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. 2009 and 2010 catch data were updated (and added).
2. The Eastern Bering Sea (EBS) shelf survey 2010 biomass and length composition estimates were added.
3. The Eastern Bering Sea (EBS) slope survey 2010 biomass and length composition estimates were added.
4. The 2010 Aleutian Islands survey data are evaluated changes in relative abundance between regions.

Changes to the assessment model

The model used this year was modified last year's SS3 version (3.11c) of the Stock Synthesis software. As noted in last year's assessment, the planned change was to stabilize the early 1960s recruitment estimates where size and age data are lacking (but significant removals of Greenland turbot occurred). This configuration was implemented and used for this assessment. Instead of estimating individual recruitments during the 1960s a separate expected value period from 1960-1969 was assumed for recruitment.

Changes in the assessment results

The 2010 **EBS shelf trawl survey** biomass estimate was more than double the 2009 estimate the highest biomass since 2003. More significantly, the population numbers was the highest ever recorded (since the standard survey began in 1982). The total 2010 population estimate (in numbers, all ages) from the EBS survey was over five times the average for Greenland turbot. The high numbers were almost entirely due to indications of one-year old Greenland turbot in this survey. While the EBS region is showing good signs of Greenland turbot, the 2010 Aleutian Islands survey is the lowest on record and about one third of the value estimated in 2006. This may be a concern because in recent years the proportion of Greenland turbot taken in the Aleutian Islands has increased significantly.

Model results based on these surveys and data from longline and trawl fisheries result in an estimate of $B_{40\%}$ equal to 28,419 t (female spawning biomass). The current estimate of the 2010 female spawning biomass is 49,200 t. There appears to be a favorable recruitment pattern in recent years and the 2010 survey saw the largest abundance of 1-yr old Greenland turbot on record. Recommended ABCs are set to the maximum permissible there are indications of excellent recruitment and that the 2010 slope trawl survey was completed. The corresponding maximum permissible ABC levels for Greenland turbot under Tier 3a are 6,137 and 5,750 t, respectively. The 2011 and 2012 overfishing levels, based on the $F_{35\%}$ rate are 7,217 t and 6,764 t corresponding to a full-selection F of 0.293.

Response to SSC comments

There were no comments specific to Greenland turbot assessment this year.

Summary

Quantity/Status		Last year 2010	Last year 2011	This year **2011**	This year 2012
M (natural mortality)		0.112	0.112	0.112	0.112
Specified/recommended Tier		3a	3a	**3a**	3a
Projected biomass (ages 1+)		61,100	55,000	74,000	69,700
Female spawning biomass (t)					
Projected		39,953	35,468	45,504	40,407
$B_{100\%}$		60,637	60,637	71,048	71,048
$B_{40\%}$		24,255	24,255	28,419	28,419
$B_{35\%}$		21,223	21,223	24,867	24,867
F_{OFL}		0.315	0.315	0.293	0.293
$maxF_{ABC}$		0.255	0.255	0.247	0.247
Specified/recommended F_{ABC}		0.255	0.255	0.247	0.247
Specified/recommended OFL (t)		7,460	6,860	7,217	6,764
Specified/recommended ABC (t)	BSAI	6,120	5,370	**6,137**	**5,750**
	EBS	4,220	3,700	4,590	4,301
	AI	1,900	1,670	1,547	1,449
Is the stock being subjected to overfishing? Is the stock currently overfished? Is the stock approaching a condition of being overfished?		No		**No**	

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; Sohn 2009; Fig. 5.1). 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. 5.2). 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. From 1990- 1995 Council set the ABC's (and TACs) to 7,000 t as an added conservation measure citing concerns about recruitment. Since 1996 the ABC levels have varied but averaged 7,660 t (with catch for that period averaging 4,550 t). The size frequency of the catch from the fisheries over time shows the how there are usually two modes present representing males at the smaller mode and females at the larger (Fig. 5.3).

In 2008 and 2009 (and likely 2010), trawl-caught Greenland turbot has exceeded the level of catch by longline vessels (Table 5.1). The shift in the proportion of catch by sector was due to changes arising from Amendment 80 passed in 2007. Amendment 80 to the BSAI Fishery Management Plan (FMP) was designed to improve retention and utilization of fishery resources. The amendment extended the American Fisheries Act (AFA) Groundfish Retention Standards to all vessels and established a limited access privilege program for the non-AFA trawl catcher/processors. This authorized the allocation of groundfish species quotas to fishing cooperatives and effectively provided better means to reduce bycatch and increase the value of targeted species.

The longline fleet generally targets pre-spawning aggregations of Greenland turbot; the fishery opens May 1 but usually occurs June-Aug in the EBS to avoid killer whale predation. 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 12.6% of all Greenland turbot caught in groundfish fisheries were discarded (on average) during 2004-2010.

By gear-type and region, trawl catch was most significant in the Aleutian Islands in 2009 and 2010 whereas in the EBS there was high trawl catch in 2008 but then a switch to higher longline catches in 2009 and 2010 (Table 5.3). By target fishery, the gain in trawl-fishery has occurred primarily in the Greenland turbot and "arrowtooth flounder" fisheries in 2008 - 2010 (Table 5.4).

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 are becoming available for Greenland turbot. Age-determination methods have improved in the last few years and new age data are used this 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) and absolute sample sizes for the period of the domestic fishery by sex and fishery from 1989 – 2010 are given in Table 5.5.

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 ship 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 Miller Freeman for calibration purposes. However, the 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 and in 2010 (Table 5.6).

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 (Figs. 5.4 and 5.5). The shelf survey biomass estimates are therefore treated as a relative abundance index.

The estimated biomass of Greenland turbot in this region has fluctuated over the years. When US-Japanese slope surveys were conducted in 1979, 1981, 1982 and 1985, the combined survey biomass estimates from the shelf and slope indicate a decline in EBS abundance. After 1985, the combined shelf plus 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 17 years (1993-2010) is 24,600 t. The number of hauls and the levels of Greenland turbot sampling in the shelf surveys are presented in Table 5.7. The EBS shelf survey in 2010 found an exceptional abundance level of Greenland turbot which was also more ubiquitous in the proportion of tows with Greenland turbot present (Fig. 5.6). These observations suggest that the extent of the spatial distribution has remained relatively constant prior to 2010 (with a slight increase) and that the most recent survey has both high densities and wider-spread spatial distribution.

The 2010 EBS slope trawl survey biomass estimate was up by 11% from the 2008 survey and 19,900 t but below the average (2002-2010) of 25,500 t. Most of the change in biomass estimates is due to the changes in Greenland turbot abundance found in the 400-600 m depth strata (Table 5.8).

Survey size composition
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 that are consistent with the trends in biomass (Fig. 5.7). 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, 1998, and 2007 surveys) were used instead of the earlier data. Research on Greenland turbot age-validation methods continues at the AFSC.

Aleutian Islands survey
The 2010 Aleutian Islands bottom trawl survey estimate was 6,800 t, well below the 1991-2010 average level of 15,800 t (Table 5.6). The distribution of Greenland turbot in 2010 indicate lower abundances and variability of Greenland turbot in the survey compared to other recent surveys (Fig. 5.8). The breakdown of area specific survey biomass for the Aleutian Islands region shows that the eastern region has the highest densities and contains about 61% of the biomass, on based on average biomass from survey data from 1991-2010 (Fig. 5.9; Table 5.9). The trawl-survey area-swept data for the Aleutian Islands component of the Greenland turbot stock is not presently included in the stock assessment modoel.

Longline survey
The sablefish longline survey alternates years between the Aleutian Islands and the Eastern Bering Sea slope region. This year the EBS region was covered but an unusually high number of orca depredation events occurred: 10 out of 16 stations were affected. Some investigations on how to account for these events highlight the need for more detailed analysis. For this year's assessment, the 2009 and 2010 data were assigned CVs of 0.3 whereas a CV of 0.2 was used for the earlier period.

The survey time series (through 2010) indicates 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	2009	2010
Bering 4		11,729		13,072		16,082		11,965		3,717		1,561		1,899	
Bering 3		6,172		6,156		5,005		3,784		1,822		1,754		422	
Bering 2		27,936		33,848		24,766		24,660		15,268		13,523		6,603	
Bering 1		13,491		10,068		4,788		6,206		2,297		1,235		2,067	
NE Aleutians	23,133		16,124		12,987		10,942		8,551		3,031		3,155		2,032
SE Aleutians	2,142		1,806		1,201		1,397		937		566		297		163
Bering Sea (total)		59,328		63,144		50,641		46,616		23,103		18,074		10,991	
Aleutians (total)	25,275		17,930		14,188		12,339		9,487		3,597		3,452		2,196
Combined (/1000)	114.1	76.2	80.9	81.1	64.0	65.1	55.7	59.9	42.8	29.7	16.2	23.2	15.6	14.1	9.9

The combined time series shown above (1996-2010) was used as a relative abundance index. It was computed by taking the average RPN from 1996-2010 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 (1996-2010) 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. The time series of length frequency data from the longline survey extends back to the cooperative longline survey and is shown in Fig. 5.10.

Annual research catches (t, 1977 - 2010) from NMFS longline and trawl surveys are estimated as follows:

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
NMFS Bottom trawl survey	62.5	48.4	103	124	2	1	175	0.2	0.5	19	0.6	0.7	9.0	0.9	1.4	2.0
Longline surveys	3	3	6	11	9	7	8	7	11	6	16	10	10	22	23	23
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NMFS Bottom trawl survey	1.4	1.5	1.2	1.4	1.0	5.1	1.1	5.3	1.1	11.0	0.7	0.76	0.59	0.49	0.42	0.816
Longline surveys												1.1	3.5	n/a	n/a	n/a

Analytic approach

Model Structure

A version of the stock synthesis program (Methot 1990) has been used to model the eastern Bering Sea component of Greenland turbot since 1994. The software and assessment model configuration has changed over time, particularly in the past four years as newer versions have become available.

Total catch estimates used in the model were from 1960 to 2010. Model parameters were estimated by maximizing the log posterior distribution of the predicted observations given the data. Prior distributions consisting of very small penalties on recruitment deviations from a mean value were assumed. This was required to stabilize estimates of recruitment early in the time series when data were limiting. The model included two fisheries, those using fixed gear (longline and pots) and trawls, together with three surveys covering various years (Table 5.10). An archive of the software and model configuration for the final model can be found at http://www.afsc.noaa.gov/refm/docs/2010/BSAIGturbot.zip.

Some key assumptions from past models were retained—most importantly that the slope-trawl survey is treated as an absolute index representing 75% of the Greenland turbot stock inhabiting US waters. In 2010 the NMFS survey extended into waters well north of the normal survey area but relatively minor amounts of Greenland turbot were found (Fig. 5.11).

This year an old feature was re-introduced. Namely, instead of estimating individual recruitments during the 1960s a separate expected value period from 1960-1969 was assumed for recruitment. During this period data on age composition of the catch and population is unavailable but is important to model because high-levels of catches occurred from 1960 through to the mid-1980s. This resolved previous issues with the model assigning an extremely large value to a single recruitment (about which there is no information) and set the early period to something like an independent mean value.

Selectivity Patterns
Gender-specific size-based selectivity functions were estimated for each survey and fishery described below. For the trawl fishery, foreign operations occurred prior to the domestic fishery hence could be treated as a single fishery with an allowance for different size-based selectivity patterns estimated for 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 periods. 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 5.11.

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 1960-2010 (parameterized as deviations scaled to the estimated mean recruitment)
- Selectivity for the 2 fisheries, and 3 surveys over different time frames, and
- Growth: 5 parameters (2 for each sex, one in common).

Model evaluation

Size composition data are unavailable 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

In general, the model fit to the index data has a less than ideal pattern of residuals but fall generally well within the confidence bands assumed for the data (Fig. 5.12). The fit to the slope survey (considered to best cover the habitat for Greenland turbot) fits well and the residual pattern appears to be reasonable. The current assessment results in similar abundances during the mid 1970s compared to assessments prior to 2009 (Fig. 5.13).

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 a gradual decline over the past 3 decades with the 2011 total begin-year biomass (age 1 and older) estimate to about **74,000** t (Table 5.12).

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 5.12; Fig. 5.14). A comparison of this year's model result with the 2008 assessment is also presented in Table 5.12. The estimated historical numbers at age is given in Table 5.13.

Selectivity
Estimates of selectivity (using recommended option #24 in SS3—a "double normal" parameterization which describes the ascending and descending limbs of the curve with defined initial and final selectivity levels as parameters) provide patterns that appear reasonable over time for the shelf survey and other gear types (Fig. 5.15). 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 has comprised about 70% females with a distinct trend towards 50:50 in recent years (Fig. 5.16). The slope trawl survey also shows that in there is variability in the proportion female. In 2002, 2008, and 2010 the survey resulted in far more males than females—opposite of what was estimated for 2004 (more females than males; Fig. 5.17). This highlights the variability within the same region between years regarding observed sex ratios.

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. 5.15). Note that the average selectivity estimates for the slope and shelf surveys indicate that the surveys sample intermediate size fish (35-50cm) poorly. 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 approximate age and sex-specific selectivity estimates (for 2010) from each gear type for Greenland turbot in the BSAI is given in Table 5.14. These are approximate because selectivity processes are modeled as a function of size. Similarly, approximate age-and-sex-specific weights are available and these are used in the projection model (Table 5.15).

Fit to age and size composition data
The model fit the available length-at-age data reasonably well and indicates that females grow larger than male Greenland turbot (Fig. 5.18). Size composition observations from the fisheries and surveys are matched by the model predictions reasonably well (see Attachment 5.A, Figs. 5.22 -5.27). 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, and especially in 2010, there has been evidence of big increases in recruitment for Greenland turbot (Fig. 5.19).

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 1978-2009 gives a long-term average female spawning biomass of 28,419 t. The estimated 2011 female spawning biomass is about 45,500 t, above the estimate of $B_{35\%}$ (24,867 t).

Specification of OFL and Maximum Permissible ABC and ABC Recommendation

In the past several years, the ABC has been set below the maximum permissible estimates. For example, in 2008 the ABC recommendation was 21% of the maximum permissible level. The rationale for these lower values have been generally due to concerns over stock structure uncertainty, lack of apparent recruitment, and modeling issues. This year a slope survey was conducted and while some areas show lower abundances (i.e., the Aleutian Islands) the signs of recruitment are the best ever seen for this stock. Hence, the arguments for keeping the ABC recommendation below the maximum permissible are less compelling. Therefore we recommend that the ABC be set to the maximum permissible.

The projected Greenland turbot maximum permissible ABC and OFL levels for **2011** and 2012 are shown below (catch for **2011** was set equal to the ABC recommendation):

Year	Catch (for 2012projection)	Maximum permissible ABC	Recommended ABC	OFL	Female spawning biomass
2011	6,137 t	6,137 t	6,137 t	7,217 t	45,504 t
2012		5,750 t	5,750 t	6,764 t	40,407 t

The estimated overfishing level based on the adjusted $F_{35\%}$ rate is 7,217 t corresponding to a full-selection F of 0.293. 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 unallocated 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 but is beginning to increase (Fig. 5.20).

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 5.16).

Recent research on recruitment processes holds promise for clearer understanding (e.g., Sohn et al. (In Review) and Sohn 2009). Stock structure between regions remains uncertain and therefore the policy has been to harvest the "stock" evenly by specifying region-specific ABCs. Based on eastern Bering Sea slope survey estimates and Aleutian Islands surveys, the proportions of the adult biomass in the Aleutian Islands region over the past three surveys (when both areas were covered) were 26.4%, 23.7%, and 25.5%. These average 25.2% which when applied to the BSAI ABC gives the following region-specific allocation:

	ABC
Aleutian Islands ABC	1,547
Eastern Bering Sea ABC	4,590
Total	6,137

Standard harvest scenarios and projections

A standard set of projections for population status under alternatives were conducted to comply with Amendment 56 of the FMP. 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 2010 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2011 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2010 (here assumed to be 3,234 t). In each subsequent year, the fishing mortality rate is prescribed based on 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 2011, 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. Due to current conditions of strong recruitment and a projected increasing biomass, the recommendation is set equal to the maximum permissible ABC.

Scenario 3: In all future years, F is set equal to the 2006-2010 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 2010 and above its MSY level in 2023 under this scenario, then the stock is not overfished.)

Scenario 7: In 2011 and 2012, 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 2023 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 1 through 7 were projected 13 years from 2010 (Table 5.17). Fishing at the maximum permissible rate indicate that the spawning stock will gradually drop to near the $B_{40\%}$ by 2021 (Fig. 5.21).

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 2010 spawning biomass estimated at 49,198 t relative to $0.5B_{35\%}$ = 12,433 t). Under the guidelines, since the 2010 biomass estimate is above the $B_{35\%}$ level (and $B_{40\%}$) and the stock is not overfished.

Projections with fishing at the maximum permissible level result in an expected value of spawning biomass of 42,139 t by 2023. These projections illustrate the impact of the recent recruitment observed in the survey. For example, under all scenarios except the no-fishing alternative, the spawning biomass is expected to decline until 2015 when the recruits in recent years mature.

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.

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, and

- Evaluating the extent that Greenland turbot are affected by temperature and environmental conditions relative to survey gear.

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. 5.20). Management parameters of interest derived from this assessment are presented in Table 5.18.

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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	7,000	7,000
1995	3,978	4,215	8,194	7,000	7,000
1996	1,653	4,902	6,555	7,000	7,000
1997	1,209	5,989	7,199	9,000	9,000
1998	1,830	7,319	9,149	15,000	15,000
1999	1,799	4,057	5,857	9,000	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	8,000	8,000
2003	908	2,605	3,513	4,000	4,000
2004	675	1,544	2,220	3,500	3,500
2005	729	1,831	2,559	3,500	3,500
2006	360	1,605	1,965	2,740	2,740
2007	429	1,400	1,829	2,440	2,440
2008	1,935	806	2,741	2,540	2,540
2009	3,080	1,417	4,196	7,380	7,380
2010	1,824	1,410	3,234*	6,120	6,120

*Catch estimated as of October 2010

Table 5.2. Estimates of discarded and retained (t) Greenland turbot based on NMFS estimates by "target" fishery, 1992-2010 (the "arrowtooth" fishery was combined with the Greenland turbot fishery from 2003-2010).

