ASPECTS OF THE BIOLOGY OF TWO SCYLIORHINID SHARKS, *APRISTURUS BRUNNEUS* AND *PARMATURUS XANIURUS*, FROM THE UPPER CONTINENTAL SLOPE OFF SOUTHERN CALIFORNIA

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ABSTRACT

The distribution, abundance, reproductive cycle, and food habits of two scyliorhinid sharks are discussed. Catsharks occurred on 87% of 71 longline sets and in 6% of 48 trawls. Longline catches were stratified by habitat into banks (hard substrate) and mud (soft substrate). *Apristurus brunneus* occurred more frequently on mud sets than on bank sets, but its abundance was similar in both habitats. *Parmaturus xaniurus* occurred equally frequently on mud and bank sets, but it was more abundant on bank sets. Catches of both species consisted of adults and adolescents; juveniles were rare or absent. Historical collections suggest that juveniles are mesopelagic.

Male *P. xaniurus* matured at a smaller size than male *A. brunneus*. Females of both species matured at about the same size and fecundity increased with female size. The proportion of body weight devoted to gonads and maximum oocyte size were greater among *P. xaniurus*, but fecundity and the proportion of females carrying egg cases were greater among *A. brunneus*. Seasonal changes in gonadal development were not well defined for either species. Members of both populations may have been reproductively active throughout the year.

The diets of both species comprised, in order of importance, crustaceans, teleosts, and squids. Most prey consumed were pelagic; however, it is not known where in the water column the catsharks obtained their prey.

The Scyliorhinidae is the largest family of living sharks with about 94 valid species (Nelson 1984). Commonly known as catsharks, they occur worldwide from tropical to cold-temperate and arctic waters from the intertidal to depths greater than 2,000 m. Little is known about the biology of most scyliorhinid sharks despite their abundance and widespread distribution (Springer 1979; Compagno 1984).

Apristurus brunneus Gilbert, the brown catshark, occurs in the eastern Pacific Ocean from northern British Columbia, Canada, to northern Baja California, Mexico, and perhaps south to Central America and Peru. It is common on the outer continental shelf and upper slope off British Columbia, Washington, and northern California (Springer 1979) but is considered uncommon off central and southern California (Miller and Lea 1972). DeLacy and Chapman (1935) and Cox (1963) described its egg case. Jones and Geen (1977) made observations on its distribution, reproduction, and food habits in British Columbia waters.

Parmaturus xaniurus Gilbert, the filetail catshark, occurs in the eastern Pacific Ocean from central California to the Gulf of California, Mexico. It is fairly common on the outer continental shelf and upper slope (Compagno 1984). Cox (1963) described its egg case. Lee (1969) reported that juveniles were captured by midwater nets in the Santa Barbara basin off southern California. Springer (1979) reported that *P. xaniurus* were observed eating moribund lanternfishes (Myctophidae) at the bottom of the oxygen-poor Santa Barbara Basin.

The objective of this study was to increase the knowledge of the life histories of *A. brunneus* and *P. xaniurus* by analyzing data on the distribution, abundance, reproduction, and food habits of these species collected during a survey of the fishes of the upper continental slope off southern California (Cross 1987).

MATERIALS AND METHODS

Fishes occurring on or near the bottom between 290 and 625 m were collected by otter trawl and longline. Forty-eight trawls were made between November 1981 and August 1983 (Fig. 1). A single warp semiballoon trawl with 7.6 m headrope, 8.8 m

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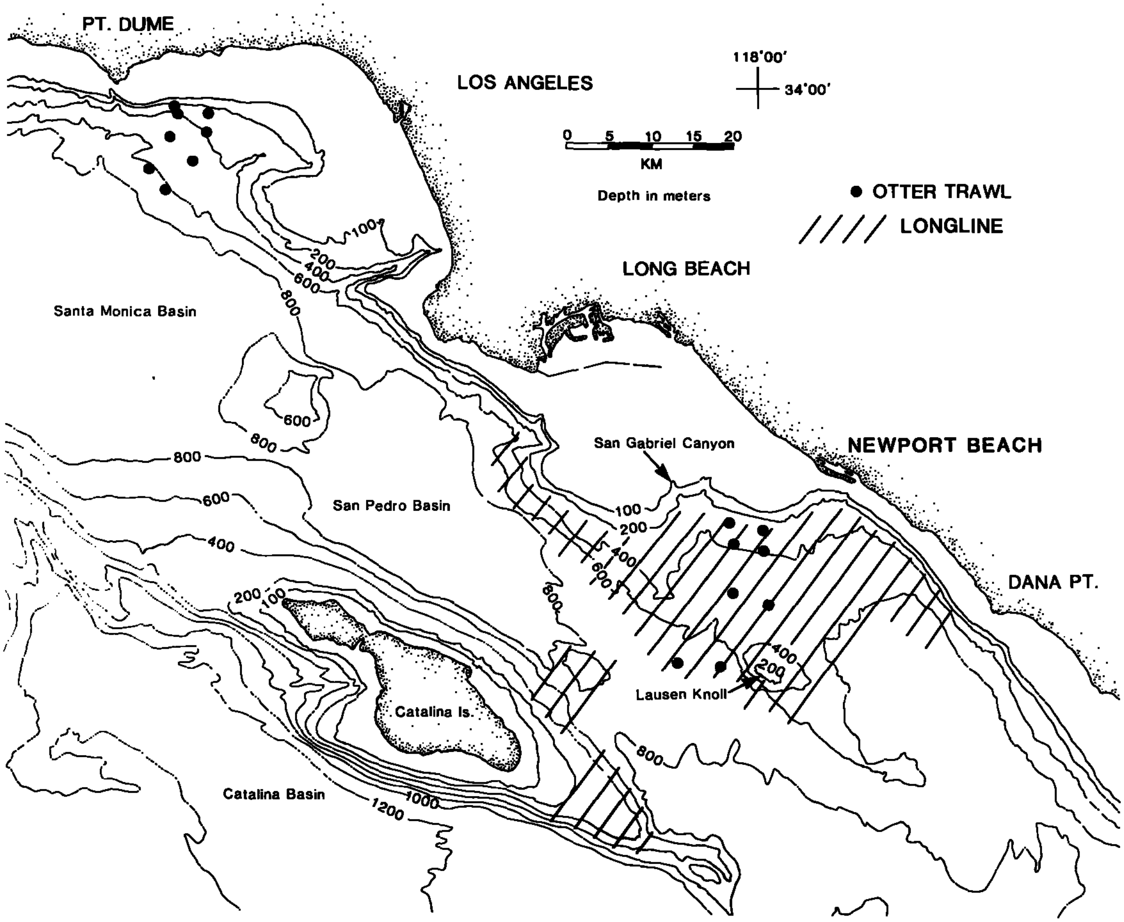

