LIFE HISTORY AND FISHERY OF THE CALIFORNIA SCORPIONFISH, *SCORPAENA GUTTATA*, WITHIN THE SOUTHERN CALIFORNIA BIGHT

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ABSTRACT

We examined the life history of the California scorpionfish in the Southern California Bight. Based on sportfish creel census data, the species was most abundant in the southern part of the Bight, particularly around Catalina, San Clemente, and the Coronado Islands. Trawl studies from 1974 to 1984 indicated that California scorpionfish populations varied considerably in abundance, with numbers peaking in 1982. Though the species usually associates with hard substrata, it was abundant over mud about the Palos Verdes Peninsula, site of a major sewage outfall. We think that this anomalous abundance was due to the presence of large numbers of a prey species, the ridgeback prawn, *Sicyonia ingentis*, which was attracted to the nutrient-rich substrata.

Female California scorpionfish lived to 21 years, males to 15. Females grew faster than males. Von Bertalanffy age-length parameters for females were $L = 44.3$, $k = 0.13$, $t_0 = -1.9$, and for males $L = 36.3$, $k = 0.12$, $t_0 = -3.86$. Over 50% of both females and males were mature at 2 years of age. Males tended to mature at a slightly smaller size. Spawning occurred from May through August, peaking in July. California scorpionfish formed large offshore spawning aggregations in waters deeper than their off-season habitat. Tagging results indicated that fish return to the same spawning area annually. Crabs, primarily juvenile *Cancer anthonyi*, were the most important food item of fishes inhabiting soft substrata in shallow water.

The family Scorpaenidae is represented by four genera in the northeastern Pacific—*Scorpaena*, *Scorpaenodes*, *Sebastes*, and *Sebastolobus* (Eschmeyer et al. 1983). One *Scorpaena* species, *S. guttata*, the California scorpionfish, is abundant as far north as southern California.

The California scorpionfish is a medium-sized [to 43 cm TL (total length)], generally benthic species, found from central California into the Gulf of California between the intertidal and 183 m (Eschmeyer et al. 1983). It occurs on rocky reefs (often lodged in crevices), although in certain areas and seasons it aggregates over sandy or muddy substrata (Frey 1971; present paper). This species is oviparous, producing floating, gelatinous egg masses in which the eggs are embedded in a single layer (Orton 1955). Like others in the genus *Scorpaena*, California scorpionfish produce a toxin in their dorsal, anal, and pelvic spines, which produces intense, painful wounds. California scorpionfish comprise a minor part of the California sport and commercial fisheries (Wine and Hoban[3], Wine[4], Knaggs[5], present paper).

Perhaps because of this relatively small catch, the species has not been the subject of an in-depth life history study. Rather, much of what is known has been gleaned from larger ecological surveys (Table 1), in which the species played a minor role. However, California scorpionfish have recently become important in pollution-related studies (Table 1), deriving from 1) its abundance about the Palos Verdes Peninsula (heavily polluted from the Whites Point sewage outfall which services Los Angeles), 2) its ease of capture by otter trawl and by hook and line, and 3) its ability to adapt to laboratory aquaria.

This increased interest has given rise to questions regarding the species' growth rate, age at first maturity, and movements. Our paper details some

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[3] Wine, V., and T. Hoban. 1976. Southern California independent sportfishing survey annual report, July 1, 1975–June 30, 1976 Calif. Dep. Fish Game, 109 p.

[4] Wine, V. 1979. Southern California independent sportfishing survey annual report, July 1, 1977–June 30, 1978. Calif. Dep. Fish Game, 100 p.

[5] E. Knaggs, California Department of Fish and Game, Long Beach, CA, pers. commun. May 1985.

Manuscript accepted September 1986.
FISHERY BULLETIN: VOL. 85, NO. 1, 1987.

TABLE 1.—Previous studies involving *Scorpaena guttata*. Not included are geographical species lists.

Systematics.—Girard 1854, 1858; David 1943; Phillips 1957; Tsuyuki et al. 1968; Eschmeyer and Bailey 1970; Greenfield 1974.

Anatomy and Physiology.—Clothier 1950; Halstead 1951; Halstead et al. 1955; Saunders 1959; Halstead and Mitchell 1963; Taylor 1963; Munz 1964; Russell 1965, 1969; Carlson et al. 1971; Schaeffer et al. 1971; Baines 1975; Sullivan and Somero 1980.

Pollutant Levels and Effects.—MacGregor 1972; Young and Mearns 1978; Stout and Beezhold 1981; Brown et al. 1982, 1984a-c; Gossett et al. 1982a, b, 1984; Jenkins et al. 1982; Mearns 1982; Schafer et al. 1982; Szalay 1982; Gadbois and Maney 1983; Bay et al. 1984a, b; Perkins and Rosenthal 1984; Rosenthal et al. 1984; Cross et al. 1985.

Life History, Distribution, and Behavior.—Jordan and Gilbert 1881; Holder 1900; Richardson 1905; Wilson 1908, 1935; Barnhart 1932; David 1939; Limbaugh 1955; Orton 1955; Montgomery 1957; Causey 1960; Kunnenkeri and Martin 1963; Rosenblatt 1963; Taylor 1963; Arai and Koski 1964; Carlisle et al. 1964; Clarke et al. 1967; Quast 1968a-c; Carlisle 1969; Cressey 1969; Taylor and Chen 1969; Turner et al. 1969; Frey 1971; Hobson 1971; Ho 1972; Miller and Lea 1972; Varoujean 1972; Feder et al. 1974; Allen et al. 1976; Burreson 1977; Mearns 1979; Dailey et al. 1981; Helvey and Dorn 1981; Hobson et al. 1981; Stephens and Zerba 1981; Eschmeyer et al. 1983; Love and Moser 1983; Barnett et al. 1984; DeMartini and Allen 1984; Larson and DeMartini 1984; Thresher 1984; Love and Westphal 1985.

Fishery.—Phillips 1937; Daugherty 1949; Roedel 1953; Frey 1971.

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aspects of the growth, reproduction, food habits, movements, and fisheries of the California scorpionfish.

METHODS

Distribution and Movements of Adults and Juveniles

To estimate relative abundance of California scorpionfish over reefs and hard substrata, we used the California Department of Fish and Game creel census data, gathered from throughout the Southern California Bight from April 1975 to December 1978. In this study, Fish and Game personnel rode aboard randomly chosen commercial passenger vessels (hereafter referred to as "partyboats") and measured and identified all fish captured. The sampler also noted numbers of anglers, fishing hours, and location and depth of each fished site. Catch per unit effort was used as our estimate of relative abundance, where effort was measured in angler hours (number of anglers × number of hours fished).

For several reasons, data from this study could not give a completely unbiased estimate of California scorpionfish abundance. First, virtually all fishing effort aboard partyboats occurs over reefs and hard substrata. Hence, this data base does not effectively measure abundance over soft substrata. Second, most angling involved fishing with live bait (primarily northern anchovies, *Engraulis mordax*) or with lures simulating fishes. Thus the sample was biased away from very small individuals. However, California scorpionfish develop relatively large mouths and become mesocarnivores at relatively early sizes and our data indicates that most size classes were represented. As angling techniques were similar throughout the Southern California Bight, we believe this survey allows for an acceptable representation of abundance of all but the smallest size classes.

To measure relative abundance of California scorpionfish living on soft substrates, we used trawl data collected by the Southern California Coastal Water Research Project (SCCWRP) and the Orange County Sanitation District. These data were based on 10-min tows of a 7.6 m headrope otter trawl fished on the bottom at about 23, 61, and 137 m off Palos Verdes and Huntington Beach (trawling stations are illustrated in Cross [1985] and Orange County Sanitation District[6]). We analyzed data taken about Palos Verdes and Huntington Beach from January 1974 to December 1984 (except that no data was taken for Huntington Beach during 1975). Fishes in this survey were measured using standard length. We converted these measurements to total lengths using conversion factors based on measurements of 1,083 California scorpionfish. These factors are $TL = (1.21)SL + 1.02$; $SL = (0.82)TL - 0.69$.

