Some Aspects of the Life History of *Siganus canaliculatus* (Park) (Pisces: Siganidae) in Palau

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Abstract.—Certain aspects of the life history of *Siganus canaliculatus* from the Western Caroline Islands were examined. Average fecundity was 295,750 eggs per female with an average egg diameter of 0.5 mm. In most females ovary enlargement began in late February with a cyclic pattern of high modes indicating spawning in mid-March, mid-April, and mid-May. Spawning dates were four or five days after the new moon. Spawning areas were characterized by access to the open ocean via channels, large *Enhalus* flats, and extensive mangrove flats. Spawning schools were at least twice the size of nonspawning schools, with a sex ratio of 1: 2 favoring males instead of 3: 1 favoring females in the nonspawning school. Observations of captive fish indicated an evening or early morning spawning time.

The first three weeks of life for *S. canaliculatus* were not investigated, but all parameters indicate a pelagic existence during this period. Twenty to twenty-two days after spawning, schools of 2.3 cm SL fish appeared on the reef flats. *S. canaliculatus* grows to 80% of its adult size in six months and reaches maturity in one year. Individual fish probably spawn several times in a given year. Longevity is at least two years, with females surviving at a higher rate after one year.

S. canaliculatus is a continuous grazer with schools usually consisting of similar sized fish except for juvenile schools. In mixed species schools, *S. canaliculatus* was usually the most numerous species. Older fish were more wary than juveniles. Predator attacks resulted in the scattering of the school which reformed immediately. Drastic changes in coloration were exhibited when fish were stressed by predators or low oxygen levels. Oxygen levels below 2.5 ppm were not tolerated. Nocturnal activity was minimal on moonless nights but greatly elevated on moonlit nights.

Introduction

Interest in tropical aquaculture has necessitated life history studies of potential culture organisms. Certain members of the fish family Siganidae may offer possibilites (Lam, 1974; Tsuda et al., 1974) but the slow growth to marketable size (150 g) compared to other species may be a drawback (Von Westernhagen and Rosenthal, 1976). A recent literature review of siganids was presented by Lam (1974). A preliminary report based on this study was presented at the International Symposium on Indo-Pacific Tropical Reef Biology, Agana, Guam (McVey and Madraisau, 1974).

Though fishery statistics are not available, Palauan fishermen agree that the size and number of *Siganus canaliculatus* has decreased. According to older fisher-

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men, spawning schools covering an area of 100 m^2 were common before 1930 whereas present day schools are usually less than 10 m^2. Fishing by means of explosives during World War II and shortly thereafter may have resulted in the first noticeable decline. A second decline occurred within the last 15 years when motorboats and large (500–1500 m) cotton and nylon nets came into use. Records of the Palau Fishermens Co-Op show *S. canaliculatus* as one of the two most common siganids. Helfman (1968) reported 500 metric tons of siganids landed at the Co-Op in 1968.

Materials and Methods

Observations of *S. canaliculatus* were made from July 1972 to June 1973 in the Palau Islands, Western Caroline Islands. Palau is a group of approximately 350 islands ranging in size from Babelthaup (330 km^2) to the "rock islands" (<100 km^2) (Fig. 1). *S. canaliculatus* ranges from the Andaman Islands east to the Santa Cruz Islands and New Guinea north to Yap (David Woodland, Pers. Comm.).

Fecundity studies were based on fish from the Palau Fishermens Co-Op. Fish were weighed and the standard length (SL) measured. Spawning conditions of the testes were noted, then they were discarded. Ovaries were frozen and random 0.1 g samples of eggs removed and placed in 4% formalin for one week. Eggs were counted with a binocular scope and diameters of 15 per sample measured. A fish was considered in spawning condition when gonad weight was 2% or greater of the total body weight (TBW). Internal examination of both sexes showed this to be the approximate value at which gonads began to enlarge rapidly prior to spawning.

Spawning dates were determined by gonad weight change. From July to mid-February, fish were examined weekly except for three weeks in mid-November and January when no fish were available due to bad weather. From mid-February to June, fish were examined twice weekly.

Growth estimates were based on wild specimens. Young of the year fish were dated to specific spawnings by size. By June, fish from the February through May spawnings (four sizes) were found together on the *Enhalus* flats. This size difference was obvious until the fish were about eight months old. Data showed the adult fish were mostly 15–17 cm SL or 19–23 cm SL. Fish <18 cm SL were considered in age group I while those >18 cm SL were considered II. Growth rates of captive fish indicated this was an accurate means of separating the age groups [unpublished data, Micronesian Mariculture Demonstration Center (MMDC)].

Oxygen requirements were determined using completely filled 76-liter aquaria containing natural seawater pumped from Malakal Harbor. Fish were placed in the aquaria at a ratio of four grams of fish per liter of water. The aquaria were sealed and O_2 readings taken with a Model 51a YSI oxygen meter at half-hour intervals until death. Seven trials were run with three fish per trial.

