

THE LIFE HISTORY AND ECOLOGY OF BLACK CROAKER, *CHEILO TREMA SATURNUM*

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ABSTRACT

Results from spatial and temporal distribution analysis of 5,157 black croaker (*Cheilotrema saturnum*) collected by gillnet from 1995–2004 at stations from Newport to Santa Barbara, California, including Santa Catalina Island, indicated that peak catch per unit effort (CPUE) occurred along the Palos Verdes Peninsula. Annual gillnet CPUE was greatest in 2000. The highest black croaker abundance was recorded in 1997 using standardized impingement data from two Santa Monica Bay generating stations. Length–frequency analyses from both gill net and impingement sampling indicated that a large proportion of black croaker were small in size immediately prior to and during the 1997–98 El Niño Southern Oscillation, and then increased in size with time. Observed black croaker ages ranged up to 21 years old, with most fish less than 14 years old. Von Bertalanffy growth parameters were $L_{\infty} = 237.7$, $k = 0.31$, $t_0 = -1.778$, and $N = 779$, with no significant differences between the sexes. Gonosomatic indices peaked in June, followed by August, suggesting late-spring to summer spawning. Mortality adjusted hindcasting indicated that peak recruitment occurred in 1997.

INTRODUCTION

Sciaenids comprise significant portions of the nearshore ichthyofauna within the Southern California Bight (SCB), accounting for six of the ten most abundant species observed from August 1996 to June 1998 (Pondella and Allen 2000). Black croaker (*Cheilotrema saturnum*) ranked as the fourth most abundant species along the mainland during this study. Although highly abundant, black croaker was the only member of the family common to coastal southern California that does not support either a targeted recreational or commercial fishery (Limbaugh 1961; Love et al. 1984). Black croaker reach a maximum size of 381 mm standard length (SL) and range from Magdalena Bay, Baja California Sur, Mexico, to Point Conception, California. They occur from the surface to depths of 45 m, with the greatest concentrations in depths from 3–15 m (Limbaugh 1961; Miller and Lea 1972; Feder et al. 1974; Love et al. 2005).

Principal habitat consists of open coast rocky reefs and coastal embayments throughout their range, with adults occasionally observed over sand patches during the summer (Limbaugh 1961; Quast 1968; Feder et al. 1974; Allen 1985). In waters with low turbidity, adults have been observed in large caves or crevices within the reef, while in murky conditions aggregations have been observed at 3 m above the bottom (Limbaugh 1961). Undoubtedly, black croaker comprise an important component of the nearshore rocky-reef ichthyofauna in the SCB (Stephens et al. 2006).

Most demographic population models, such as the Adult Equivalent Loss (AEL) and Fecundity Hindcasting (FH), require multiple life-history parameters, including some estimation of longevity, age and growth, mortality, and spawning seasonality (Parker 1980; Jensen et al. 1982; Saila et al. 1997; Lo et al. 2005; Newbold and Iovanna 2007). While many of these life-history parameters have been determined for commercially important species, such as northern anchovy (*Engraulis mordax*) (Hunter and Macewicz 1980; Hunter and Goldberg 1980; Butler et al. 1993), similar effort has not been expended on exclusively recreational species, and even less has been applied to forage species. Interest in analyzing the potential effects of non-fishing anthropogenic uses of coastal marine waters (wastewater discharges, power plant once through cooling, storm-water runoff, etc.) has focused more on species that either exclusively support recreational fisheries or function as forage species, such as black croaker. Assessments were often limited by the life-history parameters available, such as during the recent assessment of the cooling water system at Huntington Beach Generating Station (MBC and Tenera 2005¹).

Despite the need to understand anthropogenic effects and its abundance within the SCB, little research has been conducted on black croaker. Published research has been limited to preliminary information on the life-history and ecology (Limbaugh 1961) and an assessment of spawning seasonality (Goldberg 1981). To better un-

¹MBC Applied Environmental Sciences and Tenera Environmental. 2005. AES Huntington Beach Entrainment and Impingement Final Report, April 2005.

derstand black croaker demographics and population abundance trends, life-history parameters must be described. This study was undertaken to document aspects of the life-history parameters of black croaker, e.g., age at length, the length-weight relationship, reproductive biology and seasonality for both sexes, spatial distribution throughout the SCB, an examination of population trends over time, and recruitment trends. While black croaker is not the subject of any species-specific fishery management plan, its perceived role in the ecosystem may become important with a shift towards ecosystem-based fishery management, such as in marine protected areas. This study aims to provide greater understanding of the life-history parameters of one member of the rocky-reef community.

MATERIAL AND METHODS

Collection of Specimens

Individual black croaker were collected using experimental gillnets as part of the California Department of Fish and Game's monitoring via the Ocean Resource Enhancement and Hatchery Program (OREHP) (Pondella and Allen 2000). From 1995–2004 experimental gillnets were set overnight at seven stations along the California coast; Santa Barbara, Ventura, Malibu, Palos Verdes, Seal Beach, and Newport (fig. 1). Three stations were occupied at Santa Catalina Island, California, including the west and east ends of the island as well as Catalina Harbor. Due to low abundance, all data from island stations were summed together as Santa Catalina Island. Sampling occurred annually in April, June, August, and October from 1995 through 2004. Ventura, Malibu, Palos Verdes, Seal Beach, and Newport were sampled in all years. Santa Barbara and the Santa Catalina stations were sampled beginning in August 1996. Sampling at Marina del Rey (the third Santa Catalina station) began in October 1996. All stations were sampled continuously thereafter.

