

# **1. Stock assessment for eastern Bering Sea walleye pollock**

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## **1 Executive summary**

This chapter covers the Eastern Bering Sea (EBS) region—the Aleutian Islands region (Chapter 1A) and the Bogoslof Island area (Chapter 1B) are presented separately. A multi-species stock assessment is provided separately and available [here](#). A list of this document contents, including tables and figures is provided in Section [17](#).

### **Summary of changes in assessment inputs**

Relative to last year's BSAI SAFE report, the following substantive changes have been made in the EBS pollock stock assessment. This includes the 2023 NMFS bottom-trawl survey (BTS) covering the EBS and NBS. As before, these data were treated with a spatio temporal model for index standardization. Age data from this survey effort was compiled and included (also with an extensive spatio-temporal model treatment). The NMFS acoustic-trawl survey (ATS) age composition data was revised from the preliminary estimates developed in 2022. The BTS chartered boats also collected acoustic data and the series was updated this year (AVO). Explorations were presented in Ianelli (2023).

### **Changes in the data**

1. Observer data for catch-at-age and average weight-at-age from the 2022 fishery were finalized and included.
2. Total catch as reported by NMFS Alaska Regional office was updated and included through 2023.
3. In summer 2023, the AFSC conducted the bottom trawl survey in the EBS and extended into the NBS. A VAST model evaluation (including the cold-pool extent) was used as the main index.
4. We refined estimates of weight-at-age data used to compute spawning biomass as presented to the Plan Team and SSC in September/October 2023 (see Ianelli (2023) for details).
5. We applied a new time series from the acoustic data collected from the bottom trawl survey covering 2006-2023 (except for 2020) as presented in Ianelli (2023).
6. We applied updated age-composition from the 2022 ATS survey (last year a preliminary estimate was used based on the BTS age-length data plus a juvenile sample from the ATS).

## **Changes in the assessment methods**

The assessment method changes were presented in September 2023 (Ianelli (2023)). In that document we re-evaluated the relative weights specified as input variances and sample sizes. We also applied different tuning approaches which achieved a balance between the observation errors and model process errors, specifically for the acoustic time series. We examined additional model sensitivities under development that included an exploration of using a generalized Gamma distribution for the bottom trawl index, age-determination errors, and simplified error structures for the bottom trawl index. We adopted alternative estimates of weight-at-age applied to the spawning biomass calculations. The modified estimates are intended to reflect data available closest to the peak spawning season. The Plan Team and SSC agreed with the data and model changes, and those present the new base case presented here.

### **1.1 Summary of EBS pollock results**

The results from the 2022 assessment have largely been confirmed: the 2018 year class appears to be one of the most abundant on record. Nonetheless, the bottom-trawl survey was lower than expected (about 28% below the long-term mean and the tenth lowest over the 41-year survey period). The new AVO index (presented in September 2023) expanded the area covered by acoustics and provided more precision (lower CV in the point estimates) than in the past. Ancillary data indicate that the pollock in 2023 are substantially skinnier than average given their length. The average weight-at-age was about average for the 2018 year class, but lighter for most other ages.

The following table is based on results from the selected model (“Model 23.0”) based on changes presented in Ianelli (2023). The ABC recommendation is based on Tier 3 calculation as a proxy for Tier 1 because of the variability indicated by the very high value based on the  $F_{MSY}$  estimate and the large but uncertain 2018 year class.

### **1.2 Response to SSC and Plan Team comments**

#### **SSC General groundfish stock assessment comments**

The following are relevant SSC comments from their December 2022 minutes.

- The SSC recommends that for future Tier 1-3 assessments some consideration be given as to how best to represent biomass estimates in the Executive Summary table for each stock (currently, model total biomass and spawning stock biomass are provided) so that the relationship of the biomass to the OFL and ABC in the stock status table is clear.  
*- We agree. Within the document we include biomass estimates that are outcomes for ABC and OFL calculations. However, the estimates involve an application of expected age-specific selectivity which can be variable.*

Quantity	As estimated or <i>specified</i> <i>last year for:</i>		As estimated or <i>recommended</i> <i>this year for:</i>	
	2023	2024	2024	2025
M (natural mortality rate, ages 3+)	0.3	0.3	0.3	0.3
Tier	1a	1a	1a	1a
Projected total (age 3+) biomass (t)	12,389,000 t	11,445,000 t	10,184,000 t	9,437,000 t
Projected female spawning biomass (t)	4,171,000 t	3,944,000 t	3,518,000 t	3,255,000 t
$B_0$	6,653,000 t	6,653,000 t	6,728,000 t	6,728,000 t
$B_{msy}$	2,674,000 t	2,674,000 t	2,689,000 t	2,689,000 t
$F_{OFL}$	0.491	0.491	0.422	0.422
$\max F_{ABC}$	0.434	0.434	0.379	0.379
$F_{ABC}$	0.365	0.365	0.33	0.33
$OFL$	3,381,000 t	4,639,000 t	3,162,000 t	3,449,000 t
$\max ABC$	2,987,000 t	4,099,000 t	2,837,000 t	3,095,000 t
$ABC$	1,910,000 t	2,275,000 t	2,313,000 t	2,401,000 t
Status	2021	2022	2022	2023
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

- For all assessments using VAST, the SSC requests a figure comparing the VAST estimate used in the previous assessment to the current assessment (if new data are added), noting that VAST will refit the time series when additional data are added and the estimated extent and directionality of spatial correlation may change. - *We include model comparisons showing the impact of new (updated) VAST time series.*

**The SSC suggests that walleye pollock is a good candidate for considering the impacts of highly variable recruitment on reference points in the context of the Council's harvest control rules** (see discussion on working groups in the JGPT report section). For example, the SAFE authors suggested exploring an explicit harvest control rule that maintains productivity at the level observed over recent decades (p. 33). The SSC supports considerations of modified harvest control rules, particularly for stocks with highly variable and uncertain recruitment. If the Council chooses, this could include considerations for stabilizing catches over time or including other economic considerations in the harvest control rules.

- *For the 2023 assessment we examine the variability of the biological reference points historically and note that there is general stability in the  $B_{MSY}$  estimates. The Tier 1 ABC/OFL calculations can result in highly variable estimates as the stock approaches  $B_{MSY}$  and drops below that value (as happened in the 2009-2010 period).*

The SSC had the following additional recommendations for the authors:

- Maturity and growth information from the NBS has not been examined yet. Given the possible importance of the NBS to walleye pollock and other species in the future, the SSC suggests this should be a high priority.
  - *These data are being processed and this work is underway*
- The SSC supports efforts to implement recent advances in improving the statistical treatment of compositional data using the Dirichlet distribution or other approaches.
  - *Tradeoffs in data weighting were pursued in September 2023 and sought to find a balance between observation error and process errors. In general, trade-offs in data weighting appear consistent with sampling levels and include objective approaches to their specifications.*
- The SAFE document lists a number of research recommendations (p. 36/37). The SSC notes that some of these are at least in progress. The SSC generally supports these recommendations but requests that the authors update the list of priorities to clarify to what extent some of these priorities have been partially or fully addressed.
  - *We updated the priorities and listed those that have been completed or are continued to be underway*
- In particular, the SSC notes that genetic sample collection and analyses are listed as a research priority across all pollock stocks and that some work has been completed. The SSC highlights the importance of additional genetics work and would appreciate an update on the status of this work either as part of the assessment or separately.
  - *We revisited the stock structure work attached as an appendix to the 2015 SAFE report chapter and are examining the extent that this work needs updating. Updated genetics work indicate that the Bering Sea pollock represent a distinct stock. This work indicates that GOA pollock seems to be similar to some Aleutian pollock but some AI pollock are distinct (Spies and Schaal, pers. comm.).*
- The SSC appreciated the adjustments to weight-at-age in the survey that was included in this year's assessment and suggests that these changes may be substantial enough to warrant an examination of their impact on assessment results.
  - *This publication has been completed and in the present assessment we evaluated the implication of alternative spawning biomass-at-age assumptions.*
- With respect to the multi-species CEATTLE model, the SSC concurs with Plan Team recommendations to use the model to inform risk table discussions and to consider ways in which model outputs, in particular estimates of predation mortality, can inform single-species assessments.
  - *We included some comments to this effect.*

- The SSC encourages the authors to consider model-based solutions to uncertain recruitment estimates rather than ad-hoc adjustments. In particular, reductions in the assumed recruitment variance parameter may result in less extreme recruitment estimates. Other systematic approaches to addressing the uncertainty may also be considered.
  - *We revisited applying the age-determination error matrix as a sensitivity as this can impact the recruitment variability and estimation uncertainty.*
- The SSC suggests that authors include a plot to compare estimates of recent recruitments as they change over time similar to Fig 3.33 (pg. 88) in the sablefish assessment.
  - *We provide a figure of estimated recruitment by year class (1977 – 2019) in number of age-1 fish (billions of fish) for the 2022 and 2023 models.*
- The SSC supports the move across assessment from design-based estimates of survey biomass to VAST estimates. The SSC recommends that the design-based estimates be produced as a check on VAST estimates and as a fallback option if needed, although they may not need to be included in the assessment.
  - *We provide a table showing the design-based estimates and conduct a model run with those estimates. This may be an approach to adopt so that bridging across assessment modeling platforms can be facilitated (most other assessment model platforms are unable to deal with index time series that have a covariance matrix)*
- The SSC noted that a consideration of whether the observed sensitivity in the SRR to prior specification should constitute an increased risk level specification within the assessment or population dynamics related considerations should be considered. This could provide a clearer justification for the use of the Tier 3 calculation as the basis for harvest specification.
  - *We evaluated factors affecting the Tier classification in the 2020 assessment and showed that the priors used reflect the SRR curve were conservative and justified based on residual patterns near the origin (as opposed to alternatives that fit data on the descending slope of the Ricker SRR).*
- The SSC recommends that if the assessment is considered in the appropriate Tier, buffers should be based on the use of the Risk Table rather than the continued use of Tier 3 calculations for a Tier 1 stock.
  - *We agree.*
- The SSC also notes that an alternative approach to consider for a buffer below the maximum permissible would be apply Tier 2 control rule. This tier uses the SR relationship for stock status and OFL, but uses the ratio of SPR rates for adjustments when the stock is below  $B_{MSY}$ .

- An examination of Tier 2 as an option resulted in a value of 2,472,000 t (or a hybrid of Tier 1 and 2 of 2,217,000 t) for 2024 ABC values. We note that selecting Tier 2 would require similar reliance on the underlying productivity estimates (via the stock-recruitment relationship) and how that affects the reference fishing rate ( $F_{MSY}$ ).
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**The SSC had a number of recommendations for additional research supporting this assessment:**

**From previous requests:**

The SSC also looks forward to estimates of movement and abundance along the US-Russia EEZ boundary based on echosounders fixed to moorings in this area.

- *The data evaluation from the moored sounders has been completed and initial results show that the flux of pollock back and forth over the maritime boundary is considerable, and appears to be a function of temperature conditions.*

## **2 Introduction**

### **2.1 General**

Walleye pollock (*Gadus chalcogrammus*; hereafter referred to as pollock) are broadly distributed throughout the North Pacific with the largest concentrations found in the Eastern Bering Sea. Also known as Alaska pollock, this species continues to play important roles ecologically and economically.

### **2.2 Review of Life History**

In the EBS pollock generally spawn during March-May and in relatively localized regions during specific periods (Bailey (2000)). Generally spawning begins nearshore north of Unimak Island in March and April and later near the Pribilof Islands (Bacheler et al. (2010)). Females are batch spawners with up to 10 batches of eggs per female per year (during the peak spawning period). Eggs and larvae of EBS pollock are planktonic for a period of about 90 days and appear to be sensitive to environmental conditions. These conditions likely affect their dispersal into favorable areas (for subsequent separation from predators) and also affect general food requirements for over-wintering survival (Gann et al. (2015), Heintz et al. (2013), Hunt Jr. et al. (2011), Ciannelli et al. (2004)). Duffy-Anderson et al. (2016) provide a review of the early life history of EBS pollock.

Throughout their range juvenile pollock feed on a variety of planktonic crustaceans, including calanoid copepods and euphausiids. In the EBS shelf region, one-year-old pollock are found throughout the water column, but also commonly occur in the NMFS bottom trawl survey. Ages 2 and 3 year old pollock are rarely caught in summer bottom trawl survey gear and are more common in the midwater zone as detected by mid-water acoustic trawl surveys. Younger pollock are generally found in the more northern parts of the survey area and appear to move to the southeast as they age (Buckley et al. (2009)). Euphausiids, principally *Thysanoessa inermis* and *T. raschii*, are among the most important prey items for pollock in the Bering Sea (Livingston (1991); Lang et al. (2000); Brodeur et al. (2002); Ciannelli et al. (2004); Lang et al. (2005)). Pollock diets become more piscivorous with age, and cannibalism has been commonly observed in this region. However, Buckley et al. (2015) showed spatial patterns of pollock foraging varies by size of predators. For example, the northern part of the shelf region between the 100 and 200 m isobaths (closest to the shelf break) tends to be more piscivorous than pollock found in more near-shore shallow areas.

### **2.3 Stock structure**

Stock structure for EBS pollock was evaluated in Ianelli et al. (2015). In that review past work on genetics (e.g., Bailey et al. (1999), Canino et al. (2005)) provided insight on genetic

differentiation. The investigation also compared synchrony in year-classes and growth patterns by region. Pollock samples from areas including Zhemchug Canyon, Japan, Prince William Sound, Bogoslof, Shelikof, and the Northern Bering Sea were processed and results presented in Ianelli et al. (2021).

A group of researchers at AFSC led by Drs. Ingrid Spies and Sara Schaal have updated the recent genetics study and this is summarized here:

Adult samples of walleye pollock were collected from 15 locations spanning Japan, the Bering Sea, and the Gulf of Alaska and were used for genetic analysis. Researchers performed low-coverage whole genome sequencing on 547 individuals from these sampling locations, which resulted in roughly 2 million polymorphic loci found throughout the genome. Although genetic differentiation is subtle in walleye pollock compared to other species, there are two strong and notable genetic breaks that highlight the genetic stock structure present. The first is between all the US samples and Japan (Figure 1: the split on PC axis 1) and the second is between the Bering Sea and the GOA/Aleutian Islands (Figure 1: the split on PC axis 2). This suggests that Bering Sea walleye pollock are genetically distinct from GOA/Aleutian Islands walleye pollock. Walleye pollock in the Aleutian Islands and Bogoslof show weak divergence with the GOA. Individuals caught in Adak and Atka comprise two genetic groups (Figure 1: dark green points). One group is not differentiated from the rest of the GOA (Figure 1 : dark green points clustering behind the GOA points in pink) and the other shows some divergence along PC axis 1. This complex group warrants further investigation to understand the genomic regions that may be divergent between these two genetic groups present in the Adak and Atka. Additionally, individuals from Bogoslof show weak divergence from GOA samples (Figure 1: light green points). Walleye Pollock are currently managed as four distinct groups: 1) GOA, 2) Bering Sea, 3) Aleutian Islands and 4) Bogoslof. Our genetic groups mostly align with these delineations. However, the Aleutian Islands/Bogoslof stocks show subtle differentiation from the rest of the GOA.

For management purposes, the preliminary conclusions from these genetics results are: 1) there is stock structure in pollock that appears to be stable through time and 2) Some aspect of stock structure is latitudinal—Bering Sea pollock appear distinct from fish collected from the Gulf of Alaska and the Aleutian Islands. The results appear strong enough that a GTseq panel could be designed in the future to determine stock of origin of pollock, the scale of which may be relatively large, such as “Bering Sea” or “GOA”.

## **3 Fishery**

### **3.1 Description of the directed fishery**

Historically, EBS pollock catches were low until directed foreign fisheries began in 1964. Catches increased rapidly during the late 1960s and reached a peak in 1970–75 when they ranged from 1.3 to 1.9 million t annually. Following the peak catch in 1972, bilateral agreements with Japan and the USSR resulted in reductions. During a 10-year period, catches by foreign vessels operating in the “Donut Hole” region of the Aleutian Basin were substantial totaling nearly 7 million t (Table 1). A fishing moratorium for this area was enacted in 1993 and only trace amounts of pollock have been harvested from the Aleutian Basin region since then. Since the late 1970s, the average EBS pollock catch has been about 1.2 million t, ranging from 0.810 million t in 2009 to nearly 1.5 million t during 2002–2006 (Table 1). United States vessels began fishing for pollock in 1980 and by 1988 the fishery became fully domestic. The current observer program for the domestic fishery formally began in 1991 and prior to that, observers were deployed aboard the foreign and joint-venture operations since the late 1970s. From the period 1991 to 2011 about 80% of the catch was observed at sea or during dockside offloading. Since 2011, regulations require that all vessels participating in the pollock fishery carry at least one observer so nearly 100% of the pollock fishing operations are monitored by scientifically trained observers. Historical catch estimates used in the assessment, along with management measures (i.e., OFLs, ABCs and TACs) are shown in (Table 2).

#### **Catch patterns**

The “A-season” for directed EBS pollock fishing opens on January 20th and fishing typically extends into early-mid April. During this season the fishery targets pre-spawning pollock and produces pollock roe that, under optimal conditions, can comprise over 4% of the catch in weight. The summer, or “B-season” presently opens on June 10th and fishing extends through noon on November 1st. The A-season fishery concentrates primarily north and west of Unimak Island depending on ice conditions and fish distribution. There has also been effort along the 100m depth contour (and deeper) between Unimak Island and the Pribilof Islands. The general pattern by season (and area) has varied over time with recent B-season catches occurring in the southeast portion of the shelf (east of 170°W longitude; Figure 2).

Since 2011, regulations and industry-based measures to reduce Chinook salmon bycatch have affected the spatial distribution of the fishery and to some degree, the way individual vessel operators fish (Stram and Ianelli (2014)). Comparing encounters of bycatch relative to the effort (total duration of all tows) the pollock fleet had a slight increase in the Chinook salmon bycatch rate (Figure 3). The nominal catch rate of sablefish in the pollock fishery continue to be above historical averages (Figure 3) while for herring, the rate was low compared to 2020.

The catch estimates by sex for the seasons indicate that over time, the number of males and females has been fairly equal but in the period 2017-2022 the A-season catch of females has

been slightly higher and conversely, in the B-season there has been a slightly higher number of males taken (Figure 4). The pattern of catch numbers is impacted by the magnitude of the quota (e.g., the drop in 2022 when the TAC was lower) but also in the relative size of fish. For example, in 2020 estimated absolute numbers of catch were relatively high because fish were smaller (and younger) than average.

The 2023 A-season fishery spatial pattern had a relatively more catch around the Pribilof Islands compared to 2021 (Figure 5). The amount of fishing near the Pribilof Islands was lower than commonly observed in 2022. The 2023 A-season nominal catch rates were near peak levels for all fleet sectors (middle panel, Figure 6). Beginning in 2017, due to a regulatory change, up to 45% of the TAC could be taken in the A-season (previously only 40% of the TAC could be taken). This conservation measure was made to allow greater flexibility to avoid Chinook salmon in the B-season. The pollock fleet as a whole continues to take advantage of this flexibility (Figure 7). This figure shows that the proportion of the TAC has been consistent over time. Pollock roe production remains at a low level but increased over 2022 (Figure 8).

The summer-fall fishing conditions for 2023 were similar to 2022 (Figure 6). The number of hours the fleet required to catch the same tonnage of pollock was also improved relative to 2020. In the B-season catches in the northwestern area increased relative to the previous two years (Figure 9). We updated our work on a measure of fleet dispersion: the relative distance or spread of the fishery in space. Briefly, the calculation computes for a given day, the distance between all trawl tows (within and across boats). These distances are then averaged for year and season. Updated to this year, results indicated that in the A-season dispersion increased slightly but for the B-season in 2023, the fleet appeared to be less dispersed than all the other years and since 2000 (Figure 10).

We continued to investigate the tow specific mean weight of fish. These provide a direct mean somatic mass (pollock body weight) for pollock within a tow. The data arise from the sampled total weight (e.g., of several baskets of pollock) divided by the enumerated number of fish in that sample. Such records exist for each tow. Summing these by extrapolated weight of the pollock catch within that tow, and binning by weight increments (here by 50 gram intervals), allows us to obtain some additional fine-scale information on the size trends in the pollock fishery. The annual patterns of these data suggest that the 2023 A-season size was consistent with the expectation of the 2018 year class predominating the catch (Figure 11). However, the 2023 B-season pattern was smaller than expected. Compiling the data by week we show that the fish size was consistent with the pattern of fish being consistently smaller than expected through the B-season (Figure 12).

The catch of EBS pollock has averaged 1.26 million t in the period since 1979. The lowest catches occurred in 2009 and 2010 when the limits were set to 0.81 million t due to stock declines (Table 2). The recent 5-year average (2019-2023) catch has been 1.304 million t. Pollock catches that are retained or discarded (based on NMFS observer estimates) in the Eastern Bering Sea and Aleutian Islands for 1991–2023 are shown in Table 3. Since 1991, estimates of discarded pollock have ranged from a high of 9.6% of total pollock catch in 1991 to recent lows of around 0.6% to 1.2%. These low values reflect the implementation of the

NMFS' Improved Retention /Improved Utilization program. Prior to the implementation of the American Fisheries Act (AFA) in 1999, higher discards may have occurred under the "race for fish" and pollock marketable sizes were caught incidentally. Since implementation of the AFA, the vessel operators have more time to pursue optimal sizes of pollock for market since the quota is allocated to vessels (via cooperative arrangements). In addition, several vessels have made gear modifications to avoid retention of smaller pollock. In all cases, the magnitude of discards counts as part of the total catch for management (to ensure the TAC is not exceeded) and within the assessment. Bycatch of other non-target, target, and prohibited species is presented in the section titled Ecosystem Considerations below. In that section it is noted that the bycatch of pollock in other target fisheries is more than double the bycatch of other target species (e.g., Pacific cod) in the pollock fishery.

### **3.2 Management measures**

The EBS pollock stock is managed by NMFS regulations that provide limits on seasonal catch. The NMFS observer program data provide near real-time statistics during the season and vessels operate within well-defined limits. In most years, the TACs have been set well below the ABC value and catches have stayed within these constraints (Table 2). Allocations of the TAC split first with 10% to western Alaska communities as part of the Community Development Quota (CDQ) program and the remainder between at-sea processors and shore-based sectors. For a characterization of the CDQ program see Haynie (2014). Seung and Ianelli (2016) combined a fish population dynamics model with an economic model to evaluate regional impacts.

Due to concerns that groundfish fisheries may impact the rebuilding of the Steller sea lion population, a number of management measures have been implemented over the years. Some measures were designed to reduce the possibility of competitive interactions between fisheries and Steller sea lions. For the pollock fisheries, seasonal fishery catch and pollock biomass distributions (from surveys) indicated that the apparent disproportionately high seasonal harvest rates within Steller sea lion critical habitat could lead to reduced sea lion prey densities. Consequently, management measures redistributed the fishery both temporally and spatially according to pollock biomass distributions. This was intended to disperse fishing so that localized harvest rates were more consistent with estimated annual exploitation rates. The measures include establishing: 1) pollock fishery exclusion zones around sea lion rookery or haulout sites; 2) phased-in reductions in the seasonal proportions of TAC that can be taken from critical habitat; and 3) additional seasonal TAC releases to disperse the fishery in time.

Prior to adoption of the above management measures, the pollock fishery occurred throughout each of the three major NMFS management regions of the North Pacific Ocean: the Aleutian Islands (1,001,780 km<sup>2</sup> inside the EEZ), the Eastern Bering Sea (968,600 km<sup>2</sup>), and the Gulf of Alaska (1,156,100 km<sup>2</sup>). The marine portion of Steller sea lion critical habitat in Alaska west of 150°W encompasses 386,770 km<sup>2</sup> of ocean surface, or 12% of the fishery management regions.

From 1995–1999 84,100 km<sup>2</sup>, or 22% of the Steller sea lion critical habitat was closed to the pollock fishery. Most of this closure consisted of the 10 and 20 nm radius all-trawl fishery exclusion zones around sea lion rookeries (48,920 km<sup>2</sup>, or 13% of critical habitat). The remainder was largely management area 518 (35,180 km<sup>2</sup>, or 9% of critical habitat) that was closed pursuant to an international agreement to protect spawning stocks of central Bering Sea pollock. In 1999, an additional 83,080 km<sup>2</sup> (21%) of critical habitat in the Aleutian Islands was closed to pollock fishing along with 43,170 km<sup>2</sup> (11%) around sea lion haulouts in the GOA and Eastern Bering Sea. In 1998, over 22,000 t of pollock were caught in the Aleutian Island region, with over 17,000 t taken within critical habitat region. Between 1999 and 2004 a directed fishery for pollock was prohibited in this region. Subsequently, 210,350 km<sup>2</sup> (54%) of critical habitat in the Aleutian Islands was closed to the pollock fishery. In 2000 the remaining phased-in reductions in the proportions of seasonal TAC that could be caught within the BSAI Steller sea lion Conservation Area (SCA) were implemented.

On the EBS shelf, an estimate (based on observer at-sea data) of the proportion of pollock caught in the SCA has averaged about 44% annually. During the A-season, the average is also about 44%. Nonetheless, the proportion of pollock caught within the SCA varies considerably, presumably due to temperature regimes and the relative population age structure. The annual proportion of catch has ranged from an annual low of 11% in 2010 to high of 60% in 1998—the 2019 annual value was 58% and quite high again in the A-season (68%). The higher values in recent years were likely due to good fishing conditions close to the main port. The recent transition from at-sea observer sampling of many catcher vessels to a combination of at-sea electronic monitoring and shore-based observer sampling has resulted in a temporary hiatus in to associate catches with specific areas. Work has progressed to link the position information to offloads so that haul records could be used to evaluate fishing patterns.

The AFA reduced the capacity of the catcher/processor fleet and permitted the formation of cooperatives in each industry sector by the year 2000. Because of some of its provisions, the AFA gave the industry the ability to respond efficiently to changes mandated for sea lion conservation and salmon bycatch measures. Without such a catch-share program, these additional measures would likely have been less effective and less economical (Strong and Criddle (2014)).

An additional strategy to minimize potential adverse effects on sea lion populations is to disperse the fishery throughout more of the pollock range on the Eastern Bering Sea shelf. While the distribution of fishing during the A-season is limited due to ice and weather conditions, there appears to be some dispersion to the northwest area (Figure 5).

The majority (about 56%) of Chinook salmon caught as bycatch in the pollock fishery originate from western Alaskan rivers. This was updated at the June 2022 Council meeting and is activities are monitored and reported closely at the Council ([at this website](#)). In summary, additional Chinook salmon bycatch management measures went into effect in 2011 which imposed revised prohibited species catch (PSC) limits. These limits, when reached, close the fishery by sector and season (Amendment 91 to the BSAI Groundfish Fishery Management Plan (FMP) resulting from the NPFMC's 2009 action). Previously, all measures for salmon

bycatch imposed seasonal area closures when PSC levels reached the limit (fishing could continue outside of the closed areas). The current program imposes a dual cap system by fishing sector and season. A goal of this system was to maintain incentives to avoid bycatch at a broad range of relative salmon abundance (and encounter rates). Participants are also required to take part in an incentive program agreement (IPA). These IPAs are approved and reviewed annually by NMFS to ensure individual vessel accountability. The fishery has been operating under rules to implement this program since January 2011.

Further measures to reduce salmon bycatch in the pollock fishery were developed and the Council took action on Amendment 110 to the BSAI Groundfish FMP in April 2015. These additional measures were designed to add protection for Chinook salmon by imposing more restrictive PSC limits in times of low western Alaskan Chinook salmon abundance. This included provisions within the IPAs that reduce fishing in months of higher bycatch encounters and mandate the use of salmon excluders in trawl nets. These provisions were also included to provide more flexible management measures for chum salmon bycatch within the IPAs rather than through regulatory provisions implemented by Amendment 84 to the FMP. The new measure also included additional seasonal flexibility in pollock fishing so that more pollock (proportionally) could be caught during seasons when salmon bycatch rates were low. Specifically, an additional 5% of the pollock can be caught in the A-season (effectively changing the seasonal allocation from 40% to 45% (as noted above in the discussion associated with Figure 7)). These measures are all part of Amendment 110 and a summary of this and other key management measures is provided in Table 4.

