5. Assessment of Greenland Turbot in the Eastern Bering Sea and Aleutian Islands

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Executive summary

Relative to last year's assessment, the following changes have been made in the current assessment.

Changes to the input data

1. 2007 and 2008 catch data were updated (and added).
2. The Eastern Bering Sea (EBS) shelf survey 2008 biomass and length composition estimates were added.
3. An updated aggregated longline survey data index for the EBS and Aleutian Islands regions extending through 2008 was included.
4. EBS slope survey estimates for 2008 were included

Changes to the assessment model

The model used this year was developed using the Stock Synthesis 2 (SS2) software and is unchanged from last year's model configuration.

Changes in the assessment results

The **BSAI longline survey** index was down from the 2007 value and remains below the 1996-2005 values. The 2008 **EBS shelf trawl survey** biomass estimate was down by about 19% from the 2007 estimate and estimates from the last three years average about 68% of the long-term mean value from this survey. The 2008 **EBS slope trawl survey** biomass estimate was 17,900 t compared to the next most recent (2004) estimate of 36,600 t. Most of this difference was attributed to the lack of Greenland turbot found in the 400-600 m depth strata compared to the other years.

As in past years, the slope-trawl survey was assumed to index 75% of the Greenland turbot stock inhabiting U.S. waters. Model results based on these surveys and data from longline and trawl fisheries result in an estimate of $B_{40\%}$ equal to 43,731 t (female spawning biomass). The current estimate of the year 2008 female spawning biomass is 56,433 t. There appears to be a favorable recruitment pattern in recent years after a period of relatively few small fish occurring on the shelf in surveys. Recommended ABCs are adjusted from the maximum permissible given uncertainties highlighted by the different abundance indices in this region and the lack of evidence of substantive stock increases. Under this calculation, the 2009 and 2010 ABC levels for BSAI Greenland turbot of 7,380 and 7,130 t respectively. The corresponding maximum permissible ABC levels under Tier 3 are 11,900 and 10,800 t, respectively. The 2009 and 2010 overfishing levels, based on the $F_{35\%}$ rate are 14,800 t and 14,400 t corresponding to a full-selection F of 0.566.

The Tier 5 ABC and OFL estimates are 5,140 t and 6,850 t respectively. These estimates were based on the mean biomass estimate of 61,200 t (computed as the sum of mean biomass estimates since 2002 for the Aleutian Islands, EBS slope, and EBS shelf surveys) and a natural mortality rate of 0.112. If the stock trend is indexed by the longline survey over the last six years, then the value for Tier 5 ABC drops to 2,300 t with an OFL of 3,100 t.

Response to SSC comments

The SSC requested comparisons of the assessment results with management strategy evaluation work being undertaken for the Atlantic stock of Greenland turbot. *Results of analyses presented during a February 2008 workshop on the Atlantic stock are compared and contrasted.*

Summary

Status and catch specifications (t) of Greenland turbot in recent years. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2009 and 2010 are recommendations made in this assessment. Catch data are current through 10/31/08.

Year	Area	Age 1+ Bio.	OFL	ABC	TAC	Catch
2007	BSAI	119,000	15,600	2,440	2,440	1,946
	EBS			1,680	1,680	1,313
	AI			760	760	516
2008	BSAI	104,100	15,600	2,540	2,540	2,541
	EBS			1,750	1,750	1,949
	AI			787	787	592
2009	BSAI	104,583	14,800	7,380		
	EBS			5,092		
	AI			2,288		
2010	BSAI		14,400	7,130		
	EBS			4,920		
	AI			2,210		

Introduction

Greenland turbot (*Reinhardtius hippoglossoides*) within the US 200-mile exclusive economic zone are mainly distributed in the eastern Bering Sea (EBS) and Aleutian Islands region. Juveniles are believed to spend the first 3 or 4 years of their lives on the continental shelf and then move to the continental slope (Alton et al. 1988). Juveniles are absent in the Aleutian Islands regions, suggesting that the population in the Aleutians originates from the EBS or elsewhere. In this assessment Greenland turbot found in the two regions are assumed to represent a single management stock. NMFS initiated a tagging study in 1997 to supplement earlier international programs. Results from conventional and archival tag return data suggest that individuals can range distances of several thousands of kilometers and spend summer periods in deep water in some years and in other years spend time on the shallower EBS shelf region.

Prior to 1985 Greenland turbot and arrowtooth flounder were managed together. Since then, the Council has recognized the need for separate management quotas given large differences in the market value between these species. Furthermore, the abundance trends for these two species are clearly distinct (e.g., Wilderbuer and Sample 1992).

The American Fisheries Society uses “Greenland halibut” as the common name for *Reinhardtius hippoglossoides* instead of Greenland turbot. To avoid confusion with the Pacific halibut, *Hippoglossus stenolepis*, common name of Greenland turbot which is also the “official” market name in the US and Canada (AFS 1991) is retained. For further background on this assessment and the methods used refer to Ianelli and Wilderbuer (1995).

Catch history and fishery data

Catches of Greenland turbot and arrowtooth flounder were not reported separately during the 1960s. During that period, combined catches of the two species ranged from 10,000 to 58,000 t annually and averaged 33,700 t. Beginning in the 1970s the fishery for Greenland turbot intensified with catches of this species reaching a peak from 1972 to 1976 of between 63,000 t and 78,000 t annually (Fig. 5.1). Catches declined after implementation of the MFCMA in 1977, but were still relatively high in 1980-83 with an annual range of 48,000 to 57,000 t (Table 5.1). Since 1983, however, trawl harvests declined steadily to a low of 7,100 t in 1988 before increasing slightly to 8,822 t in 1989 and 9,619 t in 1990. This overall decline is due mainly to catch restrictions placed on the fishery because of apparent low levels of recruitment. For the period 1992–1997, the Council set the TAC's to 7,000 t as an added conservation measure due to concerns about recruitment in the past several years. In response to concerns regarding the status of the stock, the Council sharply reduced TAC's from a high for the decade of 15,000 t in 1998 to 2,440 t in 2007. As of September 2008, the total catch of Greenland turbot exceeded the ABC by one ton.

In 2008, trawl-caught Greenland turbot has apparently exceeded the level of catch by longline vessels (Table 5.1). This shift in the proportion of catch by sector may have resulted from the passage of Amendment 80 in 2007. Amendment 80 to the BSAI Fishery Management Plan (FMP) was intended to: 1) improve retention and utilization of fishery resources by the non-American Fisheries Act (AFA) trawl catcher/processor fleet by extending the AFA's Groundfish Retention Standards to all vessels and 2) establish a limited access privilege program for the non-AFA trawl catcher/processors and authorize the allocation of groundfish species to cooperatives to encourage lower discard rates and increased value of harvested fish while lowering costs. Catch information prior to 1990 included only the tonnage of Greenland turbot retained Bering Sea fishing vessels or processed onshore (as reported by PacFIN). Discard levels of Greenland turbot have typically been highest in the sablefish fisheries (at about one half of all sources of Greenland turbot discards during 1992-2002) while Pacific cod fisheries and the "flatfish" fisheries also have contributed substantially to the discard levels (Table 5.2). About 11% of all Greenland turbot caught in groundfish fisheries were discarded (on average) during 2004-2008. By gear-type, the gain in trawl-fishery has occurred primarily in the "arrowtooth flounder" target fishery in 2008 (Table 5.3) and this may be due to changes introduced by Amendment 80.

The catch data were used as presented above for both the longline and trawl fisheries. The early catches included Greenland turbot and arrowtooth flounder together. To separate them, the ratio of the two species for the years 1960-64 were assumed to be the same as the mean ratio caught by USSR vessels from 1965-69.

Size and age composition

Fishery age composition data is currently unavailable for Greenland turbot. Age-determination methods have improved in the last few years and it is expected that a time series of age composition will be available in the next year. Extensive length frequency compositions have been collected by the NMFS observer program from the period 1980 to 1991. The length composition data from the trawl and longline fishery are presented in the appendix (along with the expected values from the assessment model).

Resource Surveys

EBS slope and shelf bottom trawl survey

The older juveniles and adults on the slope have been surveyed every third year from 1979-1991 (also in 1981) as part of a U.S.-Japan cooperative agreement. From 1979-1985, the slope surveys were conducted by Japanese shore-based (Hokuten) trawlers chartered by the Japan Fisheries Agency. In 1988, the NOAA R/V Miller Freeman was used to survey the resources on the EBS slope region. In this same year, chartered Japanese vessels performed side-by-side experiments with the R/V Miller Freeman for calibration purposes. However, the R/V Miller Freeman sampled a smaller area and fewer stations in 1988 than the previous years. The Miller Freeman sampled 133 stations over a depth interval of 200-800 m while during earlier slope surveys the Japanese vessels usually sampled 200-300 stations over a depth interval of 200-1000 m. In 2002, the AFSC re-established the bottom trawl survey of the upper continental slope of the eastern Bering Sea and a second survey was conducted in 2004. Planned biennial slope surveys lapsed (the 2006 survey was canceled) but resumed in the summer of 2008 (Table 5.4).

The trawl slope-surveys are likely to represent under-estimates of the BSAI-wide biomass of Greenland turbot since fish are found consistently in other regions. Hence, the slope survey is treated as an index representing 75% of the stock based on earlier assessment analyses (Ianelli et al. 1993). A similar issue likely affects the distribution of Greenland turbot on the shelf region, particularly given the extent of the cold pool and warm conditions in recent years. Therefore the shelf survey biomass estimates are treated as a relative abundance index.

The combined estimates from the shelf and slope indicate a decline in EBS abundance for the 4 years of observations that were available when US-Japanese slope surveys were conducted in 1979, 1981, 1982, and 1985. After 1985, the slope biomass estimates (comparable since similar depths were sampled) have averaged 55,000 t, with a 2004 level of 57,500 t. The average shelf-survey biomass estimate during the last 16 years (1993-2008) is 29,400 t. The number of hauls and the levels of Greenland turbot sampling in the shelf surveys are presented in Table 5.5. The biomass trends track somewhat differently than the proportion of tows with Greenland turbot, suggesting that the extent of the spatial distribution has remained relatively constant (or increased slightly) while the density within stations increased but recently declined (Fig. 5.2).

The 2008 **EBS slope trawl survey** biomass estimate was 17,900 t compared to the next most recent (2004) estimate of 36,600 t. Most of this difference was attributed to the lack of Greenland turbot found in the 400-600 m depth strata compared to the other years (Table 5.6).

A time series of estimated size composition of the population was available for the shelf and slope trawl surveys and for the longline survey. The slope surveys typically sample more turbot than the shelf trawl surveys; consequently, the number of fish measured in the slope surveys is greater. The shelf survey appears to be useful for detecting some recruitment patterns which are consistent with the trends in biomass (Fig. 5.3). In the last 7-8 years an advancing mode of smaller fish are apparent and suggest new recruitment after a period of 9-10 years without much sign of recruitment. Also apparent is recruitment in the past year based on the mode of Greenland turbot at about 10cm.

Survey size-at-age data was available and used for estimating growth and growth variability were previously available from 1975, 1979-1982. Gregg et al. (2006) revised age-determination methods for Greenland turbot and 403 samples (from 1994 and 1998 surveys) were used instead of the earlier data. Research on Greenland turbot age validation methods continues at the AFSC.

Aleutian Islands survey

In 2006 NMFS scientists surveyed the Aleutian Islands region with bottom trawls and longline gear and the shelf region of the EBS were surveyed with trawl gear. The 2006 Aleutian Islands bottom trawl survey estimate was 20,900 t, an increase of 85% from the 2004 survey estimate and is above the 1991-2006 average level of 17,100 t (Table 5.4). The distribution of Greenland turbot in 2006 indicate fewer survey stations with moderate catches of Greenland turbot but somewhat higher variability compared to data from other recent surveys (Fig. 5.4). The breakdown of area specific survey biomass for the Aleutian Islands region shows that the eastern region has the highest densities and contains about 62% of the biomass, on average (Fig. 5.5; Table 5.7). The trawl-survey area-swept data for the Aleutian Islands component of the Greenland turbot stock was excluded from the stock assessment model but is used for the Tier 5 calculations.

Longline survey

The domestic longline survey effort extends into the Bering Sea and part of the Aleutian Islands (in alternate years). This sampling shows that about 25% of the population along the combined slope regions survey is found within the northeast (NE) and southeast (SE) portions of the Aleutian Islands:

Relative Population No. (RPN)				Year									
Area	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Bering 4		11,729		13,072		16,082		11,965		3,717		1,561	
Bering 3		6,172		6,156		5,005		3,784		1,822		1,754	
Bering 2		27,936		33,848		24,766		24,660		15,268		13,523	
Bering 1		13,491		10,068		4,788		6,206		2,297		1,235	
NE Aleutians	23,133		16,124		12,987		10,942		8,551		3,031		3,155
SE Aleutians	2,142		1,806		1,201		1,397		937		566		297
Bering Sea (total)		59,328		63,144		50,641		46,616		23,103		18,074	
Aleutians (total)	25,275		17,930		14,188		12,339		9,487		3,597		3,452
Combined	114,457	76,142	81,193	81,039	64,251	64,993	55,875	59,827	42,962	29,651	16,287	23,196	15,632

The combined time series shown above (1996-2008) was used as a relative abundance index. It was computed by taking the average RPN from 1996-2008 for both areas and computing the average proportion. The combined *RPN* in each year (RPN_t^c) was thus computed as:

$$RPN_t^c = I_t^{AI} \frac{RPN_t^{AI}}{p^{AI}} + I_t^{EBS} \frac{RPN_t^{EBS}}{p^{EBS}}$$

where I_t^{AI} and I_t^{EBS} are indicator function (0 or 1) depending on whether a survey occurred in either the Aleutian Islands or EBS, respectively. The average proportions (1996-2008) are given here by each area as: p^{AI} and p^{EBS} . Note that each year data are added to this time series, the estimate of the combined index changes (slightly) in all years and that this approach assumes that the population proportion in these regions is constant. A coefficient of variation of 20% for this index was assumed. The time series of length frequency data from the longline survey extends back to the cooperative longline survey and is shown in Fig. 5.6.

Annual research catches (1977 - 2008) from NMFS longline and trawl surveys (t) are estimated as follows:

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
NMFS Bottom trawl survey	62.5	48.4	103.0	123.6	1.8	0.6	175.1	0.2	0.5	18.5	0.6	0.7	9.0	0.9	1.4
Longline surveys	3	3	6	11	9	7	8	7	11	6	16	10	10	22	23
Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
NMFS Bottom trawl survey	2.0	1.4	1.5	1.2	1.4	1.0	5.1	1.1	5.3	1.1	11.0	0.7		0.59	
Longline surveys	23												1.1	3.5	

Analytic approach

Model Structure

The stock synthesis program (Methot 1990) has been used to model the eastern Bering Sea component of Greenland turbot since 1994. The assessment model configuration has changed over time, particularly in the past two years as newer versions (SS2) have become available. A key assumption used in past models was retained: the slope-trawl survey is treated as an absolute index representing 75% of the Greenland turbot stock inhabiting US waters. This results in very similar recent biomass levels.

Total catch estimates used in the model were from 1960 to 2008. It was assumed that the stock was at or close to its virgin biomass level at the beginning of the catch data time series.

Model parameters were estimated by maximizing the log posterior distribution of the predicted observations given the data. Prior distributions consisted of penalties on recruitment deviations from a fixed stock-recruitment curve. This was required to stabilize estimates of recruitment early in the time series when data were limiting. The underlying parameters of the stock-recruit curve play an insignificant role in fitting the model to the data. The model included two fisheries, those using longline and trawl gear, and three surveys. Table 5.8 summarizes the extent of the data used in the different likelihood components. An archive of the software and model configuration can be found at http://www.afsc.noaa.gov/refm/docs/2008/BSAIGturbot.zip.

Selectivity Patterns
A dome-shaped size-based selectivity function was estimated for each survey and fishery described below. For the trawl fishery, the periods of length frequency data collections from the domestic and foreign fleet did not overlap. Consequently, the foreign and domestic trawl fishery data were treated as a single fishery and the selectivity patterns were allowed between the respective periods. Because the EBS shelf trawl surveys appear to cover only part of the range of this stock, selectivity was allowed to vary over time at roughly 5-year blocks. This increased the overall model uncertainty but reflected the uncertain nature of Greenland turbot occurrence on the EBS shelf region.

Parameters estimated independently

Natural mortality, length at age, length-weight relationship
The natural mortality of Greenland turbot was assumed to be 0.112 based on Cooper et al. (2007). This is also more consistent with re-analyses of age structures that suggest Greenland turbot live beyond 30 years (Gregg et al. 2006).

Parameters describing length-at-age are estimated within the model. Length at age 1 is assumed to be the same for both sexes and the variability in length at age 1 was assumed to have an 8% CV while at age 21 a CV of 7% was assumed. This appears to encompass the observed variability in length-at-age. As with last year, size-at-age information from the methods described by Gregg et al. (2006) were used and this information is summarized in Table 5.9.

The length-weight relationship for Greenland turbot estimated by Ianelli et al. (1993) was:

$$w = 2.69 \times 10^{-6} L^{3.3092} \quad \text{for females}$$

and

$$w = 6.52 \times 10^{-6} L^{3.068} \quad \text{for males}$$

where L = length in mm, and w = weight in grams.

Maturation and fecundity
Recent studies on the fecundity of Greenland turbot indicate that estimates at length are somewhat higher than most estimates from other studies and areas (Cooper et al., 2007). In particular, the values were higher than that found from D'yakov's (1982) study. The data for proportion mature at size from the new study suggest a larger length at 50% maturity but data were too limited to provide revised estimates. For this analysis, a logistic maturity-at-size relationship was used with 50% of the female population mature at 60 cm; 2% and 98% of the females are assumed to be mature at about 50 and 70 cm respectively. This is based on an approximation from D'yakov's (1982) study.

Parameters estimated conditionally

The key parameters estimated within the model include:

- Annual recruitment estimates from 1960-2007 (2008 set to mean).
- Selectivity parameters for the 2 fisheries, and 3 surveys,
- Growth parameters: 5 parameters (2 for each sex, one in common), and
- Parameter that scales the expected value of recruitment.

Model evaluation

Size composition data are not available until 1977 hence recruitment estimates information during the early period (1960s) are highly uncertain. The removal of 574,000 tons of Greenland turbot between 1972 and 1981 (compared to a total 52,800 t between 1997-2008) and the observed trends in abundance indicate that recruitment during the 1960s must have been high. Lacking information on the age (or sizes) of these fish impedes estimation of which (or how many) year classes were high. In previous assessments sensitivity to these estimates was performed. Evaluations of alternative model configurations were limited due to complexity related to selectivities, gear types, and general paucity of information specific to Greenland turbot.

Results

This year's model configuration was essentially identical to last year's and unsurprisingly yields similar estimates to previous models, particularly in the recent period (Fig. 5.7). The model fit to the survey indices have undesirable residual patterns with periods of consecutive observations being above and below the model prediction (Fig. 5.8). This is particularly disturbing for the longline sablefish survey and the EBS shelf trawl survey. Fortunately, the fit to the slope survey (considered to best cover the habitat for Greenland turbot) fits well and the residual patterns are reasonable. The shifts in selectivity were intended to reflect inter-annual habitat changes (e.g., extent of the cold pool or some other environmental factor) and random changes in spatial distribution.

Trends in Abundance

The biomass of Greenland turbot increased during the 1970s from the early 1960s level and is currently about 61% of the level expected under no fishing using average recruitment since 1977. The recent trend shows an increase of about 4% from the 2004 level bringing the 2008 total begin-year biomass (age 1 and older) estimate to about 104,400 t (Table 5.10).

The historical fishing mortality rates (combined gears) began at high levels (but highly uncertain), decreased then peaked in recent decades in 1980 through 1983 (Table 5.10; Fig. 5.9). A comparison of this year's model result with the 2007 assessment is also presented in Table 5.10. The estimated historical numbers at age is given in Table 5.11.