All nets at the open coastal stations were set perpendicular to the shoreline. Six horizontal gillnets were set on the bottom at each station from dusk to dawn. Each net was 45.7 m long and 2.4 m deep, with two sets of three different-sized mesh panels (25.4 mm, 38.2 mm, and 50.8 mm square mesh). All nets were set in 5–14 m of water just outside of the surf zone, typically adjacent to kelp beds or the fringe of rocky reefs. Exceptions were Marina del Rey and Seal Beach, which have neither kelp beds nor rocky reefs. At Marina del Rey, a private boat marina, nets were set outside of the vessel traffic lanes at two sites, parallel to the rip-rap between the U.S. Coast Guard and University of California, Los Angeles docks and perpendicular to the shoreline at Mother's Beach. At Seal Beach, nets were set parallel near the west jetty just downcoast of the Seal Beach Pier.

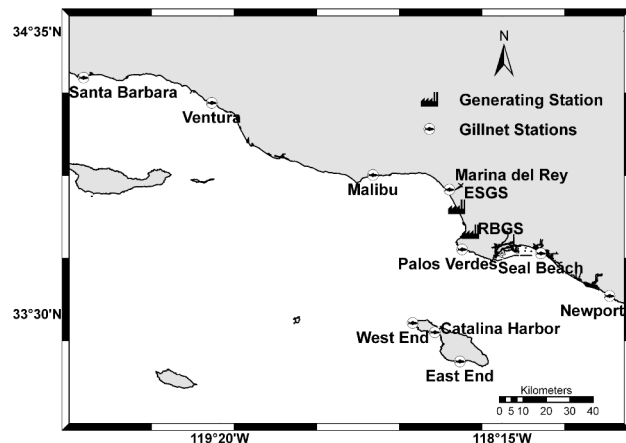


Figure 1. Map depicting all gillnet and power plant sampling locations for black croaker (*Cheilotrema saturem*) study during 1995–2004.

From April 1995–August 2001 and October 2003–October 2004, all samples were measured to the nearest 5 mm unit SL. Beginning in October 2001 through August 2003, all samples were measured to the nearest millimeter for SL, fork length (FL), head length (HL), and total length (TL), and weighed to the nearest gram (g), sexed macroscopically, while gonads were weighed to the nearest 0.5 g, and sagittal otoliths were removed.

Distribution

Spatial CPUE was calculated as the total annual abundance caught divided by the total number of monthly sampling events for that year. Temporal CPUE represents the monthly mean of catch per net across all sampled stations. Differences among spatial and temporal CPUE were each tested with a one-way analysis of variance (ANOVA) with a Tukey post-hoc test. Prior to the ANOVA, both CPUE data sets were transformed using $\ln(x+1)$ to satisfy the assumption of normality, which was confirmed using a Shapiro-Wilk w statistic (Legendre and Legendre 1998). Temporal CPUE was also tested for correlation with mean monthly sea surface temperature (SST) as recorded at Newport Pier (www.sccoos.org). Data from Newport Pier were used rather than Santa Monica Bay because they were collected more consistently during April 1995 through October 2004.

Standard lengths of gillnet-collected fish were combined and divided into 25 mm SL size classes for length-frequency analysis. The mean standard lengths by site and annual mean standard lengths were compared individually using an ANOVA with a Tukey post-hoc test. Pearson one-tailed correlation was used to test the relationship between mean summer SST and mean annual SL.

Additional long-term (1979–2006) inter-annual variation was examined using impingement records from the Redondo Beach and El Segundo Generating Stations, California (fig. 1). The Redondo Beach Generating Station withdraws seawater from two intake structures

within King Harbor; one located 600 m offshore near the end of the breakwater at the mouth of the harbor at a depth of 13 m and the other located 305 m offshore, but within the harbor, at a depth of 9 m. The El Segundo Generating Station withdraws seawater through two cooling-water structures located approximately 790 m offshore in Santa Monica Bay at a depth of 9 m. Abundances recorded during heat treatments were standardized to annual cooling-water flow volumes in billions of gallons (bg). For a complete description of heat treatment impingement see Miller (2007). Pearson one-tail correlation analysis was used to test the relationship between annual impingement and mean annual SST.

Age, Growth, and Morphometrics

Relationships between head, fork, and total length to standard length were described via linear regression. The length-weight relationship was examined by fitting the relationship: $W = aL^b$, where W = weight in grams, L = standard length in mm, and a and b are constants determined by nonlinear regression.

Sagittal otoliths were removed from all individuals collected from October 2001–August 2003. Each otolith was cleaned, air-dried, and stored in a pre-labeled coin envelope in the field. Each right otolith was mounted on a wood block with cyanoacrylate glue and sectioned on the transverse axis through the focus using a Buheler Isomet™ low-speed saw (Allen et al. 1995). A thin section (0.7 mm) was cut using two diamond-embedded blades (Allen et al. 1995). Sections ($N = 825$) were viewed in a black-bottomed watch glass filled with water and read under a stereoscope at 25× magnification using reflected light. Each otolith was read twice by a single reader, at least four months apart. The value from two concordant readings was accepted as the best estimate of age. When necessary, a third reading was made when two consistent values were not obtained. In the event agreement could not be reached, the sample was excluded from further analyses. Otolith edge analysis was used to confirm the seasonal deposition consistent with annuli formation. Lengths at age were estimated by deriving the mean standard length for each age class based on the otolith analysis. These data were visualized using the von Bertalanffy growth model using VONBIT (FAO 2005):

$$L_t = L_\infty (1 - \exp - k^{(t-t_0)}),$$

where:

L_t = length at time t ;

L_∞ = theoretical maximum length;

k = constant expressing the rate of approach to L_∞ ;

and t_0 = theoretical age at which $L_t = 0$.

Von Bertalanffy models were constructed for all individuals combined and by sex; immature or sex undeter-

mined individuals were excluded from the sex-specific analysis. The differences between sex-specific growth were tested by an analysis of residual sum of squares derived by non-linear regression (ARSS; Haddon 2001).

Reproduction and Recruitment

Sex distributions and gonosomatic indices were derived from 897 individuals collected during gillnet sampling from 2001–03. Deviation from an expected gonochoric sex ratio of 1:1 was tested with a X^2 analysis. Gonosomatic index (GSI) values were derived by the following (Barbieri et al. 1994):

$$\text{GSI} = (\text{Gonad Weight} / (\text{Gonad Free Body Weight})) \times 100.$$

Differences in monthly GSI values were tested using a one-way ANOVA for each sex.