FIGURE 1.—Map of the study area.

footrope, 4.1 cm (stretched) body mesh, and 1.3 cm (stretched) cod end liner was towed along an isobath at approximately 2.5 knots for 10 minutes.

Seventy-one trips were made with commercial longline fishermen between June 1983 and November 1984 (Fig. 1). A unit (tub) of longline gear consisted of about 650 m of groundline bearing approximately 600 hooks (4/0 and 5/0 standard rockcod) on short leaders. Salted pieces of *Engraulis mordax* and, to a lesser extent, *Scomber japonicus* were used as bait. Three to six tubs tied together formed a set. Usually, lines were set between the hours of 1000 and 1400 and retrieved the following day between 0600 and 1000.

Sinking and floating longlines were set. On sinking sets, weights (bricks) were tied to either end of the groundline and at intervals along the line. On floating sets, weights and floats (soda bottles) were tied alternately to groundline; the distance between two weights encompassed 50–60 hooks. Anchors and buoy lines were attached to each end of the groundline. Floating and sinking lines were set on mud, but only floating lines were set on banks. Sets on the mud ranged from 400 to 600 m deep; sets on the banks ranged from 350 to 550 m deep.

Scyliorhinid sharks were taken to the laboratory where they were measured to the nearest 1 mm total length (TL) and weighed to the nearest 0.1 g. The left clasper of males was measured to the nearest 0.5 mm. The gonads were removed and weighed to the nearest 0.1 g. All eggs larger than 4 mm in diameter were separated from the ovary and measured to the nearest 1 mm. Stomachs were removed and placed in 10% buffered formalin; the contents were washed in water, sorted, and identified to the lowest taxon practicable; pieces of bait were ignored.

Size at sexual maturity was estimated for males by change in relative size of the claspers and testes, and for females by change in relative size of the ovaries and presence of egg cases in the oviducts (Pratt 1979). Polynomial regressions were fit to the data for males (SAS 1982). The reproductive season was determined by enlarged testes in the males and the presence of full-sized eggs in the ovaries of the females. The gonadosomatic index (GSI) was calculated for the sexes of both species from

$$\text{GSI} = (\text{gonad weight/body weight}) \times 100.$$

Analyses of stomach data were summarized by the index of relative importance (IRI) modified from Pinkas et al. (1971):

$$\text{IRI} = PO(PN + PW)$$

where PO is percent occurrence, PN is percent numbers, and PW is percent weight calculated for each prey category. The length of intact prey was measured.

Catch/effort data (where a unit of effort was one tub of line) were transformed to $\log_{10}$ and analyzed for habitat, season, and depth differences by analysis of covariance (ANCOVA) for unbalanced designs (SAS 1982) with habitat and season as the main effects and depth as the covariate. Catch per tub for each positive set was determined by averaging the catches of the constituent tubs.

Fish size data were analyzed for habitat, season, and depth differences by ANCOVA for unbalanced designs. The data were not transformed because size was approximately normally distributed.

Geometric mean weight-length regressions were calculated from the logarithmic transformation of

$$W = aL^b$$

where W is weight in grams, L is total length in millimeters, and a and b are fitted constants (Ricker 1973). The regression coefficients (b) were compared by the method of Clarke (1980).

The sediments of the upper continenal slope off Newport Beach are predominantly green silty clays. Sand content is fairly constant down slope (mean = 12% by dry weight); areas around the offshore banks and the shoulders of the submarine canyons are sandier (25–50% by dry weight). Organic content increases from 5 to 7% (as total volatile solids) at 290 m to 11–14% at 625 m (SCCWRP 1983[2]). Between 600 and 700 m, the slope gives way to the low-oxygen San Pedro Basin to the northwest and to the deeper San Diego Trough to the southeast (Fig. 1).

Longline fishermen recognize two habitats on the slope: hard substrate banks and soft, relatively featureless (on a fathometer) mud bottom. Surface sediments on the banks are a mixture of coarse sand, shell hash, and occasional rocks. As used herein, banks include submerged mountains, shoulders of submarine canyons, and isolated mounds as small as a few hundred meters across and 20–30 m high. The mud bottom is green silty clay and is the predominant habitat on the slope.

Oceanographic measurements in the water column off Newport Beach showed weak and decreasing gradients with increasing depth. The mean annual temperature was 8.3°C (SD = 0.3, N = 64, min = 7.5, max = 9.1) at 300 m and 6.5°C (SD = 0.2, N = 25, min = 6.0, max = 6.9) at 500 m. Mean annual dissolved oxygen was 1.21 ppm (SD = 0.26, N = 54, min = 0.76, max = 1.94) at 300 m and 0.48 ppm (SD = 0.10, N = 20, min = 0.31, max = 0.72) at 500 m. Some of the variation at 300 m was the result of seasonal changes related to upwelling. In the spring, temperature and dissolved oxygen decreased, and salinity and density increased (SCCWRP fn. 2).

