COMPARISON OF RECREATIONAL FISH CATCH TRENDS TO ENVIRONMENT-SPECIES RELATIONSHIPS AND FISHERY-INDEPENDENT DATA IN THE SOUTHERN CALIFORNIA BIGHT, 1980–2000

ERICA T. JARVIS
Southern California Coastal Water
Research Project
7171 Fenwick Lane
Westminster, California 92683
ericaj@sccwrp.org

M. JAMES ALLEN
Southern California Coastal Water
Research Project
7171 Fenwick Lane
Westminster, California 92683

ROBERT W. SMITH
P.O. Box 1537
428 Bryant Circle, Suite 237
Ojai, California 93023

ABSTRACT

Although southern California recreational fish catches have changed in recent years, their relationship to environmental change is not well described. This study describes the relationship of recreational fish catch trends (all modes, 1980–2000) to environment-species interactions and fishery-independent population data. We used oceanic temperature and upwelling data as indicators of environmental trends, and power-generating-station data on fish impingement as indicators of fishery-independent population trends. Twenty-one dominant species showed significant changes in average catch from the 1980s to 1990s, with three species (shore-caught grass rockfish, *Sebastes rastrelliger*; boat-caught Pacific bonito, *Sarda chiliensis*, and olive rockfish, *Sebastes serranoides*) decreasing significantly both for landings and catch per unit of effort. These declines generally corresponded to a strong negative population response to temperature or a strong positive response to upwelling in southern California, with temperature being more important. Overall, 61% of 44 species examined had catch or population trends significantly correlated with environmental variables. Fishery-dependent and fishery-independent data trends were similar, with the former lagging the latter by one or more years. Cross-correlation analysis at lags of 0–7 years between the two data sets revealed significant correlations for two croakers and five rockfishes. The results in this study provide a basis for forecasting fish species responses to natural environmental change and thus may facilitate more adaptive management of recreational fisheries.

INTRODUCTION

Recreational fishing contributes millions of dollars in revenue to southern California (Weber and Heneman 2000) and provides enjoyment to many anglers. However, declines in catches of many recreational fishes in recent years have been severe, forcing fisheries managers to close several important recreational fisheries, including cowcod (*Sebastes levis*), yelloweye rockfish (*Sebastes ruberrimus*), and canary rockfish (*Sebastes pinniger*). Rebuilding plans for some species estimate several generations of no fishing pressure before populations reach prefishing levels (Butler et al. 2003). As a result, much research has been conducted in the last decade to clarify the causes of the observed declines and more successfully conserve the recreational fishery. The scientific community has become increasingly aware that multidecadal changes in oceanographic conditions have affected fished and nonfished populations (Hollowed et al. 1995; Mantua et al. 1997; Klyashtorin 1998; Hollowed et al. 2001; Brooks et al. 2002; Chavez et al. 2003). While it is evident that increased and sustained fishing pressure have severely affected several fisheries in southern California (e.g., rockfishes and abalone) (Davis et al. 1992; Love et al. 1998; Mason 1998; Schroeder and Love 2002; Butler et al. 2003), the influence of natural oceanic change on recreational fish populations in this area has not been well described. Further understanding of natural environmental influence on recreational catch trends may help to conserve our southern California recreational fisheries.

In a recent report (Allen et al. 2003), we described trends for over 100 nearshore fishes in southern California relative to atmospheric-oceanic influences. The study made use of fish abundance data from a variety of sources, including both fishery-independent and fishery-dependent data. Thus, species relationships were described in a broad context without focus on important recreational fishes. Here, we highlight the environmental responses of important recreational fishes in southern California and compare them with recreational landings data to determine the degree to which observed declines (or increases) in landings may be explained by natural variation in the environment. Because environmental variables influence fishes to varying degrees, it is of interest to relate how well landings data correspond to the species' responses we observed. Furthermore, identification of fish species with trends that deviate from natural oceanic trends may stimulate additional research addressing the extent of anthropogenic influence, such as fishing and habitat alteration, on local fish populations.

[Manuscript received 2 February 2004.]

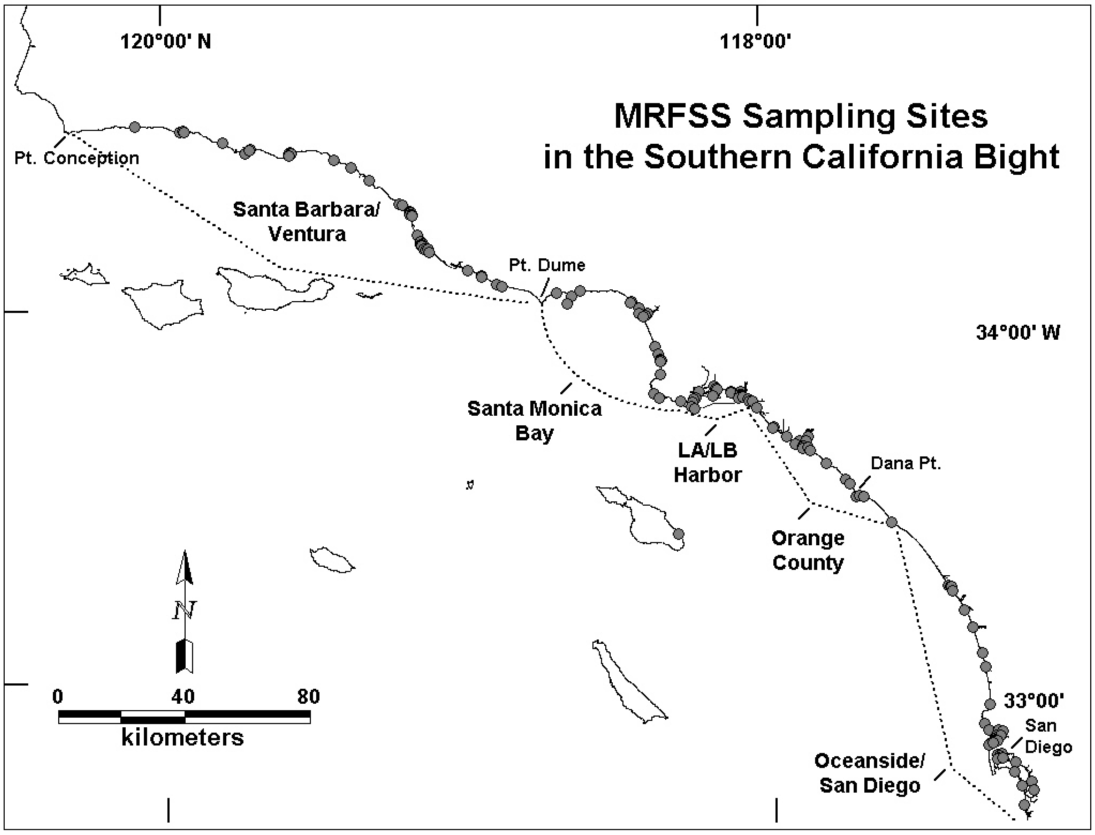


Figure 1. Location of recreational angler interview and sample sites of the Marine Recreational Fisheries Statistics Survey (MRFSS; LA/LB = Los Angeles/Long Beach Harbor), 1980–2000, within five southern California geographic regions.

Factors influencing fishery-dependent data, such as changes in fishing regulations and postings of contaminated fish advisories, make it difficult to discern whether observed changes in recreational catch data represent actual changes in the overall population. Therefore, we also compare trends in recreational catch data with those of fishery-independent data (impingement data). In cases where the two data sets are significantly correlated and an environment-species relationship exists, the extent of oceanographic influence on observed declines may be validated.

The objective of this study is to describe the relationships among catch trends for important southern California recreational fish species, our established environment-species interactions, and fishery-independent population data, with emphasis on dominant species that exhibit significant changes in landings and catch per unit of effort (CPUE) from 1980 to 2000. An understanding of these relationships may be useful in forecasting fish landings in the future (Parrish and Tegner 2001) and implementing fisheries regulations or management actions to complement observed trends in the oceanographic environment.

METHODS

Data Sources

Trends in recreational fish catch. We selected 44 southern California recreational species from Leet et al. (2001) on the basis of the fishery's geographic location and history (i.e., relative value to sport fishery). We chose fishes that were highly targeted, caught in large numbers, restricted to the recreational fishery, or showed declining catch in recent years. We used two types of recreational fish-catch data (total yearly estimates of recreational fish and sample data) reported by the Marine Recreational Fisheries Statistics Survey (MRFSS).[1] These were obtained from the Recreational Fisheries Information Network (RecFIN) Web site (http://www.psmfc.org/recfin) for the years 1980 to 2000 (with a hiatus from 1990 to 1992 due to interrupted funding).

