Section 7

FLATHEAD SOLE

by

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Executive Summary

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

Changes in the input data

1) 1999 total catch and discards through 2 October, 1999.
2) 1999 trawl survey biomass estimate and standard error.
3) 1999 length composition of the survey abundance.
4) 1998 length composition of the fishery catch.
5) Estimate of the retained and discarded portions of the 1998 catch.

Changes to assessment methodology

1) Use of $F_{35\%}$ as the overfishing fishing rate, in accordance with Amendment 56 of the fishery management plan for the groundfish fishery of the Bering Sea/Aleutian Islands.

Model results

1) Estimated 3+ total biomass for 1999 is 611,432 t.
2) Projected female spawning biomass for 2000 is 261,342 t.
3) Recommended ABC for 2000 is 73,537 t based on an $F_{40\%}$ (0.28) harvest level.
4) 2000 overfishing level is 89,958 t based on a $F_{35\%}$ (0.35) harvest level.

The following summarizes our recommendations for flathead sole fisheries conservation measures.

	1998 Assessment recommendations for the 1999 harvest	1999 Assessment recommendations for the 2000 harvest
ABC	77,300 t	73,537 t
Overfishing	117,500 t	89,958 t
F_{ABC}	$F_{0.40}$ = 0.25	$F_{0.40}$ = 0.28
$F_{overfishing}$	$F_{0.30}$ = 0.39	$F_{0.35}$ = 0.35

Introduction

The flathead sole (*Hippoglossoides elassodon*) is distributed from northern California, off Point Reyes, northward along the west coast of North America and throughout Alaska (Hart 1973). In the northern part of its range it overlaps with the related and morphologically similar Bering Flounder *(Hippoglossoides robustus)* whose range extends north to the Chukchi Sea and into the western Bering Sea. The two species are very similar morphologically and at-sea identification is extremely difficult on the production schedule of the annual trawl survey. However, we feel there has been increasing accuracy during recent years. The growth and distribution differences between the species were described in Walters and Wilderbuer (1997), which illustrated the possible ramifications of combining information. For the purposes of this section, these two species are combined under *the* heading, *Hippoglossoides sp.*

Hippoglossoides sp. are managed as a unit stock in the Bering Sea and Aleutian Islands and were formerly a constituent of the "other flaffish" SAFE chapter. In June 1994, the Council requested the Plan Team to assign a separate ABC for flathead *sole (Hippoglossoides* sp.) in the BSAI, rather than combining flathead *sole (Hippoglossoides* sp.) with other flatfish as in past assessments. This request was based on a change in the directed fishing standards to allow increased retention of flaffish.

Catch History

Prior to 1977, catches of *Hippoglossoides* sp. were combined with the species of the "other flatfish" category, which increased from around 25,000 t in the 1960s to a peak of 52,000 t in 1971. At least part of this apparent increase was due to better species identification and reporting of catches in the 1970s. After 197 1, catches declined to less than 20,000 t in 1975. Catches from 1977-89 averaged 5,286 t increasing to an annual average of 17,706 t from 1990-98 (Table 1). The resource remains lightly harvested as the 1999 catch through 2 October is only 26% of the 1999 TAC of 65,705 t. Catch locations in 1998 where flatfish comprised > 50% of the catch and flathead sole where the most abundant flaffish in the catch are shown, by quarter, in the Appendix.

Although flathead sole *(Hippoglossoides* sp.) receive a separate ABC and TAC they are still managed in the same PSC classification as rock sole and "other flatfish" and receive the same apportionments and seasonal allowances of bycaught prohibited species. In recent years, the flathead sole fishery has been closed prior to attainment of the TAC due to the bycatch of halibut ('Table 2).

Substantial amounts of flathead sole are discarded overboard in various eastern Bering Sea target fisheries. Retained and discarded amounts are estimated for recent years using observer estimates of discard rate applied to the "blend" estimate of observer and industry reported retained catch (including flathead sole prior to 1995) (Table 3).

Data

Fishery Catch and Catch-at-age Data

This assessment uses fishery catches from 1977 through 2 October, 1999 (Table l), and estimates of number caught by length group and sex for the years 1977-1998 (Tables 4-5).

Survey Data

Because *Hippoglossoides* sp. are usually taken incidentally in target fisheries for other-species, CPUE from commercial fisheries seldom reflect trends in abundance for these species. It is therefore necessary to use research vessel survey data to assess the condition of these stocks.

Large-scale bottom trawl surveys of the Eastern Bering Sea continental shelf have been conducted in 1975 and 1979-1999 by NMFS. Survey estimates of total biomass and numbers by length group and sex for the years 1982-1999 are shown in Tables 6-8 and Figure 1. The survey gear changed after 1981, and as in previous assessments (Walters and Wilderbuer 1998) only the data from 1982 to the present are used. Since the early 1980s, estimated *Hippoglossoides* sp. biomass has approximately quadrupled to the 1997 peak estimate of 807,800 t (Figure 1). However, estimated biomass declined in the 1999 survey, as the biomass estimate of 394,806 t is a 43% decline from the 1998 value and the lowest estimate since 1986.

Information on length at age for flathead sole and Bering flounder are available from aging a carefully controlled age-structure collection in 1985. The estimated von Bertalanffy parameters are

		L_{inf}(cm)	k	t_o
H. elassodon	males	37.6	0.173 1	-0.3536
	females	47.2	0.1322	-0.2102
H. robustus	males	30.4	0.2111	0.3210
	females	42.5	0.1298	0.223 1

A comparison of these functions (Walters and Wilderbuer 1997) shows the slower growth rate and smaller maximum size of Bering flounder. Fish of a given size are possibly 3 years different in age between the two species. Although Bering flounder represent less than 2% of the total (in 1997), these errors contribute to the overall uncertainty of the estimates.

A length (cm) - weight (g) relationship of the form $W = aL^b$ was also fit to *Hippoglossoides* sp., with the estimated parameters of a = 0.003965 and b = 3.25912 applying to both sexes.

In summary, the data available for flathead sole are:

1) Total catch weight, 1977-99;
2) Proportional catch numbers by length group, 1977-98;
3) Survey biomass and standard error, 1982-99;
4) Survey age composition 1982, 1985, 1992, and 1995;
5) Proportional survey numbers by length group, 1982-99.

Analytical Approach

Model Structure

To better understand the stock dynamics of the flathead sole resource since 1977 and to provide improved future estimates of recruitment, biomass and target fishing mortality for management, all available fishery and survey data were analyzed using a split sex length - based stock synthesis model (Methot 1990). In this assessment we did not attempt to incorporate the Aleutian Islands biomass estimate. Using the synthesis model allows estimation of fishing and survey selectivity, and recruitment variability. The model was configured to consider ages 3 - 21+ and lengths 6-60 cm for the period 1977-1999.

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the compositions of the fishery catch and survey abundance by length group, the survey biomass, and the fishery catches. The general approach is to assume that deviations between model estimates and observed quantities are attributable to observation error and can be described with statistical distributions. Each data component provides a contribution to a total log-likelihood function, and parameter values that maximize the log-likelihood are selected. The distributions of survey abundance and fishery catch by

length group are assumed to follow multinomial distributions, whereas the trawl survey biomass is assumed to follow the lognormal distribution. The emphasis on the survey biomass estimates is five times that of the other data components; this resulted in a better fit to the abundance trend without degrading the fit to the other data components.

Parameters Estimated Independently

We assume a natural mortality rate (M) of 0.20 on the basis of the longevity of this species. Flathead sole have been aged as high as 22 years from a recently aged sample collected in 1994.

Parameters Estimated Conditionally

The population simulation estimates the number at age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate of each cohort as it moves through the population using the basic population dynamics equations given in Methot (1998). Trawl capture selectivity was fixed as asymptotic for the older fish in the survey and fishery data, but the model was allowed to estimate the selectivity of the younger fish. Selectivities for the foreign and domestic fisheries were estimated as one fishery to allow for a single estimate of fishery selectivity by sex. The fishing mortality rates (F) for each age and year are calculated to exactly match the catch weight by solving the following equation for F:

$$\sum_a \left[N_{ay} \hat{W}_a \left(\frac{f_y S_a}{f_y S_a + M} \right) \left(1 - e^{\left(- f_y S_a + M \right)} \right) \right] - \sum_a C_{ay} \hat{W}_a = 0$$

where $F_{ay} = f_y S_a$, N_{ay} is the number of fish of age a in year y, $\hat{W}_a$ is the average weight at age, A4 is the natural mortality, C_{ay} is the catch numbers by age and year, S_a is the fishery selectivity at age, and f_y is the fully-selected fishing mortality rate in year y.

Model Results

The model results show that estimated total biomass (ages 3+) increased from a low of 172,842 t in 1977 to a peak of 795,199 t in 1992 (Figure 2, Table 9). Since 1992, estimated total biomass has declined to an estimated value of 611,432 t for 1999. Female spawning biomass shows a similar trend, although the peak value (329,354 t) occurred in 1995. The estimated survey biomass shows an increase from 1982 to the peak level of 572,915 t in 1993, and a subsequent decline to 466,380 t in 1999 (Figure 3). The model fits the survey biomass time-series well during the period of increasing biomass, but provides a poor fit to the 1994, 1997 and 1998 estimates, when it indicates a population decline while survey biomass estimates remain high and relatively stable. The continued trend of declining estimated biomass since the early 1990s results in the estimated 1999 survey biomass matching the observed biomass fairly closely (Figure 3). The model provided a good fit to the survey size compositions for the past 10 years for males and females as shown Figure 4. Reasonable fits also resulted for fishery size composition observations (Figure 5).

The changes in stock biomass are primarily a function of recruitment, as fishing pressure has been relatively light. The fully selected fishing mortality estimates remain small, and have averaged 0.05 from 1990 to 1999 (Figure 6), and the fishery shows little selectivity for flathead sole less that 30 cm (Figure 7). Age compositions for five age collections determined for *Hippogiossoides* sp. from the trawl surveys do not show recruitment of any particularly large year classes, but rather a series of strong ones. (Figure 8). Age compositions for other years, such as 1979, 1981, and 1993, are not shown here because of small sample sizes. Estimated recruitment at age 3 has generally been higher during the early potion of the data series, averaging 7.9×10^8 for the 1975-1988 year classes, and 3.9×10^8 for the 1989-96 year classes (Figure 9) The magnitude, but not the pattern, of these numbers differs from the estimated recruitment in the 1998 assessment; this is due to a change (in the assessment model) in the length-weight

relationship. The survey size composition from 1994-1999 indicates that the proportion of fish at lower sizes is reduced from the high recruitment years of the 1980s, leading to the decline in estimated biomass.

Projections and Harvest Alternatives

The reference fishing mortality rate for flathead sole is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977- 1996 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{0.40}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 133,810 t. The year 2000 spawning stock biomass is estimated as 261,342 t. Since reliable estimates of the 2000 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (261,342 t > 133,810 t), flathead sole reference fishing mortality is defined in tier 3a. For this tier, F_{ABC} is constrained to be $\leq F_{0.40}$, and F_{OFL} is defined to be $F_{0.35}$. *The* values of these quantities are

2000 SSB estimate	(B)	=	261,342 t
	$B_{0.40}$	=	133,810 t
	$F_{0.40}$	=	0.280
	F_{ABC}	$\leq$	0.280
	$F_{0.35}$	=	0.35 1
	F_{OFL}	=	0.35 1

The estimated catch level for year 2000 associated with the overfishing level of F = 0.351 is 89,958 t. Because the flathead sole stock has not been overfished in recent years and the stock biomass is relatively high, it is not recommended to adjust F_{ABC} downward from it upper bound; thus, the year 2000 recommended ABC associated with F_{ABC} of 0.280 is 73,537 t.

This year, a standard set of projections is required for each stock managed under Tiers I, 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 rnax 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 fill 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.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean harvest and spawning stock biomass for the remaining four scenarios are shown in Tables 10 and 11, respectively. The projections of future harvest levels have small confidence intervals due to small fishery selectivity values for ages *3-7* (the first five ages in the model). Similarly, the confidence intervals on projected biomass are zero for the first two projection years because the proportion mature at ages 3 and 4 is zero.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the flathead sole stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (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 2001, 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 2012 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the flathead sole are neither overfished or approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2000 of scenario 6 is 2.21 times its $B_{35\%}$ value of 117,084 t. With regard to whether the stock is likely to be in an overfished condition in the near future, the expected stock size in the year 20 12 of scenario 7 is 1.04 times its $B_{35\%}$ value.

Other considerations

The catch of flathead sole taken in research survey will be included in the catch totals in future assessments; these catch levels are shown from 1979 -1998 in Table 12.

Trophic studies indicate that flathead sole feed mainly on ophiuroids, tanner crab, osmerids, bivalves and polychaetes. Groundfish predators include Pacific cod, Pacific halibut, arrowtootb flounder and also cannibalism by large flathead sole, mostly on fish less than 20 cm standard length.

Summary

In summary, several quantities pertinent to the management of the flathead sole are listed below.