RESULTS

Distribution and Abundance

The occurrence of scyliorhinid sharks in trawl catches was markedly different from longline catches. Catsharks were caught in 3 (6%) of the 48 otter trawls. The six individuals collected accounted for <0.1% of all fish caught in trawls. Catsharks were caught on 62 (87%) of the 71 longline sets (212 tubs of gear examined). The 698 individuals collected accounted for 5.8% of the fish caught (2.8% of catch weight) on longlines.

Apristurus brunneus were caught on 50 (70%) sets; 475 individuals were collected. *Parmaturus xaniurus* were caught on 53 (75%) sets; 223 individuals were collected. The two species occurred independently on the tubs of longline gear (χ^2 = 0.39, $P > 0.05$). They were equally abundant on bank

[2]SCCWRP. 1983. A survey of the slope off Orange County, California. Report to County Sanitation Districts of Orange County. Long Beach: Southern California Coastal Water Research Project, 208 p.

sets (t = 0.56, $P > 0.05$), but *A. brunneus* were more abundant than *P. xaniurus* on mud sets (t = 3.50, $P < 0.01$) (Table 1).

Apristurus brunneus occurred on 61% of the bank sets and 79% of the mud sets. Catches were not significantly different among habitats, seasons, or depths (ANCOVA, $P > 0.05$). Mean catch per tub in the mud habitat was not significantly different between floating and sinking sets (t = 1.35, P = 0.19).

Parmaturus xaniurus occurred on 73% of the bank sets and 76% of the mud sets. Catches were significantly higher on bank sets than on mud sets (ANCOVA, $P < 0.05$). Catches were nearly twice as high on bank sets in the winter compared with bank sets in the summer. Catch increased with increasing depth on banks, but it decreased with increasing depth on mud. Catches on the mud were not significantly different between floating and sinking sets (t = 0.76, P = 0.45.).

Size

There were no significant differences in the regression coefficients of the weight-length relationships between males and females of either *A. brunneus* or *P. xaniurus* over the range of sizes examined (Table 2; Fig. 2). There were no significant differences in the size of *A. brunneus* or *P. xaniurus* among habitats, seasons, or depths (ANCOVA, $P > 0.05$).

TABLE 1.—Catch statistics for *Apristurus brunneus* and *Parmaturus xaniurus* from longline collections on banks and mud. No. = number, wt = weight in kg., N = number of positive sets, $\bar{X}$ = mean, SD = one standard deviation.

Species		Banks			Mud		
		N	$\bar{X}$	SD	N	$\bar{X}$	SD
A. brunneus	No./tub	20	2.3	2.1	30	3.7	4.6
	Wt/tub	20	0.9	0.8	30	1.5	1.8
P. xaniurus	No./tub	24	2.0	2.0	29	1.1	1.1
	Wt/tub	24	0.6	0.6	29	0.4	0.4

Reproduction

Based on relative change in clasper length and gonad weight, *A. brunneus* males reached sexual maturity between 450 and 500 mm TL; *P. xaniurus* males reached sexual maturity between 375 and 425 mm TL (Fig. 3). Females of both species reached sexual maturity between 425 and 475 mm TL (Fig. 4). Only the right ovary was functional in both species.

Seasonal changes in gonadal development were not pronounced among *A. brunneus*. Male and female GSIs were highest in winter and lowest in summer (Fig. 5). Large oocytes were present in the right ovary of females throughout the year (Fig. 6).

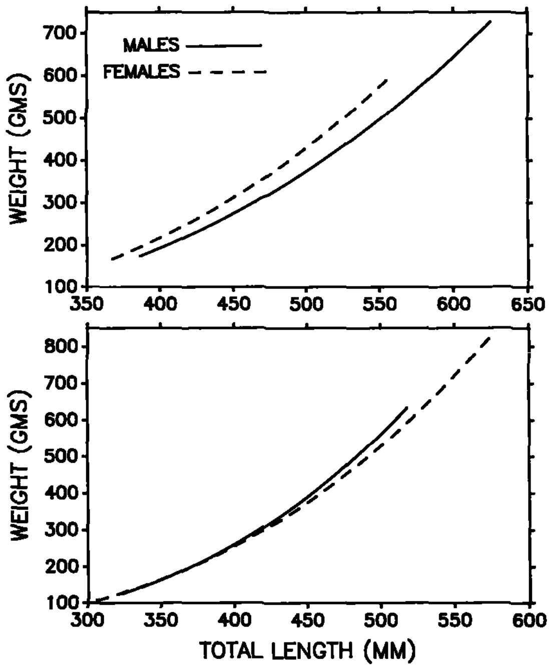

FIGURE 2.—Weight-length relationships of *Apristurus brunneus* (above) and *Parmaturus xaniurus* (below).

TABLE 2.—Geometric mean weight-length regressions for *Apristurus brunneus* and *Parmaturus xaniurus*. N = sample size, min = minimum total length (TL) in mm, max = maximum TL, W = body weight in g, L = TL, $L1$ = lower 95% confidence interval for b, $L2$ = upper 95% confidence interval, r = correlation coefficient.

