A SEVERE DECLINE IN THE COMMERCIAL PASSENGER FISHING VESSEL ROCKFISH (*SEBASTES* SPP.) CATCH IN THE SOUTHERN CALIFORNIA BIGHT, 1980–1996

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ABSTRACT

We analyzed data from the Marine Recreational Fishery Statistics Survey (MRFSS) to examine long-term trends in the Southern California Bight commercial passenger fishing vessel rockfish fishery. From 1980 to 1996 a total of 50 species were taken. There was a substantial decline in the overall catch per unit of effort (CPUE) during that time.

For individual species we observed four general temporal patterns: (1) a steady decline throughout the period; (2) high CPUE from 1983 to 1986; (3) variable catches throughout the 1980s but extremely low catches from 1993 to 1996; and (4) variable catches throughout the entire period. Among the several species with particularly large declines were bocaccio (98.7%), blue rockfish (95.2%), and olive rockfish (83.0%). Three species that were abundant in 1980 were absent by 1996 (chilipepper, swordspine, and yellowtail rockfishes). The number of species caught also decreased during the course of the survey.

We analyzed length frequencies for a subset of the species. On average, mean total length declined. This decline was due mainly to the removal of the larger size classes rather than to increased catches of juveniles. An extreme example was observed for vermilion rockfish: over the course of the survey, the fishery changed from one comprising primarily adults to almost entirely juveniles.

We conclude that the declines in rockfish catches in the Southern California Bight between 1980 and 1996 reflect reduced populations. These population declines probably result from poor long-term juvenile recruitment, caused by adverse oceanographic conditions, as well as from essentially unregulated overfishing of adults and subadults, perhaps leading to recruitment overfishing.

INTRODUCTION

Rockfishes (Scorpaenidae: genus *Sebastes*) dominate the fish communities of many California reefs (Lea 1992). Occupying a wide range of habitats and depths, this speciose group has been of major commercial and recreational importance for more than a hundred years (Lenarz 1986). In California, the value of these fisheries may have historically exceeded one billion dollars per year (Lenarz 1986).

Despite their importance, little is known about the condition of rockfish stocks in California (but see Ralston et al. 1996). Because most of the economically important species live over reefs in deeper waters, it has been difficult to determine population structure and size with the bottom trawl surveys used to assess many groundfish species. Tagging studies also present problems, because deeper-water rockfishes rarely survive being brought to the surface (O'Connell and Carlile 1994). In addition, it is not yet possible to identify all rockfish larvae to species, thus precluding estimates of spawning biomass from larval surveys.

Despite these limitations, in recent years there have been indications that at least some rockfish stocks in California are in jeopardy. Two studies of commercial passenger fishing vessel (CPFV) catches found both declining catch rates and declining mean lengths, as well as high takes of sexually immature fishes for a number of rockfish species (Reilly et al. 1993; Karpov et al. 1995). A study in Monterey Bay, central California, showed declines in the CPFV catches of a number of nearshore species, followed by a trend toward fishing for deeper-water species (Mason 1995). During the 1980s, trends in commercial rockfish landings and research trawl surveys implied some stress on stocks (Pearson and Ralston 1990; Dark and Wilkins 1994). Stocks of one species in particular, the bocaccio, are thought to be at historically low levels (Ralston et al. 1996). In addition, there is evidence of very poor survivorship of the pelagic juvenile stages of many species of rockfishes in central California (S. Ralston, pers. comm.).

All of these studies have been conducted in the central and northern part of California. Several factors indicate that the status of rockfish stocks in the Southern California Bight (SCB) may be similar to the status of stocks in the central and northern part of the state. Populations of many inshore fish species have declined markedly since the mid-1970s (Stephens et al. 1986, 1994; Holbrook and Schmitt 1996; Love et al. 1998). Much of this decline may be due to a decade-long oceanographic shift that has led to sharp declines in the juvenile recruitment of these species. Among inshore species, rockfishes appear to have been among the most

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affected. In much of the Southern California Bight, inshore rockfishes are no longer present, or their numbers are sharply reduced (Stephens et al. 1986, 1994; Love et al. 1998). This is probably due to a combination of poor juvenile recruitment and intense fishing pressure from both recreational and commercial fishermen. As in central California, survivorship of rockfish larvae and pelagic juveniles appears to be much reduced (M. Nishimoto, pers. comm.). This trend is not limited to inshore species. Stocks of deeper-water rockfishes are currently at very low levels (Love, unpubl. data). From 1995 to 1997, we used a research submersible to observe rockfish populations over deeper (50–300 m) reefs in the Southern California Bight. Most of the reefs we examined harbored few rockfishes longer than 20 cm total length, and many economically important species were absent.

There are, however, virtually no long-term published data on rockfish stocks in the Southern California Bight. In order to compare our direct observations of rockfish abundances in 1995–97 (Love, unpubl. data) we needed some assessment of rockfish stocks in the bight. In this paper we use information collected aboard CPFVs in the federally sponsored Marine Recreational Fishery Statistics Survey (MRFSS) to examine longer-term trends in Southern California Bight rockfish numbers.

METHODS

Data were taken by MRFSS observers from 1980 to 1989 and 1993 to 1996. The MRFSS program was suspended from 1990 through 1992. In addition, funding for the program was reduced in 1987–89, and monitoring activities were consequently reduced. Data during these years may not be completely comparable to other years. Observers rode aboard randomly selected CPFVs from all fishing ports in the Southern California Bight. The term CPFV includes charter boats and party boats fishing with hook and line gear only. Fishing trips selected were 1/2 and 3/4 day trips. Observers attempted to identify to species all fishes caught and to measure (mm fork and total length) as many fishes as possible. For details of the MRFSS program see U.S. Department of Commerce (1987) and Karpov et al. (1995).

Along the Pacific Coast, data from the MRFSS have been used to estimate the status of various fish stocks in central and northern California (Karpov et al. 1995). The MRFSS southern California data set targets only relatively short fishing trips (either 1/2 day or 3/4 day). During these trips, party vessels can travel only relatively short distances from port, almost entirely along the mainland; they do not have time to travel to more distant, and somewhat less fished, reefs.

A problem with this data might arise if, during the course of the survey, party vessels shifted away from fishing for rockfishes. This might happen if warm-water pelagic species such as yellowtail (*Seriola lalandi*) or Pacific bonito (*Sarda chiliensis*) were particularly abundant. In such a case, party vessels would fish in areas with few or no rockfishes, thus decreasing the rockfish CPUE even if there were no underlying decrease in rockfish populations. To counter this potential bias, we used catch data only from those CPFV trips that had caught at least one rockfish. This decreased any bias that might occur during years when fewer vessels fished for rockfishes.

We concentrated our analyses of CPUE on 21 species from the complete data set and calculated CPUE by dividing the total catch by the total cumulative fishing hours per year. The 21 target species had non-zero CPUE in at least 10 of the 14 years of data. We analyzed patterns of temporal abundance by plotting CPUE over time for each species. We present these plots in species groupings based on their patterns over time. We visually assessed similarities in the temporal patterns. Species fell into four general groupings: species that declined steadily from 1980 to 1996 (group A); species that increased from 1983 to 1986, some of which had a secondary peak in 1994 but generally were less abundant at the end of the 1990s than in the 1980s (group B); species that were extremely variable throughout the 1980s but were extremely low from 1993 to 1996 (group C); and species that were variable throughout the entire period (group D).

To summarize the CPUE patterns for these four species groups we standardized the data for each species by subtracting the mean CPUE for the entire period from each yearly value and dividing that by the standard deviation of the entire period. For each species, this gave a time series mean CPUE of 0 and a standard deviation of 1. We then fit simple linear regressions to the standardized CPUEs of each species against year, simply to summarize gross temporal trends in CPUE for each of the species groups. We present the slopes and variance explained (r^2) for each species as well as the average slope for each species group.

We also analyzed length-frequency data to determine differences among years. We performed this analysis for the 11 species with the highest CPUE in 1980. Length data for all other species were too sparse in the late 1990s to assess changes. We used length-frequency histograms to compare length frequencies graphically. We used total length in all analyses, and grouped lengths into 20 mm intervals. Small sample sizes, especially during the period 1987–89 (when sampling was reduced) and 1992–96 (when catches were greatly reduced), forced us to combine length-frequency data from some of these years. Whenever a yearly length sample contained fewer than 10 individuals, we combined that sample with the sample from the following year. We also compared mean lengths for each species by using either Student's *t*-tests (where variances were equal) and Welch ANOVAs (where variances were unequal). For these tests, we compared mean lengths for two time periods: 1980–89 (1980s) versus 1993–96 (1990s).