Quantity		Value
A4		0.20
Year 2000 Spawning stock biomass		261,342 t
F_{OFL}		0.35 1
Maximum F_{ABC}	0.280	
Recommended F_{ABC}		0.280
OFL		89,958 t
Recommended ABC		73,537 t

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Table 1. Harvest (t) of flathead sole from 1977- 1999

Year	Catch Biomass
1977	7909
1978	6957
1979	4351
1980	5247
1981	5218
1982	4509
1983	5240
1984	4458
1985	5636
1986	5208
1987	3595
1988	6783
1989	3604
1990	20245
1991	15602
1992	14239
1993	13664
1994	18455
1995	14707
1996	17344
1997	20704
1998	24397
1999	17385*

*NMFS Regional Office Report through October 2, 1999

Table 2. Restrictions on the flathead sole fishery from 1994 to 1999 in the Bering Sea - Aleutian Islands management area. Unless otherwise indicated, the closures were applied to the entire BSAI management area. Zone 1 consists of areas 508,509, 5 12, and 5 16, whereas zone 2 consists of areas 513,517, and 521.

Year	Dates	Bycatch Closure
1994	2/28 - 12/31	Red King crab cap (Zone 1 closed)
	5/7 - 12/31	Bairdi Tannner crab (Zone 2 closed)
	7/5 - 12/31	Annual halibut allowance
1995	2/21 - 3/30	First Seasonal halibut cap
	4/17 - 7/1	Second seasonal halibut cap
	8/1 - 12/31	Annual halibut allowance
1996	2/26 – 4/1	First Seasonal halibut cap
	4/13 - 7/1	Second seasonal halibut cap
	7/31 - 12/31	Annual halibut allowance
1997	2/20 - 4/1	First Seasonal halibut cap
	4/12 - 7/1	Second seasonal halibut cap
	7/25 - 12/31	Annual halibut allowance
1998	3/5 - 3/30	First Seasonal halibut cap
	4/21 – 7/1	Second seasonal halibut cap
	8/16 - 12/31	Annual halibut allowance
1999	2/26 - 3/30	First Seasonal halibut cap
	4/27 - 7/04	Second seasonal halibut cap
	8/31 - 12/31	Annual halibut allowance

Table 3. Total retained and discarded flathead sole, 1995-1999.

Year	Total Catch	Retained	Discarded	Percent Retained
1995	14707	7521	7186	51
1996	17344	8964	8380	52
1997	20704	10871	9833	53
1998	24397	17208	7189	70
1999*	17385	12982	4403	75

*NMFS regional office report through October 2, 1999

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1998	24397	17208	7189	70
1999*	17385	12982	4403	75

*NMFS regional office report through October 2, 1999

Table 4. Eastern Bering Sea flathead sole mole catch at length group (millions)

Year	Length Group (cm) 6	8	10	12	14	-16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	43	52	55	58
1977	0.00	0.00	0.w	0.04	0.12	0.31	0.86	0.84	0.80	1.84	3.05	4.04	3.83	204	071	0.13	003	0.05	0.04	0.00	0.00	0.00	0.00	0.w
1978	0.00	0.00	0.w	0.02	0.10	0.18	0.47	0.70	1.00	1.10	1.18	2.17	3.17	2.40	1 22	0.41	0 10	0.01	0.00	0.00	0.01	0.01	0.00	0.w
1979	0.00	0.w	0.00	0.62	0.13	0.22	0.32	0.82	0.70	0.44	0.45	0.68	1.15	1.67	1.15	0.51	0.17	005	0.01	0.w	0.00	0.w	0.00	0.w
1980	0.00	0.w	0.00	0.00	0.00	0.05	0.18	0.46	0.98	1.20	0.91	1.01	1.95	2 38	1.15	0.22	0.03	0.01	0.00	0.w	0.00	0.00	0.00	ow
1981	0.00	0.w	0.00	0.02	0.08	0.35	0.43	0.11	0.10	0.35	1.03	2.29	2.59	181	0.83	0 19	003	0.05	003	0.00	0.w	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.w	0.w	0.04	0.01	0.06	0.08	0.22	0.42	1.12	1.98	1.77	1.08	0.30	0 12	004	004	0.00	o w	0.00	0.00	0.w
1983	0.00	0.00	0.00	0.w	0.w	000	0.w	0.00	0.02	0.09	0.14	0.44	102	1.62	1.57	1.15	049	0.14	004	0.02	0.01	0.01	0.01	0.01
1984	0.00	0.w	0.00	0.01	0.02	003	0.07	0.28	0.33	0.28	0.40	0.74	0.52	1.41	1.43	0.74	032	0.07	0.01	0.w	0.00	0.00	0.00	0.w
1985	0.00	0.00	0.w	0.00	0.01	0.04	0.05	0.22	0.34	0.44	0 57	0.66	0.88	1.01	1.21	1.18	0.59	025	0.04	0.02	0.03	0.03	0.04	0.02
1986	0.00	0.00	0.00	0.w	0.03	0.w	0.22	0.31	0.59	1.28	1.62	1.21	1.37	1.15	1.24	0.50	0.40	0.06	0.00	0.w	0.w	0.00	o w	0.w
1987	0.00	0.w	0.w	0.w	0.00	0.00	0.01	0.01	0.04	0.10	0.16	0.31	0.50	1.15	1.47	0.84	0.22	0.02	0.w	0.00	0.00	0.00	0.00	0.00
1988	000	0.w	0.w	0.w	001	0.04	0.13	0.19	0.29	0.83	0.97	1 51	2 45	2 74	1.77	0.63	0 15	0.W	0.01	0.00	0.00	0.w	0.w	0.w
1989	0.00	0.00	0.00	0.00	0.00	000	0.04	0.13	0.22	0.23	0.45	0.68	0.89	1.04	1.00	0.58	022	0.11	0.02	0.00	0.00	0.00	S W	0.w
1990	0.00	0.00	0.w	0.00	0.01	0.03	0.00	012	0.18	027	0.39	0.72	1 28	2.34	380	4.85	343	2.00	0.73	0.40	0.14	0.03	0.00	0.00
1991	0.00	0.00	0.w	0.w	0.00	0.01	0.02	0.08	0.12	0.23	0.30	0.87	1.39	2.08	3.18	4.14	2.89	128	0.27	0.08	0.07	002	o w	0.w
1992	0.w	0.00	0.00	0.00	0.00	0.11	0.04	0.46	0.66	0.70	1.05	1 26	1.96	2.77	3.01	3.08	2.w	1.51	0.04	0.w	0.w	000	0.00	0.00
1993	0.w	0.w	0.w	0.w	001	0.02	0.02	0.01	0.08	0.18	0.53	1.12	1 29	221	340	345	1.98	1.02	0.37	0.06	o w	o w	o w	o w
1994	o w	0.w	0.w	o w	0.00	0.01	0.04	0.08	0.15	0.43	0.86	1.62	2.69	328	3.68	325	185	120	0.50	041	0.32	020	004	0.01
1995	0.00	0.00	0.00	0.00	0.00	0.w	0.01	0.03	0.08	0.14	0.28	0.68	1.32	2 27	331	3 55	237	115	0.43	024	0.04	0.00	0.00	0.00
1996	0.00	0.w	0.00	0.w	0.00	0.00	0.00	0.01	0.04	0.09	0.28	0.53	1.40	2.98	4.30	4.29	2.68	1.38	0.32	0.14	0.07	0.04	001	0.01
1997	0.00	0.w	0.00	0.00	0.00	0.01	0.03	0.00	0.15	0.41	1.17	1.88	3 15	4.88	5 15	4.75	2.00	135	0.13	o w	000	0.w	0.w	0.w
1998	0.00	0.00	0.w	0.w	0.00	0.w	0.02	0.04	0.10	021	0.49	0.99	2.13	3.98	5.88	5.94	4.36	2 26	0.39	0.09	001	0.w	o w	o w

Table 5. Eastern Bering Sea flathead sole female catch at length group (millions)

Year	Length Group (em)																						
	6	8	10	12	14	-16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	49	52	55	58
1977	0.W	0.00	0.w	004	011	0.26	0.67	0.52	0.66	0.76	1.16	1.36	1.77	1.60	1.52	1.21	0.61	0.42	0.06	0.02	001	ow	0.w	001
1978	0.W	0.00	0.00	0.01	0.03	0.09	0.22	0.45	0.53	0.57	0.53	0.60	0.88	1.28	1.43	1.18	0.63	0.73	0.20	0.04	0.01	0.00	0.00	0.00
1979	0.00	0.00	000	0.01	0.04	0.08	0.18	0.36	0.43	0.32	0.26	0.30	0.30	031	0.46	0.60	0.62	0.68	0.32	0.11	0.01	0.w	0.w	0.00
1980	0.00	O W	0.00	0.00	0.01	0.08	0.22	0.48	0.85	1.23	0.80	0.01	0.60	0.67	0.60	0.86	0.85	0.55	0.15	0.02	0.01	0.00	0.W	0.00
1981	0.00	0.00	0.00	001	0.01	0.12	021	0.08	0.05	0.09	0.29	0.07	0.00	1.12	0.86	0.81	0.54	0.56	0.26	0.07	0.01	0.00	0.w	0.00
1982	0.W	0.00	0.00	0.w	0.00	0.00	0.00	0.01	0.04	0.13	0.35	0.71	1.15	1.02	0.72	0.37	0.39	0.52	0.24	0.w	0.00	0.w	o w	0.w
1983	0.W	0.w	0.00	0.w	0.00	0.00	0.00	0.01	0.w	0.02	0.00	0.02	0.05	0.12	0.23	0.34	0.56	1.02	0.71	0.30	0.11	0.03	003	o w
1984	0.W	0.00	0.00	0.01	0.02	003	0.06	0.18	0.17	0.12	0 16	0.25	026	0.36	0.68	060	0.72	0.61	0.25	0.08	0.01	0.w	0.w	000
1985	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.09	0.18	0.16	0.19	022	0.26	0.36	051	0.12	0.81	1.08	0.41	0 12	0.08	0.02	003	0.01
1986	0.00	0.w	0.w	0.00	0.02	0.11	0.39	0.35	0.50	0.36	0.45	0.65	0.66	060	0.63	0.80	0.88	0.58	0.24	0.03	0.w	0.00	0.00	0.00
1987	0.W	0.00	0.00	0.00	0.00	0.00	0.w	002	0.01	0.04	0.09	0.15	0.22	0.35	0.63	0.67	0.01	0.47	009	0.02	0.w	0.00	0.00	0.00
1988	0.00	0.w	0.00	0.w	0.01	0.02	0.07	0.09	0.13	0.26	0.27	0.52	0.86	1.10	1.27	1.12	0.00	0.77	0.30	0 10	0.02	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.w	0.00	0.00	001	005	0.10	0.10	0.11	0.21	0.28	0.40	0.46	0.55	052	0.45	025	0.12	0.04	0.w	0.00	0.00
1990	0.00	0.00	0.w	0.00	0.W	0.01	0.00	0.04	0.w	0.08	0.19	0.23	0.47	0.65	1.28	1.93	264	3.56	259	1.23	025	0.03	0.01	0.00
1991	0.00	0.00	0.00	0.w	0.00	0.w	0.01	0.01	0.03	0.08	0.18	0.36	0.52	0.79	1.07	1.31	2.02	2.75	1.64	0.72	627	0.05	0.02	0.00
1992	0.00	0.00	0.w	0.00	0 0 0	0.00	0.w	0.00	0.w	0.w	0.06	0.21	0.27	0.80	1.31	1.63	1.90	262	1.57	0.59	0.27	o w	0.w	0.00
1993	0.W	0.00	0.w	0.00	0.w	0.00	0.w	0.01	0.01	0.10	0.14	0.22	0.46	0.66	0.87	1.21	1.39	2.63	2.10	0.57	0.14	002	0.00	0.00
1994	0.W	0.00	0.w	0.00	0.w	0.00	0.01	0.01	0.01	0.04	0.08	0.14	032	0.53	073	1.53	2 10	321	227	109	0.56	013	002	0.02
1995	0.W	0.00	0.00	0.00	0.00	0.00	0.w	0.03	0.04	0.04	0.07	0.18	0.25	046	0.w	1.w	1.17	2.25	2.41	122	0.28	0.04	0.W	0.W
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.05	0.08	0.16	'0.43	0.93	137	1.55	2.53	2.51	1.42	031	0.08	001	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.10	0.15	0.31	0.53	0.77	1.16	1.72	2.16	2.67	2.61	1.65	0.45	0.08	0.w	0.00
1998	0.00	0.00	0.w	0.00	0.w	0.00	0.w	0.00	0.01	0.05	0.09	0.21	0.43	0.77	1.23	1.62	2.19	3.39	3.17	2.24	081	0.11	001	0.w

Table 6. Estimated biomass of flathead sole from the EBS and Aleutian Islands Trawl survey.

