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. 2006 and 2007 catch data were updated (and added).
2. The EBS shelf survey 2007 biomass and length composition estimates were added.
3. An updated aggregated longline survey data index for the EBS and Aleutian Islands regions was 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. In addition, a simplified Tier 5 approach is provided for contrast to the model results.

Changes in the assessment results

The **BSAI longline survey** index was up slightly from the 2006 value but still lower than 1996-2005 values. The 2007 **EBS shelf trawl survey** biomass estimate was down by about 20% from the 2006 estimate but estimates from the last three years average about 75% of the long-term mean value from this survey.

As in past years, the slope-trawl survey was assumed to index 75% of the Greenland turbot stock inhabiting US waters. Model results based on these surveys and data from longline and trawl fisheries result in an estimate of $B_{40\%}$ equal to 38,151 t (female spawning biomass). The current estimate of the year 2008 female spawning biomass is 58,125 t. While there appears to be some favorable recruitment patterns in the past several years, fishing mortalities consistent with recent history are recommended for ABCs until another slope survey can be completed. This results in a 2008 and 2009 recommended ABC for BSAI Greenland turbot of **2,540 t** for both years which compares with corresponding maximum permissible levels of 12,171 and 12,921 t respectively under Tier 3a. The 2008 and 2009 overfishing levels, based on the adjusted $F_{35\%}$ rate are **15,600 t** and **16,030 t** corresponding to a full-selection F of 0.582.

Summing the area-swept trawl survey estimates from the EBS shelf (6 estimates) and slope (2 estimates) and from the Aleutian Islands (3 estimates) gives a mean biomass of 67,000 t which with a natural mortality rate of 0.112, indicates a Tier 5 ABC value of 5,630 t with a corresponding OFL of 7,500 t. If the stock trend is indexed by the longline survey over the last six years, then the value for Tier 5 ABC drops to 2,516 t with an OFL of 3,354 t.

Response to SSC comments

Over the past couple of years, the SSC requested increased clarity in how data and results are presented. Last year, a new format for displaying the predicted length frequency data relative to the data was introduced along with more careful presentation of implied sex ratios between fishery and survey gears.

Additionally, in 2007 an extensive review of Greenland turbot stock assessment (and other flatfish species) was undertaken by a panel of three from the Center for Independent Experts (CIE). Specific to Greenland turbot, the panel's main recommendations centered around developing means to evaluate the extent that the stock occurs outside of the US management zone and also developing management strategy evaluations (MSEs) to better judge the present system.

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 tag returns suggest that this species is capable of movement over large areas.

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 declining 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 apparent low levels of recruitment in the past several years. This has resulted in primarily bycatch-only fisheries. The distribution of the Greenland turbot catches has been fairly consistent in recent years (Figs. 5.2 and 5.3). 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 mt in 1998 to 3,500 mt in 2004 and 2005.

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 Greenland turbot directed fishery 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 2004-2007.

Catch

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

No age composition information is available from the fisheries (nor from surveys). 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 and the expected values from the assessment model are presented in previous assessments. This information is used in the assessment model and adds to our ability to estimate size-specific selectivity patterns in addition to year-class variability.

Resource Surveys

Aleutian Islands

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 5.3). 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 5.4). 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.

EBS slope and shelf bottom trawl survey

The older juveniles and adults on the slope were surveyed every third year from 1979-1991 (also in 1981) as part of a U.S.-Japan cooperative agreement. The slope surveys were conducted by Japanese shore-based (Hokuten) trawlers chartered by the Japan Fisheries Agency until 1985. 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 reestablished the bottom trawl survey of the upper continental slope of the eastern Bering Sea and a second survey was conducted in 2004. Scientists at the AFSC planned to conduct slope surveys every two years to improve sampling effort Greenland turbot habitat areas. However, the scheduled 2006 slope trawl survey was canceled due to budgetary constraints.

The trawl slope-surveys are likely to represent under-estimates the actual biomass of Greenland turbot, hence, these are treated as an index representing 75% of the stock based on earlier assessment analyses (Ianelli et al. 1993). The principal reason why trawl slope surveys may underestimate biomass is that the range of Greenland turbot appears to extend beyond the area of the survey and that the ability to tend bottom in the deeper waters may be compromised. 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 also treated as a relative index.

Abundance estimates for juvenile Greenland turbot on the EBS shelf are provided annually by AFSC trawl surveys. For the shelf survey, the extent that Greenland turbot are found in the northwestern strata ranges from 2%-34% (Ianelli et al. 2005).

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 15 years (1993-2007) is 30,500 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 has increased then stabilized (Fig. 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. 5.7). In the last 5 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. Currently AFSC scientists are following up with age validation methods for Greenland turbot.

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
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	
SE Aleutians	2,142		1,806		1,201		1,397		937		566	
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	
Combined	104,903	78,160	74,416	83,187	58,888	66,715	51,211	61,412	39,376	30,436	14,927	23,811

The combined time series shown above (1996-2007) was used as a relative abundance index. It was computed by taking the average RPN from 1996-2007 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 (1996-2007) 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. 5.8.

Comparisons among surveys

Among the three separate trawl surveys, the EBS slope averages about 61% of area-swept biomass levels compared to 15% for the Aleutian Islands and 24% for the EBS shelf region (Fig. 5.9). In aggregate, all of the indices show varying trends, with the longline survey showing the greatest relative decline (Fig. 5.10).

Annual research catches (1977 - 2007) 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	
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 2007. 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. For Greenland Turbot in the EBS the model included two fisheries, those using longline and trawl gear, and three surveys. Table 5.6 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/2007/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 fishery data were treated as from 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. New to this assessment, size-at-age information from the methods described by Gregg et al. (2006) were used and are summarized in Table 5.7.

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,
- 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 salient fact of having large Greenland turbot removals of 574,000 t between 1972 and 1981 (compared to 49,000 t between 1997-2006) and having the trends in abundance as observed, indicates that recruitment during the 1960s must have been reasonably high. Lacking information on the age (or sizes) of these fish makes estimation of which (and how many) year classes were high difficult. 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. 5.11). Estimates of selectivity (using the "double-normal" option in SS2) provides reasonable appearing patterns over time for the shelf survey (Fig. 5.12). The average selectivity patterns among all gear types was also reasonable (Fig. 5.13). 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. 5.14). The slope trawl survey shows that in there is variability in the proportion caught by sex. In 2002, the survey caught far more males than females but in 2004 they found more females than males (Fig. 5.15). This highlights the sex and size specific variability within the same region between years.

The model fit the new length-at-age information presented this year reasonably well, and is consistent with growth of females being significantly greater than males (Fig. 5.16). The fit to the survey indices in recent years resulted in model predictions that were above the recent longline and shelf survey observations, but below the slope survey (Fig. 5.17). 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 5.8).

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 5.8; Fig. 5.18). A comparison of this year's model result with the 2006 assessment is also presented in Table 5.8. The estimated historical numbers at age is given in Table 5.9.

Selectivity

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. 5.13). 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 2007) from each gear type for Greenland turbot in the BSAI is given in Table 5.10. 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 specific for each fishery (Table 5.11).

Fit to Size Composition Data

Size composition observations from the fisheries and surveys are generally poorly matched by the model predictions (Attachment 5.1). 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" 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. The nature of the inconsistencies among data types is presented below, particularly as they pertain to assessing the current stock status.

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. 5.19). Analyses on fitting the stock-recruitment relationship indicated that the residuals were highly auto-correlated (Fig. 5.20). 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 2008 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 1978-2006 gives a long-term average female spawning biomass of 38,151 tons. The current estimate of the year 2008 female spawning biomass is about 58,125 t, above the estimate of $B_{35\%}$ (33,382).

Specification of OFL and Maximum Permissible ABC and ABC Recommendation

The projected Greenland turbot maximum permissible ABC and OFL levels for 2007 and 2008 are shown below (catch for 2007 was set equal to the ABC recommendation):

Year	Catch	Maximum permissible ABC	Recommended ABC	OFL	Female spawning biomass
2008	**2,540** t	12,171 t	**2,540** t	**15,600** t	58,243 t
2009	**2,540** t	12,921 t	**2,540** t	**16,030** t	59,726 t

For ABC specification this year was based on maintaining the recent fishing mortality rates. Past recommendations have been similarly conservative to promote the recovery of Greenland turbot in the EBS and Aleutian Islands region. While the stock is technically not overfished and is currently above the $B_{40\%}$ level, extra caution is still warranted. Additional information from a survey in the main habitat area of Greenland turbot (e.g., the NMFS slope survey) is required to determine if increasing fishing mortality rates at this time is advisable.

The estimated overfishing level based on the adjusted $F_{35\%}$ rate is **15,600 t** corresponding to a full-selection F of 0.582. 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. 5.21).

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 5.12).

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	787
Eastern Bering Sea	1,753
Total	2,540

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 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007 (here assumed to be 1,820 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 2008, 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 2003-2007 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 MSFCMAs 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 2020 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, 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 2020 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 1 through 7 were projected 13 years from 2007 (Table 5.13). Fishing at the maximum permissible rate indicate that the spawning stock will gradually drop to near the $B_{40\%}$ by 2020 (Fig. 5.22).

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 2008 spawning biomass estimated at 58,125 t relative to $0.5B_{35\%}$ = 16,691 t). Under the guidelines, since the year 2007 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 37,990t by 2020.

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.

A tagging study of Greenland turbot conducted by the NMFS Auke Bay Lab staff is continuing and includes release of fish with archival tags. To date, 7 fish have been recaptured with temperature, time, and depth data. A key characteristic of these data indicate consistent diurnal migrations through nearly 1,000 m depth during a 2 week period in late January (e.g., Fig. 5.23).

Some 38 conventionally tagged Greenland turbot have been recovered as of September 2007 with 21 of these having complete recapture information. The median distance traveled by conventionally tagged turbot was about 74 nautical miles with a maximum distance between release and recapture of 371 nautical miles. The longest time at liberty for these fish was 8.11 years recaptured about 56 miles from the point of release. The average length at release is 78.5 cm. The following table shows the number of Greenland turbot released and recaptured by year.

Year	Releases	Recaptures
1997	295	0
1998	66	10
1999	188	7
2000	37	7
2001	128	5
2002	26	3
2003	97	1
2004	23	3
2005	62	2
2006	8	0
Total	930	38

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. 5.24). The management parameters of interest derived from this assessment are presented in Table 5.14.

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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	2,219	4,740	3,500
2005	729	1,831	2,560	3,930	3,500
2006	360	1,601	1,961	2,740	2,740
2007	364	1,453	1,817	2,440	2,440

Table 5.2. Estimates of discarded and retained (t) Greenland turbot based on NMFS estimates by "directed" fishery, 1992-2007.

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	1,722	45	114	534	154	93	198	5	242	230	115	60	2,546	967
2004	1,207	19	78	23	219	79	72	3	193	176	99	50	1,868	351
2005	1,530	21	63	20	156	30	134	5	326	76	149	49	2,359	200
2006	1,198	14	68	51	65	30	69	8	214	35	135	46	1,751	183
2007	1,201	24	46	28	121	88	34	13	48	22	145	41	1,596	217

Table 5.3. Survey estimates of Greenland turbot biomass (t) for the Eastern Bering Sea shelf and slope areas and for the Aleutian Islands region, 1975-2007. Note that the shelf-survey estimates from 1985, and 1987-2007 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		

Table 5.4. 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 5.5. Greenland turbot biological sampling levels 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	1228	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	50	263		
2007	376	83	499	68	334		

Table 5.6. 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	1979-2007
Slope survey: size composition and biomass estimates	1979, 81, 82, 85, 88, 91, 2002, 2004
Longline survey: size composition and abundance index	1996-2007
Total fishery catch data	1960-2007
Trawl fishery size composition	1977-87, 1989-91, 1993-2007
Longline fishery size composition	1977, 1979-85, 1992-2007

Table 5.7. Summary of the length-at-age information introduced in this year's Greenland turbot assessment based on the methods presented in Gregg et al. (2006).

	1994				**1998**			
	Females		Males		Females		Males	
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 5.8. Total harvest rate (catch / mid-year biomass), spawning and total biomass (compared with the past assessment) for BSAI Greenland turbot, 1960-2007.

			Female Spawning Biomass		Total Age 1+ Biomass	
	Total Fishing Mortality	Catch /	2006	Current	2006	Current
Year		Mid-yr Biom.	Assessment	Assessment	Assessment	Assessment
1960	0.09	0.106	153,756	142,891	282,090	261,095
1961	0.13	0.184	146,470	135,349	254,794	233,829
1962	0.24	0.197	133,710	122,143	212,817	221,415
1963	0.32	0.100	117,915	106,440	170,908	237,234
1964	0.23	0.086	106,884	98,313	189,455	296,842
1965	0.27	0.021	95,113	96,689	244,609	364,083
1966	0.06	0.022	92,902	118,191	351,429	448,033
1967	0.05	0.035	97,985	173,475	472,942	522,513
1968	0.05	0.045	128,788	246,880	585,992	588,666
1969	0.06	0.042	204,807	308,834	677,662	643,535
1970	0.05	0.029	306,306	350,142	749,151	693,551
1971	0.03	0.057	397,658	378,081	806,941	742,999
1972	0.06	0.102	453,514	394,485	822,646	759,007
1973	0.11	0.088	470,485	404,709	785,345	726,286
1974	0.10	0.113	472,146	417,988	747,973	694,861
1975	0.14	0.106	454,863	414,192	687,906	641,006
1976	0.13	0.106	431,913	399,907	633,900	592,824
1977	0.14	0.055	405,125	377,812	584,594	548,721
1978	0.08	0.079	389,573	365,503	568,655	537,232
1979	0.11	0.081	369,097	347,197	541,876	514,259
1980	0.12	0.107	350,478	330,374	516,026	491,608
1981	0.16	0.126	328,116	309,528	477,739	456,177
1982	0.19	0.126	303,927	286,811	431,927	413,039
1983	0.21	0.128	282,292	266,767	387,205	370,864
1984	0.23	0.070	257,350	243,431	344,323	330,373
1985	0.12	0.047	244,708	232,515	323,057	311,266
1986	0.08	0.033	235,739	225,239	307,654	297,838
1987	0.05	0.033	227,976	219,073	295,220	287,190
1988	0.06	0.026	218,525	211,066	281,545	275,113
1989	0.04	0.033	208,684	202,501	269,243	264,206
1990	0.06	0.051	196,762	191,685	254,450	250,615
1991	0.09	0.034	182,267	177,823	235,922	232,714
1992	0.05	0.017	170,463	166,629	222,479	219,794
1993	0.02	0.040	160,418	157,644	212,846	211,082
1994	0.05	0.052	147,301	145,344	199,025	197,916
1995	0.08	0.045	135,201	133,857	183,525	182,876
1996	0.07	0.039	124,937	124,022	170,228	169,880
1997	0.05	0.045	115,987	115,256	158,817	158,494
1998	0.06	0.062	106,699	106,084	147,108	146,717
1999	0.09	0.044	96,220	95,681	134,039	133,478
2000	0.06	0.056	88,363	87,870	124,590	123,773
2001	0.08	0.047	80,008	79,513	115,029	113,757
2002	0.07	0.034	73,523	72,958	108,640	106,494
2003	0.05	0.034	68,407	67,689	106,480	102,662
2004	0.05	0.022	63,851	62,896	106,915	100,619
2005	0.03	0.025	60,966	59,612	110,436	101,020
2006	0.03	0.019	59,424	57,254	114,586	101,645
2007	0.03	0.018	60,326	56,868	119,054	102,862
2008				58,125		104,116

Table 5.9. Estimated beginning of year numbers of Greenland turbot by age and sex (millions).

