Section 3

YELLOWFIN SOLE

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EXECUTIVE SUMMARY

The following changes have been made to this assessment relative to the November 1998 SAFE:

Changes to the input data

1) 1998 fishery age composition.
2) 1998 survey age composition.
3) 1999 trawl survey biomass point estimate and standard error.
4) Estimate of the discarded and retained portions of the 1998 catch.
5) Estimate of total catch and discard through 23 September 1999.

Assessment results

1) The projected age 2+ biomass for 2000 is 2,8 15,600 t.
2) The projected female spawning biomass for 2000 is 789,300 t.
3) The recommended 2000 ABC is 190,600 t based on an $F_{40\%}$ (0.11) harvest level.
4) The 2000 overfishing level is 226,000 t based on an F,, (0.13) harvest level.

SUMMARY

	1999 Assessment Recommendations for 2000 harvest	1998 Assessment Recommendations For 1999 harvest
Total biomass	2,815,580 t	3,197,200 t
ABC	190,600 t	2 12,000 t
Overfishing yield	226,000 t	308,400 t
F_{ABC}	$F_{0.40} = 0.11$	$F_{0.40} = 0.11$
$F_{overfishing}$	$F_{0.35} = 0.13$	$F_{0.30} = 0.16$

INTRODUCTION

The yellowtin sole (Limanda_aspera) is the most abundant flatfish species in the eastern Bering Sea (EBS) and is the target of the largest flatfish fishery in the United States. The resource inhabits the EBS shelf and is considered one stock. Abundance in the Aleutian Islands region is negligible.

Yellowfin sole are distributed in North American waters from off British Columbia, Canada, (approx. lat. 49° N) to the Chukchi Sea (about lat 70° N) and south along the Asian coast to about lat. 35° N off the South Korean coast in the Sea of Japan. Adults exhibit a benthic lifestyle and occupy separate winter, spawning and summertime feeding distributions on the eastern Bering Sea shelf. From over-winter grounds near the shelf margins, adults begin a migration onto the inner shelf in April or early May each year for spawning and feeding. The directed fishery typically occurs from spring through December.

CATCH HISTORY

Yellowfin sole have annually been caught with bottom trawls on the Bering Sea shelf since the fishery began in 1954. The catch locations of vessels targeting on yellowfin sole in 1998, by quarter, are shown in the Appendix figures. The total catch (t) since implementation of the MFCMA in 1977 are shown in Table 3.1.

Yellowfin sole were overexploited by foreign fisheries in 1959-62 when catches averaged 404,000 t annually (Fig. 3.1). As a result of reduced stock abundance, catches declined to an annual average of 117,800 t from 1963-71 and further declined to an annual average of 50,700 t from 1972-77. The lower yield in this latter period was partially due to the discontinuation of the U.S.S.R. fishery. In the early 1980s, after the stock condition had improved, catches again increased reaching a recent peak of over 227,000 t in 1985.

During the 1980s, there was also a major transition in the characteristics of the fishery. Yellowfin sole were traditionally taken exclusively by foreign fisheries and these fisheries continued to dominate through 1984. However, U.S. fisheries developed rapidly during the 1980s in the form of joint ventures, and during the last half of the decade began to dominate and then take all of the catch as the foreign fisheries were phased out of the EBS. Since 1990, only domestic harvesting and processing has occurred.

The 1997 catch of 18 1,3 89 t was the largest since the fishery became completely domestic. The catch in 1998 decreased to 10 1,20 1 t which totaled only 46% of the ABC and 54% of the TAC. The 1999 catch of 58,972 t (through 18 September) totals 28% of the ABC, taken primarily in areas 5 13 and 5 14. Fishing for yellowfin sole in 1998 was closed from November 30 to the end of the year due to the attainment of the annual halibut bycatch allowance.

The catch information presented above also includes large amounts of yellow-fin sole discarded overboard in DAP fisheries since its beginning in 1987. Discard estimates are calculated from weekly observer discard estimates, by target fishery, applied to the weekly 'blend' estimate of retained catch from the NMFS regional office summed over the fishing year.

Year	Retained	Discards
1987	3	1
1988	7,559	2,274
1989	1,279	385
1990	10,093	4,200
1991	89,054	26,788
1992	103,989	45,580
1993	76,798	26,838
1994	107,629	36.948
1995	96,718	28,022
1996	101,324	28,334
1997	149,570	31,818
1998	80,365	20,836

The rate of discard has ranged from 17% of the total catch in 1997 to 30% in 1992. Discarding occurs primarily in the yellowfin sole directed fishery, and in lesser amounts in the rock sole, flathead sole, and 'other flatfish' fisheries.

DATA

The data used in this assessment include estimates of total catch, bottom trawl survey biomass estimates and their attendant 95% confidence intervals, catch-at-age from the fishery and population age composition estimates from the bottom trawl survey. Weight-at-age and proportion mature-at-age are also available from studies conducted during the bottom trawl surveys.

Fisher-v Catch and Catch-at-Age

This assessment uses fishery catch data from 1955- September 18, 1999 (Table 3.1) and fishery catch-at-age (numbers) from 1964-98 (Table 3.2, 1977-97).

Survev Biomass Estimates and Population Age Comoosition Estimates

The survey estimates of population numbers-at-age from 1975 and 1979-98 are used in the assessment model and are shown for 1982-98 in Table 3.3. Biomass (t) estimates from AFSC surveys conducted in a standardized area of the EBS encompassing waters from 20 to 200 m and from the Alaska Peninsula north to a latitude of St. Matthew and Nunivak Islands are given below:

Year	Aue Groups 0-6	7 plus	Total	95% confidence Interval of Total
1975	169,500	803,000	972,500	812,300 - 1,132,700
1979	211,500	1,655,000	1,866,500	1,586,000 - 2,147,100
1980	235,900	1,606,500	1,842,400	1,553,200 - 2,131,700
1981	343,200	2,051,500	2,394,700	2,072,900 - 2,716,500
1982	685,700	2,692,100	3,377,800	2,571,000 - 4,184,600
1983	198,000	3,337,300	3,535,300	2,958,100 - 4,112,400
1984	172,800	2,968,400	3,141,200	2,636,800 - 3'645,600
1985	166,200	2,277,500	2,443,700	1,563,400 - 3,324,000
1986	80,200	1,829,700	1,909,900	1,480,700 - 2,339,000
1987	125,500	2,487,600	2,613,100	2,051,800 - 3,174,400
1988	45,600	2,356,800	2,402,400	1,808,400 - 2,996,300
1989	196,900	2,119,400	2,316,300	1,836,700 - 2,795,800
1990	69,600	2,114,200	2,183,800	1,886,200 - 2,479,400
1991	60,000	2'333,300	2,393,300	2,116,000 - 2,670,700
1992	145,900	2,027,000	2,172,900	•
1993	188,200	2,277,200	2,465,400	2,151,500 - 2,779,300
1994	142,000	2,468,500	2,610,500	2,266,800 - 2,954,100
1995	213,000	1,796,700	2,009,700	1,724,800 - 2,294,600
1996	161,600	2,137,000	2,298,600	1,749,900 - 2,847,300
1997	239,330	1,924,070	2,163,400	1,907,900 - 2,418,900
1998	150,756	2,178,844	2,329,600	2,033,130 - 2,626,070
1999			1,306,470	1,118,800 - 1,494,150

* 95% confidence intervals cannot be calculated for 1992 since the total estimate includes an unsampled area for which a 3 year average was used as a proxy.

Estimates are given separately for unexploited ages (less than age 7) and exploited ages (ages 7 and older) except for 1999 where age data are not yet available. The data show a doubling of biomass between 1975 and 1979 with a further increase to over 2.3 million t in 1981 for the exploitable portion of the population. Survey abundance estimates fluctuated erratically from 198 1 to 1990 with biomass ranging from as high as 3.5 million t in 1983 to as low as 1.9 million t in 1986. Estimates of biomass since 1990 show an even trend at high levels of abundance for yellowfin sole, with the exception of the results from the 1999 summer survey.

Indices of relative abundance available from AFSC surveys have also shown a major increase in the abundance of yellowfin sole during the late 1970s increasing from 2 1 kg/ha in 1975 to 5 1 kg/ha in 198 1 (Fig. 3.2, Bakkala and Wilderbuer 1990). These increases have also been documented through Japanese commercial pair trawl data and catch-at-age modeling in past assessments (Bakkala and Wilderbuer 1990).

Since 198 1, the survey CPUEs have fluctuated widely. For example, they increased from 5 1 kg/ha in 198 1 to 84 kg/ha in 1983 and then declined sharply to 49 kg/ha in 1985. They continued to fluctuate from 1986-90, although with less amplitude (Fig 3.2). From 1990-1998, the estimated CPUE was relatively stable but declined over a million t in 1999. Fluctuations of the magnitude shown between 1980 and 1990 and again between 1998 and 1999 are unreasonable considering the combined elements of slow growth and long life span of yellowfin sole and low exploitation rate, characteristics which should produce more gradual changes in abundance.

Variability of yeilowfin sole survey abundance estimates are in part due to the availability of yellowfin sole to the survey area (Nichol, 1998). Yellowfin sole are known to undergo annual migrations from wintering areas off the shelf-slope break to nearshore waters where they spawn throughout the spring and summer months (Nichol 1995; Wakabayashi 1989; Wilderbuer et al., 1992). Exploratory survey sampling in coastal waters of the eastern Bering Sea indicate that yellowfin sole concentrations can be greater in these shallower areas not covered by the standard AFSC survey. Commercial bottom trawlers have commonly found high concentrations of yellowfin sole in areas such as near Togiak Bay (Low and Narita, 1990) and in more recent years from Kuskokwim Bay to just south ofNunivak Island. The coastline areas are sufficiently large enough to offer a substantial refuge for yellowfin so!e from the current survey.

Over the past 15 years survey biomass estimates for yellowfin sole have shown a positive correlation with shelf bottom temperatures (Nichol 1998); estimates have been low during cold years (Figure 3-3). The 1999 survey was conducted approximately two weeks earlier than normal and bottom temperatures were exceptionally cold. In keeping with the trend, the 1999 yellowfin sole biomass estimate was unrealistically low.

We believe that in colder years, a higher percentage of yellowfin sole reside in shallow waters unavailable to the survey. Concentrations of yellowfin sole during the 1999 survey were on average greater along the nearshore survey boundary in comparison to previous years (Figure 3-4), suggesting a distribution nearer shore in shallower waters.

Fadeev (1965) and Polaet al. (1985) have indicated that spring yellow-h sole migrations to shallower waters may be delayed in colder years. Because yellowfin spawn when they arrive in the shallower waters (<30 m), a delayed migration would result in delayed spawning. During "normal" survey years, many yellow-fin sole have spawned and subsequently moved to deeper water (>30 m) within the survey area. Perhaps in colder years a higher percentage of fish are still spawning at the time the survey is conducted, and therefore reside in shallow spawning waters not available to the survey. Furthermore, anecdotal information from a Bering Sea yellowfin sole fisher indicate that yellowfin sole were distributed higher off bottom in 1999 than in previous years, suggesting a higher vertical distribution which could negatively impact survey catchability.

Weight-at-Age and Maturitv-at-Ape

Mean lengths and weights at age of yellowfin sole based on 12 years (1979-90) of data from AFSC surveys and the length (cm) - weigh t(g) relationship (W = 0.0097217 * L ** 3.0564) are as follows:

	Lensth		Weisht	
Aqe	cm	in	q	lb
3	11.1	4.4	15.31	0.03
4	14.5	5.7	34.41	0.08
5	17.4	6.9	60.23	0.13
6	19.9	7.8	90.97	0.20
7	22.1	8.7	124.80	0.27
8	24.0	9.4	160.07	0.35
9	25.6	10.1	195.44	0.43
10	27.0	10.6	229.92	0.51
11	28.2	11.1	262.79	0.58
12	29.2	11.5	293.59	0.65
13	30.1	11.9	322.06	0.71
14	30.9	12.2	348.09	0.77
15	31.6	12.4	371.67	0.82
16	32.1	12.6	392.87	0.87
17	32.6	12.8	411.81	0.91
18	33.1	13.0	428.65	0.94
19	33.5	13.2	443.55	0.98
20	33.8	13.3	456.69	1.01
21	34.0	13.4	468.25	1.03
22	34.3	13.5	478.38	1.05
23	34.5	13.6	487.24	1.07
24	34.7	13.7	494.99	1.09
25	34.8	13.7	501.74	1.11
26	34.9	13.7	507.61	1.12

Maturity information collected from yellowfin sole females during the 1992 and 1993 eastern Bering Sea trawl surveys is used in this assessment (Table 3.4). Nichol(l994) estimated the age of 50% maturity at 10.5 years based on the histological examination of 639 ovaries. In the case of most north Pacific flatfish species, including yellowfin sole, sexual maturity occurs well after the age of entry into the fishery. Yellowfin sole are 90% selected to the fishery by age 11 but females have been found to be only 50% mature at this age.

Length-at-Age

Parameters of the von Bertalanffy growth curve for yellow-fin sole from 12 years of combined data have been estimated as follows:

age range	L_{inf} (cm)	K	to
3-26	35.8	0.147	0.47

ANALYTIC APPROACH

Model Structure

The abundance, mortality, recruitment and selectivity of yellow-fin sole were assessed with a stock assessment model using the AD Model builder language. The conceptual model is similar to that implemented in the stock synthesis program (Methot 1990, Fournier and Archibald 1982). The model is a separable catch-age analysis that uses survey estimates ofbiomass and age composition as auxiliary information. The assessment model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics is optimized by maximizing a log(likelihood) function.

The suite of parameters estimated by the model are classified by three likelihood components:

Data Component	Distribution assumption
Trawl fishery catch-at-age	Multinomial
Trawl survey population age composition	Multinomial
Trawl survey biomass estimates and SE.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (Table 3-5). The likelihood components may be weighted by an emphasis factor, however, equal emphasis was placed on fitting each likelihood component in the yellowfin sole assessment except for the catch. The AD Model Builder software fits the data components using automatic differentiation (Griewank and Corliss 1991) software developed as a set of libraries (AUTODIFF C++ library). Table 3-5 presents the key equations used to model the yellowfin sole population dynamics in the Bering Sea and Table 3-6 provides a description of the variables used in Table 3-5.

Sharp increases in trawl survey abundance estimates for most species of Bering Sea flatfish between 198 1 and 1982 indicate that the 83- 112 trawl was more efficient for capturing these species than the 400-mesh eastern trawl used in 1975, and 1979-8 1. Allowing the model to tune to these early survey estimates would most likely underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. Although this underestimate would have little effect on the estimate of current yellowfin sole biomass, it would affect the spawner and recruitment estimates for the time-series: Hence, the pre- 1982 survey biomass estimates were omitted from the analysis.

