Historical trends in nearshore croaker (family Sciaenidae) populations in southern California from 1977 through 1998

Kevin T. Herbinson[1], M. James Allen, and Shelly L. Moore

ABSTRACT

Although croakers (Sciaenidae) are important members of the nearshore environment, most of the knowledge about their population trends has come from changes in commercial fishery landings and recreational fishery catches. However, data from these sources may misrepresent population trends if fisheries target different species or areas at different times. The objective of this study is to use fisheries-independent data from impingement surveys at coastal power generating stations to describe historical trends in sciaenid populations in southern California. Fish samples were collected in weekly impingement surveys at five coastal power generating stations off southern California from Ventura to San Onofre, California, from 1977 to 1998. Fish were collected from protective screens in incurrent cooling water over a 24-h period, counted, measured (up to 200 fish per species), and weighed by species. During the 21-year period, sciaenids accounted for 68% of the fish abundance and 53% of the fish biomass collected in these surveys. Seven species of sciaenids were collected: queenfish (*Seriphus politus*), white croaker (*Genyonemus lineatus*), yellowfin croaker (*Umbrina roncador*), black croaker (*Cheilotrema saturnum*), California corbina (*Menticirrhus undulatus*), white seabass (*Atractoscion nobilis*), and spotfin croaker (*Roncador stearnsii*). Queenfish abundance was more than 10 times that of white croaker, the second most abundant species, and more than 1,500 times more abundant than spotfin croaker, the least abundant species. Although most species were represented by juveniles and adults, queenfish and white croaker catches were dominated by juveniles, and all white seabass were juveniles. Historical trends in catch-per-unit-effort values (i.e., abundance and biomass per million gallons of filtered water) showed that queenfish abundance was relatively stable during this period, although its biomass decreased. The abundance and biomass of most species were higher in the 1970s, but yellowfin croaker was most abundant in the 1980s. These historical trends suggest a strong relationship to warming ocean conditions during the 1980s and 1990s. Although yellowfin croaker abundance and biomass were higher during the warmer period, most species catches decreased during this period. All species showed relatively minor seasonal fluctuations.

INTRODUCTION

Croakers or drums (family Sciaenidae) are ecologically, recreationally, and commercially important fishes of southern California's nearshore marine environment. Most croakers are moderate-sized, nocturnal, schooling species occurring primarily on nearshore sandy or muddy bottoms, although some species inhabit the surf zone, rocky bottoms, kelp beds, and bays. They are caught by recreational anglers on piers, on shore, and in private boats, but some are caught from commercial passenger fishing vessels (CPFVs or party boats), with at least two species being part of commercial fisheries (Oliphant 1992a,b; Vojkovich 1992; Wild 1992, Allen *et al.* 1996). Some species have relatively high levels of contaminants and have been the subject of consumption advisories in certain locations (Pollock *et al.* 1991, Allen *et al.* 1996).

Although croakers are abundant nearshore species, most of the knowledge about their temporal population trends has come from changes in landings of commercial fisheries and commercial passenger fishing vessels, or creel surveys of recreational anglers (Oliphant 1992a,b; Vojkovich 1992; Wild 1992). However, data from these sources may reflect only the fished population levels and not unfished

[1]*Southern California Edison Company, P.O. Box 800, Rosemead, CA 91770*

population levels. Hence, a fisheries-independent assessment of croaker populations is needed to better understand population trends in these species.

For more than two decades, the operators of many coastal electric generating stations in California have collected data on the species of fish caught at their stations in southern California. These data are provided to the California Regional Water Quality Control Boards under the National Pollutant Discharge Elimination System (NPDES) data reporting program. Reports to the regional boards include the number and weight of fish entering the stations, along with the water used to cool and recondense steam in the process of producing electricity. If one accepts the assumption that an increase or decrease in the density of a fish population near an intake pipe results in a corresponding increase or decrease in the entrainment of that species, then the fluctuation of the entrained catch reflects a similar fluctuation in population density. Given this assumption, this long-term database provides a valuable source of information on the variations in fish abundance over time. Impingement data have been used in the past to demonstrate changes in nearshore rockfish recruitment and population size (Love *et al.* 1998) and have been provided to state and federal agencies for their use in better understanding California fishery stocks, especially white seabass (*Atractoscion nobilis*), chub mackerel (*Scomber japonicus*), Pacific sardine (*Sardinops sagax*), and bocaccio (*Sebastes paucispinis*).

The objective of this study is to use fisheries-independent data from impingement surveys at coastal power generating stations to show long-term trends in the abundance of the sciaenid species in shallow coastal waters (< 15 m) from Ventura County to San Diego County.

METHODS

This study utilizes data provided to State of California agencies in compliance with NPDES environmental monitoring programs conducted from 1977 to 1998 at eight intakes distributed among five different power generating stations: Ormond Beach, El Segundo (two intakes), Redondo Beach, Huntington Beach, and San Onofre (3 intakes) (Figure 1). These stations were selected because they all have intakes that are similar in design, are located offshore, and entrain water from mid-water depths (Table 1). Two of the intakes, San Onofre Units 2 and 3, were not fully operational until 1983 and 1984, respectively; San Onofre Unit 1 was taken out of service in November 1992.

Two types of fish samples are collected at power generating stations: normal operation samples and heat treatment samples. Normal operation samples are intended to measure the fish that are caught during a 24-h period of operation at each generating station. The sample taking is preceded by running all trash collection screen system long enough to clear fish and debris from the intake system. Any fish and debris that are collected on the screens are then discarded. For the following 24 h, all fish are collected from the screens; at the end of this 24-h period, the screens are run again until all fish and debris are removed. These fish and all those taken during the 24-h period comprise a single sample. The amount of water that has been pumped through the station during the 24-h period is also recorded. The number or weight of fish divided by the flow volume in gallons (one gallon = 3.785 L) provides a catch-per -unit-effort (CPUE) value for abundance or biomass that can be compared with other stations or sample periods.

Heat treatment samples are collected about every six weeks when the generating stations elevate the temperature of the seawater in the station to approximately 40° C for one hour. This practice is completed to control the growth of fouling organisms, such as mussels and barnacles. Any fish that are residing in the system will also be killed. All fish killed during the heat treatment are collected and quantified following the same procedures used in collecting the normal operation samples.

