Section 5

ARROWTOOTH FLOUNDER

by
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EXECUTIVE SUMMARY

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

<u>Changes to the input data</u>

1) 2000 survey size composition
2) 2000 survey biomass point-estimate and standard error.
3) Estimate of catch and discards through 16, September 2000.
4) Estimate of retained and discarded portion of the 1999 catch.

<u>Assessment results</u>

1) The projected age 1+ total biomass for 2001 is 700,850 t.
2) The projected female spawning biomass for 2001 is 457,600 t.
3) The recommended 2001 ABC is 130,000 t based on an $F_{0.40}$ (0.236) harvest level.
4) The 2001 overfishing level is 157,000 t based on a $F_{0.35}$ (0.285) harvest level.

	1999 Assessment recommendation for 2000 harvest	2000 Assessment recommendation for 2001 harvest
Total biomass	784,630 t	700,850 t
ABC	130,500 t	130,000 t
Overfishing	160,200 t	157,000 t
F_{ABC}	$F_{0.40} = 0.22$	$F_{0.40} = 0.236$
$F_{overfishing}$	$F_{0.35} = 0.27$	$F_{0.30} = 0.285$

INTRODUCTION

The arrowtooth flounder (<u>Atheresthes stomias</u>) is a relatively large flatfish which occupies continental shelf waters almost exclusively until age 4, but at older ages occupies both shelf and slope waters. Two species of <u>Atheresthes</u> occur in the Bering Sea. Arrowtooth flounder and Kamchatka flounder (<u>A</u>. <u>evermanni</u>) are very similar in appearance and are not usually distinguished in the commercial catches. In past years, these species were not consistently separated in trawl survey catches and are combined in this assessment to maintain the comparability of the trawl survey time series. Arrowtooth flounder ranges into the Aleutian Islands region where their abundance is lower than in the eastern Bering Sea. The resource in the EBS and the Aleutians are managed as a single stock although the stock structure has not been studied.

Arrowtooth flounder was managed with Greenland turbot as a species complex until 1985 because of similarities in their life history characteristics, distribution and exploitation. Greenland turbot were the target species of the fisheries whereas arrowtooth flounder were caught as bycatch. Because the stock condition of the two species have differed markedly in recent years, management since 1986 has been by individual species.

Arrowtooth flounder begin to recruit to the continental slope at about age 4. Based on age data from the 1982 U.S.-Japan cooperative survey, recruitment to the slope gradually increases at older ages and reaches a maximum at age 9. However, greater than 50% of age groups 9 and older continue to occupy continental shelf waters. The low proportion of the overall biomass on the slope during the 1988 and 1991 surveys, relative to that of earlier surveys, indicates that the proportion of the population occupying slope waters may vary considerably from year to year depending on the age structure of the population.

CATCH HISTORY

Catch records of arrowtooth flounder and Greenland turbot were combined during the 1960s. The fisheries for Greenland turbot intensified during the 1970s and the bycatch of arrowtooth flounder is assumed to have also increased. In 1974-76, total catches of arrowtooth flounder reached peak levels ranging from 19,000 to 25,000 t (Table 5.1). Catches decreased after implementation of the MFCMA and the resource has remained lightly exploited with catches averaging 12,200 t from 1977-99. This decline resulted from catch restrictions placed on the fishery for Greenland turbot and phasing out of the foreign fishery in the U.S. EEZ. Total catch reported through 16 September, 2000 is 10,059 t (well below the ABC of 131,000 t). NMFS Regional Office reports indicate that bottom trawling accounted for 88% of the 2000 catch.

Although research has been conducted on their commercial utilization (Greene and Babbitt 1990, Wasson et al. 1992, Porter et al. 1993, Reppond et al. 1993, Cullenberg 1995) and some targetting occurs, arrowtooth flounder currently have a low perceived commercial value as they are captured primarily in pursuit of other high value species and most are discarded.. The catch information in Table 5.1 reports the annual total catch tonnage for the foreign, JV, and DAP fisheries. The proportion of retained and discarded arrowtooth flounder in Bering Sea fisheries can be estimated from observer sampling applied to the 'blend' estimate of reported and observed retained catch as follows:

