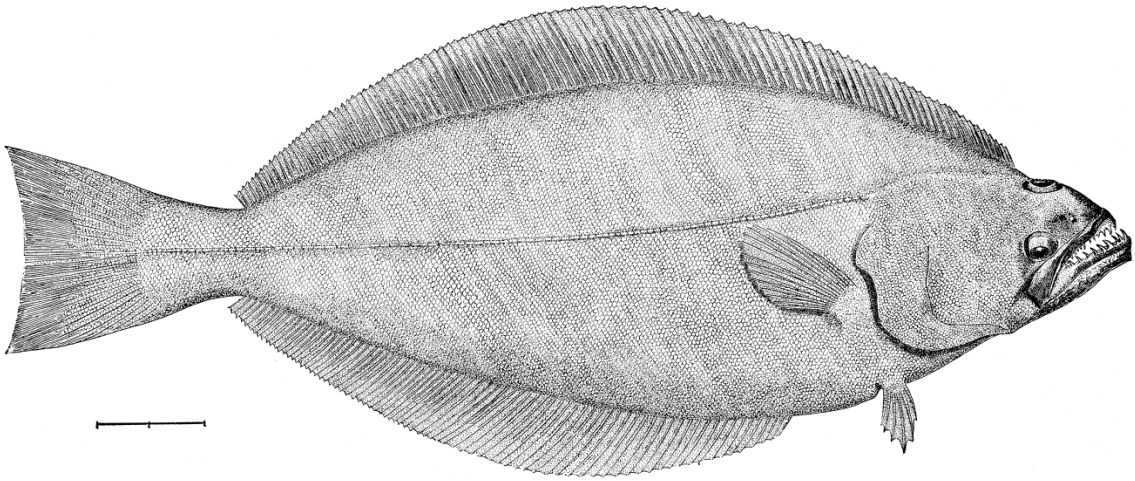
5. Assessment of the Greenland turbot stock in the Bering Sea and Aleutian Islands

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THE GREENLAND TURBOT.

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Executive Summary

Greenland turbot in the Bering Sea and Aleutian Islands are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. This stock was scheduled for a full operational model in 2025. However, due to a government lapse in funding the assessment was not completed. Consequently, a full stock assessment is presented in this chapter.

Summary of Changes in Assessment

Changes in the input data:

Relative to the last full assessment the following substantive changes have been made to assessment inputs:

- Designed based biomass estimates from the EBS shelf bottom trawl survey for 2025 and 2026.
- EBS shelf bottom trawl survey size compositions for 2025 and 2026.
- Mean length at age data from the 2024 and 2025 EBS shelf bottom trawl survey.
- Alaska Fisheries Science Center (AFSC) longline survey relative population numbers (RPNs) and size compositions for 2026.
- Fishery catch estimates were updated and include a preliminary estimate for 2026. Data on fishery size composition from 2024 - 2025 from the trawl fishery were also included in the model.

Changes in the assessment methodology:

Several tier 3 models were explored:

- Model 25.0 is the same as the last accepted model (16.4c) with an updated AFSC longline index for relative population numbers.
- Model 25.3a includes updated the input sample size for all fleets (i.e., number of hauls for the fishery fleets and bootstrap estimates from the afscISS R package for the bottom trawl surveys), fixed the parameter describing autocorrelation in recruitment to 0.437, analytically solves for survey catchability (all surveys), used the Francis method to re-weight the length composition data.
- Model 25.4a is the same as 25.3a but has two time blocks on the EBS slope survey selectivity (pre-2002 and 2002 – model end year), rather than three time blocks.
- Model 26.3 is the same as 25.4a with a start year of 1977.

In addition to the tier 3 models, the BSAI Groundfish Plan Team recommended we explore the REMA model to provide tier 5 advice. The models are as follows:

- All survey model - This model represents the approach taken in September 2026 and in 2025. It uses the region-specific RPWs and the biomass estimates from all bottom trawl surveys.
- No EBS shelf bottom trawl survey model - The EBS shelf bottom trawl survey biomass was excluded from the model to isolate its contribution to biomass.
- No AI longline survey model – The RPWs from the AI longline survey was excluded to evaluate the effect of only including the AI BTS as representative of the entire AI region.
- All survey model with RPNs -The longline survey relative population numbers (RPNs) are used instead of RPWs, to evaluate the effect of using a number-based index of abundance.

Summary of Results

The authors recommended model 25.0 for management. The alternative models explored were not recommended due to large retrospective patterns and drastic down weighting of the length composition data caused the alternative models to miss observed recruitment signals during a relatively data-rich period of the data time series. The alternative models are discussed in the chapter and clearly demonstrate that the persistent data conflicts in the models make it difficult to estimate population scale and this estimate is highly dependent on data weighting and the start year of the model.

Year-end catch was estimated using an expansion factor that represents 5-year mean ratio of total annual catch to the catch accrued through the current assessment cutoff date (2026-10-04). This was done for the trawl and longline/fixed gear fleets separately and summed for use in the projection model. A value of 193 t was used as the preliminary catch estimate in the projection model.

	As estimated or *specified* in 2024 for:		As estimated or *recommended this* year* for:	
Quantity	2025	2026	2027	2028
M (natural mortality rate)	0.112	0.112	0.112	0.112
Tier	3a	3a	3b	3b
Projected total (age 1+)	37,615	35,877	28,434	27,604
Female spawning biomass	23,999	22,061	18,414	17,040
Projected				
$B_{100\%}$	58,812	58,812	56,211	56,211
$B_{40\%}$	23,525	23,525	22,485	22,485
$B_{35\%}$	20,584	20,584	19,674	19,674
F_{OFL}	0.20	0.20	0.2	0.2
$maxF_{ABC}$	0.17	0.17	0.17	0.17
F_{ABC}	0.15	0.15		
OFL (t)	2,598	2,059	1,356	1,107
maxABC (t)	2,237	1,771	1,165	951
ABC (t)	2,013	1,594	TBD**	TBD**
	As determined *last* year for:		As determined *this* year for:	
Status	2023	2024	2025	2026
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

** Projections are based on model 25.0 and preliminary catches of 193 t in 2026 and 378 t were used in place of maximum permissible ABC for 2027 and 2028 to provide OFL and maximum ABC estimates. The preliminary catch for 2027 and 2028 was estimated as the product of the average proportion of the TAC captured (retained and discarded catch) over the previous 5 years (2021-2025), 28%, and the 2026 TAC, 1,328 t. The assumed fishing mortality ratios used in the projection were 96% trawl and 4% longline to represent the trends in the recent catch history.*

***TBD: The risk table scores are similar to the 2024 risk table scores and the SSC specified a reduction larger than the authors' suggested reduction from maxABC. Therefore, the authors' suggest using the ABC from the tier 5 assessment as a maximum threshold for a reduction and defer to the SSC to specify the exact percentage.*

Spatial Apportionment: Biologically-informed Recommended Distributions (BRDs)

Using the REMA model, the proportion of biomass in the Aleutian Islands is estimated to be 9% and in the Bering Sea the proportion biomass is 91%. These proportions were used to apportion the maxABC and ABC.

	2027 maxABC	max2028 ABC
Aleutian Islands BRD	105	86
Eastern Bering Sea BRD	1060	865
Total	1165	951

Responses to Comments

Responses to SSC and Plan Team Comments on Assessments in General

"*The Team recommended as a best practice that appendices be linked in the front of the document (as with the sablefish assessment) to allow for an easier review of the appendices.*" (Plan Team, November 2023)

Combined recommendations on the risk table:

"The SSC continues to support a three-category risk table with categories normal, increased, and extreme, and requests that the category descriptions be revised to cover the range covered by the original table."

"The SSC reiterates that only fishery performance indicators that provide some inference regarding biological status of the stock should be used."

"The SSC recommends that the risk tables consider potential future risks when these can be anticipated."

"When risk scores are reported, the SSC requests that a brief justification for each score be provided, even when that score indicates no elevated risk."

(SSC, December 2023)

A risk table is presented in the Harvest Recommendations. After completing this exercise, we suggest that a reduction in maximum ABC may be warranted given uncertainty in stock status, future recruitment, and declining catch with a declining population.

"*The SSC requests that when Bayesian model output is reported, basic convergence diagnostics are also presented.*" (SSC, December 2023)

<u>Responses to SSC and Plan Team Comments Specific to this Assessment</u>

"The SSC suggests that it might be useful for the author to explore the use of VAST for the EBS slope and longline surveys, given the recent cancelations and relative paucity of trawl surveys of the slope." (SSC, December 2020).

The authors have not developed a VAST index for the slope survey to date. One hesitation is that this will also require combining length composition data, which is unlikely straightforward and will require additional consideration before embarking on this endeavor.

The SSC recommends that the authors continue to explore the use of VAST for the slope survey as requested in December 2020, consider excluding pre-1977 data, and consider new methods for deriving apportionments given the lack of recent EBS slope data.

We have model runs exploring the exclusion of the pre-1977 data. We presented a new method developed by Jane Sullivan (AFSC ABL) for apportionment using the REMA model in 2025. The SSC indicated that "The new REMA approach to spatial apportionment is viewed as a step forward and is supported by the SSC"; therefore, we will present this in November.

The SSC appreciates the authors' development of a linear approximation approach to support the AFSC longline relative population numbers and recommends using this method in future model development where appropriate.

This has been incorporated in all models this year.

The SSC recommends the following efforts focused on the input data for the next stock assessment:
Include bootstrapped input sample sizes for all compositional data.
Along with the length-at-age data, consider using the age data from the AFSC trawl survey rather than the lengths to provide more direct information on recruitment.
As requested in 2022, include the sex-specific length data from the recent longline surveys.
Investigate and provide an explanation for the apparent binning in the length/age data for larger fish and the lack of small males in the shelf survey composition data.

We have model runs using the bootstrapped ISS for the bottom trawl surveys, which this approach is available for. The approach is not currently available for the other fleets in this assessment

A sensitivity run using the EBS shelf BTS age data was presented in 2025. The authors agree that age data should be used in the model; however, currently we have age data for the EBS shelf survey and sparse age data from the EBS slope survey. We will incorporate these data with age data from the commercial fisheries once the fishery age data are available.

A sensitivity including the sex-specific length data was presented in 2025. The authors will incorporate this in the next full assessment.

The lack of small males was due to combining females and males below 21cm. This feature has been removed from the model runs, as it had no impact on the model

Exploration of different length bins will be done for the next full assessment

Specific recommendations from the Team for future assessments included:
● *Using interpolated AFSC longline survey RPN data for all future models, following established best practices.*
● *Displaying survey mean length-at-age across all model runs to examine interactions with selectivity time blocks and Francis reweighting.*
● *Exploring later start years, closer to the 1977 regime shift, for potential insights into recruitment dynamics.*
● *Likelihood profiling over M and von Bertalanffy parameters to address retrospective bias in survey catchability (Q).*
● *Developing a Tier 5 REMA model to compare with Tier 3 models, given the data losses.*

The interpolated AFSC longline survey RPNs have been included in the assessment model

Fits to size at age are presented for all model runs

A later start year (1977) has been explored

Profiles over natural mortality were not completed because it is not an estimated parameter; profiles for R0 and asymptotic length were shown this year.

A tier 5 REMA model was presented and compared to the tier 3 model.

The Team emphasized the importance of updating the maturity schedule, reiterating prior comments made in September. The authors' efforts to collect fishery samples this year were commended, but the Team suggested increased collaboration with the Fisheries Monitoring and Analysis (FMA) Division to enhance sample sizes. Greenland turbot is not predominant in the catch and has been a lower priority for biological collections, further complicating sample acquisition.

The author and Todd ten Brink (REFM/A&G) had a special project with the observer program. The maturity samples will be processed early in 2027. A new ogive should be ready for the next full assessment.

Efforts to improve model stability by reducing parameters that are not well estimated is encouraged for future assessments. (SSC, October 2018)

This is an ongoing effort for this model.

Introduction

Greenland turbot (*Reinhardtius hippoglossoides*) is a Pleuronectidae flatfish that has a circumpolar distribution inhabiting the North Atlantic, Arctic and North Pacific Oceans (Figure 5.1). 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*, the common name Greenland turbot, which is also the "official" market name in the US and Canada (AFS 1991), is retained.

Greenland turbot is a commercially important Pan-Arctic species where specimens have been found across the Arctic in both the Beaufort (Chiperzak et al. 1995) and Chukchi seas (Rand and Logerwell 2011). In addition to the United States, the following countries have active Greenland halibut fisheries and include Norway (primarily in the Barents Sea and co-managed with Russia), Russia (Sea of Okhotsk and western Bering Sea), Greenland, Faroe Islands, Iceland, and Canada (NAFO subareas 0, 2, 3 and the Gulf of St. Lawrence). Most have stocks are above their precautionary limits and regularly specify annual catch limits. For example, The Joint Norwegian-Russian Fisherie Commission agreed to a shared total TAC of 21,000 t for 2027. Conversely, in the last year DFO advised a 0 t directed catch limit because the stock in the Gulf of St. Lawrence entered its Critical Zone. This drop in population size is attributed to bottom-water warming, hypoxic conditions, and the increase in its competitors populations causing competition for resources (Chamberland and Benoit 2026). Additionally, there are reports that fishing for Greenland halibut in the Sea of Okhotsk and off Kamchatka are closed to fishing from July 2026 until December 31, 2027 due to recruitment concerns and a steeply declining stock (Seafood News 2026).

This species primarily inhabits the deeper slope and shelf waters (between 100 m to 2000 m; Figure 5.1) in bottom temperatures ranging from -2°C to 5°C. 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). Adult Greenland turbot distribution in the Bering Sea appears to be dependent on size and maturity as larger more mature fish migrate to deeper warmer waters. In the annual summer shelf trawl surveys conducted by the Alaska Fisheries Science Center (AFSC) the distribution by size shows a clear preference by the smaller fish for shallower (< 200 m) and colder shelf waters (between -2°C and +2°C). The larger specimens are in higher concentrations in deeper (> 200 m), warmer waters (between 0°C and 4°C It appears that for years with above average bottom trawl bottom temperatures the larger turbot (> 20 cm) are found at shallower depths (Barbeaux et al. 2015).

Juveniles are generally absent in the Aleutian Islands region, suggesting that the population in the Aleutians originates from the EBS or elsewhere (Bryan, 2018). The 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 hundreds of kilometers and spend summer periods in deep water in some years and in other years spend time on the shallower EBS shelf region (Siwicke and Coutre 2020). In this assessment, Greenland turbot found in the two regions are assumed to represent a single management stock.

Greenland turbot are sexually dimorphic with females achieving a larger maximum size. Growth parameters are estimated within the stock assessment model for both male and female Greenland turbot given their sexual dimorphism and is consistent with trends observed in the North Atlantic. Collections in the North Atlantic suggest that males may have higher mortality than females. Evidence from the Bering Sea shelf and slope surveys suggest males reach a maximum size much smaller than females, but mortality may not be higher than in females. Sexually dimorphic spawning behaviors are also prevalent for this species. Siwicke et al. (2022), using archival tagging data, determined males exhibited multiple rises for an average of 20 days, while females exhibited a single spawning rise occurring at annual intervals between January and February.

Fishery and Management History

Greenland turbot and arrowtooth flounder were managed together prior to 1985. Since then, the Council has managed them separately given the large differences in market value between the species. Furthermore, the abundance trends for these two species are clearly distinct (Figure 5.3).

Catches of Greenland turbot and arrowtooth flounder were not reported separately during the 1960s (Bakala 1987). 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 in 1972 and 1974 reaching 77,384 t and 78,442 t, respectively (Figure 5. 4, Figure 5.5). Catches declined in 1977 with the implementation of the MFCMA and were followed by relatively high catches between 1979 and 1983 (Figure 5.4, Figure 5.5). Prior to 1985, catches were generally above the average of the full time series. Trawl harvest declined steadily after 1983, with the lowest catch in 2006 (361 t); however, 2026 might be the lowest. The preliminary catch estimate for 2026 is 169 t. Catch by the trawl fishery varied between a maximum of 3,080 t in 2009 and 603 t in 2025 with an average of 1,605 t between 2008 and 2025. Longline catch increased from 438 t in 1977 to 4023 t in 1981 followed by an average catch of 170 t between 1982 and 1990. Catch by the longline fishery increased from 1,1617 t in 1991 to to a peak of 7,324 t in 1993 and a secondary peak in 1998 of 7, 181 t. Catch has declined since 1999. Catch by the longline fleet has been under 46 t since 2021. Overall, catch of Greenland turbot has been low since 2013 and has been declining from 1000s of tons to 100s of tons (Table 5.1).

Catch restrictions were placed on the fishery in the 1990s because of concerns about low levels of recruitment. From 1990-1995 the Council set the ABC's (and TACs) to 7,000 t as an added conservation measure citing concerns about recruitment. Between 1996 and 2012 the ABC levels varied but averaged 6,788 t (with catch for that period averaging 4,480 t). The 2013 ABC was lowered to 2,060 to correct for changes in the stock assessment model and total catch for 2013 was 1,742 t. The ABC and TAC remained low between 2014 and 2016. In 2016, although the ABC was 3,462 t the TAC was set at 2,873 t and total catch was at 2,272 t. In 2017, the ABC was increased to 6,644 t, the TAC was set to 4,500 t and total catch was 2,834 t. ABC and TAC increased between 2017 and 2018 and have been declining since 2019. The fishery had captured a high proportion of the ABC and TAC annually prior to 2017, with lows of 16% in 2018 and 22% in 2021 and 2022 (Table 5.1). Catch has been low since 2018 and an average of 26% and 34% of the ABC and TAC have been retained between 2018 and 2025.

Historically the majority of catch over time was concentrated in deeper waters (> 150 m) along the shelf edge ringing the eastern Bering Sea (e.g., Figure 5.5 in Bryan 2022; Figure 5.6, Figure 5.7, Figure 5.8), but Greenland turbot has been consistently caught in the shallow water on the shelf as bycatch in the trawl fisheries (Table 5.2, Figure 5.7). Early in the catch time series, the trawl fishery captured Greenland turbot along the continental shelf and the shelf edge spread from the southern EBS and the northwest EBS, as well as the central and western Aleutian Islands (Figure 5.7). Trawl catch was concentrated in the southeastern portion of the EBS with much less catch in the Aleutian Islands. Since 2006, catch has been spread along the shelf edge and on the slope. Longline catch has primarily been in the deeper waters of the EBS slope over time (Figure 5.8). However, between 2008 and 2012 at a 400km^2 resolution the cells with highest amounts of catch were observed in the Eastern Aleutian Islands (Barbeaux *et al.* 2013), suggesting high densities of Greenland turbot in these areas. These areas of high Greenland turbot catch in the Aleutians are coincident with the appearance of the Kamchatka and arrowtooth flounder fishery. This fishery has the highest catch of Greenland turbot outside of the directed fishery (Table 5.2, Figure 5.9).

For the domestic fishery, the trawl sector took the majority of the catch, 96%, between 1977 and 1991 (Table 5.1). The longline fishery took the majority (~71%) of Greenland turbot catch from 1992-2007. In 2007, the Council passed Amendment 80 as part of the BSAI Fishery Management Plan (FMP) and 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. Starting in 2008 the proportion of catch per sector varied over time, but most of the catch has been captured by the trawl sector on average since 2008. Since 2021 almost all of catch has been from the trawl sector.

When the longline fleet more actively targeted Greenland turbot, they targeted pre-spawning aggregations. The fishery opens May 1, but most fishing occurs between June-August in the EBS to avoid killer whale predation. Catch information prior to 1990 included only the tonnage of Greenland turbot retained by Bering Sea fishing vessels or processed onshore (as reported by PacFIN). In 2010, there was a shift in the mean depth of the targeted Greenland turbot longline fishery fished at 667m, from 1995 to 2009, up to 555m, on average, from 2010 to 2015 (Figure 5.6). There has been a northwest trend in mean fishing latitude over time for the longline fishery (Bryan et al. 2024), but catch has been spread across the slope with an increase in catch in the Aleutian Island in the 2000s (Figure 5.8). The trawl gear fishery exhibited a southward shift in fishing at the end of the 1980s, but has operated across the shelf over time (Figure 5.7). On average the trawl fishery operated at deeper depths between 1980 and 1998 and has operated at ~400 m since 2000 (Figure 5.6).

The overall discard rate of Greenland turbot has dropped in recent years from a high of 82% discarded in 1992 (Table 5.2). The lowest discard rate of 2% occurred in 2012 and 2019. Discard levels of Greenland turbot have typically been highest in the sablefish fishery while Pacific cod fisheries and the “flatfish” fisheries also have contributed substantially to the discard levels (Table 5.2). However, due to the large numbers of small Greenland turbot encountered in the flatfish and arrowtooth/Kamchatka fisheries in 2013 and 2014 the discard rate once again rose to 20% in 2013 and 15% in 2014. The discard rate has varied between 2% and 6% since 2015.

Greenland turbot catch has primarily been from the Bering Sea; however, catch levels were similar between the Bering Sea and Aleutian Islands in 1991, 2009, and 2010 (Table 5.3). Since 1991, an average of 77% of Greenland turbot catch has been from the Bering Sea and 23% from the Aleutian Islands.

Data

The following data sources were used in the 2026 BSAI Greenland turbot assessment and used for the model runs in this document:

Source	Data	Years
NMFS Groundfish survey:	EBS shelf BTS biomass	1987-2019, 2021-2026
	EBS shelf BTS length composition	1987-2019, 2021 - 2026
	EBS shelf BTS mean length at age	1982, 1998-2019, 2021-2025
	EBS slope BTS biomass	2002, 2004, 2008, 2010, 2012, 2016
	EBS slope BTS length composition	Same as above and 1979, 1981-1982, 1985, 1988, 1991
	EBS slope BTS mean length at age	2002, 2004, 2008, 2010, 2012, 2016
AFSC longline survey	Relative population numbers	1996-2023, 2026

	Length composition	1979-1987, 1993-1994, 1996-2023, 2026
U.S. fisheries	Catch	1960-2026
	Trawl length composition	1978-1991, 1994-1996, 1998-2025
	Fixed Gear length composition	1979-1985, 1993-2020*

*Due to low catch since 2020, the number of hauls with length samples and number of length samples are limited and deemed unusable or are not available.

Fisheries data in this assessment were split into the longline (including all fixed gears) and trawl fisheries. Both the trawl and longline data include observations and catch from targeted catch and bycatch. There are also data from three surveys. The EBS shelf and slope bottom trawl surveys are conducted by the Resource Assessment and Conservation Engineering (RACE) Division's Groundfish Assessment Program of the Alaska Fisheries Science Center (AFSC). The AFSC longline survey has been conducted by the Auke Bay Laboratory (ABL) out of Juneau, Alaska. The type of data and relevant years from each can be found in Figure 5.10.

Fishery data

Catch
The catch data were used as presented above for both the longline and trawl fisheries. The early catches included Greenland turbot and arrowtooth flounder together. To separate them, the ratio of the two species for the years 1960-64 was assumed to be the same as the mean ratio caught by USSR vessels from 1965-69 (Ianelli and Wildebuer 1998). End-of-year catch was estimated using an expansion factor that represents the 5-year mean ratio of total annual catch to the catch accrued through the current assessment cutoff date (2026-10-04). This was done for the trawl and longline/fixed gear fleets separately. The expansion factor used for the trawl fleet was 1.02 and the longline fleet was 1.25.

Between 1960 and 1977 and 1982 and 1987, all catch was captured by the trawl fishery (Table 5.1, Figure 5.4). Catch in most years has been higher for the trawl fishery than the longline fishery except between 1992 and 2007.

Size and age composition
Length frequency compositions have been collected by the NMFS observer program from the period 1980 to 2026. The length composition data from the trawl and longline fishery are presented in Figure 5. 11. The absolute sample sizes for the period of the domestic fishery by sex and fishery from 1991-2026 are given in Table 5.4.Very few samples, if any, were collected from the fixed gear fisheries between 2021 and 2026 and corresponds to low catch and Greenland turbot not being a predominant species in this fishery in recent years.

Early in the time series, late 1970s to early 1980s, the trawl fishery captured a higher proportion of smaller turbot (Figure 5. 11). After 1984, there was a noticeable shift towards larger fish, where the size distribution of males caught during this time period has been fairly consistent. The longline/fixed gear fishery has consistently captured higher proportions of larger Greenland turbot over time. A higher proportion of females greater than 70 cm were caught prior to 2008 followed by a shift towards females less than 70 cm.

Survey Data

EBS slope and shelf surveys

Data from the eastern Bering Sea shelf and slope bottom trawl surveys are included in the Greenland turbot stock assessment. Due to the ontogeny of Greenland turbot, the EBS shelf bottom trawl survey primarily provides abundance estimates of juveniles and the slope bottom trawl survey provides estimates of older juvenile and adult abundance on the EBS slope (Figure 5. 11, Figure 5. 12). The EBS shelf and slope bottom trawl surveys are treated as relative indices of abundance because neither cover the full extent of the population's distribution. Specifically for the slope survey, it is to under-represent the actual abundance because of the the ability of the net to maintain bottom contact in the deeper waters may have been compromised.

The EBS slope was surveyed triennially from 1979-1991 (also in 1981) as part of an 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, 2010, 2012, and 2016. A 2014 survey was planned but was cancelled due to contracting difficulties. The 2016 survey sampled fewer stations than planned (88% of planned stations were sampled) due to contracted vessel mechanical issues. All missed tows were in the Bering Canyon (subarea 1) region where 53 of 75 planned stations were completed (Table 5.6c). This area is where we expected a large number of Greenland turbot, so 2016 abundance may be underestimated. The slope survey has not been conducted since 2016. The 2018 survey was cancelled due to contracting difficulties and due to a lack of funding the survey has been discontinued. Although the size composition data for surveys prior to 2002 were used in this assessment, abundance estimates were considered inappropriate for use due to differences in survey consistency, vessel power, gear used, and uncertainty on the extent of survey gear bottom contact.

The estimated biomass of Greenland turbot in this region has fluctuated over the years (Table 5.5, Table 5.6, Figure 5.12, Figure 5.13). 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 averaged 47,169 t, with a 2004 level of 64,958 t. Although the 2012 EBS slope biomass estimate of 18,019 t was down from 2010 estimate of 20,046 t, the population numbers in 2012 of 11,839,700 fish were more than double the 2010 estimate of 5,839,126 fish. The 2012 slope survey abundance estimate in numbers was the highest population estimate since the slope survey was reinstated in 2002.

For 2012, most of the change in population estimates was due to the changes in Greenland turbot abundance found in the two shallowest strata between 200 and 600 m depth strata (Table 5.6). In the 200-400 m strata the population was more than 7 times that of the 2010 survey estimate and the 400-600 m strata was more than double the 2010 estimate. The high numbers and low biomass results are a reflection of the large number of smaller fish moving into the slope region from the shelf due to the large 2007 through 2010 year classes as evidenced by the large number of fish between 30 cm and 50 cm observed in this survey (Figure 5.11). In the 2016 slope survey, Greenland turbot biomass increased to 24,803 t (Table 5.5)

In the 2016 slope survey, most of the biomass (83.5% of biomass and 87.9% of abundance) was located in depths between 400 and 800 meters consistent with the growing 2007-2010 year classes moving downslope (Table 5.6 b and c). For all regions except Area 1 (1.4% decrease) there was an increase in Greenland turbot biomass in the 2016 survey compared to 2012, as expected with the growth of the large 2007-2010 year classes. The 2016 slope survey also saw an increase in abundance in all regions except Area 6 which experienced a 54.5% decline in abundance. Areas 5, 4, and 3 saw a 657.1%, 112.1%, and 44.3% increases in abundance consistent with Greenland turbot migrating south as they grow.

Although the 2016 slope survey continued to see the highest abundance in area, the highest proportion of fish were located in the furthest north strata with 42.2% and 36.2% of the fish by abundance and biomass, respectively, in Area 6 (Table 5.6). This compared to the 2012 survey which saw 71.9% and 44.7% of the abundance and biomass in Area 6. Area 6 had an overall 54.5% decrease in abundance from 2012 to 2016. This demonstrates the expected southward migration of the 2007-2010 year classes into Areas 5, 4, and 3 with 657%, 112%, and 44% increases in abundance in these areas. The number of fish in areas 1 and 2 remained relatively stable with only 1.6% and 5.5% increases.

The shelf trawl survey has been conducted by the AFSC annually since 1979. Beginning in 1987 NMFS expanded the standard survey area farther to the northwest. For consistency the index of abundance used in this stock assessment only includes data post-1987 and included data from the expanded area (Table 5.5, Figure 5.12). The shelf survey is a measure of juvenile fish and appears to be highly influenced by occasional large recruitment events (Figure 5.11) The shelf survey index shows a steep decline in biomass from initial biomass estimates in 1982 of 39,603 t to a low of 5,654 t in 1986 (Table 5.5**Error! Reference source not found.**). From 1987 to 1994 biomass increased to an all-time peak of 56,997 t in 1994 following two larger than average recruitment events in the mid and late 1980s. After 1994, the shelf index once again declined steadily through 2009 to 10,919 t as recruitment remained low throughout the 1990s with only a slight improvement in 1999-2001. In 2010, the index increased to 23,339 t and was relatively stable between 2011 and 2017. In 2010 and 2011, the abundance estimates from the shelf surveys indicated a significant increase of Greenland turbot due to an increase in recruitment between 2007 and 2010 and an increase in the proportion of tows with Greenland turbot present (Table 5.7). Biomass has been declining since 2014 and in 2024 the survey biomass estimate was 4,959 t and at an all-time low. The 2025 shelf biomass estimate was similar to 2024, 5,433 t, and in 2026 there was an 87% increase in the shelf survey biomass to 10,189 t. Even with this increase biomass on the shelf remains well below average (21,680 t; Figure 5.13).

Survey data show that the extent of the spatial distribution of turbot on the shelf and upper slope presents temporal variation, possibly expanding as recruitment events occur (Figure 5.16 – Figure 5.18). For example, occurrences of small (< 30 cm) fish were relatively constant prior to 2010, albeit with some interannual variability. Between 2009 and 2012, the bottom trawl surveys detected larger numbers of small fish distributed throughout the continental shelf. Biomass and abundance on the EBS shelf have been declining since 2014. This is due to the migration of the 2007-2010 year classes off the shelf survey area, and a lack of replacement from new recruitment over the last decade (Figure 5.11, Figure 5. 14 5.14). In 2023 and 2024, small fish were observed on the EBS shelf; however, the cohort strength between 2023 and 2024 appears small (Figure 5.11, Figure 5.14, Figure 5.16)

Survey length-at-age used for estimating growth and growth variability (Figure 5.15). The data are imputed as annual, mean length-at-age. Gregg et al. (2006) revised age-determination methods for Greenland turbot and although shelf survey age composition data were included in the model, they were not included in the likelihood function (Figure 5.14). The age composition data are not included in the likelihood to avoid using the data twice given that in all years the mean length-at-age data and length data from the same source are used. It is worth noting that the age data show evidence of the 2007-2010 cohort ageing overtime and a noticeable lack of turbot less than 5 years old on the EBS shelf between 2019 and 2023. There was evidence of one-year olds in 2023 and 2024. It should be noted that the proportion of

positive hauls is much lower in recent years than between 2007-2010 when we last saw a relatively strong recruitment event.

Aleutian Islands bottom trawl survey

The Aleutian Islands bottom trawl survey is not included in the stock assessment model. Given the depth constraints of this survey (i.e., maximum depth of 500 m), and fair amount of variability, the biomass estimates are not used as a relative index of abundance in the assessment model. The majority of AI bottom trawl biomass has come from a single maximum haul, where on average 50% of the biomass is from the haul with maximum catch (Figure 5.18). This helps to explain the high uncertainty of the biomass estimates and is unlike the EBS shelf and slope bottom trawl surveys where this percentage is much lower (Figure 5.16). We report on the trends of this survey as it is used to allocate the ABC between the Bering Sea and Aleutians in years when the slope survey and the Aleutians Islands survey overlapped.

Biomass was highly variable between 1980 and 2006 with a high of 31,759 t and then consistently declined to a low 373 t in 2018. Biomass increased to 539 t in 2022 and 604 t in 2024 (Table 5.9, Table 5.13). The 2026 AI survey biomass increased to 804 t, which represents a 45% increase. Although the 2026 biomass increased, the estimate remains below average biomass between 1991 and 2026. Average biomass for the AI bottom trawl survey is 9,111 t. The index in numbers showed a similar trend and declined to a low of 54,327 in 2018 and increased to 177,309 in 2022 and 229,622 in 2024, and 313,721 in 2026. Biomass in the Aleutian Islands was generally highest in the eastern AI, followed by the central AI (Table 5.9).

Longline survey

The domestic AFSC longline survey for sablefish has conducted biennial sampling in the Aleutian Islands and biennial sampling in the Bering Sea since 1996. Area-based RPNs are in Table 5.11. The combined time series has been included in the assessment as a relative abundance index (Figure 5.13). The RPN index for Greenland turbot was computed for all previous assessments by taking the average RPN from 1997-the model end year 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 (1996-2024) 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. Additionally, it has been assumed that the log standard error is the same for all years and has been set equal to 0.198.

The status quo approach for computing the combined BSAI is problematic because it relies on long-term average RPNs interpolated between years. This often results in abrupt changes in the index that are believed to be an artifact of the interpolation method and not actual changes in the population. For 2024, we recommend a new linear approximation approach to obtain region-specific estimates in off-survey years, provide a more statistically sound continuous survey index, and to obtain annual coefficient of variance (CV) estimates (Longline Survey Team, personal comms Jan 2024). The off-survey year, area-specific RPN estimates were obtained using a linear interpolation approach executed using the na.approx function in the zoo R package (Zeileis and Grothendieck 2005). The off-year estimate was interpolated from the two nearest data points and the end years were set equal to the nearest year, resulting in a

continuous area-specific time series. This was done for the Aleutian Islands and the Bering Sea separately. The annual, area-specific RPNs were then summed to derive a single BSAI RPN time series. The same process was done for the area-specific CVs. Given that the status quo approach results in continuously changing time series, the linear approximation approach seems to be a reasonable and statistically appropriate method to derive the index. This alternative index is included in models 25.0, 25.3a, 25.4a, and 26.3.

The RPNs from the status quo approach are highly variable in the first four years of the time series and again in the latter half of the time series (Figure 5.12). The linear interpolation approach smooths this variability, but also provides realistic uncertainty estimates, which includes inter-annual variation in the uncertainty. Uncertainty is low at the beginning of the RPN time series from the linear interpolation method and then ranges between 0.14 and 0.21. The higher uncertainty estimates correspond to a period of time when RPNs declined and then leveled off.

Discussions with the survey managers have revealed whale depredation on this survey may affect the index and as such, data affected by depredation are removed from the RPN analysis. We evaluated the killer whale depredation rates with respect to the RPN index in 2024. This evaluation shows that as the rate of killer whale depredation on the survey longline sets increased and leveled off in the Bering Sea the RPN index declines and levels off to a low level (Figure 5.19). Given this moderately strong relationship between killer whale depredation and the RPNs, the variance estimates from the linear interpolation approach seems to more adequately describe the uncertainty of this index than assuming a constant CV.

Survey change as of 2026

The 2026 longline survey sampled the Bering Sea and Aleutian Islands. Previously the Bering Sea and Aleutian Islands were sampled on alternate years. For the foreseeable future, the Bering Sea and Aleutian Islands will be surveyed within the same year. As such, the 2026 RPN value is summed across the two regions and is not from the interpolation method.

The longline survey RPNs sharply declined from the start of the time series to 2006 and then the decline slowed (Figure 5.13). The 2026 RPN estimate was 47% lower than the RPNs in 2023 and remains below the time series average .

The length data from the AFSC longline survey were also included in the model (Figure 5.11). The length data included in the model are not sex-specific and generally range between 50 cm and 100 cm. There is a clear shift in the AFSC longline size distributions after 2002. Figure 5. 20 shows the number of 35cm and larger fish captured by the longline survey over space and time.

Analytic approach

General 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 seven years as newer versions have become available. Stock Synthesis version 3.30.24 was used for this assessment.

Model parameters were estimated by maximizing the log posterior distribution of the predicted observations given the data. The model included two fisheries, those using fixed gear (longline and pots) and those using trawls, and up to three surveys covering various years. The assessment model also uses the Beverton-Holt stock-recruitment curve and recruitment deviations are estimated.

Description of Alternative Tier 3 models

Several alternative models were reviewed in September 2026 and the following models were evaluated for November 2026. The table below provides a snapshot of the differences across the tier 3 models, which will be further explained within this section.

Model	Description
25.0	Model 16.4c from 2024 with the following changes: Linear interpolation method to derive AFSC LL RPNs
25.3a	25.0 with the following changes: SRR autocorrelation fixed = 0.437 Analytical solution for survey catchability values New survey multinomial sample size and Francis re-weighting
25.4a	25.3a with the following changes: Two EBS slope BTS time blocks on selectivity (pre-2002 and 2002 – end year of model)
26.3	25.4a with a start year = 1977 and early recruitment deviations 1967 – 1976

Parameters Estimated Outside the Assessment Model

All parameters estimated outside of the assessment model were the same across models and are as follows:

Parameter	Estimate	Source
Natural Mortality	0.112	Cooper et al. (2007)
Length at Age		
L_{min} CV	15%	Gregg et al. (2006)
L_{max} CV	9%	Gregg et al. (2006)
Maturity and Fecundity		
Length 50% mature	60	D'yakov (1982), Cooper et al. (2007)
Maturity curve slope	-0.25	D'yakov (1982), Cooper et al. (2007)
Eggs/kg intercept	1	D'yakov (1982), Cooper et al. (2007)
Eggs/kg slope	0	D'yakov (1982), Cooper et al. (2007)
Length-weight		
Male		
Alpha	3.43×10^{-6}	1982, 1998, 2003-2024 EBS bottom trawl survey data
Beta	3.2189	1982, 1998, 2003- 2024 EBS bottom trawl survey data
Female		
Alpha	2.44×10^{-6}	1982, 1998, 2003- 2024 EBS bottom trawl survey data
Beta	3.325	1982, 1998, 2003- 2024 EBS bottom trawl survey data
Recruitment		
Steepness	0.79	Myers et al. (1999)
Sigma R	0.6	Ianelli et al. (2011)
Autocorrelation	0.437	Thorson et al. (2014), for models 25.3a, 25.4a, 26.3

Natural mortality and length at age

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. The reference age for the first size at age is assumed to be the same for both sexes and the variability in length at age 1 was assumed to have a CV of 15% while at maximum age a CV of 9% was assumed. This appears to encompass the observed variability in length-at-age. Annual mean size-at-age data from the EBS shelf and slope bottom trawl surveys were used in this assessment.

Maturation and fecundity

Maturity and fecundity followed the same assumptions as the 2024 model (and previous models) with the female length at 50% mature at 60 cm as per D'yakov (1982). A logistic maturity-at-length 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. An updated maturity ogive is expected in 2027.

Weight at length relationship

The weight at length relationship was derived using the combined data from the Bering Sea bottom trawl surveys conducted by the Alaska Fisheries Science Center. From 2003 to 2011 the Greenland turbot stock assessment models used the same weight at length relationship for males and females ($w = 2.44 \times 10^{-6} L^{-}$

$^{3.34694}$, where L = length in cm, and w = weight in kilograms). Given the great deal of sexual dimorphism observed in this species it was thought that having separate weight at length relationships for males and females would better capture the diversity in this stock. Starting in 2012 the relationship was updated to $w = 2.43 \times 10^{-6} L^{3.325}$ for females and $w = 3.40 \times 10^{-6} L^{3.2189}$ for males. This relationship is similar to the weight at length relationship observed by Ianelli et al. (1993) and used in the Greenland turbot stock assessment prior to 2002. The weight at length analysis was first presented at the September 2012 Plan team and SSC meetings (Barbeaux et al. 2012, Appendix 5.1). Current estimates using updated data are similar (Figure 5.21).

Size composition multinomial sample size

There is always difficulty in determining the appropriate multinomial sample size for the size composition data (Hulson et al. 2023). In the last accepted model, model 16.4c, and in model 25.0 the initial annual sample sizes for each year and fishing fleet were set to 50. The annual size composition sample sizes for the shelf survey were set at 200, and the pre-2002 slope surveys set at 25, while 2002 and later set at 400. The sample size for the slope survey was increased to 400 to better balance these surveys with the more frequent shelf survey. The multinomial sample size for the AFSC longline survey was set equal to 60 in model 25.0, as was done in the last full assessment.

A new bootstrapping approach to determine the input sample size for the AFSC bottom trawl surveys has been advocated (Hulson and Williams 2024). An R package has been developed to generate bootstrap replicates of the standard design-based indices of length composition from the AFSC bottom trawl survey data. The bootstrap replicates are then used to estimate the input sample size (ISS) for these data sources. The general bootstrap framework is described in Hulson et al. (2023) for age and length composition from AFSC bottom trawl surveys. This method was used to obtain the input sample size for the EBS shelf survey and EBS slope survey length composition data for models 25.3a, 25.4a, and 26.3 as an alternative to what has been used in the past. A comparison between what is used in last accepted assessment model and 25.0 and the values from this new method are summarized in Table 5.13. The sample size output from the afscISS package accounts for the survey-specific, inter-annual variability in the starting multinomial sample size as compared the static, survey-specific sample sizes used in 25.0. Currently this approach is not available for the fishery data; therefore, as an alternative to model 25.0, we used the number of unique hauls as the starting multinomial sample size (Table 5.14).

Parameters Estimated Inside the Assessment Model

The name of key parameters estimated in the models and number of parameters within the candidate models were:

Model	25.0	25.3a	25.4a	26.3
Recruitment				
Early Rec. Devs	(1945-1970) 26	(1945-1970) 26	(1945-1970) 26	(1967-1976) 10
Main Rec. Devs	(1971-2022) 52	(1971-2022) 52	(1971-2022) 52	(1977 - 2022) 46
Future Rec. Devs	(2023-2026) 4	(2023-2026) 4	(2023-2026) 4	(2023-2026) 4
R_0	1	1	1	1
Autocorrelation ρ	1	0 (ρ= 0.437)	0 (ρ= 0.437)	0 (ρ= 0.437)
Natural mortality				
Male	0 (M = 0.112)	0 (M = 0.112)	0 (M = 0.112)	0 (M = 0.112)
Female	0 (M = 0.112)	0 (M = 0.112)	0 (M = 0.112)	0 (M = 0.112)
Growth				
L_{min} (M and F)	2	2	2	2
L_{max} (M and F)	2	2	2	2
Von Bert K (M and F)	2	2	2	2
Catchability				
q_{shelf}	0 (fixed)	0 (float)	0 (float)	0 (float)
q_{slope}	0 (fixed)	0 (float)	0 (float)	0 (float)
q_{AFSC_LLS}	1	0 (float)	0 (float)	0 (float)
Selectivity				
Trawl fishery	13	13	13	11
Longline fishery	28	28	28	28
Shelf survey	17	16	16	14
Slope survey	18	14	10	10
AFSC longline survey	2	2	2	2
Total Parameters	169	163	159	132

Recruitment and initial conditions

For all models, a single unfished recruitment parameter,R_0, was assumed for all years. The model used the Beverton-Holt stock recruitment curve with steepness (h) set to 0.79 and σ_R set to 0.6, consistent with

values found for Greenland turbot stocks in the North Atlantic and Arctic Ocean (Myers et al. 1999). An autocorrelation parameter was used in model 25.0 where the prior component due to stock-recruitment residuals (ε_i) is:

$\pi_R = \frac{\varepsilon_1^2}{2\sigma_R^2} + \sum_{i=2}^{n} \frac{(\varepsilon_i - \rho\varepsilon_{i-1})^2}{2\sigma_R^2(1-\rho^2)}$, and ρ is the autocorrelation coefficient and σ_R^2 is the assumed stock recruitment variance term. Model 25.0 uses a prior of 0.437 (SD=0.265) estimated by Thorson *et al.* (2014) for Pleuronectidae species. Models 25.3a, 25.4a, and 26.3 assume recruitment is autocorrelated at a fixed value (ρ = 0.437). This alternative is evaluated because a simulation experiment showed that SS3 poorly estimates the autocorrelation parameter (Johnson et al. 2019). It is now recommended to use an external estimate for the autocorrelation from the recruitment deviations and fix it in the model.

The first year of models 25.0, 25.3a, and 25.4a was 1945 allowing some flexibility in estimating a variety of age classes in the model given the assumed natural mortality of 0.112. Recruitment deviations for 1945-1970 (early recruitment deviations) were estimated separately from the post-1970 recruitment deviations. Separating the recruitment deviations can be used to reduce the influence of recruitment estimation in the early period when there is little data on the later period in some model configurations.

The start year for model 26.3 was 1977, a later start than the other models and matches with the majority of available data. The initial conditions of the model have been identified as a model uncertainty. Namely, the assessment model that has been used for management estimated an initially small population that is highly productive, where the model estimates the largest recruitment events in the 1960s and 1970s. This corresponds to a data-poor period of the model, where catch data start in the 1960s and the length composition data starts in the late 1970s for the fishery and some surveys. Given the model dependence on length data and the variation in length-at-age, the information the length data provide about recruitment as early as 1945 is likely limited. Length-at-age begins to asymptote around age ten Greenland turbot; therefore, the length data are likely informative about ten years prior to the start of the data (Figure 5.10). Early recruitment deviations in model 26.3 start in 1967.

Catchability

Catchability for the EBS shelf and EBS slope surveys were fixed in the last accepted assessment model and model 25.0. Since the 2015 assessment, the catchability values used in the model were $\log(q_{shelf}) = -0.485$ and $\log(q_{slope}) = -0.556$. The survey-specific catchability values were estimated from the 2015 Model 14.0 fit without the 2007 - 2015 data. This was meant to eliminate the effects of the 2007 through 2010 year classes. During the CIE review in 2021, the CIE reviewers indicated that the "practice of using estimates from an older model run is not recommended, because it uses the first part of the data twice". Models 25.3a, 25.4a, and 26.3, used the float option in SS3 where the model derives an analytical solution for survey-specific catchability.

Selectivity

Selectivity for the AFSC longline survey was modeled using the logistic selectivity pattern, where the length at 50% selectivity and the slope parameter were estimated. Selectivity for the AFSC longline survey is not sex-specific because prior to 2021. All models treat the AFSC longline survey selectivity in the same way. During the next full assessment, sex-specific selectivity for year 2021-2023 and 2026 will be explored.

Sex-specific size-based selectivity functions were estimated for the two bottom trawl surveys and the two fisheries and modeled using a double normal pattern. The double normal selectivity pattern is described by 6 parameters describing the peak of the curve, the width of the plateau, the width of the ascending arm of the curve, the width of the descending arm of the curve, the selectivity at the first length bin, and the

selectivity at the last length bin. Female selectivity for the trawl fishery and the slope survey was offset from the estimated male selectivity because the ratio of males in the length composition is generally higher than females. The male selectivity was offset from the female selectivity for the longline fishery and the shelf survey since the proportion of females caught is generally higher than males. The selectivity of the opposite sex is differentiated by 5 additional parameters:

- p1 is added to the first selectivity parameter (peak)
- p2 is added to the third selectivity parameter (width of ascending side)
- p3 is added to the fourth selectivity parameter (width of descending side)
- p4 is added to the sixth selectivity parameter (selectivity at final size bin)
- p5 is the scale of apical selectivity

Time blocks were used to estimate time varying selectivity for the fishery and the shelf and slope bottom trawl surveys. This is a longstanding feature of the Greenland turbot model and in doing so, it is assumed that selectivity changes over time due to changing availability of certain size classes (e.g., when there is a recruitment event). The time blocks used in Model 25.0 and 25.3a are as follows:

Fleet/survey			
EBS shelf survey	1945 – 1991	1992 – 1995	1996-2000, 2001 - 2026
EBS slope survey	1945 – 2001	2002 – 2010	2011 - 2026
Trawl fishery	1945 – 1988	1989 – 2005	2006 - 2026
Longline fishery	1945 – 1990	1991 – 2007	2008 - 2026

The time block structure in model is consistent with past spatial shifts and changes in the observed length composition data of the fishery fleets; therefore, we retained the fishery selectivity time blocks in all models (Bryan et al. 2024).

The EBS slope bottom trawl survey is a short time series and the 2011 – 2026 time block in models 25.0 and 25.3a includes two years of data (2012 and 2016). Given the limited temporal scope of this survey, we removed last time block from the EBS slope bottom trawl survey selectivity.

The following tables specify the estimated selectivity parameters. Models 25.4a and 26.3 had once less time block for slope selectivity, which explains the difference from the other models. Any other reductions in the estimated selectivity parameters was due to either the parameter hitting a lower or upper bound or was estimated with high variance and had little baring on the estimate of the selectivity curve.

Estimated selectivity parameters	25.0	25.3	25.4	26.3
Size_DblN_peak_FshTrawl(1)	X	X	X	X
Size_DblN_ascend_se_FshTrawl(1)	X	X	X	X
Size_DblN_descend_se_FshTrawl(1)	X	X	X	X
Size_DblN_start_logit_FshTrawl(1)	X	X	X	X
SzSel_Fem_Peak_FshTrawl(1)	X	X	X	X
SzSel_Fem_Descend_FshTrawl(1)	X	X	X	X
Size_DblN_peak_FshLL(2)	X	X	X	X
Size_DblN_top_logit_FshLL(2)	X	X	X	X
Size_DblN_ascend_se_FshLL(2)	X	X	X	X
Size_DblN_descend_se_FshLL(2)	X	X	X	X
Size_DblN_end_logit_FshLL(2)	X	X	X	X
SzSel_Male_Peak_FshLL(2)	X	X	X	X
SzSel_Male_Ascend_FshLL(2)	X	X	X	X
SzSel_Male_Descend_FshLL(2)	X	X	X	X
SzSel_Male_Final_FshLL(2)	X	X	X	X
SzSel_Male_Scale_FshLL(2)	X	X	X	X
Size_DblN_peak_SHELF(3)	X	X	X	X
Size_DblN_descend_se_SHELF(3)	X	X	X	
Size_DblN_start_logit_SHELF(3)	X	X	X	X
Size_DblN_end_logit_SHELF(3)	X	X	X	X
SzSel_Male_Peak_SHELF(3)	X	X	X	X
SzSel_Male_Ascend_SHELF(3)	X	X	X	X
SzSel_Male_Descend_SHELF(3)	X	X	X	X
SzSel_Male_Final_SHELF(3)	X	X	X	X
Size_DblN_peak_SLOPE(4)	X	X	X	X
Size_DblN_top_logit_SLOPE(4)	X	X	X	X
Size_DblN_ascend_se_SLOPE(4)	X	X	X	X
SzSel_Fem_Peak_SLOPE(4)	X	X	X	X
SzSel_Fem_Ascend_SLOPE(4)	X	X	X	X
SzSel_Fem_Descend_SLOPE(4)	X			
SzSel_Fem_Final_SLOPE(4)	X			
SzSel_Fem_Scale_SLOPE(4)	X	X		
Size_inflection_AFSC_LONGLINE(5)	X	X	X	X
Size_95%width_AFSC_LONGLINE(5)	X	X	X	X

The estimated selectivity parameters continued:

Estimated selectivity parameter	25.0	25.3	25.4	26.3
Size_DblN_peak_FshTrawl(1)_BLK7repl_1945	X	X	X	X
Size_DblN_peak_FshTrawl(1)_BLK7repl_1989	X	X	X	
Size_DblN_ascend_se_FshTrawl(1)_BLK7repl_1989	X	X	X	X
Size_DblN_descend_se_FshTrawl(1)_BLK7repl_1945	X	X	X	
Size_DblN_descend_se_FshTrawl(1)_BLK7repl_1989	X	X	X	X
SzSel_Fem_Peak_FshTrawl(1)_BLK7repl_1989	X	X	X	X
SzSel_Fem_Descend_FshTrawl(1)_BLK7repl_1989	X	X	X	X
Size_DblN_peak_FshLL(2)_BLK9repl_1945	X	X	X	X
Size_DblN_peak_FshLL(2)_BLK9repl_1991	X	X	X	X
Size_DblN_top_logit_FshLL(2)_BLK9repl_1945	X	X	X	X
Size_DblN_top_logit_FshLL(2)_BLK9repl_1991	X	X	X	X
Size_DblN_ascend_se_FshLL(2)_BLK9repl_1945	X	X	X	X
Size_DblN_ascend_se_FshLL(2)_BLK9repl_1991	X	X	X	X
Size_DblN_descend_se_FshLL(2)_BLK9repl_1945	X	X	X	X
Size_DblN_descend_se_FshLL(2)_BLK9repl_1991	X	X	X	X
Size_DblN_end_logit_FshLL(2)_BLK9repl_1945	X	X	X	X
Size_DblN_end_logit_FshLL(2)_BLK9repl_1991	X	X	X	X
SzSel_Male_Peak_FshLL(2)_BLK9repl_1945	X	X	X	X
SzSel_Male_Peak_FshLL(2)_BLK9repl_1991	X	X	X	X
SzSel_Male_Ascend_FshLL(2)_BLK9repl_1945	X	X	X	X
SzSel_Male_Ascend_FshLL(2)_BLK9repl_1991	X	X	X	X
SzSel_Male_Final_FshLL(2)_BLK9repl_1945	X	X	X	
SzSel_Male_Final_FshLL(2)_BLK9repl_1991	X			
SzSel_Male_Scale_FshLL(2)_BLK9repl_1945	X	X	X	X
SzSel_Male_Scale_FshLL(2)_BLK9repl_1991	X	X	X	X
Size_DblN_descend_se_SHELF(3)_BLK2repl_1945	X	X	X	X
Size_DblN_descend_se_SHELF(3)_BLK2repl_1992	X	X	X	X
Size_DblN_descend_se_SHELF(3)_BLK2repl_1996	X	X	X	
Size_DblN_start_logit_SHELF(3)_BLK2repl_1945	X			
Size_DblN_start_logit_SHELF(3)_BLK2repl_1992	X	X	X	X
Size_DblN_start_logit_SHELF(3)_BLK2repl_1996	X	X	X	X
Size_DblN_end_logit_SHELF(3)_BLK2repl_1945	X	X	X	X
Size_DblN_end_logit_SHELF(3)_BLK2repl_1992	X	X	X	X
Size_DblN_end_logit_SHELF(3)_BLK2repl_1996	X	X	X	X
Size_DblN_peak_SLOPE(4)_BLK8repl_2002	X	X	X	X
Size_DblN_peak_SLOPE(4)_BLK8repl_2011	X			
Size_DblN_top_logit_SLOPE(4)_BLK8repl_2002	X	X	X	X
Size_DblN_top_logit_SLOPE(4)_BLK8repl_2011	X	X		
Size_DblN_ascend_se_SLOPE(4)_BLK8repl_2002	X	X	X	X
Size_DblN_ascend_se_SLOPE(4)_BLK8repl_2011	X	X		
SzSel_Fem_Peak_SLOPE(4)_BLK8repl_2002	X	X	X	X
SzSel_Fem_Peak_SLOPE(4)_BLK8repl_2011	X			
SzSel_Fem_Ascend_SLOPE(4)_BLK8repl_2002	X	X	X	X
SzSel_Fem_Ascend_SLOPE(4)_BLK8repl_2011	X	X		

Variance adjustment of length composition data

The last accepted assessment model and model 25.0 used the following variance adjustment for the length composition data: The variance adjustment was not derived from the Francis method, rather it was an ad hoc attempt to balance the length composition weights with the survey indices CVs.

