Status of the Pacific Mackerel Resource During 1997 and Management Recommendations for the Fishery

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SUMMARY

Based on a California Department of Fish and Game (CDFG) projected biomass estimate of 91,200 metric tons for July 1, 1997, the recommended commercial fishery quota for the 1997/98 fishing season is 22,000 metric tons. Age-specific abundance for 1996 was estimated using output from a stock assessment model called ADEPT and certain assumptions about growth and fishing mortality during the first half of 1997. In this year's assessment, abundance estimates made by ADEPT were expanded back in time to cover the 68-year period of 1929 through 1996. The commercial fishery quota recommendation is based upon the prescribed harvest formula for Pacific mackerel that is specified in the California Fish and Game Code.

Several sources of information are available for the Pacific mackerel stock, all of which suggest a smaller biomass than was present in the 1980's. Landings from both California and Ensenada, Mexico have sharply decreased and catch rates from the southern California Commercial Passenger Fishing Vessel (CPFV) fleet have declined. Fishery-independent indices of abundance from aerial spotter observations and California Cooperative Oceanic Fisheries Investigations (CalCOFI) ichthyoplankton surveys show similar trends.

The 1997 biomass estimate is higher than last year's estimate of 47,160 metric tons because data added to the model this year increased abundance for fish of 1994 and older year classes (age 2+). This year's results indicate there were more fish in the older year classes than estimated in previous assessments.

THE PACIFIC MACKEREL FISHERY

Background

Pacific mackerel (*Scomber japonicus*) is a trans-boundary stock supporting commercial fisheries in the U.S. and Mexico. Landings of mackerel in both countries have declined in recent years, with the principal causes being low biomass and lack of abundance on the traditional fishing grounds in southern California waters. Also, cannery closures since 1993 may have reduced demand for Pacific mackerel, possibly leading to lower landings.

Ninety-three percent of California landings during 1996 were made by approximately 17 purse seine vessels based in the Los Angeles area, commonly known as the "wetfish" fleet. Twelve additional wetfish vessels based in Monterey accounted for the remaining 7 percent of landings in northern California.

During recent years, we suspect the stock has more fully occupied the northernmost portions of its range in response to a warm oceanographic regime in the northeast Pacific Ocean. Schools have been found as far north as British Columbia, Canada.

The Pacific mackerel fishing season is defined as the 12-month period from July 1 through June 30 of the following calendar year. The 1995/96 fishing season ended June 30, 1996 with landings of 7,613 mt, well short of the 9,796 mt quota and ranking as the lowest season total since the commercial fishery reopened in 1976. It was also the fourth consecutive season that the quota was not filled.

Annual California landings based on calendar year have declined since 1988 when 42,220 mt were landed (Table 1). In 1996 the Pacific mackerel fishery took 10,284 mt, slightly above the 19-year low of 8,666 mt landed by the wetfish fleet in 1995. The increase in 1996 is largely attributable to a surge in landings during July, when large fish were readily available. Ex-vessel value of the 1996 Pacific mackerel fishery totaled $1.51 million. The wetfish fleet targets several other schooling species in addition to Pacific mackerel, and mackerel revenues during 1996 were well below that of sardine ($2.5 million) and squid ($29.5 million).

When the 1996/97 season opened on July 1, an abundance of large mackerel off San Clemente and Santa Catalina Islands resulted in increased landings compared to preceding months. The 3,000 mt taken in July 1996 represent the highest monthly total since July 1993. Due to high quality, the price paid to fishermen at the opening of the 1996 season increased to approximately $181 per mt, well above the average price of $121 per mt for the year. Twenty-seven percent of the 8,700 mt quota for the 1996/97 season was taken during the first month. Landings for the remainder of the season were much lower, averaging about 725 mt per month. This was largely attributable to significant wetfish fleet participation in lucrative winter squid and summer tuna fisheries, which reduced fishing effort upon mackerel during those periods.

On March 12, 1997 the season quota was filled and the Pacific mackerel directed fishery was closed for the first time since 1985, although regulations allowed for incidental landings of mackerel mixed with other wetfish species. Following the closure, by-catch tolerance was limited to 35% mackerel by weight, resulting in incidental mackerel landings of about 545 mt between the closure date and the end of April 1997. Incidental landings were allowed to continue at a 35% tolerance through the close of the 1996/97 season on June 30, 1997.

POPULATION ESTIMATES

Assessment Model

We used a modified virtual population analysis (VPA) stock assessment model called ADEPT (Jacobson 1993) to estimate biomass of Pacific mackerel that employs both fishery dependent and independent data to estimate abundance. Biomass estimates are adjusted by the model to match trends in fishery independent indices of relative abundance.

Based on a VPA tuning algorithm (Gavaris 1988), ADEPT has been used by California

Department of Fish and Game to assess Pacific mackerel during the past three years (Jacobson et. al., 1994; Barnes and Hanan, 1995; Barnes et. al., 1997). A conventional VPA back-calculates age-structured biomass estimates utilizing catch-at-age data, weight-at-age data, natural mortality estimates, and fishing mortality estimates for the most recent year (terminal F). ADEPT improves upon a conventional VPA by finding the fishing mortality estimate for the last year that provides the best statistical fit (lowest log-scale sums of squares) between VPA output and survey indices of relative stock abundance including spotter pilot sightings, CalCOFI larval data from two geographic areas, and recreational fishery catch-per-unit-effort. The crux of the estimate lies in the model's ability to estimate terminal age-specific fishing mortality rates based upon the survey indices, essentially using them to tune the conventional VPA output.

We used the ADEPT model to calculate biomass estimates through the last quarter of the 1996 calendar year. We then projected an estimate of biomass for July 1, 1997, based upon: 1) number of Pacific mackerel estimated to comprise each year class during quarter four of 1996; 2) assumptions for natural (M=0.5) and fishing mortality through quarters one and two of 1997; and 3) estimates of age-specific growth.

Key Changes to the 1997 Assessment

Several important changes were made to improve our assessment during 1997. Most significantly, the span of years was extended back in time to incorporate all available data (Prager and MacCall, 1988) so that abundance estimates made by ADEPT cover the 68-year period of 1929 through 1996. Previous assessments using ADEPT included the years 1978 through 1995. The longer time series made possible several other improvements to the assessment such as the inclusion of fishery-dependent data (catch information) for years prior to 1951. However, the additional years did not impact estimates of biomass in recent years because there were no fishery-independent data (survey indices) for those years.

Modifications and additions were made to some indices of abundance. To include the earlier years in the assessment, we reduced the number of age groups in the model by one (maximum age group was 6+ in the 1996 assessment and 5+ for the present assessment) to conform with published catch-at-age data for earlier years. Further, we created a new tuning index based on icthyoplankton surveys in Mexican waters off Baja California. Since Pacific mackerel spawning grounds are centered in Baja California waters, the new larvae index provides information not available from the standard CalCOFI Southern California Bight survey grid and is particularly valuable when mackerel abundance is low. Our current larvae indices for southern California and Baja California were calculated based on annual proportion of positive tows instead of annual larvae densities used in the 1996 assessment. Another important change to 1997 survey data was recalculation of the CPFV (Commercial Passenger Fishing Vessel, or partyboat) index, which allowed us to extend the survey time series back to 1957. Finally, we programmed ADEPT to estimate parameter exponents for each index to account for non-linearity between the indices and biomass.

Catch-at-age estimates for 1996 were calculated using a new data source not previously available. For the first time, size and age data from Ensenada port sampling were provided by Instituto Nacional de la Pesca (INP). We used the Ensenada data to help estimate catch-at-age for the Mexican fishery during 1996. For earlier years, port sample data were not available from INP and we assumed quarterly age composition of Mexican landings reflected those estimated for the southern California fishery each year.

The objective function was used to estimate fishing mortality rate and other parameters in ADEPT and was changed this year from log-likelihood to a simpler but similar sums-of-squares approach. This did not significantly affect model output, but eliminated the need to specify sample size in calculating the fit to the larvae proportion-positive indices. Also, model solutions that minimize sums-of-squares between observed and predicted were intuitively easier to understand and explain.

Input Data

Catch

Prager and MacCall (1988) compiled landings data annually for the years 1929 to 1977, which we combined with quarterly CDFG landings data for years 1978 through 1996. Most data prior to 1978 were taken from Prager and MacCall (1988), although we supplemented those data with official landings data from historical CDFG sources. Landings and age composition prior to 1978 were not always reported by month or quarter, therefore available data from adjacent years or quarters were used to estimate missing data. A time series of quarterly tons landed was constructed assuming that: a) age composition was constant throughout the year; and b) average seasonal catch distribution during the 1950's and 60's was used to represent the proportional catch by season for the years 1929 through 1977.

In the absence of quarterly catch data, the annual age composition provided by Prager and MacCall (1988) was used to calculate values based on the tons landed in each quarter and each year's age composition. Also, no age composition or weight-at-age data were available for some quarters of very low catch during 1969-1974, so we substituted mean values from preceding years. The model adjusts catch in numbers of fish proportionally by age so the sum (numbers x weight) for all ages equals total tons landed. Tons landed from all fishery segments since 1978 were included (e.g., southern California recreational; Ensenada commercial; northern California commercial; and southern California commercial). Mexican landings prior to 1984 were unknown, but thought to be minor and not included in our analysis. Also, recreational catches prior to 1978 were not included in our analysis.

Random stratified port sampling was conducted by CDFG during nearly all years in the time series, with the exception of a few years of very low landings, noted above. For the first time, similar data from a sampling program conducted by INP was available for the 1996 Ensenada fishery. These two sampling programs provided data on fish length, weight (Figure 1 and Table 2), maturity and age composition of commercial landings (Figure 2). Ages were assigned to individual specimens by examining and counting otolith annuli. Unfortunately, sample sizes for the Ensenada data were quite low, so we used the weighted average of samples taken in Ensenada and California to estimate the 1996 Ensenada quarterly age composition. Because quarterly catch data is summed among fisheries and input as one value, biological information (i.e. weight at age) for 1996 were determined by proportionally weighting the California and Mexico data according to the contributed fraction of total catch. For years prior to 1996, only biological data from the CDFG sampling program was available, and we assumed that size and age compositions for all landings did not differ from those obtained from the southern California commercial landings.

