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Biology of the Spotted Scat (*Scatophagus argus*) in the Philippines

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Abstract

The spotted scat (*Scatophagus argus*) is an herbivorous, euryhaline teleost widely distributed throughout the Indo-Pacific basin. This species is a valuable brackishwater aquarium fish and an important foodfish in parts of its range. Length-weight relationships were calculated based on data from 797 females and 252 males. The sexes can be differentiated by head shape. The largest fish captured was a 1.2-kg female. Reproductive maturation first occurred in females of approximately 150 g, corresponding to fish estimated to be 7-9 months of age. Males mature at a smaller size (~80 g). Fecundity was found to be directly proportional to fish size. Data on the monthly abundance of mature females and fry (which peaked markedly in August) suggest that monsoon rains (which began in June) trigger spawning in the spotted scat. Observations of spawning behavior and early juvenile development are also reported.

Introduction

The spotted scat (*Scatophagus argus*, Linnaeus) is a euryhaline teleost widely distributed in nearshore waters of the Indo-Pacific Basin (Nelson 1976). The species has a wide salinity tolerance and is found in freshwater, brackishwater and marine habitats. It is a popular aquarium fish (Morgan 1983) and an important food fish in parts of its range, particularly in the Philippines where it is considered a delicacy.

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Because of their favorable biological characteristics and economic importance, considerable interest exists in developing propagation and culture techniques for the spotted scat. Nevertheless, there are few published accounts describing induced maturation, spawning, larviculture or grow-out of this species. With these interests in mind, we conducted laboratory and pond culture studies with the spotted scat in 1986-87 (Fast 1988). This work was successful in developing useful spawning techniques (Barry et al. 1991, in press), as well as practical pond culture methods using wild-caught fry (Fast et al. 1989).

During field collections of broodstock and fry, we obtained data on the availability, condition and habits of spotted scat in their natural habitat. These data provide some of the best information available on the natural history of this species and may be useful for establishing breeding and culture schedules using wild-caught fish.

Materials and Methods

Broodstock fish were collected by one of two methods from the southern coastal waters of Panay Island, Philippines (Fig. 1). One method, known locally as the *tambon* technique, uses nets to surround a small floating aggregation device made of logs, bamboo and coconut fronds. The device was anchored at least two weeks earlier in water 1.5-2-m deep at low tide, and typically within 0.5 km of the shore. The second method used a long net to enclose approximately 3 ha of sand and mud flat immediately adjacent to a mangrove swamp at the mouth of the Jaluad River, Leganes (Fig. 1). The net was set at high tide and fish were captured after the water receded. Adult scat were transported to the Iloilo State College of Fisheries (ISCOF), Barotac Nuevo, Iloilo, Philippines (Fig. 1) and stocked in hapa nets or floating cages in ponds, 1-m^3 concrete tanks or 9-m^3 canvas tanks.

Captive fish were fed commercial shrimp (35% protein) or milkfish (27% protein) pelleted feeds supplemented with filamentous and benthic algae. On the day following capture, fish were individually weighed (±0.1 g) and measured (standard length±0.1 cm) under anesthesia (0.3 $ml \cdot l^{-1}$ 2-phenoxyethanol). Female fish greater than 14 cm standard length (SL) and males greater than 12 cm SL (sizes when sexual maturity is attained, see below) were individually tagged.

