ASPECTS OF THE LIFE HISTORY AND FISHERY OF THE WHITE CROAKER, *GENYONEMUS LINEATUS* (SCIAENIDAE), OFF CALIFORNIA

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ABSTRACT

White croaker, *Genyonemus lineatus* (Ayres), was a dominant species off southern California in nearshore, sandy substratum waters, and comprised 29.7% of all fish taxa taken in otter trawl hauls. Juveniles occurred in waters <27 m and the mean length of all individuals increased with depth. The maximum depth of capture was 183 m.

White croaker live to 12 years, exhibiting rapid growth which is essentially constant throughout the species' life. Females grew at a slightly faster rate than males. Von Bertalanffy age-length parameters for females were $L_\infty = 60.7, k = 0.04, t_0 = -7.6$, and for males $L_\infty = 59.2, k = 0.03, t_0 = -8.7$. After 1 year, more than 50% of the individuals are mature, but others delay maturity for 4 years. Larger females had longer spawning seasons than did smaller individuals. Although spawning occurred throughout the year, principal spawning occurred between November and April, with a February-March peak. White croaker are batch spawners; females spawned 18-24 times a season. Batch fecundities ranged from 800 to 37,200 eggs. White croaker reproduction off Monterey differed significantly from that off southern California. Large-scale spawning occurred from at least July through February, and continued throughout the year. Colder water off Monterey may have allowed for extended spawning activity.

White croaker larvae were a significant constituent of the southern California ichthyoplankton fauna, second in abundance to northern anchovy, *Engraulis mordax*, in waters <36 m deep. Data from ichthyoplankton surveys indicated two spawning centers, one located from Redondo Beach to Laguna Beach and a smaller one centered about Ventura. Highest larval densities were found near the substratum in 15-22 m of water. White croaker is an important part of the skiff sportfishery and the basis of a growing commercial gill net fishery. Size frequencies of white croaker taken in both fisheries indicated that few juveniles were captured.

Fishes of the family Sciaenidae (drums) are a major constituent of the fauna of the eastern temperate Pacific coast off California (Skogsberg 1939; Frey 1971). Eight species have been recorded off California, primarily in inshore waters. With the exception of the shortfin corvina, *Cynoscion parvipinnis*, and black croaker, *Cheilotrema saturnum*, all six of the other species known from off California (white seabass, *Atractoscion nobilis*; white croaker, *Genyonemus lineatus*; California corbina, *Menticirrhus undulatus*; spotfin croaker, *Roncador stearnsii*; queenfish, *Seriphus politus*; yellowfin croaker, *Umbrina roncador*) are of sport or commercial importance.

The white croaker is an abundant species that associates with soft (primarily sand) substrata in the coastal zone. White croaker are small (reaching lengths of 41.4 cm total length, Miller and Lea 1972) and active fishes that range from the surf zone to depths of 183 m between Vancouver Island, British Columbia, Canada, south to Magdalena Bay, Baja California, Mexico. Within this geographic range, they are most abundant between San Francisco Bay and northern Baja California. White croaker are omnivores, feeding on a variety of benthic and epibenthic forms (crustaceans, clams, polychaetes, and small fishes, particularly the northern anchovy, *Engraulis mordax* (Phillips et al. 1972; Morejohn et al. 1978; Ware 1979)).

White croaker are the mainstay of pier and small boat sportfish catches in both southern (Pinkas et al. 1968; Wine and Hoban 1976) and central California (Miller and Gotshall 1965). In addition, commercial catches have increased in recent years to 200,000 kg/yr.[4] Despite this, *G. lineatus* is a much maligned species, as it is small and adept at bait-stealing. More-

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over, there is a firmly held belief that white croaker are unusually wormy. In fact, the frequency of occurrence of nematodes (larval *Anisakis* and *Phocanema*) in white croaker muscle is lower than that for at least some other important sport and commercial species such as California halibut, *Paralichthys californicus*, and chilipepper rockfish, *Sebastes goodei* (Dailey et al. 1981).

Because white croaker are abundant around sewage outfalls and tolerant of degraded environments, much of the recent research on this species has been pollution-centered. Several published works deal with pesticide levels (Castle and Woods 1972; MacGregor 1972; Stout and Beezhold 1981) and pollution-implicated diseases and abnormalities (Russell and Kotin 1957; Mearns 1974, 1979; Mearns and Sherwood 1977; Sherwood 1978). Five small-scale studies have been conducted on its life history (Issacson 1964, 1967; Goldberg 1976; Morejohn et al. 1978; Ware 1979)

This contribution represents a summation of unpublished white croaker data obtained from three sources: a life history and fishery study by Love, ichthyoplankton work by McGowen and Lavenberg, and a trawling survey by Westphal.

METHODS

Collection of Juveniles and Adults

Samples were collected monthly (3-6 per month) from October 1978 to February 1981 with a 7.6 m or 4.9 m headrope otter trawl in 15-65 m of water between Palos Verdes and Huntington Beach, Calif. Reduced numbers of white croaker also were collected monthly from April 1979 to September 1981 in Monterey Bay with a 4.9 m otter trawl in 10-60 m of water or were purchased from local fishermen. All of these specimens were frozen for later dissection. After thawing, all fish were measured (total length, fork length, standard length), weighed, sexed, and the gonads were weighed.

Collection of Depth Preference Data for Adults and Juveniles

Information on white croaker depth preference was based on data from a trawling program aboard the RV *Vantuna*. Trawling was conducted at a speed of 2-3 kn for 20 min with a 7.6 m (occasionally 4.9 m) otter trawl having a net of 0.6 cm stretch mesh. From September 1972 through December 1980, 18 stations (Fig. 1) were sporadically sampled at 10 depths, although most of the trawling effort was performed at depths between 59 and 91 m. After shipboard sorting, fishes were measured (board standard length) and discarded. All lengths were converted to total length (TL) using conversion factors based on measurements of 100 white croaker (Table 1).

TABLE 1.—Conversion factors between standard (SL), fork (FL), and total (TL) lengths (cm), based on measurements of 100 white croaker from southern California.

SL = 0.442 + 0.79 TL	FL = 0.088 + 0.96 TL	TL = 0.892 + 1.19 SL
= 0.379 + 0.82 FL	= 0.849 + 1.14 SL	= 0.023 + 1.04 FL

Techniques for Aging Juveniles and Adults

Sagitta were removed from each side of the head, and the otoliths were cleaned, air dried, and stored in vials. Because whole croaker otoliths are difficult to age, they were sectioned on a Buehler Isomet[5] low speed saw. Otoliths were placed on wood blocks and completely embedded in clear epoxy (Ciba 825 hardener and Ciba 6010 resin). Each block with its otolith was emplaced on the saw and a dorsal-ventral 0.05 cm wafer was cut through the otolith, using two diamond-edge blades separated by a stainless steel shim. Wafers were stored in water for a few days to soften the epoxy (which was removed), then the wafers were placed in a black-bottomed water glass filled with water and read under a dissecting microscope at a magnification of 10×. All otoliths were read twice, about 4 mo apart, by Love. When readings did not agree, the otoliths were read again. The value of two coincident readings was accepted as the best estimate of age. Fifteen percent of all otoliths were unreadable due to a lack of recognizable annuli.

Procedures for Determining the Timing of Maturation and Reproduction

We estimated length at first maturity by classifying gonads as immature or mature based on the techniques of Bagenal and Braum (1971). Smaller mature fish and fish just entering their first mature season become reproductive later in the spawning season. Hence we estimated length at first maturity during the peak spawning period of January, February, and March. To ascertain spawning season duration and its relation to body size, we sampled at least 150 females/mo in 1 cm size intervals throughout the

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

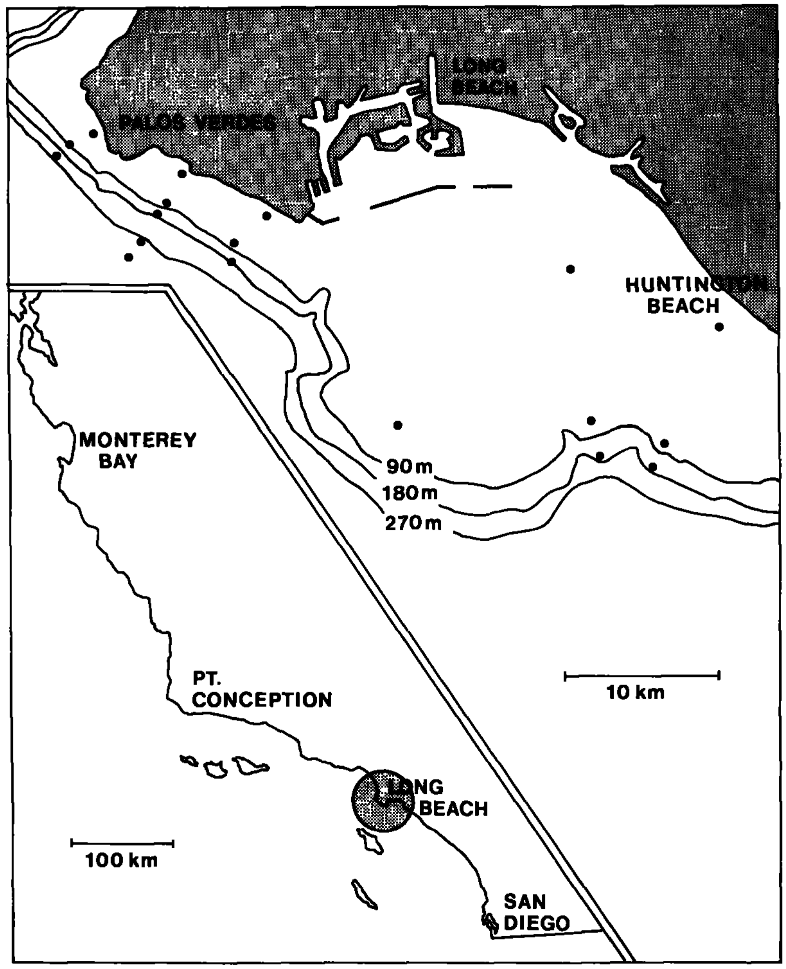

FIGURE 1.—Location of white croaker sampling sites.

year. A gonadosomatic index (gonad weight)/(total body weight) × 100 was computed from frozen specimens to quantify changes in gonad size with season. Ovaries for use in fecundity studies were fixed in modified Gilson's fluid (Bagenal and Braum 1971) for 4-8 mo. We measured fixed egg diameters from 11 individuals, all of which contained some hydrated eggs. Batch fecundity was estimated by the gravimetric method of Bagenal and Braum (1971). The time between spawning events per female was computed by estimating the percent of females with hydrated eggs on any given night during the spawning season.