Aerial Observations

Pilots employed by the wetfish fleet to locate Pacific mackerel schools reported data for each flight on standardized logbooks and provided them under contract to National Marine Fisheries Service, Department of Commerce (NMFS). Raw logbook data were compiled and analyzed based on a delta log-normal model (Lo et al. 1992) to produce an annual (calendar year) spotter index of relative abundance for 1963-1996 (Figure 3). We used the 1963 to 1996 time series in the 1997 stock assessment, unlike previous Pacific mackerel assessments where the time series did not extend backward beyond 1980.

CPFV Catch-Per-Unit-Effort

California Fish and Game Code requires CPFV skippers to provide records of catch and effort data to CDFG. As with spotter pilot data, we generated an index of relative abundance by calculating annual CPUE estimates for the time period of 1957 through 1996. For this assessment, we defined CPUE as catch of mackerel per passenger in southern California, unlike the 1996 assessment where effort was defined as total number of boat trips and CPUE was calculated as fish per boat trip. Utilizing this unit of effort allowed addition of several years to the time series with no significant change in previously identified trends (Barnes et al. 1997). A comparison of commercial and recreational length composition data (Barnes et al. 1997) suggests that CPFV catch is composed mostly of older fish; therefore CPUE data from this source may be used as a tuning index for ages 2+ prior to 1993. In more recent years, the recreational fishery took even older fish, ages 3+. To account for the difference, we altered the age-specific fishery selectivities used in the index between 1992 and 1993. The CPUE time series demonstrates a declining trend since the late 1980's, which is consistent with other information (Figures 3 and 4). The model output closely fits the CPFV data, although the relationship is non-linear. An index exponent of 0.3 gave the best fit because the decline in biomass was greater than changes in catch rate.

CalCOFI (Southern California) Larvae Index

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) research program was founded in the early 1950's to study the California Current and organisms that live in it. Principal CalCOFI members over the past five decades have included Scripps Institution of Oceanography, NMFS Southwest Fisheries Science Center, and CDFG.

CalCOFI conducted quarterly plankton surveys in the Southern California Bight using both bongo (CALBOBL) and CALVET plankton nets; bongo nets captured Pacific mackerel larvae which were used in our assessment. Based on preliminary runs, we assumed a linear relationship between proportion positive (larvae caught) bongo tows and size of adult spawning stock. The modeled relationship used numbers of fish at age, fecundity at age (eggs per gram), weight at age, maturity at age, spawning frequency at age, and maturity ogives (Dickerson et al. 1992) to estimate larval abundance (in terms of proportion positive). We compiled CalCOFI data for quarters two and three of each year from 1951-1995 and calculated an annual index of proportion positive net tows for the Southern California Bight (Figure 5). Data from all years was used in our stock assessment and the fit of the data to model output improved significantly over previous assessments.

In annual assessments prior to 1996, the relationship between southern California CalCOFI bongo data and abundance was calculated using an index of larval density (Barnes and Hanan, 1995; Jacobson et al, 1994) rather than proportion positive. Unlike the previous study (Barnes et al. 1997), we did not down weight the CalCOFI survey data in tuning the model because the relationship between observed and predicted improved with the additional years of data in our analysis.

Baja California Larvae Index

Although Pacific mackerel range from southern Baja California northward to British Columbia, spawning grounds are centralized in waters off central and northern Baja. Because recent CalCOFI cruises occupying the Southern California Bight survey only the northern fringe of spawning area, we calculated a new index (similar to the CalCOFI proportion positive index) for icthyoplankton data collected in northern and central Baja. In addition to historic CalCOFI data this Baja California larvae index includes results from a 1996 CDFG research cruise conducted in Mexican waters (Barnes, 1996), utilizing standard CalCOFI bongo tows. Geographic limits for the index were determined by area surveyed during the 1996 CDFG research cruise. The area was bound in the north by CalCOFI stations along line number 97 and in the south by CalCOFI stations along line number 143, and extending offshore to CalCOFI stations numbered 50. The new Baja California larvae index spans the years 1951-1996, although no icthyoplankton surveys were conducted off Mexico during 1985-1995 (Figure 6).

Recruitment

Our estimate of year class abundance for quarter four of 1996 was obtained from estimates of age-specific fishing mortalities (terminal F) and associated selectivities (Figure 7). Data were insufficient to allow the model algorithm to directly estimate selectivities in the terminal year (1996) because cumulative fishing mortalities for the two youngest year classes were quite low. Terminal selectivities were derived by taking mean fourth-quarter values for 1991-1996, then repeating the model run for five iterations (until convergence) using the new means as fixed values (Figure 7).

Mean recruitment during 1929-1996 was 639 million fish, ranging from a low of 3.5 million in 1969 to a high of 8,970 million in 1981 (Figure 8). Our estimate for 1996 year class recruitment (164 million fish) is less than one-half that of 1995 recruitment (395 million), and the lowest since 1975. This follows a trend of poor recruitment in recent years, as has spawning success in terms of recruits-per-spawner (Figure 9). The additional year of input data and other improvements in our current assessment have reduced the estimate of 1995 year class recruitment by about 14% compared to that calculated last year (Barnes et al. 1997). Recruits-per-spawner for both 1995 and 1996 year classes was not high. Unlike the 1996 assessment, it was unnecessary to constrain the abundance of new recruits to fall within historical limits.

Mortality

Our biomass estimate for July 1, 1997 for fish of ages one and older was dependent upon estimates of age-specific fishing mortalities (terminal F) during the last quarter of 1996, as described above. We assumed that age specific fishing mortality during the first and second quarters of 1997 will be equal to the average values for 1991-1996, and that instantaneous natural mortality (M=0.5) remained unchanged. Given the numbers of fish in each year class during the last quarter of 1996, we used our mortality assumptions to calculate number of fish alive as of July 1, 1997. Weight at age data for 1996 were used to convert numbers of fish remaining alive to biomass for each age, and were summed over all ages to obtain total biomass (Table 3).

Because of low cumulative fishing mortality values (the total fishing mortality incurred by each year class throughout the time series) during the 1920-30's and 1970-80's (Figure 10), the VPA algorithm is unable to precisely estimate biomass for those years. This may explain discrepancies in biomass between our ADEPT output and those values generated by earlier methods (Prager and MacCall 1988) and previous ADEPT runs (Barnes et al. 1997; Barnes and Hanan 1995; and Jacobson et al. 1994).

Estimates of biomass over 200,000 mt during the 1980's (Figure 11) are very imprecise (Prager and MacCall 1988 - Figure 4). Because cumulative mortality by year class at those times was very low (around 0.3), it is difficult for the model to estimate biomass. Combining age groups 5 and 6+ contributed to the uncertainty. In comparing outputs from this year's assessment with previous years, peak biomass estimates in 1981 and 1982 more than doubled, illustrating the uncertainty in our assessments during periods of low fishing mortality and high biomass.

Results

We estimate the July 1, 1996, Pacific mackerel biomass to have been 109,700 mt (Figure 11). This estimate is significantly higher than last year's CDFG projection of 47,200 mt for 1996, because our initial projections for the abundance of the 1994 and older year classes were too low. Updating this assessment by accounting for anticipated 1996 year class success, we project the total biomass of Pacific mackerel will be 91,200 at the beginning of the 1997/98 fishing season, July 1, 1997.

By expanding the time series backward and incorporating additional data into the model (Figure 11), estimates of older (age 2+) fish in the 1990's increased. Biomass estimates for the 1960's were significantly smaller than those for the 1990's, giving the model a new low by which to scale abundance indices. Consequently, our biomass estimates for the 1990's were higher than values calculated in the 1996 assessment (Barnes et al. 1997).

When expanding the time series of survey indices, the fit between observed and predicted improved in most cases. For example, in the 1996 assessment, we significantly down weighted the impact of southern California bight CalCOFI survey data (both proportion positive and density indices) because they did not appear to fit other trends in abundance. However, once the 1951-1978 time period was included, a much better fit of the proportion positive data ensued.

A warm water oceanic regime has dominated the California Current region for about 15 years, and we speculate that it may have caused a northern emigration of Pacific mackerel, particularly the older year classes. A latitudinal cline in mean size is apparent in fishery samples, lending support to the hypothesis that the older fish tend to move farther north (Figure 12). By-catch of presumed large (old) mackerel in the Oregon whiting fishery has been notable in recent years, although catches have remained small (less than 500 tons) compared to the directed fishery in California. The apparent northern migration with age may have been exacerbated in 1992-1993, because of another strong El Niño influence on sea-surface temperatures. Such emigration would decrease availability of older fish in the stock to the southern California wetfish fleet. Estimates of age specific fishing availability used in our assessment are consistent with this hypothesis, since there is reduced availability for each successive age beyond age 1 (Figure 7). Reduced fishing availability for older ages should help offset potential bias in model output associated with northern emigration of those age classes.

SEASON QUOTAS

Commercial landings of Pacific mackerel in California are quota-limited according to a harvest formula given in Section 8412 of the Fish and Game Code. The formula specifies that when the biomass is between 18,140 mt and 136,050 mt, the season's quota shall be 30 percent of the biomass in excess of 18,140 mt. If total biomass is less than 18,140 mt, no directed landings are allowed; there is no limitation on catch if total biomass is greater than 136,050 mt. Because the 1997/98 biomass estimate is above 18,140 mt but below 136,050 mt, a quota will be in effect.

Based on our projected biomass estimate of 91,200 mt for July 1, 1997, the recommended commercial fishery quota for the 1997/98 fishing season is 22,000 mt. Although it is more than double last season's quota of 8,700 mt (Figure 13), the 1997/98 quota is quite low compared to the magnitude of the fishery during the 12-year period of 1980-1991. Despite higher landings during that period, total fishing mortality upon the stock was relatively low (Figure 14), with values at or below 10% annually throughout the 1980's. Conversely in recent years with a smaller total biomass, the stock has undergone significantly increased fishing mortality (Figure 14), with annual values averaging 15.5% since 1992.