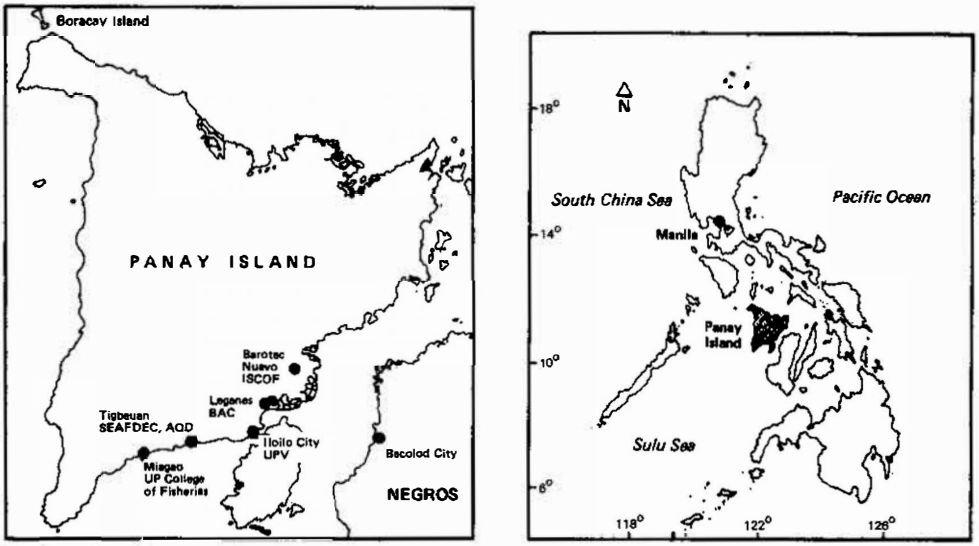

Fig. 1. Maps showing the location of Panay Island within the Philippine archipelago, and the locations of major aquaculture research institutions on the southern coast of Panay. ISCOF, Iloilo State College of Fisheries; UPV, University of the Philippines in the Visayas; BAC, UPV-Brackishwater Aquaculture Center; SEAFDEC-AQD, Southeast Asian Fisheries Development Center-Aquaculture Department. Most of the spotted scat fry and broodstock were captured near the mouth of the Jaluad River, Leganes, and Zarraga, or in the nearshore waters off Barotac Nuevo.

Oocyte samples were taken with a 0.87 mm I.D., 1.27 mm O.D. polyethylene cannula. Oocytes were preserved in a 0.1 M formalin 0.60% NaCl solution, and their diameters immediately measured to the nearest 0.01 mm using an ocular micrometer. Our induced maturation and spawning experiments determined that spotted scat oocytes are approximately 0.65 mm in diameter just prior to ovulation, and that only females with oocytes approximately 0.40 mm in diameter or larger can be induced to spawn (Barry et al., in press). We refer to these females as "mature." Male fish were sampled for running milt by gently squeezing their abdomens and were classified according to the following scale: (0) = no milt; (+) = small volume of milt after repeated squeezes; (++) = large volume of milt after a single squeeze (Barry et al. 1991).

Fry were collected along the seashore near the mouth of the Jaluad River, or along its banks, primarily by one fisher family using meter-long, handheld, V-shaped nets made of bamboo and mosquito netting. Most fry were caught at high tide. Fry were transported to ISCOF, placed into 250-l plastic tanks, and fed artemia and filamentous algae several days before stocking into earthen

ponds. In agreement with Bañada (1983), we found that spotted scat fry were seldom captured using traditional Filipino milkfish fry collecting techniques.

Results and Discussion

Field Capture of Broodstock Spotted Scat

During 16 months of collection, we captured 1,162 spotted scat by the broodstock collection methods. The smallest fish was less than 1.5 cm, and the largest was 28 cm. Most fish were longer than 8 cm. Monthly mean length varied between 11.2 and 16 cm (Table 1). Total number of female scat captured each month always exceeded total number of males. The overall ratio was 3.1 females captured for every male (785/243). The monthly female to male ratio ranged from 1.3:1 to 5.8:1 (Fig. 2). Arrunyagasemsuke (1975) also reported that few males were captured during sampling for spotted scat in the Gulf of Thailand.

Characteristics of the spotted scat include: a deep, strongly compressed body form; a small mouth and head, small teeth in bands; small ctenoid scales; a distinct lateral line running parallel to the back profile, a continuous dorsal fin; and four anal spines (Fig. 3). All members of the family *Scatophagidae* have paired poison glands associated with each fin spine (Cameron and Endean 1970). We found that punctures are moderately painful and can ache for hours. Injuries from the spines were rare; captured scats are not aggressive and typically lie flat without moving when handheld.

Food Preferences

The name *Scatophagus argus* is translated from Greek as "spotted feces-eater," and was derived from the habit of scat to gather in harbors and feed on offal and other wastes dumped from ships. It is uncertain, however, if scats are true coprophages since their acceptance, and/or preference for fecal matter has not been confirmed. It is possible that the fish actually feed on attached algae associated with waste discharges.

Although we did not make a detailed study of the natural food preferences of the spotted scat, routine inspection of the gut

Table 1. Standard fish length (cm) and size class frequency data for *Scatophagus argus* captured by the "broodstock" collection methods, July 1986-October 1987.