We also conducted a tagging program to give some insight into this species' movements. We tagged trawl-caught California scorpionfish with Floy[7] tags (orange FD-68BC) from an area between the southern part of Santa Monica Bay and Huntington Beach. The tags (consisting of a plastic tube 50 mm long with a 10 mm cross bar) were injected into the dorsal musculature between the second and third dorsal spines, leaving the brightly colored end free. Most of the tagging effort was centered on Dago Bank, about 11 km southeast of Long Beach Harbor—an area we had identified as a spawning ground. A monthly otter trawl survey indicated that California scorpionfish were rare in this area between October and April, with large numbers of ripe individuals occupying the habitat during late spring and summer.

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[6] Orange County Sanitation District. 1984. Annual Report, 300 p.

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

Juveniles and Adults Collection

Individuals used in the analysis of age and length, length-weight, and reproduction were sampled monthly (2-10 samples/month) from May 1981 to June 1982 (and sporadically thereafter through May 1983). We used a 7.6 m (25 ft) or 4.9 m (16 ft) headrope otter trawl in 7-90 m of water, between Ventura and San Onofre, CA. All specimens were frozen for later dissection. After thawing, all fish were measured (total length and standard length), weighed, and sexed, and the gonads were removed and weighed.

Fish for food habit studies were taken by otter trawl over soft substrata in 6-16 m of water between Santa Monica Bay and San Onofre. These samples were frozen immediately after collection. In the laboratory, food items were identified to lowest possible taxa, then weighed and counted.

Techniques for Aging Juveniles and Adults

We attempted to age California scorpionfish by a variety of calcified structures (sagittae, scales, vertebrae, and pterygiophores) and found that cross sections of anal pterygiophores gave best results. The fused first and second anal pterygiophores (supporting the first and second anal spines) were removed from 613 specimens, cleaned, and stored in paper coin envelopes. Pterygiophores were placed on wood blocks and embedded in clear epoxy (Ciba 825 hardener and Ciba 6010 resin). Each block with its pterygiophore was placed on a Buehler Isomet low speed saw and an 0.05 cm wafer was cut through it, using two diamond-edge blades separated by a stainless steel shim. The cut was made near the pterygiophore's site of articulation with an anal spine. Wafers were read under a compound microscope at a magnification of 100×, with both reflected and transmitted light. All wafers were read twice, by M. S. Love, approximately 6 mo apart. When readings did not agree, they were read again. The value of two coincident readings was accepted as the best estimate of age.

We compared the age-length curves of males and females using an analysis of variance of regression coefficients over groups, testing the slopes of the two curves (Dixon 1981). Parenthetically, this was the same test used in comparing male and female length-weight curves. Back calculations of length on age were made using the techniques of Chen (1971).

Procedures for Determining the Timing of Maturation and Reproduction

We estimated length at first maturity by classifying gonads as immature or matured based on the techniques of Bagenal and Braum (1971). Smaller mature fish and fish just entering their first reproductive season become reproductive later in the year. Hence we estimated length at first maturity from just before spawning season (March) through its conclusion (August). A gonadosomatic index [(gonad weight)/(total body weight) × 100] was computed from frozen specimens to quantify changes in gonad size with season.

We computed condition factor ($100 \times \frac{(W - GW)}{L^3}$, where W = body weight in grams, GW = gonad weight in grams, and L = total length in centimeters), of mature California scorpionfish. Condition factor was computed using body weight with gonad weight subtracted so as to minimize the effects of seasonal changes in gonad size. We compared these values between seasons within sexes and between sexes, using the Mann-Whitney U-Test (Sokal and Rohlf 1969).

Fishery

To describe the California scorpionfish's role in the commercial passenger vessel (partyboat) sport fishery, we used the previously discussed California Department of Fish and Game creel census data. We also examined the commercial fishery, interviewing fishermen and utilizing the fish landing data of the California Department of Fish and Game.

RESULTS AND DISCUSSION

Distribution and Movements

Data from the Fish and Game creel census indicated differences in abundance between the northern and southern part of the Southern California Bight (Fig. 1). Catch rates were lowest near the city of Santa Barbara and generally increased to the south. Highest catch rates occurred off San Diego and around Catalina, San Clemente, and the Coronado Islands.

Utilizing the same data base, we examined California scorpionfish depth distribution (Fig. 2). Overall, California scorpionfish were taken from barely subtidal waters to 170 m. Depth distribution changed with season. We plotted catch per unit effort in 6

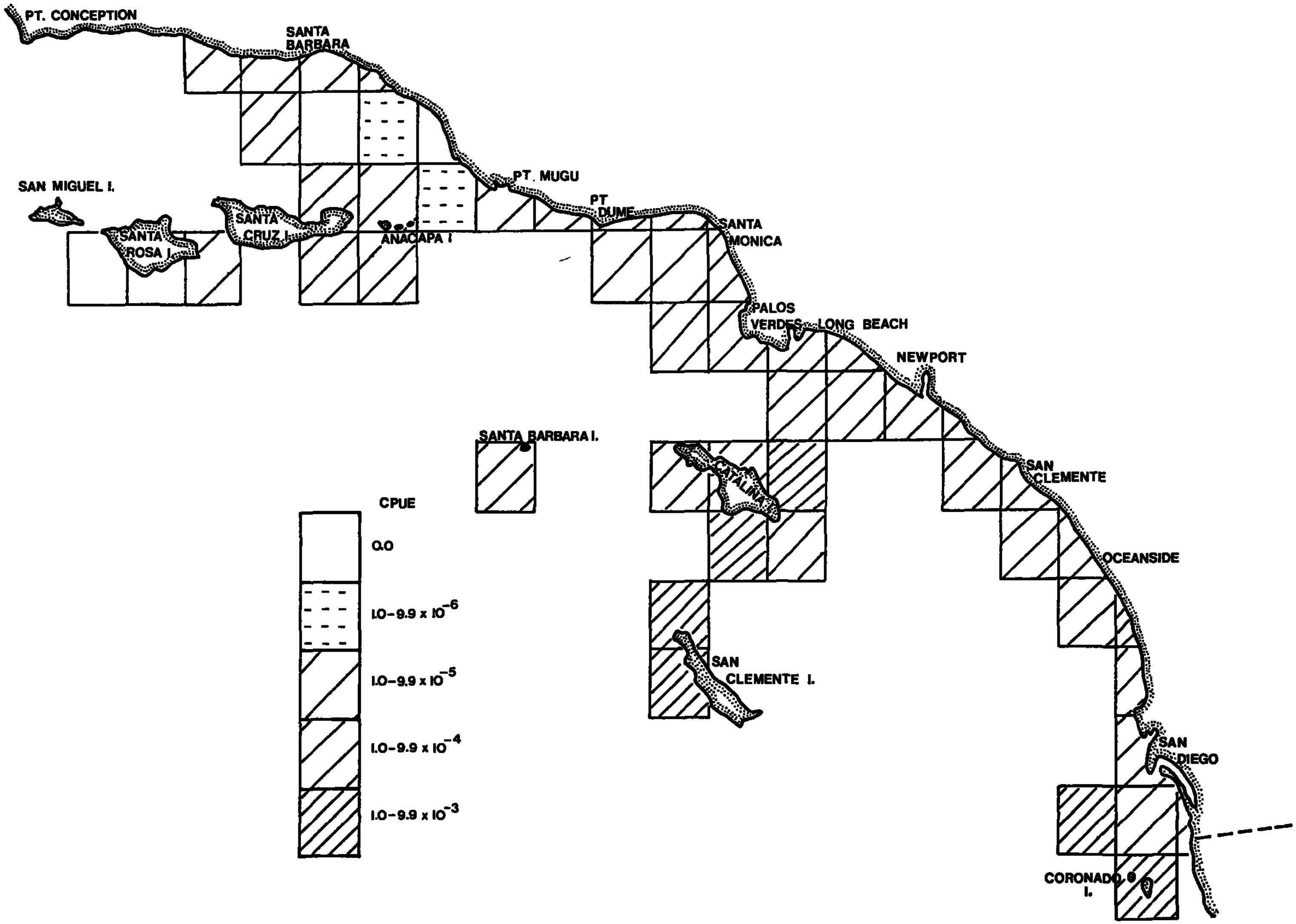

FIGURE 1.—Relative abundances (based on catch per unit effort, fish per angler-hour, in the partyboat sport fishery) of California scorpionfish taken from 1975 to 1978 in the Southern California Bight.