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Table 1. Pacific Mackerel Commercial Landings, 1929-1996 (Metric Tons)

Year	California	Ensenada	Total
1996	10284	5604	15888
1995	8666	4821	13487
1994	10040	13319	23359
1993	12391	7741	20132
1992	18570	24345	42915
1991	30459	17450	47909
1990	36716	35767	72483
1989	35548	13387	48935
1988	42200	4884	47084
1987	40961	2082	43043
1986	40616	4883	45499
1985	34053	2582	36635
1984	41534	128	41662
1983	32028	135	32163
1982	27916	0	27916
1981	38304	0	38304
1980	29139	0	29139
1979	27198	0	27198
1978	11193	0	11193
1977	5333	0	5333
1976	293	0	293
1975	129	0	129
1974	60	0	60
1973	26	0	26
1972	49	0	49
1971	71	0	71
1970	282	0	282
1969	1070	0	1070
1968	1421	0	1421
1967	529	0	529
1966	2100	0	2100
1965	3198	0	3198
1964	12169	0	12169
1963	18254	0	18254
1962	22035	0	22035
1961	20008	0	20008
1960	16696	0	16696

Year	California	Ensenada	Total
1959	17056	0	17056
1958	12541	0	12541
1957	28143	0	28143
1956	22686	0	22686
1955	10574	0	10574
1954	11518	0	11518
1953	3403	0	3403
1952	9346	0	9346
1951	15204	0	15204
1950	14810	0	14810
1949	22576	0	22576
1948	17865	0	17865
1947	21082	0	21082
1946	24438	0	24438
1945	24366	0	24366
1944	37947	0	37947
1943	34117	0	34117
1942	23838	0	23838
1941	35456	0	35456
1940	54660	0	54660
1939	36700	0	36700
1938	36219	0	36219
1937	27641	0	27641
1936	45606	0	45606
1935	66419	0	66419
1934	51641	0	51641
1933	31577	0	31577
1932	5658	0	5658
1931	6466	0	6466
1930	7499	0	7499
1929	26297	0	26297

Table 2. Mean Weight-at-Age (g), Season 2, 1929-1996

(1929-1977 data based on Prager and MacCall, 1988)

	Age 1	Age 2	Age 3	Age 4	Age 5
1996	72.6	167.8	397.2	548.9	570.8
1995	101.1	159.2	253.6	312.3	469.2
1994	99.8	258.6	349.3	467.2	609.2
1993	87.5	215.9	412.8	529.4	581.7
1992	308.4	213.2	421.8	526.2	681.2
1991	136.1	362.9	449.1	589.7	772.5
1990	222.3	290.3	508.0	598.8	751.1
1989	117.9	331.1	449.1	712.2	811.3
1988	172.4	358.3	480.8	585.1	743.0
1987	263.1	349.3	430.9	535.2	656.2
1986	195.0	326.6	430.9	480.8	521.8
1985	154.2	231.3	376.5	430.9	688.7
1984	166.5	235.9	331.1	408.2	520.1
1983	145.2	249.5	349.3	462.7	541.6
1982	95.3	226.8	290.3	825.6	586.1
1981	122.5	276.7	390.1	458.1	666.8
1980	166.5	299.4	458.1	607.8	841.5
1979	117.9	394.6	557.9	775.7	996.1
1978	113.4	385.6	423.2	571.1	695.1
1977	188.2	426.4	834.6	646.1	800.5
1976	210.9	336.1	567.2	646.1	800.5
1975	210.9	336.7	567.2	646.1	800.5
1974	181.9	336.7	567.2	646.1	800.5
1973	181.9	336.7	567.2	646.1	800.5
1972	181.9	336.7	567.2	646.1	800.5
1971	181.9	336.7	567.2	646.1	800.5
1970	181.9	336.7	567.2	567.0	691.3
1969	252.7	363.3	473.6	621.9	732.1
1968	193.7	323.0	476.7	562.5	691.3
1967	187.3	274.4	455.4	574.3	718.0
1966	168.3	325.2	485.4	586.1	777.9
1965	182.3	337.9	457.2	568.8	584.7
1964	261.3	375.1	507.6	595.1	733.0
1963	291.2	396.0	495.8	585.6	707.6
1962	230.4	340.7	471.3	560.6	671.3
1961	176.5	303.0	461.3	560.6	660.0
1960	165.1	313.0	473.6	582.9	689.9
1959	187.8	333.4	439.1	515.3	639.1
1958	187.3	316.2	382.8	495.8	587.0
1957	205.5	300.3	422.3	514.4	608.7
1956	180.5	295.7	407.8	495.3	636.4
1955	158.8	252.2	403.3	525.7	679.0
1954	155.1	335.7	487.6	556.6	673.1
1953	198.7	358.3	435.0	552.9	667.2
1952	277.1	356.1	479.9	550.2	654.1
1951	160.1	313.9	383.7	476.7	594.7
1950	209.6	255.8	364.7	480.4	651.8
1949	148.3	261.7	391.9	572.4	671.3
1948	159.2	336.1	480.8	578.3	673.1
1947	231.3	361.1	475.4	549.3	657.7
1946	186.4	296.7	438.2	546.1	645.5
1945	167.4	330.2	437.7	535.7	653.2
1944	209.1	335.2	409.6	536.2	645.0
1943	217.3	279.9	428.2	513.5	627.8
1942	172.8	318.9	408.2	518.5	664.5
1941	218.6	310.7	400.5	504.9	599.7
1940	194.6	260.8	360.6	446.3	580.6
1939	168.3	315.3	447.2	547.0	630.1
1938	173.7	309.8	448.2	531.6	582.4
1937	176.5	317.5	428.7	460.9	502.1
1936	192.8	284.0	337.9	393.3	452.7
1935	185.5	217.3	250.8	379.2	472.2
1934	142.0	197.8	232.7	430.9	538.0
1933	82.6	200.5	299.4	493.1	584.7
1932	80.7	277.1	379.2	508.5	604.2
1931	114.3	276.2	399.2	526.6	606.5
1930	138.8	301.2	422.3	511.2	603.3
1929	166.9	297.1	402.3	522.5	614.6

Table 3. Projected Pacific Mackerel Biomass for Beginning of 1997/98 Season

YEAR CLASS (YC)	F MORT 4TH QTR 1996	F MORT 1ST QTR 1997	F MORT 2ND QTR 1997	F MORT 10/96-7/97	M MORT (M=.5/YR) 10/96-7/97	TOTAL M (Z=M+F) 10/96-7/97	# FISH/YC (10^6) 10/1/96	# FISH/YC (10^6) 7/1/97	WT/AGE (G/FISH) 7/1/97	KG/YC (10^6) 7/1/97
1996	0.0363	0.0894	0.0306	0.1563	0.375	0.5313	143	84.063	169.2916	14.231
1995	0.0809	0.1167	0.0619	0.2594	0.375	0.6344	175	92.796	313.3685	29.079
1994	0.0470	0.0841	0.0852	0.2163	0.375	0.5913	82	45.397	496.3104	22.531
1993	0.0457	0.0679	0.0666	0.1801	0.375	0.5551	23	13.202	636.6233	8.405
<1992	0.0306	0.0163	0.0285	0.0753	0.375	0.4503	38	24.222	699.9319	16.954