There are three time/area closures in regulation to minimize herring PSC impacts: *Summer Herring Savings Area 1* an area south of 57°N latitude and between 162°W and 164°W longitude from June 15 through July 1st. *Summer Herring Savings Area 2* an area south of 56° 30' N latitude and between 164°W and 167°W longitude from July 1 through August 15. *Winter Herring Savings Area* an area between 58° and 60°N latitude and between 172°W and 175°W longitude from September 1st through March 1st of the next fishing year.

## 4 Data

The following lists the data used in this assessment:

*Note the 2020 acoustic survey data based on unmanned surface vessel (USV) transects and age-specific proportions were unavailable in this year*

Source	Type	Years
Fishery	Catch biomass	1964–2023
Fishery	Catch age composition	1964–2022
Fishery	Japanese trawl CPUE	1965–1976
EBS bottom trawl	Area-swept biomass and age-specific proportions	1982–2019, 2021–2023
Acoustic trawl survey	Biomass index and age-specific proportions	1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006–2010, 2012, 2014, 2016, 2018, 2020, 2022
Acoustic vessels of opportunity (AVO)	Biomass index	2006–2019, 2021–2023

## 4.1 Fishery

### Catch

Biological sampling by scientifically trained observers form the basis of a major data component of this assessment (as evaluated in Barbeaux et al. 2005). The catch-at-age composition was estimated using the methods described by Kimura (1989) and modified by Dorn (1992). Length-stratified age data are used to construct age-length keys for each stratum and sex. These keys are then applied to randomly sampled catch length frequency data. The stratum-specific age composition estimates are then weighted by the catch biomass within each stratum to arrive at an overall age composition for each year. Data were collected through shore-side sampling and at-sea observers (Barbeaux et al. (2005)). The three strata for the EBS were: i) January–June (all areas, but mainly east of 170°W); ii) INPFC area 51 (east of 170°W) from July–December; and iii) INPFC area 52 (west of 170°W) from July–December. This method was used to derive the age compositions from 1991–2022 (the period for which all the necessary information is readily available). Prior to 1991, we used the same catch-at-age composition estimates as presented in Wespestad et al. (1996).

The catch-at-age estimation method uses a two-stage bootstrap re-sampling of the data. Observed tows were first selected with replacement, followed by re-sampling actual lengths and age specimens given that set of tows. This method allows an objective way to specify the starting values for the input sample size for fitting fishery age composition data within the assessment model. In addition, estimates of stratum-specific fishery mean weights-at-age (and variances) are provided which are useful for evaluating general patterns in growth and growth variability. For example, Ianelli et al. (2007) showed that seasonal aspects of pollock condition factor could affect estimates of mean weight-at-age. They showed that within a year, the condition factor for pollock varies by more than 15%, with the heaviest pollock caught late in the year from October–December (although most fishing occurs during other times of the year) and the thinnest fish at length tending to occur in late winter. They also showed that spatial patterns in the fishery affect mean weights, particularly when the fishery is shifted more

towards the northwest where pollock tend to be smaller at age. Grüss et al. (2021) showed cold-pool-extent impacts on the spatial map of summer condition and relating environmental conditions to fish condition continues to be an active area of research.

In 2011 the winter fishery catch consisted primarily of age 5 pollock (the 2006 year class) and later in that year age 3 pollock (the 2008 year class) were present. In 2012–2016 the 2008 year class was prominent in the catches with 2015 showing the first signs of the 2012 year-class as three year-olds in the catch (Figure 14; Table 5). However, by 2017 the 2013 year-class began to be also evident and surpassed the 2012 year-class in dominance and persist through to 2021. The unusual pattern of switching adjacent year-classes was examined in 2021 to see if there was a pattern of spatial differences. There was a distinct spatial distribution of the different year-classes. Having adjacent strong year-classes appears to be a new characteristic of the stock. In 2020, an unusual presence of age-2 pollock appeared in the catch, along with some from the 2014 year-class while the 2012 year-class was a smaller part of the catch (Figure 14). By 2021 and 2022, the predominance of 3- and 4-year olds in the catch confirms the abundance year-class from 2018. We note that the center of locations of the 2018 year-class, as plotted based on the locales of samples from that cohort, appears to be more oriented to the south east (by age) when compared to another abundant year-class (the 2008; Figure 15).

The sampling effort for age determinations, weight-length measurements, and length frequencies is shown in Table 6, Table 7, and Table 8. Sampling for pollock lengths and ages by area has been shown to be relatively proportional to catches. The precision of total pollock catch biomass is considered high with estimated CVs to be on the order of 1% (Miller (2005)).

Scientific research catches are reported to fulfill requirements of the Magnuson-Stevens Fisheries Conservation and Management Act. The annual estimated research catches (1963–2022) from NMFS surveys in the Bering Sea and Aleutian Islands Region are given in (Table 9). Since these values represent extremely small fractions of the total removals (about 0.02%) they are ignored for assessment purposes.

## 4.2 Surveys

### Bottom trawl survey (BTS)

Trawl surveys have been conducted annually by the AFSC to assess the abundance of crab and groundfish in the Eastern Bering Sea since 1979 and since 1982 using standardized gear and methods. For pollock, this survey has been instrumental in providing an abundance index and information on the population age structure. This survey is complemented by the acoustic trawl (AT) surveys that sample mid-water components of the pollock stock. Between 1991 and 2023 the BTS biomass estimates ranged from 2.28 to 8.39 million t (Table 10) for the design-based estimates). The values used for the assessment (VAST index, see Section 16 for details) are shown in Figure 16. In the mid-1980s and early 1990s several years resulted in above-average biomass estimates. The stock appeared to be at lower levels during 1996–1999

then increased moderately until about 2003 and since then has averaged just over 4 million t (from the standard EBS region using design-based estimators).

These surveys also provide consistent measurements of environmental conditions, such as the sea surface and bottom temperatures. Large-scale zoogeographic shifts in the EBS shelf documented during a warming trend in the early 2000s were attributed to temperature changes (e.g., Mueter and Litzow (2008)). However, after the period of relatively warm conditions ended in 2005, the next eight years were mainly below average, indicating that the zoogeographic responses may be less temperature-dependent than they initially appeared (Kotwicki and Lauth (2013)). Bottom temperatures increased in 2011 to about average from the low value in 2010 but declined again in 2012–2013. In the period 2014–2016, bottom temperatures increased and reached a new high in 2016. In 2018 bottom temperatures were nearly as warm (after 2017 was slightly above average) but was highly unusual due to the complete lack of “cold pool” (i.e., a defined area where water near bottom was less than zero degrees. In 2019, the mean bottom temperature was the warmest during the period the survey has occurred (since 1982; Figure 17). In 2022 and 2023, the bottom temperatures have declined but remain above average.

The AFSC has expanded the area covered by the bottom trawl survey over time. In 1987 the “standard survey area” comprising 6 main strata was increased farther to the northwest and covered in all subsequent years. These two northern strata have varied in estimated pollock abundance. In 2023 about 10% of the pollock biomass was found in these strata compared to a long term average of 5% (Table 10). Importantly, this region is contiguous with the Russian border and the NBS region, and treatment of the extent stock shifts between regions continues (e.g., O’Leary et al. (2021)).

After the increase in 2022, the 2023 survey estimate is similar to the 2021 value and is about 72% of the long term mean. The 2023 pollock density by station appeared to be lower overall with some slight increases on the outer shelf area to the northwest (Figure 18). The VAST model provides density-weighted population shifts in distribution. This can be expressed in north-south and east-west trends over time. A representation of such center of gravity estimates indicate that the stock has moved steadily north since the mid 2000s, but last year shifted south. This year it has shifted back north to some degree (Figure 19). The stock center of gravity also moved east from 2010 to about 2017, then shifted west and seems about at its long term mean.

The BTS abundance-at-age estimates show variability in year-class strengths with substantial consistency over time (Figure 20). The abundance of 5-year old pollock (the 2018 year-class) dropped from 2022, but still represents the most abundant year class. The abundance of age-1 pollock in 2023 appears to be about average.

Pollock above 40 cm in length generally appear to be fully selected and in some years, many 1-year olds occur on or near the bottom (with modal lengths around 10–19 cm). Generally speaking, age 2 or 3 pollock (lengths around 20–29 cm and 30–39 cm, respectively) are relatively rare in this survey because they tend to be more pelagic as juveniles. Compared to recent years,

the size compositions were consistent with the mid-range categories and consistent with the age data (Figure 21).

Observed fluctuations in survey estimates may be attributed to a variety of sources including unaccounted-for variability in natural mortality, survey catchability, and **horizontal** migrations and **vertical availability** (Monnahan et al. (2021); O’Leary et al. (2022)). As an example, some strong year classes appear in the surveys over several ages (e.g., the 1989 year class) while others appear only at older ages (e.g., the 1992 and 2008 year class). Sometimes, initially strong year classes appear to wane in successive assessments (e.g., the 1996 year class estimate (at age 1) dropped from 43 billion fish in 2003 to 32 billion in 2007 (Ianelli et al. (2007))). Retrospective analyses (e.g., Parma (1993)) have also highlighted these patterns, as presented in Ianelli et al. (2006, 2011). Kotwicki and Lauth (2013) also found that the catchability of either the BTS or AT survey for pollock is variable in space and time because it depends on environmental variables, and is density-dependent in the case of the BTS survey.

The 2023 survey age compositions were developed from age-structures collected during the survey (June-July) and processed at the AFSC labs within a few weeks after the survey was completed. The level of sampling for lengths and ages in the BTS is shown in Table 11. The estimated numbers-at-age from the BTS for strata 1–9 (except for 1982–84 and 1986, when only strata 6 were surveyed) are presented in Table 12 (based on the method in Kotwicki et al. (2014) and then using VAST—see Section 16 for those details). Compared to the previous design-based age composition estimates, those derived from the spatio-temporal model were generally very similar (Figure 22).

In the previous assessments, the BTS mean body mass-at-ages was computed based on the sex-specific mean length-at-age in each year and converted to weight using sex-specific length-weight parameters that were estimated from data prior to 1999. In reconsidering this approach, data on weight-at-age from intervening years have become available and some new methods applied including those corrected by spatio-temporal modeling (Indivero et al. (2023)). This work was adopted in 2022 and values used are shown in Table 13. The time series of BTS survey indices is shown in Table 14.

The NBS survey area was sampled in 2010, 2017, 2018 (limited to 49 stations), 2019, and 2021–2023. Given that the pollock abundance was quite high in 2017 and 2018, a method for incorporating this information as part of the standard survey was desired. One approach for constructing a full time series that includes the NBS area is to use observed spatial and temporal correlations. We used the vector-autoregressive spatial temporal (VAST) model of Thorson (2019) together with the density-dependent corrected CPUE values from each station (including stations where pollock were absent; Table 14). Please refer to the Section 16 for further details on the implementation. The appendix also includes results that indicate the VAST model diagnostics are reasonable and provide consistent interpretations relative to the observations. Notably, results indicate increased uncertainty in years and areas when stations were missing. As noted in past assessments, application of this index within the stock assessment model required accounting for the time-series covariance estimate.

To date, given other commitments, work on comparing the age-and-growth from NBS samples has stalled. We hope to evaluate these data when they become available in the near future to look at maturity and growth conditions from this region.

### **Acoustic trawl surveys**

Acoustic trawl surveys are typically conducted every other year and are designed to estimate the off-bottom component of the pollock stock (compared to the BTS which are conducted annually and provide an abundance index of the near-bottom pollock). Estimated pollock biomass for the EBS shelf has averaged over 3.2 million t since the time-series was revised to include the water column to 0.5 m (from the historical midwater pollock index to 3 m off bottom) starting in 1994 (Table 14). The early 2000s (a relatively ‘warm’ period) were characterized by low pollock recruitment, which was subsequently reflected in lower pollock biomass estimates between 2006 and 2012 (a ‘cold’ period; Honkalehto and McCarthy (2015)). In 2014 and 2016 (another ‘warm’ period) with the growth of the strong 2012 year class, AT biomass estimates increased to over 4 million t (Table 14). The number of trawl hauls, lengths, and ages sampled from the AT survey are presented in Table 15. These surveys have also provided insight on the relative abundance of pollock in areas considered critical to Steller sea lions (the “SCA”; Table 16).

Pollock midwater abundance and distribution were last assessed in 2022. In addition to the traditional (core) survey area, a region north of most transects (the northern extension) was surveyed. Transect spacing, typically 20 nmi, ranged from 40 nmi in the east and middle shelf to 20 nmi in the western shelf due to ship staffing constraints and consequent survey schedule uncertainties.

The 2022 estimated amount of pollock in the core survey area was 9.67 billion fish with a biomass of 3.834 million metric tons (t), just over a 50% increase from the estimate of 5.55 billion fish with a biomass of 2.497 million t in 2018. This was a 6% increase over the 3.617 million t estimated in 2020 by the acoustics-only Saildrone survey. Preliminary population age estimates from 2022 using BTS ages were revised in 2023 using ages from the AT survey. Four-year-olds (2018 year class) dominated the pollock population numbers in the core survey area (Table 17) comprising 71% of the core area biomass followed by 3-year-olds (2019 year class, 7.6 % of the core area biomass). Slightly more than one-half million t (0.539 million t) of pollock were observed distributed sparsely along the northern extension transects, 12% of the shelf-wide total. Eight year-olds (2014 year class) were the dominant aged pollock in the northern extension (29% by biomass), followed by 7 year-olds (17% of the northern extension biomass) and 4 year-olds (15% of the northern extension biomass).

Relative estimation errors for the total biomass were derived from a one-dimensional (1D) geostatistical method, which accounts for observed spatial structure for sampling along transects (Petitgas (1993), Walline (2007), Williamson and Traynor (1996)). The 2022 relative estimation error for the core survey area was 0.068, slightly higher than the time series mean of 0.043,

likely due to increased transect spacing. As in previous assessments, the other sources of error (e.g., target strength, trawl selectivity) were accounted for by inflating the annual error estimates to have an overall average CV of 20% for application within the assessment model. This value was consistent with past model fitting procedures (i.e., the standard deviation of the normalized residuals was very close to 1.0).

### 4.3 Other time series used in the assessment

#### Japanese fishery CPUE index

An available time series relating the abundance of pollock during the period 1965–1976 was included. This series is based on Japanese fishery catch rates which used the same size class of trawl vessels as presented in Low and Ikeda (1980). In lieu of an objective estimate, we applied a default coefficient of variation of 20% to these data

#### Biomass index from Acoustic-Vessels-of-Opportunity (AVO)

Acoustic backscatter data (Simrad ES60, 38 kHz) were collected aboard two fishing vessels chartered for the AFSC summer 2023 bottom trawl surveys (F/V Alaska Knight, F/V Northwest Explorer). We have processed these Acoustic Vessels of Opportunity (AVO) data each year since 2006 to provide an index of age-1+ midwater pollock abundance. This is the first year implementing a new subsampling methodology (Levine and De Robertis (2019)) to generate a more spatially extensive AVO index. In developing the new index, we analyzed a 10% systematic subsample of the BTS backscatter data throughout the typical ATS geographic footprint. The new methods were applied to reanalyze years 2009, 2010, 2012, 2014-2019, and 2021-2023. For the remaining 5 years of the time series, the original AVO index (Honkalehto et al. (2011), Stienessen et al. (2020)) was rescaled to match the mean of the new AVO time series (Figure 24).

Relative to the original index, the correlation between the AVO index and the AT survey biomass was higher ( $R^2 = 0.9$ , compared to  $R^2 = 0.6$  for the same seven ATS-BTS years from the original index). The new and rescaled index trend dropped 15% relative to 2022 but still is 13% above the long-term mean (Figure 24, Table 18; note that the relative error is based on a variance estimation from Petitgas (1993), while the final magnitude of the error term was ascertained based on other model components via an iterative re-weighting process as noted in Ianelli (2023)). The densest spatial distribution of pollock backscatter was predominantly measured along the southern portion of the EBS shelf in the northwest half of the index area (Figure 25). The three grid cells (20 by 20 nautical mile grids used for annual bottom-trawl survey stations) having the strongest pollock backscatter were  $2^\circ$  south of St. Matthew Island close to  $(58^\circ\text{N}, 172^\circ\text{W})$  and attributed to dense midwater pollock aggregations.

## 5 Analytic approach

### 5.1 General model structure

We used a statistical age-structured assessment model conceptually outlined in Fournier and Archibald (1982) and extended (e.g., Methot (1990)). This was developed as an appendix to Wespestad et al. (1996) with current specifications presented in the Section 14 (Ianelli and Fournier (1998)). The model was written in ADMB—a library for non-linear estimation and statistical applications (Fournier et al. (2012)). The data updated from last year’s analyses include:

- The 2022 fishery age composition data
- The catch biomass estimates through the current year
- The 2023 bottom-trawl survey index, weight, and age composition data
- The 2022 acoustic-trawl age composition data were revised using only samples collected from that survey (previously the age compositions were estimated using the bottom-trawl survey age-length keys)
- A completely revised time series of AVO backscatter data collected opportunistically from the bottom trawl survey.

A simplified version of the assessment (with mainly the same data and likelihood-fitting method) is included as a supplemental multi-species assessment model. As presented since 2016, it allows for trophic interactions among key prey and predator species and for pollock, and it can be used to evaluate age and time-varying natural mortality estimates in addition to alternative catch scenarios and management targets (see this volume: [EBS multi-species model](#)).

### 5.2 Description of alternative models

In the 2019 assessment, the spatio-temporal model fit to BTS CPUE data *including stations from the NBS* was expanded using the VAST methods detailed in Thorson (2018). This data treatment was included as a model alternative and adopted for ABC/OFL specifications by the SSC in 2020 along with other modifications including a spatio-temporal treatment of the age composition data. This year, we examined additional model and data modifications as presented in Ianelli (2023).

By the SSC’s numbering scheme, last year’s model was designated Model 20.0, which here we contrast with a revised model 23.0. As usual, we also provide an incremental evaluation of the influence of new data introduced in 2023 (here as applied to Model 23.0).

**m0–** The model selected last year (referred to as ”Base”)

- m1**– September revision but data only through 2022
- m2**– as m1 but with 2023 catch and 2023 AVO data point included
- m3**– as m2 but with 2022 age composition data updated (very minor change)
- m4**– as m3 but addition of fishery catch-age to 2022
- m5**– as m4 but addition of VAST BTS biomass index through 2023
- m6**– as m5 but with BTS age compositions included through 2023
- m7**– As m5 but with VAST age compositions included through 2023
- m8**– As m7 but with Hulson et al. (2023) BTS input sample sizes

As noted in Ianelli (2023), we continue to provide some facility to test different stock assessment software (as noted in Li et al. (2021)).

### **Input sample size**

Sample sizes for age-composition data were re-evaluated in Ianelli (2023) and found to be consistent with the relative variability allowed for selectivities and with the observation errors specified for the indices. Principally, this work resulted in tuning the recent era (1991-present year) to an average sample sizes of 350 for the fishery and then using estimated values for the period 1978-1990 and as earlier (Table 19). As rationalized in earlier assessments, we found that assuming average values of 100 and 50 for the BTS and ATS data, respectively resulted in consistent model fits and were (relatively) appropriate given the sampling levels among these surveys. The inter-annual variability reflects the variability in the number of hauls sampled for ages in the ATS data. For the BTS data we adopted the results presented in Hulson et al. (2023). We re-evaluated tuning following Francis (2011) (equation TA1.8).

Recent work has shown ways to improve estimation schemes that deal with the interaction between flexibility in fishery selectivity and statistical properties of composition data sample size. Specifically, the Dirichlet-multinomial using either Laplace approximation (Thorson et al. (2015)) or adnuts (Monnahan and Kristensen (2018)) should be implemented (e.g., as shown by Xu et al. (2020)). Progress in 2023 has lagged on this, but with the advent of some alternative three dimensional mixed-effects approaches to weight-at-age and selectivity (Cheng et al. (2023)), development of more elaborate approaches are being pursued.

### **5.3 Parameters estimated outside of the assessment model**

#### **Natural mortality and maturity at age**

The baseline model specification has been to use constant natural mortality rates at age ( $M=0.9$ , 0.45, and 0.3 for ages 1, 2, and 3+ respectively (Wespestad and Terry (1984))). When predation was explicitly considered estimates tended to be higher and more variable (Holsman et al. *this volume*; Holsman and Aydin (2015); Livingston and Methot (1998); Hollowed et al. (2000)). Clark et al. (1999) found that specifying a conservative (lower) natural mortality rate may be advisable when natural mortality rates are uncertain. More recent studies confirm this (e.g., Johnson et al. (2014)).

In the supplemental multi-species assessment model alternative values of age and time-varying natural mortality are presented. As in past years the estimates indicate higher values than used here. In the 2018 assessment we evaluated natural mortality, and it was noted that the survey age compositions favored lower values of  $M$  while the fishery age composition favored higher values. This is consistent with the patterns seen in the BTS survey data as they show increased abundances of “fully selected” cohorts. Hence, given the model specification (asymptotic selectivity for the BTS age composition data), lower natural mortality rates would be consistent with those data. Given these trade-offs, structural model assumptions were held to be the same as previous years for consistency (i.e., the mortality schedule presented below).

Maturity-at-age values used for the EBS pollock assessment were originally based on Smith (1981) and were later reevaluated via histological methods (e.g., Stahl (2004); Stahl and Kruse (2008), Ianelli (2005)). These studies found year-class effects and some inter-annual variability but general consistency with the original schedule of proportion mature at age.

With respect to assumptions about natural mortality, we evaluated applying results from an adjacent stock (Ianelli and McKelvey (2022)) in the 2022 assessment. We found the results were consistent with past assumptions therefore again applied the following age-specific values for  $M$  (Smith (1981)) and maturity-at-age:

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$M$	0.90	0.45	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
$P_{mat}$	0.00	0.008	0.29	0.64	0.84	0.90	0.95	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00

#### **Length and weight-at-age**

Age determination methods have been validated for pollock (Kimura et al. (1992), Kimura et al. (2006), and Kastelle and Kimura (2006)). EBS pollock size-at-age show important differences in growth with differences by area, year, and year class. Pollock in the northwest area are typically smaller at age than pollock in the southeast area. The differences in average

weight-at-age are taken into account by stratifying estimates of catch-at-age by year, area, season, and weighting estimates proportional to catch.

The assessment model for EBS pollock accounts for numbers of individuals in the population. As noted above, management recommendations are based on allowable catch levels expressed as tons of fish. While estimates of pollock catch-at-age are based on large data sets, the data are only available up until the most recent completed calendar year of fishing (e.g., 2022 for this year). Consequently, estimates of weight-at-age in the current year are required to map total catch biomass (typically equal to the quota) to numbers of fish caught (in the current year). Therefore, if there are errors (or poorly accounted uncertainty) in the current and future mean weight-at-age, this can translate directly into errors between the expected fishing mortality and what mortality occurs. For example, if the mean weight-at-age is biased high, then an ABC (and OFL) value will result in greater numbers of fish being caught (and fishing mortality being higher due to more fish fitting within the ABC).

As in previous assessments, we explored patterns in size-at-age and fish condition. Using the NMFS fishery observer data on weight given length we:

1. extracted all data where non-zero measurements of pollock length and weight were available between the lengths of 35 and 60 cm for the EBS region
2. computed the mean value of body mass (weight) for each cm length bin over all areas and time
3. divided each weight measurement by that mean cm-specific value (the “standardization” step)
4. plotted these standardized values by different areas, years, months etc. to evaluate condition differences (pooling over ages is effective as there were no size-specific biases apparent)

In the first instance, the overarching seasonal pattern in body mass relative to the mean shows that as the winter progresses prior to peak spawning, pollock are generally skinnier than average whereas in July, the median is about average (Figure 26). As the summer/fall progresses, fish were at their heaviest given length (Figure 26). This is also apparent when the data are aggregated by A- and B-seasons (and by east and west of 170°W; referred to as SE and NW respectively) when plotted over time (Figure 27, where stratum 1 = A season, stratum 2 = B season SE, and stratum 3 = B season NW). Combining across seasons, the fishery data shows that recent years were below average weight given length (Figure 28 ; note that the anomalies are based on the period 1991-2023).

Examining the weight-at-age, there are also patterns of variability that vary due to environmental conditions in addition to spatial and temporal patterns of the fishery. Based on the bootstrap distributions and large sample sizes, the within-year sampling variability for pollock is small. However, the between-year variability in mean weights-at-age is relatively high (Table 20). The coefficients of variation between years are on the order of 6% to 9% (for the

ages that are targeted) whereas the sampling variability is generally around 1% or 2%. The approach to account for the identified mean weight-at-age having clear year and cohort effects was continued (e.g., Figure 29). Details were provided in appendix 1A of Ianelli et al. (2016). The results from this method showed the relative variability between years and cohorts and provide estimates for 2023–2025 (Table 20). How these fishery weights-at-age estimates can be supplemented using survey weights-at-age is further illustrated in Figure 30.

In the 2020 and 2021 fishery, the average weight-at-age for ages 6–8 (the 2012–2014 year classes) was below the time series average. These cohorts have fluctuated around their means in recent years (Figure 29). To examine this more closely, we split the bootstrap results into area-season strata and were able to get an overall picture of the pattern by strata (Figure 31 and Figure 32). This showed that the mean weight-at-age is higher in the B-season in the area east of 170°W compared to the A-season and B-season in the area west of 170°W.

#### 5.4 Parameters estimated within the assessment model

For the selected model, 1340 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment, and stock-recruitment parameters account for 80 parameters. This includes vectors describing the initial age composition (and deviation from the equilibrium expectation) in the first year (as ages 2–15 in 1964) and the recruitment mean and deviations (at age 1) from 1964–2023 and projected recruitment variability (using the variance of past recruitments) for five years (2024–2029). The two-parameter stock-recruitment curve (see Section 14) is included in addition to a term that allows the average recruitment before 1964 (that comprises the initial age composition in that year) to have a mean value different from subsequent years. Note that the stock-recruit relationship is fit only to stock and recruitment estimates from 1979 year-class through to the 2021 year-class.

Fishing mortality is parameterized to be semi-separable with year and age (selectivity) components. The age component is allowed to vary over time; changes are allowed in each year. The mean value of the age component is constrained to equal one and the last 5 age groups (ages 11–15) are specified to be equal. This latter specification feature is intended to reduce the number of parameters while acknowledging that pollock in this age-range are likely to exhibit similar life-history characteristics (i.e., unlikely to change their relative availability to the fishery with age). The annual components of fishing mortality result in 60 parameters and the age-time selectivity schedule forms a 10x60 matrix of 600 parameters bringing the total fishing mortality parameters to 660. The rationale for including time-varying selectivity has recently been supported as a means to improve retrospective patterns (Szuwalski et al. 2017) and as best practice (Martell and Stewart (2013)).

For surveys and indices, the treatment of the catchability coefficient, and interactions with age-specific selectivity require consideration. For the BTS index, selectivity-at-age is estimated

with a logistic curve in which year specific deviations in the parameters is allowed. Such time-varying survey selectivity is estimated to account for changes in the availability of pollock to the survey gear and is constrained by pre-specified variance terms. Presently, these variance terms have been set based on balancing input data-based variances and are somewhat subjective. For the AT survey, which originally began in 1979 (the current series including data down to 0.5 m from bottom begins in 1994), optional parameters to allow for age and time-varying patterns exist but for this assessment and other recent assessments, ATS selectivity is constant over time. Overall, four catchability coefficients were estimated: one each for the early fishery catch-per-unit effort (CPUE) data (from Low and Ikeda, 1980), the VAST combined bottom trawl survey index, the AT survey data, and the AVO data. An uninformative prior distribution is used for all of the indices. The selectivity parameters for the 2 main indices (BTS and ATS) total 336 (the CPUE and AVO data mirror the fishery and AT survey selectivities, respectively).