Females

Yr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+
1977	23.08	19.26	33.27	14.64	20.64	16.02	8.56	3.53	2.34	1.88	1.67	33.95	1.34	1.22	1.08	0.94	0.79	34.21	0.50	0.40	3.20
1978	16.25	20.63	17.17	29.47	12.85	17.90	13.73	7.29	3.00	1.99	1.59	1.42	29.02	1.15	1.05	0.93	0.81	0.68	29.59	0.43	3.00
1979	11.12	14.53	18.37	15.15	25.68	11.01	15.09	11.47	6.06	2.49	1.65	1.33	1.19	24.39	0.97	0.88	0.79	0.69	0.58	25.15	2.90
1980	7.52	9.94	12.93	16.20	13.19	21.96	9.26	12.57	9.50	5.02	2.07	1.38	1.11	1.00	20.50	0.81	0.75	0.67	0.58	0.49	2.78
1981	2.82	6.72	8.84	11.36	13.97	11.11	18.09	7.52	10.14	7.66	4.06	1.68	1.12	0.91	0.82	16.90	0.67	0.62	0.55	0.49	2.68
1982	3.55	2.52	5.97	7.73	9.72	11.63	9.00	14.40	5.94	8.00	6.07	3.23	1.34	0.90	0.74	0.67	13.76	0.55	0.51	0.45	20.05
1983	2.26	3.17	2.24	5.21	6.59	8.03	9.32	7.07	11.23	4.63	6.26	4.79	2.57	1.08	0.73	0.60	0.54	11.28	0.45	0.42	16.88
1984	3.84	2.02	2.84	2.00	4.65	5.83	6.95	7.79	5.70	8.79	3.57	4.82	3.70	2.00	0.85	0.58	0.48	0.44	9.08	0.36	14.39
1985	8.03	3.43	1.81	2.53	1.79	4.13	5.12	5.99	6.59	4.75	7.26	2.95	3.99	3.07	1.67	0.71	0.49	0.40	0.37	7.68	12.12
1986	2.44	7.18	3.07	1.62	2.26	1.59	3.65	4.47	5.17	5.62	4.03	6.16	2.50	3.40	2.63	1.43	0.61	0.42	0.35	0.32	10.64
1987	3.31	2.18	6.42	2.74	1.44	2.02	1.41	3.21	3.90	4.48	4.86	3.48	5.33	2.17	2.95	2.28	1.25	0.53	0.36	0.30	9.51
1988	3.01	2.96	1.95	5.74	2.45	1.29	1.79	1.24	2.80	3.38	3.87	4.20	3.01	4.62	1.88	2.56	1.99	1.09	0.46	0.32	14.15
1989	7.59	2.69	2.65	1.75	5.13	2.19	1.14	1.58	1.09	2.45	2.95	3.37	3.66	2.63	4.03	1.65	2.24	1.74	0.95	0.41	12.64
1990	3.20	6.78	2.40	2.37	1.56	4.58	1.94	1.01	1.38	0.95	2.12	2.55	2.92	3.18	2.28	3.51	1.43	1.96	1.52	0.83	11.36
1991	1.22	2.86	6.07	2.15	2.12	1.39	4.09	1.73	0.89	1.20	0.81	1.80	2.17	2.48	2.70	1.95	3.00	1.23	1.68	1.31	10.20
1992	1.11	1.09	2.56	5.42	1.92	1.89	1.25	3.65	1.53	0.78	1.05	0.70	1.56	1.87	2.15	2.34	1.69	2.60	1.07	1.46	9.16
1993	0.96	1.00	0.98	2.29	4.85	1.72	1.69	1.11	3.26	1.36	0.69	0.93	0.62	1.38	1.65	1.89	2.06	1.48	2.28	0.94	8.62
1994	1.51	0.86	0.89	0.87	2.05	4.33	1.54	1.51	0.99	2.89	1.21	0.61	0.81	0.54	1.20	1.43	1.63	1.76	1.27	1.95	8.54
1995	3.26	1.35	0.77	0.80	0.78	1.83	3.87	1.37	1.34	0.87	2.51	1.04	0.52	0.70	0.46	1.02	1.22	1.39	1.50	1.08	8.36
1996	1.58	2.91	1.21	0.69	0.71	0.70	1.63	3.46	1.21	1.18	0.76	2.18	0.90	0.45	0.60	0.40	0.87	1.04	1.19	1.29	7.83
1997	1.88	1.42	2.61	1.08	0.61	0.64	0.62	1.46	3.08	1.08	1.04	0.67	1.90	0.78	0.39	0.52	0.34	0.75	0.89	1.02	8.13
1998	2.17	1.68	1.27	2.33	0.97	0.55	0.57	0.56	1.30	2.74	0.96	0.91	0.58	1.65	0.67	0.34	0.44	0.29	0.64	0.76	7.74
1999	6.49	1.94	1.50	1.13	2.08	0.87	0.49	0.51	0.50	1.16	2.41	0.83	0.79	0.50	1.41	0.57	0.28	0.37	0.24	0.53	7.47
2000	8.19	5.81	1.73	1.34	1.01	1.86	0.77	0.44	0.45	0.44	1.02	2.11	0.73	0.69	0.43	1.21	0.49	0.24	0.32	0.21	6.91
2001	12.07	7.33	5.19	1.55	1.20	0.91	1.66	0.69	0.39	0.40	0.39	0.89	1.83	0.62	0.59	0.37	1.03	0.41	0.20	0.27	6.43
2002	2.68	10.79	6.55	4.64	1.39	1.07	0.81	1.49	0.62	0.35	0.35	0.34	0.77	1.58	0.54	0.50	0.32	0.88	0.35	0.17	5.78
2003	1.36	2.40	9.64	5.86	4.15	1.24	0.96	0.72	1.33	0.55	0.31	0.31	0.30	0.67	1.38	0.47	0.44	0.27	0.76	0.31	5.09
2004	1.44	1.22	2.15	8.62	5.24	3.71	1.11	0.86	0.65	1.18	0.49	0.27	0.27	0.26	0.59	1.19	0.40	0.38	0.24	0.65	4.58
2005	1.86	1.29	1.09	1.92	7.71	4.68	3.32	0.99	0.77	0.58	1.05	0.43	0.24	0.24	0.23	0.51	1.05	0.35	0.33	0.21	4.06
2006	6.11	1.66	1.15	0.97	1.71	6.89	4.18	2.96	0.88	0.68	0.51	0.93	0.38	0.21	0.21	0.20	0.45	0.91	0.31	0.29	3.77
2007	6.09	5.46	1.49	1.03	0.87	1.53	6.16	3.74	2.65	0.79	0.61	0.45	0.82	0.33	0.18	0.18	0.17	0.39	0.79	0.27	3.76

Males

Yr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+
1977	23.08	19.26	33.27	14.61	20.45	15.62	8.10	3.17	1.95	1.41	1.12	20.23	0.71	0.57	0.46	0.36	0.28	10.85	0.14	0.10	0.23
1978	16.25	20.63	17.17	29.44	12.77	17.59	13.18	6.70	2.58	1.56	1.12	0.88	15.83	0.55	0.45	0.36	0.28	0.21	8.39	0.11	0.23
1979	11.12	14.53	18.36	15.13	25.51	10.81	14.49	10.56	5.24	1.98	1.18	0.83	0.65	11.59	0.40	0.32	0.26	0.20	0.15	6.05	0.22
1980	7.52	9.94	12.93	16.18	13.10	21.55	8.88	11.56	8.21	3.99	1.48	0.87	0.61	0.47	8.38	0.29	0.23	0.18	0.15	0.11	0.21
1981	2.82	6.72	8.83	11.33	13.85	10.84	17.17	6.80	8.54	5.88	2.78	1.01	0.59	0.41	0.31	5.54	0.19	0.15	0.12	0.09	2.95
1982	3.55	2.52	5.97	7.71	9.62	11.29	8.43	12.71	4.81	5.81	3.88	1.80	0.64	0.37	0.25	0.19	3.39	0.12	0.09	0.07	1.82
1983	2.26	3.17	2.24	5.19	6.51	7.76	8.65	6.12	8.77	3.18	3.71	2.42	1.10	0.39	0.22	0.15	0.12	2.01	0.07	0.05	1.11
1984	3.84	2.02	2.84	2.00	4.63	5.75	6.69	7.11	4.71	6.25	2.10	2.30	1.42	0.62	0.21	0.12	0.08	0.06	1.05	0.04	0.59
1985	8.03	3.43	1.81	2.53	1.79	4.12	5.04	5.72	5.87	3.74	4.79	1.56	1.67	1.01	0.44	0.15	0.08	0.06	0.04	0.72	0.42
1986	2.44	7.18	3.07	1.62	2.26	1.59	3.63	4.38	4.86	4.86	3.03	3.80	1.22	1.29	0.78	0.34	0.11	0.06	0.04	0.03	0.34
1987	3.31	2.18	6.42	2.74	1.44	2.02	1.41	3.19	3.78	4.13	4.07	2.50	3.11	0.99	1.05	0.63	0.27	0.09	0.05	0.03	0.71
1988	3.01	2.96	1.95	5.74	2.45	1.29	1.79	1.24	2.75	3.22	3.46	3.37	2.05	2.54	0.81	0.85	0.51	0.22	0.07	0.04	0.59
1989	7.59	2.69	2.65	1.75	5.13	2.19	1.14	1.58	1.08	2.37	2.74	2.92	2.83	1.72	2.11	0.67	0.70	0.42	0.18	0.06	0.51
1990	3.20	6.78	2.40	2.37	1.56	4.58	1.94	1.00	1.37	0.92	2.00	2.28	2.41	2.32	1.40	1.72	0.54	0.57	0.34	0.15	0.44
1991	1.22	2.86	6.07	2.15	2.12	1.39	4.09	1.73	0.89	1.18	0.77	1.64	1.83	1.89	1.79	1.07	1.31	0.41	0.43	0.26	0.37
1992	1.11	1.09	2.56	5.42	1.92	1.89	1.25	3.65	1.53	0.78	1.02	0.66	1.37	1.51	1.56	1.47	0.87	1.06	0.33	0.35	0.38
1993	0.96	1.00	0.98	2.29	4.85	1.72	1.69	1.11	3.26	1.36	0.69	0.90	0.58	1.21	1.33	1.36	1.28	0.76	0.92	0.29	0.51
1994	1.51	0.86	0.89	0.87	2.05	4.33	1.54	1.51	0.99	2.89	1.20	0.60	0.79	0.50	1.04	1.13	1.16	1.08	0.64	0.78	0.68
1995	3.26	1.35	0.77	0.80	0.78	1.83	3.87	1.37	1.34	0.87	2.48	1.01	0.50	0.64	0.40	0.82	0.90	0.91	0.85	0.50	0.71
1996	1.58	2.91	1.21	0.69	0.71	0.70	1.63	3.46	1.22	1.17	0.75	2.12	0.85	0.42	0.53	0.33	0.67	0.73	0.74	0.68	1.05
1997	1.88	1.42	2.61	1.08	0.61	0.64	0.62	1.46	3.09	1.08	1.04	0.66	1.84	0.73	0.35	0.45	0.28	0.56	0.61	0.61	1.21
1998	2.17	1.68	1.27	2.33	0.97	0.55	0.57	0.56	1.30	2.75	0.96	0.91	0.57	1.58	0.63	0.30	0.38	0.23	0.47	0.51	1.47
1999	6.49	1.94	1.50	1.13	2.08	0.87	0.49	0.51	0.50	1.16	2.42	0.83	0.78	0.48	1.33	0.52	0.25	0.31	0.19	0.38	1.58
2000	8.19	5.81	1.73	1.34	1.01	1.86	0.77	0.44	0.45	0.44	1.02	2.11	0.72	0.67	0.41	1.11	0.43	0.21	0.26	0.16	1.63
2001	12.07	7.33	5.19	1.55	1.20	0.91	1.66	0.69	0.39	0.40	0.39	0.89	1.81	0.61	0.56	0.34	0.92	0.36	0.17	0.21	1.55
2002	2.68	10.79	6.55	4.64	1.39	1.07	0.81	1.49	0.62	0.35	0.35	0.34	0.76	1.53	0.51	0.46	0.28	0.75	0.29	0.14	1.36
2003	1.36	2.40	9.64	5.86	4.15	1.24	0.96	0.72	1.33	0.55	0.31	0.31	0.29	0.66	1.31	0.43	0.39	0.24	0.64	0.24	1.28
2004	1.44	1.22	2.15	8.62	5.24	3.71	1.11	0.86	0.65	1.18	0.49	0.27	0.27	0.25	0.56	1.12	0.37	0.33	0.20	0.54	1.16
2005	1.86	1.29	1.09	1.92	7.71	4.68	3.32	0.99	0.77	0.58	1.05	0.43	0.24	0.24	0.22	0.49	0.97	0.32	0.29	0.17	1.17
2006	6.11	1.66	1.15	0.97	1.71	6.89	4.18	2.96	0.88	0.68	0.51	0.92	0.38	0.21	0.20	0.19	0.42	0.83	0.27	0.24	1.37
2007	6.09	5.46	1.49	1.03	0.87	1.53	6.16	3.74	2.65	0.79	0.61	0.45	0.81	0.33	0.18	0.18	0.17	0.36	0.72	0.23	1.31

Table 5.10. Age-equivalent sex-specific selectivity estimates (as estimated for 2006) 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	1.000	1.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.997	1.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.952	1.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.917	1.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.887	1.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.869	1.000	0.004	0.006	0.000	0.000
7	0.004	0.003	0.001	0.002	0.873	1.000	0.031	0.044	0.000	0.002
8	0.033	0.021	0.007	0.009	0.883	1.000	0.111	0.151	0.000	0.013
9	0.104	0.083	0.021	0.026	0.892	1.000	0.226	0.321	0.002	0.056
10	0.192	0.197	0.051	0.054	0.901	1.000	0.321	0.502	0.010	0.141
11	0.252	0.337	0.099	0.094	0.908	1.000	0.373	0.648	0.035	0.256
12	0.274	0.474	0.162	0.143	0.915	1.000	0.396	0.745	0.083	0.377
13	0.270	0.587	0.232	0.198	0.921	1.000	0.404	0.801	0.149	0.480
14	0.254	0.673	0.300	0.254	0.927	1.000	0.407	0.828	0.219	0.557
15	0.235	0.735	0.362	0.308	0.931	1.000	0.407	0.839	0.282	0.608
16	0.215	0.777	0.414	0.358	0.936	1.000	0.405	0.839	0.335	0.637
17	0.197	0.806	0.457	0.403	0.940	1.000	0.399	0.835	0.375	0.651
18	0.181	0.824	0.490	0.442	0.943	1.000	0.390	0.828	0.404	0.654
19	0.167	0.837	0.516	0.476	0.946	1.000	0.378	0.820	0.426	0.651
20	0.154	0.844	0.536	0.505	0.949	1.000	0.363	0.811	0.442	0.643
21	0.144	0.848	0.551	0.530	0.952	1.000	0.347	0.804	0.453	0.634
22	0.134	0.851	0.563	0.551	0.954	1.000	0.330	0.796	0.461	0.624
23	0.126	0.852	0.572	0.568	0.956	1.000	0.314	0.790	0.467	0.614
24	0.120	0.852	0.579	0.583	0.958	1.000	0.298	0.784	0.472	0.605
25	0.114	0.851	0.584	0.596	0.959	1.000	0.283	0.778	0.475	0.596
26	0.109	0.851	0.588	0.607	0.960	1.000	0.269	0.774	0.478	0.588
27	0.104	0.850	0.592	0.616	0.962	1.000	0.257	0.770	0.479	0.581
28	0.101	0.849	0.595	0.624	0.963	1.000	0.246	0.766	0.481	0.575
29	0.097	0.848	0.597	0.630	0.964	1.000	0.236	0.763	0.482	0.569
30	0.095	0.848	0.599	0.636	0.964	1.000	0.227	0.760	0.483	0.565

Table 5.11. 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	14.01	14.05	0.01	0.01
2	22.86	22.53	0.09	0.08
3	30.71	29.84	0.24	0.22
4	37.68	36.13	0.47	0.41
5	43.87	41.55	0.78	0.65
6	49.35	46.21	1.16	0.94
7	54.22	50.23	1.59	1.24
8	58.54	53.70	2.05	1.55
9	62.37	56.68	2.53	1.86
10	65.77	59.25	3.03	2.15
11	68.79	61.46	3.52	2.44
12	71.47	63.36	4.01	2.70
13	73.85	65.00	4.48	2.95
14	75.95	66.42	4.92	3.17
15	77.82	67.63	5.34	3.37
16	79.48	68.68	5.73	3.55
17	80.96	69.58	6.11	3.71
18	82.26	70.36	6.46	3.85
19	83.42	71.03	6.78	3.98
20	84.45	71.61	7.08	4.09
21	85.37	72.10	7.35	4.19
22	86.18	72.53	7.59	4.27
23	86.89	72.90	7.81	4.35
24	87.53	73.22	8.01	4.41
25	88.10	73.49	8.19	4.47
26	88.60	73.73	8.34	4.52
27	89.05	73.93	8.49	4.56
28	89.44	74.10	8.61	4.59
29	89.79	74.25	8.72	4.63
30	90.10	74.38	8.82	4.65

Table 5.12. Estimated total Greenland turbot harvest by area, 1977-2007. Values for 2007 are through Nov. 8th, 2007 and are preliminary.

Year	EBS	Aleutians	Year	EBS	Aleutians
1977	27,708	2,453	1992	1,767	2,462
1978	37,423	4,766	1993	4,878	6,330
1979	34,998	6,411	1994	3,875	7,141
1980	48,856	3,697	1995	4,499	5,855
1981	52,921	4,400	1996	4,258	4,844
1982	45,805	6,317	1997	5,730	6,435
1983	43,443	4,115	1998	7,839	8,329
1984	21,317	1,803	1999	5,179	5,391
1985	14,698	33	2000	5,667	5,888
1986	7,710	2,154	2001	4,102	4,252
1987	6,519	3,066	2002	3,011	3,153
1988	6,064	1,044	2003	2,467	960
1989	4,061	4,761	2004	1,775	381
1990	7,702	2,494	2005	2,120	440
1991	3,781	4,397	2006	1,437	523
			2007	1,366	451

Table 5.13. Mean spawning biomass, F, and yield projections for Greenland turbot, 2007-2020. 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 38,151 and 33,382 tons, respectively.

