SEASONAL SPAWNING CYCLE, SPAWNING FREQUENCY, AND BATCH FECUNDITY OF THE CABEZON, *SCORPAENICHTHYS MARMORATUS*, IN PUGET SOUND, WASHINGTON[1]

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ABSTRACT

The seasonal spawning cycle, spawning frequency, and batch fecundity of the cabezon, *Scorpaenichthys marmoratus*, were studied in Puget Sound, Washington, USA between September 1984 and October 1985 using scuba techniques. Seasonal embryo mass abundance and ovarian condition indicated that the spawning season started in November and continued 10 months through the following September while peak spawning activity occurred during March and April. Three factors revealed in this study indicated that females may spawn more than once during a single spawning season: 1) the presence of an intermediate mode of yolked oocytes, 2) a low wet gonadosomatic weight index, and 3) a protracted spawning season. Batch fecundities predicted from regressions on weight and length ranged between 66,000 and 152,000 eggs for females from 2.5 kg to 10.5 kg and between 57,000 and 137,000 eggs for females from 500 mm to 775 mm.

Out of approximately 300 cottid species worldwide (Nelson 1984), the cabezon, *Scorpaenichthys marmoratus*, is perhaps the largest (Jordan and Everman 1898) and can attain a length of 990 mm and a weight of 11.4 kg (Feder et al. 1974). Cabezon range from Pt. Abrejos, Baja California (Miller and Lea 1972) to Samsing Cove near Sitka, AK (Quast 1968). Their depth range in California is from nearshore tidepools to 76 m (Feder et al. 1974). Cabezon are demersal and solitary and are usually associated with reefs, boulders, or beds of kelp, algae, or eelgrass.

A small recreational fishery exists for cabezon. For divers who spearfish, cabezon are prime targets because of their trophy size, desirable food qualities, and general vulnerability in shallow nearshore habitats. Knowledgeable anglers also enjoy catching and eating cabezon even though they are not generally targeted (Olander 1984).

Although cabezon are not targeted by a commercial fishery at present, they are incidental in commercial catches and they do occasionally appear in fish markets along the west coast (Ayres 1854; O'Connell 1953; personal observations in fish markets in Seattle, WA).

There is little published information on cabezon reproductive biology aside from a life history study in Monterey, CA done by O'Connell (1953), studies of cabezon roe toxicity (Fuhrman et al. 1969, 1970; Hashimoto et al. 1976; Hubbs and Wick 1951; Pillsbury 1957), and diving observations of cabezon nesting behavior in a California kelp forest (Feder et al. 1974). Spawning season, spawning frequency, and batch fecundity of cabezon north of California have to date, not been studied. Thus, it seems prudent that we learn about the reproductive biology of cabezon in other areas, especially because of their value as a fishery resource. The objective of this study was to examine the spawning ecology of cabezon in Puget Sound, WA and to make a geographical comparison with data for cabezon in California.

METHODS AND MATERIALS

Study Sites

Sampling consisted of transect and collection dives. Sampling began in September 1984 and ended in October 1985 and was done using scuba techniques. Edmonds Underwater Park and the Edmonds Marina breakwater, both located in Edmonds, WA, USA (lat. 47°48'N, long. 122°22'W; Fig. 1), were chosen as study sites because they had been previously identified by the author as spawning areas for cabezon. Two transects, each covering 250 m^2, were established along a scuttled dry dock at Edmonds Underwater Park. Transect 1 was the remains of the northern bulkhead of the drydock