Annual recruitment was estimated using both standardized generating station impingement and gillnet abundances. Year-class abundances were drawn from the current age and growth study. Catch-curve analysis was used to estimate instantaneous mortality (Z) (Haddon 2001). Abundances by year class were plotted independently for the 2002 and 2003 collections. Due to the lack of a sustained fishery (commercial or recreational), $Z \approx M$ (Haddon 2001). Hindcasted annual recruitment was estimated by adjusting the age-class abundance for each year by the following (Allen et al. 1995):

$$N_t = N_0 (1/S)^t$$

where:

N_0 = number of fish in a year class at $t = 0$;

N_t = estimated number of recruits at t years in past corrected for mortality; and

S = annual estimated survivorship.

Total year-class recruitment estimates represent the summation across estimates calculated for each collection year. Recruitment success over time was estimated from recorded lengths of fish impinged at Redondo Beach Generating Station and El Segundo Generating Station. Abundances of young-of-year (YOY) individuals, as determined by the current age-at-length study (<151 mm SL), were standardized to the annual cooling-water flow (bg). Pearson one-tailed correlation analysis was used to test the relationship between SST and each recruitment index (hindcasted and impingement). The potential relationship between kelp canopy coverage along Palos Verdes Peninsula coastline (MBC 2006²) was compared with mortality-corrected hindcasted recruitment with a Pearson one-tailed correlation analysis. We also tested the relationship between the standardized

²MBC Applied Environmental Sciences. 2006. Central Region Kelp Consortium annual report.

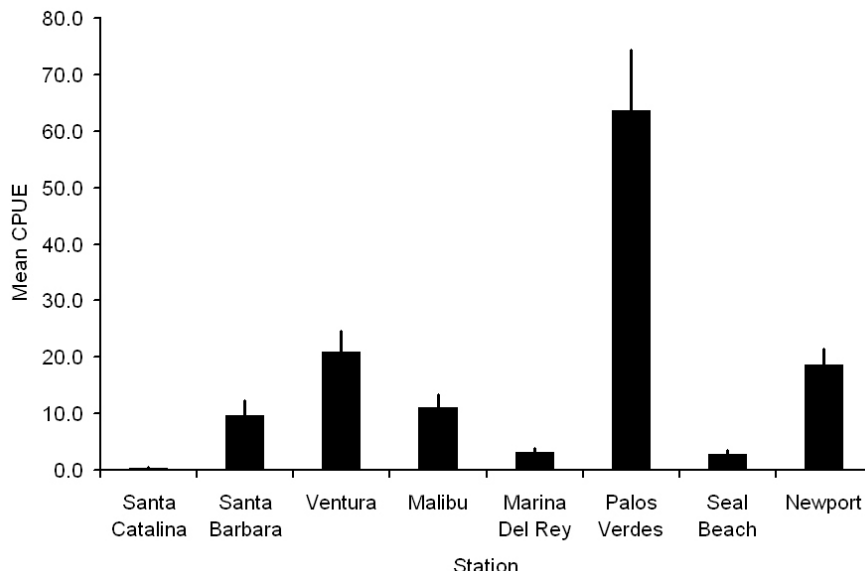


Figure 2. Mean gill net catch per unit effort (CPUE) of black croaker (*Cheilotrema satunum*), plus one standard error, by gill net station, 1995–2004.

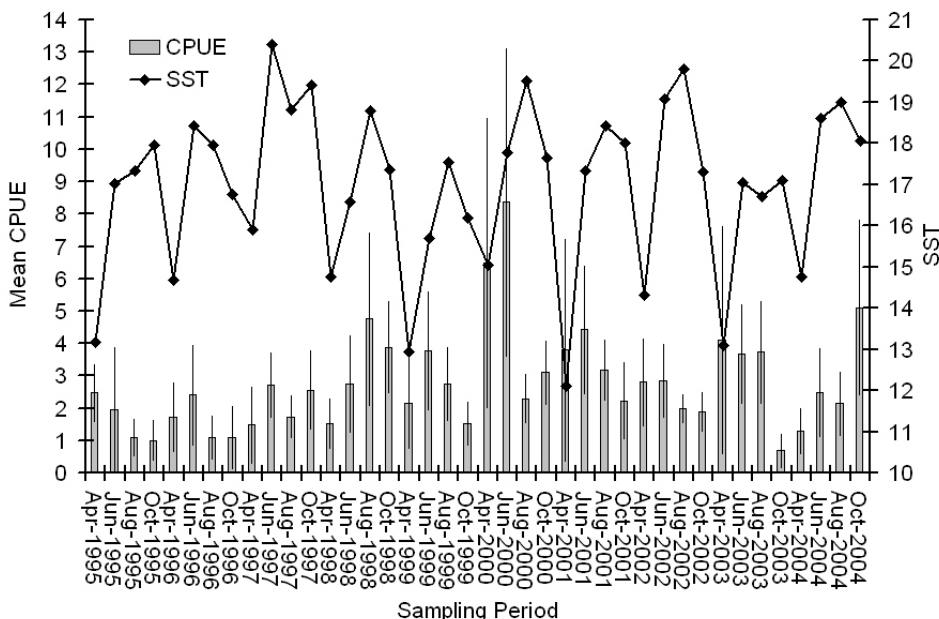


Figure 3. Mean monthly gill net catch per unit effort (CPUE) of black croaker (*Cheilotrema satunum*) plus standard error, and mean monthly summer sea surface temperature (SST) for all sampling periods, 1995–2004.