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	1,842	95	98	534	165	95	198	5	114	176	79	55	2,497	961
2004	1,244	37	78	24	221	79	72	3	154	158	99	50	1,868	352
2005	1,677	28	63	19	156	30	134	5	179	69	149	49	2,359	200
2006	1,340	33	62	52	65	31	69	8	107	19	135	46	1,778	188
2007	1,091	28	59	71	127	91	36	13	30	35	198	50	1,541	288
2008	1,537	417	42	82	17	70	142	1	96	30	203	103	2,038	703
2009	3,649	336	69	54	65	21	69	8	52	13	148	14	4,053	445
2010	2,819	94	61	27	35	18	9	0	23	73	69	8	3,015	219

Table 5.3. Estimates of Greenland turbot catch by gear and area based on NMFS Regional Office estimates, 2003-2010.

Area	Gear	2003	2004	2005	2006	2007	2008	2009	2010
Aleutian Islands	Fixed	650	218	138	346	338	111	97	226
	Trawl	315	196	301	179	178	712	2,164	1,623
	Aleutian Islands Total	965	414	439	525	516	824	2,261	1,849
EBS	Fixed	1,918	1,326	1,693	1,259	1,061	694	1,321	1,184
	Trawl	575	479	427	181	251	1,222	916	201
	EBS Total	2,493	1,805	2,120	1,440	1,313	1,917	2,237	1,386
Grand Total		3,458	2,220	2,559	1,965	1,829	2,741	4,497	3,234

Table 5.4. Estimates of Greenland turbot catch (t) by gear and "target" fishery, 2004-2010. Source: NMFS AK Regional Office catch accounting system. *Note, 2010 data are preliminary.*

	"Target" fishery	2004	2005	2006	2007	2008	2009	2010
Longline and pot	Greenland turbot	1,168	1,527	1,212	1,097	573	1,192	1,140
	Sablefish	90	75	114	130	119	122	87
	Pacific cod	221	170	77	129	76	84	46
	Shallow-water flatfish	64	57	61	15	15	7	77
	Arrowtooth flounder	0	2	140	16	0	9	59
	Others	1	0	3	12	22	4	0
Trawl	Greenland turbot	61	24	0	2	205	1,349	118
	Pacific cod	79	15	19	89	11	2	7
	Arrowtooth flounder	53	154	21	3	1,176	1,435	1,595
	Atka mackerel	123	167	117	130	201	118	54
	Flathead sole	191	150	28	30	98	49	13
	Pollock	18	31	65	107	82	44	23
	Rockfish	74	139	74	47	143	73	9
	Other Flatfish	51	34	1	12	11	4	1
	Rock sole	4	1	27	8	0	2	3
	yellowfin sole	1	7	8	1	1	4	1
	Sablefish	12	7	0	0	6	0	0
	Others	8	0	0	0	0	0	0

Table 5.5. Greenland turbot BSAI fishery length sample sizes by gear type and sex, 1989-2010. Source: NMFS observer program data.

	Trawl fishery			Longline fishery		
Year	Female	Male	% Female	Female	Male	% Female
1989	1,335	5,002	21%	0	0	
1990	3,864	5,762	40%	0	0	
1991	1,851	1,752	51%	0	0	
1992	0	0		0	0	
1993	0	0		3,921	915	81%
1994	1,122	1,027	52%	503	150	77%
1995	217	355	38%	1,870	715	72%
1996	112	390	22%	941	442	68%
1997	0	0		2,393	1,014	70%
1998	307	696	31%	3,510	2,127	62%
1999	1,044	1,556	40%	7,961	2,835	74%
2000	724	1,328	35%	6,550	2,962	69%
2001	467	892	34%	4,054	1,550	72%
2002	186	433	30%	4,725	1,811	72%
2003	197	325	38%	4,608	2,113	69%
2004	179	433	29%	4,286	2,564	63%
2005	118	211	36%	4,639	1,902	71%
2006	15	76	16%	3,338	1,473	69%
2007	34	23	60%	3,816	2,127	64%
2008	421	1,572	21%	1,577	1,481	52%
2009	1,017	2,993	25%	3,486	2,704	56%
2010	252	3,209	7%	1,944	1,596	55%

Table 5.6. 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 surveys prior to 1990 used different operational protocols and may not compare well with subsequent surveys. 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
2009	10,956		
2010	23,548	19,873	6,795

Table 5.7. 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	45	290	280
2005	373	61	441	56	55	293	277
2006	376	56	427	49	48	262	239
2007	376	83	499	68	68	334	311
2008	375	78	406	59	59	245	235
2009	376	103	856	72	32	351	136
2010	376	144	3,199				

Table 5.8. Eastern Bering Sea slope survey estimates of Greenland turbot biomass (t), 2002, 2004, 2008, and 2010 by depth category.

Depth (m)	**2002**	**2004**	**2008**	**2010**
200-400	4,081	2,889	4,553	1,166
400-600	**14,174**	**25,360**	**6,707**	**10,352**
600-800	4,709	5,303	4,373	5,235
800-1000	2,189	1,800	1,487	2,041
1000-1200	1,959	1,206	781	1,079
Total	27,113	36,557	17,901	19,873

Table 5.9. Time series of Aleutian Islands survey sub-regions estimates of Greenland turbot biomass (t), 1980-2010.

Year	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
2010	1,070	1,544	3,698	482	6,795
Avg. since 1991	1,749	2,607	9,735	1,755	15,846

Table 5.10. Data sets used in the stock synthesis (SS3) 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, 1998, 2007
Shelf survey: size composition and biomass estimates	1979-2010
Slope survey: size composition and biomass estimates	1979, 1981, 1982, 1985, 1988, 1991, 2002, 2004, 2008, 2010
Longline survey: size composition and abundance index	1996-2010
Total fishery catch data	1960-2010
Trawl fishery size composition	1977-87, 1989-91, 1993-2010
Longline fishery size composition	1977, 1979-85, 1992-2010

Table 5.11. Summary of the length-at-age information used for this BSAI Greenland turbot assessment (see Gregg et al. 2006 for methods).

	1994				**1998**				**2007**			
	Males		Females		Males		Females		Males		Females	
Age	Avg. length (cm)	N	Avg. length (cm)	N	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	11.79	24	12.18	17
2	18.17	3	19.60	8	24.44	9	22.40	5	20.86	7	22.50	4
3	28.33	9	31.50	4	25.25	8	25.56	9	25.17	6	30.00	1
4	37.82	11	38.89	9	33.50	16	32.50	8	35.00	4	39.50	2
5	44.75	12	47.17	6	35.00	2	31.50	2	44.40	15	46.18	17
6	48.00	4	54.75	4					47.18	22	47.00	17
7	51.00	1	59.50	2	49.50	2			51.70	23	50.72	18
8							63.00	1	52.67	15	54.67	15
9	66.00	2	74.00	1	54.00	1	68.00	1	59.00	3	60.45	11
10	60.33	6			64.50	2	67.00	1	55.00	3	64.80	5
11	65.70	10	76.00	2			77.00	2	58.80	5	63.0a0	1
12	65.11	9	76.50	6			75.00	2			62.00	3
13	67.40	15	72.00	9	73.00	1	80.00	2			65.00	7
14	66.53	17	80.71	7	66.00	2	75.00	2				
15	70.00	9	80.54	13			76.50	4			61.67	3
16	64.50	10	79.65	17					69.00	1	80.00	1
17	66.67	6	83.33	9			72.00	1	77.00	3	90.00	4
18	68.60	10	86.80	15			82.00	1	77.50	2	85.00	1
19	64.00	5	88.82	11							91.67	3
20	72.67	3	85.36	11			82.00	1			87.00	2
21	75.00	1	82.50	4			81.00	2	76.50	2	90.67	3
22	67.00	4	82.00	2							87.00	1
23	69.50	2					84.00	1				
24			84.50	2					84.00	1		
25			89.00	2					72.00	1		
26			92.00	1							92.00	3
27	72.00	2	88.00	2								
28			95.00	1								
29			95.00	2					82.00	1	92.00	1
30			92.00	1								
31									79.00	1		
Totals		152		152		46		50		139		140

Table 5.12. Total harvest rate (catch / mid-year biomass), spawning and total biomass (compared with the 2008 assessment) for BSAI Greenland turbot, 1960-2010.

			Female Spawning Biomass		Total Age 1+ Biomass	
Year	Total Fishing Mortality	Catch / Mid-yr Biom.	2008 Assessment	Current Assessment	2008 Assessment	Current Assessment
1960	0.07	0.058	134,017	258,392	242,758	474,088
1961	0.12	0.096	127,543	249,139	215,567	448,382
1962	0.14	0.106	115,725	233,857	173,759	410,807
1963	0.08	0.062	99,810	217,227	171,413	382,489
1964	0.09	0.066	88,473	207,912	227,498	387,637
1965	0.02	0.019	80,369	199,234	311,971	405,268
1966	0.03	0.022	84,501	201,923	427,509	454,564
1967	0.04	0.035	112,275	214,194	541,343	513,301
1968	0.06	0.046	184,121	236,920	642,446	572,267
1969	0.05	0.043	283,351	267,433	723,430	628,292
1970	0.03	0.029	372,973	303,476	788,654	687,282
1971	0.07	0.056	438,738	344,265	843,964	754,980
1972	0.12	0.097	476,783	378,122	859,695	800,335
1973	0.10	0.080	492,555	398,008	823,749	802,344
1974	0.12	0.097	502,063	419,604	787,665	804,777
1975	0.11	0.087	493,459	433,239	728,755	779,701
1976	0.11	0.083	475,391	445,162	675,772	755,006
1977	0.05	0.042	450,462	448,813	627,372	726,749
1978	0.07	0.058	434,977	455,179	611,963	726,596
1979	0.07	0.058	414,063	448,328	585,338	710,828
1980	0.10	0.076	394,753	438,277	559,354	692,314
1981	0.11	0.087	371,601	421,551	520,810	658,565
1982	0.12	0.085	346,501	401,701	474,692	614,943
1983	0.12	0.083	324,080	383,432	429,593	569,952
1984	0.06	0.044	297,955	364,461	385,997	523,769
1985	0.04	0.030	284,423	354,272	363,701	496,953
1986	0.03	0.021	274,730	344,867	346,891	474,170
1987	0.03	0.021	266,136	334,294	332,679	452,610
1988	0.02	0.017	255,520	320,364	316,939	428,782
1989	0.03	0.022	244,070	304,839	302,343	405,651
1990	0.05	0.033	230,149	286,540	285,093	379,923
1991	0.03	0.022	213,275	265,271	263,947	349,900
1992	0.01	0.012	198,387	246,392	247,035	325,430
1993	0.03	0.028	186,004	229,402	234,450	305,148
1994	0.06	0.037	170,405	209,171	217,482	280,792
1995	0.05	0.032	155,864	190,557	198,975	255,222
1996	0.04	0.028	143,062	173,884	182,755	232,722
1997	0.04	0.034	131,539	158,867	168,445	212,765
1998	0.06	0.047	119,730	143,845	153,976	193,194
1999	0.05	0.034	106,890	128,066	138,281	172,775
2000	0.06	0.045	97,046	115,466	126,439	156,575
2001	0.06	0.038	86,786	102,728	114,453	140,403
2002	0.04	0.029	78,609	92,402	105,382	127,252
2003	0.04	0.030	71,867	83,723	99,811	117,110
2004	0.03	0.020	65,737	75,762	96,076	108,454
2005	0.04	0.025	61,245	69,472	94,884	102,061
2006	0.03	0.020	57,623	63,755	94,014	95,884
2007	0.03	0.020	55,902	59,422	93,914	90,773
2008	0.07	0.032	55,876	56,110	94,795	86,111
2009	0.11	0.055	56,499	53,151	97,524	81,298
2010	0.10	0.042		49,176		76,979
2011				45,504		73,981

Table 5.13. 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+
1977	27.8	19.6	37.6	14.3	24.5	15.8	2.9	4.7	25.5	19.2	14.9	12.2	10.5	9.6	8.8	8.3	7.7	6.9	1.0	0.9	7.2
1978	16.8	24.8	17.5	33.5	12.6	21.4	13.7	2.5	4.1	22.0	16.6	12.9	10.6	9.1	8.3	7.6	7.2	6.7	6.0	0.9	7.0
1979	10.0	15.0	22.1	15.5	29.4	11.0	18.4	11.7	2.1	3.5	18.8	14.2	11.0	9.1	7.8	7.2	6.6	6.2	5.8	5.2	6.7
1980	6.0	8.9	13.4	19.6	13.7	25.5	9.4	15.7	9.9	1.8	3.0	16.1	12.1	9.5	7.8	6.7	6.2	5.7	5.3	5.0	10.1
1981	1.8	5.4	8.0	11.9	17.2	11.7	21.6	7.9	13.1	8.3	1.5	2.5	13.6	10.3	8.0	6.6	5.7	5.2	4.8	4.5	12.7
1982	1.9	1.6	4.8	7.0	10.3	14.6	9.8	17.9	6.5	10.9	6.9	1.3	2.1	11.4	8.6	6.7	5.5	4.8	4.4	4.0	14.4
1983	1.0	1.7	1.4	4.3	6.1	8.8	12.3	8.1	14.8	5.4	9.0	5.8	1.0	1.7	9.5	7.2	5.7	4.7	4.0	3.7	15.6
1984	2.2	0.9	1.5	1.3	3.7	5.2	7.4	10.2	6.7	12.3	4.5	7.5	4.8	0.9	1.5	8.0	6.1	4.8	3.9	3.4	16.3
1985	5.6	2.0	0.8	1.4	1.1	3.2	4.5	6.3	8.7	5.8	10.5	3.9	6.5	4.2	0.8	1.3	6.9	5.3	4.1	3.4	17.1
1986	1.9	5.0	1.8	0.7	1.2	1.0	2.8	3.9	5.5	7.6	5.0	9.2	3.4	5.7	3.6	0.7	1.1	6.1	4.6	3.6	18.0
1987	2.5	1.7	4.5	1.6	0.6	1.1	0.9	2.5	3.5	4.8	6.7	4.4	8.1	3.0	5.0	3.2	0.6	1.0	5.3	4.1	19.1
1988	2.3	2.2	1.5	4.0	1.4	0.5	0.9	0.8	2.2	3.0	4.2	5.8	3.9	7.1	2.6	4.4	2.8	0.5	0.9	4.7	20.4
1989	6.4	2.1	2.0	1.4	3.5	1.3	0.5	0.8	0.7	1.9	2.7	3.7	5.2	3.4	6.3	2.3	3.9	2.5	0.5	0.8	22.2
1990	2.7	5.7	1.8	1.8	1.2	3.1	1.1	0.4	0.7	0.6	1.7	2.3	3.3	4.5	3.0	5.5	2.0	3.4	2.2	0.4	20.2
1991	0.8	2.4	5.1	1.6	1.6	1.1	2.7	1.0	0.4	0.6	0.5	1.5	2.0	2.9	3.9	2.6	4.8	1.8	3.0	1.9	18.0
1992	0.7	0.7	2.1	4.6	1.5	1.4	0.9	2.4	0.8	0.3	0.6	0.4	1.3	1.8	2.5	3.5	2.3	4.2	1.6	2.6	17.4
1993	0.6	0.7	0.6	1.9	4.1	1.3	1.2	0.8	2.1	0.7	0.3	0.5	0.4	1.1	1.6	2.2	3.1	2.0	3.7	1.4	17.7
1994	1.0	0.5	0.6	0.6	1.7	3.7	1.2	1.1	0.7	1.9	0.7	0.2	0.4	0.3	1.0	1.4	1.9	2.7	1.8	3.2	16.6
1995	2.5	0.9	0.5	0.5	0.5	1.5	3.3	1.0	1.0	0.6	1.6	0.6	0.2	0.4	0.3	0.8	1.2	1.7	2.3	1.5	17.2
1996	0.9	2.3	0.8	0.4	0.5	0.5	1.4	2.9	0.9	0.9	0.6	1.4	0.5	0.2	0.3	0.3	0.7	1.0	1.4	2.0	16.3
1997	1.2	0.8	2.0	0.7	0.4	0.4	0.4	1.2	2.6	0.8	0.7	0.5	1.2	0.4	0.2	0.3	0.2	0.6	0.9	1.3	15.9
1998	1.0	1.0	0.7	1.8	0.6	0.3	0.4	0.4	1.1	2.3	0.7	0.6	0.4	1.0	0.4	0.1	0.2	0.2	0.5	0.8	14.8
1999	3.4	0.9	0.9	0.6	1.6	0.6	0.3	0.3	0.3	1.0	2.0	0.6	0.5	0.4	0.9	0.3	0.1	0.2	0.2	0.5	13.2
2000	3.8	3.1	0.8	0.8	0.6	1.4	0.5	0.3	0.3	0.3	0.8	1.7	0.5	0.5	0.3	0.7	0.3	0.1	0.2	0.1	11.8
2001	4.9	3.4	2.7	0.7	0.7	0.5	1.3	0.5	0.2	0.3	0.3	0.7	1.5	0.4	0.4	0.3	0.6	0.2	0.1	0.1	10.2
2002	0.9	4.4	3.0	2.4	0.6	0.7	0.5	1.2	0.4	0.2	0.2	0.2	0.6	1.2	0.4	0.3	0.2	0.5	0.2	0.1	9.0
2003	0.4	0.8	3.9	2.7	2.2	0.6	0.6	0.4	1.0	0.4	0.2	0.2	0.2	0.5	1.1	0.3	0.3	0.2	0.5	0.2	7.8
2004	0.4	0.4	0.7	3.5	2.4	1.9	0.5	0.5	0.4	0.9	0.3	0.2	0.2	0.2	0.5	0.9	0.3	0.3	0.2	0.4	6.9
2005	0.6	0.4	0.3	0.6	3.1	2.2	1.7	0.5	0.5	0.3	0.8	0.3	0.1	0.2	0.1	0.4	0.8	0.2	0.2	0.1	6.4
2006	4.1	0.6	0.3	0.3	0.6	2.8	1.9	1.6	0.4	0.4	0.3	0.7	0.2	0.1	0.1	0.1	0.3	0.7	0.2	0.2	5.7
2007	5.4	3.6	0.5	0.3	0.3	0.5	2.5	1.7	1.4	0.4	0.4	0.3	0.6	0.2	0.1	0.1	0.1	0.3	0.6	0.2	5.2
2008	12.4	4.8	3.3	0.4	0.3	0.2	0.5	2.2	1.5	1.2	0.3	0.3	0.2	0.5	0.2	0.1	0.1	0.1	0.3	0.5	4.7
2009	24.1	11.1	4.3	2.9	0.4	0.2	0.2	0.4	2.0	1.4	1.1	0.3	0.3	0.2	0.5	0.2	0.1	0.1	0.1	0.2	4.6
2010	6.9	21.6	9.9	3.8	2.6	0.4	0.2	0.2	0.4	1.7	1.2	0.9	0.2	0.2	0.2	0.4	0.1	0.1	0.1	0.1	4.1

Table 5.13 (cont'd). Estimated beginning of year numbers of Greenland turbot by age and sex (millions).