Additional fishing mortality rates used for recommending harvest levels are estimated conditionally on other outputs from the model. For example, the values corresponding to the  $F_{40\%}$ ,  $F_{35\%}$  and  $F_{MSY}$  harvest rates are found by satisfying the constraint that, given age-specific population parameters (e.g., selectivity, maturity, mortality, weight-at-age), unique values exist that correspond to these fishing mortality rates. The likelihood components that are used to fit the model can be categorized as:

- Total catch biomass (log-normal,  $\sigma = 0.05$ )
- Log-normal indices of pollock biomass; bottom trawl surveys assume annual estimates of sampling error, as represented in Figure 16 along with the covariance matrices (for the density-dependent and VAST index series); for the AT index the annual errors were specified to have a mean CV of 0.20; while for the AVO data, a value a mean CV was tuned for consistency with other data and resulted in a value of 23%).
- Fishery and survey proportions-at-age estimates (multinomial with effective sample sizes presented Table 19).
- Age 1 index from the AT survey (CV set equal to 30% as in prior assessments).
- Selectivity constraints: penalties/priors on age-age variability, time changes, and decreasing (with age) patterns.
- Stock-recruitment: penalties/priors involved with fitting a stochastic stock-recruitment relationship within the integrated model.
- “Fixed effects” terms accounting for cohort and year sources of variability in fishery mean weights-at-age estimated based on available data from 1991-2022 from the fishery (and 1982-2023 for the bottom-trawl survey data) and externally estimated variance terms as described in Appendix 1A of Ianelli et al. (2016; see Figure 30).

Work evaluating temperature and predation-dependent effects on the stock- recruitment estimates continues (Spencer et al. (2016)). This approach modified the estimation of the stock-recruitment relationship by including the effect of temperature and predation mortality. A relationship between recruitment residuals and temperature was noted (similar to that found in Mueter et al. (2011) and subsequently noted in Thorson et al. (2020b)) and lower pollock recruitment during warmer conditions might be expected. Similar results relating summer

temperature conditions to subsequent pollock recruitment for recent years were also found by Yasumiishi et al. (2015) where research suggests that summer warmth is associated with earlier diapause of copepods (Thorson et al. (2020a)), such that a fall (but not spring) survey of copepod densities is also associated with cold conditions and elevated recruitment (Eisner et al. (2020)).

## 6 Results

### 6.1 Model evaluation

A sequential sensitivity of available new data showed that adding the new data from 2023 had very minor changes and impact on the spawning biomass estimates (Figure 33; top panel). The largest effect on all the changes arose from the revision to the mean body weight-at-age used for the spawning biomass calculations (Figure 33; bottom panel). This was shown in Ianelli (2023). Nonetheless, diagnostics of all the changes relative to model fits are given in Table 21 and a comparison of management quantities for the final base model is given in Table 22).

In the 2020 assessment, SRR evaluations related to Tier 1 classification showed that dropping the influence of the 1978 year-class in the estimation lowered the steepness of the curve and that when the influence of the prior distribution was removed the residual pattern for estimates near the origin was particularly bad (all below the curve). From those results we conclude that the prior specification was appropriate because we place priority on fitting estimated recruits near the slope at the origin better. In the 2021 assessment we showed that conditioning the SRR to fit the condition of having the “actual”  $F_{MSY}$  equal some  $F_{MSY}$  proxies (e.g., equal  $F_{35\%}$ ) resulted in more conservative ABCs due to shallower initial slopes. A conclusion from these exercises was that the SPR proxy for  $F_{MSY}$  implies a reasonable “shape” to the SRR.

The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) was consistent with the estimated population trends for this period (Figure 34). The model fits the fishery-independent index from the 2006–2023 AVO data well through most of the period but the model predicts lower biomass than the index data indicate in 2023 (Figure 35). The model fits to the bottom-trawl survey biomass (the density-dependent corrected series) were reasonable and within the observation error bounds (Figure 36). The model fit to the BTS biomass index predicts fewer pollock than observed in the 2014 and 2015 survey but then varied in subsequent years (Figure 36). The fit to the acoustic-trawl survey biomass series (including the USV data from 2020) was consistent with the specified observation uncertainty (Figure 37).

The estimated parameters and standard errors are provided [online](#). The code for the model (with dimensions and links to parameter names) and input files are available [here](#).

The input sample size (as tuned in 2016 using “Francis Weights”) can be evaluated visually for consistency with expectations of mean annual age for the different gear types (Figure 38; Francis 2011). The estimated selectivity pattern changes over time and reflects to some degree

the extent to which the fishery is focused on particularly prominent year-classes (Figure 39). The model fits the fishery age-composition data quite well under this form of selectivity (Figure 40).

Bottom-trawl survey selectivity estimates are shown in Figure 41. The pattern of bottom trawl survey age composition data in recent years shows a decline in the abundance of age 10+ pollock since 2011 (Figure 42). Through the time series of the available data, the model predicted proportions of the 2012 and 2013 year classes varied in terms of under- and over- estimates as the 2013 year-class became more common in the data (Figure 42). The ATS selectivity varies slightly among ages and years (Figure 43). This enhances the fit to the age composition data while still tracking the large year classes through the population (Figure 44).

As in past assessments, we evaluated the multivariate posterior distribution using Monte-Carlo Markov chain (MCMC) simulation methods. This year we adopted the no-turn sampling approach from ADMB but upgraded and packaged within R (adnuts, Monahan and Kristensen (2018)). This allowed thorough sampling diagnostics and was able to sample the posterior efficiently within a few hours (or less). This new package also demonstrated that the asymptotic parameter standard deviations were reasonable approximations of the marginal densities from the integrated posterior distribution (Figure 45). As before, we evaluated how selected parameters relate by doing a pairwise (along with their marginal distributions; Figure 46). This illustrates how key parameters relate to management parameters of interest. For example, the stock recruitment steepness is negatively correlated to the resulting  $B_{MSY}$  estimate. We also compare the point estimates (highest posterior density) with the mean of the posterior marginal distribution of the 2023 spawning biomass. This showed that the point estimate was similar to the mean of the marginal posterior distribution (Figure 47). As an additional part of the Tier 1 consideration, we evaluated the posterior density of  $F_{MSY}$  and is provided in Figure 48 for reference.

We added code for producing posterior predictive distributions (e.g., for the two acoustic indices in Figure 49). Additionally, we developed some preliminary diagnostics to evaluate how the model's posterior components affect key parameters of interest. For example, it is useful to know the relative impact of the 2018 year-class on the next year's spawning biomass (Figure 50). Additionally, what different components (in negative log-likelihood terms) conflict or interact with such a critical parameter (Figure 51)

## Retrospective analysis

Running the assessment model over a grid with progressively fewer years included (going back to 10 years, i.e., assuming the data extent ended in 2013) results in a fair amount of variability in spawning biomass (Figure 52). Last year with the lower than expected survey biomass estimate followed by an increase this year, the retrospective pattern degraded with an average bias (Mohns  $\rho$  equal to 0.273 for the 10 year retrospective).

For the recruitment side, the retrospective pattern shows two key results. First, the 2018 year-class (age 1 recruits in 2019) shows up as a big estimate just this year (Figure 53). Second, the retrospective pattern shows how an equally abundant year-class occurred from the 2012 year-class for three years (with data terminating in 2016, 2017, and 2018). Then, in 2019 and in subsequent years that estimate dropped by over 10% and became the 2012 and the 2013 year-class. In the 2022 assessment we adjusted the value downwards to be equal to the mean of some earlier year classes. This year, we simply accepted the estimate for projections given a better confirmation on the magnitude of the 2018 year class.

Related to this issue of consistency in year-class estimation, and in response to an SSC request, we evaluated how the influence of additional years of data affected year-class estimates. Figure 54 and Figure 55 illustrate how year-class estimates can vary for retrospective analyses. These figures show some of the change in relative abundance between the 2012 and 2013 year-classes and how the 2008 year estimate dissipated some as more data became available.

In response to previous SSC requests to evaluate how selectivity is used for ABC and catch advice, we used the retrospective runs to show how the “projected” selectivity compared with subsequent estimates which had the benefit of more data (Figure 56). To explain this figure, and taking the 2023 panel as an example, the blue line in that panel represents the projected estimate from the 2022 “peel” (the current model projecting to 2023 using only data up until 2022). The dots represent estimates from each “peel” and the dots in the 2022 panel are based on this year’s estimated selectivity. In general, the projected selectivity conformed reasonably well with subsequent estimates. To further summarize these results, we also computed a summary statistic as the mean age of selection (independent of any age-specific stock size):

$$\bar{a} = \frac{\sum S_a a}{\sum S_a}$$

where  $S_a$  is the selectivity at age (ages 1 to 11). This statistic showed that recently the projection was biased towards younger pollock but earlier on, the bias was toward older fish (Figure 57).

Since selectivity varies over time, and the fact that fishing mortality rates for management advice depend on the assumed future selectivity, we evaluate the pattern of  $F_{MSY}$  rates given different selectivity assumptions (i.e., Figure 39). In the 2020 and 2021 assessment, because of the indications of small pollock being unusually present in the fishery, we chose a selectivity pattern from history that reflected tendency towards younger fish (specifically, that from 2005). Using the statistic on mean selected age, we found that the corresponding  $F_{MSY}$  showed a correlation (Figure 58). This figure reveals how shifts in the relative age of fish selected impact  $F_{MSY}$  estimates.

## 6.2 Time series results

The time series of begin-year biomass estimates (ages 3 and older) suggests that the abundance of Eastern Bering Sea pollock remained at a high level from 1982–88, with estimates ranging

from 8 to 12 million t (Table 23). Historically, biomass levels increased from 1979 to the mid-1980s due to the strong 1978 and relatively strong 1982 and 1984 year classes recruiting to the fishable population. The stock is characterized by peaks in the mid-1980s, the mid-1990s and again appears to be increasing to a peak of more than 12 million t in 2016 following the low in 2008 of 4.38 million t. The estimate for 2023 is trending downward and at 10.8 million t with 2024 estimated at 10.18 million t.

The level of fishing relative to biomass estimates shows that the spawning exploitation rate (SER, defined as the percent removal of egg production in each spawning year) has been mostly below 20% since 1980 (Figure 59). During 2006 and 2007 the rate averaged more than 20% and the average fishing mortality increased during the period of stock decline. The estimate for 2009 through 2018 was below 20% due to the reductions in TACs relative to the maximum permissible ABC values and increases in the spawning biomass. The fishing mortality has fluctuated since 2010-2015 but, unlike last year's upward trend, the improved spawning biomass condition has held this rate tending toward lower levels. Age specific fishing mortality rates reflect these patterns and show some increases in the oldest ages from 2011–2013 but relatively stable (Figure 60). The estimates of age 3+ pollock biomass showed a large drop last year compared to several of the earlier years but this has reversed in the current assessment (Figure 61, Table 23).

Estimated numbers-at-age are presented in (Table 24) and estimated catch-at-age values are presented in (Table 25). Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment are given in (Table 26).

To evaluate past management and assessment performance it can be useful to examine estimated fishing mortality relative to reference values. For EBS pollock, we computed the reference fishing mortality from Tier 1 (unadjusted) and recalculated the historical values for  $F_{MSY}$  (since selectivity has changed over time). Since 1977 the current estimates of fishing mortality suggest that during the early period, harvest rates were above  $F_{MSY}$  until about 1980. Since that time, the levels of fishing mortality have averaged about 35% of the  $F_{MSY}$  level (Figure 62). Projections of spawning stock biomass given the 2024 estimate of fishing mortality rate given catches equal to the 2023 values shows a decline through 2021 and then an increase after; albeit with considerable uncertainty due to uncertainty in recruitment (Figure 63).

## Recruitment

Model estimates indicate that the 2008, 2012, 2013, and now the 2018 year classes are above average (Figure 64). The 2018 year class is nearly 4 times bigger than average with a CV of about 16%. The stock-recruitment curve as fit within the integrated model shows the variability of the estimated curve (Figure 65). Note that the 2021 and 2022 year classes (as age 1 recruits in 2022 and 2023) were excluded from the stock-recruitment curve estimation as per convention and guidance from NPFMC. Separate from fitting the stock-recruit relationship within

the model, examining the estimated recruits-per-spawning biomass shows variability over time but seems to lack trend and also is consistent with the Ricker stock- recruit relationship used within the model (Figure 66).

Environmental factors affecting recruitment are considered important and contribute to the variability. Previous studies linked strong Bering Sea pollock recruitment to years with warm sea temperatures and northward transport of pollock eggs and larvae (Wespestad et al. 2000; Mueter et al. 2006). As part of the Bering-Aleutian Salmon International Survey (BASIS) project research has also been directed toward the relative density and quality (in terms of condition for survival) of young-of-year pollock. For example, Moss et al. (2009) found age-0 pollock were very abundant and widely distributed to the north and east on the Bering Sea shelf during 2004 and 2005 (warm sea temperature; high water column stratification) indicating high northern transport of pollock eggs and larvae during those years. Mueter et al. (2011) found that warmer conditions tended to result in lower pollock recruitment in the EBS. This is consistent with the hypothesis that when sea temperatures on the eastern Bering Sea shelf are warm and the water column is highly stratified during summer, age-0 pollock appear to allocate more energy to growth than to lipid storage (presumably due to a higher metabolic rate), leading to low energy density prior to winter. This then may result in increased over-winter mortality (Swartzman et al. (2005), Winter et al. (2005)). Ianelli et al. (2011) evaluated the consequences of current harvest policies in the face of warmer conditions with the link to potentially lower pollock recruitment and noted that the current management system is likely to face higher chances of ABCs below the historical average catches. Also, as part of the evaluation of stationarity given periods of “regimes”, we revisited estimated mean recruitment during different periods previously identified as being unique (Figure 67). This shows that given the revised estimate of the 2018 year class, the impact of the recent warm conditions suggest that the recent period (2000-present) is similar to the mean since 1977.

## 7 Harvest recommendations

### 7.1 Status summary

The estimate of  $B_{MSY}$  is 2,689 kt (with a CV of 20%) which is less than the projected 2024 spawning biomass of 3,500 kt; (Table 27). For 2024, the estimates put the stock in Tier 1a. The corresponding maximum permissible ABC would thus be 2,837,000 t with a fishable biomass estimated at around 7,493 kt (Table 28). For the current year spawning biomass this corresponds to 137% of the  $B_{MSY}$  level. A diagnostic (see Section 14) on the impact of fishing shows that the 2023 spawning stock size is about 58% of the predicted value had no fishing occurred since 1978 (Table 27).

The probability that the current stock size is below 20% of  $B_0$  (a level important for additional management measures related to Steller sea lion recovery) is <0.1% for 2024 and 2025.

In response to a past request from the SSC, we continued to include results from projections based on Tier 2. We report the “standard” Tier 2 ABC calculation using the point estimate (the mean of the posterior distribution) of  $F_{MSY}$ . Therefore, for 2024 the Tier 2a ABC would be 2,472,000 t. Since we have estimates of the harmonic mean (from Tier 1 calculations) an alternative Tier 2 estimate using that in place of the arithmetic mean  $F_{MSY}$  results in an ABC of 2,217,000 t.

In summary, the criterion for Tier 1 depends on a reliable estimate of  $F_{MSY}$  and the uncertainty (the PDF). Tier 2 also requires a reliable estimate of  $F_{MSY}$  (without the PDF requirement). Given the seemingly reasonable posterior marginal density for  $F_{MSY}$ , it seems if Tier 1 criterion is unmet, then so would the requirement for Tier 2. Adopting Tier 3, while in principle may result in more conservative catch advice, uses less information available about the stock productivity and requires adopting more assumptions (i.e., that  $F_{35\%}$  is a reasonable proxy for  $F_{MSY}$ ). As noted below in the section on risk evaluations, there are reasons for increased concerns. However, these seem to be unrelated to overall stock productivity as relates to the SRR and estimates of  $F_{MSY}$ . Consequently, our overall analysis continues to support the SSC’s classification of this stock to be within Tier 1.

## 7.2 Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines overfishing level (OFL), the fishing mortality rate used to set OFL (FOFL), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC ( $F_{ABC}$ ) may be less than this maximum permissible level, but not greater. Estimates of reference points related to maximum sustainable yield (MSY) are currently available. However, we present both reference points for pollock in the BSAI to retain the option for consideration of either Tier 1, 2, or Tier 3 values from the harvest control rules provided in Amendment 56. These Tiers require reference point estimates for biomass level determinations. Consistent with other groundfish stocks, the following values are based on recruitment estimates from post-1976 spawning events (recognizing the the 1978 year class is excluded from the MSY calculations but included in the SPR calculations):

$B_{MSY}$	= 2,689 kt female spawning biomass
$B_0$	= 6,728 kt female spawning biomass
$B_{100\%}$	= 5,885 kt female spawning biomass
$B_{40\%}$	= 2,354 kt female spawning biomass
$B_{35\%}$	= 2,060 kt female spawning biomass

## 7.3 Specification of OFL and Maximum Permissible ABC

Under Amendment 56 of the [BSAI Groundfish FMP](#), the SSC qualified this stock as satisfying the Tier 1 conditions. As such, the harmonic mean value of  $F_{MSY}$  —here computed as an

exploitation rate—is applied to the fishable biomass for computing ABC levels. For details on the risk-averse properties of this approach see Thompson (1996). For a future year, the fishable biomass is defined as the sum over ages of predicted begin-year numbers multiplied by age specific fishery selectivity and estimated mean body mass-at-age. The uncertainty in the average weights-at-age projected for the fishery and “future selectivity” has been demonstrated to affect the buffer between ABC and OFL (computed as 1-ABC/OFL) for Tier 1 maximum permissible ABC (Ianelli et al. 2015). The uncertainty in future mean weights-at-age had a relatively large impact as did the selectivity estimation (see the section above on retrospective behavior and Figure 58).

Since the 2024 female spawning biomass is estimated to be above the  $B_{MSY}$  level (2,689 kt) and above the  $B_{40\%}$  value (2,354 kt) in 2024 and if the 2023 catch is as specified above, then the OFL and maximum permissible ABC values by the different Tier categorizations would be:

Tier	Year	MaxABC	OFL
1a	2024	2,837,000	3,162,000
1a	2025	3,095,000	3,449,000
2a	2024	2,471,600	3,162,000
2a	2025	2,696,160	3,449,000
3a	2024	2,313,000	2,838,000
3a	2025	2,401,000	2,919,000

Note that the values presented for 2024 assumed a catch of 1,300,000 t in 2023.

## 7.4 Standard Harvest Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56 to the FMP. 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). While EBS pollock is generally considered to fall within Tier 1, the standard projection model requires knowledge of future uncertainty in  $F_{MSY}$ . Since this would require a number of additional assumptions that presume future knowledge about stock-recruit uncertainty, the projections in this subsection are based on Tier 3.

For each scenario, the projections begin with the vector of 2023 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2024 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2023. 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. Annual recruits are simulated from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from the estimated age-1 recruits. Spawning biomass is computed in each year based on the time of peak spawning and the maturity

and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes and catches under alternative fishing mortality rate scenarios.

Five of the seven standard scenarios support the alternative harvest strategies analyzed in the Alaska Groundfish Harvest Specifications Final Environmental Impact Statement. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2024, are as follows (“ $\max F_{ABC}$ ” refers to the maximum permissible value of FABC under Amendment 56):

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

**Scenario 2:** In 2024 and 2025 the catch is set equal to 1.30 million t and in future years  $F$  is set equal to the Tier 3 estimate (Rationale: this has been about equal to the catch level in recent years).

**Scenario 3:** In all future years,  $F$  is set equal to the 2022 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  $F_{60\%}$ . (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.)

**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) below its MSY level in 2023 or 2) below half of its MSY level in 2023 or below its MSY level in 2033 under this scenario, then the stock is overfished.)

**Scenario 7:** In 2024 and 2025,  $F$  is set equal to  $\max F_{ABC}$ , and in all subsequent years,  $F$  is set equal to  $F_{OFL}$ . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) below its MSY level in 2025 or 2) below 1/2 of its MSY level in 2025 and expected to be below its MSY level in 2035 under this scenario, then the stock is approaching an overfished condition).

The latter two 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 (for Tier 3 stocks, the MSY level is defined as  $B_{35\%}$ ).

## 7.5 Projections and status determination

For the purposes of these projections, we present results based on selecting the  $F_{40\%}$  harvest rate as the  $F_{ABC}$  value and use  $F_{35\%}$  as a proxy for  $F_{MSY}$ . Scenarios 1 through 7 were projected 14 years from 2023 (Table 32 for Model 23.0—including the 1978 year-class as is convention for Tier 3 estimates). Under catches set to Tier 3 ABC estimates, the expected spawning biomass is well above  $B_{35\%}$  and is expected to drop below  $B_{40\%}$  by 2026 (given mean recruitment; Figure 68 and assuming catches >2 million t in 2025).

Any stock that is below its minimum stock size threshold (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 overfished? This depends on the stock's estimated spawning biomass in 2023:

- If spawning biomass for 2023 is estimated to be below  $1/2 B_{35\%}$  the stock is below its MSST.
- If spawning biomass for 2023 is estimated to be above  $B_{35\%}$ , the stock is above its MSST.
- If spawning biomass for 2023 is estimated to be above  $1/2 B_{35\%}$  but below  $B_{35\%}$ , the stock's status relative to MSST is determined by referring to harvest scenario 6 (Table 29 through Table 32). If the mean spawning biomass for 2033 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:

- If the mean spawning biomass for 2023 is below  $1/2 B_{35\%}$ , the stock is approaching an overfished condition.
- If the mean spawning biomass for 2023 is above  $B_{35\%}$ , the stock is not approaching an overfished condition.
- If the mean spawning biomass for 2025 is above  $1/2 B_{35\%}$  but below  $B_{35\%}$ , the determination depends on the mean spawning biomass for 2035. If the mean spawning biomass for 2035 is below  $B_{35\%}$ , the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

For scenarios 6 and 7, we conclude that pollock is above MSST for the year 2023, and it is expected to be above the “overfished condition” based on Scenario 7 (the mean spawning biomass in 2023 is between the  $1/2 B_{35\%}$  and  $B_{35\%}$  estimate but by 2035 the stock is above  $B_{35\%}$ ; (Table 32). Based on this, the EBS pollock stock is being fished below the overfishing level and is not approaching an overfished condition.

To fulfill reporting requirements for [NOAA's Species Information System](#), we computed the average fishing mortality rate corresponding to the specified OFL for the last complete year (2022). This hypothetical 2022  $F_{OFL}$  from this year's model was estimated to be 0.262 for EBS pollock (assuming this year's estimated 2022 selectivity and weight-at-age).

## 7.6 ABC Recommendation

ABC levels are affected by estimates of  $F_{MSY}$  which depend principally on the estimated stock-recruitment steepness parameter, demographic schedules such as selectivity-at-age, maturity, and growth. The current stock size (both spawning and fishable) is estimated to be above average levels and projections indicate the potential for further declines. Updated data and analysis result in an estimate of 2023 spawning biomass (3,690 kt) which is about 137% of  $B_{MSY}$  (2,689 kt). This follows a short period of decline from 2017-2020 followed by a previously unexpected increase due to revised estimates of the 2018 year class. Treating all new data the same way as in the past, this estimate suggests that it would be the biggest year-class on record (75,800 age 1 numbers), but with considerable uncertainty.

Given the same estimated aggregate fishing effort as in 2022 and given the estimated stock trend, the constant-F scenario would yield about 1.3 million t. To obtain 2023 catches on the order of 1.45 million t, given the base model estimates, would require about 18% more effort than what was estimated from 2022.

### Should the ABC be reduced below the maximum permissible ABC?

The SSC in its September 2018 minutes recommended that assessment authors and Plan Teams use the risk table below when determining whether to recommend an ABC lower than the maximum permissible. The details of the risk table are provided below. Given the concerns listed there, we recommend reducing the ABC to the value provided under Tier 3 projections.

Considerations				
	Assessment-related	Population dynamics	Environmental & ecosystem	Fishery performance
Level 1 No concern	Typical to moderately increased uncertainty & minor unresolved issues in assessment	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental & ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2 Major Concern	Major problems with the stock assessment, very poor fits to data, high level of uncertainty, strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level, and/or b) up or down trophic levels (i.e., predators and prey of stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 3 Extreme concern	Severe problems with the stock assessment, severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented. More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock. Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock.

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. Examples of the types of concerns that might be relevant include the following (as identified by the work-group):

## 1. Assessment considerations

- *Data-inputs:* biased ages, skipped surveys, lack of fishery-independent trend data
- *Model fits:* poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs.
- *Model performance:* poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds.
- *Estimation uncertainty:* poorly-estimated but influential year classes.
- Retrospective bias in biomass estimates.

## 2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.

3. Environmental/ecosystem considerations–trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.
4. Fisheries considerations–fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.”

### **Assessment considerations**

The EBS pollock assessment model has appeared to track the stock from year-to-year based on retrospective analysis in previous assessments. In 2022 the surveys showed an increase from the relatively low observation from 2021. This affected the retrospective analyses which last year indicated a tendency to over estimate the stock trend. This year the model tracks the available data reasonably well and fishery data confirm an apparently very strong 2018 year class. The trend towards fishing being below average in body weight so far has been limited, despite the observation that the condition (weight-given length) in 2023 seems to be the lowest on record. **We therefore rated the assessment-related concern as Level 1, No Concern.**

### **Population dynamics considerations**

The age structure of EBS pollock has exhibited some peculiarities over time. On the positive side, some strong year-classes appear to have increased in abundance based on the bottom-trawl survey data (e.g., the 1992, 2012, 2013 and 2018 year classes). Conversely, the period from 2000–2007 had relatively poor year-class strengths which resulted in declines in stock below  $B_{msy}$  and reduced TACs due to lower ABC values. Given new support for the strong year-class strength from 2018, it appears that the mean recruitment since 2000 has been nearly average but with greater variability than earlier years (Figure 67). The stock is estimated to be above  $B_{msy}$  at present, and projections indicate a increases given recent catch levels. Recruitment in the near term is about average and highly uncertain. Additional age-specific aspects of the spawning population indicate that the stock has increased from a low diversity of ages (for both the population and the mean age of the spawning stock weighted by spawning output Figure 70). **We therefore rated the population-dynamics concern as level 1, No Concern**

### **Environmental/Ecosystem considerations**

**Summary for Environmental/Ecosystem considerations** The following summarizes “Environmental/Ecosystem” considerations (see Section 15 for details):

- September 2022 - August 2023 oceanographic conditions, based on sea surface and bottom temperatures, sea ice, and cold pool extent, were near respective time series averages.

- The 2023 cold pool spatial extent was near its time series average (1982-2023).
- 2023 chlorophyll-a biomass was among the lowest in the time series
- 2023 coccolithophore index was among the highest ever observed in the timeseries
- pH and Ωaragonite remain near threshold levels of biological significance
- Zooplankton were dominated by small copepods. Large copepods and euphausiids had low lipid content; abundances increased to the north with hot spots around St. Lawrence Island
- Age-0 pollock condition (length-weight residual, % lipid, and energy density residual) was below average in 2023 and continued decreasing trends
- Juvenile pollock (100-250mm) condition was below average in the SEBS and NBS in 2021 and has decreased since 2021
- Adult pollock (>250mm) condition was below average in the SEBS and has decreased since 2019, while condition was above average in the NBS and has increased since 2021
- Trends in potential competitors are mixed over the shelf, with increases in jellyfish over the northern shelf, increases in herring biomass, mixed trends in salmon run strengths and juvenile salmon condition (negative over the southern shelf, positive over the northern shelf), and a continued decline in the biomass of the pelagic forager biomass.
- In 2023, with an average cold pool extent, predation pressure from cannibalism may have been mitigated as adult pollock avoided the cold pool and their center of distribution shifted north and west.
- Northern fur seal pup production at St. Paul Island in 2022 continued a declining trend since 1998.
- Trends in other potential predators are mixed over the shelf, especially in the NBS, with increased jellyfish abundance and decreased chum salmon abundance.

Together, the most recent data available suggest an ecosystem risk of **Level 2 – “Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock).”** Multiple indicators of primary and secondary productivity show adverse signals borne out in continued declining trends in juvenile and adult fish condition.

## Fishery performance

As noted above, the 2023 fishery again experienced good nominal fishing rates that were improved over 2020 and 2021 conditions. The 2023 fishery seemed to have generally smaller-than-expected pollock in the fishery and there was indications that the fish were unusually skinny given their length. The fleet dispersion (the relative distance or spread of the fishery in space) as shown in the past has indicated that the seasonal dispersion levels increased slightly but was still relatively low (indicating relatively good fishing; Figure 10).