In both normal and heat treatment samples, fish were collected from protective screens in incurrent cooling water over a 24-h period, identified to species, counted, and measured (up to 200 fish per species) to the nearest millimeter standard length (SL) (total length for elasmobranchs), and weighed by species. Gender was determined for up to 50 individuals of certain key species, including most of the sciaenids.

The annual CPUE is determined by dividing the number (or biomass) of fish impinged on the screens by the amount

FIGURE 1. Location of five coastal power generating stations in southern California with historical fish impingement data from 1977 to 1998.

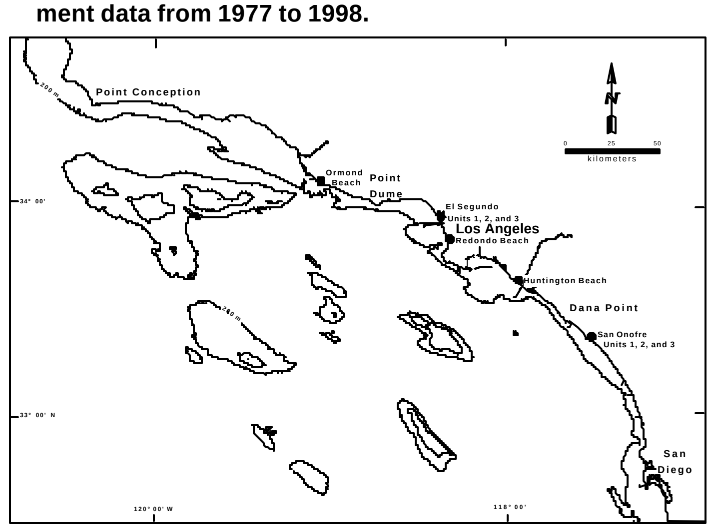


TABLE 1. Characteristics of intake structures for coastal power generating stations in southern California where fish impingement surveys were conducted from 1977 to 1998.

Power Generating Station Intake	Distance Offshore (m)	Bottom Depth (m)	Intake Height (m)	Opening Height (m)	Entrance Velocity (mps)	Maximum Flow Rate (gpm)	Maximum Flow Rate (Lpm)
Ormond Beach	793	6.1	4.6	1.2	0.82	476,000	1,801,660
El Segundo Unit 1	698	5.2	4.6	0.6	0.73	144,000	545,040
El Segundo Unit 2	702	6.1	4.4	1.0	0.73	276,000	1,044,660
Redondo Beach	289	9.2	4.5	1.2	0.76	468,000	1,771,380
Huntington Beach	458	5.3	4.8	1.5	0.61	356,600	1,349,731
San Onofre Unit 1	908	3.5	4.7	1.2	0.67	350,620	1,327,097
San Onofre Unit 2	971	3.8	5.5	2.1	0.52	830,000	3,141,550
San Onofre Unit 3	971	3.8	5.5	2.1	0.52	830,000	3,141,550

gpm = gallons per minute; Lpm = liters per minute; mps = meters per second.

of water filtered. The unit of measurement of water filtered is usually "per million gallons" since gallons are the unit of measurement used by the generating station operators. One million gallons equals 3.785412 kilosteres (1 kilostere is equal to 1,000 m^3). Normal operation data and heat treatment data are combined for a given period, usually one year. The number (or biomass) of fish caught in normal operation samples is divided by the amount of water filtered during those sample intervals. Then the number (or biomass) of fish caught during heat treatments is divided by the total amount of water filtered during the entire year. The two values (normal operation and heat treatment) are then added together. By using the CPUE, differences in sampling effort and station flow volumes are minimized.

RESULTS

Total Catch

A total of 6,581 fish impingement samples were taken among the eight generating station intakes from 1977 through 1998 (Table 2). Twenty-two year totals for each intake varied from 316 at El Segundo Generating Station Units 1 and 2 to 1,181 at Redondo Generating Station. The number of samples taken over the eight intakes by year ranged from 110 in 1995 to 498 in 1980. During years when intakes were active, the numbers of samples collected per year at an intake ranged from 1 to 108.

A total of 11,205,492 fish (all species) weighing 336,879 kg were sampled at the eight intakes during the 22-year period (Table 3). Sciaenids occurred in 75% of the samples collected, with 7,656,150 fish (68%) weighing 178,139 kg (53%) being processed. The seven species of sciaenids collected were queenfish (*Seriphus politus*), white croaker (*Genyonemus lineatus*), yellowfin croaker (*Umbrina roncador*), black croaker (*Cheilotrema saturnum*), California corbina (*Menticirrhus undulatus*), white seabass, and spotfin croaker (*Roncador stearnsii*). Queenfish was taken most frequently (in 73% of the total samples), followed by white croaker (39%) and black croaker (16%). Queenfish was also the most abundant species (accounting for 62% of the total catch) and had the highest biomass (accounting for 53% of the total biomass) (Table 3). Queenfish abundance was more than 10 times that of white croaker, the second most abundant species, and more than 1,500 times more abundant than spotfin croaker, the least abundant species. White croaker, second in abundance, comprised 6% of the total catch and biomass. The remaining six sciaenid species accounted for less than 1% each of the total catch and biomass, with the exception of biomass for yellowfin croaker (5%) and spotfin croaker (1%).

Overall, sciaenids ranged in length from about 10 to 756 mm; however, most fish were well under 500 mm (Figure 2). The largest sciaenid taken was a white seabass; queenfish, white croaker, and black croaker had the smallest individuals. The length frequencies of most species showed bimodal or multimodal distributions. Distributions for queenfish, white croaker, and California corbina were skewed to the right, with the highest mode being below or near 100 mm SL. Black croaker and white seabass showed more normally distributed distributions, with primary modes just below 200 mm SL; whereas yellowfin croaker and spotfin croaker were skewed more to the left, with primary modes between 200 and 300 mm SL.