TOTAL BIOMASS
(7/1/97)
KILOGRAMS (10^6) 91.2

METRIC TONS
(Thousands) 91.2

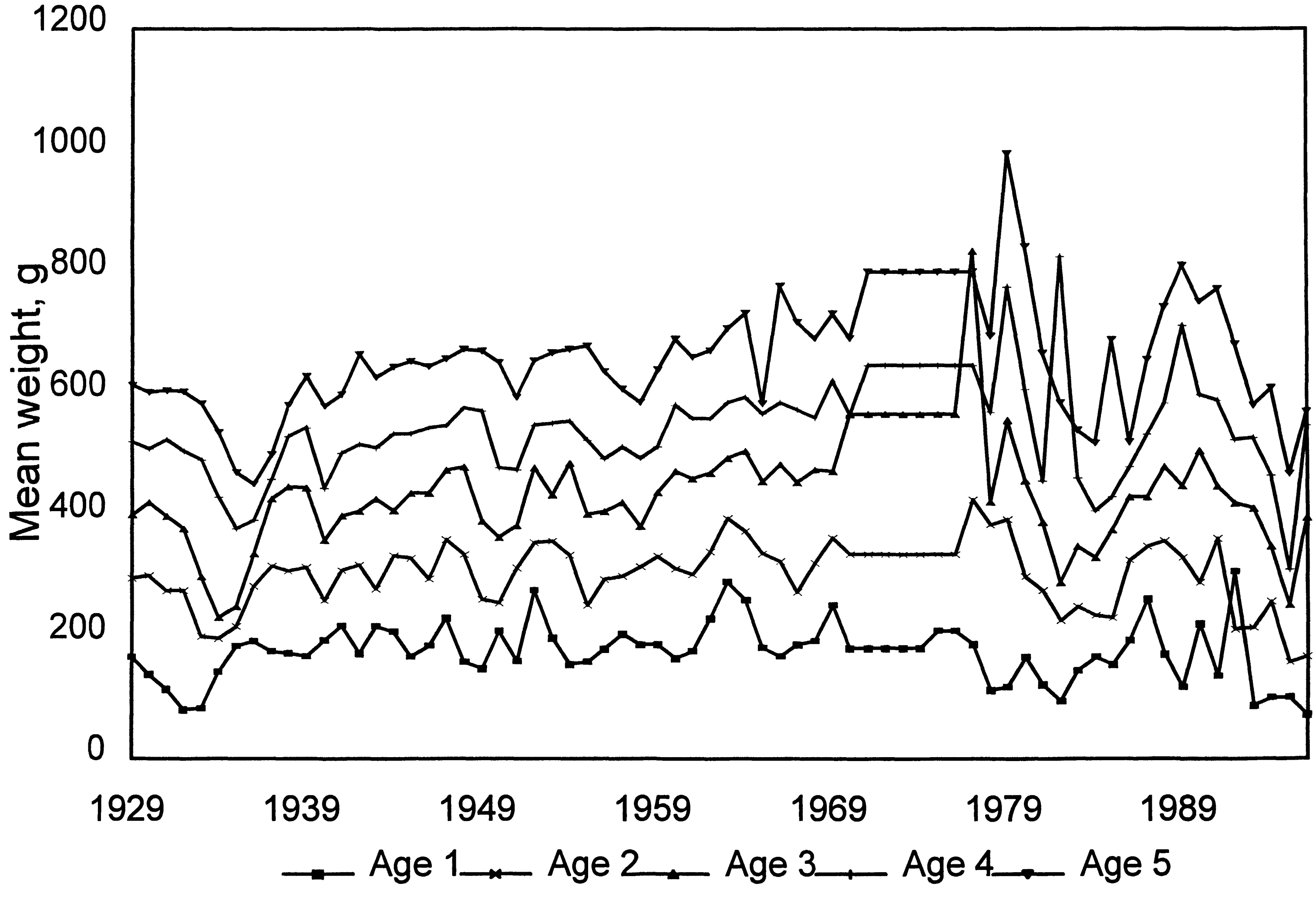

Figure 1. Mean Weight-at-age, Season 2, 1929-1996

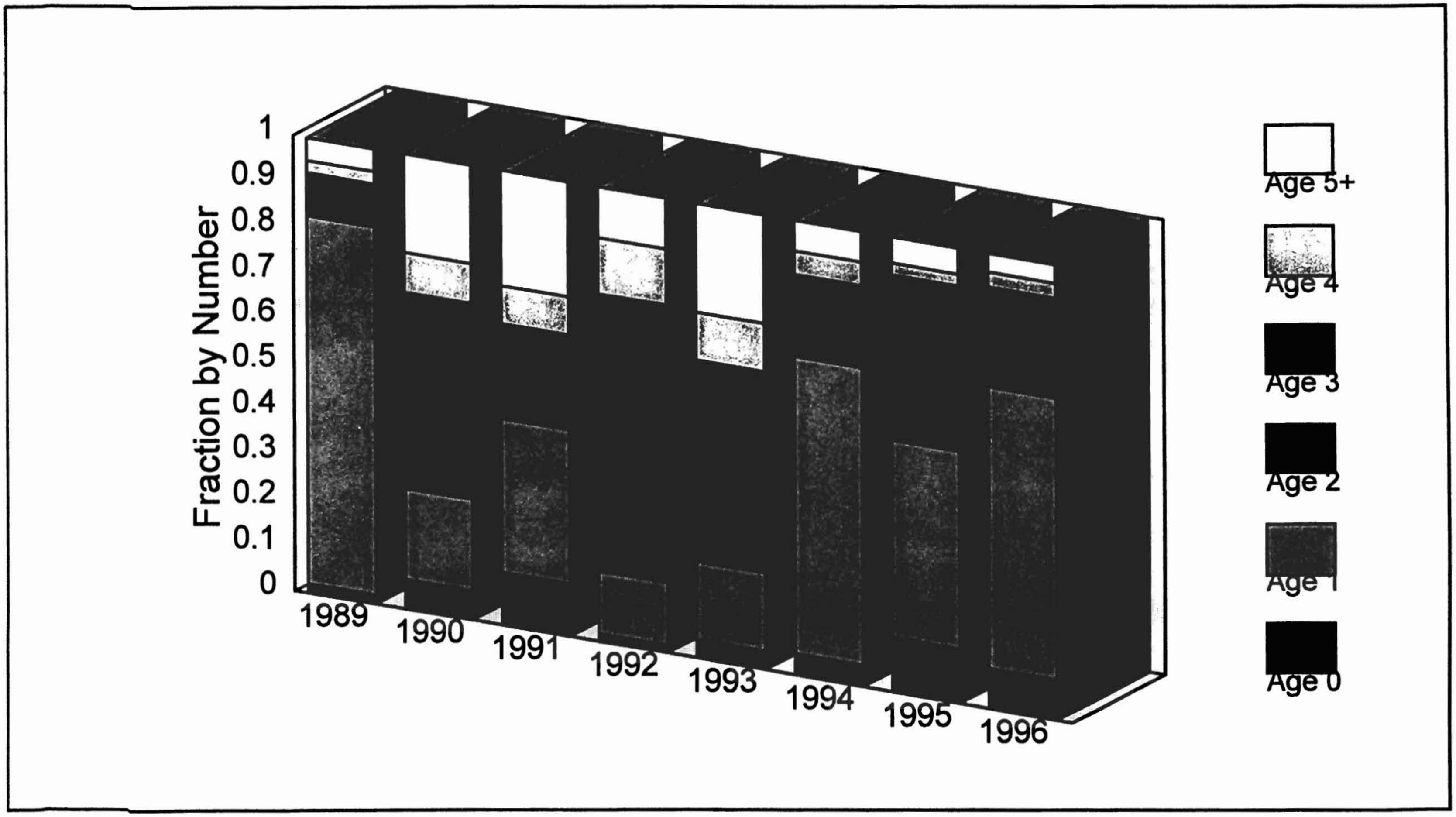

Figure 2. Proportional Catch-at-age

