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. 2004 and 2005 catch data
2. 2004 (and limited 2005) fishery catch-at-length by gear type
3. EBS shelf survey 2005 biomass and length composition estimates
4. Revised EBS slope survey 2004 biomass and length composition estimates
5. An updated aggregated longline survey data index for the EBS and Aleutian Islands regions

Changes to the assessment model

There were no major changes to the main assessment model. An alternative approach was developed that scales the relative abundance estimates from the longline survey to absolute values (borrowing an estimate of the catchability coefficient from the 2004 sablefish assessment).

Changes in the assessment results

The longline survey result for 2005 indicated a continued downward trend. The alternative calculation using re-calibrated longline survey catchability indicated that the absolute magnitude of the abundance based on the 2004 assessment was about 33% lower than the survey average prediction. The 2005 shelf-survey biomass estimate was down by about 24% of the 2004 estimate as warm conditions on the Eastern Bering Sea shelf continued.

The value of $B_{40\%}$ based on the mean estimated recruitment for the period 1978-2004 is estimated to be 47,400 t. The current estimate of the year 2006 female spawning biomass is about 43,470 t. Given the fact that spawning biomass estimates are at their lowest levels and stock structure uncertainty, an ABC which stabilizes abundance in the near term was evaluated. This results in a 2006 and 2007 recommended ABC for BSAI Greenland turbot of **3,000 t.** This level of catch is projected to halt declines in the near term while providing sufficient bycatch in other fisheries. This compares with a maximum permissible level under Tier 3b of 11,400 t**.** The 2006 overfishing level, based on the adjusted $F_{35\%}$ rate is **14,200 t** corresponding to a full-selection F of 0.61.

Response to SSC comments

There were no specific comments on Greenland turbot assessment. The SSC requested that SAFE chapter sections be consistent so that relevant sections can be easily found. To this end, the AFSC developed a checklist for SAFE chapters which this assessment follows.

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 we assume that the Greenland turbot found in the two regions 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*, we retain the common name of Greenland turbot which is also the “official” market name in the US and Canada (AFS 1991). 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).

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). Greenland turbot were 73% retained in the 2003 Bering Sea fisheries.

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, we assumed that the ratio of the two species for the years 1960-64 was 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 2004 NMFS scientists surveyed the Aleutian Islands region with bottom trawls and longline gear and both the slope and shelf regions of the EBS were surveyed with trawl gear. The 2004 Aleutian Islands bottom trawl survey estimate was 11,300 t, an increase of 15% from the 2002 survey estimate (Table 5.3). However, the 11,300 t is below the 1990-2004 average level of 16,500 t. The distribution of Greenland turbot from the recent Aleutian Islands surveys are shown in Fig. 5.4. In 2004 a relatively large fraction of the Greenland turbot (29%) were found in the eastern-most area of the Aleutian Islands survey (Table. 5.3). For modeling purposes, the Aleutian Islands component of the Greenland turbot stock is omitted.

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. Due to limited vessel time, the R/V Miller Freeman sampled a smaller area and fewer stations 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. This survey is planned to be done every two years and has improved sampling effort Greenland turbot habitat areas.

The trawl slope-surveys are likely to represent under-estimates the actual biomass of Greenland turbot for a number of reasons, hence, these are treated as relative indices of abundance. For example, the species 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 (Paul Spencer, pers. comm., Fig. 5.5).

Abundance estimates for juvenile Greenland turbot on the EBS shelf are provided annually by AFSC trawl surveys. For the shelf survey, the extent of Greenland turbot found in the northwestern strata (Fig. 5.6) ranges from 2%-34% (Table 5.4). The extent that the shelf-survey estimates are affected by temperature (with smaller fractions found in the northerly zones during colder years) indicates that abundance indices may be affected. For this assessment, alternative abundance estimates were evaluated (see below).

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—the 2004 level is 57,500 t. The average shelf-survey biomass estimate during the last 11 years (1993-2004) is 28,000 t.

The following table summarizes the sampling that has occurred for the EBS bottom trawl survey data since 1982:

Year	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	
No. hauls	329	354	355	353	354	342	353	353	352	351	336	
No. Lengths	969	951	536	196	195	82	200	183	232	360	440	
Year	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
No. hauls	355	355	356	355	356	355	353	352	355	355	356	376
No. Lengths	400	398	313	297	197	93	207	248	274	322	622	na

Survey size-at-age data was available and used for estimating growth and growth variability were available from 1975, 1979-1982.

Currently, the domestic longline survey effort extends into the Bering Sea and part of the Aleutian Islands (in alternate years). This new sampling area represents a smaller region than in past but shows that about 25% of the population along the slope regions is found within the northeast (NE) and southeast (SE) portions of the Aleutian Islands compared to the abundances along the slope of the EBS:

Relative Population No. (RPN)				Year						
Area	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Bering 4		11,729		13,072		16,082		11,965		3,717
Bering 3		6,172		6,156		5,005		3,784		1,822
Bering 2		27,936		33,848		24,766		24,660		15,268
Bering 1		13,491		10,068		4,788		6,206		2,297
NE Aleutians	23,133		16,124		12,987		10,942		8,551	
SE Aleutians	2,142		1,806		1,201		1,397		937	
Bering Sea		59,328		63,144		50,641		46,616		23,103
Aleutians	25,275		17,930		14,188		12,339		9,487	
Combined	102,751	78,682	72,890	83,743	57,680	67,161	50,161	61,823	38,568	30,640

Longline survey

The combined time series shown above (1996-2005) was used as a relative abundance index (Fig. 5.7). It was computed by taking the average RPN from 1996-2005 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 (1996-2005) 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.

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 Greenland turbot size compositions from the 2004 Aleutian Islands and EBS slope trawl surveys are given in Fig. 5.8. The EBS shelf trawl survey extended into the northern region in 2004 and found relatively large numbers of smaller Greenland turbot (Fig. 5.9). This provides additional evidence that the stock extends further north than the standard survey area and could be indicative of a successful recruitment event. The length frequency from the longline survey is shown in Fig. 5.10.

Scientific research catches are reported to fulfill requirements of the Magnuson-Stevens Fisheries Conservation and Management Act. The following table documents annual research catches (1977 - 1998) from NMFS longline and trawl surveys (in tons):

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
NMFS Bottom trawl surveys	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	
Cooperative Longline surveys	3	3	6	11	9	7	8	7	11	6	16	10	10	
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
NMFS Bottom trawl surveys	0.9	1.4	2.0	1.4	1.5	1.2	1.4	1.0	5.1	1.1	5.3	1.1	11.0	0.7
Domestic Longline surveys	22	23	23											

Analytic approach

Model Structure

The use of the stock synthesis program (Methot 1990) to model the eastern Bering Sea component of Greenland turbot stock was presented in previous assessments (Ianelli et al. 1994, 1995). Before 1994, stock assessments of Greenland turbot in the eastern Bering Sea and Aleutian Islands have relied in part on stock reduction analysis (SRA) to provide historical trends in the fishery (Wilderbuer and Sample 1992). As with past years, the length-version of the stock synthesis program (Methot 1990) was used for this assessment (updated to the 2003 version of the computer program). Catch data used in the stock synthesis model were from 1960 to 2004. 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 likelihood (L) of the predicted observations given the data. Data are classified into different components. For example, age composition from a survey and catch per unit effort (CPUE) from a fishery are different components. The total L is a sum of the likelihoods for each component. The total L may also include a component for a stock-recruitment relationship and penalty functions to help stabilize parameter estimates. The likelihood components may be weighted by an emphasis factor. For Greenland Turbot in the EBS the model included two fisheries, those using longline and trawl gear, and three surveys. Table 5.5 summarizes the extent of the data used in the different likelihood components. All emphasis factors were set to 1.0, effectively relying on proper weights from the assumed (or in most cases, estimated) variances for the data sources.

Annual recruitments are estimated as parameters in the model, they can be thought of as “anomalies” from an underlying stock-recruitment curve. These recruitment anomalies can be due to process and observation errors. Process errors refer to the real differences from the mean stock-recruitment curve caused by natural variation in recruitment success. Observation errors refer to our ability to estimate the true recruitment levels due to sampling problems. In this application, observation error is considered negligible compared to the magnitude of recruitment variability (process error). Consequently, the underlying parameters of the stock-recruit curve play an insignificant role in fitting the model to the data. For further details on the model specifications of the length-version of the stock synthesis program, see Thompson *et al.* (2004).

Selectivity Patterns
A dome-shaped size-based selectivity function (Methot 1990) 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, we treated the foreign and domestic trawl data as from a single fishery and simply let the selectivity pattern be different between the respective periods. Because larger fish have been observed in the recent EBS shelf region trawl surveys, selectivity was also was estimated separately for two periods: 1994-present and 1982-1993.

Parameters estimated independently

Natural mortality, length at age, length-weight relationship
The natural mortality of Greenland turbot was assumed to be 0.18. This estimate was used because it is slightly less than that of other flatfish species with a slightly lower maximum age. Greenland turbot taken by the commercial fishery have been aged as old as 21 years. A recent study (Cooper et al., In review) found that based on relating GSI and life-history characteristics, natural mortality should be lower, closer to 0.10.

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 in the previous assessments, size-at-age information from surveys conducted between 1976-82 were used in the model to help estimate the relationship between age and length. 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
Maturation and fecundity by size or age is poorly understood for Greenland turbot. Alton *et al.* (1988) present the results from studies of Greenland turbot in different areas in addition to the EBS region. For this analysis, we chose a logistic size-maturity relationship which has 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 1960-2004 (1965-1969 aggregated to have a single mean value),
- Selectivity parameters for the 2 fisheries, and 3 surveys,
- Growth parameters: 5 parameters (2 for each sex, one in common),
- Parameter that scales the expected value of recruitment, and
- Effective effort-fishing mortality rates for trawl and longline fisheries (solved by matching predicted catch biomass to the observed catch biomass exactly), 1960-2005.

Model evaluation

Size composition data are not available until 1977 hence we are unable to resolve recruitment strength information during the early period (1960s) with the model. Based on earlier assessments (e.g., Ianelli et al. 1999), setting the individual recruitment estimates from 1960-69 equal to that predicted by an equilibrium stock-recruitment relationship gave a poor fit to the size composition data and a high unfished biomass (>1.8 million mt). When all recruitment deviations were estimated (the full model), a single large deviation resulted in the early part of the time series. This indicated a year class more than an order of magnitude greater than the mean estimated recruitment since 1970. Both the full model and the equilibrium recruitment models were therefore unsatisfactory. To compensate, we pooled recruitment deviation estimates from 1965-69 as in Ianelli et al. (1993). The assumed slope-survey catchability was fixed as before at 0.75. A complete analysis of alternative model configurations was not attempted this year due to complexity related to selectivities, gear types, and general paucity of information specific to Greenland turbot.

Alternative models were evaluated relative to revised data assumptions. First, last year's model was simply re-run with each of the revisions included incrementally:

Reference 2004 model (all data unchanged)

a) 2004 model with 2004 slope estimate revised

b) 2004 model with 2004 slope estimate revised and revised 1982-2004 survey estimates from standard strata (1-6)

c) 2004 model with 2004 slope estimate revised and revised 1985-2004 shelf survey data including all strata (1-9)

Model a) evaluates the effect of the revised slope survey estimate (which dropped by 4% from the value used in the 2004 assessment). Models b) and c) introduce revised shelf bottom-trawl survey estimates and ignore the years prior to 1982 since the survey gear was different. Model c) differs from Model b) in that the strata northwest of the "standard" survey area are included. Using the northwest strata may be important since Greenland turbot are thought to be distributed to northern regions.

Results

The revised slope survey data for 2004 affect the biomass estimate trend more than the other changes in the data (Fig. 5.11). Somewhat surprisingly, the model appears to be insensitive to the change in time series of the shelf survey abundance trends including the northwestern strata. Model c) above was selected for analyses presented below including the new updated data.

Trends in Abundance

The fits to the abundance indices are given in Fig. 5.12. The assessment model predictions for shelf survey biomass are considerably below the observed estimates during the early years. Since 1993, the point where selectivity is allowed to change, the fit to the index is biased high. The shift in selectivity was intended to reflect the appearance of larger Greenland turbot on the shelf than in the past. Some modeling that better accounts for habitat changes (e.g., extent of the cold pool or some other environmental factor) may be preferred to more reasonably reflect changes in distribution. This is an area for future research. The reason that the model fits the early period of the shelf trawl survey index poorly is because such high levels of recruitment are inconsistent with observations of numbers of older fish later in the time series. The overall trend for the slope survey estimates is mimicked by the assessment model. The general trend of the longline survey index shows decreasing numbers that are tracked by the model.

The biomass of Greenland turbot increased during the 1970s from the early 1960s level and is currently about 43% of the unfished level. The 2004 total beginning of the year biomass (age 1 and older) estimate is about 98,300 (Table 5.5; Fig. 5.13). In past years, harvest levels of Greenland turbot were set using extra precaution due to the lack of recruitment. For example, the model excludes biomass estimates from the Aleutian Islands, which averages about one fourth to one third of the adult population biomass.

The historical fishing mortality rates (combined gears) increased over time and was highest in 1980 through 1983 (Table 5.6). A comparison of this year's model result with a similar model from the 2004 assessment is also presented in Table 5.6. The estimated historical numbers at age is given in Table 5.7.

Alternative abundance calculations

As a check, a novel approach to using the longline survey data was attempted. The idea is to use the implied ratio of the survey abundance index to absolute population numbers for sablefish and apply this ratio to the longline survey abundance index for Greenland turbot. First, sablefish catchability (*q*) for the longline survey was computed as:

$$RPN_y^{sable} = q\sum \hat{N}_{y,a}^{sable}\hat{s}_a^{sable}$$

where $\hat{N}_{y,a}^{sable}$ are numbers at age a in year y and $\hat{s}_a^{sable}$ is the estimated longline survey selectivity, both from the 2004 sablefish assessment (Hanselman, pers. comm.). For all the years where an RPN values exist for sablefish, the value for q was calculated and the average was used to generate a model-prediction of Greenland turbot RPN values:

$$q\sum_a \hat{N}_{y,a}^{turbot}\hat{s}_a^{turbot} \; .$$

These values were averaged over all years and computed relative to the observed survey RPN's for turbot and the result was a value of 0.67. This suggests that, assuming the longline survey catchability (availability) of Greenland turbot is the same as sablefish and that the magnitude of sablefish assessed abundance relative the survey is correct, that the absolute abundance estimates are low. If Greenland turbot selectivity and availability to this gear is lower than sablefish, then the absolute abundance would be even higher than the values presented here. From a conservation perspective, these results provide some assurance that the stock is unlikely to be overestimated.

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 (Fig. 5.14). 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 not clear; however, we feel that it is related to the apparent bi-modality in the size distribution observed in the trawl fishery. The age-equivalent sex-specific selectivity estimates (for 2004) from each gear type for Greenland turbot in the BSAI is given in Table 5.8. 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 to each fishery (Table 5.9).

Fit to Size Composition Data

Size composition observations from the fisheries and surveys are generally poorly matched by the model predictions (Appendix 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 has been poor since the early 1980s based on EBS shelf trawl surveys. There were several strong year-classes through the 1970s, which were followed by moderate recruitment of Greenland turbot during the 1980s and poor levels through the 1990s (Fig. 5.15). The declining trend seems to have slowed since 2000 but these estimates must be viewed with caution. Preliminary analyses on fitting the stock-recruitment relationship indicated that the residuals were highly auto-correlated. 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 many functional forms can fit the data equally well. As presented above, the harvest strategy relative to reductions in spawning biomass per recruit (e.g., $F_{40\%}$) 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 we selected a conservative configuration (assuming slope-survey catchability=0.75). The status of the projected spawning biomass in year 2006 relative to $B_{40\%}$ would place Greenland turbot in Tier 3b of Amendment 56.

The $B_{40\%}$ value using the mean recruitment estimated for the period 1978-2004 gives a long-term average female spawning biomass of about 47,400 tons. The current estimate of the year 2006 female spawning biomass is about 43,470 t, above the estimate of $B_{35\%}$ (41,400).