RESULTS

Catch per Unit of Effort

Over the course of the survey a total of 50 species were caught (table 1). Many of these species, however, were caught in only one year or in only a few years of the survey.

Between 1980 and 1996, the overall rockfish CPUE substantially declined (fig. 1). For the 21 target species, the total CPUE was 3,000 in 1980; decreased to 192 in 1995; and increased slightly to 345 in 1996.

The overall decline was largely reflected in the temporal patterns for the individual species. Over the sampling period, catch patterns varied among species (figs. 2 and 3). Four general patterns were observed. The first was a steady decline throughout the period (group A). Of the 6 species that made up this group (swordspine, blue, cow, flag, and olive rockfishes, and bocaccio), 3 (bocaccio and blue and olive rockfishes) had the first, second, and third highest CPUEs in 1980. The second general pattern was highest CPUE during 1983–86 (group B). These 6 species (greenspotted, starry, speckled, squarespot, bank, and rosy rockfishes) all had CPUEs in 1980 of about half the values during 1983–86. Some of these species had a secondary peak in 1994 but generally ended the 1990s lower than the 1980s. The third pattern, shown by 6 more species (group C), was characterized by variable catches throughout the 1980s but extremely low catches (or zero) from 1993 through 1996.

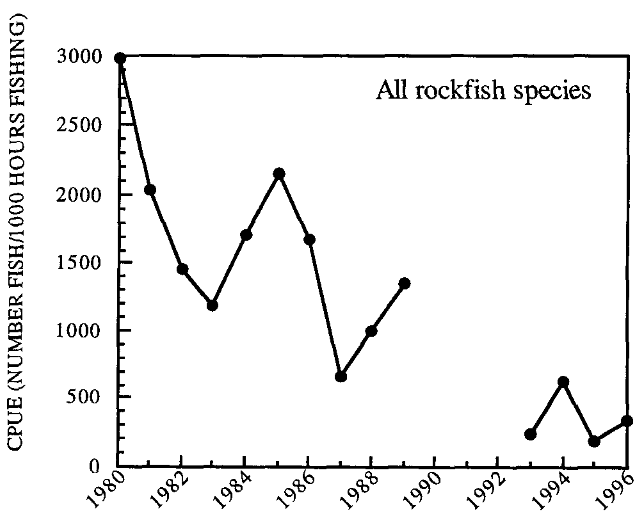


Figure 1. Catch per unit of effort for the 21 target species analyzed in this paper for 1980–96. No data are available for the period 1990–92.

The last pattern included 3 species which were variable throughout the entire period (group D).

We based our initial characterization of these groups on visual similarity of temporal patterns. However, we wanted to quantitatively assess the similarity of the patterns. To do this, we standardized CPUE, plotted each species group together, and fitted simple linear regressions to each species separately (fig. 4). We were not

TABLE 1
***Sebastes* Species Caught during the MRFSS Survey, 1980–96, in Descending Order of Total CPUE**

Common name	Scientific name
Bocaccio*†	*S. paucispinis*
Chilipepper rockfish*†	*S. goodei*
Blue rockfish*†	*S. mystinus*
Bank rockfish*	*S. rufus*
Halfbanded rockfish	*S. semicinctus*
Greenspotted rockfish*†	*S. chlorostictus*
Squarespotted rockfish*	*S. hopkinsi*
Vermilion rockfish*†	*S. miniatus*
Yellowtail rockfish*†	*S. flavidus*
Olive rockfish*†	*S. serranoides*
Widow rockfish*†	*S. entomelas*
Speckled rockfish*	*S. ovalis*
Starry rockfish*†	*S. constellatus*
Rosy rockfish*	*S. rosaceus*
Gopher rockfish	*S. carnatus*
Copper rockfish*†	*S. caurinus*
Brown rockfish*	*S. auriculatus*
Honeycomb rockfish*	*S. umbrosus*
Greenstriped rockfish	*S. elongatus*
Rougheye rockfish	*S. aleutianus*
Flag rockfish*	*S. rubrivinctus*
Canary rockfish*	*S. pinniger*
Chameleon rockfish	*S. phillipsi*
Pink rockfish	*S. eos*
Swordspine rockfish*†	*S. ensifer*
Treefish*	*S. serriceps*
Greenblotched rockfish	*S. rosenblatti*
Calico rockfish	*S. dalli*
Kelp rockfish	*S. atrovirens*
Cow rockfish*	*S. levis*
Black rockfish	*S. melanops*
Blackgill rockfish	*S. melanostomus*
Bronzespotted rockfish	*S. gilli*
China rockfish	*S. nebulosus*
Grass rockfish	*S. rastrelliger*
Black and yellow rockfish	*S. chrysomelas*
Yelloweye rockfish	*S. ruberrimus*
Rosethorn rockfish	*S. helvomaculatus*
Mexican rockfish	*S. macdonaldi*
Redbanded rockfish	*S. babcocki*
Tiger rockfish	*S. nigrocinctus*
Stripetail rockfish	*S. saxicola*
Splitnose rockfish	*S. diploproa*
Shortbelly rockfish	*S. jordani*
Silvergray rockfish	*S. brevispinis*
Darkblotched rockfish	*S. crameri*
Redstripe rockfish	*S. proriger*
Sharpchin rockfish	*S. zacentrus*
Quillback rockfish	*S. maliger*

*Species for which CPUE data were analyzed. These species were caught in at least 10 of the 14 years of surveys.
†Species for which length frequencies were analyzed. These species had the highest CPUE values in 1980 and sufficient numbers in the late 1990s to make it possible to analyze patterns in time.

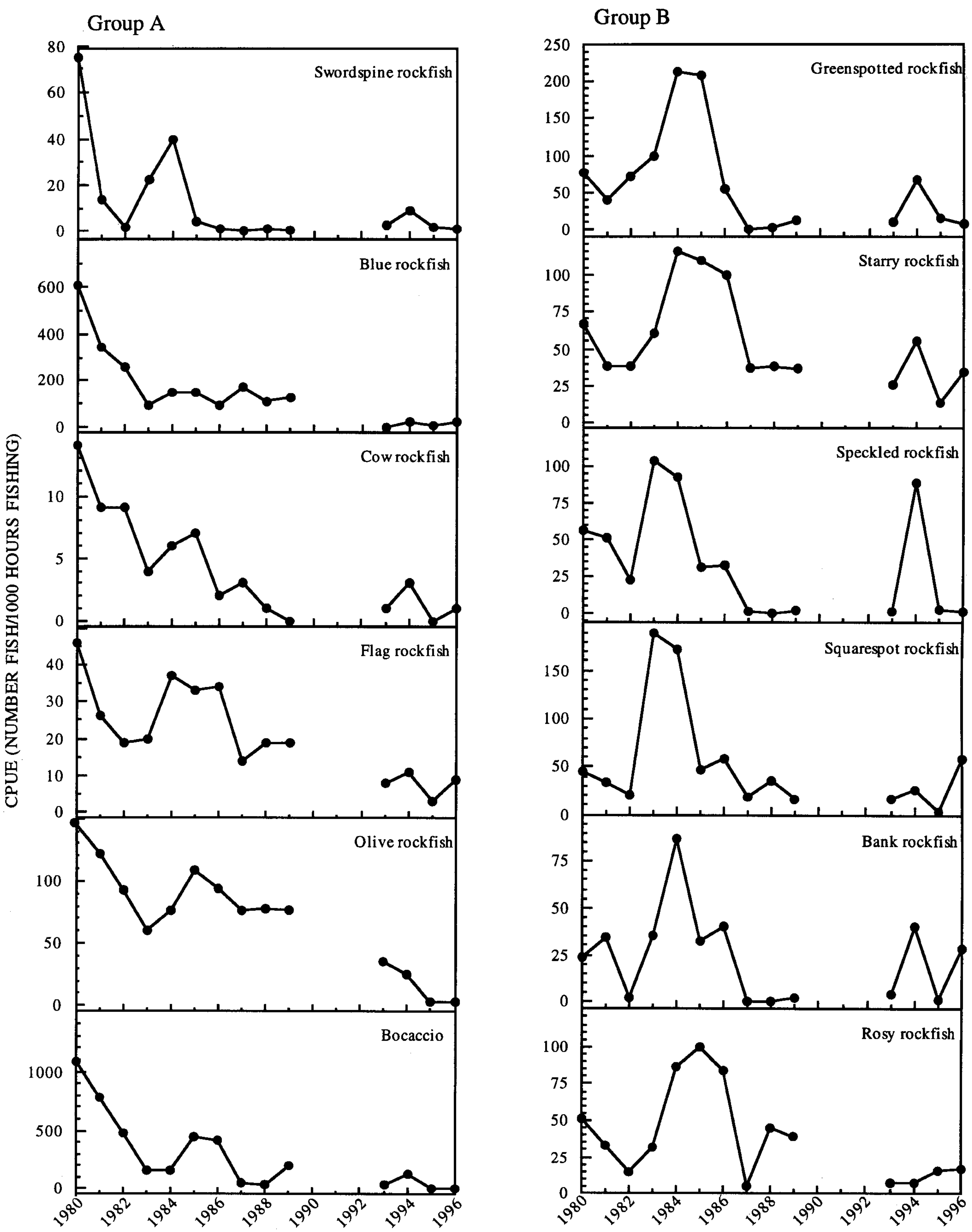


Figure 2. Catch per unit of effort versus year for each of the species in Groups A and B (see Methods).