Species	Sex	N	min	max	$W = aL^b$	$L1$	$L2$	r
A. brunneus	F	149	369	556	$W = 2.379 \times 10^{-6} L^{3.059}$	2.839	3.279	0.899
	M	90	389	625	$W = 3.577 \times 10^{-6} L^{2.971}$	2.809	3.134	0.966
P. xaniurus	F	76	307	574	$W = 9.377 \times 10^{-7} L^{3.242}$	3.045	3.439	0.965
	M	89	325	516	$W = 3.163 \times 10^{-7} L^{3.427}$	3.166	3.688	0.934

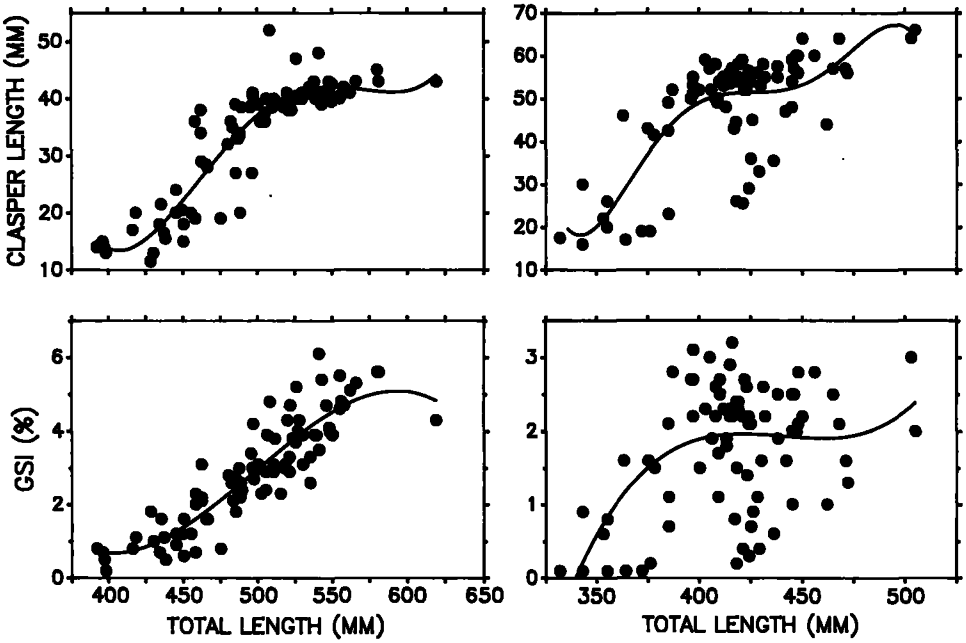

FIGURE 3.—Left clasper length and gonadosomatic index (GSI) versus total length of male *Apristurus brunneus* (left) and *Parmaturus xaniurus* (right).

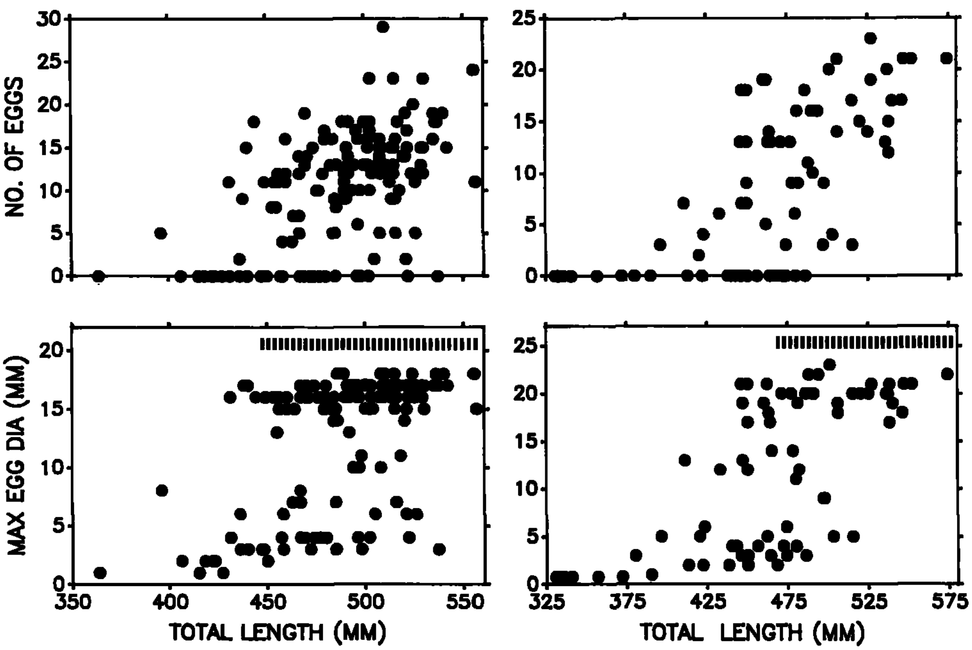

FIGURE 4.—Number of oocytes (>4 mm) and maximum oocyte diameter versus total length of female *Apristurus brunneus* (left) and *Parmaturus xaniurus* (right). Cross-hatched bar indicates size of fish carrying egg cases.

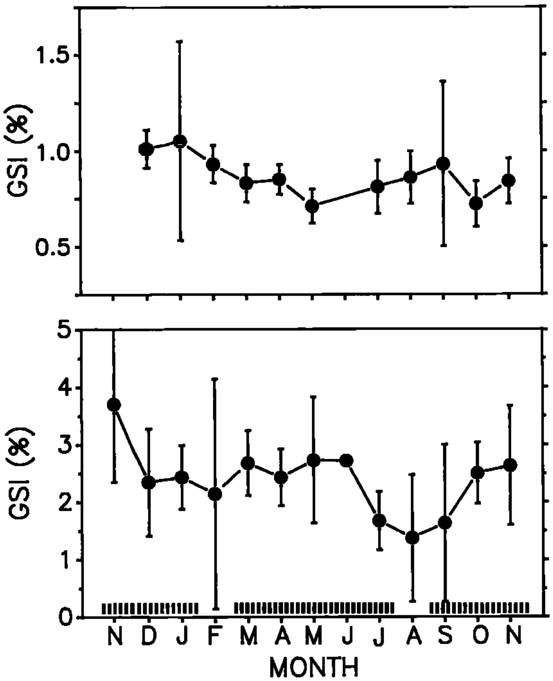

FIGURE 5.—Mean gonadosomatic index (GSI) of *Apristurus brunneus* males (above) and females (below) from November 1983 through November 1984. Cross-hatched bar indicates months when females were carrying egg cases. Vertical bars are 95% confidence intervals.