Snorkeling gear was used for observations of daily activities. On occasion, six hours per day were spent watching schools of fish. These observations docu-

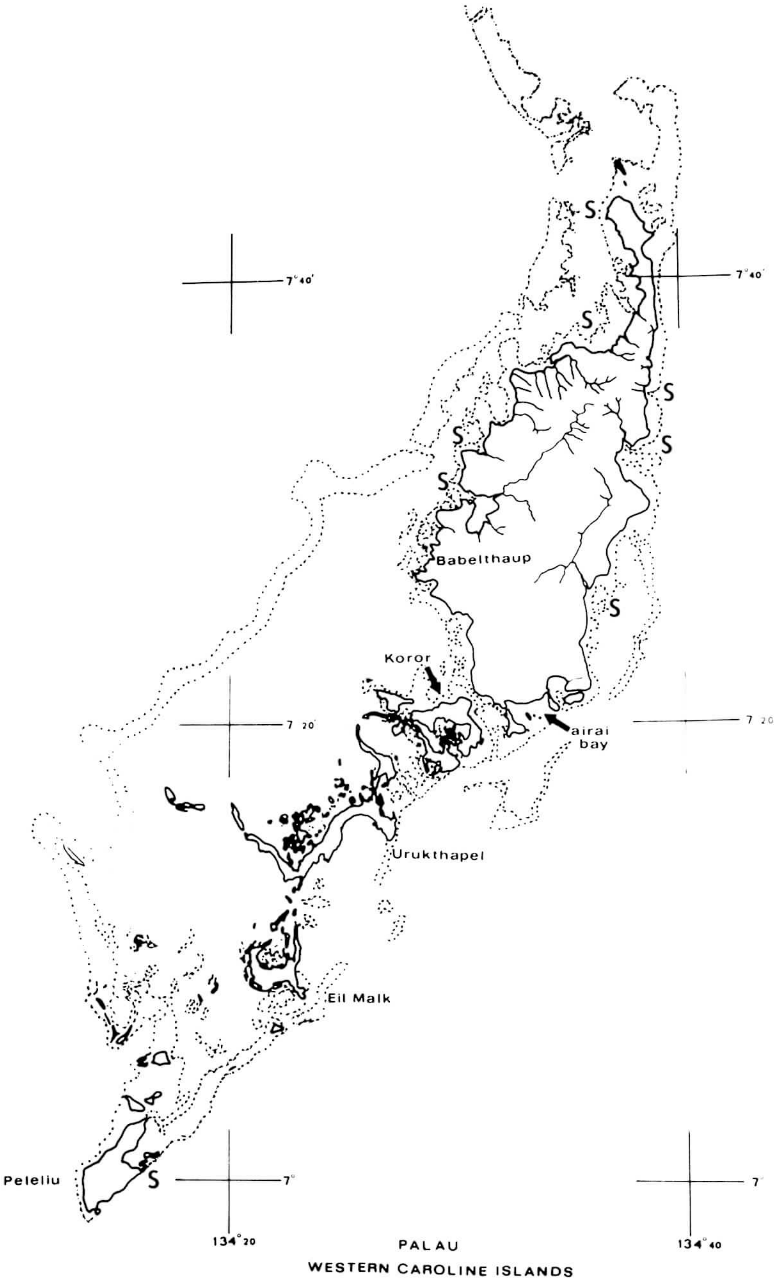

Fig. 1. Study locale in the Pacific Ocean, approximately 800 km east of the Philippines. "S" indicates secondary areas where *S. canaliculatus* gather to spawn, Airai Bay being the primary area. Based on N.O. chart 81141.

mented the arrival of juvenile *S. canaliculatus* on the *Enhalus* flats. School size was determined by drifting in a boat or snorkeling and counting the fish on the *Enhalus* flats. Drew (1973) described the Palauan fishing methods used during this study.

Spawning area locations and characteristics were based on Palauan fishermen information. A 48-hour vigil at Airai Bay was conducted during the April spawning. Piscine activities on spawning dates were observed by standing on the reef flats where the fish gathered before spawning. Attempts to observe the actual spawnings were unsuccessful.

Results

FECUNDITY AND SPAWNING

Ovaries averaged 13,600 eggs per gram on spawning days (n=10, range (r)= 11,030–16,990). Since ovaries averaged 21.7 g at spawning (n=10, r=13.83–38.92 g), the mean number of eggs per female was 295,750. Mean egg diameter was 0.5 mm (n=26, r=0.475–0.530 mm) but increased to 0.69 mm (n=13, r= 0.65–0.72 mm) after extrusion. Ovaries contained eggs of one size.

Ovaries were <2% TBW from August to January. One female taken on 12 January had ovaries of 12.8% TBW. A small number of three-week-old juveniles were found in early March indicating some spawning in early February. Small numbers of juveniles were also found in early July and August indicating additional spawnings in early June and July. In the third week of February ovaries enlarged, a cyclic pattern developing (Fig. 2). Spawning occurred on the evenings of March 10 and 11, April 8 and 9, and May 7 and 8. Spent gonads indicated some individuals spawned a few days before or after the above dates. These dates were four or five days after the new moon when the evening low tides were within 90 minutes of darkness. During spawning week, testes averaged 12% TBW (n=10) dropping to 7% TBW the following week (n=78). Milt could be squeezed from most males a week before spawning dates.