Catch	*Max FABC*	*.75FABC*	*5-year avg.*	*F75%*	*No Fishing*	*Scenario 6*	*Scenario 7*
2007	1,820	1,820	1,820	1,820	1,820	1,820	1,820
2008	12,171	2,000	2,540	2,802	0	14,981	12,171
2009	10,996	9,691	2,612	2,872	0	13,013	10,996
2010	10,398	9,284	2,734	2,997	0	11,964	12,840
2011	9,922	8,951	2,848	3,114	0	11,158	11,817
2012	9,321	8,519	2,919	3,184	0	10,242	10,737
2013	8,599	7,988	2,946	3,204	0	8,607	9,258
2014	7,698	7,467	2,950	3,201	0	7,395	7,768
2015	6,944	7,063	2,956	3,200	0	6,781	6,999
2016	6,590	6,762	2,975	3,214	0	6,597	6,724
2017	6,527	6,526	3,009	3,247	0	6,693	6,767
2018	6,642	6,453	3,059	3,297	0	6,939	6,981
2019	6,836	6,491	3,118	3,358	0	7,226	7,249
2020	7,046	6,584	3,182	3,424	0	7,488	7,500
Fishing M.	*Max FABC*	*.75FABC*	*5-year avg.*	*F75%*	*No Fishing*	*Scenario 6*	*Scenario 7*
2007	0.064	0.064	0.064	0.064	0.064	0.064	0.064
2008	0.462	0.070	0.090	0.099	0.000	0.582	0.462
2009	0.462	0.346	0.090	0.099	0.000	0.582	0.462
2010	0.462	0.346	0.090	0.099	0.000	0.582	0.582
2011	0.462	0.346	0.090	0.099	0.000	0.582	0.582
2012	0.462	0.346	0.090	0.099	0.000	0.582	0.582
2013	0.462	0.346	0.090	0.099	0.000	0.539	0.559
2014	0.448	0.346	0.090	0.099	0.000	0.503	0.516
2015	0.426	0.346	0.090	0.099	0.000	0.483	0.492
2016	0.412	0.343	0.090	0.099	0.000	0.473	0.478
2017	0.403	0.335	0.090	0.099	0.000	0.468	0.471
2018	0.398	0.327	0.090	0.099	0.000	0.466	0.468
2019	0.395	0.322	0.090	0.099	0.000	0.465	0.467
2020	0.394	0.319	0.090	0.099	0.000	0.466	0.467
Spawning biomass	*Max FABC*	*.75FABC*	*5-year avg.*	*F75%*	*No Fishing*	*Scenario 6*	*Scenario 7*
2007	56,868	56,868	56,868	56,868	56,868	56,868	56,868
2008	58,243	58,243	58,243	58,243	58,243	58,243	58,243
2009	54,480	60,015	59,726	59,585	61,082	52,916	54,480
2010	50,997	57,110	60,584	60,313	63,229	48,338	50,997
2011	47,139	53,652	60,457	60,063	64,359	43,681	45,795
2012	43,207	49,985	59,731	59,221	64,854	39,179	40,845
2013	39,892	46,802	59,067	58,450	65,348	35,498	36,799
2014	37,604	44,519	58,863	58,150	66,217	33,366	34,220
2015	36,409	43,109	59,128	58,331	67,463	32,514	33,083
2016	36,095	42,381	59,749	58,878	68,983	32,481	32,862
2017	36,332	42,171	60,625	59,687	70,690	32,913	33,167
2018	36,834	42,321	61,625	60,626	72,469	33,528	33,697
2019	37,413	42,653	62,656	61,601	74,234	34,148	34,260
2020	37,989	43,074	63,683	62,576	75,955	34,712	34,784

Table 5.14. 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 2007)	3a
Approximate age at full recruitment	10 years
$F_{35\%}$ (F_{OFL})	0.67
$F_{40\%}$	0.51
$B_{100\%}$	95,377 t
$B_{40\%}$	38,151 t
$B_{35\%}$	33,382 t
Year 2008 female spawning biomass	58,125 t
Year 2008 total (age 1+) biomass	104,116 t
$F_{ABC} = F_{40\%}$ (max permissible)	0.3461
2008 Maximum permissible ABC	12,171 t
2009 Maximum permissible ABC (2008 catch = 1,800 t)	12,921 t
F_{ABC} = *5-year average F*	0.09
Recommended ABC: 2008	**2,540 t**
2009	**2,540 t**
$F_{overfishing} = F_{35\%}$	0.582
2008 Greenland turbot OFL	**15,600 t**
2009 Greenland turbot OFL (2008 catch = 1,800 t)	**16,030 t**

Figures

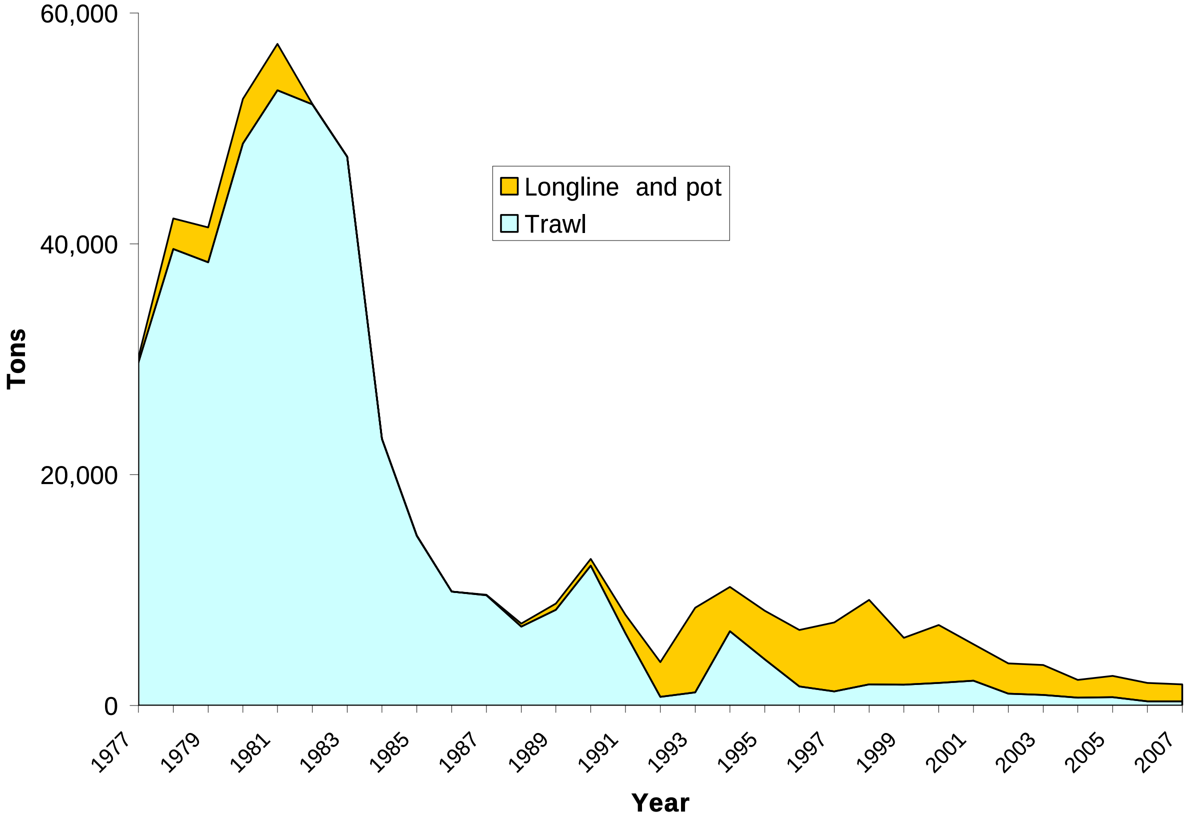


Figure 5.1. Trawl and longline catches of Greenland turbot in the combined EBS/AI area, 1977-2007. Source: NMFS Regional Office.

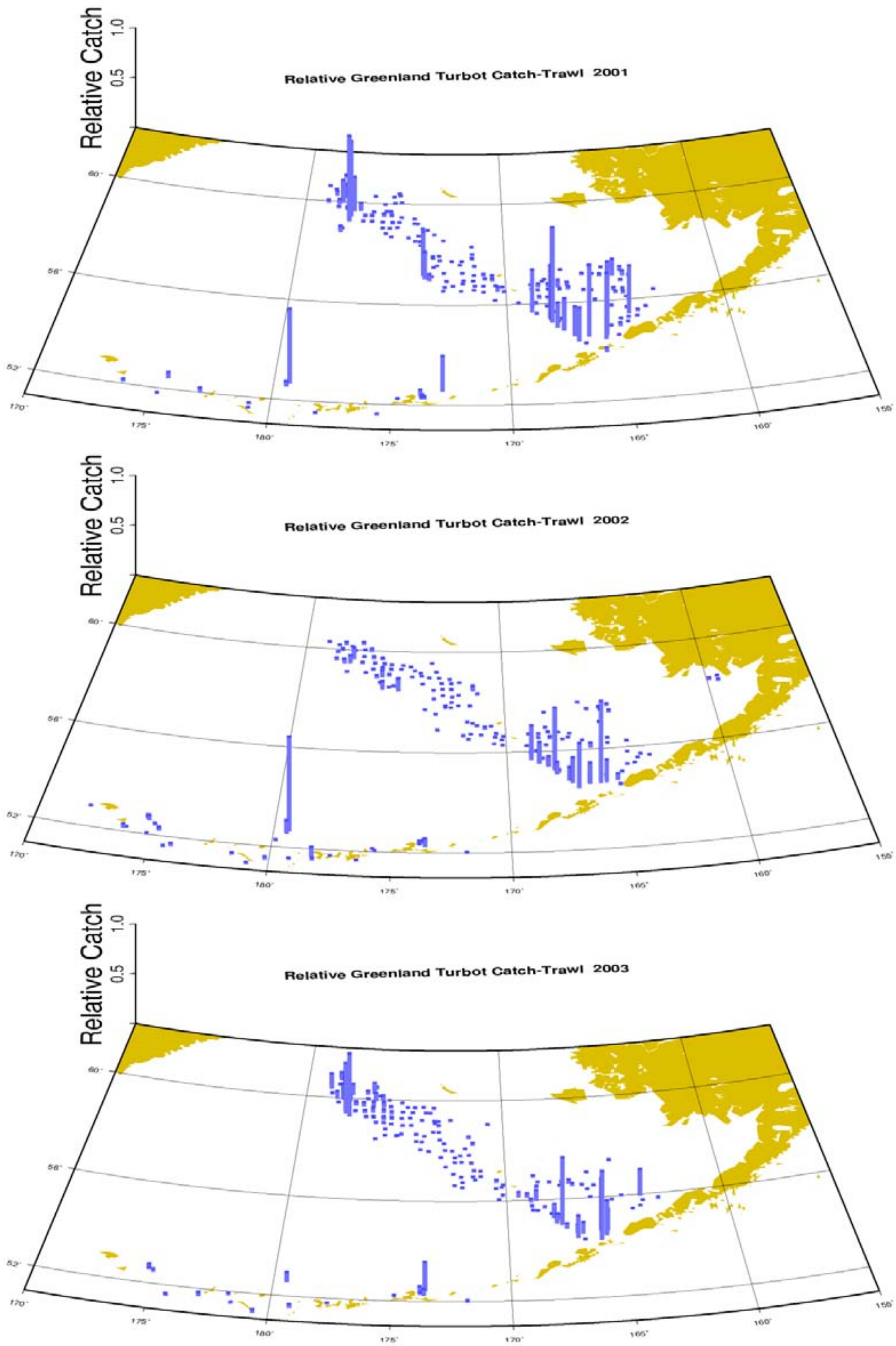


Figure 5.2. Distribution of Greenland turbot catch by trawl vessels based on aggregated NMFS observer data, 2001-2003. Vertical lines represent the relative magnitude of Greenland turbot catch for each 30’ longitude by 15’ latitude grids.

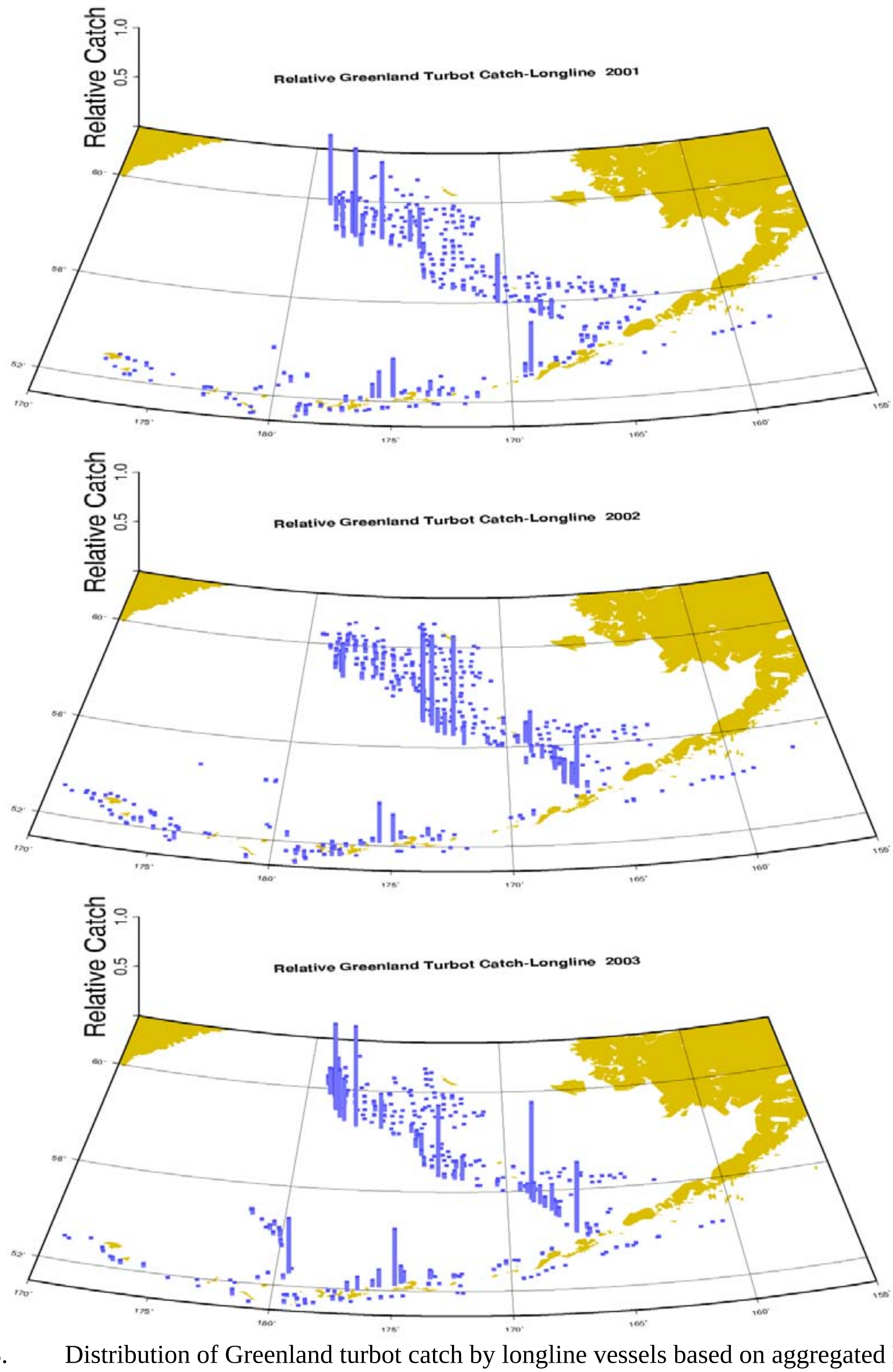


Figure 5.3. Distribution of Greenland turbot catch by longline vessels based on aggregated NMFS observer data, 2001-2003. Vertical lines represent the relative magnitude of Greenland turbot catch for each 30’ longitude by 15’ latitude grids.