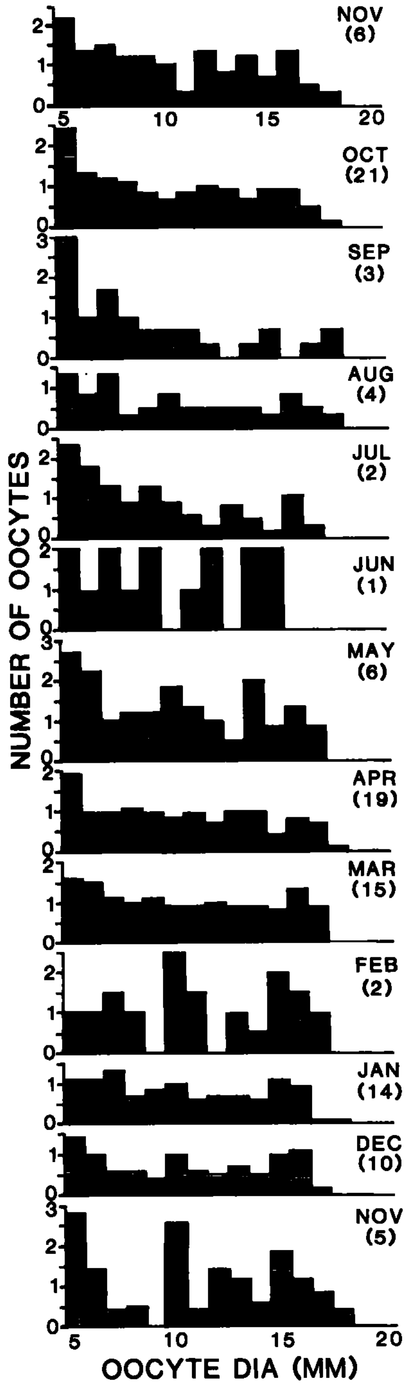

FIGURE 6.—Mean monthly oocyte (>4 mm) size-frequency distribution of *Apristurus brunneus* from November 1983 (bottom) to November 1984 (top). Sample size in parentheses.

The number of oocytes larger than 4 mm was correlated with size among mature females (r = 0.425, $P < 0.001$); the maximum number was 29. Atretic oocytes were observed from March through November and spent fish (no oocytes larger than 2–3 mm; N = 2) were collected in December and July.

Egg cases were found in the oviducts of 48 *A. brunneus* females larger than 450 mm (37% of mature females); the egg cases were not completely formed in only one individual. Females with egg cases were collected every month except February and August (Fig. 5). More mature females carried egg cases from December through May (42%) than from June through November (29%), although the difference was not significant (χ^2 = 2.24, $P > 0.1$). Egg case length (measured between the tendrils) was correlated with female total length (r = 0.386, $P < 0.02$). The mean ratio of egg case length to female total length was 0.114 (SD = 0.019).

Seasonal changes in gonadal development were not pronounced among *P. xaniurus*. Male GSI was high throughout the year; female GSI was highest in winter and lowest in summer (Fig. 7). Large

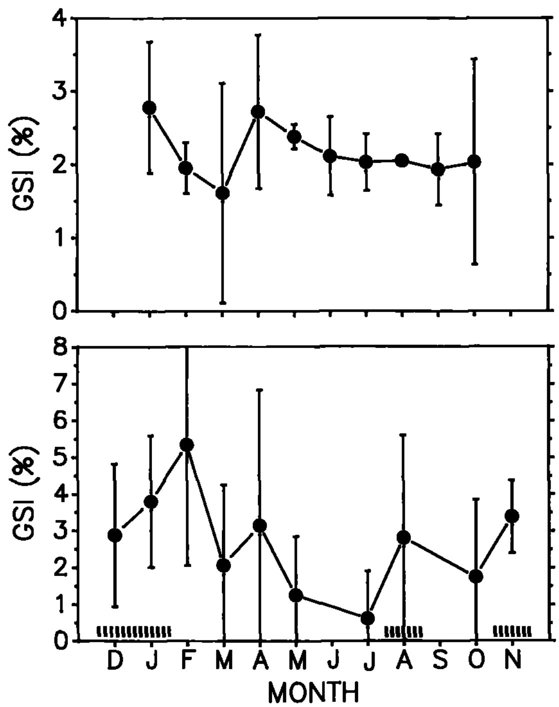

FIGURE 7.—Mean gonadosomatic index (GSI) of *Parmaturus xaniurus* males (above) and females (below) from December 1983 through November 1984. Cross-hatched bar indicates months when females were carrying egg cases. Vertical bars are 95% confidence intervals.