Males

Yr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	27.8	19.6	37.6	14.3	24.3	15.3	2.7	4.2	20.9	14.5	10.4	7.9	6.4	5.5	4.7	4.3	3.8	3.2	0.5	0.4	2.1
1978	16.8	24.8	17.5	33.5	12.6	21.0	13.1	2.2	3.5	17.4	12.0	8.6	6.5	5.3	4.5	3.9	3.5	3.1	2.6	0.4	2.0
1979	10.0	15.0	22.1	15.5	29.3	10.8	17.6	10.7	1.8	2.8	14.0	9.7	6.9	5.2	4.2	3.6	3.2	2.8	2.5	2.1	1.9
1980	6.0	8.9	13.4	19.6	13.6	25.1	9.0	14.5	8.7	1.5	2.2	11.2	7.8	5.6	4.2	3.4	2.9	2.5	2.3	2.0	3.3
1981	1.8	5.4	8.0	11.9	17.1	11.5	20.6	7.2	11.4	6.8	1.1	1.7	8.7	6.0	4.3	3.3	2.6	2.3	2.0	1.8	4.1
1982	1.9	1.6	4.8	7.0	10.3	14.3	9.3	16.1	5.5	8.7	5.2	0.9	1.3	6.6	4.6	3.3	2.5	2.0	1.7	1.5	4.4
1983	1.0	1.7	1.4	4.3	6.1	8.6	11.5	7.2	12.3	4.2	6.5	3.9	0.7	1.0	5.0	3.4	2.5	1.9	1.5	1.3	4.4
1984	2.2	0.9	1.5	1.3	3.7	5.1	6.9	8.9	5.5	9.3	3.2	4.9	2.9	0.5	0.7	3.7	2.6	1.8	1.4	1.1	4.3
1985	5.6	2.0	0.8	1.4	1.1	3.2	4.3	5.7	7.4	4.5	7.6	2.6	4.0	2.4	0.4	0.6	3.1	2.1	1.5	1.1	4.4
1986	1.9	5.0	1.8	0.7	1.2	1.0	2.7	3.7	4.8	6.2	3.8	6.4	2.2	3.4	2.0	0.3	0.5	2.6	1.8	1.3	4.7
1987	2.5	1.7	4.5	1.6	0.6	1.1	0.8	2.4	3.1	4.2	5.3	3.3	5.5	1.9	2.9	1.7	0.3	0.4	2.2	1.5	5.1
1988	2.3	2.2	1.5	4.0	1.4	0.5	0.9	0.7	2.0	2.7	3.6	4.5	2.8	4.7	1.6	2.5	1.5	0.2	0.4	1.9	5.7
1989	6.4	2.1	2.0	1.4	3.5	1.2	0.5	0.8	0.6	1.8	2.3	3.1	3.9	2.4	4.1	1.4	2.1	1.3	0.2	0.3	6.5
1990	2.7	5.7	1.8	1.8	1.2	3.1	1.1	0.4	0.7	0.5	1.5	2.0	2.6	3.4	2.1	3.5	1.2	1.8	1.1	0.2	5.9
1991	0.8	2.4	5.1	1.6	1.6	1.1	2.7	0.9	0.3	0.6	0.5	1.3	1.7	2.2	2.8	1.7	2.9	1.0	1.5	0.9	5.0
1992	0.7	0.7	2.1	4.6	1.4	1.4	0.9	2.3	0.8	0.3	0.5	0.4	1.1	1.4	1.9	2.4	1.5	2.5	0.8	1.3	5.1
1993	0.6	0.7	0.6	1.9	4.1	1.3	1.2	0.8	2.1	0.7	0.3	0.4	0.3	1.0	1.3	1.7	2.1	1.3	2.2	0.7	5.7
1994	1.0	0.5	0.6	0.6	1.7	3.7	1.2	1.1	0.7	1.8	0.6	0.2	0.4	0.3	0.8	1.1	1.4	1.8	1.1	1.9	5.6
1995	2.5	0.9	0.5	0.5	0.5	1.5	3.3	1.0	1.0	0.6	1.6	0.5	0.2	0.3	0.2	0.7	0.9	1.2	1.5	0.9	6.2
1996	0.9	2.3	0.8	0.4	0.5	0.5	1.4	2.9	0.9	0.9	0.6	1.4	0.4	0.2	0.3	0.2	0.6	0.7	1.0	1.3	6.0
1997	1.2	0.8	2.0	0.7	0.4	0.4	0.4	1.2	2.6	0.8	0.8	0.5	1.2	0.4	0.1	0.2	0.2	0.5	0.6	0.8	6.2
1998	1.0	1.0	0.7	1.8	0.6	0.3	0.4	0.4	1.1	2.3	0.7	0.7	0.4	1.0	0.3	0.1	0.2	0.1	0.4	0.5	6.0
1999	3.4	0.9	0.9	0.6	1.6	0.6	0.3	0.3	0.3	1.0	2.1	0.6	0.6	0.4	0.9	0.3	0.1	0.2	0.1	0.3	5.5
2000	3.8	3.1	0.8	0.8	0.6	1.4	0.5	0.3	0.3	0.3	0.9	1.8	0.6	0.5	0.3	0.8	0.2	0.1	0.1	0.1	5.0
2001	4.9	3.4	2.7	0.7	0.7	0.5	1.3	0.5	0.2	0.3	0.3	0.8	1.6	0.5	0.4	0.3	0.6	0.2	0.1	0.1	4.2
2002	0.9	4.4	3.0	2.4	0.6	0.7	0.5	1.2	0.4	0.2	0.2	0.2	0.6	1.3	0.4	0.4	0.2	0.5	0.2	0.1	3.6
2003	0.4	0.8	3.9	2.7	2.2	0.6	0.6	0.4	1.0	0.4	0.2	0.2	0.2	0.6	1.1	0.3	0.3	0.2	0.4	0.1	3.2
2004	0.4	0.4	0.7	3.5	2.4	1.9	0.5	0.5	0.4	0.9	0.3	0.2	0.2	0.2	0.5	1.0	0.3	0.3	0.2	0.4	2.8
2005	0.6	0.4	0.3	0.6	3.1	2.2	1.7	0.5	0.5	0.3	0.8	0.3	0.1	0.2	0.2	0.4	0.9	0.3	0.2	0.1	2.8
2006	4.1	0.6	0.3	0.3	0.6	2.8	1.9	1.6	0.4	0.4	0.3	0.7	0.3	0.1	0.1	0.1	0.4	0.7	0.2	0.2	2.5
2007	5.4	3.6	0.5	0.3	0.3	0.5	2.5	1.7	1.4	0.4	0.4	0.3	0.6	0.2	0.1	0.1	0.1	0.3	0.6	0.2	2.3
2008	12.4	4.8	3.3	0.4	0.3	0.2	0.5	2.2	1.5	1.2	0.3	0.3	0.2	0.6	0.2	0.1	0.1	0.1	0.3	0.5	2.2
2009	24.1	11.1	4.3	2.9	0.4	0.2	0.2	0.4	2.0	1.4	1.1	0.3	0.3	0.2	0.5	0.2	0.1	0.1	0.1	0.2	2.3
2010	6.9	21.6	9.9	3.8	2.6	0.4	0.2	0.2	0.4	1.8	1.2	0.9	0.2	0.2	0.1	0.4	0.1	0.1	0.1	0.1	1.9

Table 5.14. Age-equivalent sex-specific selectivity estimates (as estimated for 2010) 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	
Age	Female	Male	Female	Male
1	0.019	0.021	0.003	0.003
2	0.059	0.072	0.003	0.002
3	0.129	0.176	0.003	0.001
4	0.214	0.321	0.003	0.001
5	0.294	0.483	0.003	0.001
6	0.359	0.635	0.005	0.001
7	0.398	0.760	0.022	0.002
8	0.407	0.851	0.084	0.007
9	0.380	0.908	0.191	0.022
10	0.328	0.929	0.303	0.048
11	0.276	0.916	0.387	0.083
12	0.236	0.879	0.439	0.120
13	0.209	0.831	0.468	0.156
14	0.192	0.782	0.483	0.189
15	0.181	0.738	0.491	0.217
16	0.174	0.700	0.495	0.240
17	0.169	0.669	0.497	0.260
18	0.165	0.644	0.498	0.276
19	0.162	0.623	0.499	0.290
20	0.160	0.607	0.499	0.301
21	0.158	0.594	0.499	0.311
22	0.156	0.583	0.499	0.319
23	0.154	0.575	0.500	0.326
24	0.153	0.568	0.500	0.332
25	0.152	0.562	0.500	0.337
26	0.151	0.558	0.500	0.342
27	0.150	0.554	0.500	0.345
28	0.150	0.551	0.500	0.348
29	0.149	0.549	0.500	0.351
30	0.148	0.545	0.500	0.355

Table 5.15. 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	11.65	11.65	0.02	0.02
2	14.95	14.95	0.09	0.08
3	22.84	22.51	0.24	0.21
4	30.69	29.80	0.47	0.41
5	37.64	36.08	0.78	0.65
6	43.80	41.48	1.16	0.93
7	49.27	46.13	1.58	1.22
8	54.11	50.14	2.04	1.53
9	58.40	53.59	2.52	1.83
10	62.21	56.55	3.01	2.12
11	65.58	59.11	3.49	2.40
12	68.57	61.31	3.96	2.65
13	71.22	63.20	4.41	2.89
14	73.57	64.84	4.84	3.10
15	75.65	66.24	5.25	3.30
16	77.49	67.45	5.63	3.47
17	79.13	68.49	5.98	3.62
18	80.58	69.38	6.30	3.76
19	81.87	70.15	6.60	3.88
20	83.00	70.82	6.87	3.98
21	84.01	71.39	7.11	4.07
22	84.91	71.88	7.33	4.15
23	85.70	72.31	7.53	4.22
24	86.41	72.67	7.71	4.28
25	87.03	72.98	7.87	4.34
26	87.58	73.25	8.01	4.38
27	88.07	73.49	8.14	4.42
28	88.50	73.69	8.25	4.46
29	88.89	73.86	8.36	4.49
30	89.23	74.01	8.55	4.54

Table 5.16. Estimated total Greenland turbot harvest by area, 1977-2010. Values for 2010 are through Nov. 4th, 2010 and are preliminary.

Year	EBS	Aleutians	Year	EBS	Aleutians
1977	27,708	2,453	1994	3,875	7,141
1978	37,423	4,766	1995	4,499	5,855
1979	34,998	6,411	1996	4,258	4,844
1980	48,856	3,697	1997	5,730	6,435
1981	52,921	4,400	1998	7,839	8,329
1982	45,805	6,317	1999	5,179	5,391
1983	43,443	4,115	2000	5,667	5,888
1984	21,317	1,803	2001	4,102	4,252
1985	14,698	33	2002	3,011	3,153
1986	7,710	2,154	2003	2,467	960
1987	6,519	3,066	2004	1,805	414
1988	6,064	1,044	2005	2,120	439
1989	4,061	4,761	2006	1,440	525
1990	7,702	2,494	2007	1,313	516
1991	3,781	4,397	2008	1,917	824
1992	1,767	2,462	2009	2,237	2,261
1993	4,878	6,330	2010	1,386	1,849

Table 5.17. Mean spawning biomass, F, and yield projections for Greenland turbot, 2010-2022. 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 28,419 and 24,867 tons, respectively.

Catch	Max F_{ABC}	Recc. F_{ABC}	5-year avg.	F75%	No Fishing	Scenario 6	Scenario 7
2010	3,234	3,234	3,234	3,234	3,234	3,234	3,234
2011	6,137	6,137	1,470	1,699	0	7,217	6,137
2012	5,750	5,750	1,469	1,693	0	6,658	5,750
2013	5,762	5,762	1,553	1,784	0	6,588	6,780
2014	6,132	6,132	1,725	1,978	0	6,944	7,117
2015	6,809	6,809	1,987	2,274	0	7,646	7,804
2016	7,671	7,671	2,320	2,651	0	8,545	8,689
2017	8,165	8,165	2,580	2,941	0	9,004	9,134
2018	8,206	8,206	2,719	3,093	0	8,952	9,064
2019	7,999	7,999	2,781	3,155	0	8,633	8,729
2020	7,665	7,665	2,789	3,157	0	8,192	8,271
2021	7,293	7,293	2,766	3,124	0	7,728	7,794
2022	6,941	6,941	2,729	3,077	0	7,304	7,358
2023	6,635	6,635	2,690	3,027	0	6,944	6,989
Fishing M.	*Max FABC*	*FABC*	*5-year avg.*	*F75%*	*No Fishing*	*Scenario 6*	*Scenario 7*
2010	0.120	0.120	0.120	0.120	0.120	0.120	0.120
2011	0.247	0.247	0.057	0.066	0.000	0.293	0.247
2012	0.247	0.247	0.057	0.066	0.000	0.293	0.247
2013	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2014	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2015	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2016	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2017	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2018	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2019	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2020	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2021	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2022	0.247	0.247	0.057	0.066	0.000	0.293	0.293
2023	0.247	0.247	0.057	0.066	0.000	0.293	0.293
Spawning biomass	*Max FABC*	*FABC*	*5-year avg.*	*F75%*	*No Fishing*	*Scenario 6*	*Scenario 7*
2010	49,198	49,198	49,198	49,198	49,198	49,198	49,198
2011	45,504	45,504	45,504	45,504	45,504	45,504	45,504
2012	40,407	40,407	42,955	42,831	43,754	39,815	40,407
2013	36,478	36,478	41,148	40,913	42,670	35,434	36,478
2014	34,397	34,397	40,916	40,579	43,121	32,991	33,912
2015	34,918	34,918	43,273	42,831	46,195	33,174	34,000
2016	37,898	37,898	48,371	47,806	52,134	35,770	36,523
2017	41,624	41,624	54,600	53,888	59,372	39,047	39,734
2018	44,370	44,370	60,092	59,216	66,007	41,316	41,938
2019	45,565	45,565	64,056	63,008	71,184	42,059	42,613
2020	45,552	45,552	66,659	65,439	75,008	41,657	42,142
2021	44,757	44,757	68,197	66,817	77,726	40,553	40,972
2022	43,526	43,526	68,958	67,430	79,587	39,095	39,455
2023	42,139	42,139	69,228	67,569	80,867	37,554	37,861

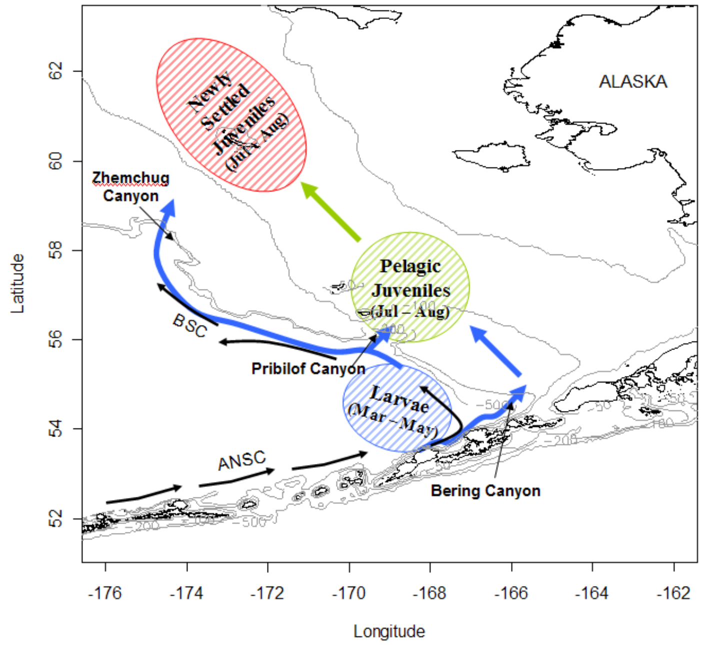
Table 5.18. Summary management values based on this assessment. Note that the fishing mortality rates assume 50:50 contribution from longline gear and trawl gear.