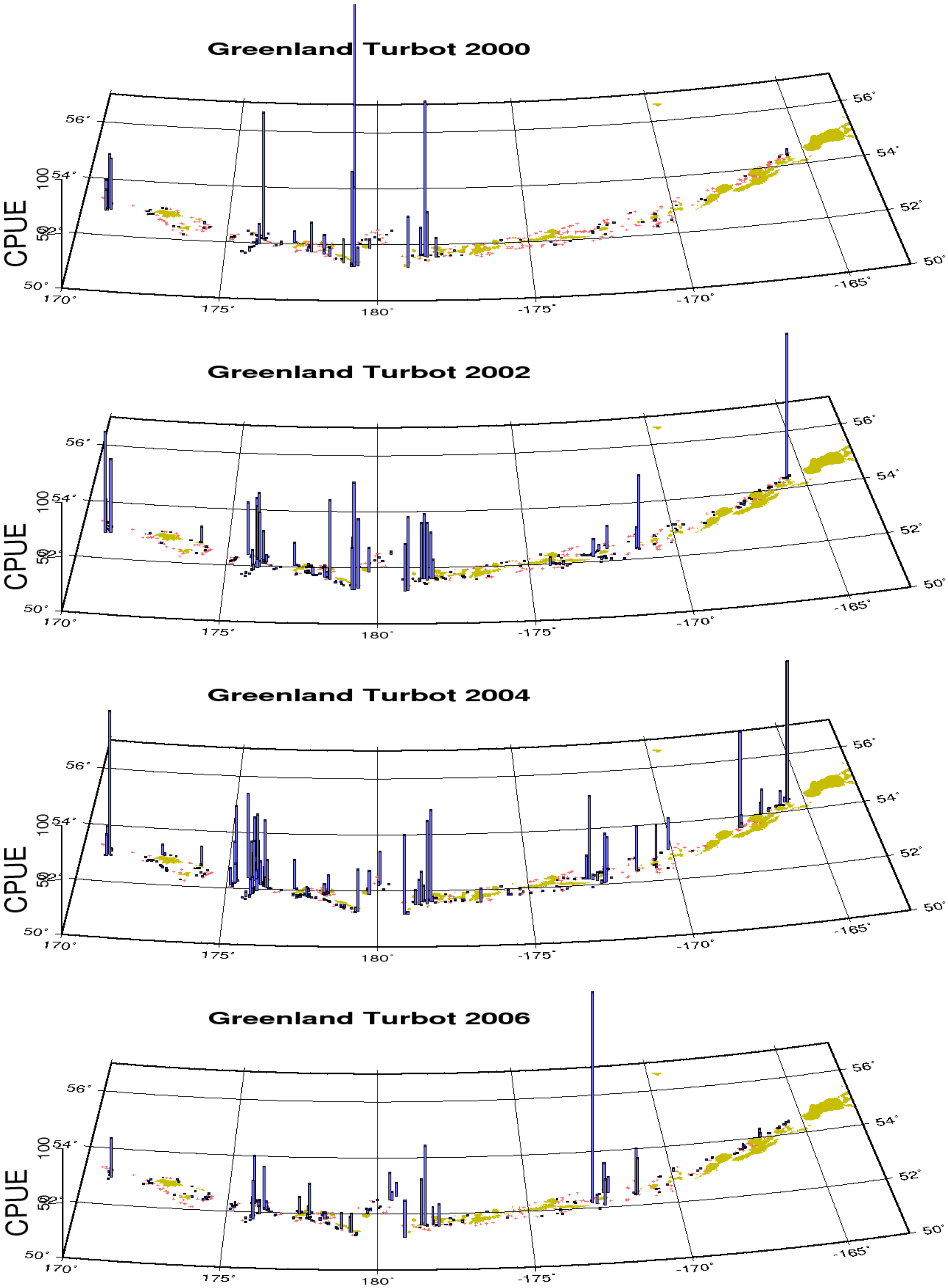


Figure 5.4. Greenland turbot catch per unit effort (relative values by weight, vertical bars) from the Aleutian Islands region bottom trawl survey, 2000-2006.

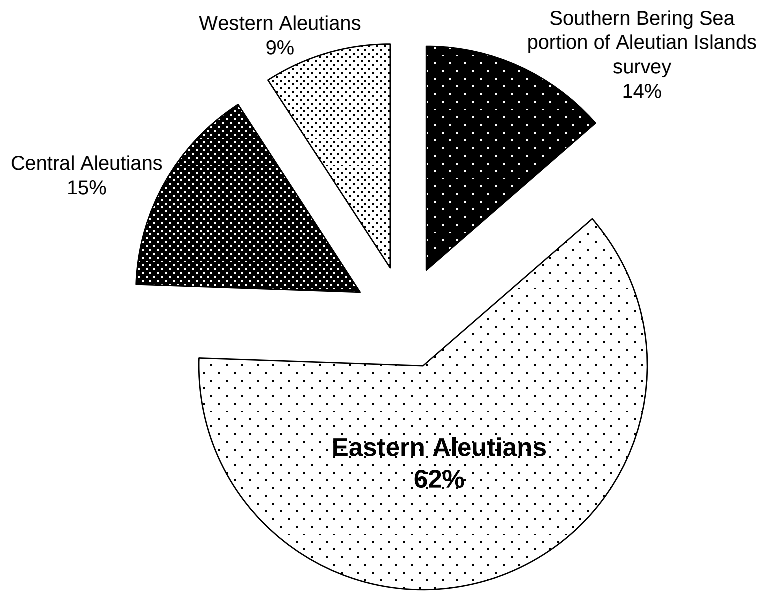
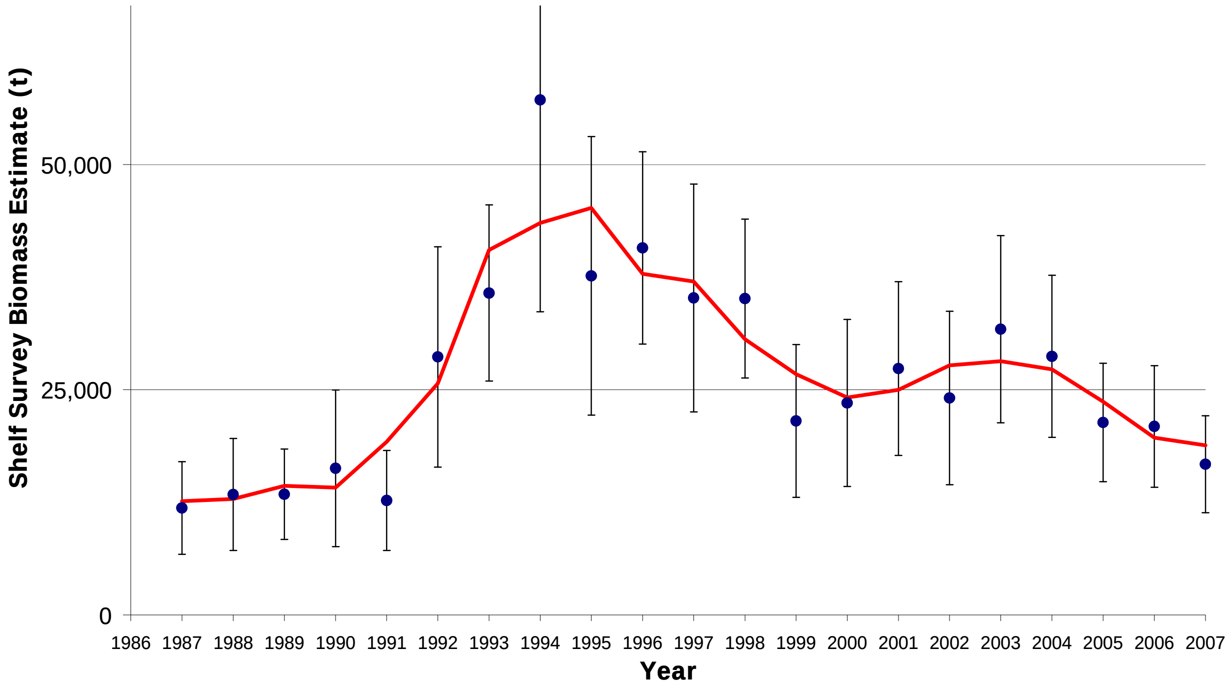


Figure 5.5. Average Greenland turbot relative biomass from the Aleutian Islands surveys by region, 1980-2006.



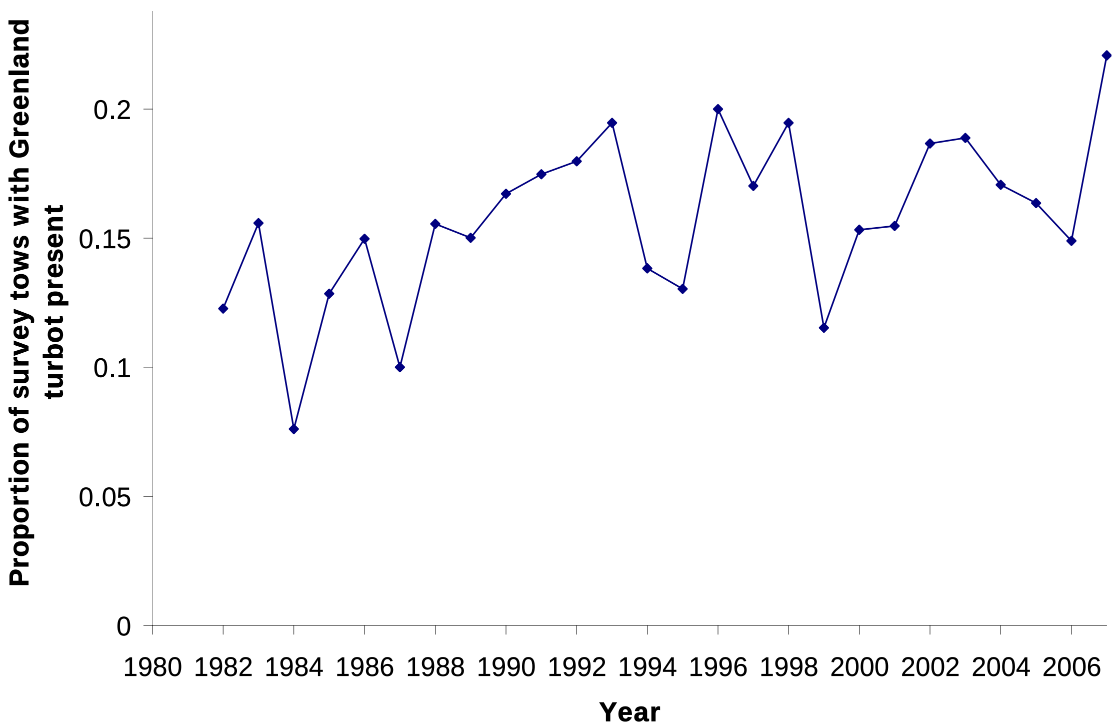


Figure 5.6. Survey biomass estimates of Greenland turbot from the EBS shelf trawl survey (top) and the proportion of tows that caught at least one Greenland turbot (bottom), 1982-2007. The line in the top figure is a moving average value.

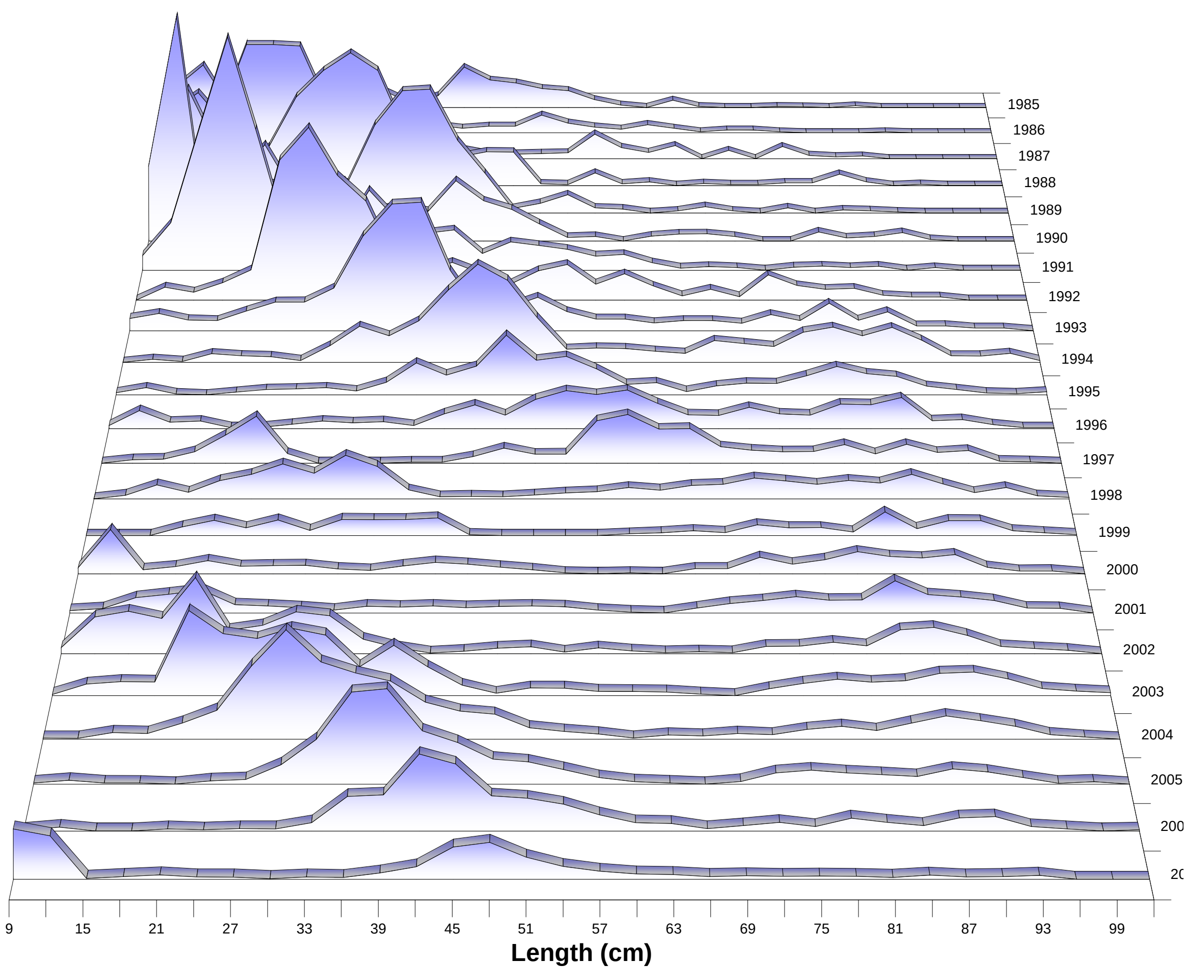


Figure 5.7. Abundance-at-length (cm) for Greenland turbot observed from the summer NMFS shelf trawl surveys, 1985-2007 (sexes combined, all strata except for 1986 where only strata 1-6 were sampled).

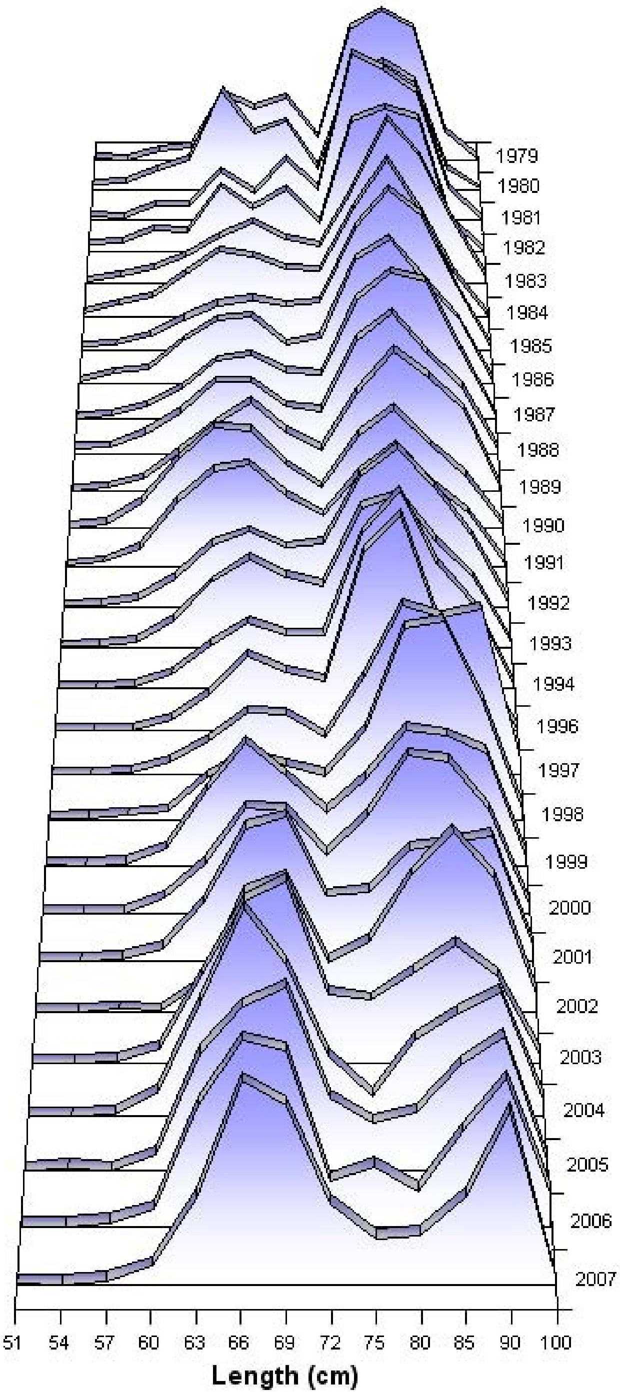


Figure 5.8. Longline survey Greenland turbot proportions at length over time (sexes combined) as used in the model.