Fleet	Sample size (same in all years)	Variance adjustment	Adjusted sample size
Trawl fishery	50	0.25	12.5
Longline fishery	50	0.5	25
EBS shelf survey	200	0.25	100
EBS slope survey	400	0.5	200
AFSC longline survey	60	0.5	30

The starting sample sizes were updated from the afscISS R package for the bottom trawl surveys or the number of unique observed hauls from each fishery in models 25.3a, 25.4a, and 26.3. The starting sample sizes were much larger compared to model 25.0. Therefore; to scale the sample size of the length composition data and to balance the length composition and index data, the Francis method to iteratively re-weight composition data was used (Table 5.14).

Description of Tier 5 models

In 2025, the Plan Team requested that the authors present the results of a Tier 5 assessment for this stock. In September 2026, we presented a REMA model (Sullivan et al. 2022b) fit to all available survey data: biomass from the EBS shelf, EBS slope, and AI bottom trawl surveys, and relative population weights (RPWs) from the AFSC longline survey in the EBS and AI. That model estimated two process error terms. One was for the EBS shelf, which mostly samples juvenile fish, and the other was shared by the AI and EBS slope strata, which sample adults. It also estimated two parameters (q), which scaled the AI and EBS RPWs to biomass in the corresponding bottom trawl survey strata.

Following Plan Team and SSC feedback and consultation with AFSC staff familiar with REMA, we propose a model fit to a reduced set of surveys: the AI BTS, the EBS slope BTS, and the EBS LLS RPWs. The EBS shelf BTS was excluded because it mostly encounters small fish that are not exploited by the fishery. The AI LLS was excluded because it samples only the eastern AI and does not match the spatial extent of the AI bottom trawl survey (Shotwell and Sullivan 2024). The EBS slope longline survey is retained because it is the only source of recent information on adult abundance on the EBS slope, where the bottom trawl survey was discontinued after 2016. The resulting biomass estimate represents adult Greenland turbot on the EBS slope and in the AI.

The preferred tier 5 model has two spatial strata, AI and EBS slope, which share a single process error term because they represent the same adult population. A single q scales the EBS slope longline survey RPWs to EBS slope biomass. The model starts in 1991, the first year of the AI bottom trawl survey.

We ran four alternative configurations to evaluate the effect of including different subsets of survey indices:

1. The September 2026 model, with all surveys. This model represents the approach taken in September and in 2025, to be compared to the new proposed model.

2. All surveys except the EBS shelf bottom trawl survey, to isolate the contribution to biomass of the EBS shelf population.
3. All surveys except the AI longline survey, to evaluate the effect of only including the AI BTS as representative of the entire AI region.
4. The proposed model with longline survey relative population numbers (RPNs) instead of RPWs, to evaluate the effect of using a number-based index of abundance.

The use of the tier 5 model could be twofold. The first is that it will be used for the spatial apportionment of ABC between the Bering Sea and the Aleutian Islands. The Plan Team and SSC approved of this in 2024. The second, would be to use as an interim alternative to the tier 3 stock assessment model.

Age Structured Model Results

Evaluation of Model(s) and Associated Uncertainty

Model 25.0 is the 2026 base model. It is an update of model 16.4c (the 2024 assessment model used for management). The main difference is that model 25.0 includes the Plan Team and SSC recommended RPNs derived using an interpolation method to combine the Bering Sea and Aleutian Islands components of the AFSC longline survey prior to 2026. Model comparisons are largely made between model 25.0 and the higher numbered alternatives.

The likelihood results for all models are reported in Table 5.15. Given that there are differences in some of the data components (i.e., length composition data weighting) between Model 25.0 and the alternative models they are not all directly comparable; however, they do provide a general overview of how well the models fit the data components.

Overall, the alternative models demonstrate that persistent data conflicts and differential data weighting can result in different perspectives on the scale of this stock. Models 25.3a, 25.4a, and 26.3 strongly down weight the length composition data thereby upweighting the survey indices. Model fits to the indices were evaluated by comparing the RMSE values and likelihoods across models (Table 5.15, Table 5.16). The lowest overall survey likelihood indicates a better fit to models implementing the Francis method to reweight the length composition data, which strongly down weighted the length comps. This is largely driven by an improvement in fit to the AFSC longline RPNs (Table 5.15, Figure 5.22). With this improved overall survey likelihood, the RMSE and survey likelihood values for the shelf bottom trawl survey are similar across models. The fit to the EBS slope survey degrades with the down weighting of the length composition data, where the RMSE and slope survey likelihood is lowest for model 25.0. Models 25.3a, 25.4a, and 26.3 fit the 2002 slope data point better than model 25.0 but underestimates the second and last data points more so than model 25.0 (Figure 5.22). The model fits to the survey indices indicate that there is some conflict between the AFSC longline survey and EBS shelf bottom trawl survey with the EBS slope bottom trawl survey.

The estimates of catchability differed greatly when comparing the alternative models to model 25.0 (Table 5.16, Table 5.17). The fixed value of log(q) used in model 25.0 for the EBS shelf survey was -0.49 (or q = 0.61), whereas the alternative models all estimate log(q) to be a positive number and greater than 1 when exponentiated. Studies have shown that trawl surveys often have a catchability greater than one for flatfish due to their antipredator behavior of delayed movement to remain cryptic until predators are at a close distance (Ryer 2008, Bryan et al. 2014). This effectively allows for close contact with the fishing gear and herding of flatfish by the sweep of the trawl net as they try to move away. Catchability in model 25.0 for the EBS slope survey is set equal to log q = -0.56. The estimate of log q from models the alternative models were larger and were approximately -0.43, -0.46, and -0.16 for models 25.3a, 25.4a,

and 26.3, respectively (Table 5. 17). The log catchability estimate for the AFSC longline survey was ~1.02 from model 25.0 and ~1.42, 1.44, and 1.8 for models 25.3a, 25.4a, and 26.3, respectively. Exponentiated q is ~2.77, 4.13, 4.22, and 6.04 for models 25.0, 25.3a, 25.4a, and 26.3, respectively. The longline survey estimates seem to be in the realm of possibility given that the longline catchability estimate for sablefish is ~6 (Goethel et al., 2023).

The down weighting of the length composition data also resulted in lower size-at-age likelihoods for models 25.3a, 25.4a, and 26.3 than 25.0 (Table 5.14). This improvement in the fit to the mean length-at-age data suggests some conflict between the length composition data and the mean length-at-age. The estimated growth curves indicate a higher female and male asymptotic growth for models 25.3a, 25.4a, and 26.3 than 25.0 (Table 5.17, Figure 5.23). The estimates of the growth coefficient and minimum length at age were similar across models, indicating the improvement in the size-at-age likelihood was due to the estimate of asymptotic growth. Model fits to the separate data sources, EBS shelf survey and EBS slope survey, indicate that the residual patterns are similar across models while models 25.3a, 25.4a and 26.3 with smaller residuals than model 25.0 (Figure 5.24 – Figure 5.27). The EBS shelf survey size-at-age likelihood is lowest for models 25.4a and 25.3a has the lowest likelihood for the EBS slope survey (Table 5.15).

The fit to the aggregated longline/fixed gear length composition data was relatively similar among the models overall fit the distribution can captured the overall and annual modes well (Figure 5. 28- Figure 5. 31, Figure A.2). The fit to the aggregated male lengths from the trawl fishery was similar across models, all underestimate the overall and annual mode(s) of the distribution (Figure A.1). The fit to the female trawl fishery length distribution was best for model 25.0, where all alternative models over-estimate the mode. The fit to the aggregate EBS shelf length and EBS slope length composition data were better fit by model 25.0 than the alternative models. Whatever lack of fit model 25.0 exhibited was enhanced in the alternative models. The alternative models either under- or overestimate the first mode of the annual length distributions more so than 25.0 (Figure A.3). All models underestimated the peak of the male length distribution from the EBS slope survey. Fit to the aggregate AFSC longline length composition was similar among models. The standard deviation of the normalized residual (SDNR) was estimated to be around 1 for all fleets across models. This is an indication that the data variances are correctly specified. The SDNR for the slope bottom trawl survey in model 25.0 has an SDNR = 1.2 indicating they data may be overweighted.

Estimates of selectivity varied across the models, especially for the bottom trawl surveys (Figure 5. 32- Figure 5.36). The down weighting of the length composition data in the alternative models (25.3a – 26.3) led to differing estimates of selectivity that fit the fishery length data similarly (Figure 5. 32, Figure 5.33, Figure A.1, Figure A.2). The estimate of selectivity for the first time block of the trawl fleet had the greatest difference between model 25.0 and the alternatives. All had a dome shape, but the alternative models shifted towards and had higher selectivity on larger individuals (Figure 5. 32). Model 26.3 estimated the peak of the female selectivity during the first time block to be at it upper bound (i.e., largest length bin) and was therefore fixed to the value estimated by model 25.4a. Female trawl selectivity became less domed in the alternative models during the second time block, while all other trawl selectivity curves were similar across models. The female longline selectivity curves for the pre-1991 and 1991-2007 time block subtly shifted toward larger fish and the scale of male selectivity for the longline fishery was much lower for the alternative models than model 25.0 (Figure 5.33). The estimate of selectivity for the last time block for the two fishery fleets was most consistent across models.

The EBS shelf survey selectivity showed the greatest differences between model 25.0 and the alternative models (Figure 5. 34). Models 25.3a, 25.4a, and 26.3 estimated larger peak selectivity than model 25.0 for the first three time blocks, with the pre-1992 and 1996-2000 selectivity curves effectively shifting towards higher selectivity on larger fish and having a narrower dome. The within time block annual

length distributions exhibit cohort effects where individuals grow larger over time and the length distributions have secondary modes. The down weighting of the length composition data also indicates to the model that the data are uncertain and can be ignored allowing the model flexibility in estimating selectivity and helps to explain the shift in peak selectivity. The EBS slope survey selectivity exhibited variation across models for the 2002-2010 time block and 2011-2016 time block. The slope selectivity for the post 2002 time blocks widened and suggested higher selectivity on smaller fish for models 25.3a, 25.4a, and 26.3 (Figure 5. 35). This leads to greater overestimation of smaller individuals than in the observed length distributions. In 2008 and 2010, smaller (less than 70cm fish) were captured that were not present in 2002 and 2004 creating a bimodal distribution. This was also true in 2012 where the peak of the observed distribution is ~35cm. Therefore, with the lower data weight on the length composition data, the model estimated a wider selectivity curve. The estimate of the AFSC longline selectivity was fairly consistent among models (Figure 5.36).

Models 25.0, 25.3a and 25.4a estimates two large recruitment events prior to 1980 (Figure 5.37a). The level of estimated or assumed autocorrelation in recruitment impacted the magnitude of the recruitment peak in the early 1960s. Model 25.0 estimated a higher autocorrelation value than the fixed value in 25.3a and 25.4a, which spread the recruitment over several more years in the 1960s. Model 26.3 started in 1977 and estimated a much higher unfished recruitment (ln R0) than the other models (Table 5.16). All models estimated recruitment to be below average post-1980s; however, recruitment was smoothed over time by the alternative models (Figure 5.37b). In years where observations indicate that there was relatively strong recruitment (e.g., 2007-2010), the recruitment deviation estimates are lower for models 25.3a, 25.4a, and 26.3 than in model 25.0. The primary data informing recruitment estimation is length data and models 25.3a, 25.4a, and 26.3 employ variance adjustments that strongly down weight the length information and impacted recruitment estimation. For example, the alternative models poorly fit the annual EBS shelf length data and in particular underestimate the EBS shelf bottom trawl's proportions at smallest lengths from 2007-2010 (Figure A.3). This data set is a key source of information about recruitment.

A commonality among models 25.0, 25.3a, and 25.4a, is that they estimate an initially small population and then needs to estimate large recruitment deviations early in the time series to support the large catches observed in the 1960s - late 1970s (Figure 5.37a). Model 26.3 starts later and estimates an initially large. All models estimate a similar declining trend in SSB after the late 1970s (Figure 5.37c). Model 26.3 estimates early recruitment deviations prior to the model start year to initialize the population age structure rather than early recruitment deviations that allow variation in age-0 recruitment. The model therefore estimates a larger initial population to support the imputed equilibrium catch, which was the average observed catch from 1960 - 1977. Additionally. the alternative models estimate initial biomass to be larger than model 25.0. The shifts in the trawl and longline selectivity to have higher selectivity on larger fish in the first time block and thereby reducing selectivity on some portion of maturing fish, also allows the model to estimate higher initial biomass. Model 25.0 estimates SSB to be higher than the other models after 1970. Models 25.3a and 25.4a converge to a similar end year SSB, while model 26.3 estimates slightly lower SSB. A comparison with the 2024 estimate of SSB from the last assessment model and models from this year also demonstrates this pattern (Figure 5.37e).

The estimate of fishing mortality is highest for model 26.3 (Figure 5.37d).

Retrospective analysis (within model)

A retrospective analysis was completed for all models and was conducted in SS3 by removing annual data systematically for 10 years. All models have a positive pattern indicating that with each new year of data the estimates of SSB are less optimistic than the previous assessment. The Mohn's rho from the previous assessment using model 16.4c was 0.14. The retrospective pattern increased in 2026 using model 25.0 to 0.21 (Table 5.20). The alternative models have much larger retrospective patterns with Mohn's rho values $\geq$0.39. This larger retrospective pattern was largely driven by the analytical solution for the EBS shelf

bottom trawl survey catchability that declined with each peel effectively increasing the estimate of SSB (Figure 5. 38-Figure 5. 40). Additionally, the AFSC longline survey catchability also declined over the majority of peels. Model 26.3 had the largest retrospective pattern (Mohn's rho for SSB = 0.71). The analytical solutions of catchability for the bottom trawl surveys declined with each peel for Model 26.3. The same was true for the AFSC longline survey; however, the decline was steeper than what was exhibited by model 25.3a and then it leveled to a low of approximately 5.

Convergence Status and Criteria

A jitter analysis was also conducted to determine the stability of the candidate models. Starting from the parameter file the parameters were jittered by a 0.02 increment for 100 iterations. Model 25.0 had the 77 converged iterations, model 25.3a had 88, 25.4a had 83, and model 26.3 had converged iterations. This differed from the results in September 2026. After the September 2026 Groundfish Plan Team meeting we found an error in the jittering code that was resolved for November. An increase of the jitter fraction to 0.1, which is often used in stock assessments, altered the results, where 73, 31, and 38 iterations converged for models 25.0, 25.3a, and 25.4a, respectively.

Likelihood profiles for the growth parameters and unfished recruitment (lnR0) were conducted. The likelihood profile results for the asymptotic length parameter and unfished recruitment can be found in Appendix B. The likelihood profiles for lnR0 demonstrate that the recruitment likelihood, which is an indication of how well the expected recruitment fits the stock recruitment relationship, and length likelihoods were in conflict (Figure B.3). The recruitment likelihood was minimized at a higher value of lnR0 than the length likelihood for models 25.0, 25.3a, and 25.4a. The lower estimate for the length likelihood is driven by the EBS shelf bottom trawl survey length likelihood that was minimized at lower estimates of lnR0 than the EBS slope bottom trawl survey likelihood across models. Model 26.3 was the only model that included equilibrium catch and estimated equilibrium fishing mortality since the model starts in 1977 and the authors wanted to retain the early catches in the model. The equilibrium catch likelihood was in conflict with the other likelihoods and suggested that lnR0 should be larger. The lnR0 profiles also indicate some model instability.

The length at maximum age (i.e., asymptotic length in this model) of the von Bertalanffy growth relationship was largely driven by the length-at-age likelihood, where the survey specific likelihoods were in better agreement for the models that strongly down weighted the length composition data (i.e., not model 25.0). for the female growth relationship (Figure B.1). There was some conflict between the length likelihood components for the separate bottom trawl surveys in model 25.0. The asymptotic length for males was also largely driven by the size at age likelihood, but the bottom trawl surveys were in conflict across models (Figure B.2).

Leave one out (LOO) analyses were also conducted. The LOO results can be found in Appendix C. The LOO results for 25.0 and 25.4a suggest that the EBS slope survey and the AFSC longline survey act in opposite ways. Leaving the AFSC longline survey out from models 25.3a and 25.4a resulted in 3 selectivity parameters hitting bounds. In Each the peak of the slope survey selectivity for the pre-2002 time block reached its upper bound. In addition, the descending parameter and peak of the trawl fishery selectivity (males) also reached their upper bounds.

All models explored for this assessment demonstrated data conflicts between the length composition data and the survey data. Namely, the model best fit the AFSC longline RPNs when the length composition data were down weighted using the Francis method. The AFSC longline index is the only fishery-independent source of information about the adult Greenland turbot population. The alternative models incorporate several improvements to the model including use of AFSC longline RPNs from the linear approximation method, fixing the level of autocorrelation in recruitment (recommended by the SS3 developers), and uses the analytical solution for catchability. The increased retrospective pattern as compared to model 25.0, the relative instability of the alternative models, and the dampened estimates of

recruitment in years with observations of relatively strong recruitment (e.g., 2007-2010) are concerning and lead us to recommend **Model 25.0 to provide management advice.**

The variance adjustment in models 25.3a, 25.4a, and 26.3 led to the models effectively ignoring a large portion of the survey length data. The EBS shelf bottom trawl survey length composition data contains recruitment information in recent history. Models 25.3a, 25.4a and 26.3 resulted in recruitment estimates that were lower than model 25.0 due to underestimating the lower mode of the EBS shelf survey length composition data. It is generally recommended that Francis reweighting be applied to determine the data weights for variance adjustment. However, Francis reweighting led to down weighting of the trawl survey data and to poor fits to the length data. One possible reason for this was that length data from different sources contain competing information on population length structure, with shelf surveys capturing mostly smaller fish, and slope and longline surveys and fisheries sampling larger individuals. Additionally, possible size-selective killer whale depredation affecting longline surveys and fisheries, combined with the lack of slope survey data after 2016, means that little recent information is available on the length structure of the adult population. Another possibility for this severe down weighting may be due to asymmetric input sample size methods for the fishery fleets and bottom trawl survey input sample size. The fishery sample size was the number of hauls, whereas the bottom trawl survey sample size was based on the Hulson and Williams bootstrap approach. Future work could further explore some of these conflicts in the data and identify a variance adjustment method that weights different data sources more appropriately.

Tier 3 Projections

The projection model was run for models 25.0, 25.3a, and 25.4a. A preliminary catch estimate of 193 t was used in 2026 and 378 t were used in place of maximum permissible ABC for 2027 and 2028 to provide OFL and maximum ABC estimates. The preliminary catch for 2027 and 2028 was estimated as the product of the average proportion of the TAC captured (retained and discarded catch) over the previous 5 years (2021-2025), 28%, and the 2026 TAC, 1,328 t. The assumed fishing mortality ratios used in the projection were 96% trawl and 4% longline to represent the trends in the recent catch history.

The projected female spawning biomass is less than B40% and B35%, but greater than B17.5% in 2027 and 2028 for all models.

The projection results:

Quantity	As estimated or *specified* in 2024 for: 2025	2026	As estimated by 25.0 2027	2028	As estimated by 25.3a 2027	2028	As estimated by 25.4a 2027	2028
M (natural mortality rate)	0.112	0.112	0.112	0.112	0.112	0.112	0.112	0.112
Tier	3a	3b	3b	3b	3b	3b	3b	3b
Projected total (age 1+) biomass (t)	37,615	35,877	28,434	27,604	20,128	21,301	19,678	20,889
Female spawning biomass (t)	23,999	22,061	18,414	17,040	10,403	10,100	10,189	9,892
Projected								
$B_{100\%}$	58,812	58,812	56,211	56,211	55,877	55,877	57,544	57,544
$B_{40\%}$	23,525	23,525	22,485	22,484	22,351	22,351	23,018	23,018
$B_{35\%}$	20,584	20,584	19,674	19,674	19,557	19,557	20,140	20,140
F_{OFL}	0.2	0.2	0.2	0.2	0.22	0.22	0.22	0.22
$maxF_{ABC}$	0.17	0.17	0.17	0.17	0.20	0.20	0.20	0.20
F_{ABC}	0.15	0.15						
OFL (t)	2,598	2,059	1,356	1,107	516	511	477	472
maxABC (t)	2,237	1,771	1,165	951	445	440	411	407
ABC (t)	2,013	1,594						

Time Series Results

In this section we present the time series results from model 25.0 the recommended model. In all instances in this section "total biomass" refers to age 1+ biomass, spawning biomass is the female spawning biomass, and recruitment is age-0 numbers from the model unless otherwise specified.

Recruitment

Model 25.0 estimates an autocorrelation parameter for the recruitment deviations with a prior of 0.437 and standard deviation of the prior of 0.265. The estimated value for the autocorrelation parameter is 0.71 with a standard deviation of 0.03. The model predicts extremely large recruitments between 1960 and 1965 (Table 5.22). After 1970, the model estimates another large recruitment event in 1974-1976 with an average recruitment of 131 million age-0 fish for these three years with a maximum of 165 million age-0 fish in 1975 (Table 5.22). The current model estimates a small unfished population followed by large recruitment events to support the large early catch history. As there were no size composition prior to 1979, these early large recruitments are mainly informed by the early catches.

Recruitment from 1980 through 2007 was low with a mean of 4.8 million age-0 fish. Recruitment of age-0 fish was estimated to be 21.5 million, 17.5 million, and 2.5 million age-0 fish in 2008, 2009, and 2010, respectively (Table 5.22). Recruitment in 2008 was the largest since 1978. These recruitment events were captured over multiple years in the shelf survey size and age composition data, in the size composition from the last two slope surveys, and in the size composition data from 2012 and 2016 in the trawl fishery (Figure 5. 11). The influx of new recruits in 2007 through 2009 cause a sharp drop in the predicted

population mean size and mean age (Figure 5.41). The estimated numbers-at-age reflect the strong cohorts in the mid-1960s and late-1970s and from 2007-2009 (Table 5.22, Table 5.23, Figure 5.41). There was a noticeable lack of small turbot from the EBS shelf bottom trawl survey through 2022. The mean size on the shelf has steadily increased between 2010 and 2022 (Figure 5. 11, Figure 5. 14). Mean length declined in 2023 with a somewhat higher proportion of small fish and then increased due to a relatively higher proportion of larger fish in the observations. In general, the length data from the EBS shelf trawl survey indicates a general lack of recruitment over the last decade with a small level of recruitment in 2023.

Biomass and fisheries exploitation

The BSAI Greenland turbot spawning biomass was estimated to be 25,594 t in 2024 by model 16c and 22,724 t by model 25.0 (Table 5.24). Spawning stock biomass increased between 2014 and 2020 and has been declining since 2021. The large early 1980s fishery combined with a lack of good recruitment in the mid- to late-1980s and through the 1990s drove the steepest part of the decline in spawning biomass. The mean age-0 recruitment for 1986 to 1999 was 3.9 million fish. In 1990 the NPFMC cut the ABC to 7,000 t until 1996 to account for low recruitment; however the ABCs were exceeded in 5 of the 7 years (Table 5.1). The stock continued to decline in the 1990s as poor recruitment continued. In 1997, the NPFMC started managing the stock as a Tier 3 stock and the ABCs were allowed to increase (Table 5.1). The mean ABC between 1997 and 2002 was 9,783 t, the mean catch however was lower and averaged about 6,355 t per year over this period. From 2003 to 2008 the ABC levels remained relatively low with a high of 4,000 t in 2003 and a low of 2,440 t in 2007. The catch dropped even lower to an average of just 2,417 t per year in this period. In 2008, with Amendment 80, an arrowtooth/ Kamchatka fishery emerged and catch increased in 2009 and remained relatively high through 2012. The average catch for 2008 through 2012 was 3,988 t. The ABCs during this period, due to a clerical error in the projection model, went from 2,500 t in 2008 to 7,380 in 2009. From 2009 to 2012 the ABC averaged 7,325 t with a high at 9,660 t in 2012. Although the decline in spawning biomass began to slow in 2005 through 2007, the decline in spawning biomass again continued after 2008. This decline may be correlated with increased fishing pressure during this period. Between 1986 and 2007 the mean fishing mortality was estimated at 0.08 with a maximum of 0.13 (Table 5.22). The fishing mortality increased between 2008 and 2012 and ranged between 0.12 and 0.28. The effects of the incoming 2007-2010 year classes led to an increase in the female spawning biomass estimates between 2016 and 2019 has exhibited a declining trend since 2020.

The Model 25.0 total age 1+ biomass estimates declined between 1977 and 2013 to 53,004 t (Table 5.26). After 2013, total age-1+ biomass increased to 57,272 t in 2016 and has declined to 30,190 t in 2026 (Table 5.26). Numbers at length and age are also showing declines (Figure 5.41).

Tier 5 Model Results

The REMA model converged (convergence code: 0; maximum gradient component: 1.40e-07) and fits the survey data reasonably (Figure 5.42). Parameter estimates are in Table 5.18.

The Tier 5 estimate of adult Greenland turbot biomass in 2026 is 5,948 t (95% CI: 3,952–8,951 t; Table 5.18, **Error! Reference source not found.**). It is important to note that these values are not directly comparable to biomass estimates from the Tier 3 assessment because they only represent the adult portion of the population that inhabits the EBS and AI slope and do not include any of the EBS shelf population. However, general trends are consistent with the Tier 3 estimates. The REMA model attributed 91% of adult Greenland turbot biomass to the EBS slope, and 9% to the AI (average of the last 10 years; Table 5.20).

Sensitivity results

All models converged. Configurations that include the EBS shelf bottom trawl survey estimate higher total biomass, because they include the juvenile component of the population (Figure 5.44). Apportionment between areas changed among model configurations, but most of the biomass was attributed to the EBS

(88-96%, Table 5.20). Using RPNs instead of RPWs to fit the model produced different estimates of EBS slope biomass for the period before the start of the BTS survey (1996), and the q parameter is not comparable to the other models because it scales a different quantity to total population biomass.

We calculated the OFL and ABC estimates for the tier 5 models explored:

Model	2026 Biomass	OFL	ABC
Proposed model: No EBS shelf BTS, no AI LLS	5,948	666	500
All surveys (September model)	12,696	1,422	1,066
All surveys except EBS shelf BTS	5,901	661	496
All surveys except AI LLS	12,743	1,427	1,070
Proposed model with LLS RPN	7,042	789	592

The end year biomass estimate from the proposed tier 5 model is 5,948 t. The tier 5 OFL calculation is current year biomass estimate x natural mortality ($OFL_{preferred\ model}$= 5,968 t * 0.112). The tier 5 ABC calculation is current year biomass x 0.75*natural mortality ($ABC_{preferred\ model}$ = 5,968 t * 0.75*0.112). Therefore, the proposed tier 5 model suggests lower OFL and ABC recommendations than model 25.0.

Projections and Harvest Recommendations

Amendment 56 Reference Points

The $B_{40\%}$ value using the mean age-1 recruitment estimated for the period 1978-2024 gives a long-term average female spawning biomass of 22,485 t. The estimated 2026 female spawning biomass was at 18,414 t, which is below $B_{40\%}$ and the estimate of $B_{35\%}$ (19,674 t). Because the projected spawning biomass in year 2027 (t) is below $B_{40\%}$ and above the buffer threshold,Greenland turbot ABC and OFL levels will be determined at Tier 3b of Amendment 56.

Specification of OFL and Maximum Permissible ABC

In 2025 and 2026, the ABC set below max ABC, which has happened in previous years. For example, in 2008 the ABC recommendation was 21% of the maximum permissible level. The rationale for these lower values were generally due to concerns over stock structure uncertainty, lack of apparent recruitment, and modeling issues. The shelf survey length composition data indicated that there was strong recruitment between 2007 and 2010 (Figure 5. 11). There was also evidence of this recruitment event in the slope data in 2012 and 2016; however, there has been little evidence of a strong recruitment event after 2010. Given that recruitment remains below average, there is considerable uncertainty about future favorable environmental conditions for Greenland turbot, and the risk table scores the authors' recommend that ABC be reduced from maxABC. We do not have a specific reduction value to suggest, but we recommend using the tier 5 preferred model ABC as a threshold for a maximum reduction.

The 2027 estimated overfishing level based on the adjusted $F_{35\%}$ rate is 1,356 t corresponding to a full-selection F of 0.20. 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.

Standard Harvest Scenarios and Projection Methodology

A standard set of projections is required for stocks managed under Amendment 56, Tier 3. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2026 numbers at age as estimated in the assessment (age-1+). This vector is then projected forward to the beginning of 2027 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2026 (here assumed to be 193 t). The preliminary catch for 2027 and 2028 was estimated as the product of the average proportion of the TAC captured over the previous 5 years (2021-2025) and the 2025 TAC. 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 after 2026 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 are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2027, are as follow ($maxF_{ABC}$ refers to the maximum permissible value of F_{ABC} under Amendment 56):

- Scenario 1: In all future years, *F* is set equal to $maxF_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

- Scenario 2: In 2027 and 2028, *F* is set equal to a constant fraction of $maxF_{ABC}$, where this fraction is equal to the ratio of the realized catches in 2023-2025 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio catch to ABC will yield more realistic projections.)

- Scenario 3: In all future years, *F* is set equal to the 2021-2025 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 50% of $maxF_{ABC}$. (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 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 1) above its MSY level in 2026 or 2) above ½ of its MSY level in 2026 and above its MSY level in 2036 under this scenario, then the stock is not overfished.)

- Scenario 7: In 2027 and 2028, F is set equal to max F_{ABC}, and in all subsequent years F is set equal to FOFL. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2028 or 2) above 1/2 of its MSY level in 2028 and expected to be above its MSY level in 2038 under this scenario, then the stock is not approaching an overfished condition.)

Alternatives 1 through 7 were projected to year 2040 (Table 5.26). The 2026 biomass estimate is 19,709 t and below $B_{35\%}$ and above $B_{17.5\%}$, therefore it is not in an overfished status. The stock is not approaching an overfished status because although biomass in 2028, 17,040 t, is below $B_{35\%}$ and above $B_{17.5\%}$, the biomass in 2038 is above $B_{35\%}$.

Risk Table and ABC Recommendation

A general description of the risk table is available in the SAFE Introduction. The SSC in its December 2018 minutes recommended that all assessment authors use the risk table when determining whether to recommend an ABC lower than the maximum permissible. The following items were considered and summarized.

Assessment-related considerations

A key uncertainty in this assessment model is the starting biomass of this population. The model starts in 1945 to allow for the explicit inclusion of the early, large catch history (1960 – 1980) and to estimate the population age structure assuming no fishing pressure prior to 1960. The model estimates an initially small population in 1945 followed by large recruitment events to support the early catch history. The authors presented a model that started in 1977 (model 26.3) and demonstrated that the model would estimate the initial population to be much larger than what is currently being estimated. This suggests that there is considerable uncertainty in the estimate of initial population size and in turn stock status.

The data time series that have surveyed the adult portion of this stock and used in this assessment are becoming inconsistent. The lack of EBS slope bottom trawl survey data since 2016 and the impact of killer whale depredation on the AFSC longline survey, and the cancellation of the AFSC longline survey in 2023 add uncertainty in our understanding of the adult Greenland turbot population estimates.

All the candidate models showed positive retrospective patterns, highlighting that each new year of data resulted in a lower biomass estimate for this stock. In addition, jitter analyses and likelihood profiles highlighted considerable model instability. The model diagnostics suggested that there are some substantial structural uncertainties.

Given the unaccounted for uncertainties in the assessment model, the retrospective patterns, and the concerns for model structural uncertainty and instability, we scored this category as Level 3.

Population dynamics considerations

The BSAI Greenland turbot stock is characterized by infrequent recruitment events. The last relatively strong cohorts in the population are from 2007-2009. As they have grown and matured, we saw an increase in total biomass and spawning biomass, which is now starting to decline. Given the frequency of past recruitment events, we would have expected another in recent years. However, recruitment has been below average since 2012 and fish younger than 4 years old had not been observed in the EBS shelf bottom trawl survey between 2018 and 2022. In 2023 and 2024 we see small individuals in the data and in the age database there are observations of age-1 unsexed fish in 2023. The 2024 and 2025 age data, show evidence of this 2023 cohort, but it was a relatively small event as compared to the 2007-2010 recruitment.

Greenland turbot spawn in deep slope canyon habitats of the southeastern Bering Sea (SEBS), producing pelagic larvae and juveniles that undergo prolonged transport before settling in northern nursery areas

(e.g., near St. Matthew Island). January - March 2026 winds favored off-shelf and northwestward Ekman transport (Hennon, 2026), which may have advected larval turbot away from northern shelf nursery grounds. A positive condition in 2026 is that the 2°C cold pool was ~150% larger than in 2025 (largest since 2012) (Rohan and Barnett, 2026), providing expansive cold thermal habitat for juvenile recruitment.

We score this category as Level 2 given the uncertainty in future recruitment levels.

Ecosystem considerations

The following is a synthesis and interpretation of the most recent ecosystem information available for Greenland turbot from the Eastern Bering Sea Ecosystem Status Report (Siddon, 2026). This information supports the risk table scores and is organized below by the proposed risk table categories. We include information related to recruitment (egg, larvae, young-of-the-year or YOY, and early juvenile) in the Population Dynamics Considerations section and information on current conditions impacting late stage juveniles or adults in the Ecosystem Considerations section.

Based on ecosystem and oceanographic indicators provided in the 2026 Eastern Bering Sea Ecosystem Status Report (Siddon, 2026), the overall environmental and ecosystem-related risk for Greenland turbot is evaluated as 'Level 1 – Normal (no concern)'. Following a prolonged warm period (2014-2021), then four years of near-average thermal conditions (2022-2025), 2026 marked a sharp transition to cool oceanographic conditions across the eastern Bering Sea shelf. A late-winter (March/April) expansion of sea ice produced a 2°C cold pool ~150% larger than in 2025 (the largest since 2012) providing extensive, favorable cold benthic habitat for turbot. For early life stages and juvenile turbot, indicators of pelagic primary and secondary productivity as well as benthic productivity over the EBS shelf suggest sufficient prey resources were available in 2026. For adult turbot, survey biomass within the standard bottom trawl grid increased from 2025, though still well below the timeseries average, and individual morphometric condition (based on L/W residuals) was high (>+1 SD above the long-term mean in the northwest outer domain). Competitor and predator abundances (including apex predators like Pacific cod and arrowtooth flounder) remain below historical means, indicating minimal top-down or competitive pressure.

Summary for *Environmental/Ecosystem considerations:*

Distribution

Deep Water Habitat: Late-stage juveniles and adult Greenland turbot are cold-adapted, demersal flatfish inhabiting deep slope waters (400–800 m) and the outer continental shelf (stratum 60). The shallow Northern Bering Sea may act as a thermal barrier to northward movement during warm stanzas.

Cold Pool: The expansion of the 2°C cold pool in 2026 (~150% larger than 2025) (Rohan and Barnett, 2026), provided extensive cold benthic habitat across the middle and outer shelf.

Environmental Processes

Cool Thermal Conditions: 2026 bottom temperatures were comparable to historic cool years (1986, 1992, 2006, 2010) (Kearney, 2026) and cumulative annual SST anomalies in the SEBS dropped to their lowest point since prior to 2014, with no marine heatwaves in 2026 (Lemagie and Callahan, 2026), indicating no short- or long-term thermal stress for adult turbot in 2026.

Shelf Break Temperatures: Deep bottom temperatures along the EBS shelf break (246–255 m longline index) averaged 3.96°C, which is among the warmer years of the survey and warmer than the cold years of 2009, 2011, and 2013 (Siwicke, 2026).

Prey

Benthic Productivity & Prey Abundance: Indicators of benthic prey availability were positive in 2026. Benthic forager biomass increased 21% to its time-series mean (Whitehouse, 2026), motile epifauna biomass remained >+1 SD above its long-term mean (Whitehouse, 2026), and benthic fauna (eelpouts, poachers, sea stars) were all >+1 SD above average (Buser, 2026).

Positive Fish Condition: Morphometric condition (L/W residuals) for adult Greenland turbot was above +1 SD, with the highest condition recorded in stratum 60 (northwest outer domain) (Prohaska and Rohan, 2026), indicating good prey availability.

Competitors

Flatfish Niche Overlap: Arrowtooth flounder (ATF), Kamchatka flounder (KF), and Pacific halibut overlap ecologically with adult turbot as upper-trophic flatfish predators.

Biomass Trends: ATF survey biomass increased marginally by 1.38% from 2025 to 2026, while KF biomass increased 31.73% from 2025, both now just above their survey mean) (Whitehouse, 2026), indicating a possible increase in competitive pressure, but not outside historical levels.

Spatial Refuge: Greenland turbot occupy deeper bathymetric zones than arrowtooth flounder, providing spatial depth segregation and mitigating competitive overlap. Total apex predator biomass remains below its long-term average (Whitehouse, 2026).

Predators

Top-Down Control: Large adult turbot face minimal predation due to their deep-water demersal distribution, with potential minor depredation by toothed whales, though no ecosystem indicators exist from which to gauge changes in predation pressure for turbot.

Together, the most recent data available suggest an ecosystem risk Level 1 – Normal: “No apparent ecosystem concerns related to biological status (e.g., environment, prey, competition, predation), or minor concerns with uncertain impacts on the stock.”

Fishery-informed stock considerations

The fishery for Greenland turbot peaked in 1981. Following this period, catch declined with increasing management regulations and lowering population biomass. The lowest TAC, 2,060 t, was specified in 2013 after several years of relatively high fishing. Catch has been quite low compared to 1970 and 1980s levels since 2013 and has been declining since 2020. The longline industry has reported that they have not been fishing for Greenland turbot over the last several years due to whale interactions which may help to explain why TAC is not achieved. Conversely, the trawl fleet has obtained between 81% and 99% of the Greenland turbot catch since 2019. Industry representatives have indicated that due to avoiding the capture of other rockfish, their catch has remained low.

We score this category as a level 1.

Summary and ABC recommendation

Summarize the results of the previous subsections in a table.

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance considerations*
Level 3	Level 2	Level 1	Level 1

A reduction in maximum ABC may be warranted given the uncertainty about stock status, the loss of fishery-independent data in areas where the adult population is found, model structural uncertainty, and uncertainty about future recruitment.

Spatial Apportionment: Biologically-informed Recommended Distributions (BRDs)

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). Since 2005 the majority of the catch has been from the EBS (Table 5.3).

Stock structure between regions remains uncertain and therefore the policy has been to harvest the "stock" proportionately by specifying region-specific Biologically-informed Recommended Distribution (BRD). In 2025, the SSC agreed that we should use the REMA model to apportion between the EBS and Aleutian Islands. Using the author's preferred REMA model estimates the Aleutian Islands biomass to be 9% of the total and the Bering Sea biomass to be 91% of the total (Table 5.20).

	2027 maxABC	max2028 ABC
Aleutian Islands BRD	105	86
Eastern Bering Sea BRD	1060	865
Total	1165	951

Status Determination

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2025) is 618 t. This is less than the 2024 OFL of 2,598 t. Therefore, the BSAI stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be overfished. Any stock that is expected to fall below its MSST in the next two years is defined to be approaching an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2026:

a. If spawning biomass for 2026 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b. If spawning biomass for 2026 is estimated to be above $B_{35\%}$ the stock is above its MSST.

If spawning biomass for 2026 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6

If the mean spawning biomass for 2038 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

a. If the mean spawning biomass for 2028 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2028 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2028 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2038 If the mean spawning biomass for 2038 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and projection results presented in Table 5.26 the stock is not being overfished. Spawning biomass in 2026 is estimated to be 19,709 t and in 2028 is estimated to be 17,040 t. Both are below $B_{35\%}$ = 19,674 t, but above $B_{17.5\%}$ (9,837 t). Given that projected biomass in 2028 is between $B_{35\%}$ and $B_{17.5\%}$, we compare projected biomass in 2038 to $B_{35\%}$. Projected biomass in 2038 is 40,242 t under scenario 7; therefore, it is not approaching an overfished condition.

Ecosystem Considerations

Ecosystem Effects on the Stock

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.

The most recent large recruitment events 2007-2009 occurred during a series of years (2006-2013) in which the average bottom temperatures on the shelf were measurably colder on average and the area of cold water (< 2°C) on the Bering Sea Shelf was large (Zador *et al.* 2014). A simple Student's T test of the log recruitment by mean bottom temperatures on the EBS shelf (Barbeaux et al. 2016) as calculated by Spencer (2008) show a significant correlation (df = 31, R^2 = 0.2389, p-value = 0.0023) suggesting that favorable recruitment of Greenland turbot is dependent on colder overall bottom temperatures or larger areas with colder temperatures. Greenland turbot suitable settlement habitat is likely increased with the increase in the size of the area of the shelf < 2°C. Whether this is due to lessening competition, increased prey, or decreased predation is unknown. Foods habits data collected between 2001 and 2008 that the most frequent prey for Greenland turbot on the EBS shelf are walleye Pollock (Barbeaux et al. 2016) indicate. However temperature may be a much better predictor for Greenland turbot recruitment than pollock recruitment.

Fishery Effects on the Ecosystem

The Greenland turbot fishery has been rather small, less than 5,000 t annually since 2002, in comparison with the major Bering Sea longline and trawl gadid and yellowfin sole fisheries. The direct impact of the fishery on the ecosystem besides catch of Greenland turbot is through bycatch. FMP managed species bycatch in the Greenland turbot fishery can be found in Table 5.27. The highest bycatch has been of arrowtooth flounder (*Atheresthes stomias*) and sablefish (*Anoplopoma fimbria*), a low impact given the biomass of these species. Bycatch of Kamchatka flounder (*A. evermanni*) follows arrowtooth and sablefish. The non-FMP bycatch are summarized in and Table 5.28. Bycatch of prohibited species by gear type are summarized in Table 5.29 and Table 5.30. Grenadiers have been the highest non-FMP bycatch species in the Greenland turbot fishery, the impact to the ecosystem is thought to be minimal. Bird bycatch in the Greenland turbot fishery is limited to the longline fishery with a total of 3,922 estimated to have been caught since 2003. Northern fulmars (*Fulmarus glacialis*) are the most often captured with a total of 3,060 estimated to have been caught since 2003 (Table 5.28, Table 5.29). It is estimated that 6 endangered short-tailed albatross (*Phoebastria albatrus*) were killed incidental to the Bering Sea Greenland turbot hook-and-line fishery in 2014 based on the observed take of 2 short-tailed albatross (NMFS CAS). Despite documented interactions in the Bering Sea and Aleutian Islands groundfish fisheries, the short-tailed albatross population has been increasing at an estimated rate of 5.2 to 9.4 percent per year since 2000 (USFWS 2014) and interactions in the fishery appear to be extremely rare. NMFS monitors the fisheries for interactions with short-tailed albatross and requires use of seabird avoidance gear in the hook and line fisheries to make it unlikely that the fisheries will reduce the recovery of the short-tailed albatross population.

Data Gaps and Research Priorities

We recommend the following priorities:

- The survey data for this the adult portion of this stock is becoming more inconsistent. The eastern Bering Sea slope survey has not been conducted since 2016. The AFSC longline survey had a gap in coverage between 2023 and 2026 and the fishery is no longer targeting this stock, continued data loss is a concern. We recommend that the RACE GAP bottom trawl survey implement their proposed shelf-slope survey that surveys to at least 600m. The majority of catch from the EBS slope bottom trawl survey was below greater than 400m. Sampling the EBS slope as part of the larger EBS survey modernization would provide for a single and more comprehensive and consistent survey of the juvenile and adult habitat.
- The authors' are also planning to investigate whether close-kin mark recapture is a feasible method to develop an absolute index of abundance for this stock. The feasibility of this will be determined by whether enough samples can be collected and available funding to collect samples and conduct the genetic analysis.
- The stock assessment model for Greenland turbot is dependent on length data. The results show that there are persistent data conflicts between the length and survey data (e.g., to improve the model fit to the only survey index of the adult population the length composition had to be severely down weighted) and between the length and mean length-at-age data. A remedy to the conflicts could be the use of age data in the assessment model. We recommend and implemented a plan with the Age and Growth Program to age otoliths from the commercial fishery and we recommend that the AFSC longline survey begins collecting otoliths for Greenland turbot.
- During September plan team we discussed the potential use of a tier 4 harvest control rule for this stock. This allows for OFL and ABC to be derived from a reliable estimate of biomass (i.e., biomass from the rema model) and fishing mortality reference points to be derived given reliable estimates of maturity, which will be updated in early 2027, and selectivity. We suggest that this is evaluated for the CIE review scheduled for 2027.

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Tables

Table 5.1. Catch estimates of Greenland turbot by gear type (t; including discards), ABC and TAC values since implementation of the MFCMA, and the annual proportion of ABC and TAC achieved. *Catch estimated as of September 2026.

Year	Trawl	Longline/Fixed gear	Total	ABC	TAC	Percent ABC	Percent TAC
1977	29,722	439	30,161	40,000	-	75	-
1978	39,560	2,629	42,189	40,000	-	105	-
1979	38,401	3,008	41,409	90,000	-	46	-
1980	48,689	3,863	52,552	76,000	-	69	-
1981	53,298	4,023	57,321	59,800	-	96	-
1982	52,090	32	52,122	60,000	-	87	-
1983	47,529	29	47,558	65,000	-	73	-
1984	23,107	13	23,120	47,500	-	49	-
1985	14,690	41	14,731	44,200	-	33	-
1986	9,864	0	9,864	35,000	33,000	28	30
1987	9,551	34	9,585	20,000	20,000	48	48
1988	6,827	281	7,108	14,100	11,200	50	63
1989	8,293	529	8,822	20,300	6,800	43	130
1990	12,119	577	12,696	7,000	7,000	181	181
1991	6,246	1,618	7,863	7,000	7,000	112	112
1992	749	3,003	3,752	7,000	7,000	54	54
1993	1,145	7,325	8,470	7,000	7,000	121	121
1994	6,427	3,846	10,272	7,000	7,000	147	147
1995	3,979	4,216	8,194	7,000	7,000	117	117
1996	1,653	4,903	6,556	7,000	7,000	94	94
1997	1,210	5,990	7,200	9,000	9,000	80	80
1998	1,576	7,181	8,757	15,000	15,000	58	58
1999	1,795	4,058	5,853	9,000	9,000	65	65
2000	1,947	5,027	6,974	9,300	9,300	75	75
2001	2,149	3,164	5,312	8,400	8,400	63	63
2002	1,033	2,603	3,636	8,000	8,000	45	45
2003	931	2,181	3,111	4,000	4,000	78	78
2004	675	1,583	2,259	4,740	3,500	48	65
2005	729	1,880	2,608	3,930	3,500	66	75
2006	361	1,628	1,989	2,740	2,740	73	73
2007	458	1,546	2,004	2,440	2,440	82	82
2008	1,935	976	2,911	2,540	2,540	115	115
2009	3,080	1,435	4,515	7,380	7,380	61	61

Table 5.1 continued.

Year	Trawl	Longline /Fixed gear	Total	ABC	TAC	Percent ABC	Percent TAC
2010	1,977	2,158	4,136	6,120	6,120	68	68
2011	1,618	2,054	3,671	6,140	5,060	60	73
2012	2,613	2,054	4,667	9,660	8,660	48	54
2013	1,045	683	1,728	2,060	2,060	84	84
2014	951	684	1,635	2,124	2,124	77	77
2015	1,095	1,092	2,187	3,172	2,648	69	83
2016	1,228	1,008	2,236	3,462	2,873	65	78
2017	1,838	995	2,833	6,644	4,500	43	63
2018	1,550	285	1,834	11,132	5,294	16	35
2019	2,316	545	2,860	9,658	5,294	30	54
2020	2,035	291	2,326	9,625	5,300	24	44
2021	1,582	14	1,596	7326	6,025	22	26
2022	1,454	24	1,478	6,572	6,572	22	22
2023	1,235	46	1,281	3,960	3,960	32	32
2024	752	16	768	3,188	3,188	24	24
2025	604	15	618	1,678	1,678	37	37
2026	170	24	193*	1,328	1,328	-	-

Table 5.2. a) Overall annual discarded and retained catch and discard rates (percentage) of Greenland turbot based on NMFS estimates and b) annual discard rates of Greenland turbot within a target species group; 1991-2025.

a)

Year	Discarded	Retained	Total	Discard rate (Percent)
1991	2504	5360	7863	32
1992	3059	694	3752	82
1993	1787	6683	8470	21
1994	3232	7040	10272	31
1995	2405	5789	8195	29
1996	1823	4733	6556	28
1997	1660	5540	7200	23
1998	945	7813	8757	11
1999	729	5124	5853	12
2000	791	6184	6974	11
2001	921	4391	5312	17
2002	701	2934	3636	19
2003	534	2578	3111	17
2004	376	1882	2259	17
2005	249	2359	2608	10
2006	211	1778	1989	11
2007	299	1705	2004	15
2008	704	2207	2911	24
2009	461	4053	4515	10
2010	235	3901	4136	6
2011	94	3577	3671	3
2012	94	4573	4667	2
2013	345	1383	1728	20
2014	251	1384	1635	15
2015	113	2074	2187	5
2016	84	2152	2236	4
2017	100	2733	2833	4
2018	75	1760	1834	4
2019	62	2798	2860	2
2020	82	2244	2326	4
2021	47	1549	1596	3
2022	75	1404	1478	5
2023	71	1210	1281	6
2024	19	724	743	3
2025	21	598	618	3

Table 5.2. continued

b)

Year	Alaska Plaice - BSAI	Arrowtooth Flounder	Atka Mackerel	Flathead Sole	Greenland Turbot - BSAI	Halibut	Kamchatka Flounder - BSAI
1991	0.00	0.03	0.00	0.00	0.10	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	0.00	0.00	0.01	0.00	0.04	0.00	0.00
1994	0.00	0.00	0.00	0.00	0.04	0.00	0.00
1995	0.00	0.00	0.00	0.00	0.04	0.00	0.00
1996	0.00	0.00	0.01	0.01	0.03	0.00	0.00
1997	0.00	0.00	0.00	0.01	0.07	0.00	0.00
1998	0.00	0.01	0.01	0.01	0.03	0.00	0.00
1999	0.00	0.01	0.01	0.01	0.04	0.00	0.00
2000	0.00	0.01	0.01	0.01	0.03	0.00	0.00
2001	0.00	0.03	0.00	0.03	0.02	0.00	0.00
2002	0.00	0.04	0.00	0.01	0.02	0.00	0.00
2003	0.00	0.02	0.02	0.00	0.01	0.05	0.00
2004	0.00	0.01	0.02	0.04	0.01	0.03	0.00
2005	0.00	0.00	0.01	0.01	0.01	0.03	0.00
2006	0.00	0.01	0.02	0.00	0.01	0.00	0.00
2007	0.00	0.00	0.01	0.01	0.01	0.01	0.00
2008	0.00	0.14	0.03	0.00	0.00	0.00	0.00
2009	0.00	0.06	0.00	0.00	0.01	0.00	0.00
2010	0.00	0.02	0.00	0.00	0.00	0.02	0.00
2011	0.00	0.00	0.00	0.00	0.00	0.01	0.00
2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.10	0.00	0.01	0.01	0.01	0.02
2014	0.00	0.08	0.00	0.01	0.01	0.00	0.00
2015	0.00	0.01	0.00	0.01	0.00	0.01	0.00
2016	0.00	0.00	0.00	0.00	0.01	0.01	0.00
2017	0.00	0.00	0.00	0.00	0.01	0.00	0.00
2018	0.00	0.00	0.00	0.00	0.00	0.01	0.00
2019	0.00	0.00	0.00	0.00	0.01	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2021	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2022	0.00	0.00	0.00	0.01	0.01	0.00	0.01
2023	0.00	0.00	0.00	0.00	0.00	0.00	0.01
2024	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	0.00	0.00	0.00	0.00	0.00	0.00	0.00

b)

Table 5.2. continued
b)

Year	Other Flatfish - BSAI	Other Species	Pacific Cod	Pollock - bottom	Pollock - midwater	Rock Sole - BSAI	Rockfish	Sablefish	Yellowfin Sole - BSAI
1991	0.00	0.00	0.04	0.02	0.01	0.00	0.00	0.01	0.00
1992	0.00	0.00	0.15	0.01	0.05		0.03	0.57	0.00
1993	0.02	0.00	0.01	0.00	0.01	0.00	0.01	0.10	0.00
1994	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.22	0.00
1995	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.19	0.01
1996	0.00	0.00	0.05	0.00	0.00		0.02	0.16	0.00
1997	0.00	0.00	0.04	0.00	0.01	0.00	0.00	0.09	0.00
1998	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.00
1999	0.02	0.00	0.01	0.00	0.00		0.00	0.02	0.00
2000	0.00	0.00	0.02	0.00	0.00		0.00	0.04	0.00
2001	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.06	0.00
2002	0.01	0.00	0.04	0.01	0.00		0.00	0.06	0.00
2003	0.00	0.00	0.03	0.00	0.00		0.00	0.03	0.00
2004	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00
2005	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
2006	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.03	0.00
2007	0.00	0.00	0.05	0.00	0.02	0.00	0.01	0.04	0.00
2008	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.03	0.00
2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2013	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02
2015	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
2016	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
2017	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
2018	0.00	0.00	0.01	0.00	0.00		0.00	0.00	0.00
2019	0.00	0.00	0.01	0.00	0.00		0.00	0.00	0.00
2020	0.00	0.00	0.00	0.00	0.00		0.01	0.00	0.00
2021	0.00	0.00	0.01	0.00	0.00		0.00	0.00	0.00
2022	0.00	0.00	0.01	0.00	0.00		0.00	0.00	0.00
2023	0.00	0.00	0.02	0.00	0.00		0.00	0.02	0.00
2024	0.00	0.00	0.01	0.00	0.00		0.00	0.01	0.00
2025	0.00	0.00	0.01	0.00	0.00		0.00	0.00	0.00

Table 5.3. Estimates of Greenland turbot catch (t) by area based on NMFS Regional Office estimates, 1991-2026. The 2026 values are estimates through the week of October 4, 2026.