Spatial Variability

Sciaenid species varied spatially in frequency of occurrence, abundance, and biomass among intakes (Tables 4, 5, and 6). They were most common (89, 88, and 87% of the samples) at Units 1, 3, and 2, respectively, of San Onofre Generating Station and were least common (46%) at El Segundo Units 1 and 2 (Table 4). Six species were most common at San Onofre: white croaker and queenfish were most common at San Onofre Unit 3; and California corbina, white seabass, yellowfin croaker, and spotfin croaker were most common at San Onofre Unit 1. Black croaker was most common at El Segundo Units 3 and 4. Three species were least common in Santa Monica Bay: queenfish at El Segundo Units 1 and 2, white croaker at Redondo, and

TABLE 2. Number of fish impingement samples collected during normal operations and heat treatments at five coastal generating stations in southern California from 1977 to 1998.

Year	Ormond Beach	El Segundo 1&2	El Segundo 3&4	Redondo Beach	Huntington Beach	San Onofre Unit 1	San Onofre Unit 2	San Onofre Unit 3	Total
1977	9	10	11	104	10	77	0	0	221
1978	13	20	10	70	24	90	0	0	227
1979	84	75	72	86	68	99	0	0	484
1980	103	75	77	108	101	34	0	0	498
1981	59	8	8	54	61	42	0	0	232
1982	47	6	9	40	47	19	31	0	199
1983	58	8	4	53	58	32	65	10	288
1984	54	3	3	59	58	34	68	74	353
1985	56	6	7	62	58	68	88	74	419
1986	61	3	6	54	57	31	82	105	399
1987	58	4	5	63	54	55	72	62	373
1988	57	3	3	37	58	52	59	53	322
1989	54	2	1	53	58	57	57	59	341
1990	57	2	5	51	56	56	59	57	343
1991	56	4	1	66	56	59	57	60	359
1992	60	13	15	50	58	60	77	76	409
1993	56	15	16	48	101	26	74	75	411
1994	56	13	10	49	20	0	48	47	243
1995	16	10	14	17	18	0	17	18	110
1996	15	12	16	20	20	0	18	20	121
1997	13	15	16	18	19	0	18	18	117
1998	13	9	14	19	16	0	21	20	112
Total	1,055	316	323	1,181	1,076	891	911	828	6,581

TABLE 3. Overall abundance and biomass of croaker species and total catch collected in fish impingement samples from five coastal power generating stations in southern California from 1977 to 1998.

Species	Frequency of Occurrence (no. samples)	Abundance (no. individuals)	Biomass (kg)	Percent Total FO	Percent Total Abundance	Percent Total Biomass
queenfish	4,798	6,905,044	133,027	72.9	61.62	39.49
white croaker	2,540	666,536	20,741	38.6	5.95	6.16
black croaker	1,060	12,269	1,897	16.1	0.11	0.56
California corbina	724	5,871	1,018	11.0	0.05	0.30
white seabass	652	4805	863	9.9	0.04	0.26
yellowfin croaker	605	57,498	17,158	9.2	0.51	5.10
spotfin croaker	276	4,127	3,435	4.2	0.04	1.02
Sciaenidae	4,929	7,656,150	178,139	74.9	68.32	52.88
Total	6,581	11,205,492	336,879	100.0	100.00	100.00

FO = frequency of occurrence.

spotfin croaker (absent at both El Segundo intakes). Black croaker, California corbina, white seabass, and yellowfin croaker were least common at Ormond Beach.

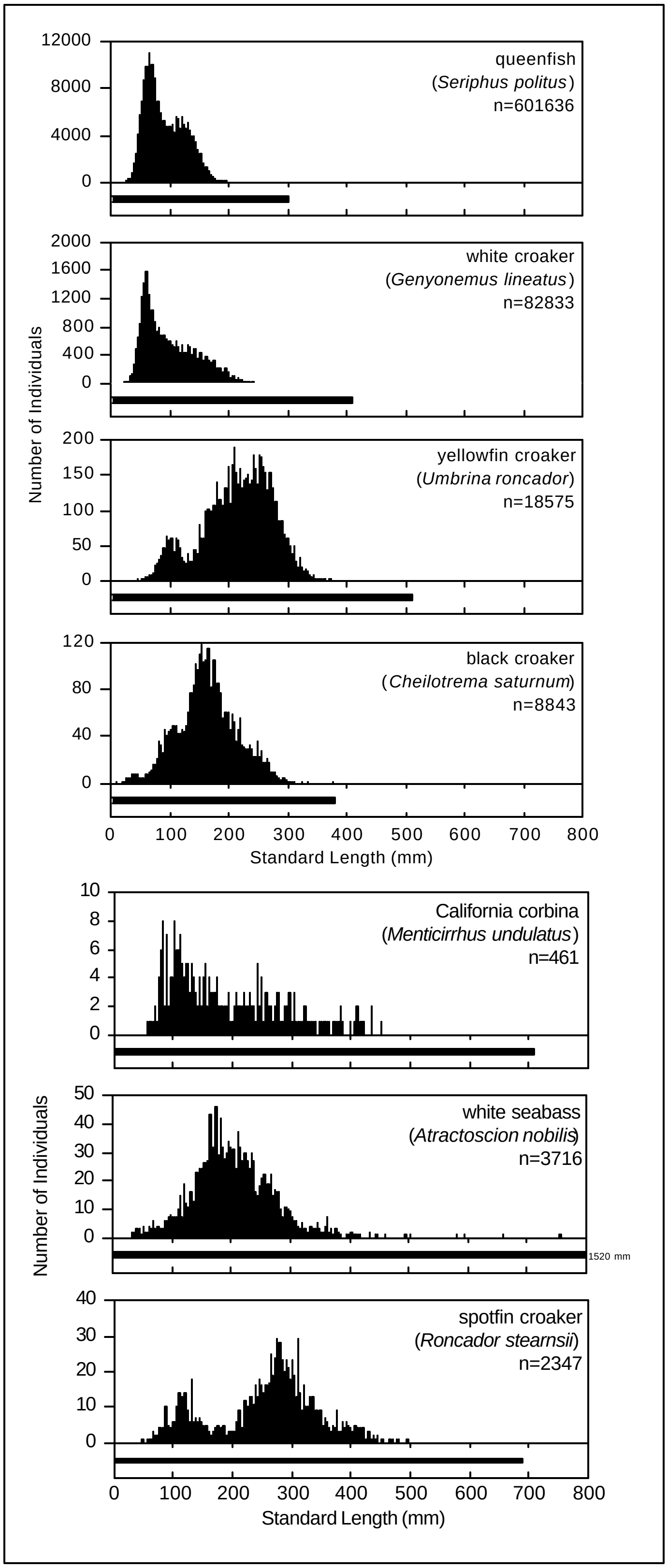
These species showed a different spatial distribution by abundance (Table 5). Overall, sciaenids were most abundant at Huntington Beach and least abundant at Redondo. Four species (queenfish, white croaker, California corbina, and white sea bass) were most abundant at Huntington Beach; whereas black croaker was most abundant at Redondo, yellowfin croaker was most abundant at San Onofre Unit 3, and spotfin croaker was most abundant at San Onofre Unit 1. Queenfish and white croaker were least abundant at Redondo; black croaker and yellowfin croaker were least abundant at Ormond Beach, California; corbina and white seabass were least abundant at El Segundo Units 1 and 2; and spotfin croaker were absent at both El Segundo intakes.