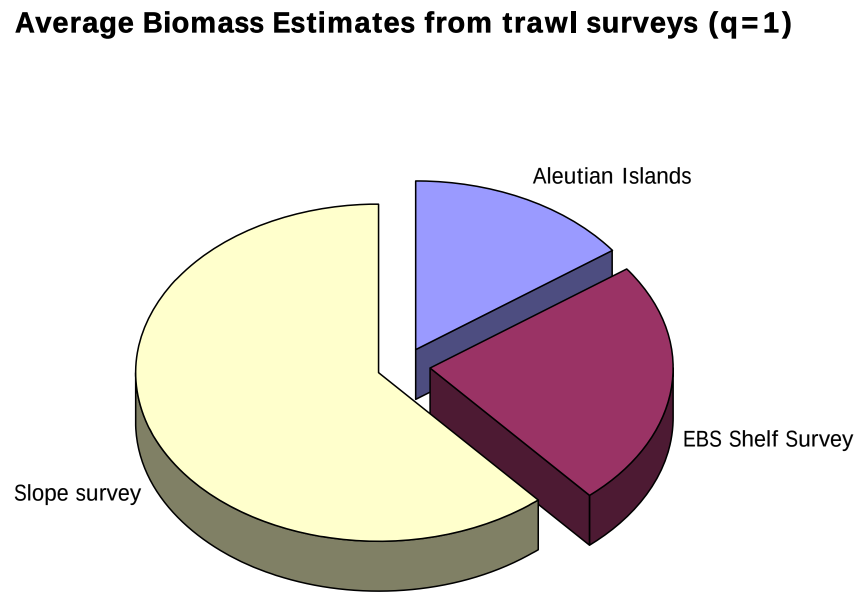


Figure 5.9. Average Greenland turbot relative biomass from the Aleutian Islands surveys by region, 1980-2006.

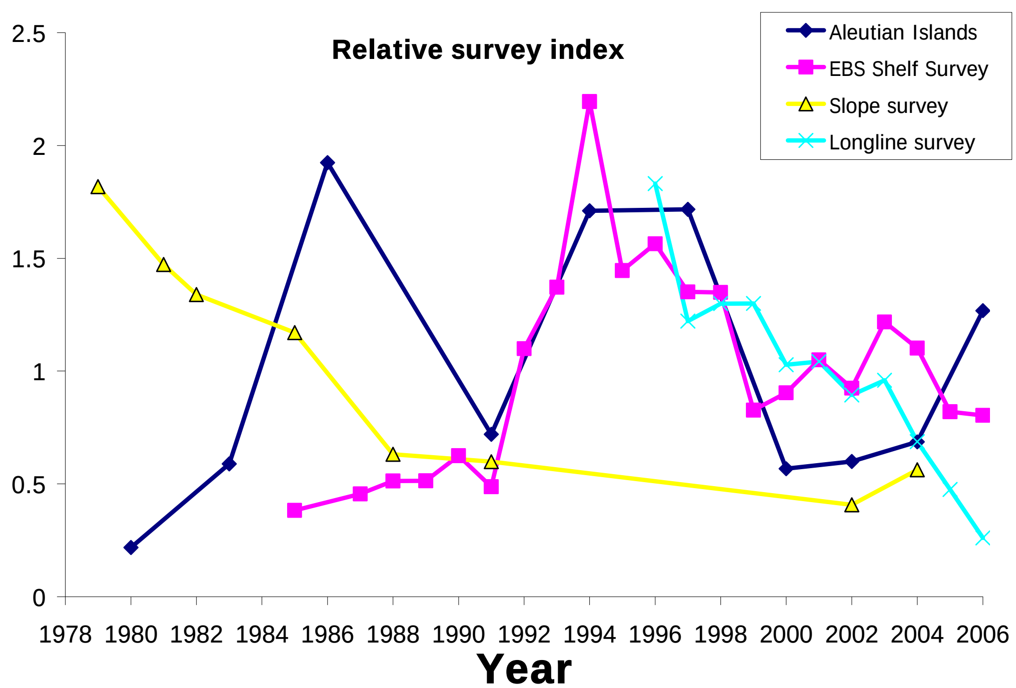


Figure 5.10. All biomass indices available for the assessment (normalized to each have a mean value of 1.0) for Greenland turbot. Note that the Aleutian Islands survey data are not used in the model.

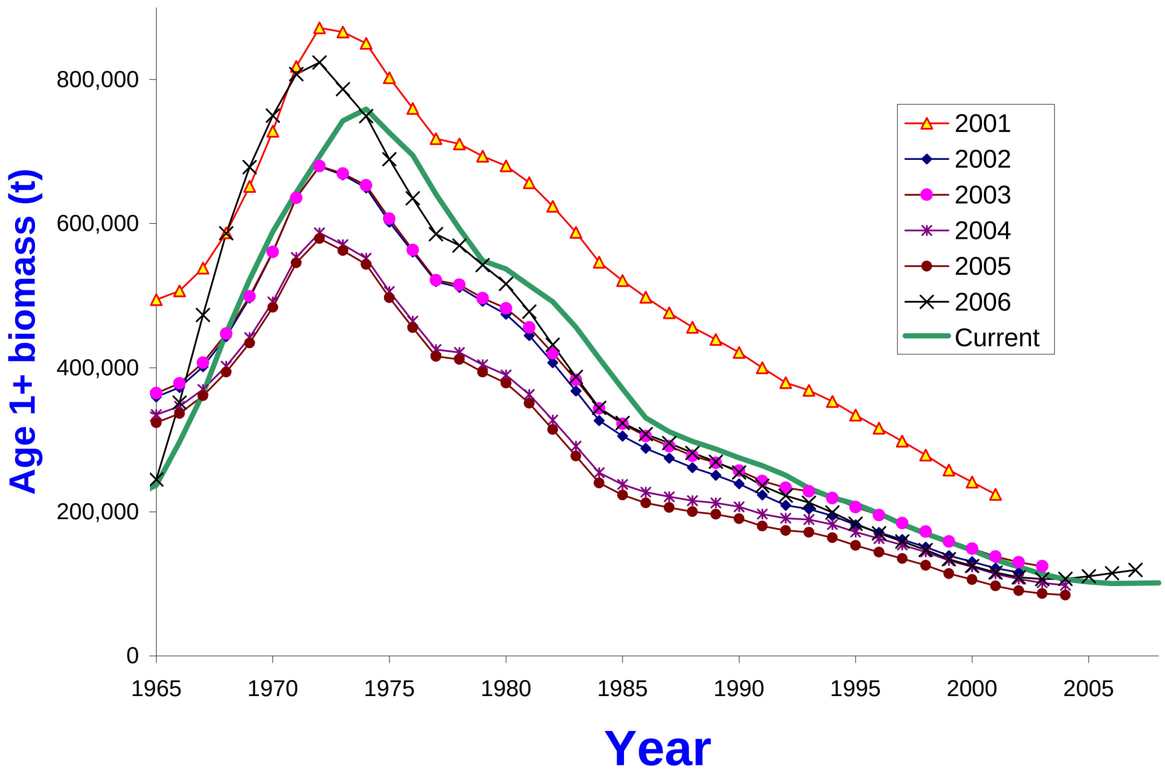


Figure 5.11 Total age 1+ biomass trend for Greenland turbot in the EBS/AI region, 1965-2007 compared to previous assessments.

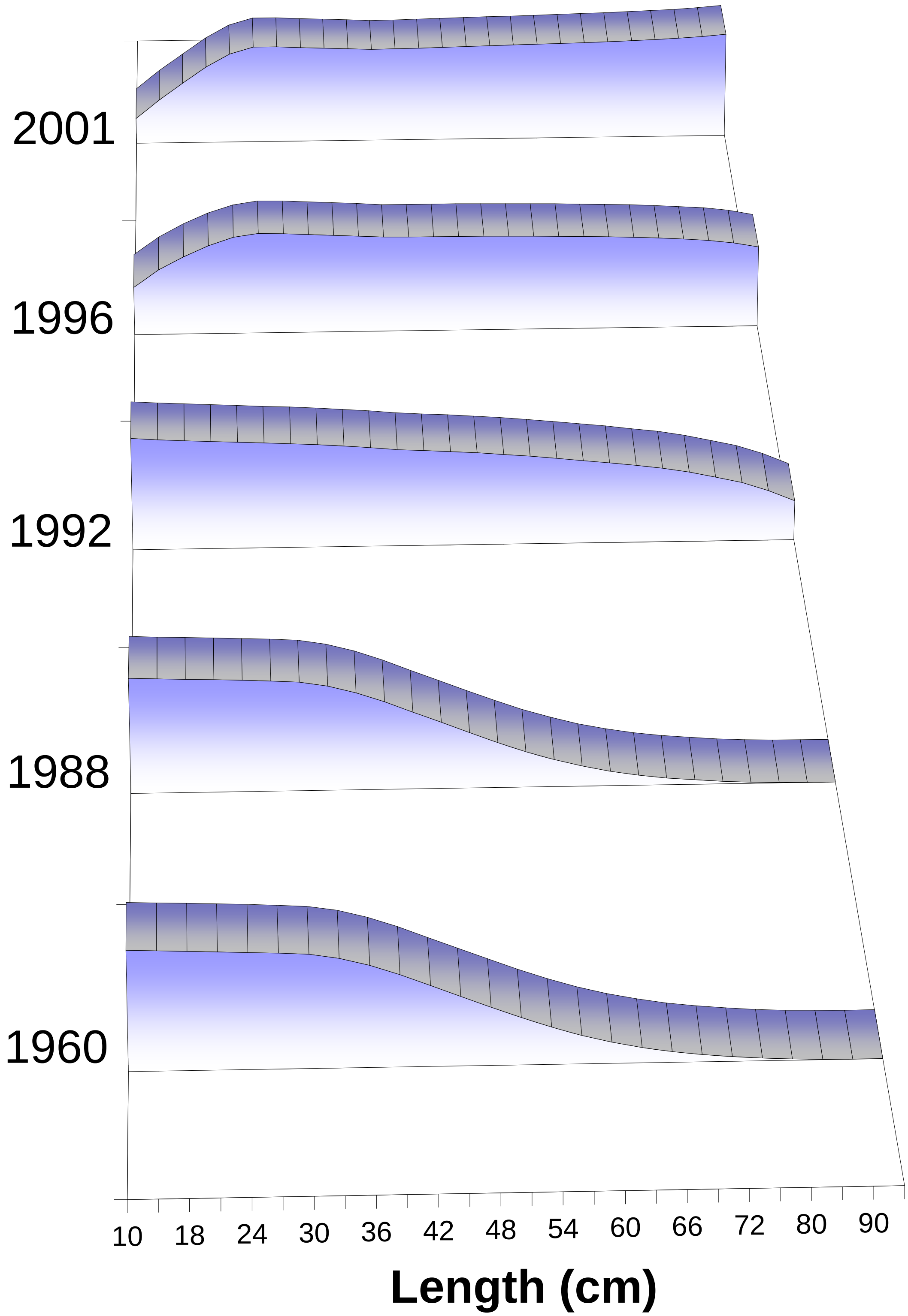


Figure 5.12. Average size-specific selectivity patterns for EBS shelf surveys over time as estimated for female Greenland turbot. The year represents the first year in which the corresponding selectivity estimate was invoked.

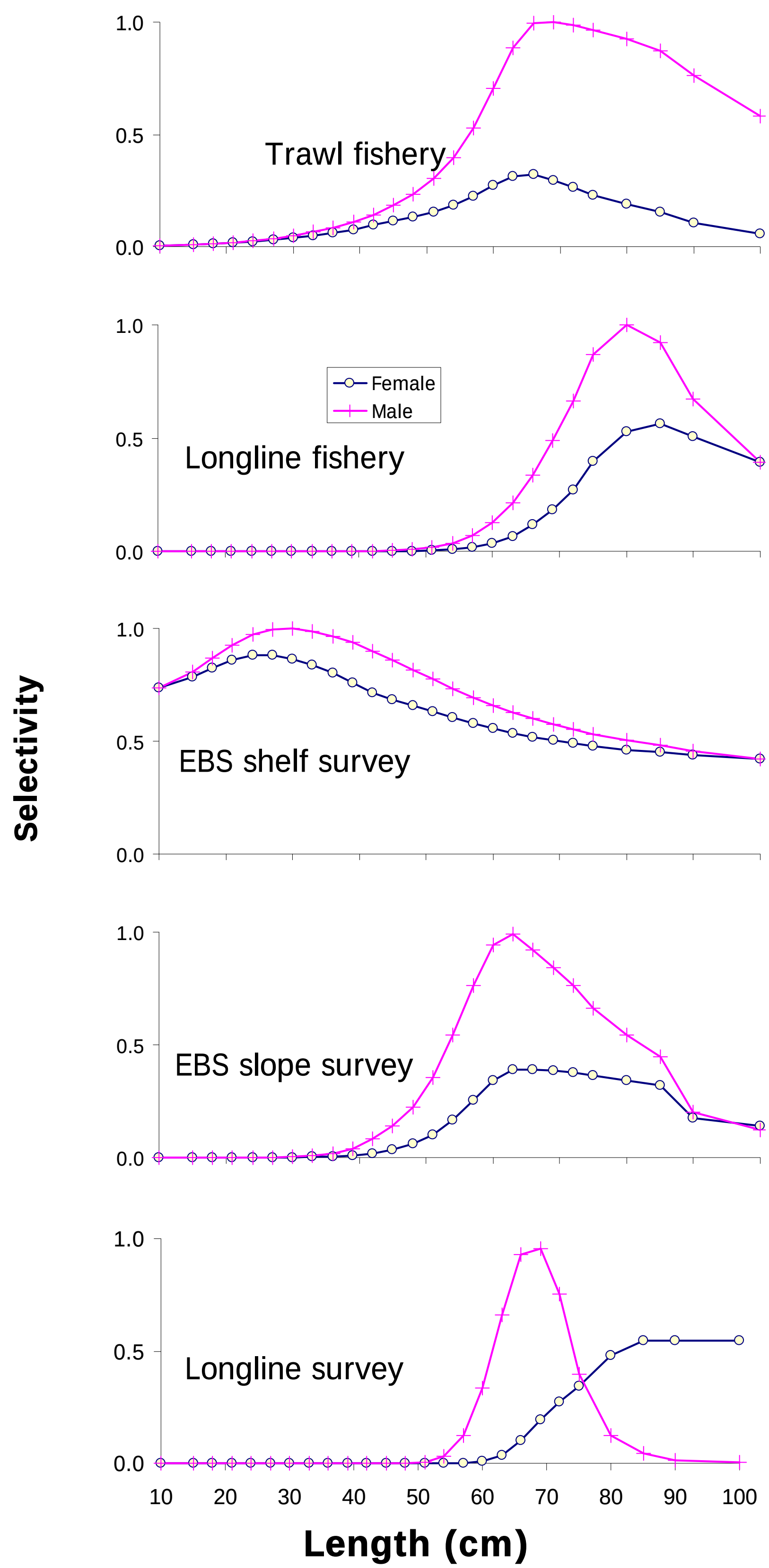


Figure 5.13. Average (over time) size-specific selectivity patterns for all fisheries and surveys for EBS Greenland turbot showing differences in sex-specific availability.

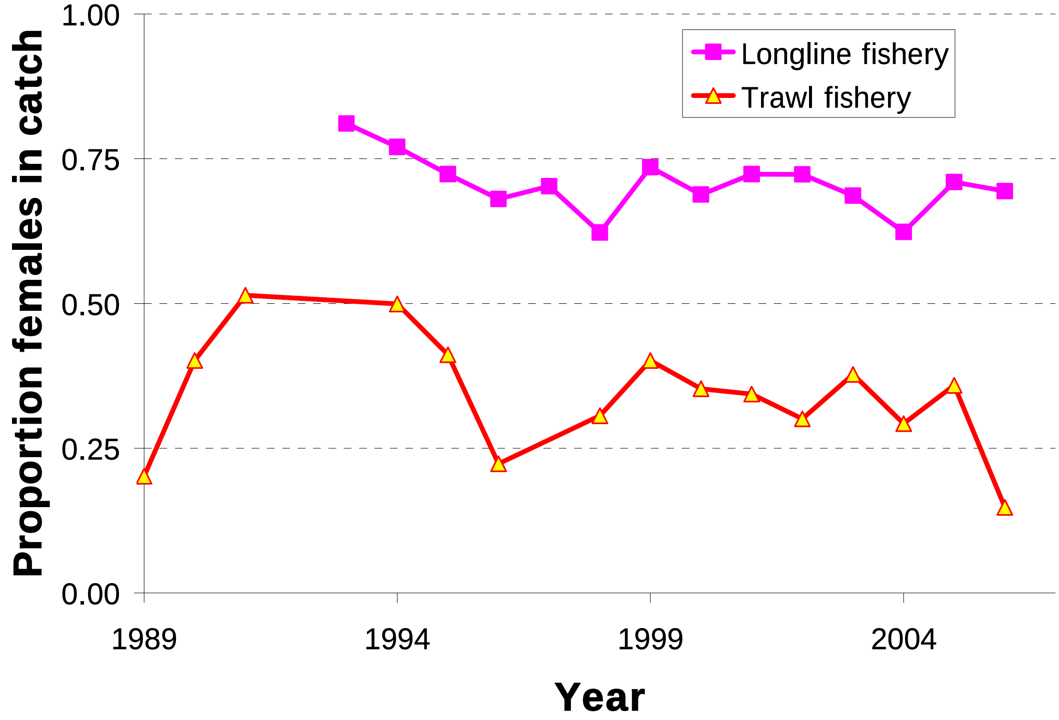


Figure 5.14. Observed Greenland turbot sex ratio over time from trawl and longline fisheries.in the BSAI region.