The MRFSS landings data are estimates of fish landed (in thousands of fish) in southern California, calculated from MRFSS samples and a telephone survey of house-

---

[1] As of 2004, the MRFSS in California has been replaced by the California Recreational Fisheries Survey (CRFS).

holds in coastal counties to estimate trips (PSMFC, http://www.psmfc.org/recfin). We used MRFSS sample data (catch rates) for fish species caught from shore and by boat (on the ocean within 4.8 km [3 mi] from shore), with all fishing gear types, from Point Conception, California, to the United States-Mexico International Border (fig. 1). Shore fishing access sites consisted of piers, docks, breakwaters, beaches, banks, bridges, and breachways; boats included privately chartered boats, commercial passenger fishing vessels (CPFVs), rental boats, and privately owned boats. We selected data representing fish kept by the angler and available for identification and species counts by the interviewer. In addition, we used only sites with the longest time-series of data to obtain more complete temporal and spatial coverage. Catch rates were estimated for missing species data,[2] and all catch rates were converted to number of fish per 10,000 hr. Fish catches were divided by the total number of hours fished in a year; therefore, CPUE reflects a measure of relative abundance or availability among species (Stull et al. 1987).

Independent and dependent variables for environment-species analysis. For the environment-species analysis we used three sources of CPUE values (dependent variables): (1) MRFSS sample data described above; (2) fish impingement data[3] for five southern California power-generating stations (1972–1999 for Ormond Beach, El Segundo, Redondo Beach, and Huntington Beach combined; 1983–2000 for San Onofre) obtained from Southern California Edison Company; and (3) demersal fish trawl data (1973–1999) obtained from County Sanitation Districts of Los Angeles County (CSDLAC) (nonoutfall stations).

The environmental variables (independent variables) were developed from a variety of data sources by means of principal component analysis (PCA). The environmental data trends selected for this study and defined by the PCA were (1) shoreline sea-surface temperature (fig. 2a) (reported by the Marine Life Research Group, Scripps Institution of Oceanography) used to construct a dummy plot of the Pacific Decadal Oscillation (PDO) without El Niño effects (fig. 2b); (2) offshore sea-surface temperature from California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise data (fig. 2c); (3) multivariate El Niño-Southern Oscillation (ENSO) indexes obtained from the National Oceanic and Atmospheric Administration (NOAA)-Cooperative Institute for Research in Environmental Sciences (CIRES) Climate Diagnostics Center (fig. 2d); and (4) coastal upwelling indexes (downwelling events are not included) obtained from the Pacific Fisheries Environmental Laboratory (fig. 2e–g).

Annual fish and environmental data were converted to z-scores (number of standard deviations above or below the mean) to standardize the data for direct comparison between species trends and environmental responses. Data were Loess smoothed to diminish short-term variability (Grosse 1989; Venables and Ripley 2002).

Data Analysis

Recreational fish catch trends. We identified catch dominants in the overall shore and boat fishing modes by using the MRFSS landings data. Dominant fish species were those comprising 75% of the total catch for both fishing modes (shore and boat). Because some species are not caught in high numbers throughout southern California, and because landings data were not available by county, we identified additional catch dominants from the MRFSS sample data as the top 10 species from five regions within the Southern California Bight (SCB): Santa Barbara/Ventura, Santa Monica Bay, Los Angeles/Long Beach Harbor, Orange County, and Oceanside/San Diego (fig. 1). Regional catches were standardized by effort.

We identified catch dominants exhibiting significant changes throughout the study period by calculating decadal differences in average bightwide landings and CPUE for each species and fishing mode from 1980 to 2000. Annual data were normalized by log-transformation and grouped by decade to calculate a mean catch (landings) and CPUE for the 1980s (1980–1989) and 1990s (1993–2000).[4] Significant differences in mean catch and CPUE between the 1980s and 1990s for each species were tested using the student's t-test ($\alpha = 0.05$). Mean values were then back-transformed. The back-transformed values for each decade were used to quantify the proportional change in average annual catch and CPUE between the two decades for each species as PC = [(1980s–1990s)/1980s]*100.

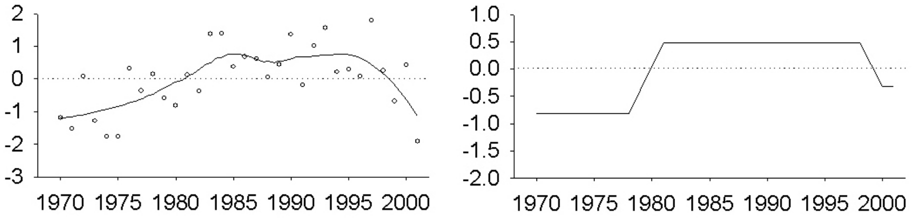
Relationship to environmental variables. Fish population responses to the atmospheric/oceanographic (temperature) and upwelling variables (independent variables) were measured with stepwise multiple-regression analysis, using two steps of analysis. We first considered the large-scale atmospheric/oceanic variables, described by temperature, and second, the more regional variables

---

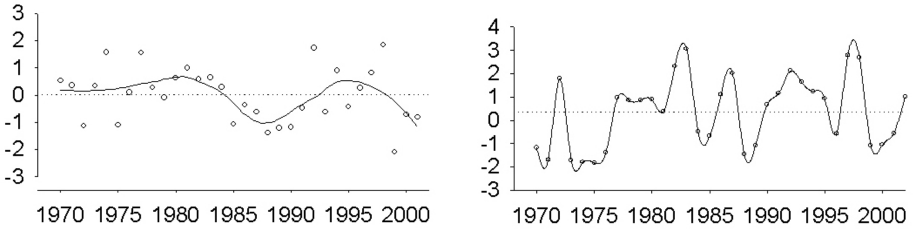
[2] Missing species data for a given site and wave (2-month period) were estimated by multiplying the average deviation in catch rate for that "fish year" (November–October) by the average catch rate of all other years for the same site and wave.

[3] Impingement data incorporate both normal operation and heat-treatment fish collection. All data were standardized to flow. We applied a heat-treatment factor to heat-treatment abundance for normalizing against an average number of fish collected during a 24-hour normal operation. Heat-treatment data were summed with normal operation data (daily fish abundance in fish/million gallons) for a yearly impingement rate per species.

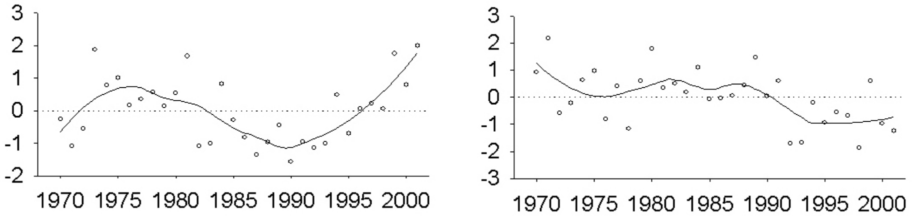
[4] Shore landings were available only from 1981 to 2000.



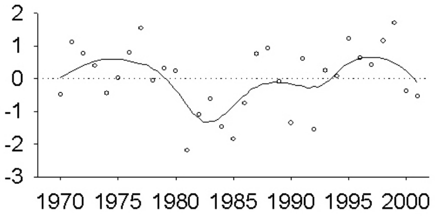
(a) Shoreline sea-surface temperature (b) Long-term PDO with lag effect



(c) OffShore sea-surface temperature (d) El Niño Southern Oscillation (ENSO)



(e) Upwelling north of SCB (f) Upwelling in SCB



(g) Upwelling south of SCB

Figure 2. Smoothed temperature and upwelling plots (from Allen et al. 2003), 1970–2002. PDO = Pacific Decadal Oscillation; SCB = Southern California Bight.

(upwelling). Thus, temperature variables were used as the independent variables and species CPUE values as the dependent variables in the initial analysis. In the second analysis, temperature effects were removed and the fish residual plots were used as the dependent variables and the upwelling trends as the independent variables.

The multiple-regression analysis output included standardized partial-regression coefficients (or the measure of correlation, *r*), R^2 values, and *p* values associated with tests of the null hypotheses for the overall regression of each fish species and independent variable. The standardized partial regression coefficients are directly comparable, since the dependent and independent variables were standardized to *z*-scores. At each stage of the regression analyses of all species, regression models were computed for all combinations of lags of 0, 1, and 2 years for each of the independent variables, except that the PDO variable was already built with a gradual 4-yr lag. The regression model with the lowest *p* value associated with the overall regression was chosen for inclusion in the results as the basis for the next level of analysis.