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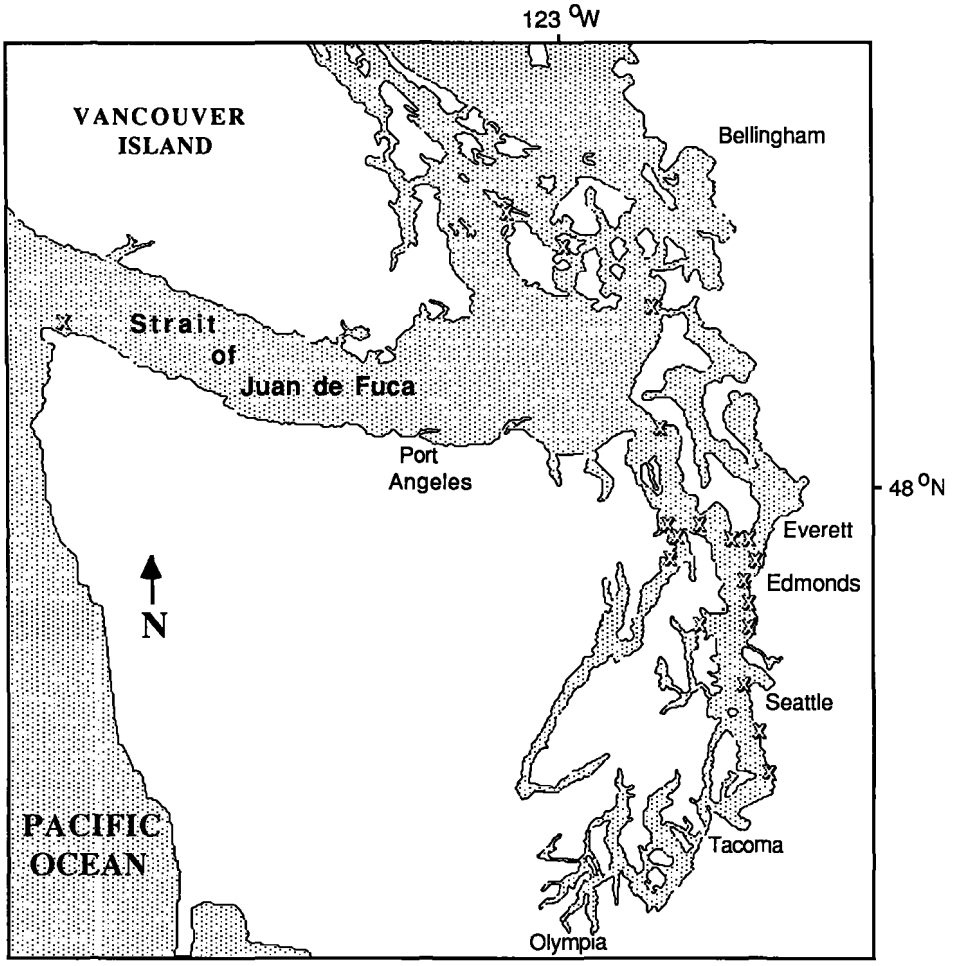

FIGURE 1.—Map of Puget Sound, Washington, USA showing the general location of scuba sampling sites (X).

and was 65.5 m long and 3.8 m wide. The southern half of the drydock, designated Transect 2, was 30 m south of Transect 1 and was 55 m long by 4.5 m wide. The eastern and western ends of both Transects 1 and 2 were in 6.0 m and 9.0 m of water (MLLW, i.e., Mean Lower Low Water), respectively.

Transect 3 was a portion of the Edmonds Marina breakwater parallel to a Washington Department of Fisheries' fishing pier. The transect was 150 m in length by 5 m in width and covered a total area of 750 m^2. The breakwater consisted of large basalt boulders that extended from 3 to 5 m (MLLW) below the surface of the water. In addition to the breakwater, the transect included a sandy area with interspersed boulders to a depth of 7 m (MLLW).

Transect and Collection Dive Sites and Procedures

Each transect was sampled at least once a month. Dives were made more frequently when spawning activity increased. Fifty transect dives totalling 46 hours of bottom time were made. Physical data collected on each dive included water temperature and depth. Biological data gathered included number of cabezon and number and depth of embryo masses. Dives in spawning areas were made during all hours of daylight. Collection of specimens for biological data was by pneumatic speargun. Forty-eight collection dives totalling 36 hours of bottom time were made. Fifty female cabezon were collected throughout Puget Sound, including areas in the Strait of

Juan de Fuca and San Juan Islands (Fig. 1). All specimens captured were weighed to the nearest 0.1 kg and total length measured to the nearest mm.

Processing of Ovaries

From 1 to 10 females were sampled each month so that the progression of ovarian development could be followed throughout the study period and spawning frequency could be determined. Entire ovaries were excised, weighed to the nearest 0.1 g, put in gauze bags, and placed in modified Gilson's solution to harden the eggs and to break down ovarian tissue (Simpson 1951).