Specification of OFL and Maximum Permissible ABC and ABC Recommendation

The projected Greenland turbot maximum permissible ABC and OFL levels for 2006 and 2007 are shown below (catch for 2006 was set equal to the ABC recommendation):

Year	Thousands of t Catch	Maximum permissible ABC	Recommended ABC	OFL	Female spawning biomass
2006	3.00	11.39	3.00	14.19	43.47
2007	3.00	10.72	3.00	13.38	42.70

For ABC specification this year the objective to halt the decline of Greenland turbot abundance was given priority. It was found that if catches are fixed for three years (2006-2008) at **3,000 t,** the abundance trend stabilized. Precaution at this level seems prudent given the anticipated further declines under alternative harvest scenarios. 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 $B_{35\%}$ level, we feel that extra caution is warranted. The survey information from the slope region provides insight on the abundance of Greenland turbot in their main habitat area.

Additional evaluations of the longline survey data also suggest that these estimates of absolute abundance are conservative.

The estimated overfishing level based on the adjusted $F_{35\%}$ rate is **14,200 t** corresponding to a full-selection *F* of 0.61. 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).

Subarea Allocation

In this assessment, we have adopted the hypothesis proposed by Alton et al. (1989) regarding the stock structure of Greenland turbot in the eastern Bering Sea and Aleutian Islands regions. 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, we examined the length compositions from the Aleutian Islands surveys and found a lack of 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 5.10).

Since we acknowledge having limited information on the movement and recruitment processes for this species and in the interest of harvesting the "stock" evenly, we recommend that the ABC be split between regions. 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%. We therefore recommend the ABC for the Aleutian Islands be set 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	930
Eastern Bering Sea	2,070
Total	3,000

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 2005 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2006 (here assumed to be 2,900 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 2006, 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 4 (5-year average F) were selected.

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

Scenario 4: In all future years, F is set equal to the 2001-2005 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as 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 ½ of its MSY level in 2006 and above its MSY level in 2016 under this scenario, then the stock is not overfished.)

Scenario 7: In 2006 and 2007, 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 2018 under this scenario, then the stock is not approaching an overfished condition.)

Scenarios 1 through 7 were projected 13 years from 2005 (Table 5.11). Fishing at the maximum permissible rate indicate that the stock will drop to below $B_{35\%}$ by 2007 and rebuild (in expectation) to above $B_{35\%}$ by 2013 (Fig. 5.16).

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 2005 spawning biomass estimated at 43,470 t relative to ½ $B_{35\%}$ = 22,600 tons). Under the guidelines, since the year 2005 biomass estimate is well above the $B_{35\%}$ level (and $B_{40\%}$) we have determined that 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. The results fishing at the maximum permissible and at the 5-year average F both suggest a continued decline in spawning biomass until about 2009 (Fig. 5.17). However, fishing at the 5-year average F is more likely to keep the stock size above the $B_{35\%}$ level (the expectation is that it will drop to 42,900 compared to the $B_{35\%}$ level of 41,400). Projections with fishing at the maximum permissible level result in an expected value of spawning biomass of 34,000 t in 2008.

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, we can only speculate on the plausibility of this scenario. 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. This year scientists aboard the longline survey tagged and released 100 Greenland turbot bringing the total number of releases up to 841. In 2002 a Greenland turbot at large for over 16 years and recaptured on the Bering Sea slope area was reported. This individual fish was tagged in the Sea of Okhotsk, suggesting that Greenland turbot in the EBS/AI may not be a closed population. In addition, the Auke Bay lab scientists tagged 45 Greenland turbot with electronic (archival) tags in the Bering Sea in 2003. Of these, 4 males were recaptured and the temperature and depth data translated. Preliminary examinations of these data show interesting seasonal patterns with high levels of activity occurring in mid-January, perhaps related to spawning behavior.

Research and data gaps

Analyses of the tagging data should be pursued and an effort to upgrade the assessment software and implementation has begun (using the same approach as for Pacific cod).

The extent that the distribution of Greenland turbot is affected by temperature and environmental conditions is also important.

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. 5.18). The management parameters of interest derived from this assessment are presented in Table 5.12.

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References

AFS Publication, 1991. Common and Scientific Names of Fishes from the United States and Canada. American Fisheries Society Special Publication 20. C. Richard Robins, Chairman. 183 p. American Fisheries Society, 5410 Grosvenor Lane, Suite 110, Bethesda, MD 20814-2199.

Alton, M.S., R.G. Bakkala, G.E. Walters, and P.T. Munro. 1988. Greenland turbot *Reinhardtius hippoglossoides* of the eastern Bering Sea and Aleutian Islands region. NOAA Tech. Rep., NMFS 71, 31 p.

Beverton, R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest., Lond., Ser. 2, 19.

Cooper, D. K. Pearson, and D.R. Gunderson. (In Review). Annual fecundity and indirect estimates of natural mortality rate for *Reinhardtius hippoglossoides* (Greenland turbot or Greenland halibut). AFSC. Draft Manuscript.

D'yakov, Yu. P. 1982. The fecundity of the Greenland turbot, *Reinhardtius hippoglossoides*, (Pleuronectidae), from the Bering Sea. J. Ichthyol. [Engl. Transl. Vopr. Ikhtiol] 22(5):59-64.

Harrison, R.C. 1993. Data Report: 1991 Bottom trawl survey of the Aleutian Islands Area. NOAA Tech. Memo. NMFS-AFSC-12. 144p.

Ianelli, J.N., T.K. Wilderbuer, and T.M. Sample. 1993. Stock assessment of Greenland turbot. *In* Stock assessment and fishery evaluation document for groundfish resources in the Bering Sea/Aleutian Islands region as projected for 1994. Section 4. North Pacific Fishery Management Council, Anchorage, AK.

Ianelli, J.N., T.K. Wilderbuer, and T.M. Sample. 1994. Stock assessment of Greenland turbot. *In* Stock assessment and fishery evaluation document for groundfish resources in the Bering Sea/Aleutian Islands region as projected for 1995. Section 4. North Pacific Fishery Management Council, Anchorage, AK.

Ianelli, J.N. and T. K. Wilderbuer. 1995. Greenland Turbot (*Reinhardtius hippoglossoides)* stock assessment and management in the Eastern Bering Sea. *In:* Proceedings of the International Symposium on North Pacific Flatfish. Alaska Sea Grant. AK-SG-95-04:407-441.

Ianelli, J.N., T.K. Wilderbuer, and T.M. Sample. 1999. Stock assessment of Greenland turbot. *In* Stock assessment and fishery evaluation document for groundfish resources in the Bering Sea/Aleutian Islands region as projected for 2000. Section 4. North Pacific Fishery Management Council, Anchorage, AK.

Kimura, D.K. 1988. Analyzing relative abundance indices with log-linear models. N. Am. Journ. Fish. Manage. 8:175-180.

Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *In* Proceedings of the symposium on applications of stock assessment techniques to Gadids. L. Low [ed.]. Int. North Pac. Fish. Comm. Bull. 50: 259-277.

Thompson, G.G., and M.W. Dorn. 2004. Chapter 2: Assessment of the Pacific Cod Stock in the Eastern Bering Sea and Aleutian Islands Area. North Pacific Fishery Management Council, Anchorage, AK. p. 185-302. http://www.afsc.noaa.gov/refm/docs/2004/BSAIpcod.pdf

Wilderbuer, T.K. and T.M. Sample. 1992. Stock assessment of Greenland turbot. *In* Stock assessment and fishery evaluation document for groundfish resources in the Bering Sea/Aleutian Islands region as projected for 1993. Section 4. North Pacific Fishery Management Council, Anchorage, AK.

Zenger, H.H. and M.F. Sigler. 1992. Relative abundance of Gulf of Alaska sablefish and other groundfish based on NMFS longline surveys, 1988-90. U.S. Dept. of Comm. NOAA Tech. Memo. NMFS F/NWC-216.

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	32	52,122	60,000	
1983	47,529	29	47,558	65,000	
1984	23,107	13	23,120	47,500	
1985	14,690	41	14,731	44,200	
1986	9,864	0	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	10,869	577	11,446	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*	792	2,075	2,866	3,600	3,500

* Catch estimates taken as the average of 2003 and 2004 catches

Table 5.2. Estimates of discarded and retained (t) Greenland turbot based on NMFS Blend estimates by directed fishery, 1992-2004. Note that after 2002 the Greenland turbot "target" fishery is lumped with flatfish.

	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	694	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	5,789	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	5,539	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	5,128	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	921
2002	1,979	73	144	207	210	139	175	18	301	217	124	49	2,934	703
2003			114	534	154	93	198	5	1,965	275	115	60	2,546	967
2004			78	23	219	79	72	3	1,400	195	99	50	1,868	351

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, 1975-2005. Note that the 2004 slope survey estimate was revised this year, as was the time series of shelf-survey estimates.

	Eastern Bering Sea				Aleutian Islands region only	Entire Aleutian survey	Percent in eastern area
Year	Shelf	Revised Shelf	Slope	Shelf and Slope Combined			
1975	126,700						
1979	225,600		123,000	348,600			
1980	172,200					48,700*	
1981	86,800		99,600	186,400			
1982	48,600	30,292	90,600	139,200			
1983	35,100	23,085				63,800*	
1984	17,900	16,725					
1985	7,700	7,711	79,200	86,900			
1986	5,600	5,316				76,500*	
1987	10,600	10,239					
1988	14,800	11,637	42,700	57,500			
1989	8,900	8,809					
1990	14,300	14,095					
1991	13,000	10,657	40,500	53,900	10,122	11,925	15%
1992	24,000	24,015					
1993	30,400	30,398					
1994	48,800	48,770			22,261	28,227	21%
1995	34,800	34,821					
1996	30,300	30,292					
1997	29,218	29,218			27,975	28,334	1%
1998	28,126	28,127					
1999	19,797	20,314					
2000	22,957	22,956			8,893	9,359	5%
2001	25,347	25,347					
2002	21,450	21,545	27,589	49,205	9,448	9,891	4%
2003	23,685	23,685					
2004	20,910	21,200	36,557	57,467	8,100	11,334	29%
2005		16,040					

* the Aleutian Islands estimates prior to 1990 were derived from surveys that were conducted using different protocols and are not comparable to more recent estimates.
The 1988 and 1991 slope estimates are from 200-800 m whereas earlier (and 2000) slope estimates are from 200-1,000m.

Table 5.4. Bottom-trawl shelf-survey biomass estimates for the standard strata (1-6) and strata 8 and 9 and the combined levels for Greenland turbot in the EBS.

Year	Strata 1-6	Strata 8-9	Combined	Percent in NW
1982	30,292			
1983	23,085			
1984	16,724			
1985	7,711	2,268	9,979	23%
1986	5,315			
1987	10,239	1,630	11,869	14%
1988	11,636	1,729	13,365	13%
1989	8,809	4,584	13,393	34%
1990	14,095	2,174	16,269	13%
1991	10,657	2,046	12,703	16%
1992	24,014	4,632	28,646	16%
1993	30,399	5,334	35,733	15%
1994	48,770	8,400	57,170	15%
1995	34,820	2,825	37,645	8%
1996	30,291	10,456	40,747	26%
1997	29,218	5,974	35,192	17%
1998	28,127	6,998	35,125	20%
1999	20,313	1,219	21,532	6%
2000	22,957	574	23,531	2%
2001	25,347	2,001	27,348	7%
2002	21,544	2,535	24,079	11%
2003	23,685	8,040	31,725	25%
2004	21,200	7,509	28,709	26%
2005	16,040	5,320	21,360	25%

Table 5.5. Data sets used in the stock synthesis 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	1975, 1979-82
Shelf survey: size composition and biomass estimates	1979-2005
Slope survey: size composition and biomass estimates	1979, 81, 82, 85, 88, 91, 2002, 2004
Longline survey: size composition and abundance index	1996-2005
Total fishery catch data	1960-2005
Trawl fishery size composition	1977-87, 1989-91, 1993-2005
Longline fishery size composition	1977, 1979-85, 1992-2005

Table 5.6. Total fishing mortality rate, spawning and total biomass (compared with the past assessment) for BSAI Greenland turbot, 1960-2005.

			Female Spawning Biomass		Total Age 1+ Biomass	
Year	F	Catch / Mid-yr Biom.	2003 Assessment	Current Assessment	2003 Assessment	Current Assessment
1960	0.070	0.064	279,657	271,162	465,702	450,078
1961	0.115	0.108	262,002	253,468	439,870	424,455
1962	0.129	0.121	234,364	225,775	400,281	385,427
1963	0.078	0.071	207,175	198,563	362,348	348,449
1964	0.088	0.080	194,437	185,884	346,700	334,072
1965	0.027	0.024	181,863	173,608	334,917	323,643
1966	0.035	0.029	182,484	174,887	346,371	336,427
1967	0.062	0.050	182,938	176,399	369,853	361,020
1968	0.085	0.067	179,185	173,889	402,066	394,016
1969	0.079	0.061	172,650	168,572	442,091	434,421
1970	0.051	0.040	173,976	171,071	491,579	483,964
1971	0.092	0.077	195,437	193,499	553,316	545,561
1972	0.154	0.138	222,090	220,539	587,296	579,284
1973	0.127	0.118	237,421	235,610	570,848	562,624
1974	0.159	0.154	256,966	254,613	551,883	543,465
1975	0.150	0.145	259,766	256,592	505,846	497,268
1976	0.154	0.147	252,042	248,079	464,594	455,667
1977	0.086	0.075	231,333	226,947	425,082	415,806
1978	0.137	0.107	222,827	218,382	421,322	411,469
1979	0.143	0.109	205,528	201,033	404,184	393,775
1980	0.190	0.147	191,483	186,806	389,936	378,708
1981	0.222	0.176	174,164	169,221	362,919	350,796
1982	0.188	0.179	156,389	151,026	327,346	314,364
1983	0.192	0.187	142,817	136,859	291,297	277,609
1984	0.107	0.101	131,186	124,408	254,403	240,202
1985	0.073	0.069	130,876	123,255	237,843	223,348
1986	0.052	0.048	131,533	123,259	227,334	212,581
1987	0.053	0.048	131,060	122,404	221,103	206,100
1988	0.043	0.036	126,867	118,112	215,547	200,163
1989	0.068	0.046	121,987	113,331	212,348	196,536
1990	0.102	0.070	115,568	107,006	206,863	190,639
1991	0.079	0.045	109,099	100,408	196,966	180,321
1992	0.062	0.022	108,619	99,506	191,170	174,120
1993	0.146	0.051	110,758	101,163	189,379	171,736
1994	0.129	0.066	106,993	97,091	182,327	164,123
1995	0.123	0.056	100,616	90,548	172,145	153,535
1996	0.122	0.048	95,898	85,526	162,903	144,083
1997	0.146	0.056	93,184	82,248	154,169	135,388
1998	0.191	0.077	89,296	77,851	144,346	125,754
1999	0.124	0.054	82,280	70,667	132,526	114,304
2000	0.159	0.070	76,712	65,244	123,752	106,085
2001	0.121	0.058	69,719	58,558	114,082	97,170
2002	0.096	0.042	64,383	53,566	106,543	90,630
2003	0.100	0.042	60,589	50,175	101,465	86,749
2004	0.066	0.027	56,942	46,996	98,264	84,590
2005	0.091	0.034		44,989		85,444