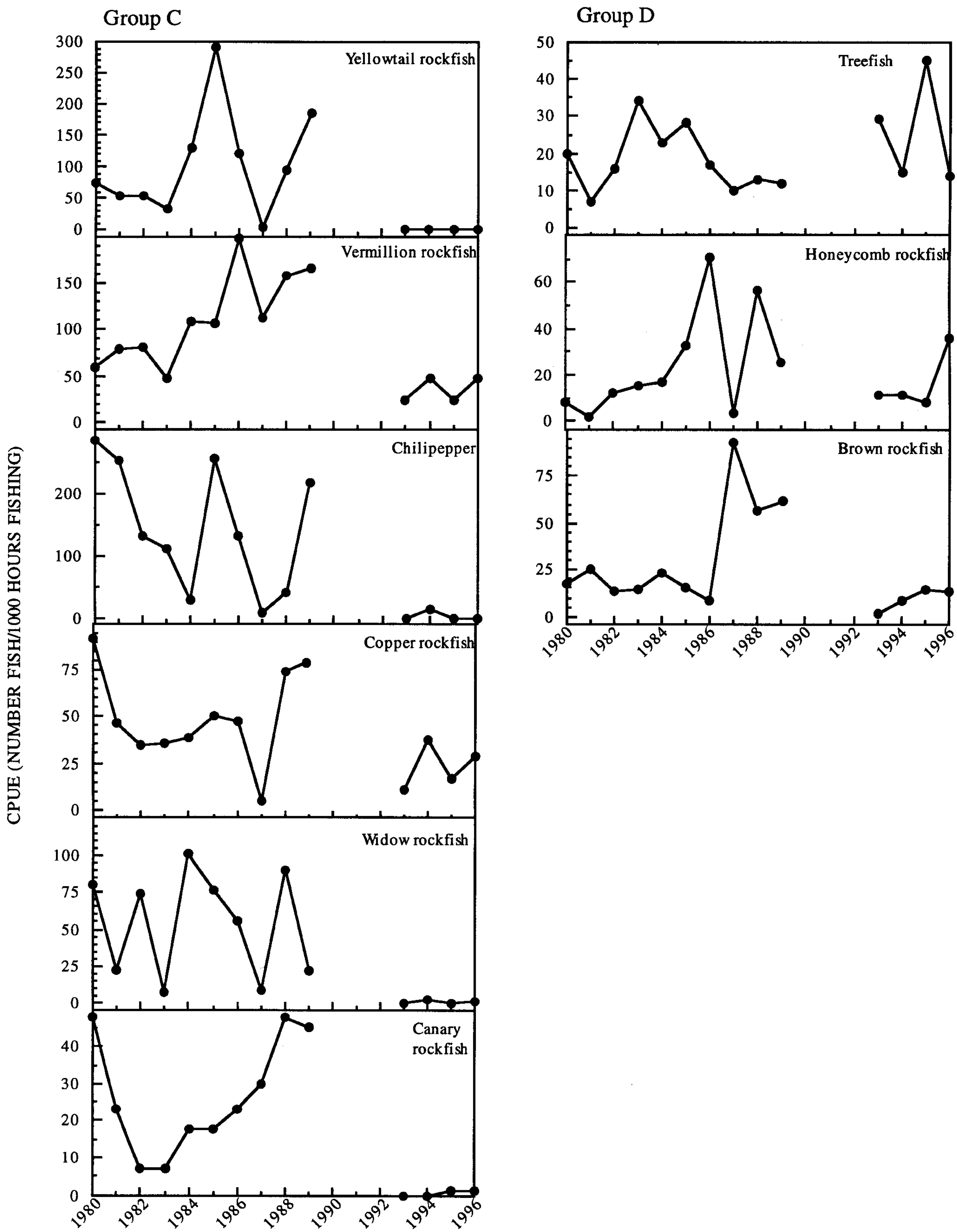
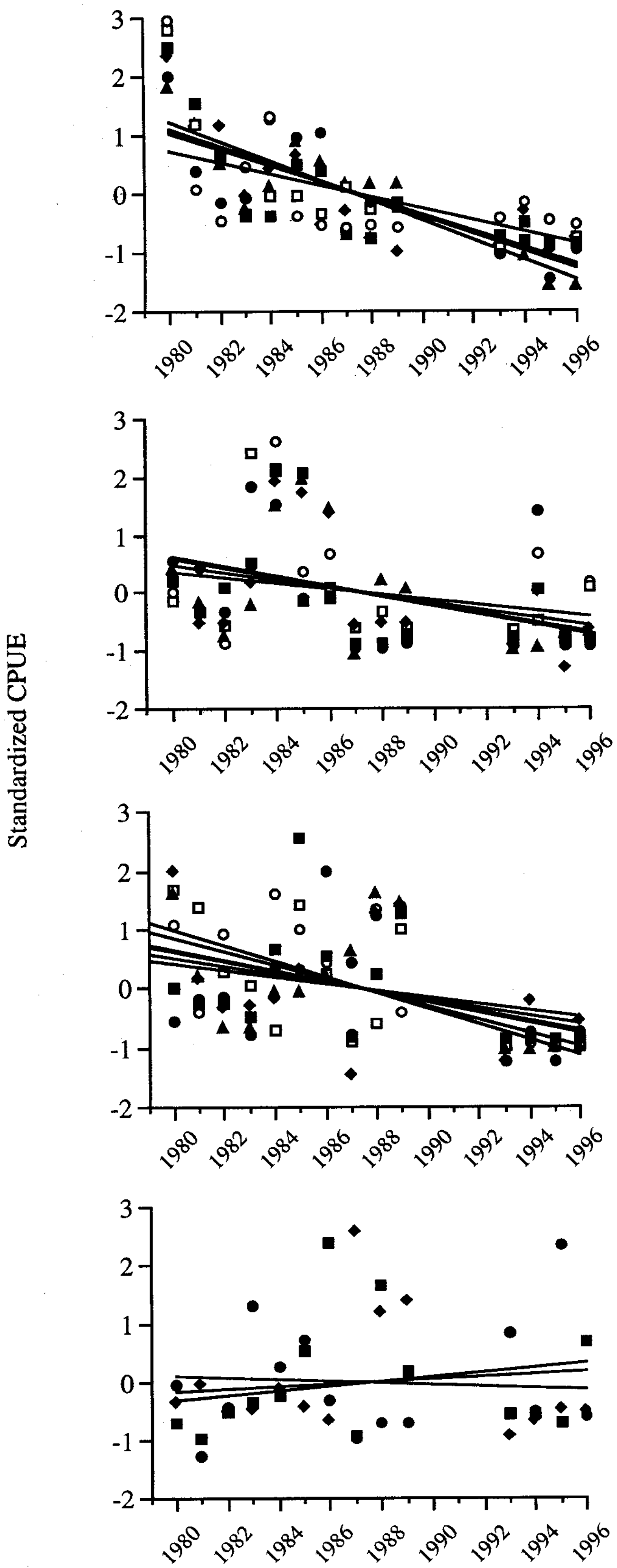


Figure 3. Catch per unit of effort versus year for each of the species in Groups C and D (see Methods).