Selectivity

Estimates of selectivity (using the "double-normal" option in SS2) provide patterns that appear reasonable over time for the shelf survey (Fig. 5.10). The average selectivity patterns among all gear types was also reasonable (Fig. 5.11). Since the male selectivity estimates were different for these gear types, the proportions at sex between gear types over time was examined. This showed that the trawl fishery tends to catch slightly less than 50% females whereas the longline fishery catch comprises about 70% females (Fig. 5.12). The slope trawl survey also shows that in there is variability in the proportion female. In 2002 and 2008 the survey resulted in far more males than females—opposite of what was estimated for 2004 (more females than males; Fig. 5.13). This highlights the sex and size specific variability within the same region between years. Females in all years tended to be larger (as expected) and in 2008 the slope survey indicated some smaller than usual Greenland turbot.

Selectivity of Greenland turbot varied considerably between all of the surveys and fisheries. The shelf survey selected only small fish whereas the slope survey caught much larger fish. A similar pattern was observed between the trawl and longline fisheries with the longline fishery consistently catching larger Greenland turbot (e.g., Fig. 5.11). Note that the average selectivity estimates for the slope and shelf surveys indicate that our surveys do not sample intermediate size fish (35-50cm) very well. The reason for this is unclear; however, it could be related to the apparent bi-modality in the size distribution observed in the trawl fishery. The age-equivalent sex-specific selectivity estimates (for 2008) from each gear type for Greenland turbot in the BSAI is given in Table 5.12. These are approximate due to the fact that selectivity processes are modeled as a function of size. Similar, approximate age-and-sex-specific weights (and maturity) are available and specific for each fishery (Table 5.13).

Fit to Size Composition Data

The model fit the available length-at-age information reasonably well, and is consistent with growth of females being significantly greater than males (Fig. 5.14). Size composition observations from the fisheries and surveys are matched by the model predictions reasonably well (Attachment 5.1). The discrepancies observed may be attributed to three issues. First, in some years, relatively few fish were measured so adjustments of the model to those data would depend on the trade-off in fitting other data, which may have had more extensive sampling. Second, unaccounted fish movement and hence changing availability affects fits to size composition data when an "average" (as opposed to annually varying) gear selectivity is used. Finally, natural mortality rate is undoubtedly variable among cohorts and years, the extent of which would affect our ability to model the age structure of the population accurately.

Recruitment

Recruitment of young juvenile Greenland turbot appeared to have been poor for about 15 years since the early 1980s after several strong year-classes during the 1970s. Recently, there has been evidence of positive recruitment for Greenland turbot (Fig. 5.15). Analyses on fitting the stock-recruitment relationship indicated that the residuals were highly auto-correlated (Fig. 5.16). Therefore, the assumptions required to pursue stock-recruitment analyses are difficult to justify.

Maximum Sustainable Yield

Maximum sustainable yield (MSY) calculations require assumptions about the stock recruitment relationship, which for Greenland turbot may be impractical as the extent the stock structure is likely to be beyond the area surveyed and fished. As with many other groundfish, a harvest strategy using spawning biomass per recruit as proxies for F_{msy} (e.g., $F_{35\%}$) was selected in the absence of information on the stock-recruitment productivity relationship required for calculating MSY levels.

Projections and harvest alternatives

Amendment 56 Reference Points

The recommended harvest levels vary considerably among models depending on the assumptions made about the catchability coefficients from the slope-trawl survey (Ianelli et al. 1999). Since there are several areas of uncertainty surrounding this assessment, for the basis for recommendations were based on a conservative model configuration (assuming slope-survey catchability=0.75). The status of the projected spawning biomass in year 2009 relative to $B_{40\%}$ would place Greenland turbot in Tier 3a of Amendment 56.

The $B_{40\%}$ value using the mean recruitment estimated for the period 1978-2007 gives a long-term average female spawning biomass of 43,731 tons. The current estimate of the year 2009 female spawning biomass is about 56,433 t, above the estimate of $B_{35\%}$ (38,265).

Specification of OFL and Maximum Permissible ABC and ABC Recommendation

The choice for recommending an ABC in recent years has been much lower than the maximum permissible estimates (in 2008 the ABC recommendation was 21% of the maximum permissible level). The rationale for this low value has been partly due to the lack of recent surveys on the slope region and partly because of concerns over stock structure uncertainty, data and modeling issues. This year a slope survey was prosecuted and there are positive signs of recruitment. Hence, the rationale for keeping the ABC recommendation so far below the maximum permissible is less defensible. As an alternative, we recommend that the ABC be set to 60% of the maximum permissible as one of an intermediate stair-step towards converting to the maximum permissible ABC level. Based on discussions with the Plan Team, this step was proposed to remain constant (i.e., 60% of maximum permissible) for 2010 as well. This rate is designed to acknowledge the issues identified in past assessments while recognizes the value of the fishery and the survey work that has been completed in 2008. Reducing ABC below the maximum permissible level also seems prudent because of concerns about uncertainties in the stock trends. Two surveys (the longline and the shelf bottom trawl survey) indicate somewhat steeper declines than predicted by the model (Fig. 5.8).

The projected Greenland turbot maximum permissible ABC and OFL levels for 2009 and 2010 are shown below (catch for 2009 was set equal to the ABC recommendation):

Year	Catch	Maximum permissible ABC	Recommended ABC	OFL	Female spawning biomass
2009	7,380 t	11,900 t	7,380 t	14,800 t	56,803 t
2010	7,130 t	10,800 t	7,130 t	14,400 t	54,024 t

The estimated overfishing level based on the adjusted $F_{35\%}$ rate is 14,800 t corresponding to a full-selection F of 0.566. The value of the Council's overfishing definition depends on the age-specific selectivity of the fishing gear, the somatic growth rate, natural mortality, and the size (or age) -specific maturation rate. As this rate depends on assumed selectivity, future yields are sensitive to relative gear-specific harvest levels. Because harvest of this, resource is not allocated by gear type, the unpredictable nature of future harvests between gears is an added source of uncertainty. However, this uncertainty is considerably less than uncertainty related to treatment of survey biomass levels, i.e., factors which contribute to estimating absolute biomass (Ianelli et al. 1999). The history of stock size relative to the reference level (based on recruitments since 1977) shows that the fishing mortality has been well below the $F_{40\%}$ level (Fig. 5.17). Despite this low level of fishing mortality, the stock has continued to decline.

Tier 5 ABC/OFL estimates
As an alternative, Tier 5 ABC and OFL estimates are 5,140 t and 6,850 t respectively. These estimates were based on the mean biomass estimate of 61,200 t (computed as the sum of mean biomass estimates since 2002 for the Aleutian Islands, EBS slope, and EBS shelf surveys) and a natural mortality rate of 0.112. If the stock trend is indexed by the longline survey over the last six years, then the value for Tier 5 ABC drops to 2,300 t with an OFL of 3,100 t.

Subarea Allocation

In this assessment, the hypothesis proposed by Alton et al. (1989) regarding the stock structure of Greenland turbot in the eastern Bering Sea and Aleutian Islands regions was adopted. Briefly, spawning is thought to occur throughout the adult range with post-larval settlement occurring on the shelf in shallow areas. The young fish on the shelf begin to migrate to the slope region at about age 4 or 5. In our treatment, the spawning stock includes adults in the Aleutian Islands and the eastern Bering Sea. In support of this hypothesis, the length compositions from the Aleutian Islands surveys appear to have few small Greenland turbot, which suggests that these fish migrate from other areas (Ianelli et al. 1993). Historically, the catches between the Aleutian Islands and eastern Bering Sea has varied (Table 5.14).

Since having limited information on the movement and recruitment processes for this species has been acknowledged and in the interest of harvesting the "stock" evenly, a split region-specific ABC is recommended. Based on eastern Bering Sea slope survey estimates and Aleutian Islands surveys, the proportion of the adult biomass in the Aleutian Islands region has ranged from 24% to 49%. The recommended ABC for the Aleutian Islands is 31% of the total ABC, with 69% allocated to the eastern Bering Sea. These rates are based on mean values observed from biomass estimates and give the following region-specific allocation:

Aleutian Islands	2,288
Eastern Bering Sea	5,092
Total	7,380

Standard harvest scenarios and projections

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

For each scenario, the projections begin with the vector of 2008 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008 (here assumed to be 2,541 t). 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 1,000 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 2009, 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 the author's recommend level. Here values equal to Scenario 3 (5-year average *F*) were selected.

Scenario 3: In all future years, *F* is set equal to the 2004-2008 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 4: In all future years, *F* is set equal to the $F_{75\%}$. (Rationale: This scenario was developed by the NMFS Regional Office based on public feedback on alternatives.

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 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 half of its MSY level in 2008 and above its MSY level in 2021 under this scenario, then the stock is not overfished.)

Scenario 7: In 2009 and 2010, 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 2021 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 1 through 7 were projected 13 years from 2008 (Table 5.15). Fishing at the maximum permissible rate indicate that the spawning stock will gradually drop to near the $B_{40\%}$ by 2021 (Fig. 5.18).

Our projection model run under these conditions indicates that for Scenario 6, the Greenland turbot stock is not overfished based on the first criterion (year 2009 spawning biomass estimated at 56,433 t relative to $0.5B_{35\%}$ = 16,691 t). Under the guidelines, since the year 2008 biomass estimate is above the $B_{35\%}$ level (and $B_{40\%}$) and the stock is not overfished.

Projections of fishable biomass 13 years into the future under alternative fishing mortality rates were examined. The same natural mortality and growth parameters that were used in the previous stock synthesis runs were employed for the projections. Projections with fishing at the maximum permissible level result in an expected value of spawning biomass of 58,800 t by 2021.

Under Scenarios 6 and 7, the projected spawning biomass for Greenland turbot is not currently overfished, nor is it approaching an overfished status.

Other Considerations

Ecosystem considerations

Greenland turbot have undergone dramatic declines in the abundance of immature fish on the EBS shelf region compared to observations during the late 1970’s. It may be that the high level of abundance during this period was unusual and the current level is typical for Greenland turbot life history pattern. Without further information on where different life-stages are currently residing, the plausibility of this scenario is speculation. Several major predators on the shelf were at relatively low stock sizes during the late 1970’s (e.g., Pacific cod, Pacific halibut) and these increased to peak levels during the mid 1980’s. Perhaps this shift in abundance has reduced the survival of juvenile Greenland turbot in the EBS shelf. Alternatively, the shift in recruitment patterns for Greenland turbot may be due to the documented environmental regime that occurred during the late 1970’s. That is, perhaps the critical life history stages are subject to different oceanographic conditions that affect the abundance of juvenile Greenland turbot on the EBS shelf.

Currently, the ecosystem group within the REFM Division is actively evaluating the pattern of mortality between different species in the EBS. One aspect of this work involves developing a multi-species model. Results from this work indicate that Greenland turbot has been an important predator.

The SSC requested that comparisons with the Atlantic Greenland turbot stock be made (particularly in reference to the Management Strategy Evaluation (MSE) work that was undertaken. A workshop was held after a series of data exchanges and implementation of a rudimentary management strategy evaluation using the software FLR (Kell et al. 2007). Comparing historical fishery patterns, the catches are generally much lower (except during the 1970) for the BSAI Greenland turbot stock and the average age estimates have been considerably higher than that of the Atlantic (Fig. 5.19; data from Healey and Mahé 2006). Estimated total stock-size based on assessments from these regions is currently of similar magnitude (Fig. 5.20). Miller et al. (2008) summarized the MSE aspects of this project and noted that alternative operating model specifications are required to complete this task.

Research and data gaps

A number of research and modeling issues continue to require further consideration. These include:

- An evaluation of possible differential natural mortality between males and females,
- Development of statistically based "effective sample size" values for size composition data (e.g., through boot-strapping original survey and observer data),
- Including more length-at-age information using the new methods, investigating age-specific natural mortality,
- Evaluating the extent that Greenland turbot are affected by temperature and environmental conditions relative to survey gear,
- A re-evaluation of the assumption that 75% of the stock is indexed by the slope surveys, and
- Including the Aleutian Islands survey data within the model.

These and a number of other issues were highlighted by the CIE panel report and will guide the research on Greenland turbot in the coming years.

Summary

The pattern of total fishing mortality relative to spawning biomass suggests that the EBS Greenland turbot stock is approaching the $B_{40\%}$ level, but that historically the fishing mortality was below the $F_{40\%}$ level (Fig. 5.17). The management parameters of interest derived from this assessment are presented in Table 5.16.

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Tables

Table 5.1. Catch estimates of Greenland turbot by gear type (t; including discards) and ABC and TAC values since implementation of the MFCMA.

Year	Trawl	Longline & Pot	Total	ABC	TAC
1977	29,722	439	30,161	40,000	
1978	39,560	2,629	42,189	40,000	
1979	38,401	3,008	41,409	90,000	
1980	48,689	3,863	52,552	76,000	
1981	53,298	4,023	57,321	59,800	
1982	52,090	31.8	52,122	60,000	
1983	47,529	28.8	47,558	65,000	
1984	23,107	12.6	23,120	47,500	
1985	14,690	40.6	14,731	44,200	
1986	9,864	0.4	9,864	35,000	33,000
1987	9,551	34	9,585	20,000	20,000
1988	6,827	281	7,108	14,100	11,200
1989	8,293	529	8,822	20,300	6,800
1990	12,119	577	12,696	7,000	7,000
1991	6,245	1,617	7,863	7,000	7,000
1992	749	3,003	3,752	7,000	7,000
1993	1,145	7,323	8,467	7,000	7,000
1994	6,426	3,845	10,272	17,200	7,000
1995	3,978	4,215	8,194	7,000	7,000
1996	1,653	4,902	6,555	10,300	7,000
1997	1,209	5,989	7,199	12,350	9,000
1998	1,830	7,319	9,149	15,000	15,000
1999	1,799	4,057	5,857	14,200	9,000
2000	1,946	5,027	6,973	9,300	9,300
2001	2,149	3,163	5,312	8,400	8,400
2002	1,033	2,605	3,638	8,100	8,000
2003	908	2,605	3,513	5,880	4,000
2004	675	1,544	2,220	4,740	3,500
2005	729	1,831	2,559	3,930	3,500
2006	360	1,605	1,965	2,740	2,740
2007	429	1,400	1,829	2,440	2,440
2008	1,572	969	2,541	2,540	2,540*

*Catch estimated as of September 2008.

Table 5.2. Estimates of discarded and retained (t) Greenland turbot based on NMFS estimates by "target" fishery, 1992-2008.

Fishery:	Greenland turbot		Sablefish		Pacific cod		Rockfish		Flatfish		Others		Combined	
Year	Retain	Discard	Retain	Discard	Retain	Discard	Retain	Discard	Retain	Discard	Retain	Discard	Retain	Discard
1992	62	13	196	2,121	135	557	180	103	13	3	107	261	693	3,058
1993	5,685	332	235	880	160	108	572	87	19	185	10	194	6,681	1,786
1994	6,316	368	194	2,305	149	211	316	37	27	235	38	76	7,040	3,232
1995	5,093	327	157	1,546	145	284	362	25	5	102	28	121	5,790	2,405
1996	3,451	173	200	1,026	170	307	598	113	171	63	143	140	4,733	1,822
1997	4,709	521	129	619	270	283	202	19	212	92	18	125	5,540	1,659
1998	6,905	301	125	171	278	154	42	2	628	249	123	171	8,101	1,048
1999	4,009	227	179	120	180	50	25	2	600	269	134	61	5,127	729
2000	4,798	177	192	253	130	108	39	1	838	176	186	75	6,183	790
2001	2,727	89	171	325	203	92	431	30	764	337	95	47	4,391	920
2002	1,979	73	144	207	210	139	175	18	301	217	124	49	2,933	703
2003	1,712	44	98	534	165	95	198	5	243	228	79	55	2,497	961
2004	1,209	19	78	24	221	79	72	3	189	176	99	50	1,868	352
2005	1,530	21	63	19	156	30	134	5	326	77	149	49	2,359	200
2006	1,198	14	62	52	65	31	69	8	248	38	135	46	1,778	188
2007	1,072	27	59	71	127	91	36	13	49	35	198	50	1,541	288
2008	999	3	40	66	30	27	137	0	843	315	74	7	2,123	418

Table 5.3. Estimates of Greenland turbot catch (t) by gear and "target" fishery, 2004-2008. Source: NMFS AK Regional Office catch accounting system.

	"Target" fishery	2004	2005	2006	2007	2008
Longline and pot	Greenland turbot	1,168	1,527	1,212	1,097	797
	Pacific cod	221	170	77	129	46
	Sablefish	90	75	114	130	102
	Shallow-water flatfish	64	57	61	15	2
	Arrowtooth flounder	0	2	140	16	0
	Others	2	0	3	11	22
Trawl	Arrowtooth flounder	53	154	21	3	1,056
	Atka mackerel	123	167	117	130	23
	Flathead sole	191	150	28	30	96
	Rockfish	74	139	74	47	137
	Greenland turbot	61	24	0	2	205
	Pollock	18	31	65	107	35
	Pacific cod	79	15	19	89	11
	Others	76	49	36	20	9

Table 5.4. Survey estimates of Greenland turbot biomass (t) for the Eastern Bering Sea shelf and slope areas and for the Aleutian Islands region, 1975-2008. Note that the shelf-survey estimates from 1985, and 1987-2008 include the northwestern strata (8 and 9) and these were the values used in the model. The Aleutian Islands estimates prior to 1990 used different protocols and are not comparable with more recent estimates. The 1988 and 1991 slope estimates are from 200-800 m whereas the other slope estimates are from 200 - 1,000m.

	Eastern Bering Sea		Aleutian Islands
Year	Shelf	Slope	Survey
1975	126,700		
1979	225,600	123,000	
1980	172,200		48,700*
1981	86,800	99,600	
1982	48,600	90,600	
1983	35,100		63,800*
1984	17,900		
1985	7,700	79,200	
1986	5,600		76,500*
1987	10,600		
1988	14,800	42,700	
1989	8,900		
1990	14,300		
1991	13,000	40,500	11,925
1992	24,000		
1993	30,400		
1994	48,800		28,227
1995	34,800		
1996	30,300		
1997	29,218		28,334
1998	28,126		
1999	19,797		
2000	22,957		9,359
2001	25,347		
2002	21,450	27,589	9,891
2003	23,685		
2004	20,910	36,557	11,334
2005	21,359		
2006	20,933		20,934
2007	16,726		
2008	13,514	17,901	NA

Table 5.5. Levels of Greenland turbot biological sampling from the EBS shelf surveys. Note that in 1982-1984, and 1986 the northwestern stations were not sampled.

Year	Total Hauls	Hauls w/ turbot	Length samples	Otolith sample hauls	Hauls w/age	Otolith Samples	Ages
1982	334	41	1,228	11	11	292	292
1983	353	55	951				
1984	355	27	536	20	263		
1985	358	46	200				
1986	354	53	195				
1987	360	36	354				
1988	373	58	414				
1989	373	56	376				
1990	371	62	544				
1991	372	65	658				
1992	356	64	616	5	7		
1993	375	73	632	7	179		
1994	376	52	530	17	196		
1995	376	49	343				
1996	375	75	450	8	100		
1997	376	64	298	11	79		
1998	375	73	445	25	21	200	127
1999	373	43	128	8	11		
2000	372	57	248	34	188		
2001	375	58	270	43	215		
2002	375	70	455	21	71		
2003	376	71	622	62	26	435	192
2004	375	64	606	45	290		
2005	373	61	441	56	293		
2006	376	56	427	49	262		
2007	376	83	499	68	334		
2008	375	78	406	59	245		

Table 5.6. Eastern Bering Sea slope survey estimates of Greenland turbot biomass (t), 2002, 2004 and 2008 by depth category.

Depth (m)	**2002**	**2004**	**2008**
200-400	4,081	2,889	4,553
400-600	**14,174**	**25,360**	**6,707**
600-800	4,709	5,303	4,373
800-1000	2,189	1,800	1,487
1000-1200	1,959	1,206	781
Total	27,113	36,557	17,901

Table 5.7. Time series of Aleutian Islands survey sub-regions estimates of Greenland turbot biomass (t), 1980-2006.