Year	AI	BS	Grand Total	Percent AI	Percent BS
1991	3,465	4,398	7,863	44	56
1992	1,290	2,462	3,752	34	66
1993	2,137	6,332	8,470	25	75
1994	3,131	7,141	10,272	30	70
1995	2,338	5,856	8,194	29	71
1996	1,712	4,844	6,556	26	74
1997	764	6,435	7,200	11	89
1998	682	8,075	8,757	8	92
1999	467	5,386	5,853	8	92
2000	1,086	5,888	6,974	16	84
2001	1,060	4,253	5,312	20	80
2002	485	3,151	3,636	13	87
2003	700	2,412	3,111	23	78
2004	434	1,825	2,259	19	81
2005	468	2,140	2,608	18	82
2006	537	1,453	1,989	27	73
2007	523	1,481	2,004	26	74
2008	822	2,089	2,911	28	72
2009	2,263	2,252	4,515	50	50
2010	1,868	2,268	4,136	45	55
2011	535	3,136	3,671	15	85
2012	1,657	3,010	4,667	36	64
2013	294	1,434	1,728	17	83
2014	165	1,470	1,635	10	90
2015	105	2,082	2,187	5	95
2016	122	2,113	2,236	5	94
2017	122	2,711	2,833	4	96
2018	163	1,671	1,834	9	91
2019	174	2,686	2,860	6	94
2020	678	1,648	2,326	29	71
2021	467	1,130	1,596	29	71
2022	440	1,038	1,478	30	70
2023	484	797	1,281	38	62
2024	305	463	768	40	60
2025	212	407	618	34	66
2026*	58	127	185	-	-
Mean				23	77

Table 5.4. Greenland turbot BSAI fishery length sample sizes by gear type and sex, 1991-2024. Source: NMFS observer program data. The % female do not include unidentified fish.

	Longline/Fixed Gear				Trawl			
Year	Female	Male	Unknown	%Female:Male	Female	Male	Unknown	%Female:Male
1991					1851	1752	9295	51
1992			71	0				0
1993	3921	915	12464	81			425	0
1994	503	150	1200	77	1024	1027	5150	50
1995	1870	715	5316	72	245	363	3528	40
1996	941	442	7482	68	112	390		22
1997	2393	1014	14833	70				0
1998	3510	2127	22794	62	307	696	822	31
1999	7875	2877	266	73	1044	1556		40
2000	6550	2962	73	69	724	1328	25	35
2001	4054	1550	271	72	467	892	43	34
2002	4725	1811	40	72	186	433		30
2003	4624	2113	2	69	197	325	1	38
2004	4340	2612	1	62	179	433	10	29
2005	4650	1902	43	71	118	211		36
2006	3339	1474	32	69	15	76		16
2007	3816	2127	134	64	34	23		60
2008	1577	1481		52	421	1572	1	21
2009	3492	2709	39	56	1017	2993	26	25
2010	3290	2860	108	53	298	3562	174	8
2011	2494	1694	7	60	853	2025	37	30
2012	3141	2292	69	58	1742	3153	14	36
2013	1087	675		62	1268	1367	2	48
2014	1022	1077		49	1150	1571	3	42
2015	1593	1070	19	60	928	1803	1	34
2016	1702	1069	36	61	1011	2057	2	33
2017	1185	947	2	56	1486	3342	625	31
2018	662	388		63	1256	1980	5	39
2019	808	449		64	995	3616	3	22
2020	401	119		77	806	2451	1	25
2021					1483	2961	80	33
2022					713	1535		32
2023					343	1487	2	19
2024					281	961		23
2025					163	919		15
2026					21	20		51

Table 5.5. Survey estimates of Greenland turbot biomass (t) for the Eastern Bering Sea shelf and slope areas and for the Aleutian Islands, 1979-2024. The Aleutian Islands surveys prior to 1990 used different operational protocols and may not compare well with subsequent surveys, the Aleutian Islands survey is not used in the stock assessment model.

Year	Shelf	Slope	Aleutian Islands
1979		123,000	
1980			3,598*
1981		99,600	
1982	39,603	90,600	
1983	24,557		9,684*
1984	17,791		
1985	10,990	79,200	
1986	5,654		31,759*
1987	11,745		
1988	13,306	42,700	
1989	13,173		
1990	16,145		
1991	12,440	40,500	11,926
1992	28,542		
1993	35,566		
1994	56,996		28,235
1995	37,516		
1996	40,495		
1997	35,196		28,343
1998	34,793		
1999	21,459		
2000	23,101		9,359
2001	27,199		
2002	23,917	27,409	9,891
2003	30,916		
2004	28,199	36,759	11,334
2005	21,230		
2006	20,858		20,934
2007	16,670		
2008	13,464	17,581	
2009	10,919		
2010	23,339	20,046	6,758
2011	26,094		
2012	21,733	18,019	2,600
2013	24,836		
2014	27,953		2,529
2015	25,176		
2016	22,357	24,803	2,378
2017	21,452		
2018	17,966		373
2019	16,008		
2021	10,690		
2022	7,869		539
2023	5,433		
2024	4,754		604
2025	5857		
2026	10,190		873

Table 5.6. Eastern Bering Sea slope survey estimates of Greenland turbot biomass (t) and numbers a) overall, b and c) by depth category, and d) by stratum in 2002, 2004, 2008, 2010, 2012, and 2016.

a)

Year	Total hauls	Hauls with weight	Hauls with number	Hauls with lengths	Biomass (t)	Stdev	Population numbers	Stdev
2002	141	102	102	102	27,409	3,279	6,726,010	809,691
2004	231	158	157	157	36,759	11,278	7,256,821	1,791,790
2008	200	135	135	135	17,581	2,263	5,307,298	878,996
2010	200	142	142	142	20,046	1,962	5,903,373	605,778
2012	189	132	132	132	18,019	1,878	11,702,723	2,616,226
2016	175	127	127	127	24,803	4,550	9,672,054	2,357,825

b) Biomass (t)

Depth (m)	**2002**	**2004**	**2008**	**2010**	**2012**	**2016**
200-400	4,082	2,889	4,423	1,170	2,279	860
400-600	14,527	25,562	6,679	10,524	10,367	15,528
600-800	4,736	5,316	4,276	5,235	3,897	5,421
800-1000	2,173	1,800	1,448	2,038	1,019	1,256
1000-1200	1,891	1,192	755	1,079	456	1,738
Total	27,409	36,759	17,581	20,046	18,019	24,803

c) Numbers

Depth (m)	**2002**	**2004**	**2008**	**2010**	**2012**	**2016**
200-400	994,449	745,401	1,740,600	422,725	3,186,079	339,322
400-600	3,794,888	4,927,418	1,967,103	3,491,729	7,080,826	6,997,625
600-800	1,074,403	1,000,540	1,200,519	1,330,888	1,110,855	1,591,302
800-1000	501,459	360,764	272,578	432,120	233,422	332,886
1000-1200	360,811	222,697	126,497	225,909	91,540	410,917
Total	6,726,010	7,256,820	5,307,297	5,903,371	11,702,722	9,672,052

d)

	Population biomass (t)						Population numbers (millions)					
Year	1	2	3	4	5	6	1	2	3	4	5	6
2002	15,565	2,313	1,721	2,315	1,275	4,221	3.56	0.73	0.43	0.59	0.44	0.98
2004	24,792	2,186	1,062	1,732	750	6,238	4.65	0.62	0.24	0.43	0.15	1.17
2008	6,253	2,239	896	1,362	558	6,272	1.43	0.74	0.19	0.30	0.19	2.45
2010	7,460	2,171	838	2,056	680	6,842	1.97	0.66	0.25	0.51	0.25	2.26
2012	5,600	1,990	696	1,060	661	8,012	1.71	0.74	0.23	0.39	0.25	8.38
2016	5,524	2,437	1,266	2,636	4,402	8,539	1.74	0.78	0.33	0.83	2.18	3.81

Table 5.7. EBS shelf bottom trawl survey total haul count, catch count, biomass (t) and abundance (numbers) estimates and the corresponding standard deviations, and number of hauls with length samples.

Year	Total hauls	Hauls weight	Hauls number	Hauls with lengths	Biomass (t)	Biomass Stdev	Population numbers	Number Stdev
1987	357	45	45	33	11,745	2,570	21,916,509	3,013,516
1988	373	63	63	58	13,306	3,098	29,102,468	5,708,312
1989	374	69	69	56	13,173	2,455	25,456,908	3,281,791
1990	371	78	78	62	16,145	4,328	28,842,650	4,048,350
1991	372	73	73	65	12,440	2,734	33,208,464	4,465,507
1992	356	73	73	64	28,542	6,090	30,877,550	4,505,782
1993	375	73	73	73	35,566	4,867	26,349,976	3,306,628
1994	375	53	53	52	56,996	11,711	23,022,216	4,180,691
1995	376	49	49	49	37,516	7,706	13,954,145	2,670,244
1996	375	75	75	75	40,495	5,314	13,755,784	1,727,589
1997	376	66	66	64	35,196	6,358	12,787,256	2,461,010
1998	375	73	73	73	34,793	4,347	12,504,380	1,751,108
1999	373	47	45	43	21,459	4,228	6,700,783	1,309,319
2000	372	61	61	57	23,101	4,552	7,946,335	1,145,103
2001	375	58	58	58	27,199	4,801	8,104,076	1,213,682
2002	375	70	70	70	23,917	4,787	13,485,062	3,167,251
2003	376	71	71	71	30,916	5,056	16,952,447	2,205,570
2004	375	64	64	64	28,199	4,414	17,761,823	2,452,894
2005	373	63	63	61	21,230	3,255	13,609,758	2,332,141
2006	376	56	56	56	20,858	3,361	11,439,309	1,717,369
2007	376	84	84	84	16,670	2,682	14,039,039	1,827,161
2008	375	79	79	78	13,464	2,902	15,089,018	2,056,510
2009	376	104	104	103	10,919	2,112	22,218,702	2,343,873
2010	376	145	145	144	23,339	3,970	137,268,463	14,593,549
2011	376	156	156	155	26,094	2,761	143,299,585	13,903,499
2012	376	110	110	109	21,733	2,951	61,188,158	6,515,801
2013	376	96	96	96	24,836	3,899	43,820,854	6,232,076
2014	376	96	96	95	27,953	3,672	30,159,805	3,819,879
2015	376	78	78	78	25,176	3,246	21,207,584	2,696,365
2016	376	80	80	80	22,357	2,997	14,089,149	1,635,006
2017	376	67	67	67	21,452	2,658	10,486,626	1,276,258
2018	376	77	77	77	17,966	2,005	7,340,786	798,778
2019	376	66	66	66	16,008	1,883	5,087,813	595,898
2021	376	48	48	48	10,690	1,801	2,747,987	420,328
2022	376	38	38	38	7,869	1,349	1,988,411	298,030
2023	376	40	40	40	5,857	1,049	3,742,560	737,924
2024	350	26	26	26	4,754	1,040	1,528,377	275,865
2025	350	28	28	28	5,433	1,232	1,535,692	323,912
2026	350	31	31	31	10,190	4,054	2,423,536	796,139

Table 5.8. Biological sampling statistics for Greenland turbot from the EBS shelf survey. Note that in 1982-1984, and 1986 the northwestern stations were not sampled.

Year	Total hauls	Number of Length samples	Hauls with aged samples	Number of otoliths	Number ages
1982	334	1228	11	292	292
1983	353	951			
1984	355	536		263	
1985	356	200			
1986	354	195			
1987	357	290			
1988	373	414			
1989	374	376			
1990	371	544			
1991	372	658			
1992	356	616		7	
1993	375	632		179	
1994	375	530		196	
1995	376	343			
1996	375	450		100	
1997	376	298		79	
1998	375	445	21	178	127
1999	373	128		11	
2000	372	248		188	
2001	375	270		215	
2002	375	455		71	
2003	376	622	46	435	407
2004	375	606	37	290	280
2005	373	441	39	293	277
2006	376	427	47	260	239
2007	376	501	66	334	311
2008	375	406	48	245	235
2009	376	856	60	351	344
2010	376	3199	65	362	358
2011	376	3721	51	427	381
2012	376	2133	52	418	408
2013	376	1160	51	382	374
2014	376	973	46	359	340
2015	376	771	57	380	368
2016	376	505	50	335	316
2017	376	373	41	234	217
2018	376	249	46	203	191
2019	376	165	43	117	109
2021	376	97	37	96	92
2022	376	73	29	70	66
2023	376	127	29	84	75
2024	350	53	21	47	47
2025	350		17	41	41

Table 5. 9. Aleutian Islands bottom trawl survey total haul count, catch count, biomass (t) and abundance (numbers) estimates and the corresponding standard deviations, and number of hauls with length samples.

Year	Haul Count	Hauls with catch	Biomass	Stdev	Numbers	Stdev	Number of hauls with length samples
1991	331	37	11,926	0.30	3,326,391	0.42	20
1994	380	49	28,235	0.32	7,757,433	0.33	49
1997	396	43	28,343	0.54	9,969,856	0.57	43
2000	419	45	9,359	0.35	2,738,349	0.40	45
2002	414	43	9,891	0.35	3,096,143	0.44	43
2004	419	43	11,334	0.22	2,963,338	0.27	42
2006	357	41	20,934	0.45	5,193,878	0.52	41
2010	418	23	6,758	0.46	1,944,423	0.56	23
2012	420	20	2,600	0.33	487,635	0.26	19
2014	410	20	2,529	0.22	568,632	0.23	20
2016	419	10	2,378	0.53	920,008	0.55	10
2018	420	5	373	0.84	54,327	0.66	5
2022	398	7	539	0.55	187,868	0.47	7
2024	307	8	604	0.38	229,622	0.37	8
2026	372	11	873	0.37	313,721	0.44	11

Table 5.10. Time series of Aleutian Islands survey sub-regions estimates of Greenland turbot; 1980-2026.

a) Numbers

Year	Western Aleutians	Central Aleutians	Eastern Aleutians	Southern Bering Sea	Grand Total
1980	0	232,804	924,561	9,881	1,167,246
1983	118,107	820,058	1,591,480	280,410	2,810,055
1986	593,934	519,528	7,122,791	2,614,622	10,850,875
1991	500,420	712,719	1,796,765	316,486	3,326,390
1994	881,506	929,025	3,994,288	1,952,614	7,757,433
1997	498,354	896,440	8,493,220	81,841	9,969,855
2000	181,735	593,387	1,816,919	146,309	2,738,350
2002	120,372	432,377	2,404,722	138,672	3,096,143
2004	471,895	742,596	758,643	990,203	2,963,337
2006	440,137	349,587	4,054,808	349,346	5,193,878
2010	276,593	332,759	1,198,540	136,532	1,944,424
2012	189,068	215,029	57,716	25,824	487,637
2014	147,713	142,076	126,252	152,591	568,632
2016	0	132,234	423,147	364,626	920,007
2018	36,955	17,372	0	0	54,327
2022	32,852	65,176	69,721	9,560	177,309
2024	8,887	109,380	98,278	13,077	229,622
2026					

b) Biomass (t)

Year	Western Aleutians	Central Aleutians	Eastern Aleutians	Southern Bering Sea	Grand Total
1980	0	799	2,720	79	3,598
1983	525	2,328	5,737	1,094	9,684
1986	1,747	2,495	19,580	7,937	31,759
1991	2,195	3,320	4,607	1,803	11,925
1994	2,401	4,007	15,862	5,966	28,235
1997	2,146	3,130	22,708	359	28,343
2000	839	2,351	5,703	467	9,359
2002	793	1,658	6,996	444	9,891
2004	2,588	2,948	2,564	3,234	11,334
2006	1,973	1,937	15,742	1,282	20,934
2010	1,071	1,507	3,695	486	6,758
2012	1,091	1,231	181	98	2,600
2014	553	989	490	497	2,529
2016	0	424	970	984	2,378
2018	321	53	0	0	373
2022	62	169	260	21	512
2024	18	320	235	32	604
2026					

Table 5. 11. Alaska Fisheries Science Center longline survey relative population numbers (RPNs) for Greenland turbot biomass by year and region.

Year	Bering 1 slope	Bering 2 slope	Bering 3 slope	Bering 4 slope	NE Aleutians slope	NW Aleutians slope	SE Aleutians slope	SW Aleutians slope
1996					0	0	2,535	7,772
1997	13,002	27,180	7,121	9,913				
1998					20,749	6,473	2,133	6,541
1999	9,600	31,445	6,951	11,186				
2000					11,529	3,596	1,356	4,158
2001	4,905	27,095	6,337	14,032				
2002					9,571	2,986	1,638	5,022
2003	5,956	24,982	4,270	9,810				
2004					7,512	2,343	1,120	3,433
2005	2,165	15,624	2,433	3,215				
2006					2,751	858	694	2,128
2007	1,199	12,313	2,256	1,251				
2008					2,885	900	373	1,143
2009	2,495	19,651	643	2,956				
2010					1,751	546	200	613
2011	1,768	10,600	795	1,427				
2012					3,919	1,222	378	1,158
2013	2,836	12,070	3,149	1,430				
2014					3,570	1,114	220	675
2015	4,393	13,355	546	2,636				
2016					2,126	663	42	130
2017	5,931	9,128	2,602	2,557				
2018					2,075	647	623	1,911
2019	108	7,795	852	1,197				
2020					3,467	1,081	60	184
2021	1,458	11,008	1,791	1,119				
2022					1,795	560	140	428
2023	92	7,134	1,101	1,952				
2026								

Table 5.12 Summary of the length-at-age information of females used for this BSAI Greenland turbot assessment (see Gregg et al. 2006 for methods). Top is average length and bottom is sample number.

	EBS Shelf														
	Year														
Age	1982	1998	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	16.8	17.7	15.7	15.0	0.0	0.0	12.2	12.8	15.0	14.1	16.4	14.2	16.1	0.0	0.0
2	24.5	24.9	22.4	21.8	25.0	24.3	22.5	18.9	22.0	23.2	23.7	23.3	22.8	21.3	22.5
3	32.7	33.1	29.7	29.9	32.2	30.3	30.0	23.1	29.7	30.2	32.2	32.1	29.3	28.5	32.4
4	40.3	32.0	33.4	34.6	35.9	39.0	39.5	28.5	33.3	34.6	37.1	36.8	36.3	32.6	37.9
5	46.4	35.0	39.0	40.9	42.6	38.0	46.2	34.5	35.5	38.0	41.6	42.3	38.3	40.5	44.3
6	48.1	0.0	47.0	43.1	48.8	42.7	47.0	44.0	0.0	42.0	46.2	46.0	43.5	46.3	50.4
7	52.5	0.0	43.7	53.0	53.3	46.6	50.7	50.1	56.0	67.0	46.5	54.8	48.8	48.7	54.5
8	0.0	0.0	50.0	57.0	62.5	54.5	54.7	53.3	56.0	0.0	57.0	47.5	52.6	57.6	55.1
9	0.0	0.0	57.5	0.0	62.0	57.9	59.8	53.8	59.6	0.0	72.0	0.0	54.5	56.1	60.8
10	0.0	65.8	51.0	70.3	67.5	65.7	62.3	59.0	63.8	62.3	65.0	69.5	0.0	66.3	62.4
11	0.0	65.0	60.0	83.0	86.0	62.0	63.0	60.3	64.0	73.0	68.7	74.0	73.0	61.0	74.0
12	0.0	78.7	78.3	78.3	77.0	71.0	62.0	70.5	0.0	67.3	0.0	75.0	0.0	75.0	82.3
13	0.0	0.0	83.7	85.6	88.0	56.5	65.0	69.7	74.5	69.5	71.5	77.0	79.3	72.0	79.8
14	0.0	75.0	83.2	83.8	81.3	77.0	0.0	0.0	78.0	73.5	0.0	80.0	78.0	0.0	0.0
15	0.0	0.0	80.0	87.2	85.5	78.0	61.7	70.0	0.0	0.0	77.0	0.0	0.0	82.0	83.0
16	0.0	76.0	84.2	82.0	0.0	84.7	80.0	84.5	0.0	80.0	0.0	0.0	0.0	86.0	0.0
17	0.0	81.0	86.4	85.2	85.0	86.3	90.0	71.0	0.0	0.0	0.0	75.0	0.0	0.0	85.0
18	0.0	0.0	85.7	91.7	92.0	88.7	85.0	92.7	0.0	97.0	66.0	84.0	85.0	0.0	0.0
19	0.0	0.0	90.7	92.5	84.6	87.6	91.7	91.0	88.0	0.0	0.0	0.0	0.0	93.0	79.0
20	0.0	80.3	89.6	89.5	90.2	90.3	89.0	66.0	90.5	0.0	87.0	81.0	81.0	81.0	0.0
21	0.0	82.0	90.0	90.7	89.0	91.0	90.7	83.0	87.7	0.0	93.5	0.0	0.0	0.0	0.0
22	0.0	0.0	88.0	0.0	87.0	90.0	0.0	89.5	94.0	94.5	0.0	0.0	90.0	98.0	0.0
23	0.0	79.0	90.2	96.5	82.0	88.0	87.0	0.0	92.5	80.5	0.0	85.0	0.0	92.0	0.0
24	0.0	79.0	90.0	97.0	88.0	0.0	0.0	94.0	100.0	0.0	0.0	100.0	0.0	0.0	91.0
25	0.0	79.0	91.3	91.0	86.8	88.5	0.0	88.0	89.0	0.0	99.0	0.0	88.0	0.0	0.0
26	0.0	95.0	92.3	94.5	96.5	0.0	92.0	0.0	93.0	88.0	0.0	0.0	89.0	98.5	100.0
27	0.0	0.0	93.7	85.7	0.0	0.0	0.0	0.0	83.0	0.0	81.7	97.5	0.0	0.0	0.0
28	0.0	0.0	92.0	91.0	0.0	0.0	0.0	95.0	93.3	0.0	0.0	0.0	0.0	95.3	0.0
29	0.0	0.0	91.8	0.0	0.0	0.0	92.0	91.0	0.0	93.0	86.0	0.0	0.0	0.0	0.0
30	0.0	0.0	91.0	0.0	88.0	107.0	90.0	93.0	89.8	92.0	96.0	0.0	91.0	98.8	75.0
N1	20	3	3	1	0	0	18	16	6	38	9	17	11	0	0
N2	33	18	30	5	1	3	4	17	41	54	76	40	30	3	11
N3	33	7	37	29	10	3	1	8	29	22	33	49	16	10	12
N4	38	1	16	10	38	2	2	2	10	7	16	31	24	10	23
N5	14	2	24	21	31	11	17	2	2	2	17	23	41	30	28
N6	9	0	3	7	13	16	17	1	0	1	6	13	20	25	22
N7	4	0	3	3	9	25	18	7	3	1	2	5	18	38	30
N8	0	0	6	1	6	19	15	4	1	0	1	2	9	23	23
N9	0	0	2	0	1	10	12	4	9	0	2	0	2	12	12
N10	0	5	1	4	2	3	6	7	4	4	2	2	0	4	9
N11	0	5	2	2	1	1	1	4	4	4	3	3	1	3	2
N12	0	3	3	4	3	6	3	2	0	8	0	1	0	3	3
N13	0	0	3	5	1	2	7	3	2	2	4	1	3	1	4
N14	0	1	5	5	3	1	0	0	2	4	0	1	1	0	0
N15	0	0	1	6	2	2	3	2	0	0	1	0	0	3	2
N16	0	2	5	4	0	3	1	2	0	1	0	0	0	1	0
N17	0	1	7	6	2	4	4	3	0	0	0	2	0	0	1
N18	0	0	6	3	3	3	1	3	0	1	1	2	1	0	0
N19	0	0	6	2	5	5	3	1	1	0	0	0	0	1	1
N20	0	3	9	2	5	6	3	1	2	0	1	1	1	1	0
N21	0	1	5	3	2	2	3	1	3	0	2	0	0	0	0
N22	0	0	4	0	1	2	0	2	1	2	0	0	1	1	0
N23	0	1	6	2	1	1	1	0	4	2	0	1	0	3	0
N24	0	2	5	1	2	0	0	1	1	0	0	1	0	0	1
N25	0	2	3	3	4	2	0	2	2	0	1	0	1	0	0
N26	0	1	3	2	2	0	3	0	1	1	0	0	1	2	1
N27	0	0	3	3	0	0	0	0	2	0	3	2	0	0	0
N28	0	0	4	1	0	0	0	1	3	0	0	0	0	3	0
N29	0	0	4	0	0	0	1	3	0	1	1	0	0	0	0
N30	0	0	5	0	1	1	1	1	4	3	1	0	1	4	1

Table 5.12 continued.

	EBS Shelf							EBS slope					
	Year							Year					
Age	2016	2017	2018	2019	2021	2022	2023	2002	2004	2008	2010	2012	2016
1	14.3	0.0	0.0	0.0	0.0	0.0	19.0	0.0	0.0	0.0	0.0	0.0	0.0
2	19.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	30.2	26.7	31.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.0	31.0	0.0
4	36.0	35.6	36.2	0.0	0.0	0.0	0.0	0.0	40.0	0.0	39.0	33.5	0.0
5	44.6	40.9	39.4	44.0	42.0	0.0	0.0	0.0	46.0	0.0	41.8	39.0	46.5
6	51.6	44.1	52.8	47.7	0.0	0.0	0.0	0.0	0.0	51.0	57.0	42.8	49.2
7	55.9	50.4	59.3	61.0	51.0	0.0	0.0	0.0	53.0	54.1	64.0	49.5	54.9
8	60.9	59.0	61.4	64.0	56.0	65.5	0.0	51.0	59.0	57.3	63.2	51.6	56.9
9	59.5	62.9	66.3	70.9	61.0	0.0	59.3	0.0	66.0	63.5	63.5	60.0	63.6
10	63.9	65.8	66.9	71.1	72.1	66.8	69.4	82.0	72.0	67.5	65.8	58.0	64.4
11	65.8	63.6	71.5	74.5	74.2	74.1	66.0	74.8	71.0	66.0	71.9	71.9	67.2
12	62.7	69.6	72.7	75.3	75.3	77.7	75.5	81.7	81.3	68.5	73.0	70.3	67.0
13	67.5	73.5	80.0	74.5	78.6	81.1	76.8	83.1	85.8	72.5	75.8	77.5	74.6
14	75.7	72.5	74.0	0.0	79.8	78.8	76.0	85.1	83.0	79.8	82.2	75.3	76.1
15	0.0	82.0	84.0	0.0	83.0	79.2	75.3	82.0	86.8	86.3	74.7	76.4	79.2
16	83.0	67.0	0.0	70.0	82.5	78.0	78.0	82.1	81.5	86.3	79.9	79.1	80.7
17	81.0	82.3	0.0	0.0	82.0	79.0	75.0	81.8	83.4	86.0	88.8	78.1	80.0
18	0.0	91.0	85.7	85.0	0.0	0.0	82.0	88.5	85.1	77.4	87.8	74.0	79.9
19	0.0	0.0	0.0	92.0	76.0	0.0	0.0	84.7	88.8	90.3	93.0	79.7	80.1
20	81.0	0.0	0.0	0.0	0.0	0.0	88.0	85.1	85.3	89.7	86.3	86.7	86.0
21	0.0	85.0	0.0	0.0	0.0	0.0	0.0	88.6	86.8	92.6	87.9	80.3	82.7
22	88.0	0.0	0.0	0.0	0.0	0.0	0.0	85.2	89.1	91.8	87.7	88.0	80.3
23	89.0	73.0	0.0	0.0	0.0	0.0	85.0	90.4	87.6	93.9	90.3	86.9	86.3
24	0.0	94.0	97.0	0.0	0.0	0.0	0.0	84.9	87.8	90.1	93.8	89.8	81.5
25	87.0	0.0	0.0	0.0	0.0	0.0	0.0	87.9	90.2	90.3	89.0	83.0	87.0
26	0.0	0.0	100.0	0.0	92.0	0.0	0.0	87.6	92.3	90.7	96.7	86.8	85.3
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.0	89.9	90.5	88.4	94.6	90.9
28	99.5	0.0	0.0	0.0	0.0	0.0	0.0	90.0	91.8	94.6	90.3	96.0	93.5
29	92.0	0.0	0.0	0.0	0.0	0.0	0.0	92.1	91.0	91.1	85.3	0.0	93.0
30	95.0	0.0	0.0	0.0	90.0	0.0	0.0	90.2	93.8	91.7	95.9	98.4	92.0
N1	6	0	0	0	0	0	2	0	0	0	0	0	0
N2	3	0	1	0	0	0	0	0	0	0	0	0	0
N3	14	3	2	0	0	0	0	0	0	0	2	2	0
N4	8	7	6	0	0	0	0	0	2	0	1	18	0
N5	16	9	7	1	2	0	0	0	1	0	5	20	4
N6	18	9	6	3	0	0	0	0	0	4	1	17	5
N7	23	7	4	7	1	0	0	0	1	7	1	12	7
N8	23	13	7	3	8	2	0	1	2	21	5	11	28
N9	8	15	25	13	1	0	4	0	1	18	13	2	23
N10	15	24	29	11	8	4	5	1	2	13	20	3	25
N11	8	13	16	21	16	8	1	4	2	10	15	7	34
N12	3	10	3	8	19	7	8	3	3	8	13	11	19
N13	2	2	1	2	8	11	4	9	4	6	6	8	16
N14	3	4	1	0	4	5	3	12	6	6	5	15	15
N15	0	3	1	0	1	5	3	13	9	3	9	12	21
N16	3	1	0	1	2	3	1	15	8	4	7	7	17
N17	1	3	0	0	1	1	2	18	16	2	5	9	10
N18	0	1	3	1	0	0	3	8	15	5	4	2	12
N19	0	0	0	1	1	0	0	13	13	3	8	3	15
N20	1	0	0	0	0	0	1	10	13	7	10	7	7
N21	0	1	0	0	0	0	0	20	21	8	16	6	12
N22	1	0	0	0	0	0	0	12	15	8	7	4	4
N23	1	1	0	0	0	0	1	9	8	8	11	7	6
N24	0	1	1	0	0	0	0	17	12	8	13	6	2
N25	1	0	0	0	0	0	0	18	20	11	12	2	1
N26	0	0	1	0	1	0	0	7	10	3	3	6	3
N27	0	0	0	0	0	0	0	4	16	4	5	7	7
N28	2	0	0	0	0	0	0	8	9	8	11	2	2
N29	1	0	0	0	0	0	0	7	7	12	4	0	3
N30	1	0	0	0	1	0	0	10	27	34	10	5	17

Table 5.13. Summary of the length-at-age information of males used for this BSAI Greenland turbot assessment (see Gregg et al. 2006 for methods). Top is average length and bottom is sample number.

	EBS Shelf														
	Year														
Age	1982	1998	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	16.6	0.0	13.0	16.3	16.0	11.5	12.5	13.1	14.3	14.1	16.1	13.5	14.6	14.0	14.0
2	24.8	25.6	22.1	23.9	24.0	21.0	21.0	19.6	21.9	23.9	23.1	22.5	22.5	22.2	22.7
3	33.7	34.0	29.0	30.3	33.2	0.0	28.7	23.4	28.6	33.3	32.1	31.3	30.8	29.2	32.3
4	40.0	33.8	36.1	34.8	37.0	39.5	35.0	30.0	33.3	36.4	36.9	36.7	34.8	35.0	39.0
5	45.7	36.5	39.0	42.6	41.3	38.4	44.4	35.5	45.0	39.8	41.8	40.9	37.9	39.1	44.8
6	50.0	50.0	40.7	43.1	47.1	43.8	47.2	44.0	42.5	42.0	45.3	47.4	41.9	43.9	48.6
7	52.0	0.0	46.2	51.2	48.0	44.3	51.7	46.3	52.0	0.0	0.0	53.0	45.2	47.9	52.2
8	0.0	49.0	49.2	58.0	51.8	47.3	52.7	51.0	53.8	50.5	55.5	0.0	51.5	50.4	55.1
9	0.0	58.0	48.5	61.8	52.0	53.2	56.0	54.6	58.3	59.0	47.0	0.0	49.0	50.1	58.5
10	0.0	58.3	66.4	63.8	72.0	64.3	55.0	55.7	54.5	0.0	0.0	66.0	0.0	63.0	57.5
11	0.0	0.0	60.0	0.0	64.7	62.3	62.8	59.0	0.0	0.0	69.0	0.0	0.0	0.0	54.0
12	0.0	59.8	72.0	73.2	0.0	74.0	0.0	0.0	0.0	60.0	65.5	0.0	0.0	0.0	68.0
13	0.0	66.8	76.0	68.7	72.5	0.0	0.0	0.0	0.0	67.0	0.0	68.0	0.0	66.0	0.0
14	0.0	75.0	0.0	0.0	76.0	0.0	0.0	0.0	0.0	0.0	0.0	56.0	0.0	69.0	0.0
15	0.0	67.5	0.0	74.0	79.0	73.0	0.0	73.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	70.0	78.0	75.5	77.0	69.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	71.0	72.0	78.0	76.0	74.0	75.5	0.0	0.0	0.0	66.0	0.0	0.0	72.0	0.0
18	0.0	0.0	72.0	77.0	76.0	76.0	77.5	83.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	74.0	78.0	81.0	74.3	79.0	0.0	0.0	78.5	0.0	73.0	0.0	0.0	0.0	0.0
20	0.0	0.0	81.5	73.5	79.0	79.0	0.0	76.0	79.0	0.0	70.0	75.0	0.0	0.0	0.0
21	0.0	0.0	76.5	0.0	0.0	0.0	76.5	71.0	70.0	73.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	81.0	0.0	0.0	74.0	77.0	80.0	77.0	73.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	74.0	0.0	0.0	88.0	0.0	0.0	0.0	88.0	0.0	0.0	0.0	0.0	77.0
24	0.0	69.5	76.3	0.0	74.0	77.0	84.0	0.0	0.0	82.0	0.0	0.0	0.0	0.0	75.5
25	0.0	0.0	73.0	0.0	75.5	83.0	72.0	0.0	71.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	77.0	0.0	0.0	0.0	0.0	0.0	78.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	74.0	0.0	73.0	0.0	0.0	75.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	78.0	0.0	0.0	78.0	0.0	79.0	76.0	0.0	0.0	0.0	0.0
29	0.0	0.0	78.0	0.0	0.0	0.0	82.0	0.0	0.0	78.0	0.0	0.0	0.0	0.0	85.0
30	0.0	81.0	0.0	0.0	0.0	0.0	79.0	0.0	76.8	0.0	0.0	76.0	0.0	0.0	0.0
N1	23	0	3	4	1	2	26	21	12	48	21	22	7	2	1
N2	43	19	34	9	2	1	8	36	73	57	90	44	30	6	27
N3	30	11	38	40	16	0	6	11	47	27	44	60	17	17	22
N4	31	5	18	18	35	2	4	4	11	14	15	25	35	10	15
N5	10	2	27	20	27	16	15	4	1	4	9	23	41	17	22
N6	3	1	9	15	10	20	22	2	2	1	3	7	21	35	34
N7	1	0	10	10	5	15	23	3	1	0	0	3	13	23	20
N8	0	1	5	1	6	16	15	9	4	2	2	0	2	18	12
N9	0	1	2	4	1	11	4	7	3	1	1	0	2	9	4
N10	0	3	5	4	1	4	3	3	2	0	0	1	0	3	2
N11	0	0	2	0	3	4	4	1	0	0	1	0	0	0	1
N12	0	4	1	5	0	1	0	0	0	1	2	0	0	0	1
N13	0	4	1	3	2	0	0	0	0	2	0	1	0	1	0
N14	0	1	0	0	1	0	0	0	0	0	0	1	0	1	0
N15	0	2	0	2	1	1	0	1	0	0	0	0	0	0	0
N16	0	0	2	2	4	2	1	1	0	0	0	0	0	0	0
N17	0	3	1	1	1	1	4	0	0	0	1	0	0	1	0
N18	0	0	1	3	1	1	2	1	0	0	0	0	0	0	0
N19	0	2	1	1	3	1	0	0	2	0	1	0	0	0	0
N20	0	0	2	2	1	1	0	1	1	0	1	1	0	0	0
N21	0	0	2	0	0	0	2	1	1	1	0	0	0	0	0
N22	0	0	2	0	0	1	1	1	2	1	0	0	0	0	0
N23	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1
N24	0	2	3	0	1	1	1	0	0	1	0	0	0	0	2
N25	0	0	2	0	2	2	1	0	1	0	0	0	0	0	0
N26	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0
N27	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0
N28	0	0	0	0	1	0	0	1	0	1	1	0	0	0	0
N29	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1
N30	0	2	0	0	0	0	1	0	4	0	0	2	0	0	0

Table 5.13. continued.

	EBS Shelf							EBS slope					
	Year							Year					
Age	2016	2017	2018	2019	2021	2022	2023	2002	2004	2008	2010	2012	2016
1	13.0	15.0	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.5	0.0	0.0
2	18.8	24.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	0.0
3	30.6	29.0	28.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	34.0	31.0	0.0
4	38.5	37.5	36.7	0.0	39.0	0.0	0.0	0.0	0.0	0.0	35.5	35.4	0.0
5	45.3	38.2	43.0	39.0	0.0	45.0	0.0	0.0	43.8	0.0	42.0	38.7	42.0
6	50.7	42.4	45.3	48.7	0.0	45.7	0.0	46.0	44.3	49.3	49.6	41.8	47.0
7	54.3	47.4	52.9	55.9	54.0	59.0	0.0	45.0	51.3	53.7	63.0	47.8	54.3
8	56.3	55.8	60.3	61.8	57.0	63.0	0.0	59.5	49.5	53.1	62.4	53.2	56.6
9	57.2	58.2	62.9	63.5	61.0	55.7	0.0	58.3	65.3	58.1	61.9	58.0	59.5
10	55.0	61.6	63.0	68.5	67.0	65.5	58.0	64.9	63.9	59.5	64.3	60.1	62.3
11	58.8	57.5	69.3	62.0	71.0	63.0	0.0	65.3	66.6	60.9	63.7	63.8	63.9
12	62.0	60.0	61.0	78.5	0.0	0.0	0.0	67.6	67.5	62.6	64.0	67.9	64.3
13	0.0	58.0	61.0	0.0	0.0	71.0	67.5	68.2	68.0	63.7	62.4	65.1	65.9
14	0.0	59.0	78.0	68.0	0.0	0.0	0.0	69.0	69.1	67.2	68.1	65.2	65.5
15	0.0	0.0	0.0	0.0	0.0	80.0	72.0	67.7	67.9	65.4	70.7	66.5	64.7
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.9	67.7	72.4	72.2	68.5	69.6
17	0.0	0.0	0.0	0.0	74.0	0.0	0.0	66.6	69.3	69.7	70.9	68.4	71.6
18	0.0	83.0	72.0	0.0	0.0	0.0	0.0	67.9	67.2	71.8	72.1	69.8	70.7
19	0.0	0.0	0.0	0.0	70.0	76.0	0.0	70.0	71.3	69.0	73.0	72.5	70.0
20	79.0	0.0	0.0	0.0	0.0	0.0	0.0	70.7	68.6	71.7	71.4	71.7	67.8
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.2	71.5	67.3	72.8	70.0	73.6
22	0.0	0.0	0.0	0.0	82.0	0.0	0.0	71.8	69.1	73.3	71.8	68.3	73.1
23	0.0	77.0	0.0	0.0	0.0	0.0	0.0	67.3	71.6	70.7	70.1	63.7	73.0
24	0.0	0.0	0.0	0.0	80.0	0.0	0.0	68.0	72.3	73.0	72.2	68.8	70.0
25	77.0	0.0	0.0	73.0	78.0	0.0	0.0	68.7	68.7	69.5	70.6	74.4	67.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.3	70.3	72.5	74.3	83.0	67.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.3	68.1	71.3	72.3	70.8	80.4
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	67.4	71.3	71.0	71.6	73.2	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.7	0.0	76.1	70.0	71.0	76.9
30	83.0	75.0	0.0	0.0	0.0	0.0	0.0	71.8	78.5	70.5	73.3	71.1	75.8
N1	6	1	3	0	0	0	0	0	0	0	2	0	0
N2	9	4	1	0	0	0	0	0	0	0	0	1	0
N3	23	6	1	0	0	0	0	1	0	0	1	4	0
N4	21	6	3	0	1	0	0	0	0	0	2	23	0
N5	12	5	7	1	0	1	0	0	6	0	2	23	1
N6	19	11	12	6	0	3	0	3	7	4	5	12	7
N7	21	7	9	12	1	1	0	2	3	9	3	13	16
N8	12	12	17	4	3	3	0	2	2	11	15	13	32
N9	13	13	11	4	4	6	0	4	9	12	37	11	39
N10	5	11	6	2	3	2	2	12	10	17	16	9	28
N11	6	6	3	3	1	1	0	12	5	16	14	14	19
N12	1	3	1	2	0	0	0	13	4	14	10	13	23
N13	0	1	1	0	0	1	2	10	9	6	9	13	23
N14	0	1	1	1	0	0	0	11	8	6	9	6	13
N15	0	0	0	0	0	1	1	10	17	8	3	10	9
N16	0	0	0	0	0	0	0	16	12	7	9	4	9
N17	0	0	0	0	1	0	0	8	12	7	8	5	12
N18	0	1	1	0	0	0	0	13	11	10	7	5	11
N19	0	0	0	0	1	1	0	13	8	5	10	2	9
N20	1	0	0	0	0	0	0	11	19	13	12	3	6
N21	0	0	0	0	0	0	0	11	17	4	11	1	5
N22	0	0	0	0	1	0	0	12	10	7	8	3	8
N23	0	1	0	0	0	0	0	14	12	7	9	3	5
N24	0	0	0	0	1	0	0	9	4	7	9	5	4
N25	1	0	0	2	1	0	0	16	16	6	11	7	2
N26	0	0	0	0	0	0	0	9	6	6	4	1	2
N27	0	0	0	0	0	0	0	4	8	6	15	4	5
N28	0	0	0	0	0	0	0	5	8	9	8	6	0
N29	0	0	0	0	0	0	0	3	0	7	7	1	7
N30	1	1	0	0	0	0	0	5	6	31	14	24	10

Table 5.14. Average starting sample size (ISS) and variance adjusted multinomial sample size using the status quo values from the last accepted model and 25.0 and the average updated ISS (number of hauls for the fishery and ISS from the afscISS R package), adjusted sample size in model 25.0 and adjusted SS using the variance adjustment values from the Francis method by fleet (applied to alternative models).

Fleet	Status quo ISS[†]	Adjusted sample size using the variance adjustment in 25.0	Average updated ISS	Average adjusted sample size using variance adjustment from Francis method
Fsh trawl	50	12.5	347	7.79
Fsh longline	50	25.0	236	54.7
Shelf survey	200	50.0	189	3.8
Slope survey (pre-2002)	25	12.5	100	5.8
2002-2016	400	200	287	16.7
AFSC longline survey	60	30	100	8.9

Table 5.15. Model a) total likelihoods and b) likelihood components.

a)

Label	2024_assessment	25	25.3a	25.4a	26.3
TOTAL	3733	3869	2727	2705	2747
Catch	0.0	0.0	0.0	0.0	0.0
Equil_catch	0	0	0	0	1.9
Survey	8.8	-19.0	-40.3	-39.4	-41.0
Length_comp	1282.9	1356.2	423.8	399.4	429.1
Age_comp	0	0	0	0	0
Size_at_age	2314.6	2391.1	2253.1	2252.7	2249.7
Recruitment	111.6	122.5	86.6	85.6	102.2
InitEQ_Regime	0	0	0	0	0
Forecast_Recruitment	10.6	13.5	0.2	0.3	0.4
Parm_priors	4.3	4.6	3.9	6.0	5.1
Parm_softbounds	0.02	0.02	0.02	0.02	0.02

b)

Model	Label	ALL	FshTrawl	FshLL	SHELF	SLOPE	AFSC_LONGLINE
16.4c	Catch_like	0.0	0.0	0.0	0.0	0.0	0.0
25.0		0.0	0.0	0.0	0.0	0.0	0.0
25.3a		0.0	0.0	0.0	0.0	0.0	0.0
25.4a		0.0	0.0	0.0	0.0	0.0	0.0
26.3		0.0	0.0	0.0	0.0	0.0	0.0
16.4c	Length_like	1282.9	161.9	106.5	503.8	290.5	220.1
25.0		1356.2	164.2	79.0	600.8	289.8	222.5
25.3a		423.8	99.6	138.6	65.6	46.6	73.4
25.4a		399.4	98.3	138.5	61.8	29.4	71.4
26.3		429.1	103.9	138.9	68.0	36.9	81.3
16.4c	sizeatage_like	2314.6	0.0	0.0	1749.1	565.5	0.0
25.0		2391.1	0.0	0.0	1826.0	565.1	0.0
25.3a		2253.1	0.0	0.0	1700.3	552.8	0.0
25.4a		2252.7	0.0	0.0	1692.1	560.7	0.0
26.3		2249.7	0.0	0.0	1694.6	555.1	0.0
16.4c	Surv_like	8.8	0.0	0.0	-7.9	-6.0	22.7
25.0		-19.0	0.0	0.0	-5.7	-5.3	-7.9
25.3a		-40.3	0.0	0.0	-5.8	-5.9	-28.6
25.4a		-39.4	0.0	0.0	-5.9	-4.6	-28.9
26.3		-41.0	0.0	0.0	-5.8	-5.2	-30.0

Table 5.16. Index catchability values, root mean square error, and log likelihood estimates for each model and survey. Within a survey the models are ordered from lowest to highest RMSE.

Model	Fleet	Qbase	Npos	RMSE	logL
25.4a	AFSC_LONGLINE	4.21	29	0.22	-28.93
25.3a	AFSC_LONGLINE	4.14	29	0.23	-28.56
26.3	AFSC_LONGLINE	6.04	29	0.23	-30.03
25.0	AFSC_LONGLINE	2.79	29	0.30	-7.90
2024_assessment	AFSC_LONGLINE	2.40	28	0.44	-
2024_assessment	SHELF	0.62	37	0.31	-
25.0	SHELF	0.62	39	0.31	-5.73
25.4a	SHELF	1.26	39	0.31	-5.85
25.3a	SHELF	1.12	39	0.31	-5.78
26.3	SHELF	1.48	39	0.32	-5.76
2024_assessment	SLOPE	0.57	6	0.19	-
25.0	SLOPE	0.57	6	0.20	-5.32
25.3a	SLOPE	0.65	6	0.22	-5.91
26.3	SLOPE	0.81	6	0.24	-5.23
25.4a	SLOPE	0.63	6	0.24	-4.64

Table 5. 17. Key parameter estimates and standard deviations.

Label	16.4c		25.0		25.3a		25.4a		26.3	
	Value	SD	Value	SD	Value	SD	Value	SD	Value	SD
Growth										
L_at_Amin_Fem_GP_1	15.64	0.14	15.70	0.14	15.81	0.14	15.77	0.14	15.73	0.14
L_at_Amax_Fem_GP_1	93.81	0.46	93.84	0.44	96.81	0.54	97.12	0.52	97.59	0.53
VonBert_K_Fem_GP_1	0.11	0.00	0.11	0.00	0.11	0.00	0.11	0.00	0.11	0.00
L_at_Amin_Mal_GP_1	15.07	0.13	15.11	0.13	15.06	0.13	15.00	0.13	14.97	0.13
L_at_Amax_Mal_GP_1	71.33	0.26	71.33	0.26	73.54	0.29	73.79	0.28	74.06	0.29
VonBert_K_Mal_GP_1	0.18	0.00	0.18	0.00	0.17	0.00	0.17	0.00	0.17	0.00
Recruitment										
SR_LN(R0)	8.96	0.18	8.68	0.18	9.17	0.15	9.14	0.15	11.18	0.05
SR_autocorr	0.70	0.03	0.71	0.03	0.44	-	0.44	-	0.44	-
Catchability										
LnQ_base_SHELF(3)	-0.49	NA	-0.49	NA	0.12	-	0.23	-	0.39	-
LnQ_base_SLOPE(4)	-0.56	NA	-0.56	NA	-0.43	-	-0.46	-	-0.21	-
LnQ_base_AFSC_LONGLINE(5)	0.88	0.07	1.02	0.06	1.42	-	1.44	-	1.80	-
Equilibrium fishing mortality										
InitF_seas_1_flt_1FshTrawl	-	-	-	-	-	-	-	-	0.11	0.02

Table 5.18. REMA model parameter estimates with 95% CI.

Parameter	**applies_to**	**estimate**	**std_err**	**lci**	**uci**
process_error	AI + EBS Slope	0.295	0.055	0.205	0.424
scaling_parameter_q	EBS slope LLS	4.119	0.523	3.212	5.284

Table 5.19. Estimates of total biomass of adult Greenland turbot on the EBS slope and AI.

year	AI	EBS Slope	Total	Total LCI	Total UCI
1997	19,359	72,048	91,407	70,032	119,307
1998	16,215	69,073	85,289	55,661	130,686
1999	13,582	66,221	79,803	58,270	109,294
2000	11,376	59,119	70,495	45,994	108,048
2001	11,045	52,778	63,824	49,081	82,994
2002	10,724	31,092	41,817	34,040	51,370
2003	11,069	39,589	50,658	37,561	68,321
2004	11,425	33,199	44,624	32,882	60,558
2005	11,962	25,232	37,194	27,859	49,657
2006	12,524	22,063	34,587	23,536	50,826
2007	10,246	19,292	29,538	20,835	41,875
2008	8,382	18,247	26,630	20,156	35,182
2009	6,858	21,012	27,869	20,376	38,118
2010	5,611	19,626	25,237	20,856	30,537
2011	4,214	15,116	19,330	14,461	25,838
2012	3,165	17,665	20,830	17,460	24,850
2013	2,797	17,601	20,398	14,627	28,446
2014	2,471	17,871	20,342	12,943	31,970
2015	2,096	18,145	20,241	14,389	28,472
2016	1,778	20,370	22,147	16,588	29,571
2017	1,362	13,640	15,002	10,511	21,411
2018	1,043	10,991	12,033	7,299	19,839
2019	944	8,856	9,800	6,396	15,015
2020	855	9,801	10,656	6,415	17,699
2021	775	10,846	11,621	7,950	16,986
2022	701	9,451	10,152	6,182	16,673
2023	693	8,235	8,929	6,238	12,780
2024	686	7,047	7,733	4,518	13,236
2025	735	6,031	6,765	3,926	11,659
2026	787	5,161	5,948	3,952	8,951

Table 5.20. Biomass apportionment under differing model configurations. Proportions represent the mean of the estimates over the last 10 years.

Model	**AI**	**EBS**
Proposed model: No EBS shelf BTS, no AI LLS	0.090	0.910
Proposed model with LLS RPN	0.076	0.924
All surveys (September model)	0.058	0.942
All surveys except EBS shelf BTS	0.119	0.881
All surveys except AI LLS	0.044	0.956

Table 5.21. Mohn's rho (measuring retrospective pattern) for the candidate models.

Model	SSB	Recruitment	F
25.0	0.21	22.64	-0.25
25.3a	0.48	4.13	-0.37
25.4a	0.39	4.20	-0.35
26.3	0.71	4.29	-0.40

Table 5.22. Spawning and total biomass, Age-0 recruits, fishing mortality, and exploitation rate for BSAI Greenland turbot, 1960-2026 for models 16.4c (2024) and model 25.0.

	16.4c (2024)				25.0			
Year	SSB (t)	Age-0 recruits	Apical F	Exploitation rate	SSB (t)	Age-0 recruits	Apical F	Exploitation rate
1960	86392	138346	0.21	0.14	70,239	133,252	0.23	0.16
1961	83340	262610	0.36	0.23	67,461	247,814	0.41	0.26
1962	74265	476642	0.43	0.26	58,734	451,614	0.49	0.31
1963	63801	532656	0.23	0.15	48,624	542,743	0.27	0.19
1964	59962	298253	0.19	0.14	44,992	324,940	0.22	0.17
1965	57815	132888	0.04	0.03	42,986	145,004	0.04	0.04
1966	61899	64801	0.03	0.03	46,713	68,868	0.03	0.03
1967	72290	37821	0.04	0.04	56,047	38,933	0.04	0.04
1968	95563	26458	0.05	0.04	77,117	26,483	0.05	0.05
1969	139318	21820	0.04	0.04	117,571	21,380	0.04	0.04
1970	205917	21032	0.03	0.02	180,744	20,330	0.03	0.02
1971	289122	23871	0.05	0.04	261,630	22,931	0.05	0.05
1972	366504	32495	0.10	0.08	338,513	31,206	0.10	0.08
1973	416949	53690	0.09	0.07	389,777	51,748	0.09	0.07
1974	450221	100607	0.12	0.08	424,354	97,963	0.12	0.09
1975	456300	164401	0.12	0.08	431,807	165,020	0.12	0.08
1976	448811	122929	0.13	0.08	425,617	131,410	0.12	0.08
1977	430374	75123	0.07	0.04	408,360	80,999	0.07	0.04
1978	417993	42828	0.10	0.06	397,243	44,400	0.10	0.06
1979	395213	15101	0.11	0.06	375,567	15,346	0.10	0.06
1980	371894	7236	0.14	0.08	353,290	7,154	0.14	0.08
1981	346490	4520	0.16	0.09	328,913	4,389	0.16	0.09
1982	323116	3642	0.15	0.09	306,802	3,514	0.15	0.09
1983	305852	3950	0.16	0.09	291,173	3,823	0.15	0.09
1984	289573	6514	0.08	0.05	276,857	6,348	0.08	0.05
1985	281150	19491	0.06	0.03	270,487	18,758	0.06	0.03
1986	273601	6266	0.04	0.02	264,887	6,179	0.04	0.02
1987	265215	5833	0.05	0.02	258,231	5,666	0.04	0.02
1988	254071	6099	0.04	0.02	248,541	5,957	0.03	0.02
1989	241762	14997	0.07	0.02	237,425	14,369	0.06	0.02
1990	225303	4931	0.11	0.04	222,053	4,761	0.10	0.04
1991	205610	1338	0.07	0.03	203,241	1,291	0.07	0.03
1992	189612	836	0.03	0.01	187,854	795	0.03	0.01
1993	176772	664	0.07	0.03	175,463	633	0.07	0.03
1994	160336	999	0.12	0.04	159,389	949	0.12	0.04

Table 5.22. Continued. Spawning and total biomass, Age-0 recruits, fishing mortality, and exploitation rate for BSAI Greenland turbot, 1960-2024 for models 16.4c (2024) and model 25.0.

	16.4c (2024)				25.0			
	SSB (t)	Age-0 recruits	Apical F	Exploitation rate	SSB (t)	Age-0 recruits	Apical F	Exploitation rate
1995	144385	3011	0.08	0.04	143,680	2,783	0.10	0.04
1996	130756	1717	0.07	0.03	130,178	1,629	0.08	0.03
1997	118940	1722	0.08	0.04	118,411	1,635	0.09	0.04
1998	107128	2142	0.11	0.05	106,606	2,029	0.13	0.05
1999	94572	7114	0.08	0.04	94,041	6,636	0.10	0.04
2000	84866	9569	0.11	0.05	84,327	9,208	0.13	0.05
2001	74539	9854	0.10	0.05	73,991	9,436	0.12	0.05
2002	66062	1811	0.07	0.04	65,510	1,751	0.09	0.03
2003	59142	705	0.07	0.03	58,576	670	0.08	0.03
2004	53085	606	0.06	0.03	52,502	572	0.07	0.03
2005	48213	1038	0.07	0.03	47,605	988	0.09	0.03
2006	43739	5256	0.06	0.03	43,088	4,920	0.07	0.03
2007	40601	9775	0.06	0.03	39,874	9,216	0.08	0.03
2008	38290	23355	0.10	0.04	37,468	21,479	0.13	0.04
2009	36407	19202	0.17	0.07	35,494	17,505	0.21	0.07
2010	33676	2756	0.16	0.07	32,688	2,491	0.22	0.07
2011	30648	1271	0.16	0.06	29,593	1,143	0.21	0.07
2012	27738	832	0.23	0.08	26,625	750	0.30	0.09
2013	24623	755	0.09	0.03	23,444	676	0.12	0.03
2014	24071	546	0.08	0.03	22,778	486	0.11	0.03
2015	24887	377	0.10	0.04	23,383	328	0.13	0.04
2016	26574	246	0.08	0.04	24,765	203	0.11	0.04
2017	28715	206	0.09	0.05	26,564	155	0.12	0.05
2018	30199	187	0.05	0.03	27,734	125	0.07	0.03
2019	31321	205	0.08	0.05	28,610	122	0.11	0.05
2020	30927	282	0.07	0.04	28,053	150	0.10	0.05
2021	29980	787	0.05	0.03	27,021	299	0.07	0.03
2022	28839	4018	0.06	0.03	25,862	1,816	0.08	0.03
2023	27315	3127	0.06	0.03	24,372	1,030	0.08	0.03
2024	25594	4608	0.04	0.02	22,724	894	0.06	0.02
2025					21,221	1,247	0.05	0.02
2026					19,709	2,541	0.02	0.01

Table 5.23. Age-0 recruits from model 25.0 with lower (LCI) and upper (UCI) 95% confidence intervals for 1977-2026 for BSAI Greenland turbot. Confidence bounds are based on 1.96×standard error.