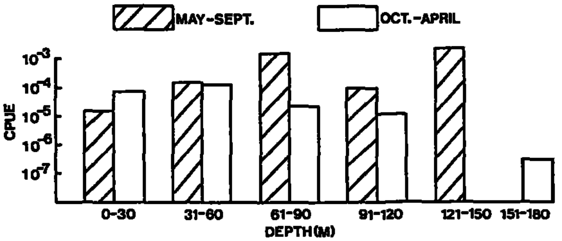

FIGURE 2.—Abundances (based on catch per unit effort in the partyboat sport fishery) of California scorpionfish taken in six depth intervals in the Southern Calfiornia Bight.

depth intervals for two seasons—spawning (May-September) and nonspawning (October-April). During spawning season, fish were most abundant in 61-90 and 121-150 m. Later in the year, there was some inshore movement, and fish were most abundant in 0-30 and 31-60 m. However, it was evident that not all scorpionfish migrate to deeper water at the same time during spawning season. Though catches during May-September were highest in deeper water, there were always some mature individuals inshore. Based on our capturing ripe fishes inshore, it is likely that some spawning occurs there.

Between 29 April 1983 and 24 September 1984, we tagged 518 California scorpionfish and 23 (4.2%) were recovered. The longest time a fish was at liberty was 916 d. Though we tagged fish from a variety of sites, most tagging occurred over Dago Bank. The results of our tagging program indicated that many scorpionfish annually return to the same spawning grounds. Of the 17 tag recoveries made on the Dago Bank, all were fish tagged on the same grounds the previous year. The Dago Bank aggregation site is occupied by scorpionfish during late spring and summer. Catches as high as 800 scorpionfish/20-min tow of a 7.6 m otter trawl occur during spawning season. As few scorpionfish live on Dago Bank during the off season, we believe these tag recoveries indicate that the fish return annually to the same area to spawn. The rest of the returns from fish tagged at their spawning grounds were taken inshore during fall and winter, from sites ranging from El Segundo on the north to Long Beach to the south (Fig. 3). The El Segundo individual had travelled at least 42 km from the spawning grounds.

Based on the SCCWRP and Orange County Sanitation trawl data, California scorpionfish exhibited considerable variation in abundance between 1974 and 1984 (Fig. 4). In the mid-1970's, populations at both sites were relatively low, then increased to a 1982 peak and declined rapidly in 1983 and 1984. An analysis of scorpionfish size frequencies indicates this influx was due to an increase in number of mature fishes. The 1983-84 decline was associated with the El Niño event.

Certainly a number of fish species moved out of their usual haunts during this period (Love et al. 1986). However, if this is correct, it is not clear

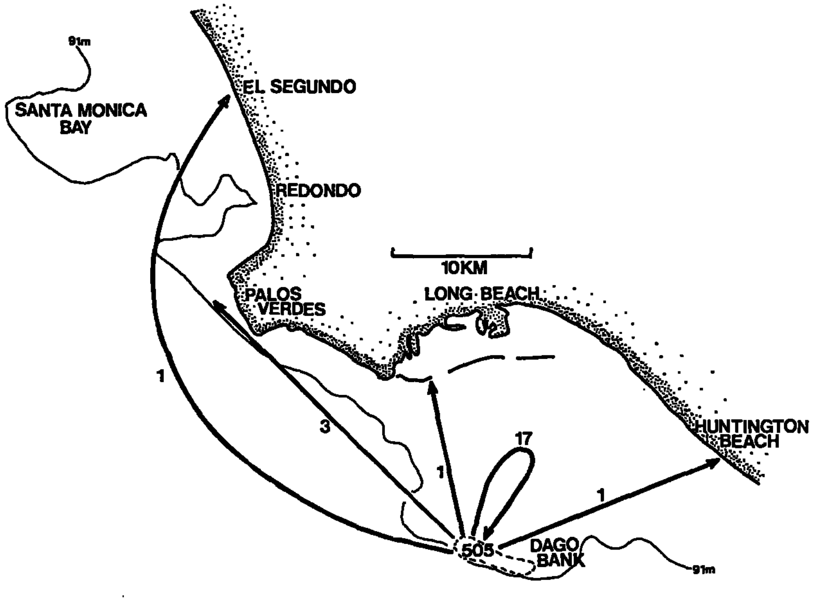

FIGURE 3.—Location of California scorpionfish tagging and return sites.

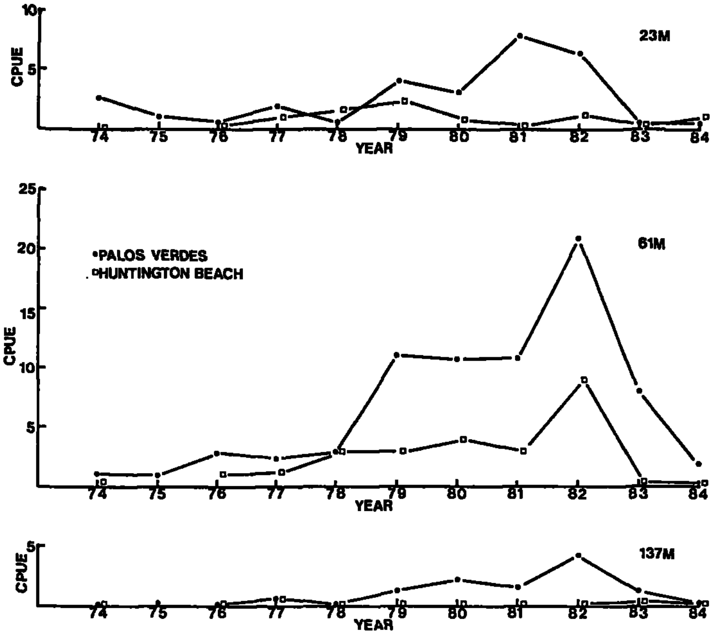

FIGURE 4.—Abundances of California scorpionfish taken by trawl off the Palos Verdes Peninsula and Huntington Beach at three depths from 1974 to 1984.

where the fish went. They did not migrate to deeper waters, as catches did not increase at the deeper stations. It is possible the fish moved north, as we observed a slight increase in commercial trawl-caught scorpionfish off Santa Barbara, 190 km to the north. The populations of several other species (notably bocaccio, *Sebastes paucispinis*; chilipepper, *S. goodei*; and California halibut, *Paralichthys californicus*) seemed to shift northward during the same period.

The presence of California scorpionfish over the soft substrata about Palos Verdes (Fig. 4) attests to the habitat plasticity of this species. This abundance is unusual. For example, the species is only occasionally found over soft substrata to the immediate south (Huntington Beach). We believe the abundance of California scorpionfish over soft substrata about Palos Verdes is linked to the large populations of the ridgeback prawn, *Sicyonia ingentis*, and untimately to the presence of the Whites Point sewer outfall. Both we and Cross[8] have noted that scorpionfish routinely regurgitate these prawns when captured from waters around Palos Verdes.