	Western Aleutian	Central Aleutian	Eastern Aleutian	Southern Bering Sea	Total
1980	0	799	2,720	79	3,598
1983	525	2,357	5,747	1,094	9,722
1986	1,747	2,495	19,580	7,937	31,759
1991	2,195	3,280	4,607	1,803	11,885
1994	2,401	4,007	15,862	5,966	28,235
1997	2,137	3,130	22,708	359	28,334
2000	839	2,351	5,703	467	9,359
2002	793	1,658	6,996	444	9,891
2004	2,588	2,947	2,564	3,234	11,333
2006	1,973	1,937	15,742	1,282	20,934

Table 5.8. Data sets used in the stock synthesis (SS2) model for Greenland Turbot in the EBS. All size and age data are specified by sex.

Data Component	**Years of data**
Survey size at age data	1994 and 1998
Shelf survey: size composition and biomass estimates	1979-2008
Slope survey: size composition and biomass estimates	1979, 81, 82, 85, 88, 91, 2002, 2004, 2008
Longline survey: size composition and abundance index	1996-2007
Total fishery catch data	1960-2008
Trawl fishery size composition	1977-87, 1989-91, 1993-2008
Longline fishery size composition	1977, 1979-85, 1992-2008

Table 5.9. Summary of the length-at-age information used for this BSAI Greenland turbot assessment (see Gregg et al. 2006 for methods).

	1994				1998			
	Males		Females		Males		Females	
Age	Avg. length (cm)	N	Avg. length (cm)	N	Avg. length (cm)	N	Avg. length (cm)	N
1	13.00	1	13.00	1	13.17	3	16.00	5
2	18.17	3	19.60	8	24.44	9	22.40	5
3	28.33	9	31.50	4	25.25	8	25.56	9
4	37.82	11	38.89	9	33.50	16	32.50	8
5	44.75	12	47.17	6	35.00	2	31.50	2
6	48.00	4	54.75	4				
7	51.00	1	59.50	2	49.50	2		
8							63.00	1
9	66.00	2	74.00	1	54.00	1	68.00	1
10	60.33	6			64.50	2	67.00	1
11	65.70	10	76.00	2			77.00	2
12	65.11	9	76.50	6			75.00	2
13	67.40	15	72.00	9	73.00	1	80.00	2
14	66.53	17	80.71	7	66.00	2	75.00	2
15	70.00	9	80.54	13			76.50	4
16	64.50	10	79.65	17				
17	66.67	6	83.33	9			72.00	1
18	68.60	10	86.80	15			82.00	1
19	64.00	5	88.82	11				
20	72.67	3	85.36	11			82.00	1
21	75.00	1	82.50	4			81.00	2
22	67.00	4	82.00	2				
23	69.50	2					84.00	1
24			84.50	2				
25			89.00	2				
26			92.00	1				
27	72.00	2	88.00	2				
28			95.00	1				
29			95.00	2				
30			92.00	1				
Totals		152		152		46		50

Table 5.10. Total harvest rate (catch / mid-year biomass), spawning and total biomass (compared with the past assessment) for BSAI Greenland turbot, 1960-2009.

			Female Spawning Biomass		Total Age 1+ Biomass	
Year	Total Fishing Mortality	Catch / Mid-yr Biom.	2007 Assessment	Current Assessment	2007 Assessment	Current Assessment
1960	0.09	0.106	142,891	134,017	261,095	242,758
1961	0.13	0.184	135,349	127,543	233,829	215,567
1962	0.24	0.197	122,143	115,725	221,415	173,759
1963	0.32	0.100	106,440	99,810	237,234	171,413
1964	0.23	0.086	98,313	88,473	296,842	227,498
1965	0.27	0.021	96,689	80,369	364,083	311,971
1966	0.06	0.022	118,191	84,501	448,033	427,509
1967	0.05	0.035	173,475	112,275	522,513	541,343
1968	0.05	0.045	246,880	184,121	588,666	642,446
1969	0.06	0.042	308,834	283,351	643,535	723,430
1970	0.05	0.029	350,142	372,973	693,551	788,654
1971	0.03	0.057	378,081	438,738	742,999	843,964
1972	0.06	0.102	394,485	476,783	759,007	859,695
1973	0.11	0.088	404,709	492,555	726,286	823,749
1974	0.10	0.113	417,988	502,063	694,861	787,665
1975	0.14	0.106	414,192	493,459	641,006	728,755
1976	0.13	0.106	399,907	475,391	592,824	675,772
1977	0.14	0.055	377,812	450,462	548,721	627,372
1978	0.08	0.079	365,503	434,977	537,232	611,963
1979	0.11	0.081	347,197	414,063	514,259	585,338
1980	0.12	0.107	330,374	394,753	491,608	559,354
1981	0.16	0.126	309,528	371,601	456,177	520,810
1982	0.19	0.126	286,811	346,501	413,039	474,692
1983	0.21	0.128	266,767	324,080	370,864	429,593
1984	0.23	0.070	243,431	297,955	330,373	385,997
1985	0.12	0.047	232,515	284,423	311,266	363,701
1986	0.08	0.033	225,239	274,730	297,838	346,891
1987	0.05	0.033	219,073	266,136	287,190	332,679
1988	0.06	0.026	211,066	255,520	275,113	316,939
1989	0.04	0.033	202,501	244,070	264,206	302,343
1990	0.06	0.051	191,685	230,149	250,615	285,093
1991	0.09	0.034	177,823	213,275	232,714	263,947
1992	0.05	0.017	166,629	198,387	219,794	247,035
1993	0.02	0.040	157,644	186,004	211,082	234,450
1994	0.05	0.052	145,344	170,405	197,916	217,482
1995	0.08	0.045	133,857	155,864	182,876	198,975
1996	0.07	0.039	124,022	143,062	169,880	182,755
1997	0.05	0.045	115,256	131,539	158,494	168,445
1998	0.06	0.062	106,084	119,730	146,717	153,976
1999	0.09	0.044	95,681	106,890	133,478	138,281
2000	0.06	0.056	87,870	97,046	123,773	126,439
2001	0.08	0.047	79,513	86,786	113,757	114,453
2002	0.07	0.034	72,958	78,609	106,494	105,382
2003	0.05	0.034	67,689	71,867	102,662	99,811
2004	0.05	0.022	62,896	65,737	100,619	96,076
2005	0.03	0.025	59,612	61,245	101,020	94,884
2006	0.03	0.019	57,254	57,623	101,645	94,014
2007	0.03	0.018	56,868	55,902	102,862	93,914
2008			58,125	55,876	104,116	94,795
2009				56,499		97,524

Table 5.11. Estimated beginning of year numbers of Greenland turbot by age and sex (millions).

Females

Yr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1978	18.13	22.21	16.71	30.60	12.93	19.47	13.94	8.91	3.42	2.38	1.86	1.51	18.07	1.04	0.93	0.82	0.70	51.09	0.47	0.40	3.02
1979	11.86	16.21	19.77	14.76	26.71	11.12	16.52	11.73	7.47	2.87	2.00	1.57	1.28	15.34	0.89	0.79	0.70	0.60	43.82	0.40	2.95
1980	7.59	10.60	14.43	17.46	12.87	22.94	9.42	13.86	9.81	6.25	2.40	1.69	1.32	1.08	13.02	0.76	0.68	0.60	0.52	37.52	2.89
1981	2.25	6.78	9.42	12.68	15.09	10.90	19.04	7.72	11.31	8.01	5.12	1.98	1.39	1.10	0.90	10.89	0.63	0.57	0.50	0.43	34.14
1982	2.66	2.01	6.02	8.25	10.89	12.63	8.90	15.33	6.18	9.06	6.44	4.14	1.61	1.14	0.90	0.74	9.00	0.53	0.47	0.42	28.93
1983	1.39	2.38	1.78	5.26	7.05	9.05	10.22	7.09	12.13	4.89	7.21	5.16	3.35	1.31	0.93	0.74	0.62	7.49	0.44	0.40	24.75
1984	3.31	1.24	2.13	1.59	4.70	6.25	7.88	8.63	5.79	9.65	3.84	5.64	4.06	2.65	1.05	0.75	0.60	0.50	6.13	0.36	20.94
1985	7.69	2.96	1.11	1.90	1.42	4.18	5.51	6.83	7.35	4.86	8.04	3.19	4.71	3.40	2.23	0.88	0.64	0.51	0.43	5.23	18.35
1986	2.44	6.87	2.64	0.99	1.70	1.27	3.70	4.83	5.91	6.31	4.15	6.86	2.73	4.03	2.92	1.92	0.76	0.55	0.44	0.37	20.57
1987	2.92	2.19	6.14	2.36	0.89	1.52	1.13	3.27	4.23	5.14	5.47	3.60	5.95	2.37	3.51	2.55	1.68	0.67	0.48	0.39	18.42
1988	2.51	2.61	1.95	5.49	2.11	0.79	1.35	0.99	2.86	3.68	4.46	4.75	3.13	5.18	2.07	3.06	2.23	1.47	0.58	0.42	16.56
1989	6.29	2.25	2.33	1.75	4.91	1.89	0.70	1.19	0.87	2.51	3.22	3.90	4.15	2.74	4.54	1.81	2.69	1.96	1.29	0.51	14.99
1990	2.42	5.63	2.01	2.08	1.56	4.38	1.68	0.62	1.05	0.76	2.18	2.79	3.39	3.61	2.38	3.96	1.58	2.35	1.71	1.13	13.65
1991	0.79	2.17	5.03	1.80	1.86	1.40	3.91	1.49	0.55	0.91	0.66	1.87	2.39	2.90	3.10	2.05	3.41	1.37	2.03	1.48	12.87
1992	0.71	0.70	1.94	4.50	1.61	1.67	1.25	3.49	1.32	0.48	0.80	0.57	1.62	2.08	2.52	2.69	1.78	2.97	1.19	1.77	12.56
1993	0.57	0.63	0.63	1.73	4.02	1.44	1.49	1.11	3.12	1.18	0.43	0.71	0.51	1.44	1.83	2.23	2.37	1.57	2.61	1.05	12.60
1994	1.04	0.51	0.57	0.56	1.55	3.59	1.28	1.33	0.99	2.77	1.05	0.38	0.62	0.44	1.25	1.59	1.92	2.04	1.35	2.24	11.70
1995	2.90	0.93	0.46	0.51	0.50	1.38	3.21	1.14	1.18	0.87	2.41	0.90	0.33	0.53	0.38	1.07	1.36	1.64	1.75	1.15	11.99
1996	1.21	2.60	0.83	0.41	0.45	0.45	1.24	2.86	1.02	1.04	0.76	2.10	0.79	0.28	0.46	0.33	0.92	1.17	1.41	1.50	11.31
1997	1.65	1.08	2.32	0.74	0.36	0.41	0.40	1.11	2.56	0.90	0.92	0.67	1.84	0.68	0.25	0.40	0.28	0.79	1.00	1.21	11.02
1998	1.62	1.48	0.97	2.08	0.66	0.33	0.36	0.36	0.99	2.28	0.80	0.81	0.59	1.60	0.59	0.21	0.34	0.24	0.68	0.86	10.41
1999	5.69	1.45	1.32	0.87	1.86	0.59	0.29	0.32	0.32	0.88	2.01	0.70	0.70	0.51	1.37	0.50	0.18	0.29	0.20	0.57	9.43
2000	7.19	5.08	1.29	1.18	0.77	1.66	0.53	0.26	0.29	0.29	0.77	1.76	0.61	0.61	0.44	1.18	0.43	0.15	0.25	0.17	8.56
2001	11.12	6.42	4.54	1.16	1.05	0.69	1.48	0.47	0.23	0.26	0.25	0.68	1.53	0.53	0.52	0.37	1.00	0.37	0.13	0.21	7.38
2002	2.22	9.94	5.74	4.06	1.03	0.94	0.62	1.33	0.42	0.21	0.23	0.22	0.59	1.32	0.45	0.45	0.32	0.85	0.31	0.11	6.51
2003	1.04	1.98	8.89	5.14	3.63	0.92	0.84	0.55	1.18	0.37	0.18	0.20	0.19	0.51	1.15	0.39	0.39	0.28	0.74	0.27	5.72
2004	1.14	0.93	1.77	7.95	4.59	3.25	0.83	0.75	0.49	1.05	0.33	0.16	0.17	0.17	0.44	0.99	0.34	0.33	0.24	0.64	5.15
2005	1.91	1.02	0.83	1.58	7.11	4.10	2.90	0.74	0.67	0.44	0.93	0.29	0.14	0.15	0.15	0.39	0.87	0.30	0.29	0.21	5.05
2006	16.80	1.71	0.91	0.75	1.42	6.35	3.67	2.60	0.66	0.60	0.39	0.82	0.26	0.12	0.13	0.13	0.34	0.75	0.26	0.25	4.55
2007	28.54	15.02	1.53	0.82	0.67	1.27	5.68	3.28	2.32	0.59	0.53	0.35	0.73	0.23	0.11	0.12	0.11	0.29	0.65	0.22	4.17
2008	5.76	25.51	13.43	1.37	0.73	0.60	1.13	5.08	2.93	2.07	0.52	0.47	0.31	0.64	0.20	0.09	0.10	0.10	0.26	0.57	3.83

Males

Yr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1978	18.13	22.21	16.71	30.55	12.82	18.99	13.18	7.99	2.84	1.79	1.24	0.88	9.26	0.47	0.37	0.29	0.23	14.76	0.12	0.09	0.15
1979	11.86	16.21	19.77	14.73	26.47	10.84	15.62	10.53	6.22	2.16	1.34	0.91	0.65	6.73	0.34	0.27	0.21	0.16	10.58	0.08	0.17
1980	7.59	10.60	14.43	17.41	12.74	22.33	8.88	12.41	8.15	4.71	1.60	0.98	0.66	0.47	4.82	0.24	0.19	0.15	0.12	7.48	0.18
1981	2.25	6.78	9.42	12.64	14.89	10.53	17.71	6.76	9.09	5.77	3.25	1.08	0.65	0.44	0.30	3.13	0.16	0.12	0.10	0.07	4.91
1982	2.66	2.01	6.02	8.22	10.71	12.10	8.13	12.99	4.72	6.10	3.74	2.05	0.67	0.40	0.26	0.18	1.87	0.09	0.07	0.06	2.94
1983	1.39	2.38	1.78	5.24	6.93	8.61	9.20	5.83	8.83	3.07	3.81	2.28	1.22	0.40	0.23	0.15	0.11	1.07	0.05	0.04	1.71
1984	3.31	1.24	2.13	1.59	4.68	6.13	7.43	7.56	4.47	6.23	1.99	2.30	1.29	0.66	0.21	0.12	0.08	0.05	0.53	0.03	0.84
1985	7.69	2.96	1.11	1.90	1.42	4.16	5.37	6.35	6.23	3.53	4.73	1.46	1.64	0.90	0.46	0.14	0.08	0.05	0.03	0.35	0.57
1986	2.44	6.87	2.64	0.99	1.70	1.27	3.67	4.66	5.38	5.14	2.85	3.73	1.13	1.26	0.69	0.35	0.11	0.06	0.04	0.03	0.69
1987	2.92	2.19	6.14	2.36	0.89	1.52	1.12	3.22	4.02	4.56	4.29	2.34	3.04	0.91	1.01	0.55	0.28	0.08	0.05	0.03	0.57
1988	2.51	2.61	1.95	5.49	2.11	0.79	1.34	0.98	2.78	3.42	3.81	3.54	1.91	2.46	0.74	0.81	0.44	0.22	0.07	0.04	0.47
1989	6.29	2.25	2.33	1.75	4.91	1.88	0.70	1.19	0.86	2.39	2.91	3.21	2.96	1.59	2.03	0.61	0.67	0.36	0.18	0.06	0.42
1990	2.42	5.63	2.01	2.08	1.56	4.38	1.67	0.62	1.03	0.73	2.01	2.41	2.63	2.41	1.29	1.64	0.49	0.54	0.29	0.14	0.38
1991	0.79	2.17	5.03	1.80	1.86	1.40	3.91	1.49	0.54	0.88	0.61	1.63	1.92	2.06	1.85	0.98	1.24	0.37	0.40	0.22	0.39
1992	0.71	0.70	1.94	4.50	1.61	1.67	1.25	3.49	1.32	0.47	0.76	0.52	1.37	1.58	1.69	1.51	0.79	1.00	0.30	0.32	0.48
1993	0.57	0.63	0.63	1.73	4.02	1.44	1.49	1.11	3.11	1.17	0.42	0.67	0.46	1.20	1.39	1.47	1.32	0.69	0.87	0.26	0.70
1994	1.04	0.51	0.57	0.56	1.55	3.59	1.28	1.33	0.99	2.76	1.03	0.37	0.58	0.39	1.03	1.18	1.25	1.11	0.58	0.74	0.81
1995	2.90	0.93	0.46	0.51	0.50	1.38	3.21	1.14	1.17	0.86	2.35	0.86	0.30	0.47	0.31	0.81	0.93	0.98	0.87	0.45	1.19
1996	1.21	2.60	0.83	0.41	0.45	0.45	1.24	2.86	1.01	1.03	0.74	2.00	0.72	0.25	0.39	0.26	0.66	0.75	0.78	0.69	1.31
1997	1.65	1.08	2.32	0.74	0.36	0.41	0.40	1.11	2.56	0.90	0.91	0.65	1.72	0.62	0.21	0.32	0.21	0.55	0.62	0.65	1.66
1998	1.62	1.48	0.97	2.08	0.66	0.33	0.36	0.36	0.99	2.27	0.79	0.79	0.56	1.48	0.52	0.18	0.27	0.18	0.46	0.52	1.92
1999	5.69	1.45	1.32	0.87	1.86	0.59	0.29	0.32	0.32	0.88	1.99	0.69	0.67	0.47	1.22	0.43	0.15	0.22	0.14	0.37	1.95
2000	7.19	5.08	1.29	1.18	0.77	1.66	0.53	0.26	0.29	0.28	0.77	1.73	0.59	0.57	0.40	1.02	0.36	0.12	0.18	0.12	1.88
2001	11.12	6.42	4.54	1.16	1.05	0.69	1.48	0.47	0.23	0.26	0.25	0.66	1.47	0.49	0.47	0.32	0.83	0.29	0.10	0.14	1.59
2002	2.22	9.94	5.74	4.06	1.03	0.94	0.62	1.33	0.42	0.21	0.22	0.21	0.56	1.22	0.40	0.38	0.26	0.67	0.23	0.08	1.38
2003	1.04	1.98	8.89	5.14	3.63	0.92	0.84	0.55	1.18	0.37	0.18	0.20	0.19	0.48	1.04	0.34	0.32	0.22	0.56	0.19	1.21
2004	1.14	0.93	1.77	7.95	4.59	3.25	0.83	0.75	0.49	1.05	0.33	0.16	0.17	0.16	0.41	0.88	0.29	0.27	0.18	0.46	1.16
2005	1.91	1.02	0.83	1.58	7.11	4.10	2.90	0.74	0.67	0.44	0.93	0.29	0.14	0.15	0.14	0.35	0.75	0.24	0.23	0.16	1.38
2006	16.80	1.71	0.91	0.75	1.42	6.35	3.67	2.60	0.66	0.60	0.39	0.82	0.25	0.12	0.13	0.12	0.30	0.63	0.21	0.19	1.29
2007	28.54	15.02	1.53	0.82	0.67	1.27	5.68	3.28	2.32	0.59	0.53	0.34	0.72	0.22	0.10	0.11	0.10	0.26	0.54	0.18	1.26
2008	5.76	25.51	13.43	1.37	0.73	0.60	1.13	5.08	2.93	2.06	0.52	0.47	0.30	0.62	0.19	0.09	0.09	0.09	0.22	0.47	1.23

Table 5.12. Age-equivalent sex-specific selectivity estimates (as estimated for 2008) from each gear type for Greenland turbot in the BSAI. Note that selectivity processes are modeled as a function of size and that some selectivities-at-length are allowed to vary over time.