The CPUE of PSC species and other bycatch declined in 2023. Sablefish, herring and Chinook salmon bycatch rates (per hour of fishing) all decreased from 2021 (except for a slight increase in herring CPUE during the B season from low levels; Figure 3).

The way the ABC control rule interacts with actual fishing is worth considering. Specifically, given the 2 million t OY cap for all of groundfish, when the EBS pollock stock is above target levels, the fishing effort is lower (a lower  $F$ ). As it approaches the target ( $B_{MSY}$ ), it increases and then when it drops below, the fishing mortality rate is ratcheted downwards rapidly. This can be exacerbated when there are sudden unanticipated changes in survey estimates (like what was apparently the case in 2021 which caused the retrospective pattern to degrade). The mean weight-at-age for the 2021 B-season was near average, but in general, pollock were skinny given their length. However, concerns over the amount of 2-year old pollock in the 2020 fishery data has been ameliorated with continued positive signs of that year-class which is projected to be an abundant number of 5-year olds in 2023. For this reason, we **conclude that that the fishery performance warrants a score of 1, No Concern.**

These results are summarized as:

Considerations			
Assessment-related	Population dynamics	Environmental ecosystem	Fisheries
Level 1: No concern	Level 1: No concern	Level 2: Major concern	Level 1: No concern

Having a score at level 2 suggests that adjustments to the ABC may be prudent. In the past, the SSC has considered factors similar to those presented above and selected an ABC based on Tier 3 estimates. Last year the SSC requested examining Tier 2 values as an alternative. Unlike Tier 3, using Tier 2 would have a constant buffer relative to the Tier 1 value (at about 11%). Setting the ABC to Tier 3 levels provides a very large buffer but one that could be warranted given that the impact on subsequent spawning biomass levels will be much more variable and have a high probability of dropping below the target stock size and result in much reduced future ABCs under the current FMP. It is worth noting that fishing at the full Tier 1 ABC would imply a more than doubling of effort and well exceed the 2 million t groundfish catch limit. Even fishing at a full Tier 3 ABC shows there is a relatively high probability of falling below  $B_{MSY}$  values or proxies thereof. Under our standard scenarios, Alternative 3 shows trajectories if fishing effort is held equal to the recent 5-year average. It is noteworthy

that this provides stock sizes that have a good probability of being above targets and avoiding drastic reductions in yeild (lower overall variability in ABC/yields; Figure 69).

The SSC has requested “an explicit set of concerns that explain the ABC adjustment.” In response, we direct attention to the decision table (Table 34) and the fact that the biological basis for the continued stock productivity has most to do with the OY constraint which has effectively maintained fishery production at around 1.3 million t since 1990. Demonstrations that would allow fishing to near  $F_{MSY}$  catch quantities would show that catch variability would be extremely high (and unrealistic given current capacity and OY limits for combined BSAI groundfish; Ianelli 2005). Furthermore, the frequency of being at much lower spawning stock sizes would be much higher, and would likely be riskier and fishing effort would need to be much higher. While the biological basis for ABC setting is founded in sound conservation of spawning biomass, the history of the current fishery productivity should inform desirable biomass. In only 6 of the 41 years since 1981 has the stock been below the  $B_{MSY}$  level (15% of the years). The mean spawning biomass over this period has averaged about -1% higher than the estimated  $B_{MSY}$ . In terms of an actual “management target”, Punt et al. (2013) developed some robust estimators for  $B_{MEY}$  (Maximum Economic Yield) noting that a typical target would be  $1.2 \times B_{MSY}$  or about -17% lower than the mean value or a target female spawning biomass at 3.226 million t. It therefore seems worth considering developing an explicit harvest control rule that achieves the level of productivity observed over the past 30 years.

In recent years when the pollock biomass was estimated to be well above average, the catch was constrained by other factors. Specifically, the 2 million t BSAI groundfish catch limit and bycatch avoidance measures has an impact on the potential for large increases in catch. As the stock is presently estimated to be below  $B_{MSY}$ , the maximum permissible ABC under the FMP can become the limiting factor for TAC specification. Unfortunately, this ABC can ratchet down quickly because as the stock declines further below this target stock size, the ABC fishing mortality rate is adjusted downwards nearly proportionately. This part of the FMP control rule can create high variability in the TAC. Less variability in the catch, accordingly, would also result in less spawning stock variability and reduce risks to the fishery should the period of poor recruitment continue.

To more fully evaluate these considerations performance indicators as modified from Ianelli et al. (2012) were developed to evaluate some near-term risks given alternative 2024 catch values. These indicators and rationale for including them are summarized in Table 33). Model 23 (the “base”) results for these indicators are provided in Table 34. Each column of this table uses a fixed 2024 catch and assumes the same effort for the four additional projection years (2025–2028). Given this specification, there is a low probability that any of the catches shown in the first row would exceed the  $F_{MSY}$  level. Also, in the near term it appears unlikely that the spawning stock will be below  $B_{MSY}$  (rows 3 and 4). Relative to the historical mean spawning biomass, by 2024 it is more likely than not that the spawning biomass will be lower than the historical mean (fifth row). The range of catches examined have relatively small or no impact on the age diversity indicators. The table indicates that for the 2024 catch to equal the 2023 value, about the same level of fishing effort would be required. In terms of catch

advice, the results presented in the decision table indicates that catches above 1.3 million t will very likely result in 2025 spawning stock estimates being below the long term mean (but above  $B_{MSY}$ ).

In the past, another approach/rationale for stabilizing effort by setting the fishing mortality equal to the current year. Doing so this year suggests setting the fishing mortality to 2023 levels results in a catch of 1,150,000 t. Given the revisions to last year's model results and the positive increases in stock size, maintaining a constant fishing mortality rate seems unnecessary at this time.

## 8 Additional ecosystem considerations

In general, a number of key issues for ecosystem conservation and management can be highlighted. These include:

- Preventing overfishing;
- Avoiding habitat degradation;
- Minimizing incidental bycatch;
- Monitoring bycatch and the level of discards; and
- Considering multi-species trophic interactions relative to harvest policies.

For the case of pollock in the Eastern Bering Sea, the NPFMC and NMFS continue to manage the fishery on the basis of these issues in addition to the single- species harvest approach (Hollowed et al. 2011). The prevention of overfishing is clearly set out as the main guideline for management. Habitat degradation has been minimized in the pollock fishery by converting the industry to pelagic-gear only. Bycatch in the pollock fleet is closely monitored by the NMFS observer program and managed on that basis. Discard rates of many species have been reduced in this fishery and efforts to minimize bycatch continue.

In comparisons of the Western Bering Sea (WBS) with the Eastern Bering Sea using mass-balance food-web models based on 1980–85 summer diet data, Aydin et al. (2002) found that the production in these two systems is quite different. On a per-unit-area measure, the western Bering Sea has higher productivity than the EBS. Also, the pathways of this productivity are different with much of the energy flowing through epifaunal species (e.g., sea urchins and brittlestars) in the WBS whereas for the EBS, crab and flatfish species play a similar role. In both regions, the keystone species in 1980–85 were pollock and Pacific cod. This study showed that the food web estimated for the EBS ecosystem appears to be relatively mature due to the large number of interconnections among species. In a more recent study based on 1990–93 diet data, pollock remain in a central role in the ecosystem. The diet of pollock is similar between adults and juveniles with the exception that adults become more piscivorous (with consumption of pollock by adult pollock representing their third largest prey item).

Regarding specific small-scale ecosystems of the EBS, Ciannelli et al. (2004a, 2004b) presented an application of an ecosystem model scaled to data available around the Pribilof Islands region. They applied bioenergetics and foraging theory to characterize the spatial extent of this ecosystem. They compared energy balance, from a food web model relevant to the foraging range of northern fur seals and found that a range of 100 nautical mile radius encloses the area of highest energy balance representing about 50% of the observed foraging range for lactating fur seals. This has led to a hypothesis that fur seals depend on areas outside the energetic balance region. This study develops a method for evaluating the shape and extent of a key ecosystem in the EBS (i.e., the Pribilof Islands). Furthermore, the overlap of the pollock fishery and northern fur seal foraging habitat has been identified (see Sterling and Ream (2004), Zeppelin and Ream (2006)).

A brief summary of these two perspectives (ecosystem effects on pollock stock and pollock fishery effects on ecosystem) is given in (Table 39). Unlike the food-web models discussed above, examining predators and prey in isolation may overly simplify relationships. This table serves to highlight the main connections and the status of our understanding or lack thereof.

## **8.1 Ecosystem effects on the EBS pollock stock**

The pollock stock trends appear to be responding to ecosystem conditions in the EBS. The conditions on the shelf during 2008 apparently affected age-0 northern rock sole due to cold conditions and apparently unfavorable currents that retain them into the over- summer nursery areas (Cooper et al. (2014)). It may be that such conditions favor pollock recruitment. Hollowed et al. (2012) provided an extensive review of habitat and density for age-0 and age-1 pollock based on survey data. They noted that during cold years, age-0 pollock were distributed primarily in the outer domain in waters greater than 1°C and during warm years, age-0 pollock were distributed mostly in the middle domain. This temperature relationship, along with interactions with available food in early-life stages, appears to have important implications for pollock recruitment success (Coyle et al. (2011)).

A separate section presented again this year updates a multispecies model with more recent data and is presented as a supplement to the BSAI SAFE report. This approach incorporates a number of simplifications for the individual species data and fisheries processes (e.g., constant fishery selectivity and the use of design-based survey indices for biomass). However, that model mimics the biomass levels and trends with the single species reasonably well. It also allows specific questions to be addressed regarding pollock TACs. For example, since predation (and cannibalism) is explicitly modeled, the impact of relative stock sizes on subsequent recruitment to the fishery can be now be directly estimated and evaluated (in the model presented here, cannibalism is explicitly accounted for in the assumed Ricker stock-recruit relationship).

## **8.2 EBS pollock fishery effects on the ecosystem.**

Since the pollock fishery is primarily pelagic in nature, the bycatch of non-target species is small relative to the magnitude of the fishery (Table 35). Jellyfish represent the largest component of the bycatch of non-target species and had averaged around 5–6 kt per year but more than doubled in 2014, then dropping again in 2015. The 2018 value was high, dropped and then was again high in 2021. The data on non-target species shows a high degree of inter-annual variability, which reflects the spatial variability of the fishery and high observation error. This variability may reduce the ability to detect significant trends for bycatch species.

The catch of other target species in the pollock fishery (defined as any trawl set where the catch represents more than 80% of the catch) represents about 1% of the total pollock catch. Incidental catch of Pacific cod has varied but after a period of low catch levels it increased to over 9,000 t in 2020 and 2021 but in 2022 was under 4 thousand t (Table 36). There has been a marked increase in the incidental catch of Pacific ocean perch in the since 2014 with a peak just under 8 thousand t in 2019. The incidental catch of sablefish peaked in 2020 at about 3.5 thousand t but was less than 300 t in 2022. The incidental catch of pollock in other target fisheries is more than double the bycatch of target species in the pollock fishery with the largest pollock catches in the yellowfin sole and Pacific cod fisheries (Table 37).

The number of non-Chinook salmon (nearly all made up of chum salmon) taken incidentally varies considerably over time. The bycatch increased since 2014 with the 2017 number in excess of 465 thousand fish, the third highest non-Chinook salmon bycatch that's been observed since 1991. Since then, 7 of the top 10 highest bycatch years have occurred with nearly 550 thousand taken in 2021 (Table 38). Chinook salmon bycatch has varied (42% CV since 2011) and averaged just under 19 thousand fish from 2011-2023 (Table 38). After a recent high bycatch of over 32,000 fish in 2020, the 2022 and 2023 bycatch was 6,415 and 11,750 Chinook salmon, respectively. Ianelli and Stram (2014) provided estimates of the bycatch impact on Chinook salmon runs to the coastal west Alaska region and found that the peak bycatch levels exceeded 7% of the total run return. Since 2011, the impact has been estimated to be below 2%. Updated estimates given new genetic information and these levels of PSC as provided to the Council continue to suggest that the impact is low.

## **9 Data gaps and research priorities**

The available data for EBS pollock are extensive yet many processes behind the observed patterns continue to be poorly understood. The recent patterns of abundance observed in the northern Bering Sea provide an example. As such, we recommend the following research priorities:

- Support developing a team of analysts to evaluate all aspects of the current model against alternatives (e.g., Rceattle, WHAM, Stock Synthesis, etc.). *This work has progressed*

*and presently, developments on the Gulf of Alaska assessment adopting WHAM appears promising.*

- Continue to investigate using spatial processes for estimation purposes (e.g., combining acoustic and bottom trawl survey data). The application of the geostatistical methods seems like a reasonable approach to statistically model disparate data sources for generating better abundance indices. Also, examine the potential to use pelagic samples from the BASIS survey to inform recruitment and subsequent spatial patterns. *Work on developing data from the BASIS survey to inform recruitment has not been pursued. The work to refine the AVO data has helped with information used in this assessment.*
- Develop methods to use spatio-temporal models to estimate composition information (specifically, weight-at-age in the survey). *Two papers, (Indivero et al. (2023)) and (Cheng et al. (2023)) have been published targeting this type of activity. The former is presently used in this assessment while the latter has yet to be applied.*
- Study the relationship between climate and recruitment and trophic interactions of pollock within the ecosystem. This would be useful for improving ways to evaluate the current and alternative fishery management systems. In particular, a careful re-evaluation of the current FMP harvest control rule should be undertaken. *As part of the ACLIM program, progress is being made. However, a full evaluation of the FMP control rules is pending.*
- Apply new technologies (e.g., bottom-moored echosounders) to evaluate pollock movement between regions and supplement this work with analytical approaches. *The data have been processed completely and a manuscript is being submitted. Next steps is to use this information to develop scenarios for flux over the maritime boundary and evaluate relative fishing effort impacts on either side.*
- Expand genetic sample collections for pollock (and process available samples) and apply high resolution genetic tools for stock structure analyses. *Additional analyses have been completed and are expected to lead to a publication in 2024.*

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## 12 Tables

Table 1: Pollock catch from the Eastern Bering Sea by area, and season (through October 25th 2023). The A season starts January 20th and B season starts on June 10th. The Southeast area refers to the EBS region east of 170W; the Northwest is west of 170W.

Year	Northwest A	Northwest B	Southeast A	Southeast B	NW	SE	A	B	Total
1991	12,191	529,897	297,202	356,353	542,088	653,555	309,393	886,250	1,195,643
1992	101,597	458,143	454,947	375,612	559,740	830,559	556,544	833,755	1,390,299
1993	93,013	139,160	475,143	619,287	232,173	1,094,430	568,156	758,447	1,326,603
1994	11,026	165,751	586,105	566,470	176,777	1,152,575	597,131	732,221	1,329,352
1995	3,631	88,310	600,499	571,807	91,941	1,172,306	604,130	660,117	1,264,247
1996	1,804	104,135	549,297	537,545	105,939	1,086,842	551,101	641,680	1,192,781
1997	2,363	302,180	557,106	262,784	304,543	819,890	559,469	564,964	1,124,433
1998	1,508	131,007	476,214	410,353	132,515	886,567	477,722	541,360	1,019,082
1999	4,139	202,558	414,030	368,953	206,697	782,983	418,169	571,511	989,680
2000	19,363	274,170	439,023	400,154	293,533	839,177	458,386	674,324	1,132,710
2001	108,013	317,207	444,565	517,412	425,220	961,977	552,578	834,619	1,387,197
2002	36,693	283,747	561,061	599,272	320,440	1,160,333	597,754	883,019	1,480,773
2003	151,465	406,123	446,152	487,039	557,588	933,191	597,617	893,162	1,490,779
2004	50,661	339,883	556,469	533,538	390,544	1,090,007	607,130	873,421	1,480,551
2005	120,320	560,548	476,970	325,184	680,868	802,154	597,290	885,732	1,483,022
2006	18,789	642,034	585,507	241,700	660,823	827,207	604,296	883,734	1,488,030
2007	62,504	563,748	505,306	222,943	626,252	728,249	567,810	786,691	1,354,501
2008	44,801	463,079	358,936	123,762	507,880	482,698	403,737	586,841	990,578
2009	81,575	370,957	247,944	110,307	452,532	358,251	329,519	481,264	810,783
2010	199,011	356,061	124,670	130,443	555,072	255,113	323,681	486,504	810,185
2011	102,252	348,897	401,755	346,128	451,149	747,883	504,007	695,025	1,199,032
2012	104,926	481,418	380,373	238,497	586,344	618,870	485,299	719,915	1,205,214
2013	94,763	480,331	415,014	280,652	575,094	695,666	509,777	760,983	1,270,760
2014	50,465	388,712	469,973	388,267	439,177	858,240	520,438	776,979	1,297,417
2015	258,574	366,752	267,095	429,153	625,326	696,248	525,669	795,905	1,321,574
2016	81,531	104,078	458,044	709,028	185,609	1,167,072	539,575	813,106	1,352,681
2017	37,730	143,430	544,028	633,993	181,160	1,178,021	581,758	777,423	1,359,181
2018	3,842	326,753	598,533	450,160	330,595	1,048,693	602,375	776,913	1,379,288
2019	2,649	304,532	614,949	487,217	307,181	1,102,166	617,598	791,749	1,409,347
2020	85,717	421,102	560,438	299,978	506,819	860,416	646,155	721,080	1,367,235
2021	56,779	295,470	554,774	469,234	352,249	1,024,008	611,553	764,704	1,376,257
2022	9,018	197,610	487,216	411,573	206,628	898,789	496,234	609,183	1,105,417
2023	11,335	408,832	568,447	306,154	420,167	874,601	579,782	714,986	1,294,768

Table 2: Time series of 1964–1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977–2023 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports. Note that the 2023 value is based on catch reported to October 25th 2023 plus an added component due to bycatch of pollock in other fisheries.

Year	Catch	Year	OFL	ABC	TAC	Catch
1964	174,792	1977	-	950,000	950,000	978,370
1965	230,551	1978	-	950,000	950,000	979,431
1966	261,678	1979	-	1,100,000	950,000	935,714
1967	550,362	1980	-	1,300,000	1,000,000	958,280
1968	702,181	1981	-	1,300,000	1,000,000	973,502
1969	862,789	1982	-	1,300,000	1,000,000	955,964
1970	1,256,565	1983	-	1,300,000	1,000,000	981,450
1971	1,743,763	1984	-	1,300,000	1,200,000	1,092,055
1972	1,874,534	1985	-	1,300,000	1,200,000	1,139,676
1973	1,758,919	1986	-	1,300,000	1,200,000	1,141,993
1974	1,588,390	1987	-	1,300,000	1,200,000	859,416
1975	1,356,736	1988	-	1,500,000	1,300,000	1,228,721
1976	1,177,822	1989	-	1,340,000	1,340,000	1,229,600
		1990	-	1,450,000	1,280,000	1,455,193
		1991	-	1,676,000	1,300,000	1,195,664
		1992	1,770,000	1,490,000	1,300,000	1,390,299
		1993	1,340,000	1,340,000	1,300,000	1,326,602
		1994	1,590,000	1,330,000	1,330,000	1,329,352
		1995	1,500,000	1,250,000	1,250,000	1,264,247
		1996	1,460,000	1,190,000	1,190,000	1,192,781
		1997	1,980,000	1,130,000	1,130,000	1,124,433
		1998	2,060,000	1,110,000	1,110,000	1,102,159
		1999	1,720,000	992,000	992,000	989,680
		2000	1,680,000	1,139,000	1,139,000	1,132,710
		2001	3,536,000	1,842,000	1,400,000	1,387,197
		2002	3,530,000	2,110,000	1,485,000	1,480,776
		2003	3,530,000	2,330,000	1,491,760	1,490,779
		2004	2,740,000	2,560,000	1,492,000	1,480,552
		2005	2,100,000	1,960,000	1,478,500	1,483,022
		2006	2,090,000	1,930,000	1,485,000	1,488,031
		2007	1,640,000	1,394,000	1,394,000	1,354,502
		2008	1,440,000	1,000,000	1,000,000	990,578
		2009	977,000	815,000	815,000	810,784
		2010	918,000	813,000	813,000	810,206
		2011	2,450,000	1,270,000	1,252,000	1,199,041
		2012	2,474,000	1,220,000	1,200,000	1,205,293
		2013	2,550,000	1,375,000	1,247,000	1,270,827
		2014	2,795,000	1,369,000	1,267,000	1,297,849
		2015	3,330,000	1,637,000	1,310,000	1,322,317
		2016	3,910,000	2,090,000	1,340,000	1,353,686
		2017	3,640,000	2,800,000	1,345,000	1,359,367
		2018	4,797,000	2,592,000	1,364,341	1,379,301
		2019	3,914,000	2,163,000	1,397,000	1,409,235
		2020	4,085,000	2,043,000	1,425,000	1,325,792
		2021	2,594,000	1,626,000	1,375,000	1,339,000
		2022	1,469,000	1,111,000	1,111,000	1,105,677
		2023	3,381,000	1,910,000	1,300,000	1,259,161
1977–2023 mean		2,468,438	1,495,681	1,221,247	1,203,410	

Table 3: Estimates of discarded and retained pollock (t) for the Northwest and Southeastern Bering Sea, 1991–2023. SE represents the EBS east of 170W, NW is the EBS west of 170W, source: NMFS Blend and catch-accounting system database. 2023 data are preliminary.

Year	NW Discarded	SE Discarded	NW Retained	SE Retained	Total	Discarded %
1991	48,257	66,792	493,852	586,763	1,195,664	9.6%
1992	57,578	71,194	502,163	759,365	1,390,299	9.3%
1993	26,100	83,986	206,073	1,010,443	1,326,602	8.3%
1994	16,084	88,098	160,693	1,064,476	1,329,352	7.8%
1995	9,715	87,492	82,226	1,084,814	1,264,247	7.7%
1996	4,838	71,368	101,100	1,015,474	1,192,781	6.4%
1997	22,557	71,032	281,986	748,858	1,124,433	8.3%
1998	1,581	14,291	130,934	957,098	1,103,903	1.4%
1999	1,912	26,912	204,786	756,071	989,680	2.9%
2000	1,942	19,678	291,591	819,499	1,132,710	1.9%
2001	2,450	14,874	422,770	947,103	1,387,197	1.2%
2002	1,441	19,430	319,002	1,140,904	1,480,776	1.4%
2003	2,959	13,795	554,629	919,397	1,490,779	1.1%
2004	2,781	20,380	387,763	1,069,628	1,480,552	1.6%
2005	2,586	14,838	678,282	787,316	1,483,022	1.2%
2006	3,677	11,877	657,147	815,330	1,488,031	1.0%
2007	3,769	12,334	622,484	715,915	1,354,502	1.2%
2008	1,643	5,968	506,237	476,730	990,578	0.8%
2009	1,936	4,014	450,596	354,238	810,784	0.7%
2010	1,270	2,490	553,802	252,623	810,186	0.5%
2011	1,376	3,444	449,773	744,438	1,199,031	0.4%
2012	1,190	4,080	585,154	614,791	1,205,214	0.4%
2013	1,225	4,084	573,869	691,582	1,270,760	0.4%
2014	1,786	12,556	437,391	845,684	1,297,417	1.1%
2015	2,418	7,055	622,907	689,193	1,321,574	0.7%
2016	1,036	8,124	184,574	1,158,948	1,352,681	0.7%
2017	1,356	6,848	179,803	1,171,173	1,359,181	0.6%
2018	2,005	9,170	328,590	1,039,523	1,379,288	0.8%
2019	1,979	7,126	305,202	1,095,040	1,409,346	0.6%
2020	2,450	9,364	504,370	851,053	1,367,236	0.9%
2021	1,534	12,379	350,715	1,011,629	1,376,258	1.0%
2022	3,538	9,925	203,091	889,124	1,105,677	1.2%
2023	3,660	8,820	405,467	841,214	1,259,161	1.0%
Mean	7,292	24,964	386,031	846,225	1,264,512	2.1%

Table 4: Highlights of some management measures affecting the pollock fishery.

Year	Management
1977	Preliminary BSAI FMP implemented with several closure areas
1982	FMP implement for the BSAI
1982	Chinook salmon bycatch limits established for foreign trawlers
1984	2 million t groundfish OY limit established
1984	Limits on Chinook salmon bycatch reduced
1990	New observer program established along with data reporting
1992	Pollock CDQ program commences
1994	NMFS adopts minimum mesh size requirements for trawl codends
1994	Voluntary retention of salmon for foodbank donations
1994	NMFS publishes individual vessel bycatch rates on internet
1995	Trawl closures areas and trigger limits established for chum and Chinook salmon
1998	Improved utilization and retention in effect (reduced discarded pollock)
1998	American Fisheries Act (AFA) passed
1999	The AFA was implemented for catcher/processors
1999	Additional critical habitat areas around sea lion haulouts in the GOA and Eastern Bering Sea are closed.
2000	AFA implemented for remaining sectors (catcher vessel and motherships)
2001	Pollock industry adopts voluntary rolling hotspot program for chum salmon
2002	Pollock industry adopts voluntary rolling hotspot program for Chinook salmon
2005	Rolling hotspot program adopted in regulations to exempt fleet from triggered time/area closures for Chinook and chum salmon
2011	Amendment 91 enacted, Chinook salmon management under hard limits
2015	Amendment 110 (BSAI) Salmon prohibited species catch management in the Bering Sea pollock fishery (additional measures that change limits depending on Chinook salmon run-strength indices) and includes additional provisions for reporting requirements (see <a href="https://alaskafisheries.noaa.gov/fisheries/chinook-salmon-bycatch-management">https://alaskafisheries.noaa.gov/fisheries/chinook-salmon-bycatch-management</a> for update and general information)
2016	Measures of amendment 110 go into effect for 2017 fishing season; Chinook salmon runs above the 3-run index value so bycatch limits stay the same
2017	Due to amendment 110 about 45% of the TAC is taken in the A-season (traditionally only 40% was allowed).
2018	In-river estimates of Chinook salmon (three river index) fell below the threshold and therefore a lower PSC limit applies (from a performance standard of 47,491 to 33,318 and a PSC limit from 60,000 to 45,000 Chinook salmon overall). Additionally, squid have been recategorized as an ecosystem component.
2019	Some pollock sectors experienced high bycatch levels for chum and Chinook salmon and also for sablefish.
2020	Bycatch rates unusually high again for sablefish. Herring PSC occurred in the A season and triggered area closures that will persist into 2021. Salmon bycatch rates (relative to hours fished) was lower than last year for both chum and Chinook.
2021	Bycatch rates for sablefish and herring moderate (but above average). Chinook salmon bycatch rates (relative to hours fished) was lower than last year but there was a marked increase in the rate for chum salmon (2nd highest since 1991). In-river estimates of Chinook salmon (three river index) fell below the threshold and therefore a lower PSC limit applies (from a performance standard of 47,491 to 33,318 and a PSC limit from 60,000 to 45,000 Chinook salmon overall).
2022	Chum and Chinook salmon bycatch dropped by more than half of the 2021 levels while the rate (salmon per ton of pollock) were about 59% of the 2021 rates.
2023	The Council initiated and review preliminary analyses on the feasibility of proposed alternatives for additional management measures to minimize chum salmon bycatch in the Bering Sea.

Table 5: Eastern Bering Sea pollock catch at age estimates based on observer data, 1979–2022.  
 Units are in millions of fish.