The main spawning area was Airai Bay (Fig. 1). Other spawning areas were less important (according to the Palauan fishermen who rated the areas based on the number of fish available for capture). These areas had the following characteristics: (1) easy access to the open ocean by channels or major breaks in the barrier reef, (2) large areas of *Thalassia* and *Enhalus* flats, and (3) extensive mangrove flats along the shore. Water temperatures at spawning sites were 28–30°C.

S. canaliculatus was found throughout Palau except at spawning times. A few days prior to spawning dates, reports from fishermen indicated that *S. canaliculatus* were moving to the spawning grounds. During the March spawning, a fishermen hired by the MMDC fished off the southwest portion of Koror but caught no *S. canaliculatus* the day before spawning. He had caught 25 and 40 fish on the two previous days using identical equipment and fishing the same length of time.

Schools sighted in Airai Bay on spawning days were assumed to be spawning

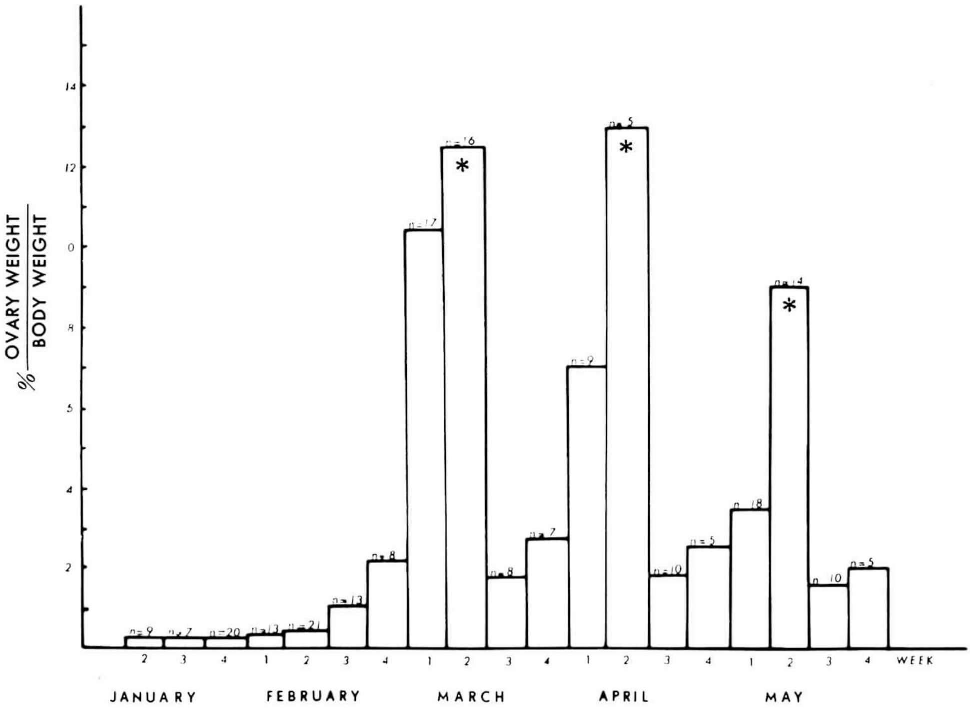

Fig. 2. Average percent ovary weight/body weight of female *S. canaliculatus* at weekly intervals from February to May 1973. During the remainder of the year (except for a small number of fish in June and July) the percent ovary wt/body wt was less than 2%. * denotes spawning week.

schools. Gonad examination of these schools indicated most fish were ripe. Spawning schools averaged 28 fish (n=9, r=13–60) while nonspawning schools averaged 12 fish (n=46, r=4–22). A chi-square test indicated a significant difference ($P<0.05$). Adult sex ratios changed from 3: 1 favoring females during nonspawning times (n=337) to 1: 2 favoring males at spawning times (n=174). Spawning females showed a bimodal average size of 16.0 and 20.0 cm SL while males averaged 15.9 cm SL (Fig. 3).

Actual spawning activities were not observed because of rough surf. Schools of fish were seen moving across the reef flats towards the open ocean for 90 minutes before low tide. Fish caught at the spawning sites the next morning had spent ovaries. All schools examined on the first day of the spawning period contained ripe fish. Of six schools captured on the second day of the two day spawning period, three contained ripe fish while the other schools were mostly spent fish. On the first day of the April spawning period, schools usually were of mixed siganid species with *S. canaliculatus* comprising 38–50% of the fish (n=3 schools). On the second spawning day, schools were 100% *S. canaliculatus* except for one school which was 24% *S. lineatus* (n=6 schools).

