

FLATHEAD SOLE

by

Paul D. Spencer, Gary E. Walters, and Thomas K. Wilderbuer

Executive Summary

The following changes have been made to this assessment relative to the November 1999 SAFE:

Changes in the input data

- 1) 2000 total catch and discards through 23 September, 2000.
- 2) 2000 trawl survey biomass estimate and standard error.
- 3) 2000 length composition of the survey abundance.
- 4) 1999 length composition of the fishery catch.
- 5) Estimate of the retained and discarded portions of the 1999 catch.

Changes to assessment methodology

- 1) Change in the implementation software from the stock synthesis model to the Stock Assessment Model (SAM), which was developed with AD Modelbuilder.

Model results

- 1) Estimated 3+ total biomass for 2000 is 618,234 t.
- 2) Projected female spawning biomass for 2001 is 267,988 t.
- 3) Recommended ABC for 2000 is 83,964 t based on an $F_{40\%}$ (0.30) harvest level.
- 4) 2000 overfishing level is 102,485 t based on a $F_{35\%}$ (0.38) harvest level.

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

| | 1999 Assessment recommendations for the 2000 harvest | 2000 Assessment recommendations for the 2001 harvest |
|-------------------|--|--|
| ABC | 73,537 t | 83,964 t |
| Overfishing | 89,958 t | 102,485 t |
| F_{ABC} | $F_{0.40} = 0.28$ | $F_{0.40} = 0.30$ |
| $F_{overfishing}$ | $F_{0.35} = 0.35$ | $F_{0.35} = 0.38$ |

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 flatfish" 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 flatfish.

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 1971, catches declined to less than 20,000 t in 1975. Catches from 1977-89 averaged 5,286 t increasing to an annual average of 17,720 t from 1990-99 (Table 1). The resource remains lightly harvested as the 2000 catch through 23 September is only 34% of the 2000 TAC of 52,652 t. Catch locations in 1999 where flatfish were the largest species group and flathead sole where the most abundant flatfish 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 23 September, 2000 (Table 1), and estimates of number caught by length group and sex for the years 1977-1999 (Tables 4-5).

Survey Data

Because *Hippoglossoides* sp. are often 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 1979-2000 by NMFS. Survey estimates of total biomass and numbers by length group and sex for the years 1982-2000 are shown in Tables 6-8 and Figure 1. The survey gear changed after 1981, and as in previous assessments (Spencer et al. 1999) 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 and 2000. The 2000 estimate of 399,298 is a 1% increase from the 1999 value and a 42% decline from the 1998 value.

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_{∞} (cm) | k | t_0 |
|---------------------|---------|-------------------|--------|---------|
| H. <u>elassodon</u> | males | 37.6 | 0.1731 | -0.3536 |
| | females | 47.2 | 0.1322 | -0.2102 |
| H. <u>robustus</u> | males | 30.4 | 0.2111 | 0.3210 |
| | females | 42.5 | 0.1298 | 0.2231 |

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, 1977-2000;
- 2) Proportional catch numbers by length group, 1977-1999;
- 3) Survey biomass and standard error, 1982-2000;
- 4) Survey age composition 1982, 1985, 1992, and 1995;
- 5) Proportional survey numbers by length group, 1982-2000.

Analytical Approach

Model Structure

The Stock Assessment Model (SAM) has a length-based formulation, which is underlaid by an age-based model. A transition matrix (**TR**) is used to convert the selectivity at length to selectivity at age, and to convert the predicted catch and numbers at age to catch and numbers at length.

An age-structured, split-sex population dynamics model was used to obtain estimates of recruitment, numbers at age, and catch at age for each sex. Population size in numbers at age a in year t for sex s was modeled as

$$N_{s,t,a} = N_{s,t-1,a-1} e^{-Z_{s,t-1,a-1}} \quad 4 \leq a < A, \quad 2 \leq t \leq T$$

where Z is the sum of the instantaneous fishing mortality rate ($F_{s,t,a}$) and the natural mortality rate (M_s), A is the maximum number of ages in the population, and T is the terminal year of the analysis. The numbers at age A are a “pooled” group consisting of fish of age A and older, and are estimated as

$$N_{s,t,A} = N_{s,t-1,A-1} e^{-Z_{s,t-1,A-1}} + N_{t-1,A} e^{-Z_{s,t-1,A}}$$

The total numbers of age 3 fish over all years are estimated as parameters in the model, and modeled with a lognormal distribution

$$N_{t,3} = e^{(\mu_R + \nu_t)}$$

where ν is a time-variant deviation. The number of recruits is divided equally between males and females. The numbers at age in the first year are modeled to be in equilibrium with an historical catch of 1500 t, and requires estimation of a historic recruitment parameter (R_0) and a historic fishing mortality rate (f_{hist}).

The fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of a fishery age-specific selectivity function ($fishasel$) and a year-specific fully-selected fishing mortality rate f . The fully selected mortality rate is modeled as the product of a mean (μ_f) and a year-specific deviation (ϵ_t), thus $F_{t,a}$ is

$$F_{t,a} = fishasel_a * f_t \equiv fishasel_a * e^{(\mu_f + \epsilon_t)}$$

The fishery selectivity at age is obtained from the selectivity at length and the transition matrix \mathbf{TR}_s , where the transition matrix \mathbf{TR}_s indicates the proportion of each age (rows) in each length group (columns) for each sex; the sum across each age is equal to one. Because of growth differences between the sexes, there is a separate transition matrix and age –based selectivity vector for each sex. Further, because growth is assumed to occur throughout the year, the transition matrix differs among months of the year. The transition matrix used was that in June, the midpoint of the calendar year. The selectivity at age vector is computed from the fishery selectivity at length vector (**fishlssel**) as

$$\mathbf{fishasel}_s = \mathbf{TR}_s * \mathbf{fishlssel}$$

Finally, the selectivity at length vector, assumed identical for each sex, was modeled as

$$fishlssel_l = \frac{1}{1 + e^{-slope(l - fifty)}}$$

where the parameter *slope* affects the steepness of the curve and the parameter *fifty* is the length at which $fishlssel_l$ equals 0.5. There are 24 length bins ranging from 6 to 58 cm, and 19 age groups ranging from 3 to 21+. The age- and length-based selectivity for the survey is modeled in a similar manner.