	1979	101.4	543	719.8	420.1	392.5	215.5	56.3	25.7	35.9	27.5	17.6	7.9	3	1.1	2,567
1980	9.8	462.2	822.9	443.3	252.1	210.9	83.7	37.6	21.7	23.9	25.4	15.9	7.7	3.7	3.7	2,421
1981	0.6	72.2	1,012.70	637.9	227	102.9	51.7	29.6	16.1	9.3	7.5	4.6	1.5	1	1	2,175
1982	4.7	25.3	161.4	1,172.20	422.3	103.7	36	36	21.5	9.1	5.4	3.2	1.9	1	1	2,004
1983	5.1	118.6	157.8	312.9	816.8	218.2	41.4	24.7	19.8	11.1	7.6	4.9	3.5	2.1	1	1,745
1984	2.1	45.8	88.6	430.4	491.4	653.6	133.7	35.5	25.1	15.6	7.1	2.5	2.9	3.7	1	1,938
1985	2.6	55.2	381.2	121.7	365.7	321.5	443.2	112.5	36.6	25.8	24.8	10.7	9.4	9.1	1	1,920
1986	3.1	86	92.3	748.6	214.1	378.1	221.9	214.3	59.7	15.2	3.3	2.6	0.3	1.2	1	2,041
1987	-	19.8	111.5	77.6	413.4	138.8	122.4	90.6	247.2	54.1	38.7	21.4	28.9	14.1	1	1,379
1988	-	10.7	454	421.6	252.1	544.3	224.8	104.9	39.2	96.8	18.2	10.2	3.8	11.7	1	2,192
1989	-	4.8	55.1	149	451.1	166.7	572.2	96.3	103.8	32.4	129	10.9	4	8.5	1	1,784
1990	1.3	33	57	219.5	200.7	477.7	129.2	368.4	65.7	101.9	9	60.1	8.5	13.9	1	1,746
1991	1	111.6	43.5	85.1	156.1	184.5	500.5	76.2	289.2	28	139.5	18.3	93.6	76.9	1	1,804
1992	1.1	84.6	675.1	129.9	79.5	108.6	133.6	253.4	102.2	146.9	57.9	46.3	13.4	78.2	1	1,911
1993	0.1	7.4	260.3	1,145.50	102.9	66.1	66.3	56.4	86.1	21.1	32.7	12.3	13.5	22.9	1	1,893
1994	0.7	30.2	55.1	360.8	1,058.60	175.5	53.5	19.1	13.1	20.1	9.7	9.4	7.5	12.3	1	1,826
1995	-	0.5	72.8	146.6	395.1	760.3	136.1	34.5	12.3	7.5	17.5	5	5.8	10.6	1	1,605
1996	-	21.6	48	71.7	160.8	361.5	481.2	184.5	33.6	13.4	7.9	8.8	4.3	11.1	1	1,409
1997	1	77.6	40.3	118.9	454.7	288.7	256.1	198.4	64	13.3	6	4.6	2.9	13.9	1	1,540
1998	0.3	42	84.4	70.4	153.2	702.1	199.4	131.6	110.6	27.8	6.1	5.6	2.6	7	1	1,543
1999	0.2	10.3	298.4	224.8	102.9	156.9	469.3	130.9	56.4	33.1	4	2.2	0.9	2.5	1	1,493
2000	-	16.1	82.4	428.1	346.2	106.6	168.2	357.4	84.8	29.7	22	5.2	1.4	1.6	1	1,650
2001	-	3.2	42.7	154.3	580.5	414.6	137	128.9	157.1	57.8	33.6	16.2	5.5	5	1	1,736
2002	0.8	47	107.9	217.6	287.3	605.7	267.7	98.4	85.8	93.8	34.6	14.4	11	4.8	1	1,877
2003	-	14.5	411.4	323.8	360	301.2	337.3	158.4	49.4	39.2	35.7	22.9	6.6	6.8	1	2,067
2004	-	0.5	89.5	830.3	480.2	236.6	169.1	156.1	64.9	16.1	17	25.2	9.4	12.8	1	2,108
2005	-	4.8	52.1	392.5	862.9	484.1	159.3	68	66.6	30.1	10	9.1	3.2	5.9	1	2,149
2006	-	9.9	84.1	295.5	619	597	278.3	107.2	48	38.3	17.7	8.2	8.3	12.5	1	2,124
2007	1.7	15.7	59.1	139	389	511.5	300.5	136.9	47.6	27.5	21.8	8.9	6.5	14.2	1	1,680
2008	-	25.2	58.8	79.1	146.9	309.4	242	148.6	84.2	22.2	17.5	14.4	8.6	15.4	1	1,172
2009	-	1.3	175.3	200.4	82.5	114.3	124.2	104.2	66.6	40.2	23.5	7.6	7.5	11.4	1	959
2010	1.1	26.4	31.8	558.8	220.3	54.7	43	57.6	51.7	31.8	15.9	8.6	6	9.5	1	1,117
2011	0.4	10.3	193.1	115.3	808.4	284.4	63.5	37.5	38.5	41.4	25.8	12.5	1.8	8.3	1	1,641
2012	-	22.2	116.6	945.8	172.6	432.1	141.4	36.6	17.4	14.6	15.9	13.5	7.4	9.5	1	1,946
2013	1.8	1	63.9	342.1	954.9	194.2	156.4	69.9	20.7	12.7	12.7	10.8	7.8	10.5	1	1,859
2014	-	39.2	31	167.6	398.9	751	210	86.1	29.8	9	4.5	4.5	4.6	8.8	1	1,745
2015	-	15.5	631.8	196.2	228.3	383.9	509.6	88.7	42.1	17.6	2.9	2.1	3.1	3.9	1	2,126
2016	-	0.5	90.5	1,388.90	159.7	174.3	174.6	224.5	34	13.8	8	0.5	1.2	1.7	1	2,272
2017	-	2.2	28.1	548.5	898.1	215.3	147.4	122	97.2	21.7	7.2	5.6	0.5	0.4	1	2,094
2018	-	1.3	13.8	114.9	1,214.90	506.1	104.7	81.9	60.6	25.9	4.3	1.1	0.4	1.1	1	2,131
2019	0.7	10.9	12.3	18.3	157.4	915.9	422	93.1	52.1	52.9	10	2.9	0.8	-	1	1,749
2020	3.7	245.9	85.6	99.2	134.1	548.5	598.3	126.6	53.0	37.8	27.0	6.9	1.7	1.2	1	1,970
2021	0.0	111.3	1295.7	144.0	110.0	107.1	309.3	295.8	72.1	26.5	16.1	8.5	2.0	0.4	1	2,499
2022	0.0	64.6	174.7	1037.4	182.1	70.8	80.1	139.1	80.7	16.7	13.4	4.7	6.8	1.0	1	1,872
Mean	5.8	58.0	218.7	369.2	385.4	333.1	217.2	117.8	65.1	33.0	22.1	10.9	7.5	10.5	1	1,852

Table 6: Numbers of pollock NMFS observer samples measured for fishery catch length frequency (by sex and strata), 1977–2022.

Year	Length Frequency samples							
	A Season		B Season SE		B Season NW		Total	
	Males	Females	Males	Females	Males	Females		
1977	26,411	25,923	4,301	4,511	29,075	31,219	121,440	
1978	25,110	31,653	9,829	9,524	46,349	46,072	168,537	
1979	59,782	62,512	3,461	3,113	62,298	61,402	252,568	
1980	42,726	42,577	3,380	3,464	47,030	49,037	188,214	
1981	64,718	57,936	2,401	2,147	53,161	53,570	233,933	
1982	74,172	70,073	16,265	14,885	181,606	163,272	520,273	
1983	94,118	90,778	16,604	16,826	193,031	174,589	585,946	
1984	158,329	161,876	106,654	105,234	243,877	217,362	993,332	
1985	119,384	109,230	96,684	97,841	284,850	256,091	964,080	
1986	186,505	189,497	135,444	123,413	164,546	131,322	930,727	
1987	373,163	399,072	14,170	21,162	24,038	22,117	853,722	
-	-	-	-	-	-	-	-	
1991	155,876	143,625	148,385	132,539	123,516	122,241	826,182	
1992	152,566	148,024	150,829	152,003	93,073	94,701	791,196	
1993	136,211	126,635	145,280	137,384	24,797	26,057	596,364	
1994	138,179	146,067	154,311	148,497	26,431	26,380	639,865	
1995	128,719	125,847	175,115	150,323	16,142	16,327	612,473	
1996	147,992	139,905	193,493	149,814	18,101	18,288	667,593	
1997	123,454	102,619	114,846	106,001	58,492	51,498	556,910	
1998	135,136	109,119	205,282	174,676	31,968	39,475	695,656	
1999	36,035	32,407	38,229	35,084	16,258	18,321	176,334	
2000	64,430	58,030	63,746	41,027	40,839	39,105	307,177	
2001	79,190	75,491	54,037	51,179	44,232	45,766	349,895	
2002	71,502	69,467	65,299	64,243	37,661	39,285	347,457	
2003	74,902	77,533	49,307	52,899	51,764	53,435	359,840	
2004	75,208	75,811	63,146	61,957	47,261	44,220	367,603	
2005	75,784	68,665	43,271	33,917	68,831	63,022	353,490	
2006	72,543	63,349	35,378	27,939	77,620	67,219	344,048	
2007	66,533	63,969	38,104	29,558	76,755	70,504	345,423	
2008	51,303	46,296	23,467	20,462	64,126	60,678	266,332	
2009	43,476	41,540	17,343	16,148	45,418	47,926	211,851	
2010	41,019	39,495	20,577	19,194	40,914	40,449	201,648	
2011	62,295	58,481	65,057	60,208	48,055	50,927	345,023	
2012	57,946	53,557	46,942	45,024	53,243	49,968	306,680	
2013	62,148	51,984	44,582	37,307	49,649	49,161	294,831	
2014	58,066	55,954	51,743	46,568	46,067	46,642	305,040	
2015	56,419	55,646	43,601	46,853	41,183	45,117	288,819	
2016	58,915	57,478	69,654	72,973	9,015	10,264	278,299	
2017	64,693	55,965	65,982	70,285	14,125	15,871	286,921	
2018	64,628	57,156	49,653	56,243	32,796	35,811	296,287	
2019	64,665	49,191	54,927	59,416	27,753	34,955	290,907	
2020	65,609	60,018	47,791	53,161	48,459	53,985	329,023	
2021	75,561	59,580	53,205	61,208	27,641	30,833	308,028	
2022	57,459	46,843	43,299	47,450	16,811	18,006	229,868	

Table 7: Number of EBS pollock measured for weight and length by sex and strata as collected by the NMFS observer program, 1977-2022

	Weight-length samples						
	A Season		B Season SE		B Season NW		Total
	Males	Females	Males	Females	Males	Females	
1977	1,222	1,338	137	166	1,461	1,664	5,988
1978	1,991	2,686	409	516	2,200	2,623	10,425
1979	2,709	3,151	152	209	1,469	1,566	9,256
1980	1,849	2,156	99	144	612	681	5,541
1981	1,821	2,045	51	52	1,623	1,810	7,402
1982	2,030	2,208	181	176	2,852	3,043	10,490
1983	1,199	1,200	144	122	3,268	3,447	9,380
1984	980	1,046	117	136	1,273	1,378	4,930
1985	520	499	46	55	426	488	2,034
1986	689	794	518	501	286	286	3,074
1987	1,351	1,466	25	33	72	63	3,010
-	-	-	-	-	-	-	-
1991	2,893	2,791	1,209	1,116	2,536	2,408	12,953
1992	1,605	1,537	556	600	2,003	1,940	8,241
1993	1,278	1,205	451	437	1,412	1,459	6,242
1994	1,638	1,553	174	166	1,591	1,584	6,706
1995	1,258	1,220	232	223	1,352	1,331	5,616
1996	2,165	2,117	-	-	1,393	1,421	7,096
1997	629	630	552	536	674	620	3,641
1998	1,958	1,865	357	335	936	982	6,433
1999	4,813	5,337	3,767	3,546	7,182	7,954	32,599
2000	11,346	12,457	7,736	7,991	7,800	12,463	59,793
2001	14,411	14,965	9,064	8,803	10,460	10,871	68,574
2002	13,564	14,098	7,648	7,213	13,004	12,988	68,515
2003	15,535	14,857	10,272	10,031	10,111	9,437	70,243
2004	7,924	7,742	4,318	4,617	6,868	6,850	38,319
2005	7,039	7,428	6,426	6,947	4,114	5,139	37,093
2006	6,566	7,381	6,442	7,406	3,045	4,006	34,846
2007	6,640	6,695	7,081	7,798	3,202	4,305	35,721
2008	4,501	4,865	5,855	6,264	2,236	2,624	26,345
2009	4,033	4,382	4,655	4,511	1,723	1,934	21,238
2010	4,258	4,536	3,883	4,125	2,012	2,261	21,075
2011	5,845	6,388	4,954	4,647	5,929	6,456	34,219
2012	5,494	5,979	4,923	5,346	4,507	4,774	31,023
2013	5,689	6,525	4,844	4,920	3,599	4,313	29,890
2014	5,675	5,871	4,785	4,652	4,753	5,180	30,916
2015	5,310	5,323	4,648	4,194	4,365	4,064	27,904
2016	5,312	5,725	1,077	909	6,872	6,635	26,530
2017	5,238	6,047	1,586	1,343	6,575	6,254	27,043
2018	5,583	6,174	3,430	3,172	5,506	4,850	28,715
2019	4,513	6,086	3,594	2,953	5,809	5,499	28,454
2020	6,116	6,846	5,325	4,815	5,376	4,900	33,378
2021	5,852	7,368	6,247	5,468	2,886	2,698	30,519
2022	4,862	5,817	2,240	1,858	531	506	15,814

Table 8: Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977–2022, as sampled by the NMFS observer program.

	A Season		B Season SE		B Season NW		Total
	Males	Females	Males	Females	Males	Females	
1977	1,229	1,344	137	166	1,415	1,613	5,904
1978	1,992	2,686	407	514	2,188	2,611	10,398
1979	2,647	3,088	152	209	1,464	1,561	9,121
1980	1,854	2,158	93	138	606	675	5,524
1981	1,819	2,042	51	52	1,620	1,807	7,391
1982	2,030	2,210	181	176	2,865	3,062	10,524
1983	1,200	1,200	144	122	3,249	3,420	9,335
1984	980	1,046	117	136	1,272	1,379	4,930
1985	520	499	46	55	426	488	2,034
1986	689	794	518	501	286	286	3,074
1987	1,351	1,466	25	33	72	63	3,010
-	-	-	-	-	-	-	-
1991	439	431	367	349	263	289	2,138
1992	399	396	178	180	391	375	1,919
1993	476	445	122	124	496	507	2,170
1994	201	200	142	132	574	571	1,820
1995	313	299	131	123	420	439	1,725
1996	465	479	-	-	436	443	1,823
1997	437	434	343	341	313	286	2,154
1998	663	595	237	222	311	316	2,344
1999	506	541	298	308	748	750	3,151
2000	629	667	293	254	596	847	3,286
2001	563	603	205	178	697	736	2,982
2002	672	663	247	202	890	839	3,513
2003	653	588	274	262	701	671	3,149
2004	547	561	221	245	698	600	2,872
2005	599	617	420	422	490	614	3,162
2006	528	609	507	568	367	459	3,038
2007	627	642	552	568	485	594	3,468
2008	513	497	538	650	342	368	2,908
2009	404	484	440	432	240	299	2,299
2010	545	624	413	466	418	505	2,971
2011	581	808	404	396	582	660	3,431
2012	517	571	485	579	480	533	3,165
2013	666	703	525	568	401	518	3,381
2014	609	629	413	407	475	553	3,086
2015	653	642	511	493	508	513	3,320
2016	488	599	157	125	929	969	3,267
2017	604	778	179	163	777	753	3,254
2018	569	662	366	358	621	591	3,167
2019	552	778	387	332	558	531	3,138
2020	757	899	405	420	450	408	3,339
2021	760	910	588	542	270	256	3,326
2022	608	776	616	558	209	211	2,978

Table 9: NMFS total pollock research catch by year in t, 1964–2022.

Year	Bering Sea	Year	Bering Sea	Year	Bering Sea
1964	0	1983	508	2002	440
1965	18	1984	208	2003	285
1966	17	1985	435	2004	363
1967	21	1986	163	2005	87
1968	7	1987	174	2006	251
1969	14	1988	467	2007	333
1970	9	1989	393	2008	168
1971	16	1990	369	2009	156
1972	11	1991	465	2010	226
1973	69	1992	156	2011	1322
1974	83	1993	221	2012	219
1975	197	1994	267	2013	183
1976	122	1995	249	2014	308
1977	35	1996	206	2015	256
1978	94	1997	262	2016	198
1979	458	1998	121	2017	363
1980	139	1999	299	2018	269
1981	466	2000	313	2019	338
1982	682	2001	241	2020	13
				2021	898
				2022	246

Table 10: Survey biomass estimates (age 1+, t) of Eastern Bering Sea pollock based on design-based area-swept expansion methods from NMFS bottom trawl surveys 1982–2023 .

Year	Survey biomass			
	Strata 1-6	Strata 8-9	Total	%NW
1982	2,854,067	54,333	2,908,400	1.9%
1983	5,910,351	-	5,910,351	
1984	4,538,253	-	4,538,253	
1985	4,543,845	1,388,121	5,931,966	23.4%
1986	4,830,239	-	4,830,239	
1987	5,101,495	386,312	5,487,807	7.0%
1988	6,988,785	179,531	7,168,316	2.5%
1989	5,891,474	642,812	6,534,286	9.8%
1990	7,086,231	189,055	7,275,286	2.6%
1991	5,060,594	62,291	5,122,885	1.2%
1992	4,310,567	208,971	4,519,538	4.6%
1993	5,196,757	98,257	5,295,014	1.9%
1994	4,974,941	49,563	5,024,503	1.0%
1995	5,408,305	68,377	5,476,682	1.2%
1996	2,988,107	143,394	3,131,501	4.6%
1997	2,866,779	692,854	3,559,633	19.5%
1998	2,141,303	550,487	2,691,790	20.5%
1999	3,592,006	199,345	3,791,350	5.3%
2000	4,981,435	118,285	5,099,720	2.3%
2001	4,141,748	51,030	4,192,778	1.2%
2002	4,744,887	197,356	4,942,242	4.0%
2003	8,107,657	285,661	8,393,318	3.4%
2004	3,745,935	118,370	3,864,305	3.1%
2005	4,723,494	137,326	4,860,820	2.8%
2006	2,842,370	199,328	3,041,698	6.6%
2007	4,152,074	179,550	4,331,625	4.1%
2008	2,829,351	188,832	3,018,183	6.3%
2009	2,226,322	51,057	2,277,379	2.2%
2010	3,542,594	186,598	3,729,191	5.0%
2011	2,942,823	166,349	3,109,172	5.4%
2012	3,280,469	205,701	3,486,170	5.9%
2013	4,286,060	276,788	4,562,848	6.1%
2014	6,549,316	876,186	7,425,501	11.8%
2015	5,943,128	449,089	6,392,217	7.0%
2016	4,698,980	211,474	4,910,454	4.3%
2017	4,690,053	125,651	4,815,704	2.6%
2018	3,016,181	97,024	3,113,204	3.1%
2019	4,968,072	483,937	5,452,009	8.9%
2020				
2021	2,694,658	336,330	3,030,988	11.1%
2022	4,006,148	147,823	4,153,971	3.6%
2023	3,029,110	125,558	3,154,668	4.0%
Average	4,400,658	266,553	4,647,706	5.7%

Table 11: Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982–2023.

Year	Number of Hauls	Lengths	Aged	Year	Number of Hauls	Lengths	Aged
1982	329	40,001	1,611	1999	373	32,532	1,385
1983	354	78,033	1,931	2000	372	41,762	1,545
1984	355	40,530	1,806	2001	375	47,335	1,641
1985	434	48,642	1,913	2002	375	43,361	1,695
1986	354	41,101	1,344	2003	376	46,480	1,638
1987	356	40,144	1,607	2004	375	44,102	1,660
1988	373	40,408	1,173	2005	373	35,976	1,676
1989	373	38,926	1,227	2006	376	39,211	1,573
1990	371	34,814	1,257	2007	376	29,679	1,484
1991	371	43,406	1,083	2008	375	24,635	1,251
1992	356	34,024	1,263	2009	375	24,819	1,342
1993	375	43,278	1,385	2010	376	23,142	1,385
1994	375	38,901	1,141	2011	376	36,227	1,734
1995	376	25,673	1,156	2012	376	35,782	1,785
1996	375	40,789	1,387	2013	376	35,908	1,847
1997	376	35,536	1,193	2014	376	43,042	2,099
1998	375	37,673	1,261	2015	376	54,241	2,320
				2016	376	50,857	1,766
				2017	376	47,873	1,623
				2018	376	48,673	1,486
				2019	376	42,382	1,519
				—	—	—	—
				2021	376	53,545	1,528
				2022	376	36,687	1,578
				2023	376	xx,xxx	x,xxx

Table 12: Bottom-trawl survey estimated numbers (in tens of millions) at age used for the stock assessment model. Note that in 1982–84 and 1986 only strata 1–6 were surveyed. Note these estimates are based on design-based procedures.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1982	1,131	2,750	3,291	4,544	1,516	217	147	71	47	25	13	10	3	1	0	13,765
1983	451	656	1,619	3,060	6,727	1,979	367	193	75	69	53	18	9	7	2	15,286
1984	340	332	453	1,563	1,811	4,535	897	203	87	32	20	8	5	6	3	10,294
1985	2,825	686	3,172	1,421	4,743	2,406	1,720	355	87	68	19	6	7	1	0	17,516
1986	2,256	344	399	1,989	1,092	2,010	1,641	1,388	472	77	32	15	0	3	-	11,720
1987	305	630	893	583	5,633	1,141	1,369	519	1,671	235	88	30	4	2	2	13,105
1988	754	697	1,460	3,750	1,481	5,329	1,701	1,307	728	1,598	161	86	15	31	11	19,111
1989	792	332	655	2,147	4,770	1,054	3,986	582	749	284	727	136	107	61	69	16,452
1990	1,714	349	103	938	1,630	5,951	1,315	3,325	361	567	100	767	57	68	53	17,299
1991	3,102	1,021	132	77	641	594	1,945	740	1,684	410	568	116	313	45	32	11,419
1992	1,394	436	2,171	501	516	810	629	795	375	863	312	371	159	111	98	9,541
1993	1,637	305	1,137	3,972	684	511	305	466	629	394	352	255	165	109	131	11,050
1994	1,091	585	566	1,702	4,242	817	200	207	194	358	207	306	106	91	156	10,828
1995	1,465	98	445	1,955	2,748	4,630	1,634	349	285	240	314	148	224	80	111	14,726
1996	1,497	354	144	378	1,006	1,338	1,293	392	105	92	77	147	40	85	90	7,038
1997	2,535	312	194	229	3,129	1,348	864	1,026	154	58	67	80	94	32	115	10,238
1998	660	628	252	204	465	2,610	720	465	345	88	30	11	27	25	59	6,590
1999	1,064	948	854	1,016	591	966	2,833	765	424	349	144	46	21	27	82	10,131
2000	1,090	389	379	1,744	1,720	1,050	758	2,773	1,003	548	205	162	30	16	83	11,949
2001	1,675	954	511	542	1,311	1,490	568	307	969	715	252	208	71	30	76	9,679
2002	761	425	729	1,063	1,286	1,661	921	473	571	1,158	552	250	149	43	42	10,083
2003	412	162	684	2,063	2,201	1,995	2,479	1,369	576	888	1,875	759	283	103	69	15,918
2004	367	267	156	1,250	1,439	1,049	612	669	317	201	197	365	155	35	28	7,106
2005	383	145	195	1,028	2,747	2,210	1,206	447	382	276	74	149	267	95	90	9,693
2006	866	43	45	370	990	1,269	843	391	227	198	98	56	85	113	110	5,704
2007	2,338	40	101	450	1,461	1,735	1,281	902	390	166	148	146	61	82	146	9,450
2008	505	93	65	147	530	1,163	861	597	402	150	129	99	48	28	143	4,963
2009	793	138	400	458	236	362	530	446	350	159	103	35	32	18	69	4,130
2010	548	119	148	2,902	1,396	414	364	378	386	270	228	85	48	27	65	7,377
2011	1,113	101	243	364	1,788	908	257	165	244	235	186	152	59	30	80	5,924
2012	1,173	197	380	3,199	744	1,282	411	193	123	165	143	122	107	38	64	8,340
2013	1,204	89	133	958	4,953	1,171	737	259	82	79	101	79	71	37	47	10,000
2014	2,238	517	106	382	1,691	6,261	3,210	737	380	149	56	68	62	37	78	15,971
2015	1,167	771	2,166	603	1,181	2,283	4,471	1,324	314	140	22	18	39	15	30	14,543
2016	734	375	646	3,258	1,341	936	1,338	1,909	372	142	47	10	8	5	4	11,125
2017	850	249	415	2,401	3,299	1,399	1,096	1,082	1,354	406	165	49	8	10	7	12,790
2018	1,027	447	161	361	2,609	1,510	501	373	375	281	91	13	2	-	4	7,754
2019	2,545	659	303	487	1,464	5,477	2,241	561	426	244	132	56	23	14	-	14,633
2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2021	906	522	1,251	668	554	435	1,174	1,359	355	134	107	72	14	10	3	7,563
2022	904	292	500	3,218	1,571	694	763	1,088	859	254	101	88	39	14	-	10,386
2023	1,384	329	258	627	2,681	630	325	315	554	387	97	42	44	8	11	7,693
Mean	1,219	458	681	1,429	2,015	1,845	1,232	763	475	321	205	138	75	39	55	10,948

Table 13: Mean EBS pollock body mass (kg) at age as estimated for the summer NMFS bottom trawl survey, 1982–2023.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	0.032	0.077	0.181	0.340	0.411	0.777	1.051	1.188	1.401	1.567	2.235	1.990	1.904	1.524	2.946
1983	0.021	0.101	0.209	0.342	0.536	0.774	1.016	1.453	1.406	1.667	1.529	1.577	2.013	2.127	1.834
1984	0.017	0.084	0.215	0.314	0.432	0.603	0.926	1.313	1.268	1.473	1.985	1.688	1.905	1.426	2.122
1985	0.031	0.093	0.229	0.368	0.481	0.715	0.910	1.213	1.723	1.436	1.532	1.777	2.038	1.652	2.634
1986	0.019	0.073	0.169	0.310	0.414	0.608	0.767	1.018	1.304	1.650	1.276	1.381	1.983	2.233	2.223
1987	0.023	0.123	0.253	0.332	0.422	0.547	0.718	0.849	1.008	1.261	1.581	1.612	2.202	2.045	2.395
1988	0.019	0.133	0.281	0.330	0.446	0.494	0.590	0.814	0.908	1.040	1.230	1.285	1.571	0.686	1.740
1989	0.022	0.082	0.169	0.277	0.371	0.549	0.662	0.837	1.027	1.000	1.115	1.014	1.260	1.144	1.103
1990	0.029	0.097	0.187	0.356	0.478	0.545	0.614	0.735	1.029	0.979	1.023	1.188	0.855	1.390	1.714
1991	0.030	0.145	0.201	0.333	0.565	0.650	0.777	0.856	1.016	1.105	1.287	1.370	1.347	1.733	1.691
1992	0.030	0.134	0.255	0.400	0.464	0.570	0.756	0.771	0.929	1.008	1.138	1.520	1.539	1.426	1.563
1993	0.016	0.098	0.250	0.409	0.464	0.548	0.662	0.783	0.987	0.999	1.149	1.285	1.509	1.576	1.909
1994	0.025	0.117	0.212	0.401	0.536	0.672	0.648	1.046	1.166	1.107	1.219	1.241	1.367	1.436	1.451
1995	0.018	0.105	0.169	0.363	0.478	0.648	0.624	0.785	0.911	1.281	1.222	1.254	1.399	1.422	1.740
1996	0.021	0.112	0.151	0.300	0.487	0.583	0.758	0.820	0.979	1.023	1.350	1.461	1.487	1.639	1.964
1997	0.017	0.095	0.189	0.277	0.382	0.530	0.674	0.776	0.996	0.966	1.211	1.465	1.090	1.566	1.951
1998	0.016	0.081	0.213	0.332	0.446	0.519	0.811	0.887	1.078	1.293	1.592	1.415	1.516	1.669	1.905
1999	0.020	0.097	0.216	0.351	0.392	0.526	0.616	0.882	1.038	1.008	1.279	1.132	1.666	1.760	2.192
2000	0.017	0.085	0.219	0.398	0.470	0.521	0.722	0.759	0.925	1.035	1.236	1.338	1.782	1.626	2.048
2001	0.022	0.092	0.201	0.356	0.617	0.729	0.750	1.000	0.982	1.031	1.278	1.419	1.474	1.766	1.539
2002	0.025	0.107	0.269	0.402	0.544	0.685	0.713	0.904	1.006	1.053	1.010	1.139	1.474	1.410	2.108
2003	0.032	0.109	0.342	0.419	0.648	0.710	0.886	0.869	1.124	1.239	1.269	1.285	1.369	1.747	1.780
2004	0.035	0.202	0.284	0.516	0.595	0.750	0.895	0.932	1.119	1.027	1.279	1.552	1.537	2.375	1.712
2005	0.034	0.112	0.231	0.394	0.539	0.698	0.859	0.931	0.993	1.223	1.383	1.229	1.401	1.504	1.682
2006	0.010	0.087	0.179	0.457	0.605	0.679	0.789	0.866	1.058	1.171	1.279	1.336	1.669	1.519	1.704
2007	0.015	0.100	0.294	0.493	0.637	0.810	0.928	1.060	1.002	1.315	1.309	1.268	1.417	1.367	1.385
2008	0.019	0.059	0.220	0.491	0.601	0.730	0.857	0.946	0.987	1.154	1.640	1.372	1.708	1.540	1.682
2009	0.019	0.070	0.241	0.509	0.688	0.815	1.010	1.068	1.121	1.359	1.449	1.769	1.767	2.049	2.486
2010	0.023	0.069	0.244	0.496	0.657	0.804	1.097	1.140	1.260	1.376	1.190	1.389	1.629	2.161	2.221
2011	0.018	0.081	0.216	0.511	0.653	0.785	0.907	1.066	1.159	1.246	1.358	1.419	1.365	1.496	2.016
2012	0.017	0.076	0.285	0.410	0.592	0.738	0.865	1.008	1.354	1.203	1.340	1.424	1.500	1.711	1.981
2013	0.020	0.067	0.228	0.516	0.577	0.721	0.973	1.173	1.265	1.461	1.513	1.404	1.717	1.822	1.965
2014	0.019	0.113	0.393	0.445	0.567	0.693	0.737	0.978	1.136	1.336	1.534	1.484	1.638	1.638	2.012
2015	0.020	0.091	0.347	0.442	0.566	0.675	0.742	0.864	1.064	1.270	1.545	1.455	1.446	1.482	1.596
2016	0.022	0.090	0.278	0.524	0.574	0.688	0.764	0.795	0.883	0.919	1.193	1.846	1.244	1.228	1.393
2017	0.026	0.096	0.242	0.488	0.621	0.649	0.740	0.782	0.889	0.923	0.998	1.013	1.323	1.020	1.813
2018	0.024	0.101	0.210	0.442	0.575	0.665	0.756	0.750	0.845	0.886	0.722	0.838	0.876	1.074	0.964
2019	0.026	0.112	0.292	0.505	0.642	0.715	0.823	0.899	0.901	0.989	0.986	1.043	1.068	1.120	1.390
2020	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2021	0.023	0.148	0.278	0.440	0.590	0.696	0.774	0.854	0.960	1.233	1.023	1.350	1.307	0.927	1.389
2022	0.020	0.104	0.347	0.452	0.583	0.668	0.764	0.853	0.945	0.972	1.122	1.474	1.242	0.895	1.247
2023	0.020	0.104	0.315	0.418	0.530	0.642	0.784	0.925	0.979	1.024	1.166	1.137	1.445	1.845	1.428
Avg	0.022	0.101	0.242	0.406	0.534	0.662	0.798	0.938	1.076	1.178	1.312	1.381	1.513	1.556	1.820

Table 14: Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1982–2023 (thousands of t). Note that the bottom-trawl survey data only represent biomass from the survey strata (1–6) areas in 1982–1984, and 1986. For all other years the estimates include strata 8–9. DDC indicates the values obtained from the Kotwicki et al. Density-dependence correction method and the VAST column is for the standard survey area including the Northern Bering Sea extension and uses the cold pool as a covariate. BTS=Bottom trawl survey, DB=Design-based, ATS=acoustic trawl survey. The ATS estimate from 2020 arises from data collected aboard uncrewed sailing vessels with acoustic backscatter scaled to be consistent with previous years. BTS estimates include northern Bering Sea extensions.