Table 5.7. 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+
1975	23.26	19.91	13.99	8.98	5.98	9.51	13.44	10.00	7.57	5.80	4.48	1.03	0.80	0.63	0.50	0.41	0.28	0.21	0.16	0.13	0.61
1976	30.78	19.38	16.48	11.31	6.96	4.45	6.89	9.61	7.11	5.37	4.12	3.18	0.73	0.57	0.45	0.36	0.29	0.20	0.15	0.12	0.53
1977	16.06	25.65	16.04	13.32	8.75	5.17	3.21	4.91	6.81	5.03	3.80	2.91	2.25	0.52	0.40	0.32	0.25	0.21	0.14	0.11	0.45
1978	32.17	13.40	21.32	13.17	10.69	6.88	4.01	2.48	3.77	5.23	3.86	2.91	2.23	1.72	0.40	0.31	0.24	0.19	0.16	0.11	0.43
1979	15.19	26.82	11.11	17.39	10.41	8.21	5.18	2.99	1.84	2.79	3.86	2.84	2.14	1.63	1.25	0.29	0.22	0.18	0.14	0.11	0.39
1980	12.33	12.67	22.25	9.06	13.74	7.98	6.18	3.86	2.21	1.36	2.05	2.83	2.07	1.55	1.18	0.91	0.21	0.16	0.13	0.10	0.36
1981	8.46	10.28	10.48	18.00	7.03	10.23	5.80	4.42	2.74	1.57	0.95	1.44	1.97	1.44	1.07	0.81	0.62	0.14	0.11	0.09	0.31
1982	5.14	7.05	8.49	8.43	13.78	5.13	7.23	4.03	3.04	1.88	1.07	0.65	0.97	1.32	0.96	0.71	0.54	0.41	0.09	0.07	0.26
1983	3.96	4.28	5.82	6.81	6.41	9.93	3.57	4.96	2.74	2.07	1.27	0.72	0.44	0.66	0.89	0.65	0.48	0.37	0.28	0.06	0.23
1984	7.14	3.30	3.54	4.67	5.17	4.61	6.90	2.44	3.36	1.85	1.40	0.86	0.49	0.30	0.44	0.60	0.44	0.33	0.25	0.19	0.20
1985	10.94	5.95	2.74	2.89	3.70	3.98	3.49	5.18	1.82	2.51	1.38	1.04	0.64	0.36	0.22	0.33	0.45	0.33	0.24	0.18	0.29
1986	10.66	9.13	4.95	2.25	2.33	2.93	3.11	2.71	4.01	1.41	1.94	1.07	0.81	0.50	0.28	0.17	0.26	0.35	0.25	0.19	0.36
1987	6.79	8.90	7.60	4.09	1.83	1.87	2.33	2.47	2.15	3.18	1.12	1.54	0.85	0.64	0.39	0.22	0.14	0.20	0.28	0.20	0.44
1988	4.37	5.67	7.41	6.28	3.33	1.47	1.49	1.85	1.96	1.70	2.52	0.89	1.22	0.67	0.51	0.31	0.18	0.11	0.16	0.22	0.50
1989	3.94	3.65	4.73	6.14	5.15	2.70	1.19	1.20	1.49	1.57	1.36	2.02	0.71	0.98	0.54	0.40	0.25	0.14	0.09	0.13	0.58
1990	5.53	3.29	3.05	3.95	5.13	4.29	2.23	0.96	0.95	1.17	1.23	1.07	1.58	0.56	0.76	0.42	0.32	0.19	0.11	0.07	0.55
1991	7.46	4.62	2.75	2.55	3.30	4.27	3.52	1.77	0.74	0.73	0.89	0.93	0.81	1.19	0.42	0.57	0.32	0.24	0.15	0.08	0.46
1992	3.23	6.23	3.86	2.29	2.13	2.75	3.53	2.86	1.42	0.59	0.57	0.70	0.73	0.63	0.93	0.33	0.45	0.25	0.18	0.11	0.42
1993	2.46	2.70	5.20	3.22	1.92	1.78	2.29	2.93	2.37	1.17	0.48	0.47	0.56	0.59	0.51	0.74	0.26	0.35	0.19	0.15	0.42
1994	2.19	2.05	2.25	4.34	2.69	1.60	1.48	1.90	2.41	1.92	0.94	0.38	0.36	0.43	0.45	0.38	0.55	0.19	0.26	0.14	0.41
1995	2.12	1.83	1.72	1.88	3.63	2.25	1.32	1.20	1.51	1.89	1.49	0.72	0.29	0.28	0.33	0.33	0.28	0.41	0.14	0.19	0.41
1996	3.09	1.77	1.53	1.43	1.57	3.03	1.86	1.08	0.97	1.20	1.49	1.17	0.56	0.22	0.21	0.25	0.25	0.21	0.31	0.11	0.45
1997	2.59	2.58	1.48	1.28	1.20	1.31	2.52	1.54	0.88	0.78	0.96	1.18	0.92	0.43	0.17	0.16	0.19	0.19	0.16	0.23	0.41
1998	2.35	2.16	2.16	1.24	1.07	1.00	1.09	2.08	1.26	0.72	0.63	0.76	0.92	0.70	0.33	0.13	0.12	0.14	0.14	0.12	0.47
1999	2.13	1.96	1.81	1.80	1.03	0.89	0.83	0.90	1.69	1.01	0.56	0.48	0.58	0.68	0.51	0.24	0.09	0.08	0.10	0.10	0.41
2000	2.73	1.78	1.64	1.51	1.50	0.86	0.74	0.68	0.73	1.36	0.80	0.44	0.38	0.44	0.52	0.39	0.18	0.07	0.06	0.07	0.37
2001	3.97	2.28	1.49	1.37	1.26	1.26	0.72	0.61	0.55	0.59	1.08	0.63	0.34	0.29	0.33	0.39	0.29	0.13	0.05	0.05	0.32
2002	6.55	3.32	1.91	1.24	1.14	1.05	1.04	0.59	0.49	0.44	0.47	0.85	0.49	0.26	0.22	0.25	0.29	0.22	0.10	0.04	0.27
2003	5.49	5.47	2.77	1.59	1.04	0.96	0.88	0.86	0.48	0.40	0.36	0.37	0.67	0.38	0.21	0.17	0.20	0.23	0.17	0.08	0.24
2004	3.57	4.59	4.57	2.31	1.33	0.87	0.80	0.72	0.71	0.39	0.32	0.29	0.30	0.53	0.30	0.16	0.13	0.15	0.17	0.13	0.24
2005	6.45	2.98	3.83	3.82	1.93	1.11	0.72	0.66	0.60	0.58	0.32	0.26	0.23	0.24	0.42	0.24	0.13	0.10	0.12	0.14	0.29

Males

Yr	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+
1975	23.26	19.91	13.98	8.99	6.03	9.69	13.86	10.40	7.88	6.03	4.66	1.08	0.84	0.67	0.55	0.46	0.32	0.25	0.20	0.16	0.84
1976	30.78	19.38	16.48	11.32	7.02	4.54	7.12	10.03	7.46	5.63	4.31	3.34	0.78	0.61	0.49	0.40	0.33	0.24	0.18	0.15	0.74
1977	16.06	25.65	16.04	13.33	8.82	5.27	3.32	5.13	7.17	5.31	4.01	3.08	2.40	0.56	0.44	0.36	0.29	0.25	0.17	0.14	0.66
1978	32.17	13.40	21.32	13.17	10.74	6.97	4.11	2.57	3.96	5.52	4.08	3.09	2.38	1.86	0.44	0.34	0.28	0.23	0.19	0.14	0.63
1979	15.19	26.82	11.11	17.40	10.47	8.31	5.30	3.10	1.92	2.95	4.11	3.05	2.31	1.78	1.40	0.33	0.26	0.21	0.17	0.15	0.58
1980	12.33	12.67	22.25	9.07	13.81	8.10	6.31	3.98	2.31	1.43	2.19	3.06	2.27	1.73	1.34	1.05	0.25	0.20	0.16	0.13	0.56
1981	8.46	10.28	10.48	18.02	7.08	10.41	5.95	4.57	2.86	1.65	1.02	1.57	2.19	1.64	1.25	0.97	0.77	0.18	0.15	0.12	0.51
1982	5.14	7.05	8.49	8.44	13.90	5.24	7.47	4.20	3.19	1.98	1.14	0.71	1.09	1.54	1.16	0.89	0.69	0.55	0.13	0.10	0.45
1983	3.96	4.28	5.82	6.82	6.47	10.17	3.71	5.20	2.89	2.18	1.36	0.79	0.49	0.76	1.08	0.81	0.63	0.49	0.39	0.09	0.40
1984	7.14	3.30	3.54	4.67	5.22	4.72	7.19	2.57	3.56	1.97	1.49	0.93	0.54	0.34	0.53	0.76	0.58	0.45	0.35	0.28	0.36
1985	10.94	5.95	2.74	2.89	3.72	4.05	3.61	5.43	1.93	2.67	1.47	1.12	0.70	0.41	0.26	0.40	0.58	0.44	0.34	0.27	0.49
1986	10.66	9.13	4.95	2.25	2.34	2.96	3.19	2.82	4.23	1.50	2.07	1.15	0.87	0.55	0.32	0.20	0.32	0.46	0.35	0.27	0.60
1987	6.79	8.90	7.60	4.09	1.84	1.89	2.37	2.54	2.24	3.36	1.19	1.65	0.91	0.69	0.44	0.26	0.16	0.26	0.37	0.28	0.70
1988	4.37	5.67	7.41	6.28	3.34	1.48	1.51	1.89	2.02	1.78	2.66	0.95	1.31	0.73	0.55	0.35	0.21	0.13	0.20	0.29	0.79
1989	3.94	3.65	4.73	6.14	5.16	2.72	1.20	1.22	1.52	1.62	1.43	2.14	0.76	1.06	0.59	0.45	0.28	0.17	0.11	0.17	0.88
1990	5.53	3.29	3.05	3.95	5.13	4.30	2.26	0.99	0.99	1.22	1.29	1.14	1.70	0.60	0.84	0.47	0.36	0.22	0.13	0.08	0.83
1991	7.46	4.62	2.75	2.55	3.30	4.28	3.57	1.85	0.79	0.78	0.95	1.00	0.88	1.31	0.47	0.65	0.36	0.28	0.17	0.10	0.71
1992	3.23	6.23	3.86	2.29	2.13	2.75	3.56	2.95	1.51	0.64	0.63	0.76	0.80	0.70	1.05	0.37	0.52	0.29	0.22	0.14	0.65
1993	2.46	2.70	5.20	3.22	1.92	1.78	2.30	2.97	2.45	1.26	0.53	0.52	0.63	0.66	0.58	0.86	0.31	0.43	0.24	0.18	0.65
1994	2.19	2.05	2.25	4.34	2.69	1.60	1.48	1.91	2.46	2.03	1.03	0.44	0.42	0.51	0.54	0.47	0.70	0.25	0.34	0.19	0.67
1995	2.12	1.83	1.72	1.88	3.63	2.25	1.33	1.22	1.56	1.98	1.62	0.82	0.35	0.34	0.40	0.42	0.37	0.55	0.20	0.27	0.68
1996	3.09	1.77	1.53	1.43	1.57	3.03	1.87	1.10	1.00	1.27	1.61	1.31	0.66	0.28	0.27	0.32	0.34	0.29	0.44	0.16	0.75
1997	2.59	2.58	1.48	1.28	1.20	1.31	2.53	1.56	0.91	0.83	1.04	1.31	1.06	0.54	0.23	0.22	0.26	0.27	0.24	0.35	0.73
1998	2.35	2.16	2.16	1.24	1.07	1.00	1.10	2.10	1.29	0.75	0.68	0.85	1.07	0.87	0.44	0.18	0.18	0.21	0.22	0.19	0.87
1999	2.13	1.96	1.81	1.80	1.03	0.89	0.83	0.91	1.73	1.06	0.61	0.55	0.69	0.86	0.69	0.35	0.15	0.14	0.17	0.17	0.84
2000	2.73	1.78	1.64	1.51	1.50	0.86	0.74	0.69	0.75	1.43	0.87	0.50	0.45	0.56	0.70	0.56	0.28	0.12	0.11	0.13	0.81
2001	3.97	2.28	1.49	1.37	1.26	1.26	0.72	0.62	0.57	0.62	1.16	0.70	0.40	0.36	0.45	0.56	0.45	0.22	0.09	0.09	0.75
2002	6.55	3.32	1.91	1.24	1.14	1.05	1.05	0.60	0.51	0.47	0.50	0.94	0.57	0.33	0.29	0.36	0.45	0.36	0.18	0.07	0.67
2003	5.49	5.47	2.77	1.59	1.04	0.96	0.88	0.87	0.49	0.42	0.38	0.41	0.77	0.46	0.27	0.24	0.29	0.36	0.29	0.15	0.60
2004	3.57	4.59	4.57	2.31	1.33	0.87	0.80	0.73	0.72	0.41	0.34	0.31	0.34	0.63	0.38	0.22	0.19	0.24	0.30	0.24	0.61
2005	6.45	2.98	3.83	3.82	1.93	1.11	0.72	0.66	0.61	0.60	0.34	0.28	0.26	0.28	0.51	0.31	0.18	0.16	0.19	0.24	0.69

Table 5.8. Age-equivalent sex-specific selectivity estimates (for 2005) from each gear type for Greenland turbot in the BSAI. Note that selectivity processes are modeled as a function of size.

	Trawl Fishery		Longline fishery		Shelf Survey		Slope survey		Longline survey	
Age	F	M	F	M	F	M	F	M	F	M
1	0	0	0	0	0.05	0.05	0	0	0	0
2	0	0	0	0	0.77	0.6	0	0	0	0
3	0	0	0	0	0.54	0.35	0.01	0.01	0	0
4	0	0	0	0	0.43	0.27	0.03	0.02	0	0
5	0.03	0.01	0	0	0.38	0.23	0.05	0.04	0	0
6	0.18	0.06	0.01	0	0.35	0.21	0.09	0.07	0.02	0.01
7	0.52	0.2	0.03	0.01	0.34	0.2	0.14	0.09	0.06	0.02
8	0.81	0.41	0.07	0.02	0.33	0.19	0.19	0.12	0.14	0.05
9	0.94	0.61	0.15	0.03	0.33	0.18	0.25	0.15	0.24	0.08
10	0.98	0.75	0.24	0.05	0.33	0.18	0.32	0.18	0.36	0.11
11	0.99	0.83	0.35	0.08	0.33	0.18	0.38	0.2	0.47	0.15
12	0.99	0.87	0.45	0.1	0.33	0.18	0.44	0.22	0.57	0.19
13	0.99	0.89	0.55	0.13	0.33	0.18	0.5	0.24	0.65	0.22
14	0.99	0.89	0.63	0.15	0.33	0.17	0.55	0.26	0.72	0.25
15	0.99	0.88	0.69	0.17	0.33	0.17	0.59	0.27	0.77	0.28
16	0.99	0.86	0.74	0.19	0.33	0.17	0.63	0.29	0.81	0.3
17	0.99	0.85	0.78	0.21	0.32	0.17	0.67	0.3	0.84	0.32
18	0.99	0.84	0.82	0.22	0.32	0.17	0.7	0.31	0.86	0.34
19	0.99	0.83	0.84	0.23	0.32	0.17	0.72	0.31	0.88	0.35
20	0.99	0.82	0.86	0.24	0.32	0.17	0.74	0.32	0.9	0.36
21	0.99	0.79	0.9	0.27	0.32	0.17	0.8	0.34	0.93	0.39

Table 5.9. Age-equivalent sex-specific weights-at-age estimates by each fishery and proportion mature female weight-at-age at time of spawning for Greenland turbot in the BSAI. Units are kg.

	Trawl fishery		Longline fishery		
Age	Females	Males	Females	Males	Wt · Maturity
1	0.1	0	0.1	0	0.0
2	0.2	0.2	0.3	0.2	0.0
3	0.7	0.4	0.8	0.4	0.0
4	1.6	0.8	1.6	0.8	0.0
5	2.9	1.3	2.7	1.2	0.0
6	4.1	1.8	4.0	1.7	0.5
7	5.1	2.2	5.5	2.1	1.8
8	6.0	2.5	6.9	2.5	3.8
9	7.1	2.7	8.3	2.9	5.7
10	8.3	2.9	9.6	3.2	7.4
11	9.5	3.1	10.9	3.5	8.8
12	10.7	3.2	12.0	3.7	10.1
13	11.9	3.4	13.1	3.9	11.4
14	13.0	3.5	14.1	4.1	12.5
15	14.0	3.6	15.1	4.2	13.6
16	14.9	3.7	15.8	4.4	14.6
17	15.7	3.7	16.5	4.5	15.4
18	16.4	3.8	17.1	4.5	16.1
19	17.0	3.9	17.6	4.6	16.7
20	17.5	3.9	18.0	4.7	17.3
21	18.7	4.0	19.2	4.8	18.8

Table 5.10. Estimated total Greenland turbot harvest by area, 1977-2004.