	Trawl Fishery		Longline fishery		Shelf Survey		Slope survey		Longline survey	
Age	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
1	0.000	0.000	0.000	0.000	0.518	0.520	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.834	0.873	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.910	0.992	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.879	0.996	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.848	0.986	0.000	0.002	0.000	0.000
6	0.004	0.003	0.000	0.003	0.837	0.974	0.004	0.014	0.000	0.001
7	0.026	0.022	0.003	0.013	0.830	0.961	0.020	0.052	0.000	0.010
8	0.081	0.083	0.015	0.039	0.822	0.948	0.056	0.124	0.001	0.047
9	0.151	0.189	0.048	0.086	0.812	0.935	0.110	0.226	0.009	0.124
10	0.200	0.321	0.111	0.153	0.801	0.923	0.169	0.341	0.032	0.232
11	0.217	0.449	0.203	0.231	0.791	0.911	0.219	0.452	0.075	0.347
12	0.212	0.557	0.311	0.311	0.780	0.901	0.254	0.548	0.131	0.447
13	0.196	0.640	0.417	0.386	0.770	0.892	0.276	0.624	0.187	0.524
14	0.176	0.700	0.510	0.453	0.760	0.884	0.289	0.683	0.234	0.576
15	0.157	0.742	0.584	0.509	0.751	0.877	0.296	0.726	0.269	0.608
16	0.140	0.770	0.641	0.556	0.743	0.871	0.300	0.757	0.295	0.625
17	0.125	0.789	0.682	0.593	0.735	0.866	0.302	0.780	0.313	0.632
18	0.112	0.801	0.712	0.623	0.728	0.861	0.303	0.795	0.325	0.632
19	0.100	0.808	0.732	0.647	0.721	0.857	0.304	0.806	0.333	0.628
20	0.091	0.812	0.746	0.666	0.715	0.854	0.304	0.814	0.338	0.622
21	0.083	0.814	0.756	0.681	0.709	0.851	0.305	0.820	0.342	0.615
22	0.076	0.815	0.762	0.692	0.705	0.848	0.305	0.823	0.345	0.608
23	0.070	0.815	0.766	0.702	0.700	0.846	0.305	0.826	0.347	0.601
24	0.065	0.815	0.769	0.709	0.696	0.844	0.305	0.828	0.349	0.594
25	0.061	0.814	0.770	0.715	0.693	0.843	0.305	0.829	0.350	0.588
26	0.058	0.813	0.771	0.720	0.690	0.841	0.305	0.830	0.351	0.583
27	0.055	0.812	0.771	0.724	0.687	0.840	0.305	0.831	0.351	0.578
28	0.052	0.812	0.771	0.727	0.684	0.839	0.305	0.831	0.352	0.574
29	0.050	0.811	0.771	0.730	0.682	0.838	0.305	0.831	0.352	0.570
30	0.048	0.810	0.770	0.732	0.680	0.837	0.305	0.831	0.352	0.567

Table 5.13. Age and sex-specific mean length and weights-at-age estimates for BSAI Greenland turbot.

	Mid-year **length** (cm)		Mid-year **weight** (kg)	
Age	Females	Males	Females	Males
1	13.90	13.90	0.014	0.014
2	22.64	22.50	0.086	0.084
3	30.42	29.85	0.230	0.217
4	37.33	36.16	0.456	0.411
5	43.48	41.55	0.758	0.655
6	48.95	46.18	1.127	0.933
7	53.81	50.14	1.547	1.230
8	58.14	53.53	2.003	1.532
9	61.99	56.43	2.482	1.830
10	65.41	58.92	2.973	2.115
11	68.46	61.05	3.467	2.383
12	71.16	62.87	3.955	2.632
13	73.57	64.44	4.424	2.860
14	75.71	65.77	4.870	3.067
15	77.62	66.92	5.293	3.252
16	79.31	67.90	5.694	3.417
17	80.82	68.74	6.074	3.563
18	82.16	69.46	6.431	3.691
19	83.35	70.08	6.763	3.803
20	84.41	70.61	7.069	3.901
21	85.36	71.06	7.348	3.987
22	86.20	71.45	7.601	4.061
23	86.94	71.78	7.830	4.125
24	87.60	72.06	8.035	4.181
25	88.19	72.31	8.218	4.229
26	88.72	72.51	8.383	4.270
27	89.19	72.69	8.530	4.305
28	89.60	72.85	8.661	4.336
29	89.97	72.98	8.778	4.362
30	90.30	73.09	8.883	4.385

Table 5.14. Estimated total Greenland turbot harvest by area, 1977-2008. Values for 2008 are through Nov. 4th, 2008 and are preliminary.

Year	EBS	Aleutians	Year	EBS	Aleutians
1977	27,708	2,453	1993	4,878	6,330
1978	37,423	4,766	1994	3,875	7,141
1979	34,998	6,411	1995	4,499	5,855
1980	48,856	3,697	1996	4,258	4,844
1981	52,921	4,400	1997	5,730	6,435
1982	45,805	6,317	1998	7,839	8,329
1983	43,443	4,115	1999	5,179	5,391
1984	21,317	1,803	2000	5,667	5,888
1985	14,698	33	2001	4,102	4,252
1986	7,710	2,154	2002	3,011	3,153
1987	6,519	3,066	2003	2,467	960
1988	6,064	1,044	2004	1,805	414
1989	4,061	4,761	2005	2,120	439
1990	7,702	2,494	2006	1,440	525
1991	3,781	4,397	2007	1,313	516
1992	1,767	2,462	2008	1,949	592

Table 5.15. Mean spawning biomass, F, and yield projections for Greenland turbot, 2008-2021. The full-selection fishing mortality rates (*F's*) between longline and trawl gears were assumed to be **50:50** (whereas recent averages are around 80:20). The values for $B_{40\%}$ and $B_{35\%}$ are 43,731 and 38,265 tons, respectively.

Catch	*Max* F_{ABC}	*0.6*F_{ABC}	*5-year avg.*	$F_{75\%}$	*No Fishing*	*Scenario 6*	*Scenario 7*
2008	2,541	2,541	2,541	2,541	2,541	2,541	2,541
2009	11,868	7,382	2,590	2,581	0	14,845	11,868
2010	10,756	7,132	2,673	2,663	0	12,878	10,756
2011	10,000	6,991	2,774	2,764	0	11,553	12,534
2012	9,136	6,821	2,856	2,846	0	9,418	10,623
2013	8,462	6,641	2,926	2,916	0	8,629	9,356
2014	8,537	6,683	3,056	3,046	0	9,279	9,720
2015	9,209	7,190	3,328	3,317	0	10,292	10,460
2016	10,597	8,116	3,736	3,724	0	11,975	12,089
2017	12,140	9,185	4,205	4,192	0	13,775	13,851
2018	13,331	10,124	4,658	4,643	0	15,015	15,066
2019	13,927	10,768	5,039	5,024	0	15,433	15,468
2020	13,938	11,067	5,319	5,303	0	15,061	15,087
2021	13,510	11,069	5,494	5,477	0	14,166	14,185

Fishing Mort	*Max* F_{ABC}	*0.6*F_{ABC}	*5-year avg.*	$F_{75\%}$	*No Fishing*	*Scenario 6*	*Scenario 7*
2008	0.088	0.088	0.088	0.088	0.088	0.088	0.088
2009	0.441	0.265	0.090	0.089	0.000	0.566	0.441
2010	0.441	0.265	0.090	0.089	0.000	0.566	0.441
2011	0.441	0.265	0.090	0.089	0.000	0.565	0.566
2012	0.433	0.265	0.090	0.089	0.000	0.506	0.536
2013	0.429	0.265	0.090	0.089	0.000	0.501	0.520
2014	0.441	0.265	0.090	0.089	0.000	0.552	0.563
2015	0.441	0.265	0.090	0.089	0.000	0.566	0.566
2016	0.441	0.265	0.090	0.089	0.000	0.566	0.566
2017	0.441	0.265	0.090	0.089	0.000	0.566	0.566
2018	0.441	0.265	0.090	0.089	0.000	0.566	0.566
2019	0.441	0.265	0.090	0.089	0.000	0.566	0.566
2020	0.441	0.265	0.090	0.089	0.000	0.562	0.562
2021	0.440	0.265	0.090	0.089	0.000	0.552	0.552

Spawning biomass	*Max* F_{ABC}	*0.6*F_{ABC}	*5-year avg.*	$F_{75\%}$	*No Fishing*	*Scenario 6*	*Scenario 7*
2008	56,433	56,433	56,433	56,433	56,433	56,433	56,433
2009	56,803	56,803	56,803	56,803	56,803	56,803	56,803
2010	51,419	54,024	56,780	56,786	58,260	49,679	51,419
2011	46,568	51,099	56,188	56,199	59,044	43,688	46,568
2012	42,968	48,951	56,050	56,065	60,207	39,343	41,555
2013	42,590	49,558	58,385	58,404	63,767	38,962	40,390
2014	46,342	53,964	64,255	64,278	70,786	42,792	43,715
2015	52,210	60,425	71,998	72,025	79,627	48,457	49,050
2016	57,529	66,330	79,171	79,201	87,921	53,444	53,869
2017	60,934	70,490	84,751	84,785	94,722	56,398	56,700
2018	62,359	72,878	88,766	88,804	100,090	57,240	57,454
2019	62,163	73,779	91,464	91,507	104,265	56,402	56,553
2020	60,806	73,526	93,081	93,129	107,443	54,446	54,553
2021	58,815	72,522	93,908	93,961	109,868	52,023	52,096

Table 5.16. Summary management values based on this assessment. Note that the fishing mortality rates assume 50:50 contribution from longline gear and trawl gear.

Management Parameter	Value
M (natural mortality)	0.112 yr^{-1}
Amendment 56 Tier (in 2009)	3a
Approximate age at full recruitment	10 years
$F_{35\%}$ (F_{OFL})	0.566
$F_{40\%}$	0.462
$B_{100\%}$	109,328 t
$B_{40\%}$	43,731 t
$B_{35\%}$	38,265 t
Year 2008 female spawning biomass	56,433 t
Year 2008 total (age 1+) biomass	99,471 t
$F_{ABC} = F_{40\%}$ (max permissible)	0.462
2009 Maximum permissible ABC	11,900 t
2010 Maximum permissible ABC	10,800 t
F_{ABC} = *60% of Max Permissible*	0.27
Recommended ABC: 2009	7,380 t
2010	7,130 t
$F_{overfishing} = F_{35\%}$	0.566
2009 Greenland turbot OFL	14,800 t
2010 Greenland turbot OFL	14,400 t

Figures

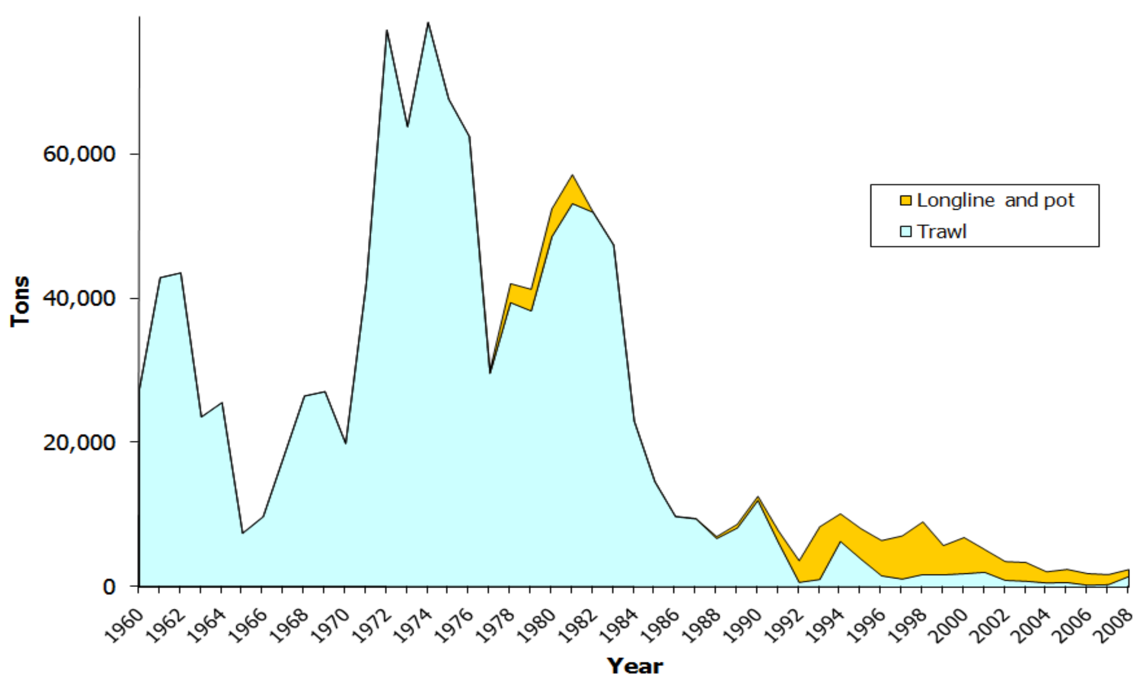


Figure 5.1. Trawl and longline catches of Greenland turbot in the combined EBS/AI area, 1960-2008.

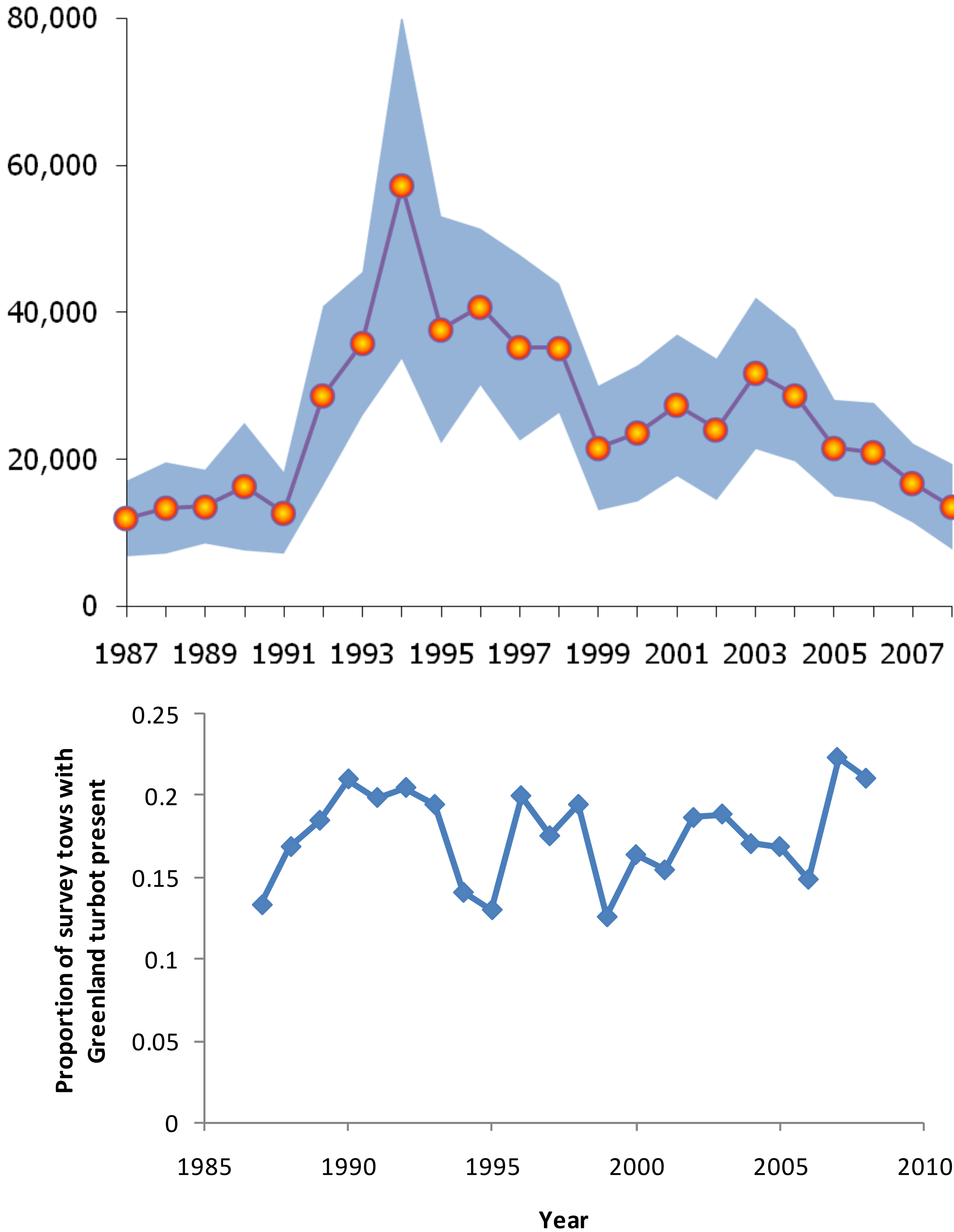


Figure 5.2. Survey biomass estimates of Greenland turbot from the EBS shelf trawl survey (top) and the proportion of tows that caught at least one Greenland turbot (bottom), 1982-2008.

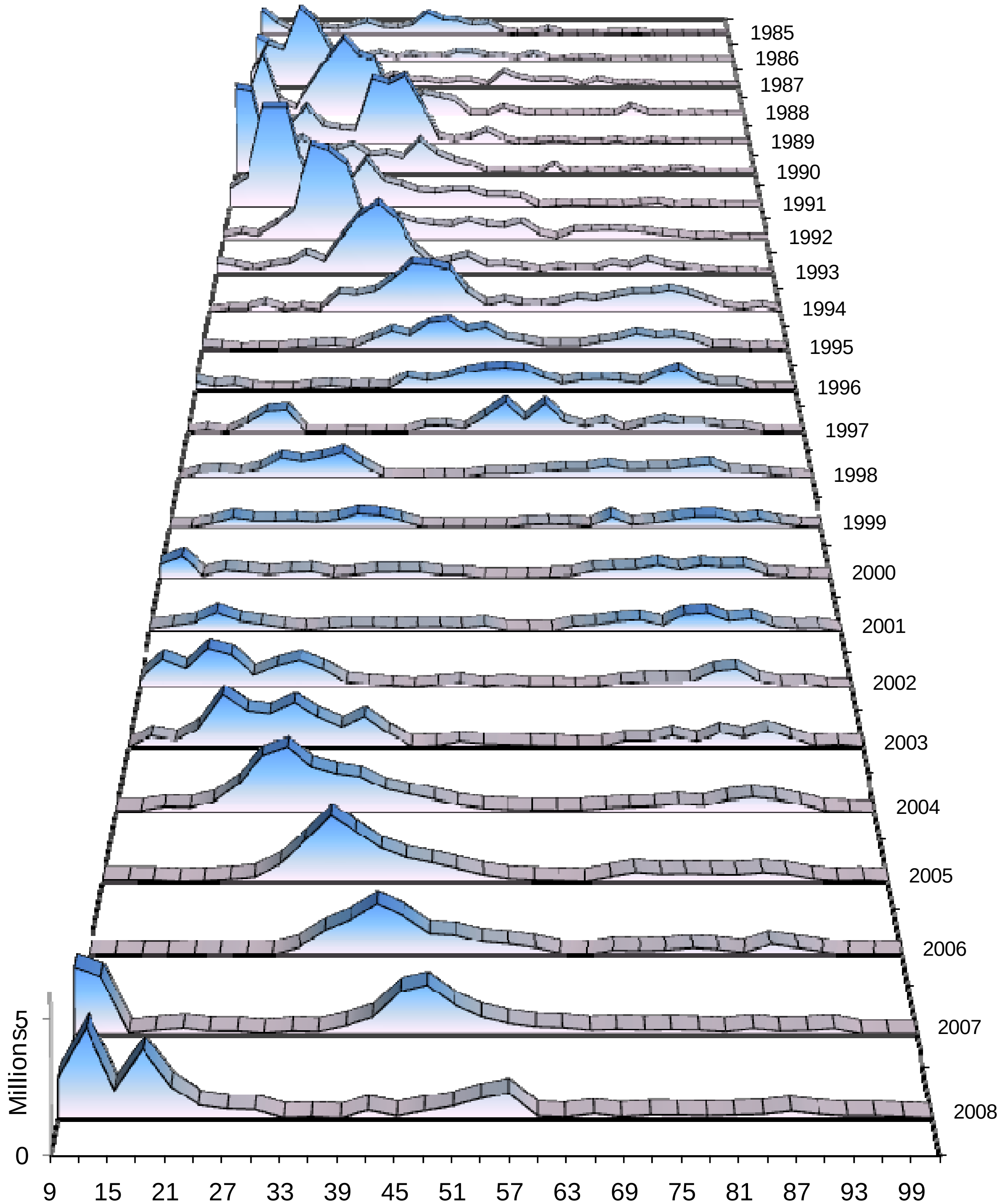


Figure 5.3. Abundance-at-length (cm) for Greenland turbot observed from the summer NMFS shelf trawl surveys, 1985-2008 (sexes combined, all strata except for 1986 where only strata 1-6 were sampled).