The mean numbers at age for each year and sex were computed as

$$\bar{N}_{s,t,a} = N_{s,t,a} * (1 - e^{-Z_{s,t,a}}) / Z_{s,t,a}$$

The transition matrix and vector of mean numbers at age were used to compute the vector of mean numbers at length, by sex and year, as

$$\bar{\mathbf{NL}}_{s,t} = \bar{\mathbf{NA}}_{s,t} * \mathbf{TR}_s^T$$

The vector of mean numbers at length was used to compute the catch as

$$C_{l,s,t} = \bar{NL}_{l,s,t} * fishlssel_l * f_t$$

$$pred_cat_t = \sum_{l,s} C_{l,s,t} * FW_{l,s}$$

where $FW_{l,s}$ is the fishery weights by length and sex, and $pred_cat$ is the predicted catch from the model. Similarly, the predicted survey biomass ($pred_biom$) is computed as

$$pred_biom_t = qsurv \sum_{l,s} \left(\bar{NL}_{l,s,t} * survlssel_l * PW_{l,s} \right)$$

where $PW_{l,s}$ is the population weight by length and sex, and $qsurv$ is the trawl survey catchability.

Finally, age composition data are assumed to be unbiased, but with some aging error. As in the stock synthesis model, the distribution of read ages around the “true” age is assumed to be normal with a variance of 0.02 times the true age, resulting in a coefficient of variation of 0.14. The vector of mean number of fish by age available to the survey is multiplied by the aging error matrix in order to produce the observed survey age compositions.

Parameters Estimated Independently

The parameters estimated independently include the age error matrix, the transition matrix, individual weight at length, natural mortality, and survey catchability (q_{srv}). The age error matrix was taken directly from the stock synthesis model used in previous assessments. The transition matrix was also obtained directly from the stock synthesis model, and is based upon a fitted growth curve and assumed variation in growth. The individual weights at age were obtained from trawl survey data, whereas q_{srv} and M were fixed at 1.0 and 0.2, respectfully, consistent with recent assessments.

Parameters Estimated Conditionally

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age compositions of the survey, length composition of the fishery and survey catches, the survey biomass, and the catch biomass. 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 minimize the log-likelihood are selected.

The log-likelihood of the initial recruitments were modeled with a lognormal distribution

$$\lambda_1 \sum_t \frac{\left(v_t + \frac{\sigma^2}{2} \right)^2}{2\sigma^2} + n \ln(\sigma)$$

where σ is a parameter representing the standard deviation of recruitment, respectively, on a log scale. The adjustment of adding $\sigma^2/2$ to the deviation was made in order to correct for bias and produce deviations from the mean, rather than the median, recruitment.

The log-likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) for the fishery length composition data, with the addition of a term that scales the likelihood, is

$$n_{f,s,t,l} \sum_{s,t,l} p_{f,s,t,l} \ln(\hat{p}_{f,s,t,l}) - p_{f,s,t,l} \ln(p_{f,s,t,l})$$

where n is the number of fish aged, and $p_{f,s,t,l}$ and $\hat{p}_{f,s,t,l}$ are the observed and estimated proportion at length in the fishery by sex, year and length. The likelihood for the age and length proportions in the survey, $p_{surv,s,t,a}$ and $p_{surv,s,t,l}$, respectively, follow similar equations.

The log-likelihood of the survey biomass was modeled with a lognormal distribution:

$$\lambda_2 \sum_t (\ln(obs_biom_t) - \ln(pred_biom_t))^2 / 2cv_t^2$$

where obs_biom_t is the observed survey biomass at time t , cv_t is the coefficient of variation of the survey biomass in year t , and λ_2 is a weighting factor.

The log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$\lambda_3 \sum_t (\ln(obs_cat_t) - \ln(pred_cat_t))^2$$

where obs_cat_t and $pred_cat_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision than other variables, λ_3 is given a very high weight so as to fit the catch biomass nearly exactly. This can be accomplished by varying the F levels, and the deviations in F are not included in the overall likelihood function. The overall negative log-likelihood function (excluding the catch component) is

$$\begin{aligned} & \lambda_1 \left(\sum_t \left(\frac{(v_t + \sigma^2 / 2)^2}{2\sigma^2} \right) + n \ln(\sigma) \right) + \\ & \lambda_2 \sum_t (\ln(obs_biom_t) - \ln(pred_biom_t))^2 / 2 * cv_t^2 + \\ & n_{f,s,t,l} \sum_{s,t,l} p_{f,s,t,l} \ln(\hat{p}_{f,s,t,l}) - p_{f,s,t,l} \ln(p_{f,s,t,l}) + \\ & n_{surv,s,t,a} \sum_{s,t,a} p_{surv,s,t,a} \ln(\hat{p}_{surv,s,t,a}) - p_{surv,s,t,a} \ln(p_{surv,s,t,a}) + \\ & n_{surv,s,t,l} \sum_{s,t,l} p_{surv,s,t,l} \ln(\hat{p}_{surv,s,t,l}) - p_{surv,s,t,l} \ln(p_{surv,s,t,l}) + \\ & \lambda_3 \sum_t (\ln(obs_cat_t) - \ln(pred_cat_t))^2 \end{aligned}$$