Class limits Lower - Upper	Class midlength	1986 Jul	1986 Sep	1986 Oct	1986 Nov	1987 Apr	1987 May	1987 Jun	1987 Jul	1987 Aug	1987 Sep	1987 Oct
0.5 - 1.49	1									1		
1.5 - 2.49	2											
2.5 - 3.49	3											
3.5 - 4.49	4											
4.5 - 5.49	5								1			
5.5 - 6.49	6											
6.5 - 7.49	7									1	1	
7.5 - 8.49	8				1	3	7	6	4	3		
8.5 - 9.49	9	1	1	1		10	13	12	20	8	1	
9.5 - 10.49	10	1	3	8		4	18	29	29	17	1	
10.5 - 11.49	11	5	5	9	1	20	19	25	49	23	1	2
11.5 - 12.49	12	9	16	14	1	16	17	22	43	13	5	3
12.5 - 13.49	13	12	8	16	2	15	11	18	26	8	1	4
13.5 - 14.49	14	6	12	10	3	10	4	5	12	11	3	8
14.5 - 15.49	15	2	13	9		7	4	9	14	4	8	1
15.5 - 16.49	16		6	6		9	2	4	9	3	6	4
16.5 - 17.49	17	3	8	4		10	4	3	11	8	2	4
17.5 - 18.49	18		8	5		11		41	7	5	5	2
18.5 - 19.49	19		7	4		4	2	5	12	3	3	
19.5 - 20.49	20	4	8	9		1		3	10	1	1	3
20.5 - 21.49	21	2	13	5		1	1	1	9	3	1	
21.5 - 22.49	22	2	4	6		1	1	1	3	1	1	1
22.5 - 23.49	23		7	5		1	1		3	1	1	
23.5 - 24.49	24	1	4	2								1
24.5 - 25.49	25		2	0						1		
25.5 - 26.49	26		1	1								
26.5 - 27.49	27		1	0						1		
27.5 - 28.49	28		1	0								1
Total fish captured		48	128	114	8	123	104	184	262	116	41	34
Mean fish length (cm)		14.3	16.0	14.4	14.3	13.6	11.2	12.3	13.2	12.8	15.4	15.8

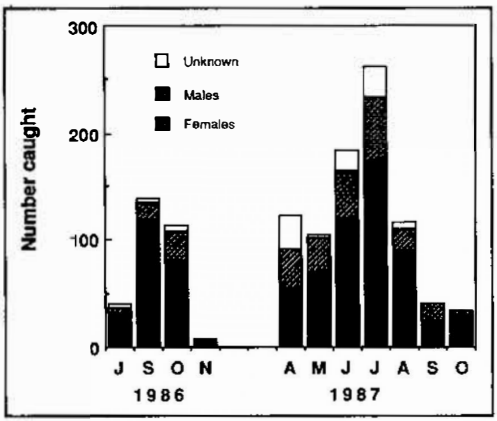

Fig. 2. Total numbers of spotted scat broodstock by sex captured using broodstock capture methods (described in the text), July 1986-October 1987.

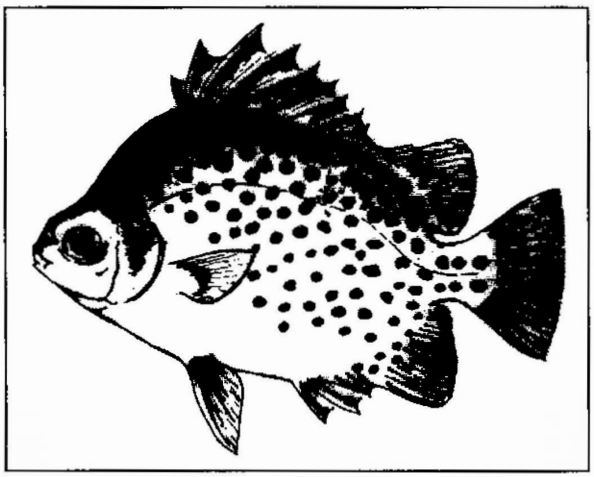

Fig. 3. Adult male spotted scat.

contents of fish which died soon after capture revealed that adult scats were primarily herbivorous. Their guts were typically full of unidentified plant material. A green filamentous algae which grows along the seashore in brackishwater and an unidentified brown seaweed attached to mangrove roots were commonly found in their stomachs. Further evidence of the scat's herbivorous diet includes its long coiled intestine, which in adults averaged approximately 3.5 times the body length, and the small, rasp-like teeth which appear adapted for scraping and shredding plant material.

Captive scat of all sizes readily ate filamentous algae. After approximately one week in captivity, scats began to accept pelleted commercial feeds. They always preferred algae, however, if both

foods were offered simultaneously. Pellet-fed fish kept in floating cages nibbled continuously on the algae which grew on the sides of the cage. Postmortem examination revealed that these fish, which generally thrived, had guts full of algae. Captive scats also fed on benthic flora common in milkfish ponds and could survive solely on this diet (Fast et al. 1989). Captive fry and juvenile scat preferred zooplankton (unidentified), artemia and mosquito larvae.

Sex Determination

Spotted scat sexes could be differentiated by head shape (Fig. 4). In females, the head profile ascends at a constant slope, whereas males have a concave curvature of the head above the eye. This difference is more prominent in larger fish, but is noticeable in fish as small as 100 g. In addition, females are often a lighter, olive-green color compared to the darker males. Sex of fish greater than 14 cm SL could be verified by gonadal biopsy using a polyethylene cannula as described above.

