SPATIAL AND TEMPORAL APPROACHES IN ANALYZING RECREATIONAL GROUNDFISH DATA FROM SOUTHERN CENTRAL CALIFORNIA AND THEIR APPLICATION TOWARD MARINE PROTECTED AREAS

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ABSTRACT

Many nearshore rockfish species have small home-range sizes and therefore may be affected by heavier localized fishing in near-port areas. For this study we examined long-term trends in rockfish and lingcod landings from the commercial passenger fishing vessel (CPFV) fishery along the south central coast (SCC) of California using data from two sources: California Department of Fish and Game (CDFG) surveys from 1988–98 and California Polytechnic State University (Cal Poly) surveys in 2003–04. The objective was to make comparisons between areas close to port (that receive greater fishing effort) and those far from port (areas receiving less fishing effort). We analyzed parameters for individual species and species assemblage composition to determine if these parameters are effective at detecting changes on a species-specific and a multi-species level for this region and what their applications are towards newly established Marine Protected Areas (MPAs) along the SCC.

A multivariate approach using non-standardized Bray Curtis similarities effectively detected both spatial and temporal changes within and between fish assemblages for areas along the SCC. For individual species, catches of some species yielded larger individuals farther from port, while catch per unit effort (CPUE) for most species did not differ between near-port and distant-port areas over time. Trends were easier to detect for species that exclusively inhabit shallower waters and suggest that these may be better indicator species for examining the effectiveness of MPAs. Results were difficult to interpret for species that occur at mixed depths since some migrate to deeper waters when they mature, whereas others inhabit both shallow and deep depths as adults.

INTRODUCTION

The status of many groundfish stocks and the overall sustainability of California's marine fisheries are in question and are thought to be influenced by fishing pressure and ocean temperatures like many marine populations. Rockfishes (*Sebastes* spp.) are of particular concern to resource managers because they are very long-lived, slow-growing, and late-maturing species that have variable recruitment patterns influenced by a suite of oceanographic conditions (Leaman 1991; Parker et al. 2000; Love et al. 2002). Intensive commercial fishing has reduced population numbers and caused stock collapses for some rockfish species (Ralston 1998). There is also strong evidence that recreational fishing has affected rockfish populations in some regions off California, including the Southern California Bight and areas off Monterey and San Francisco (Karpov et al. 1995; Love et al. 1998a; Mason 1998). In addition, increasing sea-surface temperatures and changing ocean climates have caused such negative population responses as declining catch (Bennett et al. 2004; Jarvis et al. 2004) and declines in recruitment have been associated with a warm regime in a cycle termed the Pacific Decadal Oscillation (PDO) (Stephens et al. 1983, 1984; Love et al. 1998b; Chavez et al. 2003).

As catch rates declined for certain nearshore rockfish species in areas closer to port, recreational fisheries shifted fishing effort toward less fished areas. The commercial passenger fishing vessel (CPFV) fishery began utilizing areas farther from port as early as the 1960s in some regions of central and northern California (Miller and Gotshall 1965). Mason (1995) reported similar trends for the Monterey area, noting an increasing frequency of fishing trips to deeper waters and distant-port areas over a 30-year period (1959–86). This resulted in localized overfishing for several species because of their limited movements, and also led to the truncation of size-age distributions. Reilly et al. (1993) suggested that distance from port and greater depths are factors contributing to a higher catch per unit effort (CPUE) and larger-sized fish for certain rockfish species.

The main objective of this study was to examine individual species trends and changes within fish assemblages between near-port and distant-port areas for the CPFV fishery along the south central coast (SCC) of California. Earlier studies compared trawl and partyboat fisheries (Heimann and Miller 1960), sportfish catch and effort from 1957–61 (Miller and Gotshall 1965), and life-history characteristics for blue rockfish (*Sebastes mystinus*) and lingcod (*Opiodon longatus*) (Miller et al. 1967; Miller and Geibel 1973). In addition, Karpov et al. (1995) made historical comparisons between the Miller and

Gotshall (1965) sportfish data and the Marine Recreational Fishery Statistical Survey (MRFSS) data from 1980–86, and Stephens et al. (2006) conducted an analysis of the groundfish fishery. Here we use data from a CPFV California Department of Fish and Game (CDFG) survey (1988–98) and a California Polytechnic State University survey (2003–04) to examine whether it may be possible to use individual species trends and a multi-species approach as a means to determine if greater fishing effort at near-port areas has had an impact on these species.

Additionally, we wanted to see how these approaches might be used as a means to track the effectiveness of the newly established "no-take" Marine Protected Areas along the SCC. Since different rockfish species occupy different types of habitats and various depth ranges, species are unlikely to benefit equally. Thus, another objective of this study was to use the comparison of near-port and distant-port areas as a means to compare areas with greater fishing effort to those with less fishing effort to see which species are most likely to benefit from the MPAs and thus, to track their effectiveness over time.

MATERIALS AND METHODS

Study Area

The Morro Bay South-Central Management Area includes all of the SCC, encompasses the region between Lopez Point (36°01'N, 121°34'W) and Point Conception (34°27'N, 120°28'W), and includes two major port areas, Morro Bay and Avila (Port San Luis). Lopez Point is the farthest distance traveled north by CPFVs leaving from Morro Bay, and Purisima Point (34°45'N, 120°38'W) is the farthest point south for vessels leaving Port San Luis. CPFVs from Morro Bay generally fish in the northern area from Point Buchon to Lopez Point, while those from Port San Luis mostly fish in the southern area from Point Buchon to Purisima Point (fig. 1).

The northern and southern regions were further subdivided into near-port and distant-port areas. The areas in the northern region include "Morro near," which includes near-port areas between Point Buchon and south of San Simeon, and "San Simeon north," which includes distant-port areas from San Simeon northward. The southern region areas include "Avila near," which includes near-port areas between Port San Luis and Point Buchon, and "Point Sal/Purisima," which includes distant-port areas fished from Port San Luis.

The SCC is an ideal region in which to use comparisons of species aggregations in near-port and distant areas to examine whether heavier localized fishing in near-port areas had noticeable effects on local fish populations. As noted earlier, the proportion of trips to areas distant from port increased greatly for the Monterey region over a 30-year period (Mason 1995), and in addition, high percentages of trips to distant locations (>50%) have been reported for the Bodega Bay and San Francisco regions (Wilson et al. 1996). While these regions have experienced increased fishing effort in distant locations, the percentage of trips to distant-port areas in the SCC has changed very little (<15%) over time (Reilly et al. 1993, Wilson et al. 1996). During the 2003–04 seasons, near-port fishing trips occurred five to seven days a week with sometimes several boats fishing these areas per day, while distant-port or "long-range" trips occurred once or twice a week with only one boat fishing the area.

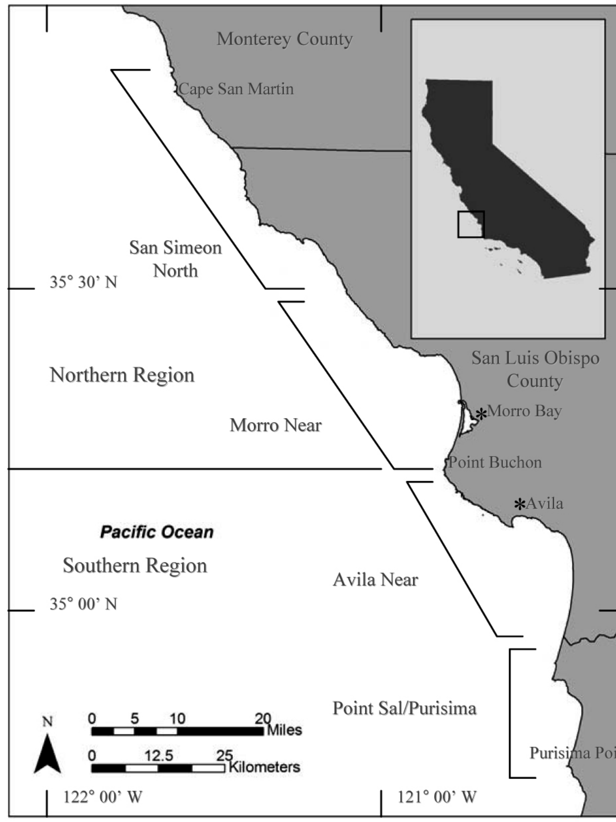


Figure 1. The Morro Bay CPFV region showing near-port and distant-port areas. Port areas indicated with an *.