Year	Area	Biomass Estimate	
1975	EBS	100,700	
1979	EBS	104,900	
1980	EBS	117,500	
	Aleut.	3,300	
1981	EBS	162,900	
1982	EBS	192,200	
1983	EBS	269,000	
	Aleut.	1,500	
1984	EBS	285,900	
1985	EBS	276,300	
1986	EBS	357,900	
		Aleut.	-9,000
1987	EBS	394,800	
1988	EBS	549,500	
1989	EBS	5 19,600	
1990	EBS	593,500	
1991	EBS	570,300	
		Aleut.	10,700
1992	EBS	618,100	
1993	EBS	6 10,200	
1994	EBS	725,100	
		Aleut.	15,400
1995	EBS	593,400	
1996	EBS	6 16,400	
1997	EBS	807,800	
	Aleut.	16,240	
1998		EBS	692,200
1999	EBS	394.806	

Table 7. Eastern Bering Sea flathead sole male numbers at length group (millions) estimated from the NMFS trawl surveys

Year	Length Group (cm)																						
	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	49	52	55	58
1977	0.27	0.30	1.42	19.37	30.56	27.81	33.81	46.44	64.95	63.58	64.46	90.19	72.52	3155	1041	3.08	0.59	042	0.00	ow	0.00	000	000	ow
1978	0.47	1.38	10.16	47.96	28.14	49.w	65.63	56.16	49.68	57.29	7120	65.44	a241	58.61	2363	6 70	137	012	0.00	ow	0 00	ow	0.00	000
1979	0.12	1.50	10.41	3120	57.55	9449	72.03	60.62	79.63	79.91	67.22	96.03	9224	70.67	3405	1 5 9	3.57	0 12	0.00	0.14	0.00	000	o w	ow
1980	0.03	2.70	4.26	6.63	23.65	39.66	81.01	88.03	75.21	57.16	70.29	74.92	60.93	60.96	38.86	14.36	3.33	0.76	0.00	0.00	0.00	0.00	o w	0.w
1981	0.47	0.83	7.25	23.71	17.42	22.63	36.52	65.07	74.06	62.94	84.31	89.95	87.56	66.62	49.43	20.70	6.90	1.66	0.11	0.00	0.w	0.w	0.00	0.00
1982	0.W	0.21	7.51	24.00	27.07	44.09	43.96	53.56	03.01	79.70	76.04	90.86	99.30	97.64	55.07	28.65	14.99	3.62	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.54	1.63	5.23	30.89	77.10	101.69	73.97	78.37	64.69	70.67	75.16	88.13	115.83	137.93	120.56	51.74	17.67	5.16	026	0.00	0.00	ow	0.00	0.w
1984	000	1.54	17.37	7004	40.33	4344	127.71	102.70	102.99	72.95	74.62	76.26	76.47	126.41	127.72	58.91	16.03	3.02	0.00	0.w	0.w	0.00	0.00	0.w
1985	0.00	1.30	4.75	17.32	74.03	76.17	64.41	94.99	114.40	99.89	98.77	97.66	109.67	136.15	132.40	69.94	27.55	5.46	0.50	0.w	0.00	0.00	0.w	0.w
1986	0.10	0.70	12.03	6.60	1032	4757	91.91	125.65	119.07	112.65	111.63	92.10	101.79	95.91	107.64	72.53	21.38	4.77	0.45	0.08	0.00	0.00	0.00	0.00
1987	0.00	0.02	3.46	44.65	74.64	45.93	49.46	91.69	126.61	160.59	144.34	118.W	124.41	135.70	136.54	68.97	32.19	6.56	0.32	0.02	0.16	0.00	0.w	0.w
1988	0.W	0.91	6.95	13.50	19.31	5626	6441	61.04	72.45	109.60	139.13	136.74	121.69	126.75	117.63	66.64	26.74	7.10	0.24	0.w	0.00	0.00	0.00	0.w
1989	0.00	0.69	4.87	20.10	43.45	6578	67.74	15.73	86.50	82.69	126.66	142.66	157.12	153.69	144.32	95.41	31.71	637	0.39	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.12	1.01	7.66	19.00	34.32	43.99	60.15	70.06	65.63	106.64	133.01	152.53	136.54	119.62	72.88	31.93	10.52	0.50	0.14	0.00	0.w	0.00	0.w
1991	0.07	0.63	3.16	19.70	36.02	35.65	55.73	69.11	74.66	77.99	6921	116.17	139.29	145.65	135.79	85.00	33.76	12.36	1 0 1	0.00	0.w	0.03	0.00	0.00
1992	0.08	0.48	3.01	10.40	12.46	24.23	30.26	40.34	53.39	66.34	73.61	91.47	14320	152.03	145.64	102.15	53.45	23.64	237	1.65	0.w	ow	0.00	0.00
1993	0.06	1.26	17.16	34.48	16.23	26.35	29.32	37.45	46.65	69.57	77.23	04.44	135.44	161.06	157.74	1W.W	59.75	14.97	264	044	0.00	0.w	0.00	ow
1994	0.00	0.46	2.61	7.34	20.22	10.06	17.74	29.29	31.16	46.06	59.45	65.46	78.45	9603	62.37	45.35	21.04	10.86	1.04	0 10	0.00	0.00	000	0.06
199s	0.w	0.00	0.w	0.w	0.w	0.00	0.00	0.w	0.00	0.00	0.w	0.w	0.00	0.00	0.w	0.00	0.00	o w	0.00	0.w	0.00	0.00	0.00	0.00
1996	0.w	0.00	0.00	0.w	0.00	0.00	0.00	0.00	0.00	0.00	0.w	0.00	0.w	0.00	0.00	0.w	0.00	0.00	0.00	0.w	0.00	0.00	0.00	0.00
1997	0.w	0.00	0.w	0.00	0.00	0.00	0.00	0.w	0.w	0.00	0.00	0.w	0.00	0.00	0.00	0.00	0.w	0.00	0.00	0.w	0.w	0.00	o w	0.00
1998	0.00	0.w	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.w	0.00	0.w	0.00	0.w	0.w	0.w	0.00	0.w
1999	0.00	0.00	0.00	0.00	0.w	0.00	0.00	0.00	0.00	0.00	0.w	0.00	0.w	0.w	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.w	6.00	0.00

Table 8. Eastern Bering Sea flathead sole female numbers at length group (millions) estimated from the NMFS trawl surveys

Year	Length Group (cm)																						
	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	49	52	55	58
1977	0.00	0.00	123	16.77	24.10	19.75	29.37	4662	46.32	48.18	53.37	66.17	70.42	55.20	32.85	13.46	675	6.7,	167	040	ow	0.00	0.00	0.00
1978	0.00	0.48	11.91	38.92	24.91	4347	55.95	53.01	45.10	50.33	55.24	61.64	78.61	78.66	7O.M	32.20	15.53	907	1.57	047	0.w	0.00	0.w	0.00
1979	0.00	0.81	8.07	33.44	58.49	60.36	62.89	56.56	71.60	71.37	72.40	83.43	83.20	64.64	64.32	56.W	28.95	12.30	1.28	0.92	0.03	O.W	0.w	0.00
1980	0.w	1.18	1.24	7.94	21.60	33.11	52.72	7633	67.73	50.09	49.00	53.25	54.64	56.40	52.36	34.41	23.56	1447	416	1.01	0.00	0.00	0.w	0.00
1981	0.06	0.47	3.44	12.09	13.38	17.44	30.88	46.66	64.65	75.02	66.41	00.68	88.37	7082	74.52	55.19	40.46	30.46	697	2.00	0.16	0.00	0.00	0.00
1982	0.00	0.00	4.28	18.41	28.98	39.89	40.57	46.66	45.24	58.28	66.52	70.32	71.67	70.27	7662	60.34	46.75	35.05	13.75	2.76	0.10	0.00	0.00	0.00
1983	0.w	0.00	2.56	19.33	12.88	96.75	92.24	114.64	80.83	74.65	78.16	76.62	7920	101.69	194.46	97.65	69.76	63.72	20.02	3.46	1.34	O.w	0.00	0.w
1984	0.90	0.14	15.55	43.40	26.12	39.99	1o440	103.79	199.92	77.05	62.33	67.97	76.15.	68.05	65.35	91.01	67.13	65.46	28.58	7.98	o.al	0.00	0.w	0.00
1985	0.00	0.20	1.05	13.16	59.w	70.00	48.57	67.66	91.46	93.57	62.66	74.66	66.36	77.59	72.16	03.78	80.79	91.95	39.88	11.26	2.42	0.00	0.w	0.00
1986	0.00	0.84	5.00	4.75	8.97	31.83	69.33	95.63	94.66	104.16	99.36	89.17	86.35	7735	a647	76.63	107.67	124.83	4433	14.63	0.96	O.w	0.00	0.00
1987	0.00	0.00	3.88	30.13	54.07	42.64	48.51	75.78	102.93	123.14	115.07	114.32	63.74	79.04	64.56	85.11	61.45	94.70	51.89	16.50	2.48	0.13	0.00	0.00
1988	0.04	0.53	4.66	9.93	19.37	50.29	59.06	46.11	70.67	95.05	97.59	169.16	10675	85.77	73.98	87.04	58.95	95.20	49.32	15.80	2.66	0.08	0.w	0.w
1989	0.00	0.41	2.31	13.29	31.96	47.10	BB.62	58.17	47.42	74.88	97.27	118.66	12557	11265	96.71	77.67	78.94	103.18	70.94	25.65	3.59	0.32	0.00	0.00
1990	0.00	O.w	1 16	524	15.94	30.57	38.90	54.44	50.61	49.62	62.06	80.36	87.85	92.64	80.90	6726	59.77	69.60	50.64	16.61	5.56	0.25	0.00	0.00
1991	0.w	0.18	3.94	16.72	28.21	43.66	47.93	61.57	81.11	66.25	65.12	64.30	75.63	88.04	93.11	81.05	52.62	72.76	5134	23.32	3.15	0.28	0.00	0.w
1992	0.00	0.49	1.81	0.57	14.30	21.96	29.35	36.26	41.09	47.46	59.28	63.51	60 61	84.6,	112.36	108.09	9804	129.84	108.43	33.09	7.92	0.61	0.w	0.00
1993	0.00	0.58	12.84	23.99	11.43	20.99	26.26	41.44	45.34	47.69	66.89	72.37	81.31	76.22	84.19	89.04	80.66	67.72	57.65	24.86	11.34	1.39	0.00	0.00
1994	0.00	0.14	2.12	5.82	14.45	15.77	14.66	19.89	26.42	34.79	40.97	40.77	43.54	4923	64.20	59.79	45.34	42.79	27.76	15.04	7.70	0.95	0.17	0.00
1995	0.00	O.w	0.00	0.00	0.00	0.00	0.00	0.00	0.w	0.w	0.w	0.w	0.00	0 00	0.00	0.00	0.w	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0 .w	0.00	0.00	0.w	0.00	o w	10.00	0.w	0.00	0.w	0.00	o w	0.00	0.00	0.00	o w	0.00
1997	0.00	0.00	O.W	0.00	O.w	0.00	0.00	0.00	0.00	0 00	0.00	0.00	0.00	0.00	o w	0.00	o w	0.00	000	0.00	0 00	0.00	O.w	0.00
1998	0.27	0.30	1.42	19.37	30.56	27.61	33.61	46.44	54.95	63.66	84.48	Be.19	72.52	31.55	10.41	3.08	0.59	0.42	000	0.w	0.w	0.00	o w	0.w
1999	0.47	1.36	16.88	47.96	28.14	49.w	85.83	56.18	49.68	57.29	71.20	65.44	82.41	58.61	23.63	670	1.37	0.12	000	o w	0.00	0 00	o w	0.w

Table 9. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 1998 SAFE estimates

	Female Spawner Biomass (t)		Total Biomass (t)		Recruitment (thousands)	
	Assessment		Assessment		Assessment	
Year	1999	1998	1999	1998	1999	1998
1977	47244	40253	172842	144473		
1978	43563	36596	197891	166378	147950	347641
1979	41110	34161	23 1379	196064	4745 15	789500
1980	41523	34719	276638	235698	819210	1226870
1981	49862	43273	3223 16	277545	738959	1242225
1982	71803	6395 1	372011	322783	864262	1364029
1983	98942	88338	433637	37996 I	1252783	2048367
1984	123024	109960	498628	440762	1194949	1952885
1985	145276	130558	550999	492072	559821	1019668
1986	167303	151534	597844	537640	680215	1098748
1987	192011	175692	647057	585677	1029087	1684840
1988	220925	204273	698803	637345	11585371	974244
1989	249369	232 172	739555	678717	856121	1445573
1990	272811	255154	781930	72276 1	990442	1717930
1991	28293 1	265402	78789 1	732278	269926	526088
1992	294334	277569	795 199	74288 1	637614	1085515
1993	307558	291811	791613	743783	430373	783359
1994	319928	305178	7826 12	738774	5 19882	875484
1995	329354	3 14840	761835	72228 1	262658	516830
1996	328618	3 15493	733991	699638	378272	662666
1997	320588	308956	696485	667594	190990	390009
1998	306801	298181	656047	6355 17	333926	856249
1999	288826		611432		346270	

Table 10. Projected future catch (t) of flathead sole under various harvest rates.