We computed condition factor $\frac{100\,(W-GW)}{L^3}$, where W = body weight in grams, GW = gonad weight in grams, and L = total length in centimeters—of mature southern California and Monterey croaker. Condition factor was computed using body weight with gonad weight subtracted to minimize the effects of seasonal changes in gonad size.

Larval Sampling

Ichthyoplankton data presented here were collected monthly between August 1979 and July 1980 along 20 sites within the Southern California Bight aboard the RV *Seawatch* (Table 2). Stations were established at 8 and 22 m along each transect (with exception of Palos Verdes and Laguna Beach where 15 m was substituted for 8 m). Additional stations at 15 and 36 m depths were maintained at three sites (Ormond Beach, Redondo Beach, San Onofre). Oblique bongo tows from the bottom to the surface were made at all stations. A 70 cm diameter bongo net sampler (McGowan and Brown 1966), equipped with wheels to prevent damage when the sampler encountered the bottom, was lowered to the bottom with canvas

TABLE 2.—Southern California ichthyoplankton collection sites, August 1979-July 1980. Location abbreviations used in Figures 13-15 are in parentheses.

Collection sites	Lat. N	Long. W
Coho Bay (80)	34°26′	120°26′
Refugio to El Capitan, 8 m (DR)	34°27′	120°02′-120°05′
North of Refugio, 22 m	34°27′	120°06′
Santa Barbara to Goleta Pt. (8.15)	34°25′	119°44′-119°51′
Pt. Gorda to Rincon Pt. (RN)	34°22′-34°23′	119°28′
Ventura (83)	34°16′	119°17′
Ormond Beach (OB)	34°07′	119°10′
Arroyo Sequit (85)	34°03′	118°57′
Malibu Beach (MU)	34°02′	118°41′
Playa del Rey (87)	33°57′	118°27′
Redondo Beach (RB)		
Redondo Breakwater, 8, 15, and 22 m	33°51′	118°24′
Hermosa Pier, 36 m	33°52′	118°25′
Palos Verdes (PV)	33°43′	118°25′
Huntington Harbor (88)	33°41′	118°04′
Balboa (BA)	33°36′	117°54′
Aliso Creek (Laguna Beach) (90)	33°31′	117°46′
San Onofre (SO)	33°21′	117°33′
Santa Margarita River (91)	33°15′	117°28′
Agua Hedionda (Carlsbad) (CD)	33°08′	117°23′
San Dieguito River (Del Mar) (93)	32°58′	117°16′
Mission Beach (MB)	32°48′	117°16′
San Diego (95)	32°38′	117°09′

doors over the mouth openings. The canvas doors were removed by a cable messenger, allowing the nets to fish. Immediately thereafter the sampler was retrieved at a constant rate of about 10 m/min (0.17 m/s); a wire angle of 51 ± 5° was maintained. The ship's speed (0.95 ± 0.03 m/s) plus the retrieval rate brought the net speed to about 1.12 m/s.

In addition, stratified (surface, midwater, bottom) tows were made at each of the four stations on transects at Ormond Beach, Redondo Beach, and San Onofre. Horizontal midwater tows were made with the previously described bongo sampler towed at a rate of 1.06 ± 0.06 m/s. For these tows the sampler was lowered to a depth about half-way between the surface and the bottom, opened via cable messenger, fished, closed via cable messenger, and retrieved. Surface samples were taken with a manta sampler (Brown 1979) towed at a rate of 1.07 ± 0.06 m/s. This net had a rectangular opening (88 × 16 cm). Bottom collections were taken using an auriga net[6] with a 200 × 50 cm mouth. The auriga net fished a zone 2 m wide by 0.5 m deep, about 0.25 m above the substratum, and was fished at a rate of 1.07 ± 0.46 m/s. All nets were equipped with 335 μ mesh. A General Oceanics flowmeter was mounted in the mouth of each net. The field program is described in greater detail by Lavenberg and McGowen.[7]

Additional data from a 4-yr study off Redondo Beach were derived from monthly surface tows made from January 1974 to February 1977, using meter nets with 335 μ mesh. A TSK flowmeter was mounted in the mouth of each net. This field program is described in greater detail by McGowen.[8]

Fishery

Although white croaker are usually the most important species in the private vessel sportfishery, no size-frequency data were available. For this reason, 4,941 croaker taken by anglers aboard skiffs and other small private vessels were measured during the period June 1980 to July 1981, between Oxnard and Dana Point. From September 1980 through August 1981, 1,748 white croaker were taken off southern California by commercial gill net vessels and were measured.

RESULTS

Depth Preference

Our trawling study indicated that white croaker preferred nearshore habitats and their abundance declined in deeper waters. Ranking first of all species taken, white croaker was the dominant species at the shallowest (18-27 m) stations (Table 3), and composed 29.7% by number of the total catch and appeared in 68% of the trawls. At the 59-73 m stations, white croaker catches had declined to 3.3% of total catch, frequency of occurrence 20.7%, and at the 91-109 m station, the species made up 1.2% of total catch, frequency of occurrence 14.0%. At stations between 165 and 183 m, white croaker comprised 0.6% of the total catch, with a frequency of occurrence of 1.7%. On the basis that no individuals were captured at greater depths, we accept 183 m as their maximum depth.

Though white croaker was supplanted as the dominant species at deeper stations, it remained an important community component to depths of 109 m. Two other species, the California tonguefish, *Symphurus atricauda*, and the Pacific sanddab, *Citharichthys sordidus*, were among the 10 most abundant species throughout these depths. Pacific

[6]Mitchell, C. T. Auriga: A wheeled epibenthic plankton sampler for rocky bottoms. Unpubl. rep., 12 p. Marine Biological Consultants Inc., 947 Newhall Street, Costa Mesa, CA 92627.

[7]Lavenberg, R. J., and G. E. McGowen. Coastal ichthyoplankton of the Southern California Bight: temporal and spatial distribution (August 1979-July 1980). Manuscr. in prep. Los Angeles County Museum of Natural History, 900 Exposition Blvd., Los Angeles, CA 90007.

[8]McGowen, G. E. 1978. Effects of thermal effluent from Southern California Edison's Redondo Beach steam generating plant on the warm temperate fish fauna of King Harbor Marina. SCE Research and Development Series: 78-RD-47, 65 p.

TABLE 3.—The 10 most abundant fish species taken by otter trawls in three depth intervals off Southern California, 1972-80.

	Total no. taken	% total no.	% frequency occurence
Depth interval, 18-27 m Number of collections, 109 Total no. of fish, 14,313 Total Species, 80			
Genyonemus lineatus	4,252	29.7	67.9
Citharichthys stigmaeus	2,221	15.5	63.3
Symphurus atricauda	2,031	14.2	60.6
Seriphus politus	1,341	9.4	44.0
Phanerodon furcatus	595	4.2	59.6
Engraulis mordax	591	4.1	22.0
Pleuronichthys verticalis	476	3.3	62.4
Hyperprosopon argenteum	395	2.8	33.0
Citharichthys sordidus	301	2.1	12.8
Synodus lucioceps	206	1.4	38.5
Depth interval, 59-73 m Number of collections, 82 Total no. of fish, 13,337 Total species, 62			
Citharichthys sordidus	3,196	24.0	72.0
Microstomus pacificus	2,769	20.8	65.9
Sebastes dalli	1,565	11.3	65.9
Sebastes saxicola	867	6.5	29.3
Porichthys notatus	786	5.9	59.8
Sebastes jordani	694	5.2	17.1
Symphurus atricauda	512	3.8	51.2
Scorpaena guttata	506	3.8	63.4
Genyonemus lineatus	436	3.3	20.7
Icelinus quadriseriatus	297	2.2	25.6
Depth interval, 91-109 m Number of collections, 172 Total no. of fish, 35,488 Total species, 77			
Microstomus pacificus	12,386	34.9	76.2
Citharichthys sordidus	9,655	27.2	73.8
Sebastes saxicola	4,262	12.0	65.1
Porichthys notatus	1,688	4.8	63.4
Glyptocephalus zachirus	1,249	3.5	30.2
Scorpaena guttata	875	2.5	44.2
Sebastes jordani	802	2.3	21.5
Genyonemus lineatus	441	1.2	14.0
Symphurus atricauda	377	1.1	24.4
Zaniolepis frenata	299	0.8	25.0

sanddab dominated in waters between 59 and 109 m, declining in numbers both inshore and offshore. California tonguefish exhibited an abundance pattern like white croaker, with numbers peaking in inshore waters and declining with greater depth.

Most juvenile white croaker (50% mature by 15 cm) were limited to the inshore (18-27 m) stations (Fig. 2). Larger individuals inhabited greater depths. In fact, the mean size of white croaker was successively larger as depth increased (ANOVA, $F = 284.2, P < 0.001$).

Age and Growth

Lengths at ages were estimated by direct observation of otolith annuli and through the von Bertalanffy growth curve model

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

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.

We transformed male and female growth equations to linear form (Allen 1976) and compared these by analysis of variance. Females were found to grow significantly faster than males ($F = 16.8, P < 0.05$), hence we separated growth data by sex (Table 4).

TABLE 4.—Parameters of the von Bertalanffy equation for white croaker off southern California.

Sex	L_∞	SE	k	SE	t_0	SE
Female	60.72	0.23	0.037	0.02	−7.54	1.1
Male	59.17	0.29	0.033	0.03	−8.66	1.3

The oldest male and female white croaker we examined were 12 yr old (Fig. 3). Females grew slightly faster than males and reached a greater size. Females from age 1 (at which over 50% of the fish were mature) outgrew males.