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

Table 5.11. Mean spawning biomass, F, and yield projections for Greenland turbot, 2005-2018. The full-selection fishing mortality rates (*F's*) between longline and trawl gears were assumed **equal**. The values for $B_{40\%}$ and $B_{35\%}$ are 47,400 and 41,400 tons, respectively.

Catch	*Max F_{ABC}*	*Author's F_{ABC}*	*Half max F_{ABC}*	*5-year avg.*	*No Fishing*	*Scenario 6*	*Scenario 7*
2005	2,900	2,900	2,900	2,900	2,900	2,900	2,900
2006	11,394	2,900	6,059	2,735	0	14,193	11,394
2007	7,686	8,311	5,047	2,625	0	8,542	7,686
2008	6,512	6,788	4,714	2,583	0	6,997	8,201
2009	6,278	6,277	4,732	2,600	0	6,712	7,345
2010	6,431	6,207	4,923	2,663	0	6,896	7,241
2011	6,900	6,481	5,294	2,783	0	7,436	7,618
2012	7,629	6,995	5,701	2,944	0	8,272	8,357
2013	8,363	7,492	6,042	3,138	0	9,141	9,172
2014	8,990	7,958	6,403	3,354	0	9,867	9,874
2015	9,502	8,393	6,764	3,576	0	10,418	10,415
2016	9,897	8,770	7,100	3,792	0	10,803	10,799
2017	10,201	9,085	7,397	3,993	0	11,064	11,060
2018	10,421	9,335	7,654	4,177	0	11,228	11,226
Fishing M.	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2005	0.095	0.095	0.095	0.095	0.095	0.095	0.095
2006	0.435	0.101	0.218	0.095	0.000	0.561	0.435
2007	0.359	0.321	0.201	0.095	0.000	0.434	0.359
2008	0.340	0.297	0.199	0.095	0.000	0.404	0.438
2009	0.345	0.293	0.205	0.095	0.000	0.410	0.428
2010	0.357	0.298	0.214	0.095	0.000	0.426	0.435
2011	0.375	0.309	0.225	0.095	0.000	0.448	0.452
2012	0.397	0.323	0.232	0.095	0.000	0.477	0.478
2013	0.415	0.332	0.234	0.095	0.000	0.501	0.501
2014	0.425	0.336	0.235	0.095	0.000	0.517	0.517
2015	0.431	0.339	0.235	0.095	0.000	0.526	0.526
2016	0.435	0.341	0.235	0.095	0.000	0.532	0.531
2017	0.438	0.342	0.235	0.095	0.000	0.535	0.535
2018	0.440	0.343	0.235	0.095	0.000	0.537	0.537
Female sp. biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2005	45,547	45,547	45,547	45,547	45,547	45,547	45,547
2006	43,470	43,470	43,470	43,470	43,470	43,470	43,470
2007	36,237	42,774	40,320	42,902	45,047	34,128	36,237
2008	34,436	39,713	40,027	44,188	48,159	31,959	34,436
2009	34,908	39,313	41,181	46,507	52,068	32,382	33,691
2010	36,101	39,946	42,808	49,180	56,188	33,557	34,230
2011	37,783	41,311	44,867	52,283	60,644	35,184	35,499
2012	40,054	43,451	47,536	56,047	65,665	37,352	37,471
2013	42,473	45,936	50,567	60,257	71,119	39,589	39,613
2014	44,686	48,416	53,670	64,567	76,702	41,518	41,507
2015	46,382	50,501	56,413	68,528	81,978	42,867	42,847
2016	47,508	52,060	58,635	71,974	86,790	43,637	43,620
2017	48,231	53,200	60,408	74,942	91,141	44,039	44,027
2018	48,703	54,037	61,821	77,480	95,051	44,258	44,251

Table 5.12. Summary management values based on this assessment. Note that the fishing mortality rates assume 50% contribution from longline gear and 50% from trawl.

Management Parameter	Value
M	0.18 yr-1
Amendment 56 Tier (in 2005)	3b
Approximate age at full recruitment	10 years
$F_{35\%}$ (F_{OFL})	0.61
$F_{40\%}$	0.48
$B_{100\%}$	118,400 t
$B_{40\%}$	47,400 t
$B_{35\%}$	41,400 t
Year 2006 female spawning biomass	43,470 t
Year 2006 total (age 1+) biomass	74,200 t
$F_{ABC} = F_{40\%}$ (max permissible)	0.435
Maximum permissible ABC	11,400
F_{ABC} = *3-year fixed catch*	0.11
Recommended ABC	**3,000 t**
$F_{overfishing} = F_{35\%}$	0.61
Overfishing level	**14,200 t**

Figures

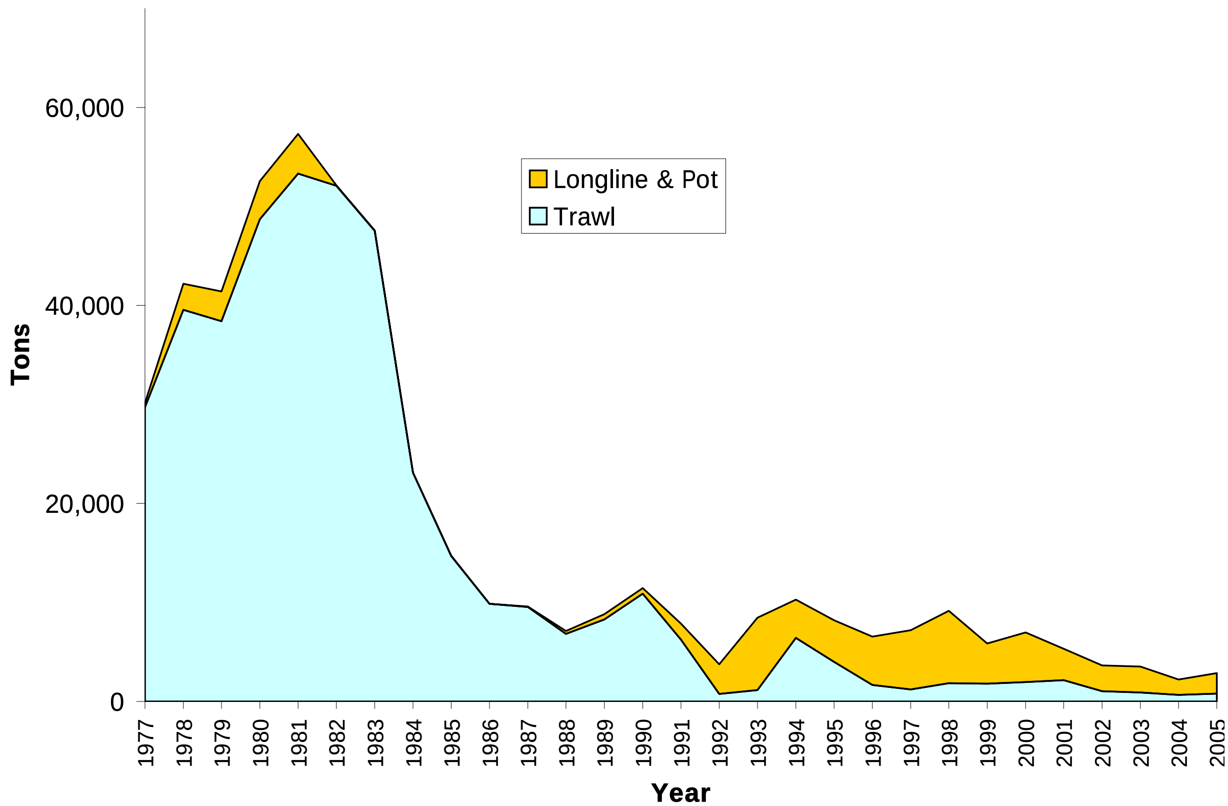


Figure 5.1. Trawl and longline catches of Greenland turbot in the combined EBS/AI area, 1977-2004. Note: catches for 2005 assumed to be the average of 2003 and 2004.

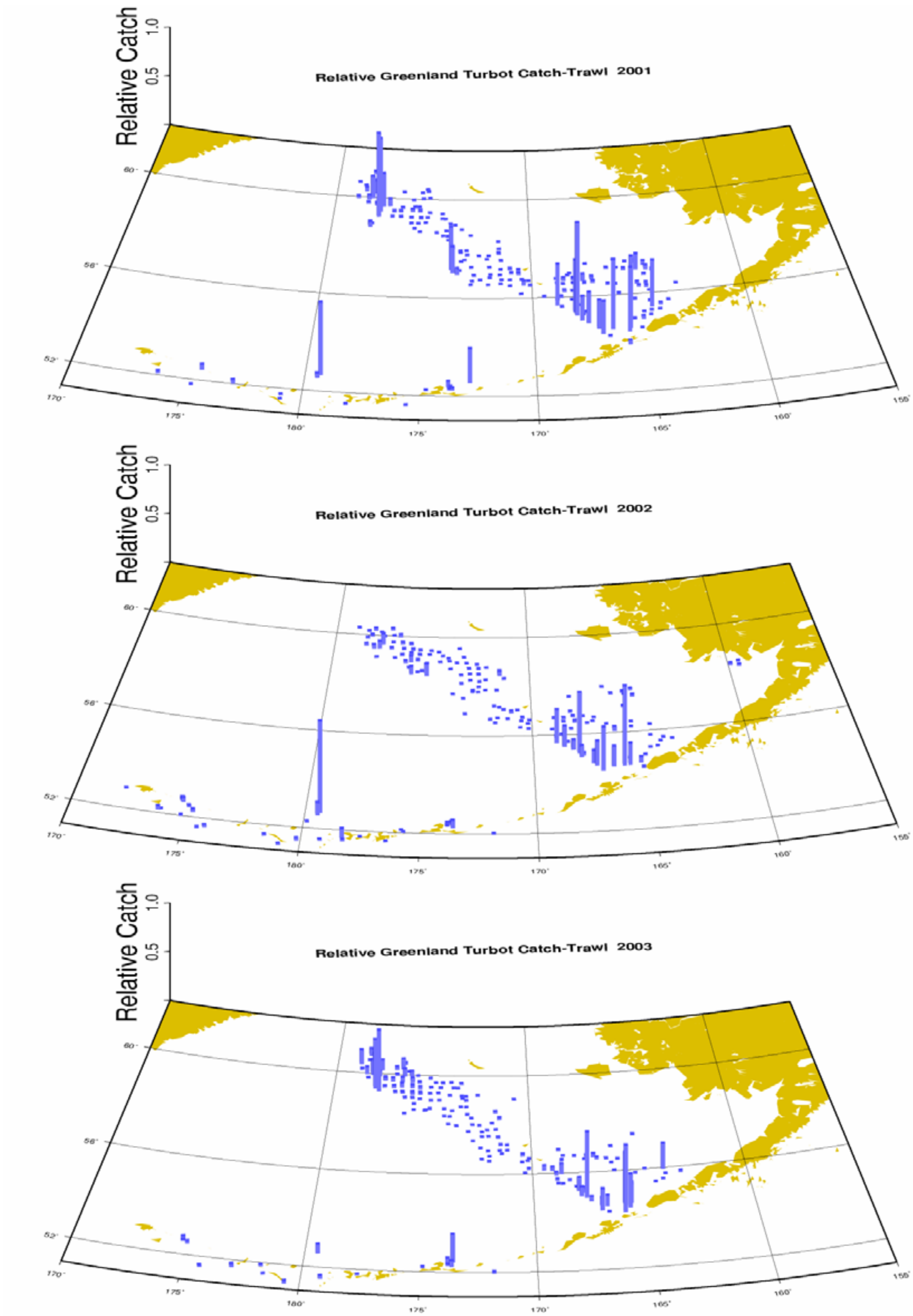


Figure 5.2. Distribution of Greenland turbot catch by trawl vessels based on aggregated NMFS observer data, 2001-2003. Vertical lines represent the relative magnitude of Greenland turbot catch for each 30’ longitude by 15’ latitude grids.

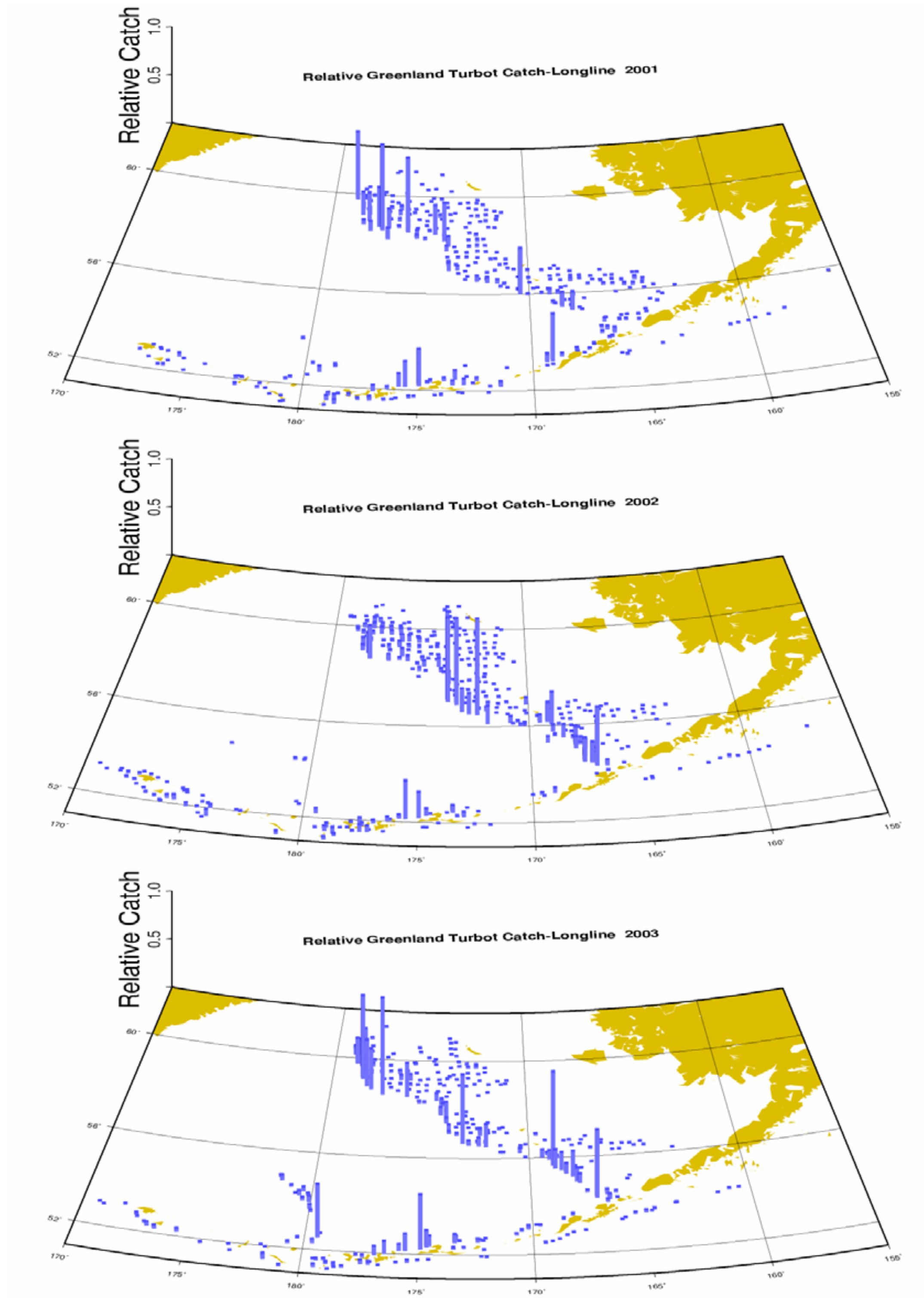


Figure 5.3. Distribution of Greenland turbot catch by longline vessels based on aggregated NMFS observer data, 2001-2003. Vertical lines represent the relative magnitude of Greenland turbot catch for each 30’ longitude by 15’ latitude grids.