After 5 to 6 months in Gilson's solution, the eggs from each ovary were separated from the ovarian tissue using a mild jet of water while passing them through a series of Tyler[3] brass sieves with openings of 1.651 mm, 0.295 mm, 0.180 mm, and 0.075 mm. Most eggs with diameters less than 0.075 mm passed through the smallest screen and were discarded. Loose eggs were retained by the sieves and stored in jars with 5% formalin.

Ova Diameter Frequencies

Eggs and water (2.5 L) were homogeneously mixed in a 4 L beaker with magnetic stirrer. A random 5 mL subsample was drawn with a pipette and the eggs were measured with a calibrated ocular micrometer.

At least 200 eggs were measured from each ovary. Ova diameters were grouped using 0.05 mm increments as midpoints. Based on ova diameter frequency histograms, ovaries were grouped into eight stages (I-VIII). Ranges, means, medians, and standard deviations were calculated for the apparent modes within each stage.

I calculated a wet gonadosomatic weight index (WGSI) for each female using the formula of Gunderson and Dygert (1988). The WGSI's for each stage of ovarian development were averaged and used as a measure of relative gonadal investment of females.

The Number of Eggs to be Spawned

The subsampling procedure for estimating the number of eggs to be spawned was identical to the one for measuring ova diameters. Subsamples were enumerated using a dissecting microscope, a gridded petri dish, and a laboratory counter. When modes in an ovary overlapped, the number of eggs from the largest mode were counted twice and averaged. At least three subsamples were taken for each ovary and the mean total number of eggs to be spawned was calculated, using a simple volumetric proportion. If the coefficient of variation was greater than 10%, additional subsamples were made until it dropped below 10%.

Unweighted least-squares linear regression was used to predict the total number of eggs to be spawned using lengths and weights of females as independent variables. All regression analyses were done with a personal computer according to methods described by Kleinbaum and Kupper (1978).

RESULTS

Seasonal Embryo Mass Abundance

The beginning and end of the spawning season were defined as the dates when embryo masses were first and last seen. During 19 collection and transect dives throughout Puget Sound from mid-September until the end of November, no cabezon embryo masses were observed. The first embryo mass observed in Puget Sound was on 6 December 1984. A sample of eggs from this embryo mass was placed in a 5 gal bucket filled with seawater and most hatched within 30 minutes. The eggs were apparently near the end of their incubation period since little of the yolk sac was remaining. Based on work from this study, incubation time until hatching is several weeks, thus the embryo mass was most likely deposited sometime in middle or late November 1984.

Along Transects 1, 2, and 3, embryo masses were first observed on 2 January 1985 and 7 and 21 December 1984, respectively. After the first embryo masses appeared, there was a steady increase in abundance with some fluctuation (Fig. 2). The peak number of embryo masses at all three transects occurred during March and April 1985, after which there was a general decline. By 30 August 1985, embryo masses were totally absent from Transects 1 and 2 and by mid-September 1985, none were found at Transect 3 or elsewhere in Puget Sound.

Between November 1984 and September 1985, there were 35 embryo masses observed on Transect 2, 23 embryo masses on Transect 1, and 15 embryo masses on Transect 3. It is possible that some embryo masses may have hatched or disappeared (e.g., predation, cannibalism, dislodged by physical dis-

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

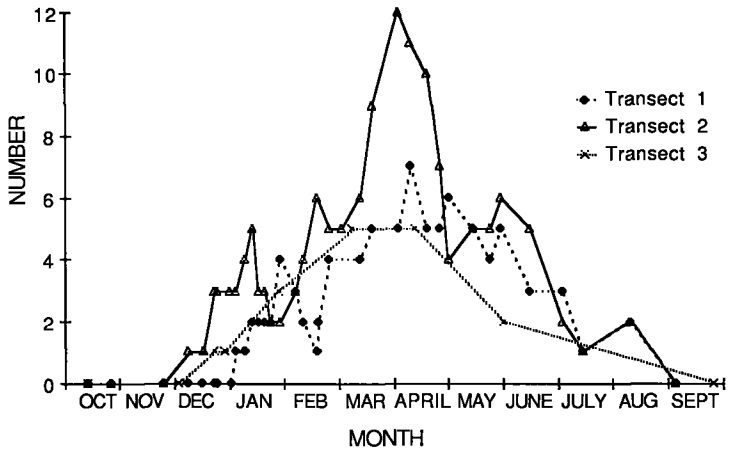

FIGURE 2.—Temporal fluctuation in the abundance of cabezon embryo masses at Transects 1, 2, and 3.

turbance) between dives; thus the totals may have been underestimated.