White croaker grew at a fairly constant rate throughout their lives, exemplified in their very low k values. No asymptote was reached within the observed 12-yr life span. Thus, the maximum predicted lengths were longer than both published (41.4 cm TL, Miller and Lea 1972) and unpublished (44.2 cm[9]) records, although the r values for the von Bertalanffy equations were high (0.84 for both sexes).

Length - Weight Relationships

A total of 581 males and 665 females from southern California and a total of 94 males and 161 females from Monterey Bay were weighed and measured. The relationships 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. 4, 5). In southern California, males tended to be heavier at a given length than females (analysis of variance, $F = 10.18, P < 0.01$), whereas off Monterey no significant difference was found (analysis of variance, $F = 0.67, P > 0.4$). To test whether this difference was an artifact caused by seasonal and gender-related factors, we subtracted

[9]R. N. Lea, California Department of Fish and Game, 2201 Garden Road, Monterey, CA 93940, pers. commun. May 1982.

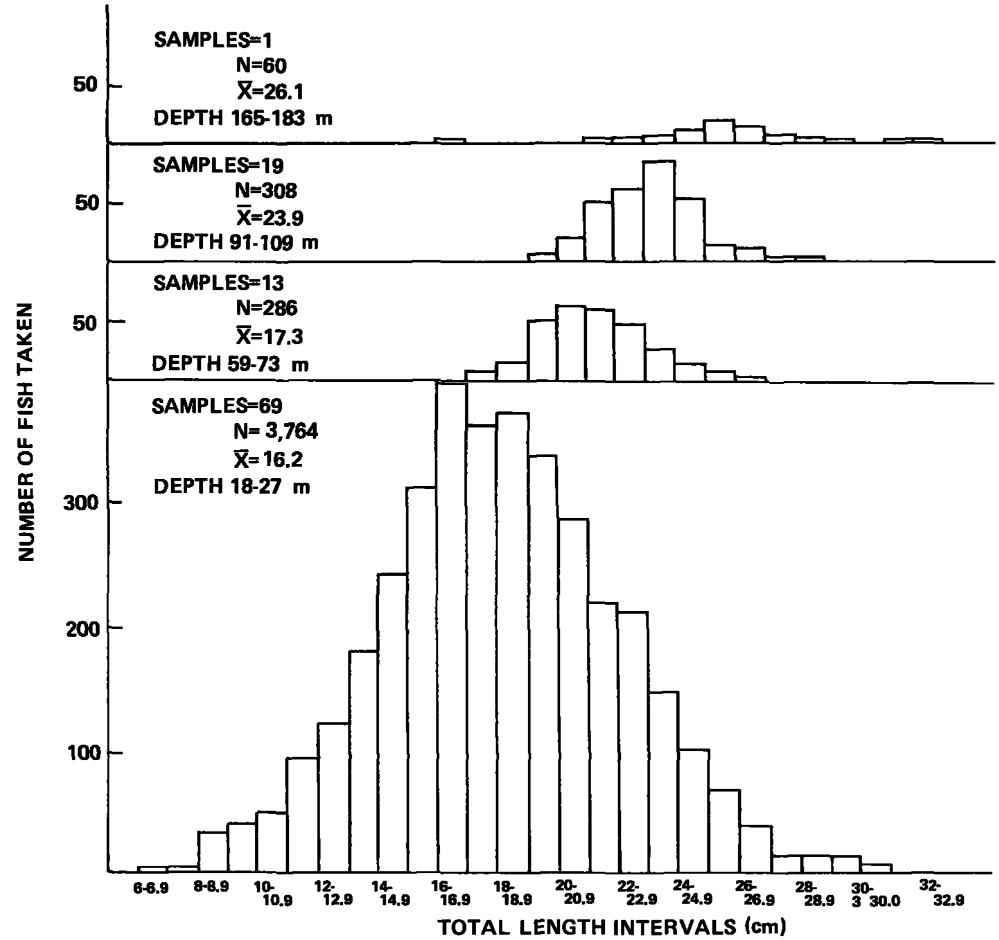

FIGURE 2.—Length intervals of white croaker taken by otter trawl off southern California.

gonad weight from body weight, generated the length-weight relationships for each sex and tested these between sexes. Again, differences between sexes existed in southern California (ANOVA, $F = 11.13, P < 0.01$), but not in Monterey Bay (ANOVA, $F = 1.33, P > 0.05$).

Condition Factor

Both male and female southern California white croaker displayed differences in condition between peak spawning and resting seasons (Table 5). In both sexes, fish were more robust during the resting season, perhaps because energy normally utilized for somatic maintenance and growth was shifted to egg and sperm production and spawning behavior. Over all seasons, whereas southern California females were more robust than males (Table 5), no such sex-

TABLE 5.—Condition factor (K) of white croaker from southern California 1978-81 and Monterey Bay, Calif., 1979-81.

	N	K	SD	F	P
Southern California					
Males					
Jan.-Mar.	264	0.34	0.53	117.4	<0.001
May-Aug.	91	0.98	0.32		
Females					
Jan.-Mar.	280	0.46	0.56	24.4	<0.001
May-Aug.	76	0.80	0.49		
Sexes Combined					
Jan.-Mar.	544	0.40	0.55	118.3	<0.001
May-Aug.	167	0.90	0.41		
All Seasons					
Males	535	0.71	0.56	4.5	<0.05
Females	617	0.78	0.54		
Monterey—All seasons					
Males	80	1.03	0.09	1.29	>0.2
Females	142	1.02	0.10		
Southern California and Monterey					
Males					
Monterey	80	1.03	0.09	26.54	<0.001
S. Calif.	535	0.71	0.56		
Females					
Monterey	142	1.02	0.10	27.83	<0.001
S. Calif.	617	0.78	0.54		

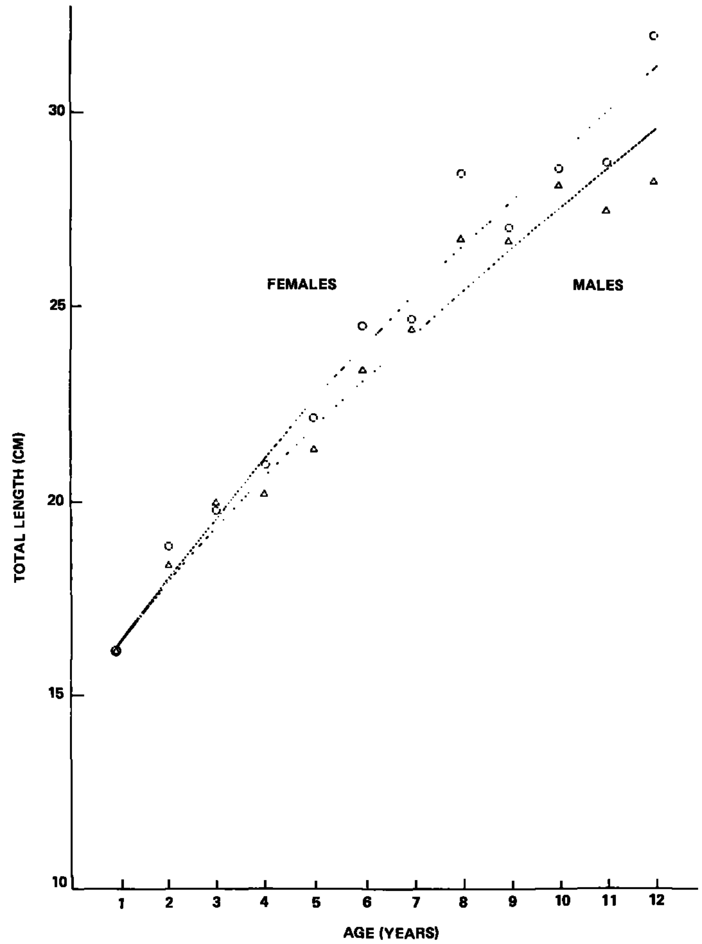

FIGURE 3.—Von Bertalanffy growth curves of female and male white croaker. Also included are mean lengths at ages (females-circles, males-triangles) computed from direct observation of otolith annuli. Based on 332 females and 250 males taken off southern California, 1977-81.

ual dimorphism was observed off Monterey. Both males and females off Monterey were more robust than their southern California counterparts (Table 5).

Maturation and Reproduction

Although a few white croaker matured before 1 yr (12.9-13.4 cm TL), over 50% of the males were mature by 14 cm TL and over 50% of the females by about 15 cm TL, which equals an age of 1 yr (Fig. 6). All fish were mature by 19 cm TL (3-4 yr).

Larger females (greater than about 17 cm TL and 1-2+ yr) spawned earlier in the year and continued to spawn later than smaller and younger individuals (Table 6). The smallest spawning females may spawn for 3-4 mo whereas larger individuals may spawn for as long as 7 mo.

Off Long Beach, white croaker spawned primarily from November through April, with January through March the peak months, based on the occurrence of hydrated eggs within ovaries. A few individuals (>18 cm TL) spawned from May through October. Ovaries increased in size in the fall and peaked in January, when they averaged 4.6% of body weight (maximum 11.8%, minimum 0.8%). Thereafter, ovarian size declined in summer to a minimum of about 1.0% of body weight (maximum 1.3%, minimum 0.07%) and remained constant through August (Fig. 7).