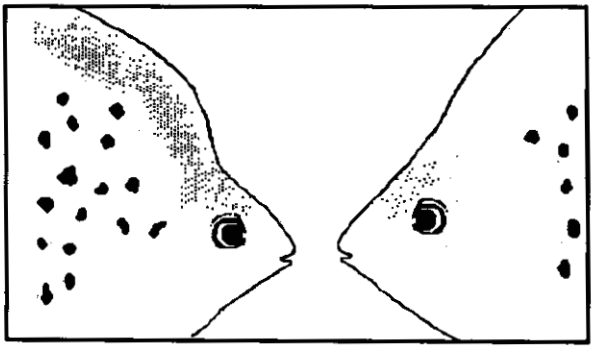

Fig. 4. The head profiles of a male (left) and female (right) spotted scat illustrating the sexual dimorphism which can be used to differentiate the sexes.

Length-Weight Relationship

Length-weight relationships for male and female spotted scat were based on individual length and weight measurements of 252 male and 797 female scat (Fig. 5). The largest fish captured was a 28-cm SL female weighing 1.20 kg. The largest male was 27 cm SL and weighed 1.05 kg. Khan (1979) reported a spotted scat of unknown sex 33.4 cm total length, weighing 1.2 kg. Average weights of male and female scat given their standard length can be

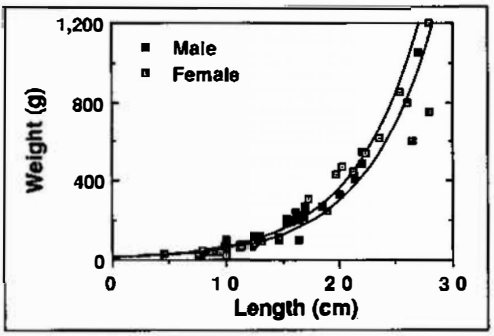

Fig. 5. Length vs. weight relationship for male (upper line) and female spotted scat (lower line). These curves were calculated using individual length and weight measurements of 797 females and 252 males. Only representative points are shown.

estimated as follows: $w = 0.07058 \times SL^{2.881}$ and $w = 0.18976 \times SL^{2.526}$, respectively, where w = weight in grams and SL = standard length. Analysis of cova-riance showed that this sex difference was significant ($P < 0.01$).

Size at First Maturity

The size when females become sexually mature was determined by plotting their ovarian weights as a function of SL (Fig. 6). The increase in gonadal weights for fish at approximately 14 cm SL (150 g) indicates the size at which females first reach sexual maturity.

Testicular weights plotted as a function of fish length did not reveal a pattern useful in determining the size of first reproduction in males. Testes weight did not differ significantly between small and large males (Fig. 6). The smallest male found with running milt (++) was 11.5 cm long and weighed 83.5 g; this may be a reasonable estimate of the size at first reproduction in male scat.

Age and Growth Predictions

The von Bertalanffy growth equation, $Lt = L_\infty \times (1-e^{-K(t-t_0)})$, is often used to describe fish growth; Lt is the mean length at time t, L_∞ is the average maximum length attainable, K is a growth constant which describes the rate at which Lt approaches L_∞, and t_0 is the hypothetical age of the fish when its length was zero. The parameters L_∞ and K have been estimated for the spotted scat from previously published length-frequency data (Ziegler 1979, in Ingles and Pauly 1984) using the ELEFAN I program (Ingles and Pauly 1984). The estimates are L_∞ = 25.0 cm and K = 1.20. The von Bertalanffy growth equation generated using these estimates suggests that female scat reach sexual maturity (i.e., are greater than 14 cm SL) in approximately 7-9 months (Fig. 7).

