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**Article** *in* Journal of World Aquaculture Society · April 1997

DOI: 10.1111/j.1749-7345.1997.tb00854.x

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Vol. 28, No. 2
June, 1997

# Natural Spawning and Mass Larviculture of Black Porgy *Acanthopagrus schlegeli* in Captivity in Taiwan

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*Abstract.*—The black porgy *Acanthopagrus schlegeli* is one of the most important marine fish cultured in Taiwan. Wild-caught broodstock were spawned naturally in captivity at water temperatures of 19–26 C in 1989 and 1990. Females produced 352,000 to 957,000 eggs per female during the spawning period. The hatched larvae were reared in 45-$m^3$ rectangular cement tanks and fed initially on rotifers, *Brachionus plicatilis*, followed by *Artemia* nauplii, and finally weaned onto an artificial diet. Larviculture trials to 40 d produced juveniles of 13.1–14.2 mm average total length, at a survival rate ranging from 18.3 to 74.8%. Lordotic deformation was observed in the juvenile stage. However, when an oil skimmer was used to remove the oil film on the water surface, the incidence of lordosis was reduced from 14.4 to 6.1%. High mortality of the larvae occurred during the initial 10–15 d after hatching and cannibalism was observed when larvae reached 7 mm total length. Juveniles grew to size of 83.7–101.4 mm total length with survival rate of 27.9–28.2% in 100 d. The results indicate that the present technique can be used for mass seed production of black porgy.

Black porgy *Acanthopagrus schlegeli*, a marine protandrous hermaphrodite (Kinoshita 1939; Hu et al. 1981), is an important sparid fish in fisheries in Taiwan. The species is widely distributed in Japan, Korea, the middle and north coast of the Mainland China, and Taiwan (Masuda et al. 1988). The fish is one of the important marine fish cultured in the southwestern part of Taiwan, Yunlin, Chiai, Tainan, Kaohsiung, Pingtung, and Penghu prefectures. Total production has been increasing over the past few years (634 tons in 1989; up to 3,220 tons in 1993, Taiwan Fisheries Bureau 1989–1993) and the fish commands a high market price (about US$6 to $7/kg wholesale, Kuo 1993).

Black porgy are serial spawners and spawn between January and April in the Pescadores (23°40′N, 119°20′E) in Taiwan Strait, when the water temperature is between 13 and 24 C (Tang et al. 1979a). Successful induction of ovulation, fertilization of eggs, and larval rearing have been reported (Kasahara et al. 1960; Hirano 1969; Tang et al. 1979a, 1979b; Lin and Yen 1980; Tseng 1982). Huang (1972) achieved induced spawning by using 4- to 5-year-old broodstock from rearing ponds. Natural spawning has been observed in Taiwan (Hu et al. 1981), and morphological development of eggs and early larvae has been described (Tseng 1982). The complete larval development of this species has also been described by Fukuhara (1987). Larval rearing of this fish has had mixed success and the individual survival figures (up to 8%) could not be guaranteed (Tang et al. 1979b; Tseng 1982). Because reliable techniques for mass production of black porgy fry have not been developed, commercially efficient intensive culture of the fish has not been developed.

The present study reports the successful results on natural spawning of captive black porgy during 1989 and 1990 breeding seasons, as well as descriptions of mass larviculture systems.

## Materials and Methods

Wild broodstock of black porgy were captured from anglers at 20 m depth off the coast waters of Yunlin, central Taiwan (23°30′N; 120°10′E) in October 1988. They were stocked in a 0.1-ha outdoor earthen pond. Fish were fed on manufactured diets containing 45% protein and 10% lipids, supplemented with raw oysters *Crassostrea*