Studies of sediments about the Santa Monica Bay, Palos Verdes, and Huntington Beach outfalls reveal that substrate deposition of organic material is much greater at Palos Verdes than at the other two sites. This is apparently due to faster water movement and hence greater sewage dispersal at the Santa Monica and Huntington Beach sites (Cross et al. 1985; Cross fn. 8). The large quantities of organics in the Palos Verdes sediment support large populations of ridgeback prawns, populations nearly absent from the other two sites. Additional evidence for this contention comes from the creel census data in Figure 1. These data are based on catches over hard bottom reefs, where ridgeback prawns are not abundant. In this study, California scorpionfish were not more abundant at Palos Verdes than at Santa Monica Bay (to the north) or Huntington Beach (to the south), which have similar environmental parameters. Thus the attraction of the soft substrata around Palos Verdes for scorpionfish is likely to be the one factor which is quite different among the sites—the presence of ridgeback prawns.

Age and Growth

Prior to this study, there was no published work on aging California scorpionfish, the use of pterygiophore sections in age studies had not been validated. To determine if the opaque and translucent zones (as observed by reflected light) were annular,

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[8] J. Cross, Southern California Coastal Water Research Project, Long Beach, CA, pers. commun. May 1985.

we observed the development of the opaque zone on the sections' edges in fishes with 2-5 opaque zones. Opaque zone deposition was seasonal, from late winter through summer (Table 2). A relatively large number of pterygiophores (208 = 34%) were not readable because of malformed or poorly delineated annuli. One hundred and eighty-two females (ages 1-21 yr) and 222 males (ages 1-15 yr) were aged.

TABLE 2.—Monthly percentages of 2-5 yr old *California scorpionfish with opaque margins.*

Month	% opaque	Month	% opaque
January	2	July	89
February	6	August	96
March	28	September	42
April	72	October	16
May	93	November	3
June	92	December	7

Lengths at ages were estimated by direct observation of pterygiophore annuli, back calculated ages, and the von Bertalanffy growth curve model (Tomlinson and Abramson 1961).

$$L_t = L_\infty [1 - \exp - k(t - t_0)]$$

where L_t = length at time t.
L_∞ = theoretical maximum length
k = constant expressing the rate of approach to L_∞
t_0 = theoretical age at which $L_t = 0$

was fitted to the direct observation age-length data.

Since females grew significantly faster than males (ANOVA, $F = 12.5, P < 0.001$) and reach a greater size (Fig. 5), we have separated growth data by sex (Table 3).

Mean lengths at ages from direct observations of annuli and those generated by the von Bertalanffy equations are plotted in Figure 5. The oldest female we observed was 21 yr old, the oldest male 15. We have few samples of fish older than 11 yr, and back-calculated lengths (Tables 4, 5) are computed to this age.

TABLE 3.—Parameters of the von Bertalanffy equation for California scorpionfish off Southern California.

Sex	L_∞	SE	k	SE	t_0	SE
Female	44.33	1.57	0.13	0.02	−1.90	0.42
Male	36.31	1.60	0.12	0.02	−3.86	0.68

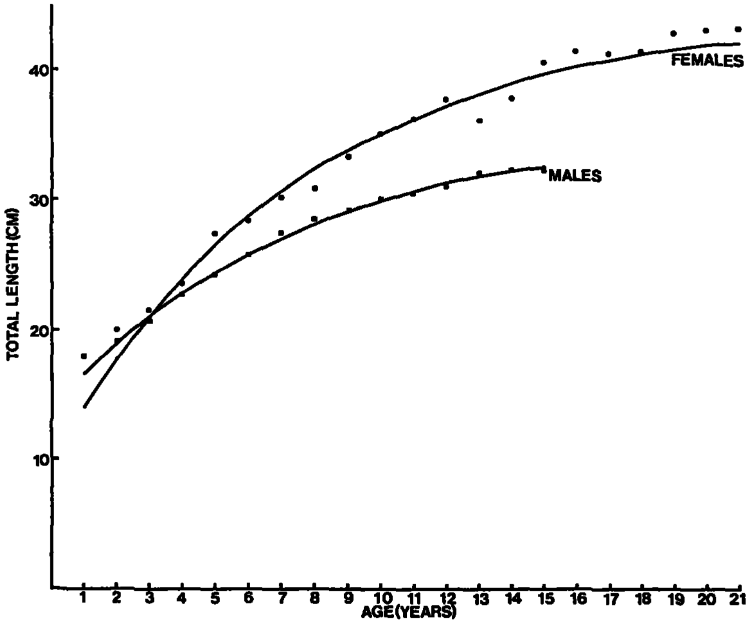

FIGURE 5.—Von Bertalanffy growth curves of female and male California scorpionfish. Also included are mean lengths at age computed from direct observation of pterygiophore annuli. Based on 183 females and 222 males taken in the Southern California Bight, 1981-83.

TABLE 4.—Mean back-calculated total length (centimeters) ±95% confidence intervals at successive annuli for male California scorpionfish captured off southern California, 1981-83.

Age group	No. of fish	1	2	3	4	5	6	7	8	9	10	11
2	7	18.1±1.6	20.4±0.9									
3	31	17.3±0.8	19.5±0.6	21.2±0.6								
4	62	17.2±0.7	19.8±0.7	21.4±0.7	22.5±0.7							
5	40	18.3±0.9	20.7±0.8	22.6±0.8	23.9±0.7	24.9±0.7						
6	15	16.8±1.2	19.9±1.2	21.7±1.0	22.8±0.9	24.0±0.8	25.0±0.6					
7	4	18.2±1.5	20.3±1.6	21.9±1.3	24.0±1.4	25.7±1.7	26.9±1.5	27.6±1.3				
8	9	20.6±1.4	22.7±1.3	24.0±1.8	25.2±1.7	26.5±1.7	27.6±1.5	28.3±1.5	29.2±1.5			
9	5	21.0±2.6	22.9±2.4	23.9±2.3	25.2±1.8	26.0±1.8	27.0±1.5	27.9±1.4	28.5±1.4	29.3±1.5		
10	7	19.7±2.2	21.2±1.8	22.9±2.0	24.2±1.8	25.2±1.5	26.0±1.5	27.0±1.5	28.0±1.5	28.8±1.3	29.4±1.3	
11	4	18.5±1.8	20.6±1.7	22.7±1.1	24.2±1.1	25.0±1.4	26.5±1.3	27.2±1.2	27.8±1.3	29.1±0.4	29.8±0.6	30.5±0.6
Average		17.8	20.2	22.0	23.3	24.5	26.0	27.7	28.4	29.1	29.5	30.6

TABLE 5.—Mean back-calculated total length (centimeters) ±95% confidence intervals at successive annuli for female California scorpionfish captured off southern California, 1981-83.

Age group	No. of fish	1	2	3	4	5	6	7	8	9	10	11
2	3	17.5±0.8	20.6±1.2									
3	31	17.3±0.7	20.2±0.7	22.5±0.7								
4	43	17.7±0.6	20.5±0.7	22.8±0.8	24.2±0.8							
5	31	19.0±1.0	21.8±1.0	24.0±1.1	25.7±1.2	26.8±1.3						
6	24	19.1±1.1	22.0±1.0	24.5±1.0	26.2±1.0	27.7±0.9	28.7±1.0					
7	11	19.1±1.6	21.8±1.8	23.9±1.8	25.5±1.6	26.9±1.6	28.2±1.6	29.4±1.6				
8	3	15.1±4.2	21.0±2.0	23.0±2.8	24.6±2.1	25.8±1.5	27.6±0.8	28.9±0.2	29.7±0.1			
9	1	14.9	23.4	26.5	28.7	30.8	32.4	32.9	34.0	34.5		
10	2	20.8±5.0	24.8±0.7	26.4±0.3	28.0±1.1	30.3±1.6	31.2±2.1	32.6±3.0	33.1±3.0	33.9±2.7	35.1±2.4	
11	1	21.8	26.6	29.5	32.0	33.4	34.4	34.9	35.5	36.3	36.8	37.3
Average		18.2	21.2	23.3	25.3	27.5	28.9	30.4	31.9	34.5	35.4	37.3

All three methods of assessing age and growth (direct observations, back calculations, and von Bertalanffy estimates) yielded roughly similar results, though the method using back-calculated lengths tended to yield faster growth rates than the other two measures, at least for the smaller size classes. Mean lengths at age for females and males were similar through about age 2. Females outgrew males beginning at age 3, when about all males and approximately 60% of females were mature. The maximum theoretical length for California scorpionfish is 44.3 cm (Table 3), close to the maximum observed length of 43 cm (Eschmeyer et al. 1983).