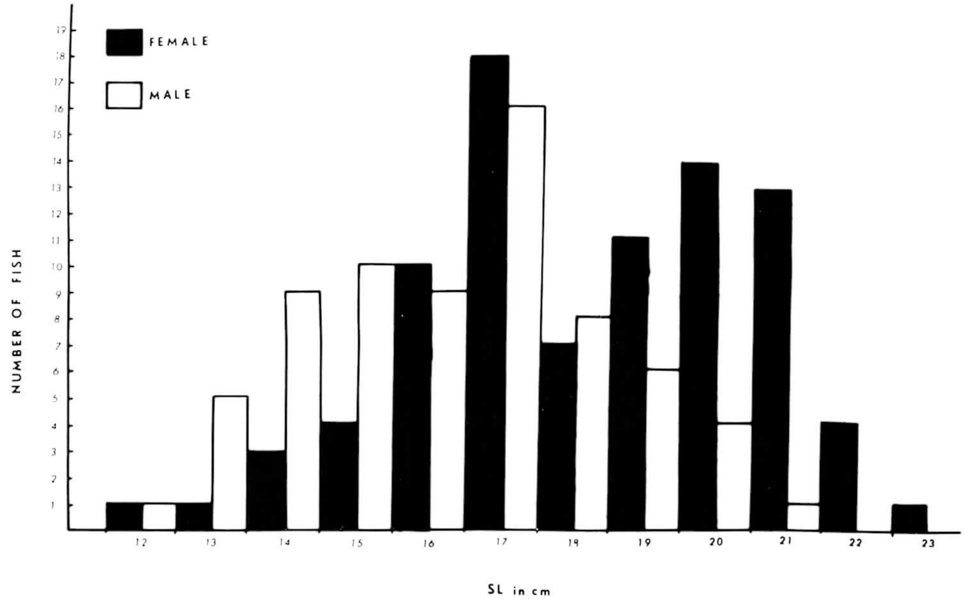

Fig. 3. *S. canaliculatus* in spawning condition from February 23 to May 9, 1973. Female modes=16.0±1.5 cm, 20.0±1.0 cm. Male mode 15.9±2.2 cm.

DAILY ACTIVITIES

During the first six months of life, *S. canaliculatus* grew to nearly 80% of its adult size (Fig. 4). The length-weight relationships for *S. canaliculatus* are expressed as:

$$W♀ = 0.110\ L^{2.46} \qquad W♂ = 0.0363\ L^{2.86}$$
$$r = 0.925,\ df = 70 \qquad r = 0.929,\ df = 70$$

where W=weight (g) and L=standard length (cm). After maturity females were heavier than males of a similiar size (Fig. 5).

Twenty to twenty-three days after spawning, schools of young ($\overline{Y}$=2.3 cm SL) *S. canaliculatus* appeared on the reef flats (Table 1). Extensive searches of the *Enhalus* flats between spawning dates and appearance of young failed to reveal post larval or small (<2.3 cm SL) *S. canaliculatus*. School sizes of young fish were much larger than for adult fish (Table 2). The average number of three-week-old fish in a school was 186, but once, schools averaging 1260 fish were located (n=9, r=200–5000).

Small barracudas (*Sphyraena barracuda*) attacked schools of three-week-old *S. canaliculatus* by slowly approaching schools from above, behind, and off to the side until they were about one barracuda length from the school. They then attacked the school. *S. canaliculatus* reacted by scattering in all directions for a quarter meter but regrouped in a few seconds. In one attack no *S. canaliculatus* were caught but another resulted in two fish being eaten and a third badly injured. One could approach small fish to within a quarter meter but with increasing size

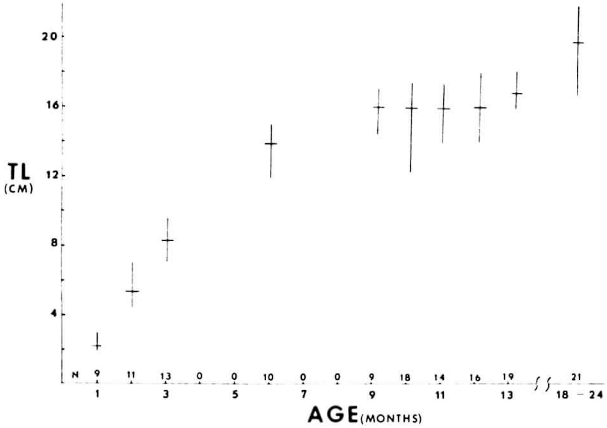

Fig. 4. Growth rate of *S. canaliculatus* based on wild fish from Palau. Vertical bar=range, horizontal bar=mean.

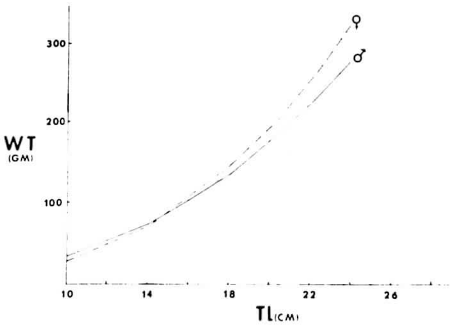

Fig. 5. Length–weight relationships for *S. canaliculatus* from Palau.