Year	DB.BTS	DDC	VAST	ATS
1982	2,614	4,359	3,872	
1983	5,910	8,393	8,929	
1984	4,538	6,405	6,594	
1985	5,932	8,225	7,522	
1986	4,830	6,818	7,242	
1987	5,488	7,875	7,598	
1988	7,168	11,062	11,808	
1989	6,534	9,770	9,944	
1990	7,275	11,864	11,591	
1991	5,123	7,383	7,140	
1992	4,520	6,201	6,658	
1993	5,295	7,092	7,860	
1994	5,025	7,093	7,107	3,629
1995	5,477	9,103	6,614	
1996	3,132	4,089	3,953	2,945
1997	3,560	5,016	4,381	3,591
1998	2,692	3,515	3,426	
1999	3,791	5,442	5,621	4,141
2000	5,100	7,347	7,251	3,626
2001	4,193	5,434	6,080	
2002	4,942	6,754	6,756	4,306
2003	8,393	13,516	11,270	
2004	3,864	5,109	5,492	4,010
2005	4,861	6,685	6,986	
2006	3,042	3,881	4,193	1,873
2007	4,332	6,137	6,783	2,278
2008	3,018	3,987	4,295	1,406
2009	2,277	2,983	2,825	1,325
2010	3,750	5,141	5,287	2,642
2011	3,109	3,945	4,510	
2012	3,486	4,614	5,159	2,296
2013	4,563	6,098	6,740	
2014	7,426	10,329	11,648	4,730
2015	6,392	8,584	11,235	
2016	4,910	6,611	8,282	4,829
2017	6,135	7,922	8,874	
2018	3,113	4,186	4,258	2,499
2019	6,619	8,767	9,288	
2020	—	—	—	3,605
2021	3,505	4,154	4,886	
2022	4,549	5,891	6,532	3,834
2023	3,519	4,279	4,934	
Avg.	4,732	6,636	6,864	3,198

Table 15: Number of (age 1+) hauls and sample sizes for EBS pollock collected by the AT surveys. Sub-headings E and W represent collections east and west of 170W (within the US EEZ) and US represents the US sub-total and RU represents the collections from the Russian side of the surveyed region.

Year	Hauls				Lengths				Otoliths				Number aged				
	E	W	US	RU	E	W	US	RU	E	W	US	RU	E	W	US	RU	
1979			25				7,722				0					2,610	
1982	13	31	48		1,725	6,689	8,687		840	2,324	3,164		783	1,958	2,741		
1985			73				19,872				2,739					2,739	
1988			25				6,619				1,471					1,471	
1991			62				16,343				2,062					1,663	
1994	25	51	76	19	4,553	21,011	25,564	8,930	1,560	3,694	4,966	1,270	612	932	1,770	455	
1996	15	42	57		3,551	13,273	16,824		669	1,280	1,949		815	1,111	1,926		
1997	25	61	86		6,493	23,043	29,536		966	2,669	3,635		936	1,349	2,285		
1999	41	77	118		13,841	28,521	42,362		1,945	3,001	4,946		946	1,500	2,446		
2000	29	95	124		7,721	36,008	43,729		850	2,609	3,459		850	1,403	2,253		
2002	47	79	126		14,601	25,633	40,234		1,424	1,883	3,307			1,000	1,200	2,200	
2004	33	57	90	15	8,896	18,262	27,158	5,893	1,167	2,002	3,169	461	798	1,192	2,351	461	
2006	27	56	83		4,939	19,326	24,265		822	1,871	2,693		822	1,870	2,692		
2007	23	46	69	4	5,492	14,863	20,355	1,407	871	1,961	2,832	319	823	1,737	2,560	315	
2008	9	53	62	6	2,394	15,354	17,748	1,754	341	1,698	2,039	177	338	1,381	1,719	176	
2009	13	33	46	3	1,576	9,257	10,833	282	308	1,210	1,518	54	306	1,205	1,511	54	
2010	11	48	59	9	2,432	20,263	22,695	3,502	653	1,868	2,521	381	652	1,598	2,250	379	
2012	17	60	77	14	4,422	23,929	28,351	5,620	650	2,045	2,695	418	646	1,483	2,129	416	
2014	52	87	139	3	28,857	8,645	37,502	747	1,739	849	2,588	72	845	1,735	2,580	72	
2016	37	71	108		10,912	24,134	35,046		880	1,514	2,394			876	1,513	2,388	
2018	36	64	100		11,031	21,173	32,204		1,105	1,750	2,855		1,100	1,743	2,843		
2022	26	36	62		4,954	11,994	16,948		671	1,691	2,362		668	1,688	2,356		

Table 16: Mid-water pollock biomass (millions of t; near surface down to 0.5m from the bottom) by area as estimated from summer acoustic-trawl surveys on the U.S. EEZ portion of the Bering Sea shelf, 1994–2023 (Honkalehto et al. 2015, McCarthy et al. 2020, and De Robertis et al. 2021). Note that in 2020 the survey was carried out by uncrewed sailing vessels.

Year	Date	Area (nmi) <sup>2</sup>	Biomass					Rel. Error	CV
			SCA	E170-SCA	W170	0.5m	Total		
1994	9 Jul - 19 Aug	78,251	0.378	0.656	2.595		3.629	0.040	19%
1996	20 Jul - 30 Aug	93,810	0.272	0.49	2.182		2.944	0.032	15%
1997	17 Jul - 4 Sept	102,770	0.274	0.853	2.463		3.59	0.029	14%
1999	7 Jun - 5 Aug	103,670	0.323	0.758	3.06		4.141	0.044	20%
2000	7 Jun - 2 Aug	106,140	0.457	0.717	2.452		3.626	0.028	13%
2002	4 Jun - 30 Jul	99,526	0.755	0.946	2.605		4.306	0.027	12%
2004	4 Jun - 29 Jul	99,659	0.550	0.918	2.528		3.996	0.031	14%
2006	3 Jun - 25 Jul	89,550	0.147	0.340	1.387		1.874	0.033	16%
2007	2 Jun - 30 Jul	92,944	0.136	0.245	1.899		2.280	0.038	18%
2008	2 Jun - 31 Jul	95,374	0.122	0.087	1.196		1.404	0.056	26%
2009	9 Jun - 7 Aug	91,414	0.156	0.058	1.117		1.331	0.069	32%
2010	5 Jun - 7 Aug	92,849	0.098	0.193	2.345		2.636	0.054	25%
2012	7 Jun - 10 Aug	96,852	0.196	0.319	1.764		2.279	0.034	16%
2014	12 Jun - 13 Aug	94,361	0.571	1.458	2.714		4.743	0.034	16%
2016	12 Jun - 17 Aug	100,674	0.542	1.268	3.028		4.838	0.019	9%
2018	12 Jun - 22 Aug	92,283	0.234	0.510	1.753		2.497	0.039	18%
2020	4 Jul - 20 Aug	102,320	0.398	0.531	2.688		3.617	0.096	45%
2022	1 Jun - 5 Aug	103,942	0.538	0.826	2.470		3.834	0.068	32%

Table 17: AT survey estimates of EBS pollock abundance-at-age (millions), 1979–2023. Age-1s were modeled as a separate index, ages 2+ modeled as proportions at age.

Year	Age										Age		
	1	2	3	4	5	6	7	8	9	10+	2+	Total	
1979	69,110	41,132	3,884	413	534	128	30	4	28	161	46,314	115,424	
1982	108	3,401	4,108	7,637	1,790	283	141	178	90	177	17,805	17,913	
1985	2,076	929	8,149	898	2,186	1,510	1,127	130	21	15	14,965	17,041	
1988	11	1,112	3,586	3,864	739	1,882	403	151	130	414	12,280	12,292	
1991	639	5,942	967	215	224	133	120	39	37	53	7,730	8,369	
1994	1,140	4,969	1,424	1,819	2,252	389	109	96	56	221	11,335	12,475	
1996	1,800	567	552	2,741	915	634	585	142	39	165	6,338	8,139	
1997	13,227	2,881	440	536	2,330	546	313	290	75	220	7,633	20,860	
1999	607	1,780	3,717	1,810	652	398	1,548	526	180	249	10,859	11,466	
2000	460	1,322	1,230	2,588	1,012	327	308	950	278	252	8,266	8,726	
2002	796	4,944	3,385	1,295	661	935	538	140	162	493	12,554	13,351	
2004	83	313	1,217	3,123	1,634	567	288	283	121	265	7,811	7,894	
2006	525	217	291	654	783	659	390	145	75	171	3,386	3,910	
2007	5,775	1,041	345	478	794	729	407	241	98	135	4,267	10,042	
2008	71	2,915	1,047	166	161	288	235	136	102	120	5,169	5,240	
2009	5,197	816	1,734	281	77	94	129	111	77	114	3,433	8,630	
2010	2,568	6,404	984	2,295	446	73	33	37	38	91	10,400	12,968	
2012	177	1,989	1,693	2,710	280	367	113	36	25	103	7,315	7,492	
2014	4,751	8,655	969	1,161	1,119	1,770	740	170	79	99	14,762	19,513	
2016	174	1,038	4,496	4,476	715	348	392	420	96	64	12,046	12,220	
2018	450	517	249	621	2,268	944	198	112	107	104	5,120	5,570	
2022	142	332	975	6,578	819	211	133	239	166	79	9,533	9,674	
Mean	4,995	4,237	2,066	2,107	1,018	601	376	208	95	171	10,878	15,873	
Median	623	1,551	1,224	1,553	789	394	298	144	85	148	8,900	10,754	

Table 18: An abundance index derived from acoustic data collected opportunistically aboard bottom-trawl survey vessels (AVO index; Stienessen et al. 2022 and updated in Ianelli 2023). Relative error developed from 1-D geostatistical estimates of sampling variability (Petitgas 1993). See Honkalehto et al. 2011 for the derivation of these estimates. The column “ $CV_{AVO}$ ” was based on consistency of model fits through an iterative re-weighting process.

Year	AT scaled biomass index	AVO index	Relative error	$CV_{AVO}$
2006	1.8729	1.741	0.0510	23%
2007	2.2779	2.002	0.0865	40%
2008	1.4056	0.992	0.0643	30%
2009	1.3248	0.695	0.1222	56%
2010	2.6423	1.922	0.0656	30%
2011	—no survey—	1.704	0.0572	26%
2012	2.2958	1.521	0.0532	24%
2013	—no survey—	2.178	0.0390	18%
2014	4.73	3.077	0.0411	19%
2015	—no survey—	3.593	0.0246	11%
2016	4.829	2.832	0.0291	13%
2017	—no survey—	2.263	0.0305	14%
2018	2.4994	2.084	0.0266	12%
2019	—no survey—	2.829	0.0489	22%
2020	3.62			
2021	—no survey—	2.410	0.0479	22%
2022	3.834	2.903	0.0341	16%
2023	—no survey—	2.481	0.0294	14%
Mean	2.848	2.190	5%	23%

Table 19: Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964–2023. Note fishery sample size for 1964–1977 was fixed at 10.

Year	Fishery	BTS	ATS
1978	39		
1979	39		
1980	39		
1981	39		
1982	39	77	
1983	39	24	
1984	39	112	
1985	39	31	
1986	39	73	
1987	39	71	
1988	39	62	
1989	39	95	
1990	39	83	
1991	259	65	
1992	227	41	
1993	343	43	
1994	285	52	43
1995	256	40	
1996	188	111	32
1997	318	42	49
1998	353	100	
1999	474	91	67
2000	481	80	70
2001	327	110	
2002	485	117	72
2003	439	80	
2004	389	89	51
2005	493	94	
2006	504	139	47
2007	498	78	39
2008	522	106	35
2009	419	67	26
2010	547	87	34
2011	725	118	
2012	605	126	44
2013	751	149	
2014	604	148	79
2015	818	203	
2016	702	174	61
2017	605	234	
2018	665	99	50
2019	698	151	
2020	563		
2021	815	129	
2022	639	163	52
2023		148	

Table 20: Mean weight-at-age (kg) estimates from the fishery (1991–2021; plus projections 2023–2025) showing the between-year variability (bottom row).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1964–															
1990	0.007	0.17	0.303	0.447	0.589	0.722	0.84	0.942	1.029	1.102	1.163	1.212	1.253	1.286	1.312
1991	0.007	0.15	0.288	0.485	0.606	0.729	0.844	0.883	1.016	1.124	1.141	1.232	1.222	1.295	1.252
1992	0.007	0.179	0.397	0.465	0.651	0.714	0.819	0.986	1.03	1.2	1.237	1.269	1.193	1.357	1.431
1993	0.007	0.331	0.495	0.612	0.652	0.775	0.934	1.062	1.198	1.24	1.423	1.54	1.576	1.609	1.508
1994	0.007	0.233	0.4	0.652	0.732	0.746	0.727	1.07	1.38	1.325	1.335	1.409	1.397	1.278	1.37
1995	0.007	0.153	0.386	0.505	0.729	0.843	0.847	0.97	1.232	1.296	1.401	1.402	1.392	1.095	1.306
1996	0.007	0.293	0.336	0.445	0.684	0.797	0.948	0.956	1.025	1.1	1.418	1.489	1.521	1.702	1.602
1997	0.007	0.187	0.327	0.477	0.559	0.748	0.889	1.074	1.095	1.236	1.287	1.4	1.561	1.363	1.338
1998	0.007	0.191	0.369	0.589	0.618	0.622	0.78	1.04	1.169	1.276	1.316	1.428	1.448	1.437	1.528
1999	0.007	0.188	0.404	0.507	0.643	0.702	0.729	0.894	1.038	1.253	1.224	1.422	0.995	0.616	1.239
2000	0.007	0.218	0.353	0.526	0.63	0.732	0.78	0.807	0.968	1.015	1.253	1.286	1.108	1.084	1.359
2001	0.006	0.227	0.329	0.505	0.668	0.786	0.964	0.986	1.061	1.133	1.32	1.411	1.568	1.472	1.495
2002	0.007	0.231	0.385	0.51	0.667	0.799	0.911	1.026	1.113	1.102	1.284	1.442	1.579	1.29	1.568
2003	0.006	0.276	0.489	0.549	0.652	0.769	0.863	0.953	1.086	1.202	1.212	1.194	1.374	1.355	1.709
2004	0.007	0.135	0.408	0.584	0.641	0.76	0.888	0.924	1.036	1.176	1.127	1.167	1.31	1.254	1.185
2005	0.007	0.283	0.351	0.508	0.641	0.742	0.88	0.96	1.062	1.074	1.216	1.268	1.217	1.075	1.342
2006	0.007	0.174	0.306	0.448	0.606	0.755	0.858	0.959	1.06	1.117	1.19	1.218	1.28	1.384	1.417
2007	0.007	0.155	0.349	0.507	0.642	0.783	0.961	1.1	1.192	1.266	1.327	1.488	1.444	1.729	1.512
2008	0.007	0.208	0.328	0.519	0.653	0.774	0.9	1.054	1.117	1.289	1.452	1.528	1.56	1.874	1.645
2009	0.007	0.136	0.34	0.525	0.705	0.879	0.999	1.13	1.398	1.479	1.558	1.576	1.807	2.026	2.222
2010	0.05	0.175	0.381	0.49	0.668	0.909	1.114	1.277	1.374	1.586	1.679	1.923	1.948	2.077	2.271
2011	0.031	0.205	0.29	0.508	0.666	0.809	0.971	1.224	1.342	1.513	1.582	1.623	2.08	1.707	2.242
2012	0.029	0.142	0.271	0.409	0.643	0.824	0.974	1.17	1.303	1.509	1.599	1.637	1.68	2.031	2.062
2013	0.095	0.144	0.29	0.442	0.564	0.781	1.13	1.281	1.44	1.685	1.827	1.786	1.934	2.159	2.182
2014	0.014	0.193	0.319	0.454	0.617	0.751	0.894	1.156	1.307	1.386	1.669	1.773	1.704	1.623	2.215
2015	0.025	0.181	0.404	0.462	0.571	0.69	0.786	0.887	1.141	1.195	1.315	1.671	1.389	1.559	2.6
2016	0.025	0.181	0.409	0.531	0.557	0.646	0.732	0.8	0.941	1.043	1.178	0.788	0.911	1.684	1.429
2017	0.025	0.191	0.408	0.499	0.65	0.694	0.752	0.827	0.894	0.911	1.028	0.961	0.312	0.701	0.688
2018	0.025	0.186	0.377	0.467	0.573	0.734	0.809	0.853	0.906	1.039	0.936	1.11	0.568	1.454	1.13
2019	0.025	0.186	0.422	0.565	0.643	0.759	0.878	0.962	1.007	1.065	1.035	1.182	0.754	1.454	1.593
2020	0.025	0.186	0.387	0.522	0.632	0.716	0.799	0.955	1.006	1.04	1.189	1.072	1.208	0.961	1.56
2021	0.025	0.186	0.393	0.48	0.574	0.69	0.757	0.841	1.011	1.13	1.16	1.269	1.214	1.405	1.56
2022	0.025	0.186	0.44	0.506	0.574	0.724	0.837	0.883	0.984	0.972	1.271	1.044	1.235	0.91	1.56
2023	0.025	0.186	0.394	0.548	0.626	0.732	0.842	0.911	0.998	1.126	1.142	1.172	1.255	1.333	1.472
2024	-	-	0.382	0.514	0.714	0.784	0.851	0.96	1.056	1.108	1.179	1.291	1.293	1.308	1.379
2025	-	-	0.382	0.507	0.642	0.84	0.907	0.969	1.071	1.159	1.202	1.265	1.37	1.364	1.372
Mean	0.007	0.18	0.318	0.462	0.605	0.73	0.842	0.95	1.05	1.122	1.193	1.244	1.277	1.305	1.33
CV	-	-	17%	11%	8%	8%	12%	13%	14%	16%	17%	20%	29%	28%	30%

Table 21: Goodness-of-fit measures to primary data for different assessment model configurations. RMSE=root-mean square log errors, NLL=negative log-likelihood, SDNR=standard deviation of normalized residuals, Eff. N=effective sample size for composition data). See text for incremental model descriptions.

Component	m1	m2	m3	m4	m5	m6	m7	m8
RMSE BTS	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
RMSE ATS	0.19	0.18	0.18	0.18	0.18	0.19	0.19	0.19
RMSE AVO	0.27	0.24	0.23	0.23	0.24	0.24	0.23	0.23
RMSE CPUE	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
SDNR BTS	0.98	1.01	1.01	1.00	1.02	1.00	1.00	1.01
SDNR ATS	1.03	1.02	1.02	1.02	1.02	1.02	1.03	1.03
SDNR AVO	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00
Eff. N Fishery	1237.96	1253.65	1254.20	1241.10	1234.60	1242.84	1238.96	1227.06
Eff. N BTS	225.24	213.23	212.36	209.35	205.24	194.99	211.99	188.90
Eff. N ATS	250.35	255.91	255.18	252.65	252.78	252.54	251.29	243.03
Catch NLL	2.45	2.57	2.57	2.82	2.88	2.70	2.83	2.94
BTS NLL	31.30	32.80	32.80	32.51	34.32	32.11	32.83	33.57
ATS NLL	8.73	8.63	8.60	8.63	8.62	8.72	8.72	8.75
AVO NLL	8.01	8.59	8.45	8.46	8.46	8.68	8.49	8.50
Fish Age NLL	145.30	158.90	158.79	162.34	162.55	159.96	161.89	160.74
BTS Age NLL	158.95	161.77	162.32	164.44	165.48	174.66	166.08	166.63
ATS Age NLL	28.97	29.17	28.67	29.07	29.09	29.03	29.53	29.91
NLL selectivity	167.61	178.40	177.95	180.55	182.76	187.76	184.73	185.57
NLL Priors	19.90	19.92	19.92	19.92	19.91	19.92	19.91	19.87
Data NLL	403.83	423.34	423.06	429.12	432.15	436.71	431.12	431.61
Total NLL	626.51	657.50	656.89	665.60	670.66	680.73	671.43	672.23

Table 22: Summary of different model results and the stock condition for EBS pollock. Biomass units are thousands of t.

Component	Last year	Model 23.0
$B_{2024}$	4,000	3,500
$CV_{B_{2024}}$	0.13	0.14
$B_{MSY}$	2,667	2,689
$CV_{B_{MSY}}$	0.2	0.2
$B_{2024}/B_{MSY}$	150%	131%
$B_0$	6,640	6,728
$B_{35\%}$	2,114	2,060
SPR rate at $F_{MSY}$	33%	34%
Steepness	0.61	0.6
Est. $B_{2023}/B_{2023, no fishing}$	0.61	0.58
$B_{2023}/B_{MSY}$	143%	137%

Table 23: Estimates of begin-year age 3 and older biomass (thousands of tons) and coefficients of variation (CV) for the current assessment compared to 2016–2022 assessments for EBS pollock.

Year	Current	CV	2022	CV	2021	CV	2020	CV	2019	CV	2018	CV	2017	CV	2016	CV
1964	1,749	21	1,691	21	1,659	21	1,855	22	1,866	22	1,744	22	1,779	22	1,834	22
1965	2,127	19	2,056	19	2,021	20	2,256	20	2,270	20	2,124	20	2,165	20	2,229	20
1966	2,277	19	2,215	19	2,188	19	2,419	19	2,433	19	2,277	19	2,326	19	2,404	19
1967	3,524	17	3,436	17	3,416	17	3,679	17	3,695	17	3,504	17	3,566	17	3,667	17
1968	4,035	17	3,950	17	3,943	17	4,201	17	4,217	17	4,011	17	4,082	17	4,198	17
1969	5,141	16	5,039	16	5,045	16	5,297	15	5,316	15	5,105	16	5,174	15	5,294	15
1970	5,559	14	5,693	15	5,713	15	5,937	14	5,957	14	5,757	15	5,820	14	5,936	14
1971	6,166	13	6,144	13	6,173	13	6,367	13	6,390	13	6,209	13	6,260	13	6,360	13
1972	5,911	12	5,838	12	5,873	12	6,038	12	6,063	12	5,902	12	5,940	12	6,024	12
1973	4,826	13	4,674	13	4,719	13	4,855	13	4,880	13	4,729	13	4,765	13	4,845	13
1974	3,631	16	3,425	16	3,481	16	3,594	16	3,619	16	3,474	16	3,510	16	3,589	16
1975	3,959	13	3,519	12	3,592	12	3,710	12	3,740	12	3,585	12	3,611	12	3,679	12
1976	3,822	10	3,428	9	3,534	10	3,670	10	3,708	10	3,515	10	3,538	10	3,608	10
1977	4,206	9	3,317	8	3,470	9	3,646	9	3,690	9	3,426	8	3,446	8	3,535	8
1978	3,694	9	3,122	8	3,333	8	3,564	8	3,607	8	3,250	8	3,273	8	3,375	8
1979	3,521	8	2,935	7	3,221	8	3,557	8	3,595	8	3,087	8	3,116	8	3,239	8
1980	4,488	7	3,594	6	4,039	7	4,537	6	4,578	6	3,856	6	3,896	6	4,068	6
1981	7,841	5	6,738	4	7,493	5	8,422	4	8,451	4	7,314	5	7,453	5	7,813	4
1982	8,301	5	7,791	4	8,541	5	9,542	4	9,569	4	8,448	5	8,645	5	9,056	4
1983	10,244	5	8,968	4	9,615	5	10,807	4	10,832	4	9,556	4	9,849	4	10,240	4
1984	9,574	4	8,967	5	9,516	5	10,622	4	10,645	4	9,428	4	9,731	4	10,033	4
1985	12,622	3	11,304	4	11,658	4	12,566	3	12,592	3	11,615	4	11,887	4	12,237	3
1986	10,547	3	10,796	4	10,997	4	11,766	3	11,790	3	11,039	3	11,278	4	11,531	3
1987	11,218	3	11,510	3	11,499	3	12,114	2	12,143	2	11,734	3	11,922	3	12,143	3
1988	9,919	2	10,913	3	10,828	3	11,217	2	11,245	2	11,125	3	11,291	3	11,497	3
1989	8,026	3	9,247	3	9,103	3	9,344	2	9,370	2	9,422	3	9,568	3	9,755	3
1990	6,759	3	7,400	3	7,232	3	7,406	3	7,431	3	7,536	3	7,671	3	7,812	3
1991	5,760	3	5,862	4	5,706	4	5,818	3	5,841	3	5,920	4	6,054	4	6,183	4
1992	8,034	2	9,121	3	8,953	3	9,252	2	9,286	2	9,065	3	9,276	3	9,476	3
1993	9,519	2	11,257	2	11,098	2	11,552	2	11,599	2	11,181	2	11,427	2	11,627	2
1994	9,788	2	11,042	2	10,883	2	11,296	2	11,342	2	10,957	2	11,188	2	11,313	2
1995	11,167	2	12,625	2	12,488	2	12,886	2	12,926	2	12,508	2	12,757	2	13,000	2
1996	9,742	2	10,996	2	10,866	2	11,257	2	11,292	2	10,751	2	10,979	2	11,239	2
1997	8,744	2	9,468	2	9,350	2	10,042	3	10,074	3	9,395	2	9,603	2	9,837	2
1998	7,866	2	9,435	2	9,316	2	9,712	2	9,738	2	9,422	2	9,609	2	9,908	2
1999	8,934	2	10,337	2	10,238	2	10,652	2	10,673	2	10,390	2	10,561	2	10,751	2
2000	8,020	2	9,495	2	9,420	2	9,796	2	9,821	2	9,582	2	9,735	2	9,955	2
2001	8,148	2	9,205	2	9,147	2	9,527	2	9,559	2	9,335	2	9,479	2	9,702	2
2002	8,199	2	9,478	2	9,448	2	9,829	2	9,877	2	9,698	2	9,811	2	10,025	2
2003	9,169	2	11,419	2	11,397	2	11,779	2	11,816	2	11,657	2	11,750	2	12,080	2
2004	9,565	2	10,749	2	10,731	2	11,087	2	11,121	2	10,999	2	11,073	2	11,401	2
2005	7,746	2	8,967	2	8,958	2	9,271	2	9,302	2	9,197	2	9,272	2	9,598	2
2006	6,714	2	6,838	2	6,837	2	7,108	2	7,135	2	7,035	2	7,110	2	7,390	2
2007	5,306	2	5,495	2	5,495	2	5,753	3	5,782	3	5,683	3	5,762	3	6,046	3
2008	4,381	3	4,452	3	4,455	3	4,699	3	4,733	3	4,651	3	4,726	3	4,945	3
2009	5,613	2	5,574	2	5,562	2	5,883	3	5,941	3	5,837	3	5,943	3	6,374	3
2010	5,095	2	5,890	3	5,849	3	6,272	3	6,356	3	6,185	3	6,327	3	6,657	3
2011	7,446	2	8,342	2	8,169	2	9,001	3	9,176	3	8,788	3	9,107	3	9,637	3
2012	8,111	2	8,372	2	8,124	2	9,111	3	9,248	3	8,722	3	9,051	4	9,626	4
2013	8,232	2	8,273	3	7,963	3	9,130	4	9,225	4	8,547	4	8,873	4	9,504	5
2014	7,822	3	7,666	3	7,324	3	8,622	4	8,624	4	7,855	4	8,143	5	8,947	6
2015	9,183	2	9,870	3	9,521	3	12,073	5	11,801	5	11,345	6	11,913	8	12,407	10
2016	10,231	2	12,681	3	11,967	3	15,486	7	14,558	6	13,293	7	13,549	10	13,495	12
2017	10,256	3	11,840	3	10,782	4	13,794	7	12,963	7	11,785	8	12,049	11	13,033	13
2018	8,618	3	9,343	4	8,373	5	10,964	8	10,484	8	10,202	9	10,965	11	NA	NA
2019	8,217	4	8,497	5	7,413	6	9,892	10	9,864	9	9,110	10	NA	NA	NA	NA
2020	6,778	6	7,299	7	6,111	9	8,693	10	9,128	10	NA	NA	NA	NA	NA	NA
2021	10,194	9	12,867	12	6,811	11	8,145	11	NA	NA	NA	NA	NA	NA	NA	NA
2022	10,798	11	13,393	12	6,839	14	NA	NA								
2023	10,801	11	12,389	13	NA	NA										

Table 24: Estimated billions of EBS pollock at age (columns 2–11) from the current assessment model.