For the model run in this analysis, λ_1 , λ_2 , and λ_3 were assigned weights of 1,1, and 500, respectively, and n was set to 200. The likelihood function was minimized by varying the following parameters:

| Parameter type | Number |
|--|--------|
| 1) fishing mortality mean (μ_f) | 1 |
| 2) fishing mortality deviations (ϵ_f) | 23 |
| 3) recruitment mean (μ_r) | 1 |
| 4) recruitment standard deviation (σ) | 1 |
| 4) recruitment deviations (v_r) | 23 |
| 5) historic recruitment (R_0) | 1 |
| 6) historic fishing mortality (f_{hist}) | 1 |
| 7) fishery selectivity parameters | 2 |
| 8) survey selectivity parameters | 2 |
| Total parameters | 55 |

Model Results

The model results show that estimated total biomass (ages 3+) increased from a low of 229,565 t in 1977 to a peak of 874,157 t in 1992 (Figure 2, Table 9). Since 1992, estimated total biomass has declined to an estimated value of 618,284 t for 2000. Female spawning biomass shows a similar trend, although the peak value (377,169 t) occurred in 1995. The estimated survey biomass shows an increase from 1982 to the peak level of 559,606 t in 1993, and a subsequent decline to 427,426 t in 2000 (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 and 2000 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) and the survey age composition (Figure 6).

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 2000 (Figure 7), and the fishery shows little selectivity for flathead sole less than 30 cm (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 portion of the data series, averaging 8.4×10^8 for the 1975-1988 year classes, and 4.0×10^8 for the 1989-97 year classes (Figure 9). The scatterplot of stock and recruitment data reveals a decreasing trend in recruitment with an increasing trend in spawner biomass (Figure 10). 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 1977-1997 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 139,276 t. The year 2001 spawning stock biomass is estimated as 267,988 t. Since reliable estimates of the 2001 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B > B_{0.40}$ (267,988 t > 139,276 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

| | | |
|-----------------------|--------|-----------|
| 2001 SSB estimate (B) | = | 267,988 t |
| $B_{0.40}$ | = | 139,276 t |
| $F_{0.40}$ | = | 0.302 |
| F_{ABC} | \leq | 0.302 |
| $F_{0.35}$ | = | 0.378 |
| F_{OFL} | = | 0.378 |

The estimated catch level for year 2001 associated with the overfishing level of $F = 0.378$ is 102,485 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 its upper bound; thus, the year 2001 recommended ABC associated with F_{ABC} of 0.302 is 83,964 t.

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 2000 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2001 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2000. 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 2001, 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 2001 recommended in the assessment to the $max F_{ABC}$ for 2001. (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 1995-1999 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.

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 its MSY level in 2001, then the stock is not overfished.)

Scenario 7: In 2001 and 2002, 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 2003 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 2001 of scenario 6 is 2.18 times its $B_{35\%}$ value of 121,867 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 2003 of scenario 7 is 1.33 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 –2000 in Table 11.

Trophic studies indicate that flathead sole feed mainly on ophiuroids, tanner crab, osmerids, bivalves and polychaetes. Groundfish predators include Pacific cod, Pacific halibut, arrowtooth 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 |
|----------------------------------|-----------|
| M | 0.20 |
| Year 2001 Spawning stock biomass | 267,988 t |
| F_{OFL} | 0.378 |
| Maximum F_{ABC} | 0.302 |
| Recommended F_{ABC} | 0.302 |
| OFL | 102,485 t |
| Recommended ABC | 83,964 t |

References

- Hart, J. L. 1973. Pacific fishes of Canada. Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada KIA OS9.
- Methot, R.D. 1998. Application of stock synthesis to NRC test data sets. *In* V.R. Restrepo (ed.), Analysis of simulated data sets in support of the NRC study on stock assessment methods. NOAA Tech Mem. NMFS-F/SPO-30. U.S. Dep. Commer., NOAA, NMFS, pp. 59-80.
- Methot, R. D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. INPFC Bull. 50:259- 277. Symposium on application of stock assessment techniques to Gadoids.
- Spencer, P.D., Walters, G. E., and T. K. Wilderbuer. 1999. Flathead sole. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1999, p.391-430. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510
- Walters, G. E., and T. K. Wilderbuer. 1997. Flathead sole. *In* Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1998, p.271-295. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Table 1. Harvest (t) of flathead sole from 1977-2000

| <u>Year</u> | <u>Catch Biomass</u> |
|-------------|--------------------------|
| 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 | 17842 |
| 2000 | 18088* |

*NMFS Regional Office Report through September 23, 2000

Table 2. Restrictions on the flathead sole fishery from 1994 to 2000 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, 512, and 516, 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 Tanner 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 |
| 2000 | 3/4 – 3/31 | First Seasonal halibut cap |
| | 4/30 – 7/03 | Second seasonal halibut cap |
| | 8/25 – 12/31 | Annual halibut allowance |

Table 3. Total retained and discarded flathead sole, 1995-2000.

| 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 | 17892 | 13282 | 4610 | 74 |
| 2000* | 18088 | 13403 | 4685 | 74 |