Because some methods of fish sampling are better estimators of actual fish population trends, significant environmental responses for a particular species were selected only from the most relevant (appropriate) fish database. The most relevant for each fish species was selected on the basis of species frequency of occurrence (>50% of years relative to a 30-yr database) and, in case of ties,

TABLE 1
Estimated Number of Recreational Fish Landings Ranked by Total Percentage of Catch in the Recreational Fishery in Southern California, 1980–2000

			Bightwide landings (×1,000)				
Scientific name	Common name	Region[a]	Shore	Boat	Total[b]	% of catch	Cum. %[c]
Scomber japonicus	**Pacific chub mackerel**	B	**13,905**	**51,517**	65,421	25.4	25.4
Paralabrax clathratus	**Kelp bass**	B	**1,019**	**28,312**	29,330	11.4	36.7
Genyonemus lineatus	**White croaker**	B	**5,160**	**13,790**	18,951	7.3	44.1
Paralabrax nebulifer	**Barred sand bass**	B	408	**18,187**	18,595	7.2	51.3
Sarda chiliensis	**Pacific bonito**	B	**1,125**	**12,562**	13,686	5.3	56.6
Sphyraena argentea	**Pacific barracuda**	B	100	**12,412**	12,512	4.8	61.4
Paralichthys californicus	**California halibut**	B	**1,737**	**6,963**	8,700	3.4	64.8
Amphistichus argenteus	**Barred surfperch**	B	**5,352**	80	5,432	2.1	66.9
Scorpaena guttata	**California scorpionfish**	B	140	**4,773**	4,913	1.9	68.8
Sebastes mystinus	**Blue rockfish**	B	12	**4,531**	4,543	1.8	70.6
Sebastes spp.	Rockfish, unidentified	—	106	4,349	4,455	1.7	72.3
Sebastes paucispinis	**Bocaccio**	B	**1,533**	**2,694**	4,227	1.6	73.9
Seriphus politus	**Queenfish**	B	**3,370**	577	3,947	1.5	75.5
Atherinopsis californiensis	**Jacksmelt**	B	**3,570**	349	3,919	1.5	77.0
Sebastes carnatus	Gopher rockfish	—	23	1,945	1,967	0.8	77.8
Embiotocidae, unidentified	Surfperches, unidentified	—	1,889	—	1,889	0.7	78.5
Sebastes miniatus	**Vermilion rockfish**	S	147	**1,682**	1,829	0.7	79.2
Caulolatilus princeps	**Ocean whitefish**	D	3	**1,777**	1,779	0.7	79.9
Hyperprosopon argenteum	**Walleye surfperch**	B	**1,687**	50	1,737	0.7	80.6
Sebastes serranoides	**Olive rockfish**	S	20	**1,697**	1,717	0.7	81.2
Seriola lalandi	**Yellowtail jack**	D	4	**1,656**	1,660	0.6	81.9
Semicossyphus pulcher	**California sheephead**	L	47	**1,207**	1,254	0.5	82.3
Umbrina roncador	**Yellowfin croaker**	O	**948**	300	1,247	0.5	82.8
Sebastes caurinus	**Copper rockfish**	S	1	**1,201**	1,201	0.5	83.3
Paralabrax maculatofasciatus	Spotted sand bass	—	99	952	1,051	0.4	83.7
Citharichthys sordidus	**Pacific sanddab**	S	28	**979**	1,006	0.4	84.1
Sebastes auriculatus	Brown rockfish	—	32	930	962	0.4	84.5
Ophiodon elongatus	Lingcod	—	38	777	815	0.3	84.8
Atractoscion nobilis	White seabass	—	92	714	807	0.3	85.1
Sebastes rosaceus	Rosy rockfish	—	2	796	797	0.3	85.4
Sebastes goodei	Chilipepper	—	0	601	601	0.2	85.6
Menticirrhus undulatus	**California corbina**	O	**563**	38	601	0.2	85.9
Scorpaenichthys marmoratus	Cabezon	—	141	390	531	0.2	86.1
Sebastes rastrelliger	**Grass rockfish**	S	**140**	321	461	0.2	86.3
Sebastes umbrosus	Honeycomb rockfish	—	—	387	387	0.2	86.4
Rhacochilus toxotes	Rubberlip seaperch	—	90	81	171	0.1	86.5
Rhacochilus vacca	**Pile perch**	L	**101**	56	157	0.1	86.5
Roncador stearnsii	**Spotfin croaker**	D	**116**	28	144	0.1	86.6
Sebastes dallii	calico rockfish	—	12	114	126	0.0	86.6
Prionace glauca	Blue shark	—	3	109	112	0.0	86.7
Sebastes rufus	Bank rockfish	—	5	102	107	0.0	86.7
Sebastes levis	Cowcod	—	—	42	42	0.0	86.7
Alopias vulpinus	Thresher shark	—	2	30	33	0.0	86.8
Isurus oxyrinchus	Shortfin mako	—	—	32	32	0.0	86.8
Coryphaena hippurus	Dolphinfish	—	—	23	23	0.0	86.8
Sebastes melanostomus	Blackgill rockfish	—	—	1	1	0.0	86.8

Source for landings data: Marine Recreational Fisheries Statistics Survey (MRFSS); no data available 1990–1992.

Note: Species in boldface represent bightwide or regional dominants by mode; remaining species are other important recreational fishes selected from Leet et al. 2001. Common names used are those of Nelson et al. 2004.

[a] Region: B = Southern California Bight (SCB), S = Santa Barbara/Ventura, D = Oceanside/San Diego, L = Los Angeles/Long Beach Harbor, O = Orange County.

[b] Total estimated landings (×1,000) in the SCB from 1980 to 2000 = 258,001.

[c] Cumulative.

highest percentage of catch. Further, we focused only on "strong" significant species correlations. Species considered to be strongly correlated with an independent variable were those with regression coefficients greater than +0.50 and less than −0.50. In a few instances, species were strongly correlated with more than one independent variable. Here, we focus on the environmental variable with the regression coefficient of greatest magnitude.

Relationship to fishery-independent data. We compared trends in recreational catch rate with trends in impingement rate where applicable. For instance, we did not examine trends of highly migratory species because of the assumed inefficiency of sampling these species from nearshore intake conduits. Upon initial investigation, visual comparisons of the species plots between the two data sets appeared to show recreational catch data lagging impingement data, suggesting that smaller individuals in a population were sampled in the impingement catch and later captured in the recreational fishery as larger individuals. Although length-frequency data are necessary to track cohorts of species through time from one database to the other, we were not able to obtain these because of time constraints.

Alternatively, we tested lag periods between the two data sets. Species plots visually identified as having similar trends in both data sets were further analyzed using product-moment correlation analysis. Cross-correlation coefficients were plotted at yearly MRFSS data lags from 0 to 7 yr. To meet the stationarity requirement for correlation analysis of autocorrelated data, the yearly catch rates from both data sets were first converted to z-scores (mean = 0, standard deviation = 1). To account for any within-series autocorrelation present in the fish data sets, we tested correlation coefficients derived from the correlation analysis against an adjusted r_{crit} value based on "effective" degrees of freedom (N*) at N/5 lags (Chelton et al. 1982; Brooks et al. 2002).

RESULTS

Trends in Recreational Fish Catch

We identified 26 dominant recreational fish species from the MRFSS estimated landings data and regional sample data from 1980 to 2000. Fourteen species made up 75% of either the bightwide shore catch or boat catch, and 12 species were identified as regional shore or boat dominants (tab. 1). Unidentified surfperch (Embiotocidae) and unidentified rockfish (*Sebastes* sp.) could not be distinguished by individual species, so they were not included in the rest of the analyses. The total cumulative bightwide catch of all 44 species was 87%, with catch dominants constituting 81% (tab. 1). In general, significant declines in landings for several recreational fish dominants were higher in frequency and magnitude than increases in both shore and boat fishing analyses. Also, the overall numbers of species showing either increases or decreases in CPUE were more evenly distributed than the numbers in the landings analysis, possibly indicating consequential shifts in target species as more desirable fishes became less abundant (available).[5]

In the shore fishery, 10 of the 15 dominant species showed significant proportional change in average annual catch (landings) between the 1980s and 1990s (fig. 3). Landings of barred surfperch (*Amphistichus argenteus*) and walleye surfperch (*Hyperprosopon argenteum*) declined the most (almost 100% fewer landings in the 1990s). Landings of queenfish (*Seriphus politus*), jacksmelt (*Atherinopsis californiensis*), pile perch (*Rhacochilis vacca*), and grass rockfish (*Sebastes rastrelliger*) declined by more than 75%. Landings of bocaccio (*Sebastes paucispinis*) also declined by more than 75%, but the decline was not significant. These declines may have influenced the significant increase in shore landings of kelp bass (*Paralabrax clathratus*) and California halibut (*Paralichthys californicus*) because similar increases in kelp bass and California halibut landings were not observed in the boat fishery (fig. 4) (shore CPUE did not also significantly increase). An increase in Pacific chub mackerel (*Scomber japonicus*) abundance and a decrease in grass rockfish abundance in the 1990s are evidenced by the significant changes in both landings and CPUE in the shore fishery. However, for three species showing significant decreases in landings (pile perch; queenfish; and Pacific bonito, *Sarda chiliensis*), CPUE also decreased (>50%), though not significantly (fig. 3).