F level	Year 2000	2001	2002	2003	2004
F_{35} (F=0.351)	89,958	69,145	53,609	36,488	26,520
90% CI	(89,949 - 89,975)	(69,104 - 69,213)	(53,474 - 53,820)	(36,103 - 37,080)	(25,413 - 28,266)
F_{40} (F=0.280)	73,537	59,393	48,103	39,647	27,748
90% CI	(73,530 - 73,551)	(59,359 - 59,447)	(47,996 - 48,272)	(38,292 - 39,196)	(26,729 - 29,354)
$F_{40}/2$ (F=0.140)	38,647	34,477	30,576	26,993	24,084
90% CI	(38,643 - 38,654)	(34,459 - 34,504)	(30,522 - 30,660)	(26,847 - 27,211)	(23,752 - 24,580)
Recent F level (F=0.05358)	15,262	14,496	13,638	12,707	11,883
90% CI	(15.261 - 15.2653	(14.489 - 14.506)	(13.618 - 13.670)	(12,651 - 12,915	- 12.074)

Table 11. Projections of future spawning biomass (t) under various harvest rates.

	Year				
F level	2000	2001	2002	2003	2004
F_{35} (F=0.351)	258,867	193,896	146,917	114,668	98,258
90% CI	(258,867 - 258,,867)	(193,896 - 193,896)	(146,906 - 146,936)	(114,393 - 115,146)	(96,215 - 101,685)
F_{40} (F=0.280)	261,342	206,253	163,610	131,640	111,830
90% CI	(261,342 - 261,342)	(206,253 - 206,253)	(163,599 - 163,630)	(131,365 - 132,121)	(109,774 - 115,279)
$F_{40}/2$ (F=0.140)	266,289	233,265	203,438	177,378	158,391
90% CI	(266,289 - 266,289)	(233,265 - 233,265)	(203,427 - 203,458)	(177,090 - 177,879)	(156,205 - 162,066)
Recent F level (F=0.05358)	269,393	251,916	233,612	215,331	201,301
90% CI	(269,393 - 269,393)	(251,916 - 251,916)	(233,601 - 233,632)	(2 15,042 - 2 15,834)	(199,100 - 205,004)
F = O	271,336	264,314	254,879	243,653	235,151
90% CI	(271.336 - 271.336)	(264.3 14 - 264.3 14)	(254.868 - 254,898)	(243.364 - 244,157)	(232,940 - 238,872)

Table 12. Research catches (t) of flathead sole in the BSAI area from 1979 to 1998.

Year	Research Catch (t)
1979	11.85
1980	6.19
1981	11.23
1982	20.36
1983	13.86
1984	13.5 1
1985	44.83
1986	13.79
1987	12.97
1988	29.86
1989	24.60
1990	26.76
1991	35.92
1992	18.92
1993	21.86
1994	30.23
1995	26.52
1996	20.87
1997	30.3 1
1998	23.02

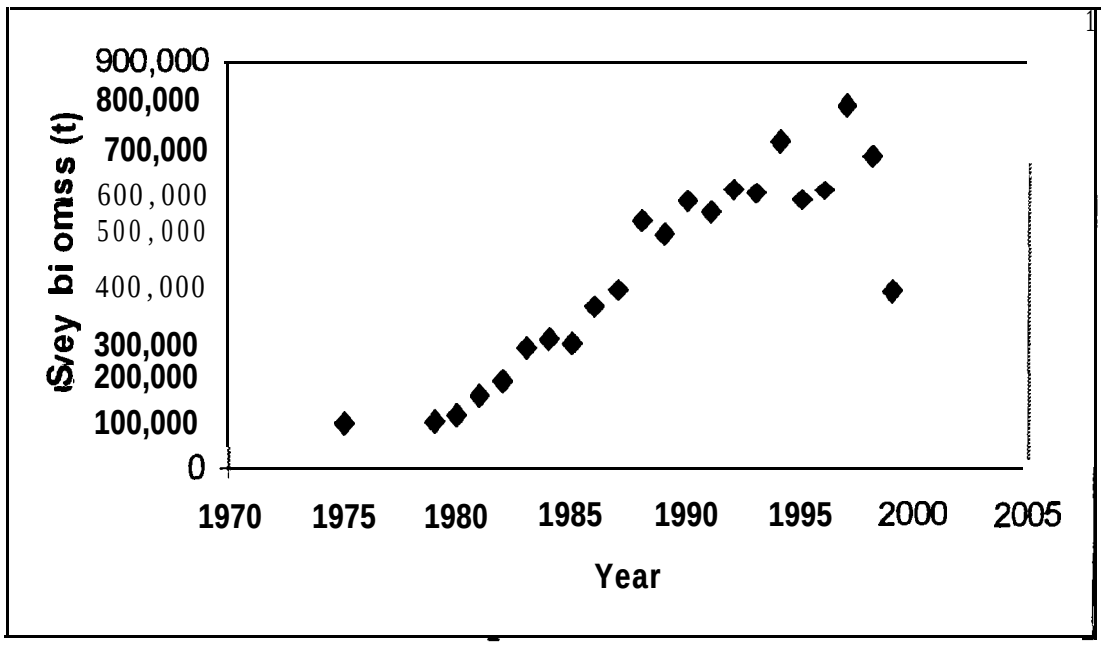


Figure 1. Estimated survey biomass of Eastern Bering Sea flathead sole.

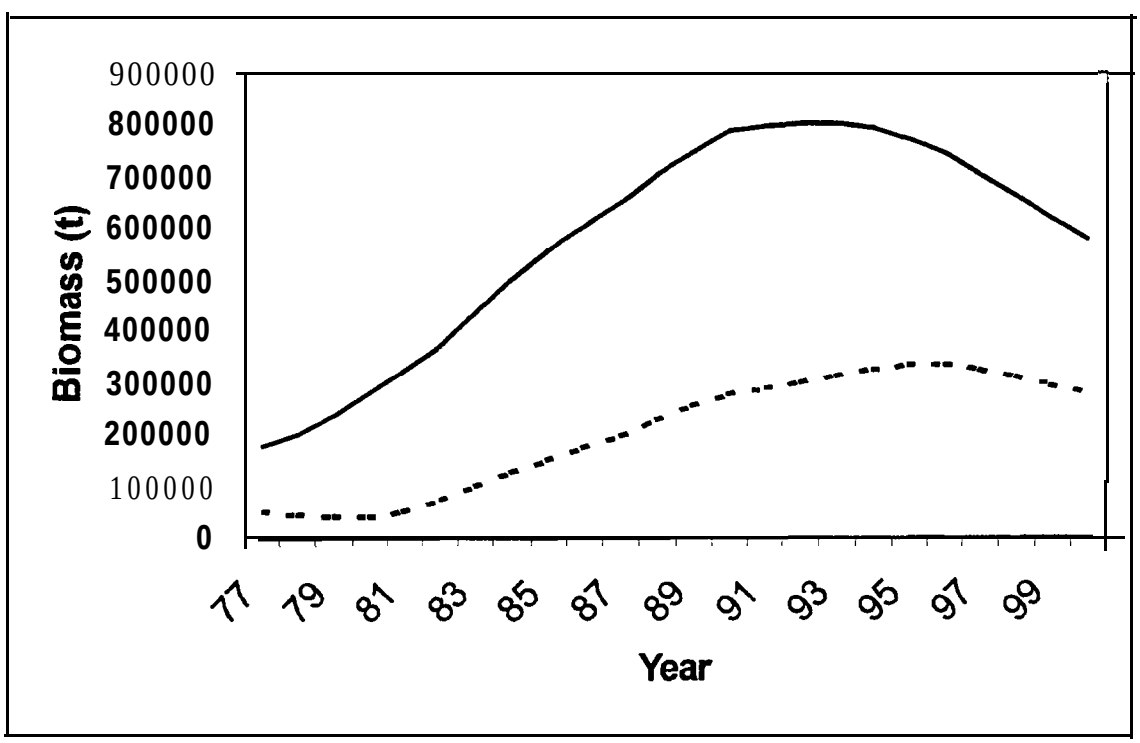


Figure 2. Estimated beginning year (solid line) and spawning biomass (dashed line) for flathead sole

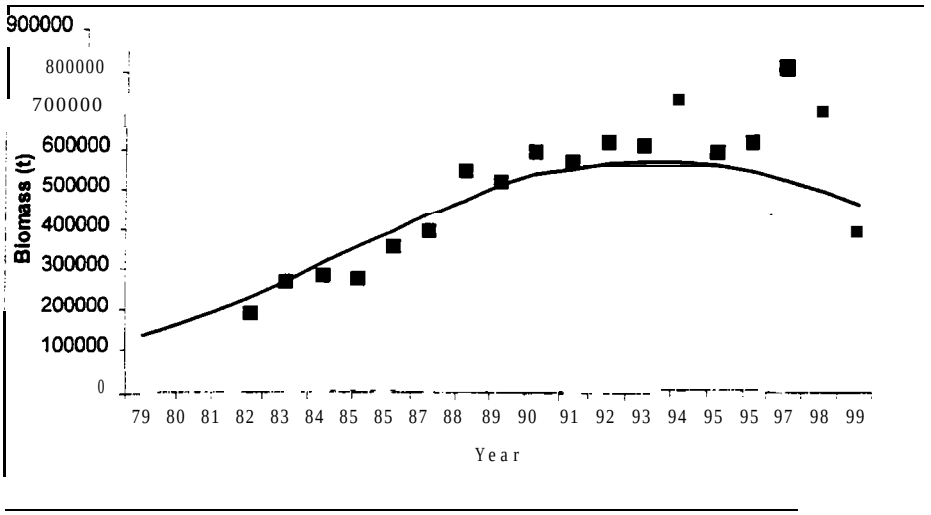


Figure 3. Estimated survey biomass of flathead sole with observed survey biomass.

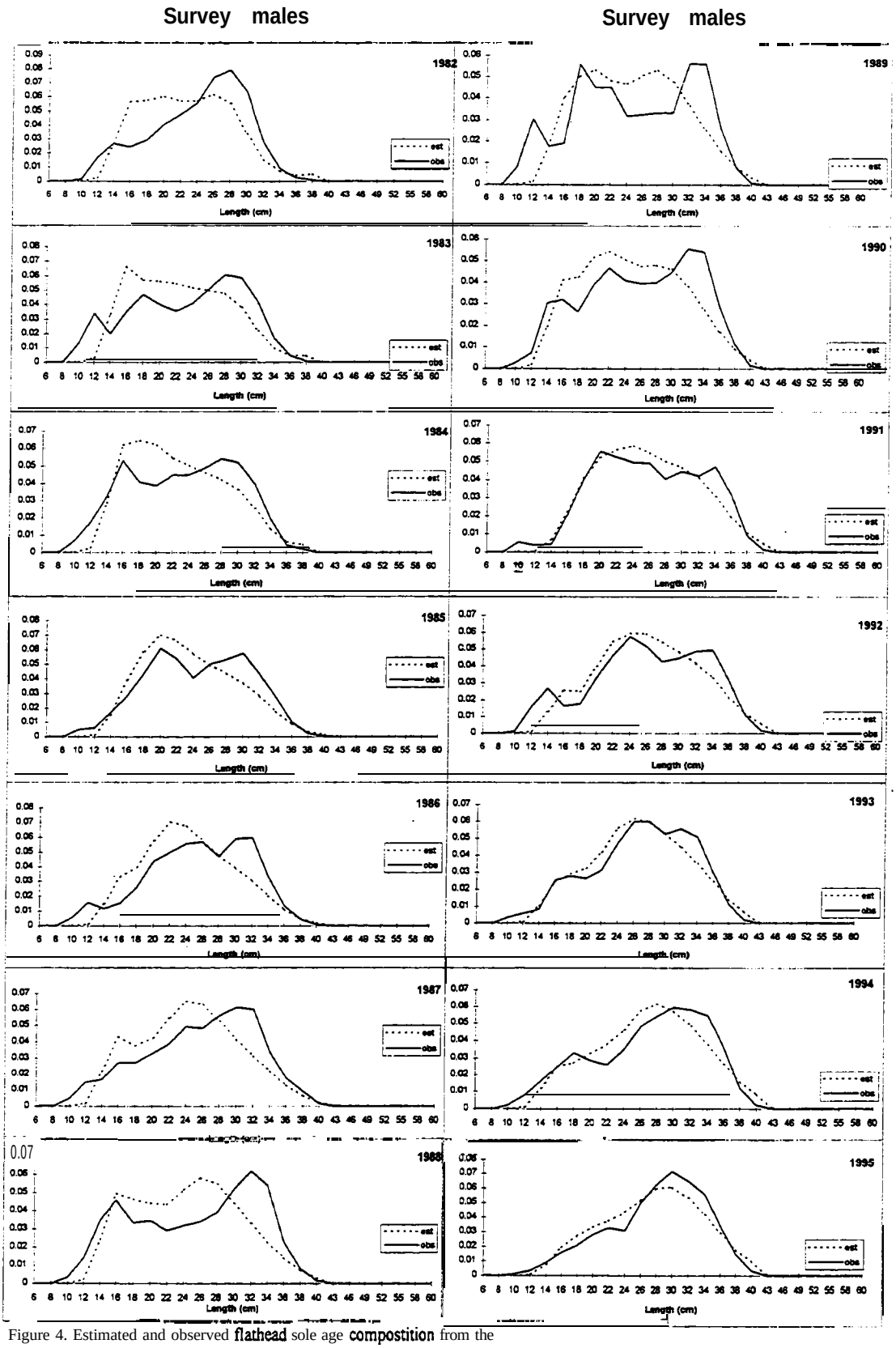


Figure 4. Estimated and observed flathead sole age compostition from the EBS trawl survey