Year*	Retained	Discarded	Total	% Retained
1985	17 t	72 t	89 t	19
1986	65 t	277 t	342 t	19
1987	75 t	320 t	395 t	19
1988	3,309 t	14,107 t	17,416 t	19
1989	958 t	4,084 t	5,042 t	19
1990	2,356 t	10,042 t	12,398 t	19
1991	3,211 t	18,841 t	22,052 t	15
1992	675 t	9,707 t	10,382 t	7
1993	403 t	6,775 t	7,178 t	6
1994	626 t	13,641 t	14,267 t	4
1995	509 t	8,772 t	9,281 t	5
1996	1,372 t	13,280 t	14,652 t	9
1997	1,029 t	9,024 t	10,054 t	10
1998	2,896 t	12,345 t	15,241 t	19
1999	2,538 t	8,035 t	10,573 t	24

*1990 % retained rate applied to the 1985-89 reported retained DAP catch.

Substantial amounts of arrowtooth flounder are discarded overboard in the various trawl and longline target fisheries. Largest discard amounts occurred in the Pacific cod, rock sole, 'other flatfish' and Greenland turbot fisheries.

DATA

The data used in this assessment include estimates of total catch, trawl survey biomass estimates and standard error from shelf and slope surveys, sex-specific trawl survey size composition and available fishery length-frequencies from observer sampling .

Fishery Catch and Catch-at-Age

Fishery catch data are available from 1970 - September 16, 2000 and fishery length-frequency data from 1978-91.

Survey CPUE

The relative abundance of arrowtooth flounder increased substantially on the continental shelf from 1982 to 1990 as the CPUE from AFSC surveys on the shelf increased steadily from 1.6 to 9.9 kg/ha (Fig. 5.1). The overall shelf catch rate decreased slightly to 7.1 kg/ha during 1991 but increased to 9.5 kg/ha during the 1992 bottom trawl survey. The CPUE continued to increase through 1996 to 12.0 kg/ha. These increases in CPUE were also observed on the slope from 1981 to 1986 as CPUE from the Japanese land-based fishery increased from 1.5 to 21.0 t/hr (Bakkala and Wilderbuer 1990).

The CPUE declined in 1997 to 10.3 kg/ha and has continued to decline to 7.4 kg/ha in the 2000 survey .

Absolute Abundance from Trawl Surveys

Biomass estimates (t) for arrowtooth flounder from U.S. and U.S.-Japanese cooperative surveys in the eastern Bering Sea and Aleutian Islands region are as follows:

	Eastern Bering Sea			Aleutian Islands
Year	Shelf	Slope	Shelf and Slope combined	
1975	28,000	--	--	--
1979	35,000	36,700	71,700	--
1980	47,800	--	--	40,400
1981	49,500	34,900	84,400	--
1982	67,400	24,700	92,100	--
1983	149,300	--	--	45,100
1984	182,900	--	--	--
1985	159,900	74,400	234,300	--
1986	232,100	--	--	125,700
1987	290,600	--	--	--
1988	306,500	30,600*	337,100	--
1989	410,700	--	--	--
1990	459,200	--	--	--
1991	329,200	28,000*	357,200	37,294
1992	414,000	--	--	--
1993	543,600	--	--	--
1994	570,600	--	--	107,019
1995	480,800	--	--	--
1996	556,400	--	--	--
1997	478,600	--	--	111,557
1998	344,900	--	--	--
1999	243,800			--
2000	340,400	--	--	93,515

*The 1988 and 1991 slope estimates were from the depth ranges of 200-800 m while earlier slope estimates were from 200-1,000 m.

Although the standard sampling trawl changed in 1982 to a more efficient trawl which may have caused an overestimate of the biomass increase in the pre-1982 part of the time-series, biomass estimates from AFSC surveys on the continental shelf have shown a consistent increasing trend since 1975. Since 1982, biomass point -estimates indicate that arrowtooth abundance has increased eight-fold to a high of 570,600 t in 1994. The population biomass remained at a high level from 1992-97. Results of the 1998 and 2000 bottom trawl surveys indicate the Bering Sea shelf population biomass has since declined to 340,000 t, 60% of the peak 1994 biomass point estimate.

Arrowtooth flounder absolute abundance estimates are based on "area-swept" bottom trawl survey methods. These methods require several assumptions which can add to the uncertainty of the estimates. For example, it is assumed that the sampling plan covers the distribution of the species and that all fish in the path of the trawl are captured (no losses due to escape or gains due to herding). Due to sampling variability alone, the 95% confidence intervals for the 2000 point estimate are 231,500 - 449,200 t.