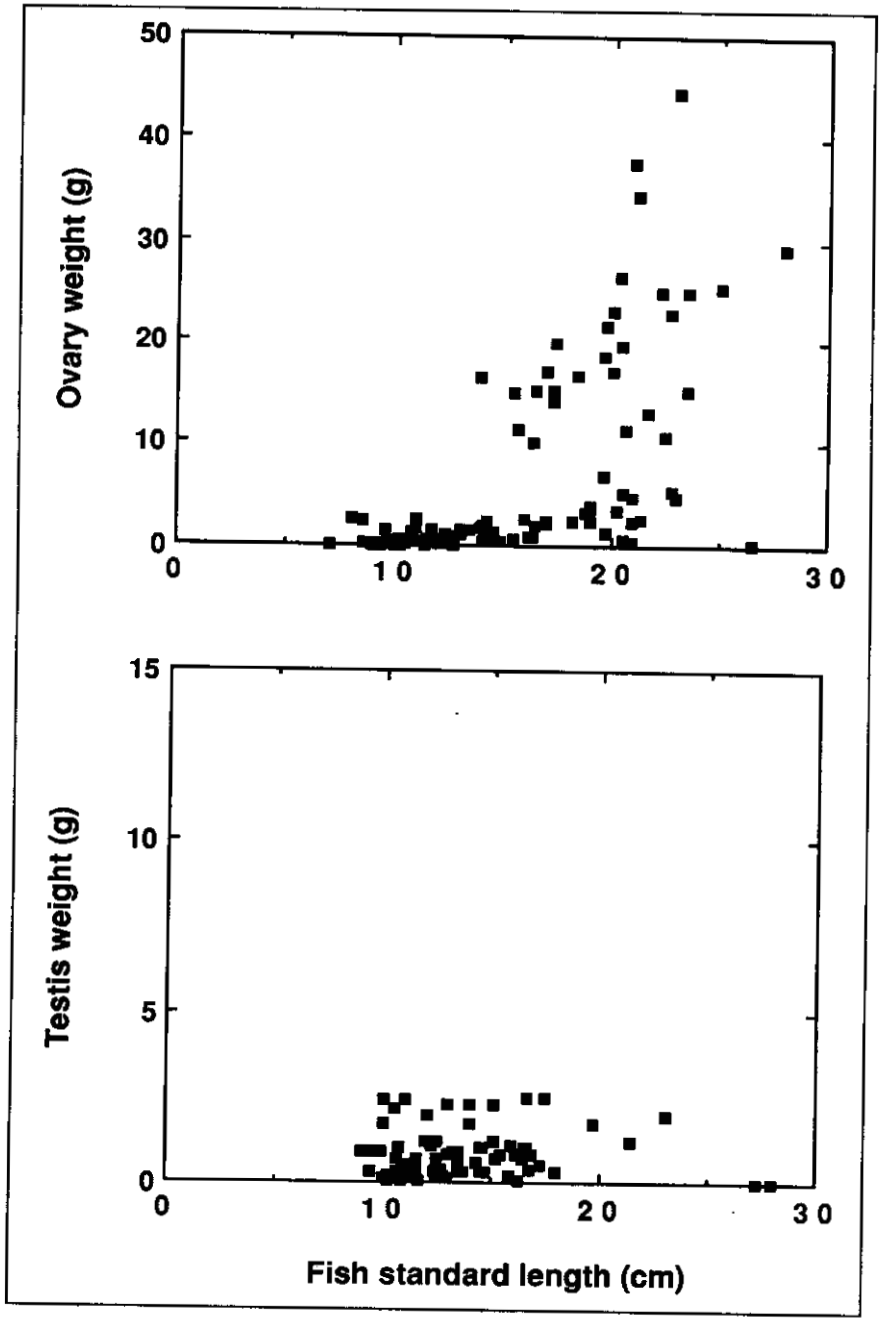

Fig. 6. Relationship between gonad weight and standard fish length for female (upper graph) and male (lower graph) spotted scat. Fish were captured July 1986 - October 1987. Standard lengths and gonad weights of 140 females and 90 males were taken.

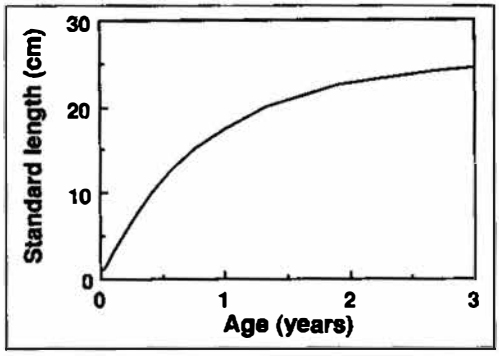

Fig. 7. Growth curve for spotted scat generated using the von Bertalanffy growth equation with assumed average maximum length (L_∞) of 25 cm and growth constant K = 1.2 (Ingles and Pauly 1984).

Spawning Season in the Iloilo Area

Based on our broodstock and fry capture data, and weather observations, we estimated the natural spawning season of the spotted scat.

Broodstock scat were collected during July, September and October 1986, and again during April-October 1987. In July 1986, over 45% of the females of reproductive size (over 14 cm) had oocytes at least 0.4 mm in diameter, i.e., they were "mature." In August, however, no mature females were captured. In 1987, we observed a similar pattern when the greatest percentages of mature females were caught in April, July and September with low percentages of mature females caught in May, June and August (Fig. 8). The fact that we caught very few fish from November through March suggests that the spotted scat may live offshore in deeper waters during the dry season. Our principal fish collector has observed for years that larger spotted scat enter shallow water each year in April and May to feed on the abundant filamentous algae growing along the shore at that time.