YOY impingement abundance and mean summer (June–September) surface chlorophyll-*a* concentration recorded at Station C8 of the Point Loma Ocean Outfall monitoring array (fig. 1) as reported by SCCOOS (www.sccoos.org). Chlorophyll-*a* densities were only available from 1998 on, which only allowed four years of overlap with the hindcasted data. Therefore, no comparisons were attempted. All statistical tests used were executed with SPSS 15 for Windows Grad Pack.

RESULTS

Distribution

A total of 5,157 individuals were collected during gillnet sampling. The catch at Palos Verdes was significantly higher (ANOVA, $F = 32.328$, $df = 7, 69$, $p < 0.001$) than all other sites, with greater than 60 fish/survey (fig. 2). Ventura and Newport Beach were the next most populous, each with approximately 20 fish/survey observed

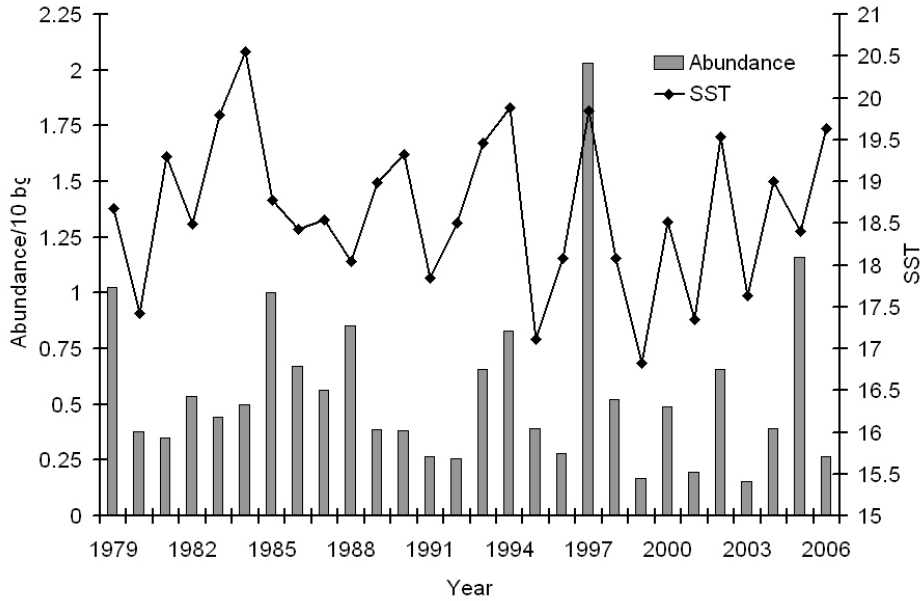


Figure 4. Total abundance of black croaker (*Cheilotrema saturnum*) per 10 bg of cooling water circulated at Redondo Beach Generating Station and El Segundo Generating Station, and mean summer Newport SST (°C), 1978–2006.

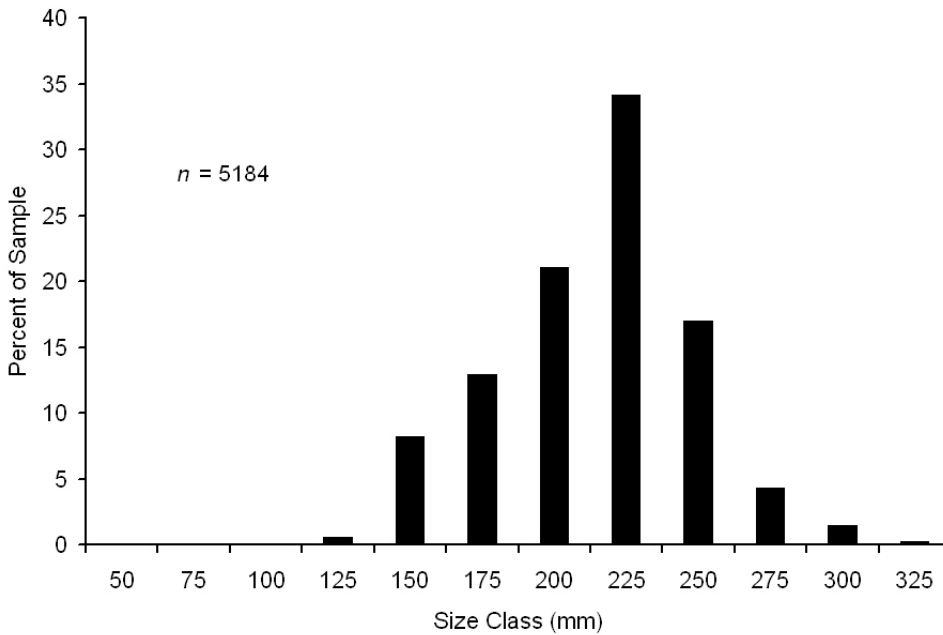


Figure 5. Percent of total gill net catch of black croaker (*Cheilotrema saturnum*) per 25 mm SL size class for all surveys, 1995–2004.

during the study period. Catch per unit effort at each of the remaining coastal sites was observed, on average, to be less than 11 fish/survey. Santa Catalina Island collections were minimal, with less than 0.5 fish/survey on average. Temporal collections were not significantly different ($p = 0.80$), although landings peaked in April and June 2000, with six and eight fish/station, on average, respectively (fig. 3). The lowest catch was recorded in

October 2003, with 0.6 fish/station, on average. Catch per unit effort was generally higher from 1998–2003 than during earlier and later periods of the survey. Cumulative impingement abundance was highly variable with a general downward trend over time (fig. 4). Abundances varied relatively consistently with SST ($r = 0.37$, $p = 0.03$), with peak abundance in 1997 at better than 2 fish/10 bg.