Group A	Slope	r^2
■ Bocaccio	-0.14	0.56
□ Blue rockfish	-0.15	0.60
● Flag rockfish	-0.15	0.62
▲ Olive rockfish	-0.17	0.82
◆ Cowcod	-0.15	0.63
○ Swordspine rockfish	-0.10	0.29
mean slope= -0.14		

Group B		
■ Greenspotted rockfish	-0.08	0.20
□ Squarespot rockfish	-0.07	0.13
● Speckled rockfish	-0.08	0.18
▲ Rosy rockfish	-0.08	0.20
◆ Starry rockfish	-0.08	0.20
○ Bank rockfish	-0.05	0.07
mean slope= -0.08		

Group C		
■ Yellowtail rockfish	-0.07	0.14
□ Chilipepper	-0.13	0.51
● Vermilion rockfish	-0.05	0.08
▲ Canary rockfish	-0.09	0.22
◆ Copper rockfish	-0.08	0.19
○ Widow rockfish	-0.11	0.36
mean slope= -0.08		

Group D		
■ Honeycomb rockfish	0.02	0.01
◆ Brown rockfish	-0.02	0.01
● Treefish	0.04	0.05
mean slope= 0.01		

Figure 4. Linear regression on standardized CPUE data for the four species groupings. Slope and r^2 are given for each species, as well as mean slope for the group. CPUE was standardized for each species by subtracting the mean CPUE for the entire period from each yearly CPUE value and dividing that by the standard deviation of the entire period.

interested in the predictive ability of the regression model; we simply wanted a means to compare the patterns. Group A (the steadily declining group) had a mean slope of −0.14, and 5 of the 6 species had an r^2 greater than 0.5. Groups B and C both had average slopes of −0.08, indicating a decline, but very low r^2s, which reflected the variability in the patterns. Group D, as expected, showed no relationship.

The general decline shown by the 21 target species reflects declines in the underlying catch rate for almost all previously abundant species (fig. 5). The species with highest CPUE in 1996 (squarespot rockfish) would have ranked only 12th in 1980. Of the 20 top species taken in 1980, about 15 were at or near historically low CPUE levels by 1996. Particularly large declines occurred in all of the 10 most commonly taken species in 1980. The first-ranked bocaccio declined by 98.7%, second-ranked blue rockfish by 95.2%, and fourth-ranked olive rockfish by 83%. The most extreme declines were those of chilipepper (third-ranked), swordspine rockfish (eighth-ranked), and yellowtail rockfish (ninth-ranked), all of which were absent in the 1996 catch. The smallest catch reduction among the top 15 species in 1980 was the starry rockfish, which declined by 20%.

Species Composition

Species composition also changed over the course of the survey. Comparing the catch rates of the top 10 species in 1980 with those of 1996, we found only 4 species (blue, olive, copper, and starry rockfishes) in common (table 2). Most striking has been the rise in importance of dwarf species, particularly squarespot and honeycomb rockfishes. Previously of only minor importance, these ranked first and third in 1996.

The number of species taken also decreased during the course of the survey (fig. 6). During 1980, 37 species were caught, compared to 31 in 1996. Species richness dropped to a low of 24 in 1995. Notably missing in 1996 were a number of primarily northern species (yellowtail, canary, yelloweye, China, black, silvergray, and redstripe rockfishes).

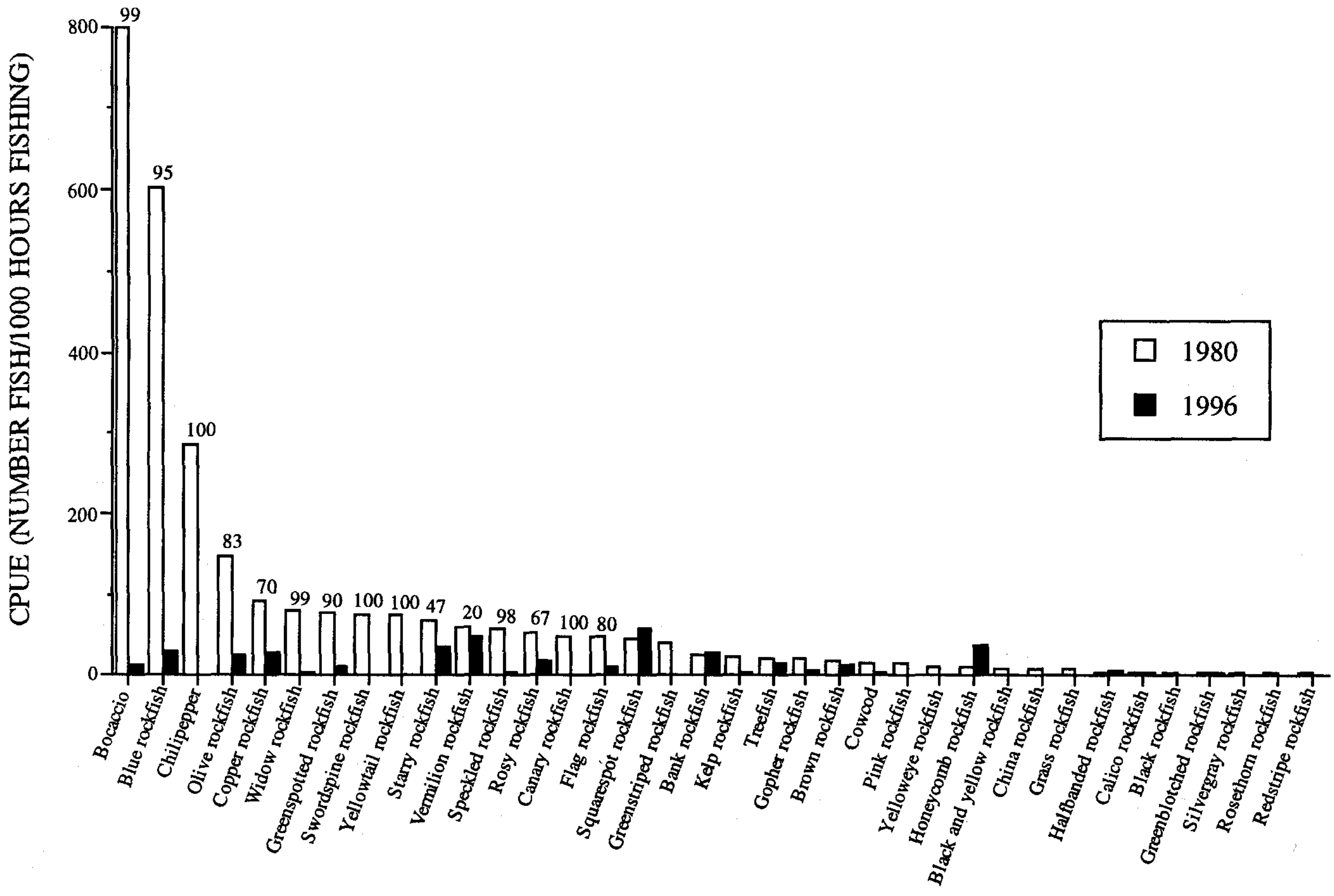


Figure 5. CPUE for 1980 (empty bars) and 1996 (filled bars) for all species in the MRFSS data set. Numbers above the bars are the percentage change from the period 1980 to 1996 for each of the top 15 species in 1980. Positive values indicate a decline over the period.

TABLE 2
Top Ten Species (on the Basis of CPUE) in 1980 and 1996

	Ranking			Ranking	
Top ten species caught in 1980	1980	1996	Top ten species caught in 1996	1996	1980
Bocaccio	1	12	Squarespot rockfish	1	16
Blue rockfish*	2	5	Vermilion rockfish	2	11
Chilipepper	3	30	Honeycomb rockfish	3	26
Olive rockfish*	4	8	Starry rockfish*	4	10
Copper rockfish*	5	7	Blue rockfish*	5	2
Widow rockfish	6	18.5	Copper rockfish*	6.5	5
Greenspotted rockfish	7	14	Bank rockfish	6.5	18
Swordspine rockfish	8.5	29	Olive rockfish*	8	4
Yellowtail rockfish	8.5	31	Rosy rockfish	9	13
Starry rockfish*	10	4	Treefish	10	20

*Species that were in the top ten during both years.

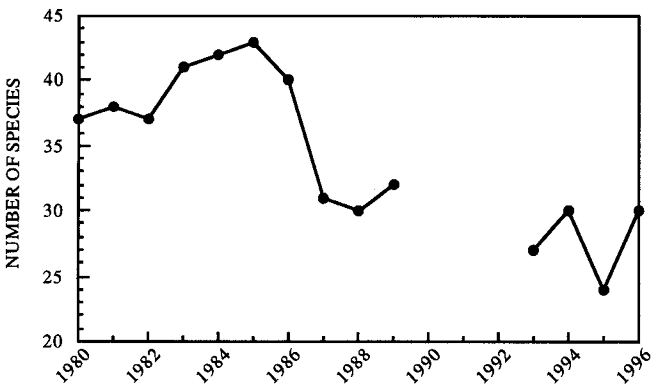


Figure 6. Number of species caught per year in the MRFSS data set.