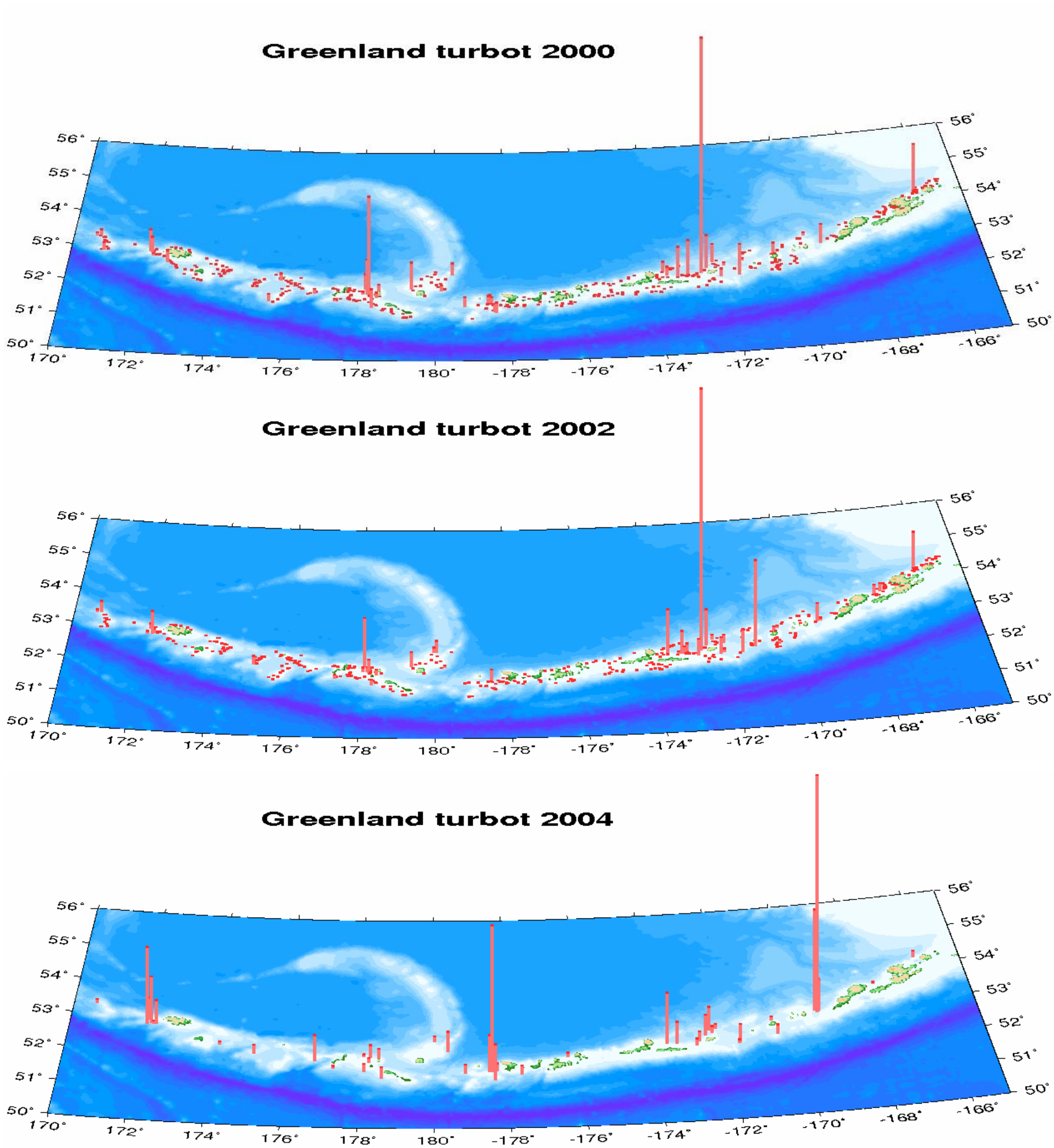


Figure 5.4. Greenland turbot catch per unit effort from the Aleutian Islands region bottom trawl survey, 2000-2004.

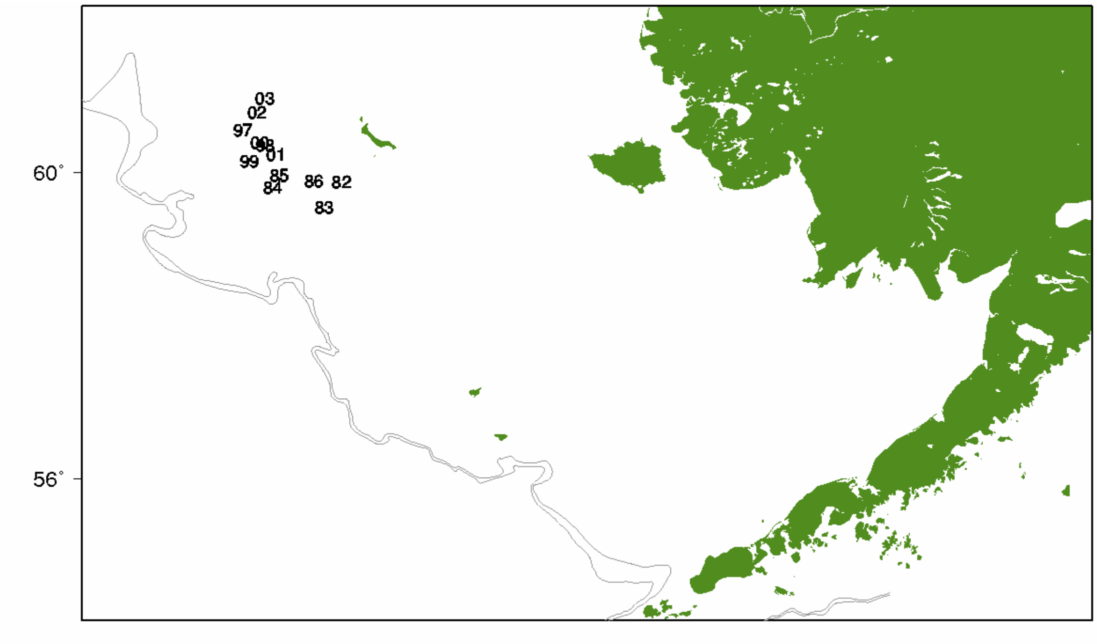


Figure 5.5. Centers of Greenland turbot summer-time EBS shelf distributions as estimated from NMFS bottom trawl survey data, 1982-1986 and 1997-2003 (other years omitted for presentation clarity). Figure courtesy P. Spencer, NMFS/AFSC.

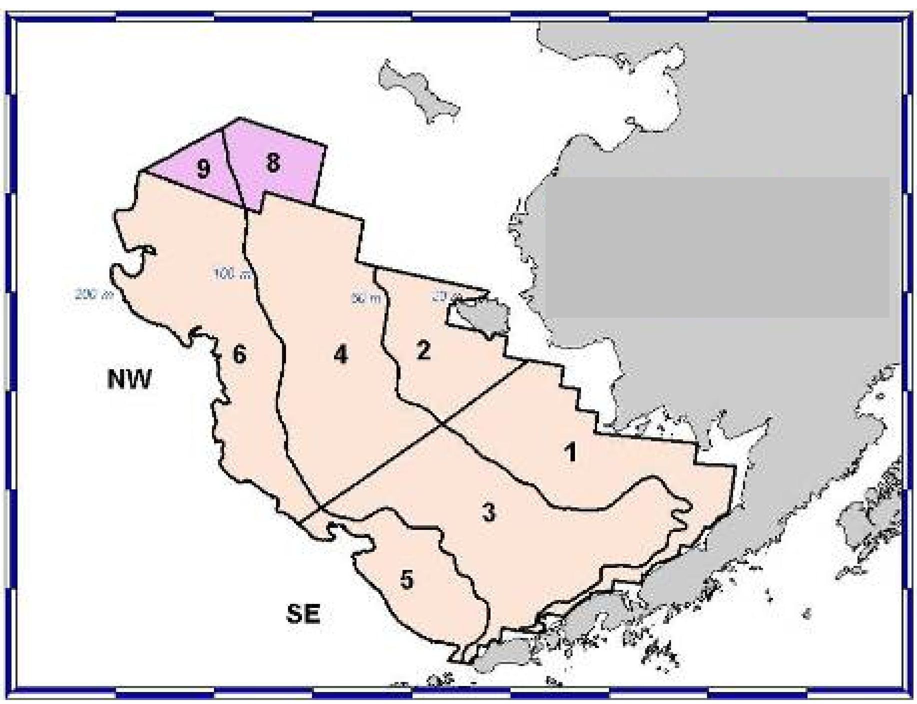


Figure 5.6. Map showing the standard NMFS bottom-trawl survey strata (1-6) and the additional strata (8 and 9). The standard survey area (done each year since 1982) measures 463,374 km^2 and includes about 356 stations. Including the expanded area (done each year since 1987) the number of stations typically totals 376.

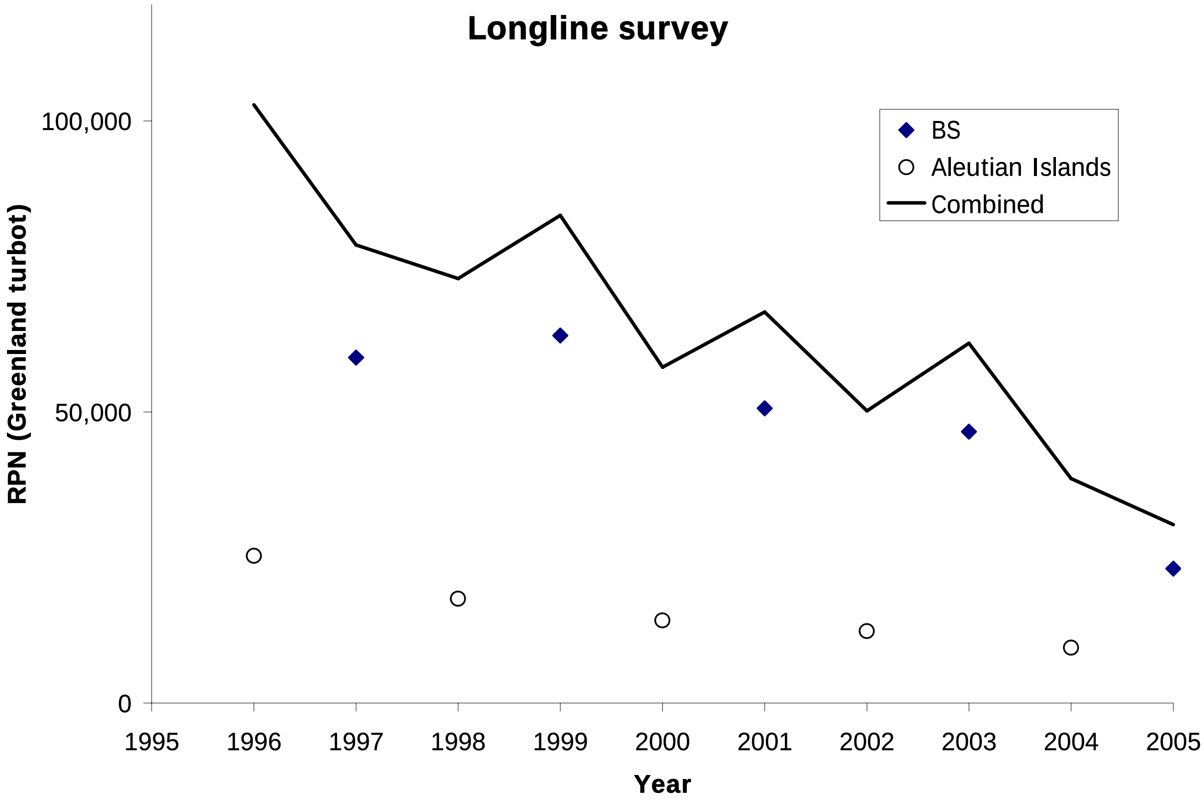


Figure 5.7. Greenland turbot longline survey abundance trends (RPN=relative population number) for the two regions and the combined values used in the assessment model.

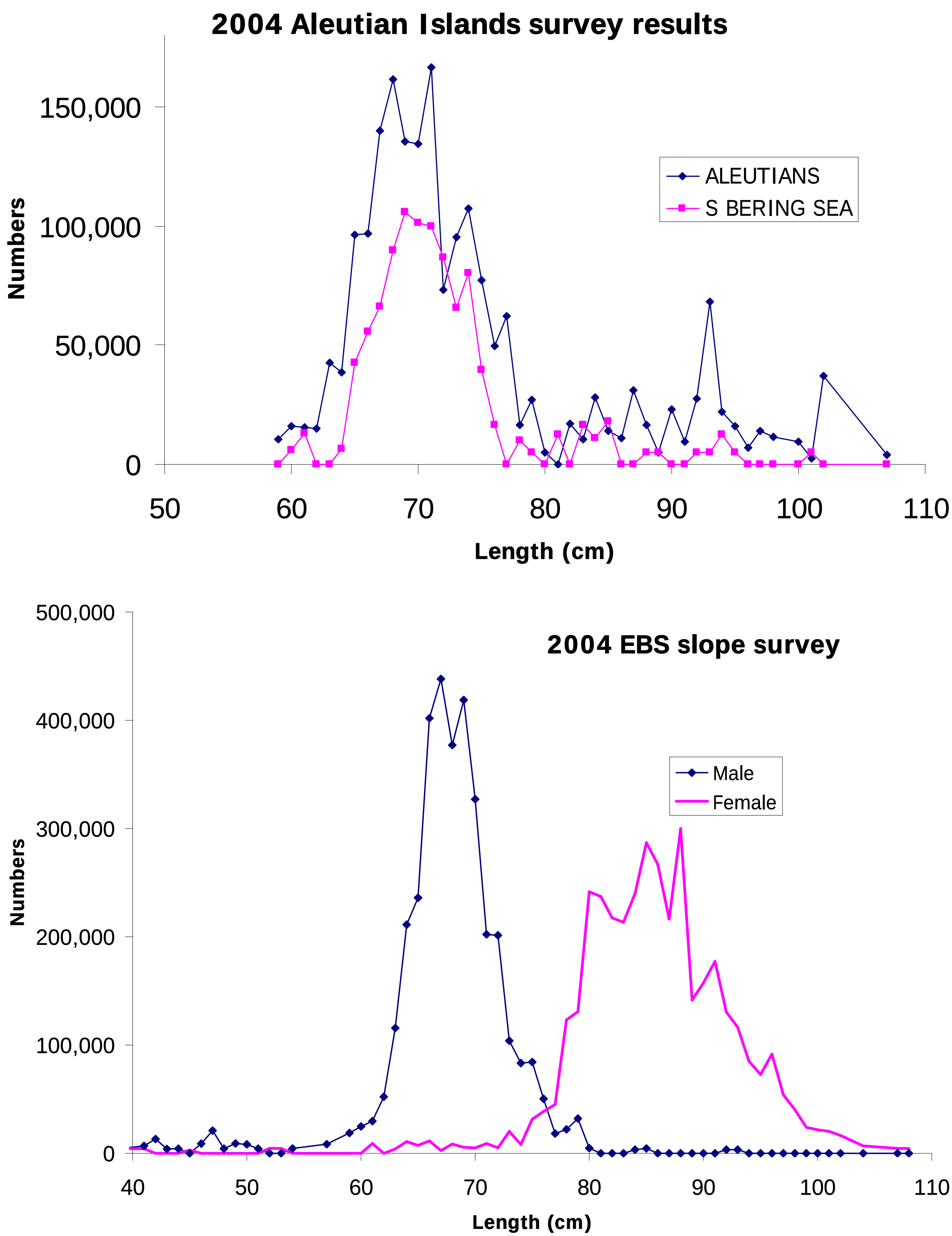


Figure 5.8. Relative length (cm) frequency of Greenland turbot observed from the summer 2004 NMFS bottom trawl Aleutian Islands (top) and EBS slope surveys (bottom).