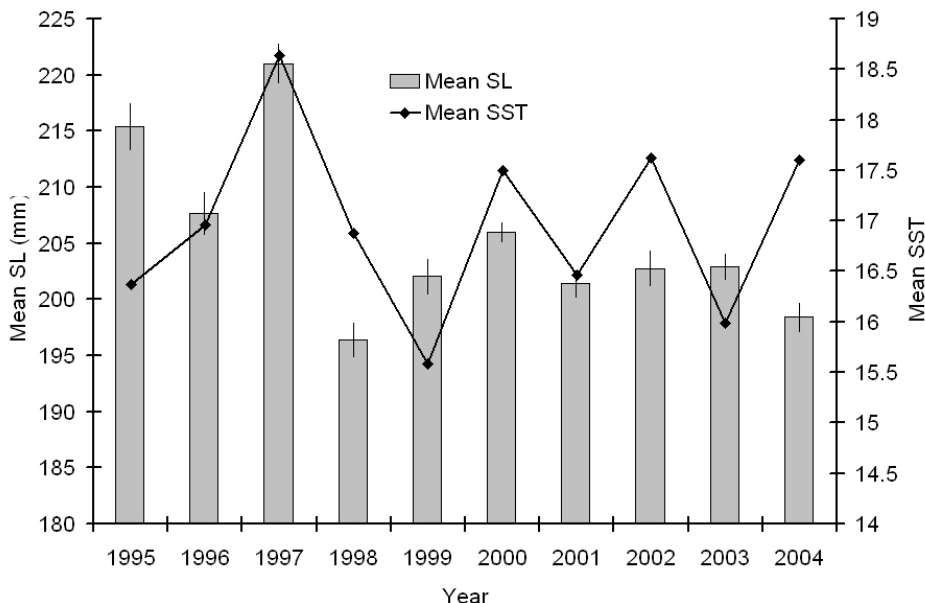


Figure 6. Annual mean standard length (mm), plus standard error, for all gillnet-collected black croaker (*Cheilotrema saturnum*) and mean annual summer sea surface temperature (SST), 1995–2004.

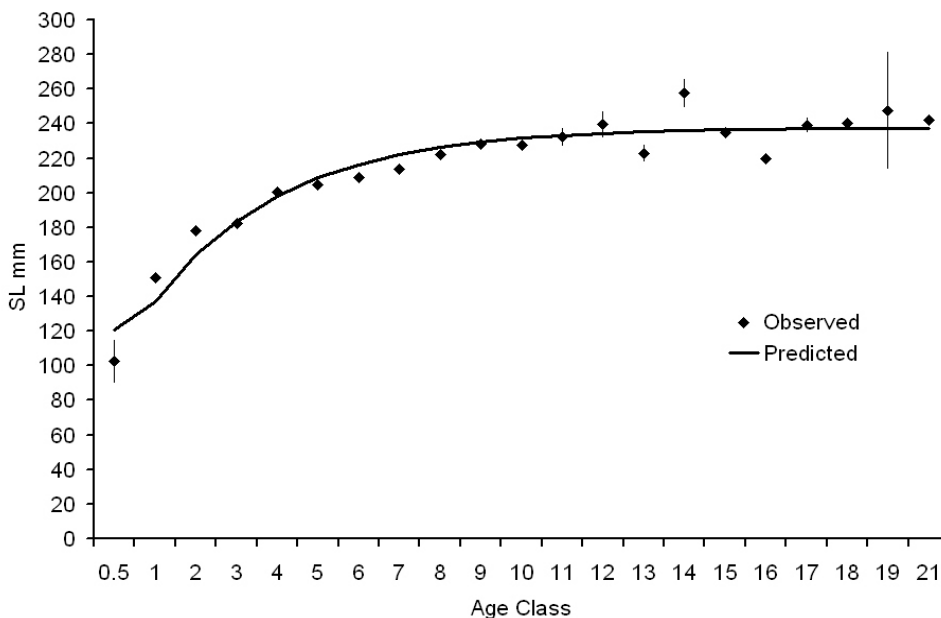


Figure 7. Von Bertalanffy predicted and observed, with standard error, age-at-length curves for all sampled black croaker (*Cheilotrema saturnum*).

Standard lengths of gillnet-collected individuals ($n = 5184$) ranged from 150 to 250 mm SL with peak abundance in the 225 mm SL size class (fig. 5). Black croaker collected at Santa Barbara were significantly larger than the remaining coastal stations, while Santa Catalina Island collections were significantly larger than those from all coastal stations (ANOVA, $F = 60.461$, $df = 7$, 5180 , $p < 0.001$). Annual mean standard length was not significantly correlated with annual mean SST ($r = 0.39$,

$p = 0.13$). Mean lengths were relatively high from 1995 to 1997 before declining precipitously in 1998, then gradually increasing to a plateau in 2001 (fig. 6).

Age and Growth

Relationships between length categories (SL, TL, FL) closely followed a linear distribution (tab. 1). The length-weight distribution fits a curve described by the equation $W = 0.00004L^{2.9223}$ ($R^2 = 0.95$, $n = 745$). Opaque

TABLE 1
 Conversion equations and associated linear fit and sample size for head length (HL), total length (TL), and fork length (FL) to standard length (SL) for black croaker (*Cheilotrema saturnum*).

Measurement	Relation to SL	R ²	N
Head Length	SL = 2.484(HL) + 59.99	0.65	879
Total Length	SL = 0.822(TL) - 0.01	0.94	882
Fork Length	SL = 0.833(FL) + 1.53	0.95	209

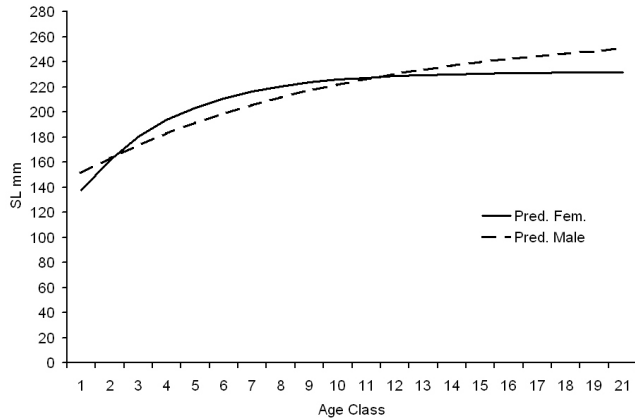


Figure 8. Von Bertalanffy predicted age-at-length curves for male and female black croaker (*Cheilotrema saturnum*).

bands were consistently formed during the spring, and translucent bands in the summer extending into fall, consistent with annual formation. The oldest fish was a 21-year-old male from Santa Catalina Island, which was small for the age but numerous readings were consistent. Nearly 97% of all fish were 13 years old or less, with most fish between five and seven years old and only 25 individuals greater than 14 years old (tab. 2). The largest fish in the data set (324 mm SL) was a 20-year-old male collected at Santa Catalina Island in 2002. The growth rate was steepest from Age-0 to Age-V (fig. 7). Male and female growth rates were not significantly different (fig. 8, ARSS, $F = 3.15$, $df = 1,702$, $p = 0.08$).