Length-Weight Relationships

A total of 656 males and 371 females from southern California were weighed and measured. The relationship between total length and weight fit the relationship $W = aL^b$, where W = weight in grams, L = total length in centimeters, and a and b are constants, with values determined using $\log_{10}$ transformation and fitting the values to a straight line by least squares (Figs. 6, 7). Males tended to be heavier at a given length (ANOVA, $F = 14.35$, $P < 0.001$). To test whether this difference was an artifact caused by seasonal and gender-related factors, we subtracted gonad weight from body weight, generated the length-weight relationship for each sex, and tested these between sexes. Again, differences between sexes existed (ANOVA, $F = 15.68$, $P < 0.001$).

Condition Factor

Both male and female California scorpionfish displayed differences in condition factor between spawning and resting seasons (Table 6). In both sexes, fish were less robust during the spawning season, perhaps because energy normally utilized for somatic maintenance and growth was shifted to egg and sperm production and spawning behavior. Male California scorpionfish were more robust than females during all seasons.

Maturation and Reproduction

Although a few fish of both sexes matured at 1 yr (14-16 cm TL), over 50% of the males were mature by 17 cm TL and over 50% of the females

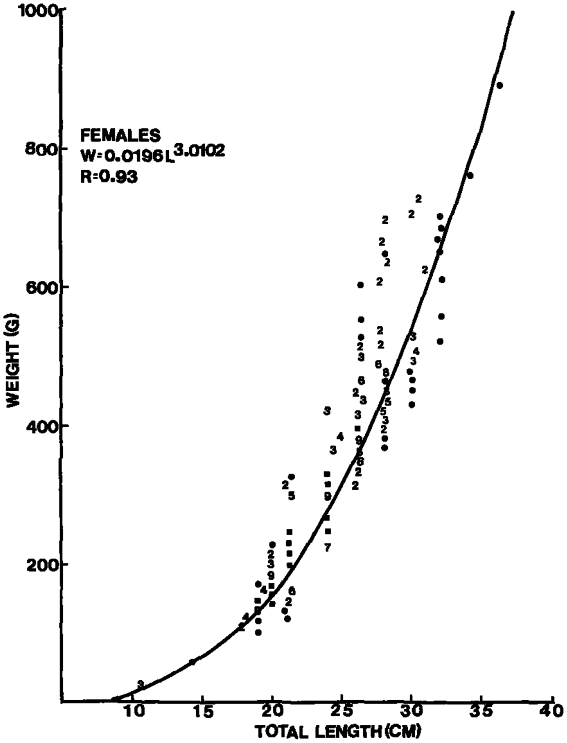

FIGURE 6.—Length-weight relationship of female California scorpionfish sampled in the Southern California Bight, 1981-83. Squares represent more than 10 individuals, dots represent a single fish.

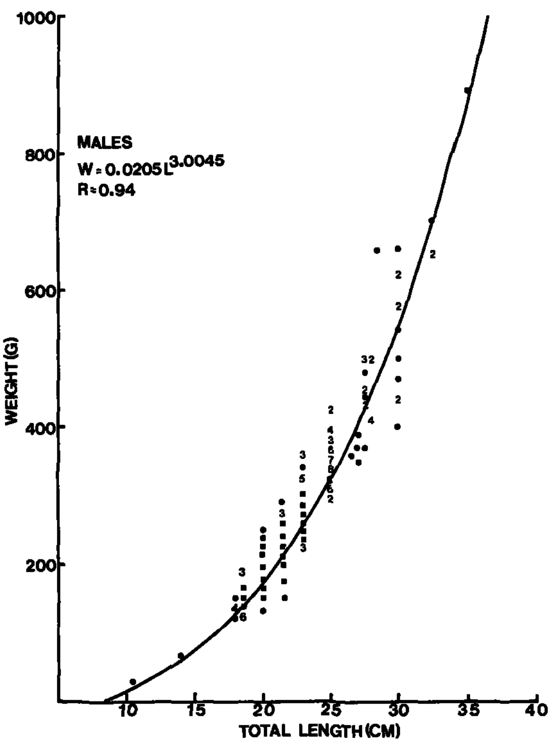

FIGURE 7.—Length-weight relationship of male California scorpionfish sampled in the Southern California Bight, 1981-83. Squares represent more than 10 individuals, dots represent a single fish.

TABLE 6.—Condition factor (K) of California scorpionfish from southern California, 1981-83.

	N	K	SD	U	*P*
Males					
May-Sept.	398	2.16	0.25	27,729.5	<0.001
Oct.-Apr.	256	1.98	0.18		
Females					
May-Sept.	216	2.07	0.28	13,375.5	<0.001
Oct.-Apr.	180	1.93	0.19		
Sexes combined					
May-Sept.	614	2.13	0.26	104,117.5	<0.001
Oct.-Apr.	436	1.96	0.19		
All seasons					
Males	654	2.09	0.24	79,709.0	<0.001
Females	396	2.00	0.25		

by about 18 cm TL, equivalent to 2 yr of age (Fig. 8). Males tended to mature at a slightly smaller size, though all fish were mature by 22 cm TL.

California scorpionfish spawned from May through August, peaking in July. Ovary and testes sizes varied seasonally (Fig. 9). Ovaries were relatively small and constant in size from September to March but began to increase in April and peaked in June and July, dropping precipitously thereafter (Fig. 9). During the peak spawning season, ovaries comprised about 5% of total weight (maximum 17.5%, minimum 1.0%), while during the transition period, ovaries made up slightly <1% (maximum 1.4%, minimum 0.06%).

Testes followed a similar pattern (Fig. 9). They made up slightly more than 0.3% of body weight during late spring and early summer (maximum 0.6%, minimum 0.2%) declining to 0.1% in winter (maximum 0.3%, minimum 0.05%).

We believe spawning takes place just before, and perhaps after dawn, in the water column. On several occasions, about 1 h before sunrise, while conducting surveys on the California scorpionfish spawning grounds, we observed dozens of scorpionfish near the surface. Fathometer tracings indicated large numbers of fish throughout the water column. These fish disappeared just after sunrise. Commercial longline fishermen, targeting scorpionfish on the same grounds, report this is a daily phenomenon. There is no evidence that California scorpionfish behave in this fashion when not in spawning condition.

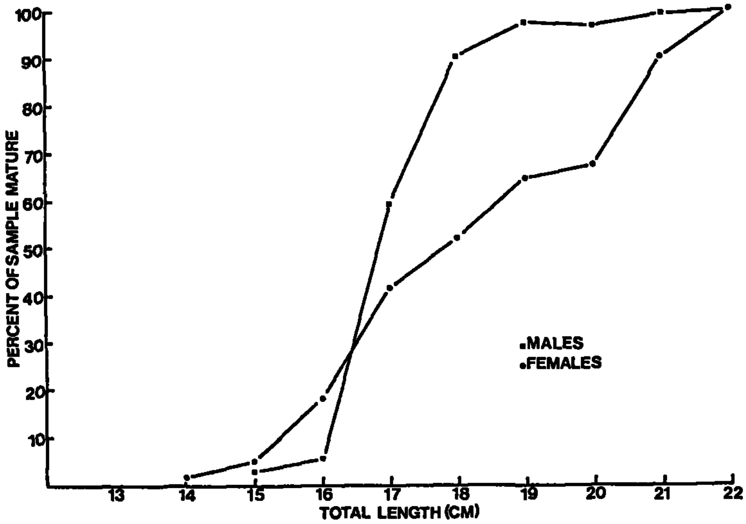

FIGURE 8.—Length-maturity relationship in 246 female and 223 male California scorpionfish collected in the Southern California Bight, 1981-83.