Similarly, testes were small during summer months

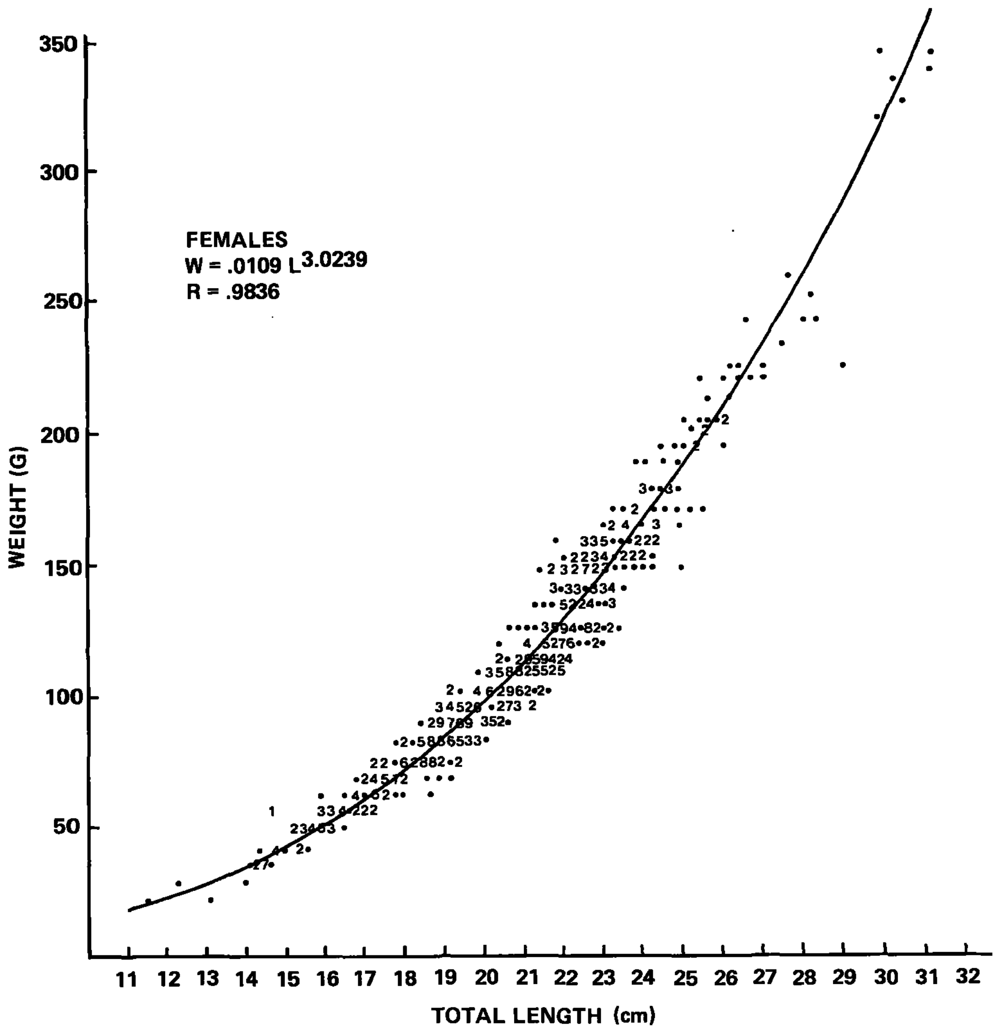

FIGURE 4.—Length-weight relationship based on 665 female white croaker sampled off southern California, 1978-81.

TABLE 6.—The percent per month of female white croaker from southern California (1978-81) that were sexually mature.

Mean total length (cm)	Percent sexually mature											
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
13.0	0	0	0	2	16	15	6	0	0	0	0	0
14.0	0	0	0	11	26	26	8	0	0	0	0	0
15.0	0	0	0	21	73	72	15	0	0	0	0	0
16.0	0	0	0	18	88	88	27	0	0	0	0	0
17.0	0	0	2	20	91	90	35	tr[1]	1	0	0	0
18.0	0	0	6	21	96	94	61	tr	tr	0	0	0
19.0	0	0	7	21	100	100	83	48	tr	0	0	0
20.0	0	tr	7	23	100	100	82	52	tr	0	tr	tr
21.0	0	0	5	31	100	100	94	51	2	tr	0	0
22.0	tr	0	6	32	99	99	93	58	1	0	0	0
23.0	0	0	7	48	100	100	95	60	tr	0	0	tr
24.0	tr	0	6	47	100	100	93	58	2	0	0	0
25.0	0	0	6	47	100	100	99	57	2	0	0	0
26.0	0	tr	6	46	100	100	98	59	1	0	tr	0

[1]Trace <1%.

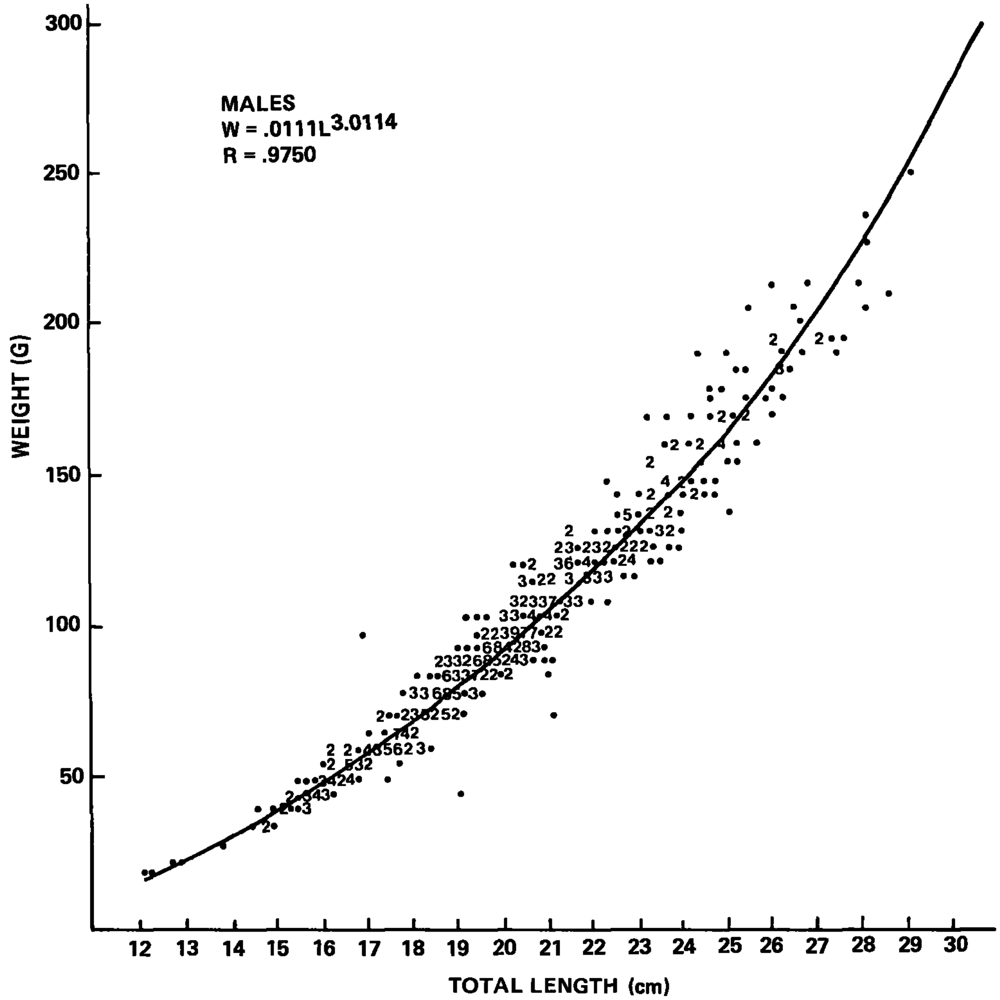

FIGURE 5.—Length-weight relationship based on 581 male white croaker sampled off southern California, 1978-81.

(Fig. 8), averaging 0.3% of body weight (maximum 0.9%, minimum 0.05%), and increased in the fall to a January peak averaging 2.6% of body weight (maximum 7.7%, minimum 0.4%).

In contrast, white croaker off Monterey Bay spawned over a longer period and may have winter and summer spawning peaks. Ovarian weights were highest in January and September (averaging about 6.5 and 7.0% of body weight, respectively) and lowest in May (1.3% of body weight). Ovaries never shrank to the minimum sizes typical of individuals in the southern California population during summer months. Testes grew to a much larger maximum size (4.6% vs. 2.6%) off Monterey. Northern white croaker spawned nearly every month, though spring spawning might have been limited. In limited sampling during the following year,[10] the second (January) peak was not evident, and thus may not be an annual event.

Batch fecundities ranged from an estimated 800 eggs in a 15.5 cm female to about 37,200 in a 26 cm female (Fig. 9). During the spawning period about 19% of all mature female white croaker sampled contained hydrated eggs, implying that a female spawned about once every 5 d. Females of ages 1 and 2 (13-18 cm) have a spawning season of 3 mo (Table 6) and spawn about 18 times per season, whereas older fish (19 cm and larger) spawn over a period of 4 mo, about 24 times/season.

[10]T. Keating, Moss Landing Marine Laboratory, P.O. Box 223, Moss Landing, CA 95039, pers. commun. January 1982.

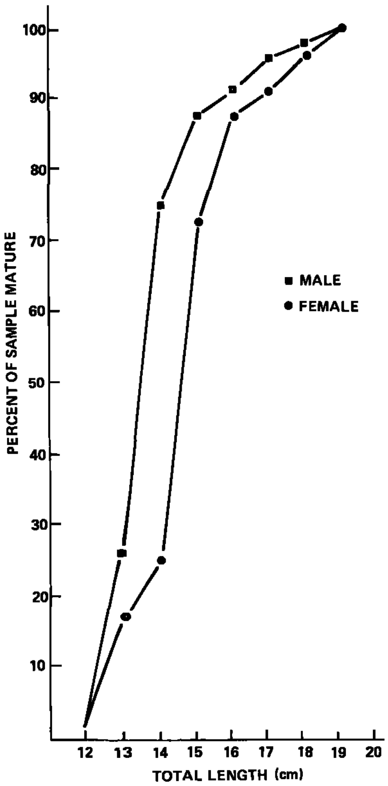

FIGURE 6.—Length-maturity relationship in 995 female and 941 male white croaker collected off southern California, 1978-81.

Larvae

Data from our ichthyoplankton surveys showed that white croaker spawning occurs every month of the year (Fig. 10). However, a distinct seasonal spawning period can be deduced from findings that few larvae were collected from June through November, whereas high densities were encountered from January through April with a strong peak in March. Results of our study in King Harbor, Redondo Beach (Fig. 11), confirm the peak densities of white croaker larvae in January, February, and March.

White croaker larvae constitute an important component of the neritic ichthyoplankton fauna of the Southern California Bight, ranking second in overall abundance behind the northern anchovy, *Engraulis mordax*. On a per transect basis (Fig. 12), white croaker larvae ranked first in abundance at all transects between Palos Verdes[11] and Laguna Beach and

[11] *Genyonemus* and *Engraulis* were virtually tied for first place at Redondo Beach with 40.1% and 40.3%, respectively.