Sampling Procedure

Data collected from CPFVs for the sportfishing groundfish fishery in 2003–04 were obtained from a collaborative research effort between CPFV vessels out of Port San Luis (Patriot Sportfishing) and Morro Bay (Virg's Sportfishing) and scientists from the Center for Coastal Marine Sciences at California Polytechnic State University (Cal Poly) in 2003–04. Two student observers accompanied CPFV vessels on trips that were targeting rockfish and lingcod and sampled the total catch of a subset of the total fishermen aboard the vessel, usually between six to 14 individuals. Observers recorded the number of observed fishers, total fishing time, GPS location, and water depth at each fishing locality. Within the subset of observed fishers the observers recorded the species caught, measured fish size in fork length to the nearest 0.5 cm, and recorded the disposition of each individual fish ("K-" for kept fish, "RA-" for fish released alive, and "RD-" for fish released dead).

Additionally, CPFV data taken by CDFG samplers from 1988–98 for the SCC were made available in Microsoft Access format. These data are partially available as unpublished administrative reports (Reilly et al. 1993, 1998; Wilson et al. 1996; Wilson-Vandenberg et al. 1995, 1996). For a more detailed description of the methods used by the CDFG survey, see Reilly et al. (1993). The Cal Poly and CDFG data sets were comparable as both protocols followed similar methodologies and contained area and depth specific information on where fish were caught. Prior to these two data sets, information was not available on an area-specific basis in central California, but rather summed up on a regional basis or by county district (Miller and Gotshall 1965; Karpov et al. 1995). Area-specific and depth-specific information, along with measurements for released fish, are available for certain areas in the Southern California Bight, including the Channel Islands, dating back to 1975 (Love et al.1985).

The Cal Poly protocol was similar to that in the Channel Islands study in that fish lengths were recorded at each fishing location throughout the day and released fish were also measured. The CDFG survey differed in that fish lengths were recorded at the end of the day, and only kept fish were measured. For individual species, CPUE can be compared between the CDFG and Cal Poly surveys since area- and depth-specific information were available. But fish lengths were only used from the Cal Poly survey because it was difficult to obtain accurate area and depth-specific data for fish lengths in the CDFG study and we did not want to introduce a size bias by including measurements of retained or kept fish.

Statistical Analysis

We used a multivariate approach with non-standardized Bray Curtis similarity indices to determine the similarity between fish assemblages from near-port and fish assemblages from distant-port areas along the SCC. We tested whether species catch rates were similar between both near-port areas since they receive similar fishing effort. The same test was applied to distant-port areas. Similarity of species catch rates from these areas was analyzed using the ANOSIM analysis from the Primer 5 statistics package (PREMEIR Biosoft International). A significance level greater than 5.0% for comparisons of two or more areas indicates that the fish assemblages are not significantly different between these areas, whereas values <5% indicate that there are differences in species catch rates between same-type areas, suggesting that fish assemblages from those areas are not similar.

Species catch rates were determined through CPUE. CPUE for each species was calculated by dividing the total catch by the number of angler hours, where angler hours = (average number of anglers * the number of minutes) / 60. Yearly CPUE values for the most abundant species were used to compare species assemblage compositions between areas. Species were selected based on abundance throughout the entire study and only species that made up ≥1% of the total recreational catch in waters ≤55 m (30 fm) from 1988–2004 were used in the analysis. A depth of 55 m (30 fm) was used for both the CDFG and Cal Poly data sets to reflect regulation changes that occurred during 2003–04. Sampling of distant-port areas at Point Sal/Purisima did not begin until 1989, and sampling of distant-port areas from San Simeon north began in 1991. Also, there were years when not enough data were available for near-port areas mainly due to a concentration on deeper-water fishing. Data from such years were excluded from the analysis.

Multi-Dimensional Scaling (MDS) plots with subsequent Cluster Analysis (CA) using 70% confidence level limits were used to assess similarity in species assemblage composition between areas. A tighter cluster between years for a particular area indicates a high degree of similarity among years, whereas a more loosely associated cluster indicates a variable catch composition between years. Similarly, a tighter cluster between comparisons of two areas indicates that fish assemblages are similar between these areas, while separate and more distinct clusters indicate that the assemblages are different for those areas. Dotted circles were drawn around each of the major areas where applicable to give an idea of how similar or different assemblages from these areas were to each other.

Annual mean sea-surface temperature (SST) anomalies were used as proxies for oceanographic events to explain shifts in assemblage composition. The annual mean SSTs were obtained by calculating the daily mean of the measurements made by the Cape San Martin (#46028) and Santa Maria (#46011) NOAA buoys and then averaging those daily means over each year (www.ndbc.noaa.gov).

A Kruskal-Wallis test was used for each species to determine if size-class distributions were different between near-port and distant-port areas. The more powerful parametric tests, a one-way ANOVA or a *t*-test, could not be used because the assumptions of normality and equal variance were not met.

The general linear ANOVA model was used to analyze CPUE between near and distant-port areas for each species. To fit normality assumptions, CPUE values were square-root transformed. Since regulations regarding the

TABLE 1
Species abundance listed by CPUE per year for near-port and distant-port areas for the top 12 species along the south central Coast.

A. San Simeon North

Species	1991	1992	1993	1994	1995	1996	1997	1998	2003	2004	Mean
Blue rockfish	1.84	2.48	2.17	1.57	0.94	1.89	3.28	3.05	2.46	3.21	2.29
Gopher rockfish	0.69	0.94	0.49	0.57	1.07	1.25	0.87	1.22	1.27	0.48	0.89
Olive rockfish	0.87	0.48	0.39	0.30	0.54	0.26	0.17	0.35	0.32	0.42	0.41
Lingcod	0.12	0.14	0.13	0.14	0.21	0.29	0.32	0.57	0.61	0.52	0.31
Vermilion rockfish	0.14	0.12	0.16	0.24	0.19	0.13	0.24	0.24	0.51	0.62	0.26
Yellowtail rockfish	0.19	0.10	0.21	0.41	0.14	0.18	0.11	0.11	0.05	0.19	0.17
Copper rockfish	0.10	0.10	0.09	0.06	0.10	0.11	0.07	0.02	0.09	0.26	0.10
Starry rockfish	0.24	0.12	0.05	0.10	0.01	0.13	0.08	0.00	0.07	0.10	0.09
Rosy rockfish	0.09	0.08	0.07	0.09	0.03	0.09	0.10	0.00	0.11	0.09	0.08
Canary rockfish	0.07	0.03	0.01	0.08	0.08	0.01	0.03	0.02	0.04	0.05	0.04
Black rockfish	0.16	0.00	0.02	0.16	0.03	0.02	0.01	0.00	0.00	0.02	0.04
Brown rockfish	0.01	0.05	0.03	0.01	0.01	0.05	0.01	0.00	0.14	0.07	0.04

B. Morro Near

Species	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	2003	2004	Mean
Blue rockfish	0.29	0.40	0.81	1.58	2.69	2.20	1.09	1.40	3.60	5.45	1.51	2.78	1.98
Gopher rockfish	0.40	0.38	0.32	0.56	0.40	0.59	0.56	0.79	0.46	0.86	1.16	0.91	0.62
Yellowtail rockfish	0.29	0.47	0.10	0.46	0.78	1.03	0.39	0.26	0.22	0.11	0.10	0.16	0.36
Vermilion rockfish	0.26	0.28	0.03	0.21	0.21	0.16	0.11	0.15	0.19	0.24	0.26	0.55	0.22
Olive rockfish	0.02	0.00	0.57	0.32	0.16	0.09	0.15	0.29	0.19	0.47	0.09	0.11	0.21
Lingcod	0.06	0.03	0.10	0.17	0.07	0.10	0.15	0.25	0.31	0.26	0.38	0.43	0.19
Rosy rockfish	0.13	0.19	0.08	0.19	0.32	0.38	0.16	0.21	0.07	0.05	0.08	0.10	0.16
Canary rockfish	0.14	0.09	0.04	0.18	0.10	0.06	0.11	0.15	0.04	0.06	0.03	0.11	0.09
Brown rockfish	0.00	0.00	0.33	0.01	0.01	0.04	0.08	0.06	0.00	0.05	0.27	0.10	0.08
Black rockfish	0.00	0.00	0.41	0.01	0.01	0.00	0.03	0.07	0.11	0.03	0.08	0.01	0.06
Copper rockfish	0.09	0.02	0.06	0.10	0.09	0.06	0.04	0.06	0.04	0.04	0.03	0.06	0.06
Starry rockfish	0.09	0.02	0.06	0.10	0.09	0.06	0.04	0.06	0.04	0.04	0.03	0.06	0.06