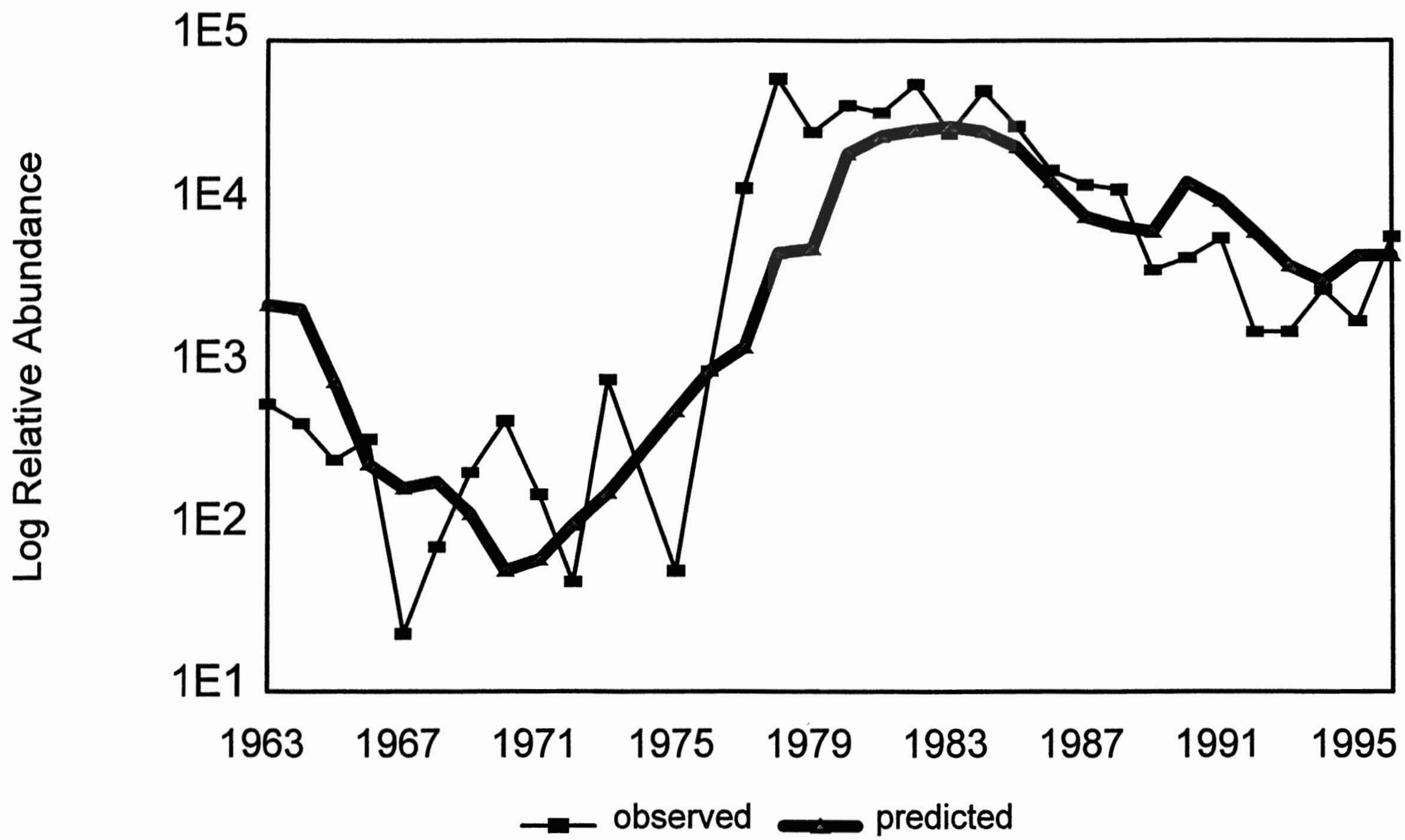

Figure 3. Spotter Pilot Sighting Index, 1963-1996

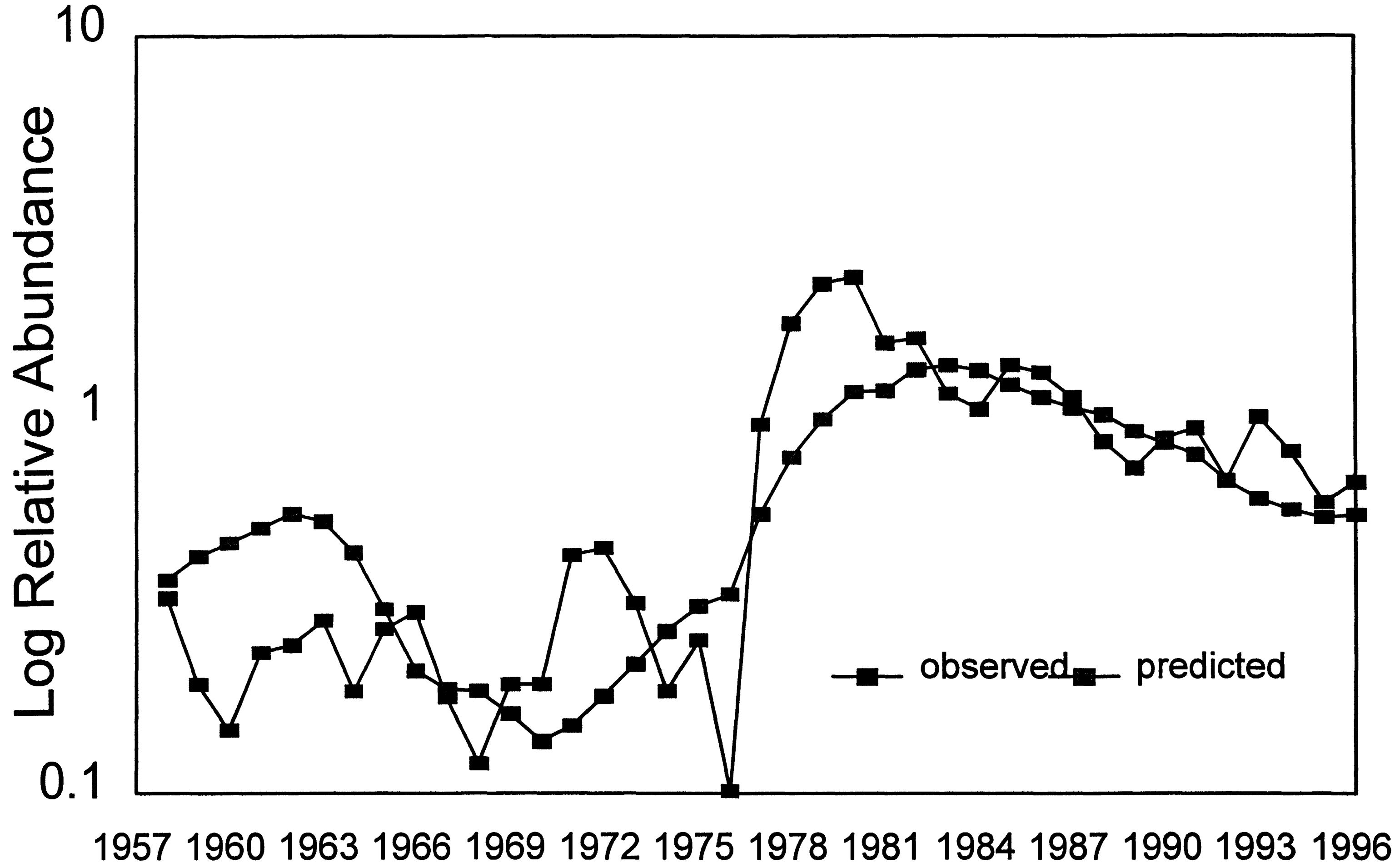

Figure 4. CPFV Abundance Index, 1957-1996

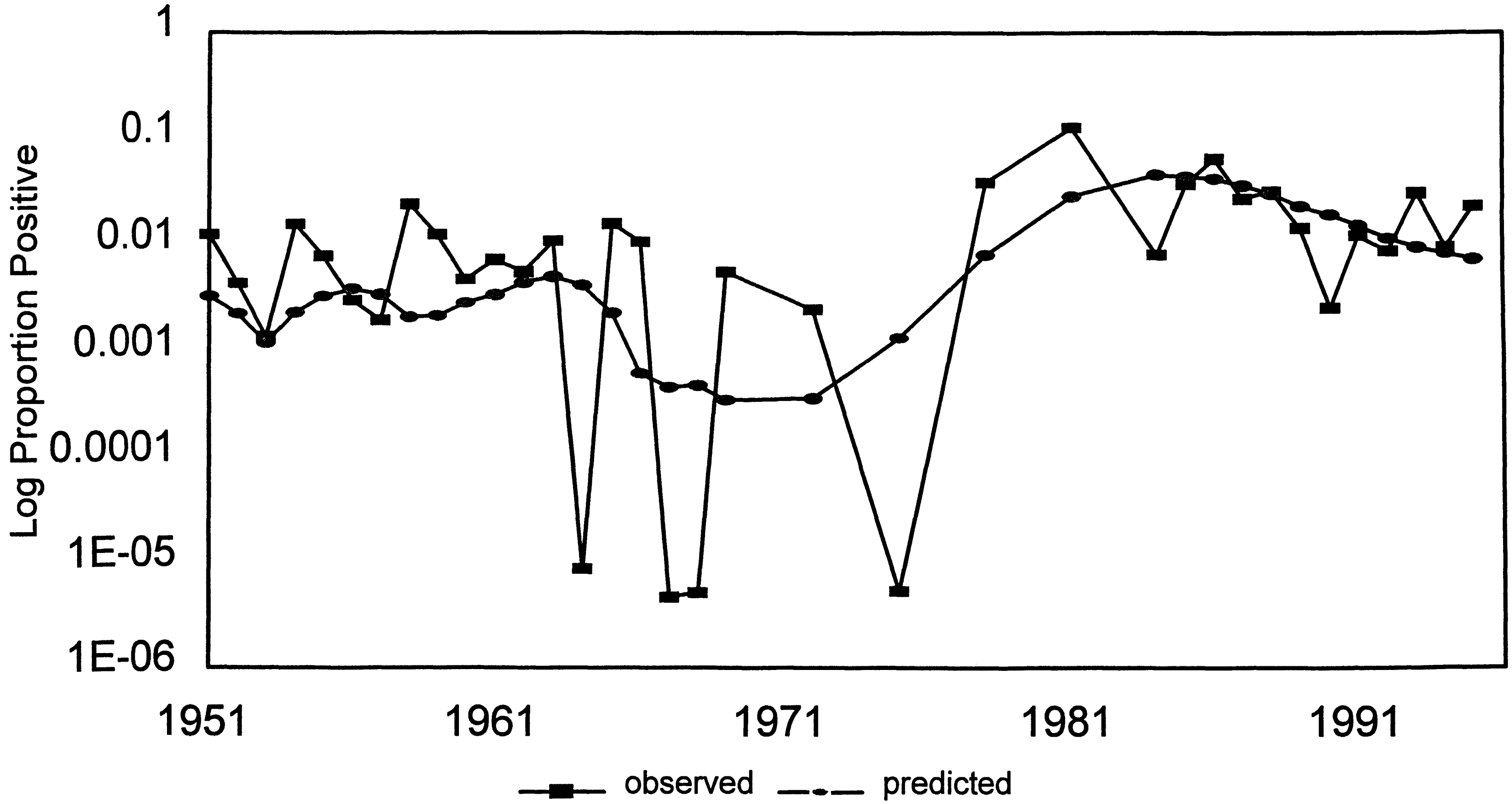

Figure 5. S. California CalCOFI Index, 1951-1996