Reproduction

Males comprised a significantly (X^2 , $F = 6.581$, $df = 1$, $p = 0.01$) greater proportion of the total observed gill-net collection. Greater than 60% of individuals collected at Malibu and Marina del Rey were male. Juveniles were collected at all coastal sites except Malibu and Marina del Rey. Both sexes were present in all age classes between 1 and 13, although males represented a measurably greater proportion among most age classes. Females accounted for substantially greater than 50% of the abundance in the 8- and 10-year-old age classes. Age-0 fish appeared to be immature, while immature individuals

TABLE 2
 Sample size (n) and the mean, standard deviation, and range of standard lengths for black croaker by age class for all samples combined and by mature sex. Von Bertalanffy parameters are listed below each group.

Age Class	All Samples				Female				Male			
	n	Mean	SD	Range	n	Mean	SD	Range	n	Mean	SD	Range
0.5	18	103	55	17-182								
1	56	151	14	130-205	21	154	12	139-180	20	152	17	130-205
2	58	178	23	144-235	24	185	21	148-222	25	177	21	155-235
3	58	182	24	138-238	20	199	22	165-238	20	178	23	150-226
4	83	201	20	161-275	41	200	18	161-253	38	201	23	166-275
5	138	205	20	149-284	59	210	17	173-246	74	202	21	149-284
6	140	209	17	168-281	50	209	12	174-235	84	210	20	168-281
7	49	214	18	178-272	25	221	20	198-272	22	207	12	186-230
8	53	222	14	198-256	17	224	10	204-240	34	221	16	198-256
9	40	228	21	187-288	19	229	23	204-288	21	227	19	187-270
10	27	227	18	203-279	12	224	12	210-248	14	231	23	203-279
11	26	233	28	200-298	10	244	31	210-298	15	221	18	200-257
12	10	240	25	210-272	5	241	29	210-272	5	239	24	210-266
13	6	223	12	209-243	4	227	14	209-243	1	215		
14	4	258	17	233-270	1	233		233-233	2	269	2	267-270
15	3	235	5	230-240	1	230		230-230	2	238	4	235-240
16	1	220							1	220		
17	3	239	8	230-245	1	243		243-243	1	245		
18	1	240							1	240		
19	4	248	69	157-324	2	206	69	157-254	2	290	48	256-324
21	1	242							1	242		
n	779				312				383			
L_{∞}	237.7				231.4				259			
k	0.31				0.34				0.13			
t_0	-1.78				-2.36				-6.33			

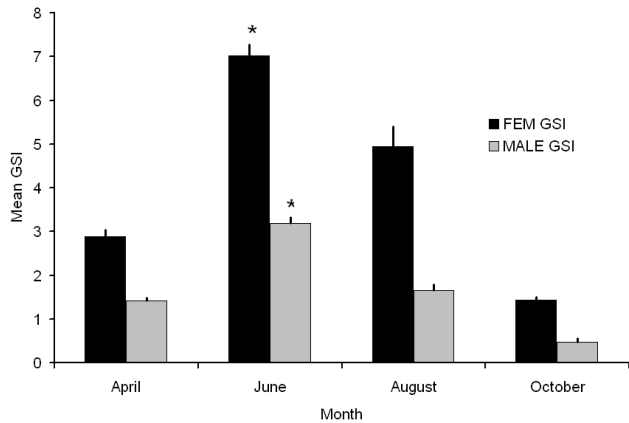


Figure 9. Mean monthly gonosomatic index (GSI), plus one standard error, for male and female black croaker (*Cheilotrema saturnum*). Asterisks denote significant difference.

decreased proportionally in Age-I and Age-II with both sexes showing some maturity during Age-I or at approximately 150 mm SL.

For males, GSI ranged from 0.17 to 8.33%, while female GSI ranged from 0 to 20.48%. Gonosomatic indices were significantly (Kruskal-Wallis, $F = 141.38$, $df = 3,893$, $p < 0.001$) higher in June samples (females = 7.01, males = 3.19, on average) for both sexes, and remained elevated through August (fig. 9). April indices were measurably elevated compared to October samples.

Year-class strength, unadjusted for mortality, peaked in 1997, with relatively strong abundances in 1996 and 1998 (fig. 10). Mean annual mortality was 0.17 and ranged from $Z = 0.2088$, based on 2002 collections, and $Z = 0.1300$, based on 2003 collections. Mortality-adjusted recruitment indicated that recruitment peaked in 1997,

with additional strong year classes in 1982 and 1994. No correlation was found between estimated annual recruitment and mean summer SST ($r = 0.02$, $p = 0.46$), but a significant negative correlation was observed between the presence of the kelp canopy along the Palos Verdes Peninsula and estimated annual recruitment ($r = -0.50$, $p = 0.03$). Analysis of impingement data indicates that peak abundances of young-of-year (YOY) individuals occurred in 1984, 1993, 1994, and with the highest in 1997 (fig. 11). Impingement abundance was significantly correlated with SST ($r = 0.48$, $p = 0.004$) and strongly correlated with mean summer surface chlorophyll-*a* densities ($r = 0.53$, $p = 0.07$).