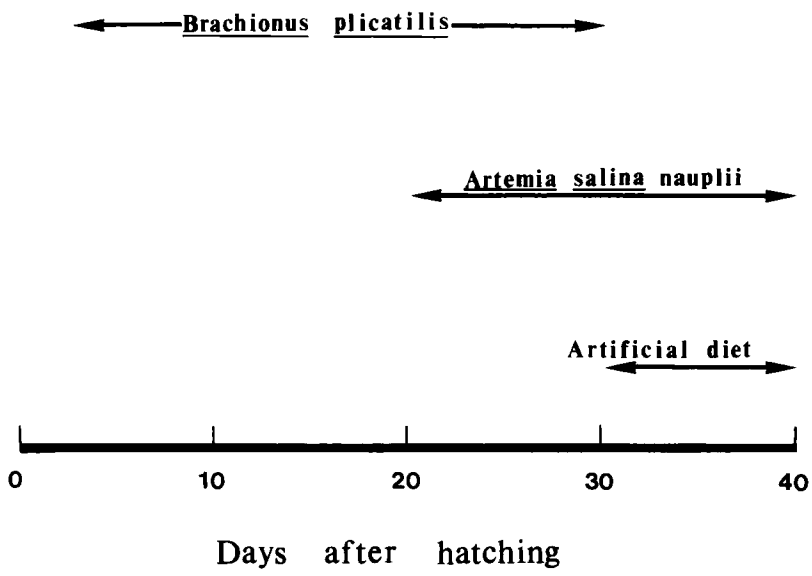


FIGURE 1. *Feeding scheme for larviculture of black porgy.*

*gigas* twice a week, at 5% body weight daily. On December 1988, 10 females (fork length = 41.6 ± 2.7 cm; body weight = 1,986.3 ± 278.4 g) and 10 males (fork length = 36.2 ± 4.5 cm; body weight = 1,693.2 ± 350.7 g) were transferred to a spawning tank. The spawning facilities consisted of rectangular, flow-through, 15-$m^3$ cement tank (5 × 2.5 × 1.2 m), where natural sea water entered at a rate of 20 L/min. Some shading with roof tiles was provided to protect the fish against strong sunshine and heavy rain. The tank was aerated and maintained with a natural photoperiod. Salinity was relatively constant at 30 ± 1 ppt.

Fertilized eggs were collected from the spawning tank using a fine net (100-μm mesh size) to filter overflow water. Unfertilized eggs which settled to the bottom of the tank were removed by siphoning. The eggs were then transferred into indoor 45-$m^3$ cement tanks for incubation and larviculture. The eggs were incubated in meshed baskets (350-μm mesh) equipped with independent airlift systems which kept the eggs in suspension. Egg number was estimated volumetrically. Fertilization and hatching rates were estimated with 100 eggs from each spawn in a 1000-mL beaker of seawater. Fertilization rate was determined as the percentage of normally developing eggs at 10 h after fertilization. Hatching rate was determined as the percentage of eggs hatched of those fertilized.

Initial larval stocking densities were 5–9 larvae/L in 1989 and 8–12 larvae/L in 1990. The feeding protocol is summarized in Fig. 1. L-type rotifers *Brachionus plicatilis* (lorica length = 215–260 μm) served as the only food for the larvae for the first 20 d after hatching. The rotifers were added to the tanks at a density of 10–15/mL from cultures fed baker yeast *Saccharomyces cerevisiae*. All rotifers were intensively fed with *Nannochloropsis* sp. for at least 3 d before they were fed to the larvae. Beginning on day 20, the larvae were also fed with newly hatched *Artemia salina* nauplii at a density of 1–2/mL. From day 30 onwards, a microcoated articicial diet (400–to 70-μm particle size) containing 43% protein, 29.5% lipid and 1.8% n-3 highly unsaturated fatty acids was offered to the larvae. The preparation of the artificial diet was described in detail elsewhere (Leu and Liou 1992). By day 41, the larvae were fed the artificial diet only.