It was assumed that incubation time of eggs till hatching was the time between when an embryo mass was first observed and when hatching was first noted. For 13 nests that were monitored from 21 January to 26 May 1985, incubation time ranged between 25 and 49 days and averaged 34 days with a standard deviation of 6.8 days. Water temperature varied between 8° and 10°C during this period.

Embryo masses were found in the intertidal to depths of 17 m and were deposited on hard substrates including wood pilings and logs, rocks, and steel. Embryo masses were always observed on exposed surfaces rather than underneath structures or inside crevices.

Spawning Frequency

Ova diameter frequency plots were used, in part, to determine the frequency of spawning. Eight stages of ovarian development, designated I to VIII, were delineated based on the modal configurations of ova diameter frequency plots (Fig. 3). Seven ovaries were in Stage I, characterized by relatively small resting oogonia with diameters ≤0.40 mm (Fig. 3I). The bulk of the eggs from Stage I were translucent, devoid of yolk, and had diameters ≤0.20 mm. Eggs of this size and with these characteristics were present in all eight stages.

Stage II ovaries were found in six cabezon (Fig. 3II). In addition to the large reserve of resting oogonia, there was another mode of opaque eggs which averaged 0.46 mm and ranged from 0.35 to 0.65 mm.

Stages III to VII represented two basic types of female spawners: those which were going to spawn for the first time (Stages III to V) and those which had already spawned once and had the potential for spawning again (Stages VI and VII). For both groups (spawned and unspawned), there were two groups of yolked oocytes.

There were seven female cabezon with Stage III ovaries (Fig. 3III). Besides the resting oogonia, there was an intermediate mode (average 0.47 mm, range 0.35 to 0.65 mm) which represented a reserve group of immature oocytes for future spawning, and a larger mode (average 0.84 mm, range 0.70 to 1.10 mm) which consisted of maturing ova destined to be spawned within the current spawning season. In Stage IV, egg hydration was beginning and the largest mode was more distinct than in Stage III ovaries (Fig. 3IV). The largest mode of yolked oocytes averaged 1.23 mm and ova diameters ranged from 1.00 to 1.45 mm in Stage IV ovaries.

For females with Stage V ovaries, spawning was imminent and there was no evidence of prior spawning (Fig. 3V). The modal configuration of an ova diameter frequency plot of a female captured while actually spawning was Stage V. For all Stage V ovaries combined, the average diameter of the largest mode (hydrated eggs) was 1.48 mm and the range was from 1.35 to 1.65 mm. Eggs from the intermediate mode had an average diameter of 0.55 mm and ranged from 0.35 to 1.0 mm.

Stage VI ovaries were characteristic of recently

spawned females (Fig. 3VI). Three females with Stage VI ovaries were collected in the immediate vicinity of freshly deposited embryo masses, presumably after spawning them. Within these ovaries, an incipient mode, which ranged in size from 0.70 to 0.95 mm and had a mean size of 0.79 mm, was apparent. A relatively small number of large diameter eggs (~1.5 mm) were scattered within all Stage VI, Stage VII, and Stage VIII ovaries (Fig. 3VI–VIII) and were presumably remnants of the recent spawning event. In Stage V females the largest mode would mask evidence of residual eggs so it was not possible to ascertain whether they had already spawned in the 1984–85 spawning season.

As the ovaries progressed to Stage VII, the eggs of the incipient mode were larger and distinct from the intermediate mode. These yolked eggs appeared to be hydrating in preparation for another spawning. Females exhibiting this condition had spawned previously and since eggs of an intermediate size were still present, these females were capable of spawning again. The incipient mode for Stage VII ovaries ranged from 0.95 to 1.50 mm with a mean of 1.16 mm. The intermediate mode of Stage VII ovaries ranged from 0.35 to 0.90 mm and averaged 0.51 mm.