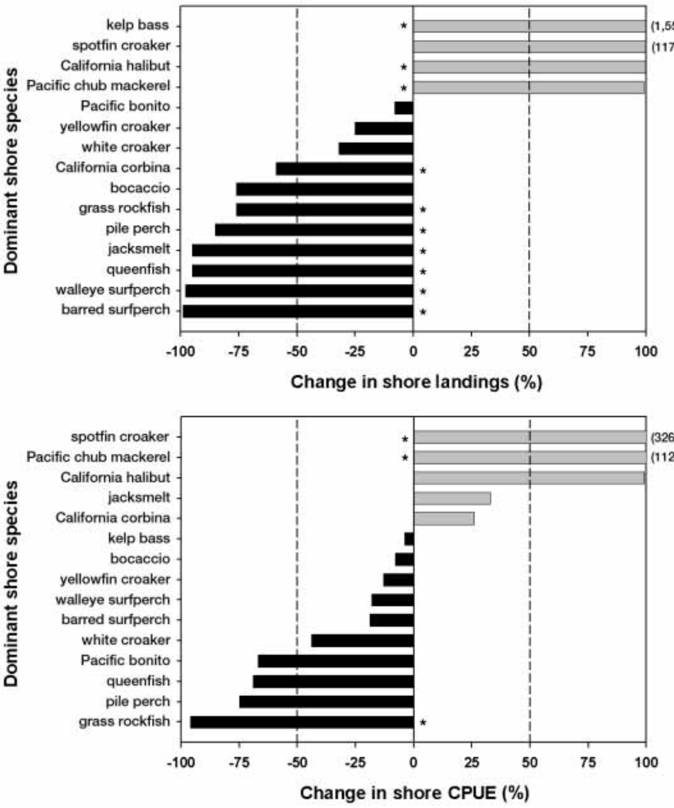


Figure 3. Percentage change in average landings (*top*) and catch per unit of effort (CPUE) (*bottom*), 1980s–1990s, of dominant fish species in the southern California recreational shore fishery. *Significant at $p < 0.05$.

Of the 18 regional dominant boat species, landings for 7 significantly decreased in the 1990s, while landings for 2 increased (fig. 4). Blue rockfish (*Sebastes mystinus*), Pacific bonito, olive rockfish (*Sebastes serranoides*), and white croaker (*Genyonemus lineatus*) declined the most (>75%), while landings of yellowfin croaker (*Umbrina roncador*) and ocean whitefish (*Caulolatilus prin-*

---

[5] Because CPUE here reflects a measure of relative availability among species, significant decadal differences in landings for a species are not always matched by significant decadal differences in CPUE.

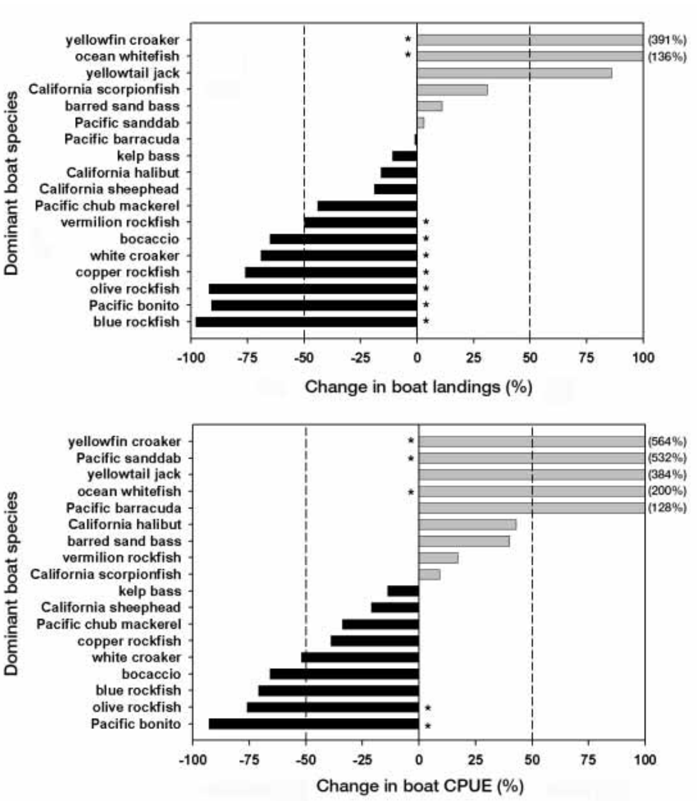


Figure 4. Percentage change in average landings (*top*) and CPUE (*bottom*), 1980s–1990s, of dominant fish species in the southern California recreational boat fishery. *Significant at $p < 0.05$.

ceps) increased by 391% and 136%, respectively. Although landings of Pacific bonito did not significantly decrease in the shore fishery, Pacific bonito landings and CPUE declined greatly in the boat fishery (>75%). Landings and CPUE for olive rockfish similarly decreased. Again, for several species in the boat fishery, it appears that either species availability or fishing effort increased in the 1990s in response to decreased availability of more desirable fishes (e.g., rockfishes). Yellowfin croaker, Pacific sanddab (*Citharichthys sordidus*), and ocean whitefish average CPUE increased by at least a factor of two in the 1990s. Although not statistically significant, yellowtail jack (*Seriola lalandi*) CPUE increased by 384%, and Pacific barracuda (*Sphyraena argentea*) CPUE increased by 128%, respectively.

Environmental Variables

Of the 45 recreational species selected in this study, 36 species correlations (representing 27 species) were identified (tab. 2). Of these 27 species, 10 were dominant species exhibiting significant changes in landings or CPUE. Overall, the highest percentage of species correlations (33%) was with the PDO, followed by upwelling in the bight (25%), upwelling in the south (20%), offshore sea-surface temperature (11%), upwelling in the north (8%), and El Niño (3%).

Of the 12 PDO correlations, 10 were negative responses (as sea-surface temperature increased throughout the 1980s and 1990s, fish population trends decreased) (tab. 2). The greatest negative responses were with ocean whitefish, rosy rockfish (*Sebastes rosaceus*), barred surfperch, gopher rockfish (*Sebastes carnatus*), and bocaccio. The PDO explained 99.9% of the variability within the barred surfperch shore data, 71% within the olive rockfish impingement data, and 77% within the bocaccio impingement data. All three species were catch dominants exhibiting declines in either shore or boat landings by more than 50%; however, the significant increase in ocean whitefish landings and CPUE is contrary to its negative response to the PDO. White seabass (*Atractoscion nobilis*) and shortfin mako (*Isurus oxyrinchus*) were the only species exhibiting positive correlations with the PDO (higher catch in the 1980s and 1990s).

All of the species trends that correlated with upwelling in the SCB were positive responses (tab. 2), indicating that residuals of the fish trends showed higher abundance (or catch) in the 1980s (relative to the 1990s) when upwelling in the SCB was greatest. Most of these species were rockfishes (chilipepper, *Sebastes goodei*; blue rockfish; bank rockfish, *Sebastes rufus*; and copper rockfish, *Sebastes caurinus*), with chilipepper showing the greatest positive correlation (0.81, 2-yr lag). Five species trends (barred sand bass, *Paralabrax nebulifer*; Pacific barracuda; Pacific sanddab; Pacific chub mackerel; and blue shark, *Prionace glauca*) were correlated with upwelling south of the SCB (tab. 2). Of these, barred sand bass (2-yr lag) and Pacific barracuda (1-yr lag) were negatively correlated, while the other three species were positively correlated. A negative correlation with upwelling south of the SCB implied higher residual abundance (or catch) in the 1980s (relative to the 1990s). Only brown rockfish (*Sebastes auriculatus*) was correlated with upwelling north of the SCB (0.58, 2-yr lag; tab. 2). Of the dominants exhibiting significant changes in landings, upwelling in the SCB explained 36% of the variability in the residuals for copper rockfish, 51% for blue rockfish (both MRFSS boat data), and 45% for spotfin croaker (*Roncador stearnsii*) (San Onofre Nuclear Generating Station impingement data). Southern upwelling explained 34% of the variability in the residuals for the Pacific sanddab CSDLAC trawl data and 56% for Pacific chub mackerel shore data.