The model of yellowfin sole population dynamics was evaluated with respect to the observations of the time-series of survey and fishery age compositions and the survey biomass trend since 1982.

Parameters Estimated Independently

Natural mortality (M) was initially estimated by a least squares analysis. Catch-at-age data were fitted to Japanese pair trawl effort data while varying the catchability coefficient (q) and M simultaneously. The best fit to the data (the point where the residual variance was minimized) produced an M value of 0.12 (Bakkala and Wespestad 1984).

The natural mortality rate value of 0.12 was also evaluated using the synthesis model in an earlier assessment (Wilderbuer 1992). Values of natural mortality were varied from 0.09 to 0.18 to determine which level would fit the observable population characteristics best. Maximum log(likelihood) values occurred at M = 0.12 when the analysis was run using fishery catch-at-age data from 1977-91 and at M = 0.16 when data from 1964-91 were included. The natural mortality rate most likely falls within the range of 0.12 - 0.16.

The survey catchability coefficient (q) was set equal to 1.0. Yellowfin sole maturity schedules were estimated as discussed in section 3.3.3 (Table 3.4).

Parameters Estimated Conditionally

The parameters estimated by the mode1 are presented below:

Fishing mortality	Selectivity	Year class strength	Total
46	4	65	115

The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery data and the entry of another year class into the observed population.

Year class strengths

The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate for each cohort as it moves through the population using the population dynamics equations given in Table,? -5.

Selectivity

Fishery and survey selectivity was modeled in this assessment using the two parameter formulation of the double logistic function, as shown in Table 3-5. The model was run with the selectivity curve fixed asymptotically for the older fish in the fishery and survey, but still was allowed to estimate the shape of the logistic curve for young fish. The oldest year classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the age category 20+ years.

Fishing Mortality

The fishing mortality rates (F) for each age and year are calculated to approximate the catch weight by solving for F while still allowing for observation error in catch measurement. A large emphasis was placed on the catch likelihood component.

MODEL RESULTS

Fishing Mortality and Selectivity

The assessment model estimates of the annual fishing mortality on fully selected ages is given in Table 3.7. The large 1997 catch corresponds to an F value of 0.108, which is higher than the 1977-98 average full selection F of 0.091 but only represents an exploitation fraction of 6%. Selectivities estimated by the model (Table 3.8, Fig. 3.5) indicate that yellowfin sole are 50% selected by the fishery at age 9 and nearly fully selected by age 14.

Abundance Trend

Model results indicates that yellowfin sole total biomass (age 2+) was at low levels during most of the 1960s and early 1970s (700,000-800,000 t) after a period of high exploitation (Table 3.9, Fig 3.5, bottom left panel). Sustained above average recruitment from 1967-76 combined with light exploitation resulted in a biomass increase to over 2.9 million t by 1985. The population biomass has remained at this high level since then, primarily due to the influence of the strong 1981 and 1983 year-classes. Over the past fifteen years stock biomass has remained stable with annual estimates oftotal biomass consistently over 2.7 million t. The model estimates the 2000 total biomass at over 2.8 million t and is projected to increase further as the very strong 199 1 year class begins to maximize its cohort biomass. The female spawning biomass is also at a high level. The resulting fit to all the observed fishery and survey age compositions input into the model are shown in the Appendix. The fit to the trawl survey biomass estimates are shown in Figure 3.5. The model does not provide a good fit the one million t decline in estimated survey biomass from 1989 to 1999. For the reasons discussed in section 3.2.2, we feel the 1999 trawl survey abundance estimate is an underestimate of the 1999 yellowfin sole population biomass. However, the 1999 survey biomass estimate does effect the trend of the model biomass estimates since 1995 by changing the stock size perception from increasing to stable.

With the exception of the 1999 trawl survey biomass estimate, both the trawl survey and the stock assessment model indicate that the yellowfin sole resource slowly increased during the 1970s and early 1980s to a peak level during the mid-1980s and that the resource has remained abundant and stable since then (Figure 3.5). This is indicative of a slow-growing species with a low natural mortality rate which is known to have been lightly exploited (Figure 3.5 top right panel) during a period of average to strong recruitment. Average to above average recruitment from the 199 1 and 1993 year-classes are expected to maintain the abundance of yellow-fin sole at a high level in the near future.

Total Biomass

The stock assessment model estimate oftotal biomass (begin year population numbers multiplied by mid-year weight at age) is used to recommend the ABC for 2000. Including the 1999 reported catch through 18 September (including discards), the model projects the total biomass for 2000 at **2,815,600 t**.

Recruitment Trends

The primary reason for the sustained increase in abundance of yellow-fin sole during the 1970s and early 1980s was the recruitment of a series of stronger than average year classes spawned in 1967-76 (Figs. 3.6, 3.7 and Table 3.11). Many of these year classes still provide a portion of the exploitable population. The 1981 year class is the strongest observed (and estimated) during the 45 year period analyzed and the 1983 year class is also very strong. In addition, survey age composition estimates and the assessment model also estimate that the 1987 and 1988 year classes are above average and the 199 1 and 1993 year classes are very strong. The future contribution from these year-classes should keep the population at its current high and stable level under current exploitation levels.

Snawner-Recruit Relationshin

The relationship between the model estimates of female spawning biomass and age 5 recruitment are shown in Figure 3.8. The forty-four data points were fit with a Ricker (1958) form of spawner-recruit curve. Estimation of recruitment using these data indicate that good year classes may result at high or low spawning stock size. The fitted curve to this data is not recommended for use in predicting recruitment for stock management purposes.

Historical Exploitation Rates

Based on results of stock synthesis modeling, annual exploitation rates of yellowfin sole ranged from 3 to 8% of the total biomass since 1977, and have averaged 5%.

ACCEPTABLE BIOLOGICAL CATCH

After increasing during the 1970s and early 1980s, estimates of total biomass from the stock assessment model have been relatively stable at over 2.7 million t since 1982 while estimates from bottom trawl surveys have fluctuated around these estimates. The model's year 2000 estimate of total biomass is 2,8 15,600 t.

The reference fishing mortality rate for yellowfin sole is determined by the amount of population information available (Amendment 44 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Equilibrium female spawning biomass is calculated by applying the female spawning biomass per recruit resulting from a constant $F_{0.40}$ harvest to an estimate of average equilibrium recruitment. For the 1999 assessment, the Alaska Fisheries Science Center policy is to use only year classes spawned in 1977 or later to calculate the average equilibrium recruitment. Using the time-series of recruitment numbers from 1978-98 from the stock assessment model results in an estimate of B,, = 576,600 t. The stock assessment model estimates the 2000 level of female spawning biomass at 789,300 t (B). Since reliable estimates of B, $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (789,300 > 576,600), yellowfin sole reference fishing mortality is defined in tier 3a. For the 2000 harvest: $F_{ABC} \leq F_{0.40} = 0.11$ (full selection F values).

Acceptable biological catch is estimated for 2000 by applying the $F_{0.40}$ fishing mortality rate and age-specific fishery selectivities to the 2000 estimate of age-specific total biomass as follows:

$$ABC = \sum_{a=a_r}^{a_{max}} \overline{w}_a n_a \left(\frac{Fs_a}{M + Fs_a} \right) \left(1 - e^{-M-Fs_a}\right)$$

where S_i is the selectivity at age, M in natural mortality, W_i is the mean weight at age, and n_i is the beginning of the year numbers at age. This calculation results in a 2000 ABC of 190,600 t.

Overfishing

The stock assessment analysis must also consider harvest limits, usually described as "overfishing" fishing mortality levels with corresponding yield amounts. Previous stock assessments used $F_{0.30}$ or the fishing mortality rate which would reduce the spawning biomass per recruit to 30% of its unfished level as the harvest limit. Amendment 56 to the BS/AI FMP now sets the harvest limit at the F_{35} fishing mortality value. The overfishing fishing mortality value, ABC fishing mortality value and their corresponding yields are given as follows:

Harvest level	2000 F value	2000 Yield
$F_{OFL} = F_{0.35}$	0.13	226,000 t
$F_{ABC} = F_{0.40}$	0.11	190,600 t

BIOMASS PROJECTIONS

This year, a standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 1999 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2000 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 1999. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2000, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario *1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2000 recommended in the assessment to the *max* F_{ABC} for 2000. (Rationale: When F_{ABC} is set at a value below ***max*** F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1994- 1998 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2000 and above its MSY level in 2010 under this scenario, then the stock is not overfished.)

Scenario 7: In 2000 and 200 1, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 20 12 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 3.12 indicate that yellow-fin are not currently overfished and are not approaching an overfished condition.

OTHER CONSIDERATIONS

Groundfish predators of yellowfin sole include Pacific cod, skates and Pacific halibut, mostly on fish ranging from 7 to 25 cm standard length. Yellowfin sole diet consists mainly ofbivalves, polychaetes, amphipods and echiurids.

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Table 3.1- Catch of yellowfin sole 1977-99. Catch for 1999 is the total through September 18, 1999.

		Domestic		
Year	Foreign	JVP	DAP	Total
1977	58,373			58,373
1978	138,433			138,433
1979	99,019			99,019
1980	77,768	9,623		87,391
1981	81,255	16,046		97,301
1982	78,331	17,381		95,712
1983	85,874	22,511		108,385
1984	126,762	32,764		159,526
1985	100,706	126,401		227,107
1986	57,197	151,400		208,597
1987	1,811	179,613	4	181,428
1988		213,323	9,833	223,156
1989		151,501	1,664	153,165
1990		69,677	14,293	83,970
1991			115,842	115,842
1992			149,569	149,569
1993			106,101	106,101
1994			144,544	144,544
1995			124,740	124,740
1996			129,659	129,659
1997			181,389	181,389
1998			101,201	101,201
1999			58,972	58,972

TABLE 3.ZYELLOWFIN SOLE FISHERY CATCH-AT-AGE IN NUMBERS (millions)

YEAR/AGE	7	8	9	10	11	12	13	14	15	16	17+
77	18.7	42.5	35.7	70.5	48.3	15.8	4.7	2.9	2.2	0.6	0.3
78	66.8	131.7	113.8	97.8	104.3	38.9	21.6	12.3	4.5	2.7	0.7
79	20.7	49.4	89.6	82.9	61.3	45.1	22.9	7.1	4.1	1.5	1.3
80	33.1	19.7	41.3	64.1	60.8	47.7	42.4	23.2	7.4	10.1	4.2
81	31.1	46.2	41.7	51.7	67.2	70.6	58.4	40.2	18.5	5.7	4.4
82	27.7	58.9	45.1	42.2	71.5	75.0	39.6	20.1	10.4	2.7	0.5
83	56.2	39.6	75.9	53.5	53.5	77.1	57.9	32.3	16.5	5.2	2.9
84	13.2	26.3	34.0	70.5	72.2	94.1	107.8	102.1	56.5	23.6	11.3
85	36.9	52.1	107.2	106.0	127.9	108.8	108.5	103.9	66.1	29.5	15.4
88	49.3	40.7	67.6	111.6	82.5	74.7	64.3	40.2	56.5	51.8	28.8
87	18.2	49.4	33.5	49.3	55.4	59.6	73.4	61.0	26.3	40.1	42.3
88	29.0	57.5	140.5	40.8	71.7	89.4	53.6	104.1	82.1	34.8	176.9
89	2.5	33.8	47.0	73.1	29.5	20.5	52.0	32.2	45.3	44.5	172.0
90	8.8	7.0	52.4	29.2	49.4	20.0	18.4	16.9	17.4	23.2	72.2
91	9.9	62.5	6.5	116.2	28.8	38.8	7.3	18.5	25.5	16.0	60.3
92	5.9	24.2	83.8	22.5	123.3	29.9	25.0	13.3	15.2	12.7	71.8
93	12.2	8.1	11.0	57.4	7.4	74.4	16.3	19.9	9.8	15.1	89.9
94	21.3	33.7	26.8	26.9	127.5	3.2	90.8	9.7	33.9	13.7	85.6
95	27.7	46.3	21.0	11.2	13.7	83.3	1.8	103.9	9.7	16.9	69.4
96	13.1	41.1	43.8	19.4	15.5	25.9	74.2	14.3	75.4	10.6	73.6
97	19.5	25.2	63.6	40.2	27.4	38.5	29.8	114.7	14.3	63.5	114.4
98	12.2	13.2	15.7	33.2	28.6	20.0	15.8	16.8	28.2	15.3	100.3

Table 3.3--Trawl survey estimates of yellowfin sole population numbers at age 1982-98 (milllons)

YEAR/AG	2	3	4	6	5	7	5	Q	10	11	12	13	14	15	16	17+
82	123.92	363.40	742.81	2882.02	3155.60	2408.06	3103.03	1445.10	1556.82	1256.34	1140.63	963.75	531.61	163.76	73.56	06.30
83	0.00	6.51	142.01	376.56	1650.47	3405.21	1836.08	2388.32	1786.45	1596.73	2070.66	1676.73	771.86	751.40	164.05	114.31
84	0.00	116.73	404.28	577.64	057.63	1554.66	1765.76	1932.76	1082.22	1750.32	053.15	1018.81	723.36	560.14	310.55	251.42
85	0.00	43.16	241.06	762.00	1640.16	618.06	1266.24	1353.31	787.56	904.66	846.54	568.07	510.46	440.47	205.60	177.02
86	0.00	35.15	66.68	310.96	606.31	1207.69	535.40	998.12	787.66	693.12	462.52	567.65	362.11	440.96	212.17	496.40
87	0.00	6.42	102.16	210.01	1554.66	032.70	1477.50	681.66	640.06	816.80	534.60	552.59	310.36	381.16	302.16	1106.67
88	1.05	4.01	32.02	782.57	133.73	2007.03	1524.25	1271.78	318.09	566.79	446.73	464.61	921.54	547.66	200.61	1.76
89	0.00	17.64	45.57	336.77	1847.06	564.12	3244.51	1350.68	078.08	255.66	280.08	603.42	351.60	540.72	267.24	1205.05
90	0.00	20.10	116.55	220.85	637.65	1047.17	366.52	2466.18	726.23	746.35	141.64	137.63	174.80	102.42	286.12	1003.50
91	0.00	12.92	220.34	504.64	256.26	718.66	1033.06	207.00	2423.15	535.66	764.55	142.63	196.50	137.61	164.99	1220.86
92	0.00	12.71	281.70	670.10	854.01	386.64	436.04	1522.33	183.38	1526.22	232.18	467.66	129.03	133.02	263.03	1140.63
93	0.00	52.70	180.61	610.32	1366.31	828.16	548.03	471.74	2418.63	147.70	1725.10	225.06	222.00	110.53	67.02	1059.50
94	4.24	75.20	165.77	388.84	044.64	1957.40	1210.83	780.64	475.32	1092.18	25.72	1137.67	99.67	405.69	153.46	434.45
95	0.00	16.60	321.67	408.22	451.46	1555.61	1102.14	368.72	314.47	90.90	1111.24	33.00	1163.36	153.10	164.54	020.02
96	0.00	82.33	249.64	1649.80	536.75	513.25	877.81	978.96	555.07	295.42	299.57	1026.43	181.20	1115.62	179.63	1151.40
97	0.00	37.60	541.50	927.00	1522.86	436.07	422.70	052.22	473.65	307.04	306.50	202.35	1014.11	122.74	576.36	046.04
98	0.00	58.02	153.23	820.26	000.47	1732.30	416.81	420.04	574.20	665.32	715.00	326.66	333.60	452.67	170.05	1074.36

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Table 3.4--Female yellowfin sole proportion mature at age from Nichol (1994).