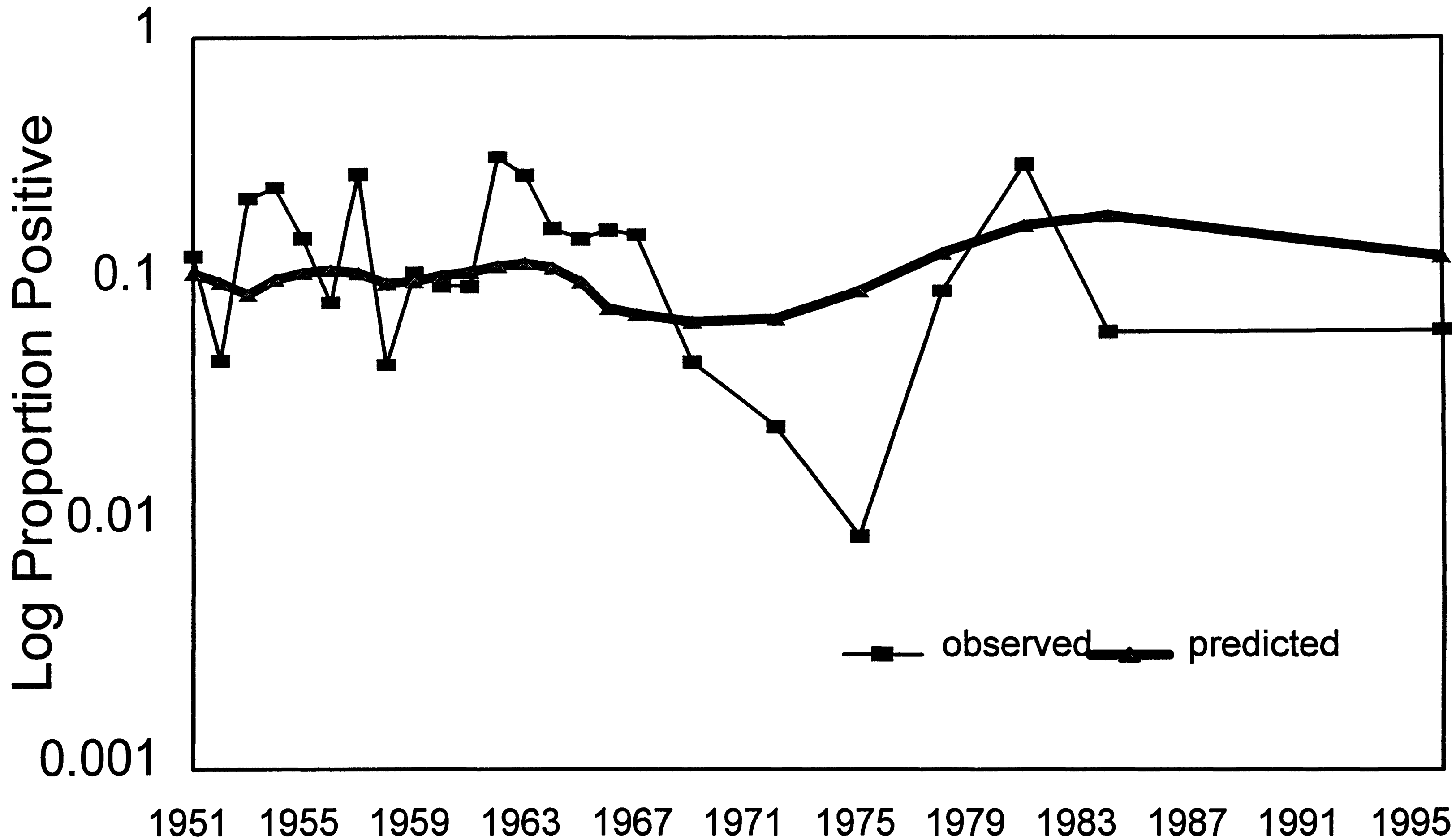

Figure 6. Mexico CalCOFI Index, 1951-1996

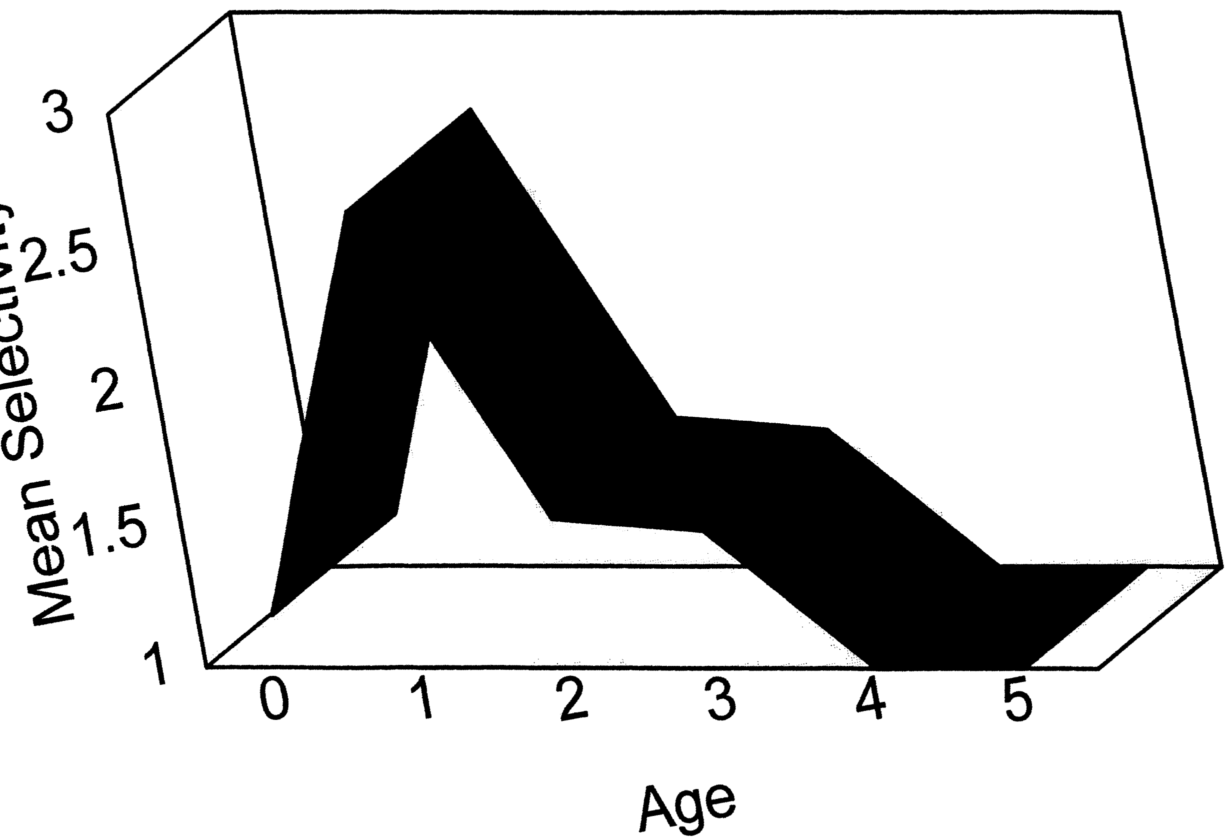

Figure 7. Fourth Quarter Selectivities, Average of 1991-1996 Values

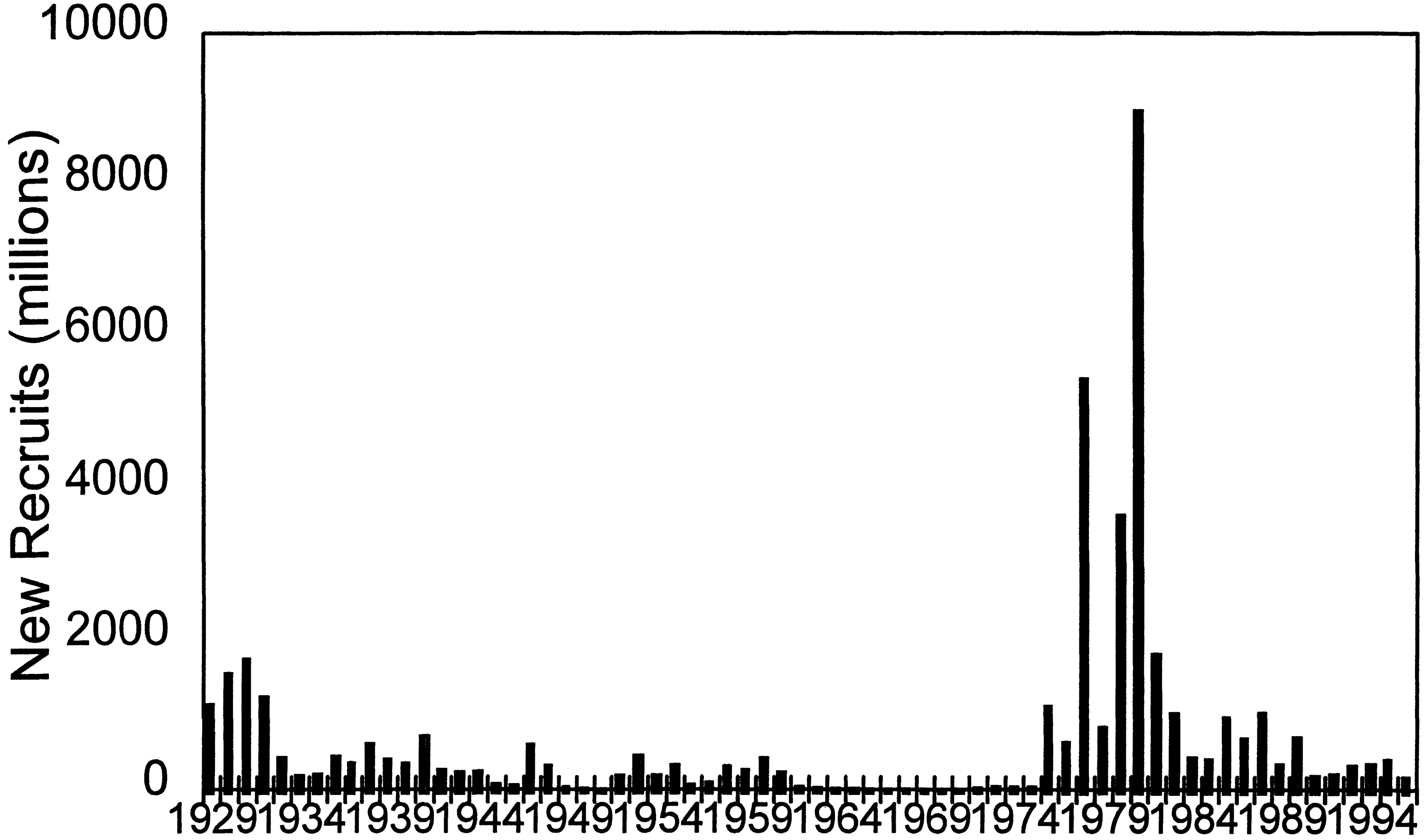

Figure 8. Year Class Abundance, July 1