Year	Age-0 Recruits	LCI	UCI
1977	80,999	25,549	148,124
1978	44,400	16,037	88,197
1979	15,346	6,099	32,505
1980	7,154	2,948	15,548
1981	4,389	1,783	9,440
1982	3,514	1,352	7,281
1983	3,823	1,338	7,444
1984	6,348	1,900	11,272
1985	18,758	3,107	25,895
1986	6,179	1,377	9,513
1987	5,666	1,186	8,503
1988	5,957	1,244	8,932
1989	14,369	2,044	18,963
1990	4,761	1,069	7,353
1991	1,291	357	2,199
1992	795	232	1,394
1993	633	190	1,125
1994	949	262	1,614
1995	2,783	549	4,080
1996	1,629	395	2,602
1997	1,635	394	2,605
1998	2,029	496	3,253
1999	6,636	1,180	9,378
2000	9,208	1,562	12,811
2001	9,436	1,453	12,738
2002	1,751	468	2,931
2003	670	200	1,187
2004	572	171	1,016
2005	988	265	1,655
2006	4,920	843	6,868
2007	9,216	1,443	12,504
2008	21,479	2,505	26,973
2009	17,505	2,199	22,369
2010	2,491	556	3,838
2011	1,143	290	1,866
2012	750	208	1,280
2013	676	188	1,155
2014	486	142	853
2015	328	104	600
2016	203	70	391
2017	155	56	308
2018	125	46	251
2019	122	44	241
2020	150	49	281
2021	299	86	520
2022	1,816	333	2,593
2023	1,030	227	1,579
2024	894	219	1,436
2025	1,247	341	2,110
2026	2,541	986	5,294

Table 5.24. Spawning and total biomass compared with the 2024 assessment and fishing mortality, exploitation rate from the current assessment for BSAI Greenland turbot, 1977-2026. The 2027 and 2028 biomass estimates are from the model 25.0 projections.

	SSB (t)		Total biomass (age1+)			
Year	2024	Current	2024	Current	Apical F	Exploitation rate
1977	430,374	408,360	741,545	718551	0.07	0.04
1978	417,993	397,243	720,901	699653	0.10	0.06
1979	395,213	375,567	693,251	674273	0.10	0.06
1980	371,894	353,290	669,146	652932	0.14	0.08
1981	346,490	328,913	632,021	618905	0.16	0.09
1982	323,116	306,802	584,806	574820	0.15	0.09
1983	305,852	291,173	535,951	528855	0.15	0.09
1984	289,573	276,857	485,075	480518	0.08	0.05
1985	281,150	270,487	454,399	451880	0.06	0.03
1986	273,601	264,887	428,607	427720	0.04	0.02
1987	265,215	258,231	405,318	405680	0.04	0.02
1988	254,071	248,541	380,884	382165	0.03	0.02
1989	241,762	237,425	358,276	360185	0.06	0.02
1990	225,303	222,053	333,261	335576	0.10	0.04
1991	205,610	203,241	304,305	306818	0.07	0.03
1992	189,612	187,854	281,932	284443	0.03	0.01
1993	176,772	175,463	264,992	267411	0.07	0.03
1994	160,336	159,389	243,505	245776	0.12	0.04
1995	144,385	143,680	220,104	222130	0.10	0.04
1996	130,756	130,178	199,708	201464	0.08	0.03
1997	118,940	118,411	181,809	183292	0.09	0.04
1998	107,128	106,606	163,996	165208	0.13	0.05
1999	94,572	94,041	145,446	146390	0.10	0.04
2000	84,866	84,327	130,660	131354	0.13	0.05
2001	74,539	73,991	115,717	116168	0.12	0.05
2002	66,062	65,510	103,688	103899	0.09	0.03
2003	59,142	58,576	94,881	94846.9	0.08	0.03
2004	53,085	52,502	87,912	87625.2	0.07	0.03
2005	48,213	47,605	82,741	82210.1	0.09	0.03
2006	43,739	43,088	77,690	76932.9	0.07	0.03
2007	40,601	39,874	73,551	72593	0.08	0.03
2008	38,290	37,468	69,596	68458.9	0.13	0.04
2009	36,407	35,494	65,197	63844.7	0.21	0.07
2010	33,676	32,688	60,287	58661	0.22	0.07
2011	30,648	29,593	57,509	55494.2	0.21	0.07
2012	27,738	26,625	56,832	54323.8	0.30	0.09
2013	24,623	23,444	56,068	53003.6	0.12	0.03

Table 5.24. Continued.

	SSB (t)		Total biomass (age1+)			
Year	2024	Current	2024	Current	Apical F	Exploitation
2014	24,071	22,778	58,543	54971	0.11	0.03
2015	24,887	23,383	60,750	56719	0.13	0.04
2016	26,574	24,765	61,691	57272	0.11	0.04
2017	28,715	26,564	61,651	56942	0.12	0.05
2018	30,199	27,734	60,027	55124	0.07	0.03
2019	31,321	28,610	58,292	53294	0.11	0.05
2020	30,927	28,053	54,690	49672	0.10	0.05
2021	29,980	27,021	50,909	45943	0.07	0.03
2022	28,839	25,862	47,383	42522	0.08	0.03
2023	27,315	24,372	43,703	38964	0.08	0.03
2024	25,594	22,724	40,194	35527	0.06	0.02
2025	23,999	21,221	37,615	32717	0.05	0.02
2026	22,061	19,709	35,877	30190	0.02	0.01
2027		18,414		28,434		
2028		17,040		27,604		

Table 5.25. Spawning biomass from Model 25.0 with lower (LCI) and upper (UCI) 95% confidence intervals for 1977-2026 for BSAI Greenland turbot. Confidence bounds are based on 1.96×standard error. The 2027 and 2028 values are from the projection model.

Year	SSB	LCI	UCI
1977	408,360	45,745	318,702
1978	397,243	42,186	314,561
1979	375,567	38,902	299,320
1980	353,290	35,835	283,054
1981	328,913	32,826	264,575
1982	306,802	29,999	248,006
1983	291,173	27,473	237,328
1984	276,857	25,208	227,451
1985	270,487	23,179	225,056
1986	264,887	21,272	223,195
1987	258,231	19,487	220,038
1988	248,541	17,842	213,572
1989	237,425	16,326	205,427
1990	222,053	14,815	193,017
1991	203,241	13,405	176,967
1992	187,854	12,162	164,016
1993	175,463	11,034	153,837
1994	159,389	9,952	139,884
1995	143,680	8,954	126,130
1996	130,178	8,079	114,344
1997	118,411	7,309	104,086
1998	106,606	6,621	93,628
1999	94,041	6,003	82,275
2000	84,327	5,458	73,629
2001	73,991	4,964	64,263
2002	65,510	4,521	56,649
2003	58,576	4,125	50,492
2004	52,502	3,766	45,122
2005	47,605	3,444	40,855
2006	43,088	3,156	36,901
2007	39,874	2,905	34,180
2008	37,468	2,687	32,201
2009	35,494	2,487	30,621
2010	32,688	2,303	28,175
2011	29,593	2,136	25,407
2012	26,625	1,988	22,729
2013	23,444	1,862	19,794
2014	22,778	1,781	19,287
2015	23,383	1,757	19,938
2016	24,765	1,788	21,260
2017	26,564	1,847	22,944
2018	27,734	1,903	24,003
2019	28,610	1,940	24,808
2020	28,053	1,947	24,238
2021	27,021	1,925	23,247
2022	25,862	1,880	22,178
2023	24,372	1,815	20,815
2024	22,724	1,735	19,323
2025	21,221	1,645	17,995
2026	19,709	1,549	16,672
2027	18,414		

2028	17,040

Table 5.26. Model 25.0 a) mean spawning biomass, b) mean fishing mortality, and c) mean fishery yield for Greenland turbot, 2027-2040 for the seven alternatives. The full-selection fishing mortality rates (*F's*) between longline and trawl gears were assumed to be 96% and 4%, respectively.

a)

Year	Max permissable F	Author's catches (est catches)	5-year maximum	Half average F	No Fishing	Overfishing	Approaching overfished
2027	18,414	18,414	18,414	18,414	18,414	18,414	18,414
2028	17,040	17,040	17,040	17,040	17,040	16,479	16,589
2029	15,777	15,777	15,777	15,777	15,777	14,893	15,069
2030	14,452	14,452	14,658	14,688	14,864	13,611	13,765
2031	13,499	13,499	13,841	13,896	14,219	12,704	12,840
2032	13,396	13,396	13,836	13,913	14,372	12,648	12,768
2033	14,935	14,935	15,493	15,595	16,205	14,220	14,325
2034	18,456	18,456	19,331	19,474	20,335	17,725	17,815
2035	23,639	23,639	25,289	25,512	26,854	22,781	22,858
2036	29,814	29,814	32,902	33,262	35,442	28,681	28,747
2037	36,224	36,224	41,486	42,048	45,500	34,665	34,721
2038	42,301	42,301	50,406	51,239	56,406	40,195	40,242
2039	47,786	47,786	59,235	60,392	67,661	45,057	45,097
2040	52,654	52,654	67,758	69,280	78,950	49,273	49,306

b)

Year	Max permissable F	Author's catches (est catches)	5-year maximum	Half average F	No Fishing	Overfishing	Approaching overfished
2027	0.04	0.04	0.04	0.04	0.04	0.16	0.14
2028	0.05	0.05	0.05	0.05	0.05	0.14	0.12
2029	0.12	0.12	0.06	0.05	0	0.13	0.13
2030	0.11	0.11	0.06	0.05	0	0.12	0.12
2031	0.10	0.10	0.06	0.05	0	0.11	0.11
2032	0.10	0.10	0.06	0.05	0	0.11	0.11
2033	0.10	0.10	0.06	0.05	0	0.12	0.12
2034	0.11	0.11	0.06	0.05	0	0.13	0.13
2035	0.12	0.12	0.06	0.05	0	0.14	0.14
2036	0.13	0.13	0.06	0.05	0	0.15	0.15
2037	0.14	0.14	0.06	0.05	0	0.16	0.16
2038	0.14	0.14	0.06	0.05	0	0.17	0.17
2039	0.15	0.15	0.06	0.05	0	0.17	0.17
2040	0.15	0.15	0.06	0.05	0	0.18	0.18

Table 5.26. continued

c)

Year	Max permissable F	Author's catches (est catches)	5-year maximum	Half average F	No Fishing	Overfishing	Approaching overfished
2027	378	378	378	378	378	1,356	1,166
2028	378	378	378	378	378	1,008	882
2029	801	801	402	343	0	794	820
2030	679	679	384	329	0	675	695
2031	696	696	423	364	0	705	722
2032	1,098	1,098	602	517	0	1,166	1,183
2033	2,163	2,163	982	843	0	2,397	2,413
2034	3,764	3,764	1,551	1,332	0	4,243	4,256
2035	5,605	5,605	2,240	1,926	0	6,343	6,353
2036	7,413	7,413	2,959	2,550	0	8,369	8,375
2037	8,946	8,946	3,630	3,135	0	10,048	10,053
2038	10,154	10,154	4,213	3,647	0	11,337	11,340
2039	11,104	11,104	4,704	4,080	0	12,329	12,331
2040	11,826	11,826	5,114	4,444	0	13,063	13,064

Table 5.27. FMP species catch in the Greenland turbot fishery for the Eastern Bering Sea and Aleutian Islands area since 1991

Year	Arrowtooth Flounder	BSAI Alaska Plaice	BSAI Kamchatka Flounder	BSAI Other Flatfish	Flathead Sole	Other Flatfish	Rock Sole	Yellowfin Sole
1991	1085						1	0
1992	4							
1993	560						0	
1994	1384						1	0
1995	2007				57	64	4	18
1996	492				52	16	3	0
1997	766				63	27	2	9
1998	1153				50	37	13	6
1999	1071				131	74	54	18
2000	764				72	47	3	4
2001	292				69	18	3	5
2002	333				35	17	1	
2003	368	1		40	76		1	1
2004	256	1		5	17		1	1
2005	185			7	7		0	
2006	195			1	3		0	0
2007	235			0	0			
2008	337			3	1		0	
2009	1339			4	5			
2010	572	1		1	11		0	
2011	247		18	4	6		0	0
2012	348		272	6	12			
2013	11		81	3	5		0	0
2014	62		52	2	8		0	0
2015	21		112	2	11			0
2016	378	1	227	7	65		0	
2017	605	0	398	53	138		1	1
2018	168		462	68	227		0	0
2019	248		956	216	498		0	0
2020	157	1	299	46	177		2	0
2021	101		122	58	60		0	
2022	82		167	97	65		0	
2023	5		13	6	11			
2024			4	1	5			

Table 5.27. Continued. FMP species catch in the Greenland turbot fishery for the Eastern Bering Sea and Aleutian Islands area since 1991.

Year	Atka Mackerel	Pacific Cod	Pollock	Sablefish	Shortraker rockfish	Pacific Ocean Perch	Other Rockfish
1991	65	154	114	504	27	3	61
1992		12	0	28	2	0	2
1993		115	6	577	196	1	77
1994	1	85	20	492	35	1	96
1995	10	111	50	555	98	12	96
1996	3	97	32	265	22	6	59
1997		82	56	267	19	14	51
1998	22	166	106	404	67	3	125
1999	133	225	151	380	44	32	56
2000	5	223	117	351	91	27	121
2001	2	110	54	229	48	52	56
2002		83	13	170	16	1	55
2003	0	32	98	174	35	1	79
2004	0	38	64	89	40	1	60
2005		22	8	99	12	0	48
2006	0	56	1	93	33	0	52
2007	0	67	3	73	78	0	56
2008	0	83	32	61	2	166	37
2009	1	13	12	81	4	0	50
2010		57	11	98	27	0	70
2011	0	78	14	31	7	0	44
2012		77	10	27	14	0	39
2013		5	2	11	6	0	17
2014		6	2	21	6	0	25
2015	0	37	20	7	4	0	29
2016		61	133	16	7	42	38
2017		53	227	120	16	37	54
2018		58	175	128	46	111	54
2019	1	42	272	637	55	150	311
2020		18	109	199	5	32	18
2021	17	4	68	121	26	109	40
2022		1	58	210	7	28	148
2023		0	3	31	1	1	7
2024			0	3	0	1	1

Table 5.27 Continued. FMP species catch in the Greenland turbot fishery for the Eastern Bering Sea and Aleutian Islands area since 1991.

Year	BSAI Skate and GOA Skate, Other	BSAI Squid	Octopus	Sculpin	Shark	Squid
1991						37.79
1992						
1993						0.34
1994						18.97
1995						12.14
1996						0.65
1997						3.2
1998						1.27
1999						3.6
2000						9.11
2001						1.99
2002						0.17
2003		3.463				
2004		6.045				
2005		0.417				
2006						
2007						
2008		4.176				
2009		22.656				
2010		0.87853				
2011	382.785823		0.0455864	0.67710535	0.42331	0.00347
2012	352.177955		0.07708533	1.47350879	0.10424016	
2013	49.8775951		0.1544667	0.27542278		0.06446
2014	42.6468392		0.07471727	2.45141722	0.03531306	0.60317
2015	207.593814		0.09142496	2.02913053		0.00165656
2016	193.731203		0.1381254	21.3391836		3.32749
2017	198.052323		1.35194397	33.4761423	0.00768	14.0354505
2018	99.7415836		0.74455622	29.8452353		22.3714203
2019	122.951325		6.78657977	26.8372254	0.11431513	
2020	101.421385		0.43688649	21.8841901	2.77159	
2021	28.7413		0.4917			
2022	16.11364		0.96806			
2023	3.73948		0.00463			
2024	0.16751		0.03103			

Table 5.28 Non-FMP species catch (kg) in the Greenland turbot fishery for the Eastern Bering Sea and Aleutian Islands for longline and pot vessels since 2003. Species with catch < 0.01 t have been excluded.

Weight	Year						
Species	2003	2004	2005	2006	2007	2008	2009
Benthic urochordata	0.03		0.00	0.01	0.00		
Bivalves	0.00		0.00				0.00
Brittle star unidentified	0.01		0.00	0.00	0.01		0.03
Corals Bryozoans - Corals Bryozoans Unidentified	0.06		0.06	0.07	0.01	0.00	0.00
Corals Bryozoans - Red Tree Coral	0.00					0.00	
Eelpouts	1.59	2.36	5.53	3.95	2.27	2.85	5.41
Giant Grenadier	44.44	135.79	1105.29	1300.83	1181.18	686.76	1775.30
Greenlings							
Grenadier - Pacific Grenadier			0.00		0.01		
Grenadier - Rattail Grenadier Unidentified	1503.57	1164.08	1029.74	216.84	234.45	20.90	46.88
Gunnels							
Hermit crab unidentified	0.00		0.00		0.00		0.00
Invertebrate unidentified	0.00		0.00	0.03	0.02		0.01
Large Sculpins	0.51	0.13	0.12	0.76	0.32		
Large Sculpins - Bigmouth Sculpin						0.28	0.11
Large Sculpins - Great Sculpin						0.07	0.04
Large Sculpins - Yellow Irish Lord						0.01	
Misc crabs	0.01	0.01	0.00	0.02	0.01	0.03	0.00
Misc crustaceans							0.01
Misc fish	2.95	1.48	1.11	2.08	0.43	1.74	0.39
Misc inverts (worms etc)							
Other Sculpins	1.18	0.40	0.36	0.37	1.29	0.37	0.74
Scypho jellies	0.01		0.02	0.01			0.00
Sea anemone unidentified	0.12	0.04	0.20	0.08	0.03	0.04	0.06
Sea pens whips	0.00		0.00				
Sea star	0.40	0.23	0.86	0.38	0.78	1.42	1.16
Snails	0.04	0.01	0.13	0.02	0.03	0.02	0.02
Sponge unidentified	0.10	0.00	0.01	0.01	0.50	0.01	0.00
urchins dollars cucumbers	0.80	0.01	0.29	0.02	0.02	0.01	0.52

Table 5. 28 Continued.

Weight Species	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Benthic urochordata	0.01									0.00	
Bivalves							0.00		0.01	0.00	
Brittle star unidentified	0.00	0.05	0.04	0.01		0.12	0.09	0.00		0.00	0.00
Corals Bryozoans - Corals Bryozoans Unidentified	0.12	0.00	0.01	0.00					0.00		
Corals Bryozoans - Red Tree Coral											
Eelpouts	5.73	7.61	7.80	2.04	2.50	4.70	3.52	1.47	0.30	0.10	0.05
Giant Grenadier	1836.14	2067.53	1364.64	534.95	294.11	1009.10	1103.25	1087.53	346.64	366.31	201.81
Greenlings		0.00									
Grenadier - Pacific Grenadier											
Grenadier - Rattail Grenadier Unidentified	697.22	341.66	288.47	16.77	173.71	10.54	2.29	51.09	64.37	13.30	0.07
Gunnels		0.03									
Hermit crab unidentified	0.00						0.00				
Invertebrate unidentified	0.00	0.26	0.06	0.25	0.01		0.15			0.00	
Large Sculpins											
Large Sculpins - Bigmouth Sculpin											
Large Sculpins - Great Sculpin											
Large Sculpins - Yellow Irish Lord											
Misc crabs	0.18	0.21	0.08	0.13	0.20	0.19	0.20	0.22	0.06	0.09	0.04
Misc crustaceans											
Misc fish	1.40	1.09	1.34	0.50	0.82	0.56	0.25	0.08	0.05	0.01	0.02
Misc inverts (worms etc)	0.00										
Other Sculpins											
Scypho jellies	0.01	0.01	0.01	0.00		0.00		0.00	0.03	0.00	0.00
Sea anemone unidentified	0.12	1.45	0.50	0.04	0.00	0.38	0.31	0.10	0.02	0.00	0.00
Sea pens whips	0.03	0.08					0.15	0.07			
Sea star	1.12	0.80	0.88	0.43	0.64	0.47	1.34	1.35	0.10	0.15	0.02
Snails	0.03	0.03	0.03	0.05	0.02	0.02	0.02	0.01	0.00	0.01	0.00
Sponge unidentified	0.00	0.02	0.01	0.00		0.00	0.03	0.01	0.00		
urchins dollars cucumbers	0.33	0.04	0.15	0.13	0.22	0.02	0.06	0.12	0.03	0.01	0.01

Table 5.29 Non-FMP species catch (kg) in the Greenland turbot fishery for the Eastern Bering Sea and Aleutian Islands for trawlers since 2003. Species with catch < 0.01 t have been excluded.

Species	2003	2004	2005	2008	2009	2010
Benthic urochordata						
Birds - Northern Fulmar						
Birds - Shearwaters						
Bivalves						
Brittle star unidentified	0.03					
Capelin		0.01				
Corals Bryozoans - Corals Bryozoans Unidentified						0.00
Eelpouts	27.85	10.70	1.00	0.27	3.42	0.04
Eulachon						
Giant Grenadier				67.46	365.00	66.40
Greenlings			0.18			
Grenadier - Pacific Grenadier					0.80	
Grenadier - Rattail Grenadier Unidentified	25.24	25.95	0.47		48.84	5.66
Hermit crab unidentified	0.01	0.00				
Invertebrate unidentified		0.88				
Lanternfishes (myctophidae)						
Large Sculpins		4.18	0.27			
Large Sculpins - Bigmouth Sculpin				1.56	0.72	
Large Sculpins - Yellow Irish Lord					0.08	
Misc crabs	0.01	0.00				0.00
Misc crustaceans						
Misc deep fish						
Misc fish	1.26	0.11	0.27	0.11	0.20	
Misc inverts (worms etc)	0.04					
Other osmerids						
Other Sculpins	4.79		0.15	0.64	0.43	
Pacific Sand lance			0.00			
Pandalid shrimp	0.01				0.01	0.00
Polychaete unidentified						
Sculpin						
Scypho jellies		0.06				
Sea anemone unidentified	0.77	0.00			0.13	0.00
Sea pens whips	0.02					
Sea star	4.63	1.96	0.25	0.00	0.06	0.00
Snails	0.51	0.14			0.01	
Sponge unidentified				0.00	0.10	0.00
Squid						
Stichaeidae						
urchins dollars cucumbers					0.03	0.00

Figure 5.29 Continued.

Species	2011	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Benthic urochordata					0.00	0.03	0.30	0.86	0.07	0.03	0.00	0.02	0.00
Birds - Northern Fulmar								0.00					
Birds - Shearwaters								0.00			0.00		
Bivalves								0.00	0.02	0.00	0.00	0.00	
Brittle star unidentified			0.00		2.14	0.48	0.00	2.73	0.87	0.53	0.02	0.03	0.00
Capelin													
Corals Bryozoans - Corals Bryozoans Unidentified		0.00				0.02	0.02	0.28	0.02		0.01	0.00	
Eelpouts	0.12	0.01	1.14	0.08	0.89	7.33	4.68	37.76	2.43	2.49	11.44	0.27	0.19
Eulachon						0.00							
Giant Grenadier	0.86	0.58	0.44	6.85	83.43	450.14	364.22	447.22	397.27	443.71	269.59	71.53	22.42
Greenlings							0.59	0.00	0.01		0.00		
Grenadier - Pacific Grenadier													
Grenadier - Rattail Grenadier Unidentified			0.36		4.22	0.01		62.32	13.86		1.88		
Hermit crab unidentified					0.00	0.00	0.00	0.05	0.05	0.00	0.05	0.01	0.00
Invertebrate unidentified						0.01	0.00	0.00		0.00			
Lanternfishes (myctophidae)			0.00			0.00	0.01	0.01	0.00		0.00	0.00	
Large Sculpins													
Large Sculpins - Bigmouth Sculpin													
Large Sculpins - Yellow Irish Lord													
Misc crabs			0.02		0.00	0.15	0.56	2.86	1.42	0.57	3.17	0.08	0.00
Misc crustaceans								0.03	0.07	0.00	0.00	0.01	0.00
Misc deep fish								0.01					
Misc fish	0.04	0.08	0.03	0.03	0.77	1.43	2.17	2.46	2.05	1.16	1.28	0.23	0.03
Misc inverts (worms etc)						0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.00
Other osmerids								0.00					
Other Sculpins													
Pacific Sand lance													
Pandalid shrimp				0.01	0.13	0.67	0.60	0.52	0.39	0.22	0.05	0.01	0.01
Polychaete unidentified						0.00	0.00	0.02	0.06	0.00	0.00	0.00	0.00
Sculpin										13.95	7.19	0.39	0.01
Scypho jellies			0.01			0.00	0.40	2.60	0.32	0.01	0.01	0.01	0.00
Sea anemone unidentified		0.00	0.08	0.35	8.28	20.23	35.36	20.50	28.72	21.76	5.44	0.31	0.08
Sea pens whips					0.14	0.33	0.01	0.03	0.13	0.06	0.01	0.01	0.00
Sea star	0.05	0.00	0.02	0.02	1.02	4.37	4.17	21.20	5.12	2.70	6.98	0.31	0.47
Snails			0.00	0.07	0.02	0.17	0.12	0.39	0.13	0.06	0.20	0.02	0.00
Sponge unidentified	0.00		0.06		0.08	1.16	0.20	1.03	1.74	1.18	0.02	0.01	0.00
Squid								65.50	29.38	13.82	15.47	4.13	0.09
Stichaeidae							0.00						
urchins dollars cucumbers			0.00		0.00	0.01	0.02	6.33	0.11	0.15	5.48	0.05	1.31

Table 5.30. Prohibited species catch in the Greenland turbot fishery for the Eastern Bering Sea and Aleutian Islands for fixed gear. Crab, herring and salmon are in number of fish, halibut are in tons.

Year	Bairdi Tanner Crab	Blue King Crab	Chinook Salmon	Golden (Brown) King Crab	Halibut	Herring	Non-Chinook Salmon	Opilio Tanner (Snow) Crab	Other King Crab	Red King Crab
1991							1.43	136.22	50.77	5.3
1992								7.61		
1993	29						4	2074	1164	3
1994			7		45			204	233	13
1995	21				81		8	650	402	50
1996	12				91		0	579	186	18
1997	14				43		22	362	206	12
1998	32				54		47	1226	1497	10
1999	28				81		24	1344	28606	5
2000	13				114		5	930	1730	20
2001	1				54		7	537	313	21
2002	64		3		49		45	562	55	6
2003	53	0	9	136	22	0	20	25		0
2004	10	0	18	151	13	0	77	0		0
2005	0	12	13	22	21	0	41	3		8
2006	28	0	8	328	5	0	26	0		13
2007	19	0	0	2438	2	0	24	34		48
2008	16	7	0	3	1	0	26	43		8
2009	85	0	0	0	2	0	15	24		0
2010	48	8	0	180	6	0	37	87		1
2011	1	1	4	58	5	0	77	20		4
2012	15	0	4	28	4	0	124	48		0
2013	0	0	0	0	1	0	22	15		0
2014	6	0	0	39	1	0	49	21		0
2015	0	0	17	47	3	0	34	7		0
2016	19	0	0	47	3	0	69	31		0
2017	7	0	6	0	2	0	36	11		0
2018	1	1	3	4	0	0	6	65		5
2019	0	0	7	0	0	0	23	9		0
2020	0	0	0	0	0	0	25	2		0

Table 5.31. Prohibited species catch in the Greenland turbot fishery for the Eastern Bering Sea and Aleutian Islands for Trawl. Crab, herring and salmon are in number of fish, halibut are in tons.

	Bairdi Tanner Crab	Blue King Crab	Chinook	Golden (Brown) King Crab	Halibut	Herring	Non-Chinook Salmon	Opilio Tanner (Snow) Crab	Other King Crab	Red King Crab
1991	14919		71			0.01	4.9	237955	11160	1398
1993								80		
1994	1916		58		371	0.00		278055	6029	329
1995	3837				267	0.02		52212	3027	966
1996	1089				6	0.09		5594	250	
1997	614				9	0.16		6138	451	
1998	680				10	0.04	1	24534	125	
1999	1048				19	0.34		2051	1198	
2000	1063				21	0.01		2689	3327	
2001	497				11	0.04		7189	471	
2002	731				1	0.01		2644	211	
2003	2884	0	0	99	8	0.02	0	1800		0
2004	0	0	0	66	2	0	0	66		0
2005	88	0	0	88	2	0	0	0		0
2008	0	0	0	132	2	0	0	0		0
2009	0	0	0	747	6	0	0	0		0
2010	0	0	0	86	2	0	0	0		0
2011	0	0	0	0	0.99	0	0	0		0
2013	0	0	0	0	0.80	0	0	0		0
2014	0	0	0	21	0	0	0	0		0
2015	0	0	0	0	0	0	0	0		0
2016	1531	0	0	464	4	0	0	117		0
2017	3262	0	0	2370	38	0.06	0	2040		0
2018	808	0	0	1291	11	0	0	78		0
2019	1495	0	0	7863	37	0.00	583	816		0
2020	4861	0	0	1334	11	0	0	3062		0
2021	1045	0	0	1783	3	0	0	162		0
2022	0	0	0	876	13	0	0	0		0
2023	0	0	0	146	0.17	0	0	0		0
2024	0	0	0	0	0.01	0	0	0		0

Figures

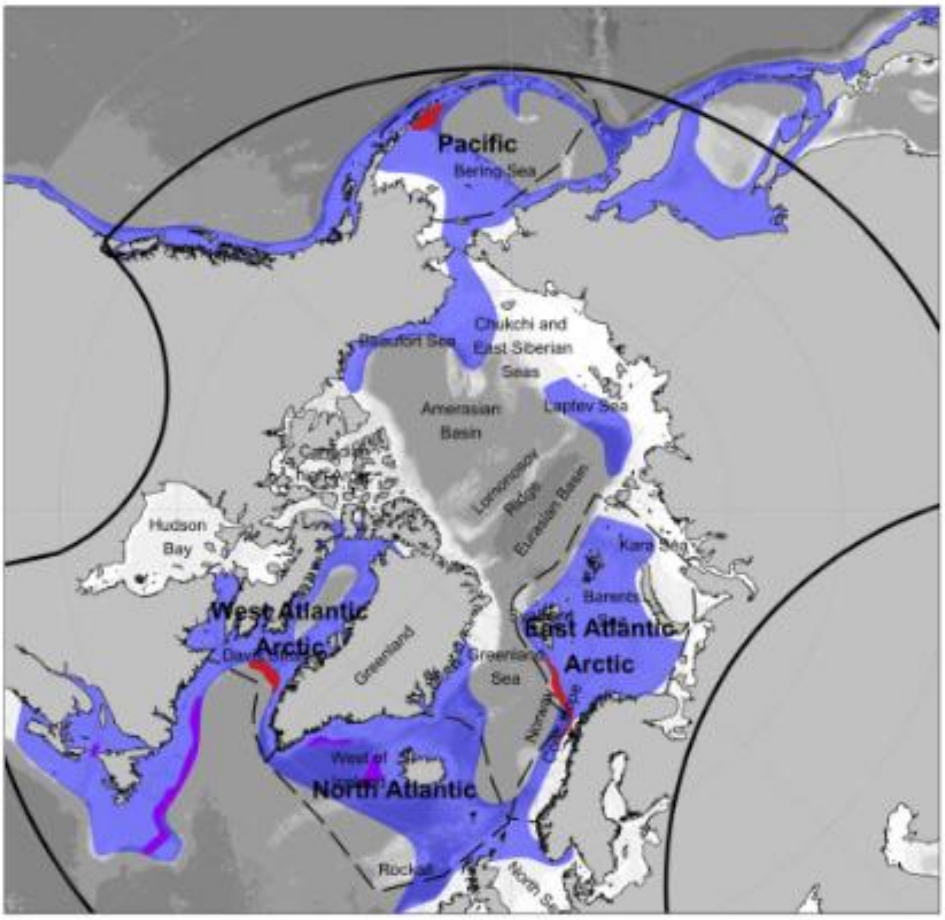


Figure 1. The current understanding of Greenland halibut distribution (blue shading). Red polygons indicate known major spawning regions and the purple polygons tentative local spawning regions. The black lines represent the coverage of the oceanographic model used in suitable habitat estimation. White and grey shading represents bathymetry. Dashed lines indicate regions where temperature–depth data were available.

Figure 5. 1. Map from Vihtakari et al. 2021

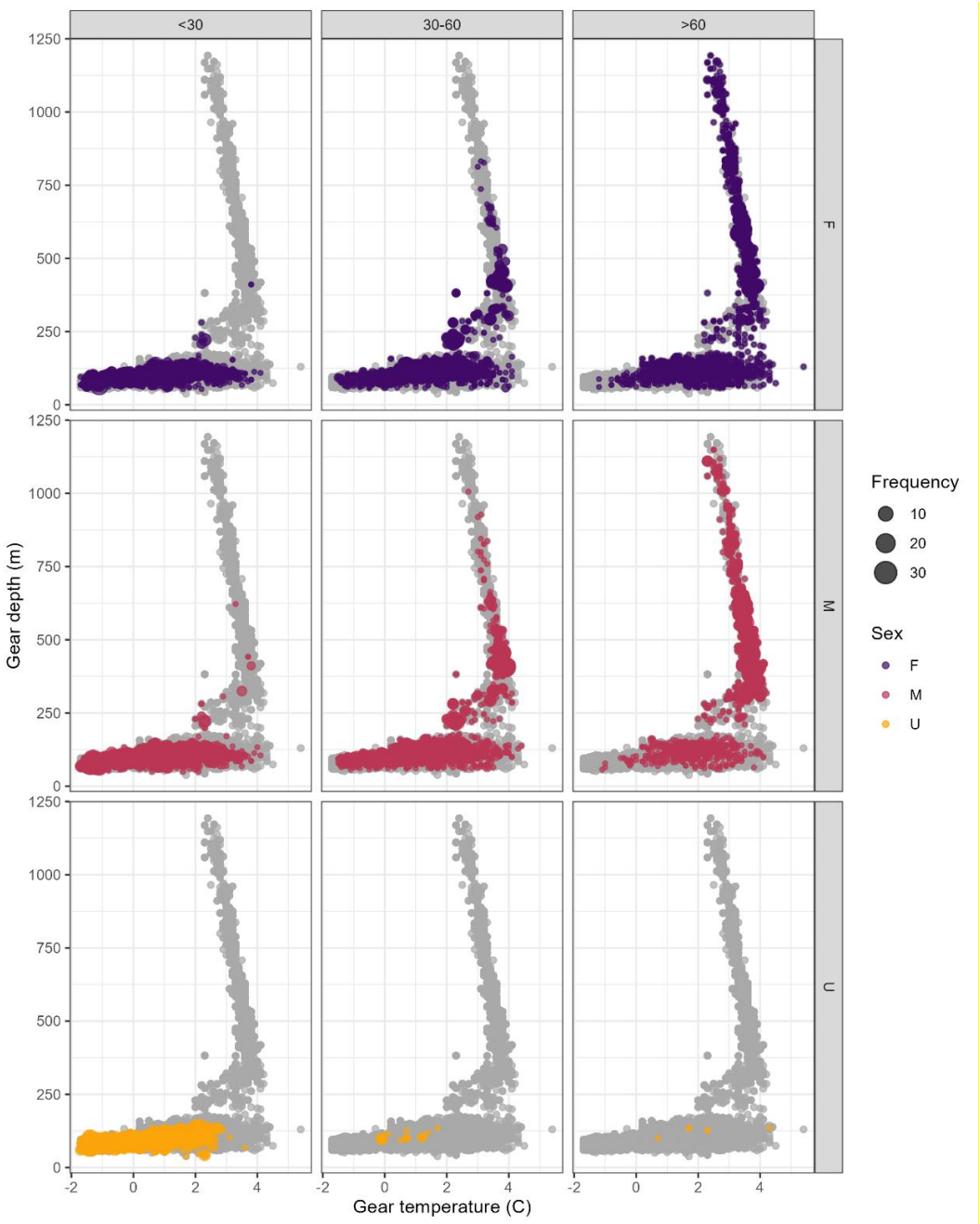


Figure 5. 2. Frequency of occurrence of Greenland turbot by gear temperature and depth in the AFSC bottom trawl survey data, for all years combined. Columns indicate size class (in cm), rows indicate sex (females, males, undetermined). The size of the bubbles indicates frequency by haul.

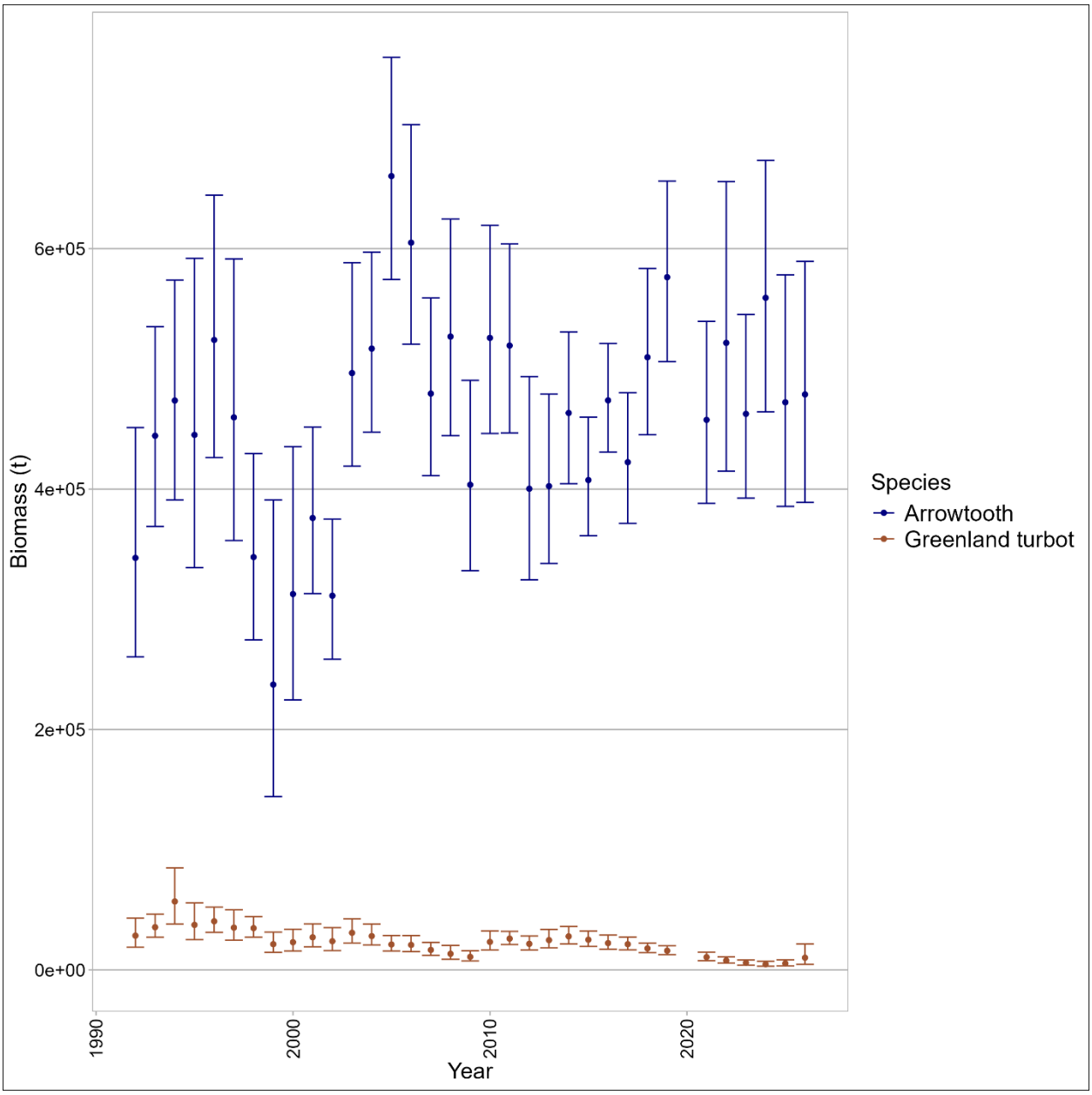


Figure 5. 3 Arrowtooth flounder and Greenland turbot biomass estimates from the EBS shelf bottom trawl survey.

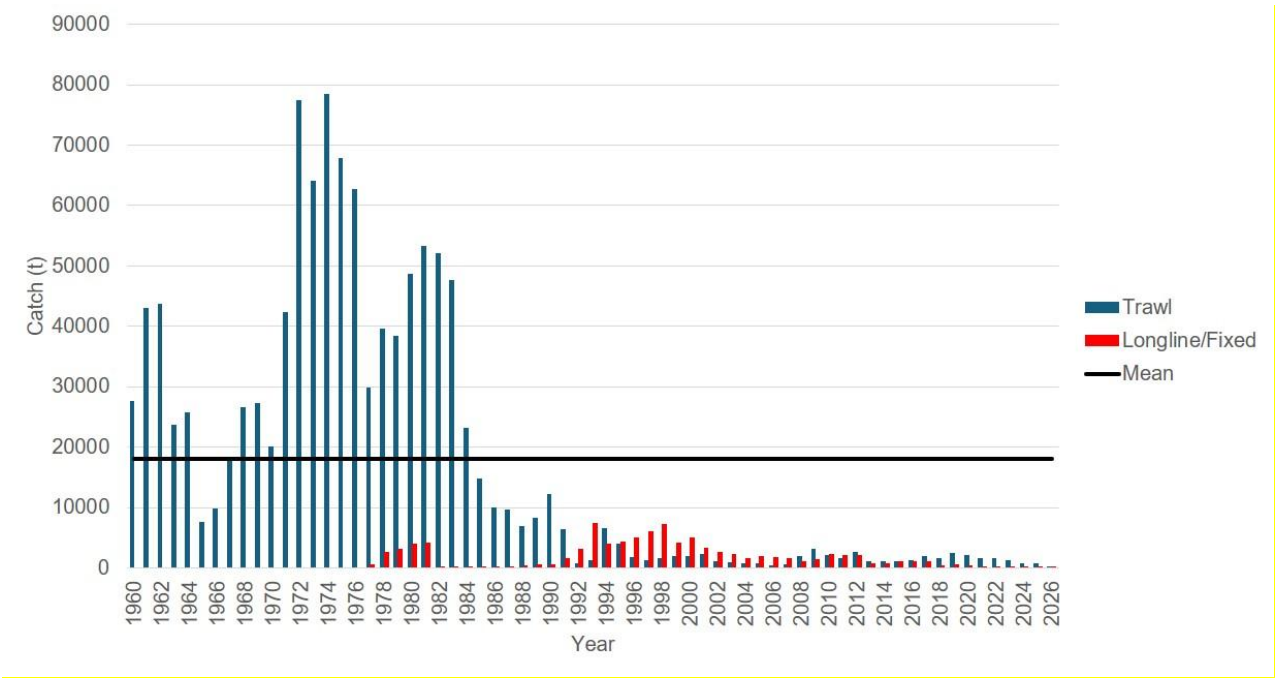


Figure 5. 4. Greenland turbot catch by gear type in the Bering Sea and Aleutian Islands from 1960 through 2026. Targeted and incidental catches are included. The black line represents the mean of total catch (gears combined) from 1960 to 2025.

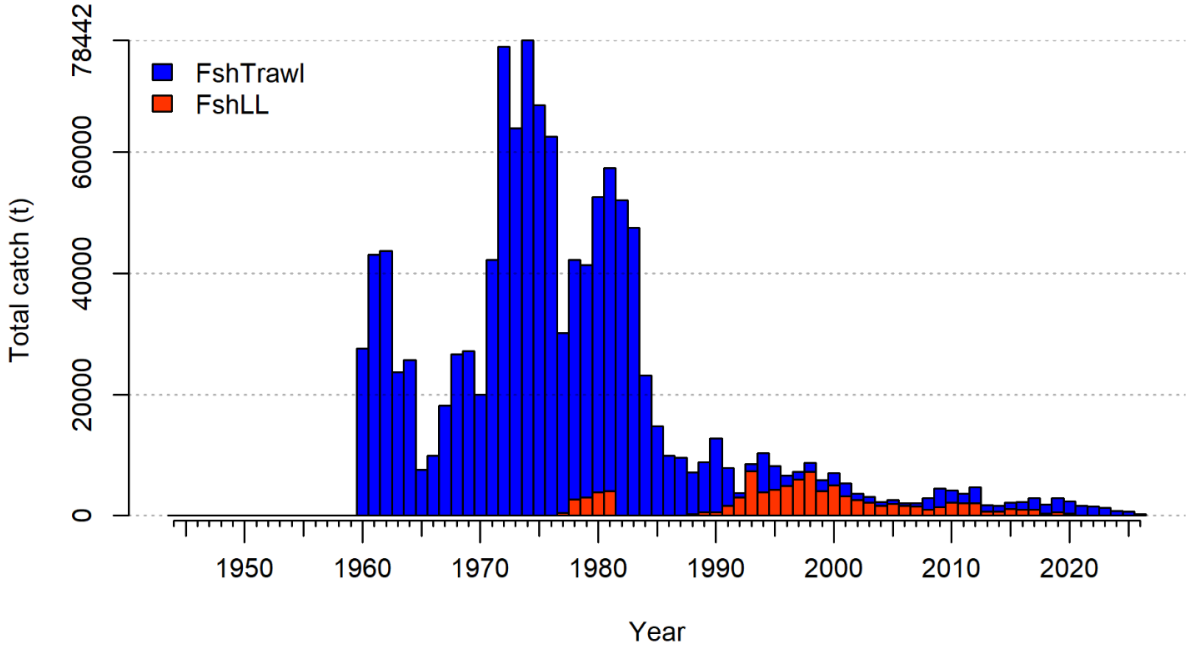


Figure 5.5. Greenland turbot longline (includes all fixed gears) and trawl catch in the Bering Sea and Aleutian Islands from 1960 through 2026. This data includes targeted catch and bycatch.

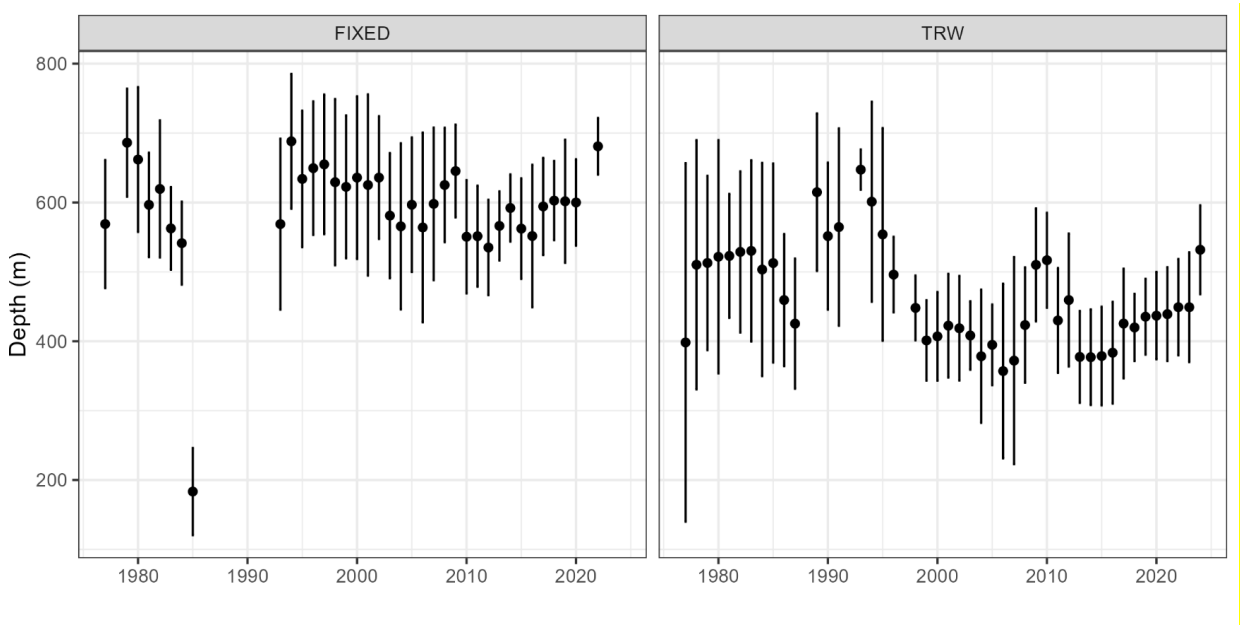


Figure 5. 6. Operating depth (m) of the fixed and trawl gear fisheries for Greenland turbot in the EBS and AI combined. Bars represent standard deviation.

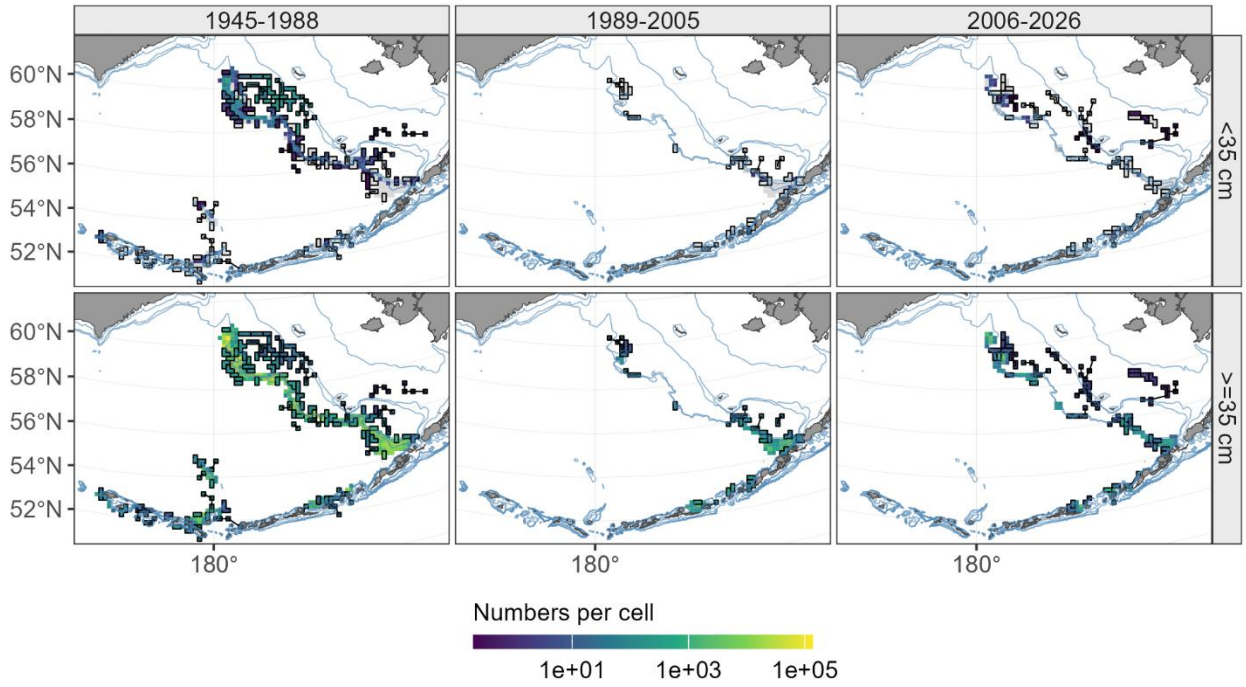


Figure 5.7. Trawl fishery: number measured in 20 x 20 km grid cells by time block (columns), for fish smaller than 35 cm (top) and fish 35 cm and longer (bottom). Numbers summed over sex and over all years in the block (log scale). Grey cells: cells with hauls but no fish in this size class. For confidentiality, cells with fewer than 4 unique identities in the block were pooled with the nearest cells with hauls (up to 3 cells away) until each pool had at least 4 hauls; cells that could not be pooled are not shown. Black outlines: pooled cells; the pool total is spread evenly over its cells. Black lines join cells of the same pool that do not share an edge. Blue lines: bathymetry contours.

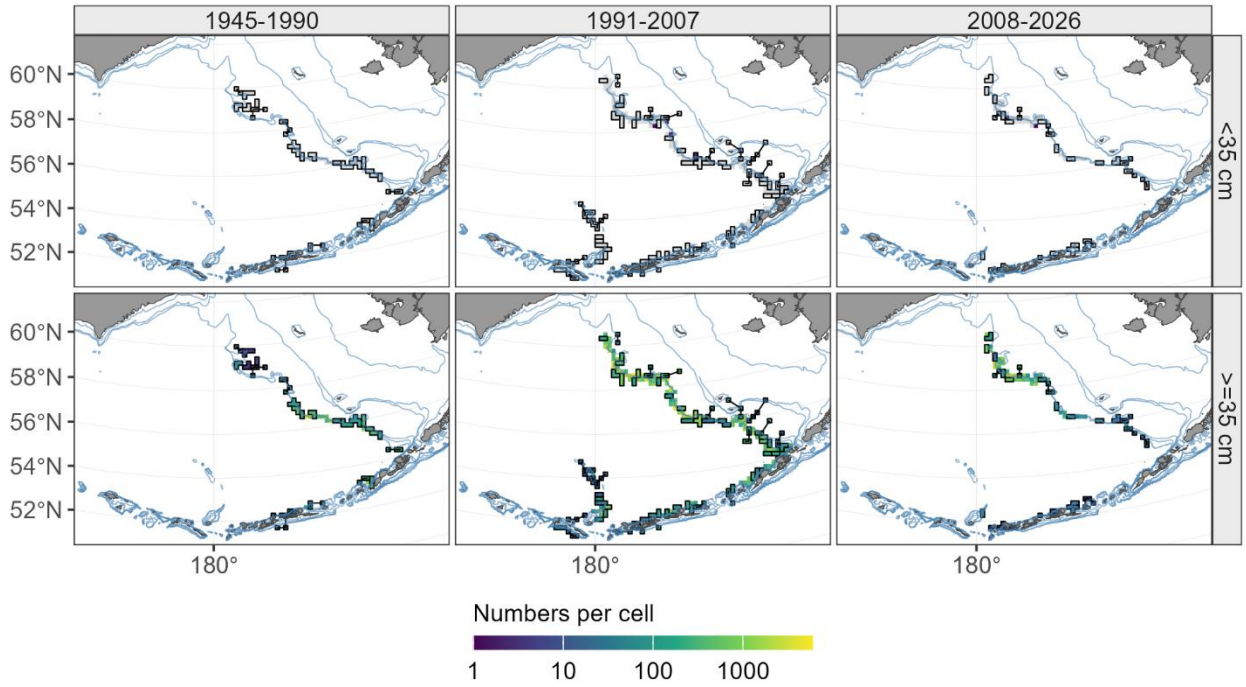


Figure 5. 8 Longline (fixed gear) fishery: numbers measured by 20 x 20 km grid cell and time block (columns), for fish shorter than 35 cm (top) and fish 35 cm and longer (bottom). Numbers summed over sex and over all years in the block (log scale). Grey cells: cells with hauls but no fish in this size class. For confidentiality, cells with fewer than 4 hauls in the block were pooled with the nearest cells with hauls (up to 3 cells away) until each pool had at least 4 hauls; cells that could not be pooled are not shown.black outlines: pooled cells; the pool total is spread evenly over its cells. Black lines join cells of the same pool that do not share an edge. Blue lines: bathymetry contours.