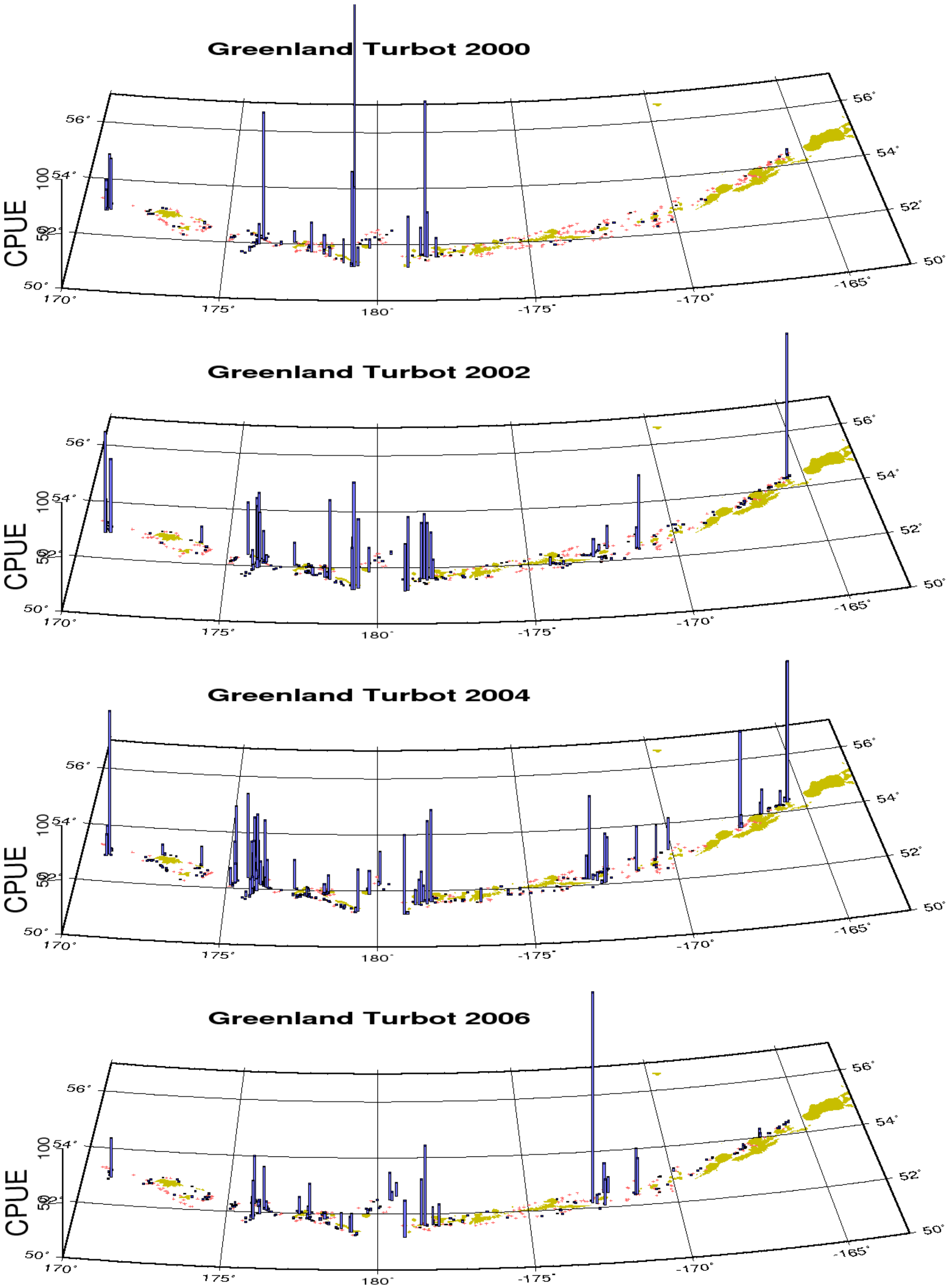


Figure 5.4. Greenland turbot catch per unit effort (relative values by weight, vertical bars) from the Aleutian Islands region bottom trawl survey, 2000-2006.

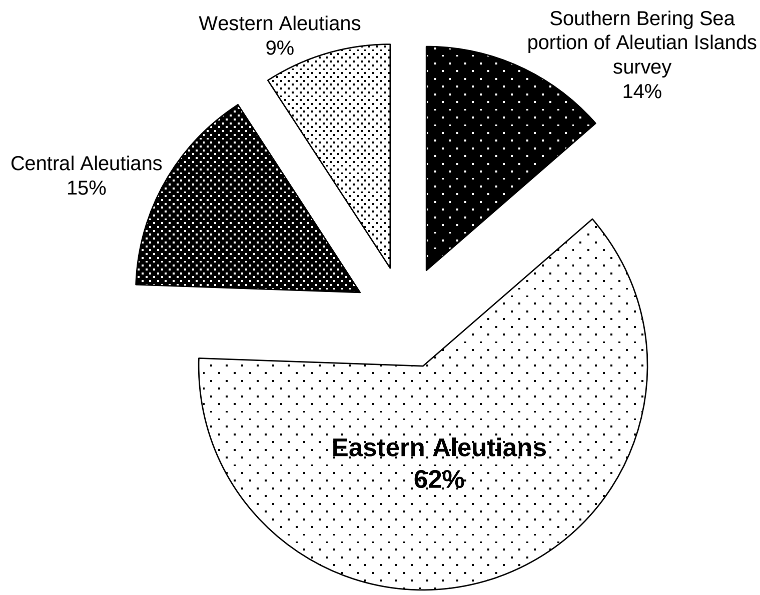


Figure 5.5. Average Greenland turbot relative biomass from the Aleutian Islands surveys by region, 1980-2006.

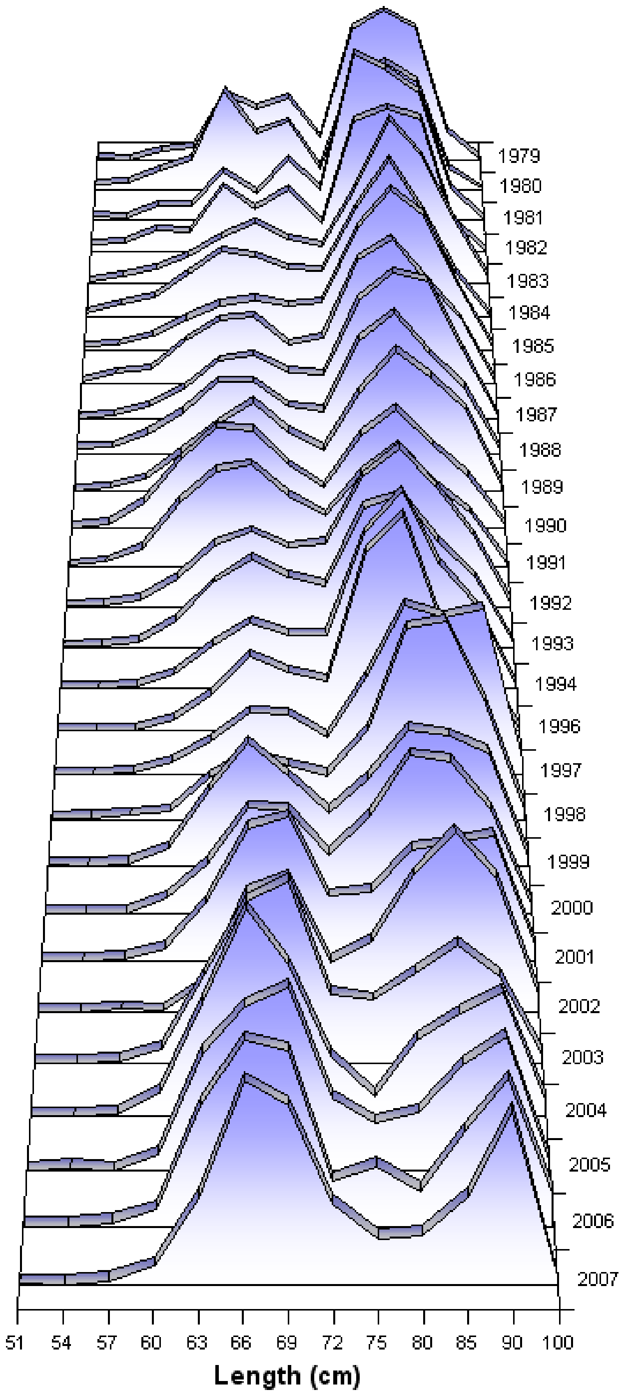


Figure 5.6. Longline survey Greenland turbot proportions at length over time (sexes combined) as used in the model.

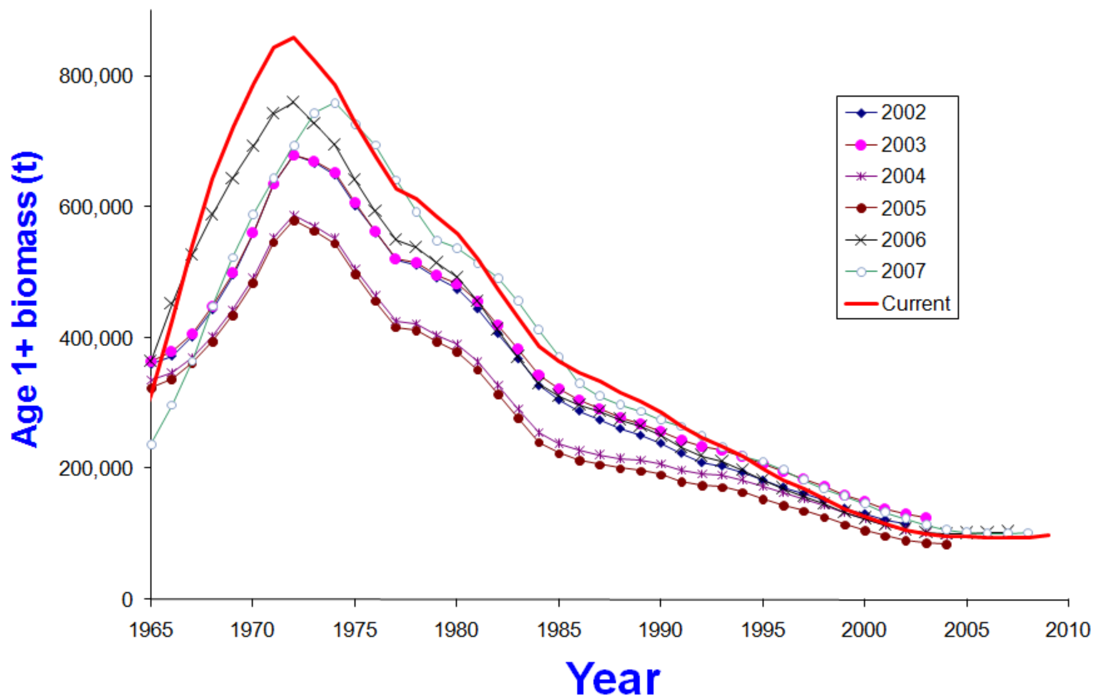


Figure 5.7 Current assessment estimates of total age 1+ biomass for Greenland turbot in the BSAI region, 1965-2009 compared to previous assessments.

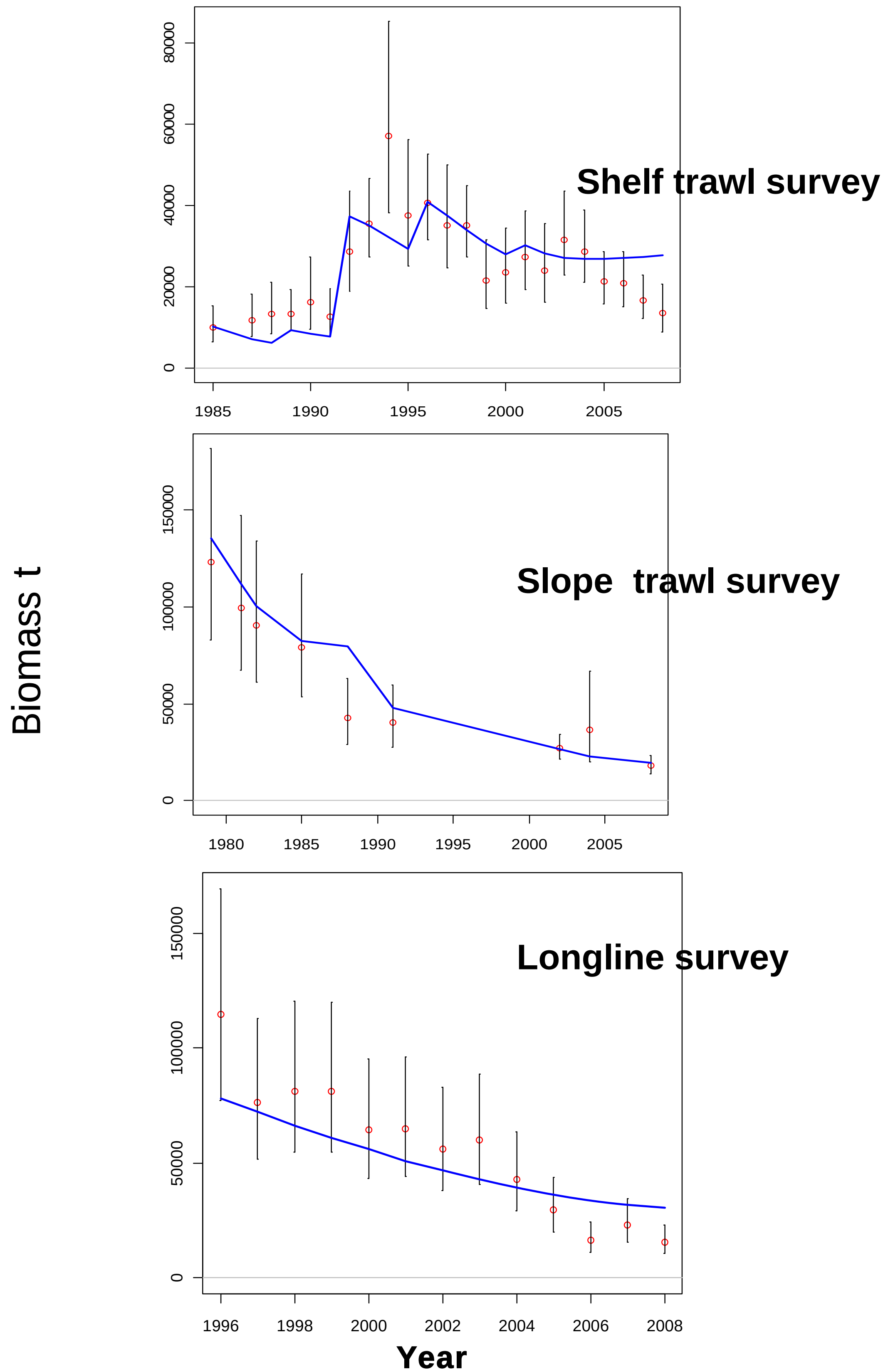


Figure 5.8. Fits to the EBS shelf trawl survey (top), the EBS slope survey (middle) and longline survey (bottom) indices for Greenland turbot in the EBS/AI region.

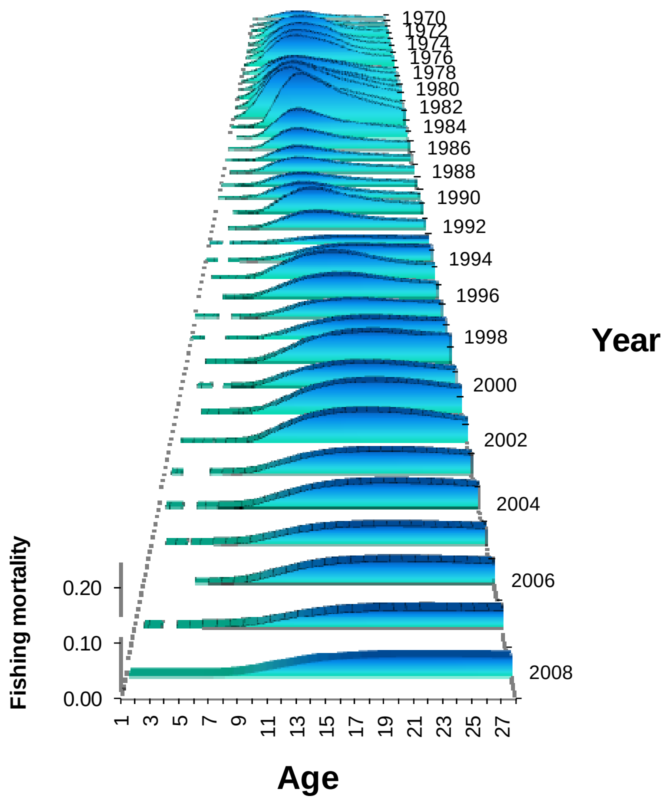


Figure 5.9. Estimated total age-specific fishing mortality rate (gears and sexes combined) for BSAI Greenland turbot, 1970-2008.

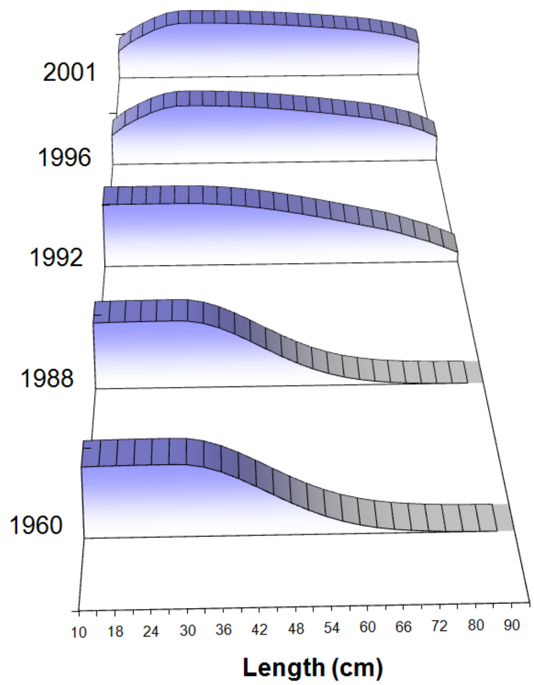


Figure 5.10. Average size-specific selectivity patterns for EBS shelf surveys over time as estimated for female Greenland turbot. The year represents the first year in which the corresponding selectivity estimate was invoked.