Two species trends were correlated with offshore sea-surface temperature (tab. 2). California corbina (*Menticirrhus undulatus*) was positively correlated (0.56, 2-yr lag), while honeycomb rockfish (*Sebastes umbrosus*) was negatively correlated (−0.66, no lag) (tab. 2). Offshore sea surface temperature accounted for 33% of the variability in the residuals of the impingement data for California corbina, whose landings significantly decreased in the 1990s.

TABLE 2
Positive and Negative Partial Regression Coefficients (Species-Correlations) by Recreational Fish Species and Environmental Variable (PDO, El Niño, Offshore Sea-surface Temperature, and Upwelling Relative to the Southern California Bight), Ranked by Magnitude

	Temperature			Upwelling				
Common name	PDO	El Niño	Offshore	North	Bight	South	R^2	Relevant Database[a]
Ocean whitefish[b]	**−1.84**	—	—	—	−1.10	−0.61	35	recfin_b
Rosy rockfish	**−1.46**	—	—	—	—	—	82	recfin_b
Barred surfperch[c]	**−1.42**	—	—	—	—	—	99	recfin_s
Gopher rockfish	**−1.21**	—	—	0.69	0.76	0.63	91	recfin_b
Bocaccio[b]	**−0.98**	—	—	—	—	—	77	imp_ns
Olive rockfish[c]	**−0.94**	—	—	—	—	—	99	imp_ns
Spotted sand bass	**−0.93**	—	—	—	—	—	45	imp_ns
Calico rockfish	**−0.90**	—	—	—	—	—	53	laco
Rubberlip seaperch	**−0.68**	—	—	—	—	—	82	imp_ns
Cabezon	**−0.55**	—	—	—	**0.61**	—	54	imp_ns
White seabass	**0.51**	—	—	—	—	—	30	imp_ns
Shortfin mako	**1.36**	—	—	—	—	—	39	recfin_b
Lingcod	—	—	—	—	**0.56**	—	50	recfin_b
Bank rockfish	—	—	0.52	0.53	**0.59**	—	45	recfin_b
Copper rockfish[c]	—	—	—	—	**0.59**	—	36	recfin_b
Blue rockfish[c]	—	—	0.63	—	**0.64**	—	51	recfin_b
Spotfin croaker[c]	—	—	—	—	**0.65**	—	45	imp_23
Chilipepper	—	—	—	—	**0.81**	—	45	recfin_b
Barred sand bass	—	—	—	—	—	**−0.57**	43	imp_ns
Pacific barracuda	—	—	—	—	—	**−0.51**	71	imp_ns
Pacific sanddab[c]	—	—	—	—	—	**0.51**	34	laco
Pacific chub mackerel[c]	—	—	—	—	—	**0.54**	56	recfin_s
Blue shark	—	—	—	—	—	**0.70**	33	recfin_b
Honeycomb rockfish	—	—	**−0.66**	—	—	—	23	recfin_b
California corbina[c]	—	—	**0.56**	—	—	—	33	imp_ns
Brown rockfish	—	—	—	**0.58**	—	—	47	imp_ns
Cowcod	—	**−0.53**	—	—	—	—	23	laco
Albacore	—	—	—	—	—	—	—	N/A[b]
Blackgill rockfish	—	—	—	—	—	—	—	recfin_b
California halibut[c]	—	—	—	—	—	—	—	imp_ns
California scorpionfish	—	—	—	—	—	—	—	laco
California sheephead	—	—	—	—	—	—	—	recfin_b
Dolphinfish	—	—	—	—	—	—	—	N/A[b]
Grass rockfish[c]	—	—	—	—	—	—	—	imp_ns
Jacksmelt[c]	—	—	—	—	—	—	—	imp_ns
Kelp bass[c]	—	—	—	—	—	—	—	imp_ns
Pacific bonito[c]	—	—	—	—	—	—	—	recfin_b
Pile perch[c]	—	—	—	—	—	—	—	imp_ns
Queenfish[c]	—	—	—	—	—	—	—	imp_ns
Thresher shark	—	—	—	—	—	—	—	recfin_b
Vermilion rockfish	—	—	—	—	—	—	—	laco
Walleye surfperch[c]	—	—	—	—	—	—	—	imp_ns
White croaker[c]	—	—	—	—	—	—	—	laco
Yellowfin croaker[c]	—	—	—	—	—	—	—	imp_ns
Yellowtail jack	—	—	—	—	—	—	—	recfin_b
Total species correlations	12	1	4	3	9	7		

Note: Boldfaced values are the species-correlation of greatest magnitude for each species. Common names used are those of Nelson et al. 2004.

[a] recfin_b = recreational boat catch data, recfin_s = recreational shore catch data, imp_ns = non-SONGS (San Onofre Nuclear Generating Station) power-generating-station impingement data, laco = County Sanitation Districts of Los Angeles County trawl data, imp_23 = SONGS 2 and 3 power-generating-station impingement data.

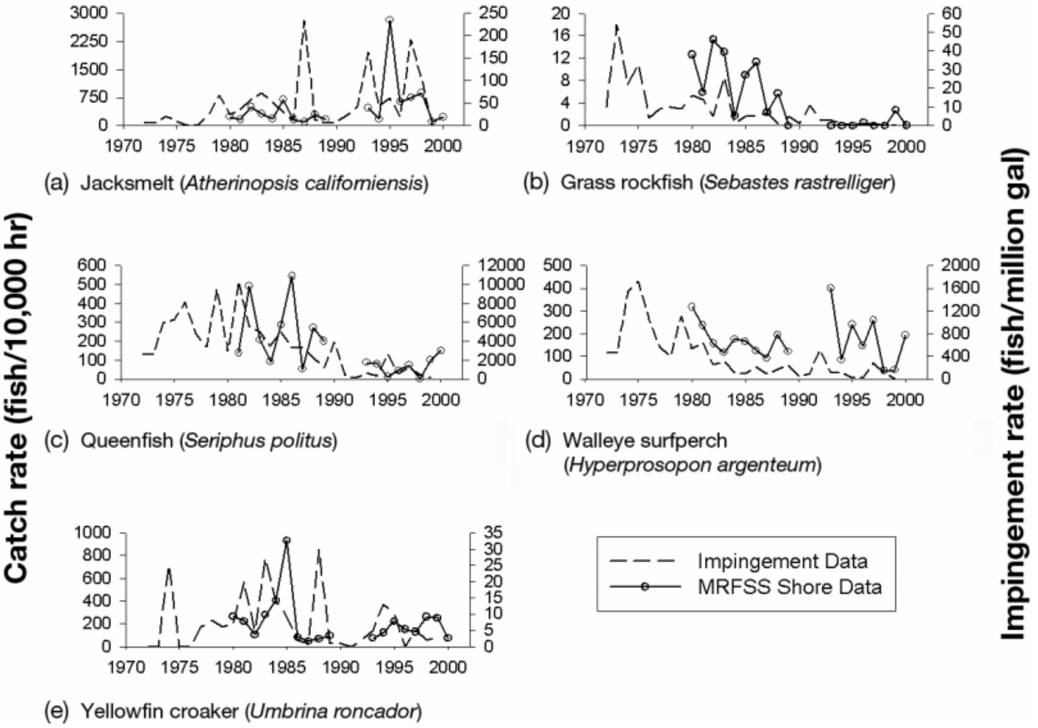
[b] N/A = not enough data for analysis.

[c] Species exhibiting significant differences in catch or CPUE between the 1980s and 1990s.

Cowcod trawl data showed a strong negative correlation (tab. 2) with El Niño at a lag of zero. As cowcod in the trawl data are typically small, the lag suggests there may be reduced recruitment of young-of-the-year from the water column to the bottom during El Niño years; larger juveniles may move to greater depths not sampled in the trawl surveys.