Table 1. Time of appearance of young *S. canaliculatus* after spawning date.

spawning date.		
Spawning Date	Appearance Date	Elapsed Time
March 10–11	April 1	20–21 days
April 8–9	May 1	21–22 days
May 7–8	May 31	21–22 days

Table 2. Number of fish per school compared with increase in age for *S. canaliculatus*.

Age	$\bar{Y}$ number of fish	Range	n
3 wks	186	21–595	14
6 wks	27	12–32	6
9 wks	12	12	2
3 mo	11	8–13	2
adult	12	4–22	46

S. canaliculatus became wary. Predation on adult fish was not observed but behavioral responses to a potential predator (man) were noted. When *S. canaliculatus* noticed the approach of an observer from beyond two meters they quickly fled, staying near the bottom. If approached less than two meters before being noticed, the fish darted to the bottom and hid in the *Enhalus* for several seconds, flattening themselves along the substrate before slowly swimming from the observer, usually on their sides. In most instances a marked change in coloration was observed (Fig. 6). This made the fish difficult to notice unless it was moving.

Similiar changes in coloration were observed in fish under low oxygen stress. Adult *S. canaliculatus* acclimated to 6.5 ppm O_2 showed rapid color changes and increased breathing rates at 2.0–2.5 ppm O_2. Death occurred within two hours at

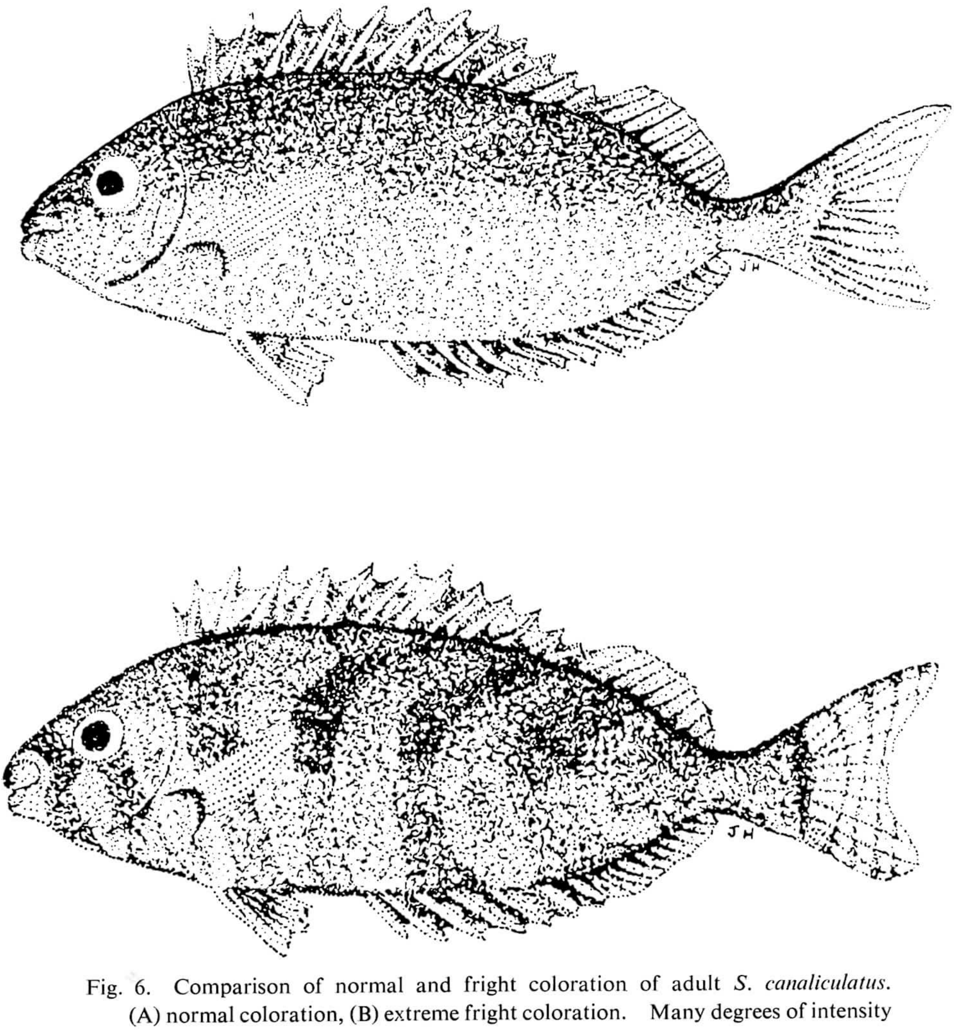

Fig. 6. Comparison of normal and fright coloration of adult *S. canaliculatus*. (A) normal coloration, (B) extreme fright coloration. Many degrees of intensity between the two illustrated patterns were observed.

concentrations of 1.2–1.8 ppm O_2.