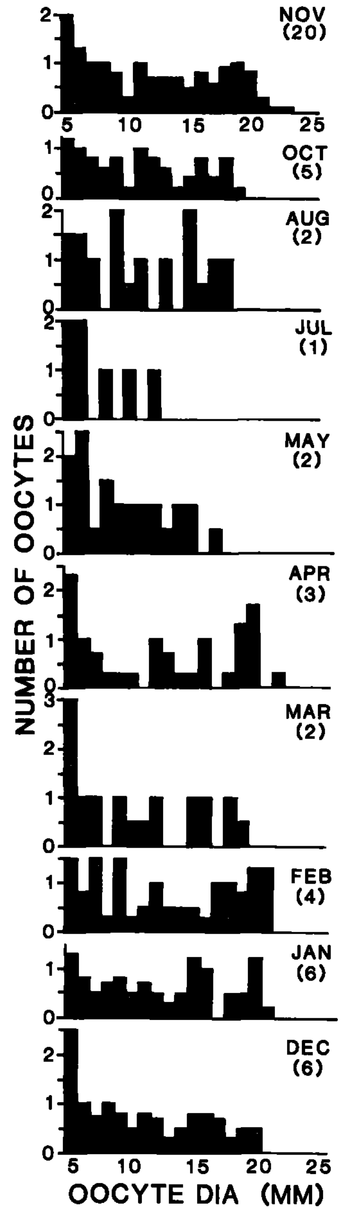

FIGURE 8.—Mean monthly oocyte (>4 mm) size-frequency distribution of *Parmaturus xaniurus* from December 1983 (bottom) to November 1984 (top). Sample size in parentheses.

oocytes were present in the right ovary of females every month except July (Fig. 8). The number of oocytes larger than 4 mm was correlated with size among mature females ($r = 0.597$, $P < 0.001$); the maximum number was 23. Atretic oocytes were observed in May, August, and November and spent fish (no oocytes larger than 3-4 mm; $N = 3$) were collected in January and March.

Egg cases were present in the oviducts of five *P. xaniurus* females larger than 470 mm (10% of mature females); the egg cases were not completely formed in one individual. One 450 mm TL female had recently released two egg cases as evidenced by distended oviducts. Egg cases were present in females collected in December, January, August, and November (Fig. 7). The mean ratio of egg case length to female total length was 0.156 (SD = 0.023).

Food Habits

Stomachs from 211 *A. brunneus* were examined; 138 (65%) were empty or contained only traces of well-digested prey. There was no seasonal trend in the proportion of empty stomachs. Crustaceans, teleosts, and molluscs constituted the diets of the remaining individuals (Table 3). Natantian decapods

TABLE 3.—Stomach contents of 73 *Apristurus brunneus* (mean size = 496 mm TL, SD = 40, min = 396, max = 619). *PO* = percent occurrence, *PN* = percent number, *PW* = percent weight, IRI = index of relative importance.

	PO	*PN*	*PW*	IRI
Crustacea	97.3	74.2	67.3	13,768
Isopoda	9.6	3.0	0.8	36
Epicaridea	9.6	3.0	0.8	36
Mysidacea	1.4	0.5	0.4	1
Euphausiacea	6.8	4.5	4.5	61
Decapoda	71.2	61.8	58.4	8,558
Natantia	61.6	52.7	48.9	6,259
Penaeidea	13.7	7.5	6.6	193
Sergestidae	12.3	5.6	4.7	127
Sergestes similis	11.0	4.9	3.9	97
Petalidium suspiriosum	1.4	0.7	0.8	2
Penaeidae	2.7	1.9	1.8	10
Bentheogennema sp.	2.7	1.9	1.8	10
Caridea	45.2	23.7	28.8	2,373
Pasiphaeidae	45.2	23.7	28.8	2,373
Pasiphaea sp.	27.4	14.0	16.3	830
Pasiphaea pacifica	13.7	5.1	8.3	184
Pasiphaea emarginata	1.4	1.4	1.4	4
Reptantia	15.1	6.6	7.8	217
Anomura	15.1	6.6	7.8	217
Galatheidae	15.1	6.6	7.8	217
Pleuroncodes planipes	5.5	1.9	2.0	21
Mollusca	20.5	8.4	11.4	406
Pelecypoda	1.4	0.3	0.1	<1
Cephalopoda	19.2	8.0	11.2	369
Coleoidea	19.2	8.0	11.2	369
Decapoda	19.2	8.0	11.2	369
Teuthoidea	19.2	8.0	11.2	369
Gonatus sp.	4.1	2.5	3.3	24
Abraliopsis felis	2.7	0.8	1.0	5
Loligo opalescens	1.4	0.5	0.8	2
Osteichthyes	42.5	16.6	21.0	1,598
Myctophidae	6.8	3.8	4.4	56

(40% of total IRI), especially carideans of the family Pasiphaeidae (15%), dominated the contents. Teleosts (10%), including myctophids, were also important. Most fish remains in the stomachs were digested beyond recognition. Squids made up the remainder of the diets (3%). There was no evidence for a size-related change in diet; the dominant prey occurred in all sizes of fish examined.

The stomachs of 73 *A. brunneus* contained an average of 2.7 prey items (SD = 1.7, max = 10) and the contents averaged 0.7% of body weight (SD = 0.4, max = 1.99). Content weight was not correlated with body weight (Spearman $r_s = 0.227$, $P > 0.2$), and carapace length of the most frequently occurring prey, *Pasiphaea* spp., was not correlated with fish size ($r_s = -0.168$, $N = 33$, $P > 0.2$). Relative content weight was not significantly different among months (Kruskal-Wallis test, $H = 14.89$, $P = 0.19$).

Stomachs from 155 *P. xaniurus* were examined; 85 (55%) were empty or contained only traces of well-digested prey. There was no seasonal trend in the proportion of empty stomachs. Crustaceans, teleosts, and molluscs constituted the diets of the remaining individuals (Table 4). Reptantian decapods (36% of total IRI), particularly the galatheid *Pleuroncodes planipes* (12%), dominated the contents. Natantian decapods (3%) and teleosts (7%), including myctophids, were also important. Most fish remains in the stomach were digested beyond recognition. Squids made up a small part of the diets (<1%). There was no evidence for a size-related change in diet; the dominant prey occurred in all sizes of fish examined.