Survey males

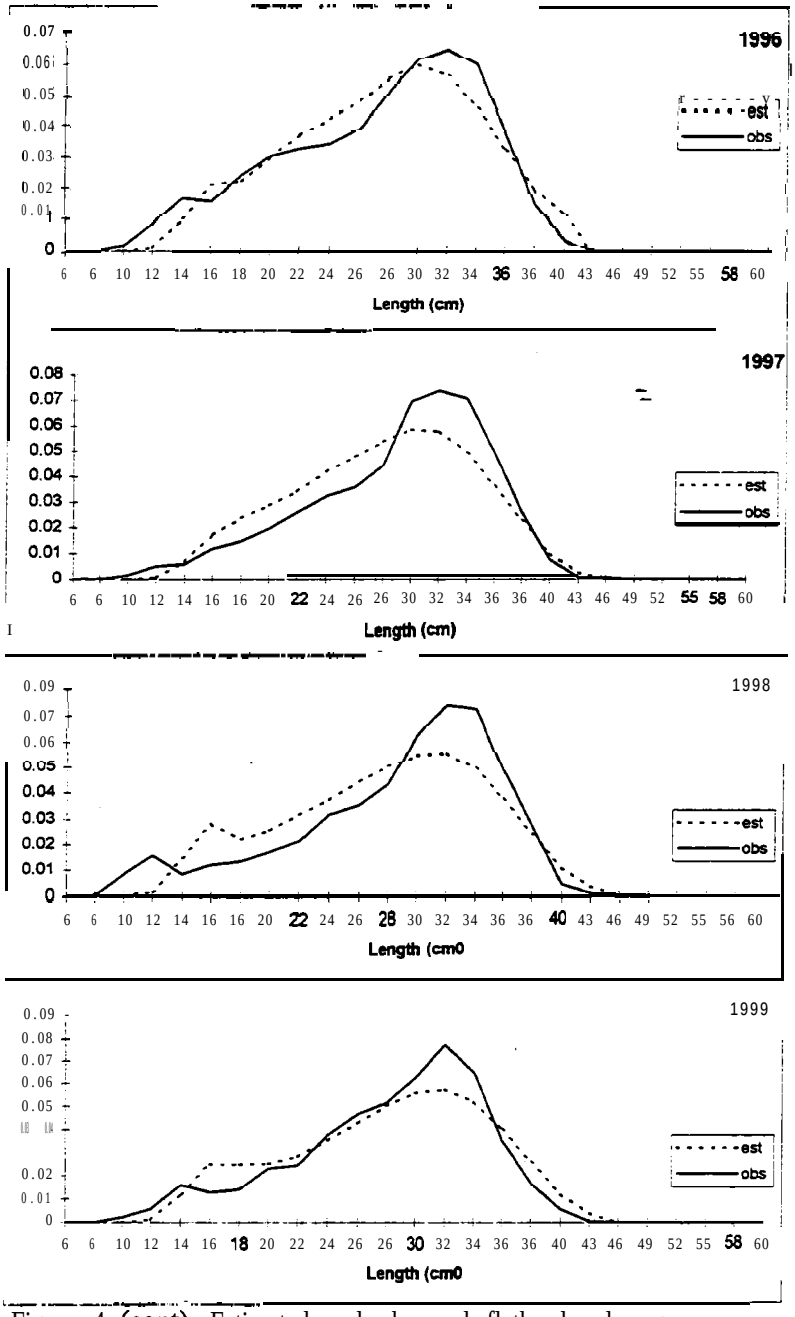


Figure 4 (cont). Estimated and observed flathead sole age compostition from the EBS trawl survey

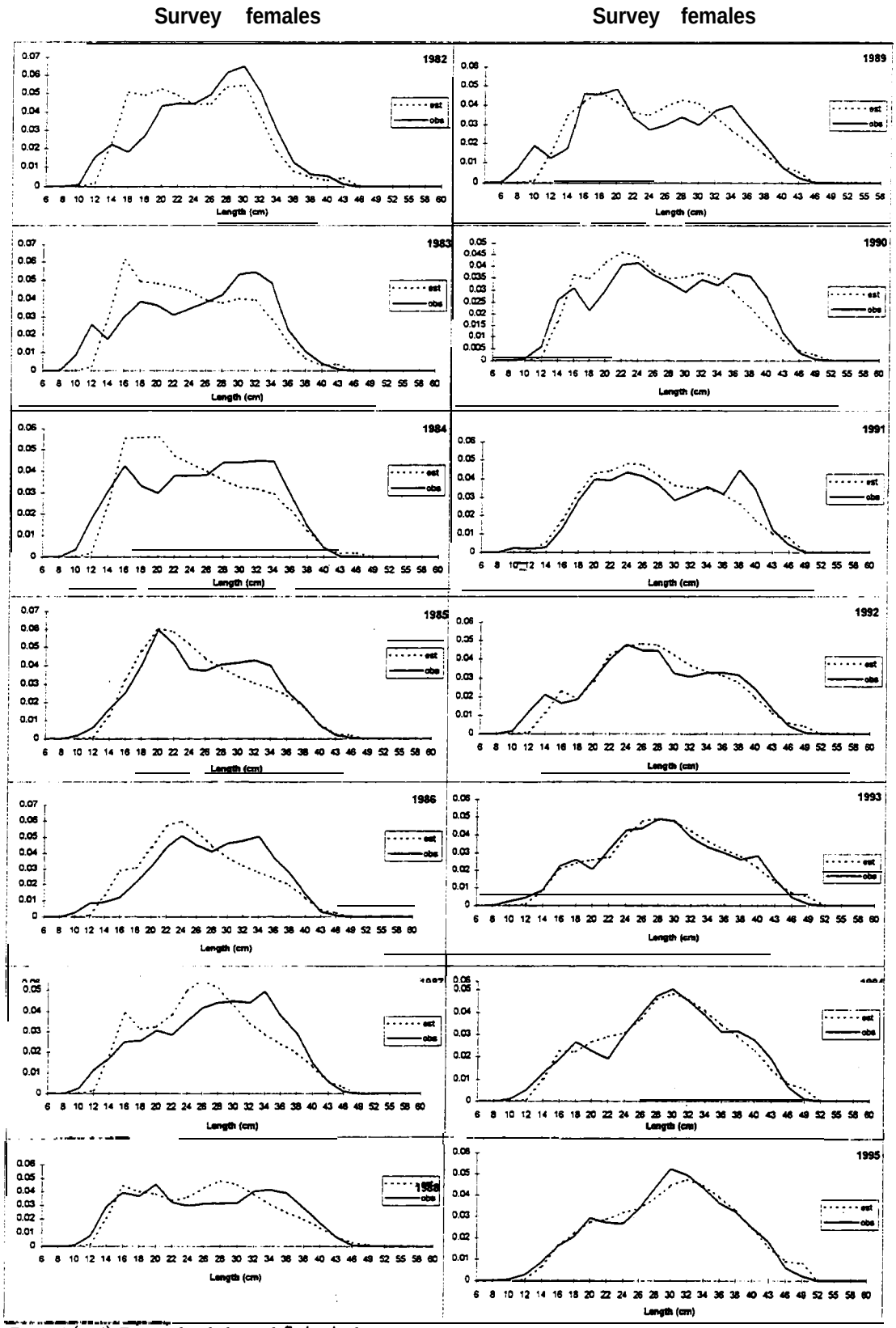


Figure 4 (cont). Estimated and observed flathead sole age compostition from the EBS trawl survey

Survey females

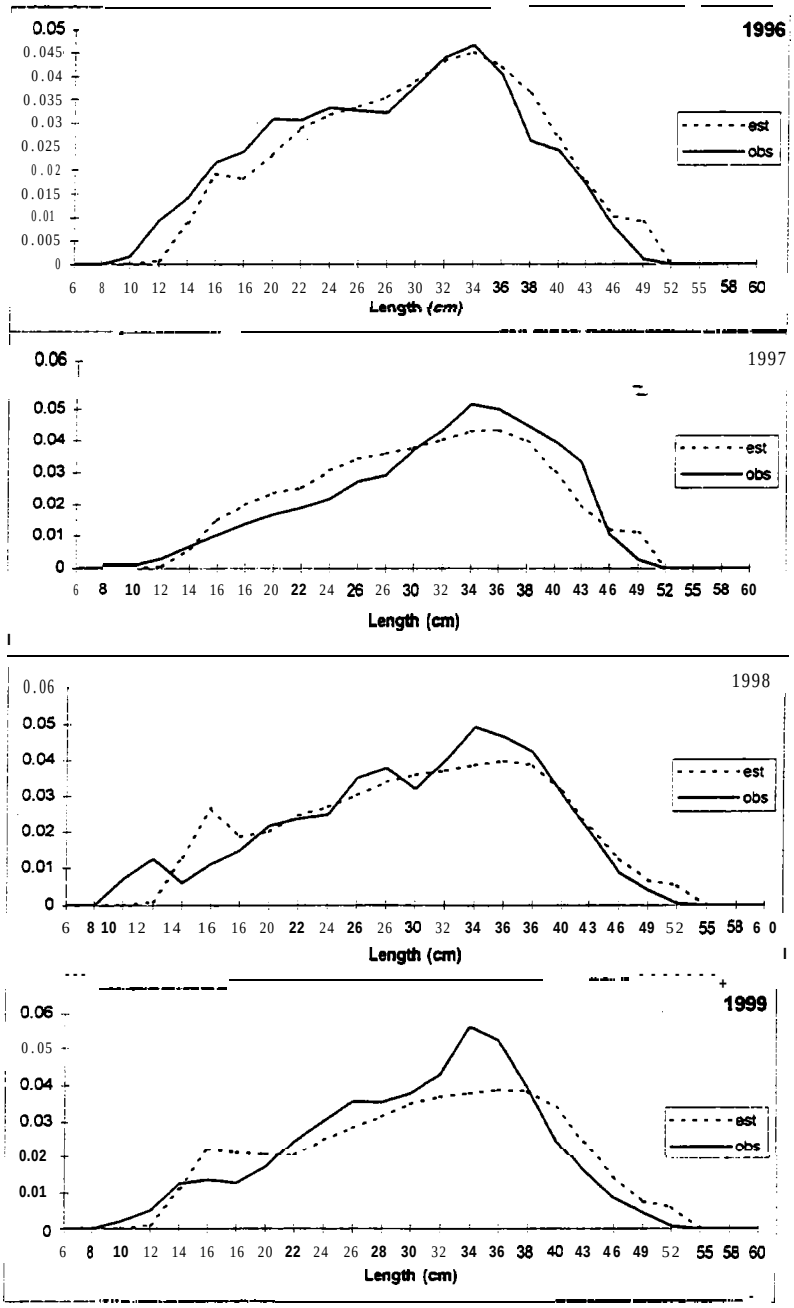


Figure 4 (cont). Estimated and observed flathead sole age compostition fi-om the EBS trawl survey