*NMFS regional office report through September 23, 2000

Table 4. Eastern Bering Sea flathead sole male 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 |
| 1977 | 0.00 | 0.00 | 0.00 | 0.04 | 0.12 | 0.31 | 0.86 | 0.84 | 0.80 | 1.64 | 3.08 | 4.04 | 3.63 | 2.04 | 0.71 | 0.13 |
| 1978 | 0.00 | 0.00 | 0.00 | 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 |
| 1979 | 0.00 | 0.00 | 0.00 | 0.02 | 0.13 | 0.22 | 0.32 | 0.62 | 0.70 | 0.44 | 0.45 | 0.66 | 1.18 | 1.67 | 1.15 | 0.51 |
| 1980 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.18 | 0.46 | 0.98 | 1.20 | 0.91 | 1.01 | 1.98 | 2.38 | 1.15 | 0.22 |
| 1981 | 0.00 | 0.00 | 0.00 | 0.02 | 0.08 | 0.35 | 0.43 | 0.11 | 0.18 | 0.35 | 1.03 | 2.29 | 2.59 | 1.81 | 0.83 | 0.19 |
| 1982 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.01 | 0.06 | 0.08 | 0.22 | 0.42 | 1.12 | 1.98 | 1.77 | 1.08 | 0.36 |
| 1983 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.09 | 0.14 | 0.44 | 1.02 | 1.52 | 1.57 | 1.15 |
| 1984 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.03 | 0.07 | 0.28 | 0.33 | 0.28 | 0.48 | 0.74 | 0.82 | 1.41 | 1.43 | 0.74 |
| 1985 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.05 | 0.22 | 0.34 | 0.44 | 0.57 | 0.66 | 0.88 | 1.01 | 1.21 | 1.16 |
| 1986 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.06 | 0.22 | 0.31 | 0.59 | 1.28 | 1.62 | 1.21 | 1.37 | 1.15 | 1.24 | 0.50 |
| 1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.04 | 0.10 | 0.16 | 0.31 | 0.50 | 1.15 | 1.47 | 0.84 |
| 1988 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.13 | 0.19 | 0.29 | 0.63 | 0.97 | 1.51 | 2.45 | 2.74 | 1.77 | 0.63 |
| 1989 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.13 | 0.22 | 0.23 | 0.45 | 0.68 | 0.89 | 1.04 | 1.00 | 0.58 |
| 1990 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.00 | 0.12 | 0.18 | 0.27 | 0.39 | 0.72 | 1.28 | 2.34 | 3.80 | 4.65 |
| 1991 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.06 | 0.12 | 0.23 | 0.39 | 0.97 | 1.39 | 2.06 | 3.18 | 4.14 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.04 | 0.46 | 0.56 | 0.70 | 1.05 | 1.26 | 1.96 | 2.77 | 3.01 | 3.08 |
| 1993 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.01 | 0.08 | 0.18 | 0.53 | 1.12 | 1.29 | 2.21 | 3.40 | 3.46 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.08 | 0.15 | 0.43 | 0.86 | 1.62 | 2.69 | 3.28 | 3.68 | 3.25 |
| 1995 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.08 | 0.14 | 0.28 | 0.68 | 1.32 | 2.27 | 3.31 | 3.55 |
| 1996 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.09 | 0.26 | 0.53 | 1.48 | 2.98 | 4.39 | 4.29 |
| 1997 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.08 | 0.15 | 0.41 | 1.17 | 1.99 | 3.15 | 4.66 | 5.18 | 4.75 |
| 1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.04 | 0.10 | 0.21 | 0.49 | 0.99 | 2.13 | 3.98 | 5.88 | 5.94 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.08 | 0.22 | 0.49 | 1.16 | 2.08 | 3.02 | 4.09 | 3.95 |

Table 5. Eastern Bering Sea flathead sole female 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 |
| 1977 | 0.00 | 0.00 | 0.00 | 0.04 | 0.11 | 0.26 | 0.67 | 0.82 | 0.66 | 0.76 | 1.18 | 1.38 | 1.77 | 1.80 | 1.52 | 1.21 |
| 1978 | 0.00 | 0.00 | 0.00 | 0.01 | 0.03 | 0.09 | 0.22 | 0.45 | 0.53 | 0.57 | 0.53 | 0.60 | 0.88 | 1.26 | 1.43 | 1.19 |
| 1979 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.08 | 0.18 | 0.36 | 0.43 | 0.32 | 0.28 | 0.30 | 0.30 | 0.31 | 0.46 | 0.60 |
| 1980 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.06 | 0.22 | 0.48 | 0.85 | 1.23 | 0.98 | 0.91 | 0.80 | 0.67 | 0.60 | 0.66 |
| 1981 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.12 | 0.21 | 0.09 | 0.05 | 0.09 | 0.29 | 0.67 | 0.99 | 1.12 | 0.86 | 0.61 |
| 1982 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.04 | 0.13 | 0.35 | 0.71 | 1.15 | 1.02 | 0.72 | 0.37 |
| 1983 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 | 0.00 | 0.02 | 0.05 | 0.12 | 0.23 | 0.34 |
| 1984 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.03 | 0.06 | 0.16 | 0.17 | 0.12 | 0.16 | 0.25 | 0.28 | 0.36 | 0.68 | 0.89 |
| 1985 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.03 | 0.03 | 0.09 | 0.16 | 0.16 | 0.19 | 0.22 | 0.26 | 0.38 | 0.51 | 0.72 |
| 1986 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.11 | 0.39 | 0.35 | 0.50 | 0.35 | 0.45 | 0.65 | 0.69 | 0.60 | 0.63 | 0.80 |
| 1987 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 | 0.04 | 0.09 | 0.15 | 0.22 | 0.35 | 0.83 | 0.87 |
| 1988 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.07 | 0.09 | 0.13 | 0.26 | 0.27 | 0.52 | 0.86 | 1.18 | 1.27 | 1.12 |
| 1989 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.10 | 0.10 | 0.11 | 0.21 | 0.29 | 0.40 | 0.46 | 0.55 |
| 1990 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.04 | 0.06 | 0.08 | 0.19 | 0.23 | 0.47 | 0.65 | 1.28 | 1.93 |
| 1991 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.03 | 0.08 | 0.18 | 0.36 | 0.52 | 0.79 | 1.07 | 1.31 |
| 1992 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.06 | 0.06 | 0.21 | 0.27 | 0.89 | 1.31 | 1.63 |
| 1993 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.10 | 0.14 | 0.22 | 0.46 | 0.68 | 0.87 | 1.21 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.04 | 0.08 | 0.14 | 0.32 | 0.53 | 0.73 | 1.53 |
| 1995 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.04 | 0.04 | 0.07 | 0.16 | 0.25 | 0.48 | 0.66 | 1.00 |
| 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 | 0.18 | 0.43 | 0.93 | 1.37 |
| 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 | 1.18 | 1.72 |
| 1998 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.05 | 0.09 | 0.21 | 0.43 | 0.77 | 1.23 | 1.82 |
| 1999 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.03 | 0.10 | 0.19 | 0.45 | 0.73 | 1.12 | 1.41 |