Management parameter	Value
M (natural mortality)	0.112 yr^{-1}
Amendment 56 Tier (in **2011**)	3a
Approximate age at full recruitment	10 years
$F_{35\%}$ (F_{OFL})	0.293
$F_{40\%}$	0.247
$B_{100\%}$	71,048 t
$B_{40\%}$	28,419 t
$B_{35\%}$	24,867 t
2010 female spawning biomass	49,198 t
2011 female spawning biomass	45,504 t
2012 female spawning biomass	40,407 t
2010 total (age 1+) biomass	76,979 t
2011 total (age 1+) biomass	73,981 t
$F_{ABC} = F_{40\%}$ (max permissible)	0.247
2011 Maximum permissible ABC	6,137 t
2012 Maximum permissible ABC	5,750 t
$F_{ABC} = F_{40\%}$	0.153
Recommended ABC: 2011	6,137 t
2012	5,750 t
$F_{overfishing} = F_{35\%}$	0.293
2011 Greenland turbot OFL	7,217 t
2012 **Greenland turbot OFL**	6,764 t*

* assuming catch **2011** = 6,137t

Figures

(a)



(b)

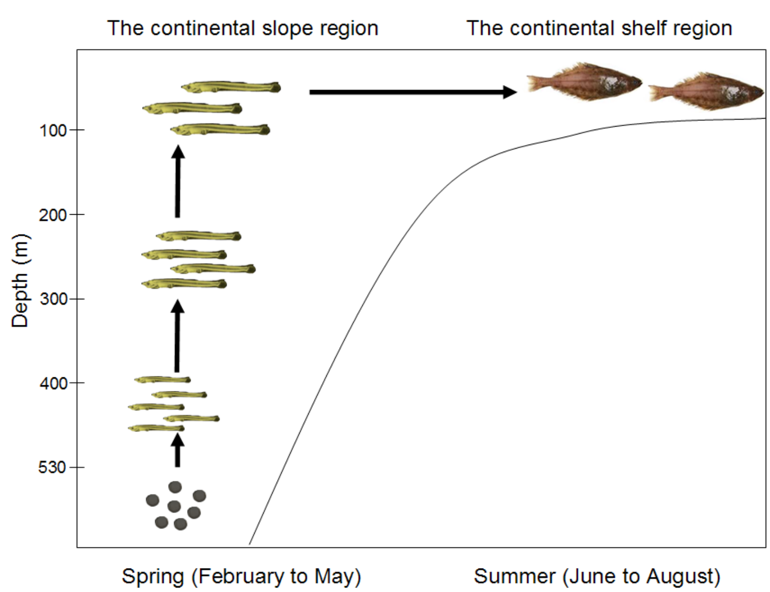


Figure 5.1. Schematic representation of Greenland halibut distribution and connectivity from larvae to settled juveniles. (a) Horizontally changed distribution through different life history stages (Blue circle: slope spawning ground, Green circle: shelf nursery ground of pelagic juveniles, Red circle: settlement ground). Blue arrows: possible larval transport routes from slope to shelf. (b) Vertically changed distribution as they develop. ***Source: Sohn (2009).***

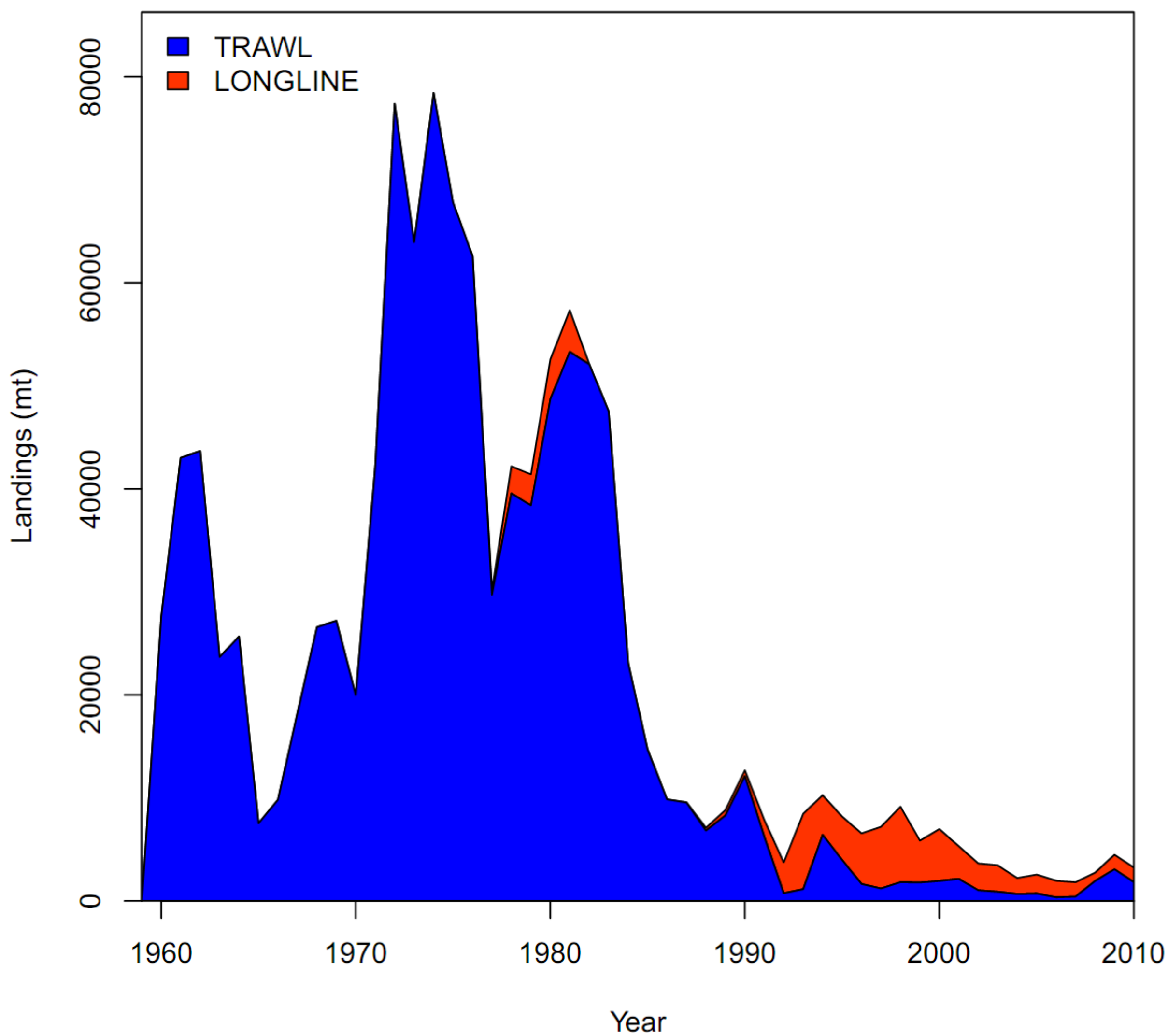


Figure 5.2. Trawl and longline catches of Greenland turbot in the combined EBS/AI area, 1960-2010.

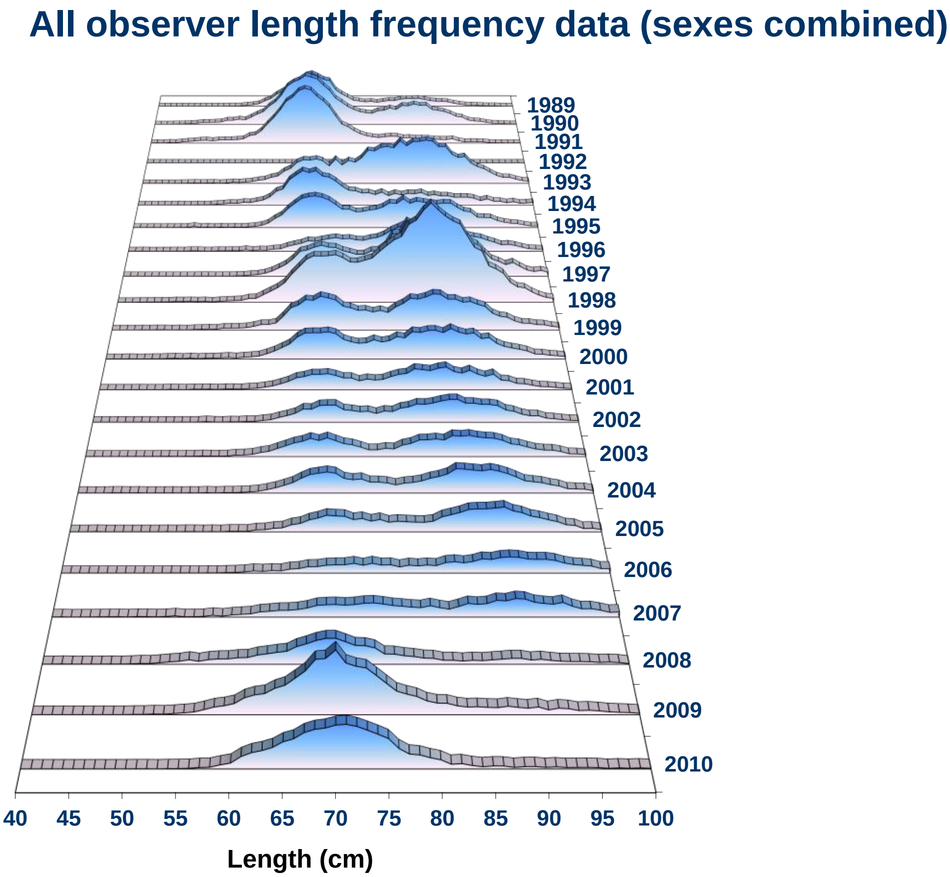


Figure 5.3. Combined fishery catch length frequency of Greenland turbot in the BSAI area, 1989-2010 based on NMFS observer program data, sexes combined.

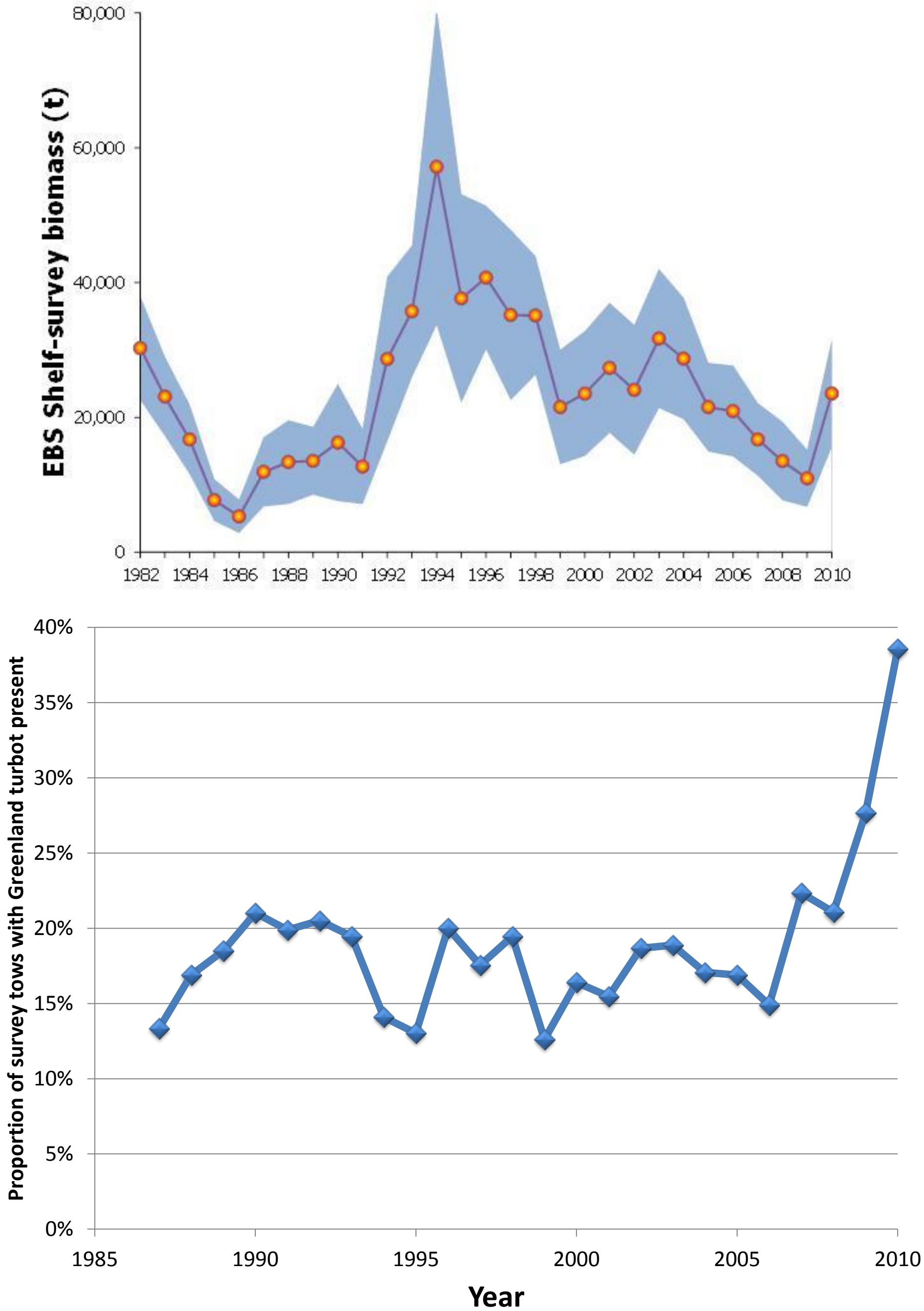


Figure 5.4. Survey biomass estimates of Greenland turbot from the EBS shelf trawl survey (top) and the proportion of tows that caught at least one Greenland turbot (bottom), 1982-2010.

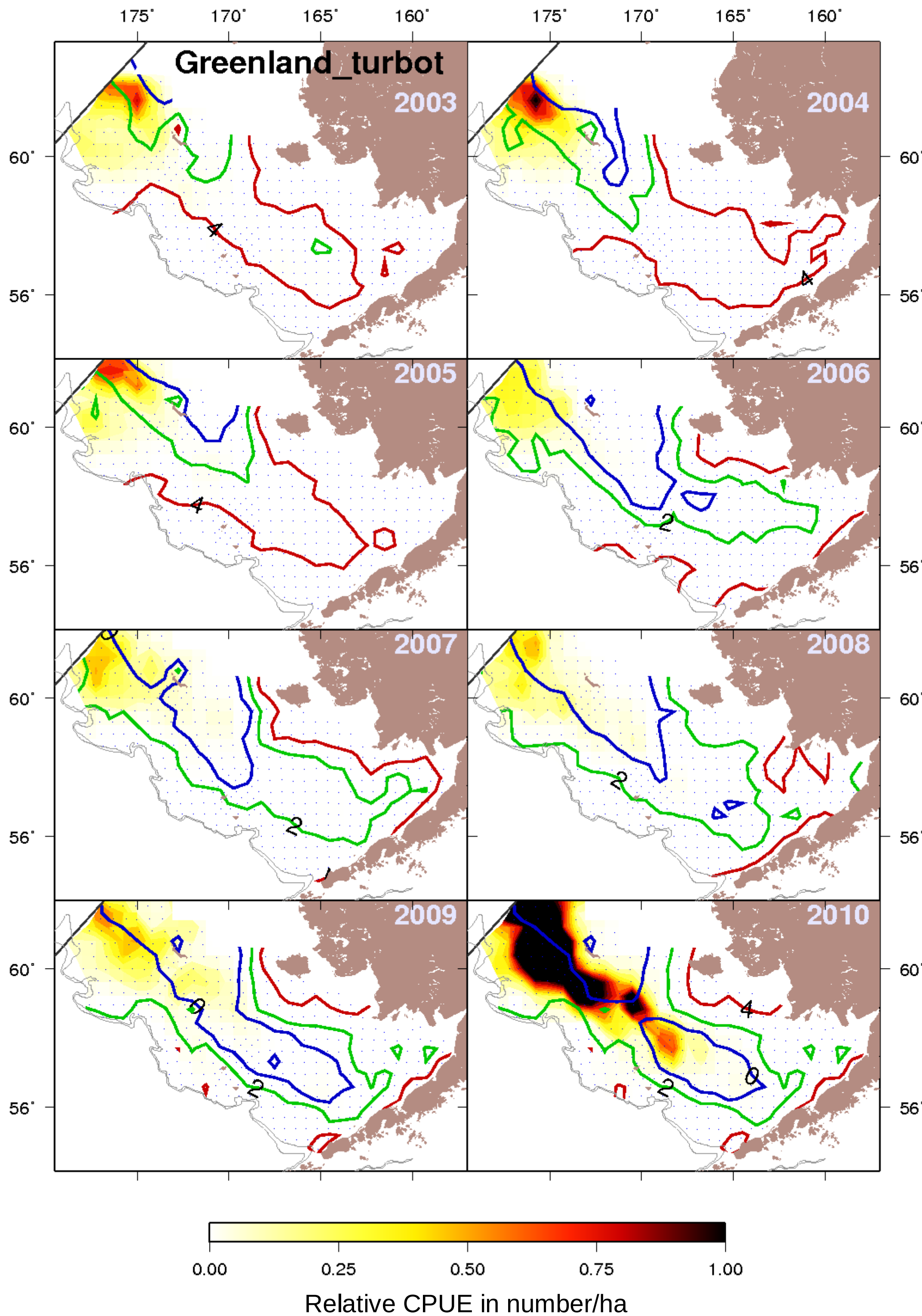


Figure 5.5. Greenland turbot relative CPUE by **number** based on NMFS EBS bottom trawl surveys, 2003-2010. Also shown are bottom temperature contours.

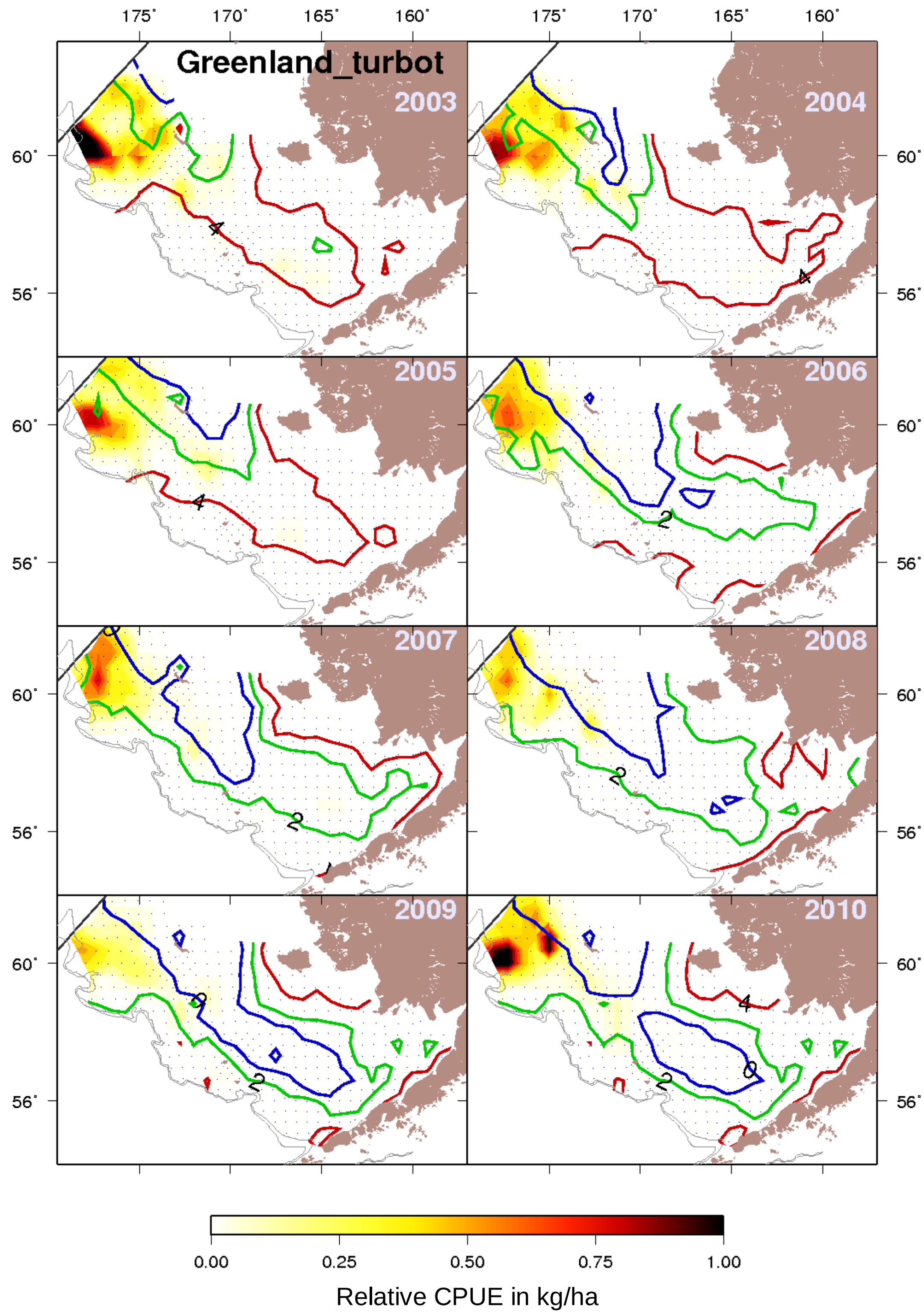


Figure 5.6. Greenland turbot relative CPUE by **weight** based on NMFS EBS bottom trawl surveys, 2003-2010. Also shown are bottom temperature contours.