The differences in spatial distribution by biomass (Table 6) were similar to those by abundance. Biomass was highest at Huntington Beach and lowest at El Segundo Units 1 and 2. For individual species, the pattern for highest biomass was the same as that for highest abundance. The highest biomass for four species (queenfish, white croaker, California corbina, and white sea bass) was at Huntington Beach; whereas the highest biomass for black croaker was at Redondo and for yellowfin croaker was at San Onofre Unit 3. The lowest biomass differed somewhat from abundance, with lowest values at El Segundo Units 1 and 2 for queenfish, white croaker, and California corbina. Spotfin croaker was absent at both El Segundo Units 1 and 2 units, and had virtually 0 biomass at Ormond Beach. Black croaker, white seabass, and yellowfin croaker had the lowest biom ass at Ormond Beach.

Annual Temporal Variability

The annual abundances and biomass varied differently among species from 1977 through 1998 (Figures 3 and 4) and showed the same differences in scale as between the populations as a whole (Table 3). In general, annual biomass trends mirrored those of annual abundance (Figure 4). Queenfish abundance was relatively constant during the period but was high from 1978 to 1981, in 1986, and in 1995.

FIGURE 2. Length-frequency distributions of croaker species collected in fish impingement surveys at five power generating stations in southern California from 1977 to 1998. Dark bar delineates known length range of species.



Queenfish CPUEs varied from 0.3438 fish per million gallons (fpmg) in 1997 to 1.5318 fpmg in 1995. In contrast, the abundance of white croaker, black croaker, California corbina, and spotfin croaker declined. Black croaker abundance was highest in 1977; white croaker and spotfin croaker abundance was highest in 1978; and California corbina abundance was highest in 1978 and 1982. Ranges of CPUEs for these four species were the following: white croaker, 0.00403 fpmg (1998) to 0.2781 fpmg (1978); black croaker, 0.00011 fpmg (1995) to 0.00415 fpmg (1977); California corbina, 0.00004 fpmg (1992) to 0.0034 fpmg (1982); and spotfin croaker, 0.00001 fpmg (1994) to 0.0022 fpmg (1978). Yellowfin croaker and white seabass had peaks within the 22-year period, with yellowfin croaker being highest in 1988 and white seabass in 1982. Yellowfin croaker CPUEs ranged from 0.00037 fpmg (1979) to 0.0112 fpmg (1988) and those of white seabass from 0.00015 fpmg (1991) to 0.00293 fpmg (1982). White seabass and yellowfin croaker were unique among the sciaenids in showing low abundances in the years from 1978 through 1980.

Seasonal Variability

The mean abundances and biomass of the sciaenid species did not vary much by season, and both varied similarly (Figures 5 and 6). Queenfish, white croaker, and California corbina were somewhat higher in abundance in the spring; black croaker and white seabass were somewhat higher in June, and yellowfin croaker and spotfin croaker were somewhat higher in September. While biomass followed a generally similar pattern, black croaker was highest in biomass in November. White seabass abundance and biomass were also relatively high in the winter.

The seasonal abundance of sciaenids varied between stations north of Point Vicente (Redondo Beach, El Segundo, and Ormond Beach) and stations south of Point Vicente (Huntington and San Onofre Units 1, 2, and 3). Queenfish were consistently more abundant at the southern stations. The southern stations also peaked in February and March (means of 1.9302 and 2.5145 fpmg, respectively), with the low (0.9539 fpmg) in August. Peak mean CPUEs in the north occurred in February and March (0.7774 and 0.7957 fpmg, respectively), with the low (0.1103 fpmg) occurring in June.

White croaker showed the most dramatic difference in seasonal abundance between north and south. The peak mean CPUE (0.1923 fpmg) in the north occurred in March with the low (0.0011 fpmg) occurring in September. In the south, the abundance first peaked in February (0.1756 fpmg), then fell in April (0.1295 fpmg), then peaked again in

TABLE 4. Frequency of occurrence of croaker species collected in fish impingement samples from five coastal power generating stations in southern California from 1977 to 1998.

	Percent Samples								
	Ormond	El Segundo		Redondo	Huntington	San Onofre			
	Beach	1&2	3&4	Beach	Beach	Unit 1	Unit 2	Unit 3	Total
Species	(n=1,055)	(n=316)	(n=323)	(n=1181)	(n=1076)	(n=891)	(n=911)	(n=828)	(n=6581)
queenfish	76.6	41.1	50.8	52.8	73.0	86.8	86.7	87.3	72.9
white croaker	30.8	18.7	26.0	10.8	46.0	52.9	53.9	58.6	38.6
black croaker	5.6	26.6	27.6	24.3	13.4	26.3	9.8	8.8	16.1
California corbina	6.3	8.5	15.2	6.4	13.5	24.1	7.5	9.2	11.0
white seabass	2.3	7.0	13.0	4.1	12.1	20.2	9.5	14.4	9.9
yellowfin croaker	0.1	4.4	9.3	9.3	2.8	19.2	14.4	14.3	9.2
spotfin croaker	0.1	0.0	0.0	0.8	1.1	15.3	7.1	6.8	4.2
Sciaenidae	76.6	45.6	56.0	58.8	74.1	88.7	86.7	87.6	74.9

n = total impingement samples per site.

TABLE 5. Abundance of croaker species collected in fish impingement samples from five coastal power generating stations in southern California from 1977 to 1998.