DISCUSSION

Distribution

Black croaker were primarily distributed along the mainland within the sampling area with few at Santa Catalina Island (fig. 2). This is consistent with the findings of both Pondella and Allen (2000) and Ebeling et al. (1980). Pondella and Allen (2000) recorded black croaker as the fourth most abundant species along the coast, but absent among the 20 most abundant species collected at Santa Catalina Island. In rocky reef surveys along coastal Santa Barbara, California, and nearby Santa Cruz Island dense aggregations of black croaker at the mainland sites were observed while no such aggregations were observed at the island stations (Ebeling et al. 1980).

During the current study, the highest CPUE was recorded adjacent to the rocky reefs around the Palos Verdes Peninsula, with smaller aggregations noted along the rocky reefs of Newport and Ventura (fig. 2). Similar

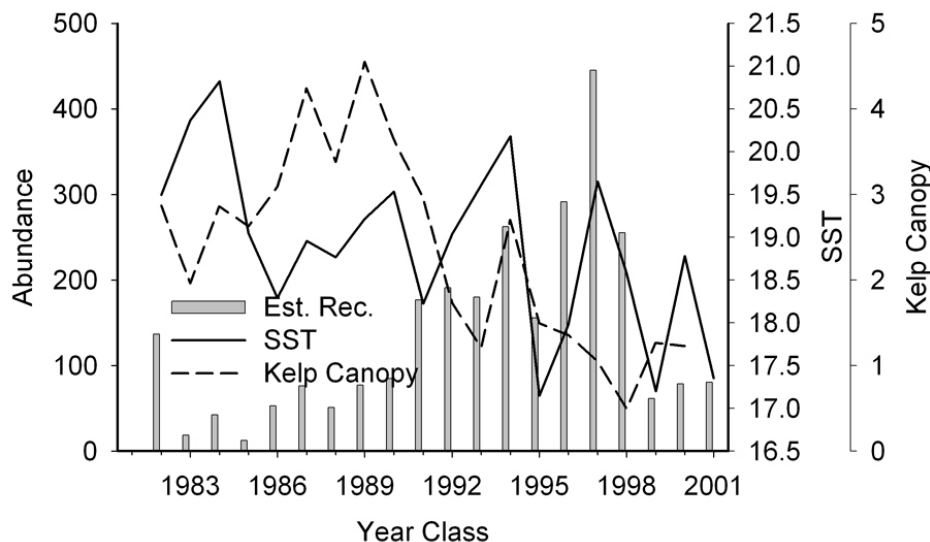


Figure 10. Hindcasted recruitment of black croaker (*Cheilotrema saturnum*), adjusted for mortality, mean annual summer SST, and maximum kelp canopy area (km^2) along the Palos Verdes Peninsula, 1982–2001.

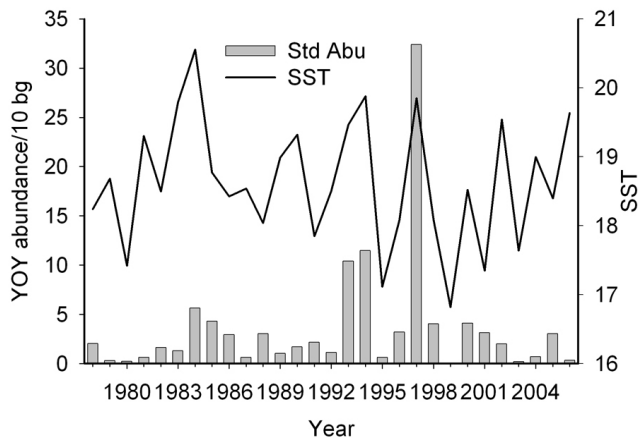


Figure 11. Black croaker (*Cheilotrema saturnum*) young-of-year (YOY) abundance per 10 bg cooling water circulated at Redondo Beach and El Segundo Generating Stations, and mean annual summer Newport SST (°C), 1978–2006.

observations were made by Herbinson et al. (2000³) in their analysis of long-term (1977–98) impingement data for sciaenids impinged at coastal generating stations ranging from Ormond Beach in Ventura County, California, to San Onofre, California. They reported peak black croaker abundances at the Redondo Beach Generating Station, located proximate to the Palos Verdes Peninsula. The increased presence of rocky reef habitat along the Palos Verdes Peninsula is consistent with the habitat affinity previously described (Limbaugh 1961; Allen 1985; Allen and Pondella 2006). The lowest CPUE values were recorded at Marina del Rey (degraded wetland) and Seal Beach (protected open coast sandy beach), which was also consistent with the reported habitat preferences.

Peak annual CPUE was recorded in 2000, followed by 1998 and 2001 (fig. 3). The peak catch in 2000 was most likely attributable to the increased availability of individuals recruiting during the El Niño Southern Oscillation event of 1997–98. These individuals would have reached a mean length of 150 mm SL within the two year span. At such lengths, individuals became more available to the size selective gillnets, which preferen-

tially collected individuals >100 mm SL in all mesh panels other than the 25.4 mm square mesh panels. Power plant impingement provided greater sensitivity in detecting YOY abundances than these gillnets. This may be due to YOY being more common in areas away from the kelp beds than near them, which could introduce a bias so that abundance estimates for power plant withdrawals are greater than for where the gillnets were set. Impingement monitoring indicated relatively high YOY abundance in 1997, suggestive of a stronger year class (fig. 11).

Age and Growth

Otolith edge analysis confirmed annuli formation in black croaker. This was consistent with findings in other sciaenids, such as weakfish (*Cynoscion regalis*) (Lowerre-Barbieri et al. 1994).