S. canaliculatus, a grazer, fed throughout the day except for three-week-old fish. At random intervals, three-week-old fish would stop feeding for up to 30 minutes. During this time they settled on the substrate or *Enhalus* blades or floated motionless a few centimeters from the substrate. In schools where three-week-old fish greatly outnumbered six-week-old fish, younger fish were often found "resting" while older fish fed. If older fish outnumbered younger fish, both sizes fed constantly. Three-week-old fish fed in a 1.5 m^2 area, moving back and forth at a slow rate. Feeding lasted 5–60 seconds then the school moved 0.5 m in a random direction and resumed feeding. Seven-week-old fish fed in the same manner but utilized a 3 m^2 area. Every 10 to 15 minutes schools moved 1–2 m and began feeding again. Schools of adult fish fed in a quarter-hectare area, moving 1–3 m per minute as they grazed.

Juvenile *S. canaliculatus* were seen with juvenile apogonids, mugilids, labrids, and lutjanids, usually greatly outnumbering the other fish. Except for three-to eight-week-old fish, *S. canaliculatus* of different sizes were not found together. Mixed adult siganid schools (*S. doliatus, S. lineatus*, and *S. canaliculatus*) were seen several times, while the only instance of a nonsiganid mix was 12 juvenile *Cheilinus undulatus* and 11 adult *S. canaliculatus*.

Nocturnal activities of wild *S. canaliculatus* were not determined but on moonlit nights, fish held in tanks at the MMDC remained active without feeding. On moonless nights, the fish remained nearly motionless near the substrate, most members of a school facing into the current.

Discussion

Our observations show that *S. canaliculatus* is sexually mature over a wider size range than previously reported though mean size is similar (Drew, 1973; Lam, 1974; Manacop, 1937; Von Westernhagen, 1973). A size difference between sexes among sexually mature fish (females larger) is characteristic of species with large egg production (Breder and Rosen, 1966). A fecundity of nearly 300,000 eggs per female and the larger size of females after maturity (Fig. 5) place *S. canaliculatus* in this category. Since *S. canaliculatus* reaches 16 cm SL in one year (Fig. 4) and fish 12 cm SL were ripe, they mature in less than one year. Juveniles collected from March to May and raised at the MMDC were spawned artificially in less than one year (May et al., 1974; Bryan et al., 1975).

Figure 2 suggests successive spawnings at four-week intervals with later spawnings being of lesser magnitude. The reduced numbers of metamorphosed young appearing on the *Enhalus* flats from June to August also indicates this trend. Bryan et al. (1975) did not find this reduction in captive fish spawned artificially. Larger fish may spawn more than once during a spawning season. Several captive females >17 cm SL spawned twice, 6–8 weeks apart, while fish <16 cm SL only spawned once. Bryan et al. (1975) reported that a captive female spawned two months consecutively and was ripe when killed accidently 1.5 months later.

The number and size of eggs for *S. canaliculatus* from Palau is similar to that for *Amphacanthus oramin* (=*S. canaliculatus*) from the Philippines (Manacop, 1937). Lam (1974) reported 300,000 to 500,000 eggs from Singapore fish. Soh and Lam (1973) described the egg development of *S. canaliculatus*. Manacop (1937) reported a developmental time of 62 hours until hatching for *A. oramin* (=*S. canaliculatus*), but this is twice as long as reported by others (McVey, 1972; Soh and Lam, 1973; May et al., 1974). The poor aeration mentioned by Manacop (1937) combined with cooler incubation temperatures than those reported by the other authors probably accounts for the longer incubation he obtained. May et al. (1974) detailed the larval stages of *S. canaliculatus* including the metamorphosis into the juvenile stage. Other siganid species have developmental stages and times similar to that of *S. canaliculatus* (Fujita and Ueno, 1954; Uchida et al., 1958; Popper et al., 1973).

Some siganids apparently spawn from January to August depending on species and location (Drew, 1973; Ikehara, 1968; Lam, 1974; Lavina and Alcala, 1973; Manacop, 1937; Popper and Gundermann, 1975). *S. vermiculatus* spawns from September to February in Fiji (Popper et al., 1976). The main spawning period of *S. canaliculatus* in Palau is from March to May with minor spawnings in February and June and July. Drew (1973) reported a minor spawning in August.

Manacop (1937) reported *A. oramin* (=*S. canaliculatus*) spawning for a two day period beginning on the fifth day after the new moon. In Palau, S. *canaliculatus* spawns four to five days after the new moon. Extreme low tides near sunset may be a factor determining spawning dates in Palau. The only time of the year that extreme low tide is at sunset is from March through June. This coincides with spawning of *S. canaliculatus*. Lam (1974) has speculated that, "some form of environmental change (probably a fall in water level) is needed to stimulate spawning in siganids." Bryan et al. (1975) believed the stress and excitement of handling triggered spawning in hormone-injected fish. Recent work by Lam and Soh (1975) indicates that photoperiod plays a part in gonad maturation of *S. canaliculatus*; however, the 18-hr daylight period found to retard gonad maturation does not exist in Palau, so the influence of this phenomenon on wild fish is unclear.