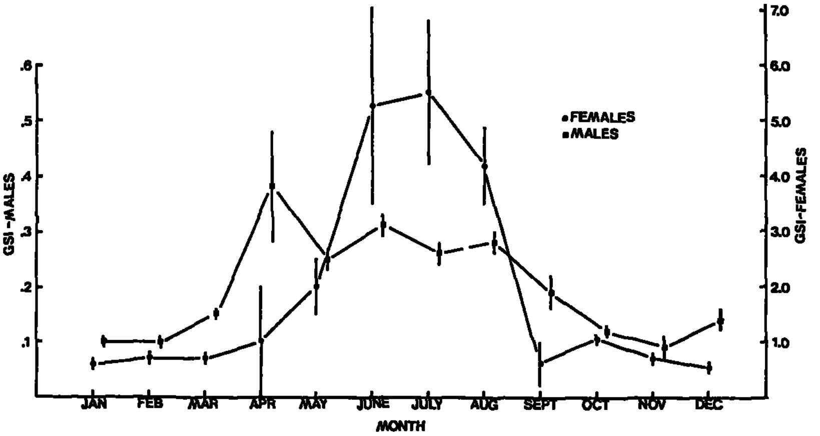

FIGURE 9.—Seasonal changes in the gonosomatic indices (GSI = gonad weight as a percentage of total body weight) of female and male California scorpionfish (based on 396 females and 654 males). Vertical lines indicate 95% confidence intervals of the mean.

We know little of the location of California scorpionfish larvae in the Southern California Bight. Over the past 30+ yr, few have been taken in offshore waters despite considerable numbers of ichthyoplankton surveys (Moser[9]). Moreover, only a few are known from ichthyoplankton surveys conducted in inshore waters (Barnett et al. 1984; McGowan[10]). Particularly puzzling is the lack of larvae taken in King Harbor, Redondo Beach. No larvae were caught during a 7-yr monthly survey, of both surface and bottom waters (Jordan[11]) despite the abundance of young-of-the-year and 1-yr-old fish in the Harbor.

It appears that California scorpionfish utilize an "explosive breeding assemblage" reproductive mode

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[9] G. Moser, Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038, pers. commun. September 1985.

[10] G. McGowan, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007, pers. commun. May 1985.

[11] G. Jordan, VANTUNA Research Group, Occidental College, 1600 Campus Road, Los Angeles, CA 90041, pers. commun. May 1985.

(Emlen and Oring 1977), in which fish migrate to, and aggregate at a "traditional" spawning site for brief (though undefined) periods. Reproduction is polygamous and sexual selection is low. Thresher (1984) speculated such behavior may be the primary reproductive mode of larger pelagic spawning reef fishes—such as snappers, jacks, and barracudas. Smaller fishes would find a spawning migration deleterious, owing to a higher predation risk while traveling.

California scorpionfish do indeed migrate to "traditional" spawning areas and are pelagic spawners. With 50% maturing at 17 cm, they are smaller than the usual explosive breeding assemblage species listed by Thresher (1984). However, it is likely that mature California scorpionfish are not heavily preyed upon (because of their toxin-carrying spines) and thus may be an exception to the rule.

The Dago Bank spawning site is, for the most part, a sandy environment, usually inhabited by relatively few fish. Spawning in a deep-water, relatively depauperate area, the California scorpionfish may avoid some of the egg predation expected in the shallow reefs inhabited during fall-spring. Moreover, by spawning well above the substrata, newly spawned eggs are kept away from benthos-dwelling predators. Many coral reef fishes exhibit the same behavior, which not only decreases egg predation but also places the fertilized eggs into surface currents, increasing the chances of larval dispersal (Thresher 1984).

We do not know how many spawning sites exist off southern California. Santa Monica Bay (Turner et al. 1969) and Dana Point (Cross fn. 6) are likely sites while Anacapa Island and the Coronado Islands (M. Love, unpubl. data) might also be utilized. We have no data on how many years these sites persist as spawning areas. Judging from other species (such as *Clupea harengus*—Cushing 1982), it is likely that scorpionfish spawning grounds are probably of long duration.

For several reasons, this behavior is unusual among fishes in southern California. First, only a few species (notably kelp bass, *Paralabrax clathratus*; barred sand bass, *P. nebulifer*; sargo, *Anisotremus davidsoni*; kelp surfperch, *Brachyistius frenatus*; señorita, *Oxyjulis californica*; and sheephead, *Pimelometopon pulchrum*, Feder et al. 1974) form relatively long-term (to a few months) spawning aggregations. It is noteworthy that, of these fishes, all except the barred sandbass are midwater, active, species particularly when compared with crevice-dwelling scorpionfish.

Second, few reef associated species move off reefs to spawn. Barred sand bass are one of the few exceptions. These form large spawning aggregations over low relief or flat substrata within the Southern California Bight (Turner et al. 1969). The vast majority of reef dwelling fish are relatively sedentary. Many are either territorial or occupy home ranges. Virtually all stay within the reef vicinity. For these species, spawning takes place within their usual habitats.

Lastly, the California scorpionfish does not have the morphology of a fish given to long movements. Such adaptations can be seen most graphically among the northeast Pacific rockfishes, genus *Sebastes*. Sedentary, territorial species, such as the gopher rockfish, *S. carnatus*, and treefish, *S. serriceps*, are very spiny, squat, and deep-bodied forms. More active, midwater species, such as the yellowtail rockfish, *S. flavidus*, and boccacio, *S. paucispinis*, are more streamlined, with reduced spines (particularly about the head). This trend culminates in the pelagic shortbelly rockfish, *S. jordani*, which resembles a mackerel or sardine. In contrast, California scorpionfish closely resemble the benthic rockfish. Yet, the species seems to move about considerably, even excluding movements to and from spawning grounds. Tagging data from studies of the California Department of Fish and Game show movements as much as 190 km (Hartmann[12]).

Food Habits

We sampled 24 California scorpionfish (TL = 21.2-32.5 cm) with food in their stomachs. Though we captured many hundreds of scorpionfish throughout the Southern California Bight, individuals taken in water deeper than about 16 m regurgitated prey during capture. The 24 individuals with prey represented 68.5% (24 of 35) of all scorpionfish taken in water <16 m.

We have graphically represented prey importance (Fig. 10), using the Index of Relative Importance (Pinkas et al. 1971). Crabs were the most important food item. These were primarily juvenile *Cancer anthonyi*, but we also found a few *Loxyrhynchus* sp., *Randalia ornata*, and *Pagurus* sp. Fishes were second in importance. Recognizable species were the northern anchovy, *Engraulis mordax*, and the spotted cusk-eel, *Chilara taylori*. Octopi, isopods, shrimp (primarily *Alphaeus* sp.), and small pebbles made up the rest of the diet.

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[12] A. R. Hartmann, California Department of Fish and Game, Long Beach, CA 90802, pers. commun. June 1984.