Relationship to Fishery-independent Data

Thirty-five recreational species trends (MRFSS sample data) were investigated for similarities to impingement data (fishery-independent data). When catch rates were plotted together on the same graph, recreational shore data trends for five species of fish (fig. 5), and boat data trends for six species (fig. 6), appeared similar to the



(a) Jacksmelt (*Atherinopsis californiensis*)

(b) Grass rockfish (*Sebastes rastrelliger*)

(c) Queenfish (*Seriphus politus*)

(d) Walleye surfperch (*Hyperprosopon argenteum*)

(e) Yellowfin croaker (*Umbrina roncador*)

Figure 5. Comparison of MRFSS shore data trends (all modes, 1980–2000) and power-generating-station impingement data trends in southern California (1972–1999). No MRFSS data for 1990–1993.

impingement data trends, with MRFSS data lagging impingement data. Of these species, shore trends for grass rockfish, queenfish, yellowfin croaker, and walleye surfperch showed declining catch rates in both data sets over time, with jacksmelt increasing (fig. 5). Boat trends for white croaker, brown rockfish, bocaccio, blue rockfish, and olive rockfish also showed declining catch rates in both data sets over time (fig. 6). Barred sand bass remained stable.

Cross-correlation analysis of the MRFSS data and impingement data revealed only six species trends with significant correlations to the impingement data trends. Two correlations (grass rockfish and yellowfin croaker) were found with shore data and four (white croaker, blue rockfish, brown rockfish, and olive rockfish) with boat data (fig. 7). Significant correlations found between the two data sets indicate a similar forcing of declines. However, environment-species relationships were found only for brown rockfish, blue rockfish, and olive rockfish (tab. 2).

Only two significant species correlations occurred at a specific lag (white croaker, boat data, 1 yr; yellowfin croaker, shore data, 1 yr) (fig. 7a,b). Cross-correlation coefficients for blue rockfish, olive rockfish, grass rockfish, and brown rockfish were significant at nearly all lags (fig. 7c–f), possibly because the MRFSS sampled several year classes of rockfish. In this case, the lag with the highest cross-correlation coefficient (strongest correlation) most likely represents a dominant year-class present in the MRFSS data. The strongest cross-correlation coefficient ($r = 0.80$, $r_{\text{crit}} = 0.45$) of all species occurred with blue rockfish boat data at a lag of five years (fig. 7c).

DISCUSSION

Nearly half of the important recreational fishes analyzed in this study showed mostly negative population responses to temperature or positive population responses to upwelling in the SCB to varying degrees, the most influential environmental variable being the PDO. These species-specific environmental responses corresponded with significant changes in landings or CPUE between the 1980s and 1990s, thus strengthening the validity of the identified responses. And, although we found few significant relationships between fishery-dependent (recreational catch) and fishery-independent (impingement) data to further validate the extent of an environmental influence, the relationships that were identified indicate another potential tool for forecasting recreational fish catches.

Most of the species negatively correlated with the PDO were rockfishes. This negative relationship with warm temperatures is consistent with widespread recruitment in 1999 (a cold year following the warm regime) of young-of-the-year (YOY) rockfishes at all of the oil platforms surveyed in the Santa Barbara Channel

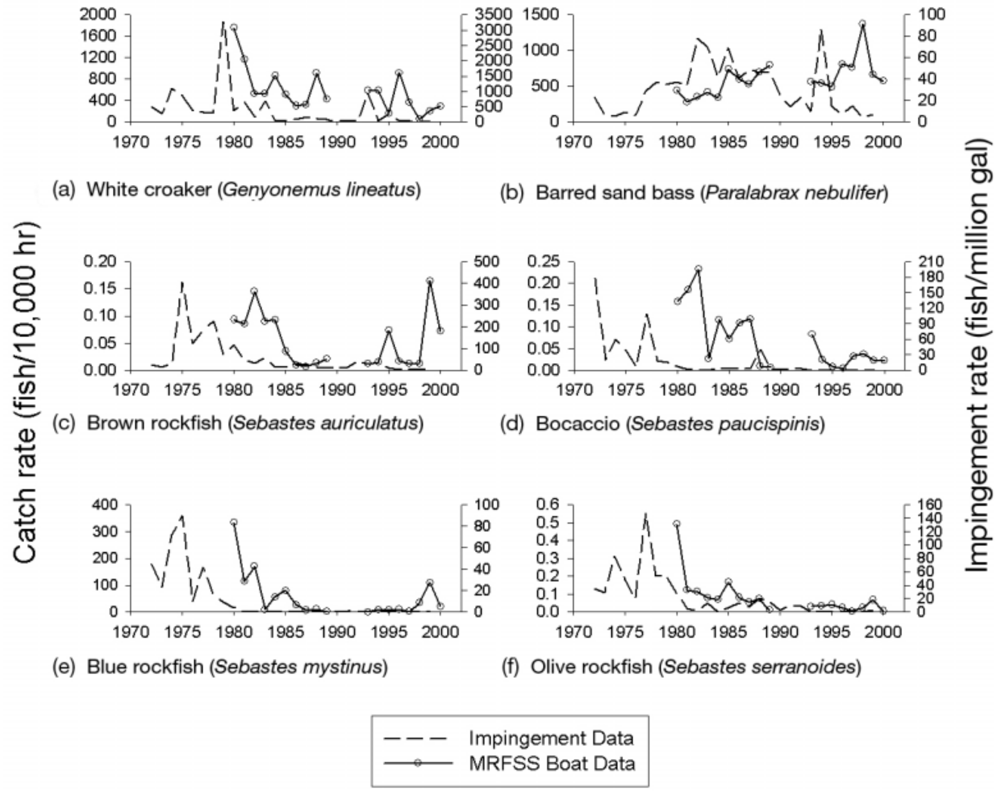


Figure 6. Comparison of MRFSS boat data trends (all modes, 1980–000) and power-generating-station impingement data trends in southern California (1972–1999). No MRFSS data for 1990–1993.

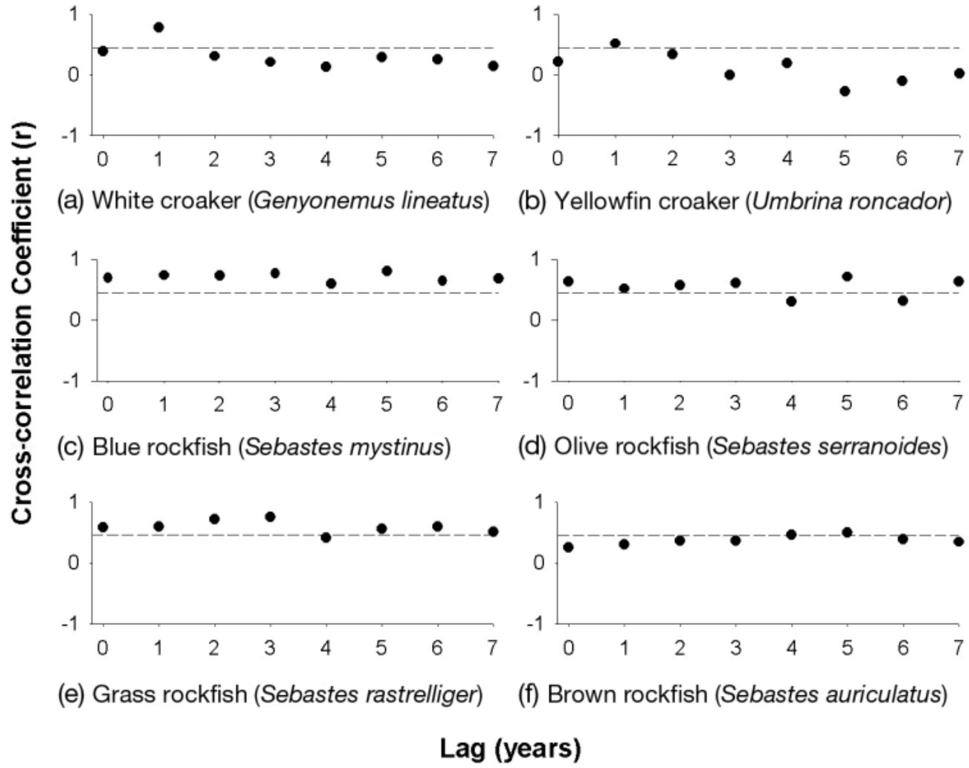


Figure 7. Cross-correlation coefficients at lags 0–7 yr. Dashed lines indicate the r_{crit} significance level at $p < 0.05$; the point falling above this line defines the lag at which MRFSS data significantly correlated with impingement data.

and Santa Maria Basin (Love et al. 2003). In addition, the 2003 stock assessment for bocaccio also indicated a strong 1999 year-class and increased abundance since 1999.[6] With the PDO accounting for 30–99% of the variability within the species plots, significant catch declines of barred surfperch, bocaccio, and olive rockfish are likely explained in part by a negative PDO response. One might expect only cold-temperate or temperate species to respond negatively to warming ocean conditions. However, many of the negative PDO responses were in warm-temperate species (ocean whitefish; spotted sand bass, *Paralabrax maculatofasciatus*; barred surfperch; rubberlip seaperch, *Rhacochilus toxotes*; calico rockfish, *Sebastes dallii*; gopher rockfish). We concluded in our earlier report that environmental variable responses appeared to be species-specific and did not show definite patterns by life-history categories,[7] but with respect to recreational fishes, other factors discussed below may have driven these results.