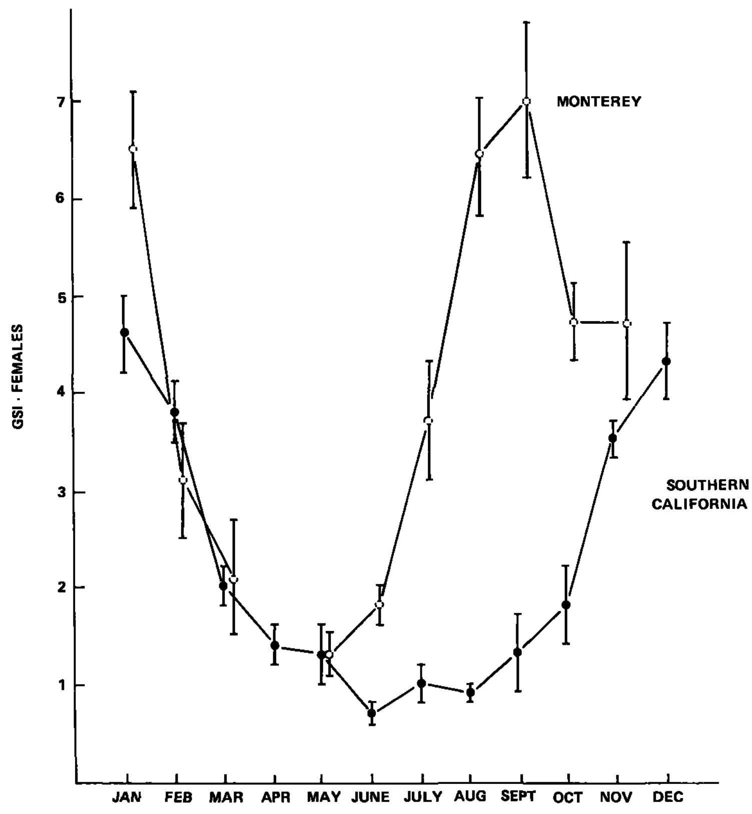

FIGURE 7.—Seasonal changes in the gonosomatic index (GSI-gonad weight as a percentage of total body weight) of female white croaker (based on 720 southern California and 223 Monterey individuals). Vertical lines indicate 95% confidence intervals of the mean.

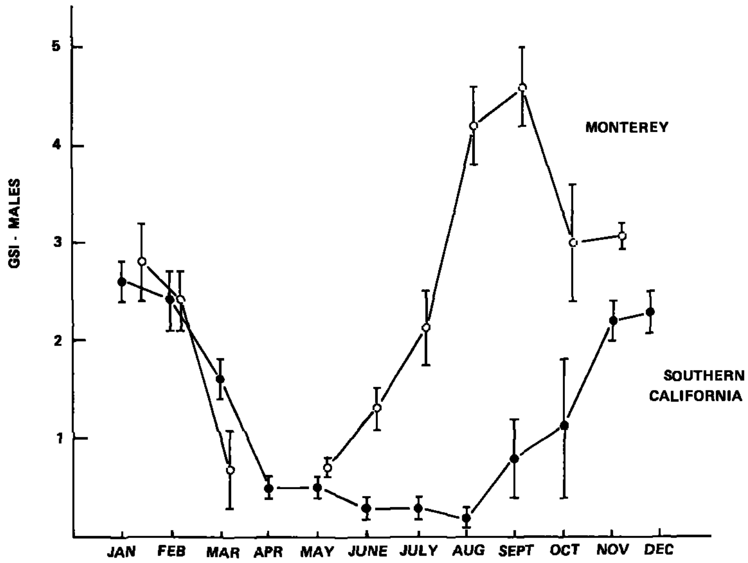

FIGURE 8.—Seasonal changes in the gonosomatic index of male white croaker (based on 631 southern California and 114 Monterey individuals). Vertical lines indicate 95% confidence intervals of the mean.

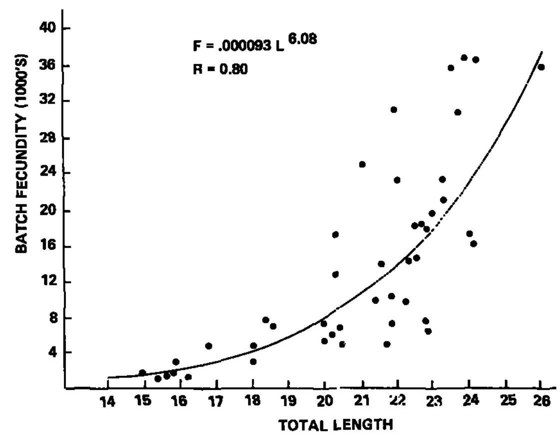

FIGURE 9.—Batch fecundity—total length relationship for 44 white croaker collected off southern California during February and March 1979-81.

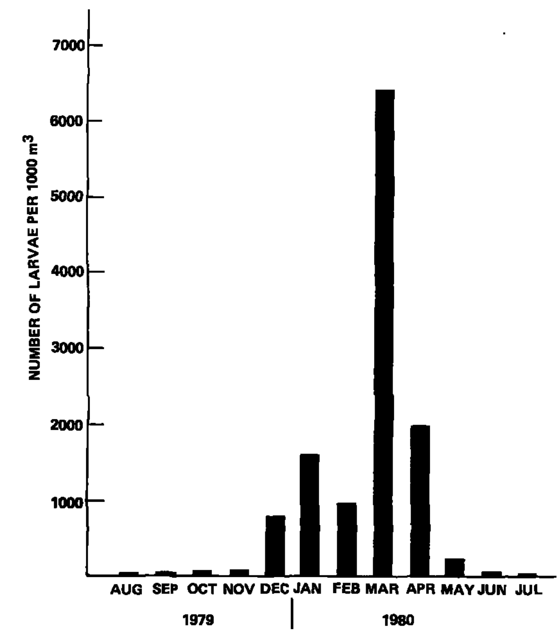

FIGURE 10.—Mean density of white croaker larvae collected in the oblique bongo tows per month between August 1979 and July 1980.

second at the remaining transects, except Mission Beach where it ranked third behind *Engraulis* and an unidentified goby. In the King Harbor study, white croaker larvae ranked either fourth or fifth depending on the year and the stations sampled.

Larval density data (number of individuals per unit volume of water) indicate two spawning centers between Point Conception and the U.S.-Mexican border (Fig. 13): The larger one extends north and south of the Palos Verdes Peninsula, from Redondo Beach to Laguna Beach, whereas the smaller one is further north around Ventura. That area from San Onofre south to the international border was striking for its low densities of white croaker larvae. Along this sec-

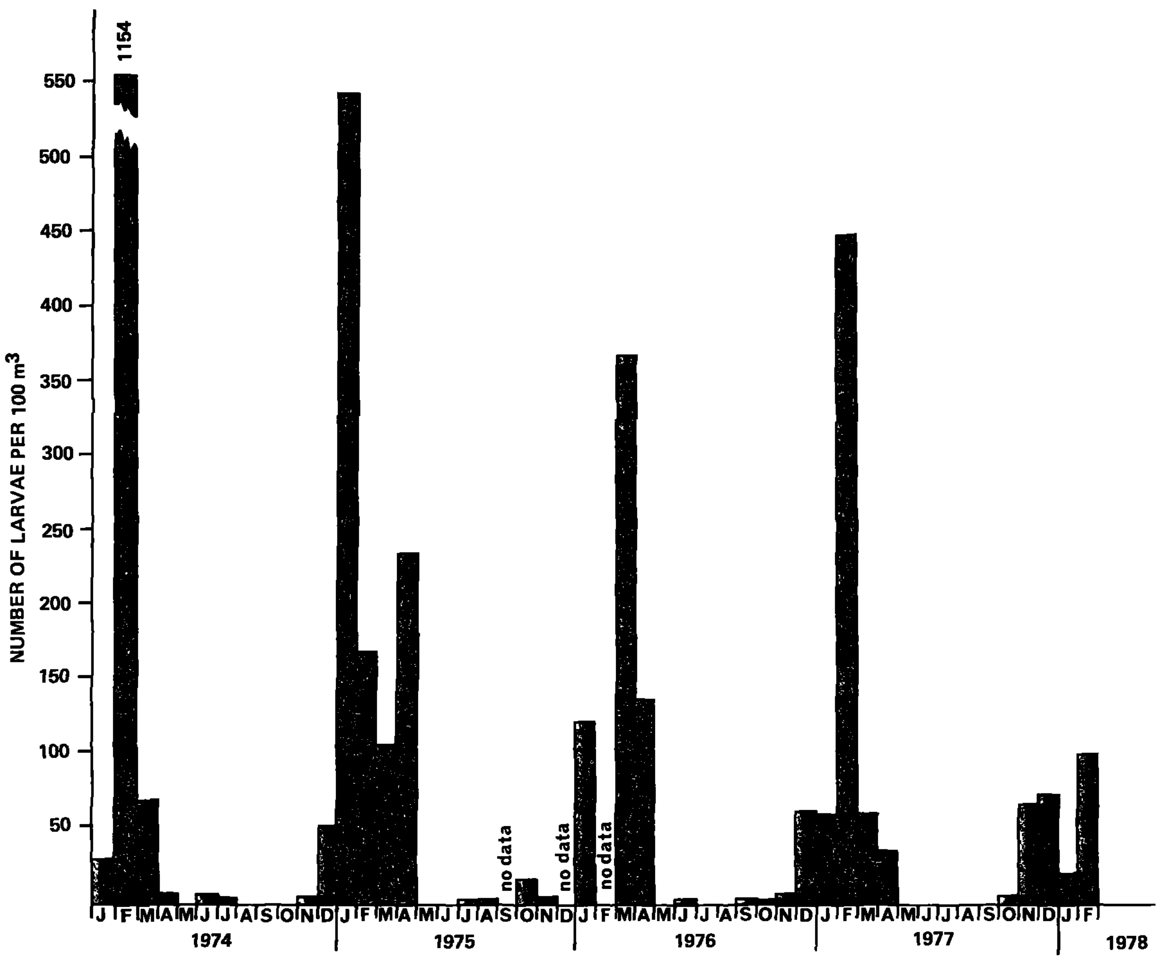

FIGURE 11.—Mean densities of white croaker larvae in the vicinity of King Harbor, Redondo Beach, Calif., between January 1974 and February 1978.

tion of the coast, white croaker larvae accounted for 11.7% of the larval fishes collected in oblique tows versus 43.6% from Laguna Beach to Redondo Beach and 17.9% from Playa del Rey to Point Conception (Fig. 14).