	Number of Individuals								
	Ormond	El Segundo		Redondo	Huntington	San Onofre			
	Beach	1&2	3&4	Beach	Beach	Unit 1	Unit 2	Unit 3	Total
Species	(n=1,055)	(n=316)	(n=323)	(n=1181)	(n=1076)	(n=891)	(n=911)	(n=828)	(n=6581)
queenfish	658,004	67,522	214,428	53,852	3,688,720	522,134	7,26,705	973,893	6,905,258
white croaker	69,861	10,757	30,666	2,990	388,295	41,472	41,938	80,565	666,544
black croaker	173	774	1,515	4,489	2,333	2,014	503	413	12,214
California corbina	285	135	378	230	3,054	1,247	277	264	5,870
white seabass	67	54	310	262	2,399	645	394	673	4,804
yellowfin croaker	38	359	1181	521	564	7,381	18,476	28,948	57,468
spotfin croaker	9	0	0	56	21	2,203	1,345	493	4,127
Sciaenidae	728,437	79,601	248,478	62,400	4,085,386	577,096	789,638	1,085,249	7,656,285

n = total impingement samples per site

TABLE 6. Biomass of croaker species collected in fish impingement samples from five coastal power generating stations in southern California from 1977 to 1998.

	Biomass (kg)								
	Ormond	El Segundo		Redondo	Huntington	San Onofre			
	Beach	1&2	3&4	Beach	Beach	Unit 1	Unit 2	Unit 3	Total
Species	(n=1055)	(n=316)	(n=323)	(n=1181)	(n=1076)	(n=891)	(n=911)	(n=828)	(n=6581)
queenfish	16,295	1,209	5,022	1,394	77,095	10,943	8,673	12,398	6,905,258
white croaker	4,074	199	1,876	227	11,452	1,600	540	773	666,544
black croaker	26	132	341	676	289	317	52	49	12,214
California corbina	118	30	107	67	371	240	35	50	5,870
white seabass	11	22	61	19	482	133	40	95	4,804
yellowfin croaker	3	89	181	58	15	1,628	5,301	9,875	57,468
spotfin croaker	0	0	0	9	2	2,486	796	142	4,127
Sciaenidae	20,527	1,681	7,589	2,450	89,706	17,347	15,437	23,381	7,656,285

n = total impingement samples per site.

FIGURE 3. Annual mean abundance of croaker species collected in fish impingement surveys at five power generating stations in southern California from 1977 to 1998.

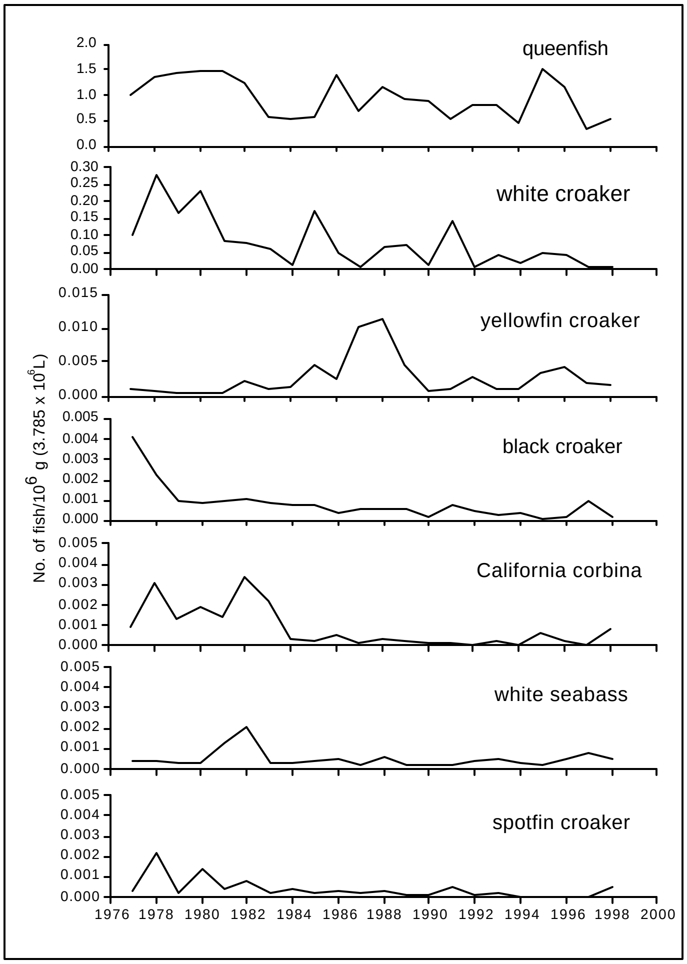
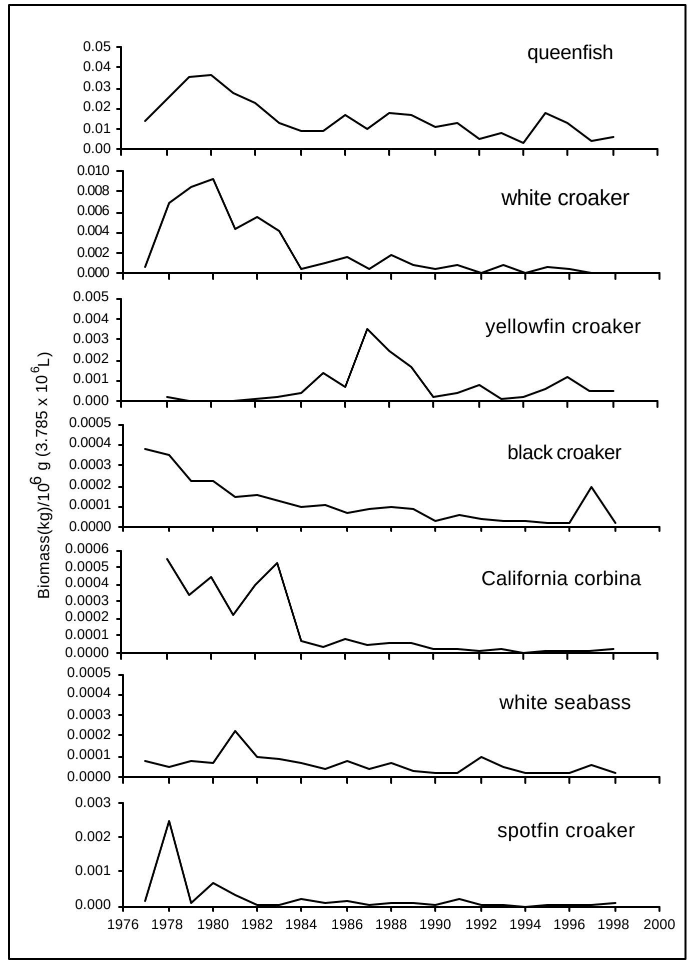


FIGURE 4. Annual mean biomass of croaker species collected in fish impingement surveys at five power generating stations in southern California from 1977 to 1998.