Stage VIII ovaries were similar to Stage I ovaries. There was a single and small mode of eggs which were deteriorating noticeably. Irregularly shaped ova were translucent or transparent and devoid of yolk. Unlike Stage I, Stage VIII ovaries had remnant eggs (~1.5 mm in diameter) from at least one previous spawning event (Fig. 3VIII).

When the eight stages were plotted against the date when females were captured, a general progression of ovarian development was seen (Fig. 4). Stage III to V ovaries were only seen in females caught between December and May. Stages VI and VII were found from February through August. Stage VIII females were caught both before and after Stage III through VII females. The early Stage VIII's were probably carry-overs from the previous spawning season. Females in Stages I and II were found prior to all other stages.

The WGSI values for the eight stages of ovarian development were in agreement with what might be expected in a multiple spawner (Fig. 5). For ovaries in the resting condition (Stage I), the WGSI was at its lowest point. The WGSI gradually increased to a maximum in Stage V when eggs were hydrated and females were in spawning condition. After the eggs were released there was an obvious drop in the weight of the ovaries relative to the body weight. The WGSI slightly increased in Stage VII and then fell in Stage VIII. Without the aid of histological techniques, it was not possible to distinguish an intermediate stage between VII and VIII; this stage would have been virtually identical to Stage V, and had there been such a stage, it is conceivable the WGSI would have reached another maximum before finally declining in Stage VIII.

Relation Between Batch Fecundity and Weight and Total Length

From ova diameter frequency plots, two basic types of female spawners were evident: 1) those which were going to spawn for the first time (unspawned; Stages III to V), and 2) those which had already spawned at least once and had potential for spawning another batch (spawned; Stages VI and VII). The number of eggs to be spawned during each spawning event (batch fecundity) was determined by estimating the number of eggs in the largest mode for females possessing ovaries in stages III to VII.

Data for spawned and unspawned females was pooled for regression analysis because the range of values for comparable fish weights and lengths was similar, and because separate regressions for spawned and unspawned females were not statistically different ($P > 0.05$). Furthermore, pooling spawned and unspawned data provided analysis over a broader size range of fish and considerably increased the sample size. The resulting regressions of batch fecundity on length and weight were significant at $P < 0.001$, and the correlation coefficients were 0.69 and 0.73, respectively (Fig. 6). The regression of batch fecundity on length predicted that females from 500 mm to 775 mm would release between 57,000 and 137,000 eggs during a spawning event, and the regression of batch fecundity on weight predicted that females from 2.5 kg to 10.5 kg would release between 66,000 and 152,000 eggs during each spawning event.

DISCUSSION

Along the western U.S. coast, the length of the spawning season for marine cottids varies from 1 month to year-round (Atkinson 1939; Jones 1962; Marliave 1975; Tasto 1975; DeMartini 1978; DeMartini and Patten 1979; Goldberg 1980; Garrison and Miller 1982). Based on temporal embryo mass abundance and ovarian condition, cabezon spawning in Puget Sound commences in late November and lasts 10 months through early September of the following year while peak spawning occurs from