Our data indicate that highest densities of white croaker larvae occur near the bottom (Fig. 15). In the coastal zone, between the 15 and 36 m isobaths, relative densities indicate little variation through the water column, being 1.5-3.5% with surface waters, 55.0-58.0% in the bottom waters, and 40.0-42.5% in middepth waters (Fig. 16). Relative densities in the surface waters at the shallow 8 m stations dramatically increased to 17.5% with a corresponding decrease in both bottom and middepth waters.

White croaker larval densities peaked at stations located at 15 and 22 m depths (Fig. 15). The densities declined sharply at the deeper (36 m) and shallower stations (8 m). The only exception to this trend was in surface water where densities steadily decreased in an offshore direction.

Only 15 of our 20 transects had stations at 8 and 22 m isobaths. Data in Figure 15 suggest that an abundance estimate based on the 8 and 22 m stations may approximate one based on the 15 and 36 m stations. If so, an estimate based on either of those station pairs should approximate one based on all four. We examined this at the three transects (OB, RB, SO), where data for all four stations were available. We tested the data from each transect for each of the 12 mo of the sampling program using the sign test (Dixon and Massey 1957). The estimated number of white croaker larvae per 1,000 m^3 based on the 8 and 22 m stations was compared with the estimate based on the 8, 15, 22, and 36 m stations; no statistically significant difference was found ($N = 26$; $P > 0.05$). The similarities of the overall estimates based on these two station groupings are shown in Figure 13.

On the basis of our 8 and 22 m stations we have extrapolated density estimates to 36 m. Estimates were made for the truncated Palos Verdes and Laguna Beach transects as well, which are likely to be upwardly biased as they are based on two high density stations (15 and 22 m). Data in Figure 13 show that these two transects are not high density ones; in fact, Palos Verdes is low for that section of the coast. The Laguna Beach transect is lower than the next two transects to the north. We included the Laguna Beach transect in the portion of the Southern California Bight where white croaker larvae are in high abundance, on the basis that the density would still be higher than the portion of the coast from San Onofre to San Diego, based on just the 8 and 22 m stations, even if the 8 m station contributed no larvae.

We estimated, from oblique bongo tows taken at the 8 and 22 m stations (15 and 22 m stations at Palos Verdes and Laguna Beach), the average density of white croaker larvae between August 1979 and July 1980 to have been 740/1,000 m^3, 2,203/1,000 m^3, and 411/1,000 m^3 for the regions between Point Conception and Playa del Rey, Redondo Beach and Laguna Beach, and San Onofre and the international border, respectively. On the basis that there is no significant difference between estimates based on the 8 and 22 m stations and one based on the 8, 15, 22, and 36 m stations, we use the 8 and 22 m density estimates to project the average number of white croaker larvae to the 36 m isobath.

It has been estimated (Lavenberg and McGowen footnote 7) that about 31 km^3 of water are located in a band along the coast between Point Conception and the U.S.-Mexican international border and extending seaward to the 36 m isobath. Of this, 15.6 km^3 (50.6%) is located in the region between Point Conception and Playa del Rey, 7.9 km^3 (25.9%) between Redondo Beach and Laguna Beach, and 7.2 km^3

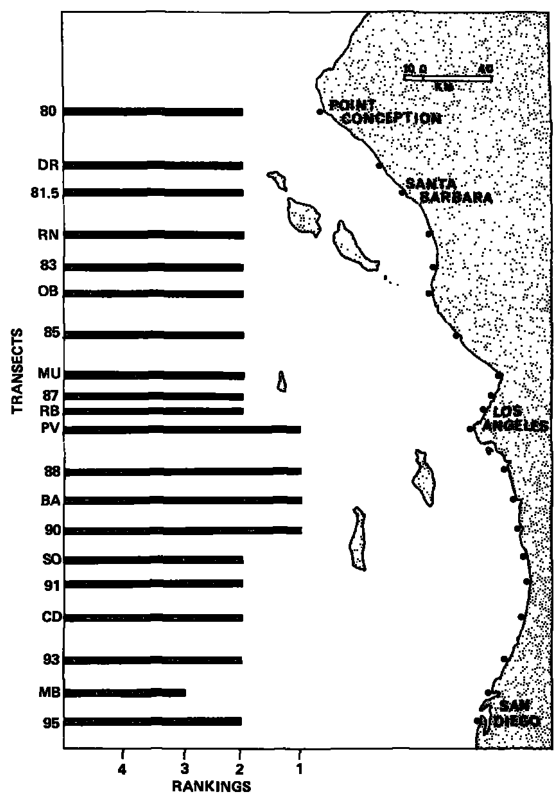

FIGURE 12.—Rank abundance of white croaker larvae collected in oblique bongo tows taken along 20 transects in the Southern California Bight between August 1979 and July 1980. See Table 2 for station abbreviation definitions.

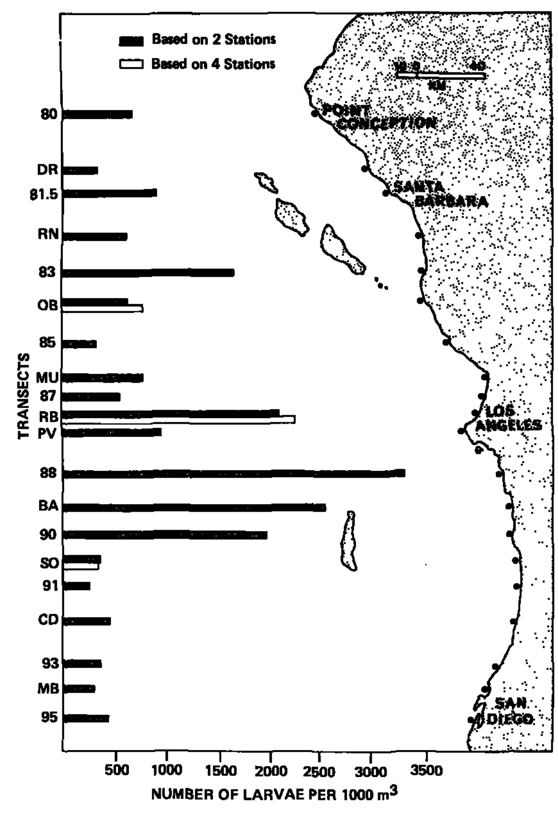

FIGURE 13.—Mean densities of white croaker larvae along 20 transects in the Southern California Bight between August 1979 and July 1980. See Table 2 for station abbreviation definitions.

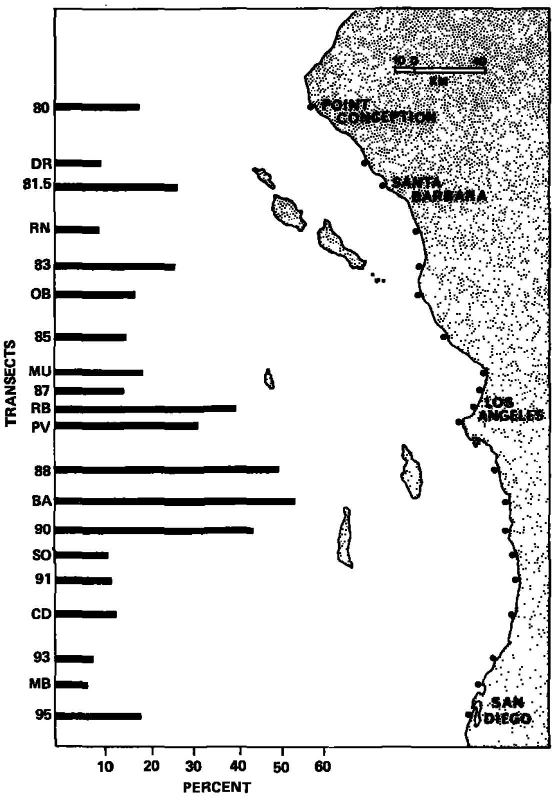

FIGURE 14.—The percentage contributed by white croaker to the total number of larvae collected along each of 20 transects in the Southern California Bight between August 1979 and July 1980. See Table 2 for station abbreviation definitions.

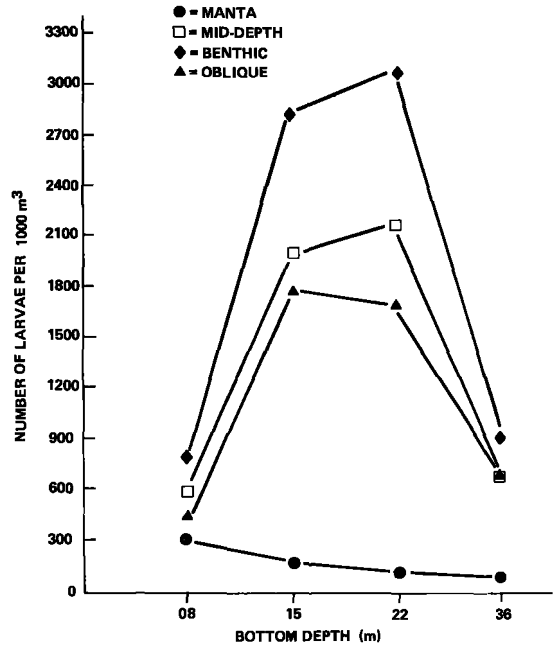

FIGURE 15.—Mean density of white croaker larvae collected with each of four different tow types along four isobaths—8, 15, 22, and 36 m—in the Southern California Bight between August 1979 and July 1980.

(23.5%) between San Onofre and the international border. Based on these values plus the density estimates, we project the average number of white croaker larvae in each of the three areas during this period to have been 1.15×10^{10}, 1.75×10^{10}, and 2.97×10^{9}, respectively. Thus, about 55% of the white croaker spawned in the area between Redondo Beach and Laguna Beach, 36% between Playa del Rey and Point Conception, and about 9% between San Onofre and the border.