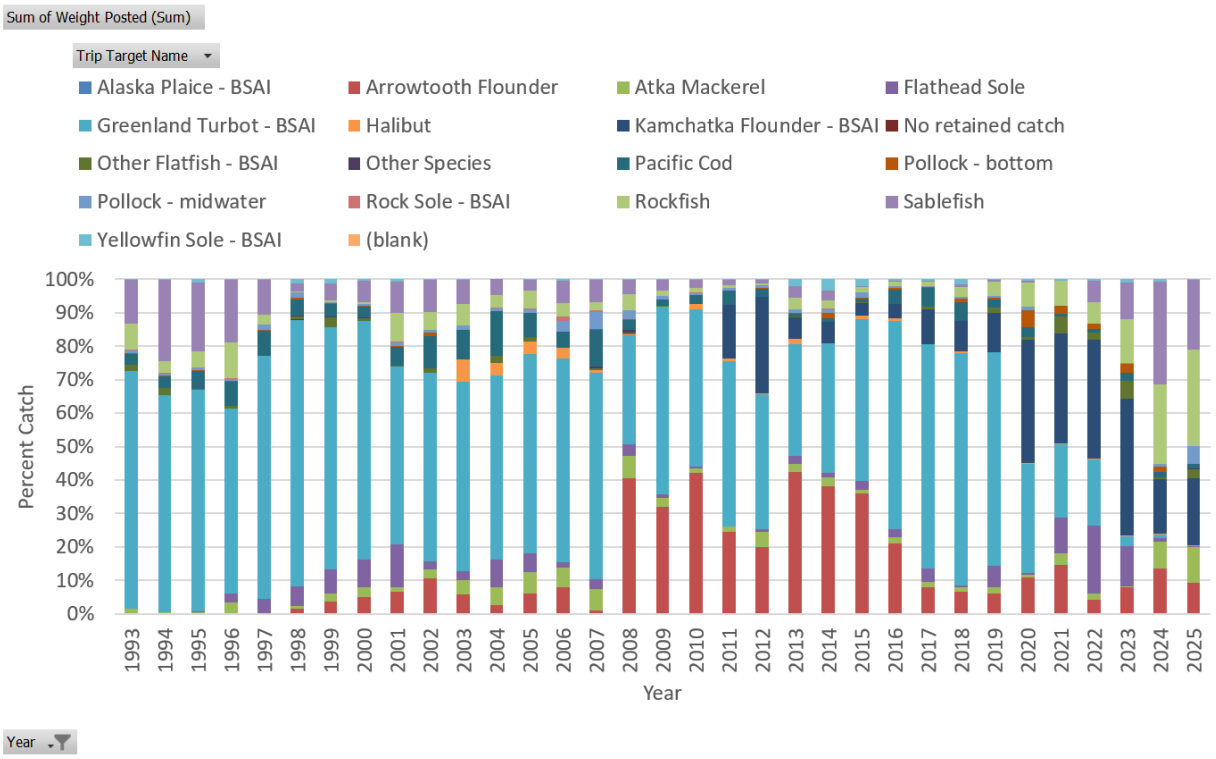


Figure 5. 9. Percent catch of Greenland turbot per trip target species, 1993 – 2024.

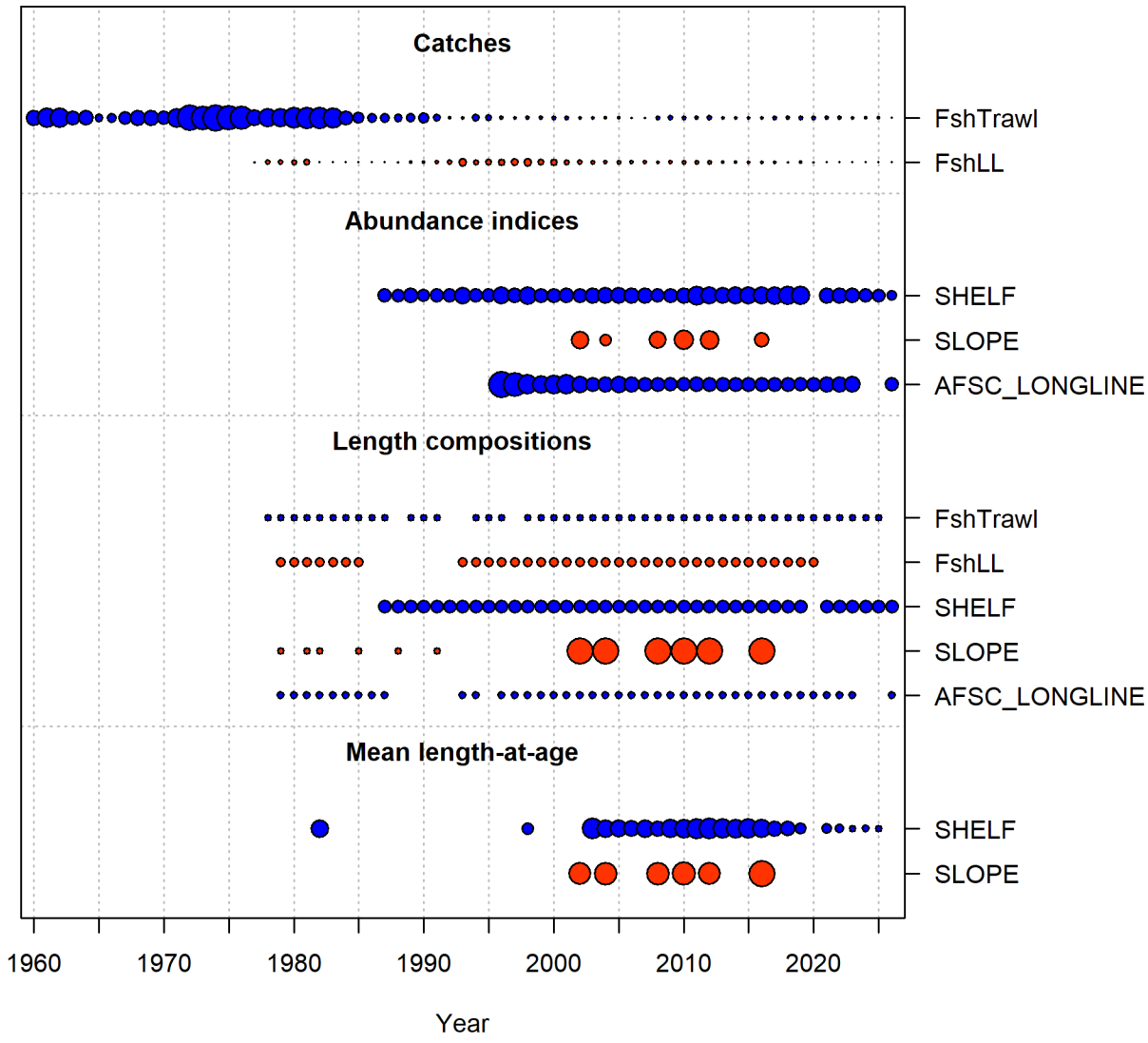
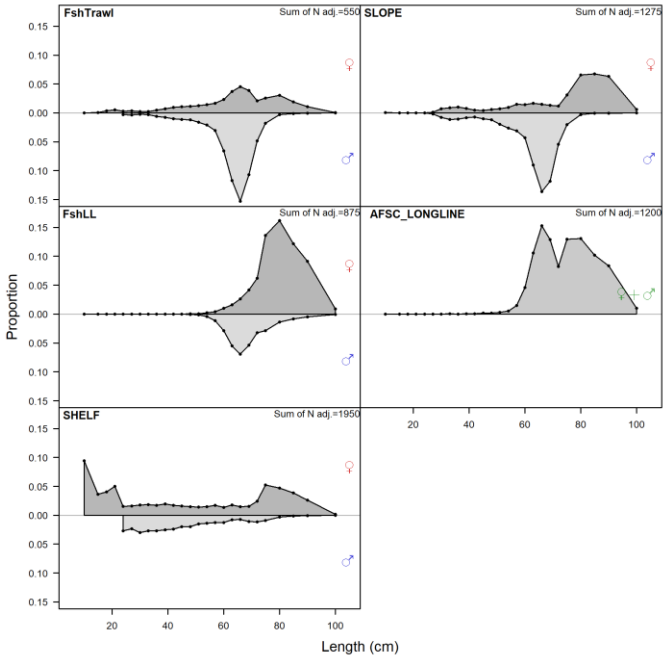


Figure 5.10. Timeline of all data included in models. Circle area is relative within a data type and scaled to the maximum. Circles are proportional total catch for catches, proportional to precision for indices, and tot sample size for composition data.

a)



b)

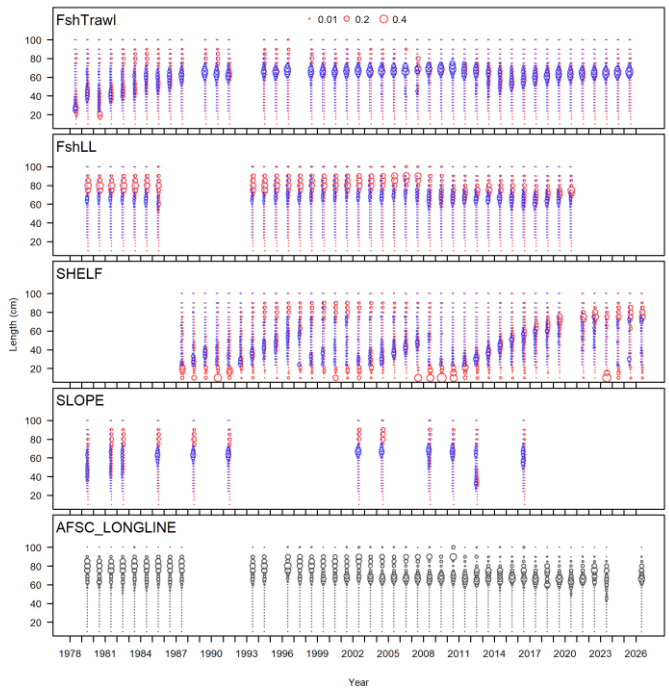


Figure 5. 11. Greenland turbot size composition data from the trawl fishery, longline fishery, shelf survey, slope survey, and longline survey; a) aggregated over all years and b) annual data where blue bubbles are males, red bubbles are females, and black bubbles are combined sex.

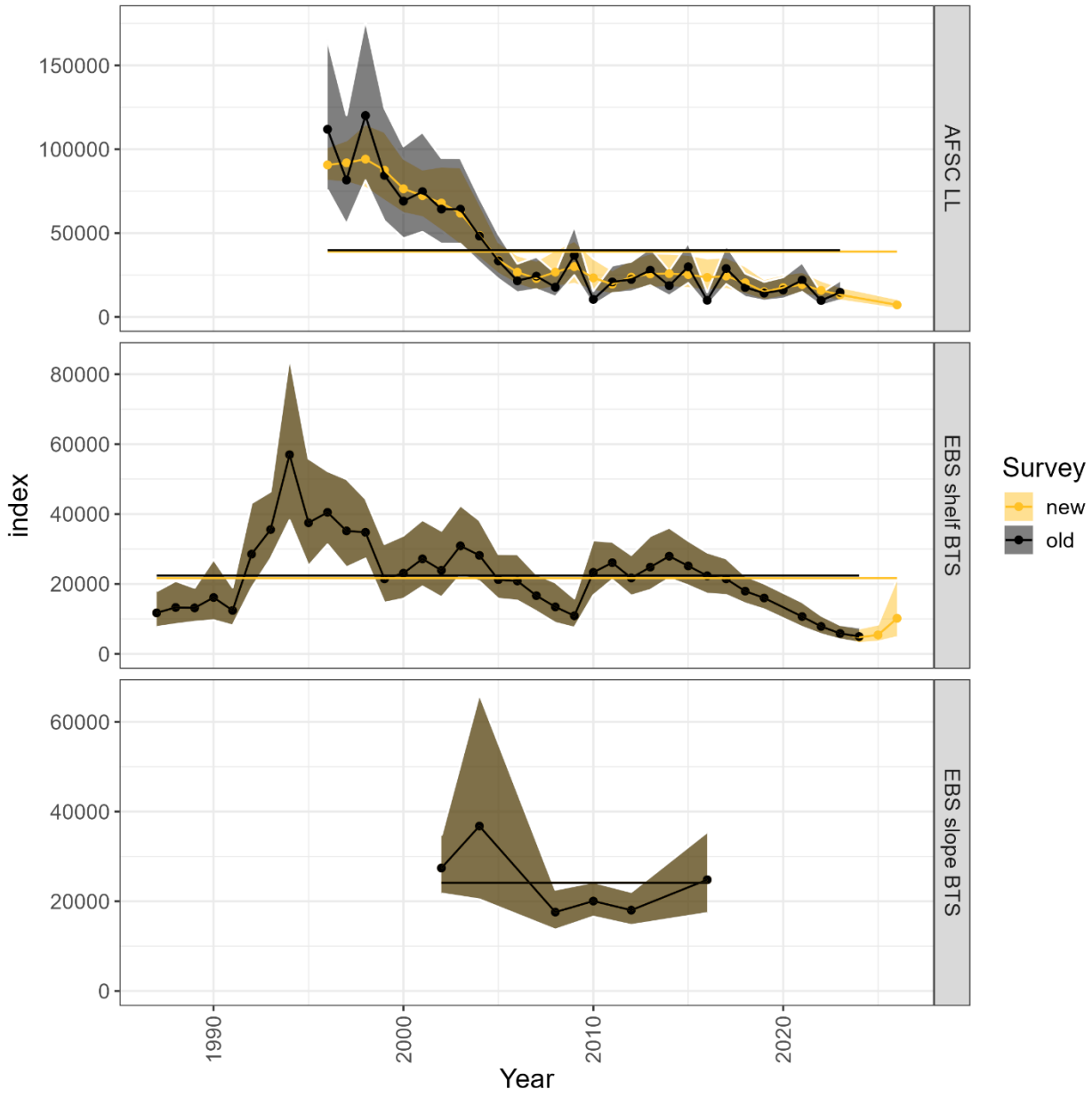


Figure 5. 12. Survey indices used in the 2024 assessment and those used in the 2026 assessment models. The 'old' AFSC longline RPN index is used in model m16.4c (2024) and the 'new' index is used in the alternative models.

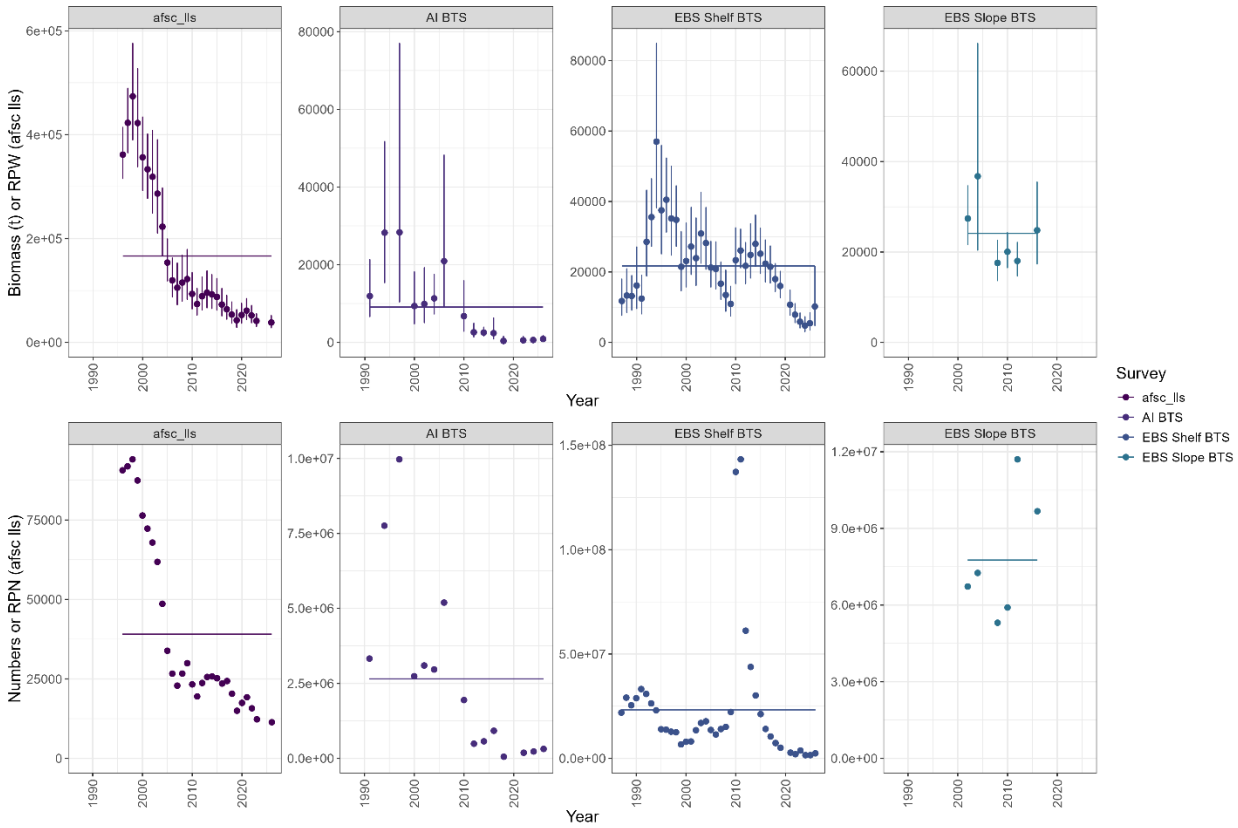
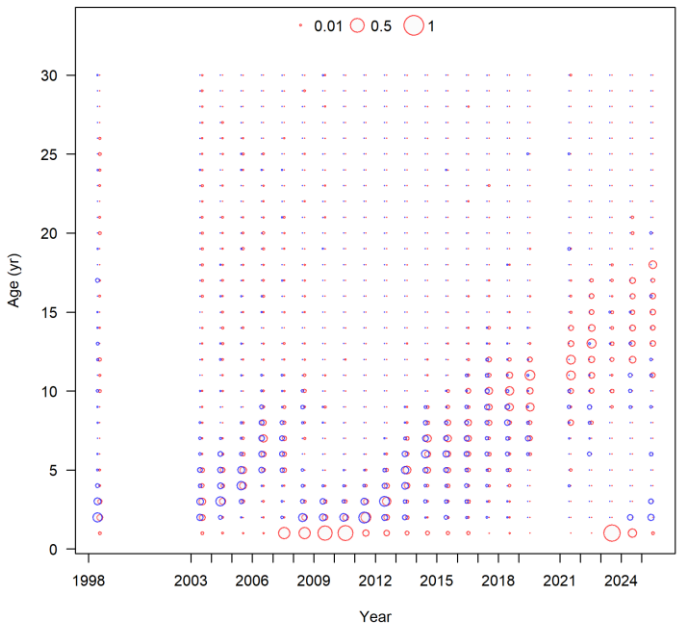


Figure 5. 13. Survey biomass (top row) and survey numbers (bottom row). Horizontal lines represent the survey-specific, time series mean.

a)



b)

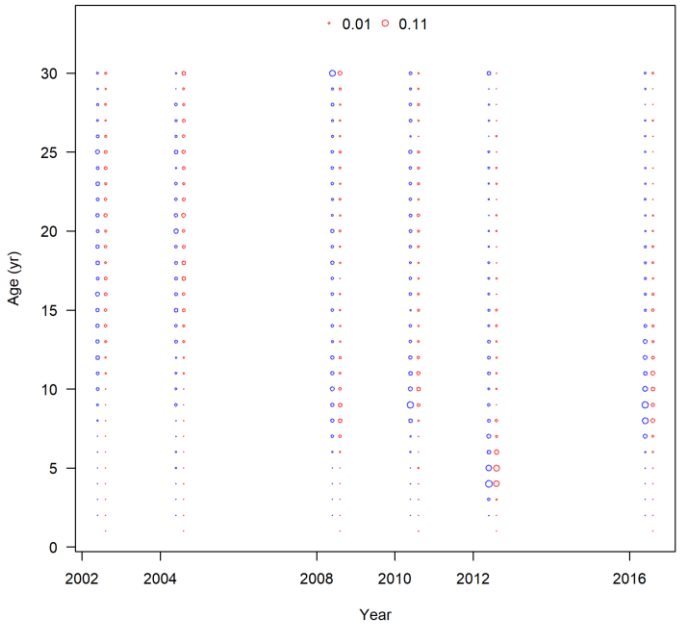


Figure 5. 14. Greenland turbot age composition data for females (red) and males (blue) from the a) EBS shelf and b) EBS slope bottom trawl surveys. These data were included in the model but not included in the likelihood.

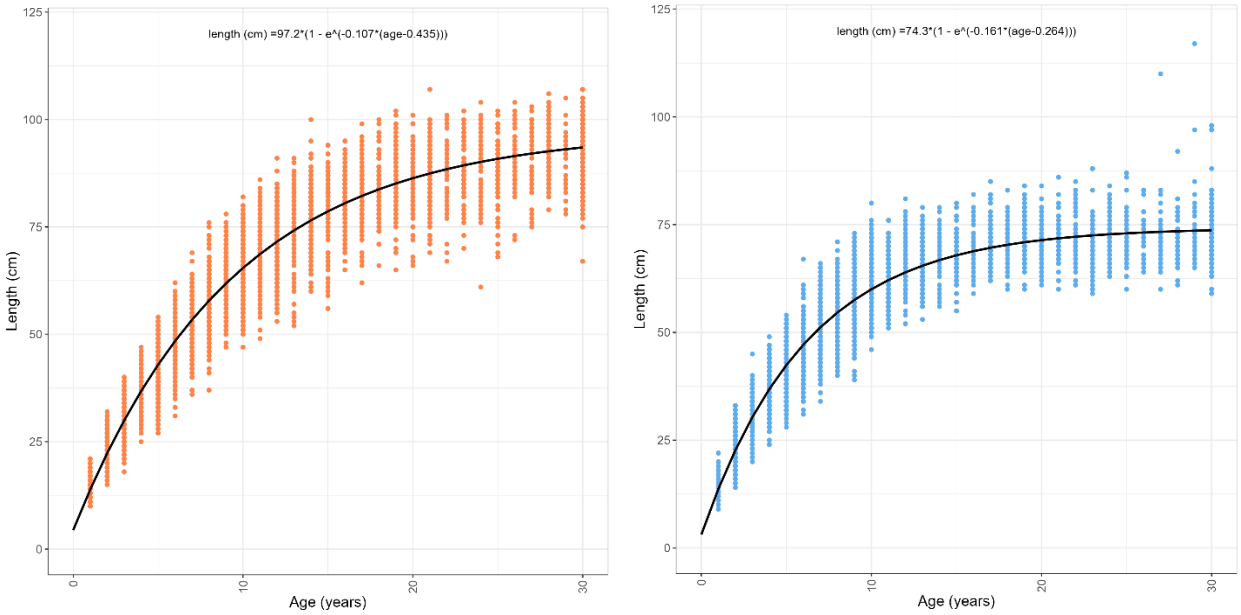


Figure 5.15. Length-at-age observations from the eastern Bering Sea bottom trawl surveys and von Bertalanffy growth estimated external to the assessment model.

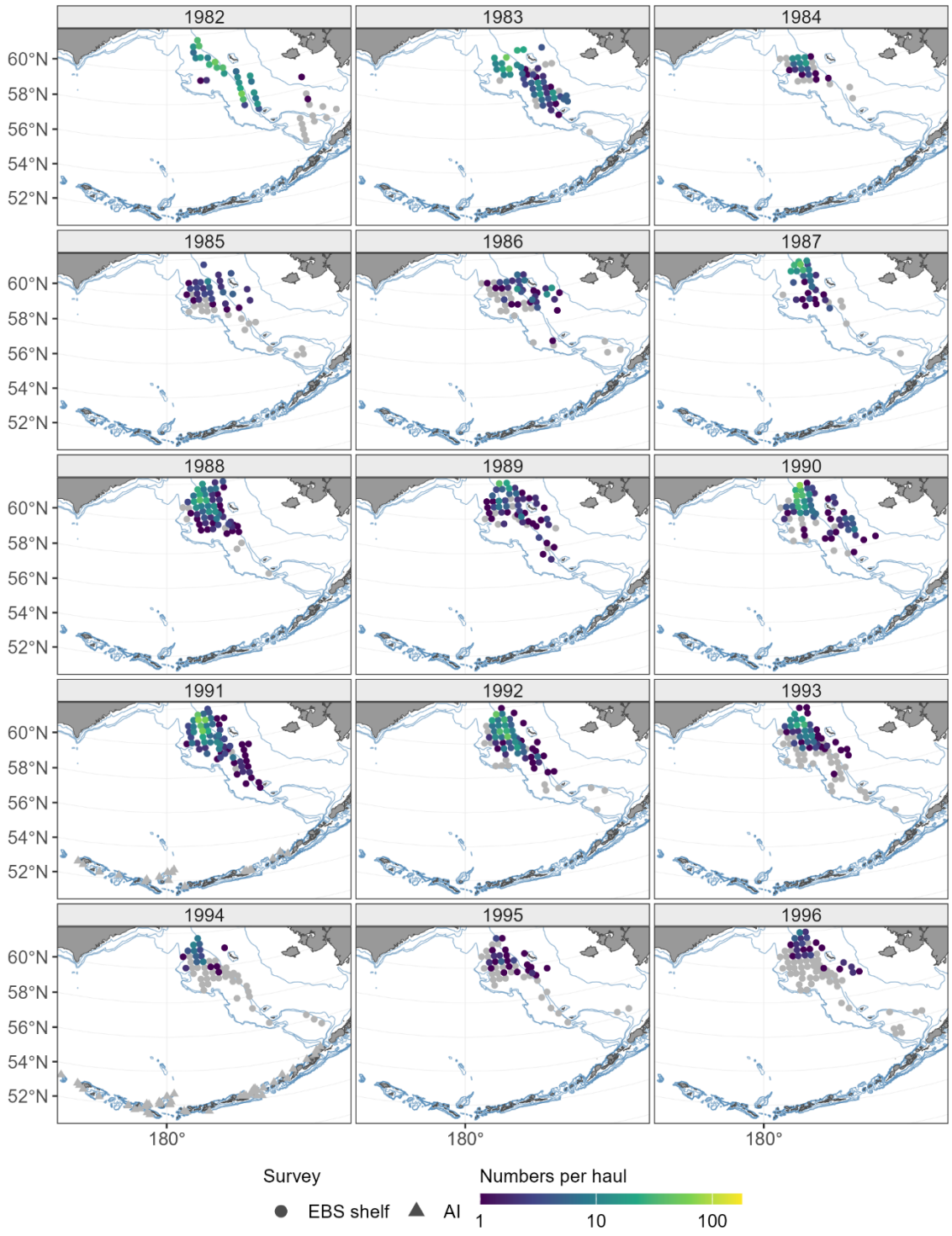
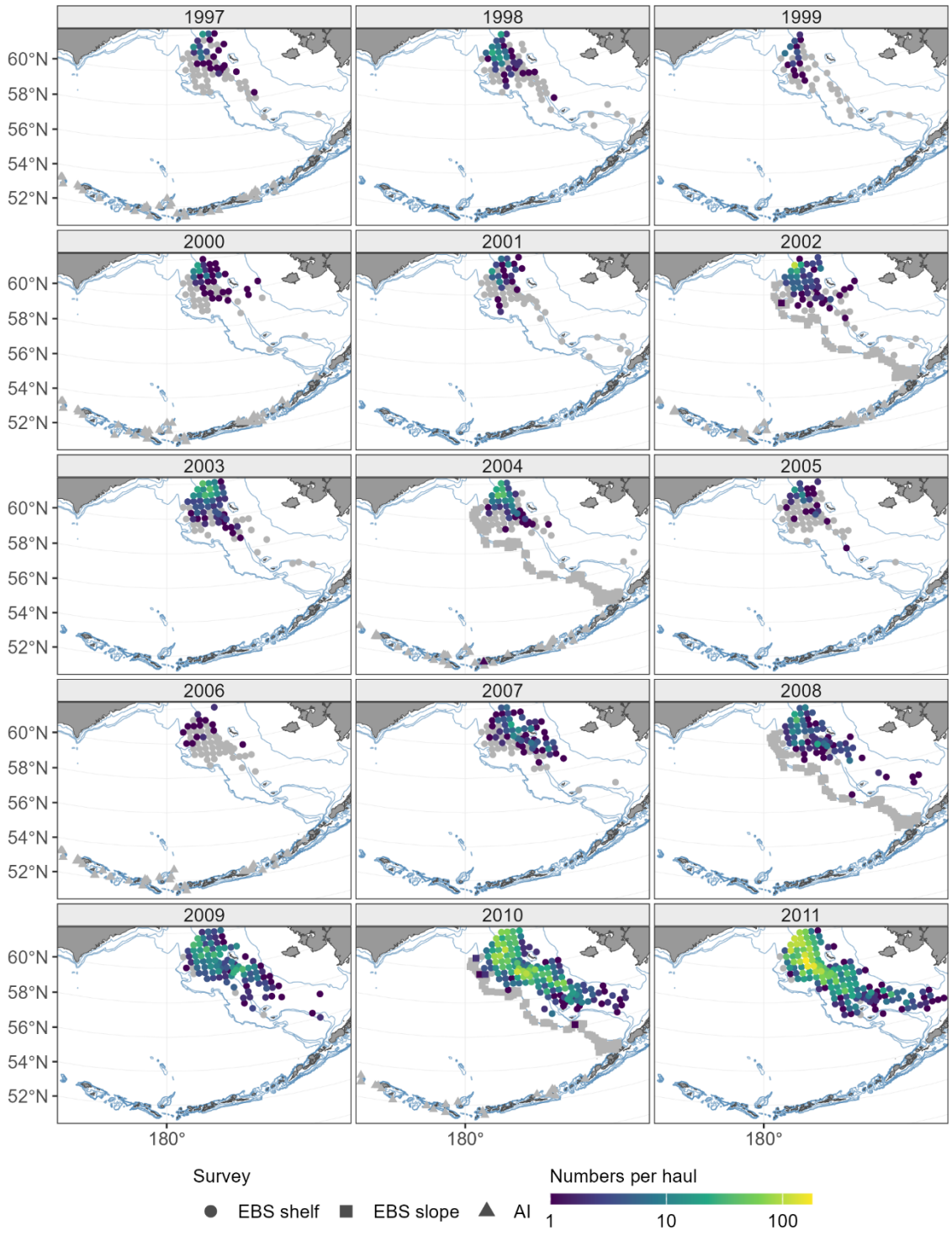
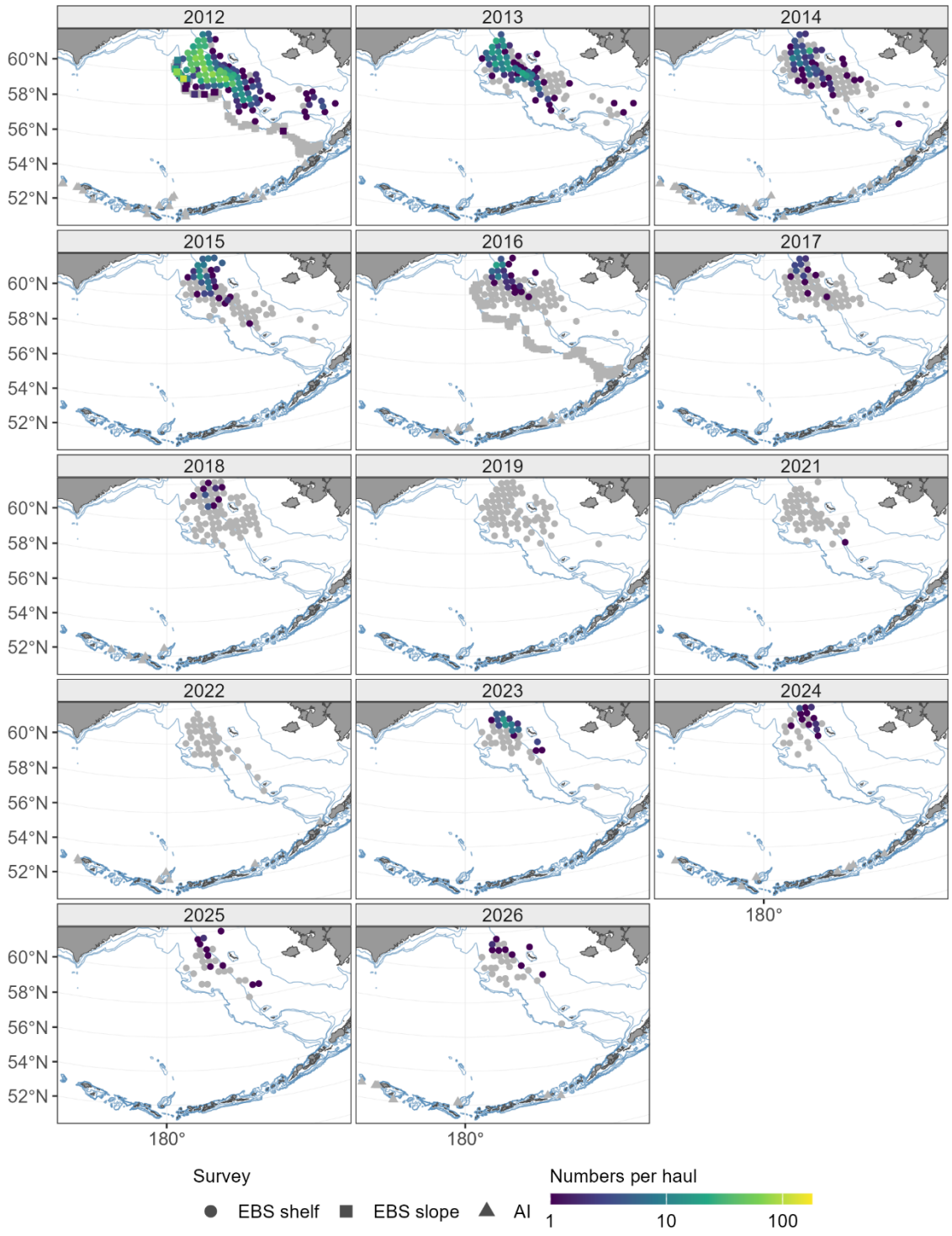


Figure 5. 16. EBS shelf bottom trawl survey, EBS slope bottom trawl survey, Aleutian Islands bottom trawl survey: fish shorter than 35 cm, 1982-1996 (1 of 3). Numbers measured per haul, summed over sex (log scale). Symbol shape indicates the survey. Grey symbols: hauls with lengths measured but no fish in this size class. Blue lines: bathymetry contours.



EBS shelf bottom trawl survey, EBS slope bottom trawl survey, Aleutian Islands bottom trawl survey: fish shorter than 35 cm, 1997-2011 (2 of 3). Numbers measured per haul, summed over sex (log scale). Symbol shape indicates the survey. Grey symbols: hauls with lengths measured but no fish in this size class. Blue lines: bathymetry contours.



EBS shelf bottom trawl survey, EBS slope bottom trawl survey, Aleutian Islands bottom trawl survey: fish shorter than 35 cm, 2012-2026 (3 of 3). Numbers measured per haul, summed over sex (log scale). Symbol shape indicates the survey. Grey symbols: hauls with lengths measured but no fish in this size class. Blue lines: bathymetry contours.

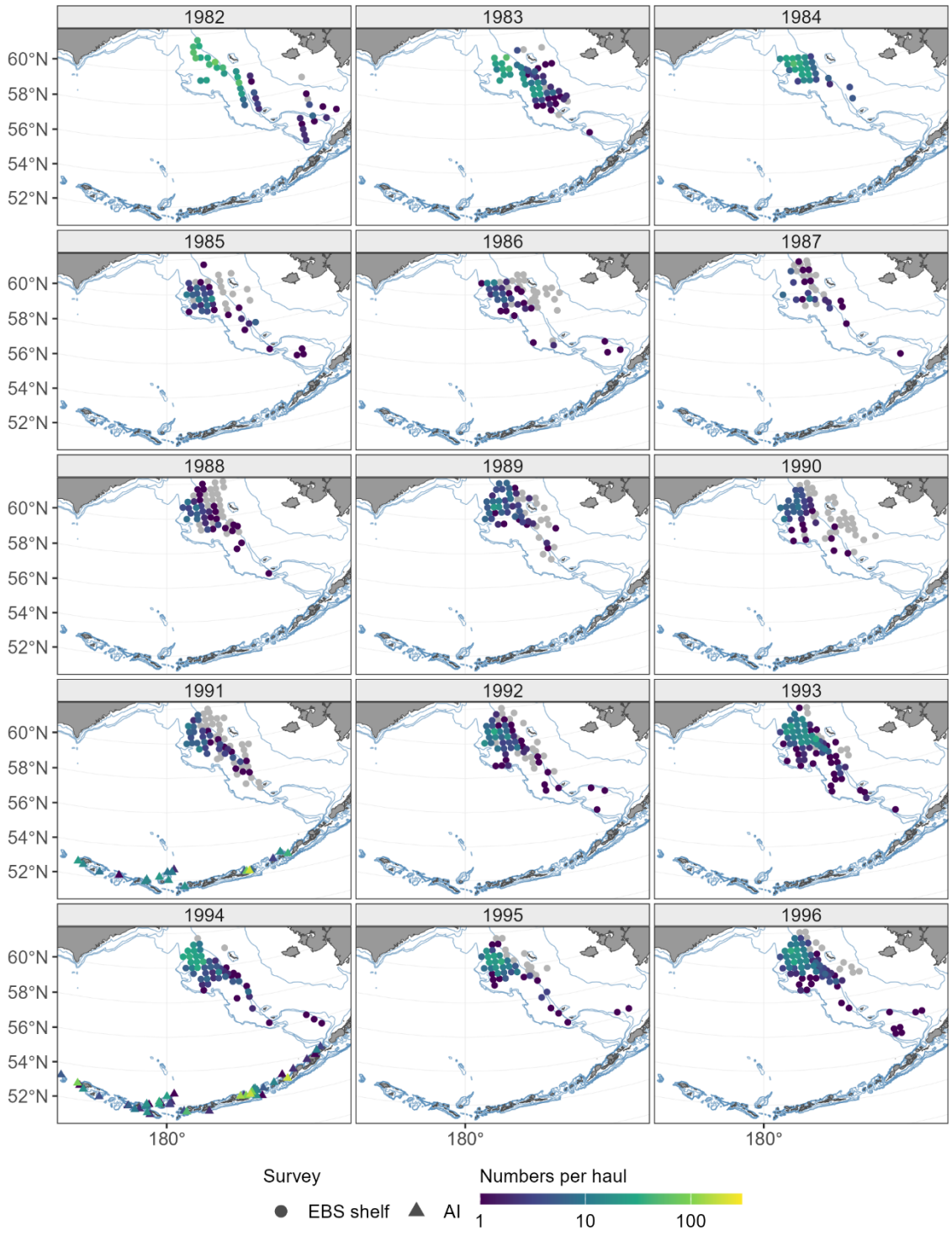
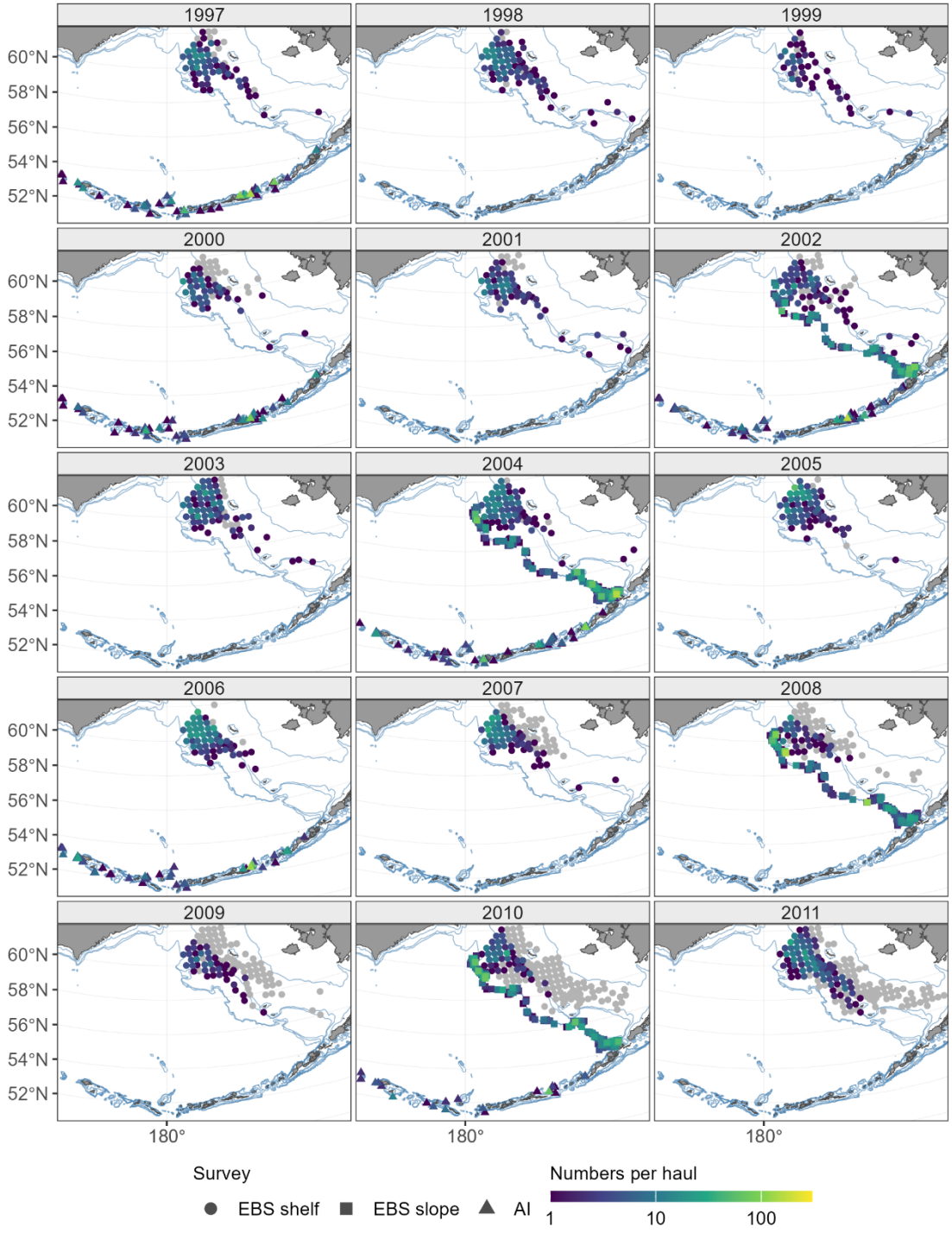
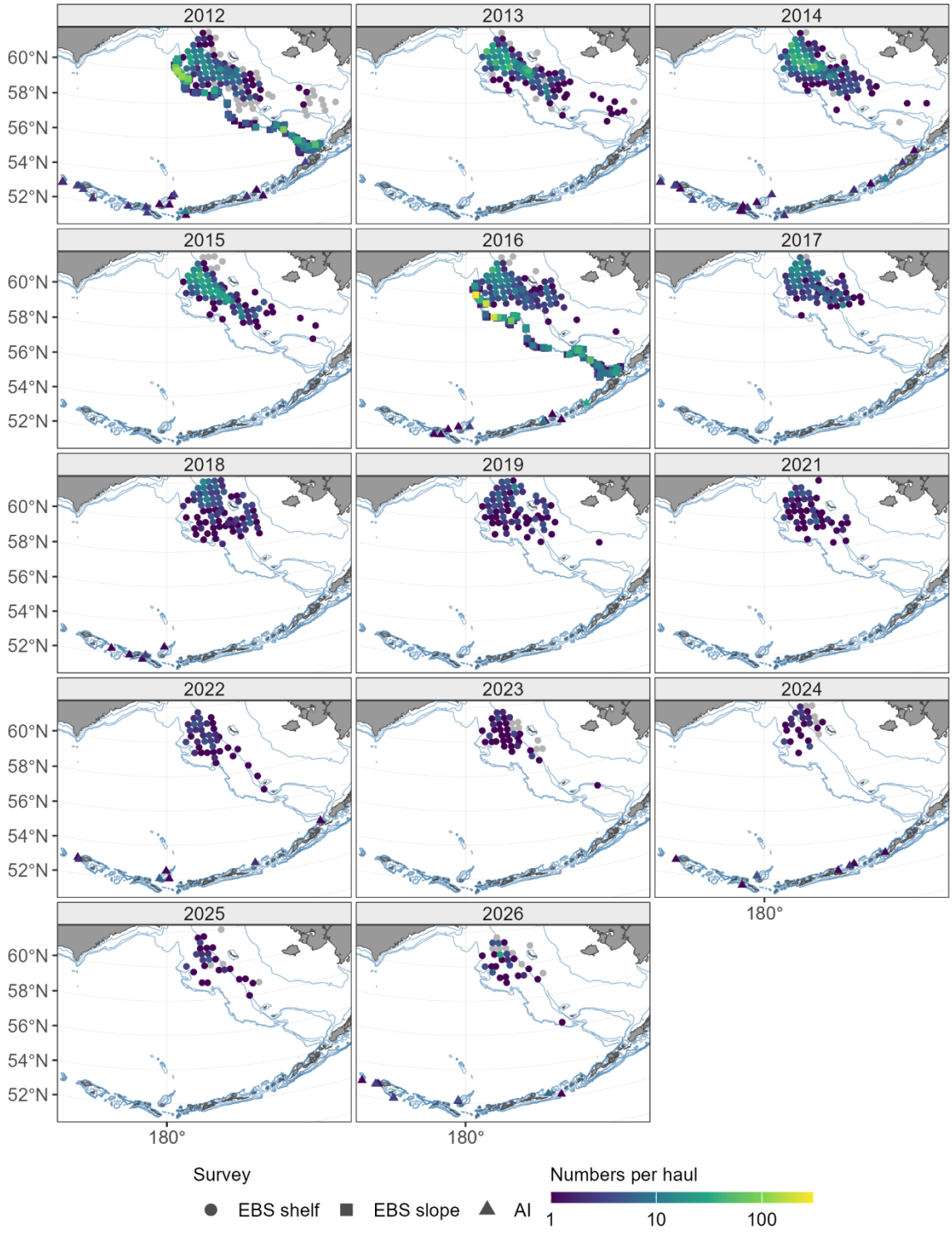


Figure 5. 17. EBS shelf bottom trawl survey, EBS slope bottom trawl survey, Aleutian Islands bottom trawl survey: fish 35 cm and longer, 1982-1996 (1 of 3). Numbers measured per haul, summed over sex (log scale). Symbol shape indicates the survey. Grey symbols: hauls with lengths measured but no fish in this size class. Blue lines: bathymetry contours.

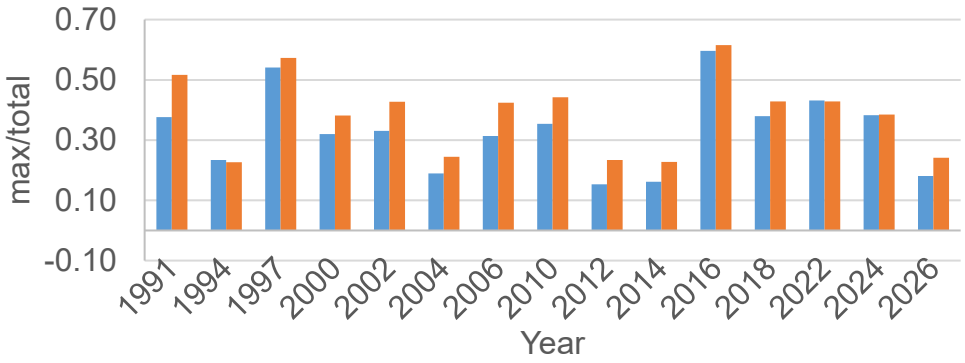


EBS shelf bottom trawl survey, EBS slope bottom trawl survey, Aleutian Islands bottom trawl survey: fish 35 cm and longer, 1997-2011 (2 of 3). Numbers measured per haul, summed over sex (log scale). Symbol shape indicates the survey. Grey symbols: hauls with lengths measured but no fish in this size class. Blue lines: bathymetry contours.

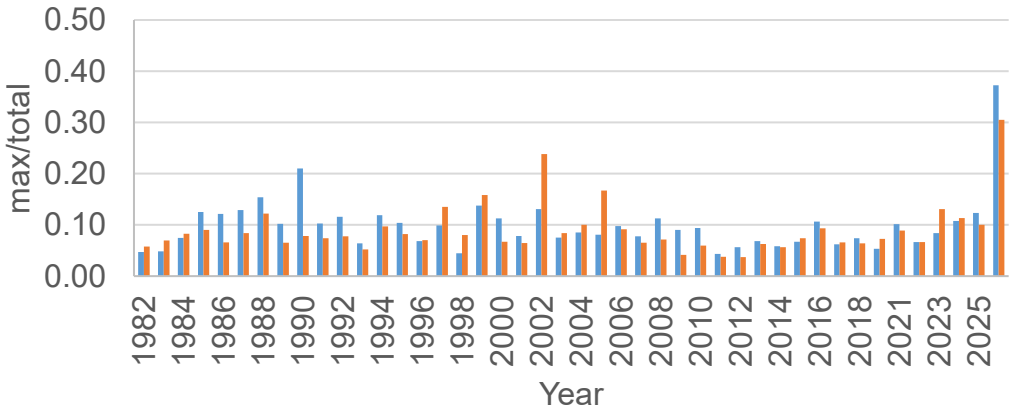


EBS shelf bottom trawl survey, EBS slope bottom trawl survey, Aleutian Islands bottom trawl survey: fish 35 cm and longer, 2012-2026 (3 of 3). Numbers measured per haul, summed over sex (log scale). Symbol shape indicates the survey. Grey symbols: hauls with lengths measured but no fish in this size class. Blue lines: bathymetry contours.

a)



b)



c)

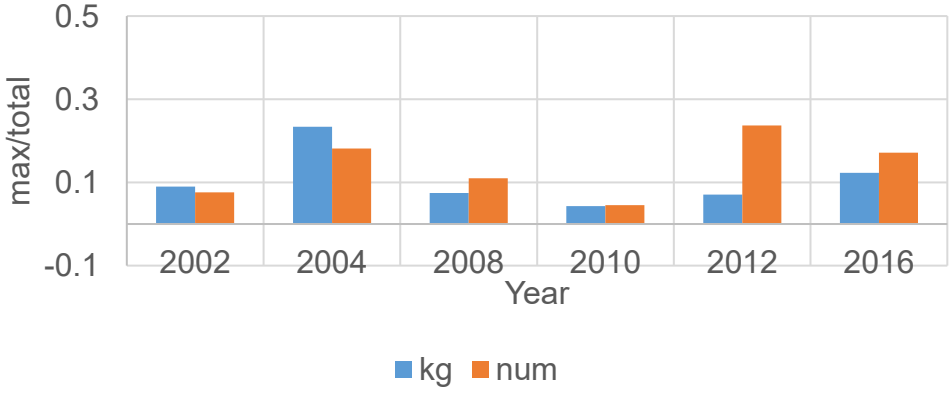


Figure 5. 18. Proportion of total survey catch (in weight and number) from haul with maximum catch: a) Aleutian Islands bottom trawl survey, b) EBS shelf bottom trawl survey, and c) EBS slope bottom trawl survey.



Figure 5. 19. AFSC longline survey RPN estimates and killer whale depredation rates for the Aleutain Islands (top) and Bering Sea (bottom).