C. Avila Near

Species	1988	1989	1991	1992	1993	1994	1995	1996	1997	1998	2003	2004	Mean
Blue rockfish	0.52	0.18	0.72	1.65	2.04	0.77	1.20	1.55	2.33	2.16	1.91	3.22	1.52
Yellowtail rockfish	0.35	0.92	0.22	0.88	0.67	0.79	0.40	0.31	0.30	0.31	0.14	0.23	0.46
Gopher rockfish	0.11	0.21	0.11	0.26	0.63	0.31	0.24	0.33	0.29	0.30	0.89	0.69	0.36
Vermilion rockfish	0.17	0.41	0.05	0.14	0.24	0.28	0.08	0.10	0.21	0.17	0.49	0.68	0.25
Rosy rockfish	0.18	0.27	0.16	0.14	0.31	0.32	0.12	0.16	0.04	0.13	0.08	0.18	0.17
Lingcod	0.09	0.38	0.04	0.16	0.14	0.14	0.17	0.28	0.30	0.11	0.51	0.36	0.22
Brown rockfish	0.00	0.03	0.00	0.26	0.24	0.10	0.12	0.04	0.19	0.31	0.61	0.20	0.18
Olive rockfish	0.00	0.00	0.08	0.26	0.22	0.05	0.10	0.06	0.10	0.07	0.13	0.09	0.10
Copper rockfish	0.11	0.20	0.00	0.09	0.06	0.19	0.07	0.10	0.07	0.12	0.04	0.08	0.09
Starry rockfish	0.11	0.20	0.00	0.09	0.06	0.19	0.07	0.10	0.07	0.12	0.04	0.08	0.09
Black rockfish	0.00	0.00	0.05	0.00	0.10	0.05	0.00	0.00	0.04	0.01	0.06	0.01	0.03
Canary rockfish	0.07	0.14	0.00	0.05	0.05	0.05	0.06	0.09	0.06	0.03	0.02	0.04	0.06

D. Point Sal/Purisima

Species	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2003	2004	Mean
Brown rockfish	1.94	1.19	1.38	1.23	0.39	1.20	2.13	1.09	0.52	1.77	1.52	1.63	1.33
Blue rockfish	0.90	0.13	0.81	1.03	0.13	0.28	0.76	0.29	1.47	2.78	1.54	1.35	0.96
Gopher rockfish	1.32	0.83	0.51	0.50	0.36	0.61	0.80	0.75	0.71	0.87	0.50	0.84	0.72
Yellowtail rockfish	1.56	0.05	0.03	0.11	0.06	0.68	0.77	0.48	0.18	0.29	0.10	0.16	0.37
Lingcod	0.31	0.23	0.45	0.28	0.05	0.07	0.43	0.27	0.38	0.28	0.41	0.60	0.31
Olive rockfish	0.21	0.50	0.48	0.14	0.16	0.13	0.26	0.22	0.62	0.00	0.34	0.19	0.27
Vermilion rockfish	0.24	0.13	0.10	0.12	0.10	0.16	0.19	0.11	0.22	0.30	0.37	0.63	0.22
Black rockfish	0.00	0.67	0.94	0.30	0.17	0.12	0.04	0.05	0.09	0.03	0.10	0.02	0.21
Copper rockfish	0.21	0.03	0.08	0.05	0.18	0.05	0.14	0.09	0.11	0.08	0.02	0.07	0.09
Canary rockfish	0.14	0.08	0.02	0.00	0.06	0.24	0.20	0.14	0.05	0.04	0.04	0.02	0.09
Rosy rockfish	0.00	0.00	0.00	0.06	0.09	0.01	0.04	0.09	0.08	0.10	0.04	0.05	0.05
Starry rockfish	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00

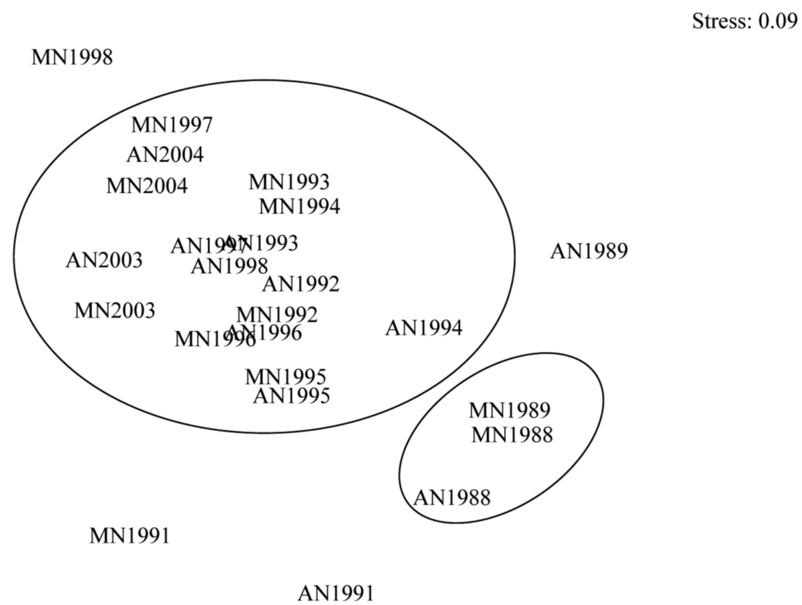


Figure 2. Bray-Curtis Multi-Dimensional Scaling plot for comparisons in species catch composition between the two near-port areas (MN = Morro Near, AN = Avila Near).

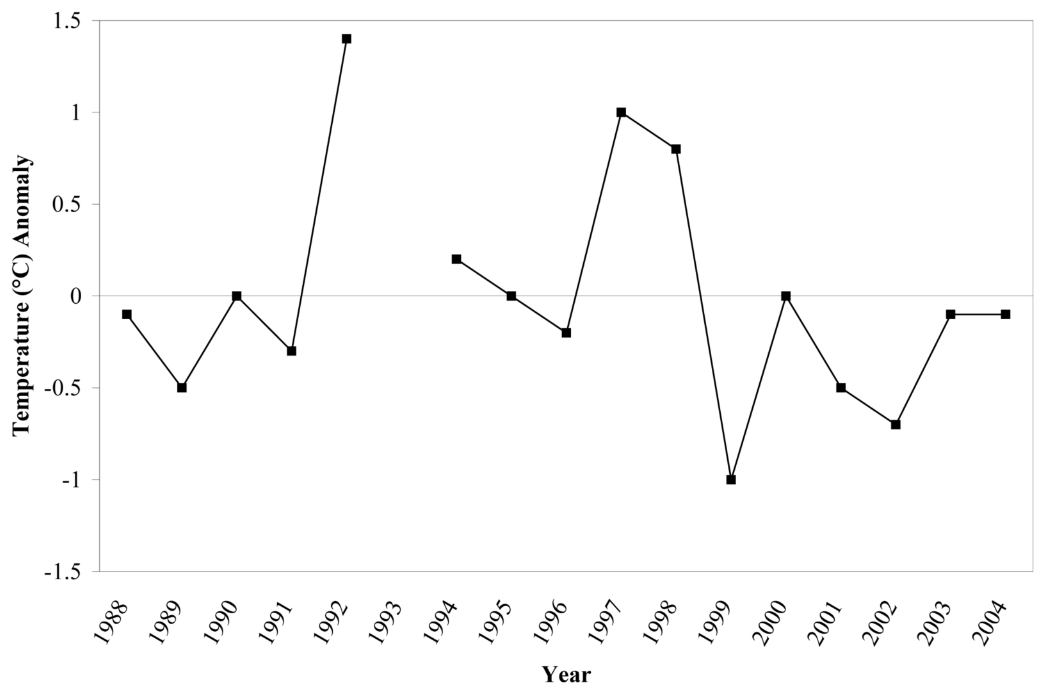


Figure 3. Annual sea surface temperature anomalies derived from daily readings taken at NOAA buoys 46028 at Cape San Martin, Monterey County, California, and 46011 at Santa Maria, Santa Barbara County, California. No data were recorded for either site in 1993.

number of allowable hooks and bag limit sizes were different between the CDFG and Cal Poly surveys, CPUEs were analyzed separately for each survey. Daily CPUE values were used rather than single yearly values because they account for greater variability. This model accounted for monthly, yearly, and area variations between near-port and distant-port areas for each species.