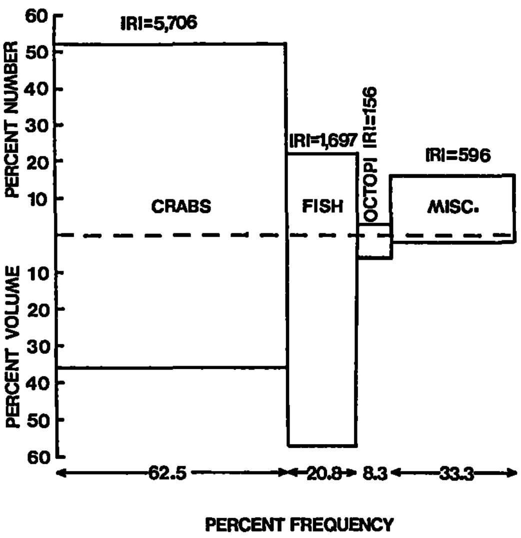

FIGURE 10.—Index of Relative Importance of prey found in stomachs of 24 California scorpionfish, captured in the Southern California Bight.

Turner et al. (1969) examined diets of California scorpionfish living on southern California artificial reefs. They found the species fed almost exclusively upon juvenile *Cancer* crabs during fall and winter; at other times scorpionfish ate octopus and fish. This is similar to our findings, in which juvenile *Cancer anthonyi* were the most important prey. Thus, though the habitat we examined was different from that surveyed by Turner et al., California scorpionfish may sometimes seek out juvenile *Cancer* crabs, regardless of whatever other potential prey are available. When juvenile crabs are not present, California scorpionfish prey on other forms, including octopus and fish.

Limbaugh (1955), Quast (1968c), and Hobson et al. (1981), surveying California scorpionfish over natural rocky reefs, have all reported roughly equivalent food habits, with demersal crustaceans (particularly crabs and shrimps) of most importance, followed by fishes, octopi, and squids. Hobson et al. speculated the species captured most prey at night.

Fishery

Within the Southern California Bight, the California scorpionfish is a relatively minor constituent of the partyboat sportfish catch (Table 7). The species ranked 15th in abundance, comprising about 1.5% of all fishes taken. As scorpionfish were less abundant in the northern part of the Bight, we deleted data from sites north of Pt. Mugu (shown in Figure 1). When species were reranked, scorpionfish moved up to 12th most abundant, forming 1.8% of the catch. Throughout the Bight, over the years 1975-78, the annual contribution of scorpionfish to the total partyboat catch, was fairly constant, hovering at about 1.5% (Fig. 11). Most of the scorpionfish taken aboard partyboats were mature (Fig. 12).

The importance of scorpionfish to the total partyboat fishery varied with season (Fig. 11). During the nearly 4 years of the creel census, scorpionfish contributed most heavily to the catch (as much as 3.0%)

TABLE 7.—The twenty most commonly taken species aboard commercial passenger vessels in the Southern California Bight, April 1975-December 1978. A. Rankings for entire Bight, total number of fish sampled = 342,052. B. Southern California Bight from Pt. Mugu south, total number of fish sampled = 278,664.

Species	No.	%
A		
1. *Sebastes paucispinis*	78,877	23.1
2. *Paralabrax clathratus*	38,315	11.2
3. *Scomber japonicus*	35,072	10.3
4. *Sebastes goodei*	27,218	8.0
5. *Sebastes serranoides*	19,455	5.7
6. *Sarda chiliensis*	16,295	4.8
7. *Paralabrax nebulifer*	13,987	4.1
8. *Sebastes mystinus*	13,646	4.0
9. *Sphyraena argentea*	8,391	2.5
10. *Genyonemus lineatus*	7,841	2.3
11. *Sebastes miniatus*	7,023	2.1
12. *Sebastes chlorostictus*	5,505	1.6
13. *Sebastes hopkinsi*	5,025	1.5
14. *Caulolatilus princeps*	4,990	1.5
15. *Scorpaena guttata*	4,976	1.5
16. *Medialuna californiensis*	3,990	1.2
17. *Sebastes entomelas*	3,969	1.2
18. *Sebastes rubrivinctus*	2,859	0.8
19. *Sebastes elongatus*	2,568	0.8
20. *Sebastes caurinus*	2,513	0.7
B		
1. *Sebastes paucispinis*	61,962	22.2
2. *Scomber japonicus*	33,076	11.9
3. *Paralabrax clathratus*	29,655	10.6
4. *Sebastes goodei*	21,408	7.7
5. *Sarda chiliensis*	16,213	5.8
6. *Sebastes serranoides*	14,987	5.4
7. *Paralabrax nebulifer*	13,371	4.8
8. *Sebastes mystinus*	9,083	3.3
9. *Sphyraena argentea*	8,376	3.0
10. *Genyonemus lineatus*	7,257	2.6
11. *Sebastes miniatus*	5,109	1.8
12. *Scorpaena guttata*	4,880	1.8
13. *Caulotilus princeps*	4,778	1.7
14. *Medialuna californiensis*	3,906	1.4
15. *Sebastes hopkinsi*	3,747	1.3
16. *Sebastes chlorostictus*	3,263	1.2
17. *Sebastes rubrivinctus*	2,381	0.9
18. *Anoplopoma fimbria*	2,279	0.8
19. *Sebastes entomelas*	2,101	0.8
20. *Sebastes constellatus*	2,019	0.7

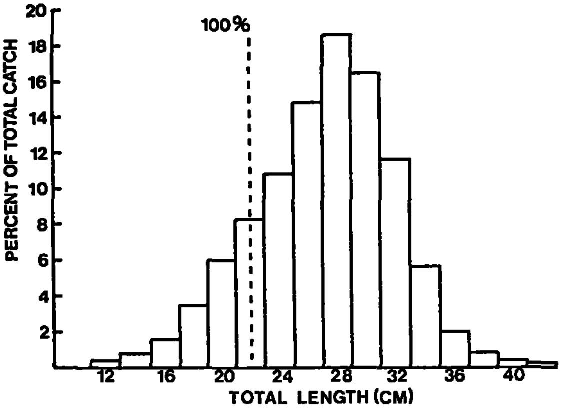

FIGURE 11.—Seasonal distribution of California scorpionfish catch in the southern California partyboat sport fishery, 1975-78.

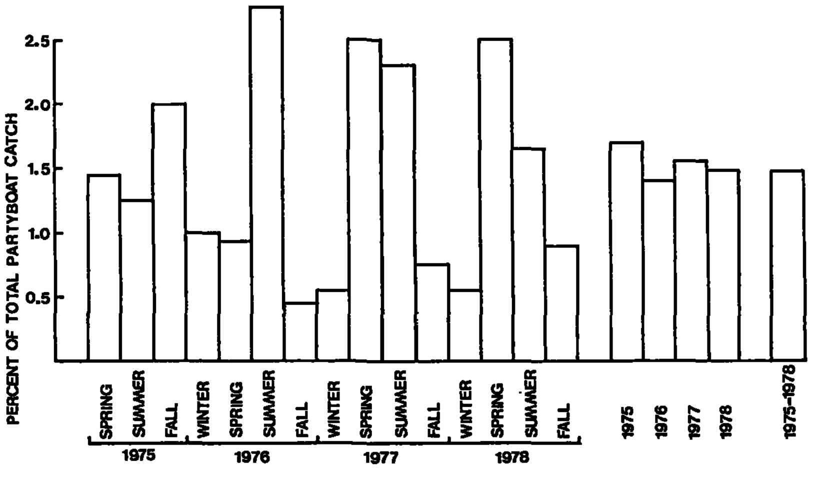

FIGURE 12.—Size distribution (with 100% maturity length) of California scorpionfish taken in the southern California sport fishery, 1975-78.

during spring and summer. This is apparently due to some vessel operators targeting spawning aggregations.

Figure 11 indicates the depths at which California scorpionfish were taken over the years 1975-78. During the May-September spawning season, fish were most abundant in 61-90 and 121-150 m. Relatively few fish were taken between 61 and 150 m from October to April, with catches ranging from 10 to 10^5 times as great in May to September. Similarly, October to April catches were highest in inshore waters.