Age	Proportion mature
1	0
2	0
3	.001
4	.004
5	.008
6	.020
7	.046
8	.104
9	.217
10	.397
11	.612
12	.790
13	.899
14	.955
15	.981
16	.992
17	.997
18	1.0
19	1.0
20	1.0

Table 3-S.-Key equations used in the population dynamics model.

$N_{t,1} = R_t = R_0 e^{\tau_t}, \quad \tau_t \sim N(0,\delta^2{}_R)$	Recruitment 1945-64
$N_{t,1} = R_t = R_\gamma e^{\tau_t}, \ \tau_t \sim N(0,\delta^2{}_R)$	Recruitment 1965-96
$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}\left(1 - e^{-z_{t,a}}\right)N_{t,a}$	Catch in year *t* for age ***a*** fish
$N_{t+1,a+1} = N_{t,a}e^{-z_{t,a}}$	Numbers of fish in year *t+1* at age ***a***
$N_{t+1,A} = N_{t,A-1}e^{-z_{t,A-1}} + N_{t,A}e^{-z_{t,A}}$	Numbers of fish in the “plus group”
$S_t = \sum N_{t,a}W_{t,a}\phi_a$	Spawning biomass
$Z_{t,a} = F_{t,a} + M$ A4	Total mortality in year *t* at age a
$F_{t,a} = s_a\mu^F \exp^{\varepsilon^F{}_t}, \ \varepsilon^F{}_t \sim N(o,\sigma^2{}_F)$	Fishing mortality
$s_a = \frac{1}{1+\left(e^{-\alpha+\beta a}\right)}$	Age-specific fishing selectivity
$C_t = \sum C_{t,a}$	Total catch in numbers
$P_{t,a} = {}^{C_{t,a}}\!/\!{}_{C_t}$	Proportion at age in catch
$SurB_t = q\sum N_{t,a}W_{t,a}v_a$	Survey biomass
$L = \sum_{t,a} m_t p_{t,a} \ln\frac{\hat{p}_{t,a}}{p_{t,a}} + (-0.5)\sum_t\left[\left(\ln\frac{surB_t}{\hat{surB_t}}\ {}^1\!/\!{}_{\sigma_t}\right)^2 - \ln\ \sigma_t\right]$	Total log likelihood

Table 3-6.–Variables used in the population dynamics model.

Variables	
R_t	Age 1 recruitment in year t
R_0	Geometric mean value of age 1 recruitment, 1945-64
R_γ	Geometric mean value of age 1 recruitment, 1965-96
τ_t	Recruitment deviation in year t
$N_{t,a}$	Number of fish in year t at age a
$C_{t,a}$	Catch numbers of fish in year t at age a
$P_{t,a}$	Proportion of the numbers of fish age a in year t
C_t	Total catch numbers in year t
$W_{t,a}$	Mean body weight (kg) of fish age a in year t
ϕ_a	Proportion of mature females at age a
$F_{t,a}$	Instantaneous annual fishing mortality of age a fish in year t
M	Instantaneous natural mortality, assumed constant over all ages and years
$Z_{t,a}$	Instantaneous total mortality for age a fish in year t
s_a	Age-specific fishing gear selectivity
μ^F	Median year-effect of fishing mortality
ε_t^F	The residual year-effect of fishing mortality
v_a	Age-specific survey selectivity
α	Slope parameter in the logistic selectivity equation
β	Age at 50% selectivity parameter in the logistic selectivity equation
σ_t	Standard error of the survey biomass in year t

Table 3.7-Model estimates of yellowfin sole fishing mortality and exploitation rate (catch/total biomass).

Year	Full selection F	Exploitation Rate
1954	0.0107	0.0081
1955	0.0127	0.0092
1956	0.0219	0.0149
1957	0.0221	0.0139
1958	0.0417	0.0243
1959	0.1869	0.0984
1960	0.5668	0.2525
1961	1.0474	0.3603
1962	1.5321	0.4169
1963	0.4643	0.1226
1964	0.5529	0.1508
1965	0.2219	0.0726
1966	0.3422	0.1288
1967	0.5339	0.2060
1968	0.2824	0.1179
1969	0.6201	0.2286
1970	0.6008	0.1982
1971	0.9507	0.2360
1972	0.3227	0.0702
1973	0.4614	0.0926
1974	0.1929	0.0419
1975	0.2140	0.0521
1976	0.1358	0.0381
1977	0.1044	0.0336
1978	0.1961	0.0691
1979	0.1144	0.0455
1980	0.0824	0.0369
1981	0.0769	0.0382
1982	0.0652	0.0357
1983	0.0657	0.0386
1984	0.0902	0.0549
1985	0.1273	0.0771
1986	0.1195	0.0718
1987	0.1070	0.0631
1988	0.1369	0.0762
1989	0.0944	0.0554
1990	0.0472	0.0294
1991	0.0525	0.0342
1992	0.0858	0.0570
1993	0.0570	0.0389
1994	0.0791	0.0530
1995	0.0705	0.0461
1996	0.0749	0.0477
1997	0.1083	0.0663
1998	0.0621	0.0375

Table 3.8--Model estimates of yellowfin sole age-specific selectivities for survey and fishery data. .

Age	Fishery (1964-98)	Survey (1982-98)
1	0.000	0.001
2	0.001	0.006
3	0.002	0.028
4	0.005	0.114
5	0.016	0.364
6	0.044	0.717
7	0.118	0.918
8	0.279	0.980
9	0.529	0.996
10	0.765	0.999
11	0.904	1.000
12	0.965	1.000
13	0.988	1.000
14	0.988	1.000
15	0.988	1.000
16	0.988	1.000
17	0.988	1.000
18	0.988	1.000
19	0.988	1.000
20	0.988	1.000

Table 3.9-Model estimates of yellowfin sole 2+ biomass and female spawning biomass from the 1998 and 1999 stock assessments.

	1998 Assessment		1999 Assessment	
Year	Female Spawning Biomass	Age 2+ Total Biomass	Female Spawning Biomass	Age 2+ Total Biomass
54	62,437	746,226	73,064	737,240
65	71,370	746,233	75,930	740,891
66	90,826	798,701	100,927	794,404
67	99,628	791,656	118,011	787,482
68	100,509	721,178	112,565	713,902
69	99,672	745,430	123,233	730,983
70	82,122	701,715	99,482	671,550
71	63,380	722,617	82,226	673,997
72	51,890	750,194	54,436	681,570
73	59,053	936,567	62,687	844,784
74	71,753	1,121,385	69,712	1,008,880
75	99,858	1,367,336	96,615	1,241,970
76	139,785	1,605,667	131,561	1,476,790
77	196,657	1,860,582	183,278	1,737,960
78	261,960	2,113,328	249,658	2,003,760
79	327,460	2,270,263	305,125	2,175,840
80	409,926	2,447,141	383,757	2,369,200
81	498,073	2,608,998	476,803	2,547,530
82	581,530	2,729,659	570,477	2,684,330
83	658,368	2,838,889	664,949	2,808,360
84	720,021	2,923,667	750,422	2,905,980
85	750,310	2,953,312	803,485	2,945,030
86	750,288	2,910,804	808,949	2,907,140
87	741,783	2,876,384	799,413	2,875,640
88	721,979	2,851,176	788,354	2,852,330
89	698,329	2,765,757	752,727	2,765,010
90	709,408	2,743,646	756,691	2,740,990
91	747,170	2,786,873	800,799	2,781,510
92	776,530	2,798,956	842,458	2,788,670
93	790,029	2,749,555	849,712	2,727,120
94	798,837	2,772,545	865,389	2,728,120
95	784,090	2,791,932	846,666	2,704,860
96	765,759	2,870,562	826,251	2,719,090
97	740,460	2,966,625	802,694	2,734,710
98	724,900	3,016,099	762,771	2,696,730
99	756,916	3,179,155	761,651	2,735,540

Table 3.10--Model estimates of yellowfin sole population numbers at age (millions of fish).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	16	17	18	19	20
1964	6616	619.4	1.4561	739.9	1,133.0	942.6	1,065.7	1,166.8	234.2	211.0	196.9	126.2	34.3	8.8	3.3	2.5	2.3	2.2	2.1	218
1965	1.246.5	782.0	726.5	1,291.8	654.3	996.2	815.9	665.5	888.6	155.1	122.6	107.0	65.6	17.6	4.5	1.7	1.3	1.2	1.1	12.3
1966	1,503.9	1.105.5	693.5	6441	1,144.4	578.3	875.0	704.9	738.2	699.4	116.0	86.9	76.6	46.8	12.6	3.2	1.2	0.9	08	9.6
1887	2.5113	1.333.8	980.2	614.7	570.2	1,009.5	505.2	745.4	568.2	546.3	477.4	75.5	567	40.5	29.6	7.9	2.0	0.8	0.6	6.6
1968	2,760.8	2.227.;	1.182.5	868.5	543.6	501.5	874.6	420.7	569.5	379.9	322.0	261.3	40.0	29.7	25.4	15.5	4.2	1.1	04	3.8
1969	2.712.5	2.446.4	1.974.9	1,048.3	769.1	460.0	439.3	750.3	344.9	435.0	271.5	221.2	176.5	26.9	19.9	17.0	104	2.8	0.7	28
1970	3.779.7	2.405.5	2.170.7	1.749.5	926.6	675.6	414.2	362.1	559.6	220.3	240.1	137.4	107.9	64.0	12.9	9.6	6.2	5.0	1.3	1.7
1971	4,651.8	3,351.9	2.132.6	1,923.1	1,546.6	814.1	583.5	342.3	271.6	361.2	123.4	123.7	66.3	52.9	416	63	4.7	4.0	24	15
1972	4.526.7	4.124.9	2,971.0	1.688.1	1,696.8	1,351.5	692.4	4627	232.6	145.7	154.8	46.3	43.6	23.7	18.3	14.4	2.2	1.6	1.4	1.4
1973	4,049.4	4.014.5	3.657.7	2,633.4	1,671.6	1.497.3	1.181.7	591.2	375.0	174.1	100.9	102.5	30.1	26.3	15.3	11.6	9.3	1.4	1.0	16
1974	4.453.3	3.591 1	3.559.6	3.241.3	2.329.8	1.471.9	1.301.3	992.6	481.0	260.5	108.5	59.0	58.3	16.9	15.9	86	6.6	5.2	08	1.6
1975	5.376.9	3.949.5	3.1647	3.155.9	2,871.7	2,060 1	1.294.4	1,128.2	834.2	3692	199.4	808	434	42.7	12.4	11.7	6.3	4.9	3.8	17
1976	3.442.9	4.7687	3.6024	2.823.4	2.7957	2.538.5	1,810.0	1.119.5	942.8	660.8	278.0	145.7	58.3	31.2	30.7	89	6.4	4.5	35	40
1977	4,038.9	3,053.4	4,229.0	3,105.6	2,502.3	2.474.3	2,238.0	1,579.8	955.9	778.0	528.1	218.0	113.4	45.2	24.2	23.8	6.9	6.5	3.5	5.8
1978	2.6689	3,582.1	2.7080	3,750.1	2.752.8	2,215.7	2.184.5	1,960.6	1360.9	892.3	637.0	426.2	174.8	90.7	38.2	19.3	19.0	55	52	7.5
1979	1.794.7	2.384.7	3.176.6	2,400.9	3.322.5	2.434.1	1.948.2	1.893.2	1.6463	1,088.1	612.4	473.2	312.8	127.8	66.3	26.4	14 1	139	4.0	92
1980	3.410.1	1.591.7	2,114.9	2.8168	2.1281	2.941.5	2.148.0	1.704.8	1,626.3	1.374.4	884.2	489.8	375.9	247.8	101.2	525	20.9	11.2	110	10.5
1981	2.427.6	3.024.4	1.411.6	1.875.5	2.497.2	1.885.0	2.599.4	1.8867	1,477.S	1.380.9	1,144.5	727.9	401.2	307.3	202.6	82.8	42.9	17.1	9.2	17.6
1982	8.8QC.Q	2.153.1	2.662.3	1.251.8	1,662.7	2.212.1	1,666.Z	2.264.7	1,637.8	1,258.3	1.154.7	946.9	599.4	329.8	252.6	166.6	680	353	141	22.0
1983	870.9	6.111.6	1.9095	2.378.7	1.109.9	1.473.2	1.966.4	1,466.4	1.989.7	1.403.3	1,063.6	965.5	786.8	498.5	274.3	210.1	136.5	566	29.3	300
1984	5,766.1	772.4	5.420.3	1,693.4	2,108.9	983.4	1,302.8	1,721.7	1.277.0	1,704.4	1.18 0 6	887.3	8037	655.4	414.3	228.0	174.6	115.1	470	49.3
1886	1,551.5	5,113.9	685.0	4.8065	1.501.1	1,867.8	868.7	1.143.3	1.489.0	1.0798	1.41 .8	967.5	7213	852.0	531.8	336.1	185.0	141 7	934	78.2
1986	1.353.1	1.376.0	4.535.3	607.4	4,260.0	1.328.7	1.847.3	759.0	878.5	1,234.6	866.8	1,115.2	758.9	564.2	5100	415.9	282.9	1447	110.6	134.2
1987	2,059.0	1.2001	1.220.3	4.021.5	538.4	3.771.3	1.172.3	1,440.6	651.1	814.7	999.3	691.6	881.4	598.1	444.7	401.9	327.8	2072	1140	1931
1988	3,108 3	1,826.1	1,064.3	1.082.1	3,564.7	476.7	3,329.1	1,026.7	1.240.1	645.7	665.8	804.6	553.3	703.4	477.3	3546	320.8	261.6	165.4	245.1
1888	3,176.8	2.7567	1.6195	943.7	959.0	3.1548	420.2	2,905.4	876.4	1.023.0	435.8	521.8	625.3	428.8	544.9	369.8	274.9	246.5	202.7	319.0
1990	1.523.2	2.817.5	2.444.8	1.4361	8368	849.3	2.7665	368.6	2,509.8	739.5	844.1	354.9	422.5	505.2	346.3	440.3	298.8	222.1	200.8	420.7
1991	1,649.8	1,351.0	2,498.8	2.168.2	1,273.4	741.4	751 7	2.457.7	322.8	2.171.1	832.6	717.4	306.8	357.7	427.7	293.2	372.7	252.9	188.0	526.1
1992	5,268.6	1.463.2	1.198.2	2,218.0	1,922.5	1.128.4	856.0	662.6	2,148.0	278.3	1.849.8	535.1	6049	253.3	301.2	360.2	246.9	313.9	213.0	601.4
1993	3.425.9	4.072.8	1,297 7	1.062.5	1.964.5	1.702.8	997.1	576.0	513.8	1,820.6	231.2	1.5182	4369	492.9	206.4	245.4	293.5	201.2	2558	663.7
1994	4.546.6	3.038.5	4.144.2	1.150.8	942.1	1.740.8	1,506.4	878.4	502.6	493.8	1.545.8	194.7	1.274.4	3682	413.2	173.0	205.8	246.1	1687	770.8
1995	2.025.1	4.032.4	2.894.7	3,875.0	1,020.3	834.5	1.538.8	1.323.7	782.0	427.7	4122	1.278.4	1600	1945.4	300.4	339.0	141.9	168.8	201.8	7708
1996	2.341.0	1.798.1	3.576.3	2.389.7	3.258.2	903.9	737.8	1.353.3	1.151.1	651.1	359.4	343.0	1.057.6	132.4	864.8	248.5	280.4	117.4	1396	8045
1887	2.224.1	2.076.2	1.592.9	3.171.4	2.118.8	2,886.4	799.0	648.7	1.175.5	881.3	545.4	297.9	283.0	8712	109.0	7124	204.7	2310	967	7777
1908	2.380.0	1,972.5	1.841 3	1.4125	2.811.1	1.875.9	2.547.8	899.7	5582	9845	801.2	438.6	238.0	225.6	694.3	88.9	5678	1632	184.1	6969
1999	2,400.1	2.1108	1.749.4	1.6329	1,252.3	2,490.8	1.859.2	2.243.2	609.9	479.0	832.6	671.7	3664	198.5	1882	579.2	725	473.8	136.1	7349