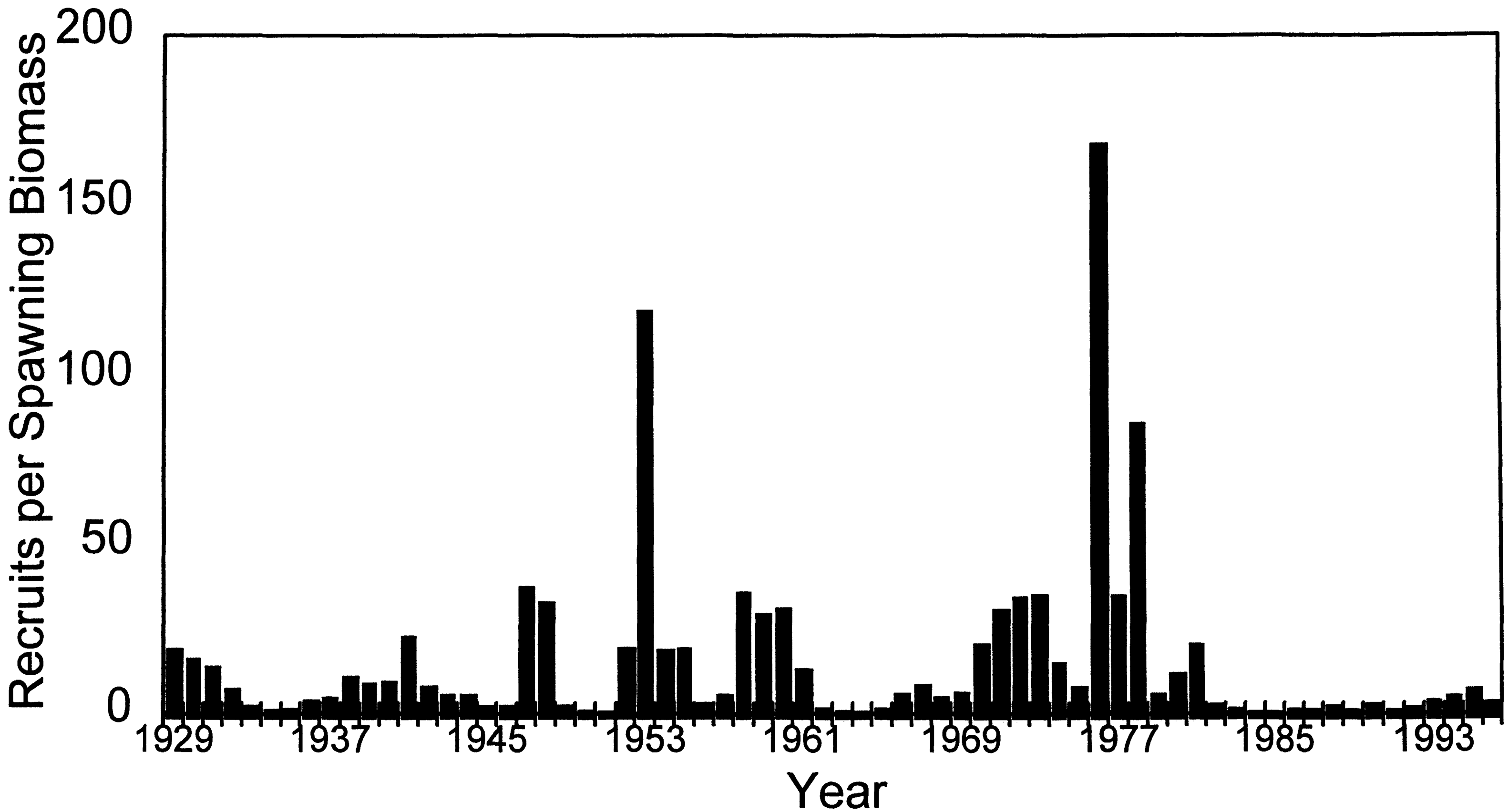

Figure 9. Reproductive Success, 1929-1996

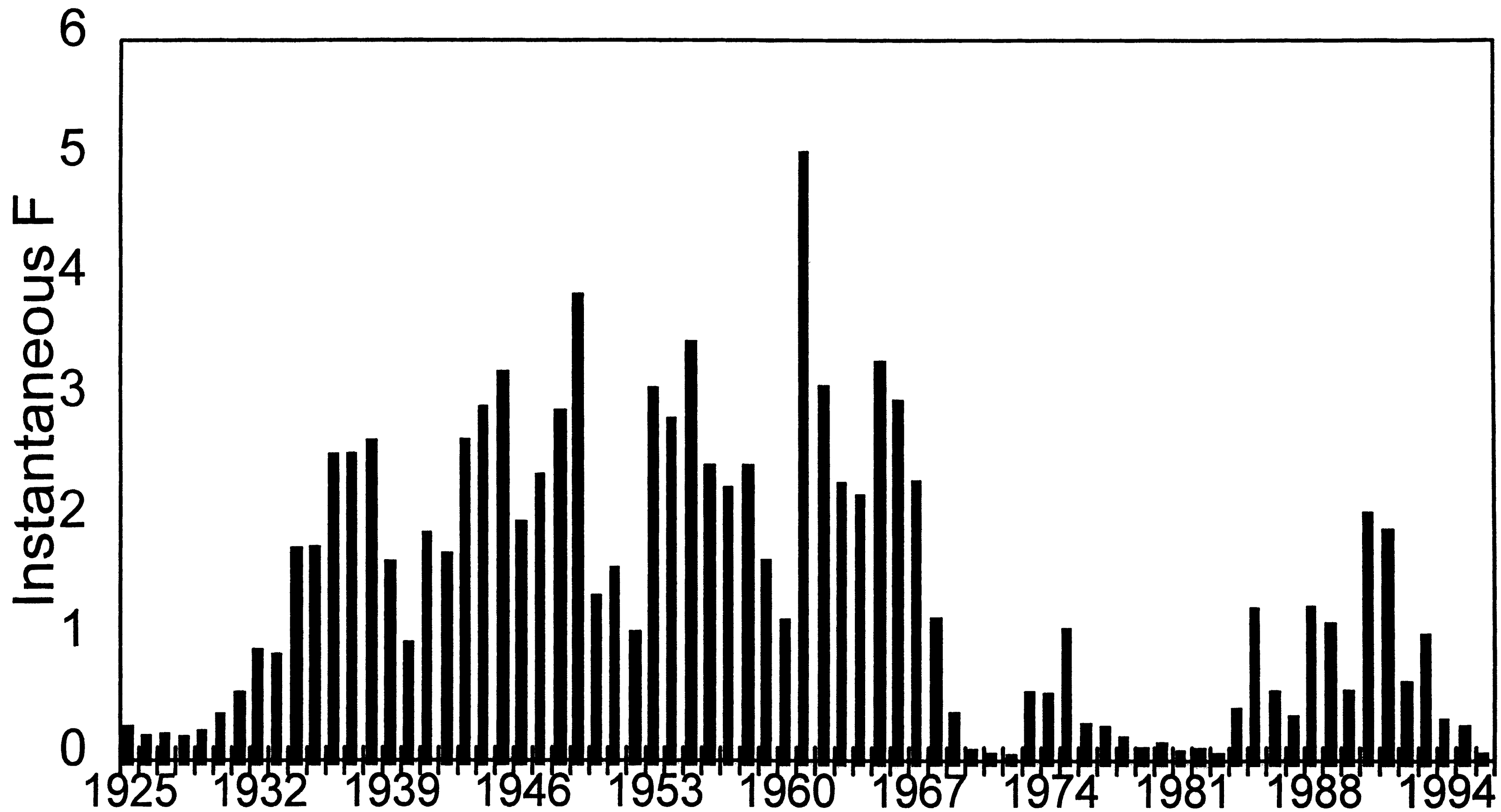

Figure 10. Cumulative Fishing Mortality by Yearclass

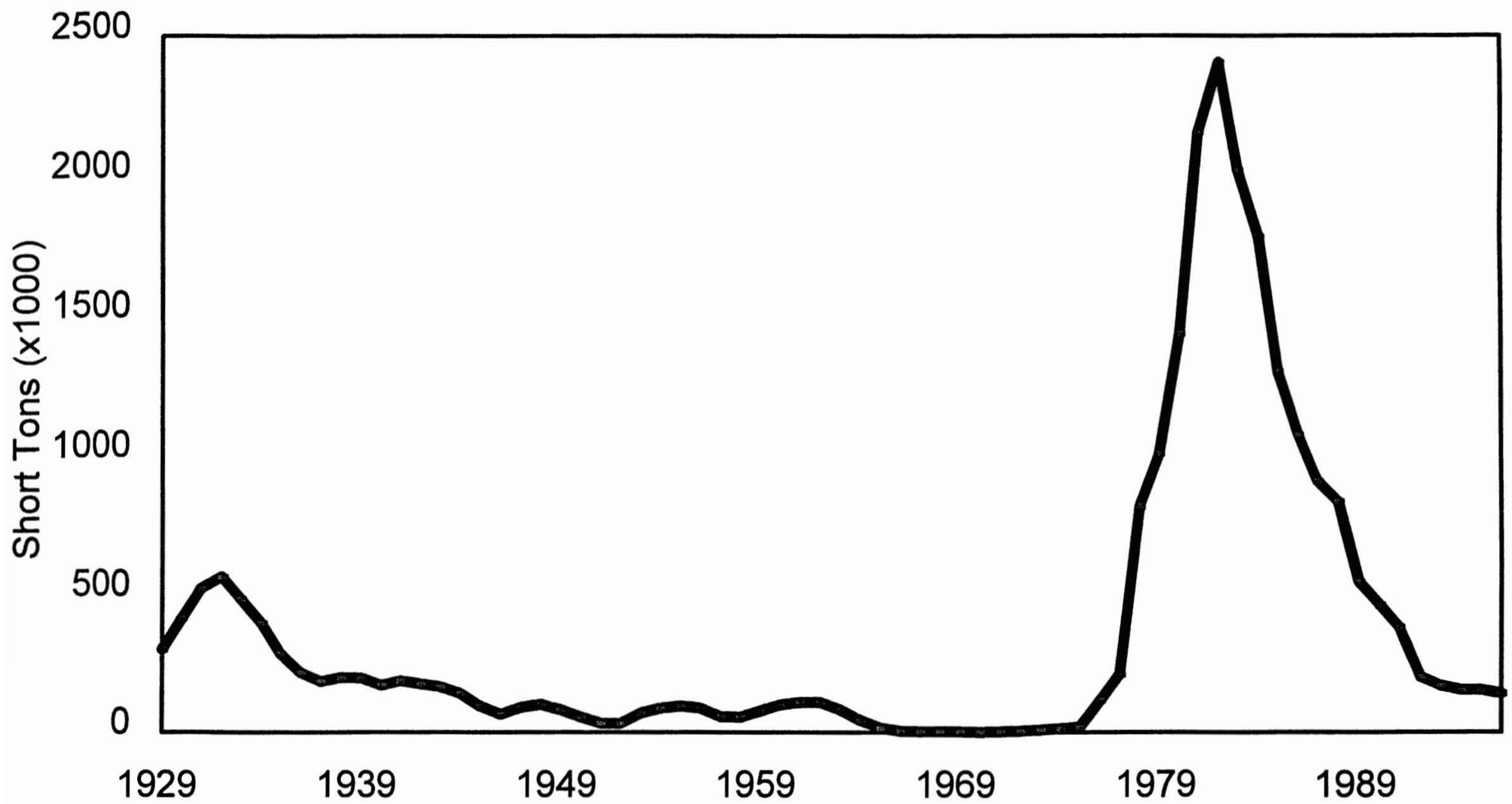

Figure 11. Pacific Mackerel Total Biomass, July 1