Length-Frequency Analysis

Length-frequency histograms are presented for the top 11 species (figs. 7–12). Mean total lengths differed between the 1980s and the 1990s for 9 of 11 species (table 3). For 7 species, fishes averaged smaller in the 1990s. Decreases in mean lengths ranged from 1.1 to 5.6 cm, with the largest percentage drop for greenspotted rockfish (18%). Two species, blue rockfish and bocaccio, averaged larger in the 1990s, increasing 1.8 and 3.6 cm, respectively. For most of these species, decreased mean lengths reflected the removal of the larger size classes from the fishery rather than an increase in catches of smaller individuals. This was particularly evident for vermilion, widow, yellowtail, olive, greenspotted, and copper rockfishes and, to a certain extent, chilipepper.

Our data show that several of the fisheries always depended primarily on juveniles. This was particularly true for widow rockfish, but also for yellowtail and olive rockfishes. In the case of widow rockfish, the fishery targeted schools of 1- and 2-year-old fish during periods of good juvenile recruitment; adults were relatively rare in most years. By the 1990s, not only were few fishes of these species taken, but no more of the occasional adults that had been caught in previous years were evident.

By the 1990s, several other fisheries appeared to be dependent on juveniles. This was particularly so for vermilion rockfish, whose catch composition during the 1980s comprised primarily adult fish. By the mid-1980s, catches were an approximately even mixture of adult and immature fish. In the 1990s, however, catches, while still relatively robust compared to most other rockfish species, were composed almost entirely of juveniles.

The bocaccio fishery also appeared to have been at least partially linked to years with successful year classes, as mean sizes tended to increase over 4- or 5-year periods (1980–83, 1985–89) driven by years with good juvenile recruitment. This was most noticeable in 1984, when a number of very small individuals entered the fishery. This year class was fished until at least 1988 and probably longer. No such year class was evident in the 1990s.

DISCUSSION

There seems little doubt that the precipitous declines in rockfish catches in the Southern California Bight between 1980 and 1996 reflect much-reduced rockfish populations throughout southern California. This statement derives not only from this survey, but also from our direct observations from a research submersible. It is likely that these population declines result from both long-term, essentially unregulated, overfishing of adults and subadults, as well as from poor juvenile recruitment. The latter may be caused by adverse oceanographic conditions or recruitment overfishing.

While there have been large overall declines in catch rates of most rockfish species, the data show substantial year-to-year variability. In particular, we note two steep drops in CPUE during the periods 1981–83 and 1986–87 (fig. 1). These short-term fluctuations may result from the filter we used to qualify a CPFV trip for inclusion in the analyses. We included only vessels that had caught

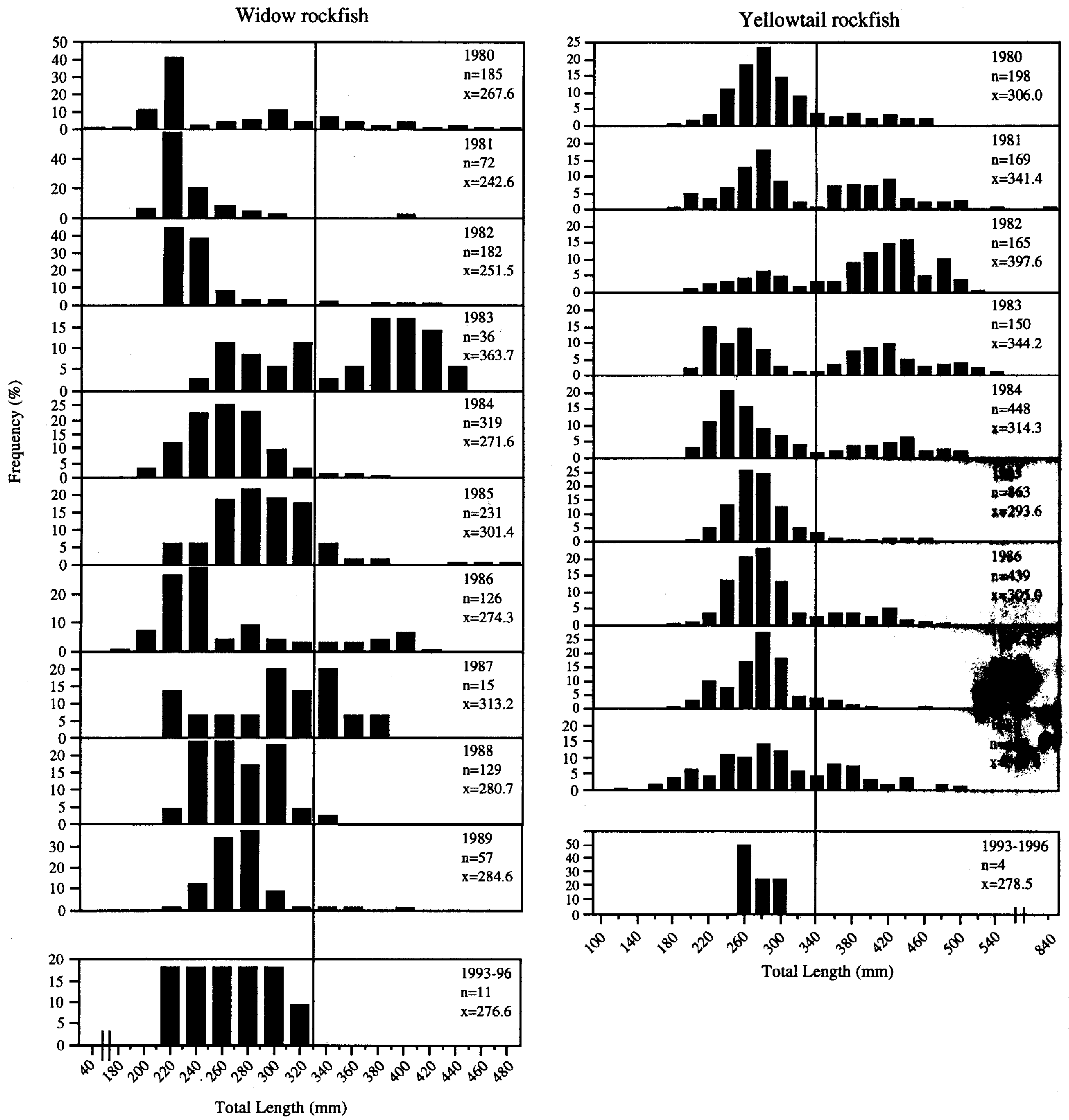


Figure 7. Length-frequency histograms for widow and yellowtail rockfishes. Lengths are total lengths divided into 20 mm bins. Sample size and mean length are given for each year. When sample size for a given year was less than 10, that sample was combined with the following year. Means in these cases are for the combined data. Vertical lines indicate the length at which 50% of the individuals are mature (values taken from Wyllie Echeverria 1987 and Love et al. 1990).

at least one rockfish. This cutoff may have been too lenient and may not have allowed us to detect vessels shifting effort away from rockfish. We chose this minimal filter because CPUE was so low by the 1990s that even vessels fishing over rockfish habitat were catching only a few rockfish. Nonetheless, these shorter-term fluctuations in CPUE do not detract from the overall longer-term decline.