June (0.2781 fpmg). The lowest mean CPUE (0.01999 fpmg) in the south occurred in November.

Yellowfin croaker rarely occurred at stations north of Point Vicente. The highest abundance in the north (0.001621 fpmg) was in November. All other months were less than 0.00062 fpmg. At southern stations, abundance increased in July and August and peaked in September (0.0201 fpmg). The lowest mean CPUE in the south occurred in April (0.00039 fpmg.)

Black croaker abundances were quite similar between north and south (this was the only sciaenid with a peak abundance higher in the north than in the south). In the north, the highest mean CPUE occurred in November (0.002629 fpmg), with a secondary peak in June (0.001248 fpmg). Two seasonal peaks also occurred at southern stations: one, similar to the north, occurring in June (0.00136 fpmg); and another in October (0.00149 fpmg).

California corbina abundance was consistently higher at southern stations, but both areas showed a peak abundance in March. In the north, the highest mean abundance (0.00081 fpmg) occurred in March, while the lowest mean abundance (0.00004 fpmg) occurred in June. In the south, abundance peaked (0.00353 fpmg) in March with a smaller increase (to 0.0012 fpmg) in June. The lowest mean CPUE in the south (0.00038 fpmg) occurred in August.

White seabass abundance was consistently higher in the south than in the north, especially during summer months. In the north, white seabass showed a moderate peak in February (0.00033 fpmg) followed by values less than 0.00009 fpmg throughout summer and fall, then a rapid increase to 0.00106 fpmg in December. In the south, mean abundance peaked at 0.00138 fpmg in January, then fell to the lowest abundance (0.00018 fpmg) in May. This decrease was followed by an increase to 0.00113 fpmg in June. After a decline in July to 0.0007 fpmg, the abundance continued to climb to 0.0012 in December.

Spotfin croaker rarely occurred at stations north of Point Vicente. The highest abundance in the north occurred in November and December, both measuring a very low 0.00007 fpmg. All other months were less than 0.00003

FIGURE 5. Monthly mean abundance of croaker species collected in fish impingement surveys at five power generating stations in southern California from 1977 to 1998.

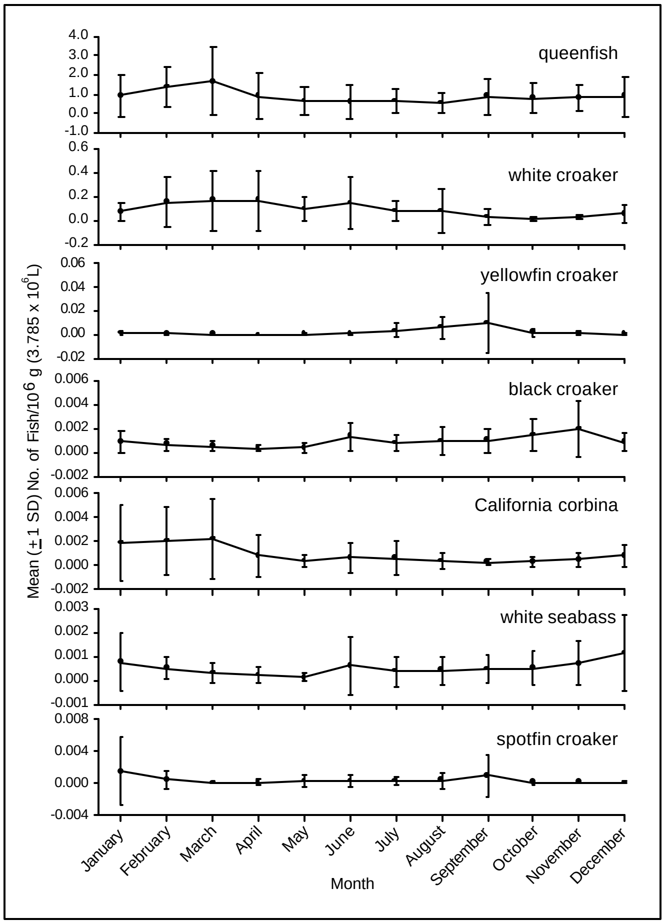
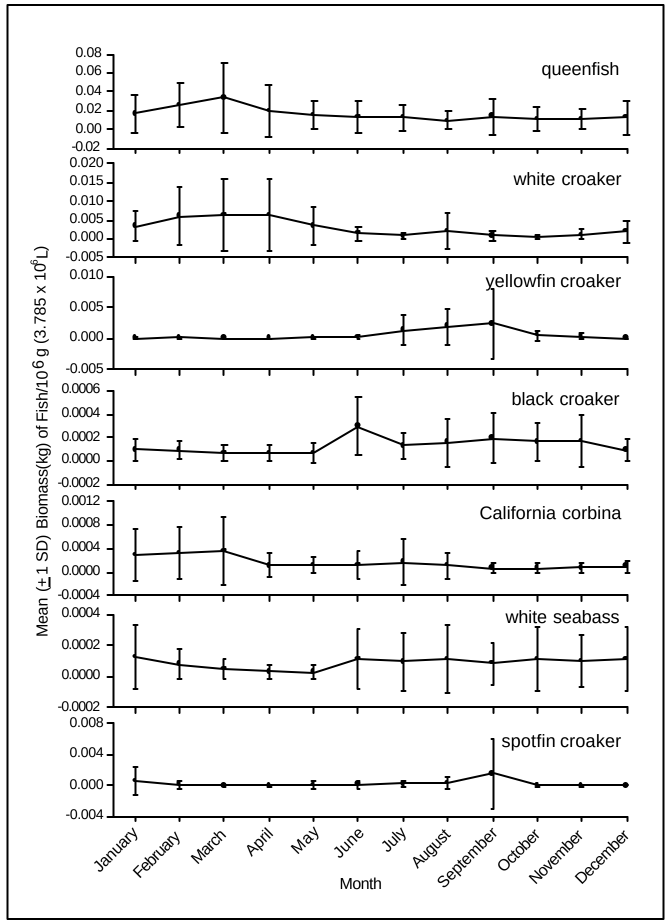


FIGURE 6. Monthly mean biomass of croaker species collected in fish impingement surveys at five power generating stations in southern California from 1977 to 1998.



fpmg. At southern stations, abundance peaked in January to 0.0201 fpmg and in August to 0.0020 fpmg. The lowest abundance in the south occurred in March (0.00012 fpmg.)