The stomachs of 70 *Parmaturus xaniurus* contained an average of 2.4 prey items (SD = 1.3, max = 5) and the contents averaged 1.2% of body weight (SD = 0.9, max = 4.7). Content weight was correlated with body weight (Spearman $r_s = 0.372$, $P < 0.002$). Relative content weight was not significantly different among months (Kruskal-Wallis test, $H = 13.26$, $P = 0.35$).

TABLE 4.—Stomach contents of 70 *Parmaturus xaniurus* (mean size = 438 mm TL, SD = 47, min = 341, max = 547). *PO* = percent occurrence, *PN* = percent number, *PW* = percent weight, IRI = index of relative importance.

	PO	*PN*	*PW*	IRI
Crustacea	97.1	75.5	72.1	14,332
Isopoda	4.3	1.6	0.5	9
Epicaridea	4.3	1.6	0.5	9
Bopyridae	2.9	1.0	0.3	4
Munidon parvum	2.9	1.0	0.3	4
Euphausiacea	24.3	8.6	5.4	340
Decapoda	81.4	56.5	59.2	9,421
Natantia	21.4	10.8	11.9	486
Penaeidea	11.4	4.6	4.0	98
Sergestidae	11.4	4.6	4.0	98
Sergestes similis	11.4	4.6	4.0	98
Caridea	12.9	5.0	7.0	155
Pasiphaeidae	12.9	5.0	7.0	155
Pasiphaea pacifica	10.0	4.0	5.8	98
Reptantia	67.1	38.5	43.4	5,495
Anomura	65.7	38.2	43.0	5,335
Galatheidae	65.7	38.2	43.0	5,335
Pleuroncodes planipes	40.0	21.9	26.1	1,920
Brachyura	1.4	0.4	0.4	1
Mollusca	5.7	1.4	1.8	18
Cephalopoda	5.7	1.4	1.8	18
Coleoidea	5.7	1.4	1.8	18
Decapoda	5.7	1.4	1.8	18
Teuthoidea	5.7	1.4	1.8	18
Osteichthyes	48.6	20.8	25.3	1,036
Myctophidae	10.0	4.8	6.1	109

DISCUSSION

Distribution and Abundance

Apristurus brunneus and *Parmaturus xaniurus* were a common, though unwanted, part of the longline catch on the upper continental slope off southern California. The abundance of both species was underestimated by trawl. Among the 29 species (12,074 individuals) caught on longlines, *A. brunneus* ranked 7th in abundance and *P. xaniurus* ranked 10th. They ranked 29th and 34th, respectively, among the 42 species (7,264 individuals) taken in trawls (Cross 1987). The bias of small trawls against large demersal fishes is well known (Day and Pearcy 1968; Haedrich et al. 1975). Most previous fish collections on the slope off southern California were taken with small trawls which explains why these sharks are not considered common.

Catches of *A. brunneus* and *P. xaniurus* were similar on bank sets, but *A. brunneus* was more abundant on mud sets. The two species occurred independently at the scale of one tub of longline gear (about 650 m). *Apristurus brunneus* was equally abundant on mud and bank sets, and seasonal differences in distribution and catch were not apparent. *Parmaturus xaniurus* was more abundant on bank sets than on mud sets, suggesting some habitat selection. Catches of *P. xaniurus* were highest on banks in the winter; the reason for this is not known.

Juvenile *A. brunneus* and *P. xaniurus* were conspicuously absent from longline and trawl collections on the slope. Catsharks are generally regarded as demersal fishes (Compagno 1984), but *A. brunneus* and *P. xaniurus* have been captured in the water column. An undisclosed number of *A. brunneus* larger than 260 mm (TL assumed) were collected up to 172 m above the bottom in 373 m of water off British Columbia, Canada (Jones and Geen 1977). Sixty-nine *P. xaniurus* (99–320 mm) were collected in 43 midwater trawls from 9 to 490 m above the bottom in 527–582 m of water in the Santa Barbara Basin, CA (Lee 1969). The livers of *P. xaniurus* contain a high proportion of squalene, a low specific gravity oil that aids in hydrostatic balance (Springer 1979).

Juveniles and adolescents of both species were taken in midwater trawls in the Santa Barbara Basin (bottom depths between 490 and 576 m) (UCSB[3]). Catsharks occurred in 31 (41%) of 75 mid-

[3]UCSB. Collections taken by the University of California, Santa Barbara, with an opening and closing net between 1965 and 1967 and deposited in the Los Angeles County Museum of Natural History.

water trawls; 83% of the individuals were collected within 250 m of the bottom. Fifty-four *A. brunneus* (99–380 mm TL, median = 177) were collected in 22 trawls and 23 *P. xaniurus* (110–229 mm TL, median = 175) were collected in 17 trawls.

The occurrence of juveniles and adolescents of both species in midwater collections suggests that the water column, especially within 200–300 m of the bottom, is their nursery area, and would explain their conspicuous absence in benthic collections during the present study. Cailliet[4] also concluded that *P. xaniurus* are mesopelagic as juveniles and demersal as adults.