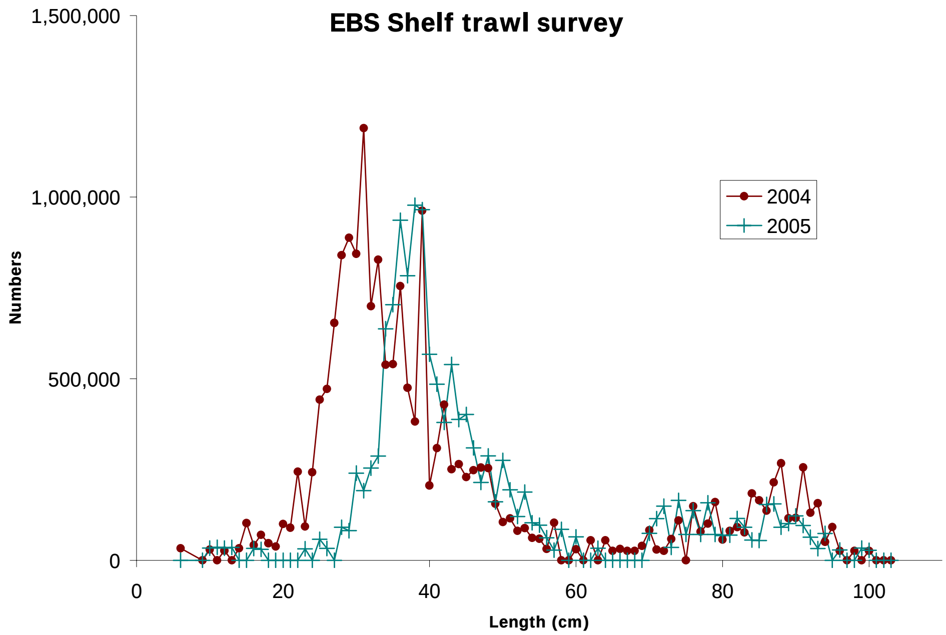


Figure 5.9. Length frequency of Greenland turbot observed from the summer NMFS EBS shelf bottom trawl survey for 2004 and 2005 (both sexes combined, all strata (1-9).

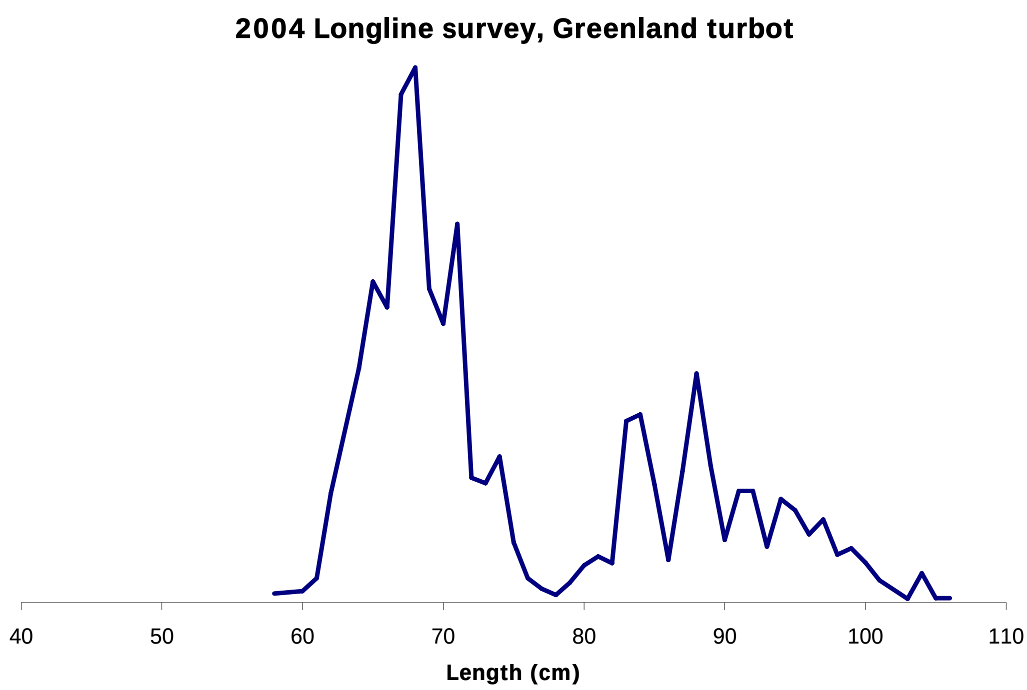


Figure 5.10. Length frequency of Greenland turbot observed from the summer 2004 NMFS longline survey (covering the eastern portion of the Aleutian Islands).

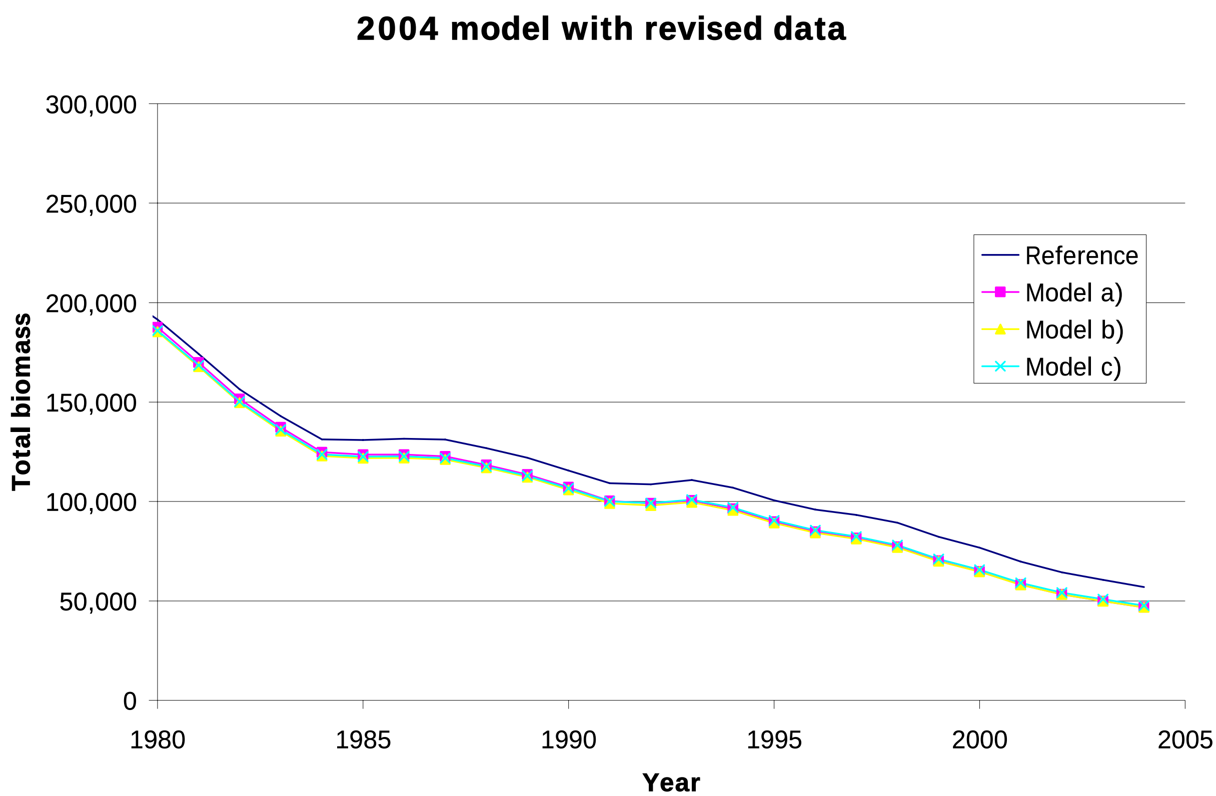


Figure 5.11. Greenland turbot model results based on the 2004 configuration with revised data: Reference-unchanged, a) revised slope survey estimate; b) revised slope and standard-area (strata 1-6) shelf survey bottom trawl data; and c) revised slope and shelf survey data including the northwest regions (strata 1-9).

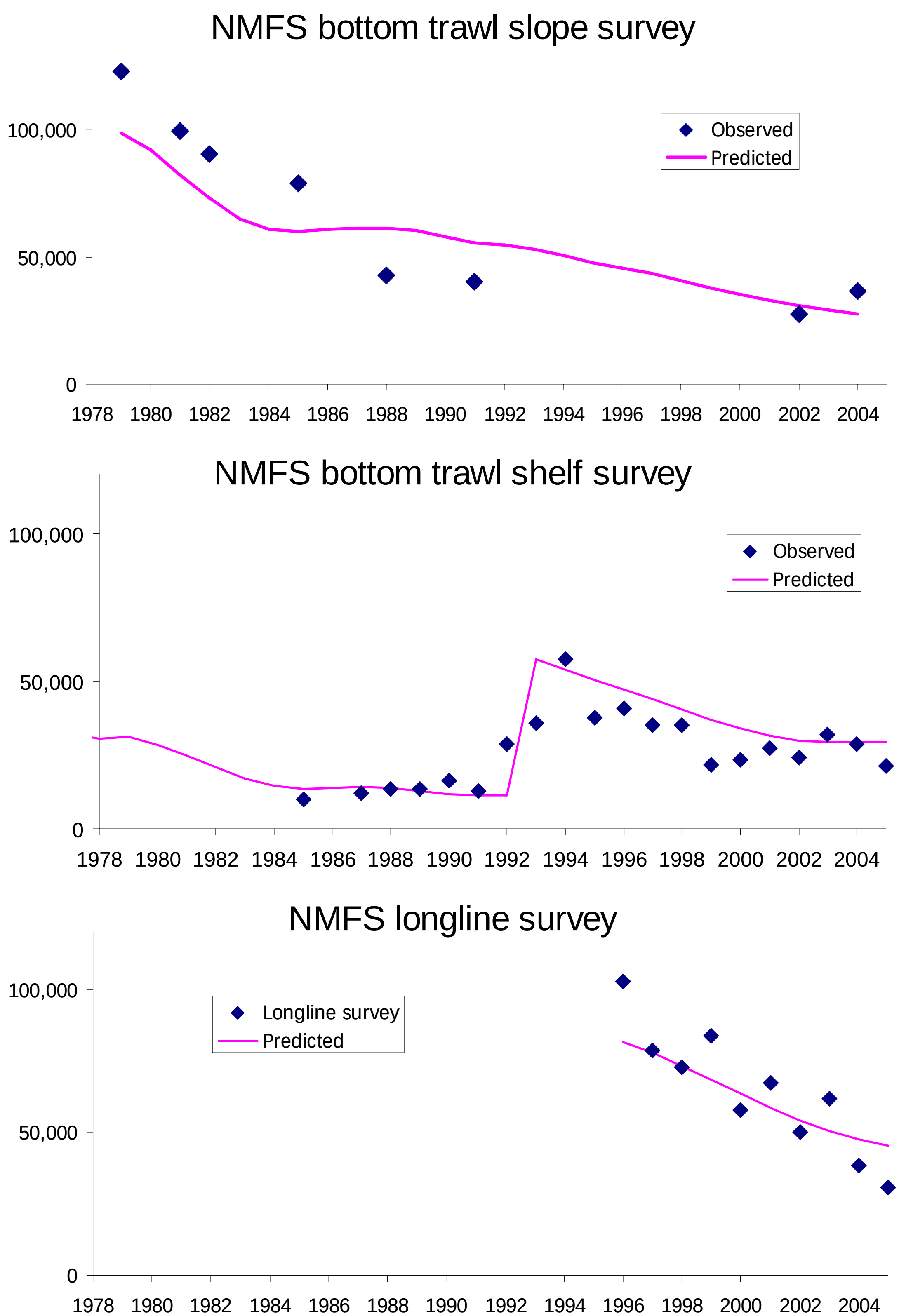


Figure 5.12. Fits to the different survey and fishery indices for Greenland turbot in the EBS/AI region.

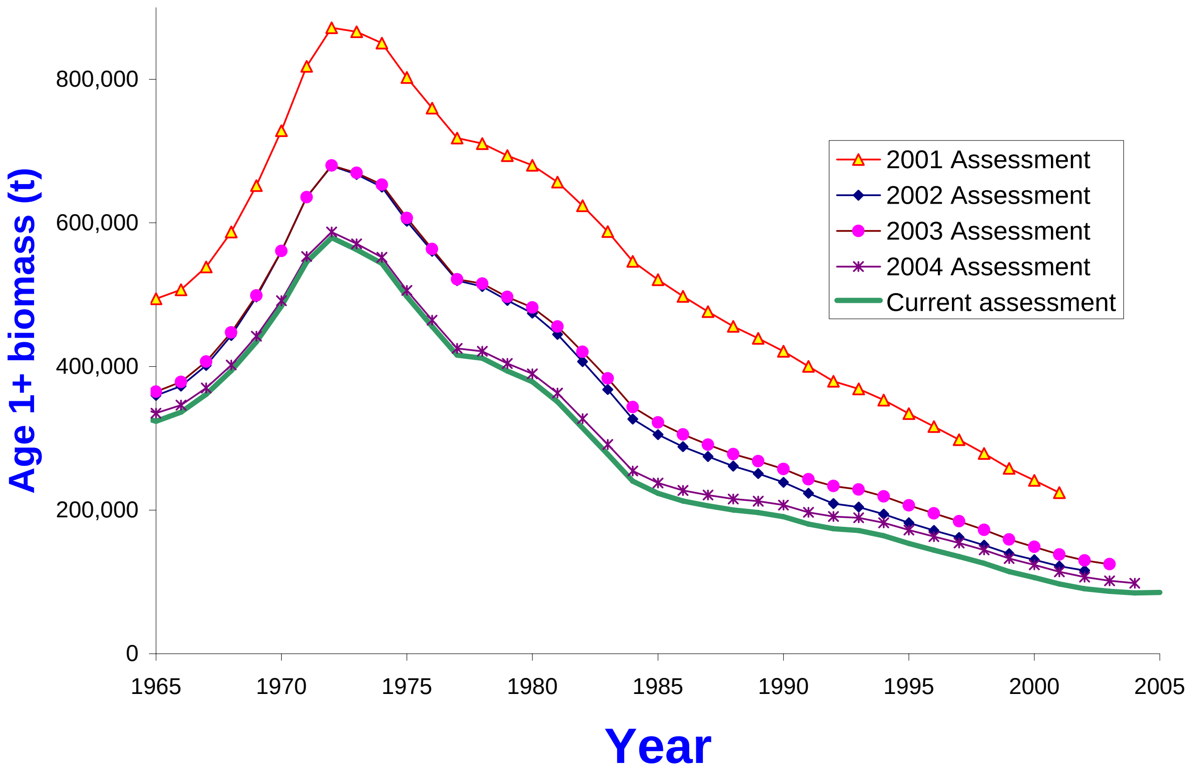


Figure 5.13 Total age 1+ biomass trend for Greenland turbot in the EBS/AI region, 1965-2005 compared to previous assessments.