The exact spawning sites and activities were not determined in this study. In the Philippines, Manacop (1937) found *A. oramin* (=*S. canaliculatus*) spawning in large schools on tidal flats as the tide receded. According to Ikehara (1968) *S. spinus* spawns on the fringing reef on Guam. All the spawning areas in Palau have tidal flats and fringing reefs often less than 30 m apart. We could not determine which of these two areas were utilized. From the spent gonads found in fish captured at the spawning site the morning after spawning, we believe the fish spawn at dusk or night. Manacop (1937) reported *A. oramin* (=*S. canaliculatus*) spawning after midnight. Bryan et al. (1975) found captive hormone-injected fish spawned late in the evening or early morning. We found uninjected *S. canaliculatus* spawning at similar times at the MMDC. *S. rivulatus* and *S. luridus* spawn in the early morning in the Red Sea (Popper and Gundermann, 1975). If the fish spawn in isolated pairs, we should have found schools consisting of ripe and spent fish. Since we only found schools where all members except an occasional individual were ripe or spent, we assume that *S. canaliculatus* performs a group spawning of individual pairs. Schools of 2 to 20 fish have spawned in captivity at the MMDC and though prespawning activities of all members of the group appeared coordinated, individual pairs were seen forming a few seconds before egg laying. Pairs or small groups of spawning siganids were seen to perform aggressive behavior with flank nibbling by males which resulted in a circular swimming motion (Popper and Gundermann, 1975).

The increase in school size at spawning may be related to group spawning behavior. A minimum number of fish may be required for successful spawning, the normal school size being too small. As the fish gather in the spawning area, schools could easily merge. Schooling species in which sexes are similar in appearance (as with *S. canaliculatus*) often form polyandrous mating associations (Breder and Rosen, 1966). During grazing activities after spawning, the schools break into smaller groups again. We often saw small groups foraging by themselves after splitting from a main group immediately after spawning dates. Frequently these fish did not rejoin the main group.

Manacop (1937) reported that the eggs of *A. oramin* (=*S. canaliculatus*) were laid on the substrate. Extensive searches in this study failed to reveal either eggs or post larval fish on the *Enhalus* flats or mangrove area. We believe that *S. canaliculatus* spends the first three weeks of life as a pelagic organism in the open waters around Palau. Though the eggs are adhesive and slowly sink in still water (McVey, 1972), agitation in and near the surf zone may keep them in the water column. Perhaps the adhesiveness of the eggs aids attachment to floating pieces of plants, etc. which are very common in the waters of the spawning sites. This may provide camouflage and aid floatation. Horn (1975) believed drift associations provided food, shelter, and visual stimuli to fish. A large number of small eggs with numerous oil globules is an indication of pelagic larvae. May et al., (1974) found *S. canaliculatus* to be highly transparent with a silver abdomen until they metamorphosed to the juvenile coloration of tan with numerous small white spots. They also noticed a change in diet from *Artemia* nauplii to *Enteromorpha* at metamorphosis. Ikehara (1968) reported "baitballs" of small siganids in depths of 45 fathoms off Guam shortly before they appeared on the reef flats. Tuna from the same area regurgitated small siganids when caught. Hida (1973) found small siganids in 3.9% of the skipjack tuna (*Katsuwonus pelamis*) stomachs he examined in the Samoa Islands.

Spawning in locations with easy access to the open sea is thought to aid dispersal of pelagic eggs (Randall, 1961a). If the eggs and young of *S. canaliculatus* developed on the reef or *Enhalus* flats, spawning areas would probably not be localized to the extent they are. Areas similar to the spawning sites except for access to the open ocean are numerous in Palau. Though the currents around Palau are not accurately known, there are indications that several current gyres are formed around the islands from mid-January to late June. These would play an important role in maintaining the planktonic siganid populations in close proximity to the islands rather than distributing them into oceanic currents which would transport them away from the juvenile and adult habitat.

In Palau, size apparently can be used to separate fish into age groups. Unpublished MMDC data and Bryan et al. (1975) show that captive *S. canaliculatus* usually are 15–17 cm SL at 12 months. Fish smaller than 17 cm SL (age group I) could often be aged to a given month provided a large enough sample was taken (Fig. 4). In the Philippines, Lavina and Alcala (1973) and Von Westernhagen and Rosenthal (1976) reported ages and lengths similar to those in this study. Considering the growth rate of *S. canaliculatus*, the bimodal distribution of female fish in Figure 3 indicates two age groups. It is assumed that the fish from 18–22 cm SL are age group II, but this can not be shown from present data. It is unknown how long *S. canaliculatus* lives. Lam (1974) postulated that they may die after spawning but Bryan et al. (1975) have refuted that hypothesis. The high number of fish larger than 15–17 cm SL (age group I) sampled in this study indicates that *S. canaliculatus* lives at least two years. Figure 3 suggests that older males may be selected against in some manner.