Although the species responses to temperature do not appear to be easily generalized, temperature responses of commercial species reported by Norton and Mason (2003) are consistent with results in this study. Norton and Mason report a significant positive correlation with white seabass commercial landings data and temperature over the last 70 years along the California coast, in addition to a negative correlation for cabezon (*Scorpaenichthys marmoratus*). Multiple-regression analysis used in this study also shows a positive relationship with temperature for white seabass and a negative correlation with cabezon (tab. 2). Norton and Mason (2003) report temperature correlations with Pacific barracuda (strong positive), Pacific chub mackerel (weak positive), and lingcod (*Ophiodon elongatus*; strong negative), where we identified only upwelling associations. The most representative database for these species in this study was the 20-yr MRFSS boat database. Many of the upwelling correlations were found in 20-yr MRFSS databases, suggesting that if these data had extended for 30 yr (to better capture the last PDO cycle), we may also have found temperature correlations with these species. Indeed, Stull et al. (1987) report higher catches at Palos Verdes Peninsula of Pacific chub mackerel and Pacific barracuda coincident with the El Niño events of 1966, 1976–1978, and 1982–1983. They also report lingcod catches highest from 1973 to 1980 (cold years) in the Palos Verdes area, but numbers were few in comparison to other local fish species.

Upwelling was also an important predictor of species trends, but it accounted for less of the variability, suggesting that over the long term changes in upwelling influence recreational fishes less than changes in temperature. Nevertheless, upwelling in and south of the SCB corresponded to a higher number of declines and increases in catch of dominant species than did the PDO. Upwelling responses reported in this study may be an artifact of fishing locality, which may in turn reflect higher fish abundance in upwelling sites with high seasonal food availability. But population trends positively correlated with upwelling were also observed with fishery-independent data for several other species (barred sand bass, Pacific barracuda, Pacific sanddab, and spotfin croaker).

Although only one El Niño correlation (cowcod) was identified, biological effects of El Niño in southern California have been studied extensively over the last two decades. Increased abundances or range extensions for many fish species, including several species in our study (e.g., Pacific chub mackerel; Pacific bonito; Pacific barracuda; and dolphinfish, *Coryphaena hippurus*) have been reported during El Niño events (Mearns 1988; Karpov et al. 1995; Lea and Rosenblatt 2000). Fish population responses to El Niño may be better characterized in combination with data on larvae and recruitment. Recent research in central California found that high juvenile recruitment of several species of rockfish occurred during either El Niño or La Niña, coinciding with relaxation and upwelling events, respectively.[8]

Many recreationally fished species that did not show responses to environmental trends are valued more highly than those that did. Some of the most targeted sport fishes are Pacific bonito, California halibut, kelp bass, yellowtail jack, albacore (*Thunnus alalunga*), dolphinfish, and thresher shark (*Alopias vulpinus*). Albacore, dolphinfish, and thresher shark are seasonal migrants (Leet et al. 2001) and did not occur in greater than 50% of the years in their most relevant database; trends for these species were most likely too incomplete to show good correlations. This was also the case for blackgill rockfish (*Sebastes melanostomus*), which is primarily commercially fished (Love and Butler 2001), bank rockfish (*Sebastes rufus*), chilipepper, and blue shark. Of species occurring in more than 50% of the years in our data, commercial catch data show weak correlations with temperature over the last 70 years for Pacific bonito (negative), California halibut (positive), and white croaker (negative) (Norton and Mason 2003), coincident with reduced catches in the 1990s of white croaker and Pacific bonito, and increased catches of California halibut found in our study. Norton and Mason (2003) also found moderately strong temperature correlations with albacore (negative), yellowtail

---

[6] MacCall, A. 2003. Status of bocaccio off California in 2003. Pacific Fishery Management Council, Portland, OR.

[7] See n. 1.

[8] Stephens, T. 2003. New studies reveal connections between oceanographic processes and rockfish populations. *In* UC Santa Cruz Currents Online, 17 February 2003, http://www.ucsc.edu/currents/02-03/02-17/rockfish.html.

jack (positive), California sheephead (*Semicossyphus pulcher*) (positive), and California scorpionfish (*Scorpaena guttata*) (positive). Still, no environmental relationships were identified in this study for seven important species (walleye surfperch, pile perch, grass rockfish, queenfish, jacksmelt, kelp bass, and yellowfin croaker) for which data appeared relevant and in sufficient frequency.

Recent recreational catch trends described by Dotson and Charter (2003) report that as the relative availability of rockfishes declined, the availability of California scorpionfish, ocean whitefish, and Pacific sanddab increased. Pacific sanddab CPFV catch reports in 1998 rose by 12,200% of the long-term mean in only four years. These trends are also evident in our reports of the significant positive proportional change in CPUE for these species (figs. 3 and 4). The increase in Pacific sanddab catch has been a heightened topic of interest over the last several years. Fish biologists and fisheries managers speculated whether the higher catch indicated an actual increase in availability or if anglers switched target species in response to rockfish regulations. While it is now agreed that the recreational catch increases represent a shift in exploitation from the rockfish fishery, data from CSDLAC time-series (fishery-independent data) also show much larger trawl catches of Pacific sanddab beginning in 1995. Although not easily explained, our environment-species data suggest that this increase in trawl catch may be partly due to increased upwelling off southern Baja California (tab. 2), which can be interpreted as upwelling relaxation in southern California in the 1990s (fig. 2).

Comparisons of the MRFSS recreational fish catch data and the fishery-independent impingement data reveal that for a few nearshore species, MRFSS sample data trends correlate with impingement data trends. Still, it is difficult to assess whether similar temporal changes reflect fishery effects or natural population dynamics. The timing of the regime shift in the SCB coincides with the expansion of several fisheries, but mainly rockfishes (Moser et al. 2000). However, environment-driven trends are indicated by negative PDO responses that we also found with nonexploited rockfishes.[9] For yellowfin croaker, the correlation between the two data sets seems even less fishery-driven. The population appears relatively stable compared with many rockfish populations, and our results (MRFSS data lag at 1 yr) correspond well with those of another report,[10] which shows that yellowfin croaker CPFV catch trends peaked a year after impingement data. The authors reasoned that impingement cohorts would probably not enter the CPFV fishery until a year or so later. If more connections such as this can be identified, impingement data (in combination with oceanographic data) may prove very useful for forecasting changes in recreational fish catches. The efficacy of using these data sources together would be strengthened with additional studies determining age-class relationships between fishery-dependent and fishery-independent data.

As mentioned above, other factors may have influenced some of our unexpected results. First, lag data suggest that our environment-species correlations may apply only to a specific life-history stage. For example, impingement data may be primarily sampling YOY of certain fish species, and, therefore, environment-species correlations may not apply to the adult population. In the case of cowcod, where El Niño was found to reduce catch, the average length sampled in the CSDLAC trawls was 15 cm—the average size of juveniles approximately two years of age (Love et al. 2002). On the other hand, CPFV catches of adult cowcod do not show marked decreases in catch during El Niño years compared with other years (Dotson and Charter 2003). Second, for species such as spotted sand bass and ocean whitefish, whose adult populations in southern California are highly dependent on sporadic recruitment events related to El Niño and upwelling (Allen et al. 1995; Rosales-Casián and Gonzalez-Camacho 2003), our results may represent fishing effects. Because of the highly variable timing and success of these recruitment pulses, our data sources for these species likely include relatively few year classes. Fishing pressure on these small populations in the SCB may be the driving force in the spotted sand bass impingement and ocean whitefish boat catch trends and consequently, in our observed negative PDO responses (L. G. Allen, CSUN, pers. comm.). Lastly, while we attempted to diminish the effects of sampling bias, it is also possible in a few instances that environment-species results may be an artifact of smoothing the data or of chance.

The extent of environmental influence on the variability of the species plots and residual species plots with respect to temperature and upwelling ranged from 30% to 91% (tab. 2). This indicates that fish populations are influenced by environmental variables to varying degrees. Therefore, the results discussed here are not meant to suggest that environmental effects are more influential on fish populations than are such factors as fishing, habitat alteration, disease, or pollution. Our findings merely emphasize the complexity of the relationships and point out where we need future work. With the continuation of long time-series of fishery-dependent, fishery-independent, and oceanographic data, we have

---

[9] See n. 1.