Table 3.1 l-Estimated age 5 recruitment (millions) from ths 1968 and 1999 assessments.

Year class	1698 Assessment	1999 Assessment
59	1,068	1,133
60	641	654
61	1,165	1,144
92	588	570
63	568	544
64	814	769
65	1,002	927
66	1,744	1,547
67	1,911	1,697
68	1,910	1,672
69	2,641	2,330
70	3,112	2,872
71	2,783	2,796
72	-1,994	2,502
73	2,646	2,753
74	3,001	3,322
75	2,086	2,128
76	2,513	2,497
77	1,693	1,663
79	1,029	1,110
79	2,046	2,109
99	1,474	1,501
81	4,295	4,260
82	476	538
93	3,649	3,565
84	915	959
8s	819	837
98	1,260	1,273
87	2,041	1,922
89	2,152	1,965
89	1,002	942
90	1,106	1,020
91	3,960	3,258
92	2,976	2,119
93	4,571	2,811
94	1,785	1,252

Table 3.12--Projections of yellowfin sole female **spawing** biomass (1 **,000s** t), **catch** (1 **,000s** t) and **full selection** fishing mortality rate for seven future harvest scenarios.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
1999	723.699	58.9748	0.13
2000	727.737	189.492	0.11
2001	711.432	189.766	0.11
2002	703.153	188.71	0.11
2003	700.69	185.433	0.11
2004	688.37	178.523	0.11
2005	667.002	170.659	0.11
2006	641.02	163.667	0.11
2007	616.018	158.306	0.11
2008	595.386	154.847	0.11
2009	580.291	151.722	0.11
2010	572.049	148.722	0.11
2011	570.142	147.568	0.11
2012	589.587	146.903	0.11

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
1999	723.699	58.9749	0.13
2OW	740.521	97.0243	0.06
2001	760.476	101.617	0.06
2002	786.44	105.264	0.06
2003	817.34	107.508	0.06
2004	835.238	107.334	0.06
2005	839.696	106.034	0.06
2006	834.295	104.596	0.06
2007	824.994	103.504	0.06
2008	815.989	102.996	0.06
2009	809.005	102.881	0.06
2010	806.634	103.135	0.06
2011	809.93	103.786	0.06
2012	812.478	104.214	0.06

Scenario 4
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
1999	723.699	58.9759	0.13
2000	735.302	135.109	0.08
2001	740.145	138.947	0.08
2002	751.412	141.55	0.08
2003	767.611	142.291	0.08
2004	771.816	139.942	0.08
2005	764.193	136.362	0.08
2006	748.784	132.913	0.08
2007	731.493	130.224	0.08
2008	716.258	128.582	0.08
2009	704.572	127.693	0.08
2010	698.315	127.432	0.08
2011	697.791	127.739	0.08
2012	697.448	127.884	0.08

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
1999	723.699	0	0
2000	753.536	0	0
2001	813.086	0	0
2002	880.343	0	0
2003	955.256	0	0
2004	1017	0	0
2005	1083.18	0	0
2006	1095.56	0	0
2007	1119.57	0	0
2008	1139.51	0	0
2009	1157.11	0	0
2010	1176.79	0	0
2011	1201.99	0	0
2012	1222.87	0	0

Table **3.12--continued.**

Scenario 6

Determination of whether yellowfin sole are currently **overfished** **B35=500.69**

Year	Female spawning biomass	catch	F
1999	723.699	58.9748	0.13
2000	722769	224.683	0.13
2001	693.055	221.101	0.13
2002	673.013	216.422	0.13
2003	659.856	209.547	0.13
2004	638.576	198.998	0.13
2005	610.249	187.956	0.13
2008	579.396	178.485	0.13
2007	552.133	165.41	0.13
2008	532774	156.067	0.12
2009	521.203	151.428	0.12
2010	516.702	160.146	0.12
2011	517.487	151.002	0.12
2012	518.959	151.859	0.12

Scenario 7

Determination of whether yellowfin sole are **approaching** an overfished **condition** **B35=500.69**

Year	Female spawning biomass	catch	F
1999	723.699	58.9749	0.13
2000	727.738	189.492	0.11
2001	711.436	189.767	0.11
2002	698.388	223.748	0.13
2003	682.501	215.894	0.13
2004	858.203	204.406	0.13
2005	627.257	192689	0.13
2006	594.417	183.032	0.13
2007	565.818	173.631	0.13
2008	545.4	163.912	0.12
2009	533.243	158.318	0.12
2010	527.549	155.761	0.12
2011	526.484	155.34	0.12
2012	525.979	155.014	0.12

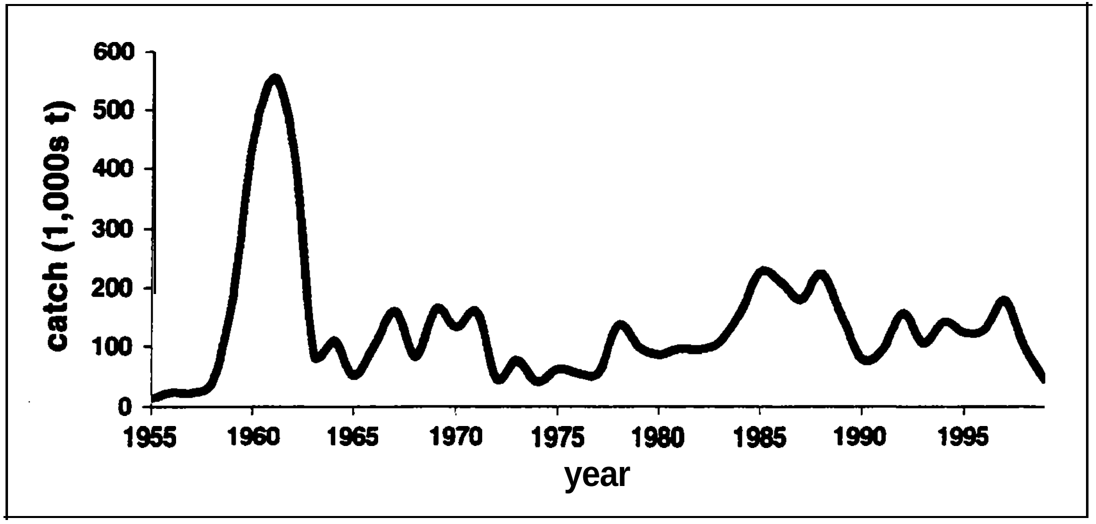


Figure 3.1 -Catch of yellowfin sole (t) **1955-September** 18, 1999.

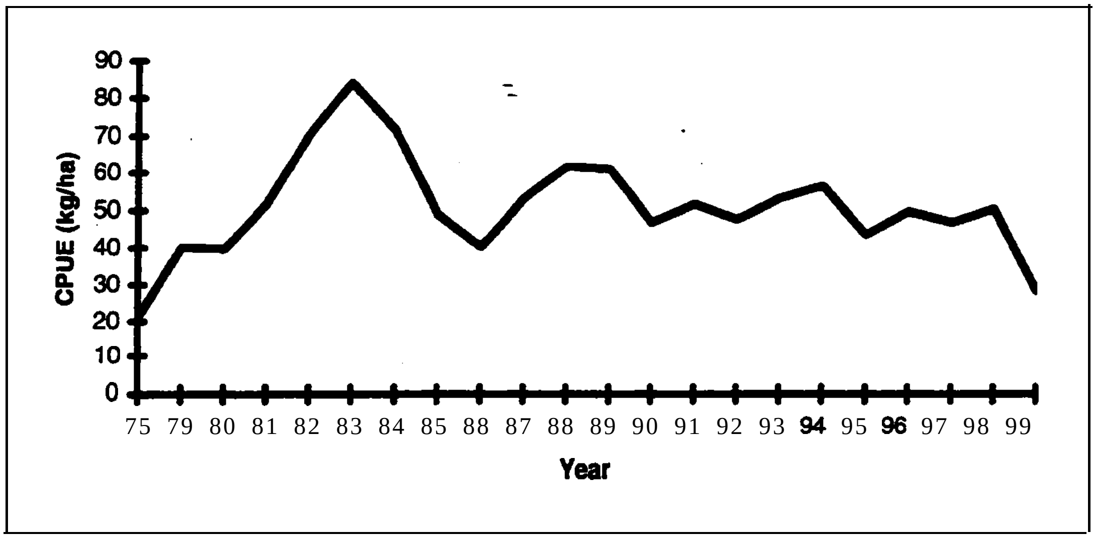


Figure **3.2--Yellowfin** sole CPUE (kg/ha) from the annual Bering Sea shelf trawl **surveys,** 1975 and 1979-99.

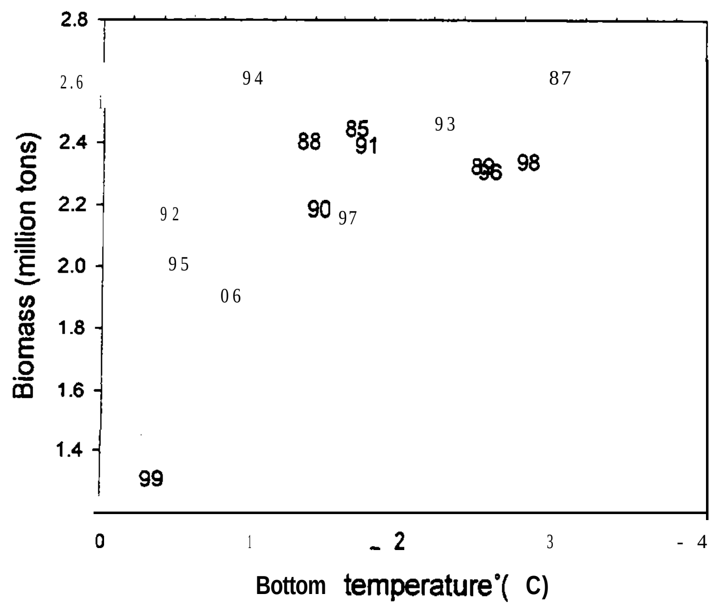


Figure 3-3.--Increase in survey estimates of yellowfin sole (*Limanda aspera*) biomass as related to mean midshelf (50-100 m) bottom temperatures for years 1985 - 1999.