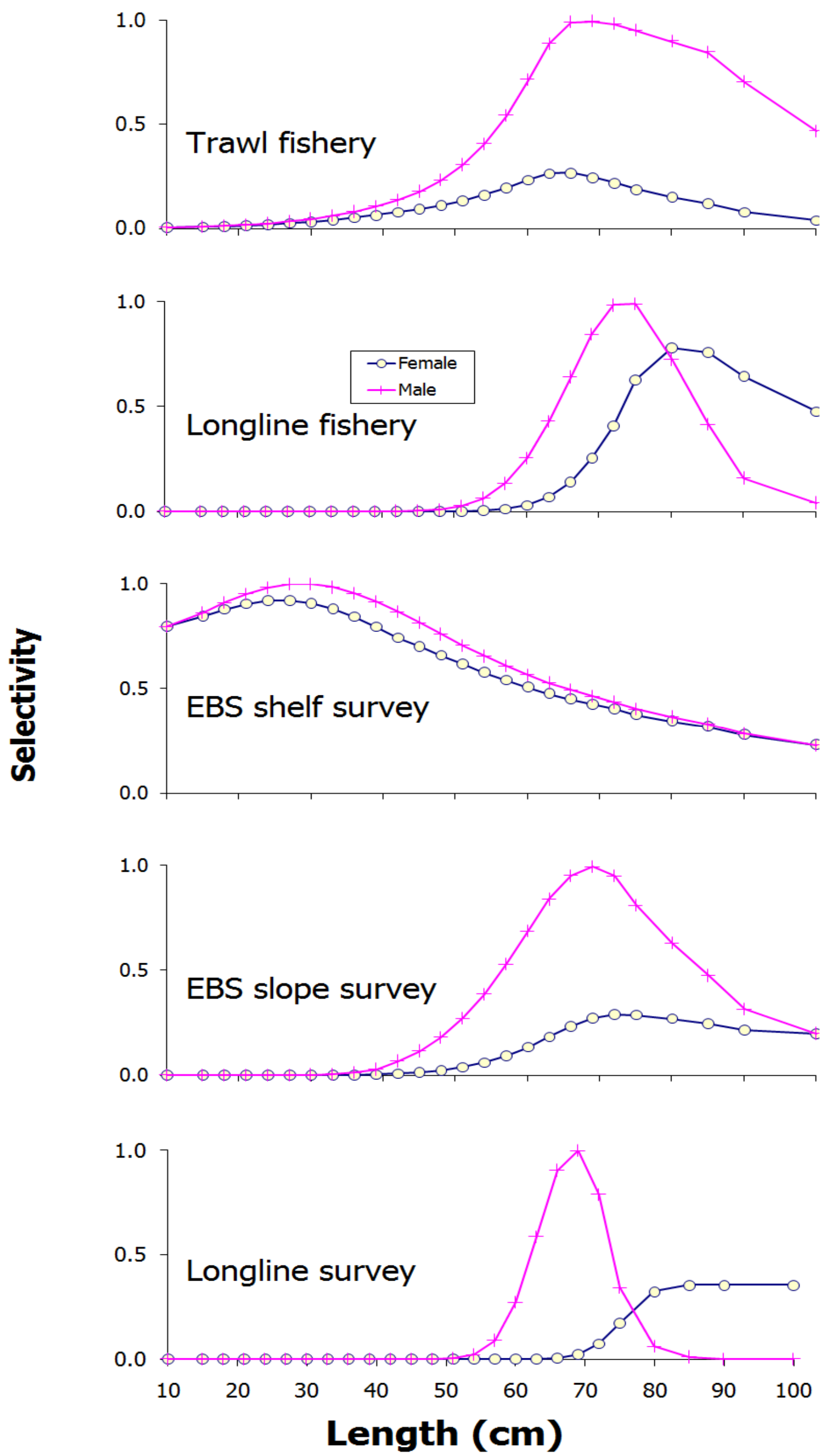


Figure 5.11. Average (over time) size-specific selectivity patterns for all fisheries and surveys for EBS Greenland turbot showing differences in sex-specific availability.

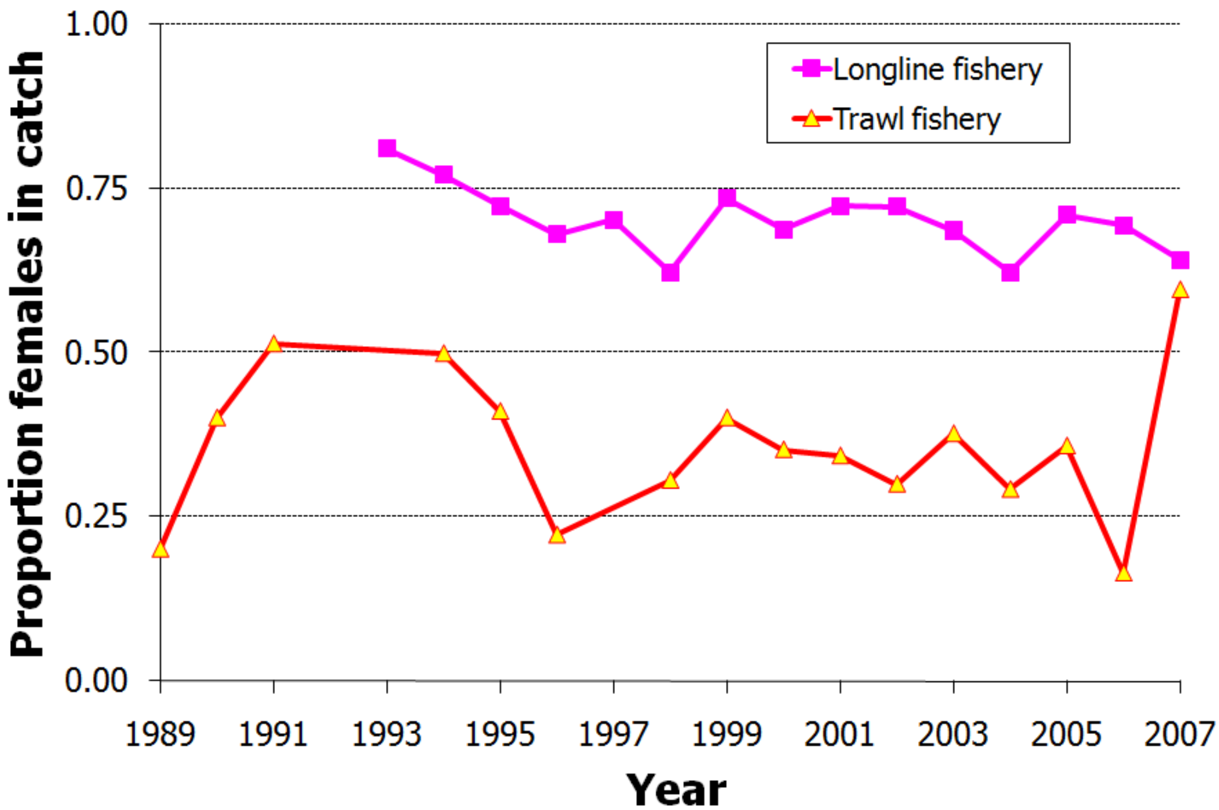


Figure 5.12. Observed Greenland turbot sex ratio over time from the BSAI region trawl and longline fisheries.

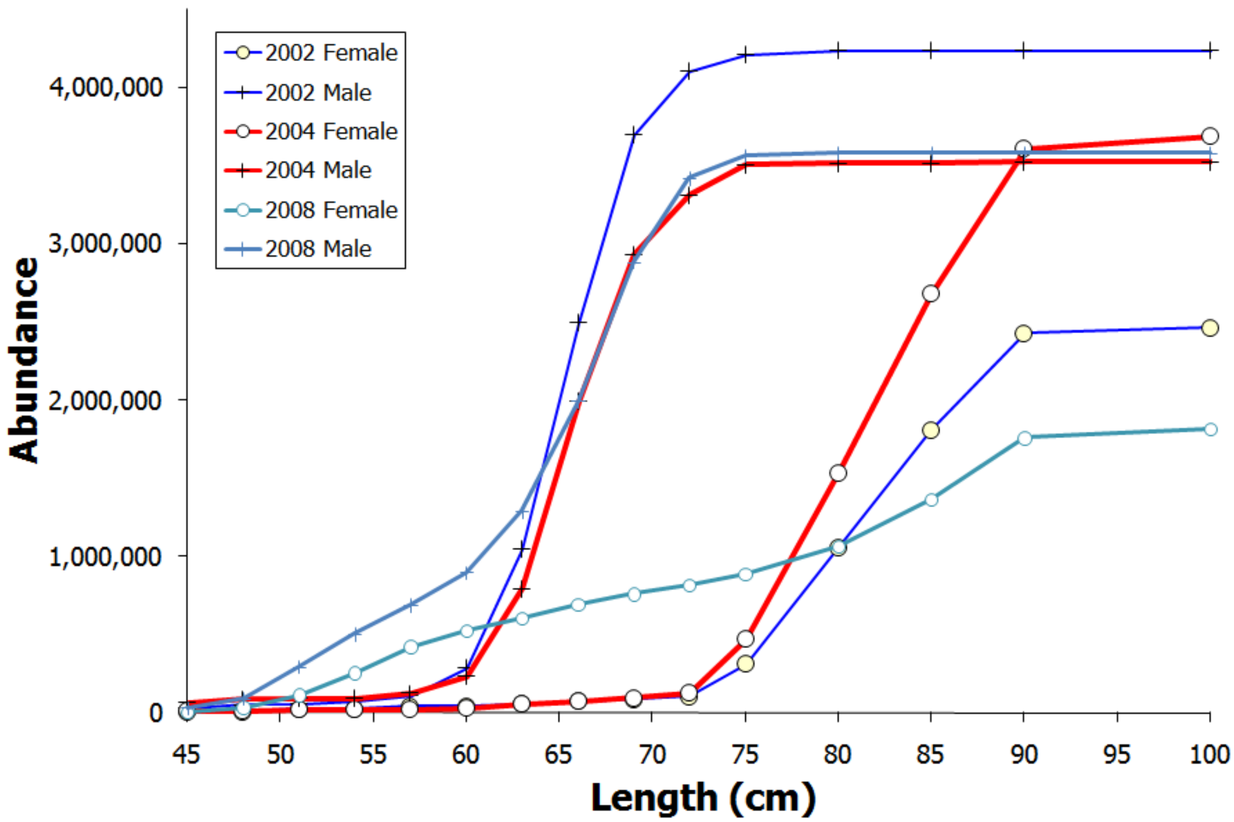


Figure 5.13. EBS slope trawl survey estimates of Greenland turbot cumulative abundance-at-length by sex for 2002, 2004, and 2008.

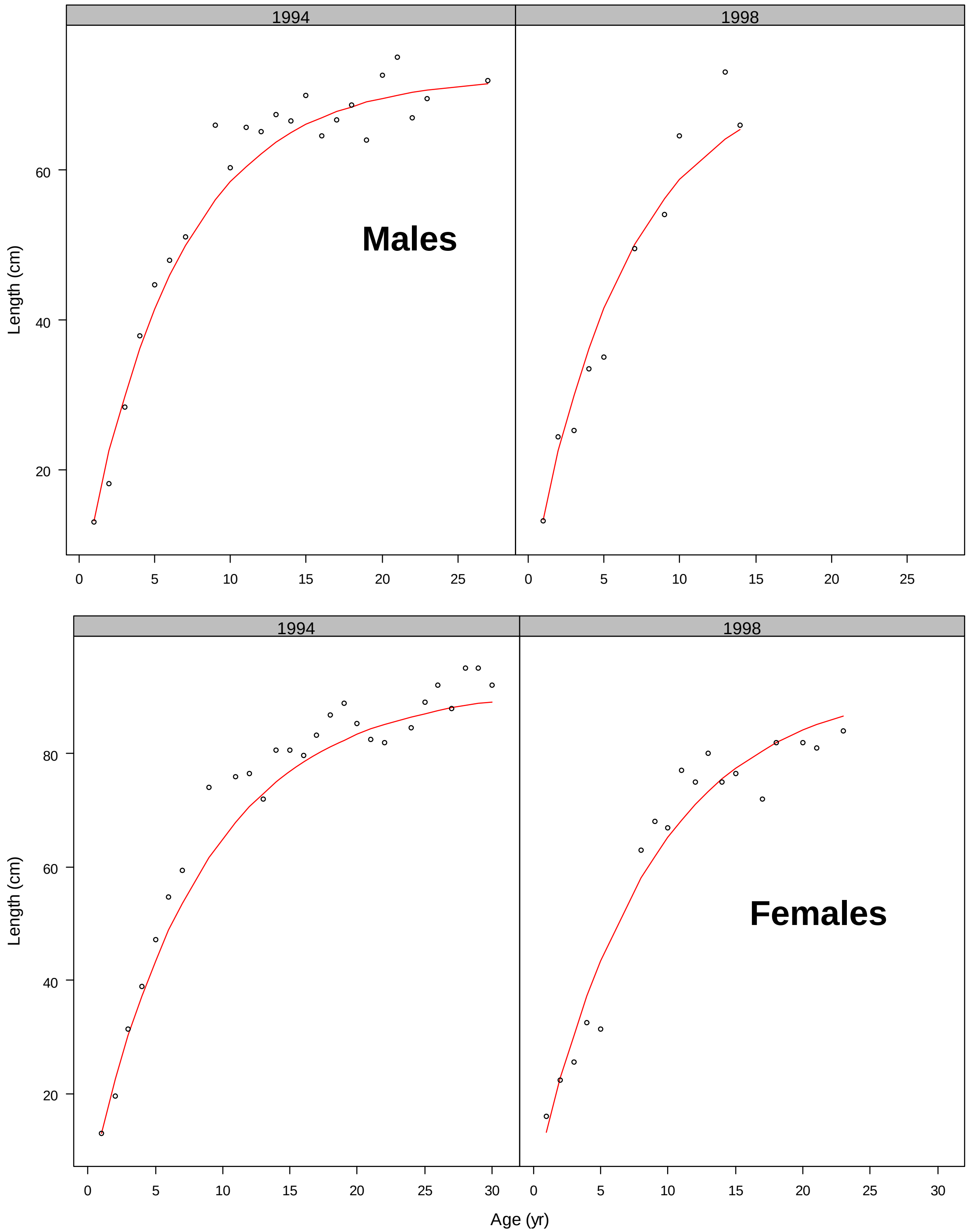


Figure 5.14. Estimated growth (length at age) of Greenland turbot by sex in the EBS/AI region as predicted by the model and compared to the new age data using the methods of Gregg et al (2006).

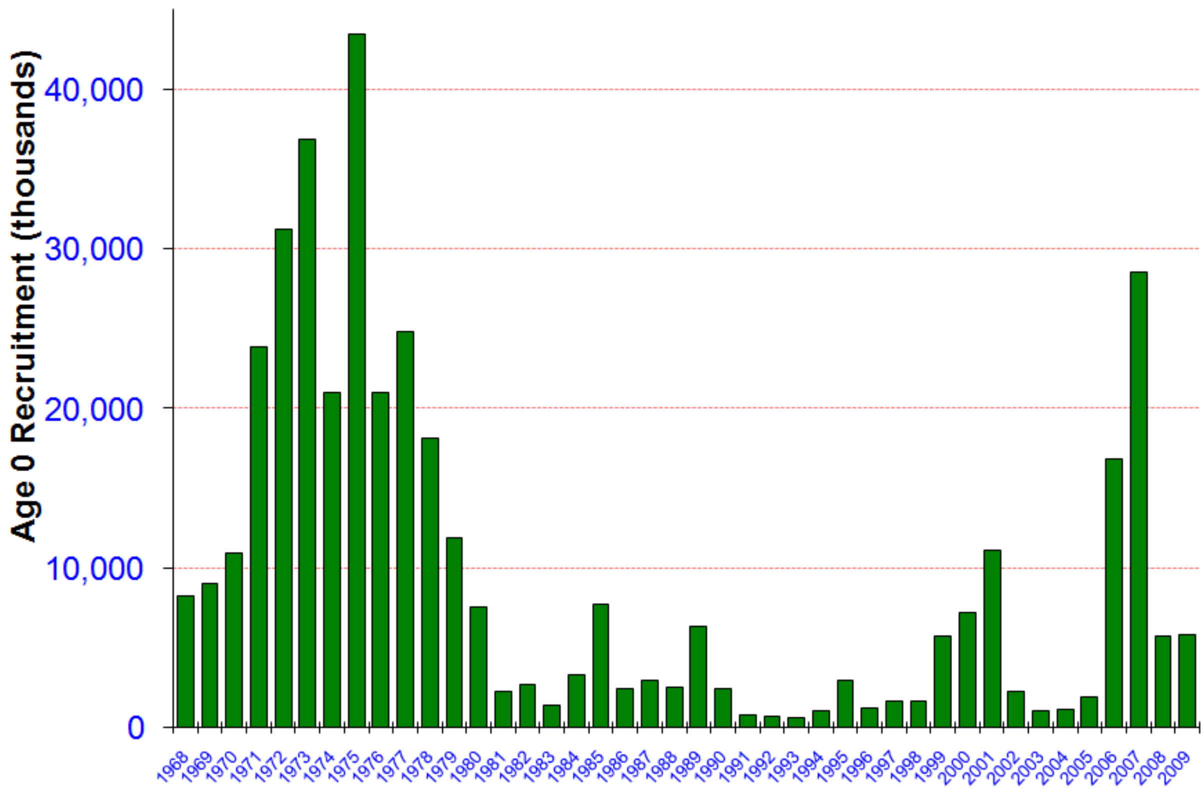


Figure 5.15. Estimated recruitment at age 0 (thousands) for Greenland turbot in the EBS/AI region, 1968-2009.

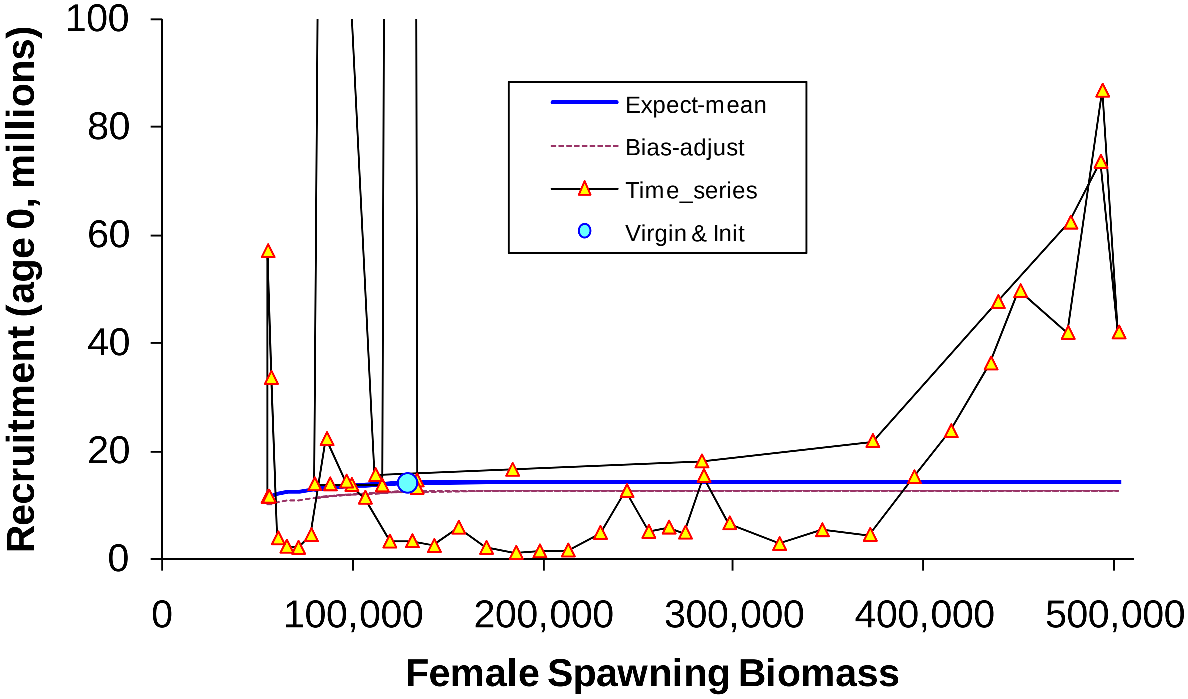


Figure 5.16. Stock and recruitment estimates compared to fixed model shape (steepness) specified within SS2 for Greenland turbot in the BSAI region, 1960-2008.