Trawl surveys on the continental slope estimate that arrowtooth flounder biomass increased significantly from 1982 to 1985. The biomass estimate in 1988 and 1991 were lower. However, sampling in 1988 and 1991 (200-800 m) was not as deep as in 1985 and earlier years (200-1,000 m). Based on slope surveys conducted between 1979 and 1985, 67 to 100% of the arrowtooth flounder biomass on the slope were found at depths less than 800 m. These data suggest that less than 20% of the total EBS population occupied slope waters in 1988 and 1991, a period of high arrowtooth flounder abundance. Surveys conducted during periods of low and increasing arrowtooth abundance (1979-85) indicate that 27% to 51% of the population weight occupied slope waters.

The combined arrowtooth/Kamchatka flounder abundance estimated from the 2000 Aleutian Islands trawl survey is 93,500 t, a continuation of the stable trend observed in the Aleutian Islands since 1994.

Weight-at-age, Length-at-age and Maturity-at-age

Parameters of the von Bertalanffy growth curve for arrowtooth flounder from age data collected during the 1982 U.S.-Japan cooperative survey and the 1991 slope survey (Zimmermann and Goddard 1995) are as follows:

Sex	Sample size	Age range	L_{inf}	k	t_o
1982 age sample					
Male	528	2-14	45.9	0.23	-0.70
Female	706	2-14	73.8	0.14	-0.20
Sexes Combined	1,234	2-14	59.0	0.17	-0.50
1991 age sample					
Male	53	3-9	57.9	0.17	-2.17
Female	134	4-12	85.0	0.16	-0.81

Based on 282 observations during a AFSC survey in 1976, the length (mm)-weight (gm) relationship for arrowtooth flounder (sexes combined) is described by the equation:

$$W = 5.682 \times 10^{-6} * L ** 3.1028.$$

Maturity information from a histological examination of arrowtooth flounder in the Gulf of Alaska (Zimmerman 1997) indicate that male and female fish become 50% mature at 46.9 and 42.2 cm, respectively.

ANALYTIC APPROACH

Model Structure

The abundance, mortality, recruitment and selectivity of arrowtooth flounder were assessed with a split-sex, length-based version of the stock synthesis assessment model (Methot 1990). The model is a separable catch-age analysis that uses survey estimates of biomass and size composition estimates as auxiliary information. The model simulates the dynamics of the population and compares the expected values of the population characteristics to the those observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulation values to the observed characteristics is optimized by maximizing the log(likelihood) function.

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

Data Component	Distribution assumption
Trawl fishery size composition	Multinomial
Trawl survey population size composition	Multinomial
Trawl survey biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (see Table 6-6). The model allows for the individual likelihood components to be weighted by an emphasis factor. The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Year class strength	Total
31	12	53	96

Natural mortality and survey catchability were estimated independently of the model. The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery catch data and the entry of another year class into the observed population.

We assume that the shelf and slope surveys measure non-overlapping segments of the arrowtooth flounder stock. The model was configured with the Bering Sea shelf comprising 87% of the population, calculated from the average proportion of shelf/shelf+slope biomass from the trawl survey time-series. In this assessment we did not attempt to incorporate the Aleutian Islands biomass estimate. For Bering Sea shelf flatfish, the accepted belief is that the trawl survey is a good indicator of the flatfish abundance level. Thus, it is desirable to obtain a reasonable fit to this data component and the model was configured with an emphasis of 5.0 was placed on fitting the shelf survey biomass trend. This resulted in a better fit to the abundance trend without degrading the fit to the other primary data components.

The most reliable and consistent data for modeling the arrowtooth flounder population are the shelf survey biomass and size composition time-series. Consequently, results are most closely linked to fitting the general trend of increasing shelf survey biomass estimates during the 1980s to its peak level in the mid-1990s, and to fitting the male and female size compositions from the shelf survey (Fig. 5.2).

Parameters Estimated Independently

Natural mortality

The natural mortality of arrowtooth flounder is assumed to be 0.20. This estimate was used because it is similar to that of other species of flatfish with approximately the same age range as arrowtooth flounder and is the same estimate used by Okada et al. (1980).