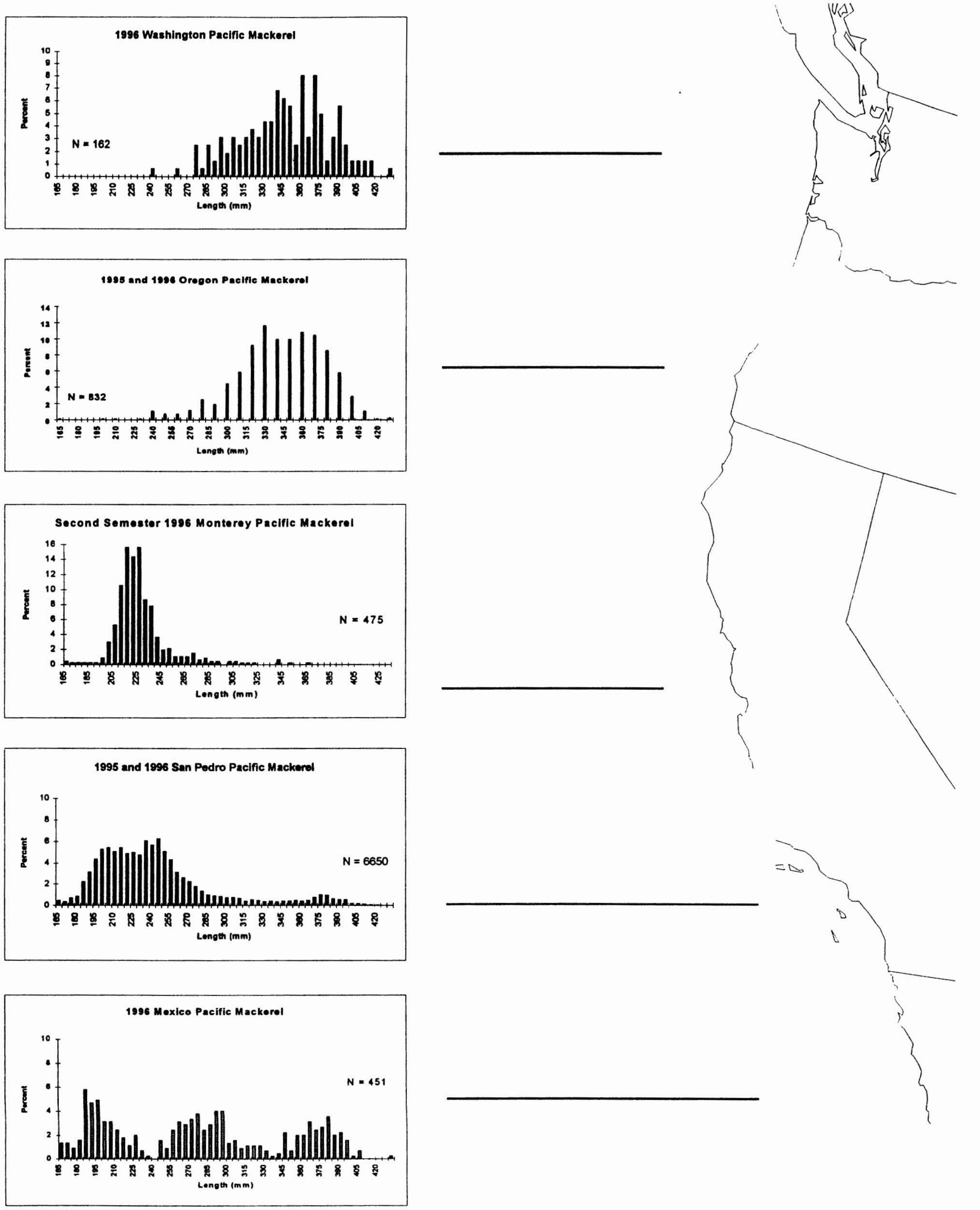

Figure 12. Pacific Mackerel Length-Frequency by Region

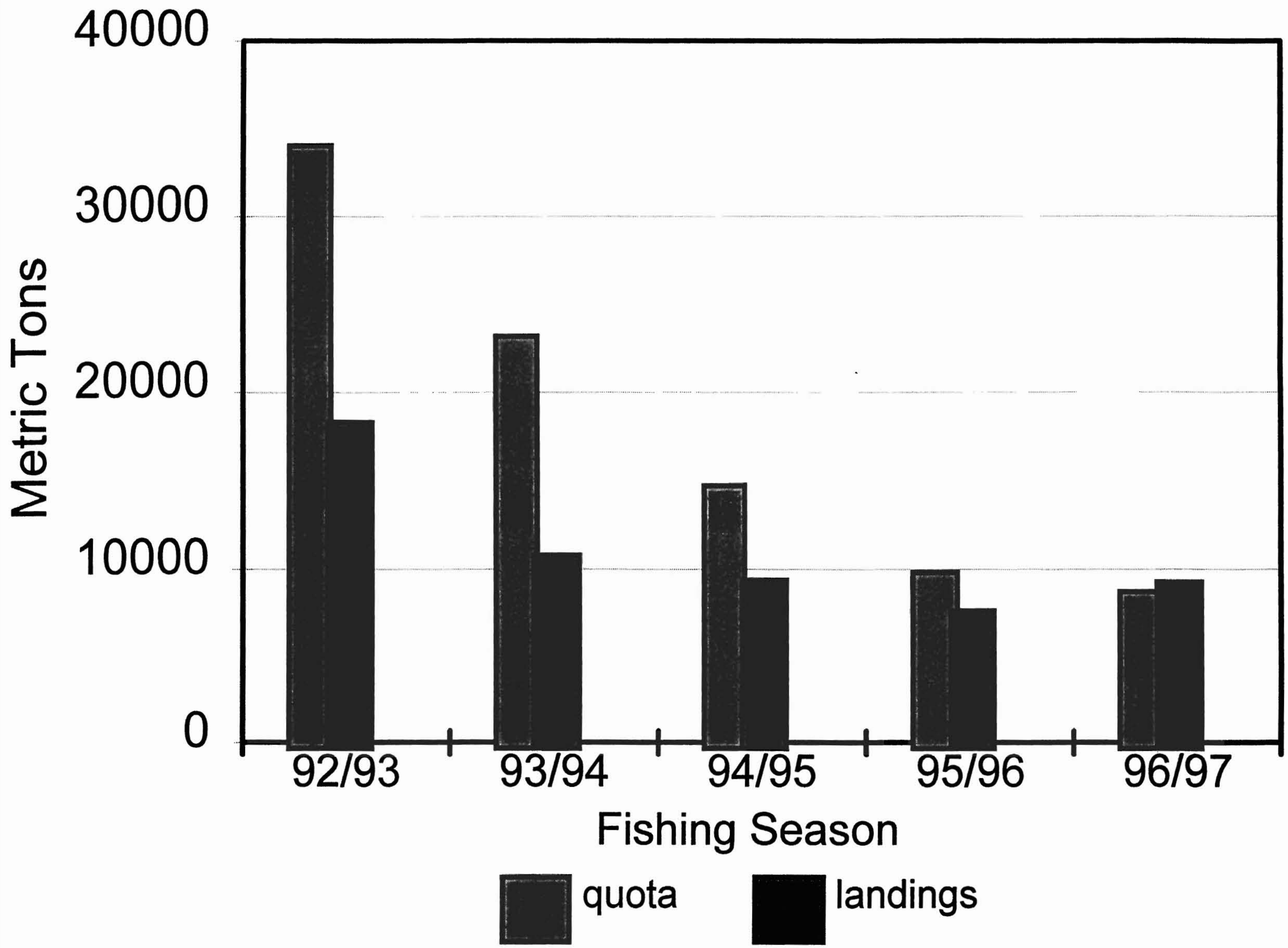

Figure 13. California Landings vs. Quota

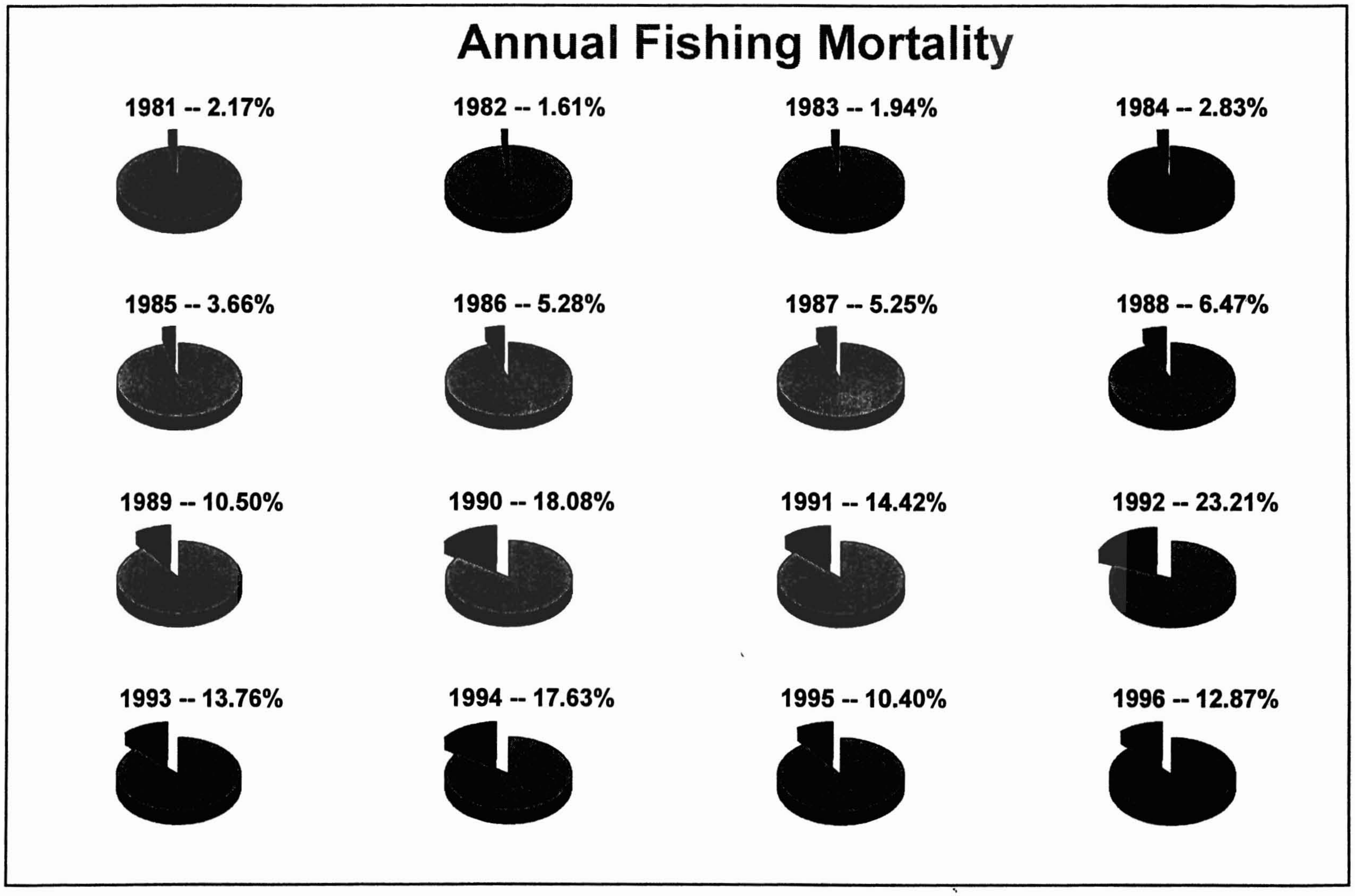

Figure 14. Annual Fishing Mortality