RESULTS

Spatial and Temporal Patterns for Fish Assemblages

Spatial and temporal patterns of fish assemblages for near- and distant-port areas are listed in Table 1. An analysis of species assemblage composition for the two

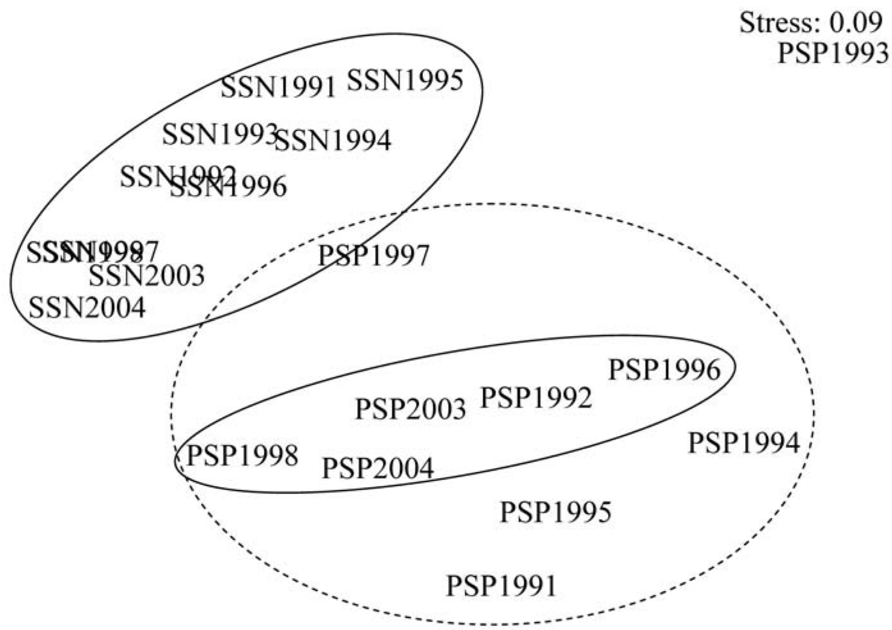


Figure 4. Bray-Curtis Multi-Dimensional Scaling plot for comparisons in species catch composition between the two distant-port areas (SSN = San Simeon north, PSP = Point Sal/Purisima).

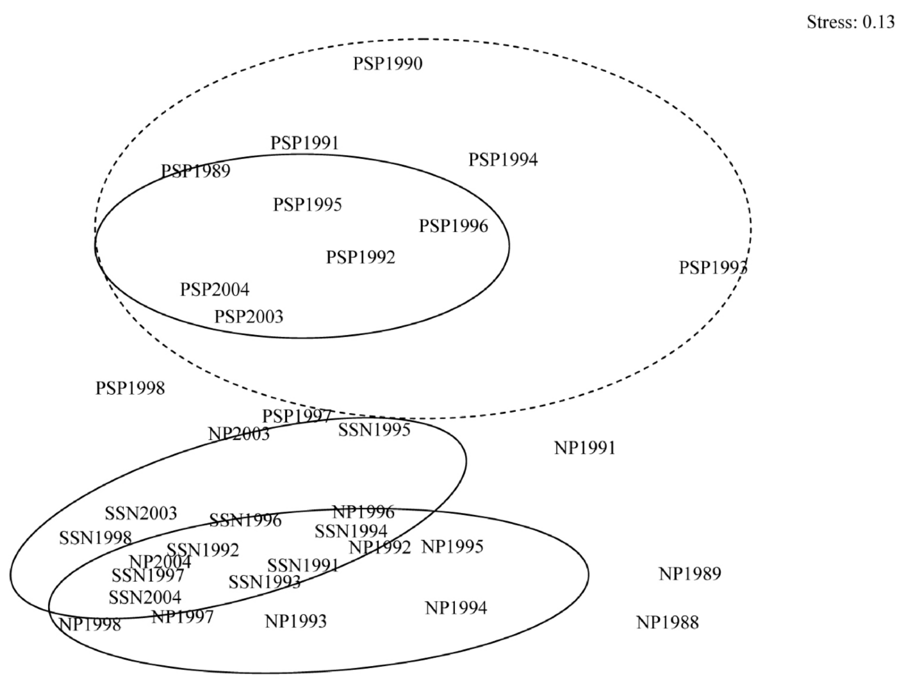


Figure 5. Bray-Curtis Multi-Dimensional Scaling plot for comparisons in species catch composition between near-port and distant-port areas (NP = near-port areas, SSN = San Simeon north, and PSP = Point Sal/Purisima).

near-port areas indicates that there was no significant difference between these areas (Significance level = 28%, $R = 0.019$). The Multi-Dimensional Scaling (MDS) plot for these areas had many close comparisons (fig. 2). There was a smaller separate cluster for some earlier years compared to a larger cluster for later years. Outlying years were 1991 for both sites, 1989 for the Avila near area, and 1998 for the Morro near area. Annual SSTs for the earlier years correspond to cooler years, while 1998 was a warmer El Niño year (fig. 3).

There was a significant difference in catch composition between the distant-port areas (Significance level = 0.1%, $R = 0.679$). The MDS plot for these areas shows a clear separation between the two areas (fig. 4) with a

TABLE 2
Median length and standard deviation between near-port areas and distant-port areas at San Simeon north for the top 11 species. Differences among distributions were tested on the median length using a Kruskal-Wallis test and were considered significant at $p \leq 0.05$. Significant differences for individual species are indicated by *.

	Near-port			Distant-port			
Species	Median Length (cm)	SD	*n*	Median Length (cm)	SD	*n*	*P*
Blue rockfish	27.00	4.56	9357	29.00	4.34	1741	<0.001*
Brown rockfish	34.50	3.88	1071	36.00	3.34	61	<0.001*
Canary rockfish	30.25	3.95	215	30.00	2.79	30	0.404
Copper rockfish	33.00	5.71	218	38.00	5.50	123	<0.001*
Gopher rockfish	26.50	2.32	3508	26.75	2.36	480	0.039*
Olive rockfish	30.50	6.78	417	37.50	6.51	239	<0.001*
Rosy rockfish	20.50	2.34	440	20.00	2.59	59	0.779
Starry rockfish	31.00	3.25	202	32.00	5.03	54	0.049*
Vermilion rockfish	32.00	6.65	2039	41.00	6.23	359	<0.001*
Yellowtail rockfish	20.00	5.82	587	27.50	4.20	78	<0.001*
Lingcod	54.00	8.31	1519	57.00	9.47	324	<0.001*

tighter cluster between years for the San Simeon north area. As indicated by a more loosely associated cluster and many outlying years, species composition of the catch in the Point Sal/Purisima area was highly variable among years.

Since the near-port areas were so similar in assemblage composition and fishing effort, we combined the data from the Avila and Morro near-port areas to compare with data from each of the distant-port areas. The combined catch composition of the near-port areas was only slightly different from that of San Simeon north (Significance level = 4.3%, $R = 0.153$), while catch from near-port areas and Point Sal/Purisima were very different (Significance level = 0.1%, $R = 0.544$). The species composition for San Simeon north was tightly clustered among years, while near-port areas showed a higher degree of inter-annual variation in species composition. Although there was a fair amount of overlap between these areas, the most anomalous years for near-port areas occurred during 1988–91, which were larger than the outliers for San Simeon north (fig. 5). Conversely, the catch composition from the Point Sal/Purisima area was clearly distinct from other areas and exhibited a loosely associated cluster with many outlying years.