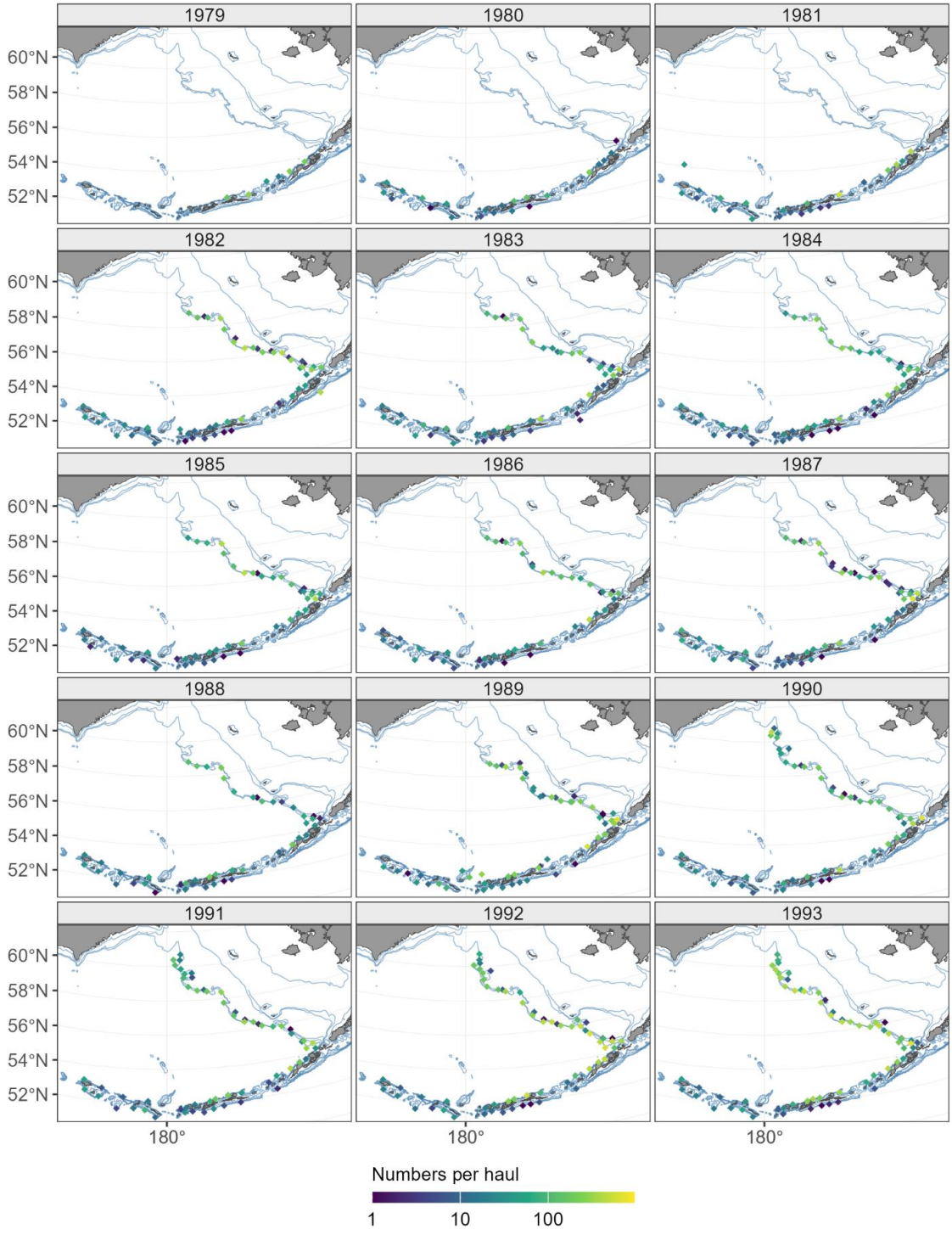
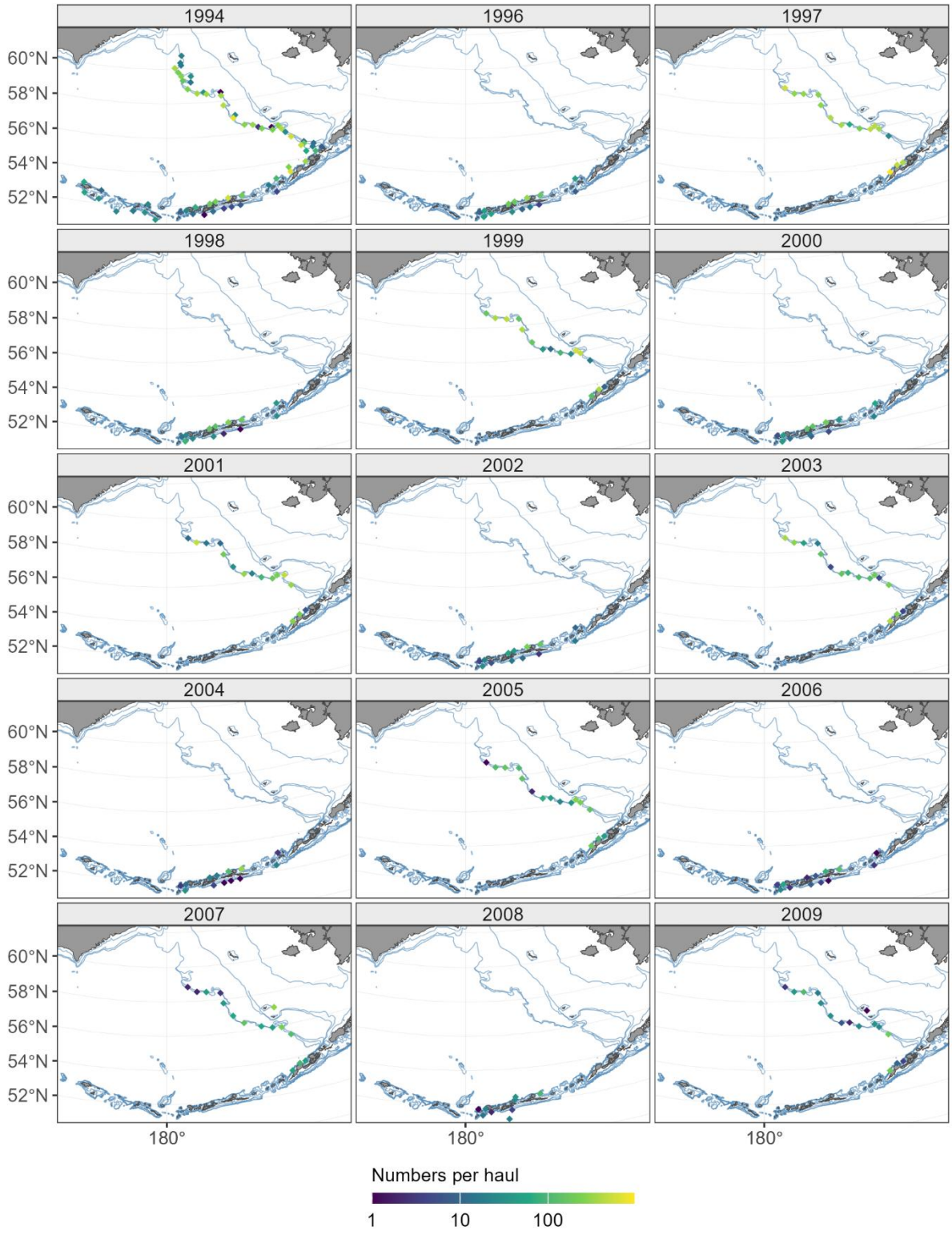
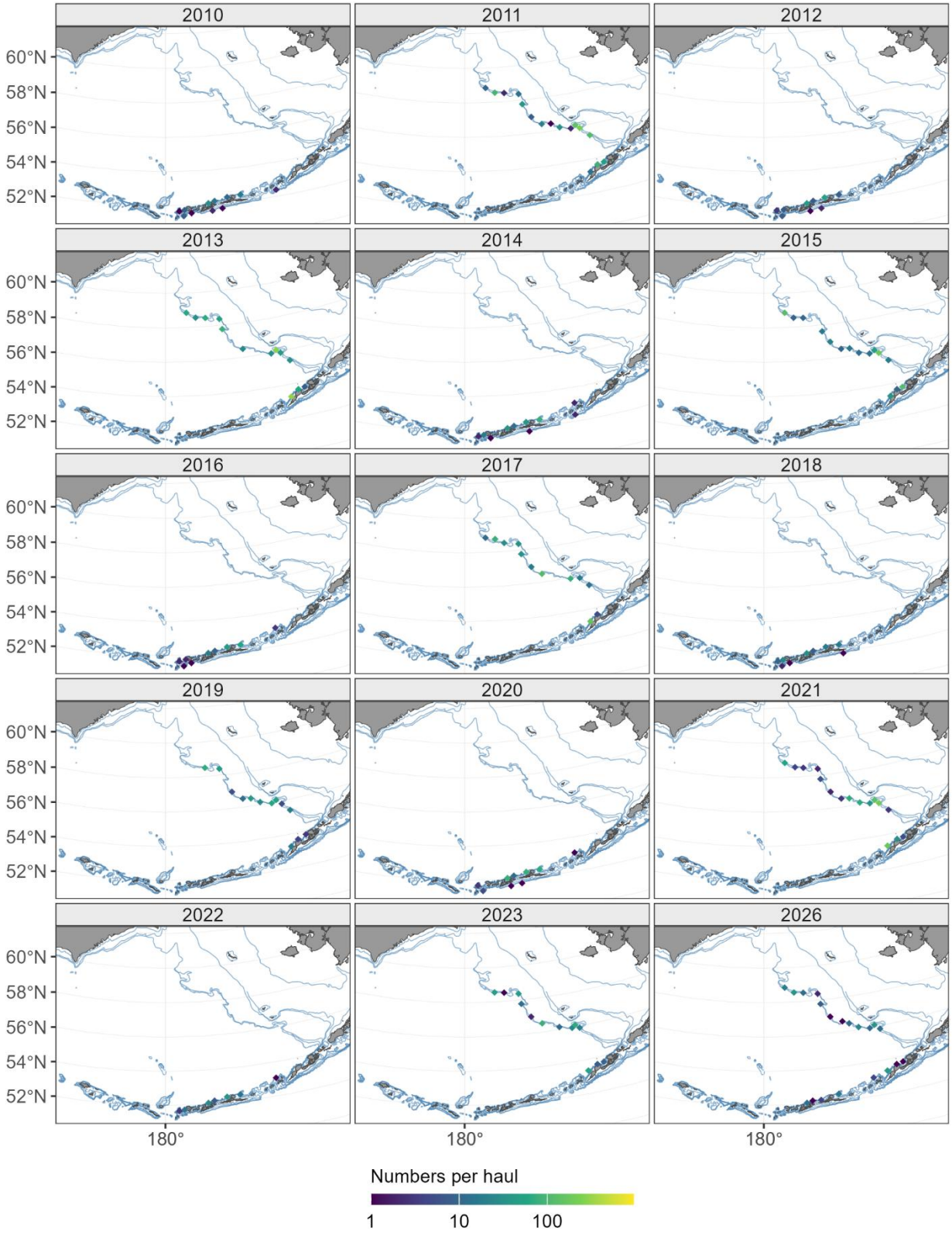


Figure 5. 20. AFSC longline survey: fish 35 cm and longer, 1979-1993. Numbers measured per haul, summed over sex (log scale). Blue lines: bathymetry contours.



AFSC longline survey: fish 35 cm and longer, 1994-2009 (2 of 3). Numbers measured per haul, summed over sex (log scale). Blue lines: bathymetry contours.



AFSC longline survey: fish 35 cm and longer, 2010-2026 (3 of 3). Numbers measured per haul, summed over sex (log scale). Blue lines: bathymetry contours.

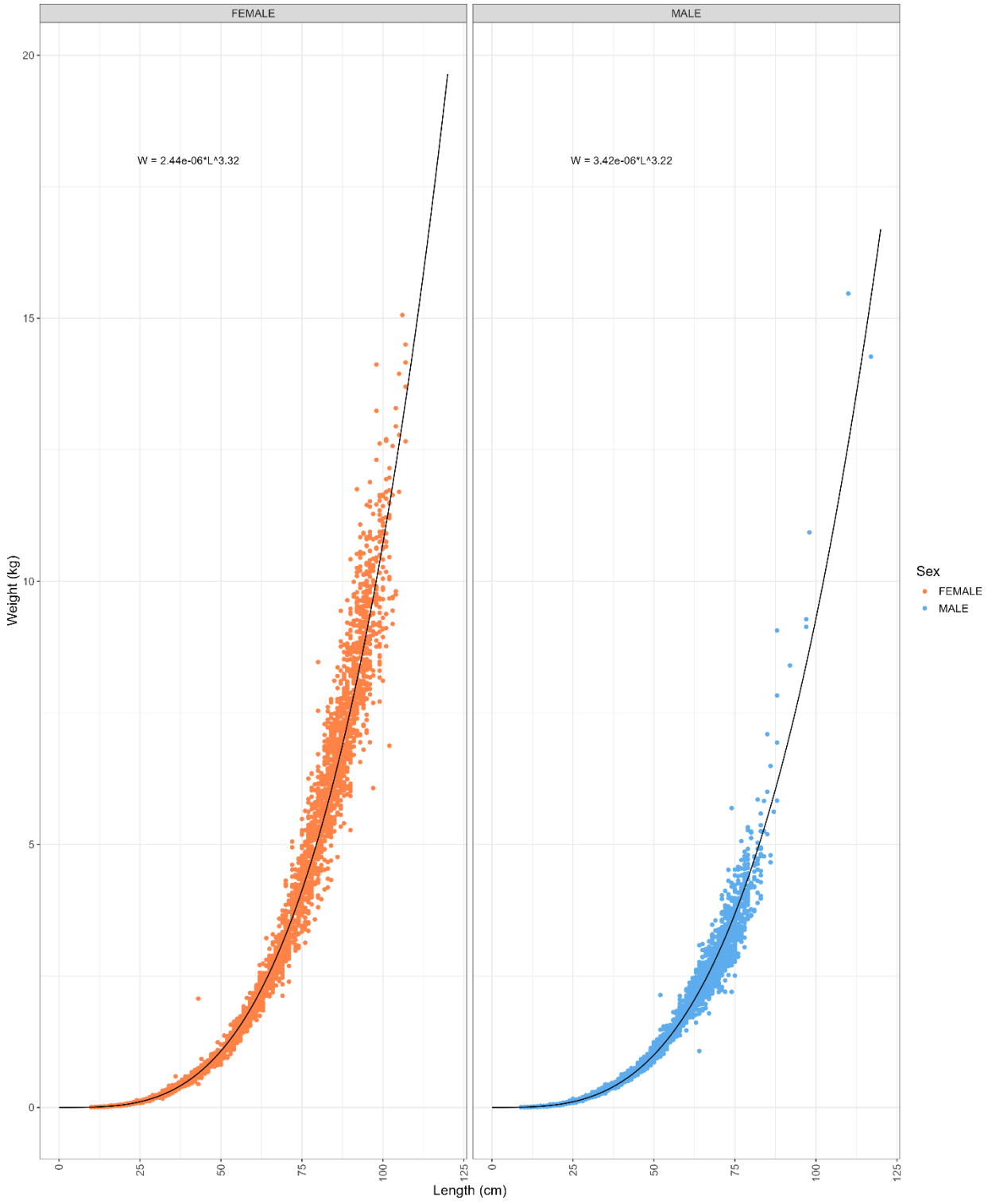


Figure 5.21. Weight at length relationship for male and female Greenland turbot fit to all AFSC survey data from the Bering Sea and Aleutian Islands area.

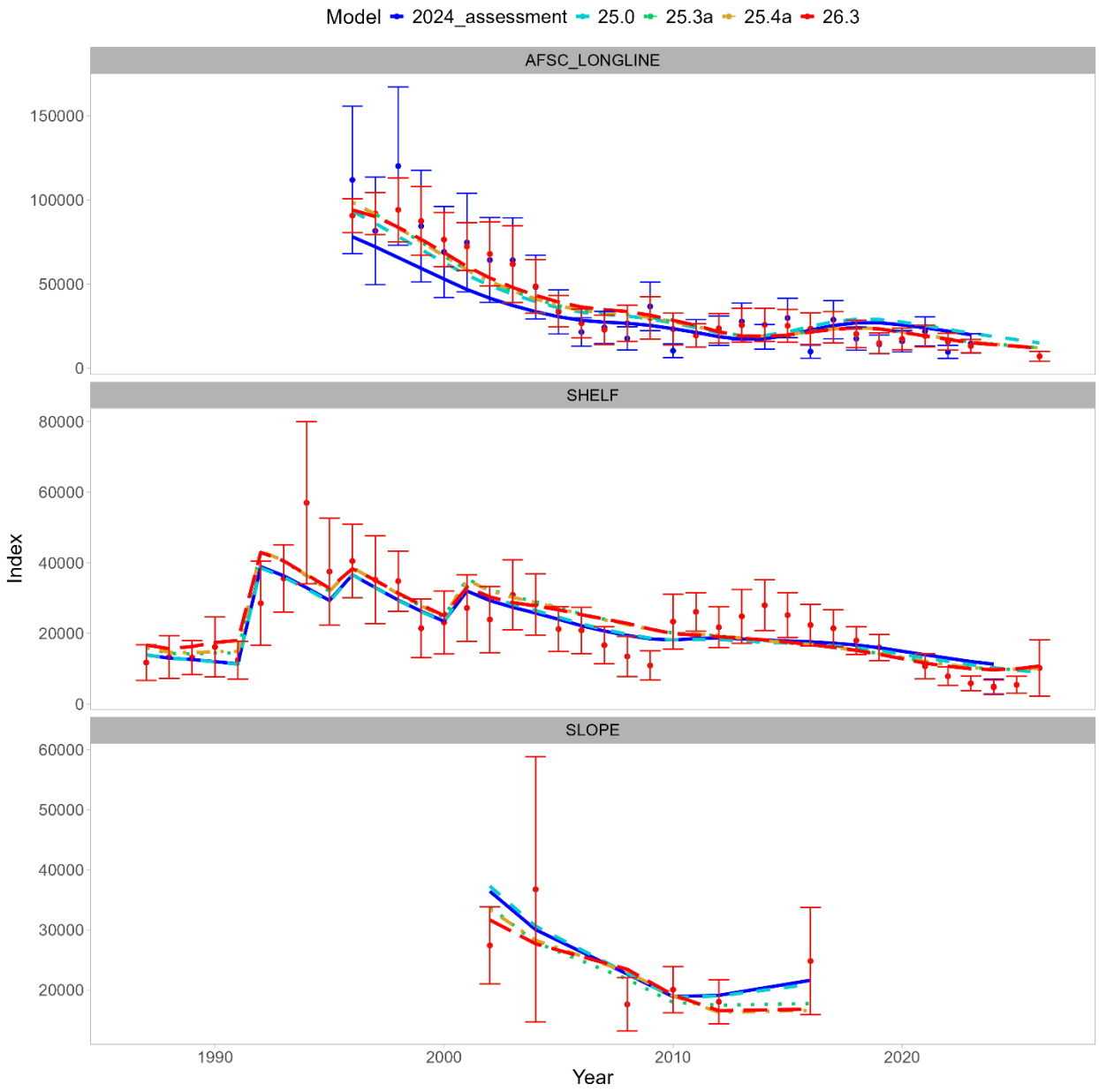


Figure 5. 22 Survey indices and model fits. Error bars are 95% confidence intervals. The units for the EBS shelf and slope surveys are tons and the units for the AFSC longline survey are relative population numbers (RPNs).

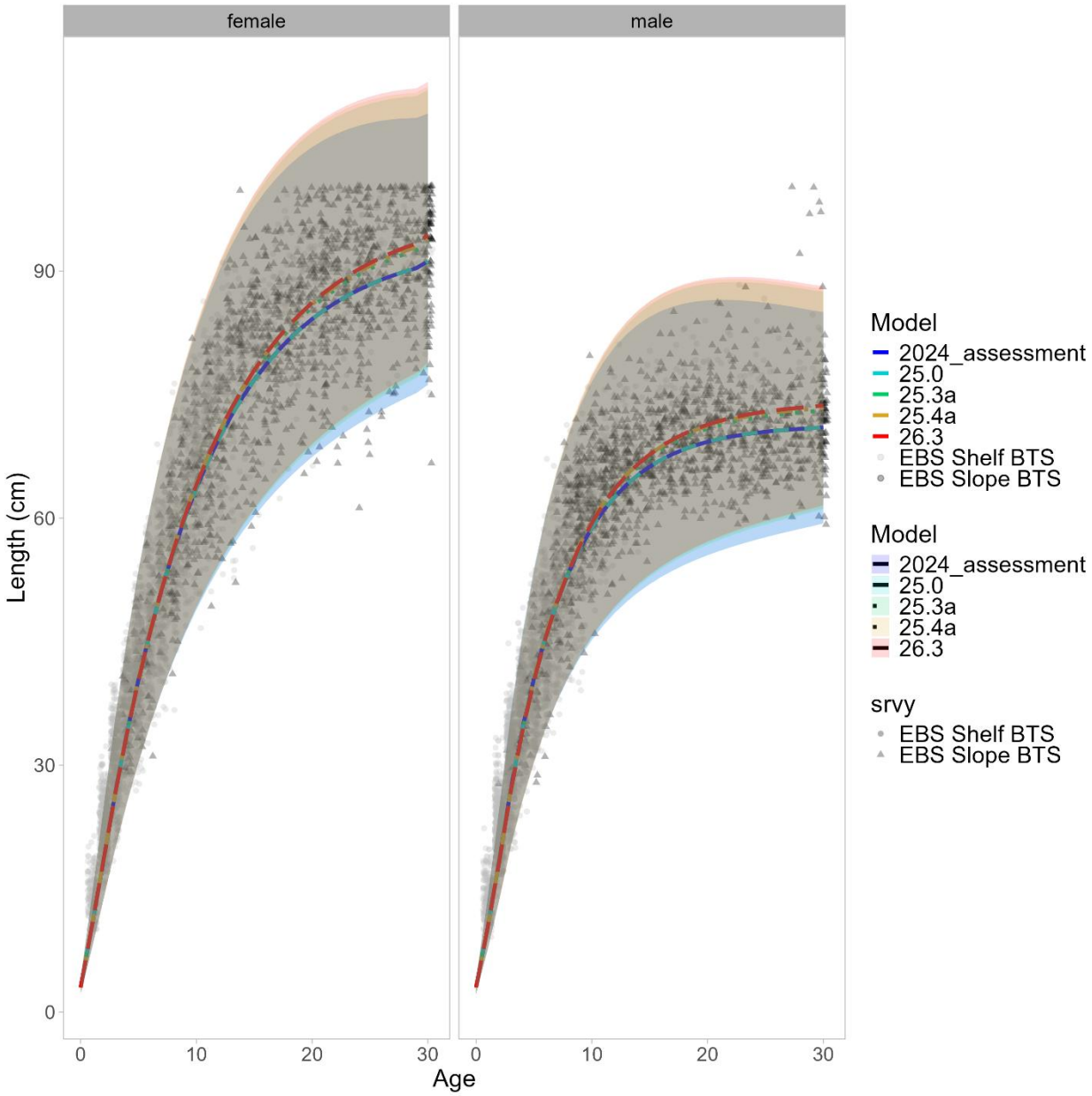


Figure 5.23. Estimated growth curves and uncertainty (95% confidence intervals) from each model plotted against the raw length at age observations from the gap_products specimen table.

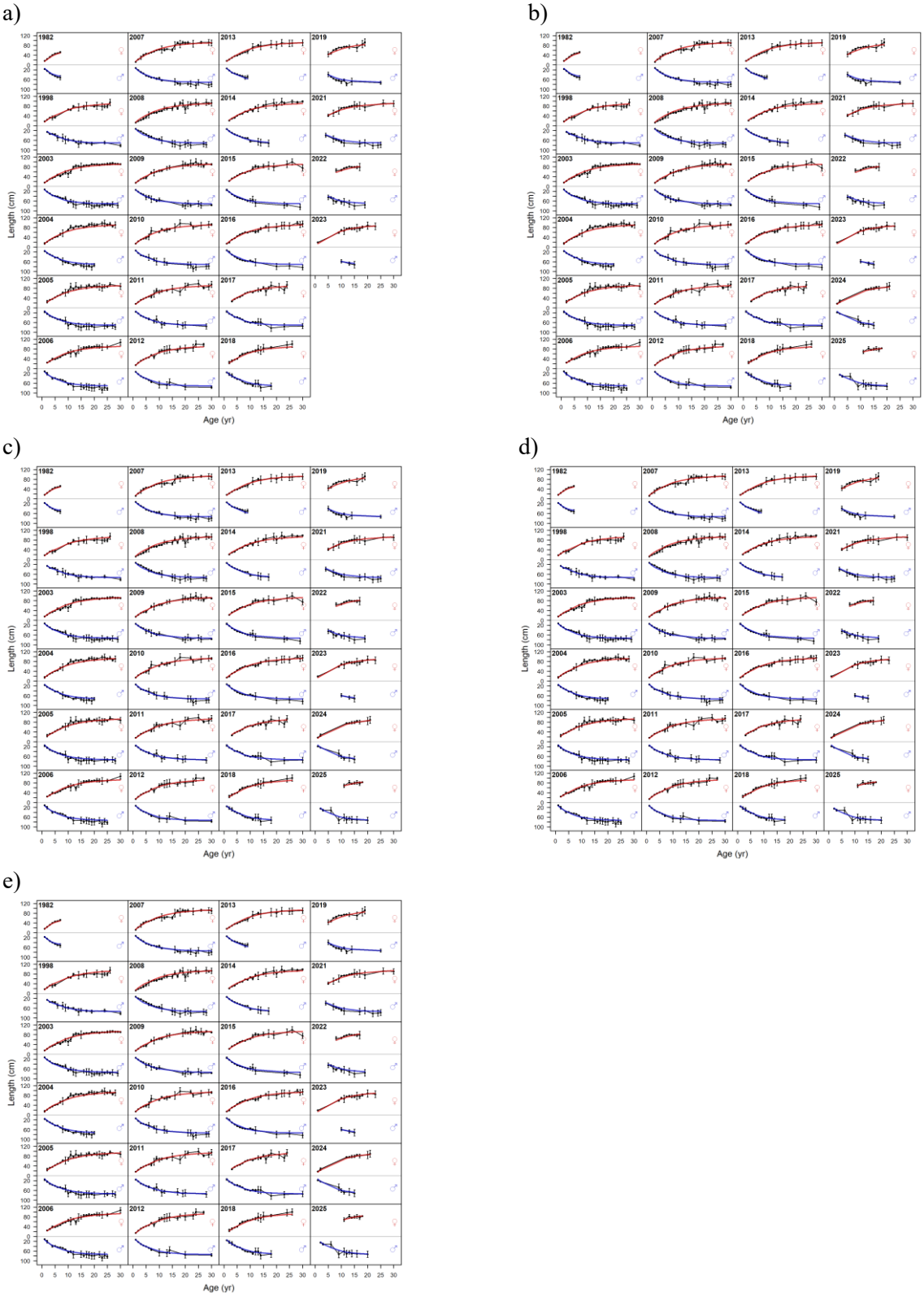
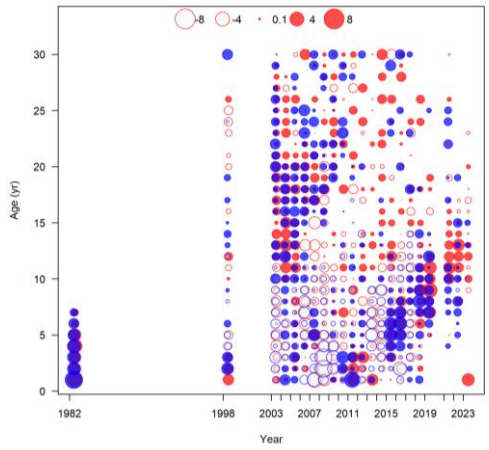
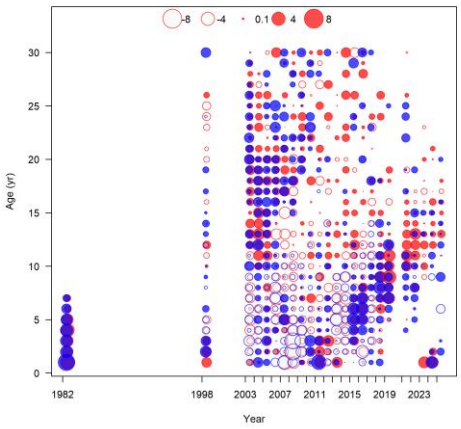


Figure 5. 24. EBS shelf bottom trawl survey mean length at age data and model fit (females - red line, males – blue line) by models a) 16.4c and b) 25.0, and c) 25.3a, d) 25.4a, and e) 26.3.

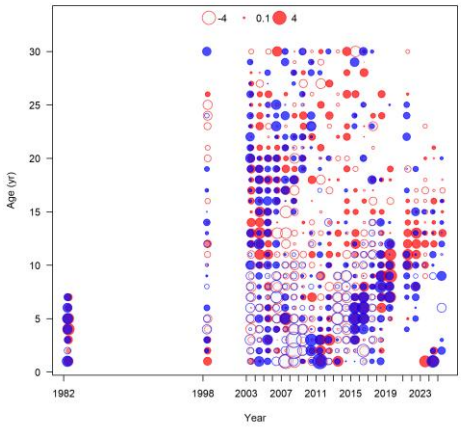
a)



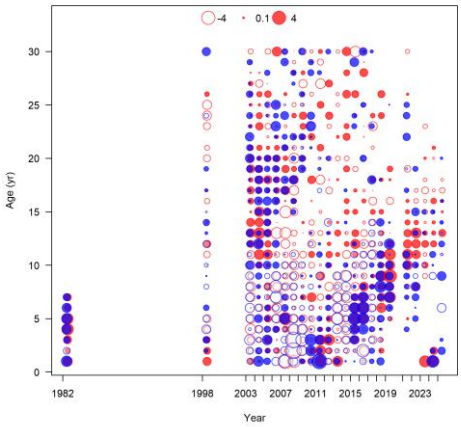
b)



c)



d)



e)

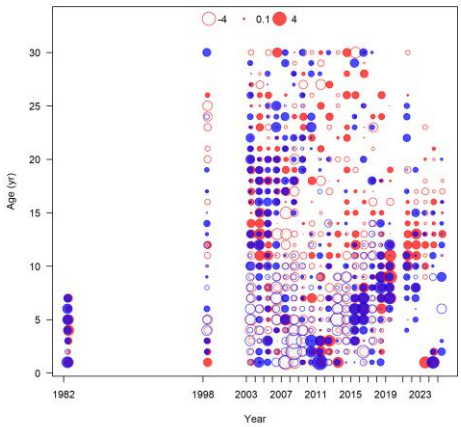


Figure 5.25. The standardized residuals for the fit to the mean length at age data from the EBS shelf bottom trawl survey for models a) 16.4c and b) 25.0, and c) 25.3, d) 25.4, and e) 26.3.The closed bubbles are positive residuals (underestimation) and open bubbles are negative residuals (overestimation). Red bubbles are female and blue are male.

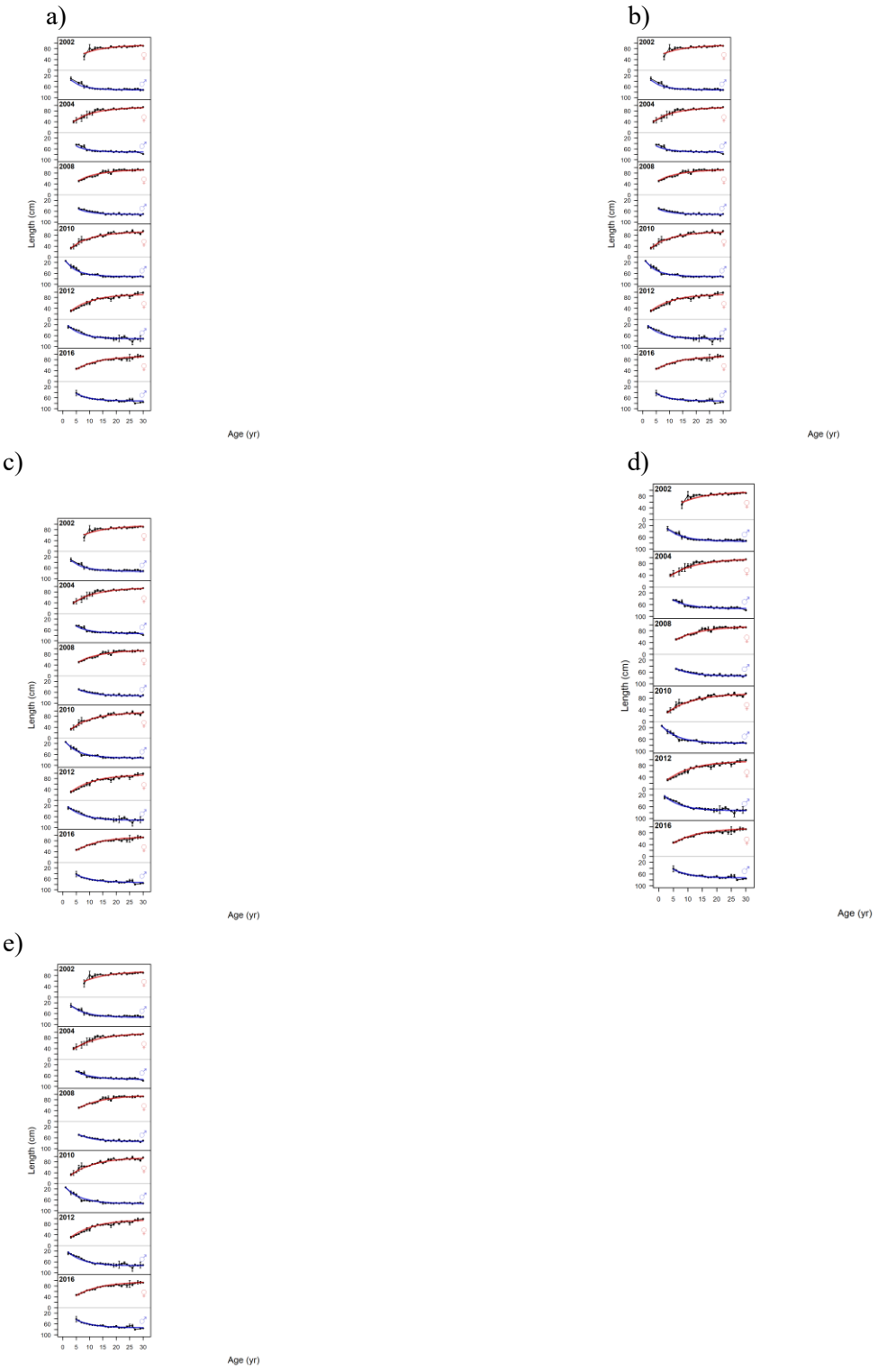
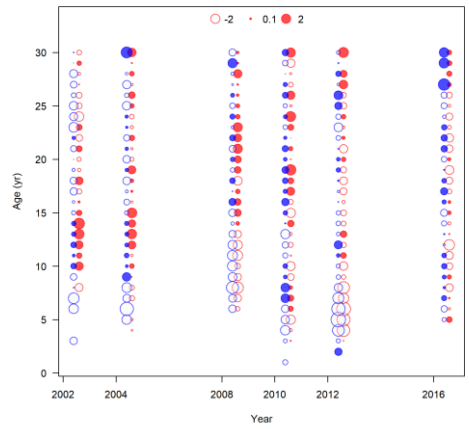
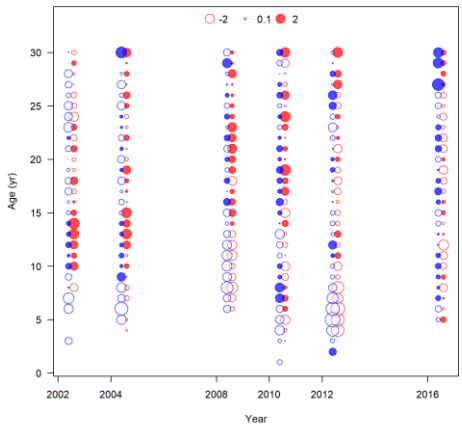


Figure 5.26. EBS slope bottom trawl survey mean length at age data and model fit (females - red line, males – blue line) and b) standardized residuals from models a) 16.4c and b) 25.0, and c) 25.3a, d) 25.4a, and e) 26.3.

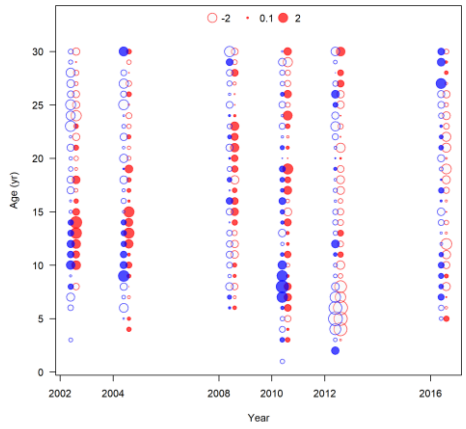
a)



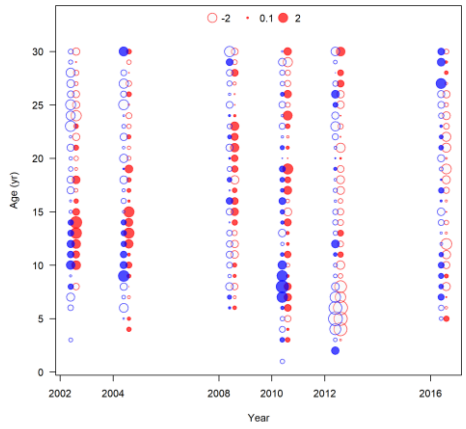
b)



c)



d)



e)

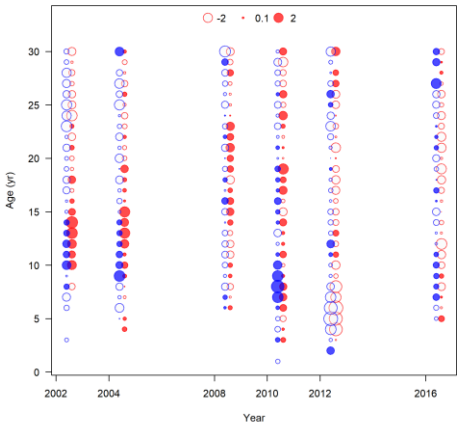
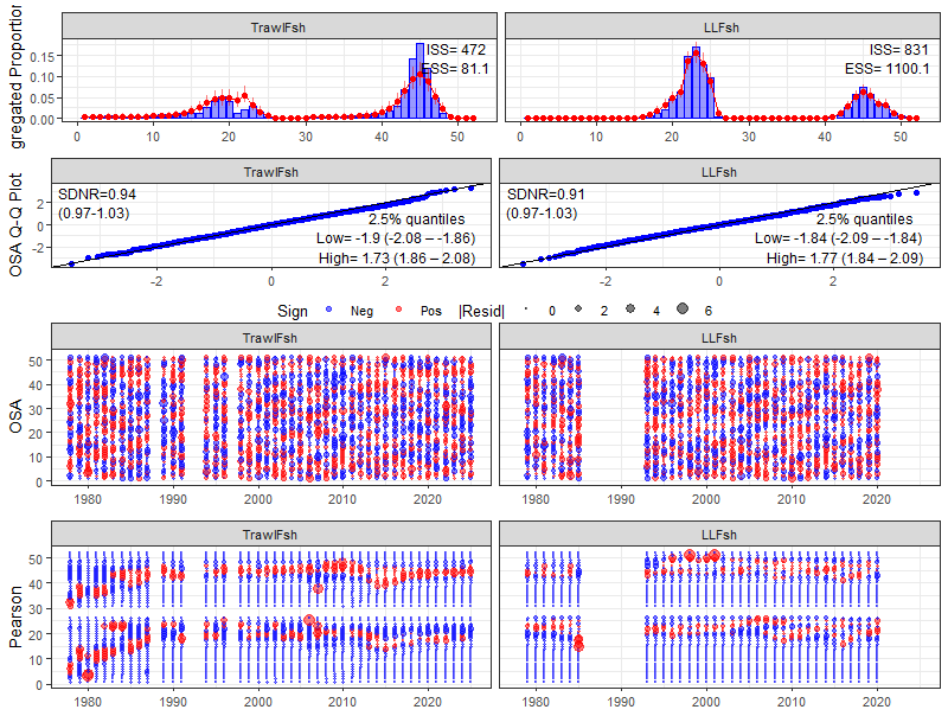


Figure 5.27. The standardized residuals for the fit to the mean length at age data from the EBS slope bottom trawl survey for models a) 16.4c and b) 25.0, and c) 25.3a, d) 25.4a, and e) 26.3.The closed bubbles are positive residuals (underestimation) and open bubbles are negative residuals (overestimation). Red bubbles are female and blue are male.

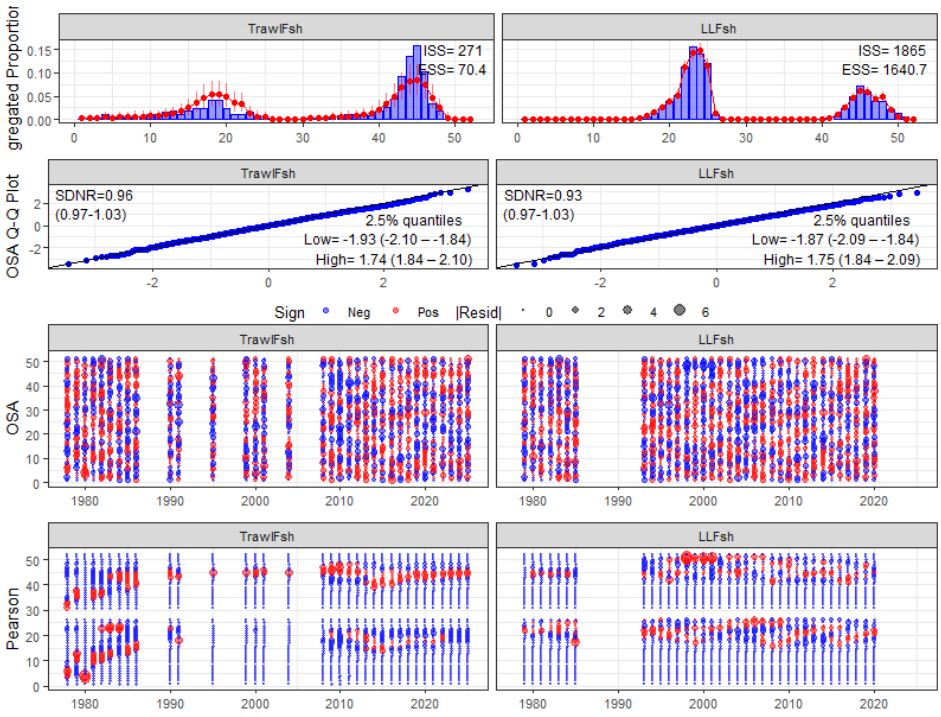
a)



b)

Figure 5. 28. Fit to the aggregated length composition dat, osa residuals, and Pearson residuals from the a) fishery fleets and b) bottom trawl surveys and AFSC longline survey for model 25.0. Bins 0 – 30 represent the female length distributions and bins 31-60 represent the male length distributions. The AFSC longline lengths are input as combined sex

a)



b)

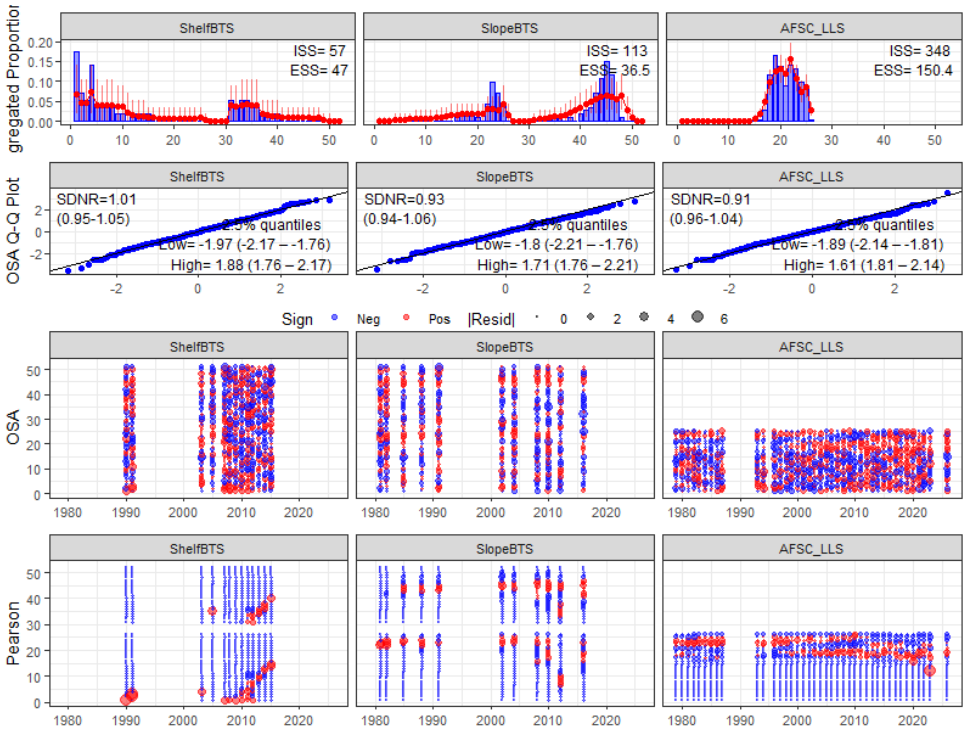
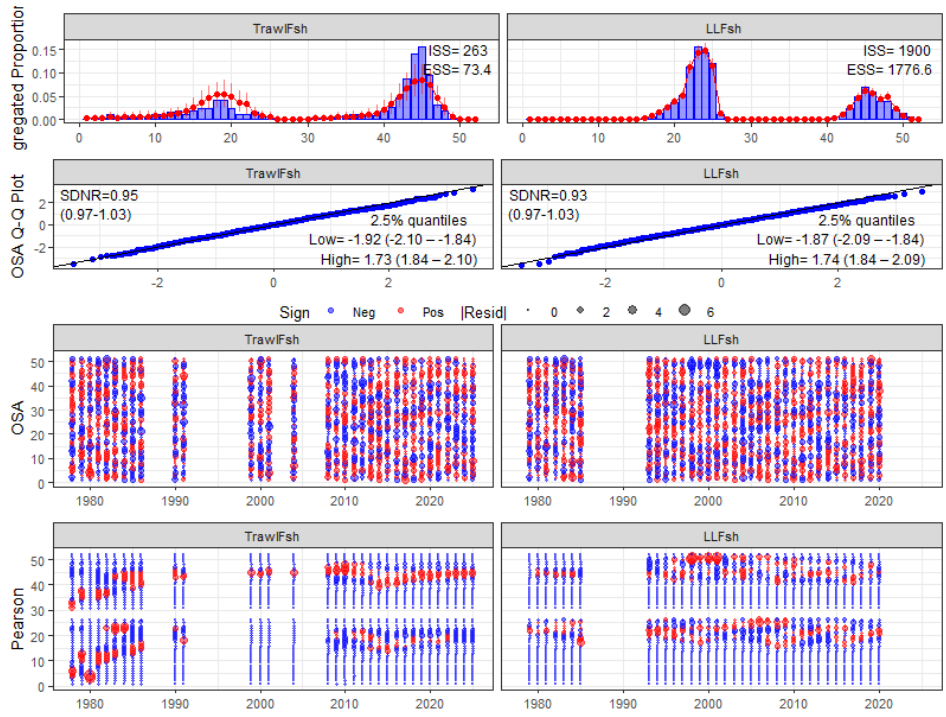


Figure 5. 29. Fit to the aggregated length composition data, osa residuals, and Pearson residuals from the a) fishery fleets and b) bottom trawl surveys and AFSC longline survey for model 25.3a. Bins 0 – 30 represent the female length distributions and bins 31-60 represent the male length distributions.

a)



b)

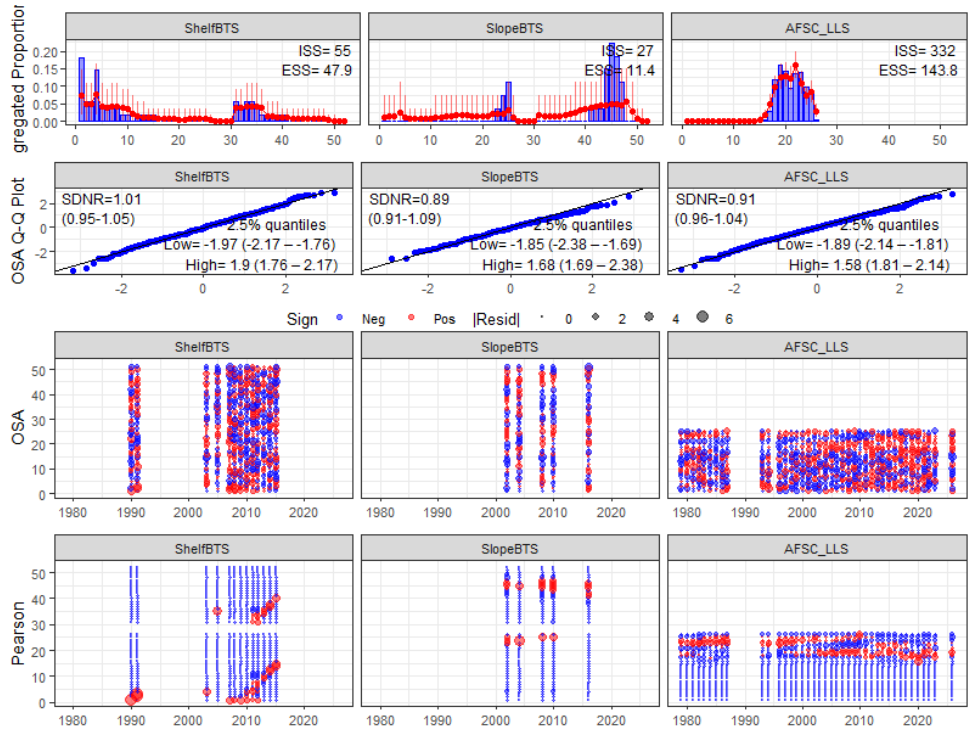
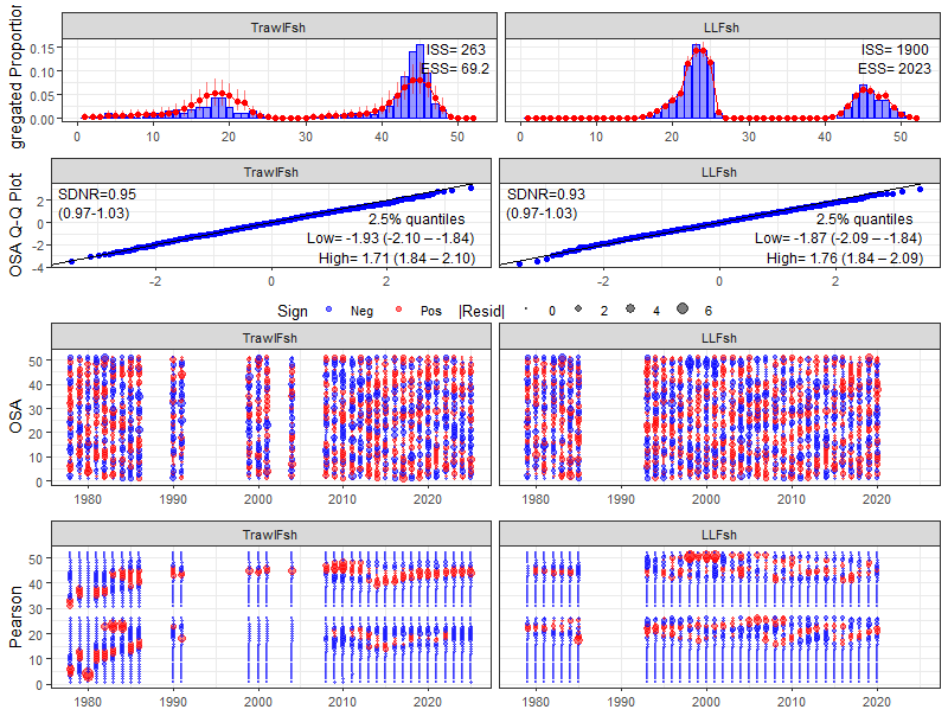


Figure 5. 30. Fit to the aggregated length composition data, osa residuals, and Pearson residuals from the a) fishery fleets and b) bottom trawl surveys and AFSC longline survey for model 25.4a. Bins 0 - 30 represent the female length distributions and bins 31-60 represent the male length distributions.

a)



b)

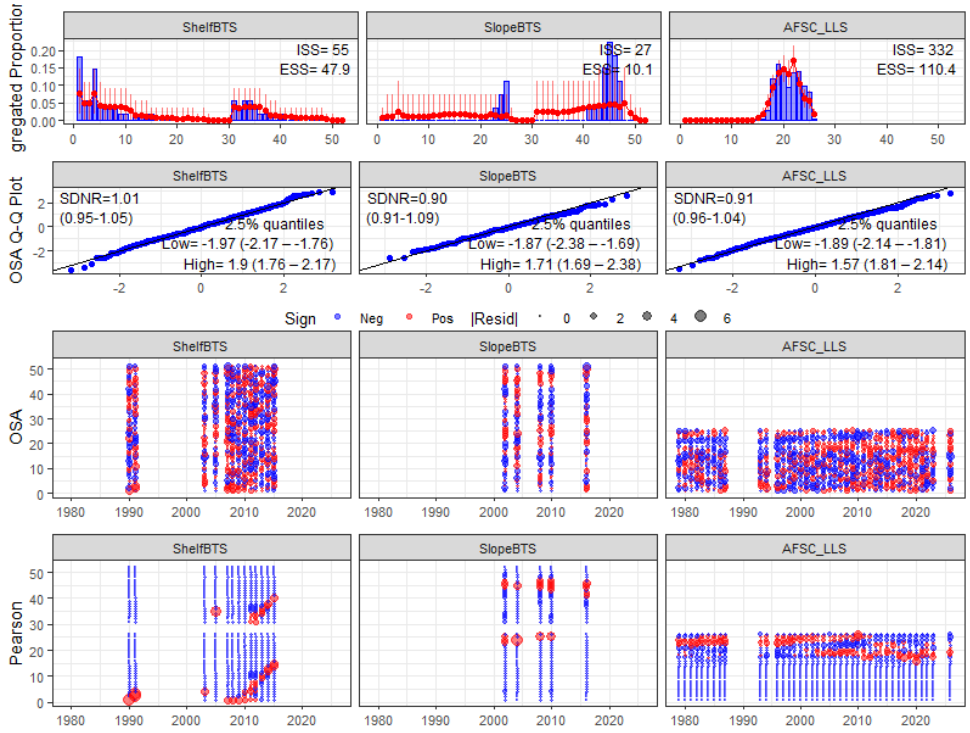


Figure 5. 31. Fit to the aggregated length composition data, osa residuals, and Pearson residuals from the a) fishery fleets and b) bottom trawl surveys for model 26.3. Bins 0 – 30 represent the female length distributions and bins 31-60 represent the male length distributions.