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 | 191,988 |
| 1983 | EBS | 269,419 |
| | Aleut. | 1,500 |
| 1984 | EBS | 341,697 |
| 1985 | EBS | 276,350 |
| 1986 | EBS | 357,951 |
| | Aleut. | 9,000 |
| 1987 | EBS | 394,758 |
| 1988 | EBS | 572,805 |
| 1989 | EBS | 536,433 |
| 1990 | EBS | 628,235 |
| 1991 | EBS | 544,893 |
| | Aleut. | 6,885 |
| 1992 | EBS | 651,384 |
| 1993 | EBS | 610,259 |
| 1994 | EBS | 726,212 |
| | Aleut. | 9,917 |
| 1995 | EBS | 593,412 |
| 1996 | EBS | 616,373 |
| 1997 | EBS | 807,825 |
| | Aleut. | 11,540 |
| 1998 | EBS | 692,234 |
| 1999 | EBS | 394,822 |
| 2000 | EBS | 399,298 |
| 2000 | Aleut | 8,970 |

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 |
| 1982 | 0.27 | 0.30 | 1.42 | 19.37 | 30.56 | 27.81 | 33.61 | 46.44 | 54.95 | 63.58 | 84.48 | 90.19 | 72.52 | 31.55 | 10.41 | 3.08 |
| 1983 | 0.47 | 1.36 | 16.88 | 47.98 | 28.14 | 49.06 | 65.83 | 56.16 | 49.88 | 57.29 | 71.20 | 85.44 | 82.41 | 58.81 | 23.63 | 6.70 |
| 1984 | 0.72 | 1.50 | 10.41 | 31.20 | 57.55 | 94.49 | 72.63 | 68.82 | 79.83 | 79.91 | 87.22 | 96.03 | 92.24 | 70.87 | 34.05 | 7.58 |
| 1985 | 0.03 | 2.70 | 4.28 | 8.83 | 23.65 | 39.88 | 61.01 | 86.03 | 75.21 | 57.16 | 70.29 | 74.92 | 80.93 | 60.96 | 38.86 | 14.30 |
| 1986 | 0.47 | 0.83 | 7.25 | 23.71 | 17.42 | 22.83 | 38.52 | 65.07 | 74.08 | 82.94 | 84.31 | 69.95 | 87.56 | 88.82 | 49.43 | 20.70 |
| 1987 | 0.06 | 0.21 | 7.51 | 24.00 | 27.07 | 44.09 | 43.98 | 53.56 | 63.01 | 79.70 | 78.04 | 90.86 | 99.30 | 97.64 | 55.07 | 28.65 |
| 1988 | 0.54 | 1.63 | 5.23 | 30.89 | 77.10 | 101.89 | 73.97 | 76.37 | 64.69 | 70.87 | 75.18 | 86.13 | 115.63 | 137.93 | 120.56 | 51.74 |
| 1989 | 0.00 | 1.54 | 17.37 | 70.04 | 40.33 | 43.44 | 127.71 | 102.70 | 102.99 | 72.95 | 74.82 | 76.26 | 76.47 | 128.41 | 127.72 | 58.91 |
| 1990 | 0.00 | 1.30 | 4.75 | 17.32 | 74.03 | 78.17 | 64.41 | 94.99 | 114.40 | 99.89 | 96.77 | 97.86 | 109.67 | 136.15 | 132.40 | 69.94 |
| 1991 | 0.10 | 0.70 | 12.03 | 8.80 | 10.32 | 47.57 | 91.91 | 125.85 | 119.07 | 112.65 | 111.83 | 92.10 | 101.78 | 95.91 | 107.64 | 72.53 |
| 1992 | 0.00 | 0.02 | 3.46 | 44.85 | 74.84 | 45.93 | 49.48 | 91.69 | 128.81 | 160.50 | 144.34 | 119.00 | 124.41 | 135.70 | 138.54 | 88.97 |
| 1993 | 0.00 | 0.91 | 6.95 | 13.50 | 19.31 | 58.28 | 64.41 | 61.04 | 72.45 | 109.60 | 139.13 | 138.74 | 121.89 | 128.75 | 117.83 | 68.84 |
| 1994 | 0.00 | 0.89 | 4.97 | 20.10 | 43.45 | 65.78 | 87.74 | 75.73 | 68.50 | 92.89 | 126.88 | 142.66 | 157.12 | 153.69 | 144.32 | 95.41 |
| 1995 | 0.00 | 0.12 | 1.97 | 7.68 | 19.00 | 34.32 | 43.99 | 60.15 | 70.08 | 65.63 | 106.64 | 133.01 | 152.53 | 138.54 | 119.62 | 72.88 |
| 1996 | 0.07 | 0.63 | 3.15 | 19.70 | 38.02 | 35.65 | 55.73 | 69.11 | 74.66 | 77.90 | 89.21 | 116.17 | 139.29 | 145.85 | 135.79 | 85.00 |
| 1997 | 0.06 | 0.48 | 3.01 | 10.40 | 12.46 | 24.23 | 30.26 | 40.34 | 53.39 | 66.34 | 73.81 | 91.47 | 143.20 | 152.03 | 145.64 | 102.15 |
| 1998 | 0.06 | 1.26 | 17.18 | 34.49 | 18.23 | 26.35 | 29.32 | 37.45 | 46.66 | 69.57 | 77.23 | 94.44 | 135.44 | 161.08 | 157.74 | 106.86 |
| 1999 | 0.00 | 0.46 | 2.61 | 7.34 | 20.22 | 16.06 | 17.74 | 29.29 | 31.18 | 48.08 | 59.45 | 65.48 | 79.45 | 98.03 | 82.37 | 45.35 |
| 2000 | 0.06 | 0.36 | 5.35 | 7.63 | 11.38 | 24.17 | 22.09 | 25.56 | 28.20 | 43.09 | 63.81 | 64.82 | 87.61 | 87.90 | 73.77 | 49.16 |