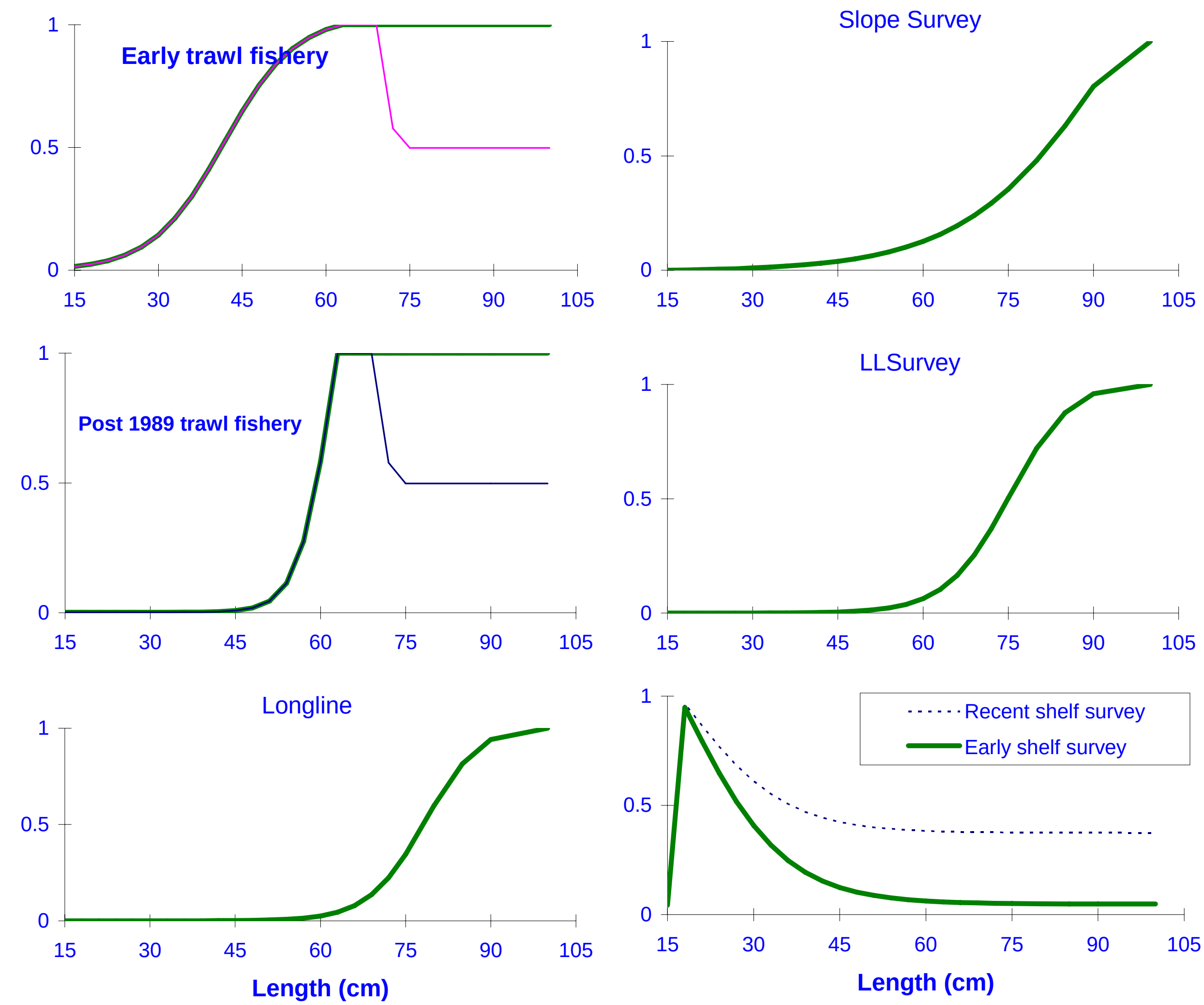


Figure 5.14. Size-specific selectivity patterns for surveys and fisheries of Greenland turbot in the EBS/AI region. Thin lines represent differential selectivity of males.

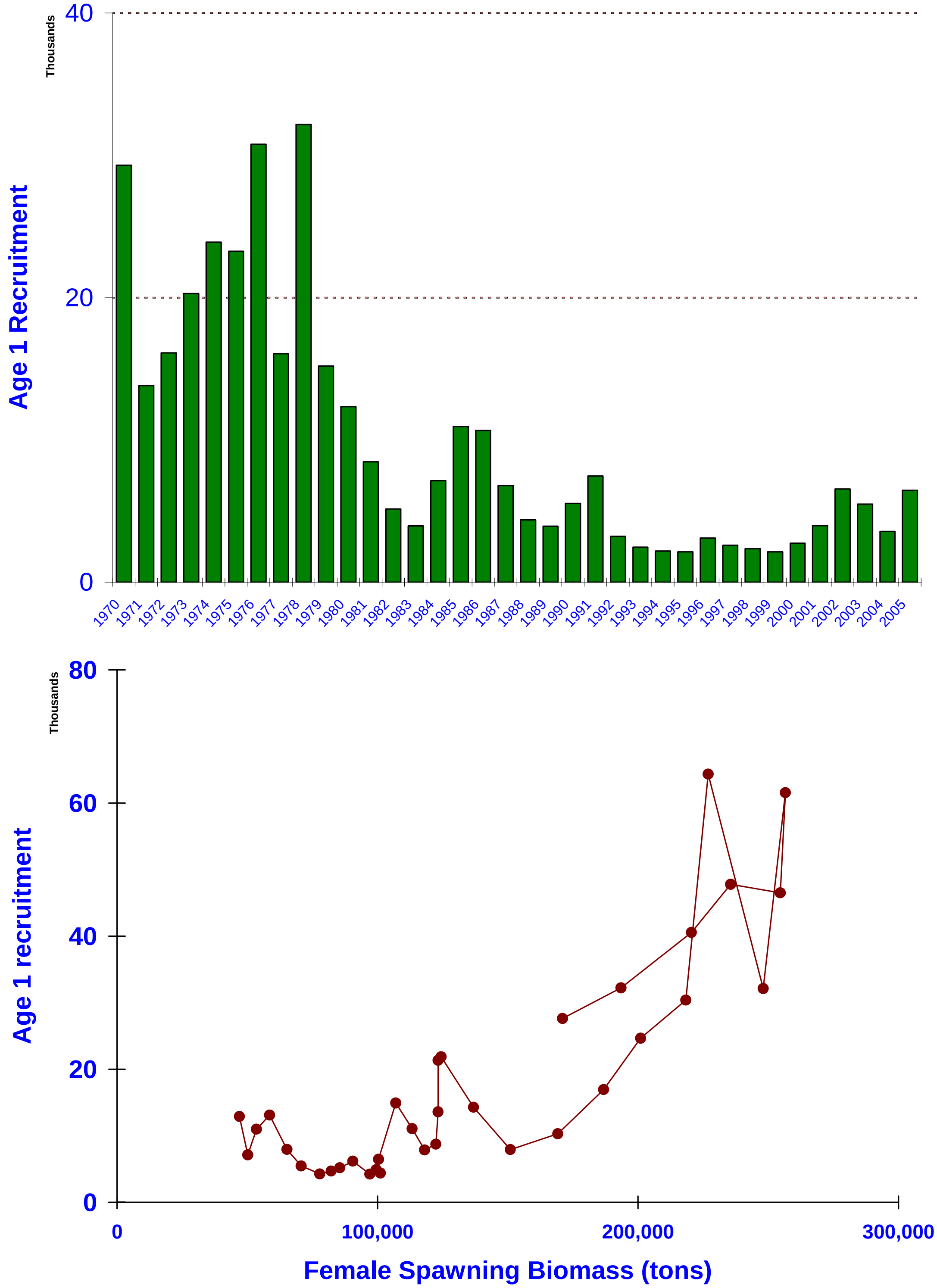
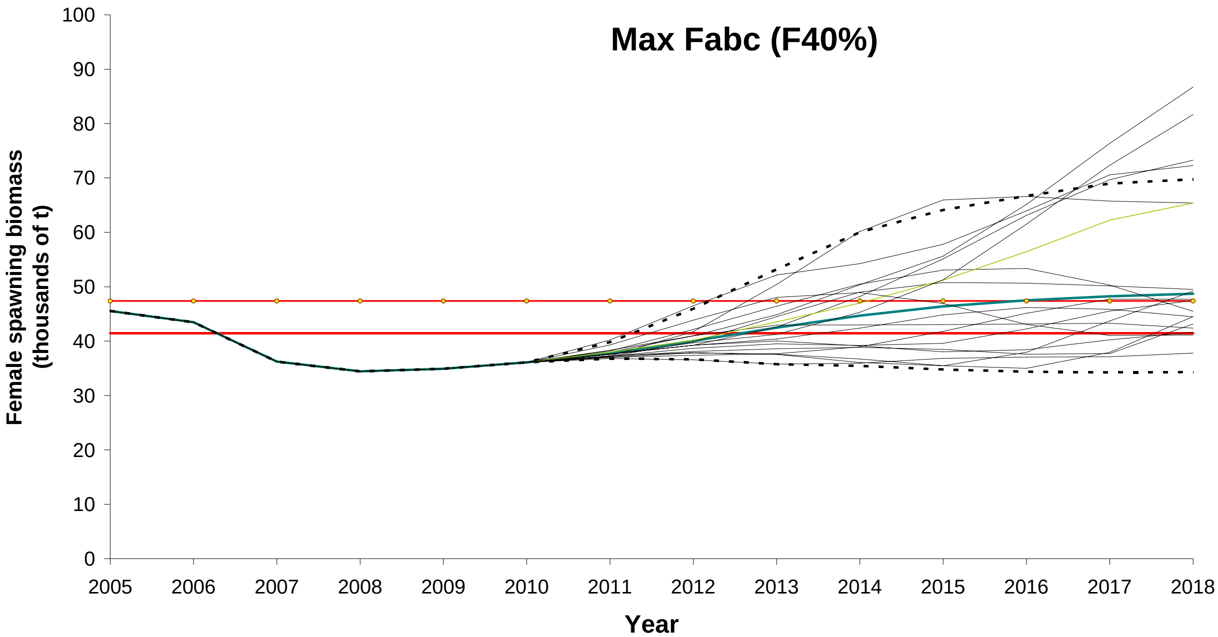


Figure 5.15. Estimated recruitment to age 1 (thousands; upper panel) and the observed stock-recruitment pattern (lower panel) of Greenland turbot in the EBS/AI region, 1970-2005.



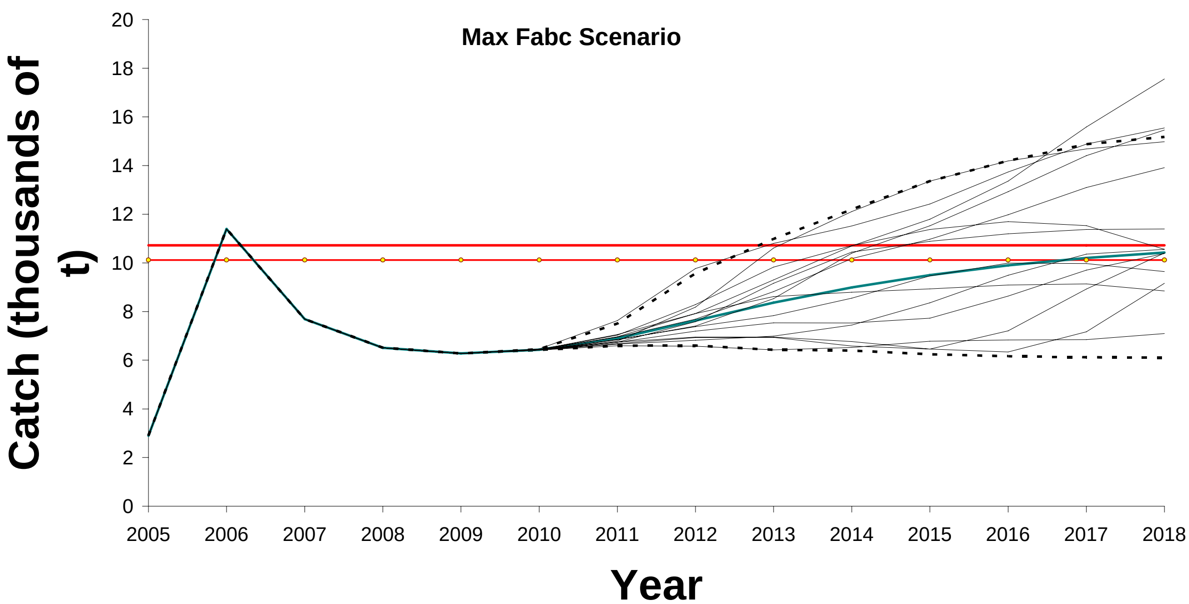
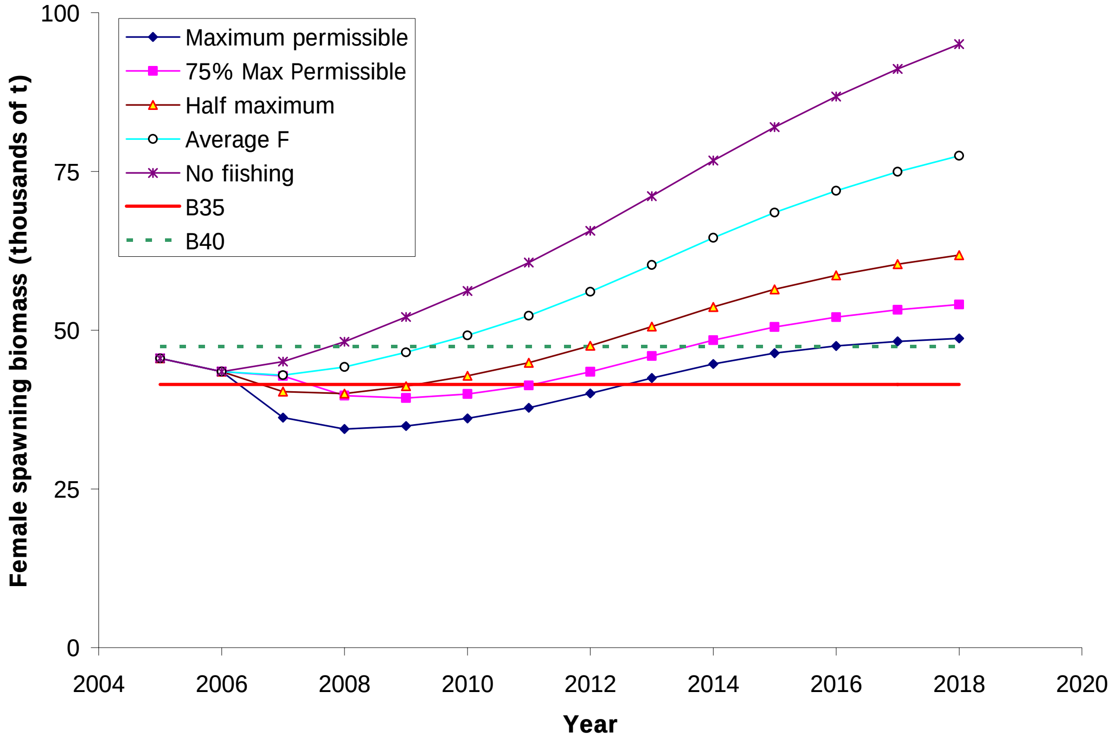


Figure 5.16. Stochastic trajectory of Greenland turbot female spawning biomass and catch for the maximum allowable fishing mortality rate under Amendment 56/56, Tier 3 The dotted lines represent the upper and lower 90% confidence limits. Horizontal lines with marks are the values associated with $B_{40\%}$ and $F_{40\%}$ while the thick horizontal line is the expected value under constant F_{OFL} rate ($F_{35\%}$).