The assemblage for the Point Sal/Purisima area was markedly different from the other assemblages in two major ways. First, fish assemblages at San Simeon north and near-port areas changed less over time than the assemblage at Point Sal/Purisima, as the MDS plots indicate (figs. 2, 4, and 5). Second, brown rockfish (*Sebastes auriculatus*) was the predominant species in catches from this region, whereas blue rockfish (*Sebastes mystinus*) was the most abundant species in catches from all other areas (tab. 1). Brown rockfish CPUE was consistently high throughout the study at the Point Sal/Purisima area and this species was the most abundant in nearly every year sampled, while it was typically among the least abundant in the other two areas.

Length Comparisons Between Near- and Distant-port Areas (2003–04)

Since fishing effort and assemblage composition were similar between near-port areas (fig. 2), data on fish lengths were combined for these areas and compared separately to distant areas. Differences in size-class distributions for 10 rockfish species and lingcod were compared between near-port areas and San Simeon north (tab. 2) and Point Sal/Purisima (tab. 3) using the Kruskal-Wallis method. Overall, three patterns were apparent in this fishery regarding species size as a function of distance fished from port: (1) some species were always larger for distant-port areas; (2) some species were larger in the north than south; and (3) some species showed little or no difference in length between near- and distant-port areas. Olive (*Sebastes serranoides*) and vermilion (*S. miniatus*) rockfish were exceptions to these trends.

Brown, copper (*S. caurinus*), and starry (*S. constellatus*) rockfishes and lingcod fit the first category in which fish sizes were always larger for distant-port areas with less fishing effort than near-port areas. Length differences were highly pronounced for copper rockfish, whose median length was 5 cm larger for San Simeon north and 7 cm larger for the Point Sal/Purisima area. Lingcod measurements were 3 cm larger for San Simeon north and 6 cm larger for the Point Sal/Purisima area. Additionally, brown rockfish were larger for both distant-port areas compared to near-port areas. Although there was only a 1 cm difference between the starry rockfish measurements from near- and distant-port areas in San Simeon north, the species was slightly larger in San Simeon north than the combined near-port areas; the results were significant ($p = 0.049$, tab. 2).

Olive and vermilion rockfish were significantly larger in distant-port areas compared to near-port areas in the San Simeon north area with median lengths of 7 and 9 cm greater, respectively. Although both of these species were much larger in size in the San Simeon north area

TABLE 3
Median length and standard deviation between near-port areas and distant-port areas at Point Sal/Purisima north for the top 11 species. Differences among distributions were tested on the median length using a Kruskal-Wallis test and were considered significant at $p \leq 0.05$. Significant differences for individual species are indicated by *.

	Near-port			Distant-port			
Species	Median Length (cm)	SD	*n*	Median Length (cm)	SD	*n*	*P*
Blue rockfish	27.00	4.56	9347	25.00	4.68	831	<0.001*
Brown rockfish	34.50	3.88	1071	37.50	4.66	979	<0.001*
Canary rockfish	30.25	3.95	215	29.00	3.51	15	0.545
Copper rockfish	33.00	5.71	218	40.00	7.08	30	<0.001*
Gopher rockfish	26.50	2.32	3508	26.00	1.98	443	0.031*
Olive rockfish	30.50	6.78	417	32.25	7.88	150	0.093
Rosy rockfish	20.50	2.34	440	21.50	2.13	25	0.034*
Starry rockfish	31.00	3.25	202	—	—	—	—
Vermilion rockfish	32.00	6.65	2039	31.50	8.11	331	0.338
Yellowtail rockfish	20.00	5.82	587	18.50	4.64	75	<0.001*
Lingcod	54.00	8.31	1519	60.00	9.48	295	<0.001*

TABLE 4
Comparisons of CPUE between near- and distant-port areas at San Simeon north for the top 11 species. † indicates significant differences in CPUE between near and distant areas for 1988–98, * indicates those of 2003–04, and *† indicates those for both periods; − indicates cases where the assumptions of the general linear ANOVA were not met.

	1988–1998			2003–2004		
Species	Month	Year	Area	Month	Year	Area
Blue rockfish	0.457	<0.001	0.679	<0.001	<0.001	0.872
Brown rockfish	—	—	—	—	—	—
Canary rockfish	0.009	0.183	0.003†	0.001	0.753	0.882
Copper rockfish	0.364	0.182	0.619	0.004	0.599	<0.001*
Gopher rockfish	0.682	0.061	<0.001†	0.004	0.001	0.057
Olive rockfish	0.062	<0.001	<0.001*†	0.003	0.421	<0.001*†
Rosy rockfish	0.152	0.055	<0.001†	0.001	0.644	0.409
Starry rockfish	0.737	0.304	0.426	0.529	0.057	0.025*
Vermilion rockfish	0.125	0.016	0.235	<0.001	0.668	0.409
Yellowtail rockfish	0.097	<0.001	<0.001†	0.001	0.533	0.654
Lingcod	0.166	0.011	0.211	0.017	0.009	0.045*

there were no significant differences in size-class distributions for these species between near-port areas and the Point Sal/Purisima area (tab. 3). Blue and yellowtail (*S. flavidus*) rockfish were larger sized for San Simeon north compared to the combined near-port areas, but the patterns were different for the Point Sal/Purisima area.

Blue and yellowtail rockfish fit the second category where fish lengths followed a north to south gradient with smaller fish found farther south. This pattern was more pronounced for yellowtail rockfish than blue rockfish. Median lengths for yellowtail rockfish from north to south were 27.5 (San Simeon north), 20 (near-port), and 18.5 cm (Point Sal/Purisima), while they were 29, 27, and 25 cm for blue rockfish (tabs. 2 and 3).

The remaining species fit the third category where little or no differences in length were observed between near- and distant-port areas. There were no differences in canary rockfish (*S. pinniger*) size distributions between near- and distant-port areas (Kruskal-Wallis test, near-port vs. San Simeon north, $p = 0.404$, tab. 2; near-port vs. Point Sal/Purisima, $p = 0.545$, tab. 3); however, significant differences were detected for the Point Sal/Purisima area for rosy rockfish (*S. rosaceus*) and for both distant-port areas for gopher rockfish (*S. carnatus*, tabs. 2, 3). While differences in length between near- and distant-port areas for both of these species are statistically significant (tabs. 2, 3), a large sample size and the small species catch size range may have masked an apparent trend.

Size-class distributions were significantly different for nine of the 11 species when comparing those from near-port areas to those from San Simeon north (tab. 2). In each case, examined lengths from distant-port areas. Conversely, differences in size-class distributions were detected for seven of 11 species with three having larger sizes in near-port areas when compared to the Point Sal/Purisima area (tab. 3). This may suggest a north-south cline for these species.

CPUE Between Near- and Distant-port Areas (1988–2004)

During the CDFG surveys, CPUE for the different species exhibited one of four major patterns: (1) CPUE

TABLE 5
Comparisons of CPUE between near and distant areas at Point Sal/Purisima north for the top 11 species. † indicates significant differences in CPUE between near and distant areas for 1988–98, * indicates those of 2003–04, and *† indicates those for both periods; − indicates cases where the assumptions of the general linear ANOVA were not met.

	1988–1998			2003–2004		
Species	Month	Year	Area	Month	Year	Area
Blue rockfish	0.298	<0.001	0.002*†	<0.001	0.002	<0.001*†
Brown rockfish	—	—	—	—	—	—
Canary rockfish	0.080	0.020	0.545	<0.001	0.581	0.348
Copper rockfish	0.174	0.347	0.003†	0.001	0.170	0.815
Gopher rockfish	0.658	0.116	0.009†	<0.001	0.234	0.134
Olive rockfish	0.036	<0.001	0.009*†	0.018	0.115	0.004*†
Rosy rockfish	0.175	0.128	0.041†	0.001	0.721	0.131
Starry rockfish	0.673	0.117	0.003†	—	—	—
Vermilion rockfish	0.134	0.013	0.196	<0.001	0.734	0.186
Yellowtail rockfish	0.790	0.002	0.495	<0.001	0.480	0.361
Lingcod	0.435	0.064	0.113	0.054	0.114	0.078

did not differ between near- and distant-port areas during 1988–98 but differed significantly during 2003–04; (2) CPUE differed between near- and distant-port areas during 1988–98 but not during 2003–04; (3) CPUE did not differ at all between near- and distant-port areas during surveys in either period; and (4) CPUE differed between near- and distant-port areas during surveys in both periods.