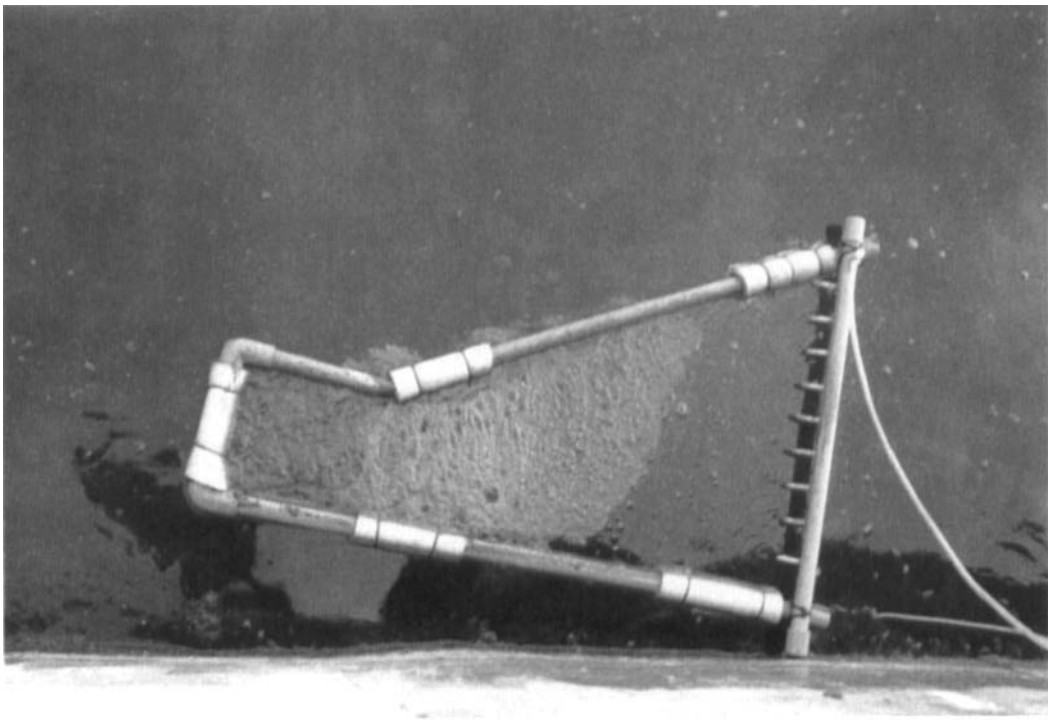

FIGURE 2. *The oil-skimmer designed to remove oil films from the surface of the water in larviculture tanks thereby decreasing the incidence of juvenile fish with lordosis.*

In the 1990 season, the spawning and larviculture trials were repeated with the same procedures, except that only eight remaining females (fork length = 44.6 ± 4.5 cm; body weight = 2,350.5 ± 358.7 g) and ten remaining males (fork length = 40.1 ± 6.9 cm; body length = 1,848.5 ± 423.8 g) were used for the experiment. Furthermore, a water surface cleaning system was used to avoid the production of juveniles with lordosis (characterized by an abnormal V-shaped curvature of the spine) (Foscarini 1988) (Fig. 2). Polyvinylchloride tubing in the form of a triangle was attached to the rim of the tank and floated on the water surface. A stream of air was blown on the water surface to remove the oil film, and air bubbles penetrated into the surface zone of the tank. The oil film was thus concentrated in a corner of the apparatus and was removed several times per day.

Incubation and rearing salinity was uniformly 30 ± 1 ppt, while water temperature ranged from 19 to 23 C in 1989 and 17 to 24 C in 1990. Water in the rearing tanks was maintained as a static system with very mild aeration (5–10 mL/min) until 9–10 d after hatching. After day 10, seawater was replaced at 10% per day. At the stage when the fish were fed *Artemia* nauplii, one third of the rearing water was changed once daily. When the larvae started feeding on the artificial diet, running water at a rate of about 15–20 L/min was applied to avoid water quality problems. Debris, unhatched eggs, and dead larvae were siphoned from the tank daily. Salinity, temperature, pH, and live foods counts were also monitored daily. At the end of each rearing trial the number of survival juveniles was determined by direct count. Correlation between percentage survival and initial larval stocking density was computed. After 40 d, all surviving juveniles were transferred to outdoor 80-$m^3$ rectangular cement tanks for further rearing.