Major efforts were made to collect fry in August-December 1986 and April-October 1987. All the fry collected in 1987 came from a single site. In 1987, no fry were collected until June when there was a sudden increase in fry abundance which peaked in August when over 18,000 fry were captured (Fig. 9). Most fry collected ranged from 0.6 to 1.2 cm total length and were the tholichthys larval form (see below) of the spotted scat. These data strongly suggest a peak spawning period some time prior to August.

In both 1986 and 1987, the rainy season began in June and continued through late autumn (Fig. 10). Average monthly air temperatures reached maxima during April and May, just before the rains began (Fig. 10). Air temperature dropped in June, concurrent with the rainy season. Average wind direction by month also showed a seasonal pattern. From December through May, wind

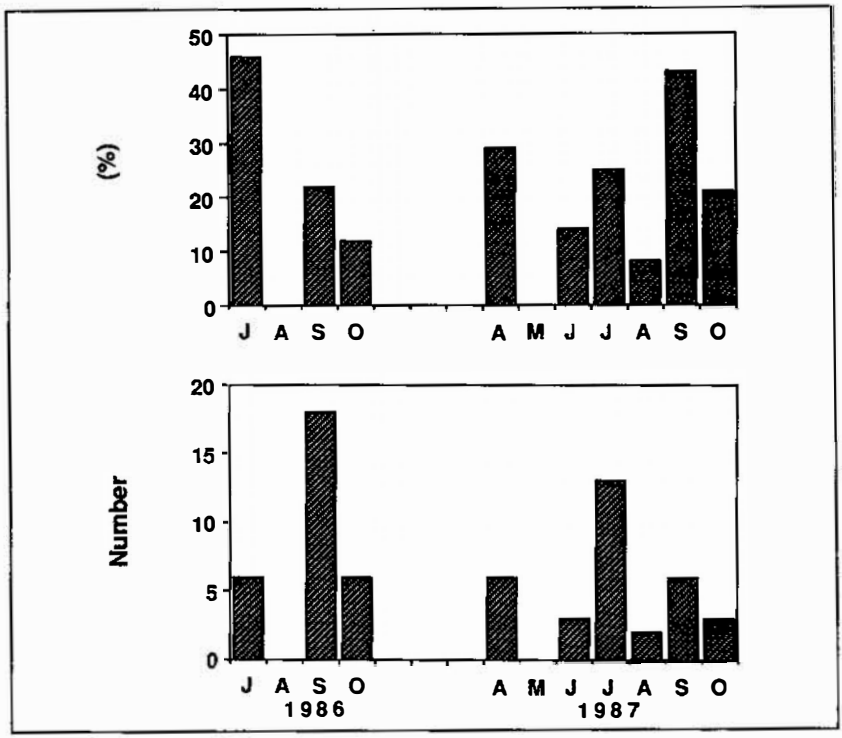

Fig. 8. Monthly abundance of mature female spotted scat captured during 1986-87. Mature females were defined as fish with oocytes greater than 0.40 mm in diameter (see text for rationale). Upper graph - the percentage of all females caught each month which were mature. Lower graph - the number of mature females caught each month on which these percentages were based.

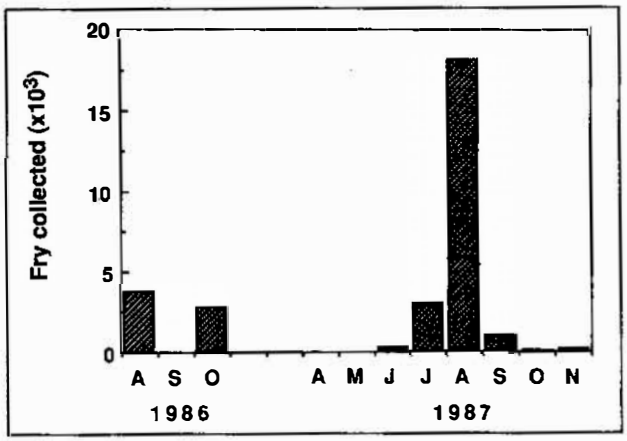

Fig. 9. Total number of spotted scat fry collected August 1986-October 1987.