DISCUSSION

The objective of this study was to use fish impingement data from coastal electric generating stations to show long-term trends in abundance and biomass of seven species of sciaenids: queenfish, white croaker, black croaker, California corbina, white seabass, yellowfin croaker, and spotfin croaker. Since the seawater intake structures of the generating stations are located less than 1 km offshore and in depths less than 15 m, these data provide valuable information on the nearshore fish community that may be missed by trawl studies, which usually sample at greater depths. Because of the distribution of the generating station intakes along the coast, it is also possible to show differences in abundance throughout much of the southern California coast.

Queenfish was the most abundant sciaenid, and usually the most abundant fish overall at coastal generating stations, especially south of Point Vicente. Queenfish school in shallow water during the day, often near beaches or in the shadows of reefs or kelp, then disperse and move offshore at night when they feed actively on mysids and other plankton in the water column (Hobson and Chess 1976, Allen 1982, Love 1996). During these nocturnal migrations and dispersal in the water column, it is likely that many of the queenfish are entrained into the generating station intakes. Queenfish were abundant throughout the survey. However, the annual abundance did fluctuate significantly, apparently in relationship with El Niño events. Although abundance remained generally strong during both warm and cool water periods, marked declines were noted during the strong El Niño events of 1982-83, 1986-87, and 1997-98. Although Allen and DeMartini (1983) reported that queenfish temporarily move offshore into deeper waters during the winter months, our data does not support this contention. It shows a higher level of entrainment during winter months, especially February, March and April, with a declining catch from May through August. This trend is consistent between both the northern and southern stations.

Unlike queenfish abundances, which fluctuated from year to year but did not show any long-term decline, white croaker abundance declined. Marked decreases in the abundance of white croaker correspond to major El Niño events in 1982-83, 1986-87, and 1997-98. Along the mainland coast, white croaker often school with queenfish (Allen 1982, Love 1996) and exhibit similar diurnal dispersal patterns; however, unlike the queenfish, white croaker are predominantly a benthic feeder (Allen 1982). Seasonal abundance data from impingement sampling data support observations by Allen and DeMartini (1983) that white croaker, unlike queenfish, may move offshore into deeper waters during winter months. This migration is indicated by a marked decline in white croaker abundance in the study area from October to December and increases from April through August. This shift, however, is only apparent at the southern stations. At stations from Redondo Beach north to Ormond Beach (in Ventura County), no such pattern appears. In fact, declines in northern white croaker densities correspond with increases in southern densities, suggesting a southern migration during spring and summer. However, the disproportionately high DDT levels in white croaker on the Palos Verdes Shelf (where DDT is high in sediments) relative to Santa Monica Bay and Dana Point (Allen and Cross 1994), suggest that white croaker are not likely to move long distances up and down the coast.

Black croaker exhibit different behavior than the other croakers. They are often found near rocky reefs and kelp beds, and frequently inhabit caves and crevasses during the day, feeding at night on benthic prey (Limbaugh 1961, Feder *et al.* 1974, Allen 1985, Love 1996). They are found in depths from 1 to 50 m, but are concentrated from 3 to 16 m. Juveniles appear from August to October, schooling over sandy bottoms near bases of rocks. As black croaker become larger, they break away from the schools and retire to caves and crevasses (Feder *et al.* 1974). Black croaker densities showed a marked decline from 1977 through 1979 during a transition from cooler to warmer seawater regimes. Since 1979, densities have declined slightly with brief increases in 1991 and 1997. Seasonally, black croaker are slightly more abundant at northern stations in the winter (October through March), but are similar in abundance, north and south, during the summer. Both locales peak in the late fall.

California corbina usually inhabit sandy shores and bays (particularly in sandy surf areas) to a depth of 15 m, although usually less than 8 m (Eschmeyer *et al.* 1983). They are highly prized by pier and surf fishermen and are reserved as a recreational resource by the State of California (Oliphant 1992a). It has been illegal to net corbina since 1909, and their purchase or sale has been illegal since 1915 (Joseph 1962). California corbina spawn from June through September, probably offshore, since running-ripe fish are not often found in the surf. Tagging studies indicate that movement is limited and that corbina have no discernible migratory pattern. The greatest distance traveled was 82 km (Oliphant 1992a). Corbina densities at coastal generating stations fell following the 1982-83 El Niño event and have not recovered since. Corbina were seen in very low numbers at stations north of Point Vicente, as might be expected since this is the northern extreme of their range (which extends from Point Conception, California, to the Gulf of California). Throughout the study range, densities were highest from January through March. This trend is the opposite of recreational catch, which is highest from summer to early fall (Oliphant 1992a). The apparent difference in seasonal abundance suggests that corbina move offshore to generating station intake depths (approximately 7 m) during the winter. It is likely they move into extremely shallow water to feed on the abundance of sand crabs (*Emerita analoga*) during the summer and fall. During these months, corbina are often seen in water less than a few centimeters deep preying on sand crabs (first author KTH, pers. obs.).