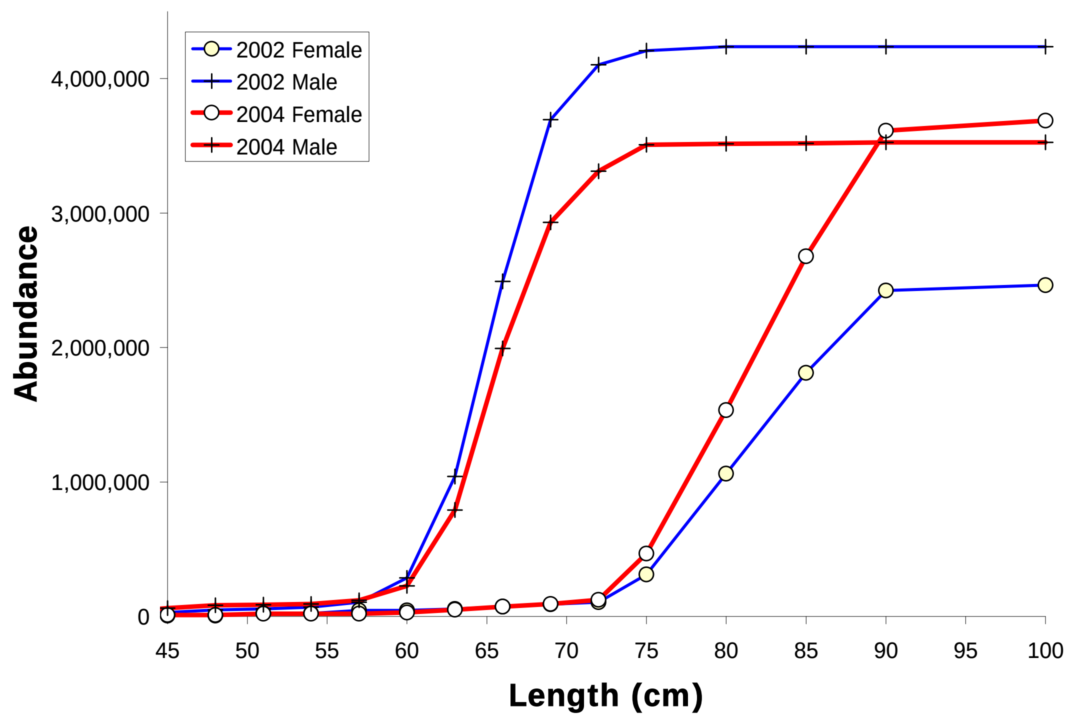


Figure 5.15. EBS slope survey estimates of Greenland turbot cumulative abundance-at-length by sex, 2002 and 2004.

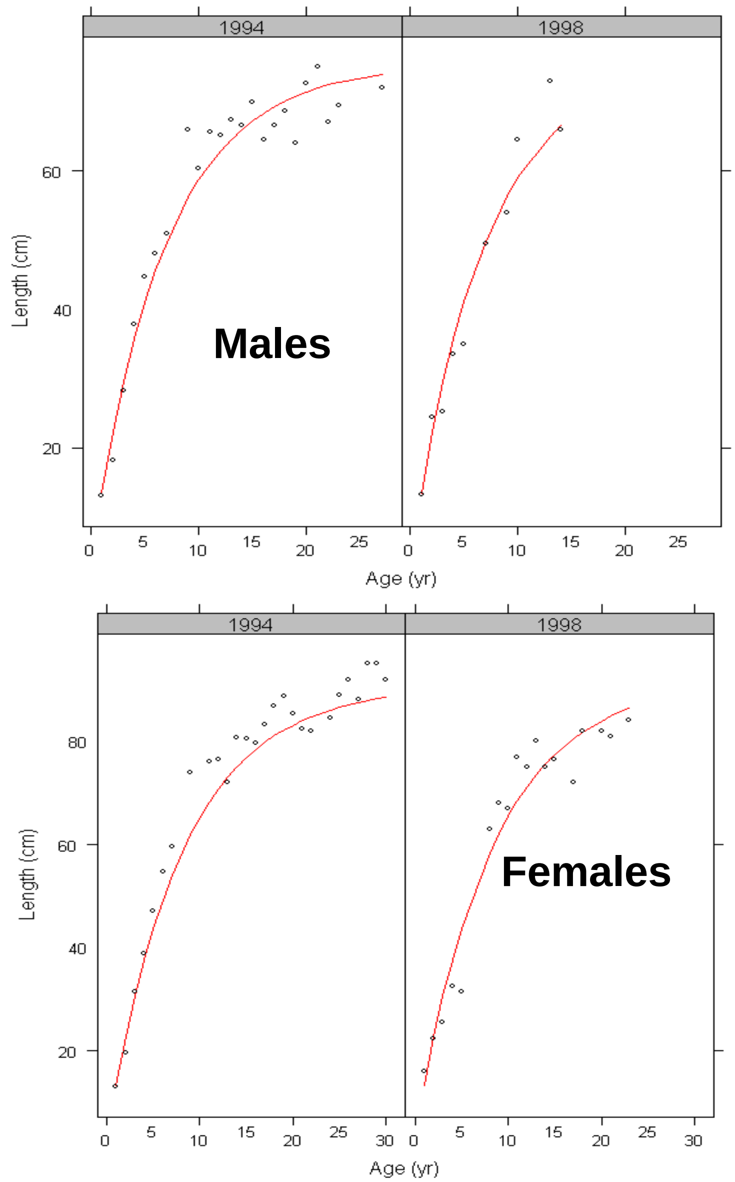


Figure 5.16. Estimated growth (length at age) of Greenland turbot by sex in the EBS/AI region as predicted by the model and compared to the new age data using the methods of Gregg et al (2006).

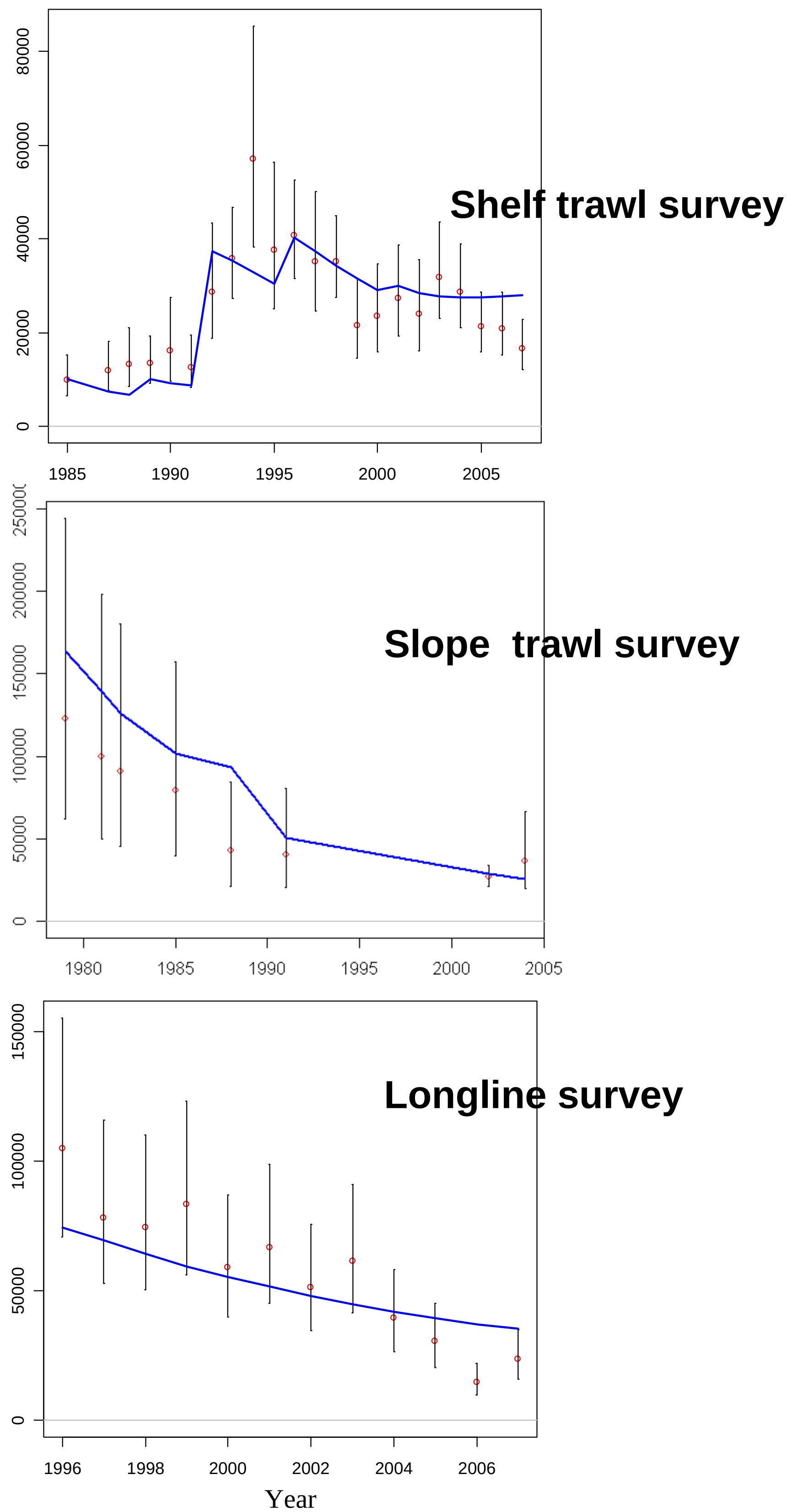


Figure 5.17. Fits to the different survey indices for Greenland turbot in the EBS/AI region.

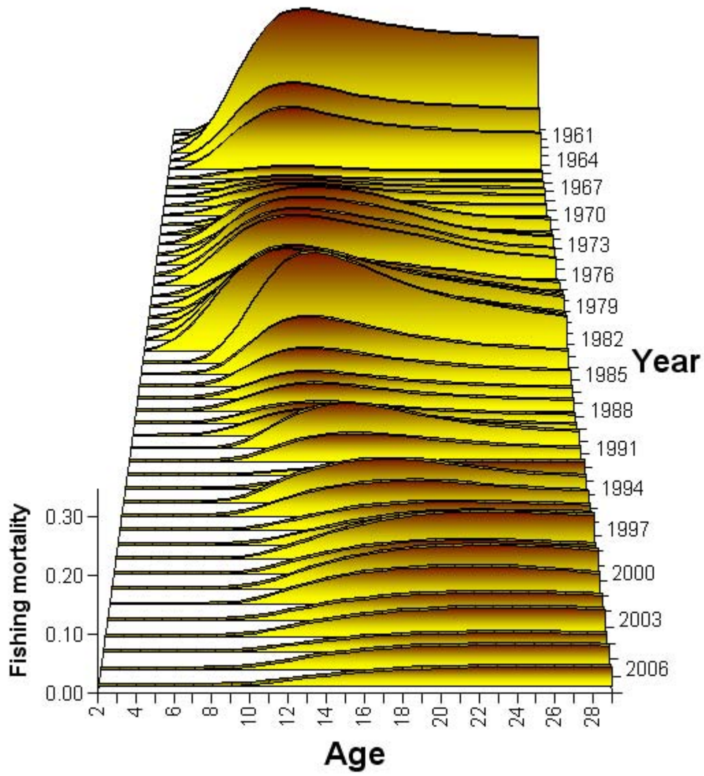


Figure 5.18. Estimated total age-specific fishing mortality rate (gears and sexes combined) for BSAI Greenland turbot, 1960-2007.

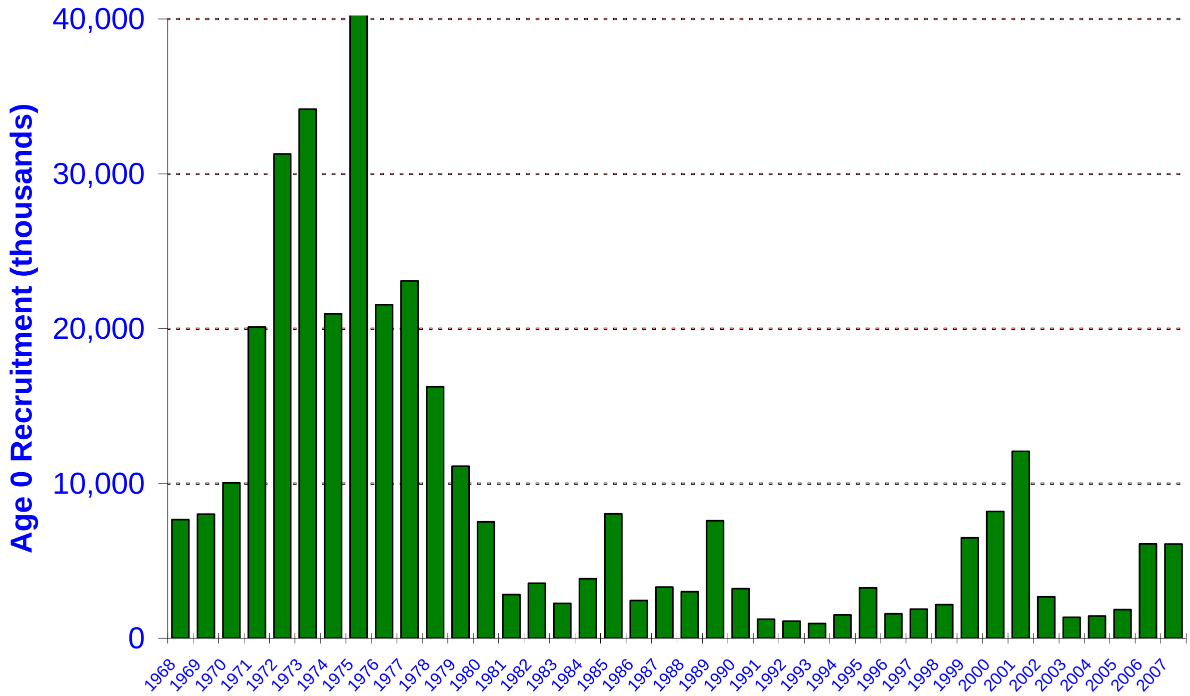


Figure 5.19. Estimated recruitment at age 0 (thousands) for Greenland turbot in the EBS/AI region, 1968-2007.

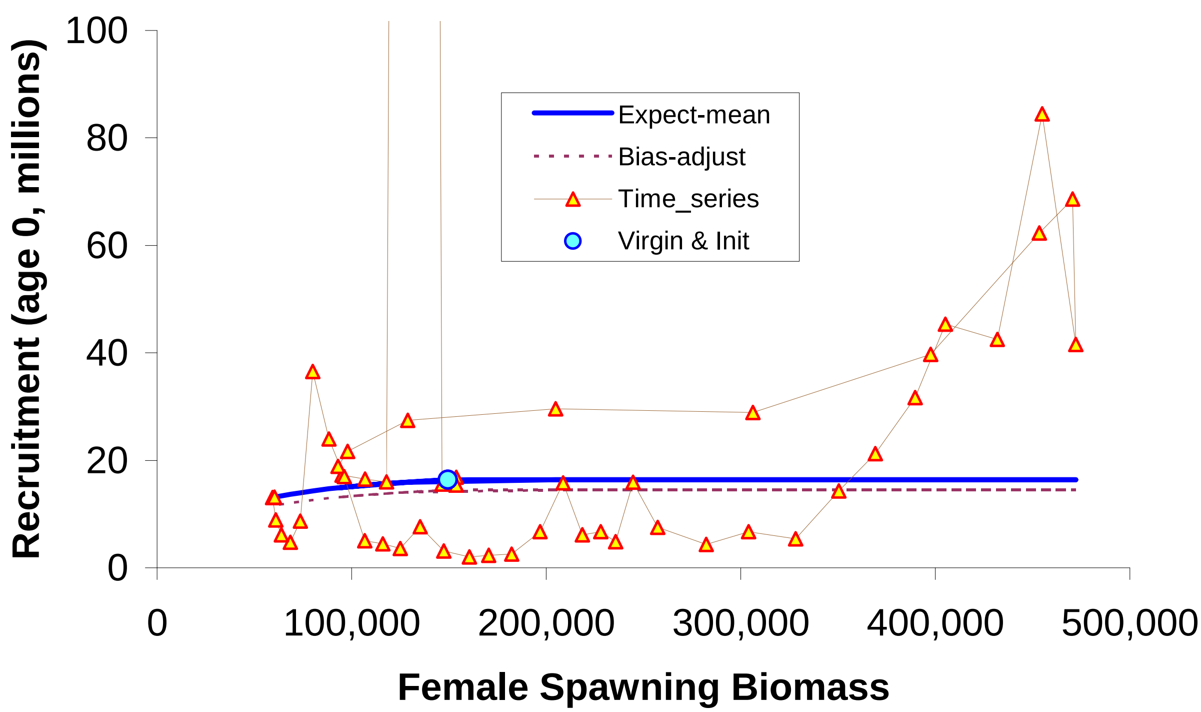


Figure 5.20. Stock and recruitment estimates compared to fixed model shape (steepness) specified within SS2 for Greenland turbot in the BSAI region, 1960-2007.