Fishery

Most of the white croaker retained by sportfishermen were adults (Fig. 17), being 21-25 cm and 5-7 yr

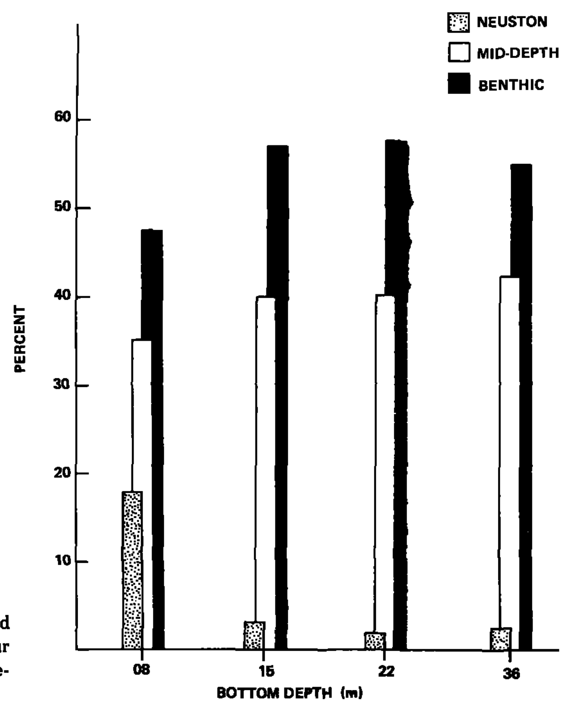

FIGURE 16.—Mean percentage of white croaker larvae collected near the surface, near the bottom and in between along each of four isobaths—8, 15, 22, and 36 m—in the Southern California Bight between August 1979 and July 1980.

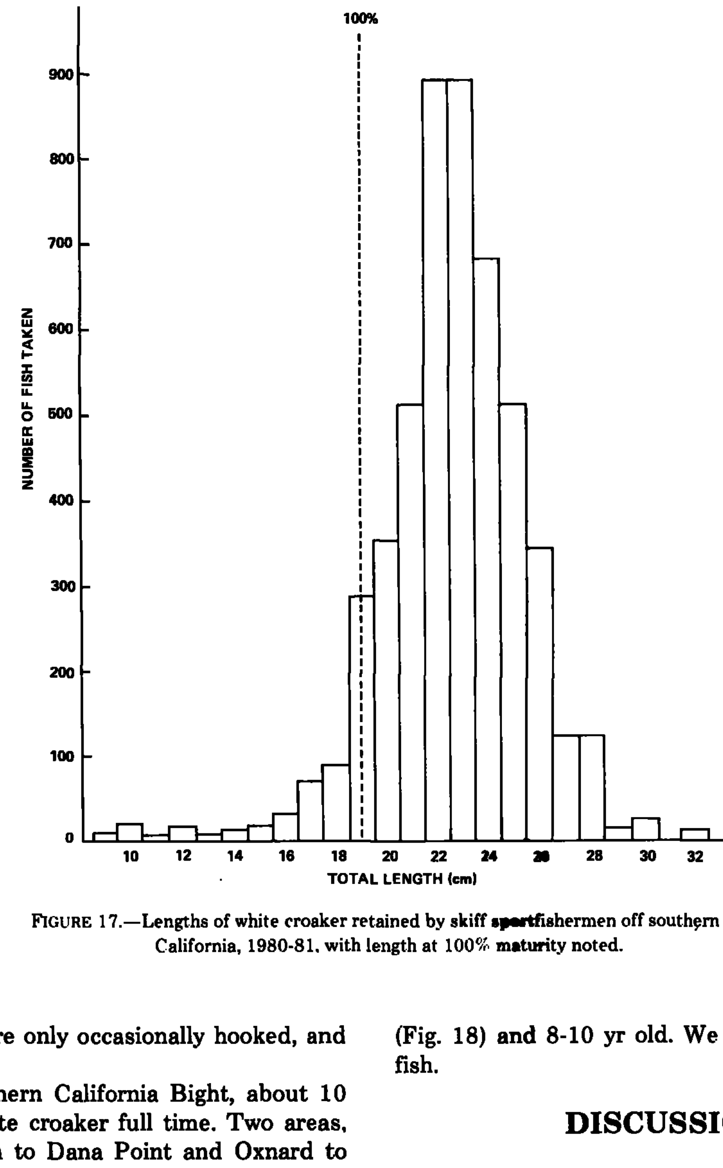

FIGURE 17.—Lengths of white croaker retained by skiff sportfishermen off southern California, 1980-81, with length at 100% maturity noted.

old. Small fish were only occasionally hooked, and rarely retained.

Within the Southern California Bight, about 10 vessels fished white croaker full time. Two areas, Long Beach south to Dana Point and Oxnard to Santa Barbara, were fished most heavily, which corresponded to the sites of peak white croaker larvae concentrations reported here.

This is a gill net fishery, and an informal agreement among fishermen sets the net mesh at 7.0 cm (2.75 in) stretch. Nets are 1.3 km (0.8 mi) long and are set on the bottom in depths of 5.5-37 m (3-20 fathoms). Mean catches of white croaker are 270-400 kg (600-900 lb) per set with maximum catches of 680-770 kg (1,500-1,700 lb). Largest catches occurred in January and February, during spawning season, when white croaker aggregated in large numbers. The prices for 1982 to fishermen were 13-18¢/kg (30-40¢/lb). Most fish taken during our study were 26-29 cm long (Fig. 18) and 8-10 yr old. We found no immature fish.

DISCUSSION

Depth Preference

Though most species of Sciaenidae prefer inshore waters, white croaker are distributed over a wider depth range than other northeastern Pacific species. Queenfish was the fourth most abundant species taken in our survey at the shallowest station (Table 3); its abundance declined rapidly with depth. Though it was present in deeper water, it contributed <0.1% of the fishes taken at 59-73 m. The white seabass is common within the 30 m contour (though they are taken as deep as 90 m during winter months). *Umbrina roncador*, *Roncador stearnsi*, and *Menticirrhus undulatus* prefer sandy beaches and bays to

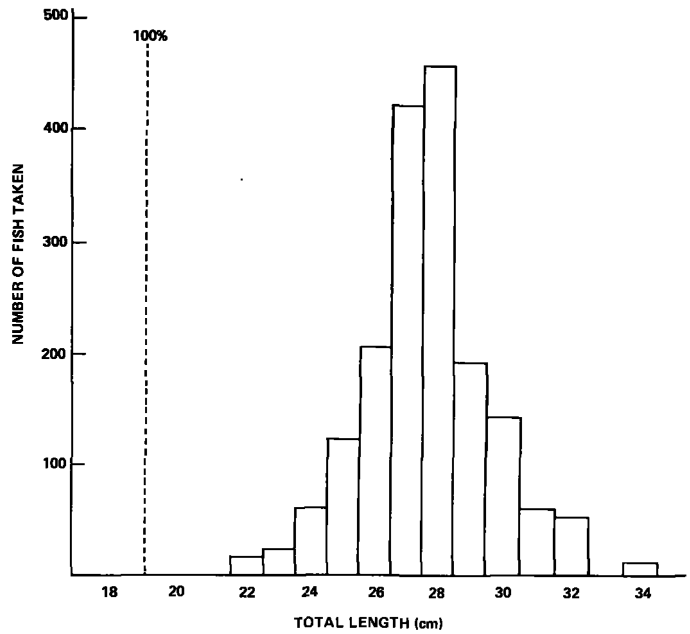

FIGURE 18.—Lengths of white croaker retained by commercial gill net fishermen off southern California, 1980-81.

depths of perhaps 9 m (Skogsberg 1939), whereas *Cheilotrema saturnum* are common over reefs to perhaps 15 m (occasionally to 45 m) (Limbaugh 1961).

Most eastern Pacific drums are limited to the warmer waters south of Point Conception (Miller and Lea 1972) or, like the queenfish and white seabass, are rare north of the Point. Conversely, white croaker are abundant north to San Francisco. Temperature preference experiments[12] indicate that juvenile white croaker have wide metabolic thermal optima (11°-17°C, based on routine oxygen consumption rates) that may account for their wide depth and latitudinal ranges.

Though white croaker are most abundant over sandy, featureless substrata, they are occasionally found in large numbers in kelp beds. This is particularly the case in beds anchored on sand, such as those off San Onofre and Santa Barbara. Similarly, though they spend most of their time near the bottom, we have noted schools in midwater, 20-40 m or more above the substrata. We have also seen white croaker at the surface, chasing anchovy schools.

Maturation and Reproduction

We computed the length-maturity relationship using standard length to compare our results with those of Issacson (1967). We found 50% of the males mature by 12.0 cm SL and 50% of females by 13.0 cm SL, both at 1 yr. This was in sharp contrast to Issacson's statement that "The white croaker matures between 147 and 164 mm standard length at an age of 3 to 4 years." Why such a disparity should exist is unclear.

White croaker is the only southern California drum that spawns in the winter. Winter spawning is unusual even among tropically derived temperate species off California. All species in the families Blenniidae, Carangidae, Labridae, Pomacentridae, Scombridae, and Sphyraenidae are either summer spawners or spring and summer spawners with a summer spawning peak. An exception are the rockfishes (Scorpaenidae), the vast majority of which spawn in winter and/or spring.

The more or less continuous (or perhaps dual-peaked) spawning season seen in white croaker in Monterey Bay is an interesting phenomenon. Most California marine fishes have restricted spawning seasons. If spawning does continue for extended periods (as in the bocaccio, *Sebastes paucispinis*), there is usually only one peak spawning period. An exception is the northern anchovy, *Engraulis mordax*, that may spawn year-round and which exhibits a major peak in late winter-early spring and a minor one in early fall.