White seabass have long been esteemed in California by both sport and commercial fishermen. They are the largest sciaenid in California and may reach a weight of 41 kg and a length of over 1.5 m (Eschmeyer *et al.* 1983). They have a history of declining and erratic catches that took a dramatic downturn from 1980 to 1982 and have never recovered (Vojkovich 1992). Efforts are currently underway to restore white seabass populations through hatchery releases from many sites along the southern California coast, including Santa Catalina Island. At least 56 white seabass captured at coastal generating stations have been identified as coming from these releases. Very few individuals over 400 mm have been captured by generating stations. It is likely that larger fish are able to overcome the intake flow velocity. Except for a brief increase in fish density in 1981 and 1982, white seabass abundance has remained uniformly low since 1977. The brief increase in 1981 and 1982 is puzzling since it corresponds with a decline in sport and commercial catch. Seasonally, white seabass occurrence at coastal stations has peaked in winter, being highest in December and January, with lowest abundance in spring. A secondary peak occurred in June. Allen and Franklin (1992), sampling with a 1.6 m beam trawl, observed that young-of-the-year (YOY) white seabass were captured over sandy bottoms in shallow water near the breaker line, most often with submerged aquatic vegetation (drift algae:

green, brown, and red), encrusting bryozoans, and terrestrial debris. They observed the greatest abundance of YOY white seabass in July. These fish were generally less than 20 mm and would not be seen in samples from generating stations because of the mesh size of the screens used to collect the fish and debris.

Yellowfin croaker have been reported as far north as San Francisco, but are rare north of Ventura (Love 1996). They typically occur in shallow surf zones and are prized by surf, pier, and jetty fishermen. They also occur routinely in commercial passenger-carrying fishing vessels (Oliphant 1992b). Like California corbina, they are reserved for sport fishing only. In 1909, it became illegal to take them with nets and, in 1915, it became illegal to sell them (Oliphant 1992b). Some yellowfin croaker are caught year-round, but late summer is usually the most productive time of the year. Long-term fish impingement data show a trend toward slightly higher densities of yellowfin croaker over time. Abundances were particularly high in 1987 and 1988 following a strong El Niño event. Few yellowfin were taken at stations north of Point Vicente, but abundances were relatively high at southern stations from Huntington Beach to San Onofre, where average monthly CPUEs exceeded 0.02 fpmg in September. Seasonally, the greatest abundance occurred from July through October, peaking in September.

Spotfin croaker have also been reserved by the State of California for sport fishing since 1915. Most of the spotfin sport catch consists of small- to medium-size fish. There appears to be an offshore reserve of larger fish that is rarely exploited. In a study by the California Department of Fish and Game, several hundred of these offshore fish were tagged, but only about 1% of them were subsequently caught by surf fishermen (Oliphant 1992b). The small- to medium-size fish tagged onshore had a return of over 6%. The tagging program also showed that spotfin croaker move around considerably without a discernible pattern. Fish tagged in Los Angeles Harbor were later taken off Oceanside. Entrainment records suggest a decline in abundance since 1980, but minor increases were found in 1991 and 1998. Seasonally, abundance has peaked in January then declined to lowest abundance in March, followed by a gradual rise through spring and summer to another peak in September. The two croakers, yellowfin and spotfin, are often seen together in study samples, suggesting they may school together (first author KTH, pers. obs.).

Although most species were represented by juveniles and adults, queenfish and white croaker catches were dominated by juveniles; virtually all white seabass were juveniles (Figure 2). Queenfish and white croaker both mature at about 1 year, with queenfish maturing at 13 cm and white croaker at 14-15 cm (Love *et al.* 1984, Love 1996). Primary modes in this study were less than 10 cm for both species (Figure 2). White seabass mature at 3 to 4 years and at lengths of 60-70 cm (Fitch and Lavenberg 1971, Frey 1971, Hart 1973). The primary mode in this study was less than 20 cm, with only about 2 to 4 white seabass sufficiently large to be mature (Figure 2). Yellowfin croaker matures at 23 cm and about 4 years (Love 1996), black croaker at 23 cm and 2 to 3 years (Fitch and Lavenberg 1975, Love 1996), California corbina at 25-30 cm and 2 to 3 years (Oliphant 1992a), and spotfin croaker at 23-32 cm and 2 to 3 years (Oliphant 1992b). In this study, primary modal sizes for these species were about 20 cm for yellowfin croaker, less than 20 cm for black croaker, less than 10 cm for California corbina, and 28-30 cm for spotfin croaker. Thus, black croaker and California corbina in this study were mostly juveniles with some adults, where as the modal size of yellowfin croaker and spotfin croaker were near the size at maturation for both species.

As a fisheries-independent database, these data provide a basis for comparing natural population fluctuations with those apparent in fisheries catch or landings data. Unfortunately, catch and landings data are usually summarized for California as a whole, and not for southern California alone (Leet et al. 1992). Since most croaker species occur or are fished primarily in southern California, these data provide relatively good estimates of croaker catches during this period. However, prior to 1980, 73% of white croaker were caught in southern California; since then, the majority of the catch (58%) was caught in central California due to an increase in southeast-Asian immigrant fishing effort (Wild 1992). The general decline in white croaker abundance seen in this survey (Figure 3) is generally reflected in the CPFV catches from 1980 to 1990 (except in 1988, which had catches three times those of the next highest year during this period). This suggests that much of the CPFV catch, a recreational fishery, may have been in southern California. If so, the juvenile population fluctuations (shown by this survey) are reflected in the recreational fishery. In contrast, commercial landings increased greatly following 1980, largely reflecting the shift in fishery focus to central California.

Commercial landings of white seabass prior to 1982 were primarily composed of fish caught off Mexico (giving the impression of a population crash at this time) (Vojkovich 1992). Since then, both commercial landings and recreational catches (both primarily from southern California) were relatively low. Trends in juvenile abundance in this study are similar (i.e., low but stable) but do not show the high years (except 1982) in the recreational fish catch.

Yellowfin croaker abundances in the fish impingement data generally follow those of the recreational fishery from 1977 to 1990, except that the abundance peak in the impingement data was in 1987 and 1988, whereas in the fishery, it was in 1989 (Oliphant 1992b). Since the impingement fish were just maturing during this time, it might be expected that this cohort would not enter the CPFV fishery for another year or so.

Although regional shifts in the white croaker and white seabass fisheries occurring in the early 1980s greatly affected commercial landings, both commercial landings and recreational catches of these species and yellowfin croaker appear to generally mirror population fluctuations in impingement data. In particular, the large cohort of maturing yellowfin croaker was reflected a year or so later in higher catches of adult fish in the party boat fishery. This suggests that impingement data from power generating stations may provide a better understanding of population and fisheries trends of sciaenid species in southern California.

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