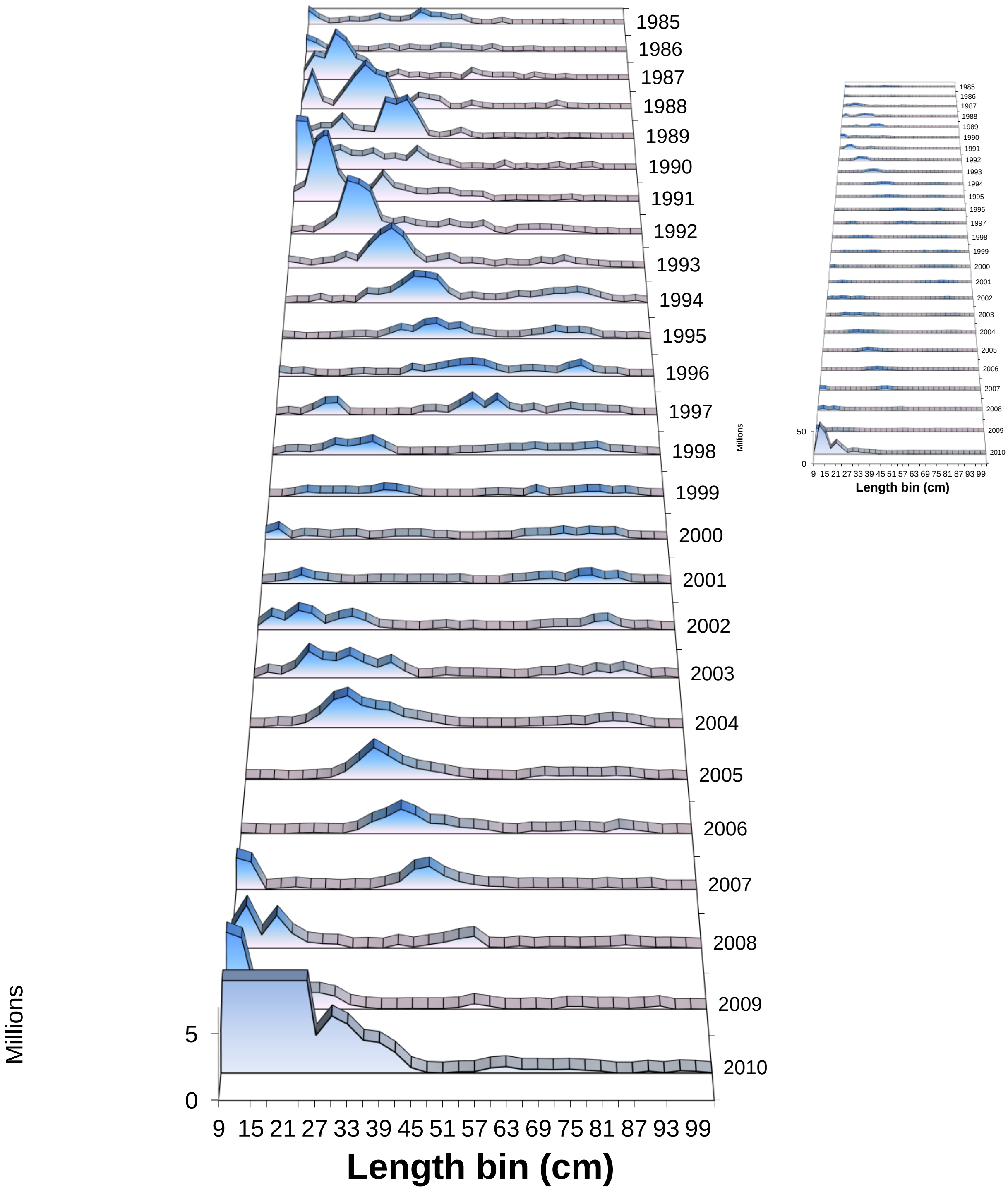


Figure 5.7. Abundance-at-length (cm) for Greenland turbot observed from the summer NMFS shelf trawl surveys, 1985-2010 (sexes combined, all strata except for 1986 where only strata 1-6 were sampled). Note that the 2010 are truncated in the main figure—the inset shows the same figure with the vertical scale magnified by an order of magnitude.

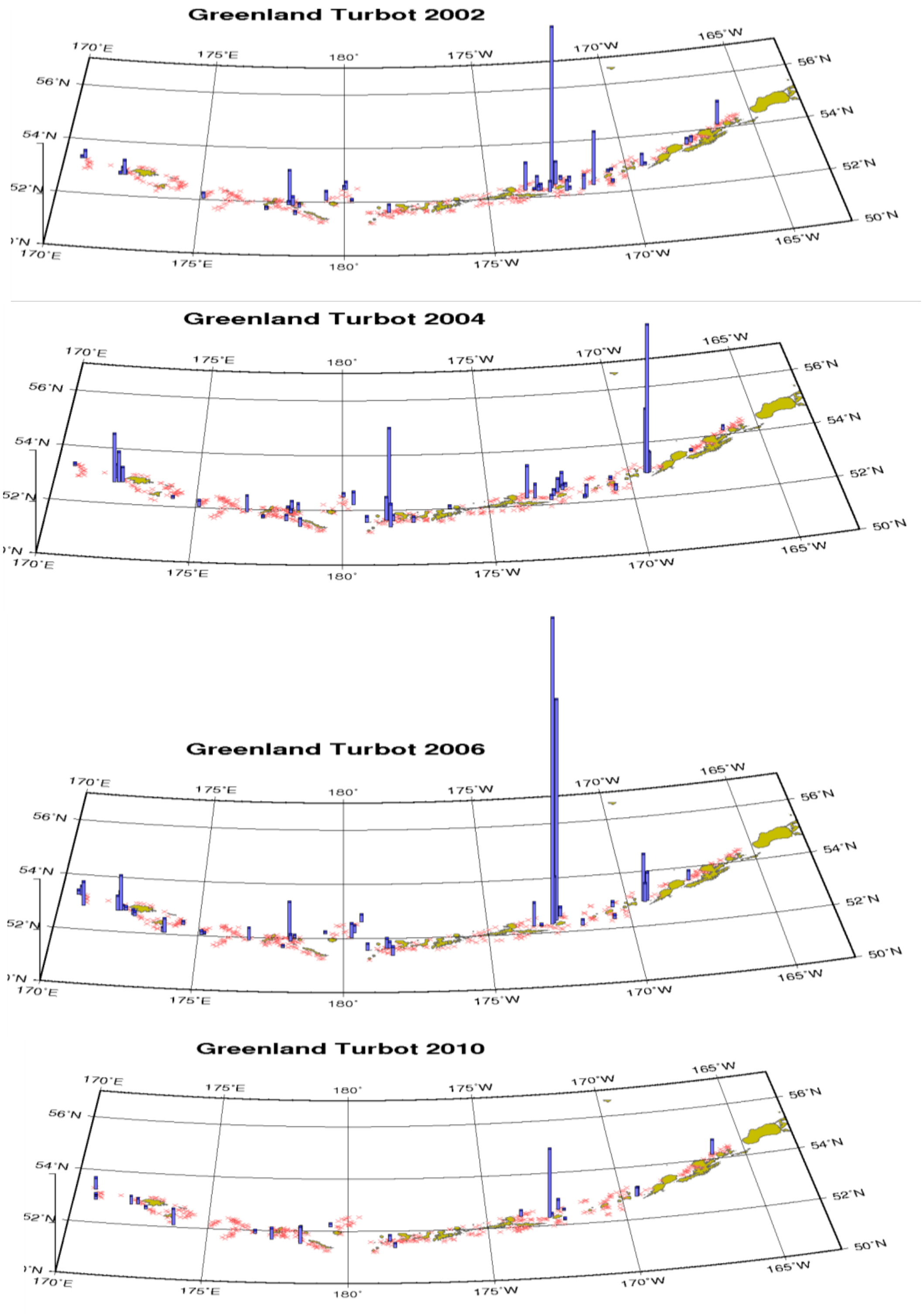


Figure 5.8. Greenland turbot catch per unit effort (relative values by weight, vertical bars) from the Aleutian Islands region bottom trawl survey, 2002-2010.

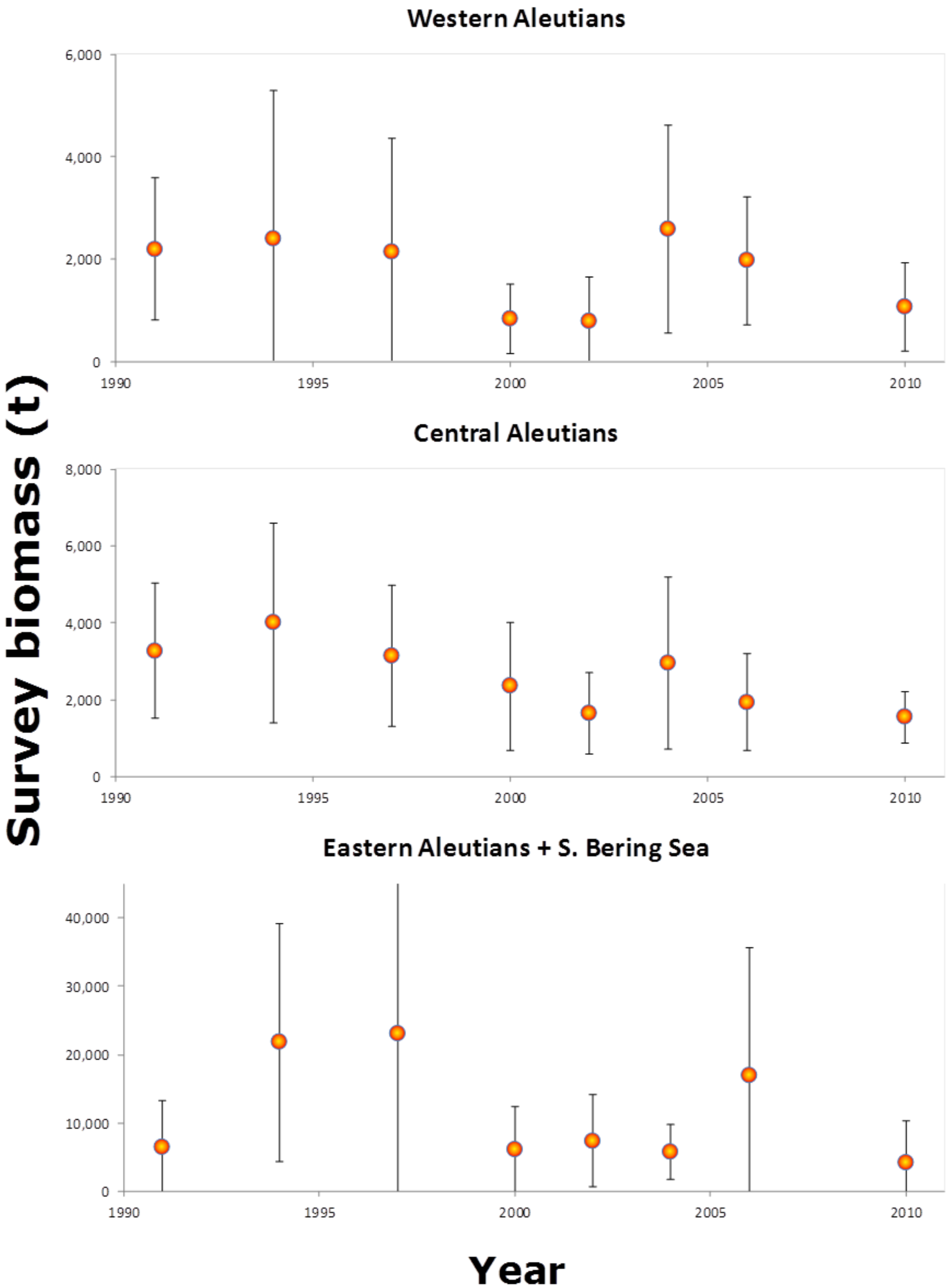


Figure 5.9. Greenland turbot relative biomass from the Aleutian Islands surveys by region, 1991-2010.

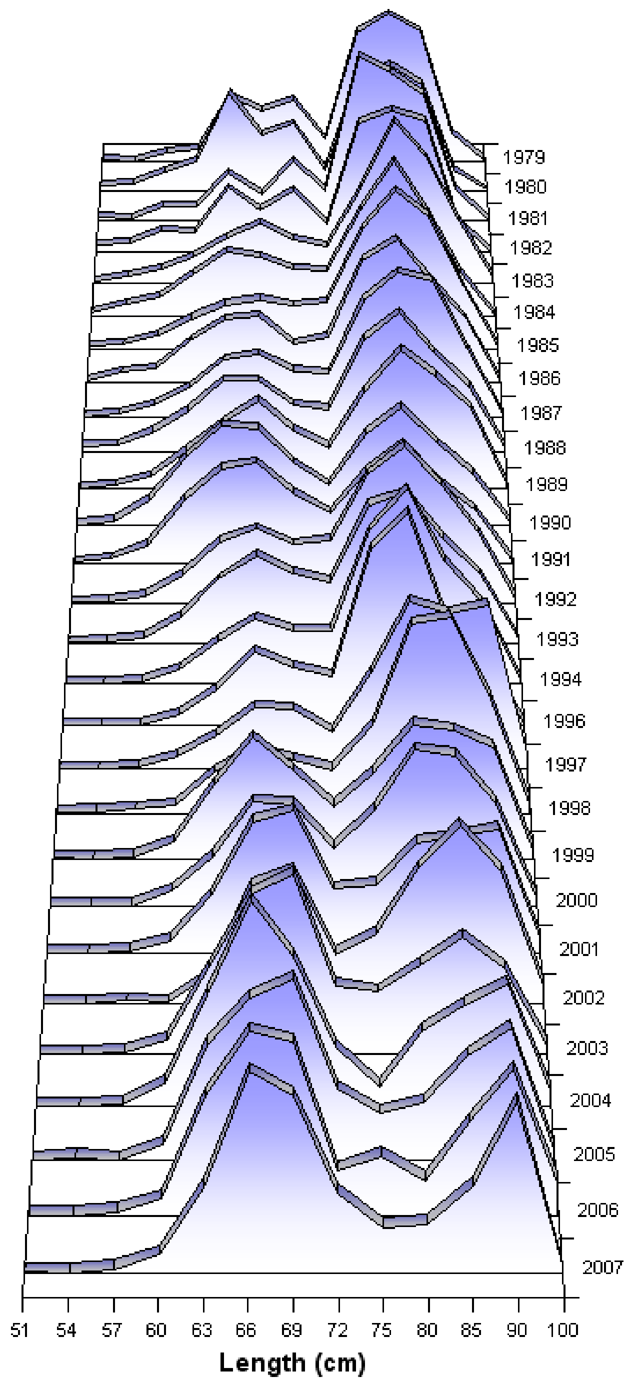


Figure 5.10. Longline survey Greenland turbot proportions at length over time (sexes combined) as used in the model.

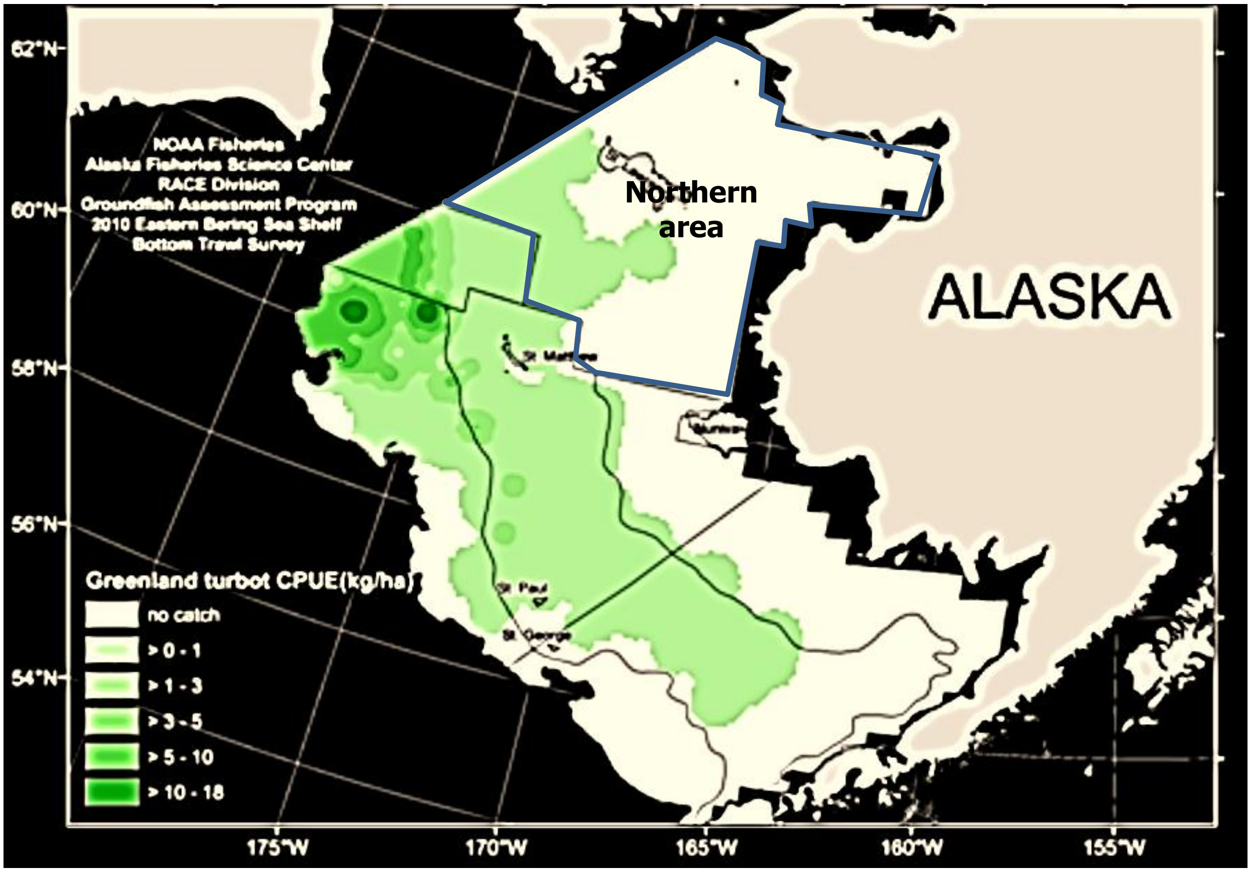


Figure 5.11. Greenland turbot distribution as estimated in the NMFS 2010 bottom trawl survey showing the extension into the added northern area that was covered.