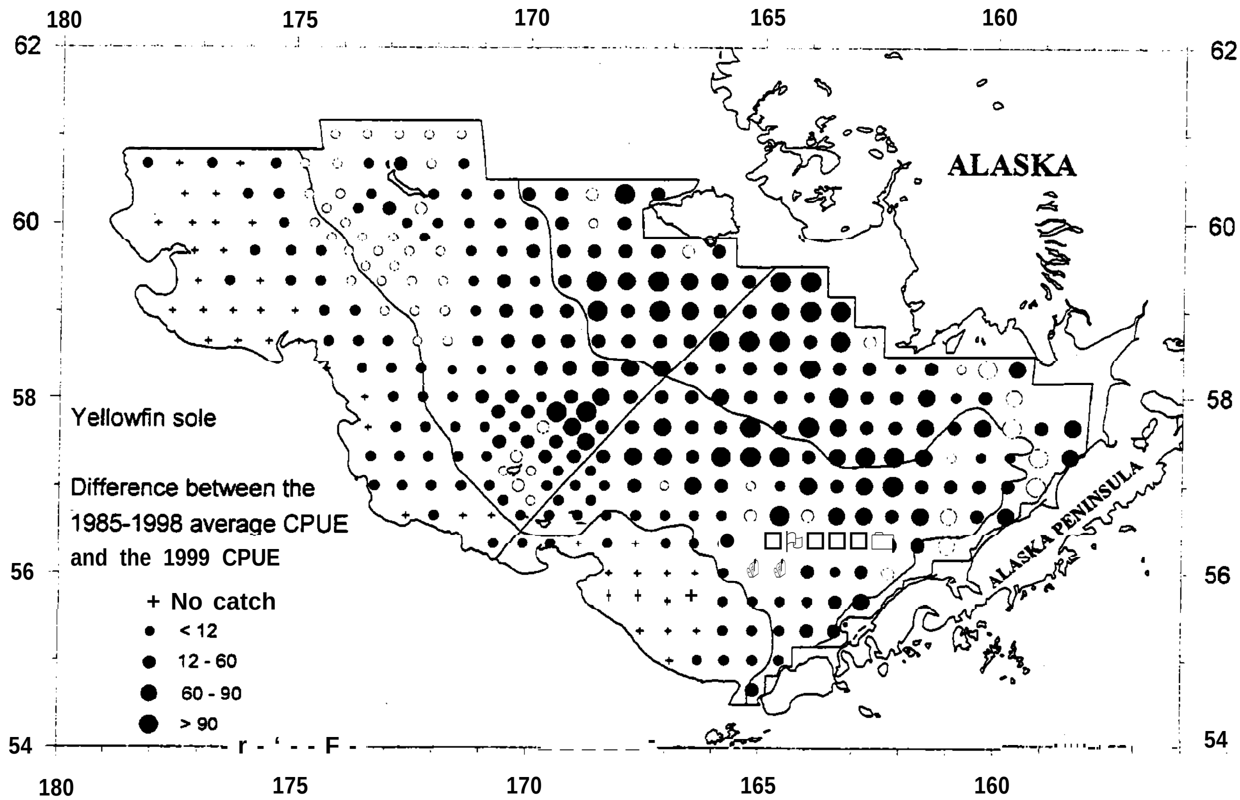


Figure 3-4.--Difference of CPUE during 1999 from the average CPUE from 1982-1998. Filled circles are lower than average (negative) and open circles are higher than average (positive).

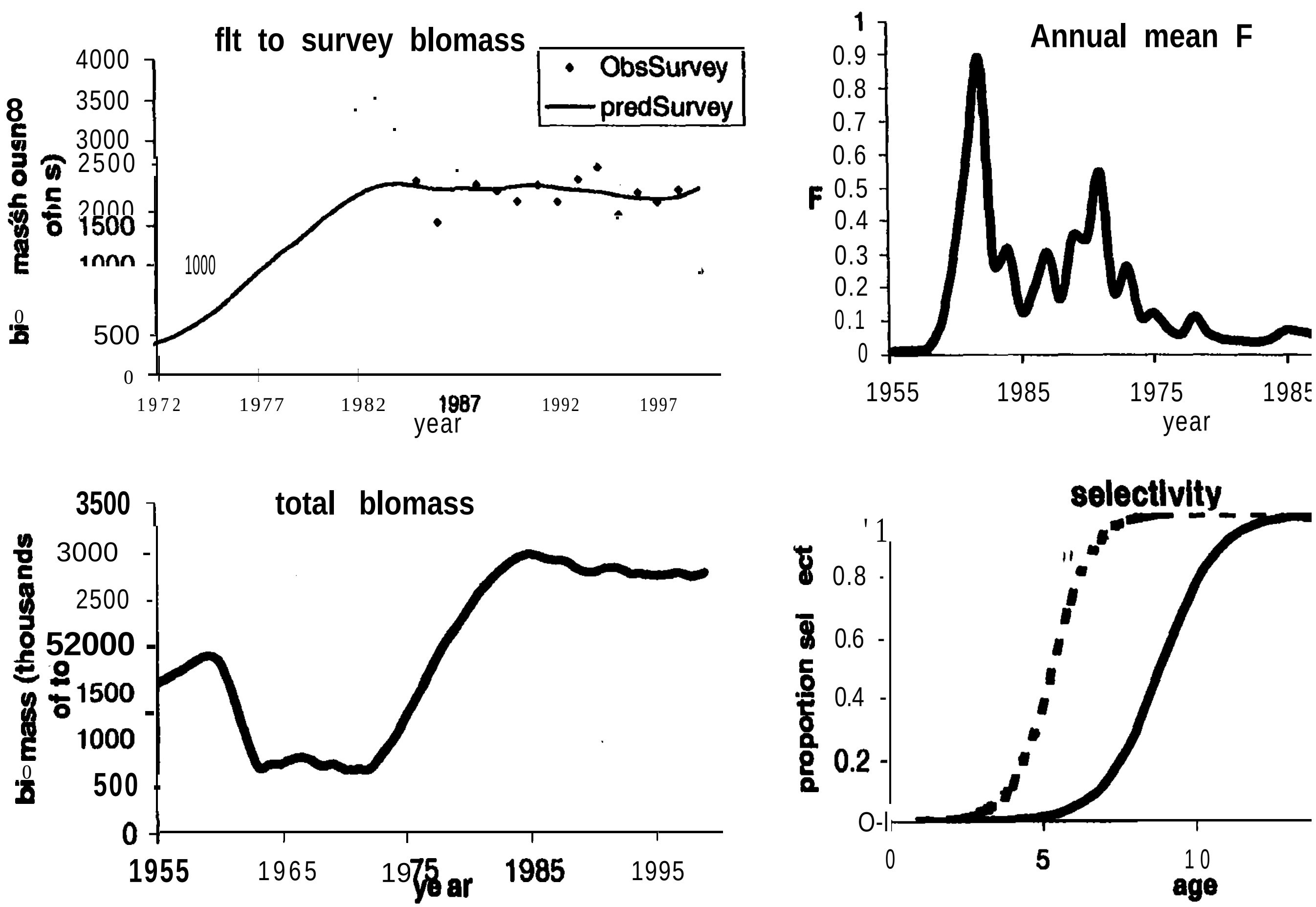


Figure 3.5--Model fit to the survey biomass estimates (top left panel), model estimate of the mean annual fishing throughout the time-series (top right panel), model estimate of total biomass (bottom left panel) and the model esti and survey selectivity (bottom right panel).

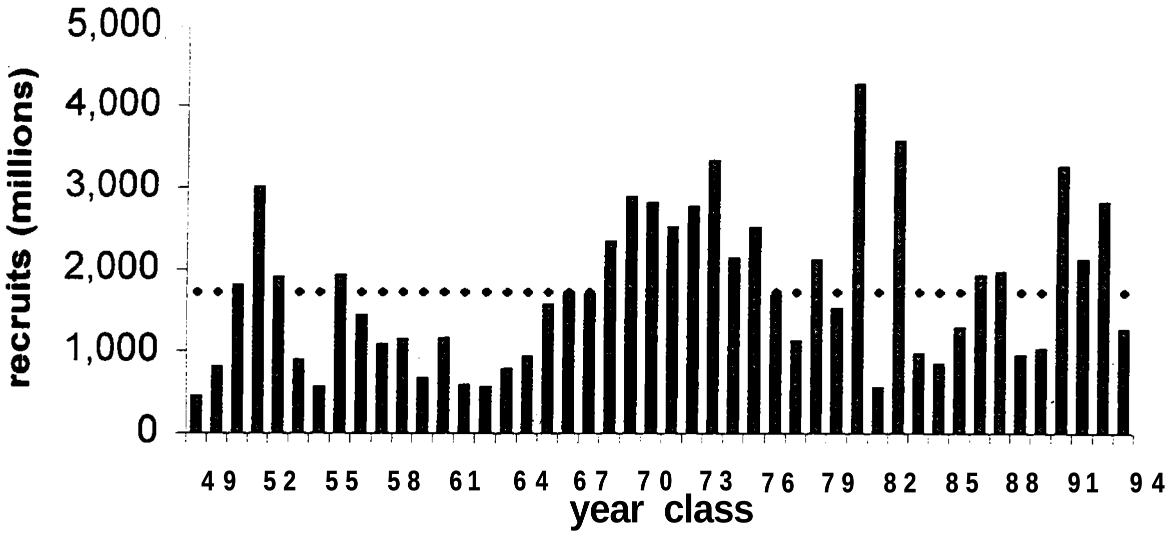


Figure 3.6-Year class strength of age 5 yellowfin sole estimated by the stock assessment model. The dotted line is the average of the estimates from 46 years of recruitment.

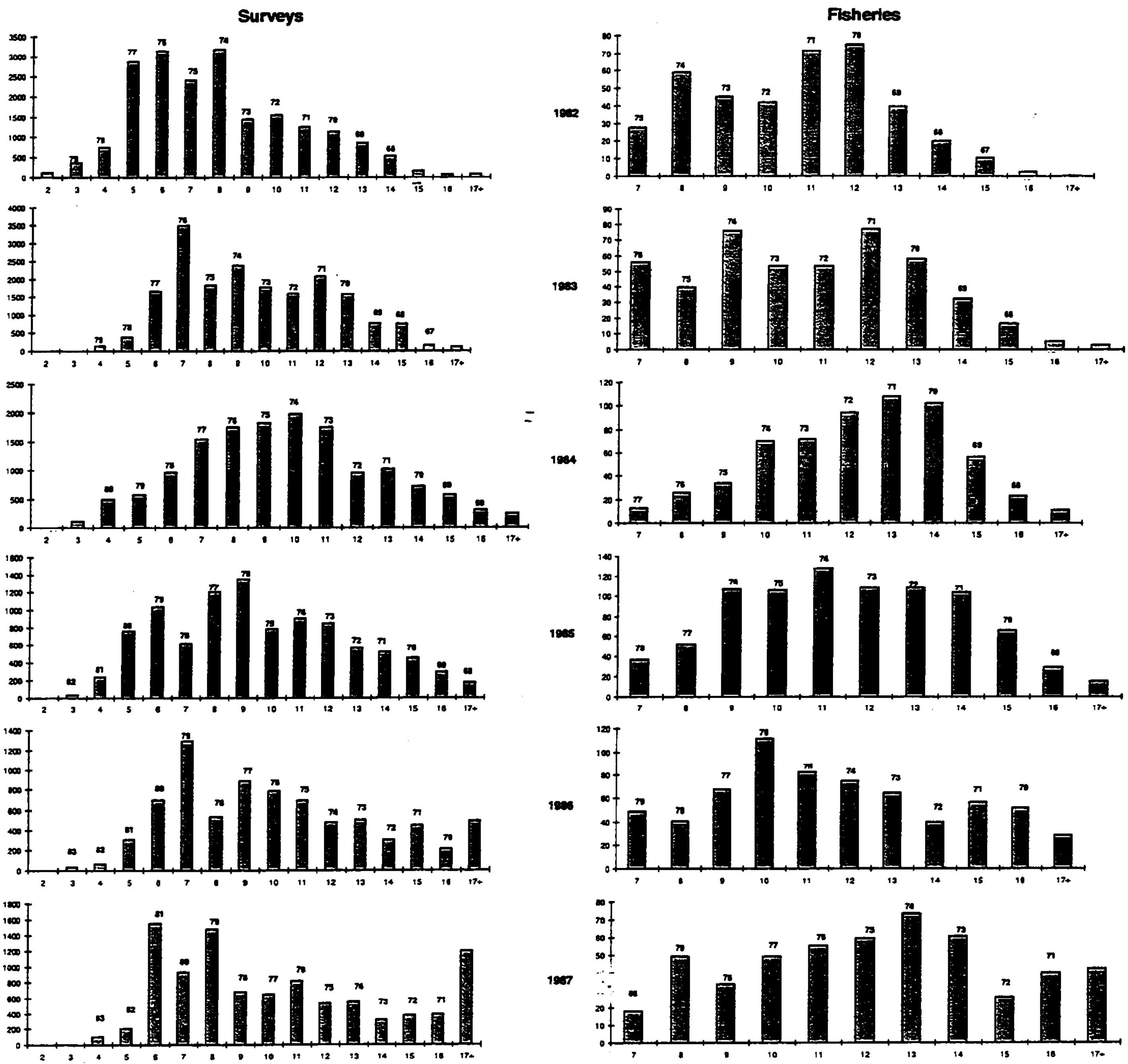


Figure 3.7--Age composition of the yellowfin sole catch and population (trawl survey estimates) in millions of fish, 1982-98. Year classes are indicated on the top of the bars.

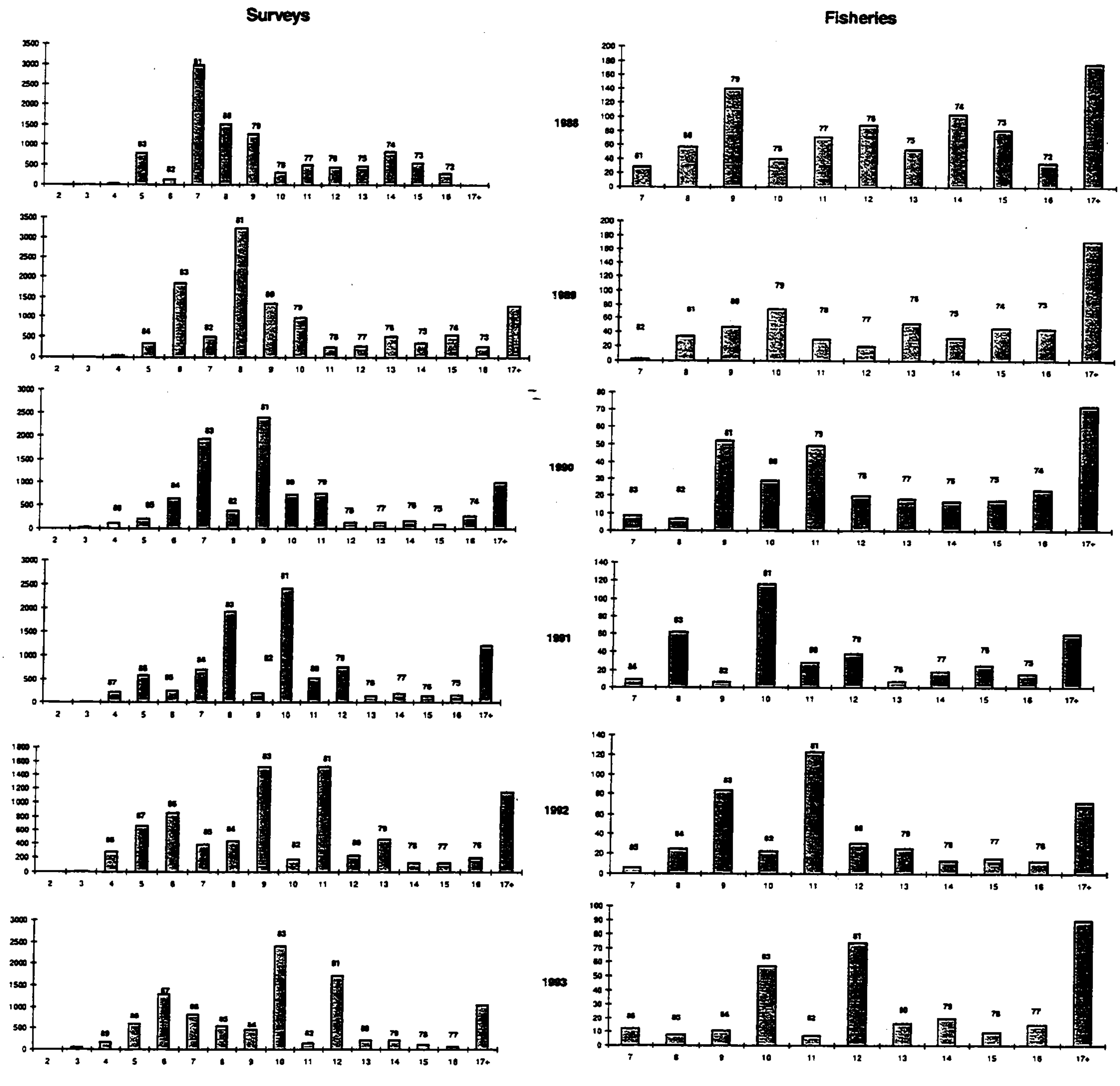


Figure 3.7--Age composition of the yellowfin sole catch and population (trawl survey estimates) in millions of fish, 1982-98. Year classes are indicated on the top of the bars.