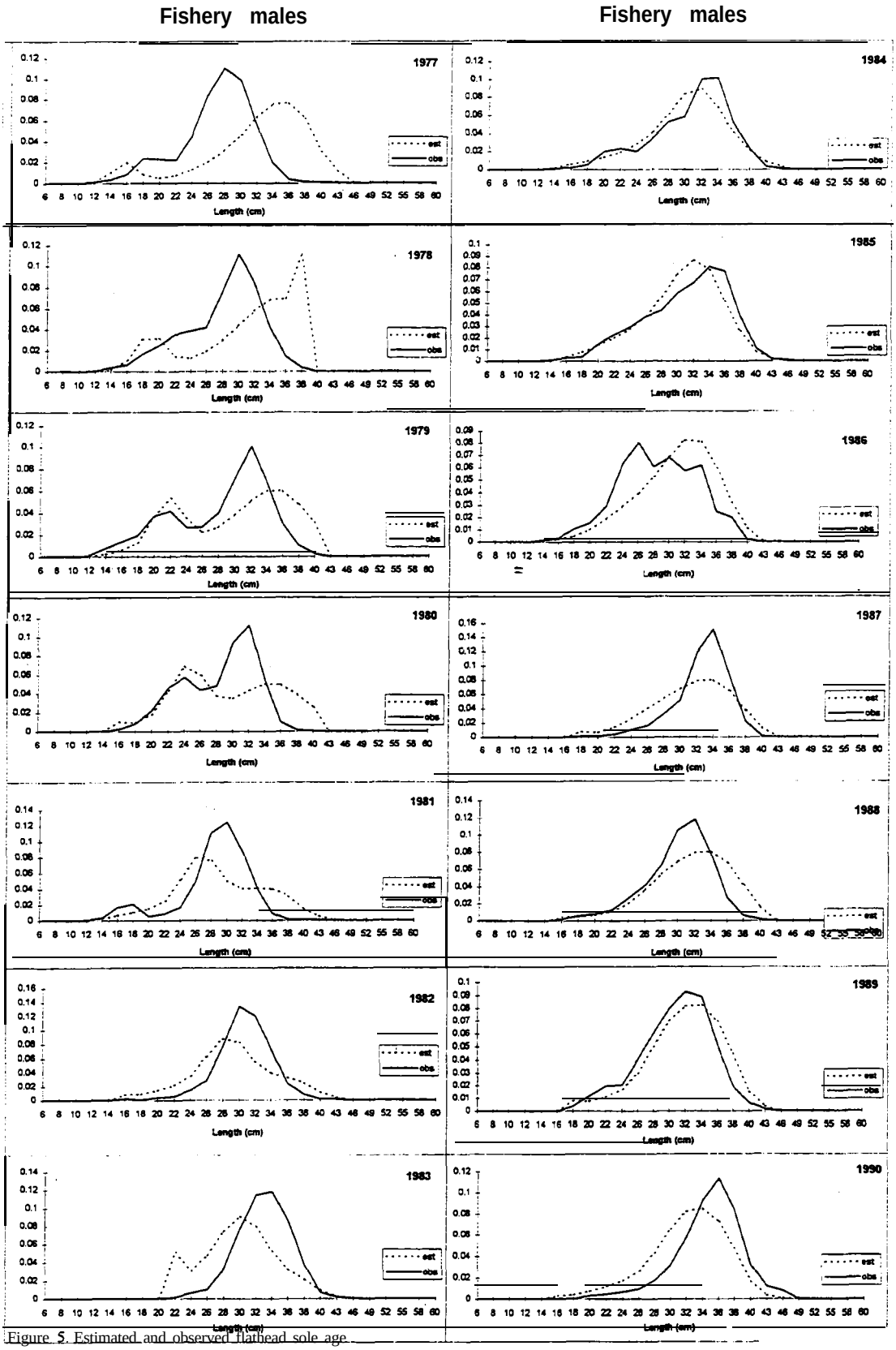


Figure 5. Estimated and observed flathead sole age compostition from the trawl fishery

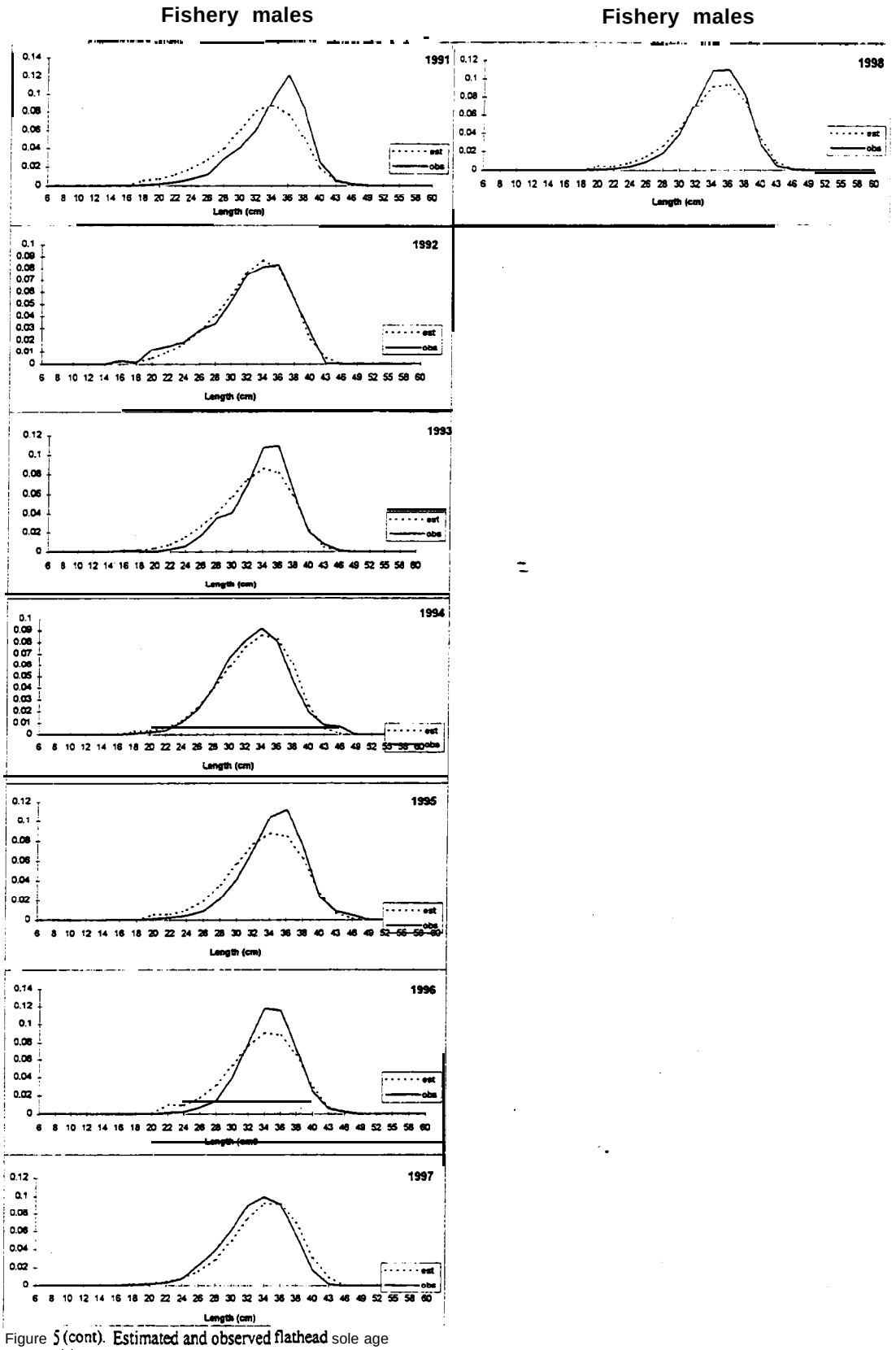


Figure 5 (cont). Estimated and observed flathead sole age compostition From the trawl fishery

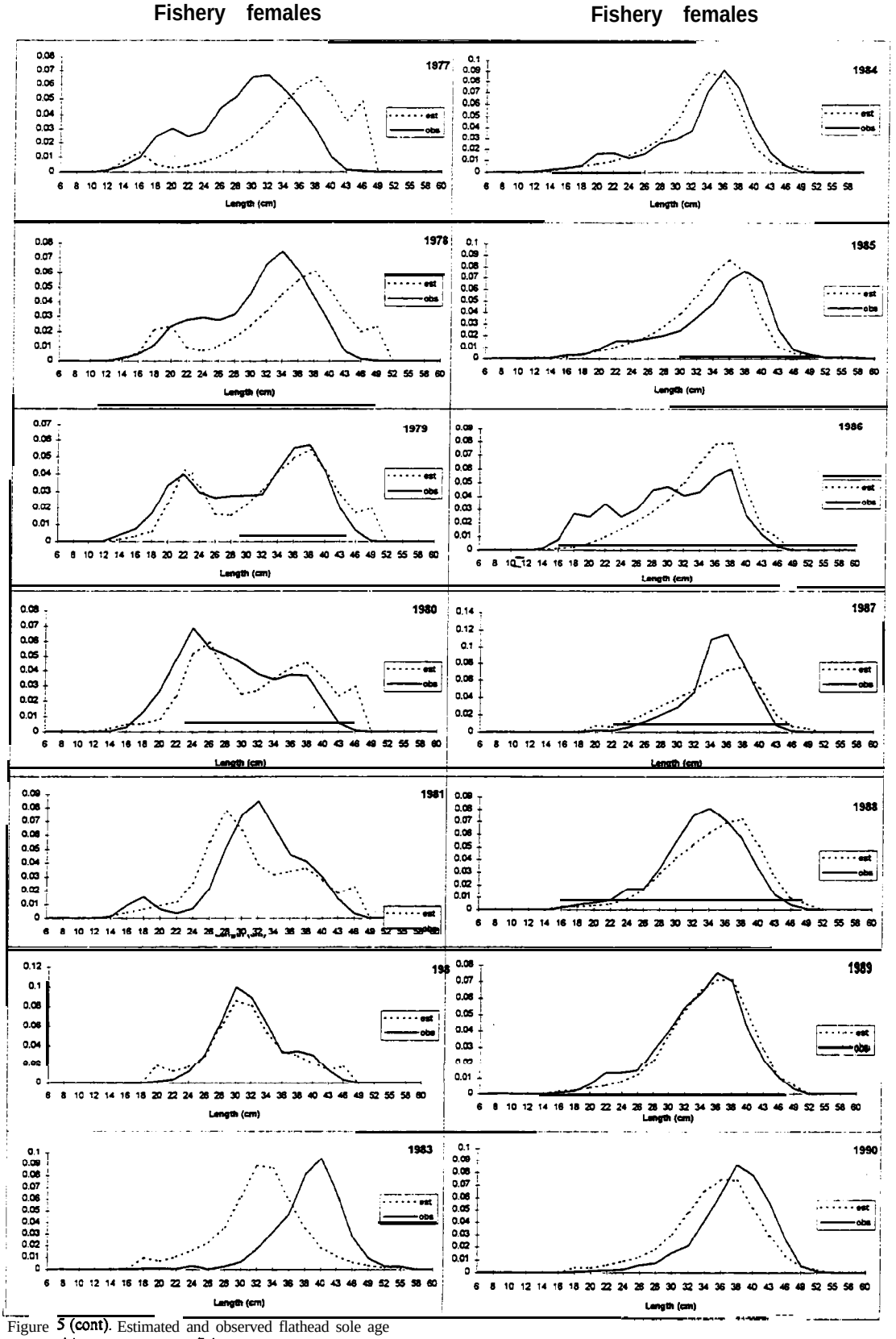
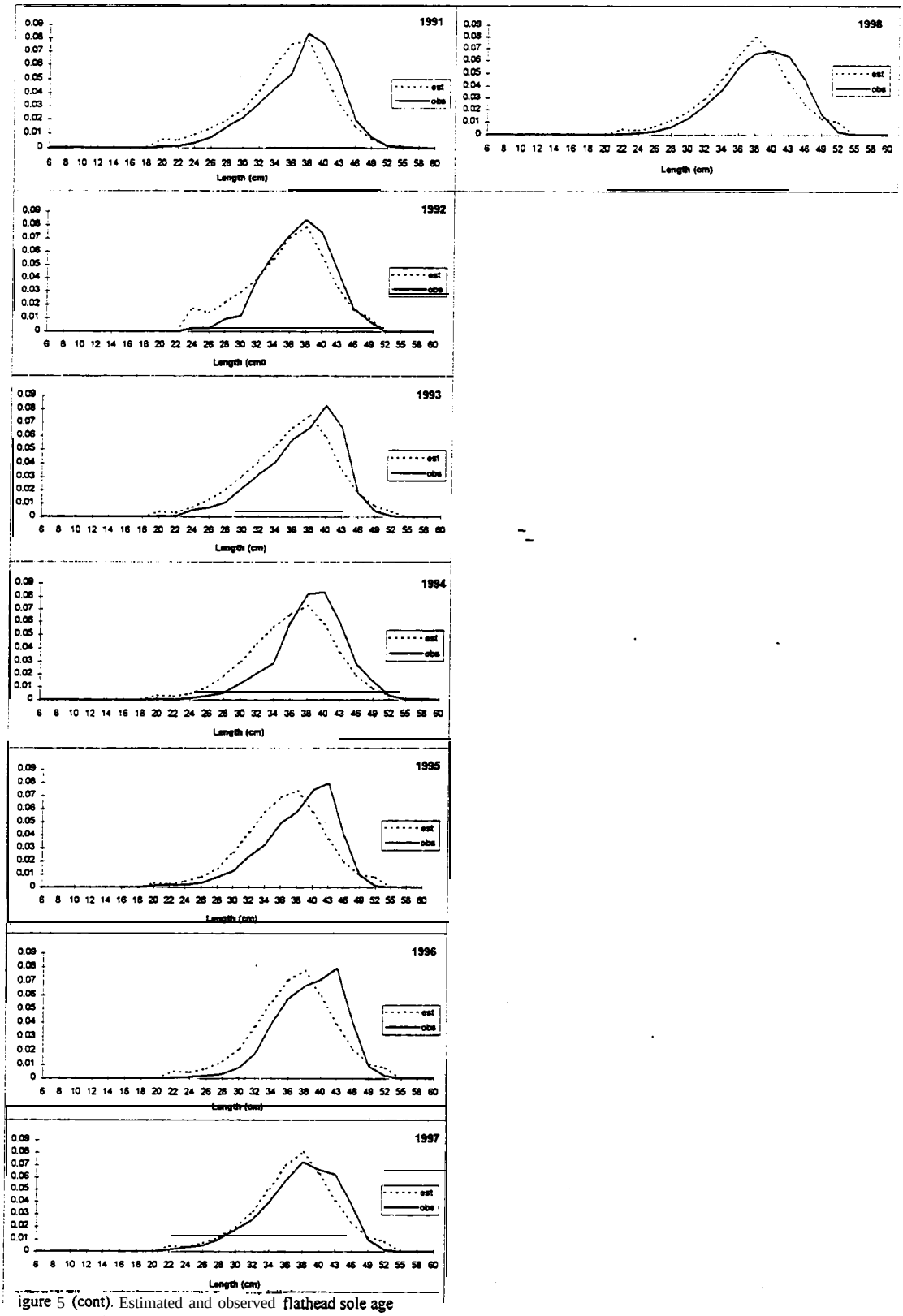