Aging by both U.S. and Japanese scientists from samples collected in the EBS during U.S.-Japanese cooperative surveys has shown age 15 to be the maximum age of arrowtooth flounder.

Catchability

A past assessment (Wilderbuer and Sample 1995) also analyzed the value of Q or catchability of the research trawl by examining fits of the models' various likelihood components over a range of fixed Q values. The results indicated that Q = 2.0 which suggests that more fish are caught in the survey trawl than are present in the "effective" fishing width of the trawl (ie. some herding may occur or the "effective" fishing width of the trawl may be the distance between the doors instead of between the wingtips of the survey trawl).

In the case of the fit to the slope survey abundance estimates, Q is less than 1.0 as the fit to this likelihood component degrades with increasing Q. This is consistent with the Q profiling presented in the Greenland turbot assessment (Ianelli et al., section 4) and our belief that the Noreastern trawl is a poor sampling tool on the Bering Sea slope (Bakkala and Wilderbuer 1990).

Parameters Estimated Conditionally

Year class strengths

The population simulation specifies the number-at-age in the beginning year of the simulation, the number of recruits in subsequent years, and the survival rate for each cohort as it moves through the population calculated from the population dynamics equations (see Table 6-6).

Selectivity and sex ratio

Survey results indicate that fish less than about 4 years old (< 30 cm) are found only on the Bering Sea shelf. Males from 30-50 cm and females 30-70 cm are found in shelf and slope waters, and males > 50 cm and females > 70 cm are found exclusively on the slope. Sex specific "domed-shaped" selectivity was freely estimated for the shelf survey; for the slope survey we assumed an asymptotic selectivity pattern.

At the present time there is no directed fishery for arrowtooth flounder in the eastern Bering Sea. Length measurements collected from the fishery represent opportunistic samples of arrowtooth flounder taken as bycatch. This results in sample size problems which make estimates of fishery selectivity unreliable. Also, we felt that a directed fishery would likely target a different segment of the stock. Accordingly, the shape of the selectivity curve was fixed asymptotic for older fish in the fishery since a directed fishery would presumably target on larger fish. This also allowed for a realistic calculation of exploitable biomass from the model estimate of total biomass.

Examination of the shelf and slope survey population estimates indicate that females are consistently estimated to be in higher abundance than males (Fig. 5.3). This difference was also evident in the Gulf of Alaska from triennial surveys conducted from 1984-96 (Turnock et al. 1998). This information was incorporated into a past assessment by adjusting the size composition data input into the model by the sex ratio proportion observed in shelf and slope trawl surveys and fishery data. This resulted in unsatisfactory results as the model gave low estimates of male selectivity which has the undesirable result of artificially increasing population estimates. This assessment assumes an equal population sex composition.

Possible reasons for the higher estimates of females in the survey observations may be: 1) there is a spatial separation of males and females where males are less available to the survey trawl, 2) there is a higher natural mortality for males than females, 3) there are some sampling problems, or 4) there is a genetic predisposition to produce more females than males.

Growth

The length-based synthesis model allows flexibility on the relationship between length and age. The model was configured to estimate the L_{inf} and K parameters by sex as was described in a past asssessment (Wilderbuer and Sample 1995). These estimates of the growth parameters provided the best fit to the slope and shelf size compositions.

Fishing mortality

The fishing mortality rates (F) for each age and year are calculated to exactly match the catch weight by solving for F as follows:

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

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

MODEL RESULTS

Fishing mortality and selectivity

The stock synthesis model estimates of the annual fishing mortality on fully selected ages and the estimated annual exploitation rates (catch/total biomass) are given in Table 5.2. The average exploitation rate has been at a low level, 4%, from 1977-1999 due to the undesirability of arrowtooth flounder as a commercial product. Age-specific selectivity estimated by the model (Table 5.3, Fig. 5.4) indicate that arrowtooth flounder are 50% selected by the fishery at about 8 and 7 years of age and are fully selected by ages 17 and 11, for males and females, respectively.

Abundance Trend

Model estimates indicate that arrowtooth flounder total biomass increased more than 5 fold from 1980 to its' most abundant level in 1994 at 914,271 t (Fig. 5.5, Table 5.4). The biomass has declined 18% since then to the 2000 estimate of 749,545 t. Female spawning biomass is also estimated at a high level, projected at nearly 437,400 t in 2001 (Table 5.4). Model estimates of population numbers by age, year, and sex are given in Table 5.5.