TABLE 1. *Results of natural spawning of female black porgy during the 1989 and 1990 spawning seasons. Values are mean ± standard deviation.*

| Year | Number of females | Body weight (g) | Spawning period (dates) | Spawning period (d) | Number of eggs collected | Fertilization rate (%) | Hatching rate (%) |
|---|---|---|---|---|---|---|---|
| 1989 | 10 | 1986.3 ± 278.4 | 3 Apr–20 Apr | 18 | 3,520 × $10^3$ | 76.9 ± 13.1 | 84.7 ± 15.1 |
| 1990 | 8 | 2350.5 ± 358.7 | 21 Feb–25Mar | 33 | 7,659 × $10^3$ | 80.8 ± 17.4 | 88.2 ± 12.1 |

## Results

Results of the spawning trials conducted in 1989 and 1990 are summarized in Table 1. In 1989, the broodstock spawned naturally 6 mo after conditioning. Spawning commenced on 3 April 1989 and continued until 20 April 1989. During this period, the water temperature in the spawning tank fluctuated between 21 and 26 C. Daily spawning (Fig. 3) varied between 7,220 and 53,250 eggs per female (average 20,705 eggs). This amounted to 352 × $10^3$ eggs per female over this period. The total number of eggs collected was 3,520 × $10^3$, of which 2,707 × $10^3$ were fertilized (about 76.9%). The total number of newly-hatched larvae was 2,293 × $10^3$. The hatching rate varied from 43.0% to 99.4% with an average of 84.7%.

In 1990, natural spawning occurred after 4 mo conditioning of the broodstock. Spawning commenced on 21 February 1990 and continued until 25 March 1990. The water temperature fluctuated between 19 and 25 C. Daily spawning (Fig. 3) varied between 12,250 and 123,100 eggs per female (average 50,387 eggs). This amounted to 957 × $10^3$ eggs per female over this period. The total number of eggs collected was 7,659 × $10^3$, of which 6,188 × $10^3$ were fertilized (about 80.8%). The total number of newly-hatched larvae was 5,458 × $10^3$. The hatching rate varied from 40.6% to 99.6% with an average of 88.2%.

Table 2 summarizes the results of the larviculture trials conducted in 1989 and 1990. In 1989, juveniles ($N$ = 531,758) reached a mean total length of 13.3 ± 1.3 mm after 40 d of rearing. The survival rate ranged from 18.3 to 59.3% with an average of 38.9%. In 1990, the juveniles ($N$ = 1,625,120) reached a mean total length of 14.2 ± 0.9 mm after 40 d of rearing. The survival rate ranged from 20.5 to 74.8% with an average of 50.0%. Lordosis was observed in 14.4 ± 5.3% of fish in 1989 and 6.1 ± 2.0% in 1990. Initial stocking densities and average survival were not significantly correlated ($P > 0.05$, $r = -0.34$).

In both 1989 and 1990, 15–25% mortality of the larvae occurred during the initial 10–15 d after hatching. The fish started biting each other when they reached 7 mm total length, and cannibalism was obvious from the time the larvae started to feed on *Artemia* nauplii.

These juveniles were transferred to 80-$m^3$ rectangular cement tanks; the stocking density was approximately 1,500 to 2,000 fish/$m^3$ with a 2-mo survival of 71.8% (381,806 juveniles) in 1989 and 56.3% (914,875 juveniles) in 1990. Therefore, total survival obtained through the rearing processes was 27.9–28.2%. At 100 d after hatching, fish grew to 83.7–101.4 mm TL.

## Discussion

Black porgy is one of the few marine fish that will readily spawn voluntarily in captivity. Voluntary spawning has the advantages of not requiring that broodstok be handled, thereby minimizing stress to the brooders and reducing labor cost. The spawning season of captive broodstock was the same as observed in wild fish (Matsuoka et al. 1975). Significant increases in fecundity over time suggests that the black porgy broodstock acclimated well to captive conditions. In 1990, eight females produced 2.7 times of the total number of eggs during