There is considerable evidence that since the late 1970s and early 1980s rockfish juvenile recruitment has been generally poor in southern California. Waters in the Southern California Bight have warmed and upwelling

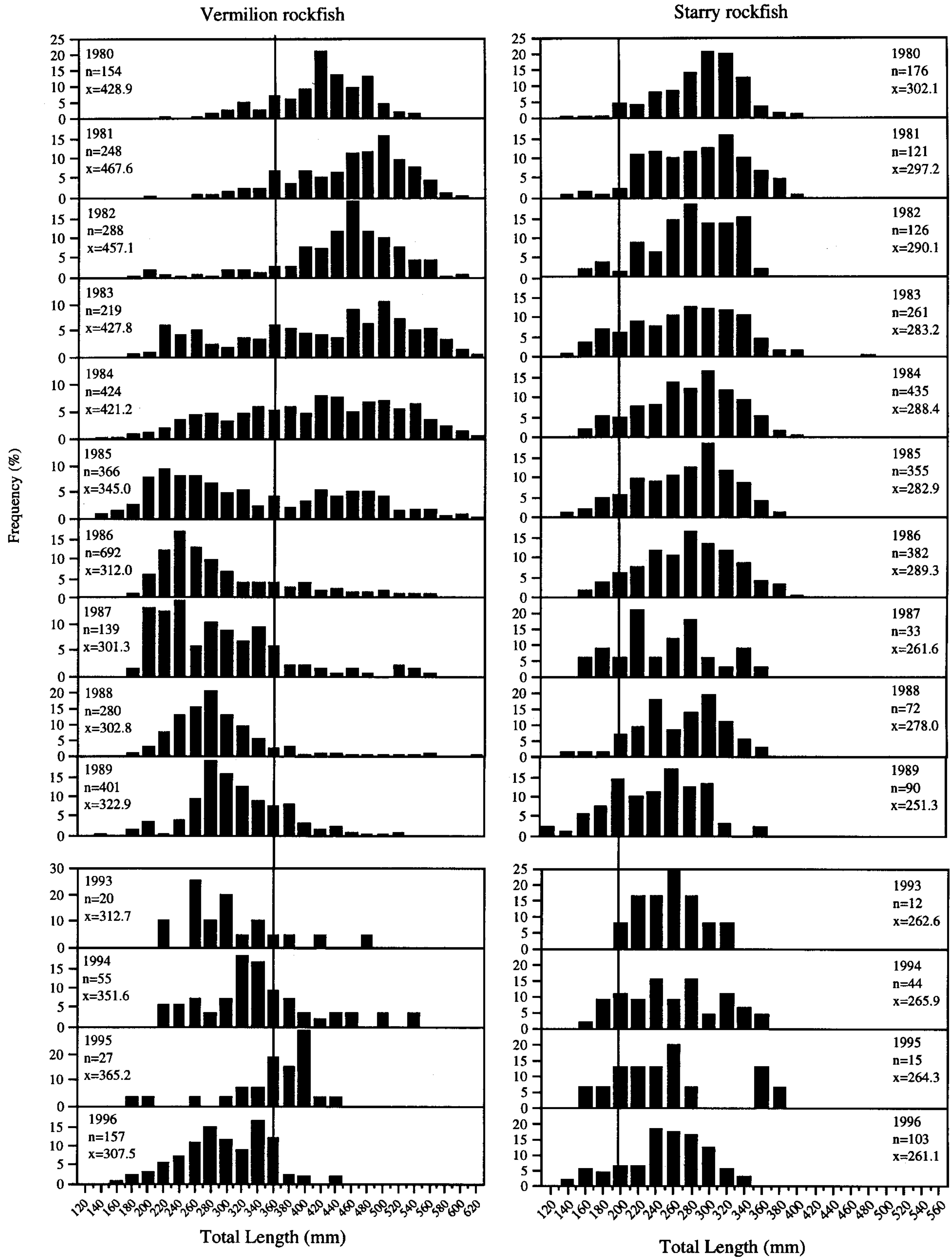


Figure 8. Length-frequency histograms for vermilion and starry rockfishes. Lengths are total lengths divided into 20 mm bins. Sample size and mean length are given for each year. When sample size for a given year was less than 10, that sample was combined with the following year. Means in these cases are for the combined data. Vertical lines indicate the length at which 50% of the individuals are mature (values taken from Wyllie Echeverria 1987 and Love et al. 1990).

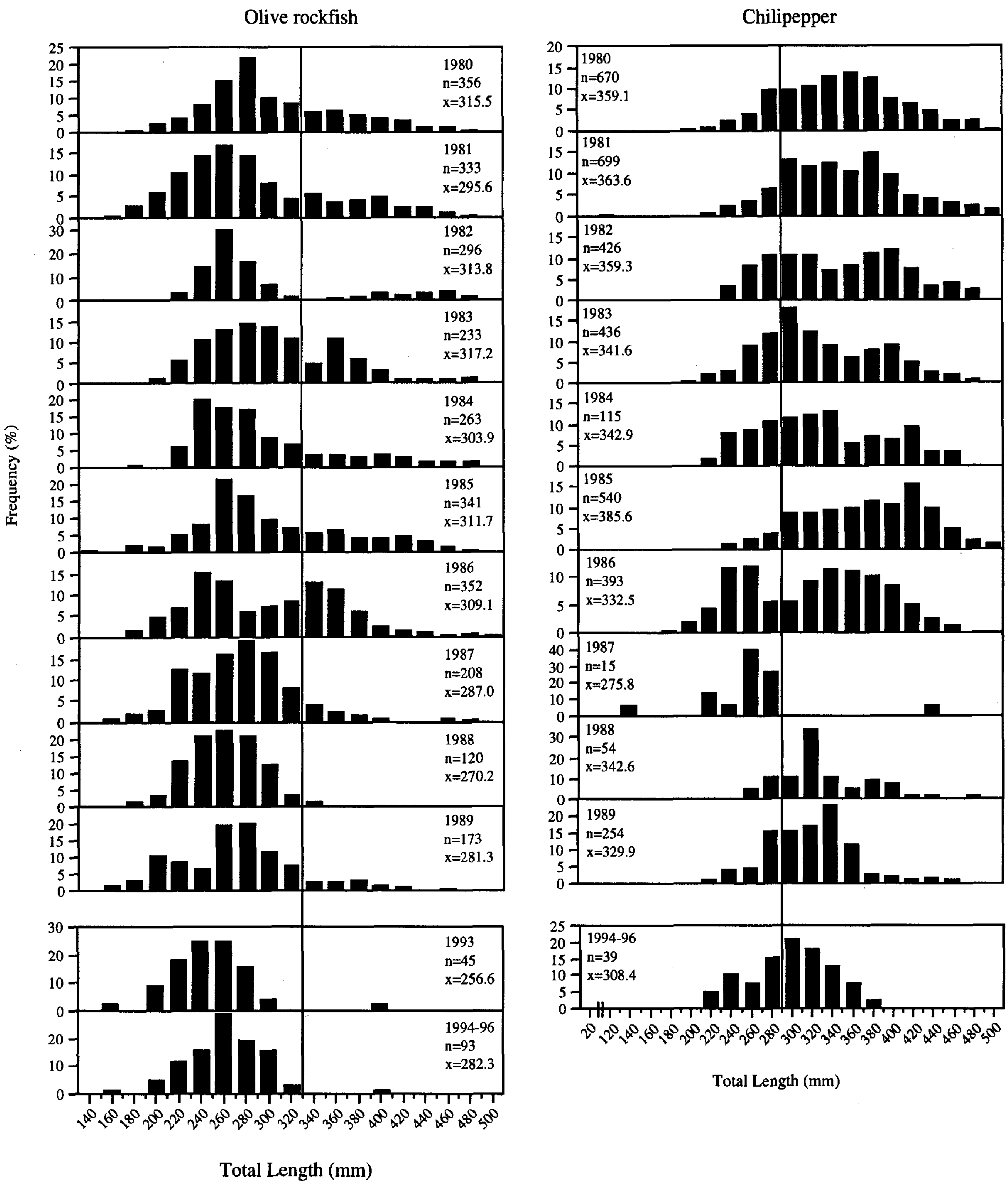


Figure 9. Length-frequency histograms for olive rockfish and chilipepper. Lengths are total lengths divided into 20 mm bins. Sample size and mean length are given for each year. When sample size for a given year was less than 10, that sample was combined with the following year. Means in these cases are for the combined data. Vertical lines indicate the length at which 50% of the individuals are mature (values taken from Love and Westphal 1981, Wyllie Echeverria 1987, and Love et al. 1990).