The model fit to the shelf survey (emphasis 5.0) tracks the abundance trend well through 1990. The model estimate of survey biomass is less than the observed values from 1993-97 and does not provide a good fit to the declining estimates from the 1998 and 1999 shelf surveys, although it provides a good fit to the 2000 estimate. The model indicates an increasing biomass trend on the slope which fits the slope survey estimates poorly (Fig. 5.5). The slope biomass represents a smaller fraction of the total stock and is not well estimated by the survey, particularly the 1991 point estimate which is considered to be an underestimate of the slope survey biomass due to the reduction in sampling depth relative to earlier surveys.

The model provided a good fit to the survey shelf size composition time-series since 1981 for males and females (1989-99), which are shown in the Appendix. Reasonable fits also resulted for slope survey size composition observations.

Recruitment Trends

Increases in abundance from 1983-95 were the result of 5 strong year-classes spawned in 1981, 1984, 1986, 1987 and 1988 (Fig. 5.6, Table 5.6). Since 1990, recruitment is estimated to be near average in 1989-91 and below average thereafter.

Otoliths for aging arrowtooth flounder have been routinely collected during AFSC surveys in the EBS, but they have been infrequently aged because of higher priority for aging other species. However, an examination of length-frequency data shows that modes formed by age groups 1 to 3 are reasonably well separated so that fish less than 25 cm can be used as a measure of recruitment for age 2 fish; some age 1 fish are also included, but they are poorly recruited to the survey trawls. Population estimates (in millions) for fish less than 25 cm are as follows:

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Population estimates	86.1	290.2	57.9	62.4	150.3	94.3	200.6	273.8	105.2	
Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Population estimates	71.7	79.4	96.8	126.6	75.1	55.6	108.8	93.6	92.1	126.3

Over this period, population estimates for this size group have averaged 120 million. Above average recruitment has occurred in 1983, 1986, 1988, 1989, 1994 and 2000. Since the estimates primarily represent age 2 fish, the year-classes producing the strong recruitment are 1981, 1984, 1986, 1987, 1992 and 1998 (Fig. 5.6). Estimates of age 2 recruitment from the synthesis model agree well with the trawl survey population estimates and also indicate average to above average recruitment for the four years following the large 1986 and 1987 year-classes. The past five surveys indicate recruitment below the 1982-99 average.

ACCEPTABLE BIOLOGICAL CATCH

Arrowtooth flounder have a wide-spread bathymetric distribution in the Bering Sea/Aleutian Islands region and are believed to be at a high level, primarily as a result of five strong year-classes spawned during the 1980s and minimal commercial harvest. They are estimated to have declined 18% since a peak population biomass in 1994. **The estimate of 2001 total biomass from stock synthesis is 700,850 t and the female spawning biomass is estimated at 457,600 t (not including the Aleutian Islands)**.

The reference fishing mortality rate for arrowtooth flounder 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). Equilibrium female spawning biomass is calculated by applying the female spawning biomass per recruit resulting from a constant $F_{0.40}$ harvest to an estimate of average equilibrium recruitment. For this assessment, the Alaska Fisheries Science Center policy is to use only year classes spawned in 1977 or later to calculate the average equilibrium recruitment. Using the time-series of age 1 recruitment from 1978-99 from the stock assessment model results in an estimate of $B_{0.40}$ = 183,100 t. The stock synthesis model estimates the 2001 level of female spawning biomass at 457,600 t (B). Since reliable estimates of B, $B_{0.40}$, $F_{0.40}$, and $F_{0.30}$ exist and $B>B_{0.40}$ (457,600 > 183,100), arrowtooth flounder reference fishing mortality is defined in tier 3a. For the 2001 harvest: $F_{ABC} \leq F_{0.40} = 0.236$ and $F_{overfishing} = F_{0.35} = 0.285$ (full selection F values).