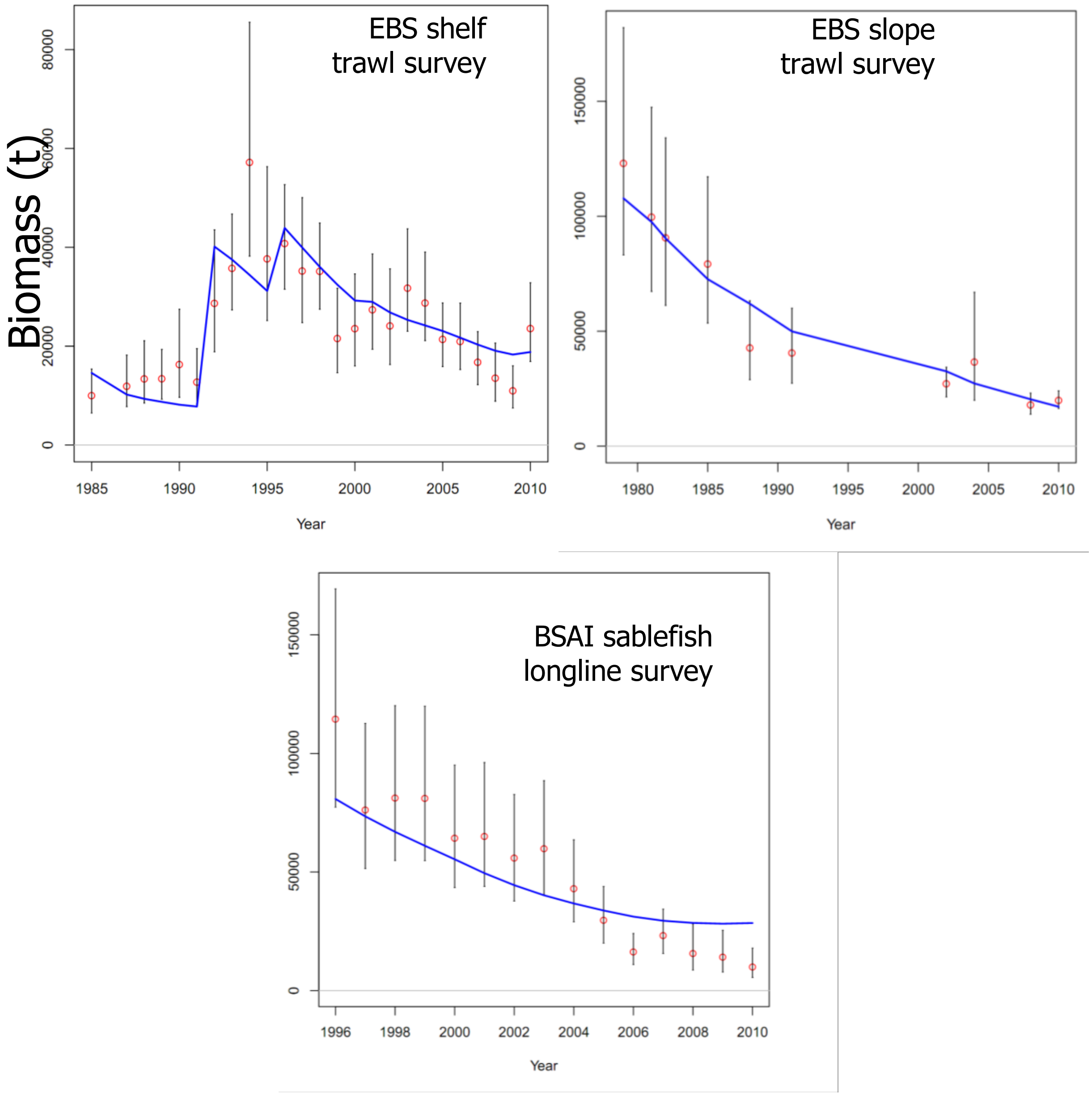


Figure 5.12. Model fits to the EBS shelf trawl survey (top left), the EBS slope trawl survey (top right) and longline survey (bottom) indices for Greenland turbot in the EBS/AI region.

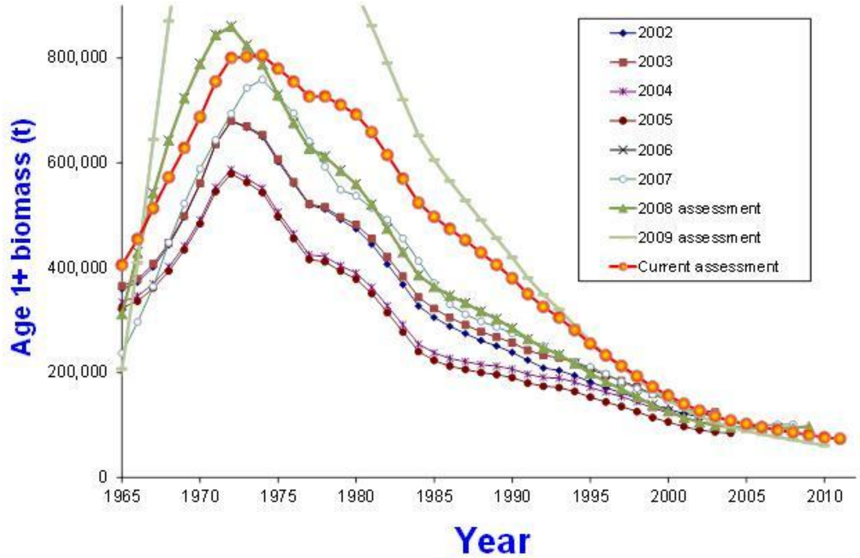


Figure 5.13 Current assessment estimates of total age 1+ biomass for Greenland turbot in the BSAI region, 1965-2010 compared to previous assessments.

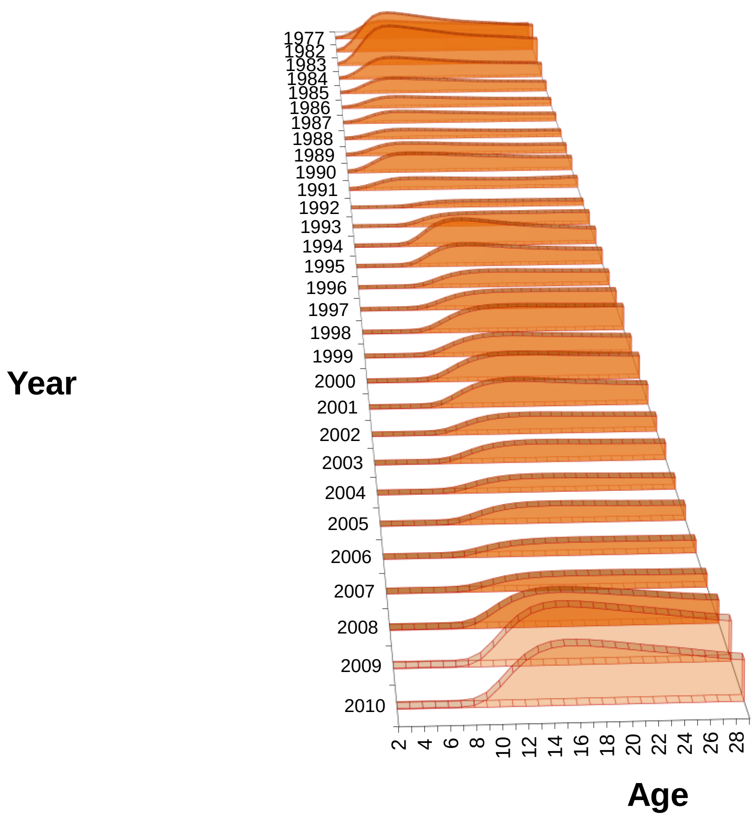


Figure 5.14. Estimated total age-specific fishing mortality rate (gears and sexes combined) for BSAI Greenland turbot, 1977-2010.

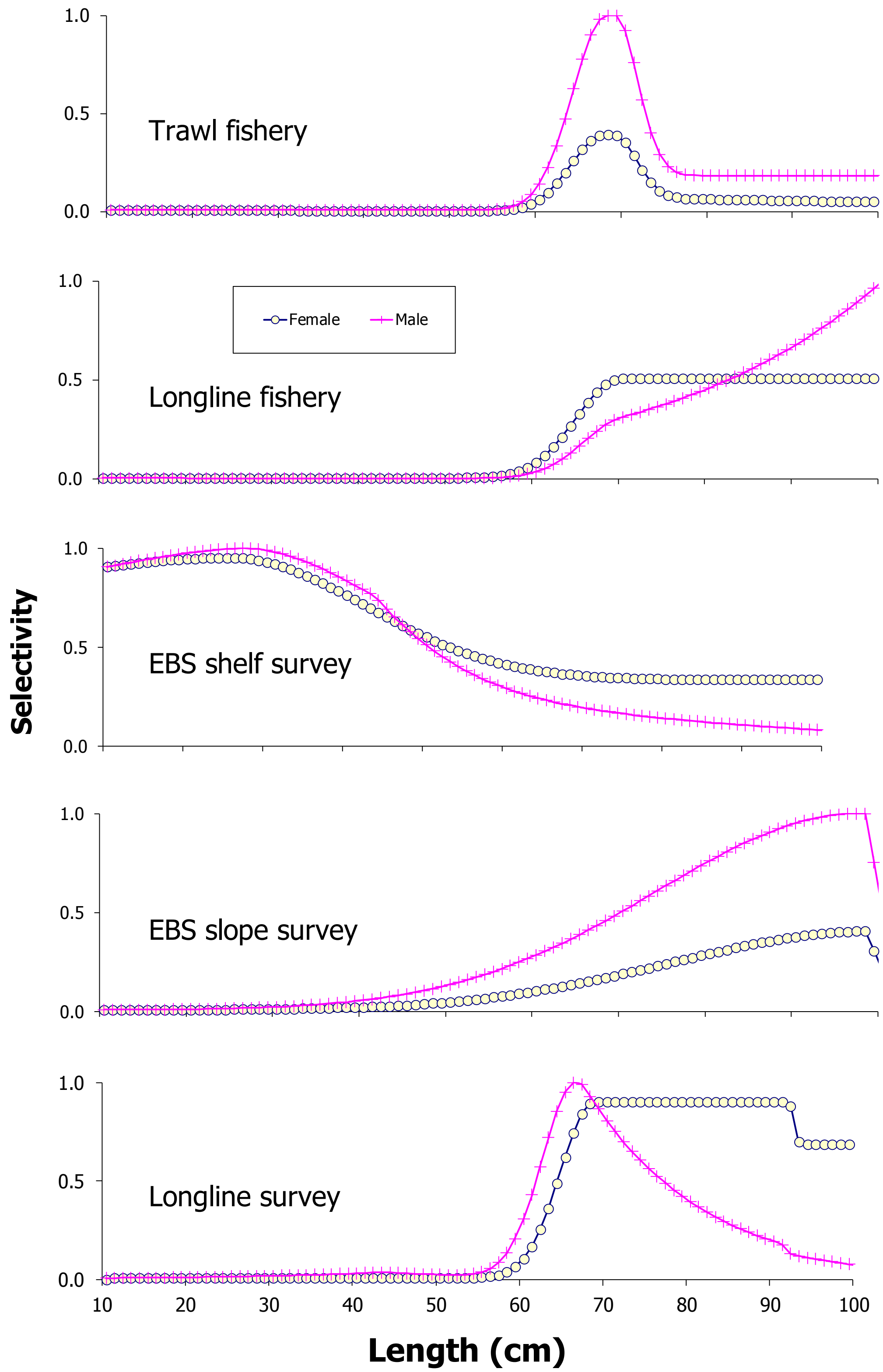


Figure 5.15. Size-specific estimates of selectivity patterns for all fisheries and surveys for EBS Greenland turbot showing differences in sex-specific availability in the current year (some earlier years had different selectivity estimates).

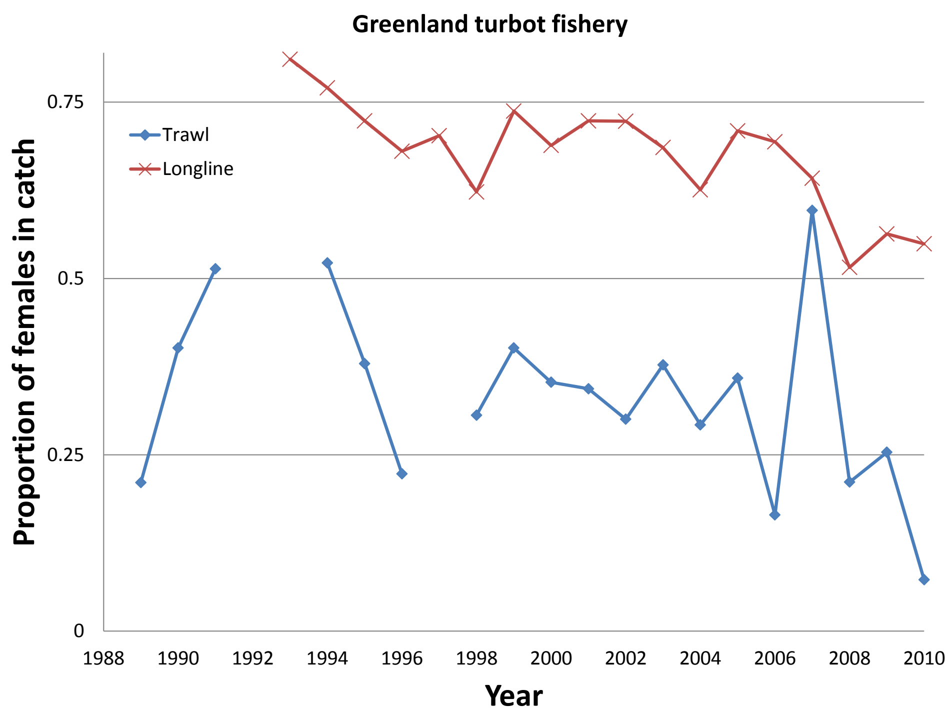


Figure 5.16. Observed Greenland turbot sex ratio over time from the BSAI region trawl and longline fisheries.

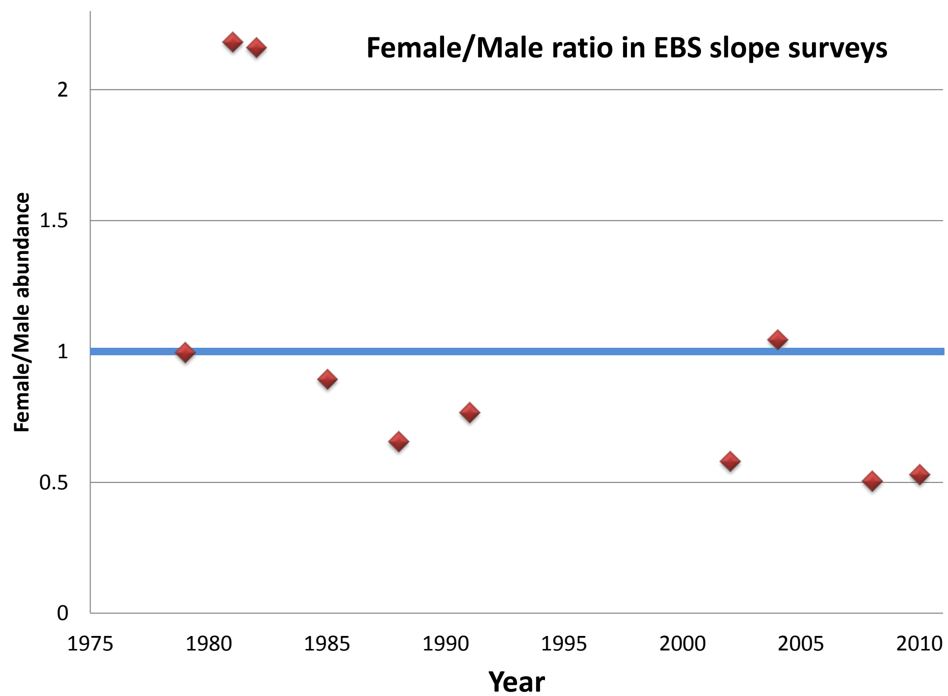


Figure 5.17. EBS slope trawl survey estimates of Greenland turbot sex ratio.