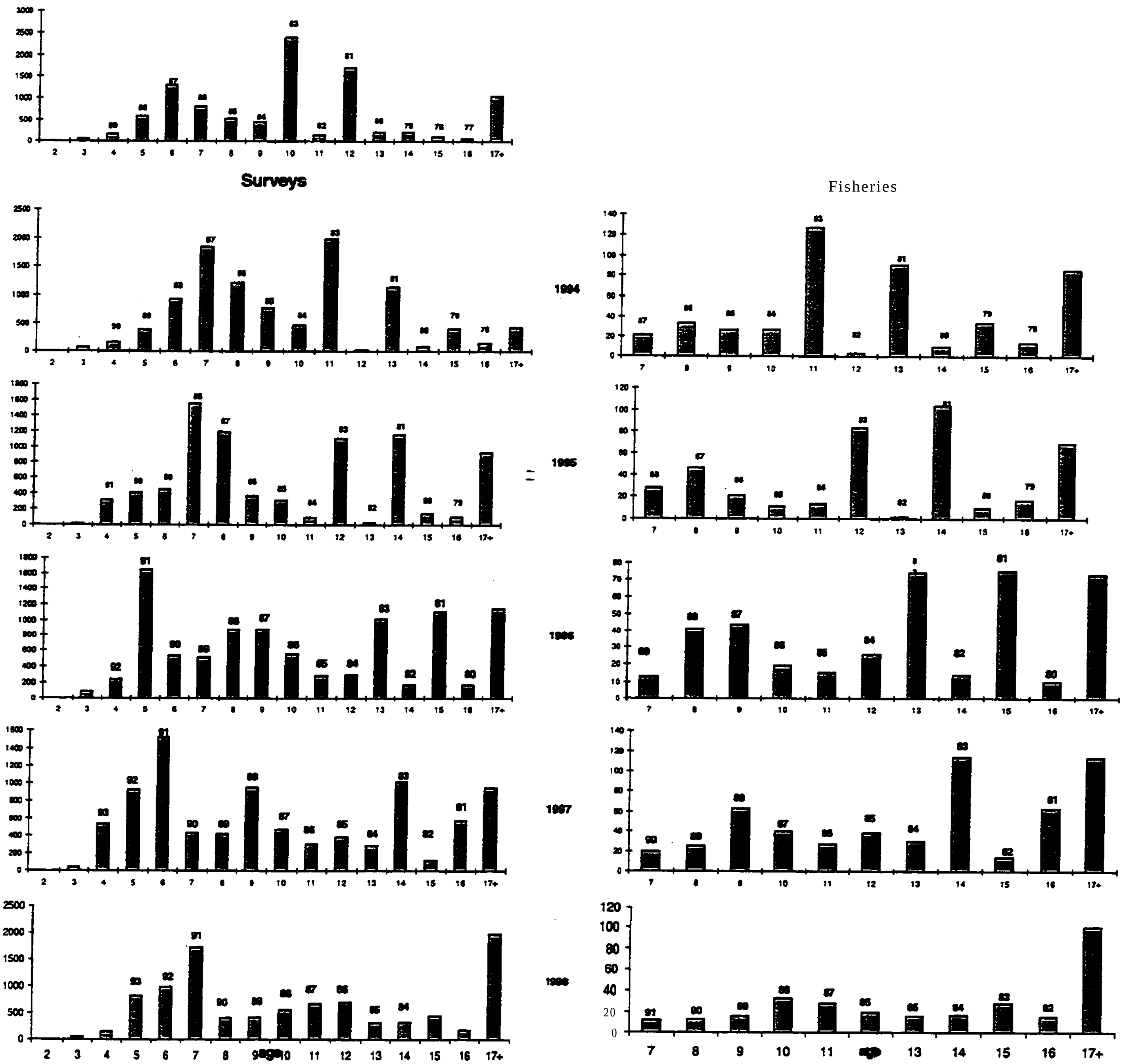


Figure 3.7-Age composition of the yelbwfin sole catch and population (trawl survey estimates) in millions of fish, 1982-98. Year classes are indicated on the top of the bars.

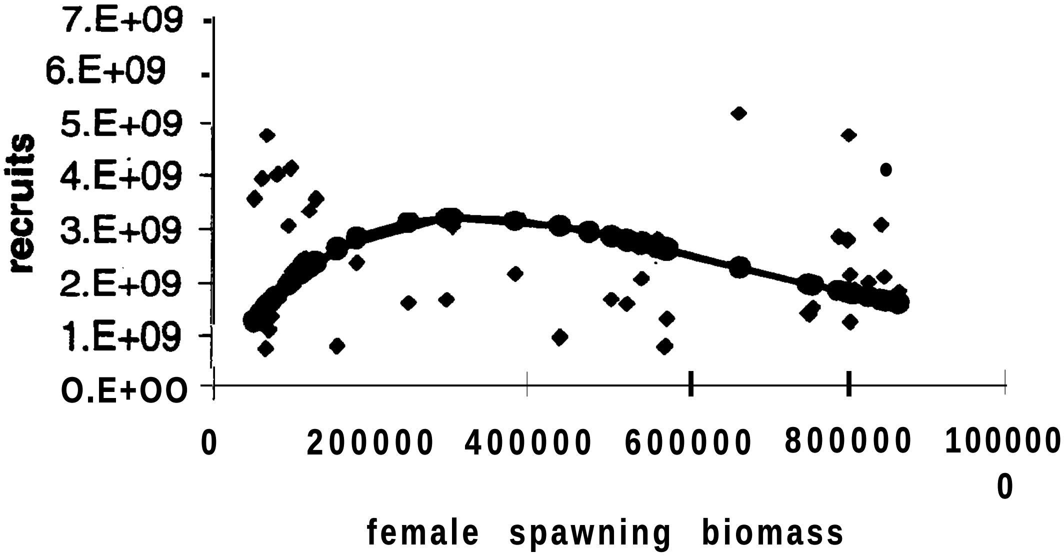


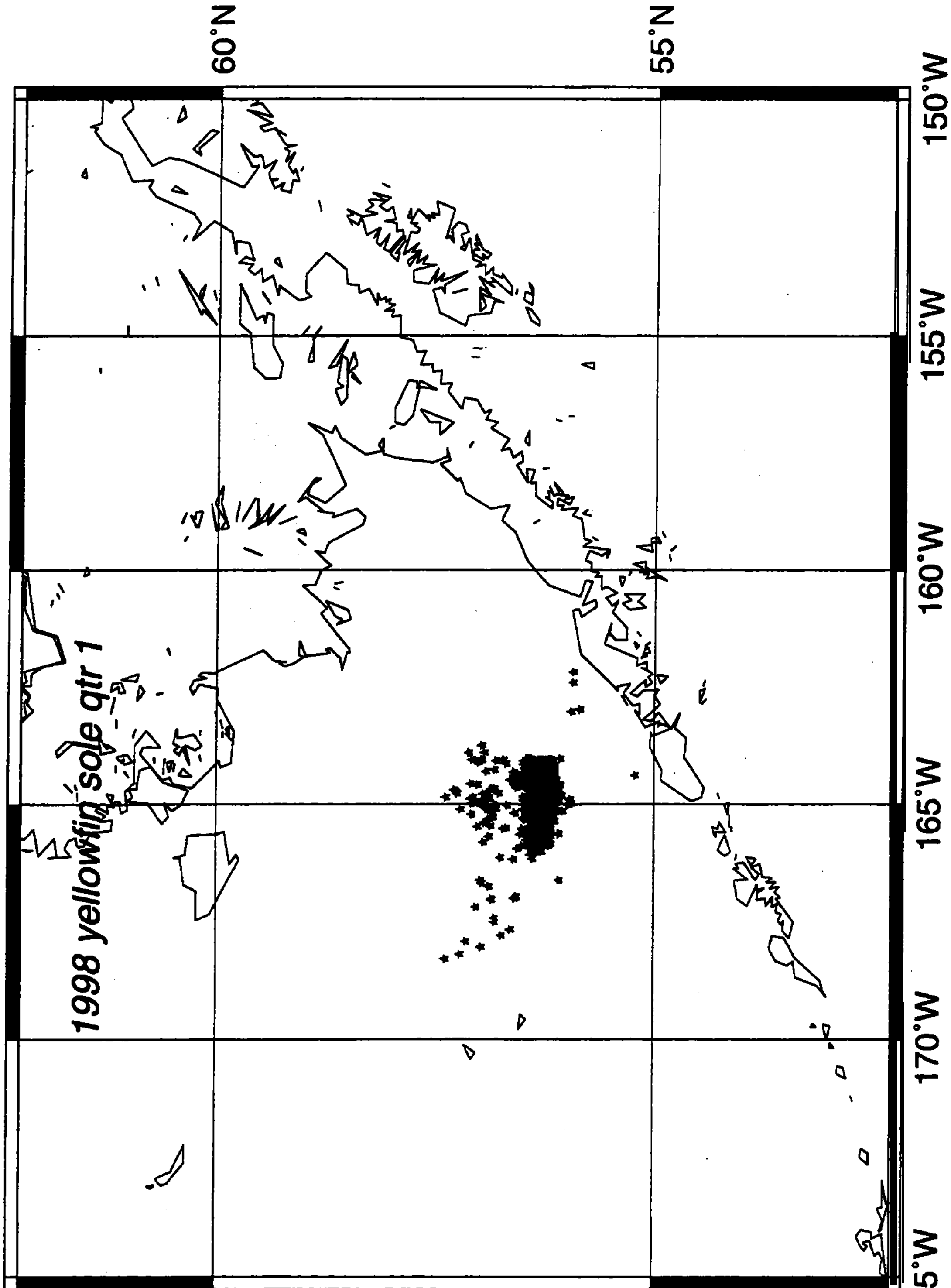
Figure 3.8-Fit of the Ricker (1958) spawner-recruit equation to model estimates of female spawning biomass and-subsequent age 5 recruitment numbers for 44 years of data.