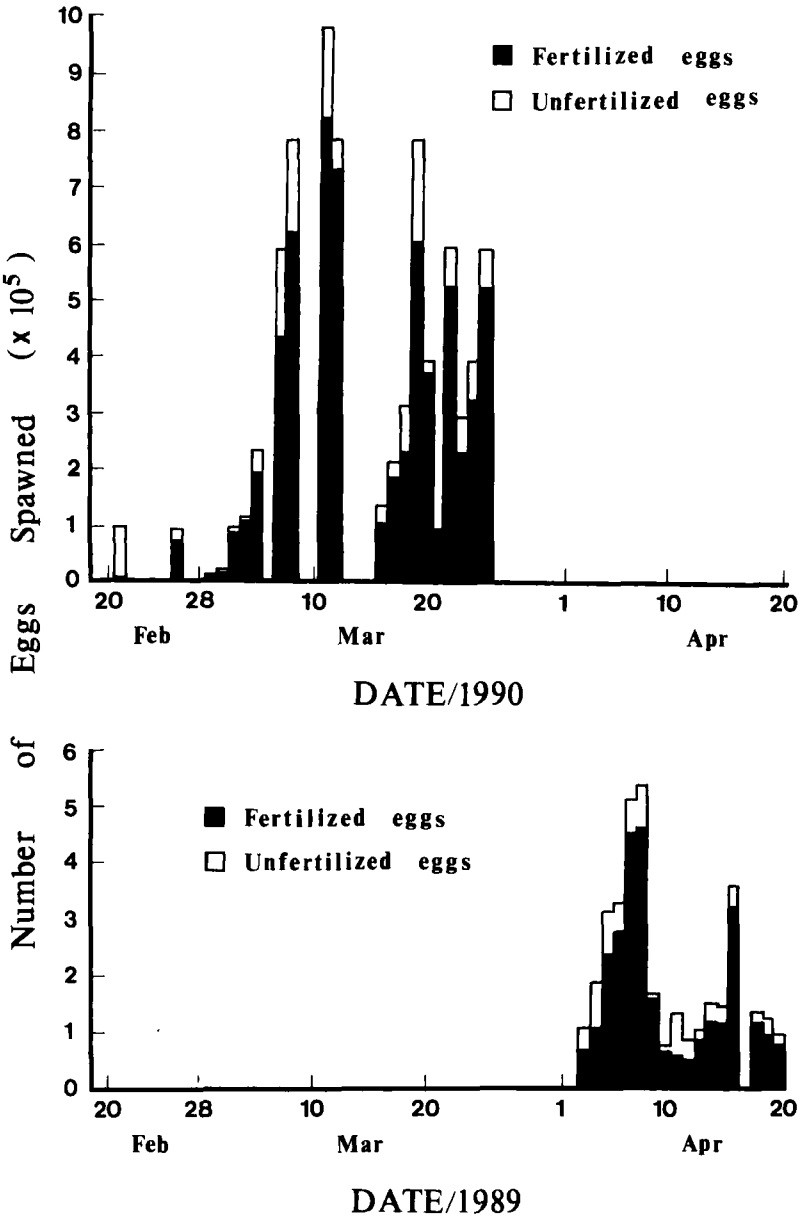


FIGURE 3. *Daily changes in the numbers of eggs produced by black porgy females during the 1989 and 1990 spawning seasons. Water temperatures were 21–26 C in 1989 and 19–25 C in 1990.*

33 d as did the ten females over the 18 d of spawning during the 1989 season.

In Japan, Kasahara et al. (1960) reported the rearing of black porgy larvae using as food the dinoflagellate *Oxyrrhis* sp., the ciliate *Stylonchia* sp., nauplii of copepods, barnacle, and *Artemia*, followed by young mysid shrimp and minced fish meat. This practice resulted in only 17.5% of the larvae surviving to 45 d of age. Larviculture of black porgy in Hong Kong, using boiled egg yolk, fertilized oyster eggs, and artificially-made shrimp feed, followed by captured planktonic food and artificial food, resulted in survival of only 11 juveniles to 35 d of age (Tseng 1982). In this study, the

TABLE 2. *Summary of production characteristics from black porgy mass larviculture trials in 1989 and 1990. SEM = standard error of the mean*