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 |
| 1982 | 0.00 | 0.00 | 1.23 | 16.77 | 24.10 | 19.75 | 29.37 | 46.82 | 48.32 | 48.18 | 53.37 | 66.87 | 70.42 | 55.20 | 32.85 | 13.48 |
| 1983 | 0.00 | 0.48 | 11.91 | 36.92 | 24.91 | 43.47 | 55.95 | 53.01 | 45.10 | 50.33 | 55.24 | 61.04 | 76.61 | 78.66 | 70.04 | 32.20 |
| 1984 | 0.00 | 0.61 | 6.07 | 33.44 | 58.49 | 80.38 | 62.89 | 56.56 | 71.80 | 71.37 | 72.40 | 83.43 | 83.20 | 84.64 | 84.32 | 56.00 |
| 1985 | 0.00 | 1.18 | 1.24 | 7.94 | 21.60 | 33.11 | 52.72 | 78.33 | 67.73 | 50.09 | 49.00 | 53.25 | 54.64 | 56.40 | 52.35 | 34.41 |
| 1986 | 0.00 | 0.47 | 3.44 | 12.09 | 13.38 | 17.44 | 30.88 | 46.88 | 64.65 | 75.02 | 66.41 | 60.58 | 68.37 | 70.62 | 74.52 | 55.19 |
| 1987 | 0.00 | 0.00 | 4.26 | 18.41 | 26.98 | 39.89 | 40.57 | 48.68 | 45.24 | 56.28 | 66.52 | 70.32 | 71.67 | 70.27 | 78.82 | 60.34 |
| 1988 | 0.00 | 0.00 | 2.50 | 19.33 | 72.66 | 98.75 | 92.24 | 114.64 | 80.63 | 74.65 | 78.18 | 78.82 | 79.20 | 101.09 | 104.48 | 97.85 |
| 1989 | 0.00 | 0.14 | 15.55 | 43.40 | 28.12 | 39.99 | 104.40 | 103.79 | 109.92 | 77.05 | 62.33 | 67.97 | 78.15 | 68.05 | 85.35 | 91.01 |
| 1990 | 0.00 | 0.20 | 1.95 | 13.16 | 59.00 | 70.08 | 48.57 | 67.86 | 91.46 | 93.57 | 82.06 | 74.66 | 66.36 | 77.56 | 72.18 | 83.78 |
| 1991 | 0.00 | 0.84 | 5.00 | 4.75 | 6.97 | 31.83 | 69.33 | 95.63 | 94.66 | 104.16 | 99.36 | 89.17 | 68.35 | 77.35 | 86.47 | 76.83 |
| 1992 | 0.00 | 0.00 | 3.99 | 30.73 | 54.87 | 42.64 | 48.51 | 75.78 | 102.93 | 123.14 | 115.07 | 114.32 | 83.74 | 79.04 | 84.58 | 85.11 |
| 1993 | 0.04 | 0.53 | 4.80 | 9.93 | 19.37 | 50.29 | 59.06 | 46.11 | 70.87 | 95.05 | 97.50 | 109.18 | 106.75 | 85.77 | 73.98 | 67.04 |
| 1994 | 0.00 | 0.41 | 2.31 | 13.29 | 31.96 | 47.10 | 66.62 | 56.17 | 47.42 | 74.66 | 97.27 | 118.08 | 125.57 | 112.85 | 96.71 | 77.87 |
| 1995 | 0.00 | 0.00 | 1.18 | 5.24 | 15.94 | 30.57 | 38.90 | 54.44 | 50.61 | 49.62 | 62.06 | 80.36 | 97.65 | 92.04 | 80.90 | 67.28 |
| 1996 | 0.00 | 0.18 | 3.04 | 18.72 | 28.21 | 43.06 | 47.93 | 61.57 | 61.11 | 66.25 | 65.12 | 64.30 | 75.83 | 88.04 | 93.11 | 81.05 |
| 1997 | 0.00 | 0.49 | 1.61 | 6.57 | 14.30 | 21.96 | 29.35 | 36.26 | 41.09 | 47.46 | 59.36 | 63.51 | 80.61 | 94.61 | 112.36 | 109.09 |
| 1998 | 0.00 | 0.58 | 12.84 | 23.99 | 11.43 | 20.98 | 28.26 | 41.44 | 45.34 | 47.69 | 66.99 | 72.37 | 61.31 | 76.22 | 94.19 | 89.04 |
| 1999 | 0.00 | 0.14 | 2.12 | 5.82 | 14.45 | 15.77 | 14.68 | 19.89 | 28.42 | 34.79 | 40.97 | 40.77 | 43.54 | 49.23 | 64.20 | 59.79 |
| 2000 | 0.25 | 0.40 | 1.71 | 4.95 | 9.06 | 17.91 | 18.47 | 21.53 | 20.59 | 29.62 | 38.01 | 40.90 | 53.51 | 58.93 | 64.24 | 69.28 |