Interestingly, 119 midwater trawls in the Santa Cruz Basin, CA and near Rodriguez Seamount (most bottom depths between 1,200 and 2,200 m) (UCSB fn 3) captured no scyliorhinid sharks (the trawls were taken concomitantly with trawls in the nearby Santa Barbara Basin). Bottom depths >1,000 m may be beyond the range of both species. The deepest recorded collection of *A. brunneus* off southern California was 933 m (Roedel 1951); the deepest recorded collection of *P. xaniurus* was 687 m (Springer 1979). The absence of both species in midwater trawls in the Santa Cruz Basin and near Rodriguez Seamount would not be surprising if juveniles do not travel far horizontally and adults do not occur below 1,000 m.

Size

The largest *A. brunneus* collected during the present study (625 mm TL male) was less than the maximum recorded size (680 mm TL; Compagno 1984). The largest *P. xaniurus* (574 mm TL female) was greater than the maximum recorded size (550 mm TL; Compagno 1984). Weight-length relationships of males and females of both species were similar. It is not known if males and females that were the same size were the same age. Attempts at determining the ages of *P. xaniurus* were unsuccessful (Cailliet 1986[5]).

Reproduction

Like many scyliorhinid sharks, *A. brunneus* and *P. xaniurus* exhibit single oviparity: one fertilized egg enters each oviduct and, after a short period, is deposited in a tough egg case on the substrate where it is anchored by tendrils (Nakaya 1975). Embryonic development takes place largely outside the mother and may require a year to produce a hatchling (Compagno 1984).

Size at sexual maturity estimated during the present study agrees with published observations for both species (Jones and Geen 1977; Compagno 1984). Male *P. xaniurus* matured at a smaller size than male *A. brunneus*. Females of both species matured at about the same size and fecundity increased with female size. Fecundity was greater among *A. brunneus* as was the proportion of mature females carrying egg cases, but the proportion of body weight devoted to gonads and maximum oocyte size were greater among *P. xaniurus*.

Seasonal changes in gonadal development were not well defined for either species; individuals in both populations may be sexually active at any time of the year. Several observations suggest that oocyte production was seasonal: the highest proportion of adult females with oocytes <10 mm in diameter and the highest frequency of atretic oocytes were observed from summer through fall when GSI was lowest.

There are few published observations on reproductive cycles of scyliorhinid sharks. *Scyliorhinus canicula*, an abundant shelf and upper slope catshark in the northeastern Atlantic Ocean, lays eggs throughout the year. Seasonal maxima in egg capsule production are apparent, but timing varies with latitude. Size at sexual maturity also varies with latitude; fish mature at a larger size at higher latitudes (Ford 1921; Capapé 1977). The fecundity of female *S. canicula* (46–50 cm TL) ranges from 23 to 34 eggs; fecundity increases with fish size. Eggs are 16 mm in diameter at ovulation. Annual fecundity is about 96–115 eggs. In the Mediterranean Sea, egg capsule incubation times range from 180 days for eggs deposited during the summer to 285 days for eggs deposited during the winter (Capapé 1977).

Food Habits

Apristurus brunneus and *Parmaturus xaniurus* consumed, in order of importance, crustaceans, teleosts, and squids. Similar diets were reported for both species by Jones and Geen (1977), Cailliet (1981, see fn. 4), and Compagno (1984). The diets of the two catsharks were broadly similar except for the occurrence of crustaceans. Reptantian decapods

[4]Cailliet, G. M. 1981. Ontogenetic changes in the depth distribution and feeding habits of two deep-dwelling demersal fishes off California: sablefish and filetail cat sharks. [Abstr.] Am. Soc. Ichthyol. Herpetol. Sixty-first Annu. Meeting, Corvallis, OR.
[5]G. M. Cailliet, Moss Landing Marine Laboratories, Moss Landing, CA, pers. commun. July 1986.

dominated the diet of *A. brunneus* (36% of total IRI) while natantian decapods dominated the diet of *P. xaniurus* (40% of total IRI). This may be a result of habitat differences between the catsharks rather than prey selection. The epicaridean isopods in the stomach contents are crustacean parasites, and were probably ingested with their hosts.

A very high percentage of *A. brunneus* and *P. xaniurus* stomachs was empty. This may not be representative of their respective populations. Sharks caught by baited hooks have a higher proportion of empty stomachs, and lower stomach content weight, than sharks caught by gill net (Medved et al. 1985).

Most of the prey consumed by *A. brunneus* and *P. xaniurus* are pelagic. Demersal adult *P. xaniurus* eat mostly crustaceans (including pelagic pasiphaeid and sergestid shrimps), fishes (primarily myctophids), and cephalopods. Mesopelagic juveniles eat more and smaller pelagic pasiphaeid, euphausiid, and sergestid shrimps and cephalopods, and fewer fishes (Cailliet fn. 4). Similar pelagic prey also dominate the diets of *Galeus melastomus* and *Apristurus* spp., common outer shelf-upper slope scyliorhinid sharks of the northeastern Atlantic Ocean (Orsi and Wurtz 1977; Mattson 1981; Mauchline and Gordon 1983). Ontogenetic changes in diet were reported for *Scyliorhinus canicula*: the importance of crustaceans declines and the importance of teleosts increases with increasing fish size (Capapé 1974).

Deep-sea benthic fishes can obtain pelagic prey by 1) feeding on prey whose vertical distribution extends close to the bottom [*P. xaniurus* were observed eating moribund myctophids in the bottom of the Santa Barbara Basin (Springer 1979)]; 2) migrating into the water column to feed [*A. brunneus* and *P. xaniurus* are captured in midwater (Jones and Geen 1967; Lee 1969; UCSB fn. 3)]; 3) feeding on carcasses that sink to the bottom (mud and terrestrial plant debris were found in several catshark stomachs during the present study, and both species took dead bait); or 4) feeding in the net (not a factor in this study) (Pearcy and Ambler 1974; Pearcy 1976; Sedberry and Musick 1978).

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