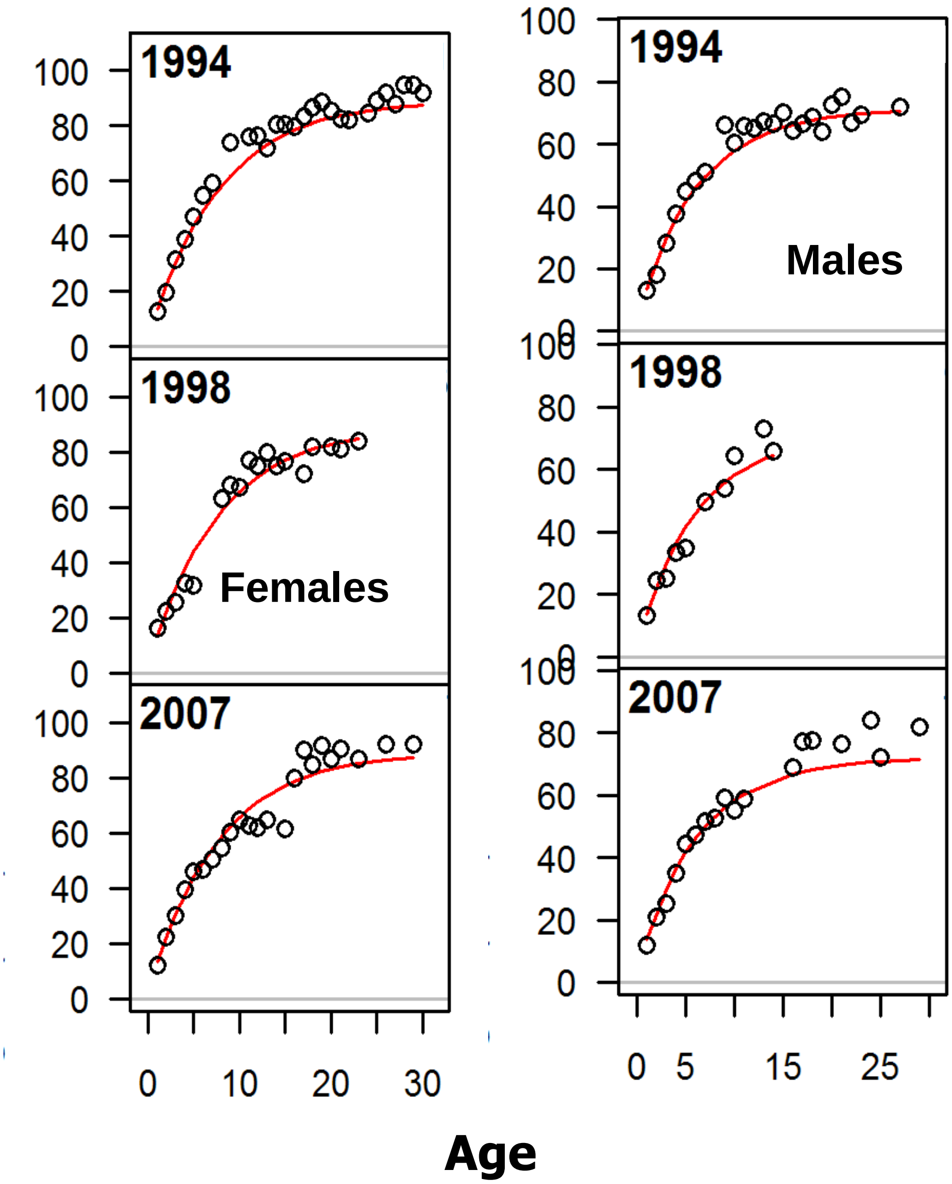


Figure 5.18. Estimated growth (length at age) of Greenland turbot by sex (female on left, males on right) in the EBS/AI region as predicted by the model and compared to the available age data using the methods of Gregg et al (2006).

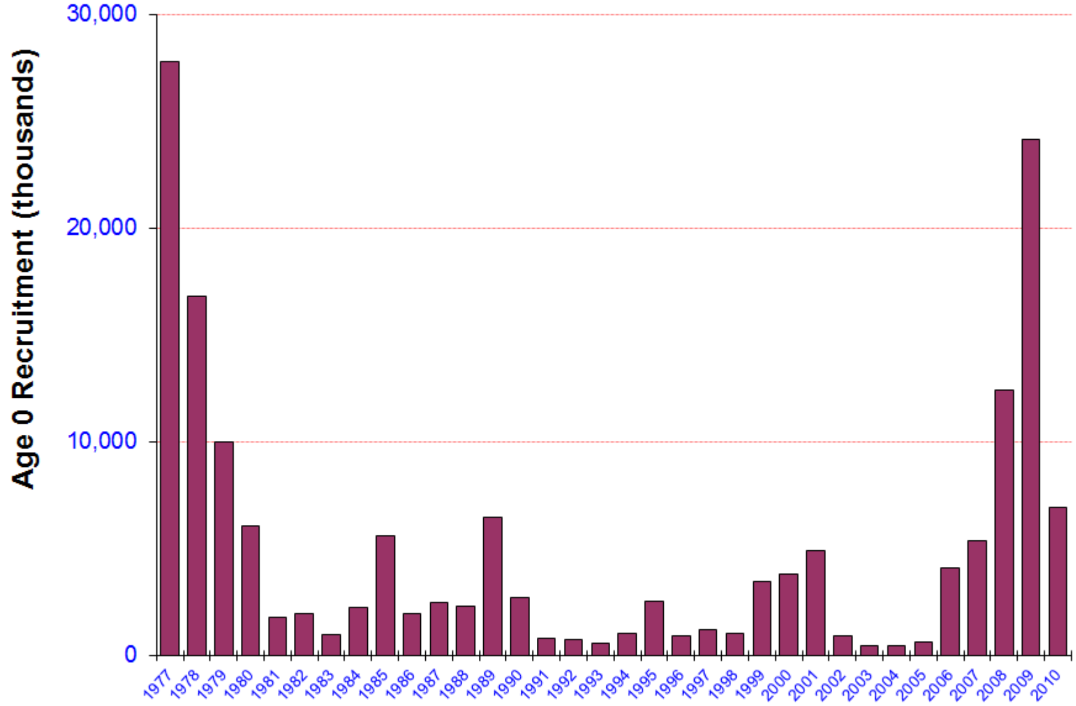


Figure 5.19. Estimated recruitment at age 0 (thousands) for Greenland turbot in the EBS/AI region, 1977-2010.

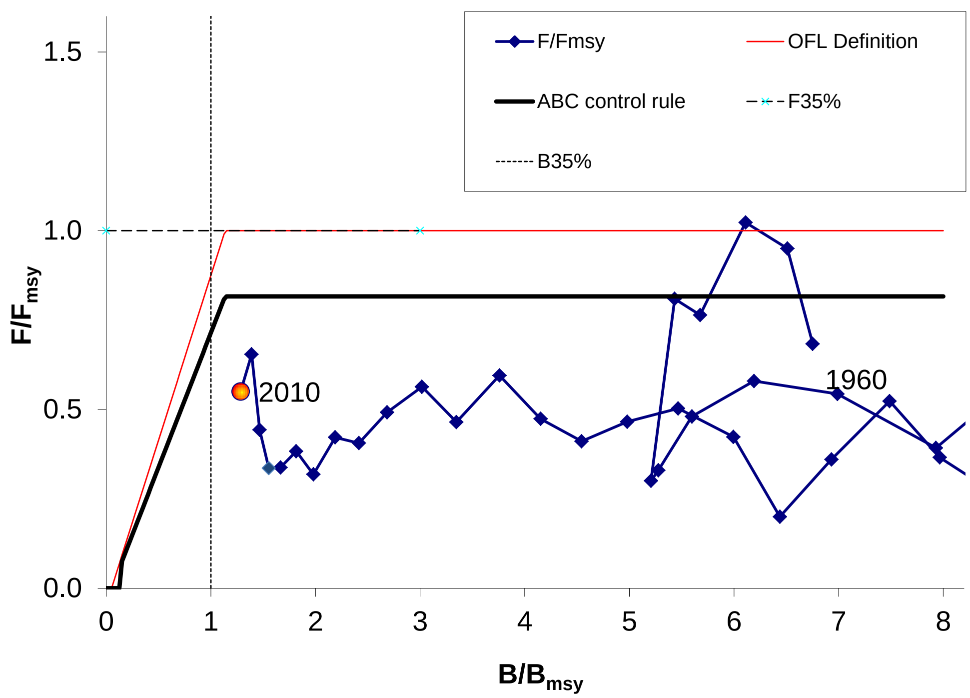
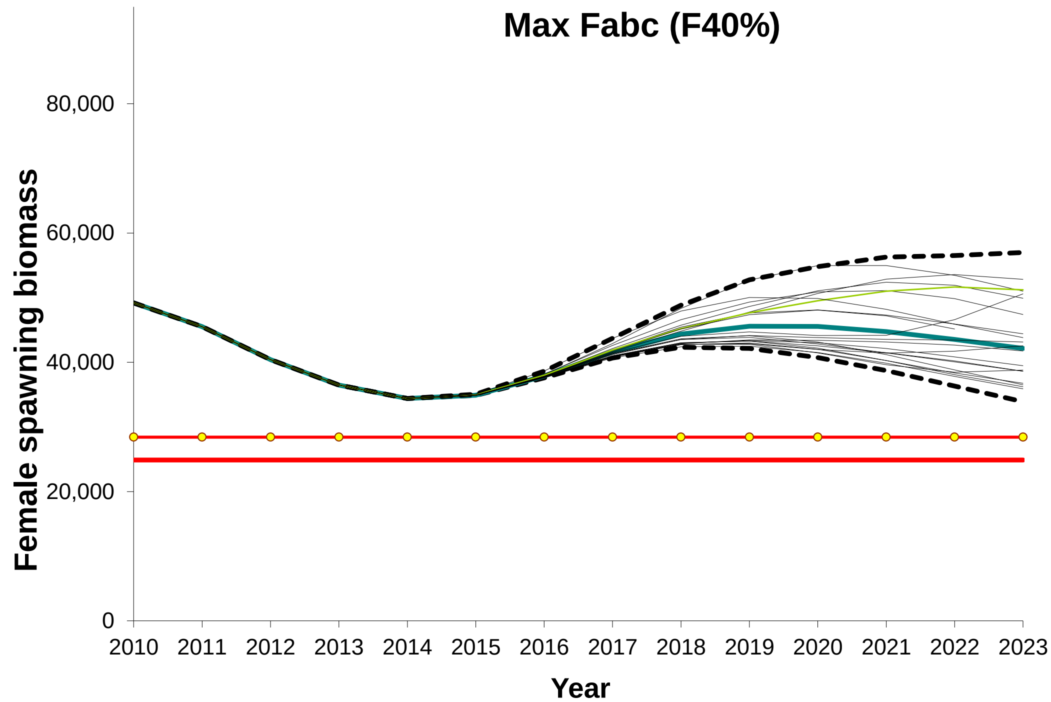


Figure 5.20. Ratio of historical F/F_{msy} versus female spawning biomass relative to B_{msy} for BSAI Greenland turbot, 1960-2010. Note that the proxies for F_{msy} and B_{msy} are $F_{35\%}$ and $B_{35\%}$, respectively.



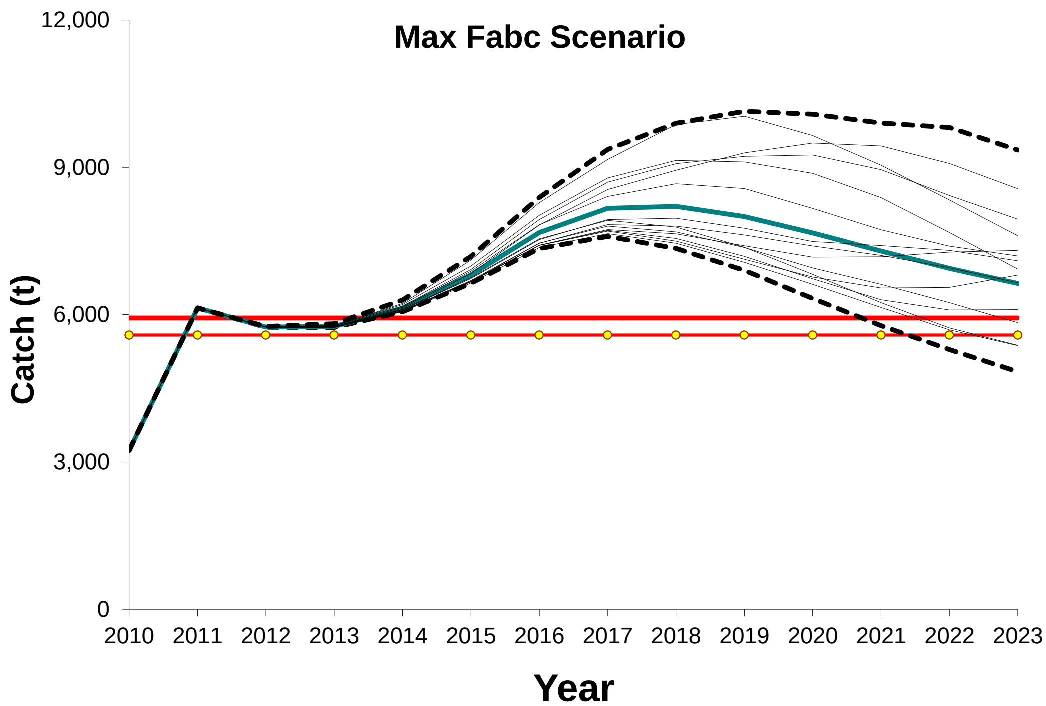


Figure 5.21. Stochastic trajectory of Greenland turbot female spawning biomass and catch for the maximum allowable fishing mortality rate under Amendment 56/56, Tier 3. The dotted lines represent the 90% confidence limits. Horizontal lines with marks are the values associated with $B_{40\%}$ and $F_{40\%}$ while the thick horizontal line is the expected value under constant F_{OFL} rate ($F_{35\%}$).

Attachment 5.A Fits to composition data

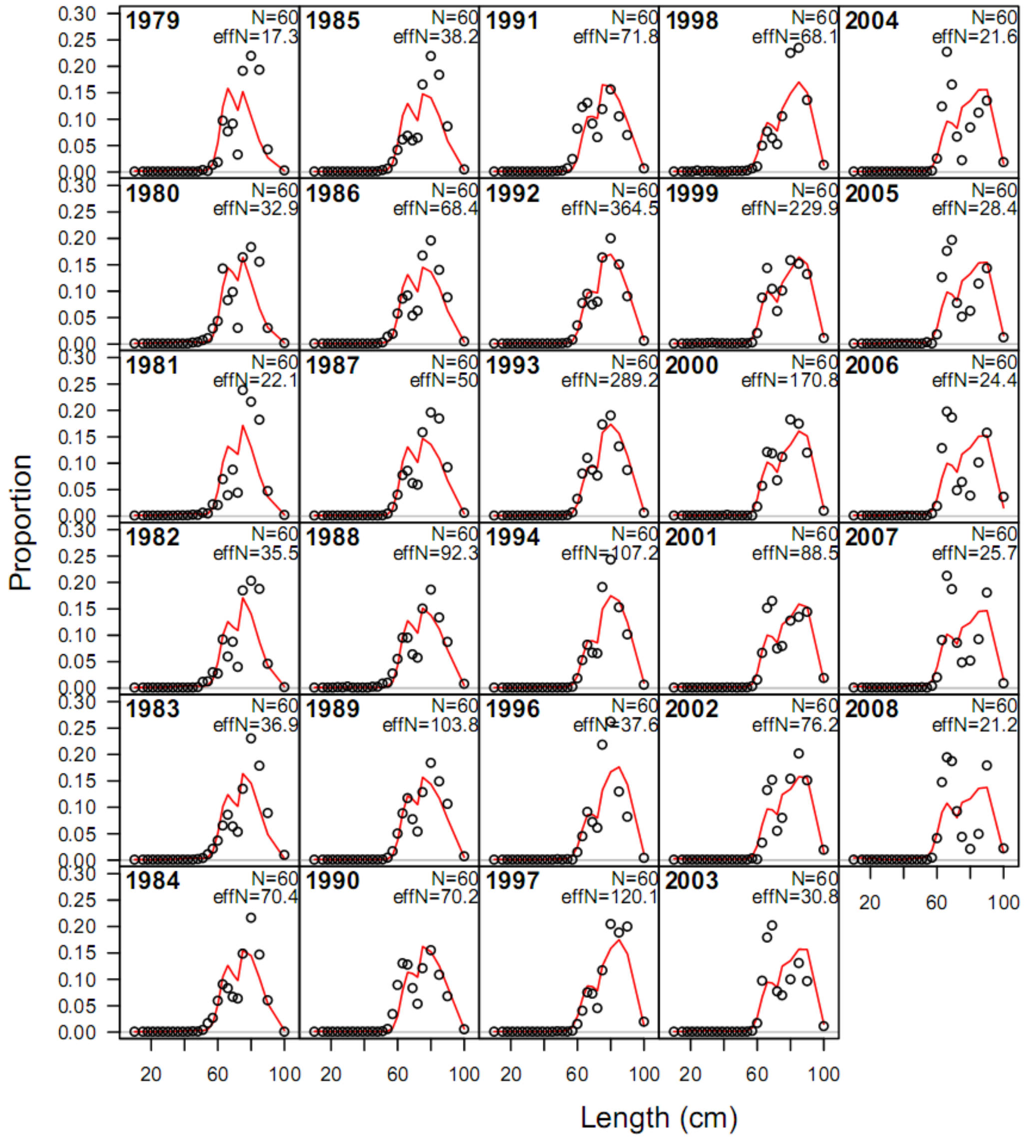


Figure 5.22. Greenland turbot model fit to longline survey length frequency data (sexes combined). Lines are model predictions, points are data.