Figure 5 (cont). Estimated and observed flathead sole age compostition from the trawl fishery



igure 5 (cont). Estimated and observed flathead sole age compostition from the trawl fishery

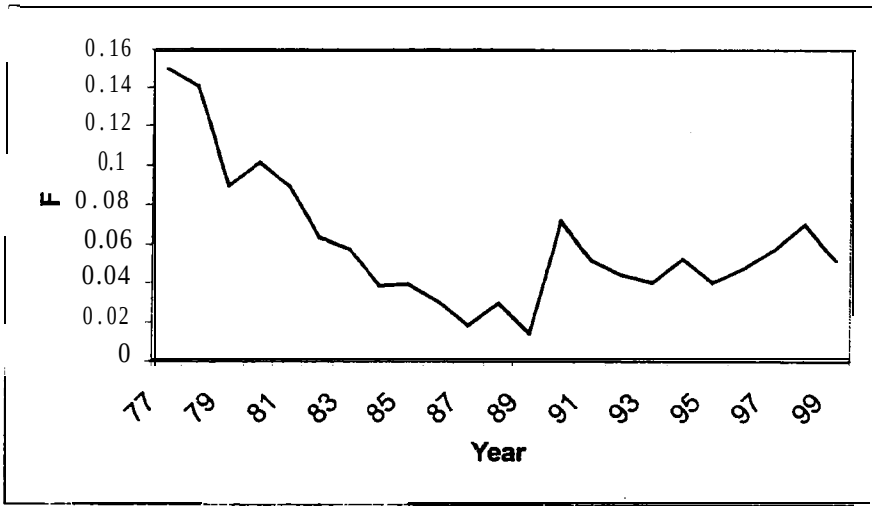


Figure 6. Estimated fully-selected fishing mortality rate by year for flathead sole

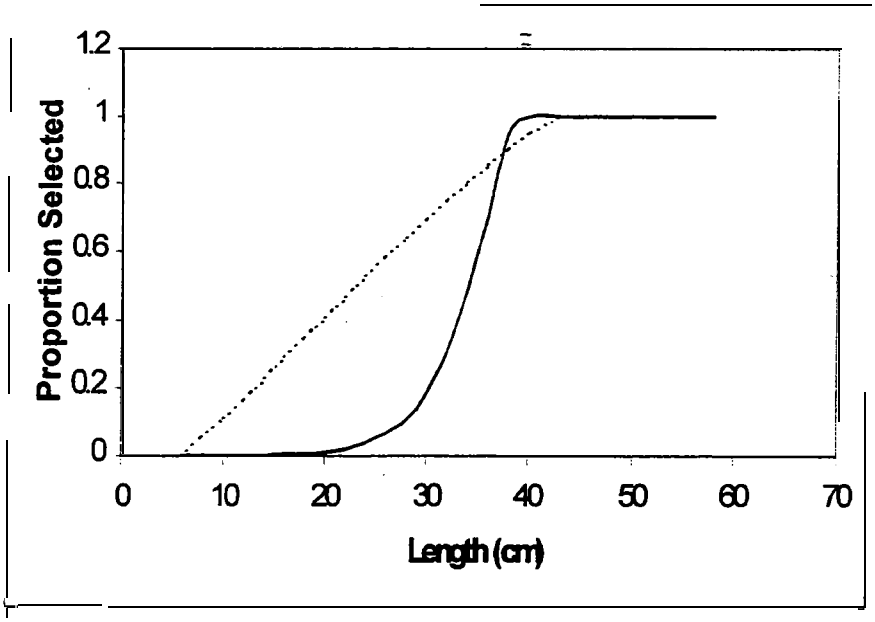


Figure 7. Estimated fishery (solid line) and survey (dashed line) selectivity curve by length

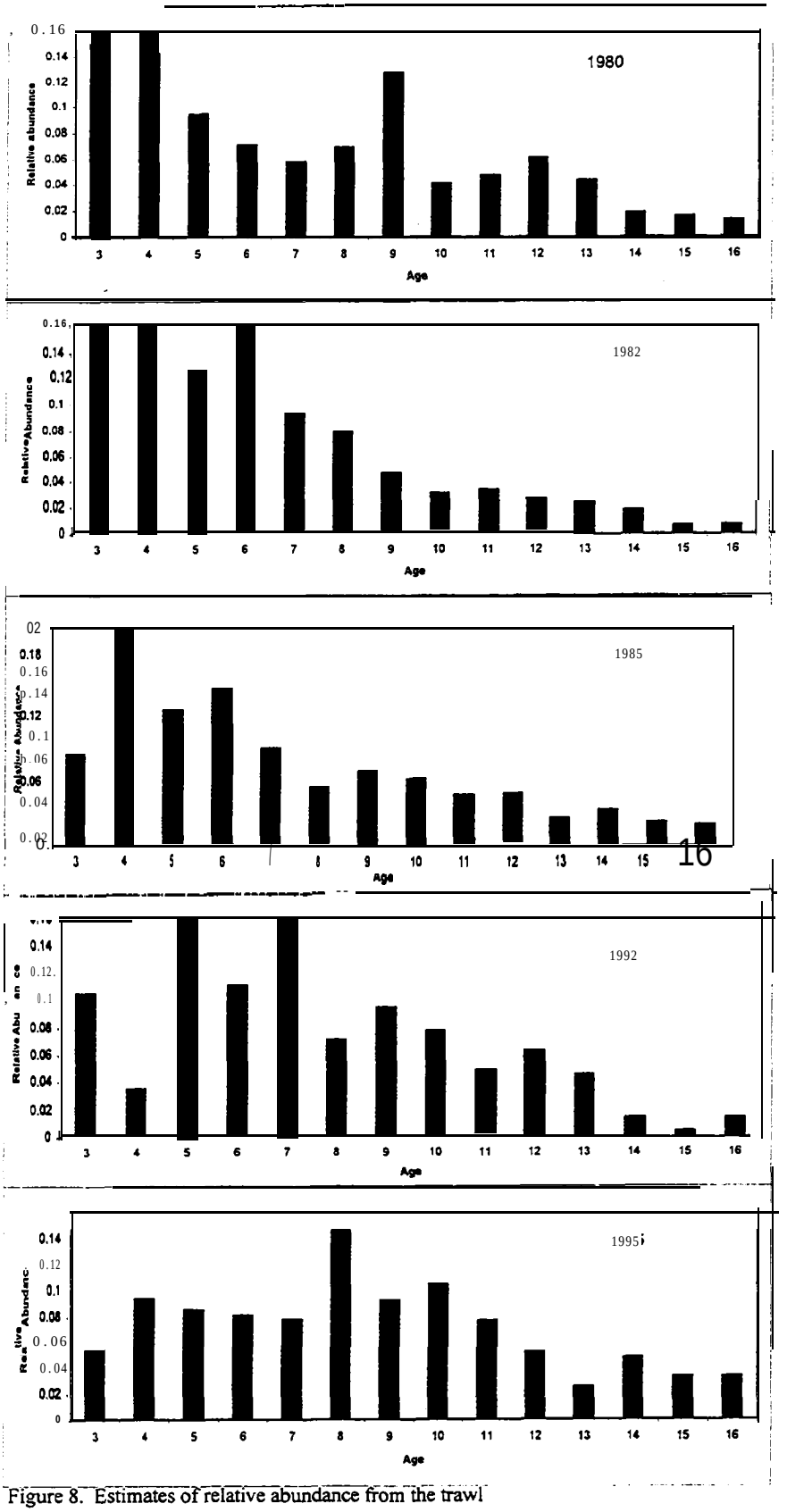


Figure 8. Estimates of relative abundance from the trawl survey for EBS flathead sole.

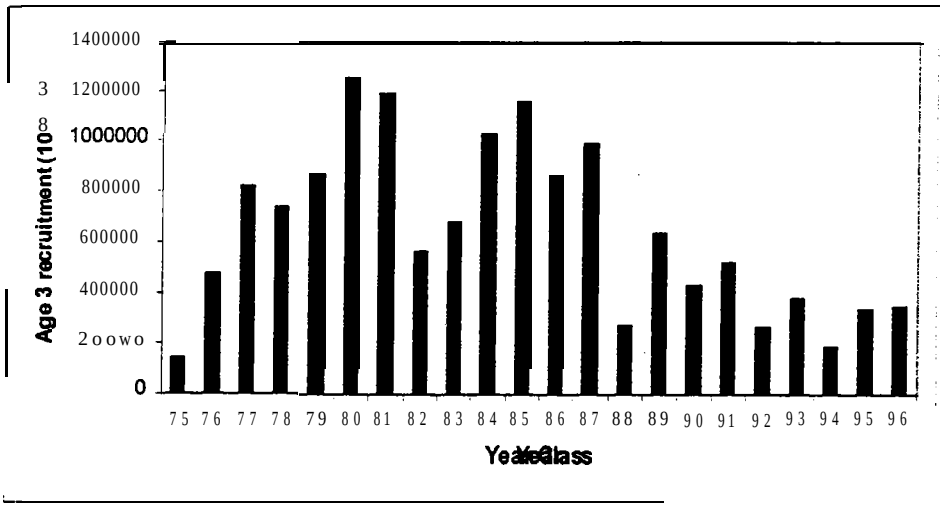
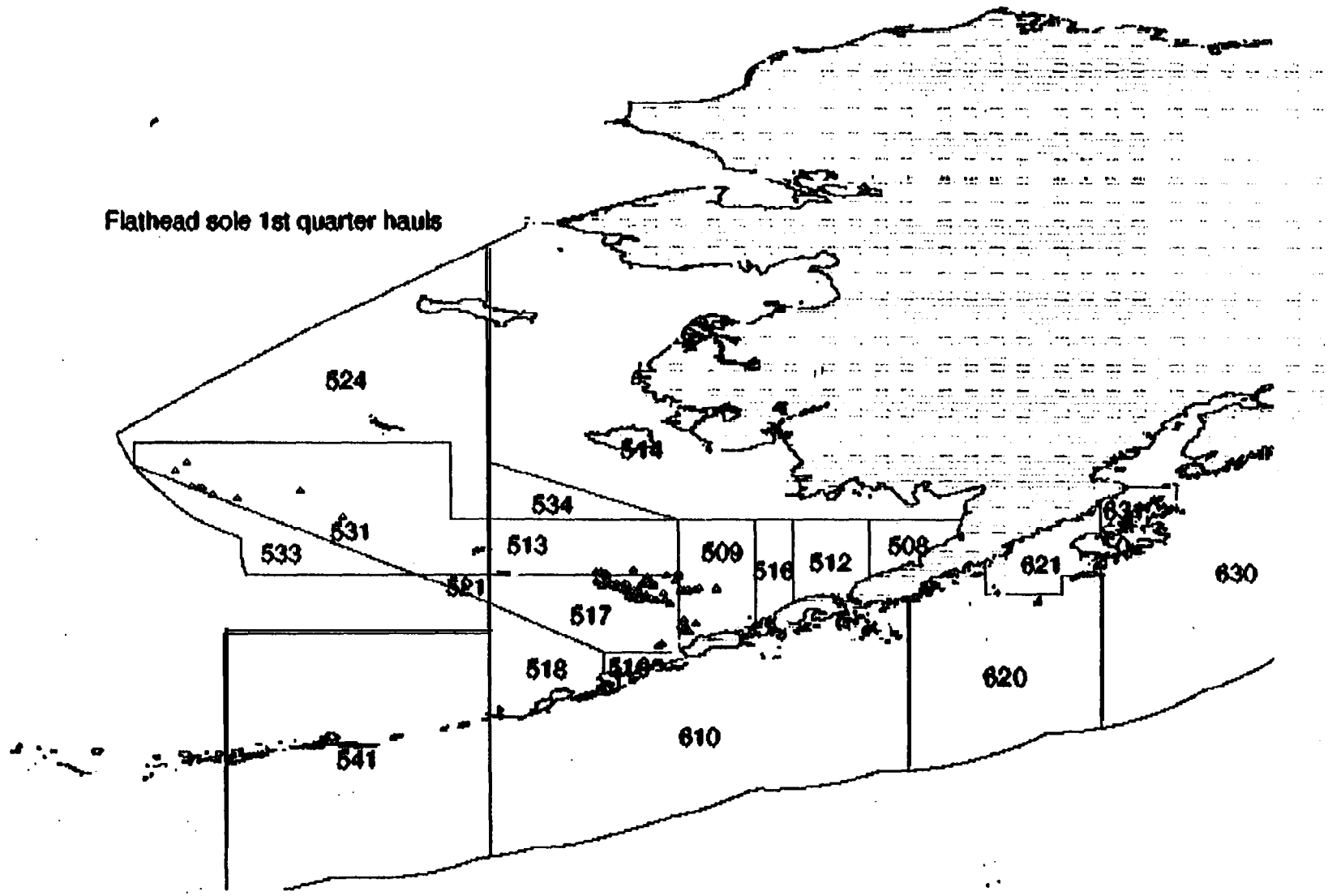


Figure 9. Estimated age 3 recruitment of flathead sole by year class.