CPUE values for lingcod, starry rockfish, and copper rockfish were not significantly different between near- and distant-port areas from 1988–98, but were during 2003–04 (tabs. 4 and 5). CPUE in 2003–04 was higher for distant-port areas for starry rockfish (fig. 6H). This also was true for lingcod and copper rockfish, but only when compared with San Simeon north (figs. 6D and J).

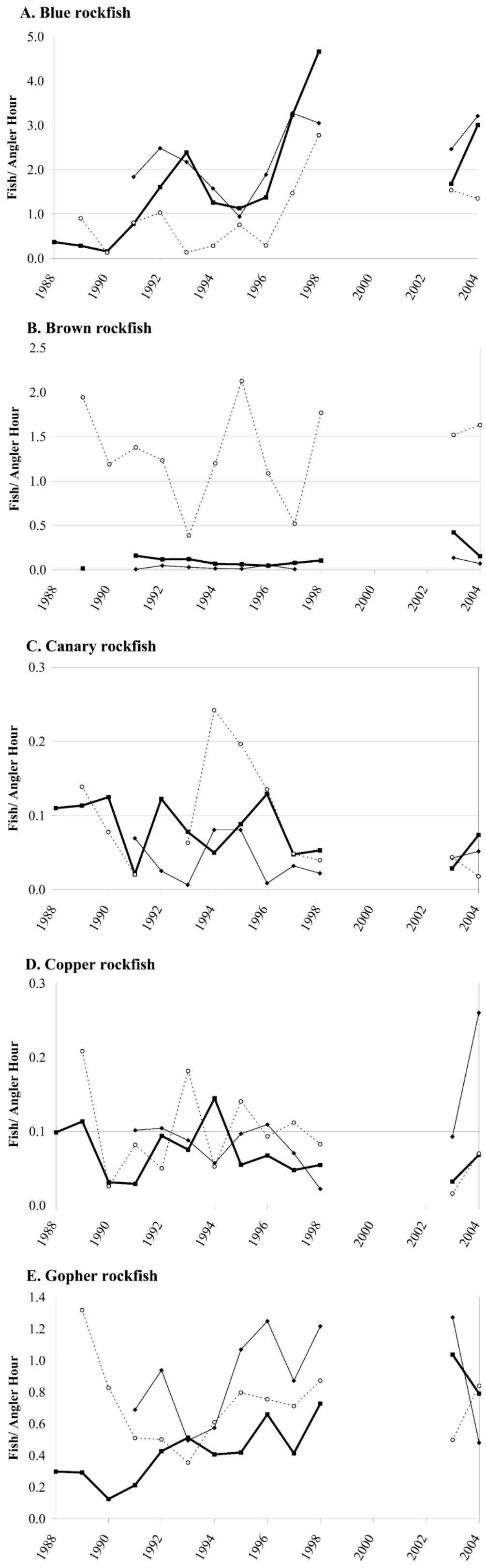
Catch rates for gopher and rosy rockfish were significantly different between near- and distant-port areas from 1988–98 but not during 2003–04 (tabs. 4 and 5). However, the CPUE for gopher rockfish was generally lower for near-port areas from 1988–98, while it was generally higher for rosy rockfish (figs. 6E and G). CPUEs for canary and yellowtail rockfish were also higher for near-port areas during 1988–98, but only when compared to San Simeon north (figs. 6C and J). CPUE for these two species did not differ significantly between near-port areas and the Point Sal/Purisima area. CPUE for copper was higher in distant-port areas during 1988–98, but only for the Point Sal/Purisima area (fig. 6D).

There were a few species for which CPUE was the same between near- and distant-port areas in both surveys. CPUE for vermilion rockfish did not differ between any of the areas; while for blue rockfish no differences in CPUE were detected between near-port areas and San Simeon north (tab. 4), nor for canary and yellowtail rockfish between near-port areas and Point Sal/Purisima (tab. 5).

CPUE patterns for olive and brown rockfish differed from the above mentioned trends. For olive rockfish, CPUE was always highest for distant-port areas during both surveys (tabs. 4, 5). The assumptions of the general linear ANOVA model were not met for brown rockfish because it was scarce throughout most of the study area. However, the plot of CPUE between near- and distant-port areas (fig. 6B) indicates that this species is only abundant in distant-port areas at the Point Sal/Purisima area, with catch rates several times higher in magnitude for this region compared to other areas.

DISCUSSION

Our multivariate analysis demonstrated clear spatial and temporal patterns in fish assemblages over different areas in the SCC by applying a multivariate approach using Bray-Curtis similarity indices. Fish assemblages from the two near-port areas were similar, while distant-port areas were markedly different both from each other and from near-port areas. The tight clustering between years for the San Simeon north area in the MDS plot suggests that this area has remained fairly stable over time (fig. 4). While changes have occurred in near-port areas, the tight clustering between years in the MDS plot for these sites indicates that these areas are similar (fig. 2). Assemblage composition in the near-port areas was not as stable as at San Simeon north, and had two separate clusters while San Simeon north had one tight cluster (figs. 2 and 4). Although greater fishing effort in near-port areas might easily explain some of these differences, these areas may also be influenced by environmental variability, with notable changes occurring during extended periods of cooler water (figs. 2 and 3). A loosely associated cluster with many outlying years and a clear separation in catch composition compared to other areas indicates that the Point Sal/Purisima area assemblage is highly variable and different than anywhere else along the SCC.



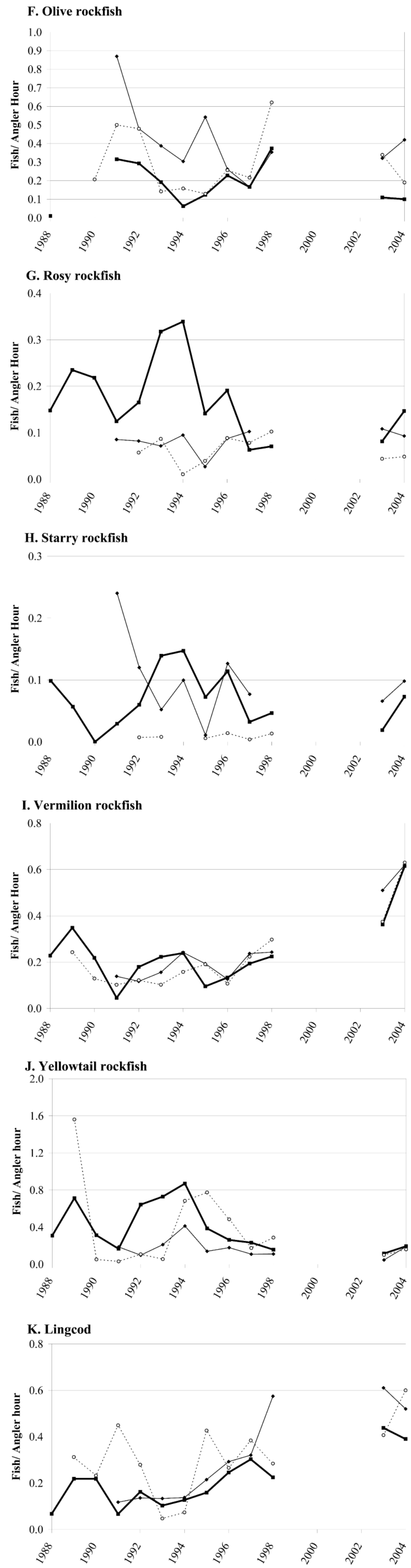


Figure 6a–k. CPUE between near and distant areas. —■— represents CPUE for near-port areas, —◆— CPUE for San Simeon north, and ----○---- for the Point Sal/Purisima area.

The fish assemblage in the Point Sal/Purisima area was the least stable of the four areas over time, despite lower fishing effort. Some of this variation may have been due to fluctuating sea surface temperatures during El Niño years and from the close proximity of this area to Point Conception, rather than to fishing. Also, the smaller number of fishing days sampled could have produced sampling error (R. Larson, pers. comm.). This area, which is closest to Point Conception, is at a transitional region between warmer temperate waters of the Southern California Bight south of Point Conception and cooler temperate waters (Oregonian) to the north.