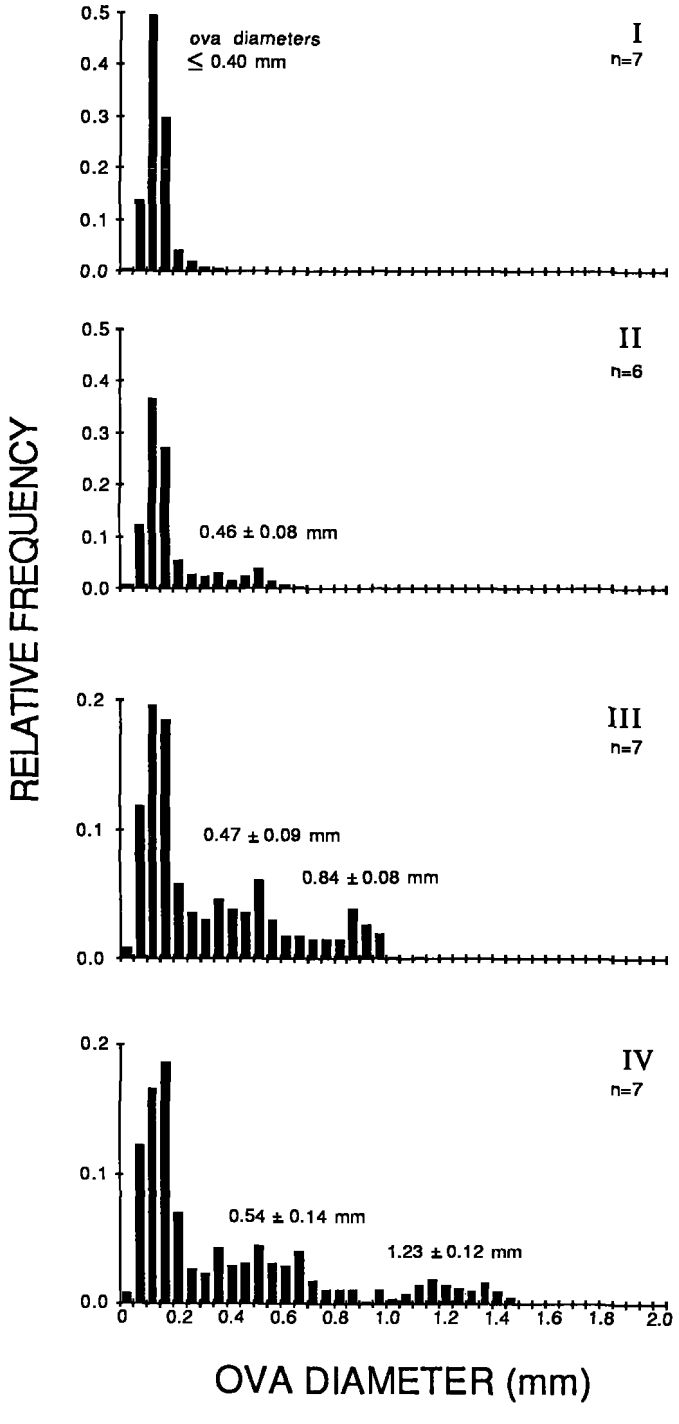

FIGURE 3.—Eight stages of ovarian development (Stages I to VIII) based on the modal configuration of ova diameter frequency plots.