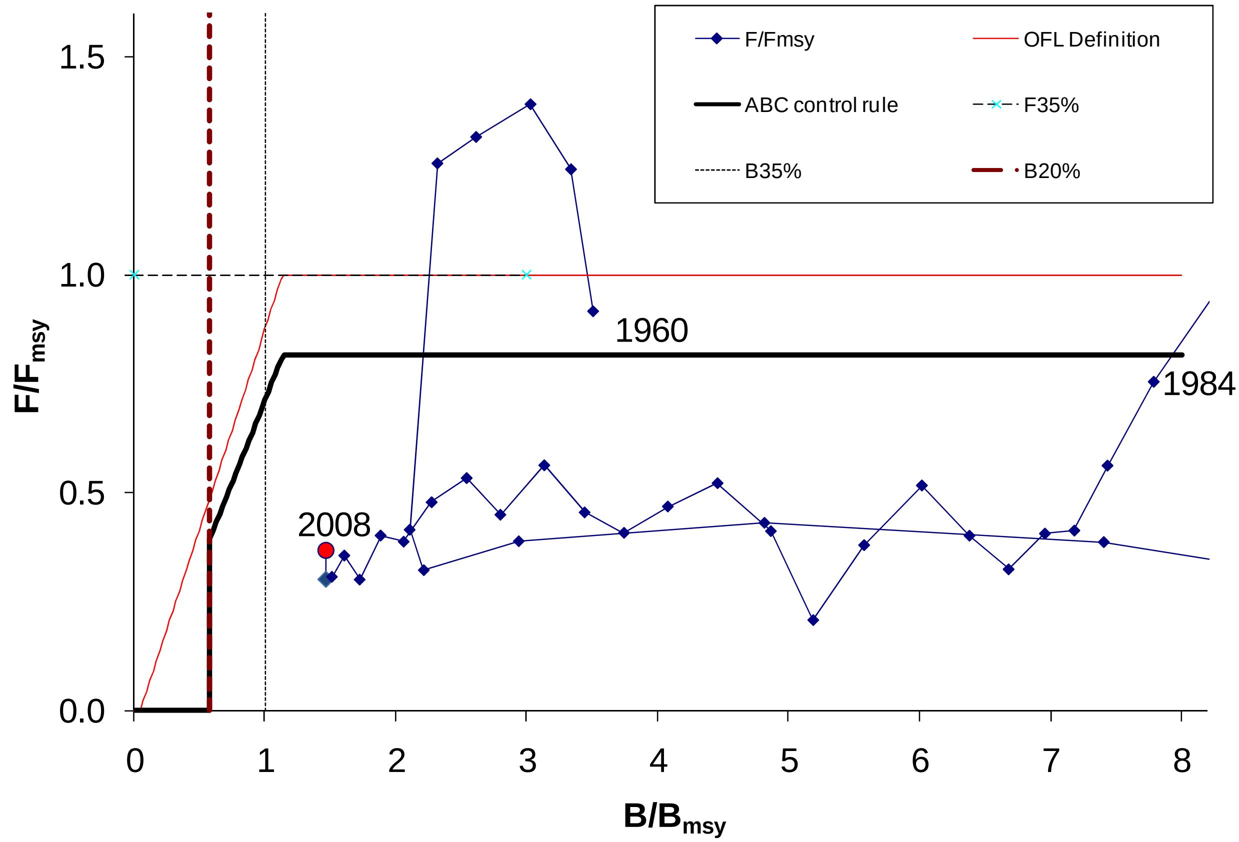
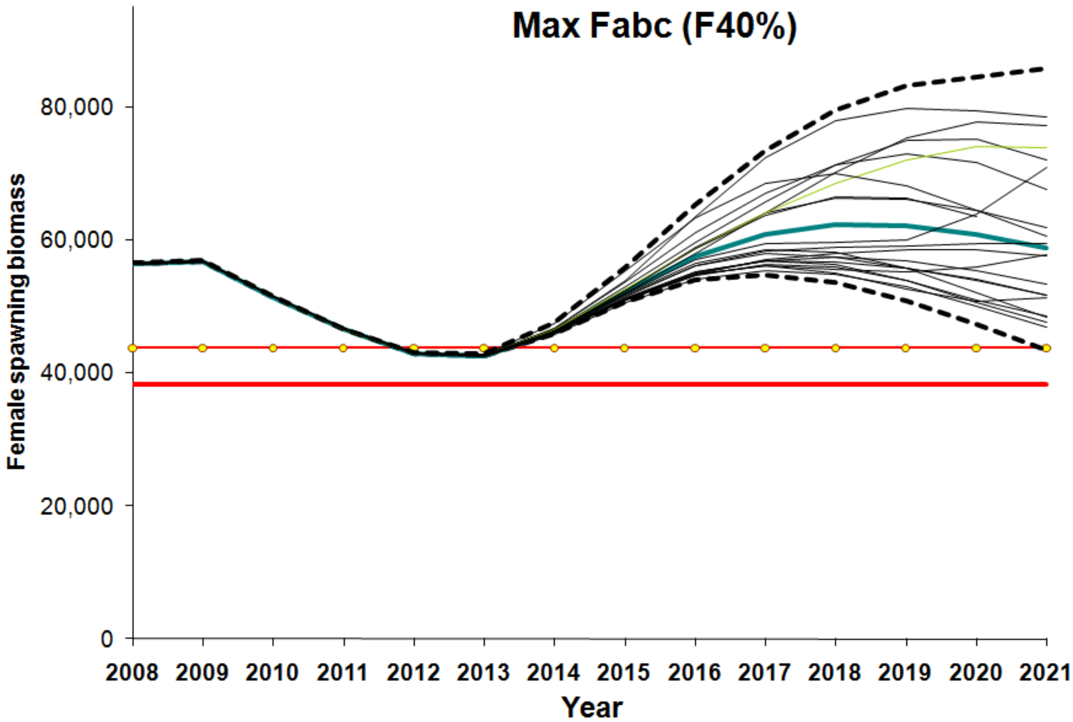


Figure 5.17. Ratio of historical F/F_{msy} versus female spawning biomass relative to B_{msy} for BSAI Greenland turbot, 1960-2008. Note that the proxies for F_{msy} and B_{msy} are $F_{35\%}$ and $B_{35\%}$, respectively.



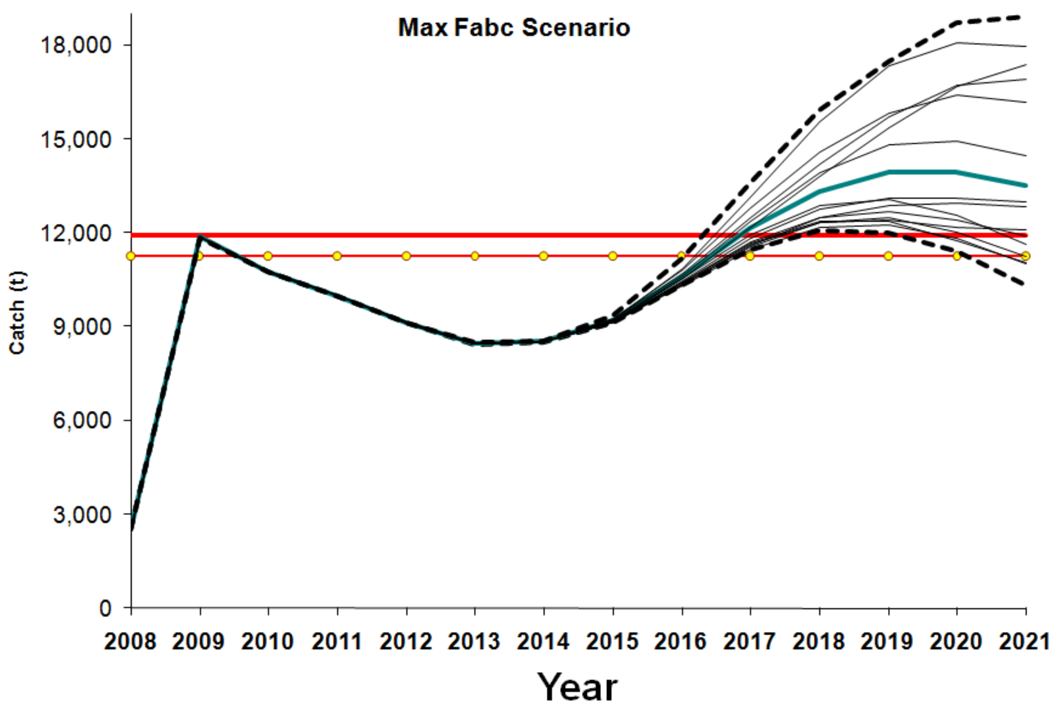


Figure 5.18. Stochastic trajectory of Greenland turbot female spawning biomass and catch for the maximum allowable fishing mortality rate under Amendment 56/56, Tier 3. The dotted lines represent the upper and lower 90% confidence limits. Horizontal lines with marks are the values associated with $B_{40\%}$ and $F_{40\%}$ while the thick horizontal line is the expected value under constant F_{OFL} rate ($F_{35\%}$).

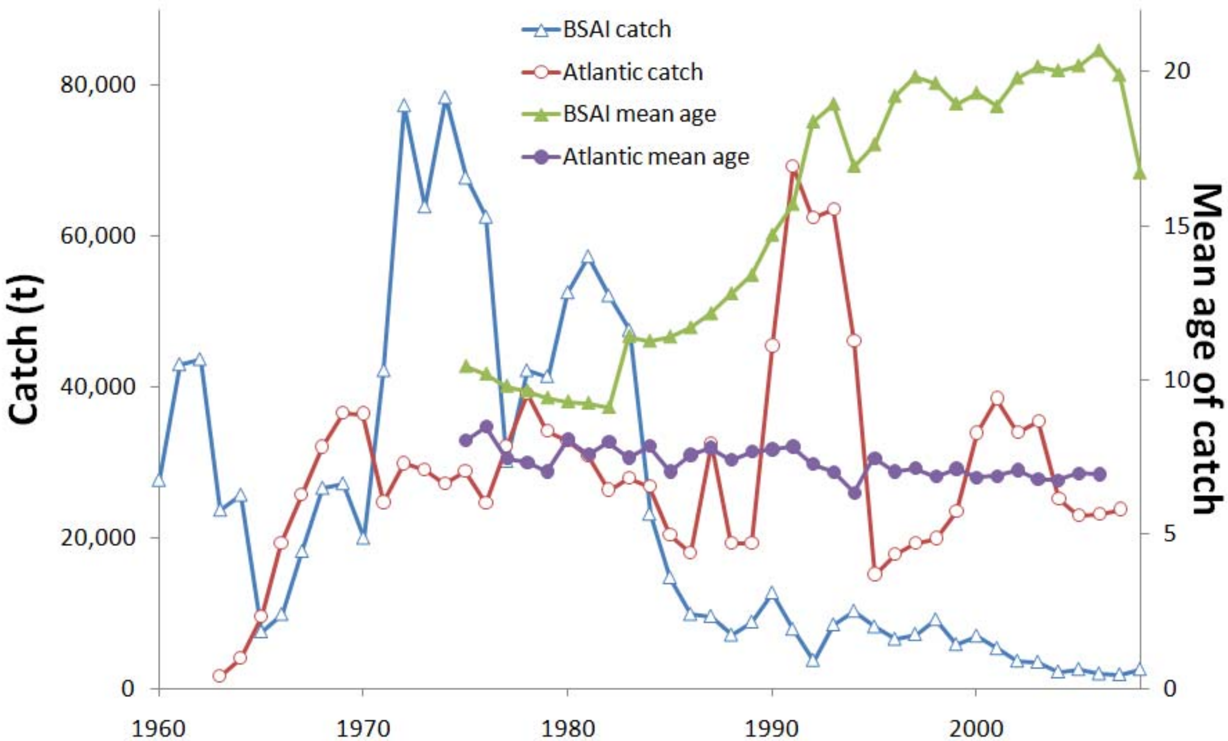


Figure 5.19. Comparisons of Greenland turbot catch and mean age of catch (all fleets combined) for the BSAI stock and that of the Atlantic (data from Healy and Mahé 2006).

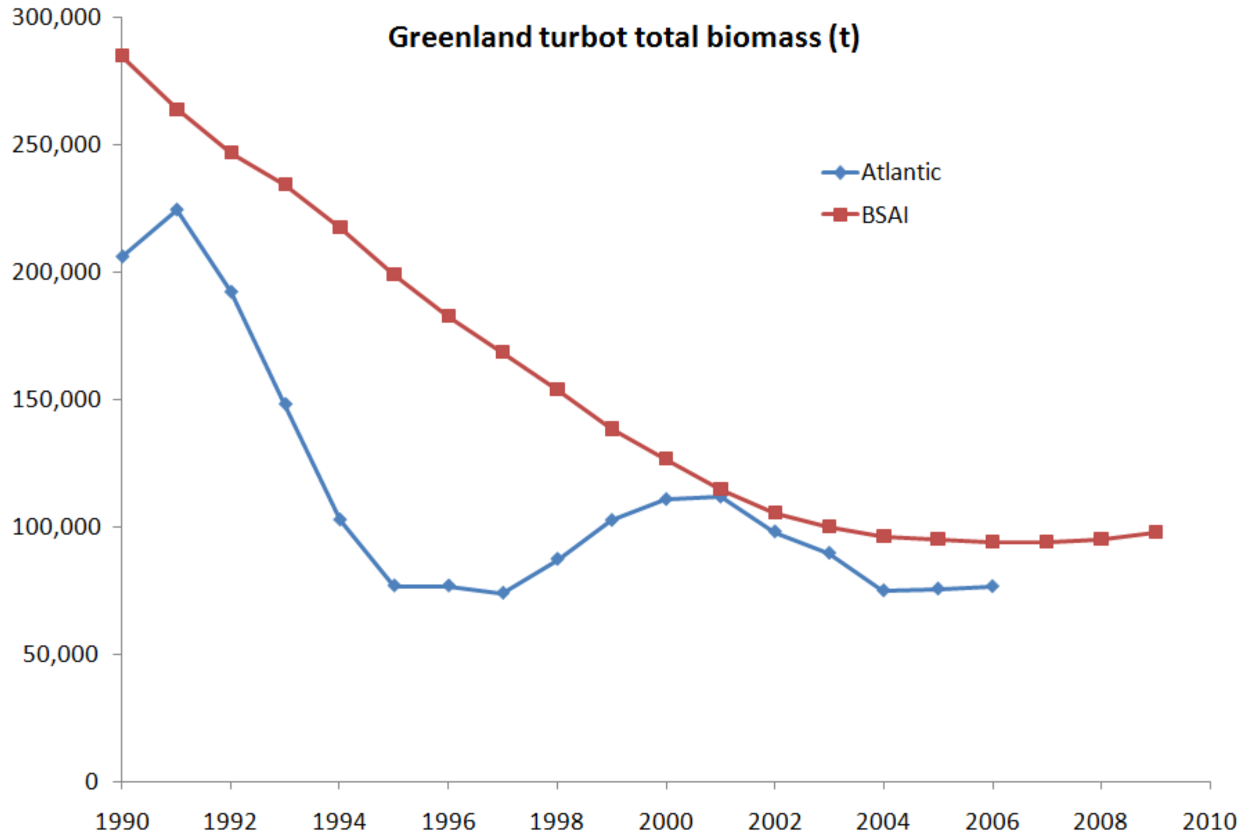
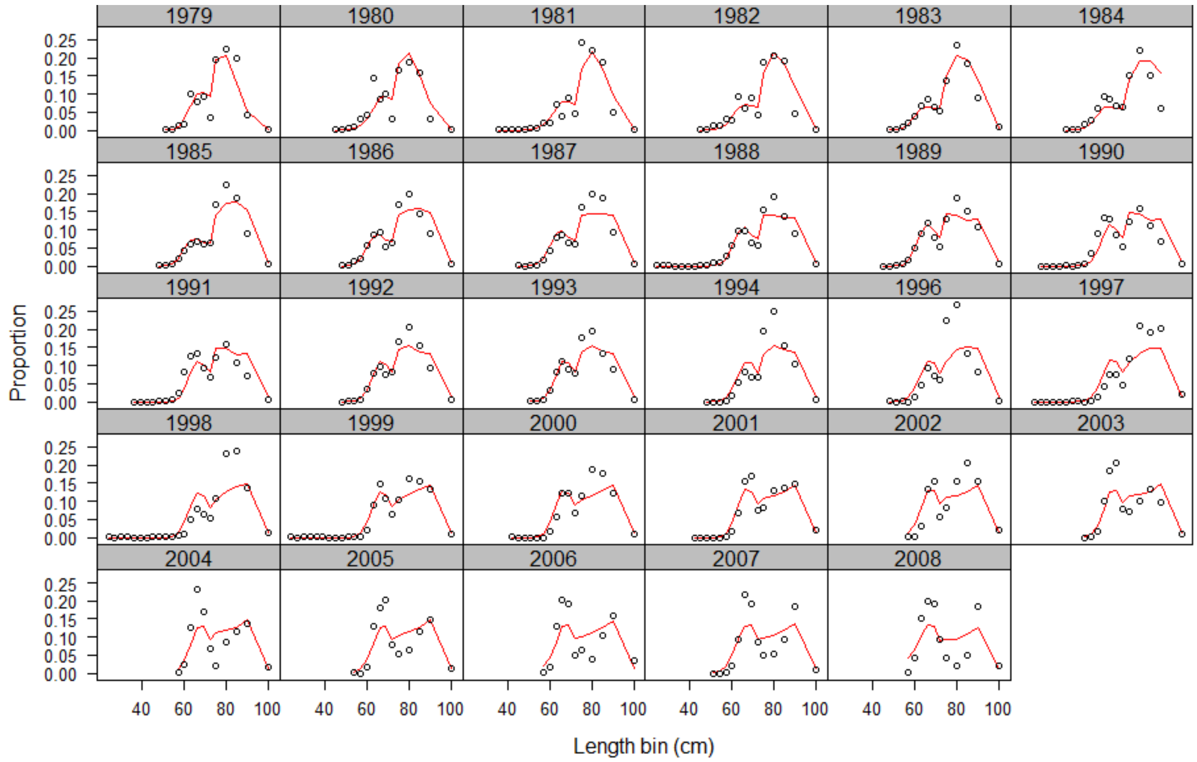
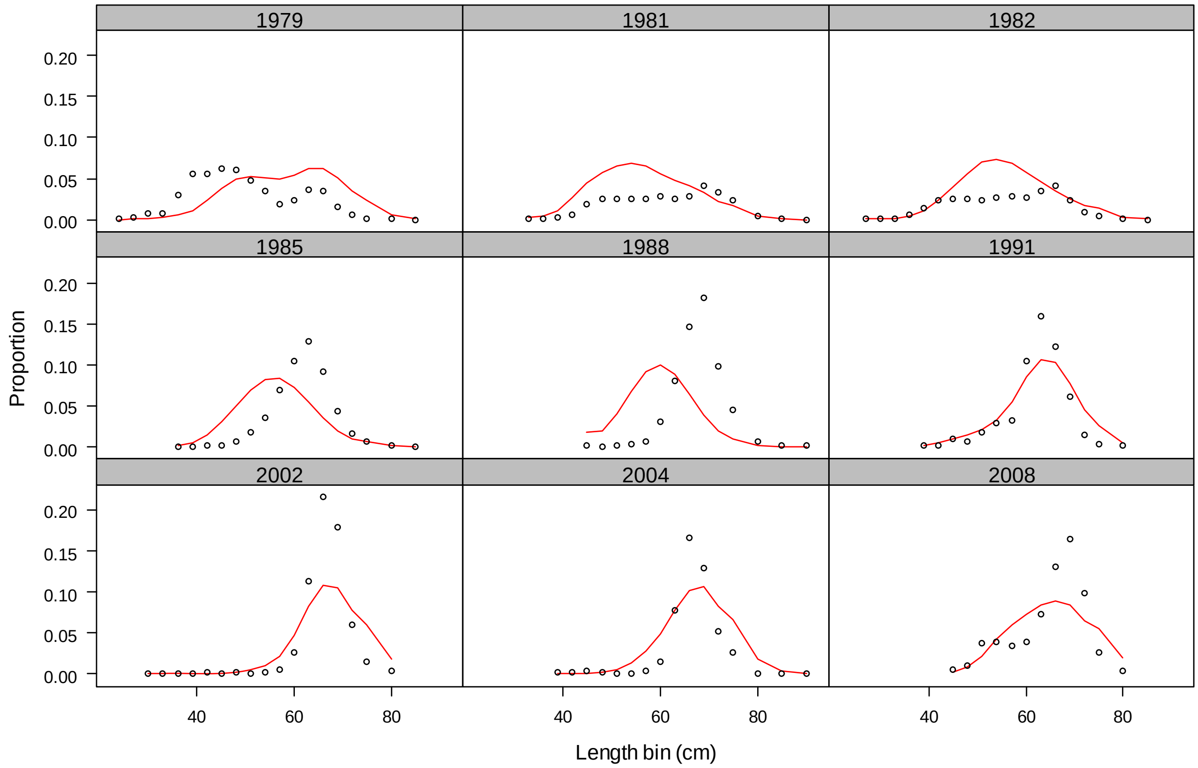