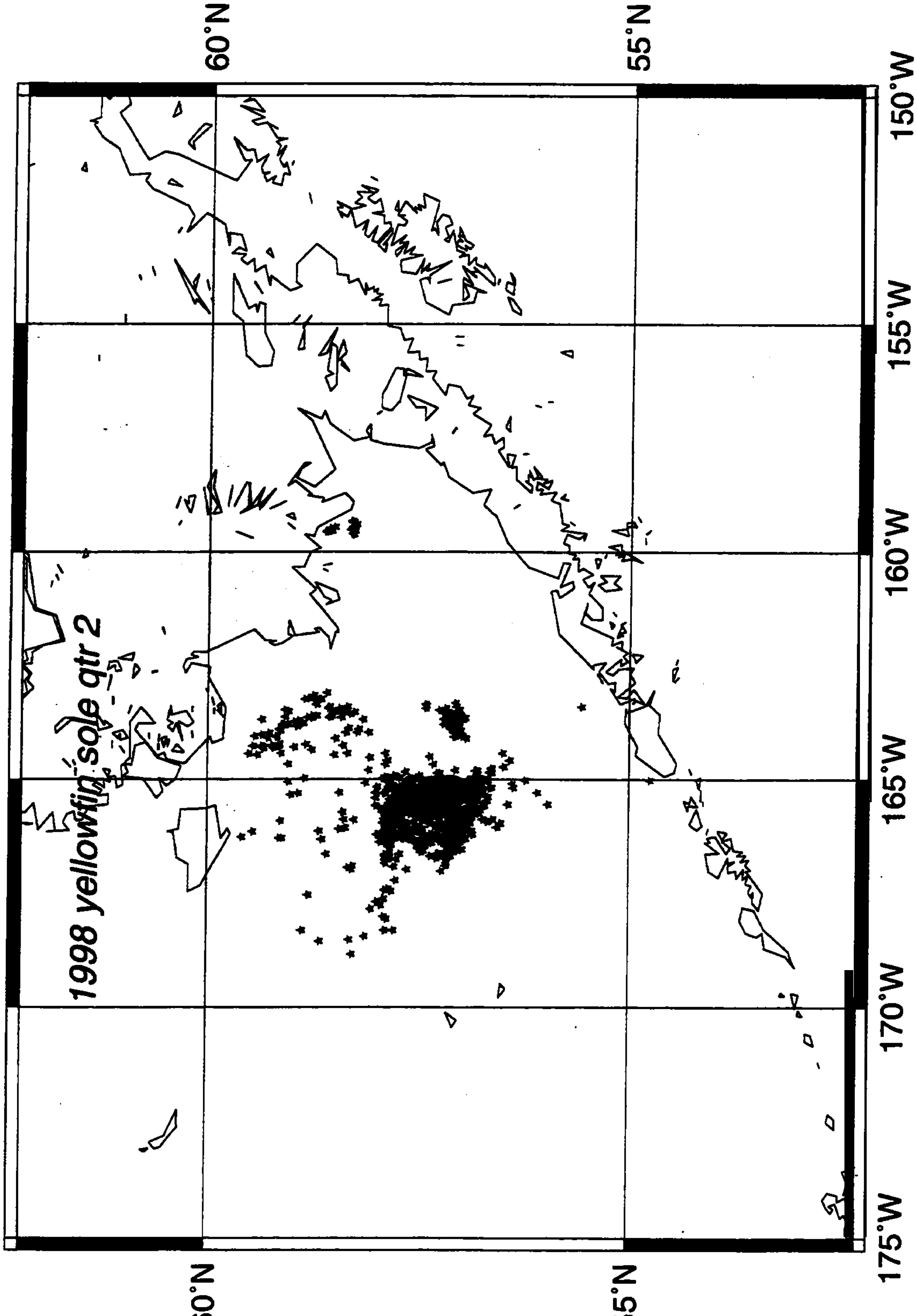
Appendix

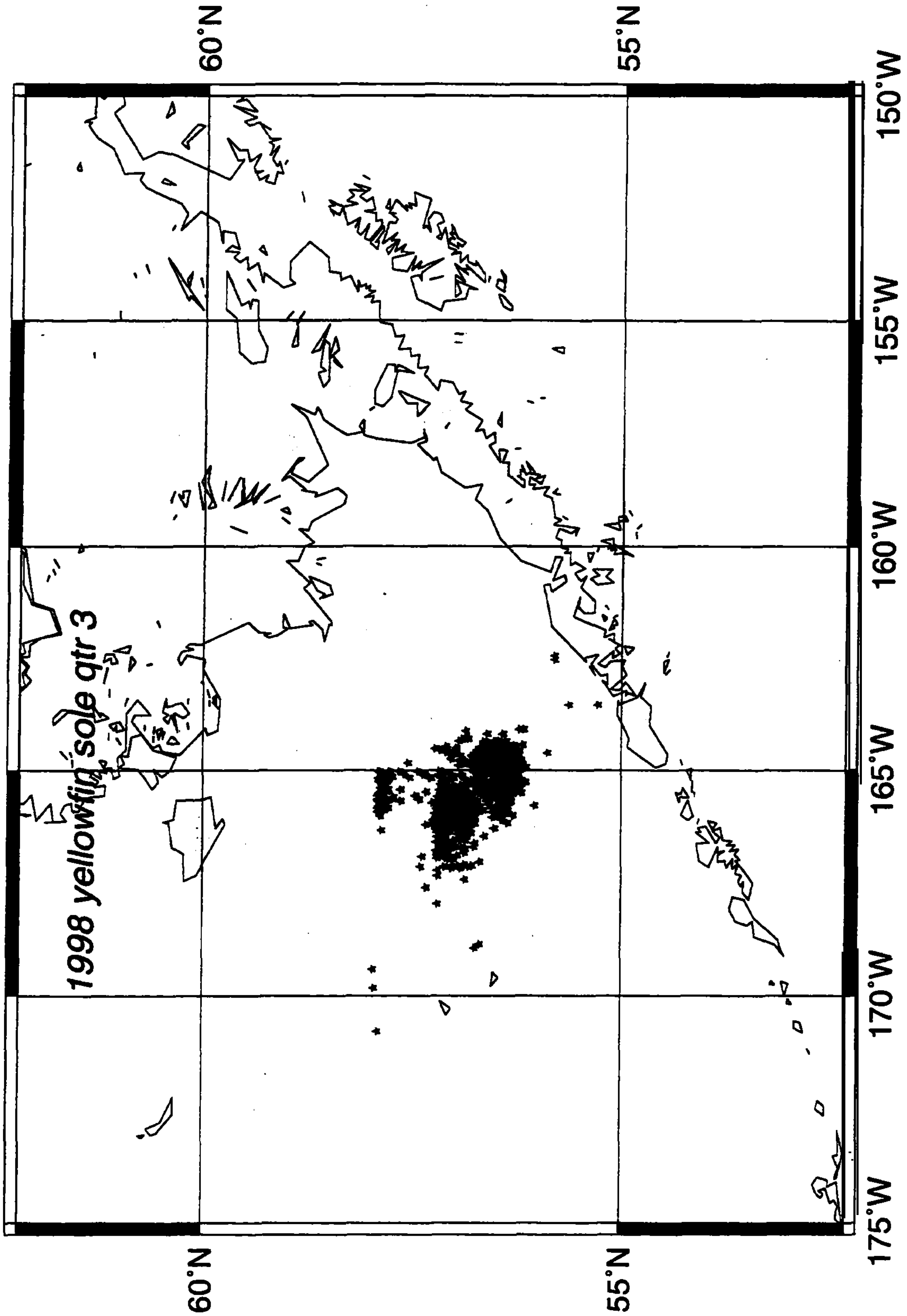
1) 1998 fishery locations by quarter where yellowfin sole comprised 20% or more of the catch.

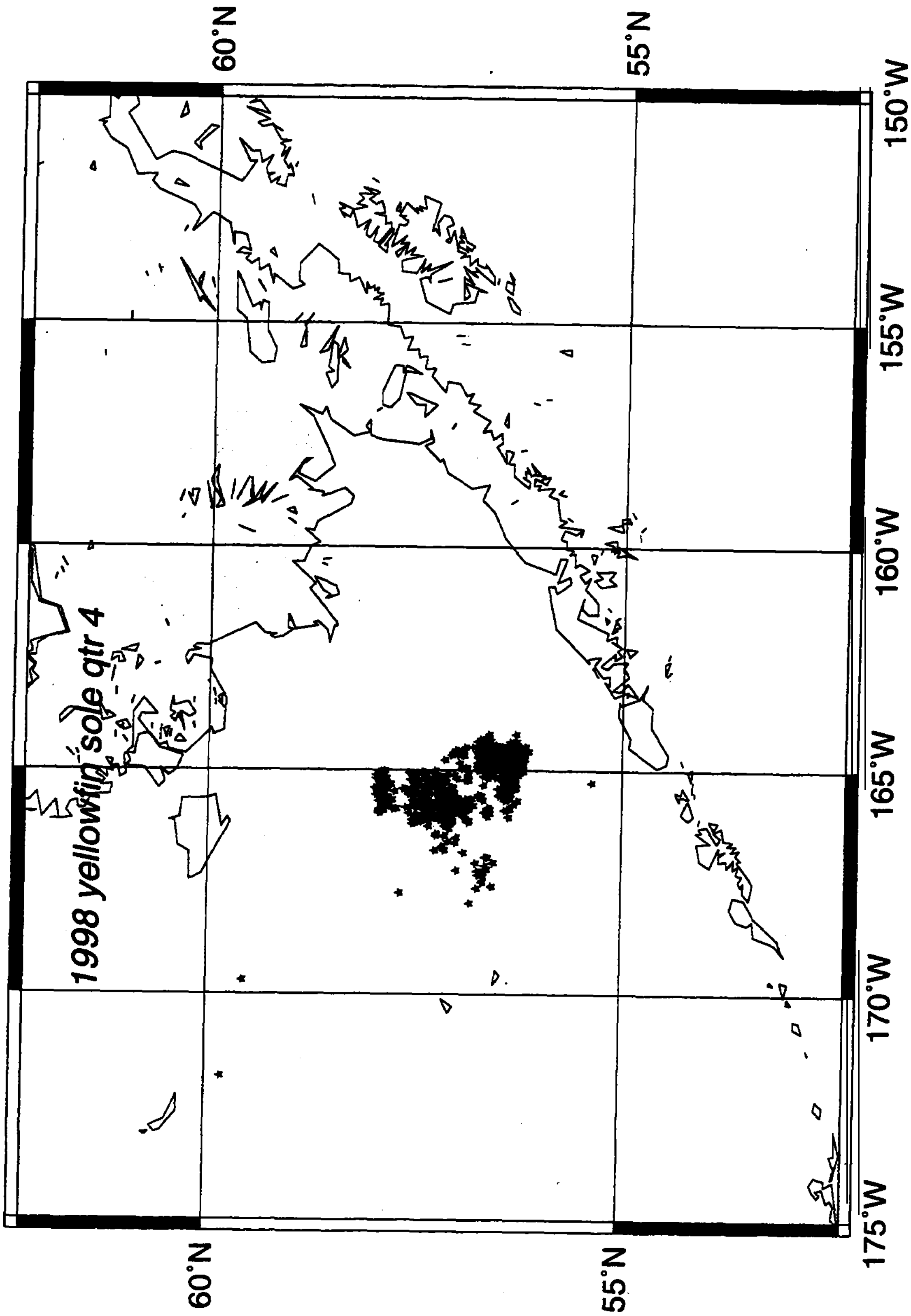
2) Figures showing the fit of the stock assessment model to the time-series of fishery and trawl survey age compositions (survey and fishery observations are the solid lines).

3) Table of yellowfin sole catch from surveys conducted in the eastern Bering Sea and Aleutian Islands area, 1977-98.

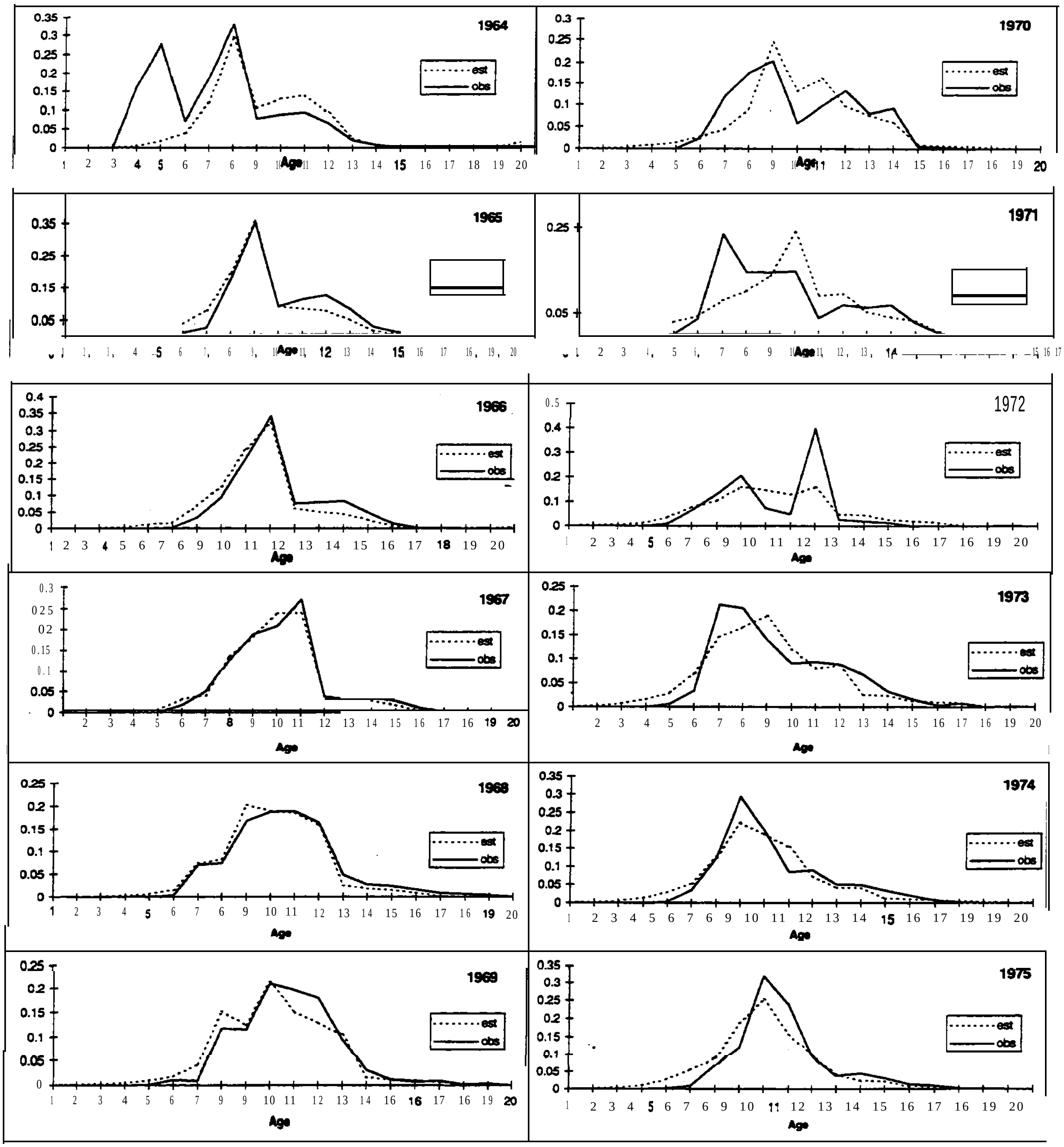

1998 yellowfin sole qtr 1
60°N
55°N
60°N
55°N
150°W
155°W
160°W
165°W
170°W
175°W


1998 yellowfin sole qtr 2
60°N
55°N
150°W
155°W
160°W
165°W
170°W
175°W
60°N
55°N


1998 yellowfin sole qtr 3
60°N
55°N
60°N
55°N
150°W
155°W
160°W
165°W
170°W
175°W