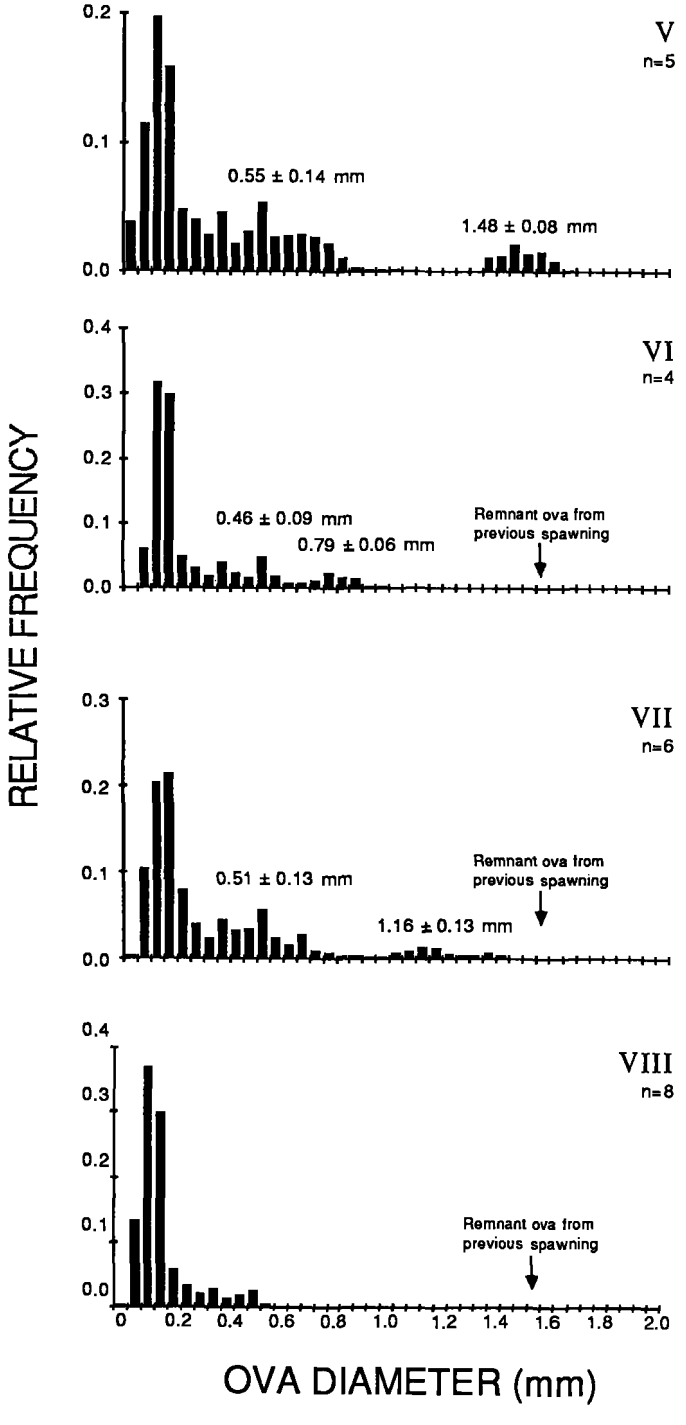

FIGURE 3.—*Continued.*—Modal average ±1 standard deviation are listed above each mode.

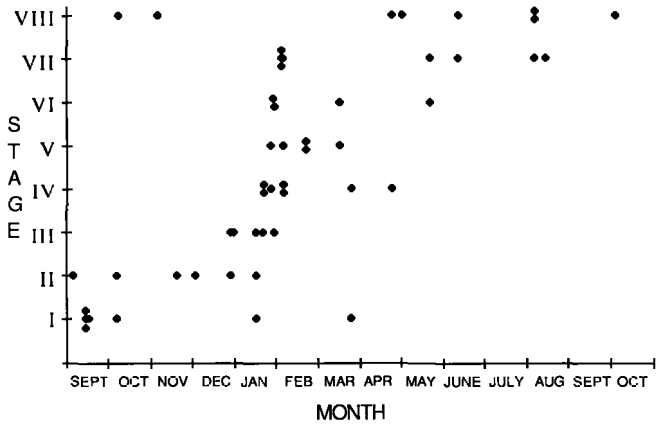

FIGURE 4.—Stage of ovarian development versus time of capture.

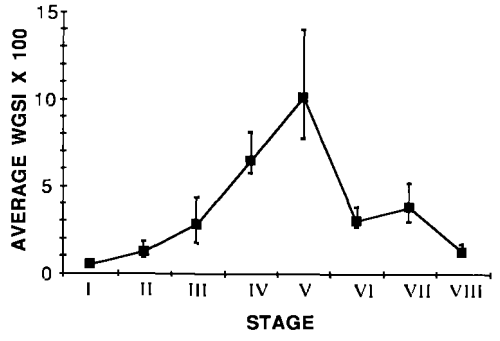

FIGURE 5.—Average wet gonad-somatic weight index (WGSI) x 100 versus stage of ovarian development. Vertical bars represent the 95% confidence limits.

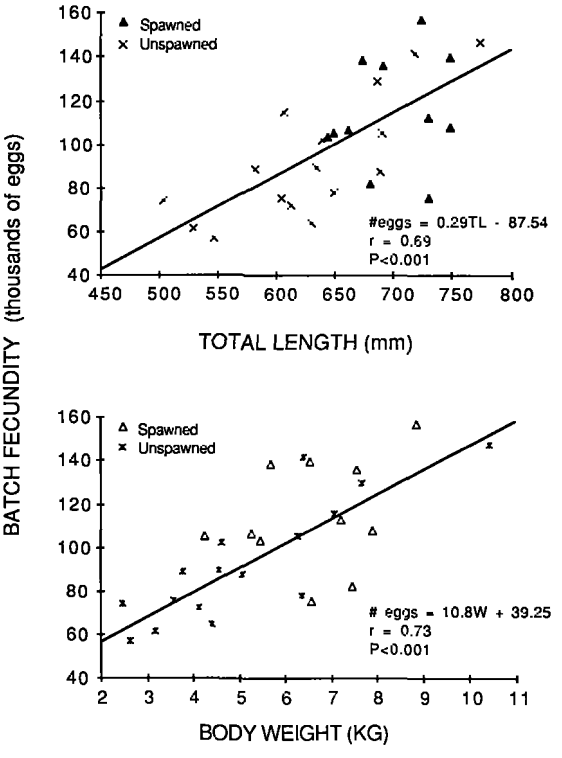

FIGURE 6.—Plots and regressions of batch fecundity (thousands of eggs) versus total length (mm) and weight (kg) for female cabezon from Puget Sound.