[10] Herbinson, K. T., M. J. Allen, and S. L. Moore. 2001. Historical trends in nearshore croaker (family Sciaenidae) populations in southern California from 1977 through 1998. *In* Southern California Coastal Water Research Project Annual Report 1999–2000, S. B. Weisberg, ed. Westminster, Calif.: S. Calif. Coastal Water Res. Proj., pp. 253–264.

the opportunity to refine our knowledge of the relationship between natural environmental change, human influence, and fish populations.

ACKNOWLEDGMENTS

A portion of this article was developed from our larger report (see n. 1), which was funded in part by the Santa Monica Bay Restoration Commission and the California State Coastal Conservancy (CSCC Proposition 12 Grant Program, SMBRP grant agreement no. 01-088). Jim Allen (Southern California Coastal Water Research Project; SCCWRP) provided insight, comments, and editorial review. Robert Smith conducted the multiple-regression analyses that were the basis of the environment-species relationships described in this study. We thank Kevin Herbinson (Southern California Edison) who provided southern California power-generating station fish impingement data; Valerie Raco-Rands (SCCWRP) for a huge contribution to database development; Brock Bernstein for input on oceanic studies; Kerry Ritter and Ananda Ranasinghe (both of SCCWRP), for statistical advice; Michele Horezcko and Tom Mason (Pacific States Marine Fisheries Commission) for spatial information and interpretation of the MRFSS data; and Larry Allen (CSUN) and one anonymous reviewer for their insightful comments on the manuscript.

LITERATURE CITED

Allen, M. J., R. W. Smith, E. T. Jarvis, V. Raco-Rands, B. B. Bernstein, and K. T. Herbinson. 2003. Temporal trends in southern California nearshore fish populations relative to environmental influences. CSCC Proposition Grant Program, SMBRP Grant Agreement no 01-088. Prepared for California Coastal Conservancy, Oakland, CA, and Santa Monica Bay Restoration Commission, Los Angeles, CA. So. Calif. Coastal Water Res. Proj., Westminster, CA, 130 pp.

Allen, L. G., T. E. Hovey, M. S. Love, and J. T. W. Smith. 1995. The life history of the spotted sand bass (*Paralabrax maculatofasciatus*) within the southern California Bight. Calif. Coop. Oceanic Fish. Invest. Rep. 36:193–203.

Brooks, A. J., R. J. Schmitt, and S. L. Holbrook. 2002. Declines in regional fish populations: have species responded similarly to environmental change? Mar. Fresh. Res. 53:189–198.

Butler, J. L., L. D. Jacobson, J. T. Barnes, and H. G. Moser. 2003. Biology and population dynamics of cowcod (*Sebastes levis*) in the Southern California Bight. Fish. Bull. U.S. 101:260–280.

Chavez, F. P., J. Ryan, S. E. Lluch-Cota, and M. Niquen C. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299:217–221.

Chelton, D. B., P. A. Bernal, and J. A. McGowan. 1982. Large-scale interannual physical and biological interaction in the California Current. J. Mar. Res. 40:1095–1123.

Davis, G. E., D. V. Richards, P. L. Haaker, and D. O. Parker. 1992. Abalone population declines and fishery management in southern California. *In* Abalone of the world: biology, fisheries and culture, S. A. Shepherd, Mia J. Tegner, and S. A. Guzman del Proó, eds. Oxford: Blackwell Scientific, pp. 237–249.

Dotson, R. C., and R. L. Charter. 2003. Trends in the southern California sport fishery. Calif. Coop. Oceanic Fish. Invest. Rep. 44:94–106.

Grosse, E. 1989. LOESS: multivariate smoothing by moving least squares. *In* Approximation theory, vol. 1, C. K. Chui and J. D. Ward, eds. New York: Academic Press, pp. 299–302

Hollowed, A. B., S. R. Hare, and W. S. Wooster. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. Prog. Oceanogr. 49:257–282.

Hollowed, A. B., and W. S. Wooster. 1995. Decadal-scale variations in the eastern subarctic Pacific, II: Response of northeast Pacific fish stocks. *In* Climate change and northern fish populations, R. J. Beamish, ed. Can. J. Fish. Aquat. Sci. 121:373–385

Karpov, K. A., D. P. Albin, and W. H. Van Buskirk. 1995. The marine recreational fishery in northern and central California: a historical comparison (1958-86), status of stocks (1980-86), and effects of changes in the California Current. Calif. Dep. Fish Game, Fish Bull. 176. 192 pp.

Klyashtorin, L. B. 1998. Long-term climate change and main commercial fish production in the Atlantic and Pacific. Fish. Res. 37:115–125.

Lea, R. N., and R. H. Rosenblatt. 2000. Observations on fishes associated with the 1997–1998 El Niño of California. Calif. Coop. Oceanic Fish. Invest. Rep. 41:117–129.

Leet, W. S., C. M. Dewees, R. Klingbeil, and E. J. Larson, eds. 2001. California's living marine resources: a status report. Calif. Dep. Fish Game, Sacramento, 592 pp.

Love, M. 1996. Probably more than you want to know about the fishes of the Pacific Coast; 2nd ed. Santa Barbara, CA: Really Big Press, 381 pp.

Love, M., and J. Butler. 2001. Blackgill rockfish. *In* California's living marine resources: a status report, W. S. Leet, C. M. Dewees, R. Klingbeil, and E. J. Larson, eds. Calif. Dep. Fish Game, Sacramento, pp. 368–369

Love, M. S., J. E. Caselle, and W. Van Buskirk. 1998. A severe decline in the commercial passenger fishing vessel rockfish (*Sebastes* spp.) catch in the Southern California Bight, 1980-1996. Calif. Coop. Oceanic Fish. Invest. 39:180–195.

Love, M. S., M. Yoklavish, and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. Berkeley: Univ. Calif. Press, 404 pp.

Love, M. S., D. M. Schroeder, and M. M. Nishimoto. 2003. The ecological role of oil and gas production platforms and natural outcrops on fishes in southern and central California: a synthesis of information. U.S. Dept. Interior, USGS, Biological Resources Division, Seattle, WA, OCS Study MMS 2003-032, 66 pp.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bull. Am. Meteorol. Soc. 78:1069–1079.

Mason, J. 1998. Declining rockfish lengths in the Monterey Bay, California, recreational fishery in 1959–1994. Mar. Fish. Rev. 60(3):15–28.

Mearns, A. J. 1988. The "odd fish": unusual occurrences of marine life as indicators of changing ocean conditions. *In* Marine organisms as indicators, D. F. Soule and G. S. Kleppel, eds. New York: Springer-Verlag, pp. 137–176

Moser, G. H., R. L. Charter, W. Watson, D. A. Ambrose, J. L. Butler, S. R. Charter, and E. M. Sandknop. 2000. Abundance and distribution of rockfish (*Sebastes*) larvae in the Southern California Bight in relation to environmental conditions and fishery exploitation. Calif. Coop. Oceanic Fish. Invest. Rep. 41:132–147.

Nelson, J. S., E. J. Crossman, H. Espinosa-Perez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. American Fisheries Society, Spec. Pub. 29. Bethesda, MD, 386 pp.

Norton, J. G., and J. E. Mason. 2003. Environmental influences on species composition of the commercial harvest of finfish and invertebrates off California. Calif. Coop. Oceanic Fish. Invest. Rep. 44: 123–133.

Parrish, R. R., and M. J. Tegner. 2001. California's variable ocean environment. *In* California's living marine resources: a status report, W. S. Leet, C. M. Dewees, R. Klingbeil, and E. J. Larson, eds. Calif. Dep. Fish Game, Sacramento, pp. 21–28.

Rosales-Casián, J. A., and J. R. Gonzalez-Camacho. 2003. Abundance and importance of fish species from the artisanal fishery on the Pacific coast of northern Baja California. So. Calif. Acad. Sci. Bull. 102(2):51–63.

Schroeder, D. M., and M. S. Love. 2002. Recreational fishing and marine fish populations in California. Calif. Coop. Oceanic Fish. Invest. Rep. 43:182–190.

Stull, J. K., K. A. Dreyden, and P. A. Gregory. 1987. A historical review of fisheries statistics and environmental and societal influences off the Palos Verdes Peninsula, California. Calif. Coop. Oceanic Fish. Invest. Rep. 28:135–154.

Venables, W. N., and B. D. Ripley. 2002. Modern applied statistics with S. 4th ed. New York: Springer-Verlag, 495 pp.

Weber, M. L., and B. Heneman. 2000. Guide to California's Marine Life Management Act. Bolinas, CA: Common Knowledge Press, 133 pp.