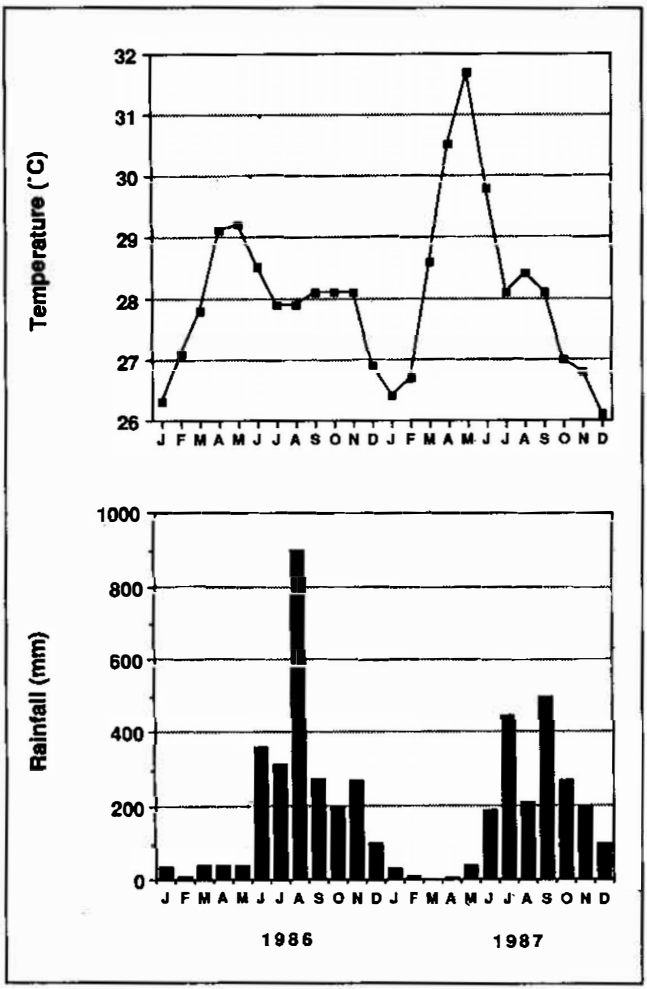

Fig. 10. Total monthly rainfall and average monthly air temperature at Iloilo during 1986-87. Data are from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) in Iloilo City, Philippines.

direction shifted 180° as the SW monsoons began, bringing rain (data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration).

These data on the seasonal abundance of mature females and fry suggest that the spawning season of the spotted scat is triggered by the start of the SW monsoons in June and July. The monsoon season brings rainfall, cooler temperatures, increased river outflows

and lower salinities, all of which could potentially serve as environmental cues stimulating final oocyte maturation and spawning. That the monsoon rains stimulate spawning in the spotted scat is supported by data showing that survival and motility of spotted scat spermatozoa is greatest in brackishwater at salinities of 25-30 ppt (Barry et al. 1988). The hypothesis also implies that the 0.6-1.2 cm fry captured in August were 1-2 months of age, which is compatible with empirically derived growth estimates of larval scat (see Fast et al. 1989).

The SW monsoonal winds may also help trigger spawning and could contribute to fry survival. Near Iloilo, the WNW through NNE winds tend to blow offshore and move plankton-rich waters away from the shore. The SW monsoons promote plankton blooms by washing nutrients from the land into the sea, and also blow plankton-rich water onshore. Thus, larval fish developing nearshore at the beginning of the rainy season should have an abundant supply of plankton-rich water.

Pairing and Mating Behavior of Captive Spotted Scat

We observed the pairing and mating behavior of spotted scat confined to tanks during September 1986. Two males with running milt (weights 267 and 256 g) and one female with oocyte diameters of 0.52 mm (weight 265 g) were placed together in a 200-l tank on 15 September 1986. The female was implanted with a pellet containing synthetic luteinizing hormone-releasing hormone analogue, des-Gly^{10},[D-Ala^{6}]LHRH as described by Barry et al. (in press). The salinity of the water was 25 ppt. Pairing behavior was immediately observed between both males and the female. The two males followed the female as she swam around the tank, and both occasionally nudged her abdomen from below with their snouts. Antagonistic behavior was seen between the males, although this was not intense. The males avoided each other by staying on opposite sides of the female. At times, one of the males would make a sudden attack on the other. When this occurred, the attacked male tilted his head downwards and held his dorsal spines erect. The aggressive male attempted to swim around the attacked fish to nip its flank. The attacked male oriented himself quickly to avoid being struck by the aggressor. We never observed the aggressor actually bite the other male, although wounds were visible on the latter's flank. After

chasing the other male for a short time (~1 min), the aggressive male returned his attention to the female.

On September 16, the dominant male and the female were seen hovering at mid-depth, facing each other. They both undulated their bodies in a rhythmic motion. This behavior lasted from 30 seconds to several minutes; the frequency of the undulations increased with time. At this point, we observed the male bite and hold the upper lip of the female for several seconds. Her upper lip was scrapped open and bloody as a result of this behavior. The dominant male resumed following the female around the tank and placed his snout to her urogenital opening with greater frequency than was seen the previous day. The beginning of abdominal distension (perhaps because of egg hydration) was observed in the female at this time.