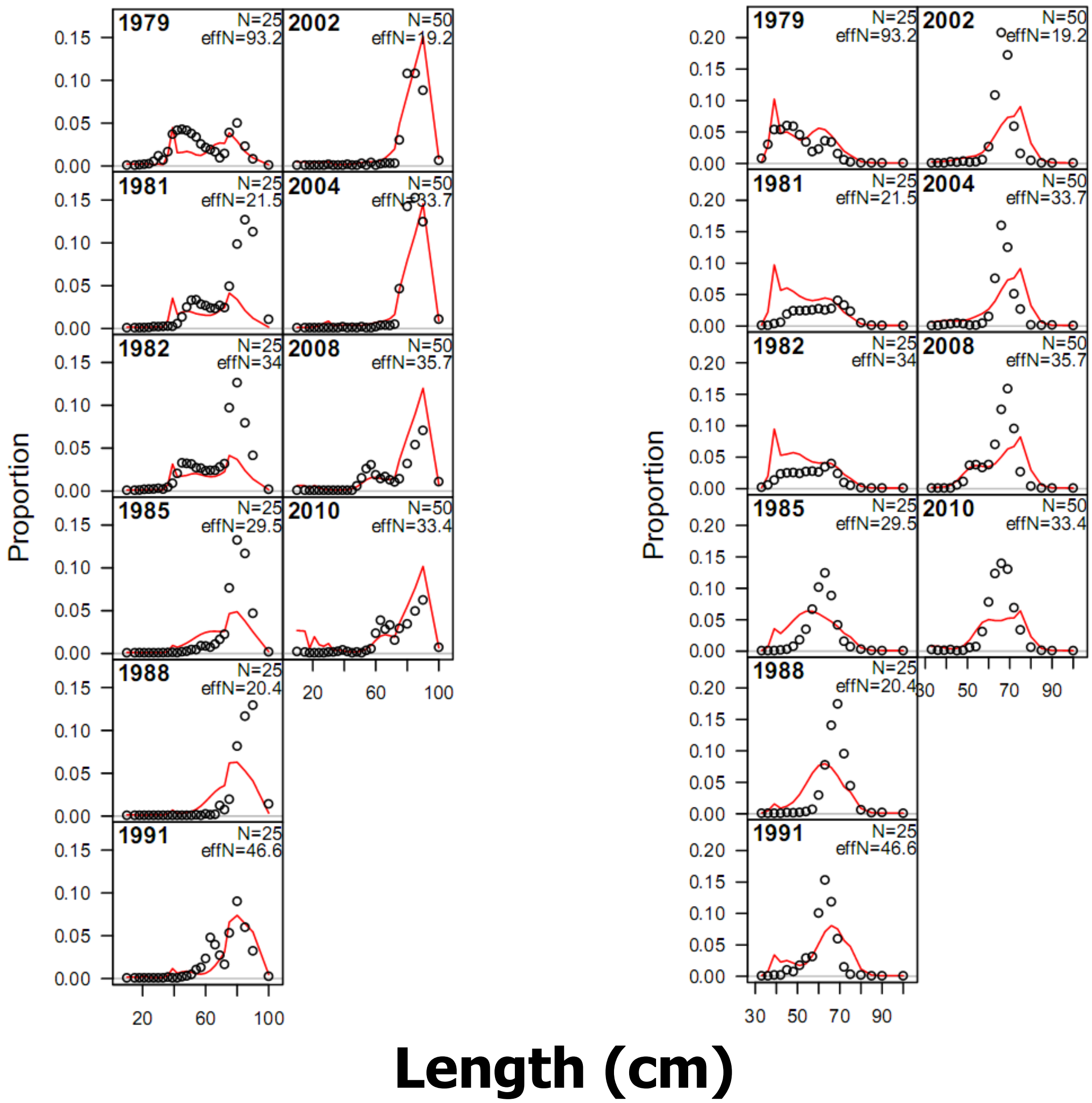


Figure 5.23. Greenland turbot model fit to EBS slope trawl survey length frequency data. The left set are females, while the right set are males. Lines are model predictions, points are data; females on left and males on right.

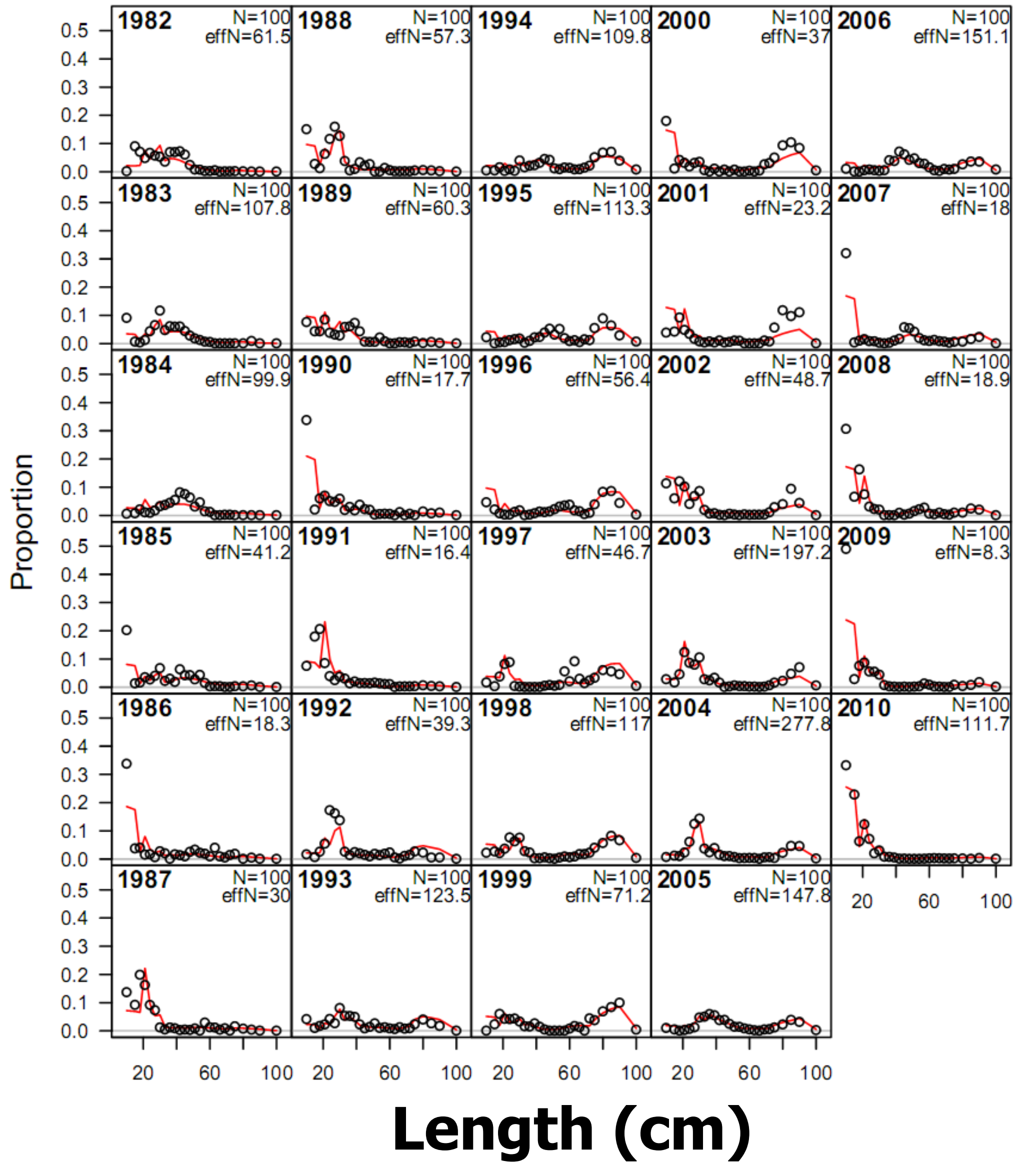


Figure 5.24. Greenland turbot model fit to EBS shelf trawl survey **female** length frequency data. Lines are model predictions, points are data.

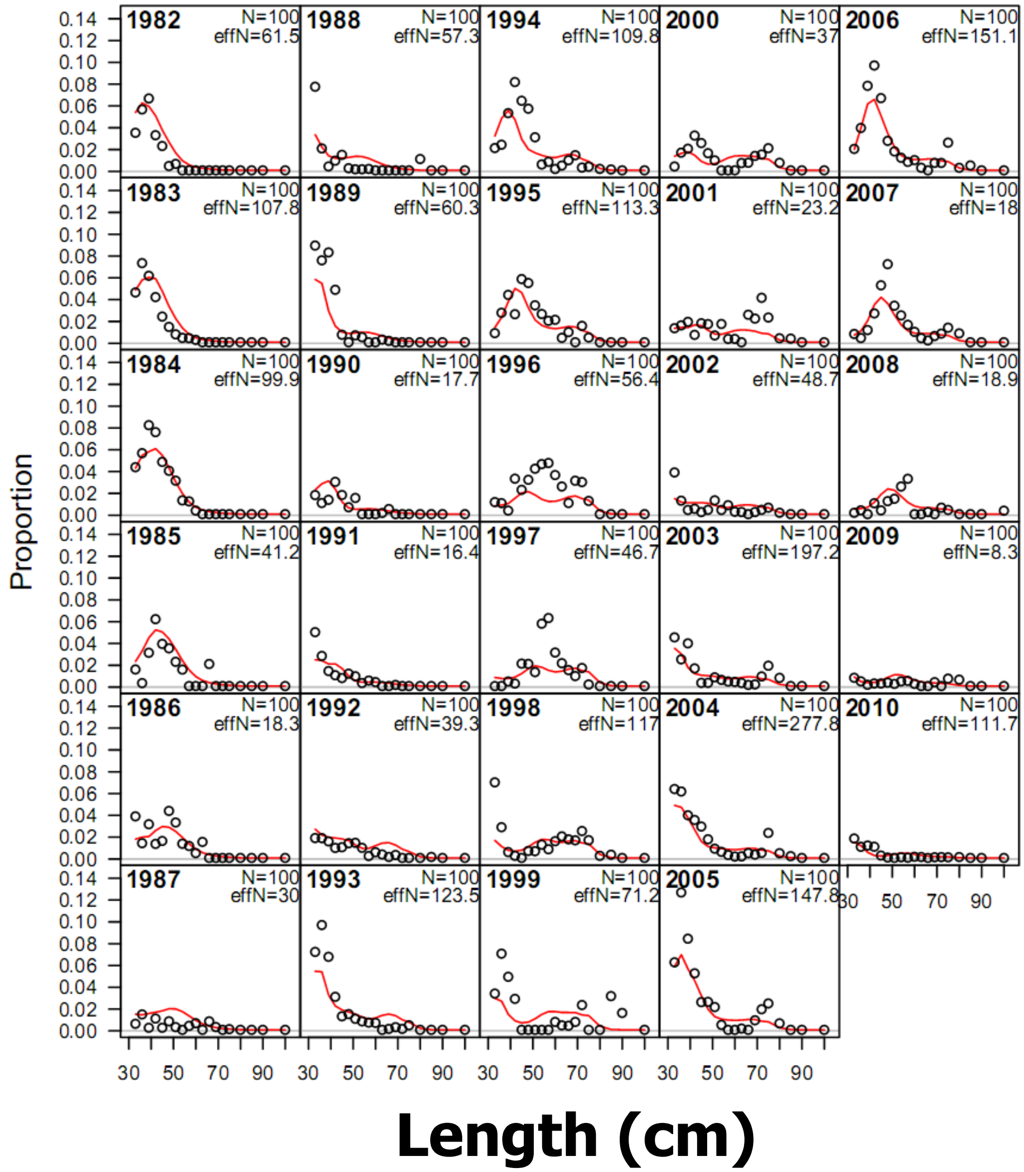


Figure 5.25. Greenland turbot model fit to EBS shelf trawl survey **male** length frequency data. Lines are model predictions, points are data

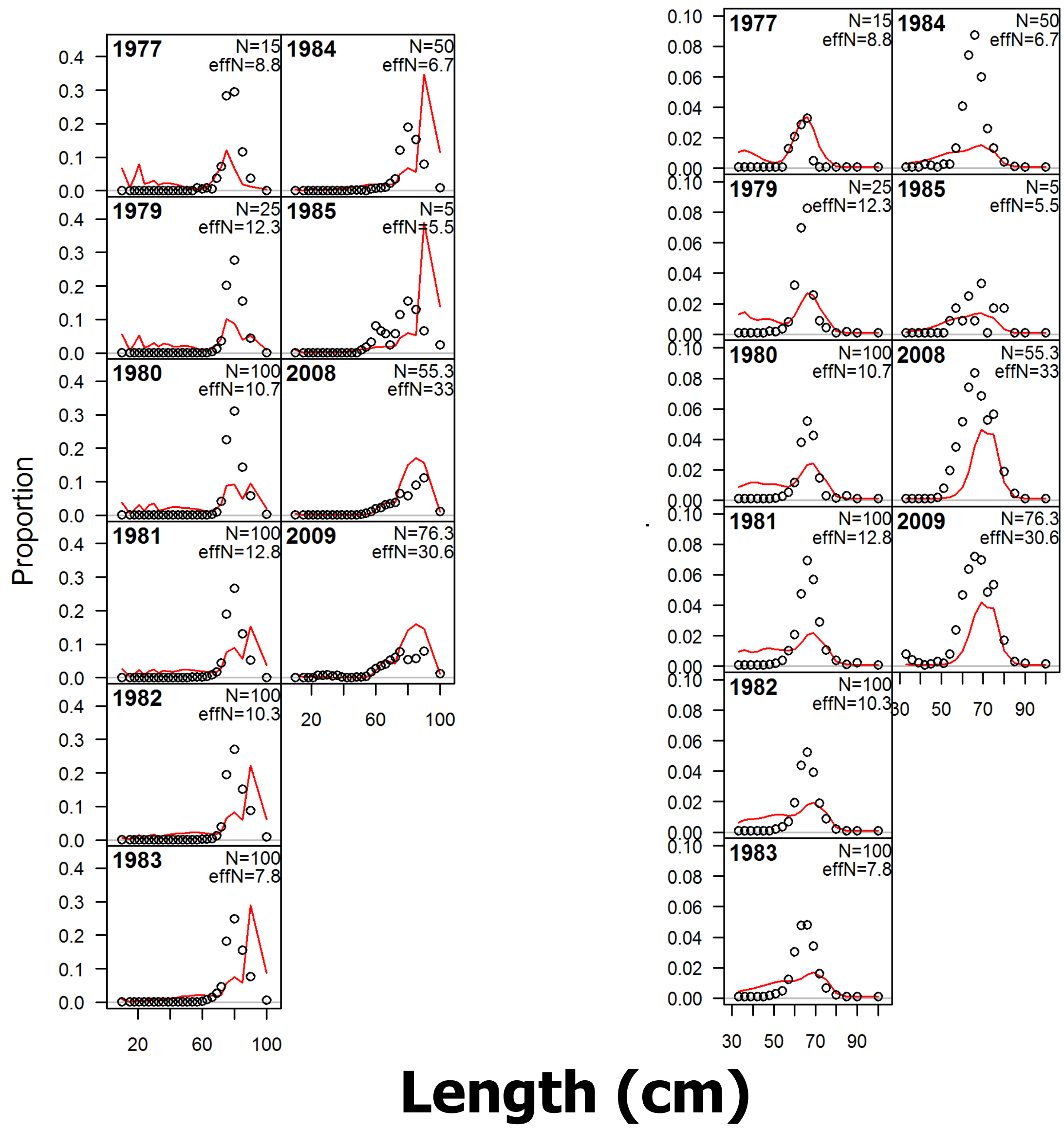


Figure 5.26. Greenland turbot model fit to EBS longline fishery length frequency data (combined sexes). Lines are model predictions, points are data; females on left and males on right.

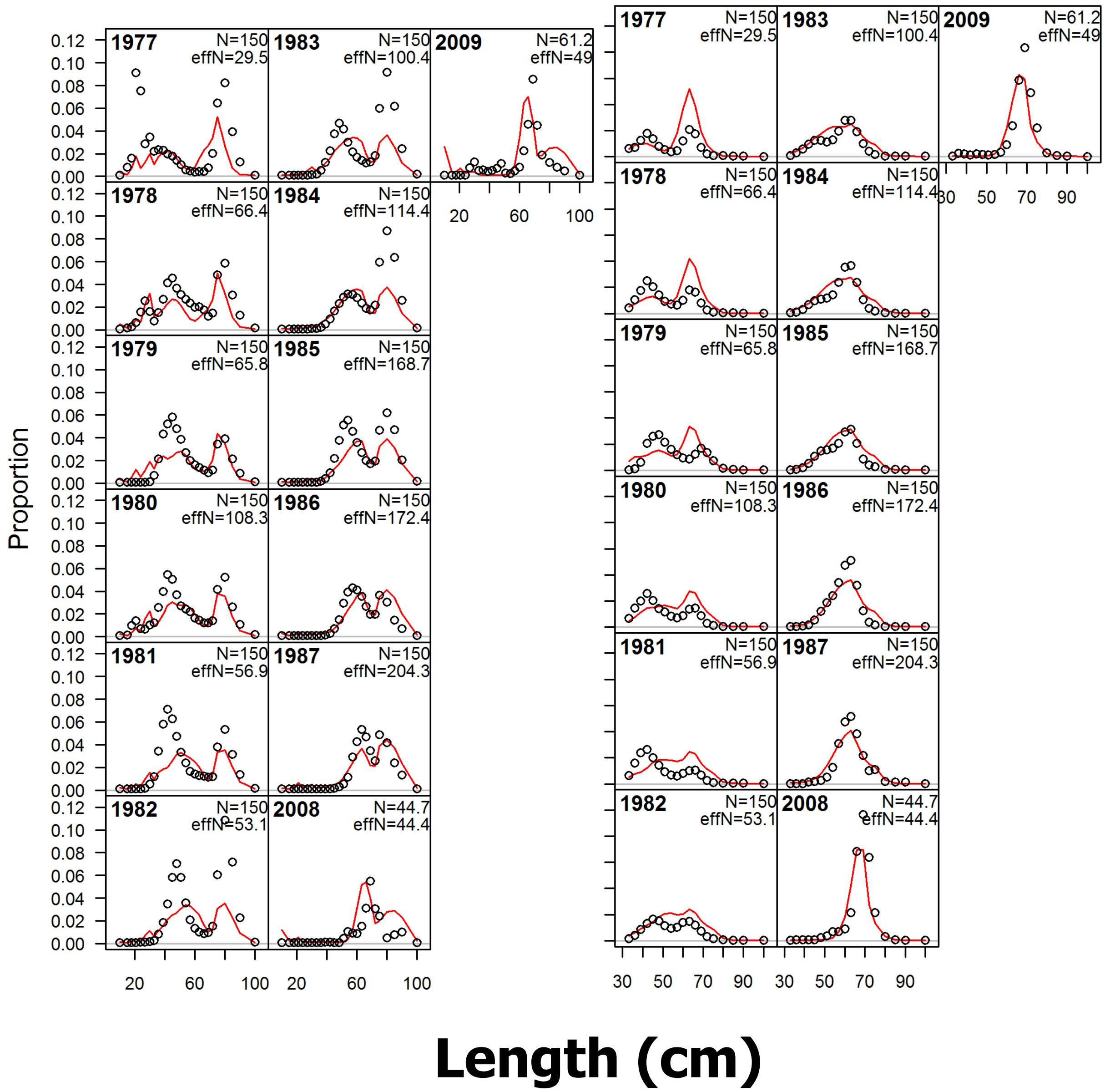


Figure 5.27. Greenland turbot model fit to EBS trawl fishery length frequency data. The left set are females, while the right set are males. Lines are model predictions, points are data; females on left and males on right.