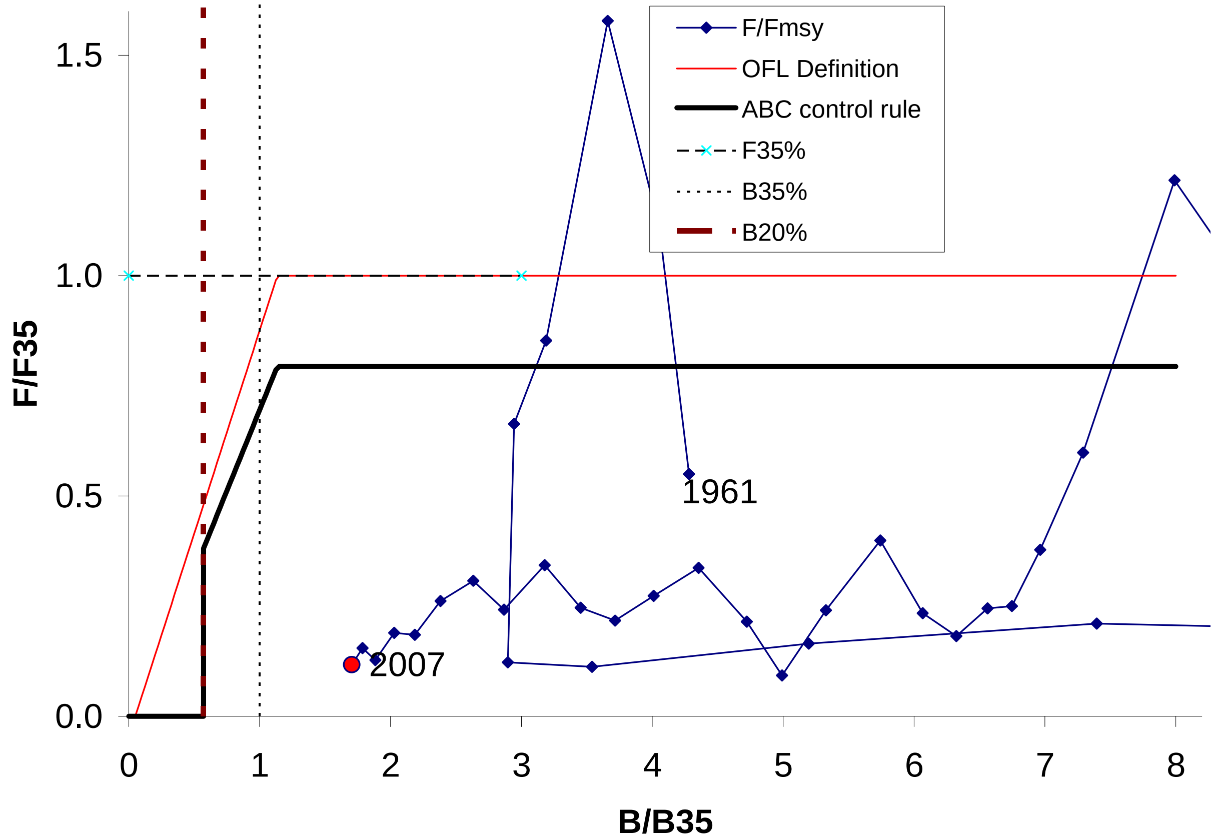


Figure 5.21. Ratio of historical F/$F_{35\%}$ versus female spawning biomass relative to $B_{35\%}$ for BSAI Greenland turbot, 1961-2007.

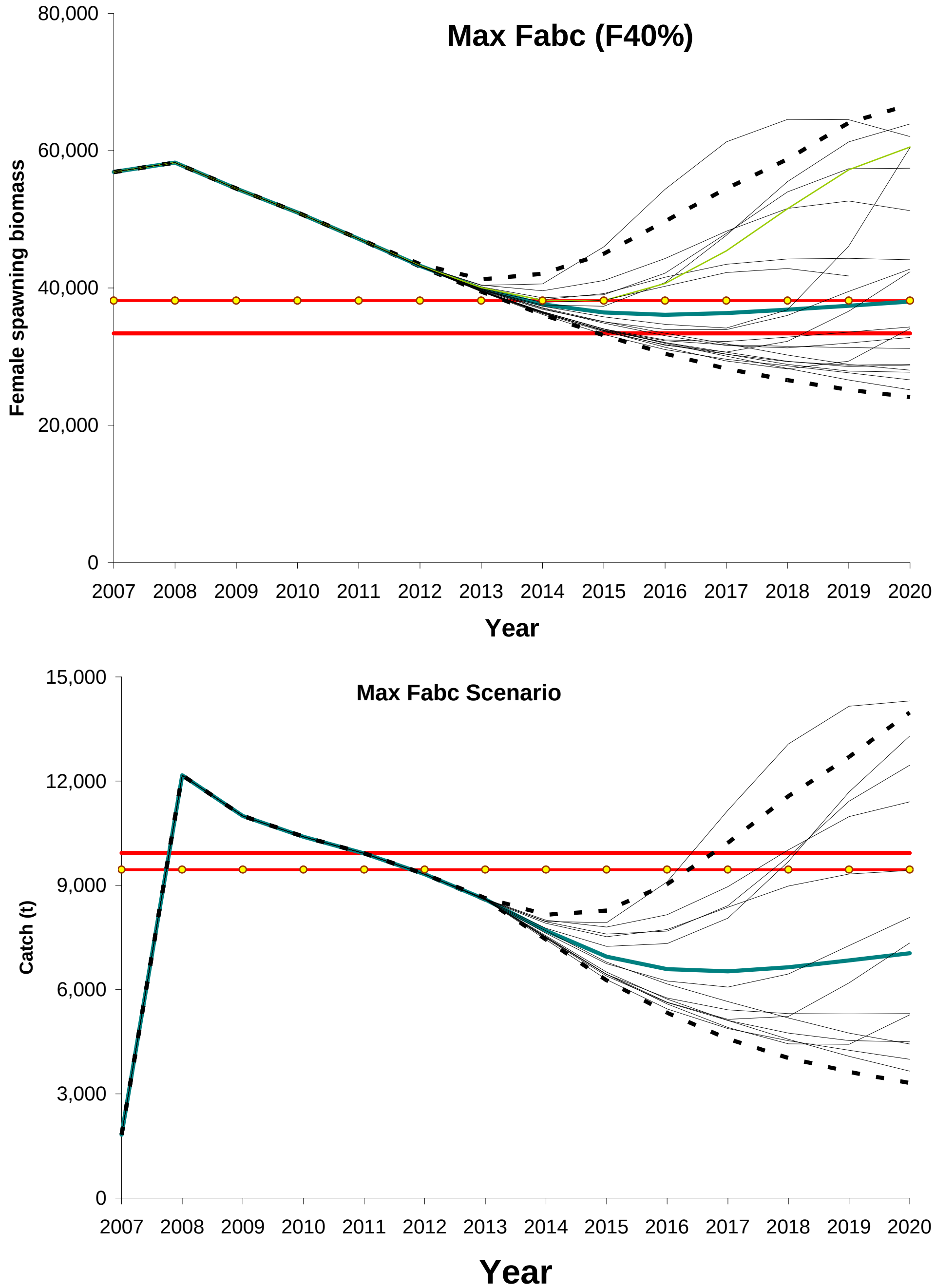


Figure 5.22. Stochastic trajectory of Greenland turbot female spawning biomass and catch for the maximum allowable fishing mortality rate under Amendment 56/56, Tier 3 The dotted lines represent the upper and lower 90% confidence limits. Horizontal lines with marks are the values associated with $B_{40\%}$ and $F_{40\%}$ while the thick horizontal line is the expected value under constant F_{OFL} rate ($F_{35\%}$).

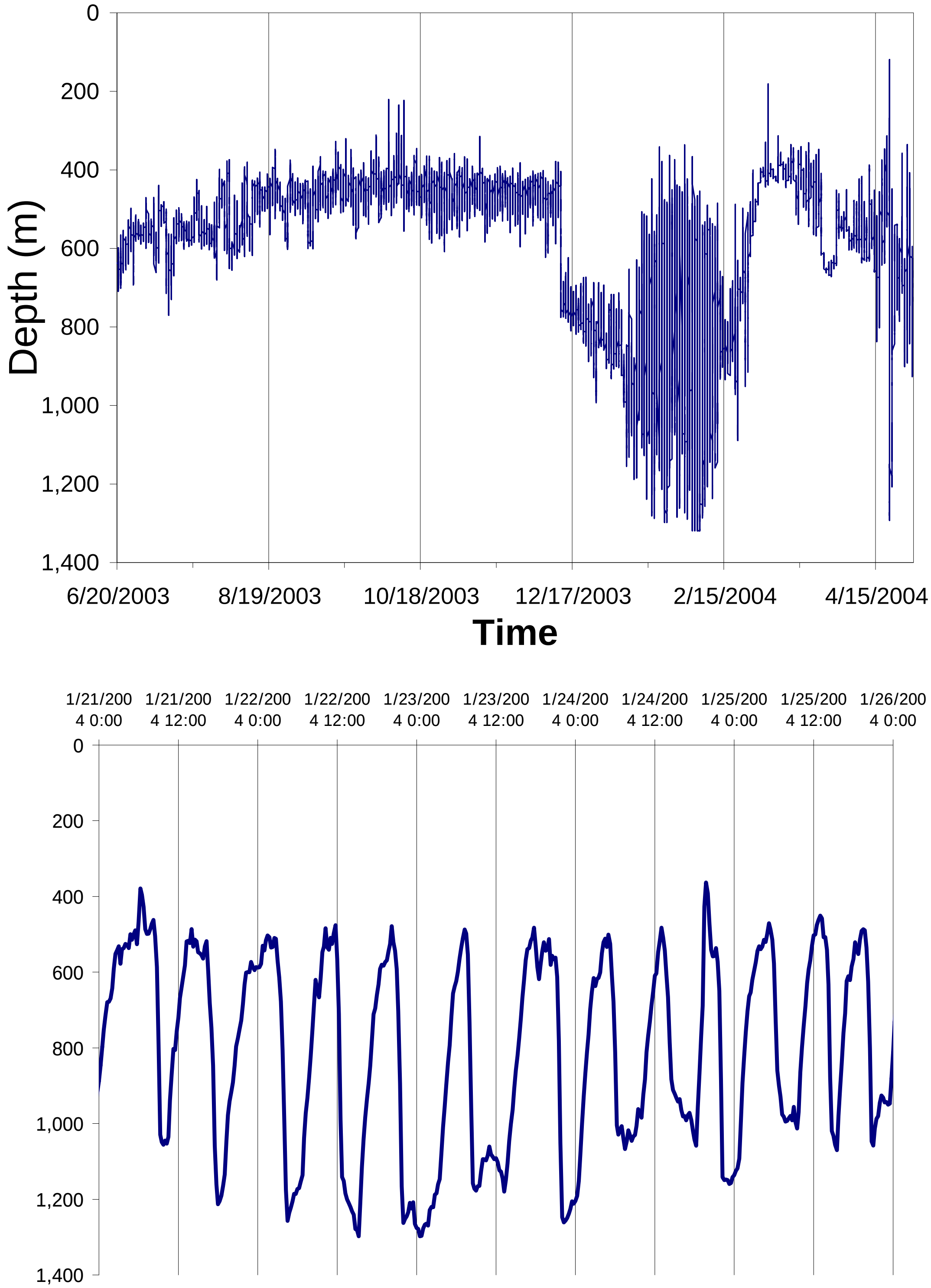
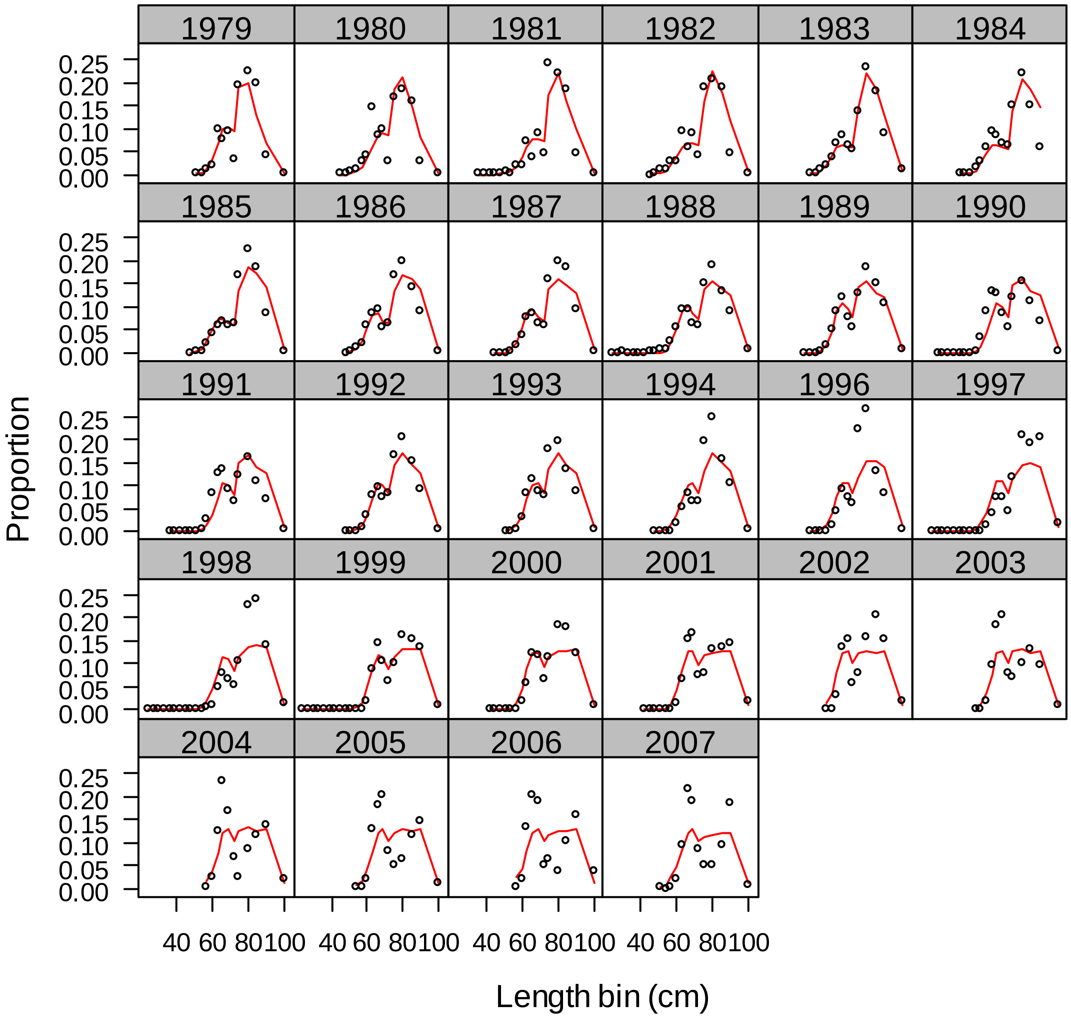
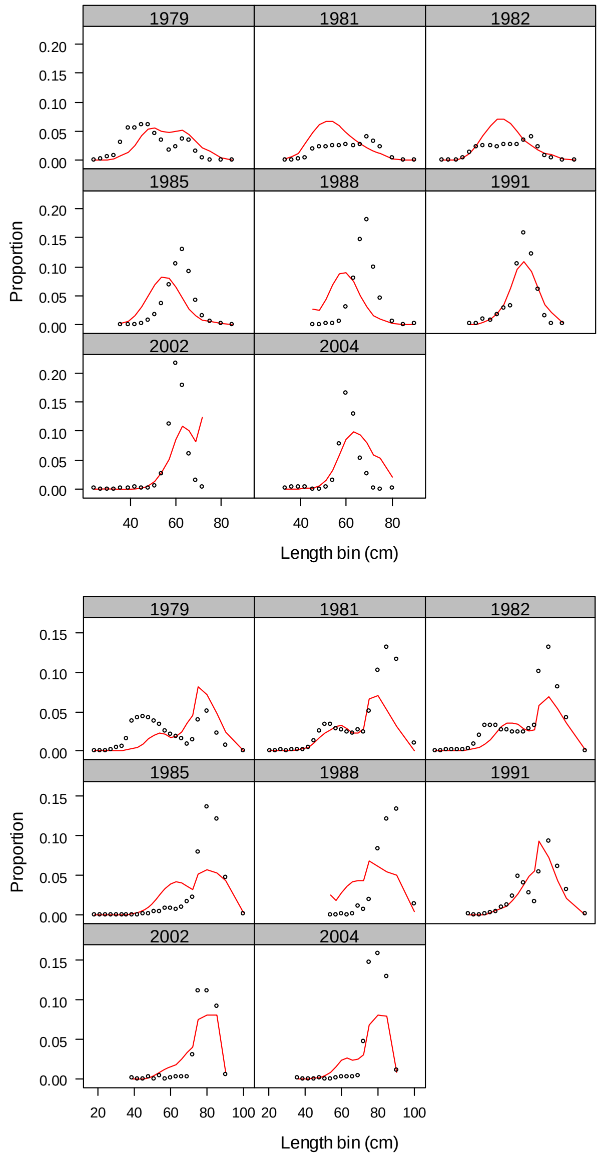


Figure 5.23. Depth pattern of Greenland turbot in the EBS based on archival tags showing depth over a 1-yr time interval (top) and over a 1-week period within that year (bottom).