Year	1	2	3	4	5	6	7	8	9	10+
1964	6.31	3.37	2.07	0.45	0.19	0.38	0.17	0.06	0.03	0.21
1965	20.84	2.56	2.12	1.46	0.28	0.12	0.24	0.11	0.03	0.16
1966	14.98	8.45	1.61	1.49	0.90	0.17	0.08	0.15	0.07	0.12
1967	25.49	6.08	5.31	1.13	0.94	0.57	0.11	0.05	0.10	0.12
1968	22.13	10.32	3.77	3.46	0.65	0.53	0.33	0.06	0.03	0.13
1969	26.21	8.96	6.37	2.45	1.99	0.37	0.31	0.19	0.04	0.09
1970	23.58	10.60	5.51	4.03	1.43	1.17	0.22	0.18	0.11	0.07
1971	14.44	9.50	6.37	3.28	2.29	0.79	0.64	0.12	0.09	0.09
1972	11.75	5.80	5.56	3.56	1.71	1.12	0.39	0.31	0.05	0.08
1973	26.86	4.72	3.29	2.89	1.72	0.81	0.53	0.18	0.13	0.05
1974	19.69	10.81	2.60	1.58	1.28	0.75	0.35	0.23	0.07	0.07
1975	16.92	7.93	5.73	1.10	0.66	0.53	0.31	0.14	0.09	0.05
1976	13.03	6.84	4.47	2.55	0.50	0.30	0.24	0.14	0.06	0.06
1977	13.97	5.28	3.94	2.20	1.18	0.23	0.14	0.12	0.07	0.05
1978	23.72	5.66	3.08	2.14	1.11	0.58	0.12	0.07	0.06	0.06
1979	58.10	9.62	3.33	1.67	1.08	0.52	0.27	0.05	0.03	0.05
1980	24.09	23.57	5.80	1.91	0.86	0.50	0.24	0.12	0.02	0.04
1981	30.28	9.78	14.59	3.61	1.01	0.41	0.23	0.11	0.06	0.03
1982	17.08	12.30	6.14	9.88	2.11	0.53	0.21	0.12	0.06	0.04
1983	49.55	6.94	7.77	4.36	6.36	1.24	0.31	0.12	0.07	0.06
1984	13.15	20.14	4.39	5.58	2.92	3.97	0.74	0.19	0.07	0.07
1985	33.15	5.35	12.76	3.15	3.78	1.80	2.42	0.45	0.11	0.09
1986	12.61	13.47	3.39	9.14	2.16	2.43	1.07	1.45	0.27	0.12
1987	7.00	5.12	8.54	2.43	6.23	1.41	1.49	0.65	0.89	0.24
1988	5.38	2.85	3.26	6.17	1.70	4.22	0.91	0.96	0.41	0.72
1989	11.49	2.19	1.81	2.28	4.23	1.09	2.64	0.55	0.58	0.69
1990	48.93	4.67	1.39	1.29	1.54	2.72	0.67	1.54	0.32	0.77
1991	25.55	19.89	2.96	0.99	0.84	0.89	1.53	0.36	0.83	0.60
1992	21.32	10.39	12.61	2.13	0.66	0.50	0.51	0.77	0.19	0.70
1993	44.63	8.67	6.57	8.75	1.42	0.40	0.26	0.23	0.33	0.36
1994	14.96	18.14	5.51	4.67	5.54	0.92	0.24	0.14	0.11	0.35
1995	10.27	6.08	11.54	4.02	3.16	3.22	0.55	0.13	0.08	0.26
1996	22.11	4.18	3.87	8.47	2.86	2.00	1.73	0.30	0.07	0.19
1997	30.32	8.99	2.65	2.83	6.15	1.95	1.14	0.84	0.14	0.14
1998	14.74	12.33	5.69	1.93	2.00	4.17	1.19	0.62	0.43	0.14
1999	15.78	5.99	7.83	4.13	1.36	1.35	2.50	0.71	0.34	0.30
2000	24.57	6.42	3.81	5.57	2.87	0.92	0.87	1.46	0.42	0.38
2001	34.33	9.99	4.08	2.75	3.76	1.83	0.58	0.50	0.79	0.46
2002	22.93	13.96	6.36	2.97	1.89	2.27	0.99	0.32	0.27	0.70
2003	14.01	9.32	8.87	4.60	2.01	1.15	1.14	0.50	0.16	0.53
2004	6.32	5.70	5.93	6.25	3.11	1.18	0.59	0.55	0.24	0.37
2005	4.49	2.57	3.63	4.30	3.92	1.87	0.66	0.30	0.28	0.33
2006	11.42	1.83	1.64	2.63	2.84	2.14	0.98	0.35	0.16	0.34
2007	24.38	4.64	1.16	1.15	1.70	1.58	1.05	0.49	0.18	0.27
2008	13.29	9.91	2.95	0.82	0.74	0.94	0.75	0.51	0.25	0.23
2009	49.23	5.40	6.30	2.13	0.54	0.42	0.43	0.35	0.24	0.23
2010	21.88	20.01	3.44	4.52	1.40	0.32	0.21	0.21	0.17	0.23
2011	13.08	8.90	12.74	2.51	2.87	0.84	0.18	0.11	0.11	0.21
2012	11.57	5.32	5.66	9.27	1.74	1.41	0.39	0.09	0.05	0.15
2013	42.79	4.70	3.38	4.10	6.05	1.12	0.65	0.18	0.04	0.09
2014	48.52	17.40	2.99	2.45	2.73	3.64	0.67	0.33	0.08	0.06
2015	20.72	19.73	11.07	2.17	1.66	1.68	2.02	0.34	0.16	0.07
2016	7.77	8.42	12.56	7.68	1.43	1.03	0.91	1.03	0.17	0.11
2017	8.38	3.16	5.37	9.21	4.48	0.90	0.61	0.52	0.54	0.15
2018	15.32	3.41	2.01	3.94	6.33	2.49	0.49	0.33	0.28	0.36
2019	75.82	6.23	2.17	1.48	2.82	3.66	1.38	0.28	0.18	0.37
2020	19.96	30.82	3.96	1.59	1.07	1.95	1.92	0.63	0.14	0.30
2021	15.79	8.11	19.46	2.85	1.10	0.68	1.00	0.91	0.32	0.21
2022	18.49	6.42	5.09	13.32	1.97	0.71	0.41	0.50	0.43	0.26
2023	18.56	7.52	4.04	3.61	8.96	1.30	0.46	0.24	0.27	0.39

Table 25: Estimated millions of EBS pollock caught at age (columns 2–11) from the current assessment model.

Year	1	2	3	4	5	6	7	8	9	10+
1964	8.45	38.16	89.51	63.24	27.14	51.86	22.59	6.98	4.28	24.66
1965	28.58	29.68	93.66	212.02	39.36	16.81	31.94	14.00	4.37	18.80
1966	20.45	101.39	77.19	197.44	117.23	21.37	9.14	17.64	7.90	13.79
1967	64.79	140.38	550.80	219.82	185.89	110.57	20.91	9.17	18.13	23.25
1968	63.82	263.16	392.86	672.56	123.11	99.50	60.26	11.54	5.15	23.88
1969	91.20	257.24	809.49	454.76	363.02	67.19	56.25	36.14	7.08	18.09
1970	141.56	493.77	940.53	817.21	319.77	260.58	51.97	47.67	30.09	20.91
1971	121.93	625.71	1356.18	844.55	674.10	229.06	191.67	40.68	34.54	35.19
1972	88.83	516.53	1448.57	1081.05	544.10	357.49	125.67	114.83	21.11	32.68
1973	180.39	527.12	1010.35	1011.16	625.48	294.74	193.73	73.37	58.22	23.63
1974	115.52	1474.79	972.57	599.89	494.53	287.17	133.63	95.29	32.44	32.28
1975	66.05	748.67	2002.28	375.35	222.26	177.70	103.32	50.80	34.04	20.32
1976	36.88	530.58	1306.92	838.23	158.94	94.93	76.28	45.48	22.28	20.98
1977	28.60	363.95	912.90	615.20	349.96	68.34	41.62	33.80	21.19	17.80
1978	40.64	357.68	713.11	603.05	350.74	181.50	36.32	22.37	19.58	20.00
1979	81.23	424.57	653.13	444.53	353.03	179.05	92.70	18.46	12.07	18.64
1980	23.70	554.06	807.53	471.70	271.82	167.92	78.82	41.24	8.45	12.60
1981	17.33	123.63	1083.57	658.60	257.87	108.09	59.86	28.70	15.44	7.48
1982	5.37	87.23	221.95	1120.83	381.06	99.76	39.26	22.20	10.79	8.38
1983	10.90	43.68	207.63	361.01	870.04	205.41	50.39	19.96	11.39	9.70
1984	2.37	100.91	115.78	410.54	422.77	617.30	119.92	29.67	11.98	12.43
1985	5.01	27.10	368.86	208.87	438.72	306.88	398.56	73.27	18.20	14.94
1986	1.49	59.89	96.09	631.88	225.82	366.17	170.34	215.62	41.62	18.86
1987	0.50	15.00	192.21	111.31	465.26	150.69	162.17	81.58	110.83	28.63
1988	0.44	10.27	158.04	395.81	195.76	569.84	153.35	152.68	64.79	107.80
1989	0.79	7.22	59.91	170.07	487.56	159.60	482.96	93.94	93.62	108.29
1990	4.11	20.96	46.22	139.16	295.22	569.09	162.88	371.15	74.78	174.34
1991	2.10	94.58	71.95	80.69	135.77	179.87	421.40	88.38	231.59	186.18
1992	2.07	64.64	692.32	187.00	103.58	128.60	175.23	287.47	75.86	279.22
1993	2.45	21.90	237.68	1104.70	149.12	72.06	69.67	62.28	90.57	97.94
1994	0.58	34.06	70.27	348.81	1030.20	161.81	50.65	28.54	23.83	73.39
1995	0.35	12.32	96.96	141.38	397.38	775.21	120.96	29.45	16.31	53.50
1996	0.80	15.58	47.51	146.30	197.25	395.55	524.02	94.65	20.77	45.73
1997	1.06	52.38	42.29	103.62	447.32	296.89	273.79	223.47	44.36	37.98
1998	0.40	41.98	101.64	77.25	153.45	689.06	204.14	138.34	110.81	33.17
1999	0.32	12.15	270.13	220.22	105.21	157.79	457.98	127.32	60.56	53.00
2000	0.50	12.20	83.62	425.00	348.22	117.18	167.19	341.91	82.26	68.62
2001	0.72	16.68	62.05	170.47	609.51	422.75	133.52	114.90	171.15	91.95
2002	0.53	33.22	124.24	218.69	298.01	632.96	278.99	88.21	71.25	159.95
2003	0.33	17.54	376.40	348.50	362.01	303.81	353.25	152.88	44.62	121.02
2004	0.12	8.05	113.95	835.63	504.19	254.79	164.53	150.22	60.84	74.95
2005	0.08	3.68	66.25	400.57	892.39	474.79	160.02	69.40	62.69	63.83
2006	0.22	3.69	66.18	291.28	616.08	635.55	279.80	98.80	43.19	83.14
2007	0.48	10.29	46.93	136.41	378.47	497.00	316.24	137.36	48.22	70.27
2008	0.26	20.68	69.92	84.53	153.36	310.68	240.05	156.50	75.06	67.15
2009	0.86	7.39	168.97	210.60	90.54	120.86	126.36	101.52	69.61	71.01
2010	0.31	23.95	40.34	562.91	224.81	61.95	47.66	55.60	45.15	60.16
2011	0.24	13.25	202.18	141.16	850.06	273.92	58.51	36.77	35.84	69.79
2012	0.21	9.83	113.25	952.35	194.16	464.17	127.81	29.32	17.36	49.55
2013	0.71	6.45	64.02	352.89	990.99	194.46	177.16	59.98	13.39	31.01
2014	0.75	26.28	51.26	178.71	405.85	788.49	184.93	94.32	24.85	19.33
2015	0.36	20.42	614.59	210.81	240.15	389.73	557.79	93.33	50.36	24.21
2016	0.10	5.52	117.58	1413.44	190.70	179.47	180.43	263.19	41.44	27.53
2017	0.11	2.28	36.01	576.21	975.23	199.74	138.60	123.32	136.89	36.79
2018	0.17	2.41	11.66	119.20	1202.23	544.67	101.77	72.10	58.41	70.22
2019	0.97	10.69	15.57	26.00	165.79	930.93	459.58	82.15	48.87	80.54
2020	0.50	251.13	101.67	94.55	130.34	517.92	601.50	179.42	43.08	85.30
2021	0.39	102.60	1280.68	165.91	117.18	113.11	290.94	291.32	93.41	59.02
2022	0.33	62.51	184.42	1057.03	182.51	75.60	81.30	119.58	89.57	52.63
2023	0.36	78.03	155.35	298.42	1007.07	151.00	96.73	48.76	54.32	87.69

Table 26: Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964–2023. Biomass units are thousands of t, age-1 recruitment is in millions of pollock.

Year	SSB	CV.SSB	Recruit	CV.Rec	Age.3..B	CV..
1964	520	27	6,308	38	1,749	22
1965	611	23	20,836	25	2,127	20
1966	706	22	14,984	32	2,277	20
1967	889	19	25,491	26	3,524	17
1968	1,106	19	22,126	28	4,035	17
1969	1,358	19	26,213	26	5,141	16
1970	1,520	18	23,577	27	5,559	15
1971	1,667	18	14,439	33	6,166	13
1972	1,587	17	11,749	34	5,911	12
1973	1,365	19	26,861	19	4,826	14
1974	1,030	22	19,686	20	3,631	16
1975	973	21	16,921	18	3,959	13
1976	938	16	13,031	17	3,822	11
1977	1,137	14	13,965	15	4,206	10
1978	1,029	13	23,720	11	3,694	9
1979	962	12	58,104	7	3,521	9
1980	1,139	10	24,086	10	4,488	7
1981	1,721	7	30,283	9	7,841	5
1982	2,347	6	17,084	12	8,301	5
1983	3,089	6	49,553	6	10,244	5
1984	3,159	6	13,152	11	9,574	5
1985	3,628	5	33,149	7	12,622	4
1986	3,554	4	12,606	10	10,547	4
1987	3,623	4	7,004	12	11,218	3
1988	3,461	3	5,383	12	9,919	3
1989	3,009	3	11,487	8	8,026	3
1990	2,542	4	48,931	4	6,759	3
1991	2,029	4	25,553	5	5,760	4
1992	1,944	4	21,315	6	8,034	3
1993	2,603	3	44,628	4	9,519	3
1994	3,025	3	14,963	7	9,788	3
1995	3,231	3	10,270	7	11,167	3
1996	3,171	3	22,106	5	9,742	3
1997	3,078	3	30,318	4	8,744	3
1998	2,609	3	14,743	6	7,866	3
1999	2,746	3	15,784	5	8,934	3
2000	2,670	3	24,565	4	8,020	3
2001	2,726	3	34,331	3	8,148	3
2002	2,545	3	22,928	4	8,199	3
2003	2,595	3	14,012	5	9,169	2
2004	2,903	3	6,319	7	9,565	2
2005	2,560	3	4,490	8	7,746	2
2006	2,338	3	11,415	5	6,714	3
2007	1,902	3	24,377	4	5,306	3
2008	1,440	3	13,289	6	4,381	3
2009	1,520	3	49,229	3	5,613	3
2010	1,562	3	21,881	5	5,095	3
2011	1,930	3	13,080	6	7,446	3
2012	2,365	3	11,570	6	8,111	3
2013	2,684	3	42,787	3	8,232	3
2014	2,612	3	48,520	4	7,822	3
2015	2,435	3	20,719	6	9,183	3
2016	2,695	3	7,771	11	10,231	3
2017	3,131	3	8,375	14	10,256	3
2018	2,980	4	15,320	14	8,618	4
2019	2,888	5	75,818	12	8,217	5
2020	2,213	6	19,958	18	6,778	6
2021	2,358	9	15,789	17	10,194	10
2022	3,215	11	18,486	20	10,798	11
2023	3,692	13	18,560	21	10,801	12

Table 27: Summary of model results and the stock condition for EBS pollock. Biomass units are thousands of t.

Component	Model 23.0
$B_{2024}$	3,500
$CV_{B_{2024}}$	0.14
$B_{MSY}$	2,689
$CV_{B_{MSY}}$	0.2
$B_{2024}/B_{MSY}$	131%
$B_0$	6,728
$B_{35\%}$	2,060
SPR rate at $F_{MSY}$	34%
Steepness	0.6
Est. $B_{2023}/B_{2023, no fishing}$	0.58
$B_{2023}/B_{MSY}$	137%

Table 28: Summary results of Tier 1 2023 yield projections for EBS pollock.

Component	Model 23.0
2024 fishable biomass (GM)	7,493,000
Equilibrium fishable biomass at MSY	5,513,000
MSY R (HM)	0.379
2024 Tier 1 ABC	2,837,000
2024 Tier 1 $F_{OFL}$ unadjusted	0.422
2024 Tier 1 OFL	3,162,000
Recommended ABC	2,313,000

Table 29: For the configuration named Model 23.0, Tier 3 projections of EBS pollock catch for the 7 scenarios.

Catch	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2024	1,350	1,350	1,350	1,350	1,350	1,350	1,350
2025	1,350	1,350	1,350	1,350	1,350	2,918	2,400
2026	2,250	2,250	1,476	1,011	0	2,155	1,921
2027	1,856	1,856	1,357	989	0	1,751	2,058
2028	1,710	1,710	1,339	1,015	0	1,670	1,799
2029	1,628	1,628	1,353	1,056	0	1,659	1,710
2030	1,610	1,610	1,381	1,101	0	1,674	1,690
2031	1,570	1,570	1,364	1,106	0	1,648	1,652
2032	1,546	1,546	1,347	1,102	0	1,626	1,626
2033	1,534	1,534	1,336	1,099	0	1,616	1,616
2034	1,528	1,528	1,328	1,096	0	1,610	1,610
2035	1,518	1,518	1,320	1,092	0	1,599	1,599
2036	1,512	1,512	1,312	1,086	0	1,595	1,595
2037	1,512	1,512	1,309	1,084	0	1,596	1,596

Table 30: For the configuration named Model 23.0, Tier 3 projections of EBS pollock ABC for the 7 scenarios. Note: scenario 2 results for 2023 and 2024 are conditioned on catches in that scenario listed in Table 29).

ABC	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2024	2,313	2,313	1,502	1,022	0	2,837	2,837
2025	2,400	2,400	1,580	1,083	0	2,918	2,918
2026	2,250	2,250	1,476	1,011	0	2,155	2,346
2027	1,856	1,856	1,357	989	0	1,751	2,058
2028	1,710	1,710	1,339	1,015	0	1,670	1,799
2029	1,628	1,628	1,353	1,056	0	1,659	1,710
2030	1,610	1,610	1,381	1,101	0	1,674	1,690
2031	1,570	1,570	1,364	1,106	0	1,648	1,652
2032	1,546	1,546	1,347	1,102	0	1,626	1,626
2033	1,534	1,534	1,336	1,099	0	1,616	1,616
2034	1,528	1,528	1,328	1,096	0	1,610	1,610
2035	1,518	1,518	1,320	1,092	0	1,599	1,599
2036	1,512	1,512	1,312	1,086	0	1,595	1,595
2037	1,512	1,512	1,309	1,084	0	1,596	1,596

Table 31: For the configuration named Model 23.0, Tier 3 projections of EBS pollock fishing mortality for the 7 scenarios.

F	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2024	0.212	0.212	0.212	0.212	0.212	0.212	0.212
2025	0.200	0.200	0.200	0.200	0.200	0.500	0.390
2026	0.390	0.390	0.239	0.157	0.000	0.500	0.390
2027	0.390	0.390	0.239	0.157	0.000	0.473	0.498
2028	0.385	0.385	0.239	0.157	0.000	0.456	0.468
2029	0.372	0.372	0.239	0.157	0.000	0.445	0.449
2030	0.364	0.364	0.239	0.157	0.000	0.439	0.440
2031	0.360	0.360	0.239	0.157	0.000	0.436	0.436
2032	0.358	0.358	0.239	0.157	0.000	0.433	0.433
2033	0.357	0.357	0.239	0.157	0.000	0.431	0.431
2034	0.357	0.357	0.239	0.157	0.000	0.431	0.431
2035	0.356	0.356	0.239	0.157	0.000	0.430	0.430
2036	0.355	0.355	0.239	0.157	0.000	0.429	0.429
2037	0.355	0.355	0.239	0.157	0.000	0.429	0.429

Table 32: For the configuration named Model 23.0, Tier 3 projections of EBS pollock spawning biomass (kt) for the 7 scenarios.

SSB	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2024	3,512	3,512	3,512	3,512	3,512	3,512	3,512
2025	3,243	3,243	3,243	3,243	3,243	3,012	3,094
2026	2,995	2,995	3,101	3,160	3,278	2,389	2,624
2027	2,752	2,752	3,115	3,342	3,857	2,282	2,500
2028	2,651	2,651	3,150	3,491	4,352	2,285	2,377
2029	2,584	2,584	3,152	3,577	4,745	2,281	2,315
2030	2,535	2,535	3,127	3,607	5,040	2,261	2,272
2031	2,509	2,509	3,101	3,618	5,278	2,249	2,251
2032	2,495	2,495	3,079	3,616	5,454	2,243	2,243
2033	2,478	2,478	3,052	3,601	5,584	2,230	2,230
2034	2,467	2,467	3,032	3,587	5,678	2,221	2,221
2035	2,452	2,452	3,009	3,566	5,733	2,208	2,208
2036	2,447	2,447	2,997	3,553	5,776	2,206	2,206
2037	2,457	2,457	3,002	3,557	5,820	2,217	2,217

Table 33: Details and explanation of the decision table factors selected in response to the Plan Team requests (as originally proposed in the 2012 assessment).

Term	Description	Rationale
$P [F_{2024} > F_{MSY}]$	Probability that the fishing mortality in 2024 exceeds $F_{MSY}$	OFL definition is based on $F_{MSY}$
$P [B_{2025} < B_{MSY}]$	Probability that the spawning biomass in 2025 is less than $B_{MSY}$	$B_{MSY}$ is a reference point target and biomass in 2021 provides an indication of the impact of 2024 fishing
$P [B_{2026} < B_{MSY}]$	Probability that the spawning biomass in 2026 is less than $B_{MSY}$	$B_{MSY}$ is a reference point target and biomass in 2024 provides an indication of the impact of fishing in 2024 and 2025
$P [B_{2026} < \bar{B}]$	Probability that the spawning biomass in 2025 is less than the 1978–2023 mean	To provide some perspective of what the stock condition might be relative to historical estimates after fishing in 2024.
$P [B_{2028} < \bar{B}]$	Probability that the spawning biomass in 2028 is less than the long term mean	To provide some perspective of what the stock condition might be relative to historical estimates after fishing in 2024.
$P [B_{2028} < B_{2024}]$	Probability that the spawning biomass in 2028 is less than that estimated for 2024	To provide a medium term expectation of stock status relative to 2024 levels
$P [B_{2026} < B_{20\%}]$	Probability that the spawning biomass in 2026 is less than $B_{20\%}$	$B_{20\%}$ had been selected as a Steller Sea Lion lower limit for allowing directed fishing
$P [p_{a_5,2026} > \bar{p}_{a_5}]$	Probability that in 2026 the proportion of age 1–5 pollock in the population exceeds the long-term mean	To provide some relative indication of the age composition of the population relative to the long term mean.
$P [D_{2025} < D_{1994}]$	Probability that the diversity of ages represented in the spawning biomass (by weight) in 2025 is less than the value estimated for 1994	To provide a relative index on the abundance of different age classes in the 2025 population relative to 1994 (a year identified as having low age composition diversity)
$P [D_{2028} < D_{1994}]$	Probability that the diversity of ages represented in the spawning biomass (by weight) in 2028 is less than the value estimated for 1994	To provide a medium-term relative index on the abundance of different age classes in the population relative to 1994 (a year identified as having low age composition diversity)
$P [E_{2024} > E_{2023}]$	Probability that the theoretical fishing effort in 2024 will be greater than that estimated in 2023.	To provide the relative effort that is expected (and hence some idea of costs).

Table 34: Outcomes of decision (expressed as chances out of 100) given different 2024 catches (first row, in kt). Note that for the 2021 and later year-classes average values were assumed. Constant Fs based on the 2024 catches were used for subsequent years.

