克美

水槽飼育されていたオキゴンベが約3ケ月半にわたって連日産卵した．水槽内で観察された本種の繁殖行動は，野外においてすでに観察されているサラサゴンベなどの他のゴンベ科魚類のそれとほぼ同様であった．

受精卵は径 0.75–0.78 mm の無色透明の球形分離浮性卵で，径約 0.1 mm の油球1個を有する．卵膜腔は狭く，卵膜および卵黄表面に特殊な構造は認められない．水温 26.2–28.4℃ で受精19時間後に孵化する．孵化直後の仔魚は全長 2.23–2.28 mm で，大きな卵黄が吻端より前方へ突出し，油球1個がその先端に位置する．黒色素胞が頭部から尾部後方にかけての体背面に十数個，尾部末端に数個存在する．孵化10日後までの飼育ができたが，仔魚の形状・形質ともに孵化4日後のものとの相違は認められなかった．

本種の仔魚はその色素配列などの点において，既報のクダゴンベおよびスミツキゴンベ(田中・大山，1991)およびグレート・バリアー・リーフで採集された全長 3.0 mm の種不明の本科仔魚 (Leis and Rennis, 1983) とよく似る．しかし，その後の仔魚における形質は Fourmanoir (1971, 1973) の体長 30 mm および 31 mm の2種とは相違した．また，本種の初期仔魚の形態は既報のハナダイ類やベラ類のそれに似るが，これらの孵化直後の仔魚の全長は 1.22–1.63 mm の範囲にあって，小型である点が本種とは相違する．

(424 清水市折戸 3–20–1　東海大学海洋研究所)