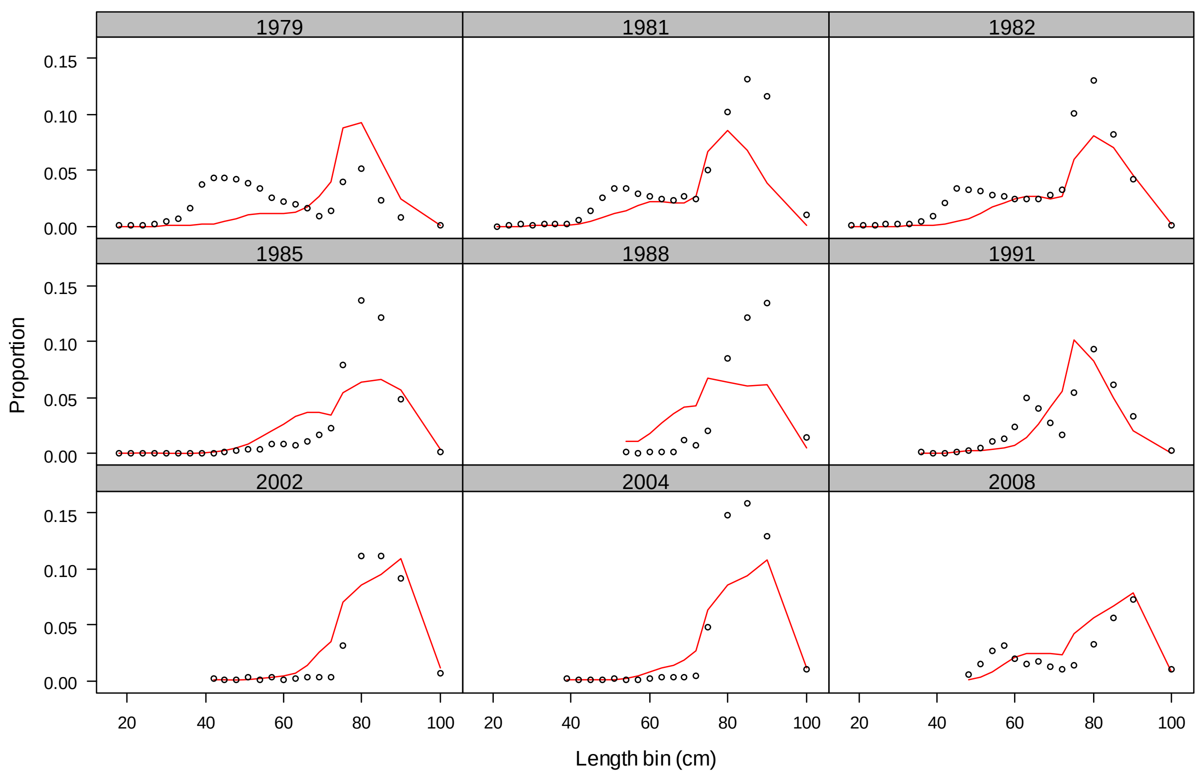
Figure 5.20. Comparisons of recent Greenland turbot total biomass estimates between the Atlantic (from Healy and Mahé 2006) and the BSAI (this assessment), 1990-2009.

Attachment 5.1 Model fits to the size composition data

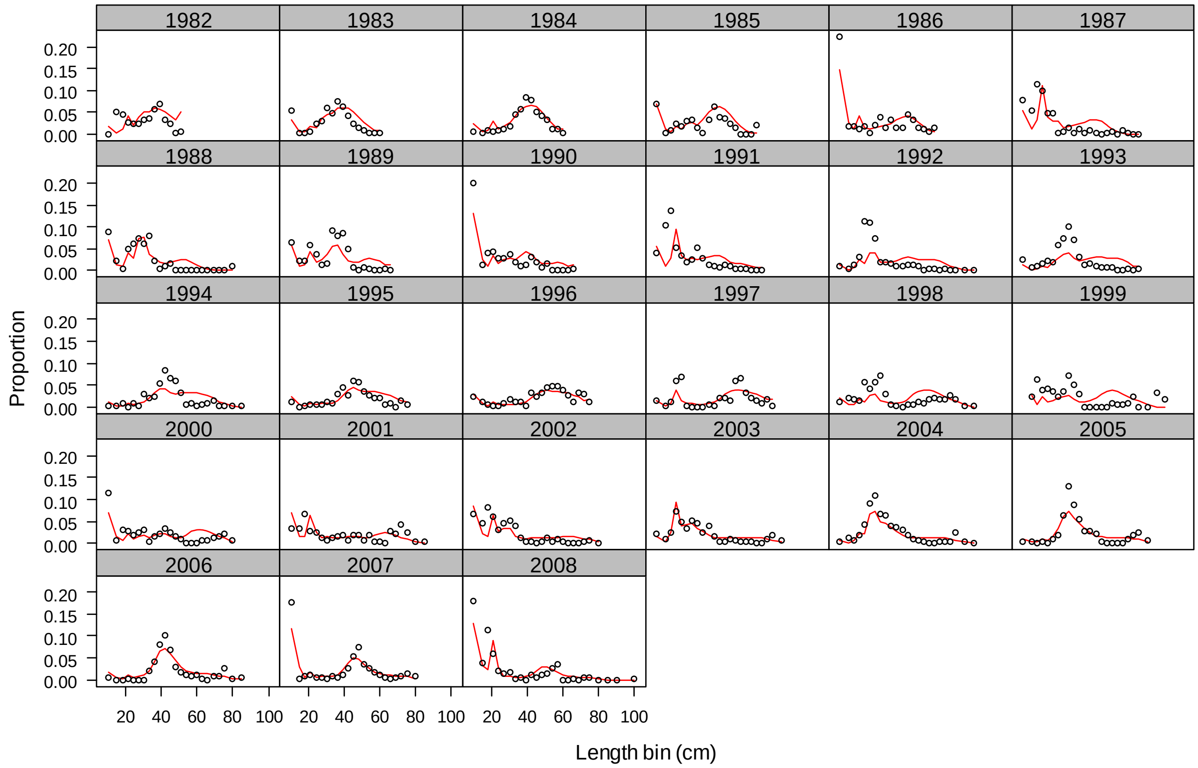


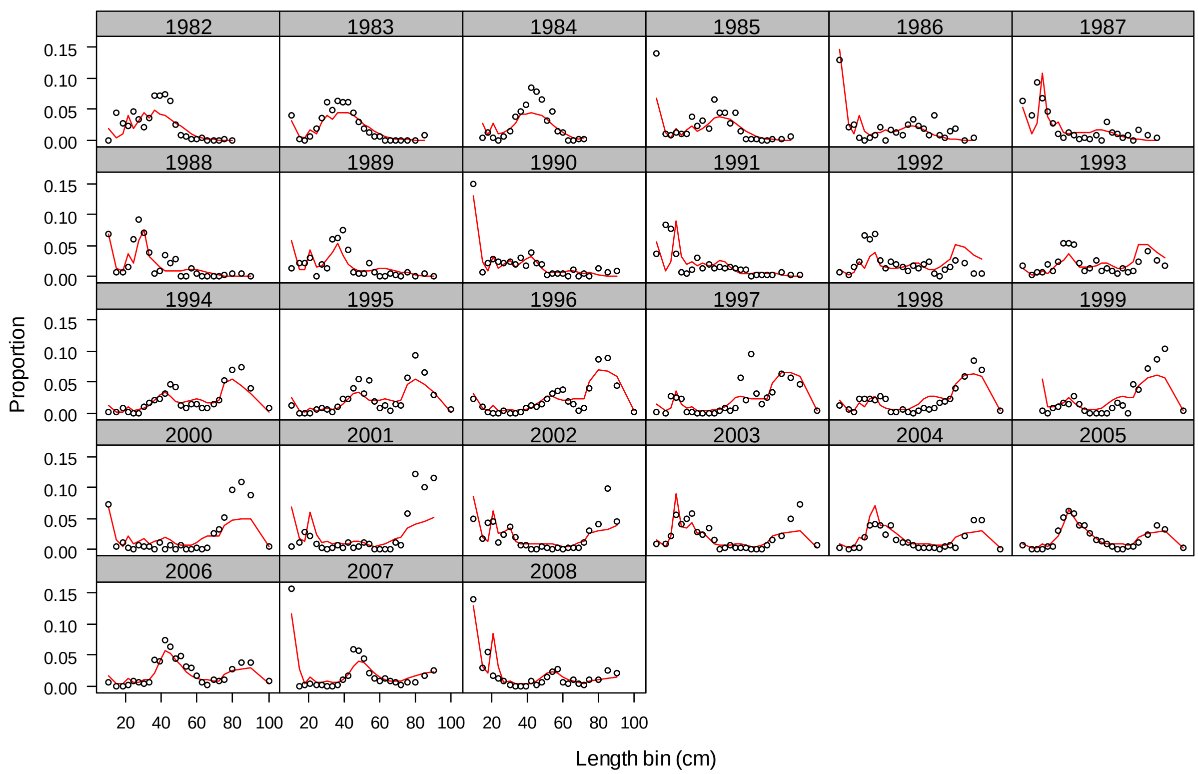
Greenland turbot model fit to longline survey length frequency data. Lines are model predictions, points are data



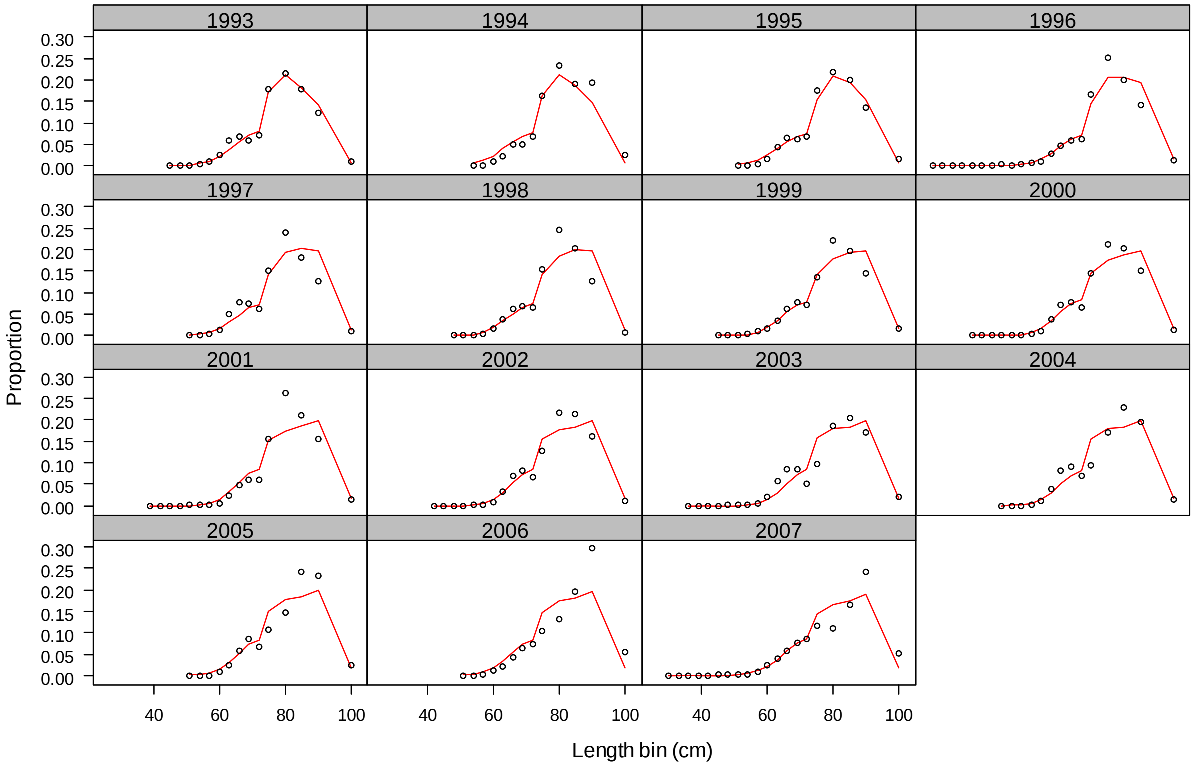


Greenland turbot model fit to EBS slope trawl survey length frequency data. The top set are males, while the bottom are females. Lines are model predictions, points are data

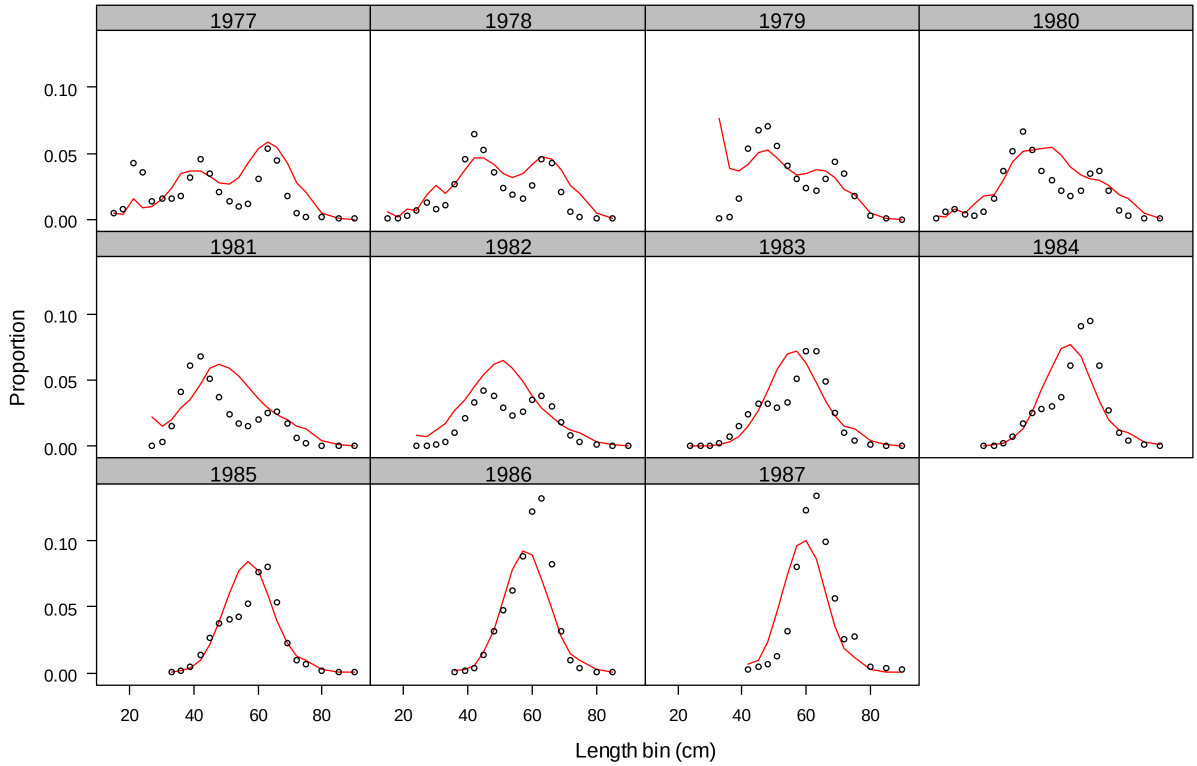


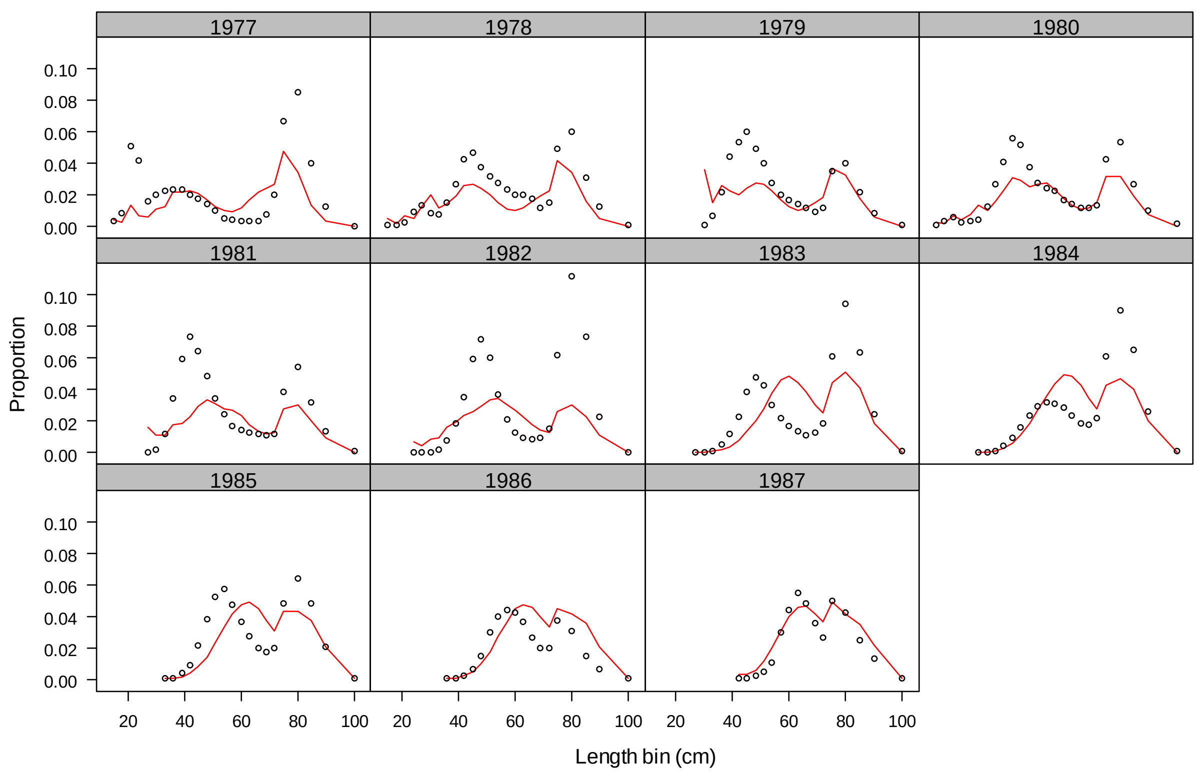


Greenland turbot model fit to EBS shelf trawl survey length frequency data. The top set are males, while the bottom are females. Lines are model predictions, points are data



Greenland turbot model fit to EBS longline fishery length frequency data (combined sexes). Lines are model predictions, points are data





Greenland turbot model fit to EBS trawl fishery length frequency data. The top set are males, while the bottom are females. Lines are model predictions, points are data.

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