Abundant brown rockfish and an overall lower abundance of blue rockfish in the Point Sal/Purisima area may reflect habitat differences. This area consists primarily of low-relief rocky outcrops, while high-relief rocky structures are typical of most of the rest of headland areas in the SCC. Brown rockfish typically utilize low-relief habitats (Love 1996), while species such as blue rockfish typically utilize high-relief structures (Love et al. 2002), which may explain why fewer blue rockfish were caught in this area. Habitat differences may also have influenced the patterns observed for temporal stability of the fish assemblage at the Point Sal/Purisima area. Research by Malatesta and Auster (1999) suggests that where the continental shelf consists of low-relief structures, it is not a homogeneous environment but rather consists of an array of habitats that can change depending on the intensity of storms, which can cover or expose rocky outcrops with sand.

The response to increased fishing effort in near-port areas differed among species, and indicates that not all species respond similarly to fishing effort along the SCC. Several factors may explain this. One is that several species migrate from shallower to deeper waters during their life cycle, and hence differences in length-frequency distributions between near-port and distant-port areas may not be found. Canary and yellowtail rockfish fit this profile; juveniles occur in shallow waters while adults typically prefer deeper depths (Love et al. 1990; Mason 1998). There were no size differences for canary rockfish between near- and distant-port areas, whereas yellowtail rockfish were generally larger sized to the north. Both canary and yellowtail rockfish have a more northerly distribution and are near the southern extent of their range along the SCC (Miller and Lea 1972; Eschmeyer et al. 1983). Few canary rockfish adults, if any, were present in our study, suggesting that while a higher proportion of adults occur farther north, younger fish may recruit to the area via southerly transport along the California Current. The fact that fewer adult yellowtail rockfish were present in the southern portion for this region supports the findings of Reilly et al. (1993) that recruitment to the fishery along this region may not depend on local adult populations but rather on adult populations to the north.

Some species of rockfish do not easily fit into specific depth ranges or categories, and thus trends between near-port and distant-port areas may not always apply under these circumstances. Copper and vermilion rockfishes are classified as all-depth species where adults are common in both shallow and deeper depths (Karpov et al. 1995). Similarly, rosy and starry rockfishes also have adults that occur in both shallow and deeper depths (Love et al. 1990; Eschmeyer et al. 1983), although adults are more common in deeper waters (Love et al. 1990). CPUE in this study was not consistent between near- and distant-port areas or between the CDFG and Cal Poly surveys for these species. This suggests that any differences detected in CPUE may not be a good indicator of stress from increased fishing effort in near-port areas. CPUE was also found not to be a reliable indicator of abundance for pelagic species of tuna in the Pacific Ocean because it does not account for shifts in fishing effort towards other species and ignores the impact of environmentally-induced recruitment variation (Hampton et al. 2005).

Although it may be possible that CPUE does scale with abundance, it appears that fishing has not had a detectable impact on fish densities. However, differences in size-class distributions may serve as better indicators of stress from increased fishing effort for near-port areas than does CPUE, particularly for species whose adults inhabit both shallow and deep waters. Fish size was significantly larger in distant-port areas when there was less fishing effort on shallow-water copper and vermilion rockfish (tabs. 4 and 5). Although adults for these two species occupy both shallow and deep water, it is surprising that a much greater proportion of adults was present in distant-port areas than in near-port areas where juveniles and sub-adults usually occurred (fig. 7).

Rockfish species that exclusively inhabit shallower waters are probably better indicators than mixed-depth species of whether increased fishing effort in near-port areas affects local populations. Shallower water species generally have smaller home-range sizes and are residential as adults. Tagging studies indicate little or no movement for shallow water benthic species such as gopher and brown rockfishes (Larson 1980a; Matthews 1990; Lea et al. 1999). Shallow water nonbenthic species such as blue and olive rockfish also show very little movement, and the high degree of site fidelity may make these species susceptible to exploitation (Miller and Geibel 1973; Hartmann 1987; Jorgensen et al. 2007). This has been documented for olive rockfish in heavily fished regions in southern California (Love 1980), and trends of lower catch rates and smaller-sized fish for near-port areas for olive rockfish were apparent in this study. Catch

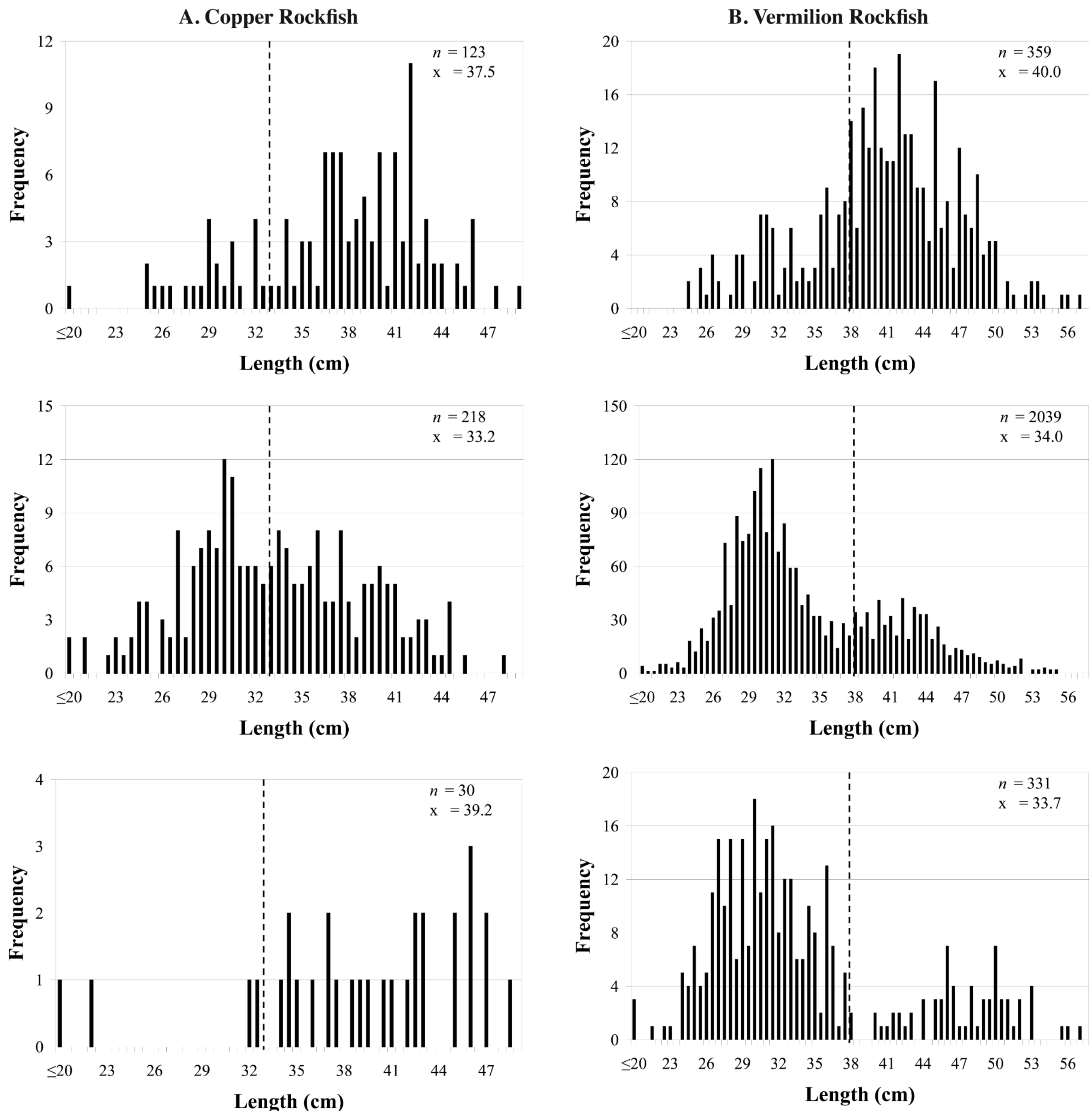


Figure 7 Length frequency histograms for fish sampled at San Simeon North (top), Near-Port (middle), and Pt. Sal/Purisima (bottom) areas in 2003-04. Sample size and mean length are given and vertical dashed line represents the size at 50% maturity.

rates for blue rockfish were not different between near and distant areas (except for Point Sal/Purisima), but there were larger-sized fish at San Simeon north compared to near-port areas (tab. 2). Even though there were proportionally larger-sized fish for the San Simeon area compared to near-port areas, both areas have a similar bimodal distribution with peaks of 25 and 32 cm corresponding to juvenile and adult size classes, respectively (fig. 8A). The presence of olive rockfish may indicate assemblage stress in near-port areas since their catch rates were lower. Also, size comparisons indicate that mostly adults reside in the San Simeon area while near-port areas had more juveniles than adults (fig. 8B).