Tsuda et al. (1974) obtained a length-weight relationship of

$$W=0.0163L^{2.96}$$

W=grams L=fork length (cm)

for captive *S. canaliculatus*. Differences between our length-weight relationship and that of Tsuda et al. (1974) are probably due to differences in growth rates between captive and wild fish and the fact that fish used in our study were 11–24 cm SL while Tsuda et al. (1974) used fish from 2.5–20 cm FL. *S. canaliculatus* from the Philippines reared on artificial diets grew to greater weights than wild caught fish (Von Westernhagen and Rosenthal, 1976).

Our sex ratio data may be biased since Palauan fishing methods favor escape of smaller fish (males are smaller than females on the average, cf. Figs. 3 and 5). We often observed nearly 60% of the catch escape under the nets. Considering the fishing techniques and earlier work done on *S. canaliculatus* in Palau (Drew, 1973), we believe the true sex ratio of the adult population is about 2: 1 favoring females, not 3: 1 as we obtained.

At present we cannot explain the apparent reversal of sex ratios at spawning times. We did not find schools consisting mostly of males which could supply "extra" males to the spawning schools. There may be increased reluctance of males to separate from females during spawning times, hence fewer escape under the nets.

Randall and Brock (1960) reported siganids less than 5 cm SL in stomachs of *Cephalopholis argus, Epinephelus merra,* and *Lutjanus vaigiensis* from the Society Islands. Both *C. argus* and *E. merra* are found in Palau (Helfman and Randall, 1973). *Synodus variegatus, Fistularia* sp., and large mullids are siganid predators in the Red Sea (Popper and Gundermann, 1975). The behavior of barracuda attacking *S. canaliculatus* is similar to that observed when attacking *Chromis* (Hartline, et al., 1972).

The striking change in coloration of *S. canaliculatus* in the fright pattern and under oxygen stress is typical of siganids in general (Lam, 1974). Burgess and Axelrod (1971: 93–95) illustrated the change of *Lo vulpinus* and *S. virgatus* with color photographs. An additional pattern of "a thick dark gray stripe along the middle of the body bordered by two thin white stripes" was reported by Drew (1973) for *S. canaliculatus* which fled from a disturbance without utilizing cover. Popper and Gundermann (1975) reported a similar pattern for *S. rivulatus* disturbed over a sandy substrate. We never observed this coloration since *S. canaliculatus* always used cover when moving away from us. Lam (1974) described the mottled appearance of *S. canaliculatus* as the "fright" stage while the pattern we considered "extreme fright" was classed as a camouflage pattern. Additional work on the classification of coloration patterns in siganids is needed in order to clear up the differences in terminology.

The difference between young and old fish reacting to danger fits a pattern where older fish flee and hide whereas younger fish react slightly (Nikolsky, 1963). The slight escape reaction in young may allow predators to capture many of them and this may be why school size decreases so dramatically 21 to 30 days after spawning. Popper and Gundermann (1975) believe this is the main reason for school size decrease in Mediterranean and Red Sea siganids. Breaking up into more numerous but smaller schools is also a possibility. The single instance of finding larger schools of young than normal resulted from a combination of extremely low tides in an area where the *Enhalus* flats were without depressions or channels. The fish were found at the edges of deep channels. The schools divided into smaller groups as they moved back onto the *Enhalus* flats following low tide.

Continuous grazing during daylight hours is found in species utilizing niches similar to *S. canaliculatus* (Hobson, 1965; Helfrich et al., 1968; Earle, 1972). Grazing groups of mixed species were reported by Earle (1972). An analysis of her results showed that in many instances, a single species outnumbered the remainder of the other species. *S. canaliculatus* frequently outnumbered other species in its grazing group. Alevizan (1976) suggested that schooling of mixed species of herbivorous fish may provide access to normally unavailable food resources. There is also the possibility that an antipredator behavioral mechanism is involved (Hobson, 1969; Ehrlich and Ehrlich, 1973) but since the other species mingling with *S. canaliculatus* differ noticeably in size and coloration, we tend to believe the former explanation is more important for survival of *S. canaliculatus*.

The reason or reasons for the "rest periods" of juvenile *S. canaliculatus* are unknown. Lack of the "rest periods" in three-week old fish may be related to protection against predators associated with schooling. Since older fish graze over a larger area than younger fish, the smaller fish must remain active or risk separation from the school. Likewise, older fish would soon outdistance younger fish if they did not graze over a smaller area when greatly outnumbered by younger fish.

Intolerance of oxygen concentrations below 2.0 ppm is consistent with data presented by other authors (Lam, 1974; Lavina and Alcala, 1973). We did not locate any natural areas in Palau where low oxygen concentrations would influence *S. canaliculatus* activities.

An increased level of activity on moonlit nights is characteristic of diurnal fishes (Hobson, 1965). Randall (1961b) reported *Acanthurus triostegus sandvicensis* in a semistuporous state resembling sleep, much like that found for *S. canaliculatus* on moonless nights. Nocturnal inactivity and camouflage coloration were found in *S. rivulatus, S. luridus* and *S. argenteus* (Popper and Gundermann, 1975).

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