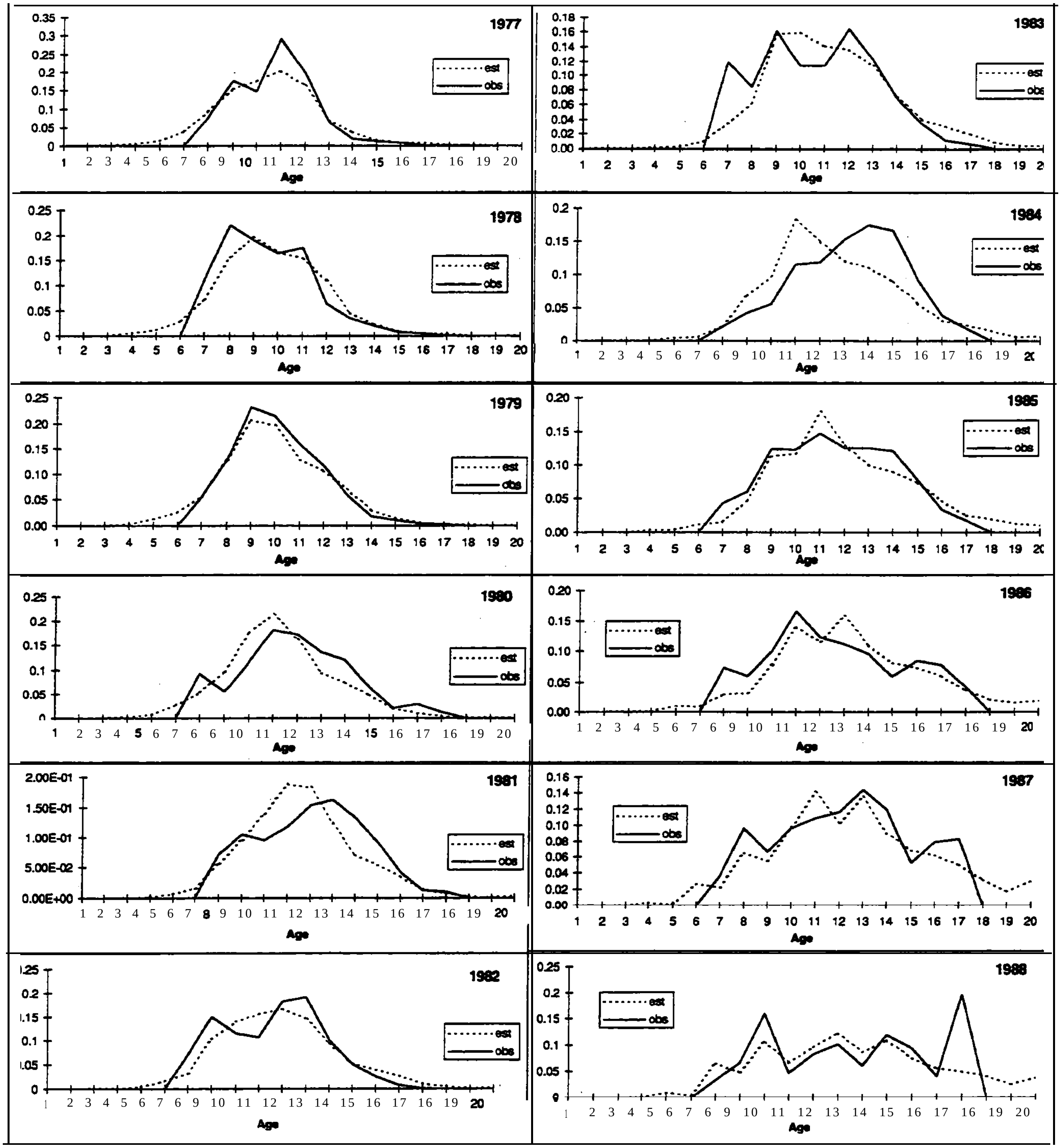

1998 yellowfin sole qtr 4
60°N
55°N
60°N
55°N
150°W
155°W
160°W
165°W
170°W
175°W

Fishery Fishery



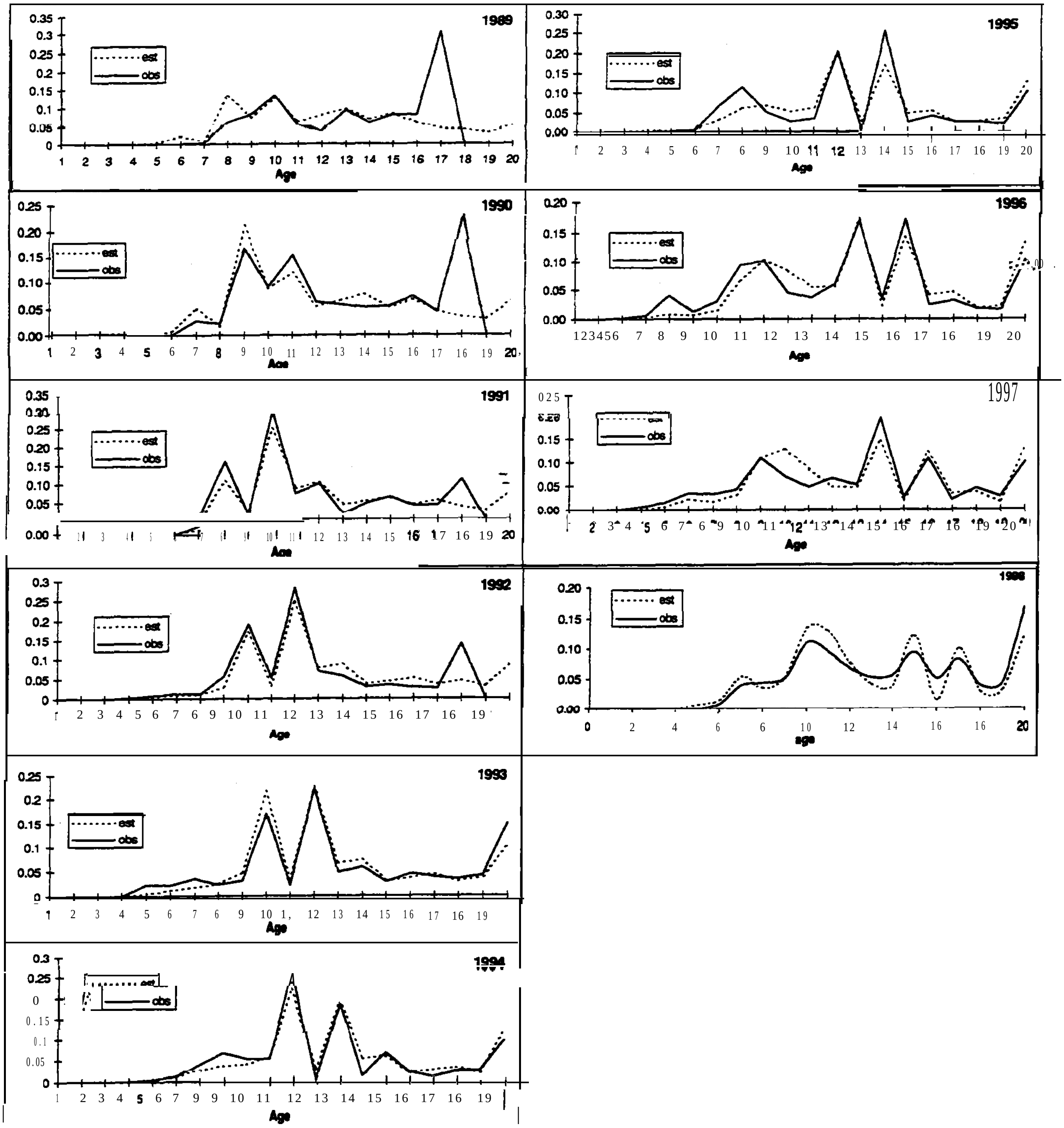
Fishery

Fishery

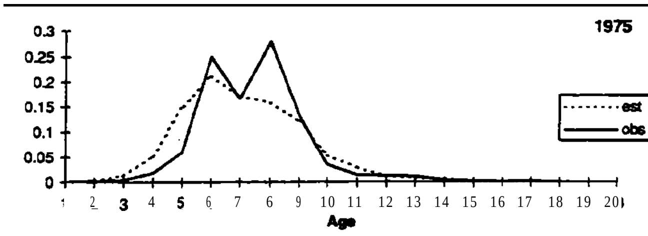


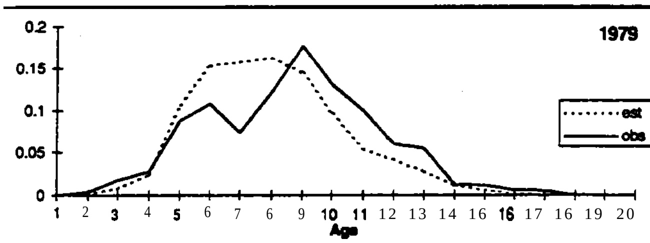
Fishery

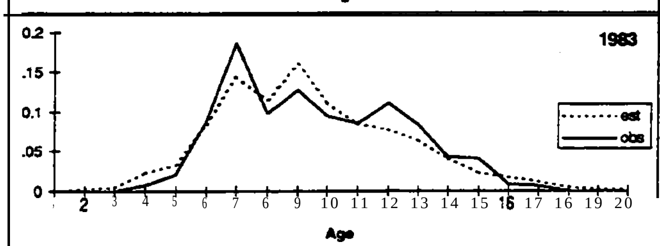
Fishery



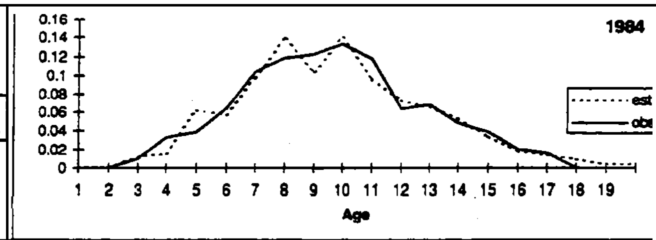
Survey

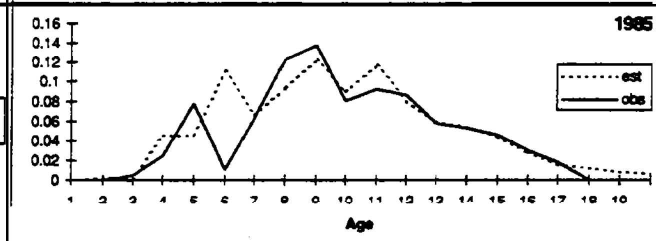


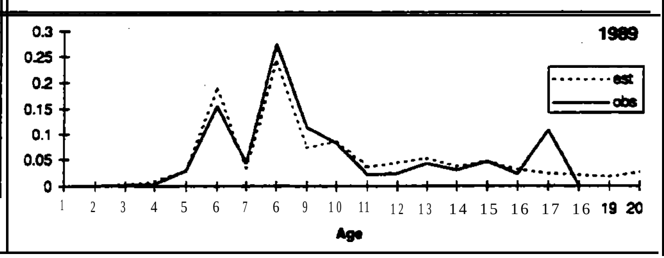




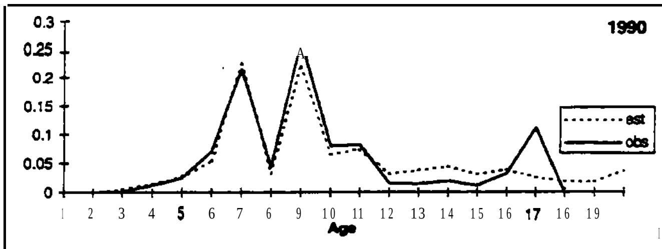
Survey

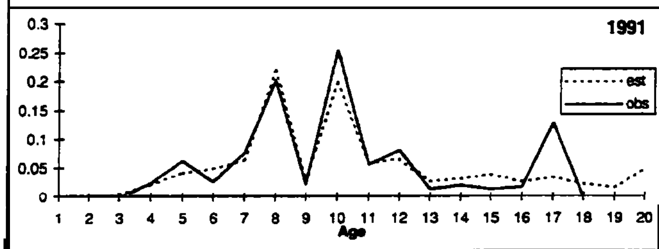


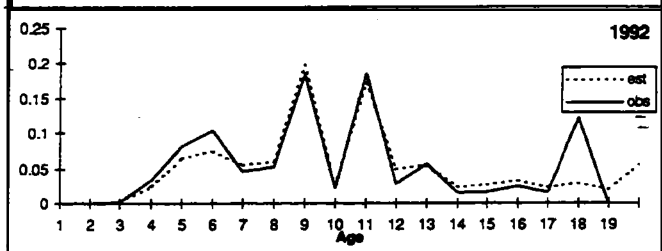


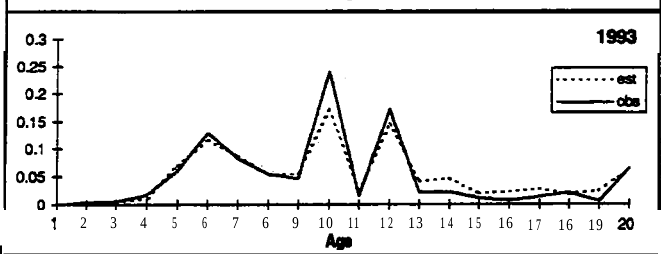


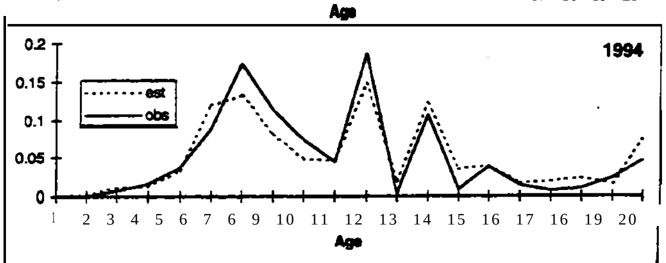
Survey

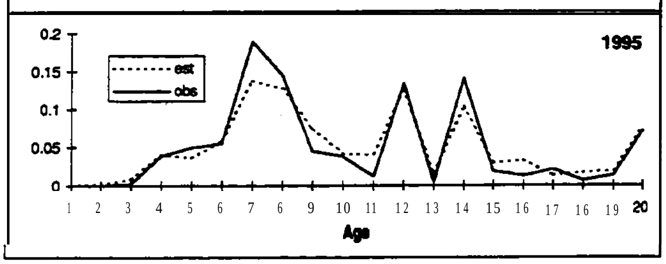




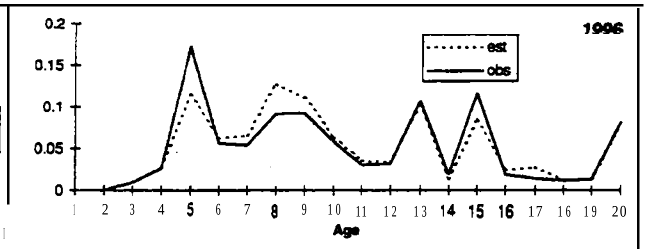


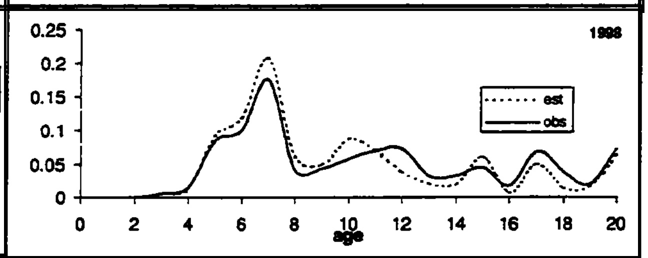






Survey





Total catch (t) of yellowfin sole due to Alaska Fisheries Science Center research activity in the Bering Sea and Aleutian Islands, 1977-98.

Year	Research catch	proportion of commercial catch
1977	60	0.00102
1978	71	0.00051
1979	147	0.00148
1980	92	0.00106
1981	74	0.00077
1982	158	0.00165
1983	254	0.00234
1984	218	0.00136
1985	105	0.00046
1986	88	0.00032
1987	92	0.00051
1988	138	0.00062
1989	148	Q.00097
1990	129	C.00161
1991	116	0.00124
1992	60	0.00038
1993	95	0.00069
1994	91	0.00063
1995	95	0.00076
1996	72	0.00056
1997	76	0.00042
1998	79	0.00078