| Trial number | Water volume ($m^3$) | Number stocked | Stocking density (number/L) | Age (d) | Survival (%) | Harvest density (number/L) | Average total length (mm) | Incidence of lordosis (%) |
|---|---|---|---|---|---|---|---|---|
| 1989 | | | | | | | | |
| Trial 1 | 45 | 390,000 | 8.7 | 40 | 35.7 | 3.1 | 12.1 | 15.1 |
| Trial 2 | 45 | 425,000 | 9.4 | 40 | 18.3 | 1.7 | 14.9 | 21.3 |
| Trial 3 | 45 | 302,000 | 6.7 | 40 | 42.5 | 2.8 | 12.5 | 8.8 |
| Trial 4 | 45 | 250,000 | 5.5 | 40 | 59.3 | 3.3 | 13.7 | 12.3 |
| Average | 45 | 341,750 | 7.6 | 40 | 38.9 | 2.7 | 13.3 | 14.4 |
| SEM | | 80,118 | 1.8 | | 17.0 | 0.7 | 1.3 | 5.3 |
| 1990 | | | | | | | | |
| Trial 1 | 45 | 369,000 | 8.2 | 40 | 56.1 | 4.6 | 14.6 | 7.0 |
| Trial 2 | 45 | 553,500 | 12.3 | 40 | 20.5 | 2.5 | 13.3 | 5.4 |
| Trial 3 | 45 | 472,500 | 10.5 | 40 | 74.8 | 7.9 | 15.2 | 8.2 |
| Trial 4 | 45 | 409,500 | 9.1 | 40 | 48.7 | 4.4 | 13.6 | 3.6 |
| Average | 45 | 451,125 | 10.0 | 40 | 50.0 | 4.9 | 14.2 | 6.1 |
| SEM | | 80,446 | 1.8 | | 22.5 | 2.2 | 0.9 | 2.0 |

use of rotifers at first feeding, followed by *Artemia* nauplii and an artificial diet, resulted in 40-d survival rates of 38.9% in 1989 and 50% in 1990. A similar feeding scheme has been used in the other sparid species, such as snapper *Pagrus auratus* achieved 50-d survival rates of 22% (Battaglene and Talbot 1992), and silver seabream *Rhabdosargus sarba* also achieved 45-d survival rates of 22.4% (Leu 1994). The L-type rotifers used in this study was considered as a suitable initial food organism. The total amount of rotifers required to raise one million black porgy larvae up to 10-mm total length was calculated to be $1.85 \times 10^9$ (Okauchi et al. 1980). Water samples collected several times a day from the rearing tank are needed to determine the concentration of rotifers in order to assure a sufficient food supply to the fish larvae.

Highest mortality occurred between day 10 and 15 in this study. Some researchers believed that small changes in temperature of even 1 C in larval culture tanks causes stress that leads to mortality in early larval stages (Lin et al. 1987). In the larviculture system used in the present study, the young larvae were reared in a semi-static system where only a portion of the water was replaced once every day from day 10. In this culture system, there was no temperature control system and the temperature usually ranged from 17–19 C in the morning to about 22–24 C in the evening. Further studies must be designed to determine the reasons for the mass mortality of larvae at this stage.

Lordotic deformation is a serious problem to many finfish species produced in hatcheries worldwide. Until now lordosis has been related with the absence of functional swimbladder at the larval stage (Chatain 1994; Kitajima et al. 1994). It has been proposed that juveniles failing to gulp air in the larval stage triggers the lordosis. Larvae without gas in their swimbladders tend to swim in a direction oblique to the body axis to maintain a position in the water due to insufficient buoyancy and this results in a gradually deforming axial skeleton. The present study indicated that a simple tool for cleaning an oil film on the water surface was effective in decreasing the incidence of lordosis in black porgy.

Cannibalism is a major problem in the juvenile phase in farming of many sparid species, such as silvery black porgy *A. cuvieri* (Hussain et al. 1981), red seabream *P. ma-*

*jor* (Fukuhara 1985), silver porgy *A. sivicolus* (Tawada 1986), snapper (Battaglene and Talbot 1992), yellowfin porgy *A. latus* (Leu and Chou 1996), and black porgy (Tang et al. 1979). Relative size heterogeneity within a population is a primary cause of cannibalism, which also induces mortality (Hecht and Pienaar 1993). In red seabream the rate of cannibalism is reduced by a reduction in density (Foscarini 1988). The optimal density in the rearing tank has yet to be determined although a similar strategy might reduce cannibalism in black porgy.

In summary, the black porgy readily spawns in captivity without the use of hormones or other treatment. A rearing methodology is now available for the mass production of black porgy larvae to juvenile stages which consistently results in survival greater than 50%. The technique developed in this study should assist with procurement of seed for the establishment of a large-scale fish culture enterprises.

## Acknowledgments

The author is grateful to Mr. C.-H. Huang for the technical assistance and other biologists of Taihsi Branch of Taiwan Fisheries Research Institute for their kind help.

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