Acceptable biological catch is estimated for 2001 by applying the $F_{0.40}$ fishing mortality rate and age-specific fishery selectivities to the projected 2001 estimate of age-specific total biomass as follows:

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

where S_a is the selectivity at age, M is natural mortality, W_a is the mean weight at age, and n_a is the beginning of the year numbers at age. **This results in a 2001 ABC of 130,000 t.**

The potential yield of arrowtooth flounder for 2001 at various levels of fishing mortality (full selection) are as follows:

F level	Exploitation rate	Potential yield
$F_{overfishing}$	0.285	156,900 t
$\mathbf{F_{0.40}}$	**0.236**	**130,000 t**

Please note that these values are estimated assuming that the "area-swept" survey estimates of biomass are unbiased (ie. "Q" = 1.0). Preliminary results suggest that "Q" > 1.0 which would result in lower biomass and ABC estimates (for the Bering Sea shelf and slope).

PROJECTED BIOMASS

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 2000. (Rationale: When F_{ABC} is set at a value below $max\ F_{ABC}$, it is often set at the value recommended in the stock assessment.)

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

Scenario 4: In all future years, F is set equal to the 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.)

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

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2001 and above its MSY level in 2011 under this scenario, 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 2013 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results (Table 5.7) indicate that arrowtooth flounder are not currently overfished and the stock is not considered to be approaching an overfished condition.

OTHER CONSIDERATIONS

Arrowtooth flounder are currently of limited economic importance as a fisheries product, however, trophic studies (Lang et al. 1991, Livingston et al. 1993) indicate they are an important predator and may be an important component in understanding the dynamics of the Bering Sea benthic ecosystem. This is particularly relevant as the Council begins to consider shifting emphasis from single species to multi-species fisheries management of the Bering Sea and Aleutian Islands (Ecosystem Considerations, 1994 SAFE). Trophic studies indicate that the main food item in the diet of arrowtooth flounder is fish, particularly for arrowtooth larger than 30 cm. Pollock are a major component of the diet as well as other fish such as zoarcids. Invertebrates are also important and include cephalopods, euphausiids and pandalid and crangonid shrimp. Preadators of arrowtooth flounder include Pacific cod and large pollock, mostly on juvenile fish.

5.9 REFERENCES

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Table 5.1.--All nation total catch (t) of arrowtooth flounder in the eastern Bering Sea and Aleutian Islands region[a], 1970-2000. Catches since 1990 are not reported by area.

Year	Eastern Bering Sea				Aleutian Island Region				
	Non-U.S. fisheries[b]	U.S. J.V.[c]	U.S. DAH	Total	Non-U.S. fisheries	U.S. J.V.	U.S. DAH	Total	Total
1970	12,598			12,598	274			274	12,872
1971	18,792			18,792	581			581	19,373
1972	13,123			13,123	1,323			1,323	14,446
1973	9,217			9,217	3,705			3,705	12,922
1974	21,473			21,473	3,195			3,195	24,668
1975	20,832			20,832	784			784	21,616
1976	17,806			17,806	1,370			1,370	19,176
1977	9,454			9,454	2,035			2,035	11,489
1978	8,358			8,358	1,782			1,782	10,140
1979	7,921			7,921	6,436			6,436	14,357
1980	13,674	87		13,761	4,603			4,603	18,364
1981	13,468	5		13,473	3,624	16		3,640	17,113
1982	9,065	38		9,103	2,356	59		2,415	11,518
1983	10,180	36		10,216	3,700	53		3,753	13,969
1984	7,780	200		7,980	1,404	68		1,472	9,452
1985	6,840	448		7,288	11	59	89	159	7,447
1986	3,462	3,298	5	6,766		78	337	415	7,181
1987	2,789	1,561	158	4,508		114	237	351	4,859
1988		2,552	15,395	17,947		22	2,021	2,043	19,990
1989		2,264	4,000	6,264			1,042	1,042	7,306
1990		660	7,315	7,975			5,083	5,083	13,058
1991									22,052
1992									10,382
1993									9,338
1994									14,366
1995									9,280
1996									14,652
1997									10,054
1998									15,241
1999									10,573
2000*									10,059

[a]Catches from data on file Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Seattle, WA 98115.
[b]Japan, U.S.S.R., Republic of Korea, Taiwan, Poland, and Federal Republic of Germany.
[c]Joint ventures between U.S. fishing vessels and foreign processing vessels.
*Catch information through 16 September, 2000 (NMFS regional office).

APPENDIX

Figures show the fit of the stock synthesis model to the time-series of shelf and slope survey size composition data by sex (estimated values are the dotted lines) and the fishery size composition data from 1978-90.

Table of arrowtooth flounder catch during research activities by the Alaska Fisheries Science Center, 1977-99.