Fishes of the northeastern Pacific tend to have a longer spawning season in the southern part of their range, as favorable conditions are usually more re-

[12]Hose, J. E., and W. H. Hunt. 1981. Physiological responses of juvenile marine fish to temperature. Occidental College Annual Report submitted to Southern California Edison, 17 p.

stricted in northern waters (Westrheim 1975). However, on examination, the water temperatures in Monterey Bay more closely approximate optimal white croaker spawning conditions than those off southern California. The peak spawning periods, based on gonosomatic indices and ichthyoplankton surveys, in southern California occur between January and March, when mean surface temperatures decrease to 13°-14°C (U.S. Department of Commerce 1956). Off Monterey, the mean temperatures of the warmest months are 13°-14°C (June-October), whereas the other months are 1°-3°C cooler. Thus white croaker encounter temperatures conducive to spawning for more months off Monterey than off southern California.

White croaker reproductive behavior is in some respects the opposite of the cooccuring queenfish. White croaker spawn almost entirely during late winter and early spring (peak February-March), but our ichthyoplankton survey gives a March-April peak, whereas queenfish are spring and summer spawners (peak April-May, DeMartini and Fountain 1981). Most egg hydration in white croaker takes place during the night, with spawning occurring from just before dawn to midmorning. Queenfish spawn between late afternoon and evening. We have not ascertained the extent that habitat partitioning has played in this separation. Off Monterey, where queenfish are rare, white croaker spawn virtually year round. As discussed before, this is perhaps a reflection of a more favorable temperature regime. It would be instructive to know if in the absence of queenfish, egg hydration and spawning time are simlar to those off southern California.

Larvae

Data from both gonosomatic indices and ichthyoplankton surveys show white croaker spawn year-round in southern California waters. However, peak spawning clearly is in the winter and spring. Our data, combined with Watson's (1982), indicate that peak densities of white croaker larvae were in either January, February, or March from 1974 through 1980. This is out of phase with other southern California sciaenids, all of which spawn primarily in the spring and summer (Lavenberg and McGowen footnote 7).

White croaker larvae are an important component of the southern California neritic ichthyoplankton fauna. Along the three sections of the Southern California Bight, defined and studied during this investigation, white croaker larvae contributed 11.7, 43.6, and 17.9% of the total larvae from south to north. Highest densities were found at stations located in 15-22 m depths (Fig. 15). The decreasing densities, as one moves shoreward of the 15 m isobath, apparently continues into the enclosed bays and estuaries of southern California. McGowen (1981) did not collect any white croaker larvae in south San Diego Bay during a 13-mo study. Larval white croaker ranked sixth, contributing 0.6% of the larvae collected in Newport Bay during an 18-mo study by White (1977). The percentage reported by White may have a bias toward lower values because the period of peak spawning was sampled only once during the 18 mo. However, even a doubling of White's percentages does not make white croaker larvae dominant members of the Newport Bay ichthyoplankton assemblage. Leithiser (1981) reported white croaker to contribute 1.9% of the total catch of larval fishes in Anaheim Bay during a 12-mo study.

King Harbor is typical of the estuarine-enclosed bay habitat rather than that of the open coast and is dominated by blennies, clinids, gobies, and engraulids (McGowen footnote 8). White croaker larvae ranked either fourth or fifth in the King Harbor study, depending on the year and the stations sampled.

Densities of white croaker larvae also decreased between the 22 and 36 m isobaths (Fig. 15). This indication that white croaker larvae are not common in offshore waters is supported by CalCOFI data. The highest any sciaenid ranked in these collections between 1955 and 1958 was 18th, contributing 0.30% of the total larval catch (Ahlstrom 1965).

This pattern of white croaker larvae being distributed in a narrow band along the coast, between the 15 and 22 m isobaths, is similar to the pattern reported by Watson (1982) and Barnett et al.[13] off San Onofre. They designated white croaker larvae as having an inner nearshore epibenthic pattern. Barnett et al. (footnote 13) indicated highest densities on the bottom, shoreward of the 22 m isobath, and the second highest densities in the water column between the 12 and 22 m isobaths and on the bottom between the 22 and 45 m isobaths. The major discrepancy between their data and ours is the higher epibenthic densities that they report shoreward of the 12 m isobath and seaward of the 22 m isobath. This discrepancy may be partially explained by dif-

[13]Barnett, A. M., A. E. Jahn, P. E. Sertic, and W. Watson. 1980. Long term spatial patterns of ichthyoplankton off San Onofre and their relationship to the position of the SONGS cooling system. A study submitted to the Marine Review Committee of the California Coastal Commission, July 22, 1980, Unpubl. rep., 32 p. Marine Ecological Consultants of Southern California, 533 Stevens Ave., Suite D-57, Solana Beach, CA 92075.

ferences in sampling strategy. They sampled within blocks defined by depth contours whereas we sampled at specific isobaths. Thus, part of their block D (between the 22 and 45 m isobaths) is located at a depth where we found high densities (22 m) and part of it where we found low densities (36 m). All of their block B (between 9 and 12 m) is located at depths where we did not sample. Their block A (between 6 and 9 m) is located in a zone where our data suggest lower densities.

Our trawling data also support this narrow band as important for the young stages of white croaker. Almost all of the juvenile white croaker taken during our study were collected at stations located between the 18 and 27 m isobaths (Fig. 2).

In summary, these data suggest that adult white croaker migrate shoreward (larger adults were taken at deeper depths; Fig. 2) and spawn in a narrow band along the coast. This band has its shoreward boundary located between the 8 and 12 m isobaths, and its seaward boundary located between the 22 and 36 m isobaths. Furthermore, the pelagic stages remain primarily within this band. At the end of the pelagic phase young white croaker move into 3-6 m and take up residence near the bottom. As these juvenile fish mature, they migrate to deeper waters (Fig. 2).

Based on this hypothesis, we believe that a realistic evaluation of the spawning activities of the white croaker can be based on data collected from the shore to the 36 m isobath. We have done this and found that about 9% of the spawning by white croaker occurred along the coast from San Onofre to the international border, about 55% from Laguna Beach to Redondo Beach, and around 36% from Playa del Rey to Point Conception. If this represents the typical annual pattern, the portion of the Southern California Bight from Laguna Beach to at least Point Conception is important for white croaker, especially the region around the Palos Verdes Peninsula from Redondo Beach to Laguna Beach. However, that portion of the bight from San Onofre to the border is relatively insignificant. The only remaining coastal zone in the U.S. portion of the Southern California Bight is around the Channel Islands. We have not investigated the coastal zones of these islands and cannot appraise their significance to the spawning activities of white croaker in the Southern California Bight.

Fishery

Historically, the commercial white croaker fishery has been minor, rarely exceeding 1 million lb/yr (Frey 1971). Most fish were caught and landed in the Long Beach-San Pedro region and Monterey Bay. Southern California accounted for about two-thirds of the catch and Monterey one-third, although during World War II, Monterey produced over one-half the total catch. Until recently, white croaker were taken commercially by otter trawl, round haul net, multifilament gill net, and hook and line. However, in the past few years, significant changes have occurred in the fishery. Gill nets, particularly monofilament nets, have almost entirely supplanted other methods.

The ubiquity of white croaker along the southern California mainland makes this species accessible to small boat sportfishermen. The ease with which it may be taken, using minimum skill or equipment, ensures that this species will be caught in considerable numbers. We commonly found two fishermen with at least 50 or more white croaker after a half day's effort. Though traditionally scorned by many, we found that the species is popular with a number of ethnic groups.

The Monterey fishery has been revived in the past 2-3 yr by newly arrived Vietnamese fishermen.[14] White croaker are fished throughout Monterey Bay, over the entire year, in 12-24 m (40-80 ft), occasionally to 37 m (120 ft) with 1.6-2.4 km (1-1.5 mi) long monofilament gill nets [6.3 cm (2.5 in) stretch mesh]. Nets are tended daily, and 450-900 kg (1,000-2,000 lb) catches are common with maximum catches to 1,800 kg (4,000 lb). Depending on catch size and fish condition, payment to fishermen ranges from 6 to 22¢/kg (15 to 50¢/lb). These white croaker are sold principally within central California (particularly the San Francisco area), although a small amount is shipped to southern California. Demand is increasing, particularly among various Asian communities.[15]

SUMMARY

In this study, white croaker was the most abundant species in nearshore (18-27 m) otter trawl collections in southern California. This species dwelled principally in shallow water and juveniles were restricted to the shallower (<27 m) parts of the species depth range. Living to 12 yr, white croaker grew at a nearly

[14]D.J. Miller, California Department of Fish and Game, 2201 Garden Road, Monterey, CA 93940, and T. Keating, Moss Landing Marine Laboratory, P.O. Box 233, Moss Landing, CA 95039, pers. commun. August 1981.

[15]Though most white croaker are retailed fresh, there is reason to believe that a potential market exists for them as surimi (fish cakes). A fish cake plant existed in Ventura during 1979, processing 3,000-4,000 lb (1,360-1,800 kg) of white croaker per day. All cakes were sold to the Asian community in Los Angeles. Demand for the product was very strong and the plant closed for reasons unrelated to profitability.

constant rate throughout the species' life. A majority of both males and females matured at about 1 yr and all were mature by 4 yr. We noted a difference in spawning season between southern and central California. Off southern California, significant spawning occurred between November and April, while central California individuals spawned all year, with large-scale activity occurring from July through February. Our ichthyoplankton survey indicated that two spawning centers occurred off southern California—one located from Redondo Beach to Long Beach and the other centered about Ventura. White croaker larvae, which were second in abundance to northern anchovy in nearshore waters, were found in greatest abundance near the substratum in 15-22 m of water. The abundance of white croaker and its ease of capture make it a major sportfish in the skiff fishery and a growing component of the commercial gill net fishery. Our study indicates that the vast majority of fishes taken in both fisheries were adults.

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Majority of the larval identifications were made by D. Carlson, D. Chandler, D. Eto, R. Feeney, S. Goodman, N. Singleton, D. Winkler, and R. Woodsum of the University of Southern California and the Natural History Museum of Los Angeles County. E. Gray and L. Games of the Southern California Edison Company and the Natural History Museum of Los Angeles County, respectively, assisted with data reduction and computer programming. We also thank M. Butler (illustrations) and R. Meier (photography) of the Los Angeles County Natural History Museum. Lastly, we thank the many people who assisted in the sorting and collecting of samples, especially the crews of RV *Vantuna* and RV *Seawatch*.

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