On the morning of September 17, the male-male antagonism had markedly increased and the dominant male spent much of his time trying to attack the other male. Interestingly, the female moved to position herself between the two males. The aggressive male made repeated attempts to go around the female to get at the submissive male which held its dorsal spines erect most of the time. After these attacks, the aggressive male immediately returned his attention to the female, nudging her abdomen from below with greater force and frequency. The dominant male, but not the submissive male, was observed with a wounded, bloody upper lip like the female's. The submissive male had more wounds along its flank. On the morning of September 18, the submissive male was found dead on the tank bottom. The female had spawned. Actual spawning behavior was not observed. It was subsequently found that all mated male and female scat which spawned had wounded upper lips.

Spawned Eggs

The spawned eggs of the spotted scat varied in size from 0.68 to 0.75 mm in diameter. The eggs are transparent and spherical, and contain a single yellow oil droplet 0.30 mm in diameter. Fecundity was directly proportional to fish weight according to the following equation: $n = 983w - 66{,}904$, where n = number of oocytes and w = wet weight of fish in grams. The most eggs we collected (~807,000) came from a 947-g fish.

We observed that unfertilized eggs turned opaque within one hour. Unfertilized eggs were easily suspended by aerating the water, but sank if the aeration was turned off. According to Winfree (1986) "fertile eggs could be distinguished within 1-2 hours by gradual changes in internal structure. Oil droplets also continued to coalesce in the fertile eggs but not in the infertile ones. Viable eggs were buoyant in seawater." Winfree also described early larval development of the spotted scat.

Tholichthys Larvae

Spotted scat larvae pass through a developmental stage known as the tholichthys (Fig. 11). This stage is unique to a few genera of teleosts, including the butterflyfishes (*Chaetodontidae*) and scats (*Scatophagidae*). Tholichthys larvae of the spotted scat are deep-bodied and laterally compressed. They are usually very dark, have rough, scaleless skin and a well-developed lateral line. They range in size from approximately 0.60 to 1.2 cm. The most distinctive features of tholichthys larvae are the bony plates which completely encase the head in a thick protective sheath. In the spotted scat, one of these plates dorsal to the eye has posteriorly-oriented projections which form spiny horns on either side of the head. These plates are slowly absorbed as the tholichthys larva develops into the juvenile form. The duration of the planktonic period of the spotted

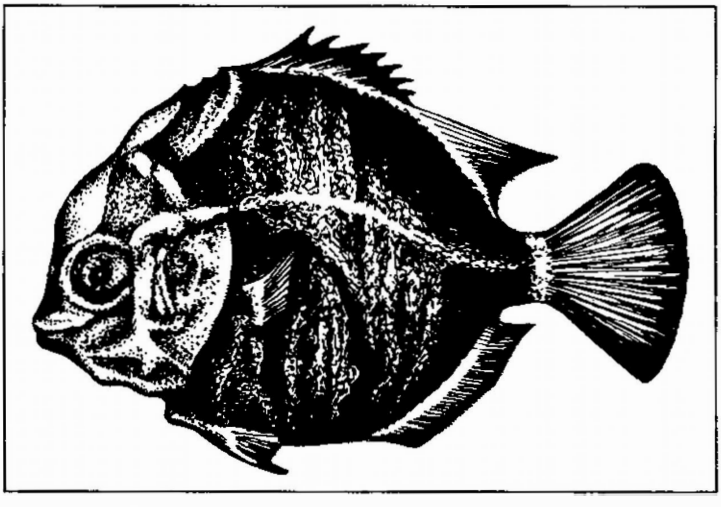

Fig. 11. Tholichthys larval stage of spotted scat at 1.2 cm total length.

scat is not known, nor is it known where the nursery grounds are for this species, although our collection data suggest they may be near the mouths of rivers in brackishwater estuarine habitat.

Juveniles

Several forms of *Scatophagus argus* have been reported in popular aquarium literature, and there has been discussion about whether these are distinct species, or merely color morphs of the same species. Two of the more popular aquarium forms are the tiger or red scat (*S. argus rubifrons* var.) and the common scat. We only observed one variety in the Iloilo area during our investigations. The juveniles had dark vertical bands with varying amounts and intensities of red markings. These fish were very similar to the *rubifrons* scats described in aquarium literature. Adults were characteristically brownish-green with black spots. We observed the red-marked juveniles develop into the typical spotted adults. This suggests that the *rubrifrons* is not a distinct variety of scat, but merely a developmental stage of the common spotted scat.

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