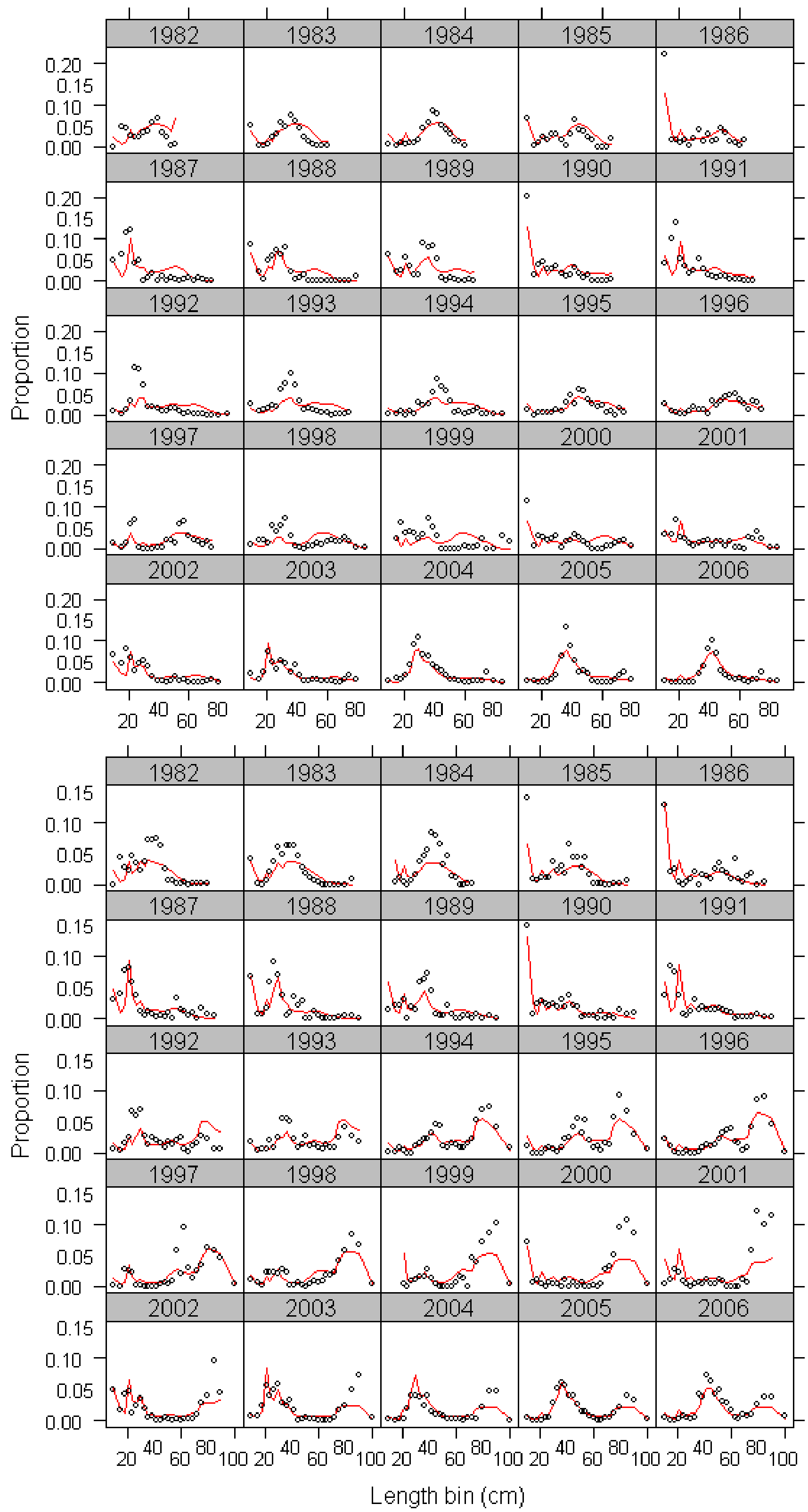
Attachment 5.1 Model fits to the size composition data



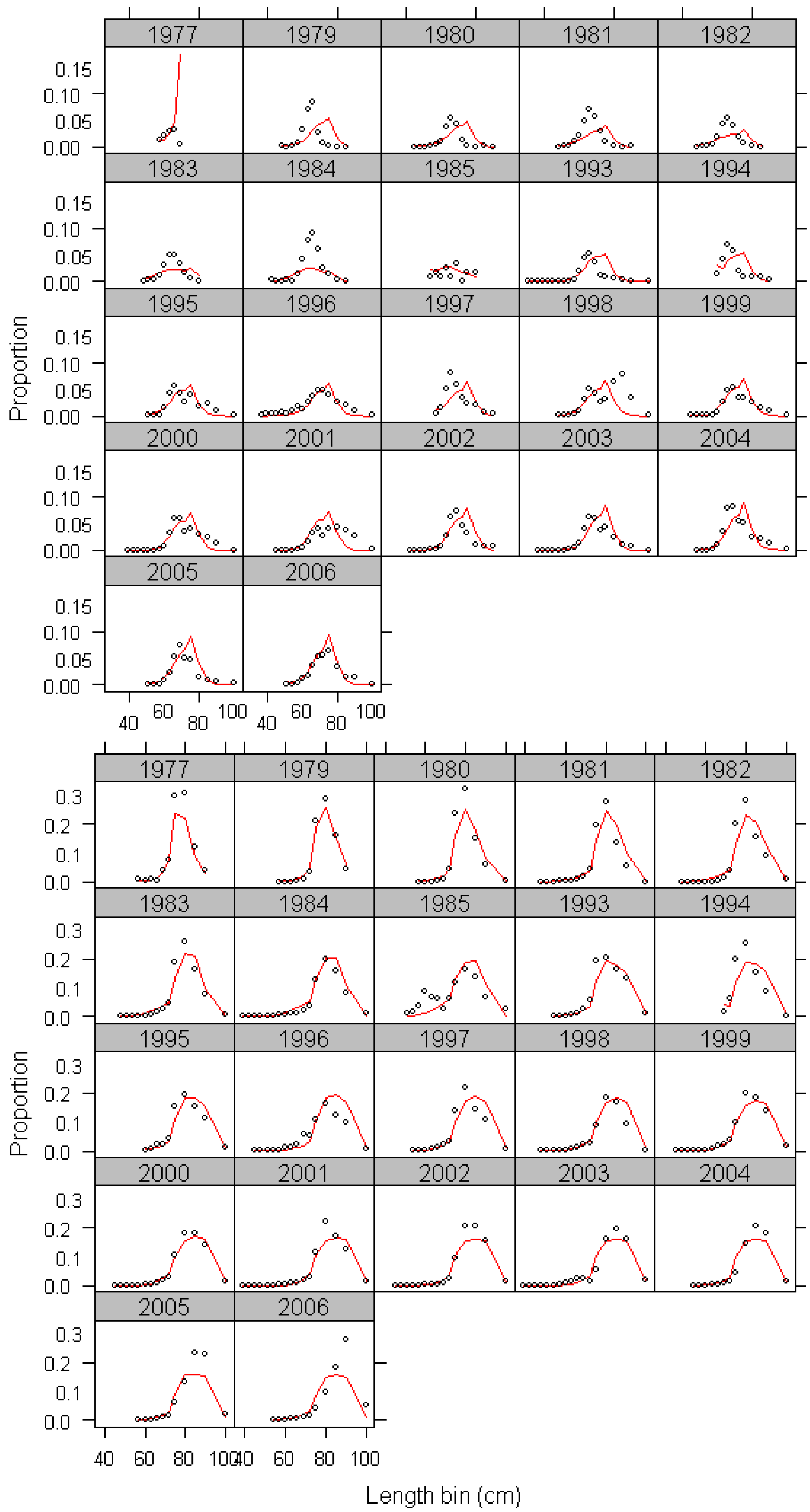
Greenland turbot model fit to longline survey length frequency data. Lines are model predictions, points are data



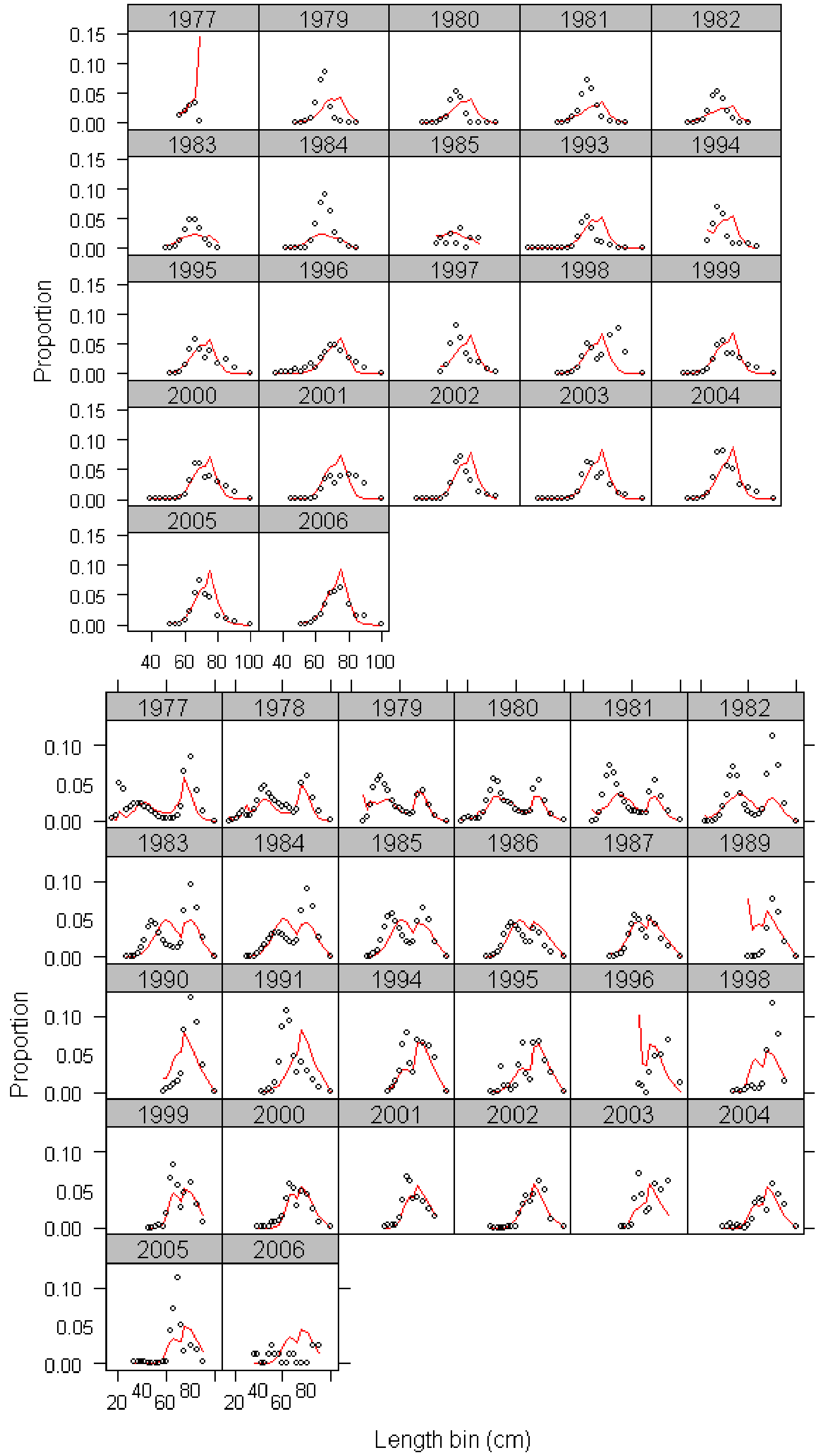
Greenland turbot model fit to EBS slope trawl survey length frequency data. The top set are males, while the bottom are females. Lines are model predictions, points are data



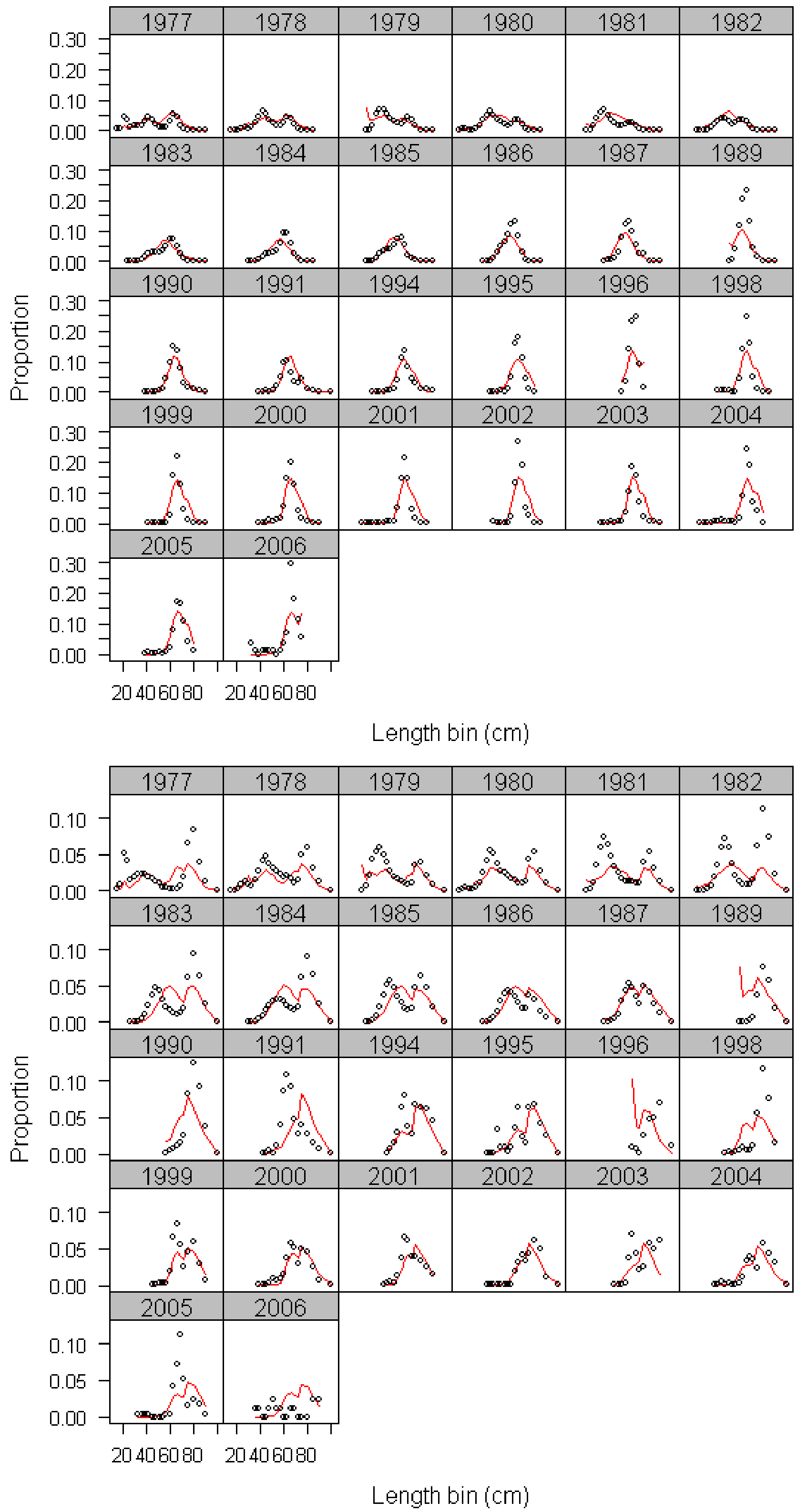
Greenland turbot model fit to EBS shelf trawl survey length frequency data. The top set are males, while the bottom are females. Lines are model predictions, points are data



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



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