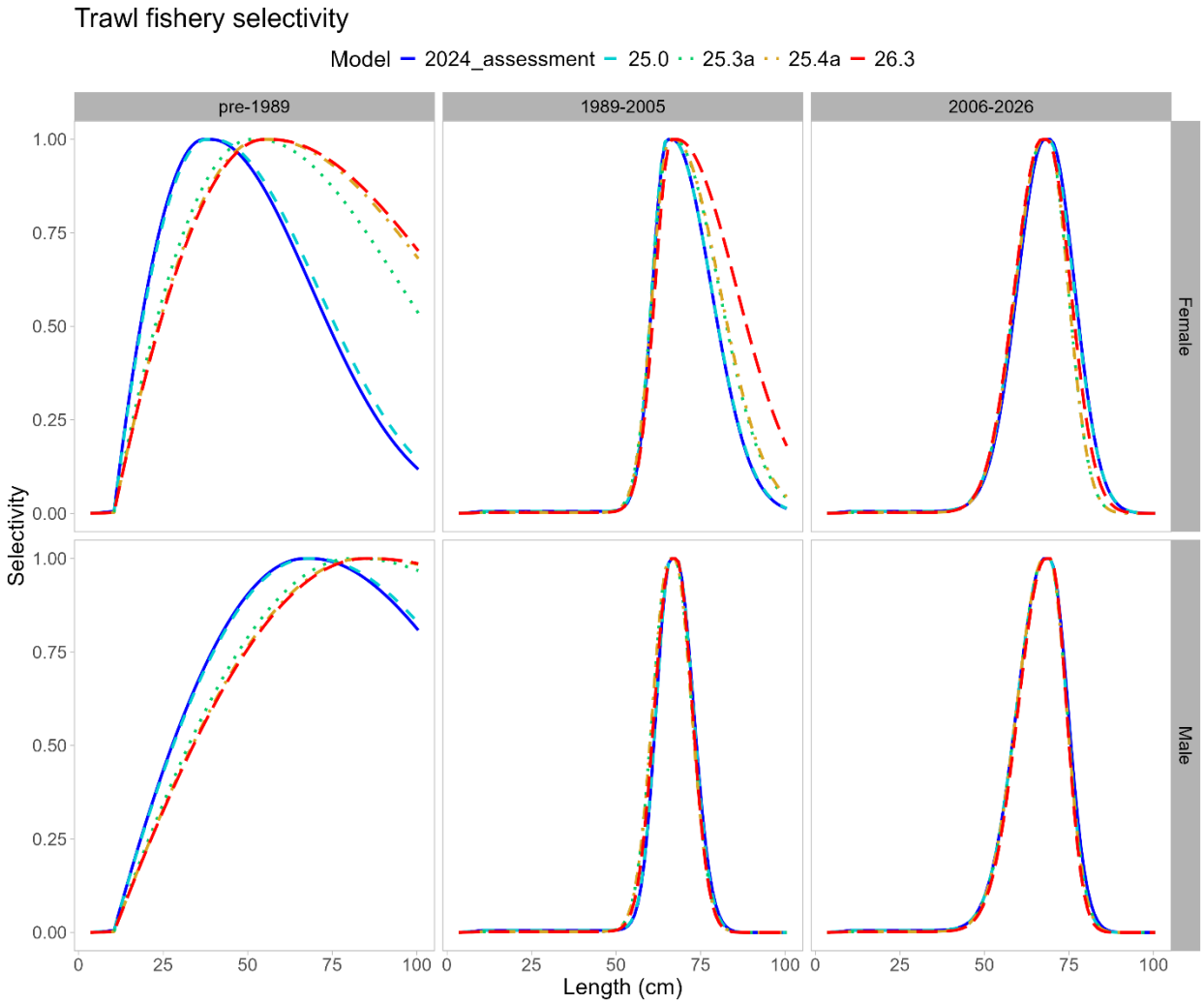


Figure 5. 32. Time-varying selectivity at length for the trawl fishery for females and males.

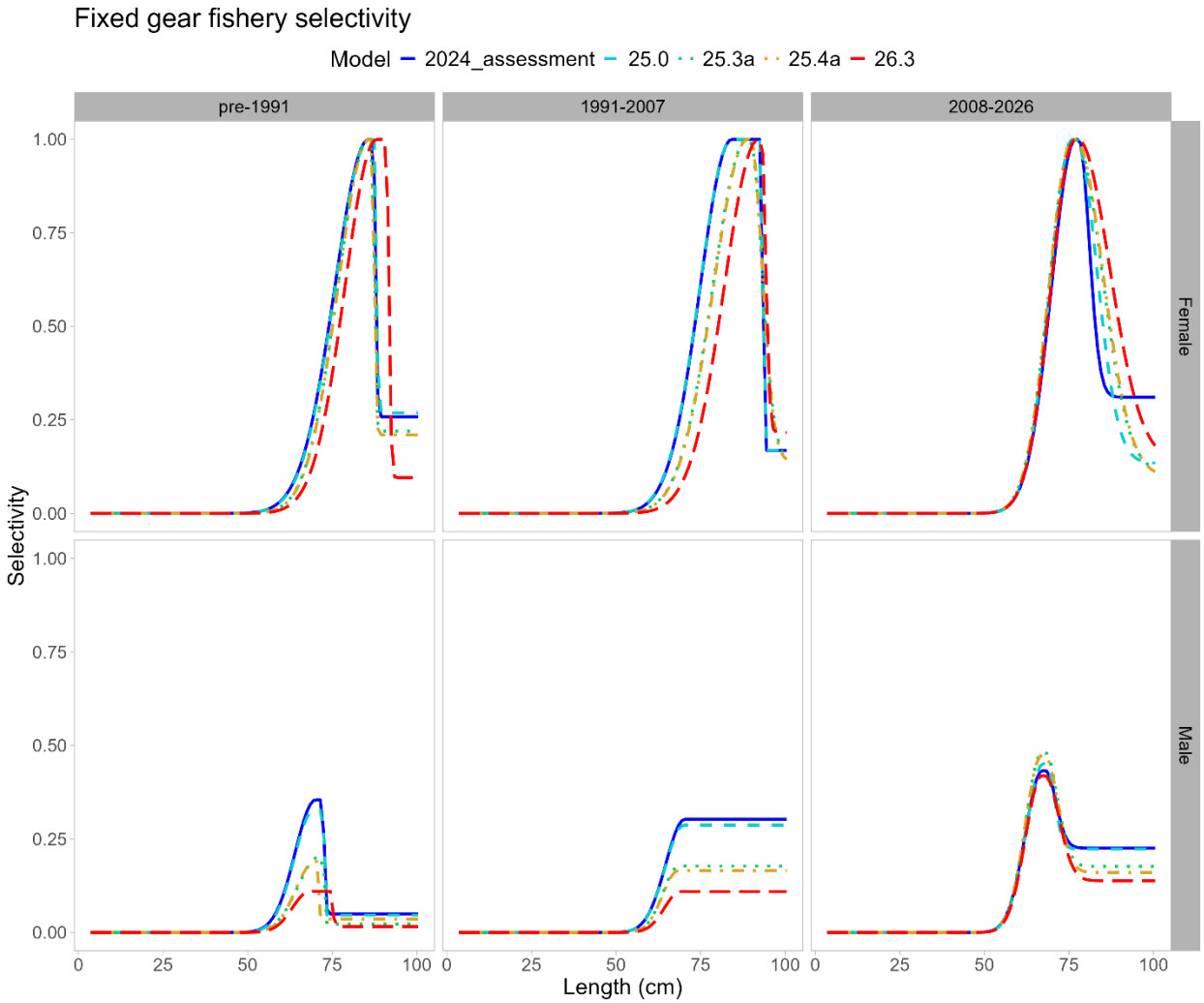


Figure 5.33. Time-varying selectivity at length (cm) for the longline fishery for females and males.

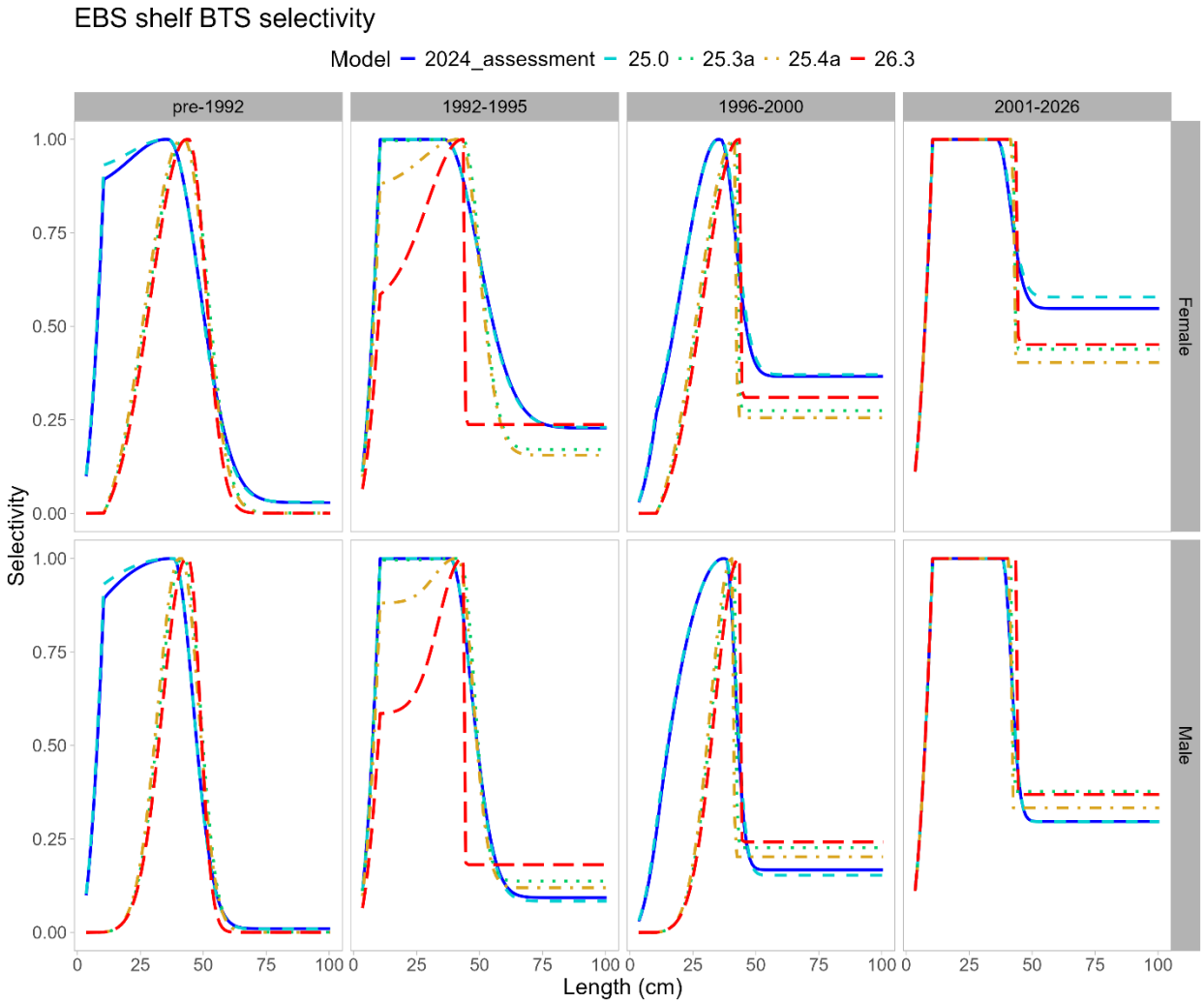


Figure 5. 34. Time-varying selectivity at length by sex for the EBS shelf bottom trawl survey. .

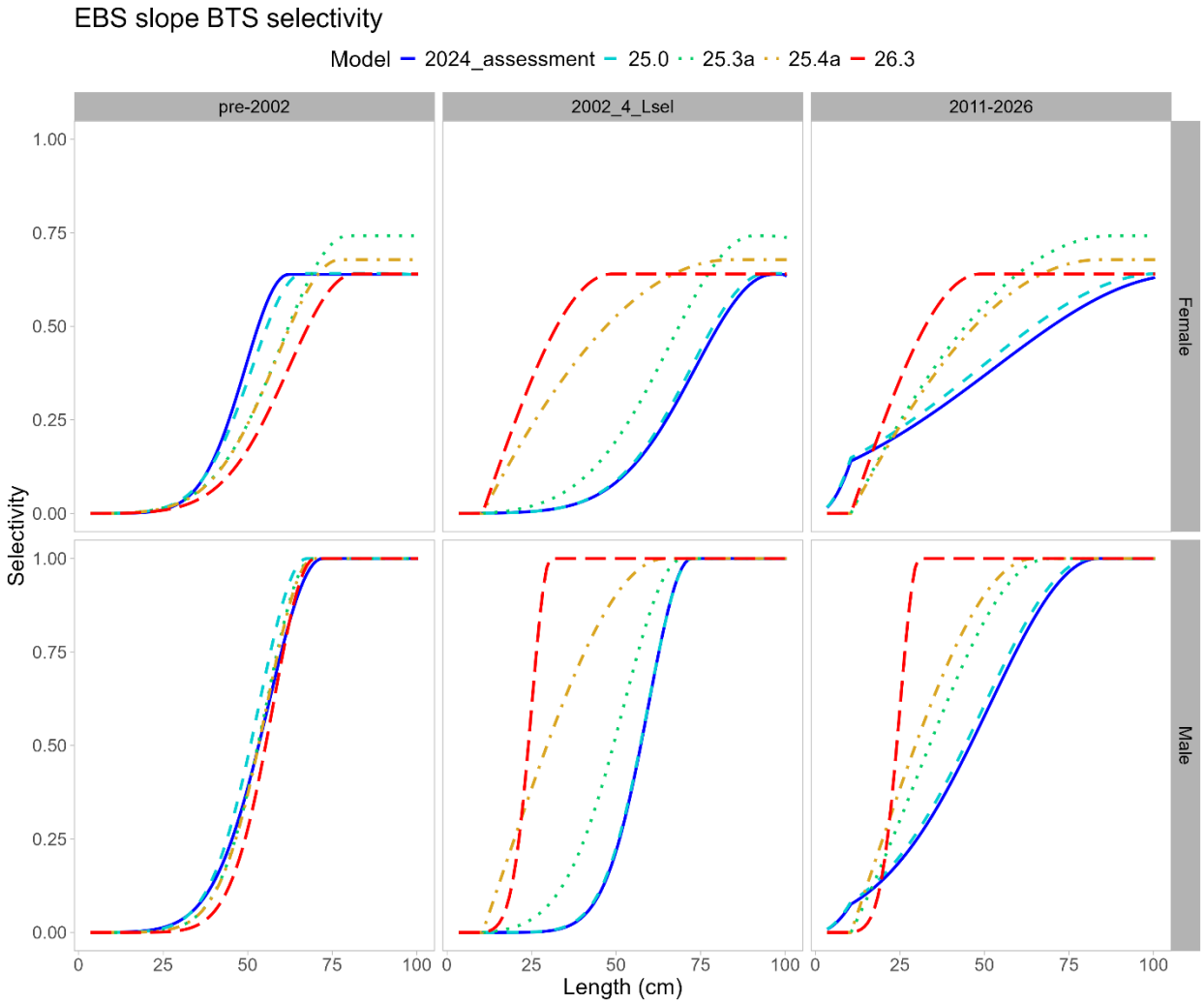


Figure 5. 35. Time-varying selectivity at size by sex for the EBS slope bottom trawl survey. The estimated selectivity for the 2002 and 2011 time blocks are the same. The two time blocks were aggregated in models 25.4a and 26.3.

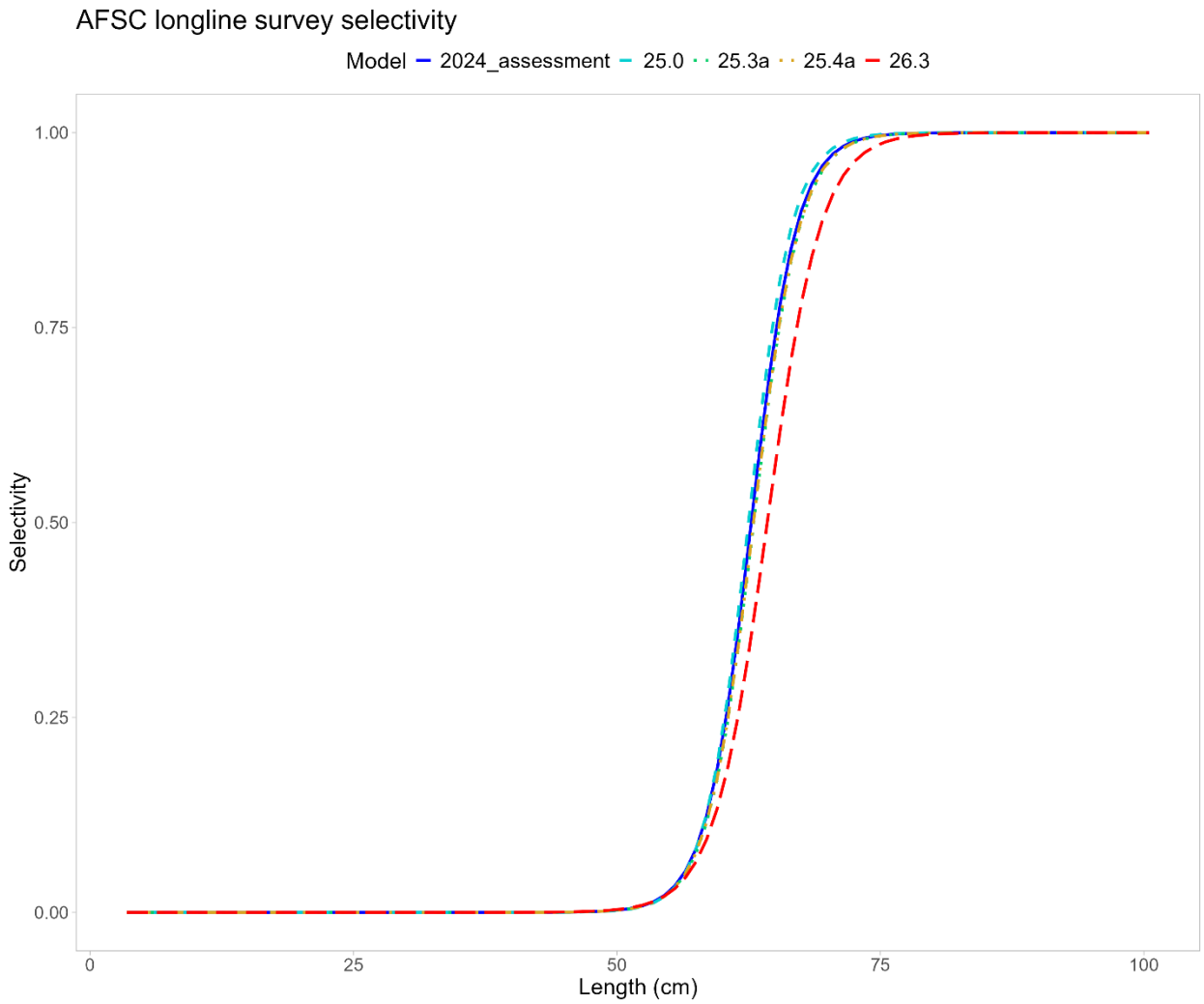


Figure 5.36. AFSC longline survey selectivity.

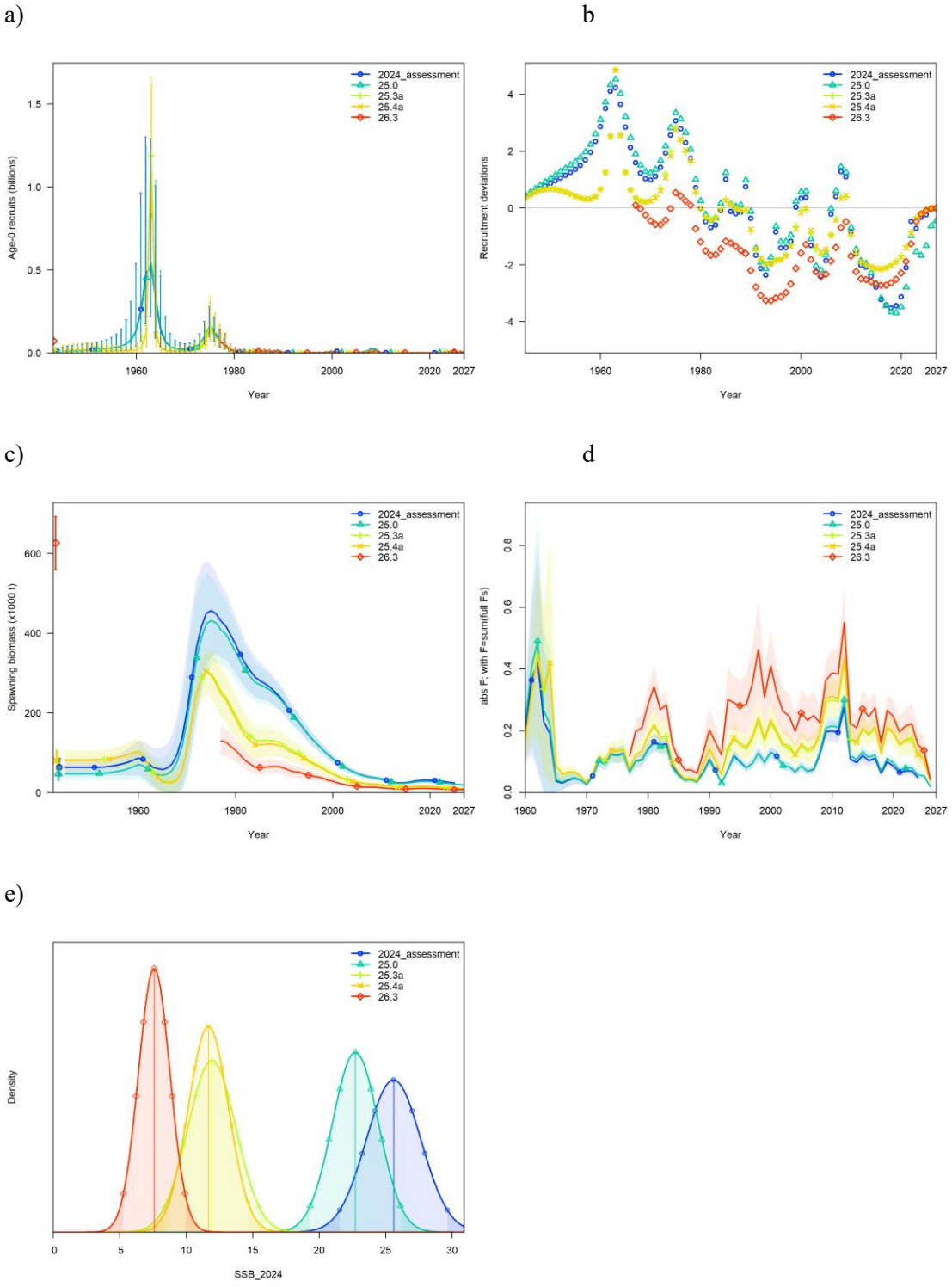


Figure 5.37. a) Age-0 recruitment, b) recruitment deviations, c) female spawning biomass, d) the posterior density of spawning biomass in 2024, and e) fishing mortality for models 16.4c (2024), 25.0, 25.3a, 25.4a, 26.3.

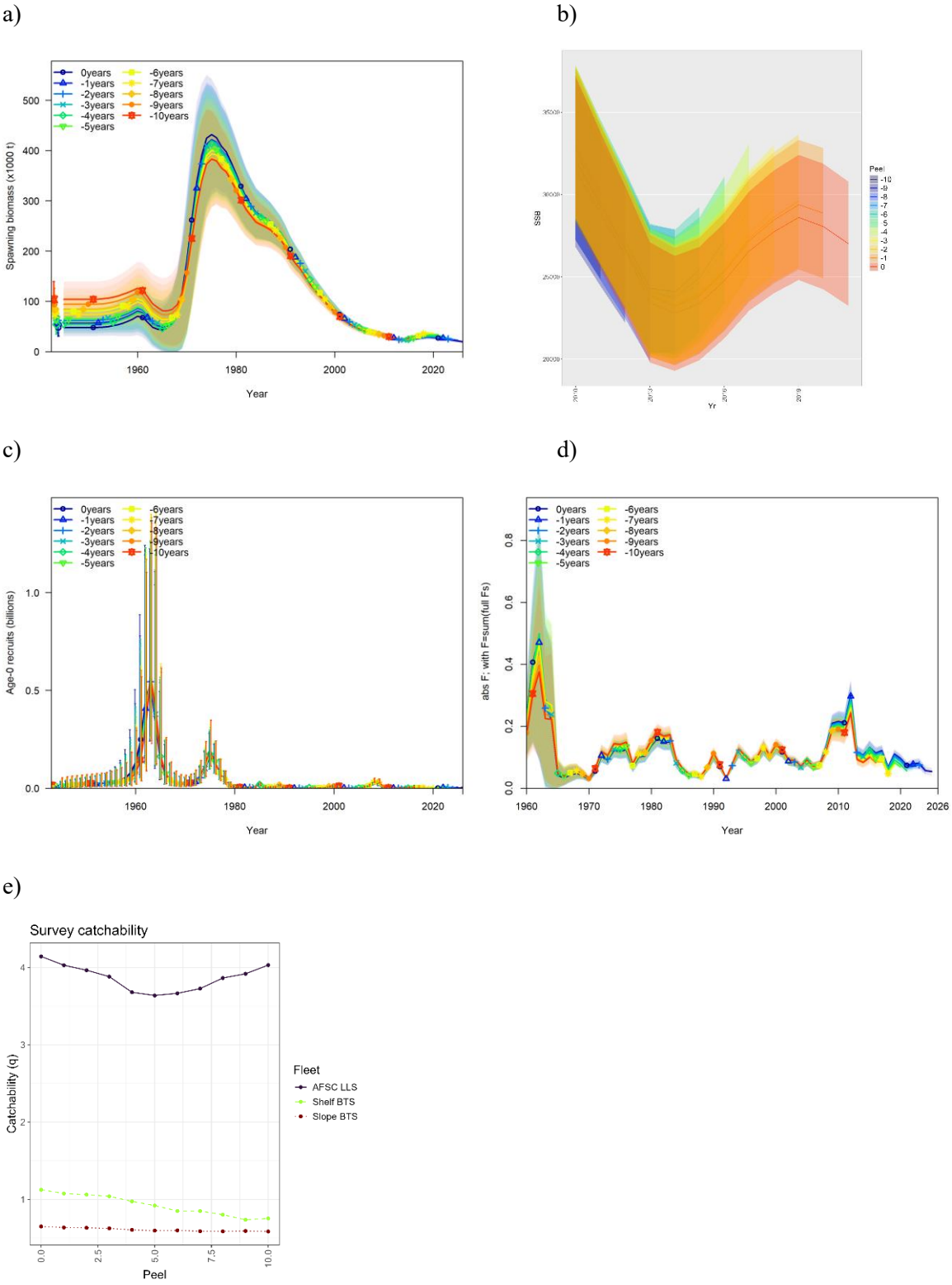


Figure 5. 38. Retrospective plots of a) female spawning biomass (fulltime series), b) female spawning biomass (last 10 years), c) age-0 recruits, d) fishing mortality, and e) analytical solutions for catchability with data sequentially removed from 2026 to 2017 for model 25.0.

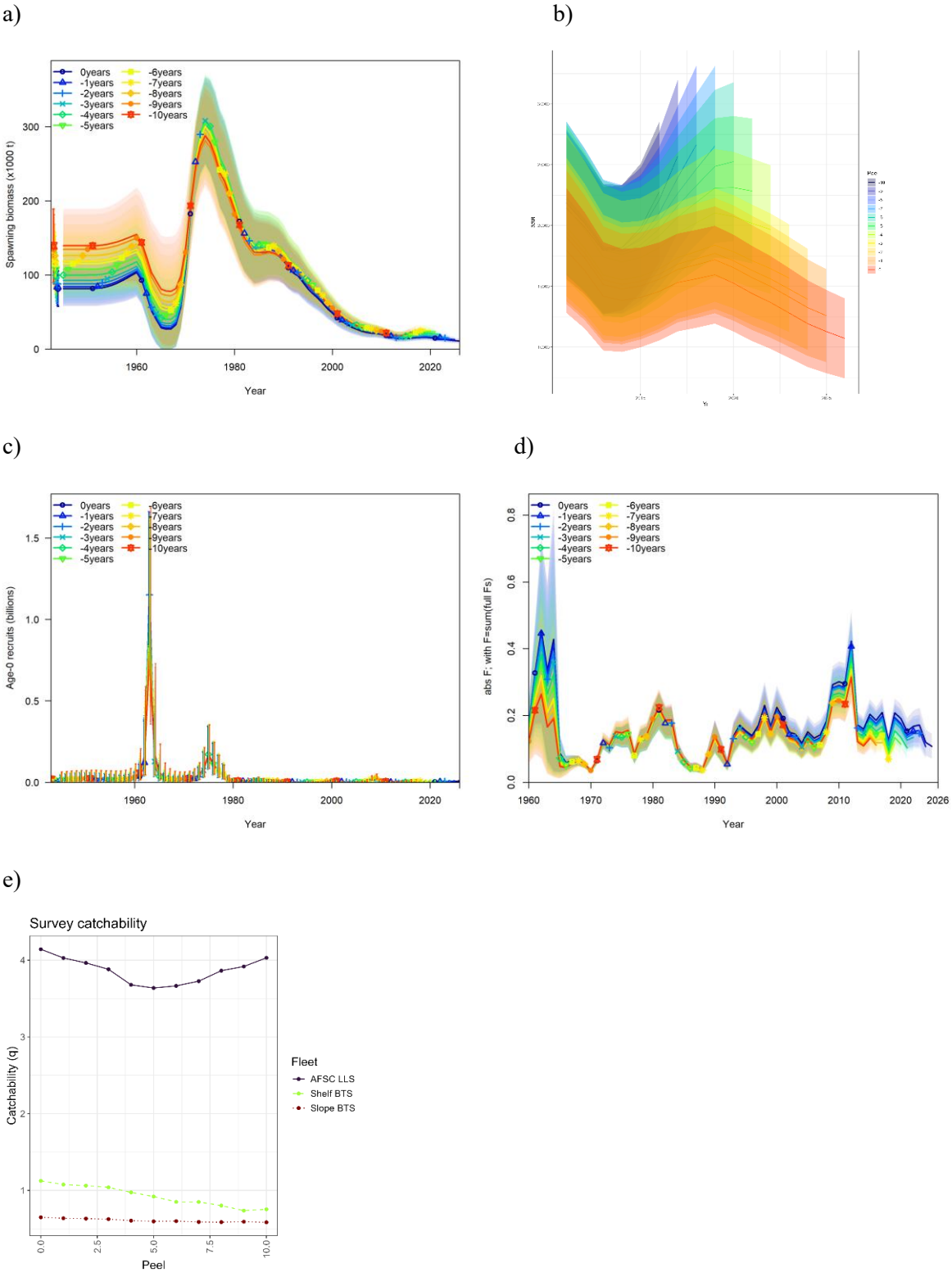


Figure 5.39. Retrospective plots for alternative model 25.3a as an example of the retrospective patterns in the alternative models. a) Female spawning biomass (full time series) b) female spawning biomass (last 10 years of the model), and c) age-0 recruits, d) fishing mortality, and e) survey catchability.

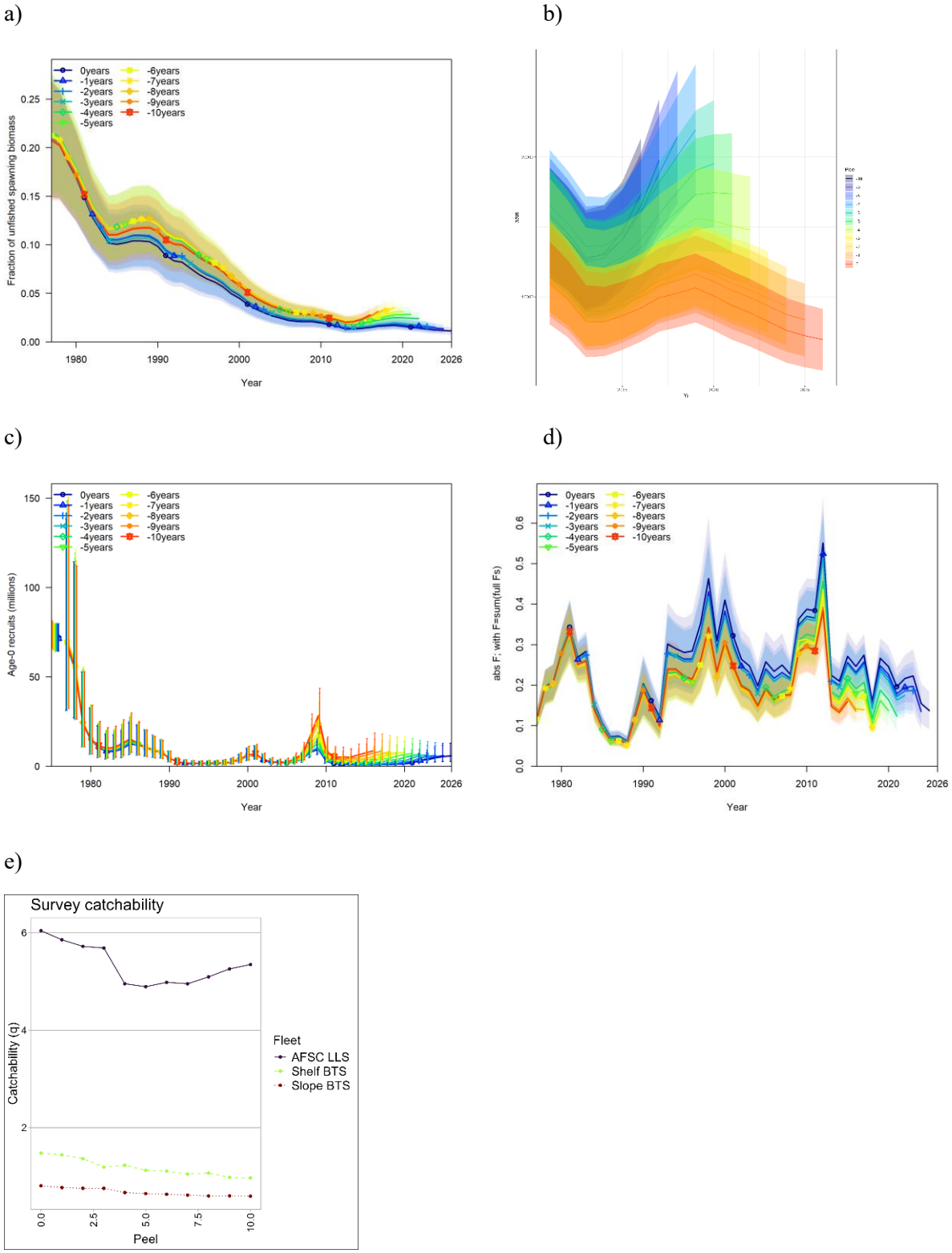


Figure 5. 40. Retrospective plots for alternative model 26.3 as an example of the retrospective patterns in the alternative models. a) Female spawning biomass (full time series) b) female spawning biomass (last 10 years of the model), and c) age-0 recruits, d) fishing mortality, and e) survey catchability.

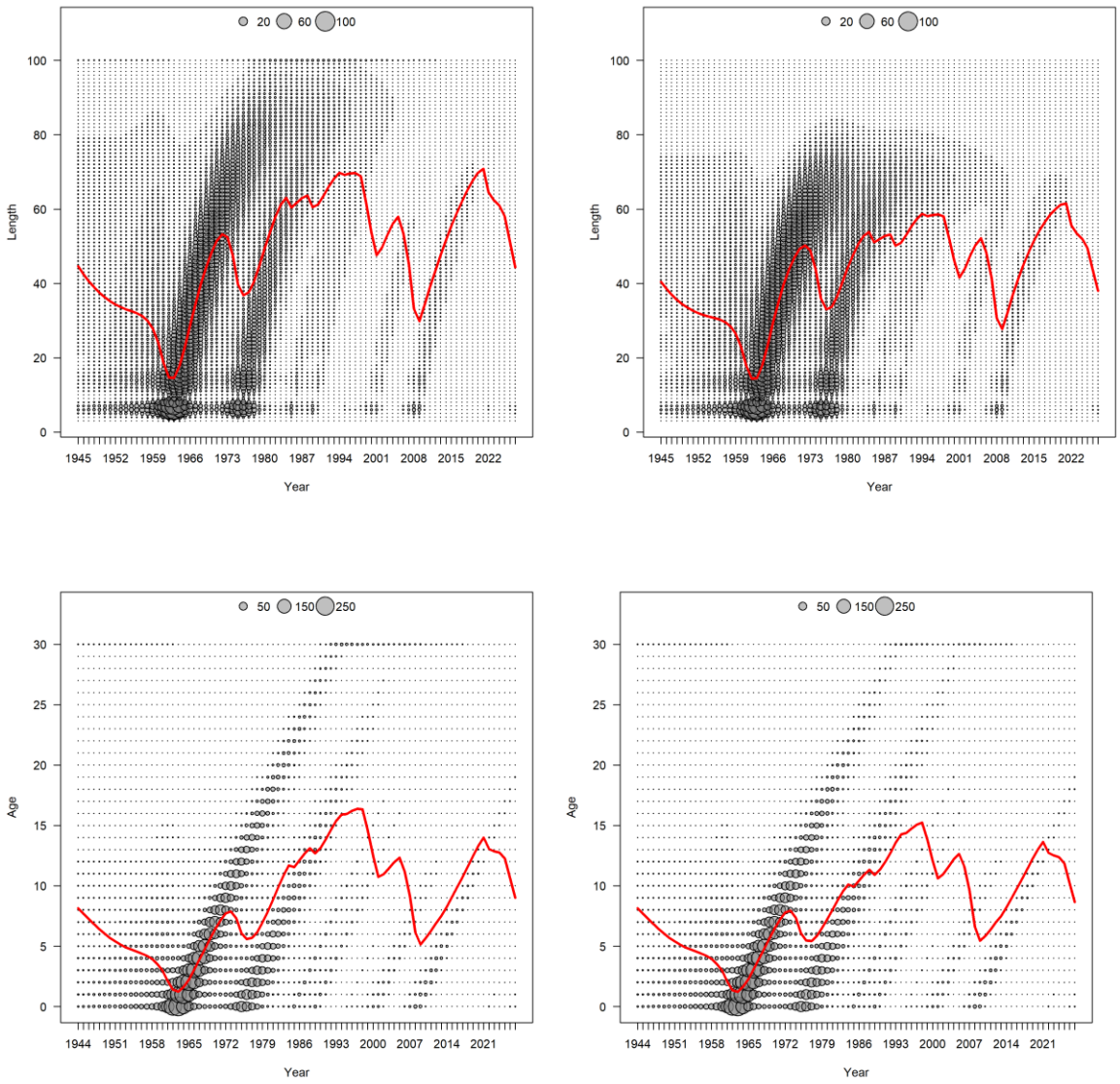


Figure 5.41. top panels: Beginning of the year numbers at length (bubbles) and mean length (red line) for females(left) and males (right). Bottom panels: Beginning of the year numbers at age (bubbles) and mean age (red line).

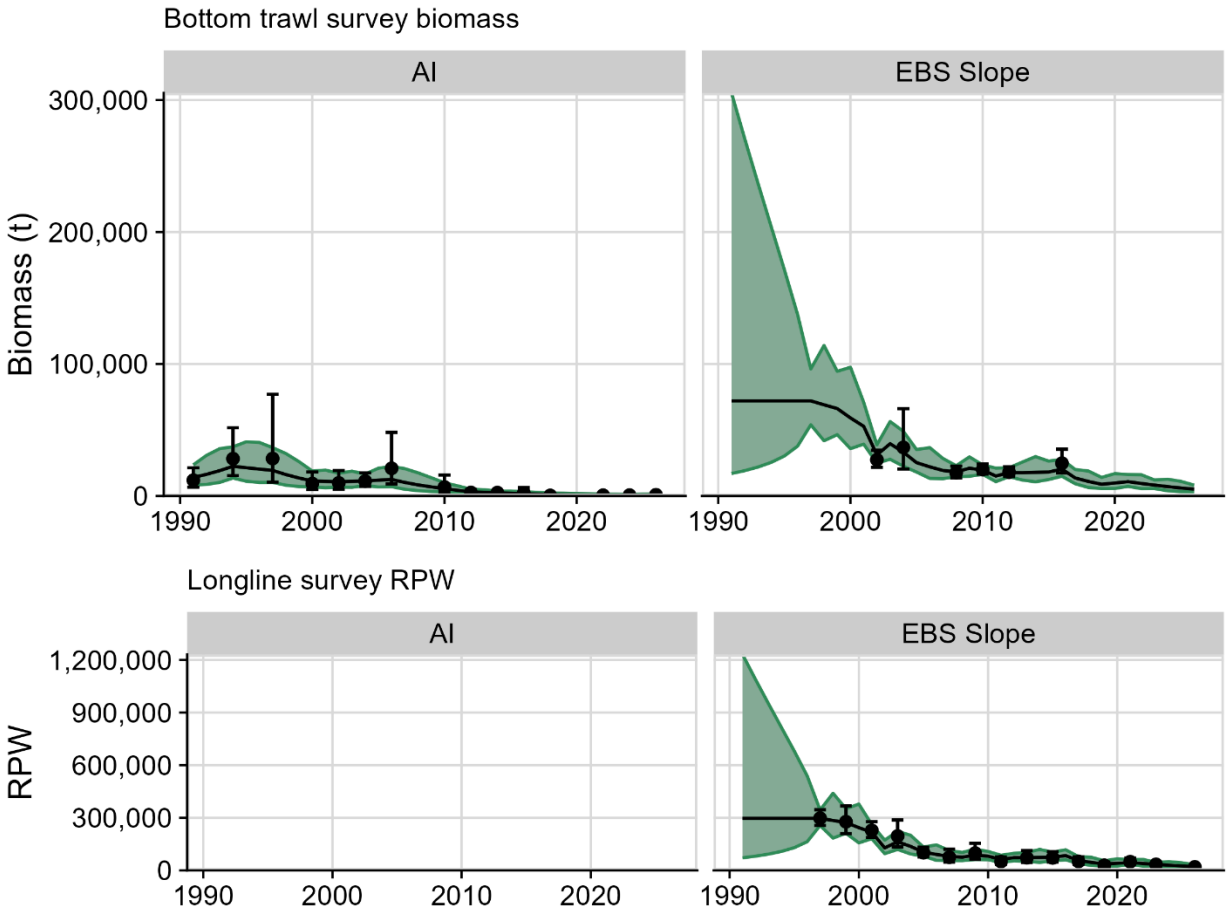


Figure 5.42. REMA model fits to survey indices. The top row represents the area-specific bottom trawl biomass and the bottom row represents the AFSC longline survey RPWs.

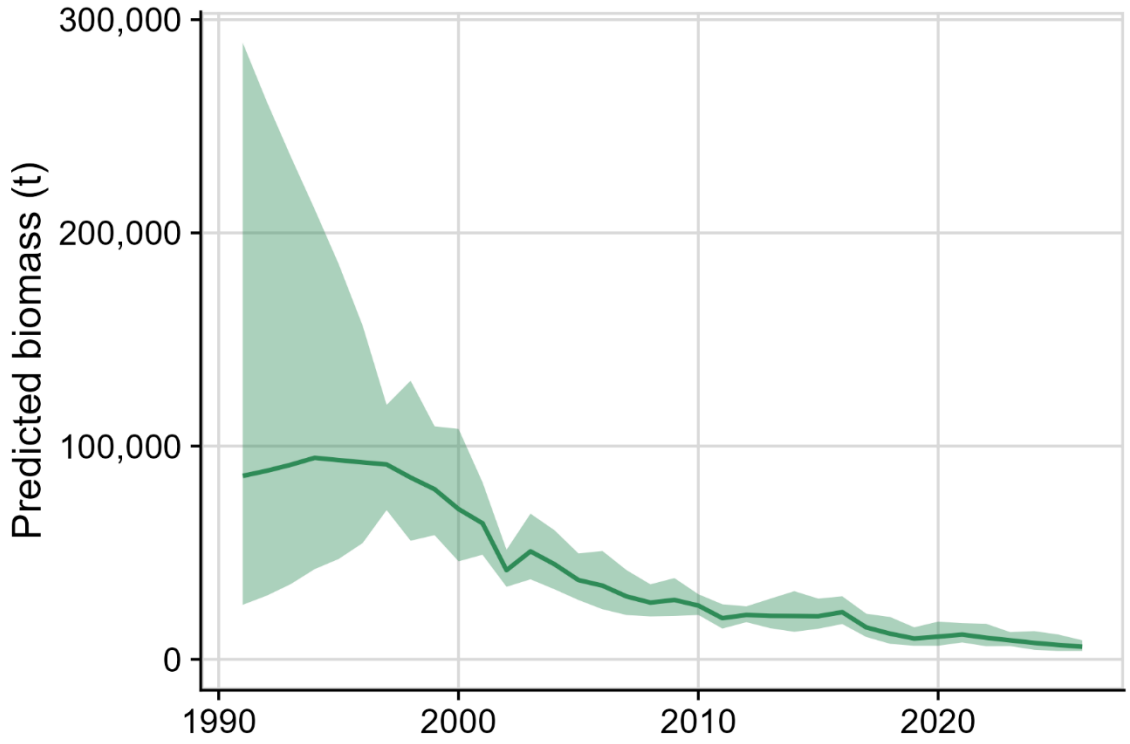


Figure 5.43. Estimates of total biomass of adult Greenland turbot on the EBS slope and AI.

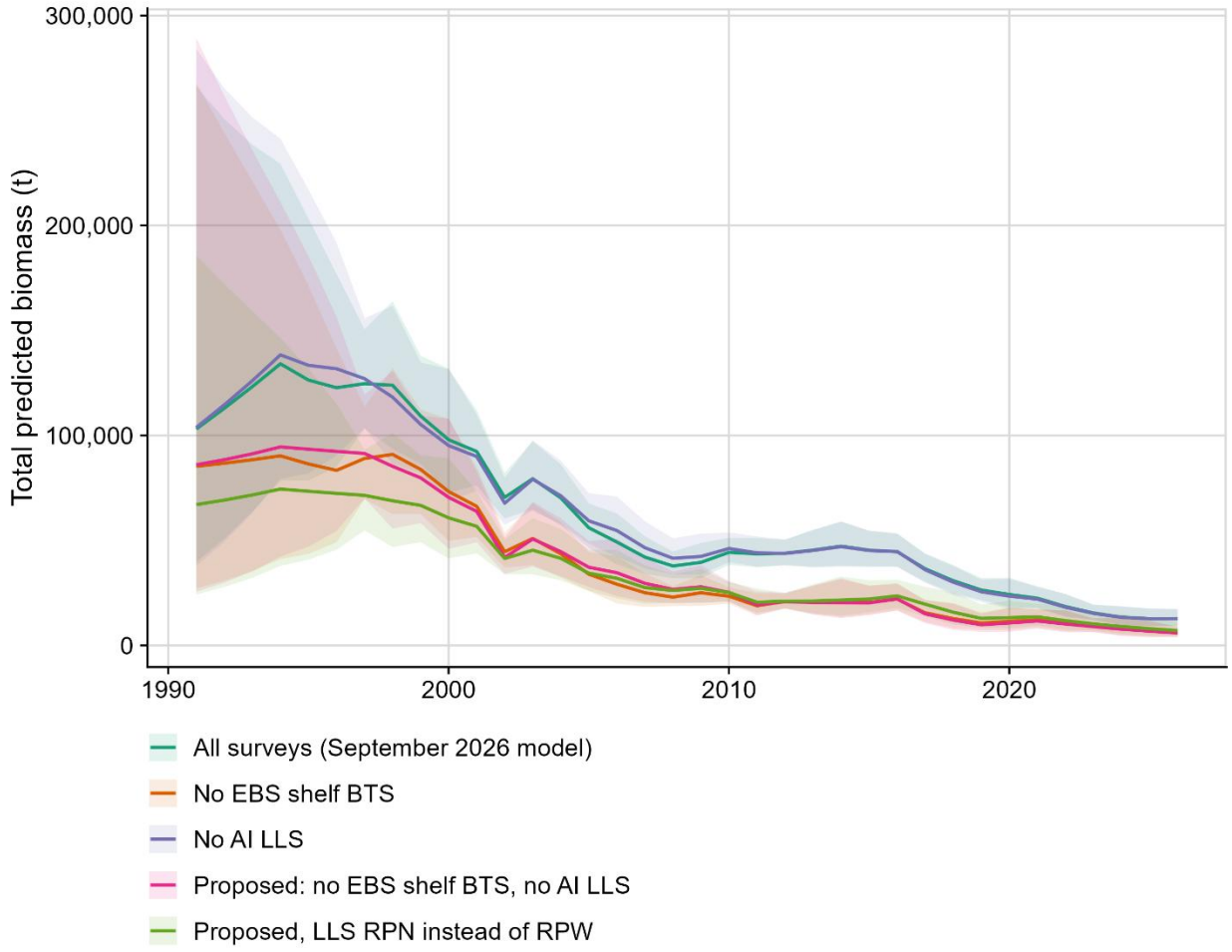


Figure 5.44. Estimates of total biomass Greenland turbot on the EBS slope and AI under differing model configurations.

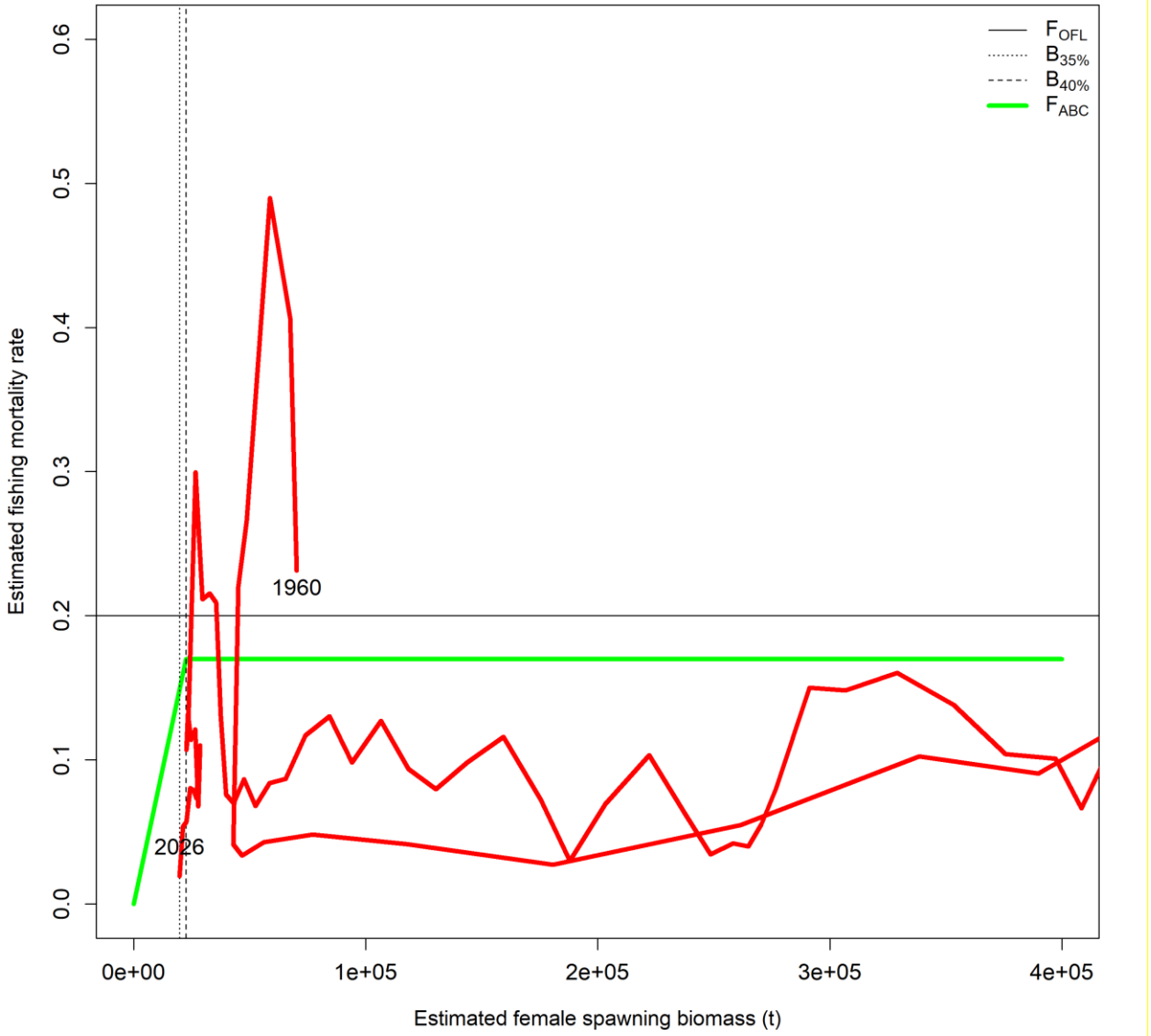


Figure 5.45. Ratio of historical fishing mortality versus female spawning biomass for BSAI Greenland turbot, 1960-2026, Model 25.0. Note that the proxies for F_{msy} and B_{msy} are $F_{35\%}$ and $B_{35\%}$, respectively. The Fs presented are the sum of the full Fs across fleets.

Appendix A.

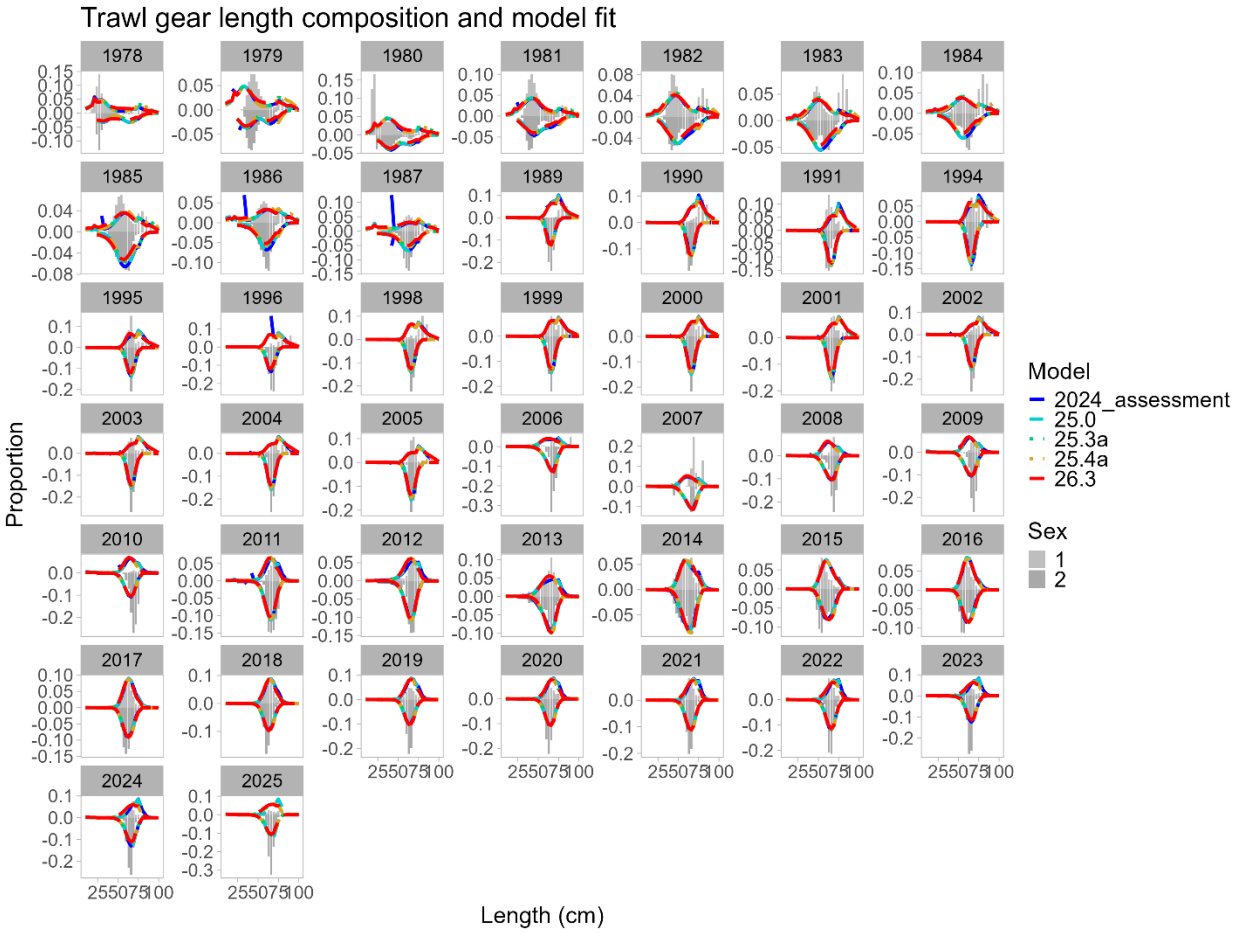


Figure A. 1. Trawl fishery annual length data and model fits.