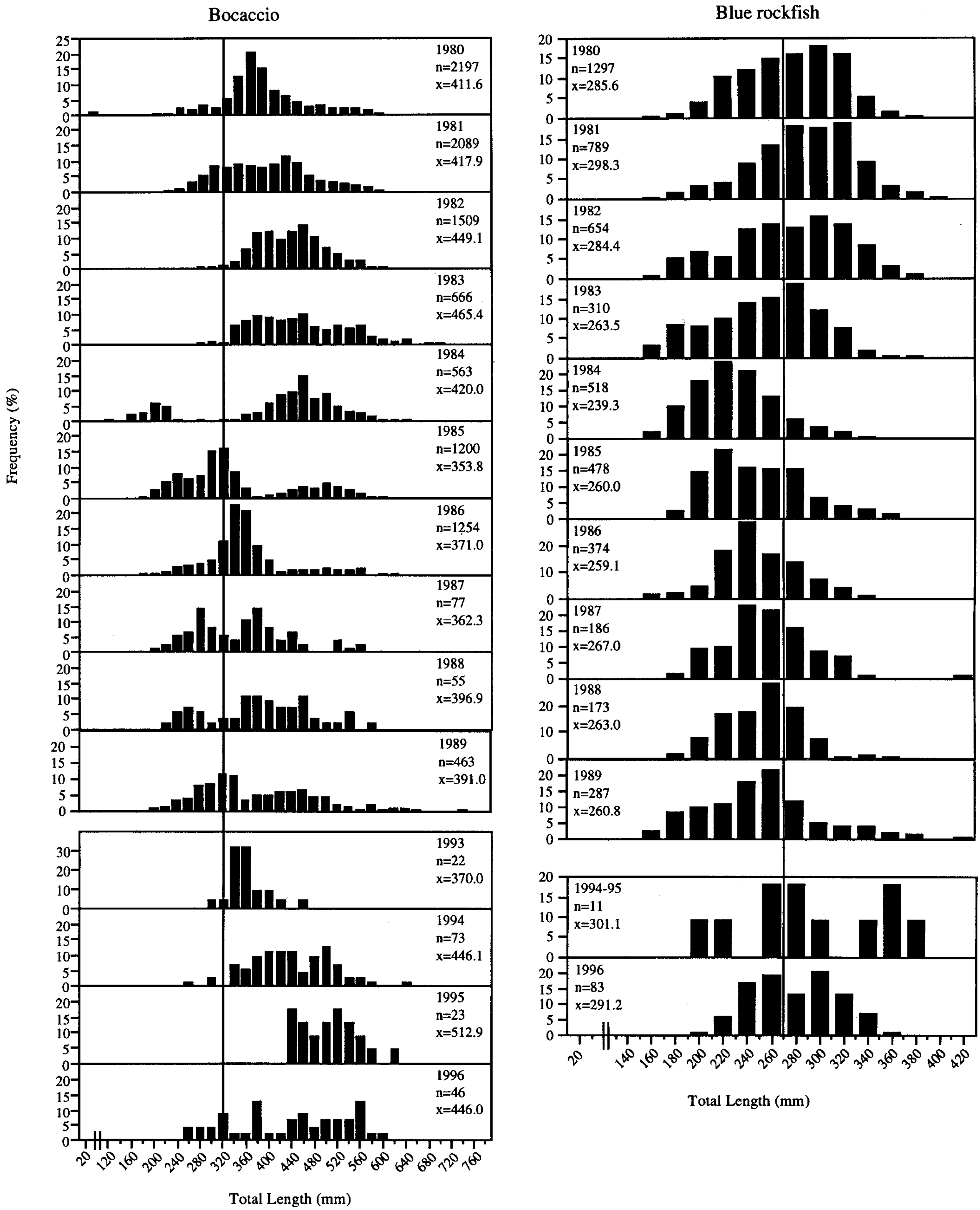


Figure 10. Length-frequency histograms for bocaccio and blue rockfish. Lengths are total lengths divided into 20 mm bins. Sample size and mean length are given for each year. When sample size for a given year was less than 10, that sample was combined with the following year. Means in these cases are for the combined data. Vertical lines indicate the length at which 50% of the individuals are mature (values taken from Wyllie Echeverria 1987 and Love et al. 1990).

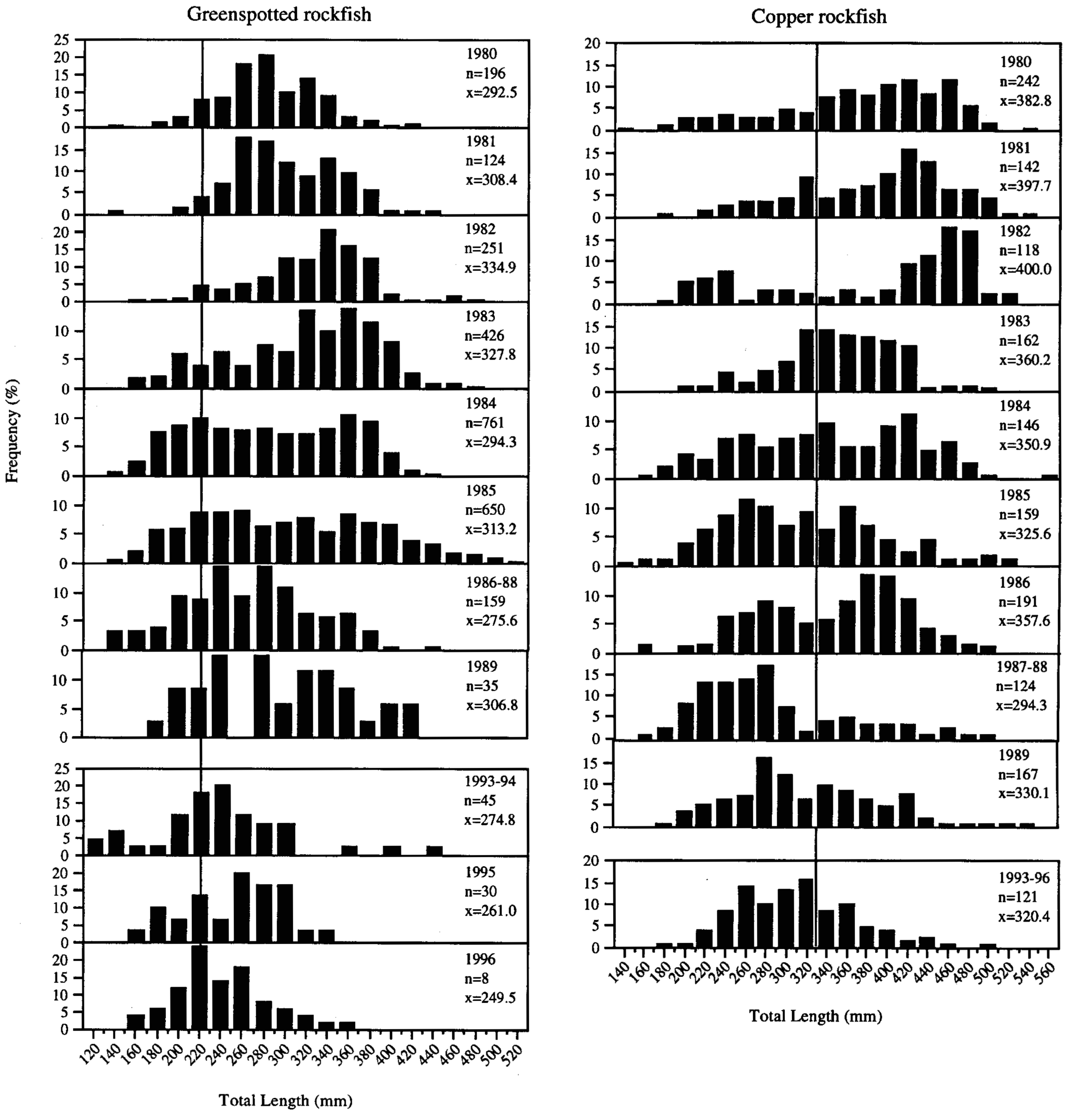


Figure 11. Length-frequency histograms for greenspotted and copper rockfishes. Lengths are total lengths divided into 20 mm bins. Sample size and mean length are given for each year. When sample size for a given year was less than 10, that sample was combined with the following year. Means in these cases are for the combined data. Vertical lines indicate the length at which 50% of the individuals are mature (values taken from Wyllie Echeverria 1987 and Love et al. 1990).

has declined, leading to reduced zooplankton production (Roemmich and McGowan 1995). In turn, larval and juvenile survival of many marine fishes has been reduced (Holbrook and Schmitt 1996). Studies of pelagic juvenile rockfishes have shown steep declines in central and northern California (S. Ralston, pers. comm.), and pelagic juveniles are relatively rare in southern California (M. Nishimoto, pers. comm.).