Factors other than depth preferences may also have influenced the patterns observed for individual species from different areas, particularly habitat type. This espe-

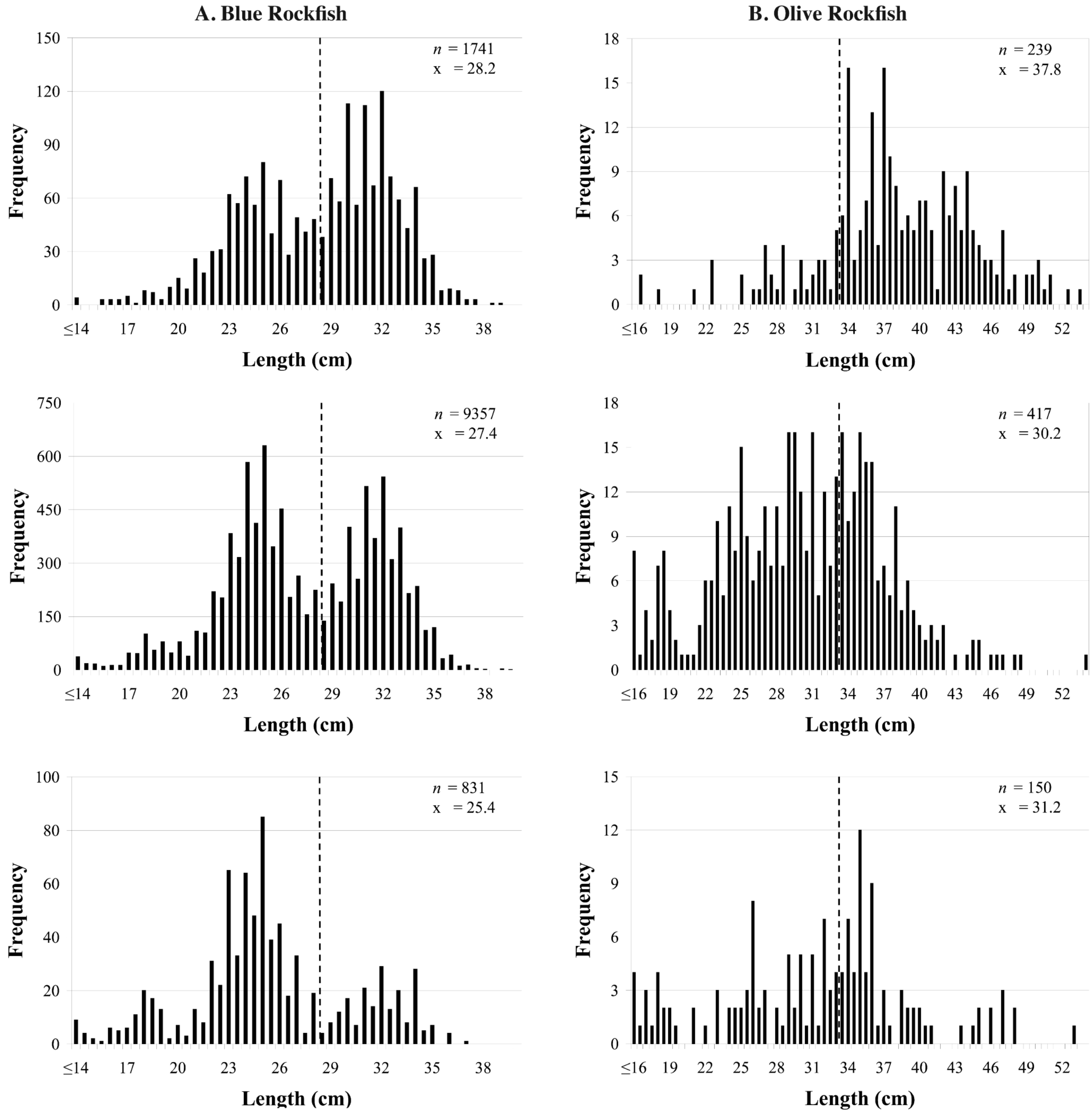


Figure 8 Length frequency histograms for fish sampled at San Simeon North (top), Near-Port (middle), and Pt. Sal/Purisima (bottom) areas in 2003-04. Sample size and mean length are given and vertical dashed line represents the size at 50% maturity.

cially seems to be the case with brown rockfish which were only abundant at the Point Sal/Purisima area. As mentioned earlier, brown rockfish typically occur in low-relief structures, such as cobblestone beds, which are found in the Point Sal/Purisima area. Blue and olive rockfish, however, are schooling and exclusively shallow-water species found over high-relief structures, which are found at the near- and distant-port areas for San Simeon. Gopher rockfish have a higher affinity for high-relief areas with much overgrowth (Larson 1980b). Since habitat and depth of capture were similar between near-port areas and San Simeon, it is not surprising that there were no gopher rockfish size differences between the two.

The results of this study have some general relevance to the establishment of Marine Protected Areas (MPAs), or "no-take" reserves, in central California in September

2007 (http://www.dfg.ca.gov/mlpa/ccmpas_list.asp#piedrassmca). Depending on the design and on the overall goal of any reserve, certain types of species groups may benefit while others may experience little effect (Carr and Reed 1993; Carr and Raimondi 1998). The no-take reserves in central California extend to depths of 20–40 fm (37–73 m), and the results from this study indicate that the species that would most likely benefit from this type of closure are those that exclusively inhabit shallow waters, such as blue, gopher, and olive rockfishes, since they do not move extensively. Marine reserves may also benefit species whose adults occur in both shallow and deep waters, such as copper and vermilion rockfish. However, this may be more difficult to discern since there is some degree of offshore movement towards deeper waters for these species. The species least likely to benefit from closure of shallow-water areas are those whose adults occur in deeper depths. Juvenile yellowtail and canary rockfish recruit to shallow-water areas and migrate to deep depths as adults. Hence, an MPA in shallow-water habitats is not likely to increase the density of adult fish in these areas. However, the closure of these areas may prevent growth overfishing and increase the proportion of juvenile fish that survive to adulthood.

Overall, the spatial and temporal patterns observed for the multi-species approach was mainly useful for elucidating habitat differences and their broad effect on species composition; it was secondarily useful in elucidating some climatically linked changes in relative abundance of species. The results from the multivariate analysis demonstrate that fishing does not appear to radically affect species composition by eradicating some heavily sought after or particularly sensitive species. The individual species trends mostly apply to shallow-water species. Thus, in examining differences in size or catch rates between heavily fished areas and those receiving less or no effort, species such as blue and olive rockfish would serve as good indicator species. Additionally, habitat differences and individual species preferences for specific habitats may have played a role in some of the differences in assemblages and CPUE between near- and distant-port areas, particularly with the Point Sal/Purisima area. This suggests that while CPUE was an effective measure for determining spatial and temporal patterns for fish assemblages, it should be used with caution for individual species and only under certain circumstances. To more effectively distinguish differences between near- and distant-port area assemblages, it would be beneficial to know the habitat type and species preferences for these habitats. A well-developed system has been established to classify seafloor habitats (Greene et al. 1999), but relatively few studies have examined benthic zones in detail in central California, with the exception of Yoklavich et al. (2002). Future studies might examine and characterize the benthic habitat along the SCC and determine whether rocky seafloor habitats in the area between Point Sal and Purisima Point are truly different from the rest of the SCC. Lastly, although patterns and trends in recreational rockfish catches within some areas of California such as the Southern California Bight are difficult to interpret due to shifts in fishing effort towards other species (i.e., yellowtail, barracuda, bonito, albacore, and kelp and barred sand basses) while fishing for rockfish (Love et al. 1998a; Dotson and Charter 2003), we can be sure that the trends examined in this study were exclusive to rockfishes and lingcod since albacore and salmon are caught on separate types of trips and were removed from the analysis for this study.

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