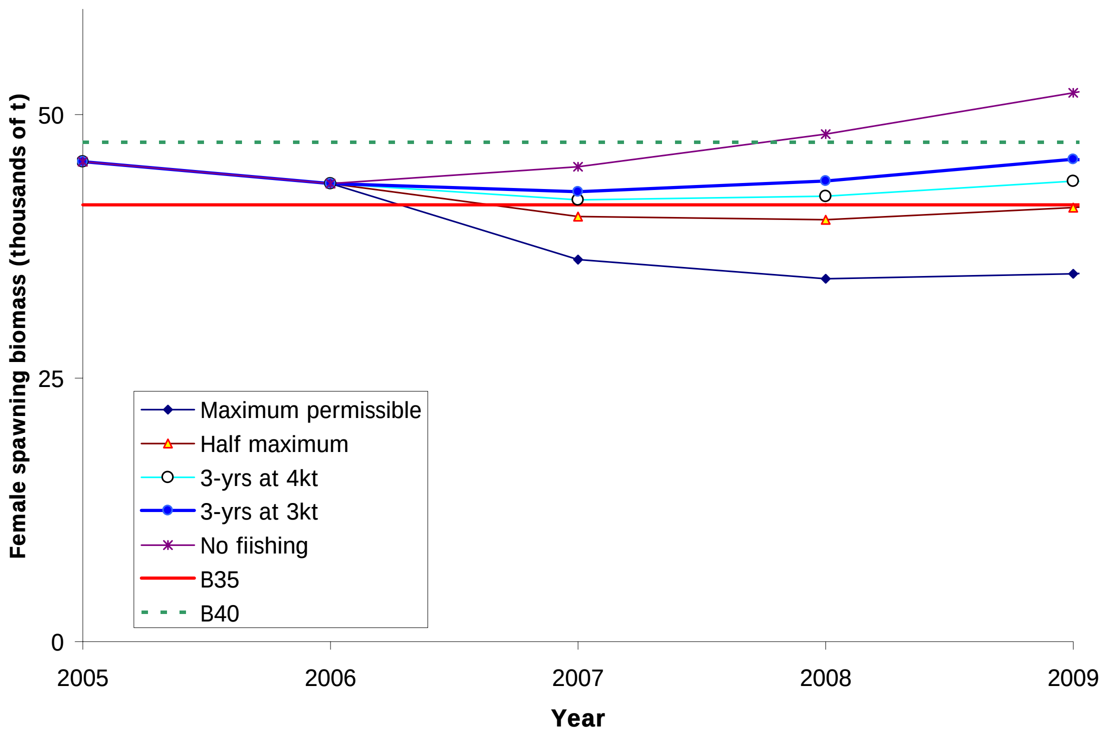


Figure 5.17. Mean trajectories of Greenland turbot female spawning biomass and catch for the maximum allowable fishing mortality rate under Amendment 56/56, versus a number of alternatives.

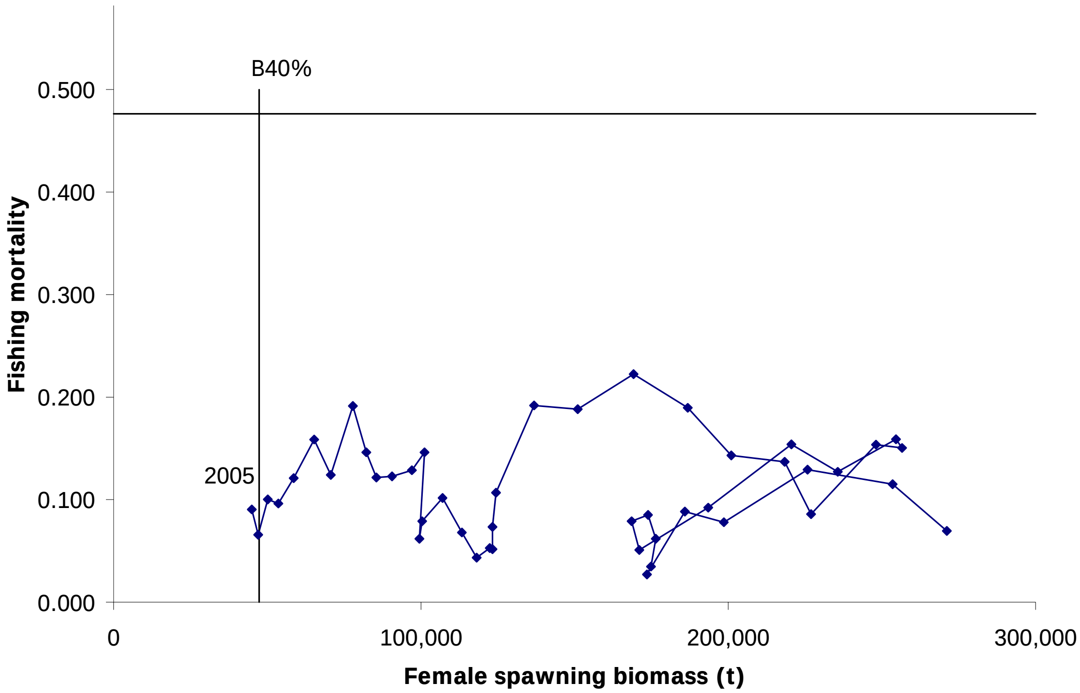
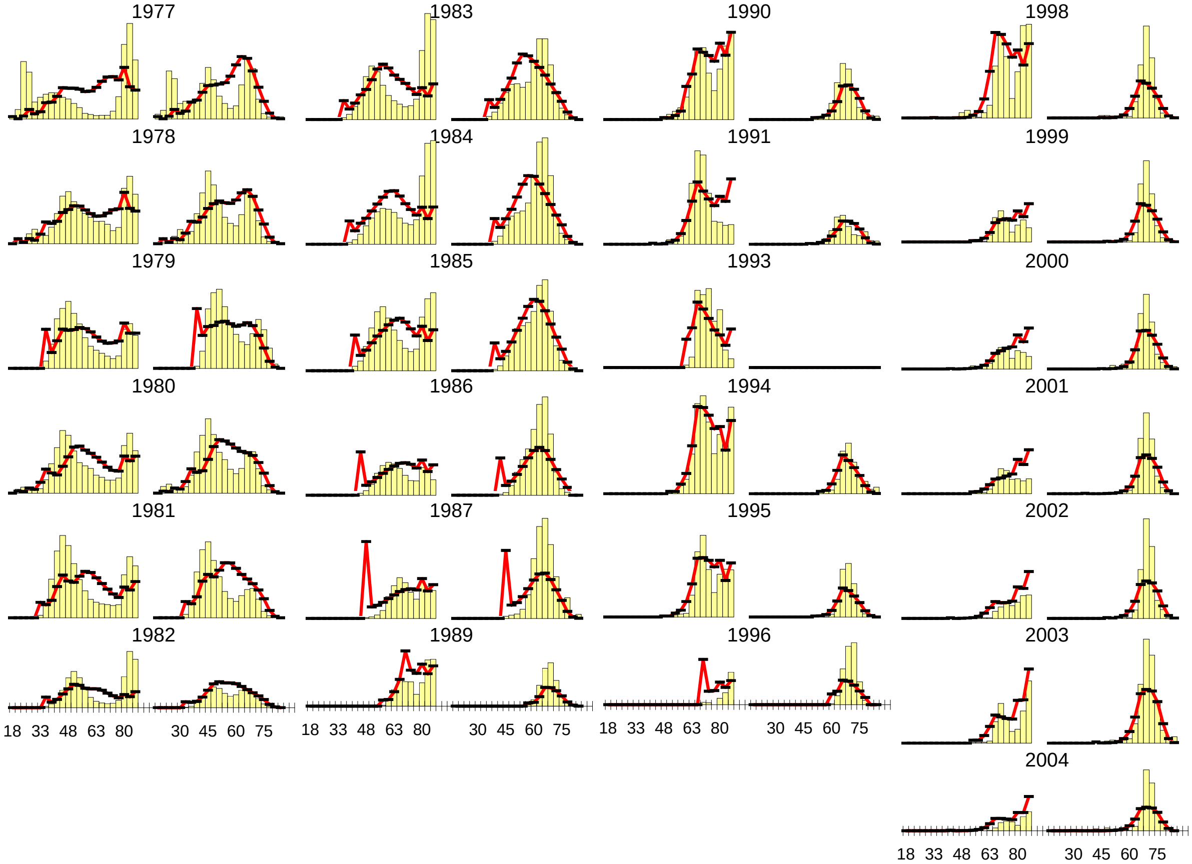


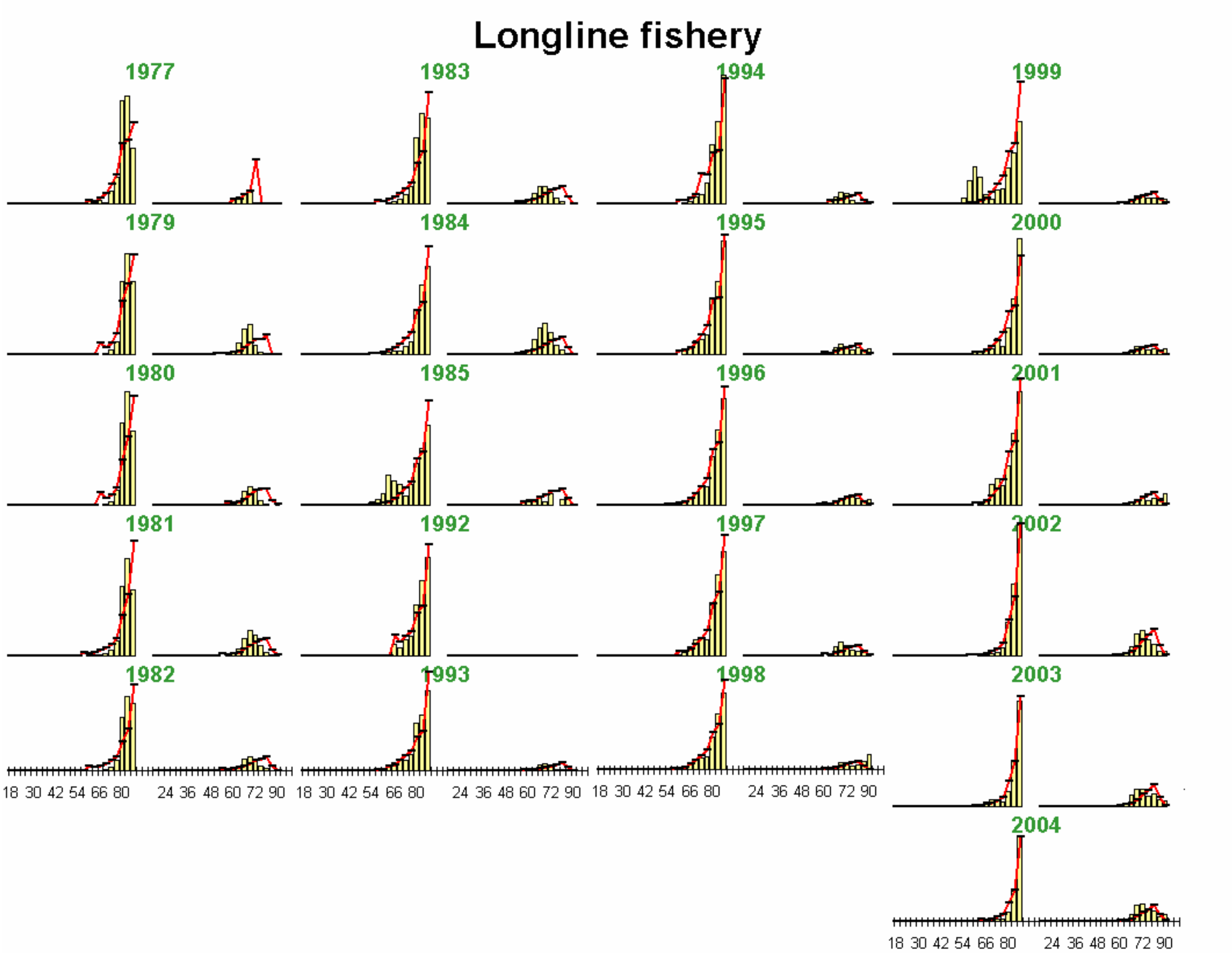
Figure 5.18. Historical estimates of total fishing mortality (vertical axis) and female spawning biomass relative to $B_{40\%}$ and $F_{40\%}$ levels for EBS Greenland turbot.

Appendix 5.1 Fits to the size composition data

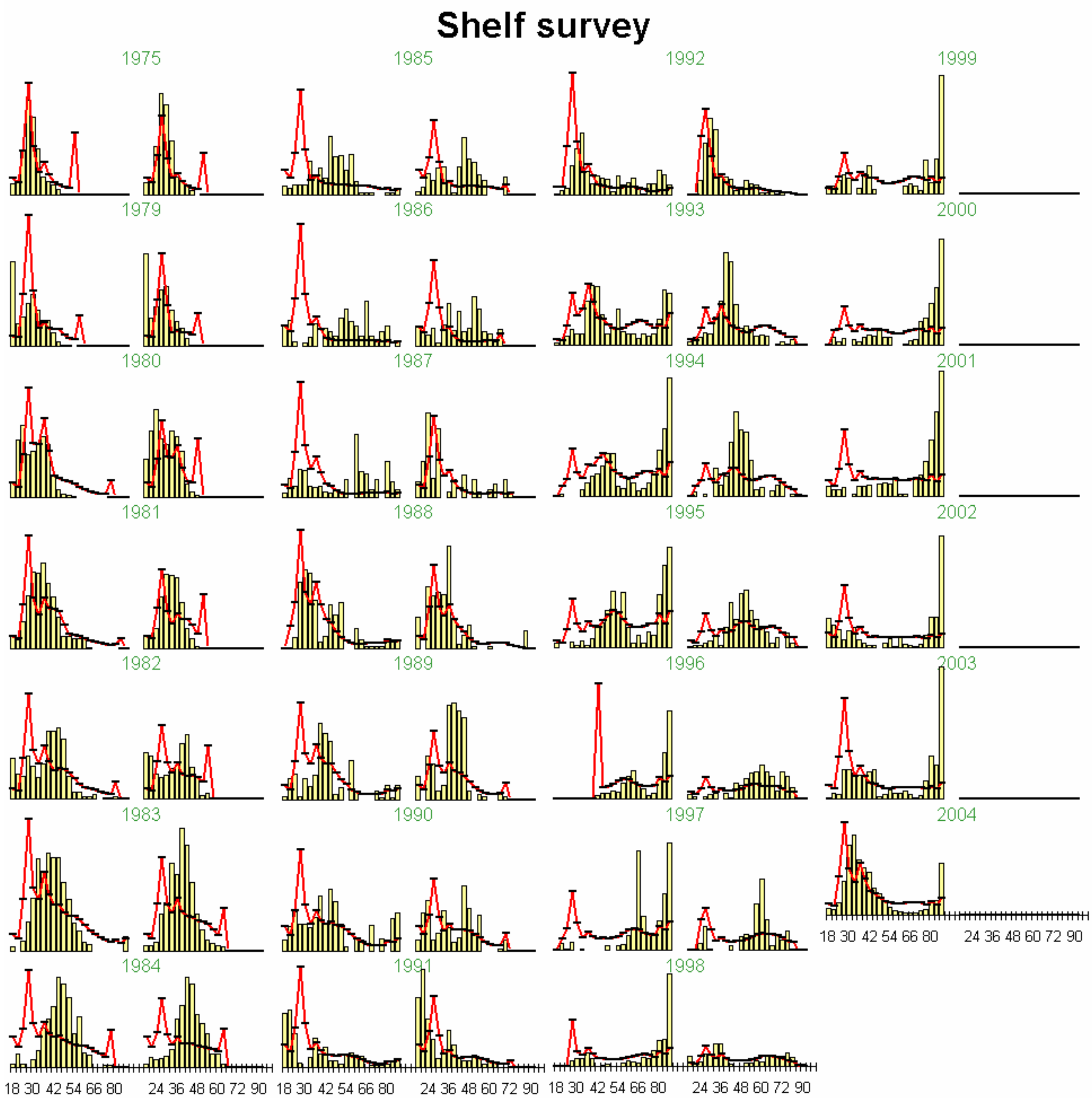
Trawl fishery



Legend: Greenland turbot relative length (cm) frequency data are presented by the bars and the model predictions are shown by the lines. For each panel, the left side represents the female component and the right side are for the males—if only one set is shown then the data are only available as both sexes combined.



Legend: Greenland turbot relative length (cm) frequency data are presented by the bars and the model predictions are shown by the lines. For each panel, the left side represents the female component and the right side are for the males—if only one set is shown then the data are only available as both sexes combined.



Legend: Greenland turbot relative length (cm) frequency data are presented by the bars and the model predictions are shown by the lines. For each panel, the left side represents the female component and the right side are for the males—if only one set is shown then the data are only available as both sexes combined.

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