Additional evidence for poor recruitment comes from the sharp declines in catches of such species as widow and yellowtail rockfishes in this study. In southern California, most of the recreational fishery for these more

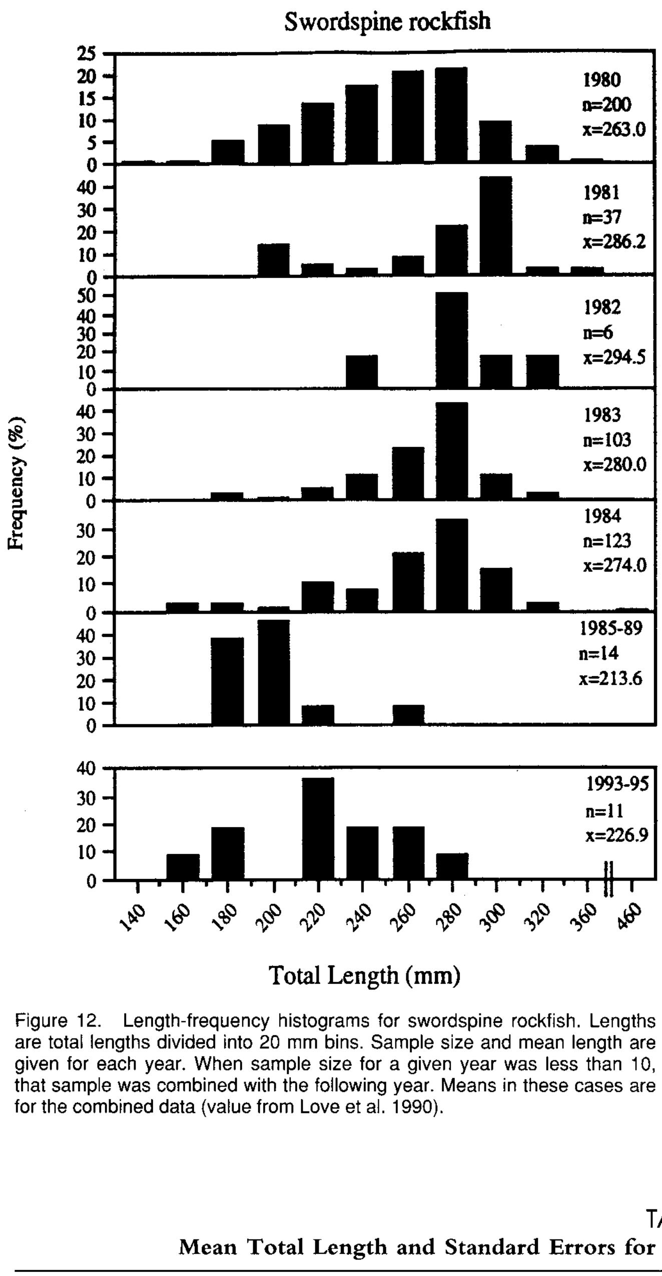


Figure 12. Length-frequency histograms for swordspine rockfish. Lengths are total lengths divided into 20 mm bins. Sample size and mean length are given for each year. When sample size for a given year was less than 10, that sample was combined with the following year. Means in these cases are for the combined data (value from Love et al. 1990).

northerly species targets young, often young-of-the-year, fishes. Successful fisheries for these species depend on relatively strong young-of-the-year cohorts, as was evident for widow rockfish in the early 1980s and perhaps again in 1986. That few widow and no yellowtail or canary rockfishes (another northern species that previously showed strong juvenile recruitment) were taken by 1996 strongly implies that there has been relatively little recruitment of these species. Our submersible surveys in central and southern California confirm the very low recruitment of these species in the Southern California Bight.

The MRFSS data also strongly imply that relatively cool-water rockfishes have declined in abundance in the Southern California Bight. In 1980 a number of primarily northern species such as yelloweye, China, black, silvergray, and redstripe rockfishes were at least occasionally taken in southern California. These species were absent in 1996. It is likely that these species had recruited during colder-water periods, and that little or no recruitment had taken place since. In addition, recruitment of even relatively warm-tolerant species, such as blue rockfish and olive rockfish, has vastly declined during this period, as reflected both in their catches and in a number of nearshore surveys (Stephens et al. 1984, 1986; Holbrook and Schmitt 1996).

Conversely, catches of a few rockfish species either increased or remained fairly constant, perhaps because of more successful juvenile recruitment. These species included either warmer-water or more cosmopolitan taxa such as treefish and honeycomb, vermilion, and brown rockfishes. The weakening influence of the California Current and a strengthening of poleward flow (Roemmich and McGowan 1995) may have caused their numbers to increase.

TABLE 3
Mean Total Length and Standard Errors for Eleven Species of Rockfish, 1980–89 and 1993–96

	1980–89			1993–96		
Species	Mean length (mm)	SE	*N*	Mean length (mm)	SE	*N*
Blue rockfish	274.1	0.6	5,066	292.4	4.8	94*
Bocaccio	409.2	0.9	10,073	445.2	6.5	164*
Chilipepper rockfish	355.8	1.0	3,602	308.4	6.5	39*
Copper rockfish	356.7	2.2	1,451	320.4	5.3	121*
Greenspotted rockfish	308.0	1.4	2,602	251.7	4.7	125*
Olive rockfish	304.0	1.2	2,675	273.9	3.1	138*
Starry rockfish	286.3	1.2	2,051	262.7	3.7	174*
Swordspine rockfish	270.2	1.8	483	226.9	9.6	11*
Vermilion rockfish	368.8	1.9	3,211	323.3	4.1	259*
Widow rockfish	277.7	1.3	1,352	276.6	10.1	11 ns
Yellowtail rockfish	311.9	1.3	2,986	278.5	10.6	4 ns

*$p < 0.001$
Means for the year groups were tested with Student's t-tests when variances were equal. When variances were unequal (chilipepper, copper rockfish, olive rockfish, and vermilion rockfish) a Welch ANOVA was used (see Methods).

Along with the large decreases in numbers taken, the sharp declines of adults in many of the fisheries are particularly disturbing. Some of the fisheries (e.g., widow and yellowtail rockfish) never depended on mature fishes and probably resulted from southerly transport of larvae from larger populations to the north. But the almost total absence of adult vermilion rockfish, a fishery formerly dependent on adults, is graphic evidence of overfishing.

Over time, relatively small species have assumed greater importance in the catches. To a certain extent, this is probably due to more successful juvenile recruitment of some small species, as mentioned above. But it also almost certainly reflects a major decrease in the availability of larger species. It is apparent from interviews with CPFV operators and from our own submersible observations that some reefs now contain essentially no larger rockfishes. An example of this is Lausen Knoll (also called the 14-Mile Bank), located about 22 miles south of Newport Beach. This reef area has been intensely fished for rockfishes by recreational and commercial anglers for many years. During 1996, we surveyed over 2 km of excellent rockfish habitat at Lausen Knoll and found only two rockfishes larger than 25 cm. At the same time, squarespot rockfish and other dwarf rockfishes were abundant. The rise in the importance of smaller species in the recreational catches, particularly of squarespot rockfish, may be a direct result of this intense harvesting. From our submersible surveys, we have noted that heavily fished reefs often have large numbers of small fishes, particularly squarespot and pygmy rockfishes (*S. wilsoni*). It is possible that removing most of the large, predatory rockfishes has increased the survival of these dwarf species.

Historically, rockfish populations have not quickly rebounded once management policies are set in place (Leaman and Stanley 1993). Thus once southern California rockfish populations have been depleted, it may prove difficult for them to rebuild. One factor is that many rockfish species appear to have highly variable juvenile recruitment (Archibald et al. 1983; Ralston et al. 1996), with strong cohorts occurring as rarely as every 10–15 years. Thus there may have to be a change in the present oceanographic regime off southern California, now characterized by warm temperatures and low productivity, before strong cohorts occur. Although it is unclear how long the present regime will last, some evidence points to a shift within the next 10 years (Ware 1995; MacCall 1996). It is more troubling, however, that in some cases, such as that of bocaccio, the absolute magnitude of stronger cohorts is diminishing (Ralston et al. 1996), implying recruitment overfishing.

In the Southern California Bight, there have been no quotas on the commercial rockfish harvest and, until recently, no limitations on commercial rockfish harvesting. Currently, the only commercial regulation is a ban on gill net fishing in waters within three miles of the mainland and one mile of the offshore islands. In the recreational fishery, there is a bag limit of 15 fish per day per angler. A problem in both industries is that except in very shallow water, fishes cannot be returned alive, making size limits ineffective.

It is probably necessary to lower overall fishing pressure to maintain those adult populations that still exist until oceanographic conditions are more favorable to successful juvenile recruitment. Only by reducing the rockfish catch of both recreational and commercial vessels can this be achieved. And while the commercial industry is certainly responsible for much of the population decline, additional responsibility must rest with CPFVs. This is true because, while commercial vessels often stop fishing an area when it is economically nonviable, recreational vessels do not. Because the quality of rockfish fishing has gradually eroded over many years, we have noted that many recreational anglers now expect fewer, smaller fish. This is exemplified by the importance of squarespot rockfish and other small species in the catch. On some trips most of the rockfish catch now comprises either dwarf or small species (such as squarespot, honeycomb, or rosy rockfishes) or juvenile rockfishes. Thus CPFVs tend to continue fishing reefs that harbor few, if any, larger rockfishes, thereby preventing a rebound in populations.

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