The size distribution of collected individuals nearly reached the reported maximum of 381 mm SL, suggesting that we sampled a good representation of the overall age range of black croaker. The growth rate of black croaker was consistent with previous unpublished estimates and evaluations of other nearshore croaker species. Limbaugh (1961) noted unpublished data in which a 14 in. TL (292 mm SL) individual was aged to 20 years using otolith analysis, consistent with ages observed by this study (fig. 7). Love et al. (1984) reported a steadily increasing rate for white croaker (*Genyonemus lineatus*) with a reported maximum age of 12 years (tab. 3). Joseph (1962) provided age estimates, based on scale analysis, of two common surf-zone associated sciaenids, California corbina (*Menticirrhus undulatus*) and spotfin croaker (*Roncador stearnsii*). He reported that both species grow at highly accelerated rates during the first four years and reach maximum ages of eight and ten years, respectively. The growth rates reported by Joseph (1962) were well in excess of those observed for black croaker, but were generally consistent with the results of Love et al. (1984); all three species had reported maximum life spans much less than black croaker. Miller and Lea (1972) report a maximum length of 391 mm SL for white croaker and greater than 680 mm SL for California corbina and spotfin croaker. The substantially larger size and reported inaccuracies of scale-based age estimates

³Herbinson, K. T., M. J. Allen, and S. L. Moore. 2000. Historical trends in nearshore croaker (family Sciaenidae) populations in southern California from 1977 through 1998. SCCWRP Biennial Report 1999-2000. pp. 253–264.

TABLE 3

Published relevant age parameters from other common nearshore marine sciaenids from the Southern California Bight.

Species	Maximum Reported Age	Difference Between the Sexes	Reference	Structure Aged
<i>Cheilotrema saturnum</i>	21	Yes	Current Study	Otolith
<i>Genyonemus lineatus</i>	12	Yes	Love et al. 1984	Otolith
<i>Menticirrhus undulatus</i>	8	NA	Joseph 1962	Scale
<i>Roncador stearnsii</i>	10 and 22	NA	Joseph 1962; VRG unpub. data	Scale; Otolith
<i>Umbrina roncadore</i>	15	Yes	Pondella et al. in press	Otolith

for sciaenids (Lowerre-Barbieri et al. 1994) raises some doubt as to the validity of the Joseph (1962) scale-based age estimates.

Reproduction

Gillnet-sampled assemblages indicated that a significant proportion (56%) of the overall population was male. Wilson and Nieland (1994) noted slightly skewed sex ratios in another common sciaenid species. They examined red drum (*Sciaenops ocellatus*) populations in the Gulf of Mexico and noted that females were the predominant sex, although not at a statistically significant level. DeMartini and Fountain (1981) observed a slightly higher proportion of males in breeding adult queenfish, but also not at a statistically significant level.

Gonosomatic indices indicate a spring-to-summer spawning season, which is consistent with previous analyses (Skogsberg 1939; Limbaugh 1961; Goldberg 1981). Additionally, peak GSI values observed in June and August are consistent with research reporting that the highest proportion of stage-4 oocytes occurred in July (Goldberg 1981). Furthermore, ichthyoplankton studies offshore of Huntington Beach, California, confirm a late-summer peak spawning season for black croaker; the maximum density of larvae (160 individuals/1000 m³) was collected in early September and the next highest density of 30 inds./1000 m³ was collected in June (MBC and Tenera 2005¹). Although the validity of GSI ratios for assessing reproductive activity has been questioned (DeVlaming et al. 1982), GSI ratios, prior histological examination, and recent temporal larval density patterns all coincide, suggesting that the spawning periodicity illustrated by the GSI values were indeed valid in black croaker.

Gillnet samples were dominated by those from the 1997 year class, with additional strong representatives from the 1996 and 1998 year classes. Mortality-adjusted recruitment did not significantly correlate to mean summer sea surface temperatures, however, it does indicate that 1996–98 were peak recruitment years, along with 1994 and 1982 (fig. 11). These peaks were consistent with higher-than-normal sea surface temperatures brought about by El Niño Southern Oscillation events. That recruitment was significantly inversely correlated with total giant kelp (*Macrocystis pyrifera*) canopy area along the Palos Verdes Peninsula from 1982–2001 further suggests that recruitment is associated with warm waters. Although the direct cause of this relationship is unknown, the kelp area relationship may represent the larger-scale oceanographic conditions in the area. Principal among these may have been increased water temperature, which may have shortened the larval stage duration, thereby reducing overall larval mortality (Houde 1996; O'Connor et al.

2007). While black croaker has been consistently included in kelp bed/rocky reef assemblages, the loss of kelp coverage does not appear to directly affect their recruitment potential. Limbaugh (1961) and Stephens et al. (2006) both defined black croaker as associated with the rocky habitat and not among the kelp canopy/stipes. Impingement surveys recorded similar patterns, with Age-I, or younger, individuals peaking in 1997, and other smaller peaks in 1984 and 1993–94. Both the hindcasted recruitment and impingement results noted relatively low recruitment in cold-water, or La Niña, years such as 1999.

A strong, but statistically insignificant relationship was detected between chlorophyll-*a* concentrations and YOY impingement abundance, suggesting that some periods of higher primary productivity corresponded to increased recruitment rates. Lasker (1981) initially addressed this issue and found that while primary productivity may be elevated, the planktonic species contributing to the bulk of the productivity was as important as the level of productivity to recruitment rates. He found that high concentrations of nutrient-poor organisms, such as the dinoflagellate (*Gonyaulax polyhedra*), failed to support larval growth and led to poor recruitment. However, insufficient localized data on the phytoplankton and zooplankton communities were available to fully evaluate this hypothesis.

In conclusion, this research indicates that black croaker are relatively long lived in relation to other local sciaenids and do not exhibit a differential growth rate based on sex. Furthermore, a relatively robust population occurs near rocky headlands along the coast, such as the Palos Verdes Peninsula, and has wide-ranging inter-annual variability in population levels, presumably controlled by recruitment patterns. These recruitment patterns are controlled by a complex set of unknown biological and oceanographic features, although water temperature appears to be a significant factor.

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