Appendix

Figures showing the distribution of flathead sole hauls sampled by fishery observers in 1998, by quarters. Flathead sole hauls are defined as flatfish comprising greater than 50% of the catch, with flathead sole being the most abundant flatfish in the catch.


Flathead sole 1st quarter hauls
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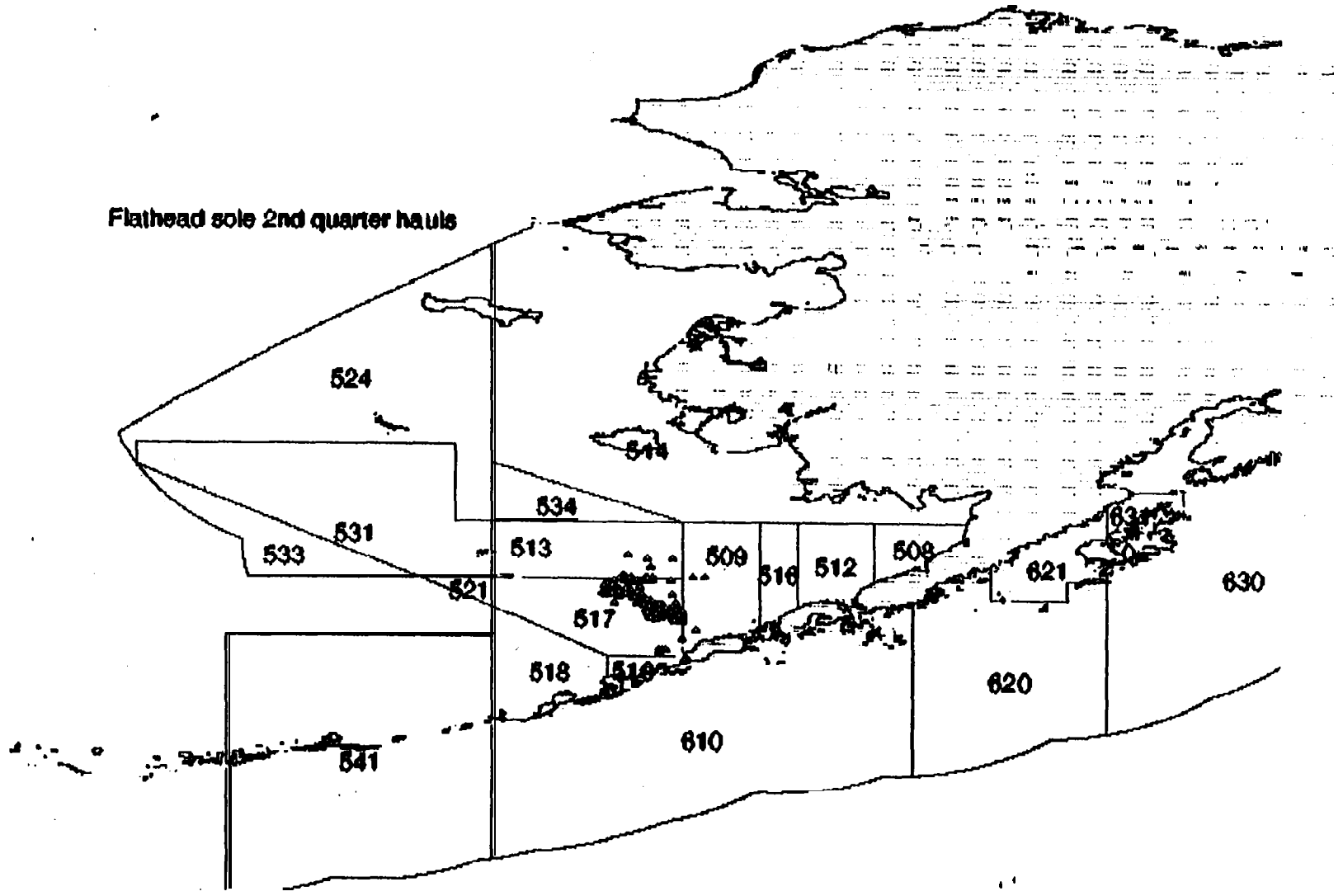
Flathead sole 2nd quarter hauls
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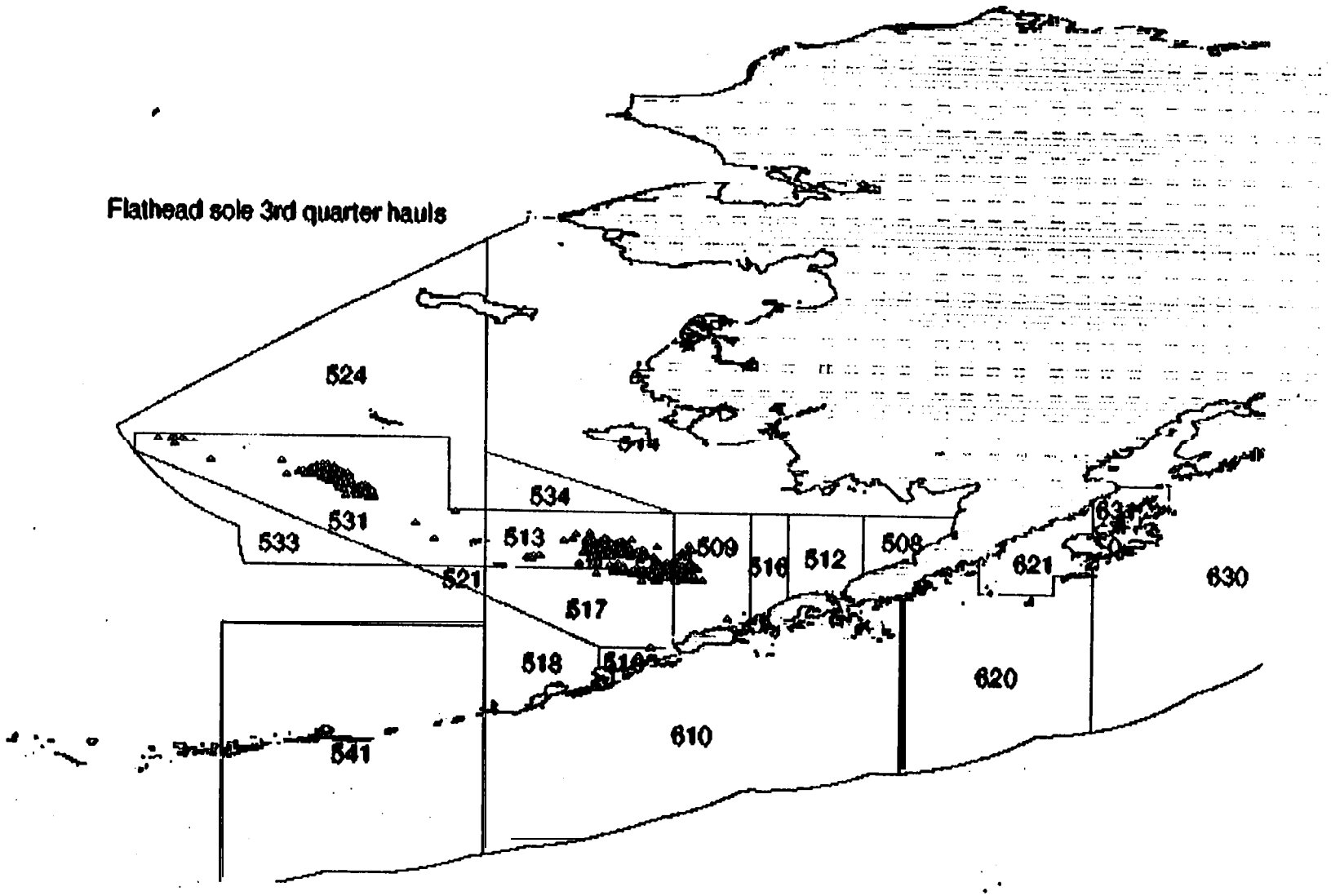
Flathead sole 3rd quarter hauls
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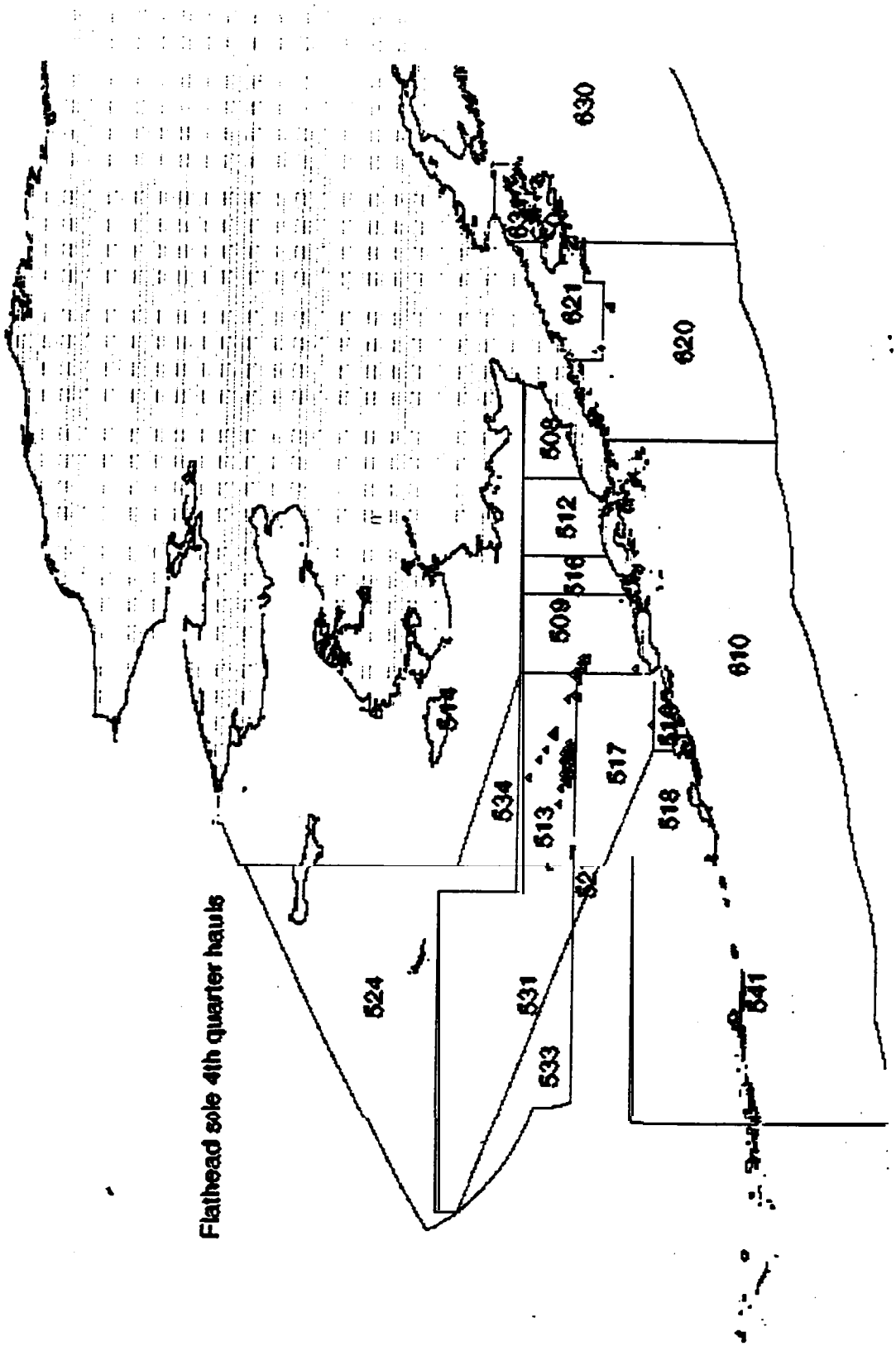
Flathead sole 4th quarter hauls
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