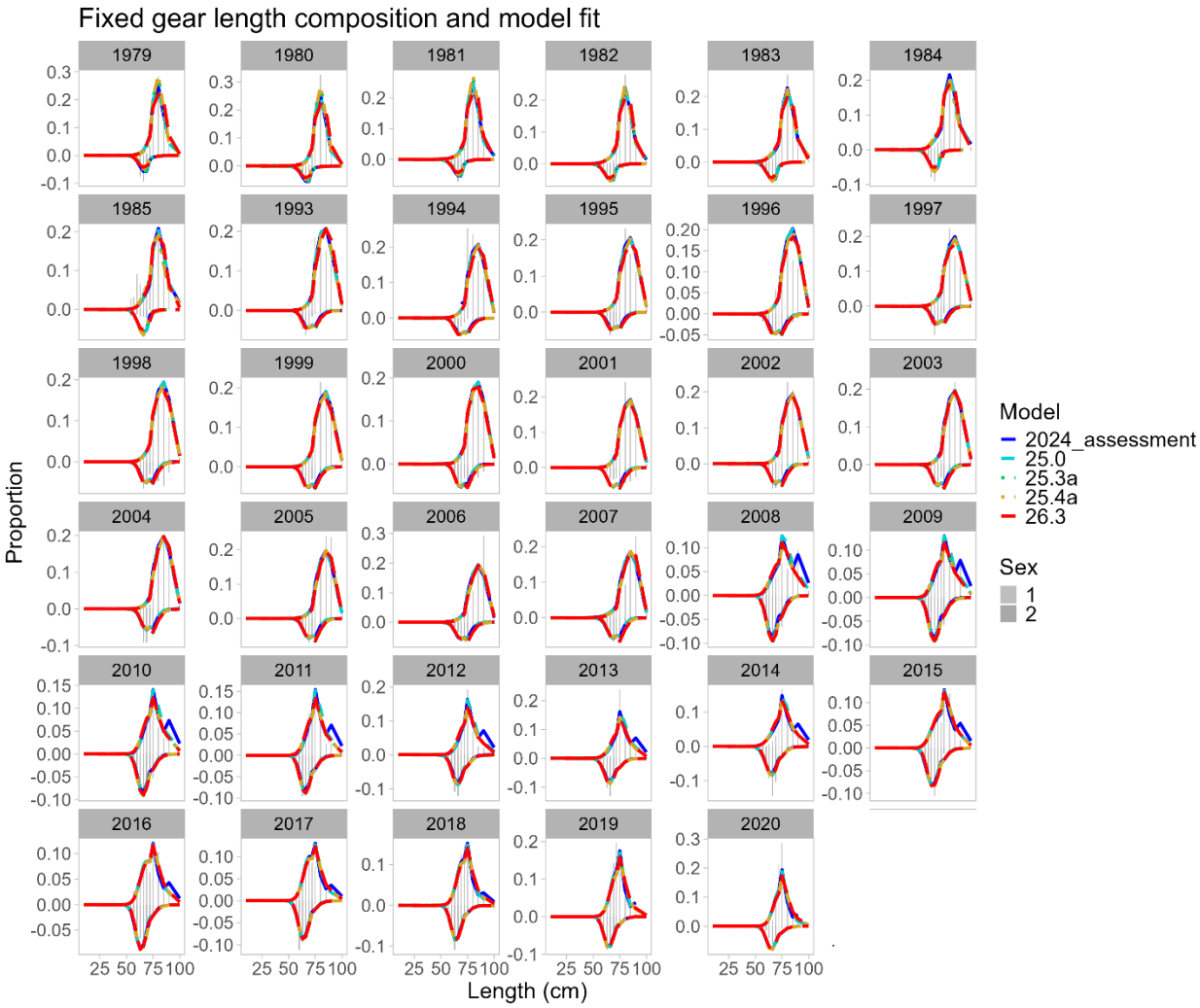


Figure A. 2. Longline fishery annual length data and model fits.

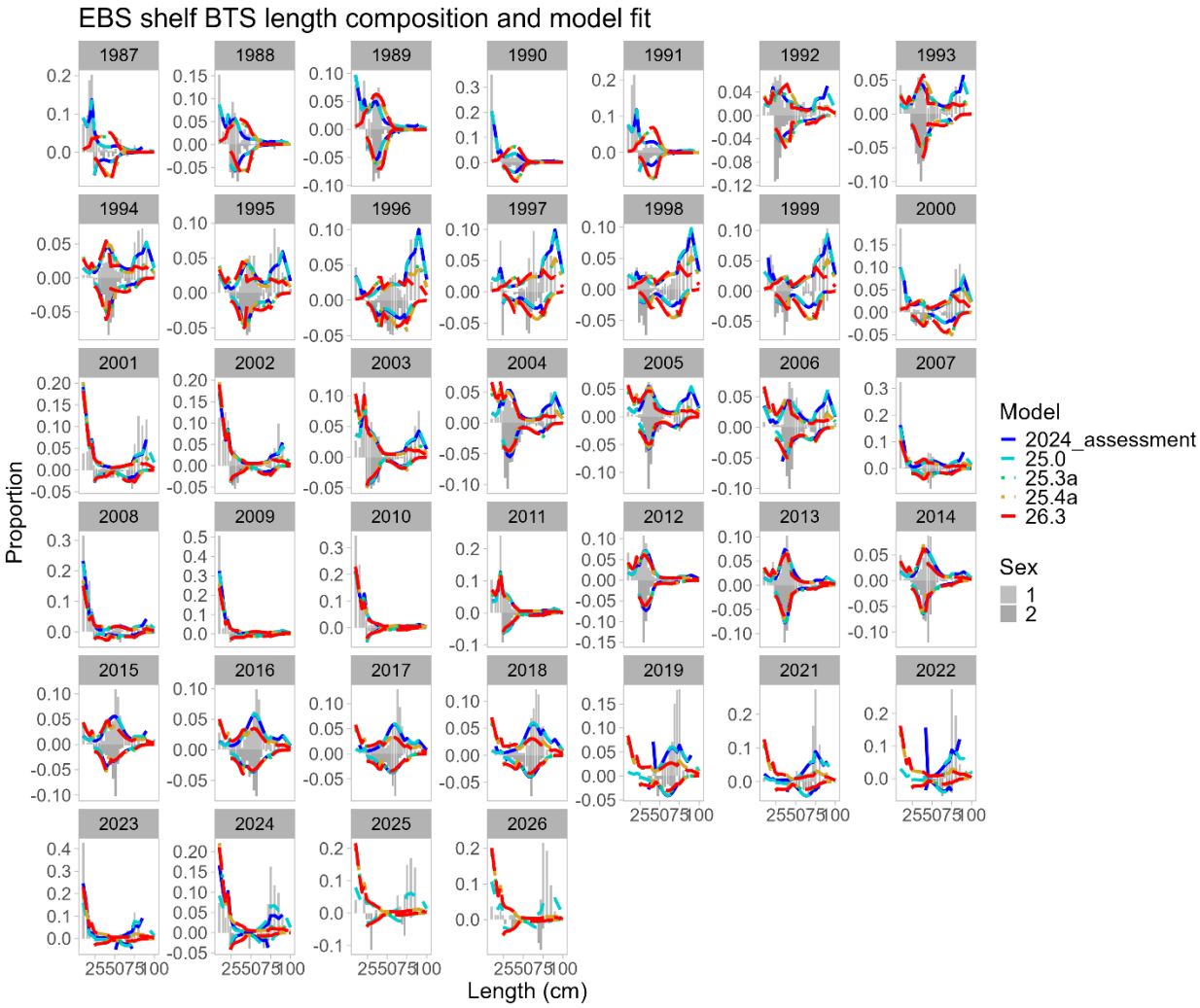


Figure A. 3. EBS shelf bottom trawl survey annual length data and model fits.

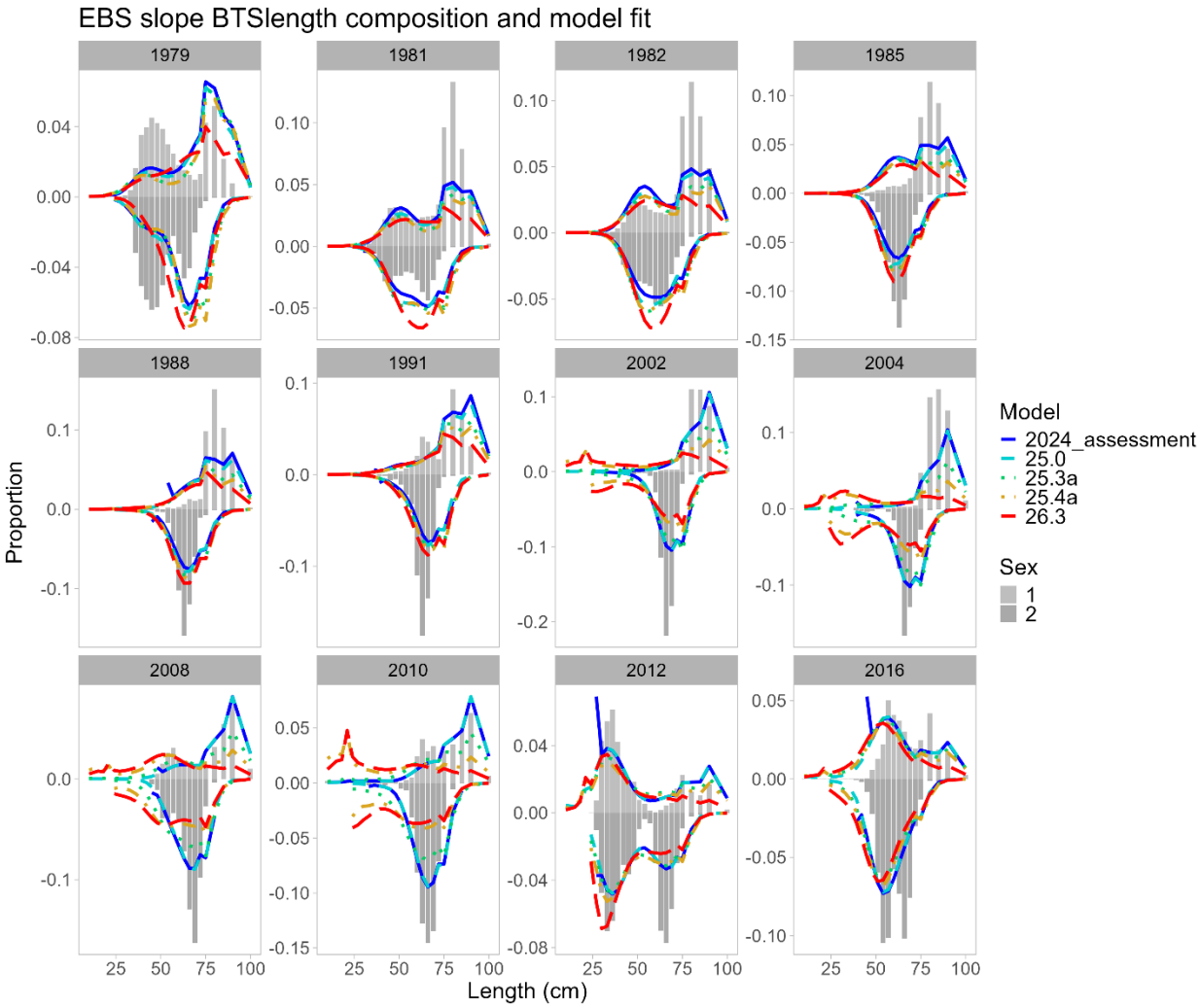


Figure A. 4. EBS slope bottom trawl survey annual length data and model fits.

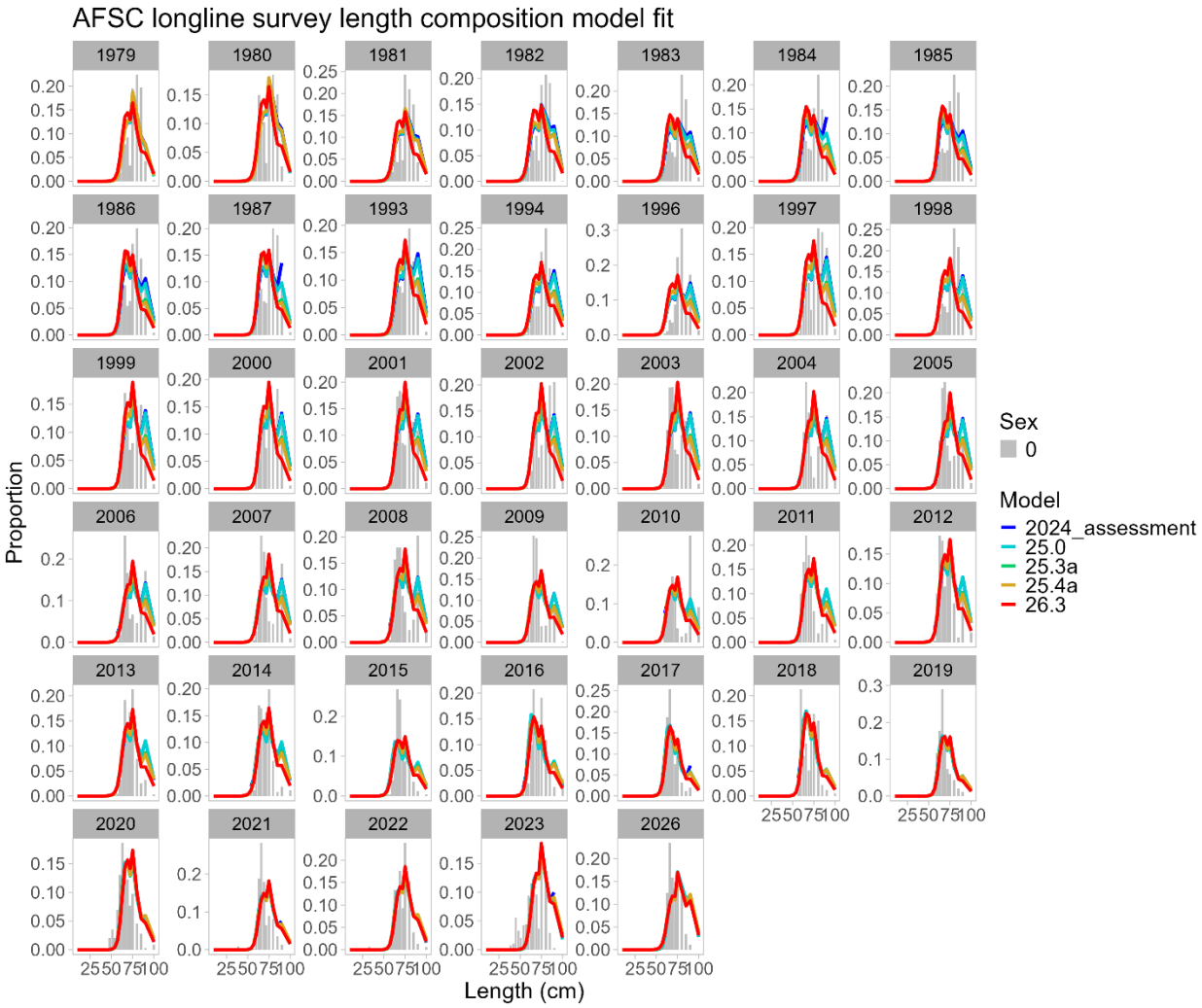
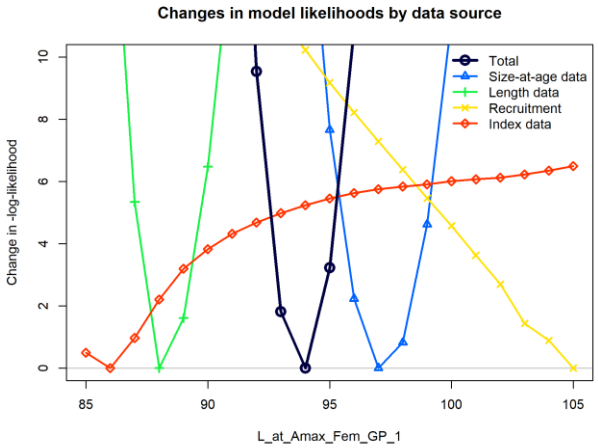


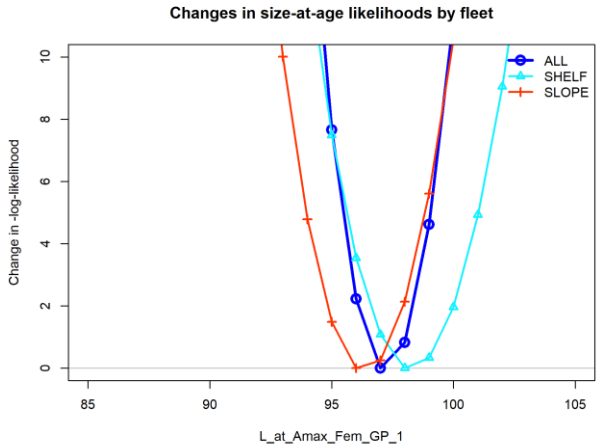
Figure A. 5. AFSC longline survey annual length data and model fits.

Appendix B. Results from the likelihood profiles

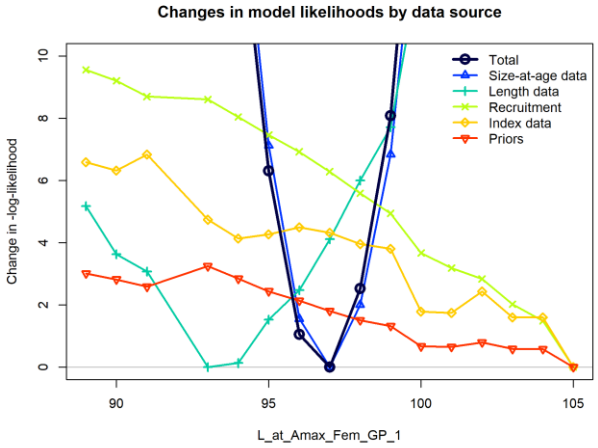
a)



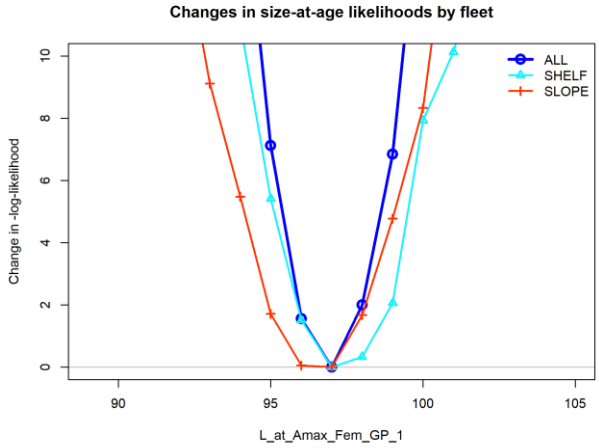
b



c)



d



e)

f)

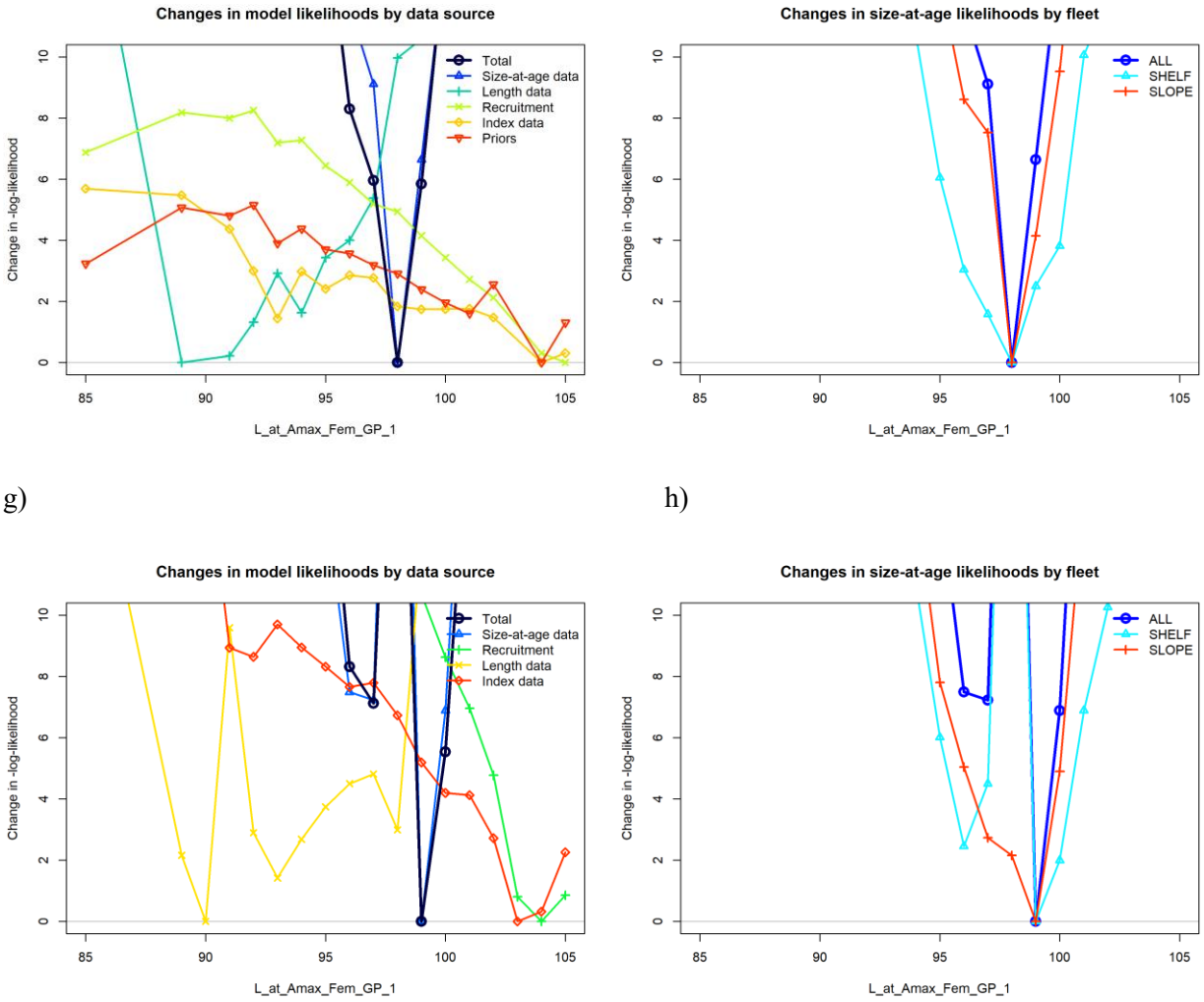
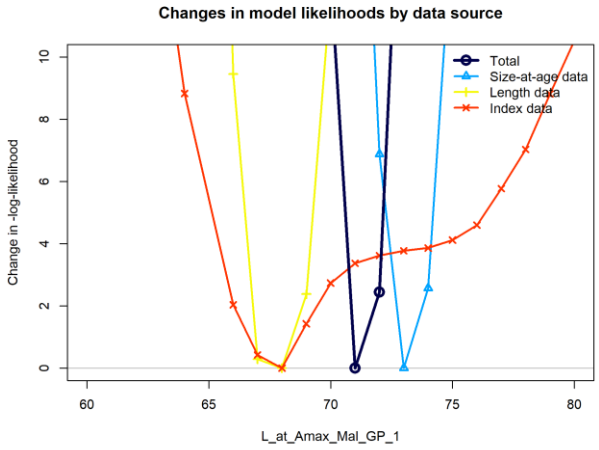
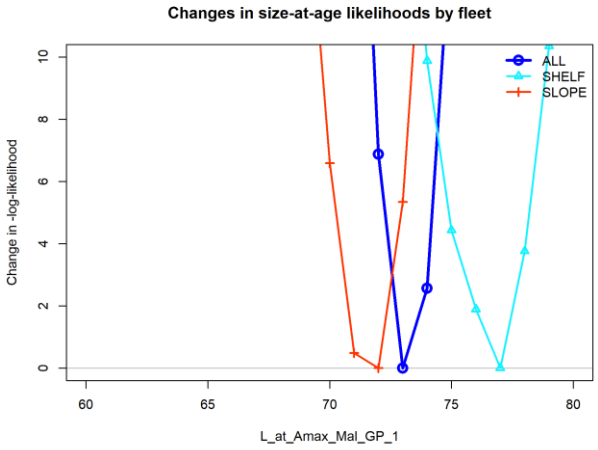


Figure B.1 Likelihood profile on the female asymptotic length parameter for models a, b) 25.0, c, d) 25.3a, e, f) 25.4a, and g, h) 26.3. The left column shows the total likelihood and the total for each likelihood component. The right column shows the fleet-specific components of the length-at-age likelihood.

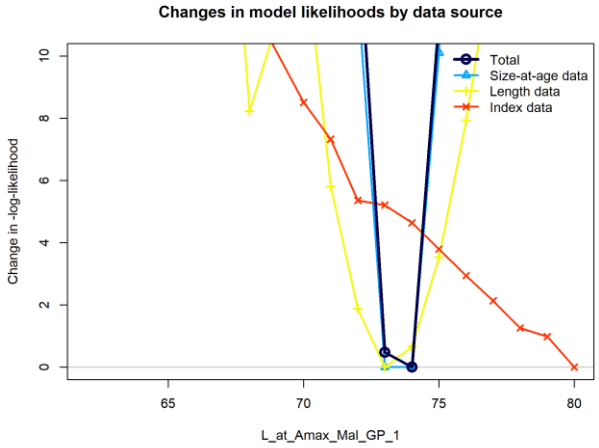
a)


Changes in model likelihoods by data source
Total
Size-at-age data
Length data
Index data
Change in -log-likelihood
L_at_Amax_Mal_GP_1

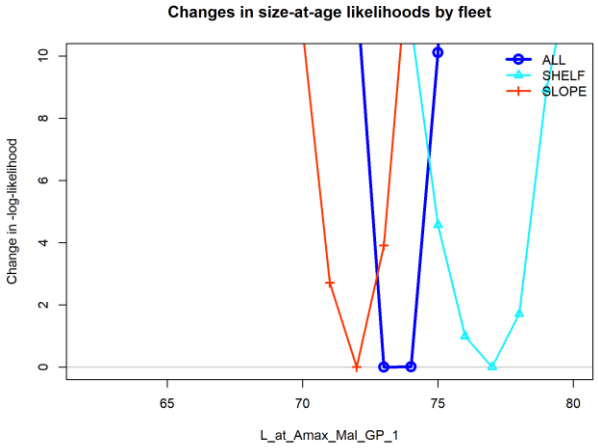
b)


Changes in size-at-age likelihoods by fleet
ALL
SHELF
SLOPE
Change in -log-likelihood
L_at_Amax_Mal_GP_1

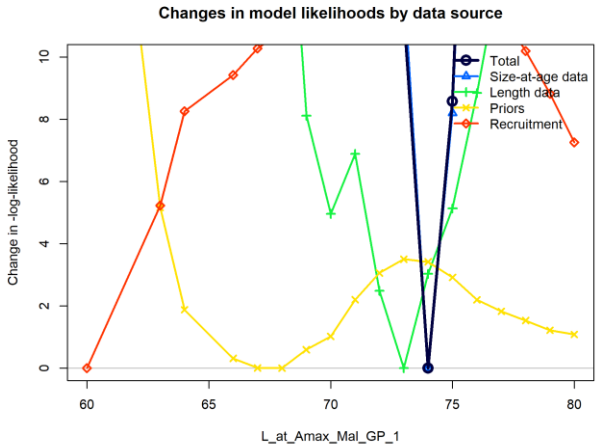
c)


Changes in model likelihoods by data source
Total
Size-at-age data
Length data
Index data
Change in -log-likelihood
L_at_Amax_Mal_GP_1

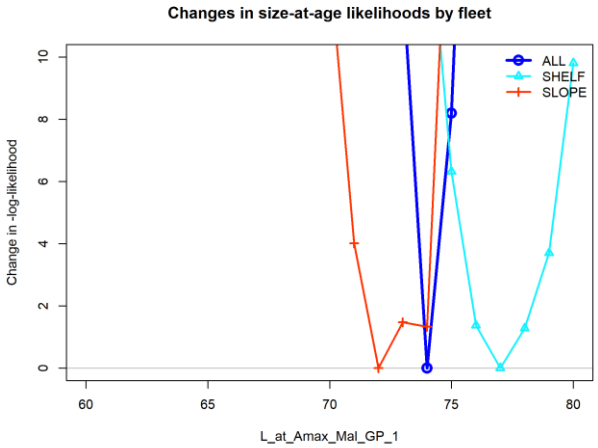
d)


Changes in size-at-age likelihoods by fleet
ALL
SHELF
SLOPE
Change in -log-likelihood
L_at_Amax_Mal_GP_1

e)


Changes in model likelihoods by data source
Total
Size-at-age data
Length data
Priors
Recruitment
Change in -log-likelihood
L_at_Amax_Mal_GP_1

f)


Changes in size-at-age likelihoods by fleet
ALL
SHELF
SLOPE
Change in -log-likelihood
L_at_Amax_Mal_GP_1

g) h)

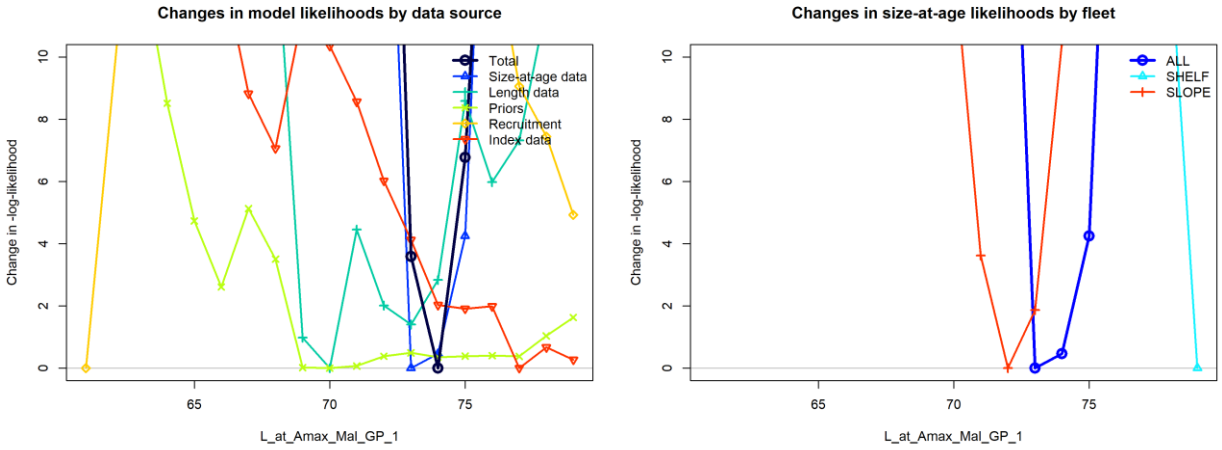
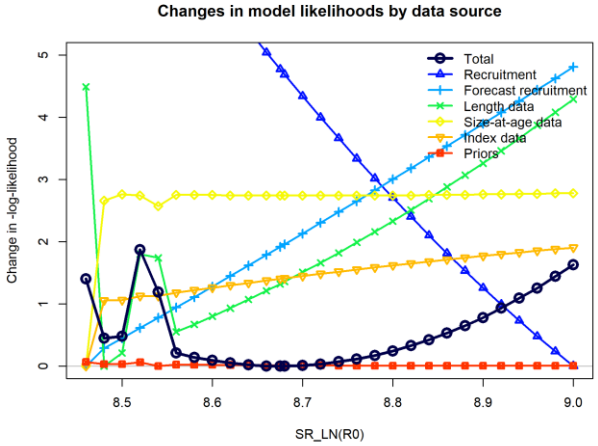
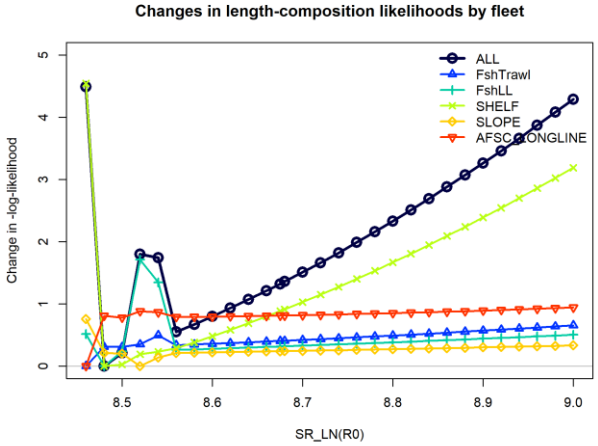


Figure B.2. Likelihood profile on the male asymptotic length parameter for models a, b) 25.0, c, d) 25.3a, e, f) 25.4a, and g, h) 26.3. The left column shows the total likelihood and the total for each likelihood component. The right column shows the fleet-specific components of the length-at-age likelihood.

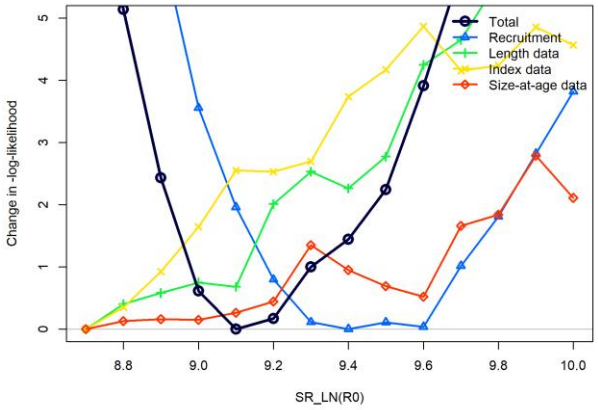
a)


Changes in model likelihoods by data source
Total
Recruitment
Forecast recruitment
Length data
Size-at-age data
Index data
Priors
Change in -log-likelihood
SR_LN(R0)

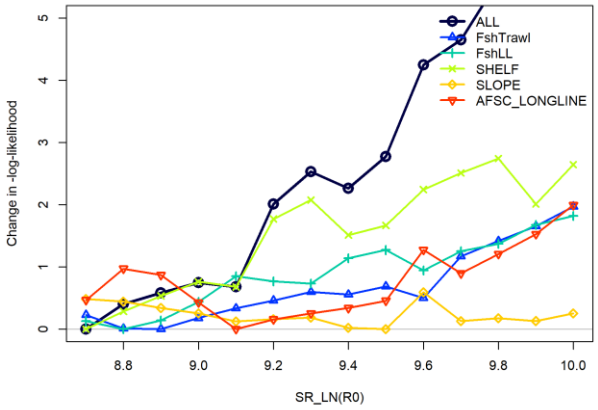
b


Changes in length-composition likelihoods by fleet
ALL
FshTrawl
FshLL
SHELF
SLOPE
AFSC_LONGLINE
Change in -log-likelihood
SR_LN(R0)

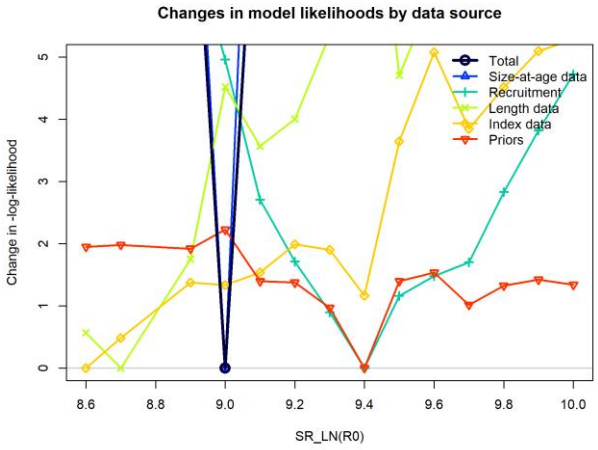
c)


Changes in model likelihoods by data source
Total
Recruitment
Length data
Index data
Size-at-age data
Change in -log-likelihood
SR_LN(R0)

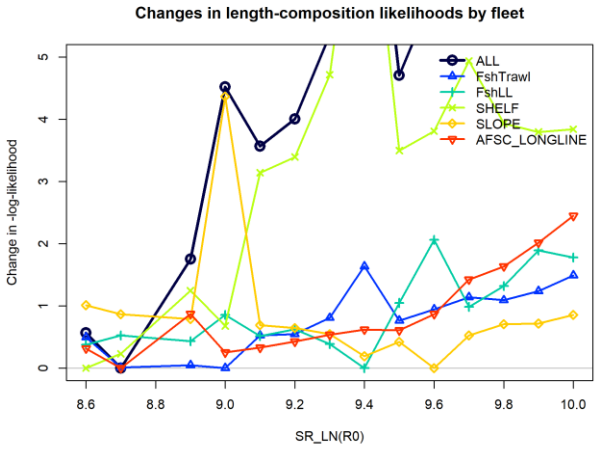
d


Changes in length-composition likelihoods by fleet
ALL
FshTrawl
FshLL
SHELF
SLOPE
AFSC_LONGLINE
Change in -log-likelihood
SR_LN(R0)

e)


Changes in model likelihoods by data source
Total
Size-at-age data
Recruitment
Length data
Index data
Priors
Change in -log-likelihood
SR_LN(R0)

f)


Changes in length-composition likelihoods by fleet
ALL
FshTrawl
FshLL
SHELF
SLOPE
AFSC_LONGLINE
Change in -log-likelihood
SR_LN(R0)

g) h)

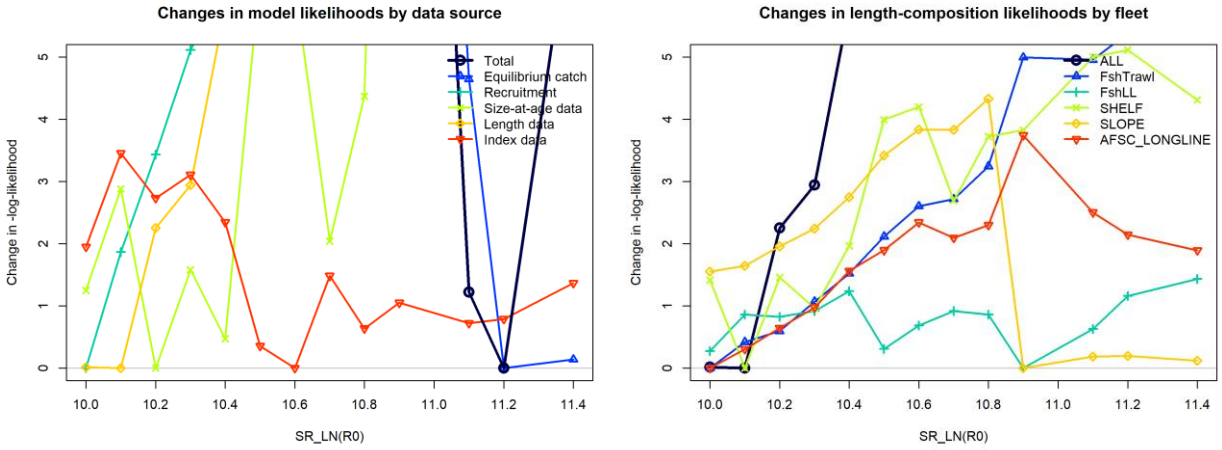
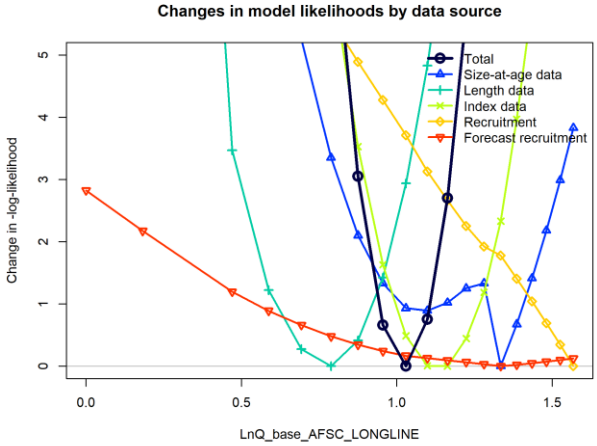
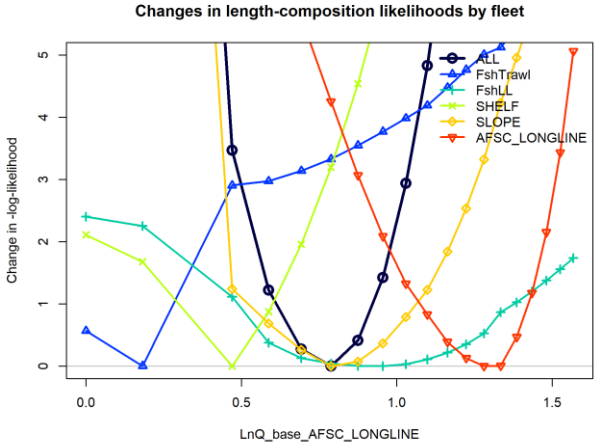


Figure B.3. R0 profiles for models a,b) 25.0, c,d) 25.3a, e,f) 25.4a, and g,h) 26.3. The left panels show the overall likelihood and overall likelihood components. The right column shows the fleet-specific components of the length likelihood.

a)



b



c)

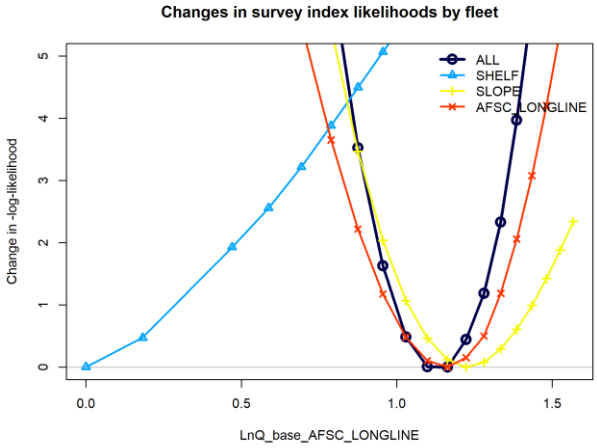
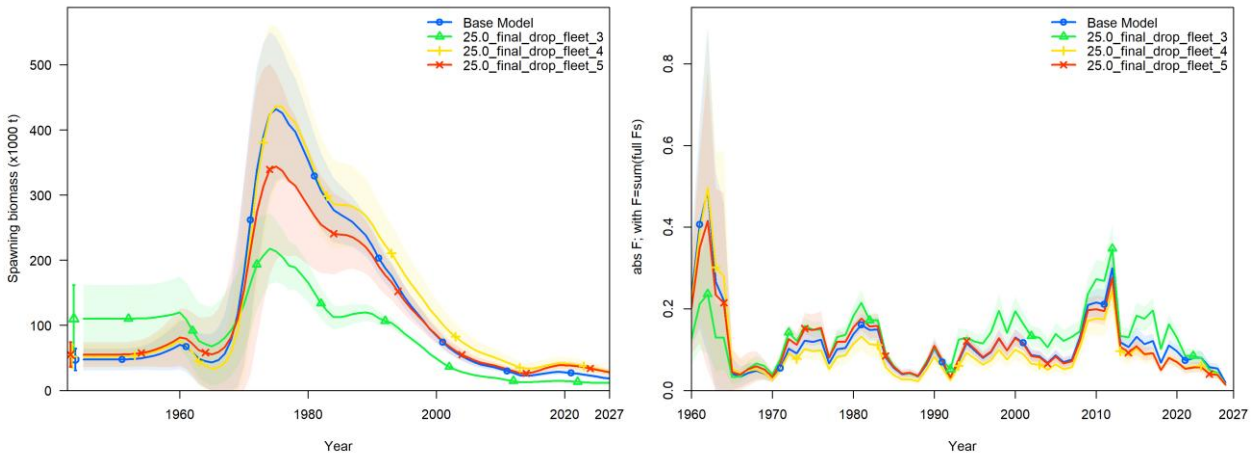


Figure B.4. Log catchability likelihood profile for model 25.0

The log catchability parameter for the AFSC longline survey was estimated in model 25.0. It was not estimated in the alternatives models in an attempt to increase parsimony in the models. The likelihood profile for this parameter indicates the length and index likelihoods are in conflict, where the index likelihood is minimized at a higher value of ln q than the length likelihood. The AFSC longline survey and the EBS slope BTS survey likelihoods are minimized at a higher value of ln q than the EBS shelf BTS driving the minimization of the survey index likelihood. This pattern is true for the fleet specific length likelihoods as well.

Appendix C. Leave-One-Out Analysis

a) b



c) b

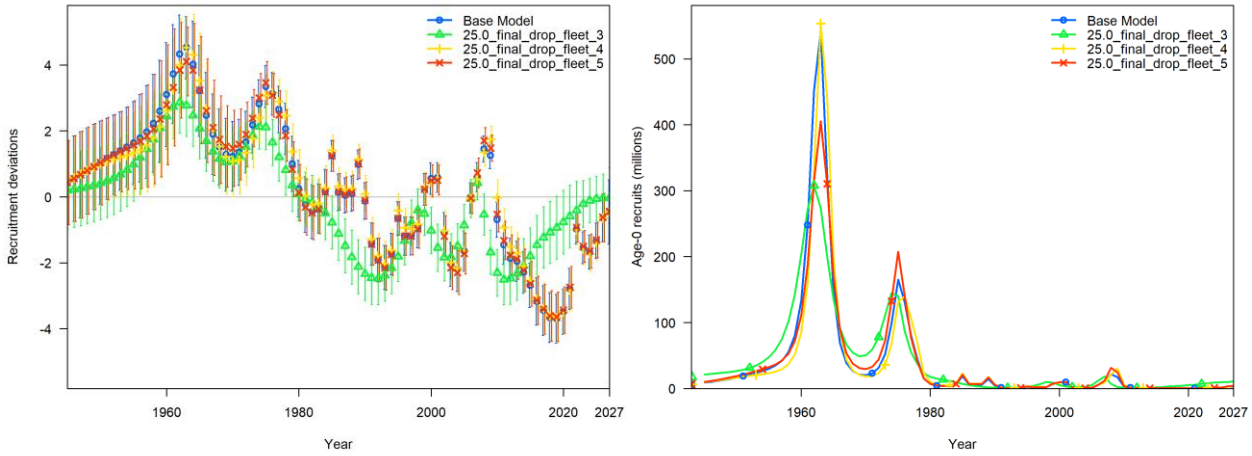


Figure C.1. Leave one out analysis results for model 25.0. drop3 represents the removal of the EBS shelf bottom trawl survey biomass and length composition data; drop 4represents the removal of the EBS slope bottom trawl survey biomass and length composition data; and drop 5 represents the removal of the AFSC longline survey RPNs and length composition data.

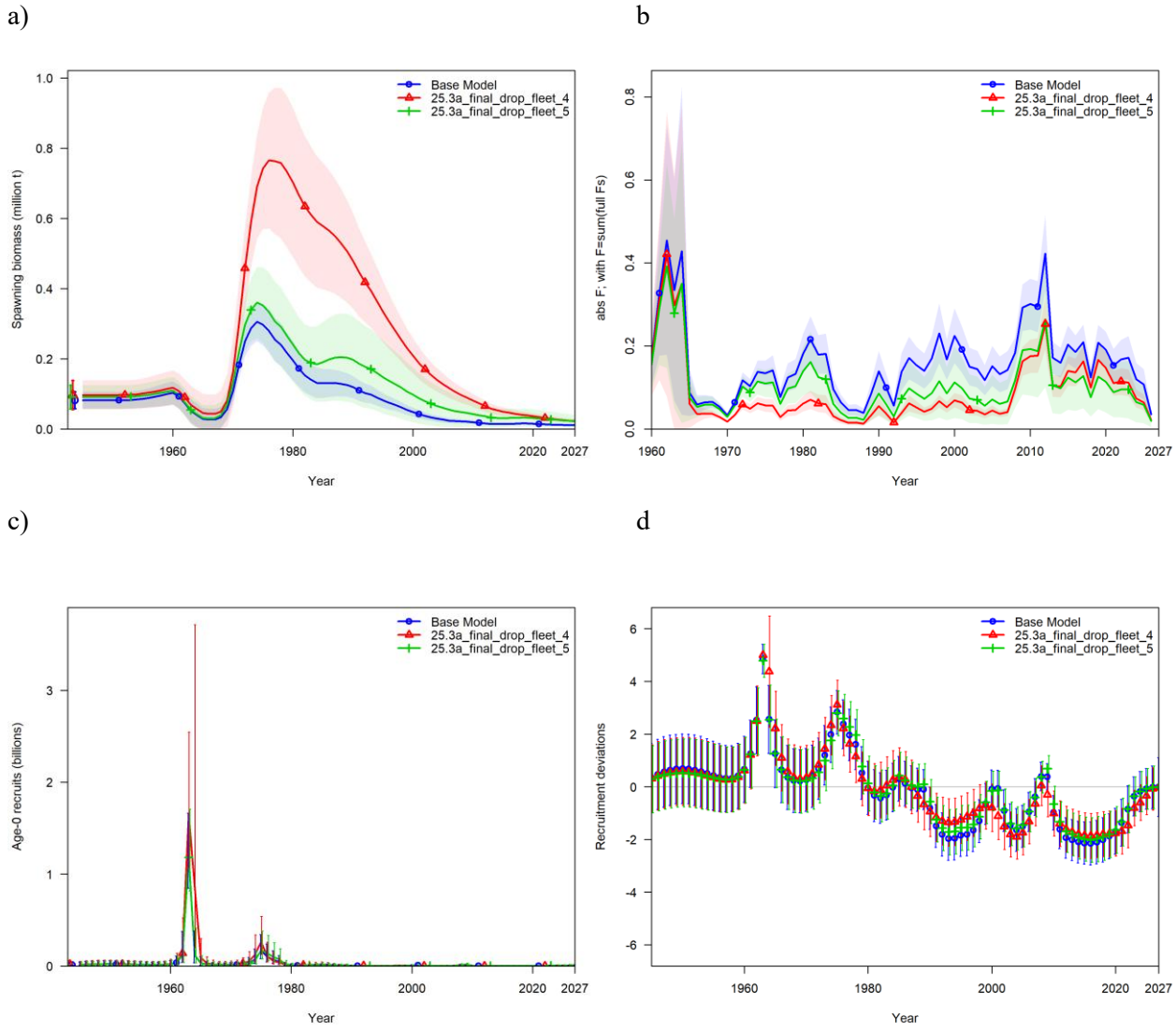


Figure C.2. Leave one out analysis results for model 25.3a. drop 4represents the removal of the EBS slope bottom trawl survey biomass and length composition data; and drop 5 represents the removal of the AFSC longline survey RPNs and length composition data.

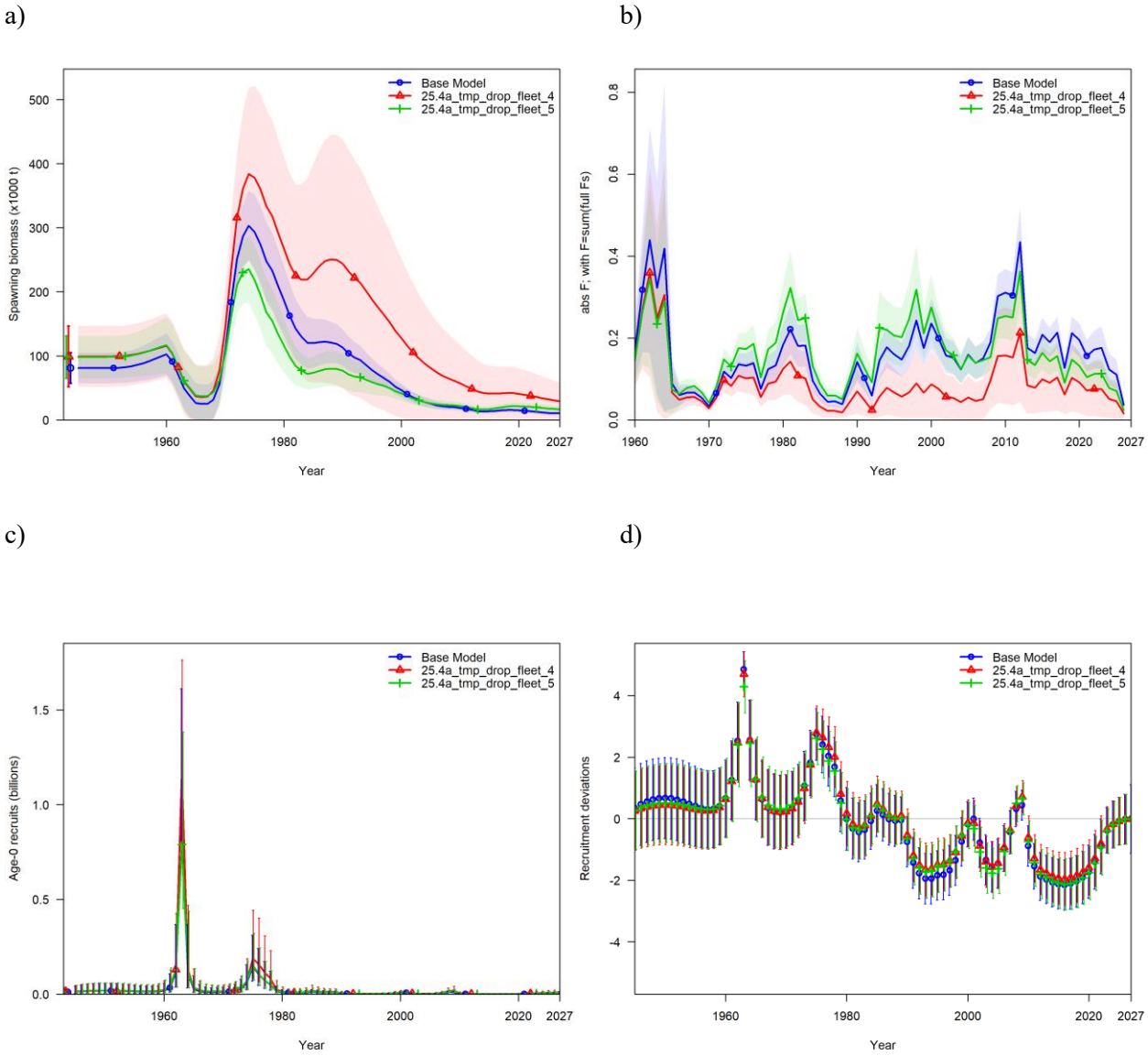


Figure C.3. Leave one out analysis results for model 25.4a. drop 4represents the removal of the EBS slope bottom trawl survey biomass and length composition data; and drop 5 represents the removal of the AFSC longline survey RPNs and length composition data.