March to April. The spawning season reported for *S. marmoratus* in California is half as long (November to March) and peak spawning occurs 3 to 4 months earlier (O'Connell 1953) than found in this study. This is contrary to what one might expect based on general patterns (Qasim 1956). Teleosts in high latitudes generally spawn once and have relatively short spawning seasons during the winter and early spring. On the other hand, most fishes at lower latitudes have protracted spawning seasons and spawn more than once. Seasonal fluctuations in production cycles (food supply) are less defined in lower latitudes, hence females are able to feed more or less continuously to build sufficient energy reserves for a longer spawning season consisting of multiple batches. Spawning time and duration usually synchronize with production cycles so that larvae have a better chance for survival (Nikolsky 1963; Cushing 1982).

Female cabezon are probably similar to other species of marine sculpins along the west coast which spawn multiple batches of eggs during a single spawning season (Atkinson 1939; DeMartini 1978; Goldberg 1980). O'Connell (1953) suspected

that cabezon in California spawned more than once. Evidence from this study also strongly suggests that sexually mature female cabezon spawn more than once during a single spawning season. Species with protracted spawning seasons characteristically spawn more than once per season compared with species with relatively short spawning seasons which spawn only once (Qasim 1956).

Another strong indication of multiple spawning is the presence of two distinct modes of yolked oocytes in ovaries. A second mode was present both in females about to spawn, and in females which had spawned at least once. An intermediate mode consisting of vitellogenic oocytes suggests that females are capable of spawning more than once in a single season (Goldberg 1981). It does not appear that the intermediate generation of yolked eggs are retained for the following season, because cabezon ovaries undergo resorption in the fall (Stage VIII) prior to beginning another cycle the following season (Stage I; Fig. 3I).

Interestingly, after March 1985, all females captured had spawned at least once. The ovaries of all females captured between March and September were either in the process of bringing another batch of eggs to maturity, or in the process of resorption. Multiple spawning is a possible explanation for the absence of females with ovaries in the unspawned condition during the March to September period.

Multiple spawning is also a logical explanation for the relatively low WGSI value for cabezon ovaries with yolked and unhydrated eggs (Stage III). Gunderson and Dygert (1988) showed a relation between "reproductive effort" (WGSI) and natural mortality (M) in numerous species of marine fish ($r^2 = 0.81$). The higher the natural mortality (M), the shorter the longevity ($t_{0.01}$) of the species and thus the greater the "reproductive effort" invested in any given year. The two extremes cited were the northern anchovy ($M = 0.92$, $t_{0.01} = 6$ years, WGSI = 0.65) and dogfish ($M = 0.09$, $t_{0.01} = 57$ years, WGSI = 0.04). Since few cabezon probably live past 20 years (O'Connell 1953; Lauth 1987), one would expect their respective WGSI to fall somewhere between the northern anchovy and dogfish. The very low cabezon WGSI is therefore consistent with multiple spawning, since it should theoretically be higher than dogfish, which it is, but only if multiple spawning is taken into consideration.

Batch fecundities predicted from regressions on weight and length ranged between 66,000 and 152,000 eggs for females from 2.5 kg to 10.5 kg and between 57,000 and 137,000 eggs for females from 500 mm to 775 mm. O'Connell (1953) also found a linear relationship between total weight of females and batch fecundity. Batch fecundities for cabezon greater than 2.7 kg were slightly higher for combined unspawned and spawned females from California and ranged from 48,700 to 96,700 eggs for females between 1.4 kg and 4.6 kg (O'Connell 1953).

Of course, total fecundity of cabezon depends on spawning frequency. The number of times a female actually spawns may depend on a host of biotic and abiotic factors such as food availability and water temperature. The intermediate mode may represent a reserve of eggs that a female can spawn within a single season. The actual number of times a female spawns and the number of eggs released each time, however, may ultimately depend on the amount of energy allotted for reproduction given the prevailing physical and biological conditions. In smaller females, more of the energy would be utilized for growth or basic metabolic needs, hence, less energy would be available for egg production.

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