Historically, California scorpionfish were taken commercially by hook and line and, occasionally, round haul nets (Daugherty 1949). Currently, the species is captured by hook and line, gill net, and, rarely, otter trawl. While hook-and-line catches predominate, gill net landings are also important. In a 1984 study, Collins et al.[13] found that scorpionfish were the 10th most abundant species in the California halibut gill net fishery. In recent years, the fishery has been almost entirely limited to the later spring and early summer months (Fig. 13), with catches between June and August accounting for about 80% of the total.

Traditionally, the bulk of California scorpionfish have been caught by a few fishermen specializing in this species. From our observations, it seems likely that the number of specialists has declined markedly since the 1950's. A few vessels of the Newport dory fishery (Cross fn. 8) specialize in fishing for California scorpionfish and their techniques are illustrative. The fishermen concentrate their activities on the spawning grounds offshore of Long Beach—the same area we utilized in our tagging study. As the precise time of fish aggregation varies from year to year, occasional exploratory trips are made to the grounds beginning in May. Most catches begin in June and end in August. Using long lines, the fishermen deploy on the bottom 1,200-2,000 hooks (4/0-5/0 long shank) in 600-1,300 m (1,970-4,265 ft) sets. The hooks (baited with anchovies,

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[13] Collins, R. A., M. M. Vojkovich, and R. J. Reed. 1985. Progress Report, Southern California nearshore gill and trammel net study 1984. Calif. Dep. Fish Game, 40 p.

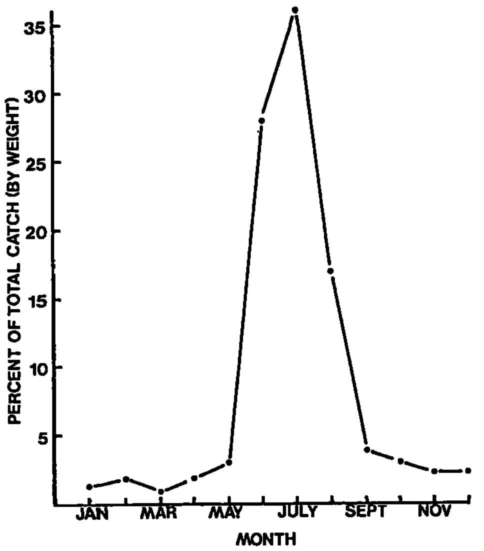

FIGURE 13.—Monthly percentile distribution of the commercial California scorpionfish catch. Based on 1970-84 California commercial landings.

mackerel, or other fish) are usually set about 1 h before sunrise and pulled 1-2 h later. Fishermen report that the fish do not seem to feed well before or after this time.

Traditionally, the Newport fishermen sell their catch to the public on the beach next to the Newport Pier. However, fishermen specializing in scorpionfish often sell their entire catch to fish processors in San Pedro, receiving a relatively high $1.98-$2.75/kg (90¢-$1.25/lb). All commercially caught scorpionfish are sold whole and fresh. Demand is particularly strong within the Asian community.

Over the past 38 yr, commercial landings of California scorpionfish have exhibited considerable fluctuation (Fig. 14), though from relatively high postwar levels, landings have gradually declined, sinking to lowest levels in 1984. Daugherty (1949) noted that fluctuations in California scorpionfish landings seemed more a reflection of fishing effort than of stock size. Certainly, some of the patterns of the last 38 yr reflects fewer fishermen targeting this species. The situation is confounded by a lack of historic population data. However, using the SCCWRP and Orange County Sanitation trawl data (Fig. 4), we note that the rise in scorpionfish population, which peaked in 1982, was matched by a peak in the commercial catch. Conversely, the sharp decline in numbers of trawl-caught fish in 1983-84 was also reflected in the commercial fishery. At least

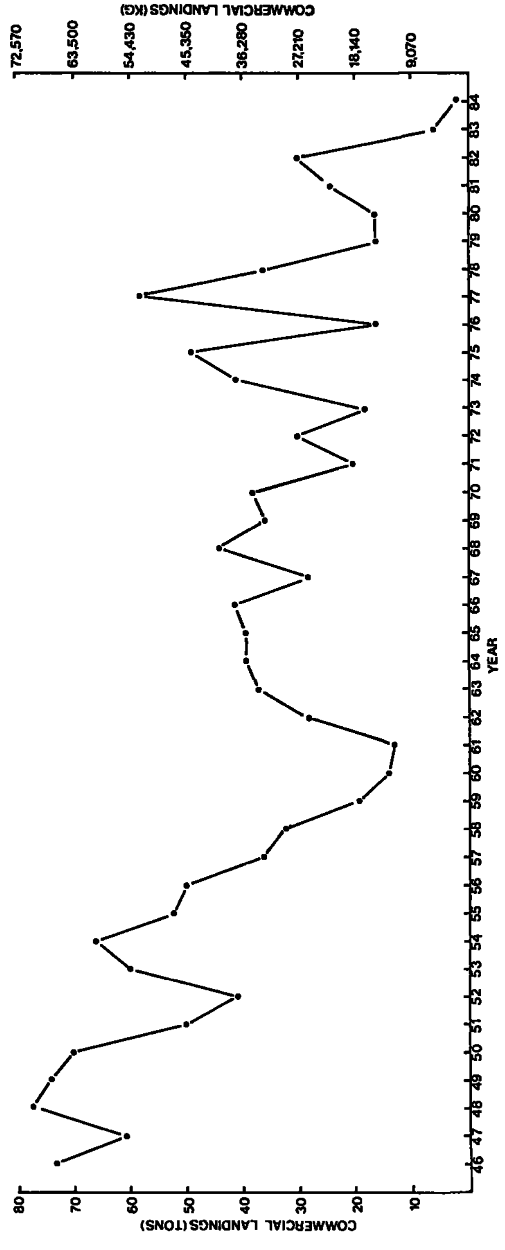

FIGURE 14.—Commercial landings of California scorpionfish caught within California waters, 1953-84.

three sharp catch declines have occurred during or just after warm-water (El Niño) incursions. The major El Niños of the later 1950's and 1983-84 and the lesser one of 1978-79 were all associated with declines in catches. Thus, it seems likely that both variation in fishery effort and fish availability have been responsible for fluctuations in the commercial catch.

As mentioned previously, most of the commercial fishery is concentrated on the spawning grounds, involving rather labor-intensive hook-and-line fishing. Relatively few vessels, primarily small skiffs, specialize in this fishery. While fisheries which occur primarily on spawning grounds are quite susceptible to rapid depletion, the relative inefficiency of this fishery and the low effort level may preclude this event. However, the introduction of other fishing techniques, such as gillnetting or trawling, might cause problems. At present, most trawling is conducted in the upper part of the Southern California Bight, where spawning aggregations are either small or absent. Trawling over spawning grounds would likely lead to a rapid decline in scorpionfish numbers.

Similarly, sportfishing can locally decrease the numbers and mean lengths of popular sport species. This is particularly true of the partyboat sport fishery, where vessels carrying 40 or more passengers may fish the same reef day after day. Particularly susceptible are the inshore rockfishes (Scorpaenidae: *Sebastes*) many of which maintain home ranges or territories on shallow reefs (Love 1978, 1980; Larson 1980). On some heavily fished reefs in southern California, only juveniles of some rockfish species remain—larger individuals are caught as soon as they are large enough to take a hook. However, because California scorpionfish are quite mobile—not permanently tied to a particular reef—they are not as susceptible to depletion as other inshore members of their family.

ACKNOWLEDGMENTS

We wish to thank Andrew Heard, Laura Madjedi, Heidi Parker, Laura Targgart and the crew of the RV *Vantuna* (Chris Dunham, Mark Kibby, and Rick Lange) for assistance in fish collection and tagging. Jeffrey Cross and William Eschmeyer supplied valuable data and unpublished manuscripts. Alfred W. Ebeling reviewed the manuscript. Sara Warschaw graciously typed the manuscript. This work was supported, in part, by the Southern California Edison Company and by Federal Aid to Sportfish Restoration (Dingell-Johnson) funds.

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