Table 9. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 1999 SAFE estimates

| Year | Female Spawner Biomass (t) | | Total Biomass (t) | | Recruitment (thousands) | |
|------|----------------------------|--------|-------------------|--------|-------------------------|---------|
| | <u>Assessment</u> | | <u>Assessment</u> | | <u>Assessment</u> | |
| | 2000 | 1999 | 2000 | 1999 | 2000 | 1999 |
| 1977 | 65538.3 | 47244 | 229565 | 172842 | | |
| 1978 | 61397.7 | 43563 | 251985 | 197891 | 170181 | 147950 |
| 1979 | 58437.9 | 41110 | 292328 | 231379 | 559669 | 474515 |
| 1980 | 59256.6 | 41523 | 350480 | 276638 | 944349 | 819210 |
| 1981 | 70090.4 | 49862 | 405273 | 322316 | 865743 | 738959 |
| 1982 | 96589.4 | 71803 | 455299 | 372011 | 980363 | 864262 |
| 1983 | 131817 | 98942 | 530695 | 433637 | 1394580 | 1252783 |
| 1984 | 161617 | 123024 | 600345 | 498628 | 1222600 | 1194949 |
| 1985 | 187860 | 145276 | 652434 | 550999 | 614671 | 559821 |
| 1986 | 214892 | 167303 | 702050 | 597844 | 691817 | 680215 |
| 1987 | 241851 | 192011 | 750382 | 647057 | 1069740 | 1029087 |
| 1988 | 274243 | 220925 | 798440 | 698803 | 1162070 | 1158537 |
| 1989 | 304792 | 249369 | 833911 | 739555 | 874994 | 856121 |
| 1990 | 330815 | 272811 | 873396 | 781930 | 997652 | 990442 |
| 1991 | 339340 | 282931 | 871356 | 787891 | 271401 | 269926 |
| 1992 | 348188 | 294334 | 874157 | 795199 | 681006 | 637614 |
| 1993 | 359137 | 307558 | 864999 | 791613 | 482185 | 430373 |
| 1994 | 369214 | 319928 | 850651 | 782612 | 537987 | 519882 |
| 1995 | 377169 | 329354 | 826528 | 761835 | 309134 | 262658 |
| 1996 | 373469 | 328618 | 797011 | 733991 | 419204 | 378272 |
| 1997 | 362585 | 320588 | 754366 | 696485 | 201993 | 190990 |
| 1998 | 346657 | 306801 | 710281 | 656047 | 329751 | 333926 |
| 1999 | 325786 | 288826 | 660285 | 611432 | 291376 | 346270 |
| 2000 | 307305 | | 618284 | | 332540 | |

Table 10. Projections of spawning biomass, catch, fishing mortality rate, and catch for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 139,276 t and 121,867 t, respectively.

| Sp. | <i>Scenario 1</i> | <i>Scenario 2</i> | <i>Scenario 3</i> | <i>Scenario 4</i> | <i>Scenario 5</i> | <i>Scenario 6</i> | <i>Scenario 7</i> |
|----------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Biomass | | | | | | | |
| 2000 | 295159 | 295159 | 295159 | 295159 | 295159 | 295159 | 295159 |
| 2001 | 267988 | 267988 | 273100 | 276463 | 278317 | 265470 | 267988 |
| 2002 | 209025 | 209025 | 236672 | 256740 | 268481 | 196574 | 209025 |
| 2003 | 163933 | 163933 | 204129 | 236214 | 256118 | 147341 | 162418 |
| 2004 | 131944 | 131944 | 177736 | 218016 | 244479 | 115120 | 124780 |
| 2005 | 113119 | 113119 | 159036 | 204689 | 236399 | 99583.7 | 104664 |
| 2006 | 106514 | 106514 | 148578 | 197419 | 233197 | 95310.7 | 98126.8 |
| 2007 | 108195 | 108195 | 145859 | 196145 | 234848 | 98605.1 | 100121 |
| 2008 | 114181 | 114181 | 148902 | 199888 | 240990 | 105478 | 106225 |
| 2009 | 120899 | 120899 | 153986 | 204870 | 247428 | 112515 | 112805 |
| 2010 | 127378 | 127378 | 160726 | 212329 | 256687 | 118682 | 118745 |
| 2011 | 132261 | 132261 | 166905 | 219392 | 265319 | 122918 | 122882 |
| 2012 | 135837 | 135837 | 172563 | 226439 | 274101 | 125686 | 125622 |
| 2013 | 138292 | 138292 | 177307 | 232653 | 281886 | 127358 | 127296 |
| F | <i>Scenario 1</i> | <i>Scenario 2</i> | <i>Scenario 3</i> | <i>Scenario 4</i> | <i>Scenario 5</i> | <i>Scenario 6</i> | <i>Scenario 7</i> |
| 2000 | 0.0567135 | 0.0567135 | 0.0567131 | 0.0567173 | 0.0567131 | 0.0567133 | 0.0567158 |
| 2001 | 0.302241 | 0.302241 | 0.15112 | 0.05333 | 0 | 0.37785 | 0.302241 |
| 2002 | 0.302241 | 0.302241 | 0.15112 | 0.05333 | 0 | 0.37785 | 0.302241 |
| 2003 | 0.302241 | 0.302241 | 0.15112 | 0.05333 | 0 | 0.37785 | 0.37785 |
| 2004 | 0.285491 | 0.285491 | 0.15112 | 0.05333 | 0 | 0.308868 | 0.336455 |
| 2005 | 0.242488 | 0.242488 | 0.15112 | 0.05333 | 0 | 0.264498 | 0.279006 |
| 2006 | 0.227401 | 0.227401 | 0.15101 | 0.05333 | 0 | 0.252295 | 0.260337 |
| 2007 | 0.230965 | 0.230965 | 0.148293 | 0.05333 | 0 | 0.261644 | 0.265953 |
| 2008 | 0.243173 | 0.243173 | 0.147533 | 0.05333 | 0 | 0.280443 | 0.282535 |
| 2009 | 0.255742 | 0.255742 | 0.147843 | 0.05333 | 0 | 0.298793 | 0.299591 |
| 2010 | 0.26645 | 0.26645 | 0.148689 | 0.05333 | 0 | 0.314095 | 0.314279 |
| 2011 | 0.273623 | 0.273623 | 0.149278 | 0.05333 | 0 | 0.323761 | 0.323694 |
| 2012 | 0.278214 | 0.278214 | 0.149838 | 0.05333 | 0 | 0.329797 | 0.329663 |
| 2013 | 0.281103 | 0.281103 | 0.150259 | 0.05333 | 0 | 0.333289 | 0.333162 |
| Catch | <i>Scenario 1</i> | <i>Scenario 2</i> | <i>Scenario 3</i> | <i>Scenario 4</i> | <i>Scenario 5</i> | <i>Scenario 6</i> | <i>Scenario 7</i> |
| 2000 | 18088.5 | 18088.5 | 18088.3 | 18089.7 | 18088.3 | 18088.4 | 18089.2 |
| 2001 | 83964.2 | 83964.2 | 44082.6 | 16066.9 | 0 | 102485 | 83964.1 |
| 2002 | 67053.9 | 67053.9 | 38783.5 | 15072 | 0 | 78056.8 | 67053.8 |
| 2003 | 53759.1 | 53759.1 | 33922.3 | 13996.1 | 0 | 60067 | 65662.7 |
| 2004 | 41827.8 | 41827.8 | 29930.4 | 13034.4 | 0 | 39749.2 | 46406.3 |
| 2005 | 30837.6 | 30837.6 | 26862 | 12246 | 0 | 29733.1 | 32814.7 |
| 2006 | 26756.6 | 26756.6 | 24743.1 | 11676.8 | 0 | 26533.4 | 28176.5 |
| 2007 | 26465.5 | 26465.5 | 23133.6 | 11314.9 | 0 | 27149.9 | 28067.7 |
| 2008 | 28221.6 | 28221.6 | 22721.7 | 11216.9 | 0 | 29806.3 | 30302.9 |
| 2009 | 30595.4 | 30595.4 | 22978.4 | 11259.4 | 0 | 32980.8 | 33212 |
| 2010 | 33138.5 | 33138.5 | 23779.2 | 11514.8 | 0 | 36134.3 | 36220.6 |
| 2011 | 35259.4 | 35259.4 | 24686.5 | 11838.2 | 0 | 38550 | 38563 |
| 2012 | 36919.3 | 36919.3 | 25628.9 | 12207.6 | 0 | 40313.1 | 40296.4 |
| 2013 | 38151 | 38151 | 26487.7 | 12567.7 | 0 | 41505.5 | 41481.1 |

Table 11. Research catches (t) of flathead sole in the BSAI area from 1979 to 2000.

| <u>Year</u> | <u>Research Catch (t)</u> |
|-------------|---------------------------|
| 1979 | 11.85 |
| 1980 | 6.19 |
| 1981 | 11.23 |
| 1982 | 20.36 |
| 1983 | 13.86 |
| 1984 | 13.51 |
| 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 | 30.31 |
| 1998 | 23.02 |
| 1999 | 16.82 |
| <u>2000</u> | <u>13.82</u> |

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 the largest species group of the catch, and with flathead sole being the most abundant.

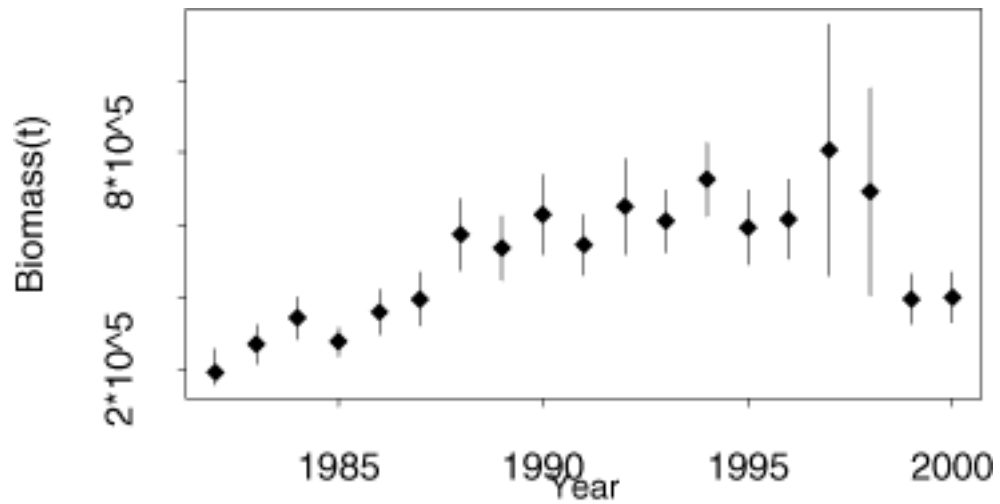


Figure 1. Estimated survey biomass and 95% CIs

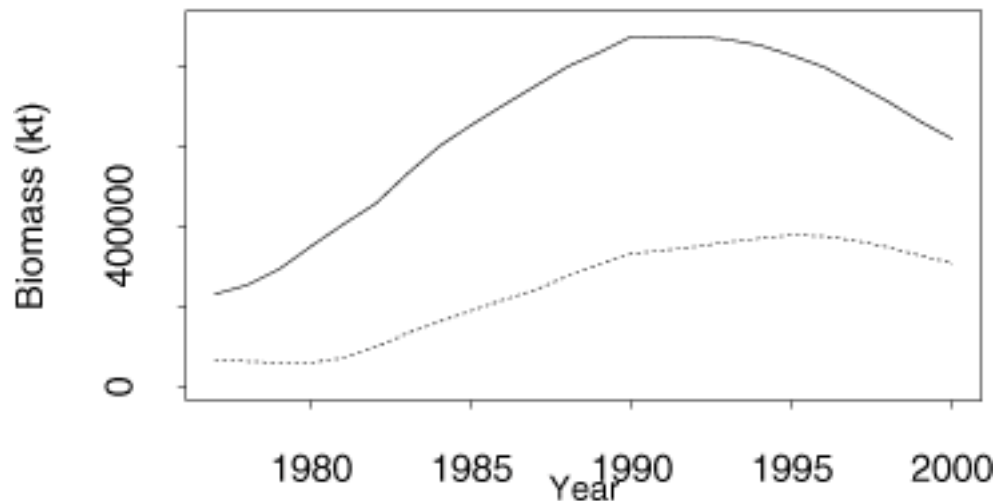


Figure 2. Estimated total (solid line) and spawner (dashed line) biomass