	10	850	1000	1260	1150	1300	1450	1600
$P[F_{2024} > F_{MSY}]$	0	0	0	0	0	0	0	0
$P[B_{2024} < B_{MSY}]$	9	17	20	24	22	25	28	31
$P[B_{2025} < B_{MSY}]$	5	17	21	28	25	30	35	40
$P[B_{2024} < \bar{B}]$	0	2	3	5	4	6	8	11
$P[B_{2027} < \bar{B}]$	0	6	9	14	12	15	18	22
$P[B_{2027} < B_{2023}]$	6	30	36	46	42	48	53	58
$P[B_{2025} < B_{20\%}]$	0	0	0	1	0	1	1	1
$P[p_{a_5, 2024} > \bar{p}_{a_5}]$	7	42	48	58	54	60	64	68
$P[D_{2024} < D_{1994}]$	2	2	2	2	2	2	2	2
$P[D_{2027} < D_{1994}]$	0	1	2	4	3	4	6	8
$P[E_{2024} > E_{2023}]$	0	4	15	43	31	47	61	71

Table 35: Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 2003–2023 based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska).

Year	Jellies	MiscFish	SeaStar	Osmerid	Grenadier	Eelpouts	Sea.pen	Anemone	Snails	Other
2003	5,643	101	89	20	9	7	0	0	1	1
2004	6,590	89	7	14	21	0	1	0	0	0
2005	5,196	157	9	14	12	1	1	0	6	2
2006	2,716	154	11	15	99	21	1	0	0	15
2007	2,397	204	5	27	138	118	3	0	0	12
2008	4,183	120	19	27	4	8	1	0	1	8
2009	8,115	135	9	4	5	4	2	1	1	3
2010	2,516	149	12	2	0	0	2	2	1	9
2011	8,232	277	27	1	1	1	2	1	1	8
2012	3,518	142	7	2	1	1	3	1	1	3
2013	5,294	121	15	0	0	1	2	2	0	9
2014	12,767	44	29	10	1	7	3	1	1	8
2015	4,950	90	41	4	24	10	2	2	1	4
2016	2,203	75	54	4	5	22	1	0	0	3
2017	6,152	48	12	2	3	18	0	1	0	1
2018	8,251	52	24	9	0	4	0	0	0	3
2019	3,889	73	50	8	0	2	0	0	0	5
2020	3,149	93	61	42	1	6	1	5	0	26
2021	7,829	35	19	54	0	0	1	3	1	3
2022	7,609	22	184	9	0	0	1	1	0	9
2023	7,007	35	27	86	0	0	1	3	1	5

Table 36: Bycatch estimates (t) of other target species caught in the BSAI directed pollock fishery, 1991–2023 based on then NMFS Alaska Regional Office reports from observers (2023 data are preliminary).

Year	P.cod	Rock.Sole	Flathead	Arrowtooth	POP	Yellowfin	Sablefish	Shark	Atka.Mkrl	Skates	Other
1991	3,018	207	0	455	53	38	1	NA	0	0	1,719
1992	14,313	3,485	2	2,917	143	247	7	NA	242	0	10,624
1993	8,632	2,089	0	557	184	579	0	NA	34	0	5,033
1994	8,131	329	0	992	76	147	1	NA	40	0	2,204
1995	10,105	422	1,131	558	128	160	10	NA	94	0	863
1996	9,297	676	1,879	1,105	267	936	3	NA	72	0	1,278
1997	5,962	919	1,774	611	334	85	2	NA	56	0	1,887
1998	5,334	194	1,466	887	571	798	2	NA	5	0	1,105
1999	3,076	757	1,792	252	94	134	5	NA	7	0	963
2000	3,066	1,411	2,158	910	7	714	12	NA	1	0	1,137
2001	3,550	1,313	1,814	433	462	158	17	NA	40	0	2,800
2002	5,741	1,720	1,715	504	539	411	26	NA	221	0	2,327
2003	5,772	1,338	1,414	550	691	149	47	NA	378	0	932
2004	6,166	2,299	2,021	541	331	650	14	NA	408	0	1,293
2005	6,391	1,034	2,079	550	503	17	10	NA	210	0	1,128
2006	6,867	1,178	2,643	952	422	165	7	NA	154	0	2,136
2007	5,274	409	3,732	2,279	459	21	11	NA	105	0	1,842
2008	5,841	1,355	3,223	1,043	190	124	0	NA	14	0	2,763
2009	4,168	1,789	2,171	993	66	96	0	NA	4	0	2,000
2010	4,422	622	2,220	555	147	380	0	NA	5	0	1,339
2011	6,776	3,076	2,927	974	435	361	0	63	99	1,206	433
2012	6,160	2,805	2,281	469	272	566	0	53	73	1,198	657
2013	5,932	1,921	1,591	370	410	538	0	42	3	936	289
2014	4,100	2,469	1,950	477	1,088	748	0	74	19	670	1,409
2015	7,410	1,103	1,948	328	1,983	498	0	50	179	769	1,858
2016	4,459	750	1,232	153	2,082	557	17	58	53	373	1,254
2017	5,157	1,478	799	90	3,026	367	75	89	48	408	1,703
2018	3,974	1,004	902	167	2,649	354	360	59	251	469	1,537
2019	5,749	960	962	248	4,974	107	1,087	97	174	446	252
2020	7,697	468	1,491	312	3,365	215	2,867	108	182	682	290
2021	6,371	491	1,209	193	1,863	78	984	168	261	631	106
2022	3,362	546	802	105	1,062	320	189	54	39	501	38
2023	3,345	264	633	141	909	20	377	268	17	323	50

Table 37: Bycatch estimates (t) of pollock caught in the other non-pollock EBS directed fisheries, 1991–2023 based on then NMFS Alaska Regional Office reports from observers.

Year	Atka.Mackerel	NRock.sole	Other.flats	Other.spp	P.cod	Yellowfin.sole
1991	129	9,711	7,992	661,886	10,695	NA
1992	108	9,824	1,371	520	20,778	13,100
1993	18	18,582	2,581	604	31,292	15,253
1994	0	15,784	6,770	89	26,594	33,200
1995	NA	7,766	5,211	63	25,691	27,041
1996	60	7,698	5,456	744	22,382	22,254
1997	NA	9,123	3,480	14	33,658	24,100
1998	58	3,960	3,011	882	10,468	15,339
1999	246	5,207	4,771	951	21,131	8,701
2000	16	5,480	7,068	503	14,508	13,425
2001	238	4,577	4,739	249	11,570	16,502
2002	2	9,942	2,220	49	15,255	14,489
2003	92	4,924	3,672	167	15,926	11,578
2004	117	8,975	6,396	80	18,650	10,383
2005	195	7,235	5,057	25	14,109	10,312
2006	121	6,986	3,826	21	15,168	5,966
2007	147	3,245	4,353	128	20,319	4,020
2008	1	4,930	4,822	15	9,533	9,827
2009	7	6,171	3,505	6	7,875	7,036
2010	NA	6,074	3,316	85	6,575	5,179
2011	144	6,931	2,301	157	8,981	8,673
2012	41	6,703	1,751	371	8,377	11,197
2013	9	7,326	4,048	228	9,801	20,171
2014	NA	11,258	6,404	202	11,502	24,712
2015	19	9,386	4,993	410	9,062	21,281
2016	1	11,850	3,687	448	9,071	22,306
2017	13	5,616	3,613	494	8,319	23,414
2018	137	5,182	3,525	819	8,008	28,235
2019	54	3,176	7,972	1,311	7,593	23,153
2020	57	6,401	2,374	668	5,512	31,651
2021	53	2,398	5,131	1,328	4,316	24,844
2022	602	2,976	5,505	2,023	6,260	26,514
2023	361	11,028	4,587	1,974	6,433	17,399

Table 38: Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997–2023 based on the AKFIN (NMFS Regional Office) reports from observers. Herring and halibut units are in t, all others represent numbers of individuals caught. Data for 2023 are preliminary.

Year	Bairdi	Chinook	Halib	Halib.M	Herring	NonChin	Snow Crab	Red King	Blue King	Goldn King
1991	1,397,836	36,348	2,155	NA	3,158	28,657	4,378,007	17,777	NA	NA
1992	1,500,764	33,672	2,220	NA	646	40,186	4,569,662	43,873	NA	NA
1993	1,649,086	36,615	1,326	NA	527	241,971	738,250	58,139	NA	NA
1994	371,213	31,880	963	688	1,626	91,764	811,733	42,360	NA	NA
1995	153,992	13,403	491	397	904	17,754	206,651	4,644	NA	NA
1996	89,415	55,467	382	320	1,241	77,173	63,398	5,933	NA	NA
1997	17,046	44,312	257	200	1,134	65,414	216,152	137	NA	NA
1998	57,036	51,244	352	278	800	60,676	123,400	14,286	NA	NA
1999	2,397	10,381	153	124	799	44,610	15,829	90	NA	NA
2000	1,484	4,242	110	90	482	56,866	6,480	0	NA	NA
2001	5,060	30,933	242	199	225	53,901	5,653	105	NA	NA
2002	2,112	32,381	165	137	108	77,167	2,697	16	NA	NA
2003	732	43,095	88	74	967	179,987	608	52	8	NA
2004	1,091	48,799	96	81	1,095	441,188	640	26	4	1
2005	601	66,208	119	100	593	703,076	2,016	0	NA	1
2006	1,288	80,915	132	111	433	305,793	2,567	288	NA	3
2007	1,465	116,329	312	269	351	86,380	3,033	7	NA	3
2008	9,025	20,602	373	311	127	15,119	8,894	670	8	33
2009	6,155	12,284	541	436	64	45,960	7,312	1,136	19	NA
2010	12,787	9,833	335	267	348	13,728	9,444	1,122	28	NA
2011	10,973	25,499	459	378	376	193,754	6,493	577	25	NA
2012	5,620	11,343	462	388	2,352	22,297	6,189	343	NA	NA
2013	12,426	13,091	333	271	958	125,525	8,605	507	34	107
2014	12,521	15,135	239	199	159	219,837	19,454	368	NA	NA
2015	8,872	18,329	152	130	1,487	237,776	8,339	0	NA	NA
2016	2,295	22,204	121	102	1,431	343,208	1,166	439	NA	26
2017	7,269	30,078	97	88	963	467,750	3,406	202	0	67
2018	2,249	13,726	75	62	474	295,818	5,143	565	-	53
2019	3,146	25,038	134	113	1,102	348,631	6,228	453	99	445
2020	10,749	32,204	128	102	3,861	343,625	40,005	479	1	522
2021	8,417	13,852	145	131	1,708	546,472	4,668	52	-	115
2022	4,758	6,415	170	156	1,708	242,375	1,952	311	59	88
2023	11,978	11,750	84	67	3,087	112,445	4,100	54	-	132

Table 39: Ecosystem considerations for BSAI pollock and the pollock fishery.

Indicator	Observation	Interpretation	Evaluation
<b>Ecosystem effects on EBS pollock</b>			
<i>Prey availability or abundance trends</i>			
Zooplankton	Stomach contents, AT and ichthyoplankton surveys, changes mean wt-at-age	Data improving, indication of increases from 2004–2009 and subsequent decreases (for euphausiids in 2012 and 2014)	Variable abundance indicates important recruitment (for prey)
<i>Predator population trends</i>			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	Possibly lower mortality on pollock	Probably no concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Pollock, Pacific cod, halibut)	Stable to increasing	Possible increases to pollock mortality	
<i>Changes in habitat quality</i>			
Temperature regime	Cold years pollock distribution towards NW on average	Likely to affect surveyed stock	Some concern, the distribution of pollock availability to different surveys may change systematically
Winter-spring environmental conditions	Affects pre-recruit survival	Probably a number of factors	Causes natural variability
Production Basin	Fairly stable nutrient flow from upwelled BS	Inter-annual variability low	No concern
<b>Fishery effects on ecosystem</b>			
<i>Fishery contribution to bycatch</i>			
Prohibited species	Stable, heavily monitored	Likely to be safe	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored	Likely to be safe	No concern
HAPC biota	Likely minor impact	Likely to be safe	No concern
Marine mammals and birds	Very minor direct-take	Safe	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be safe	No concern
Fishery concentration in space and time	Generally more diffuse	Mixed potential impact (fur seals vs Steller sea lions)	Possible concern
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern
Fishery effects on age-at-maturity and fecundity	Maturity study (gonad collection) continues	NA	Possible concern

## 13 Figures

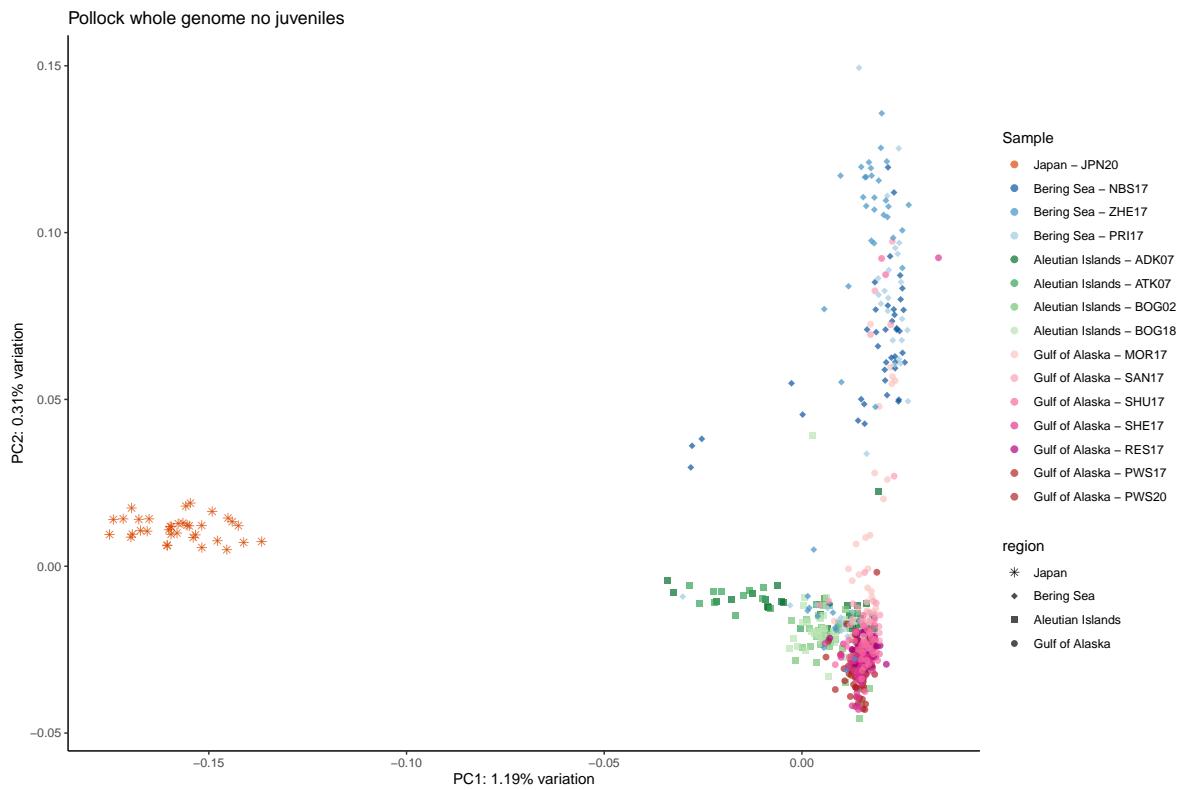


Figure 1: Principal Component Analysis of walleye pollock genetics. The color of each point indicates the sampling.

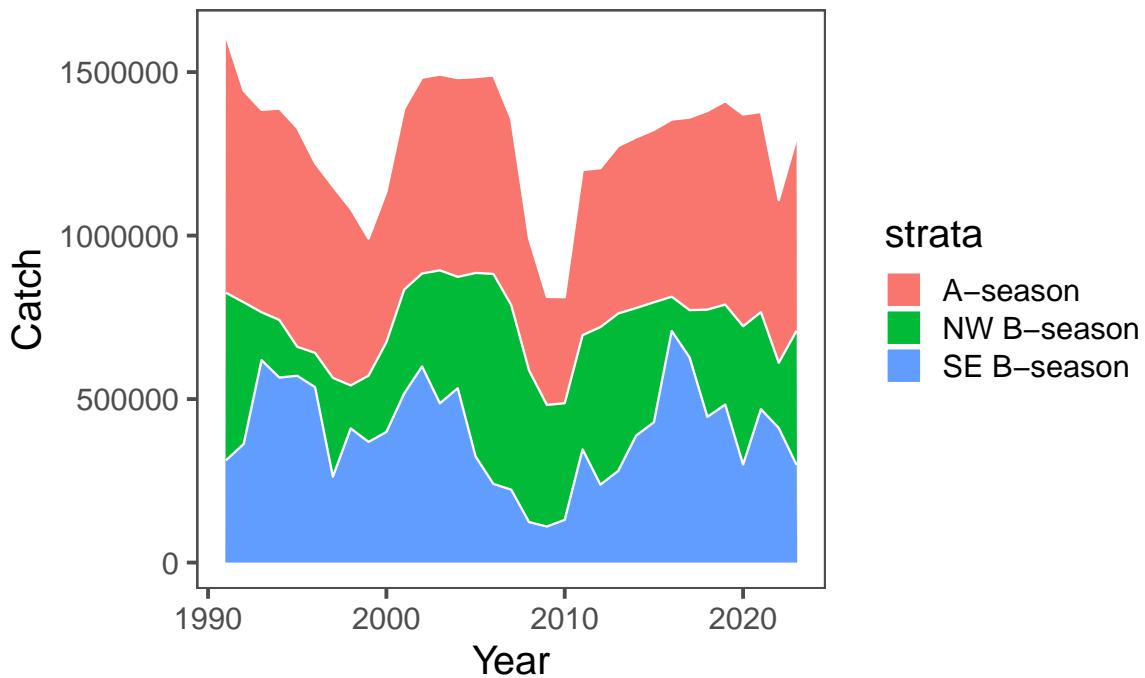


Figure 2: Pollock catch estimates (t) from the Eastern Bering Sea by season and region. The A-season is defined as from Jan-May and B-season from June-October.

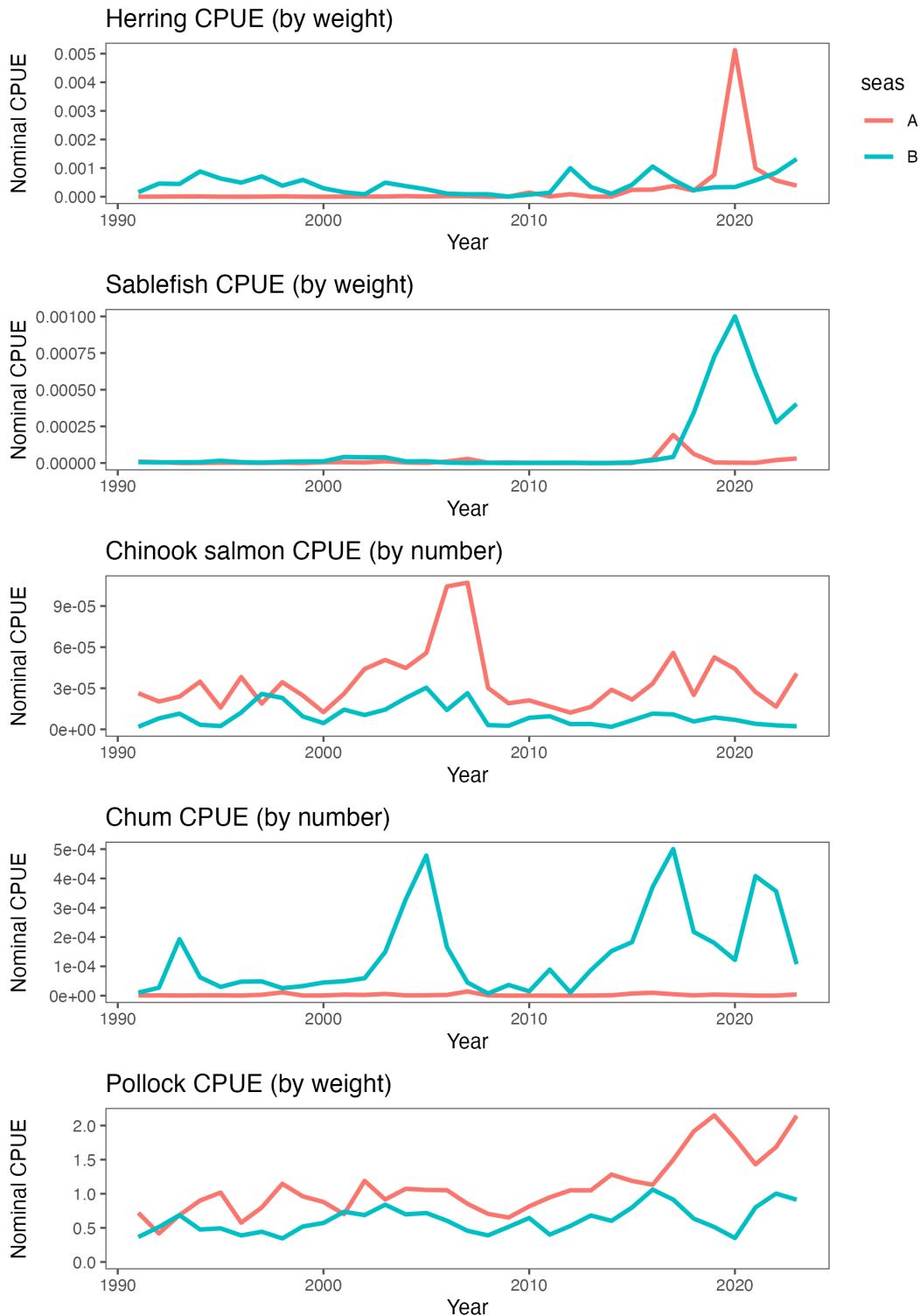


Figure 3: Nominal catch divided by effort (hours towed) for some bycatch species and pollock for the EBS pollock fleet (sectors combined), 2000-2023.

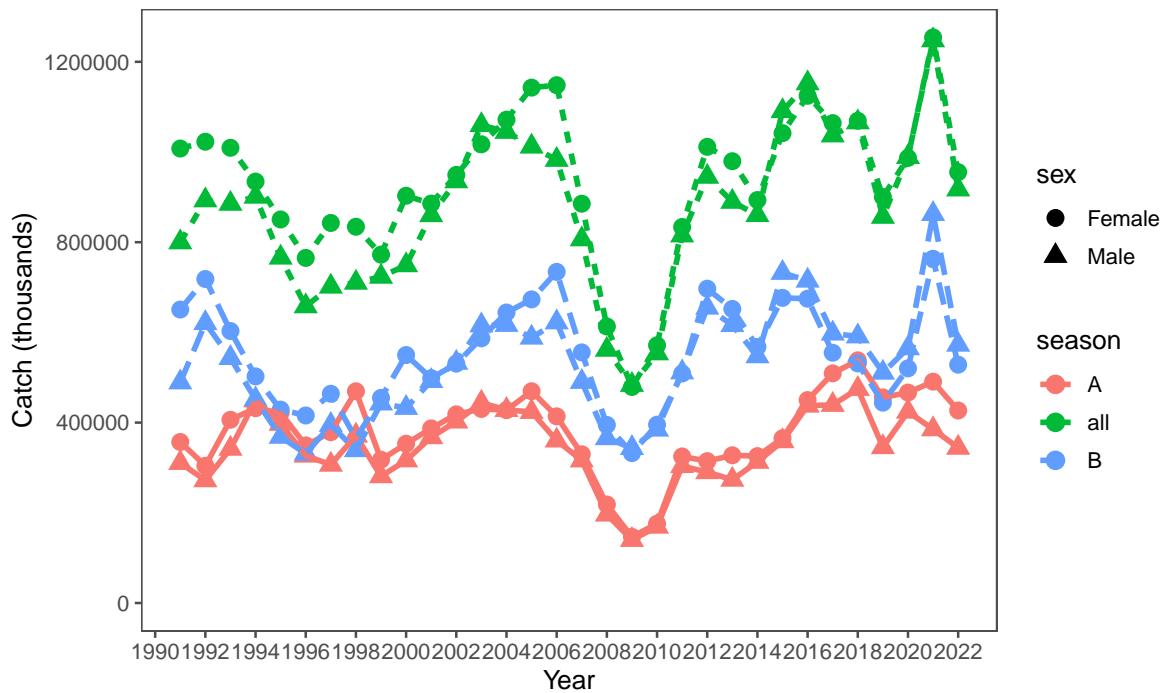


Figure 4: Estimate of EBS pollock catch numbers by sex for the A season (January-May) and B seasons (June-October) and total.

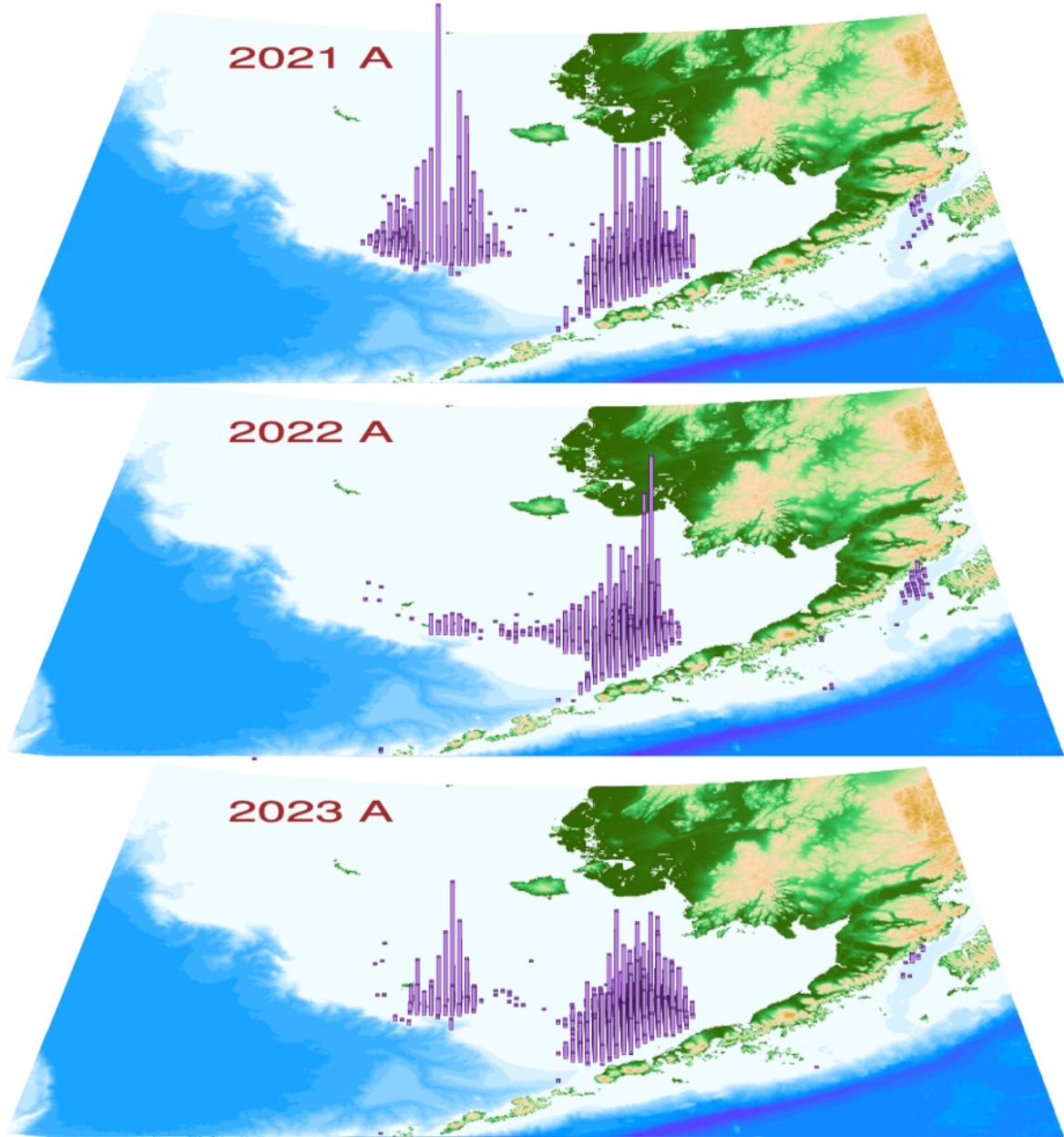
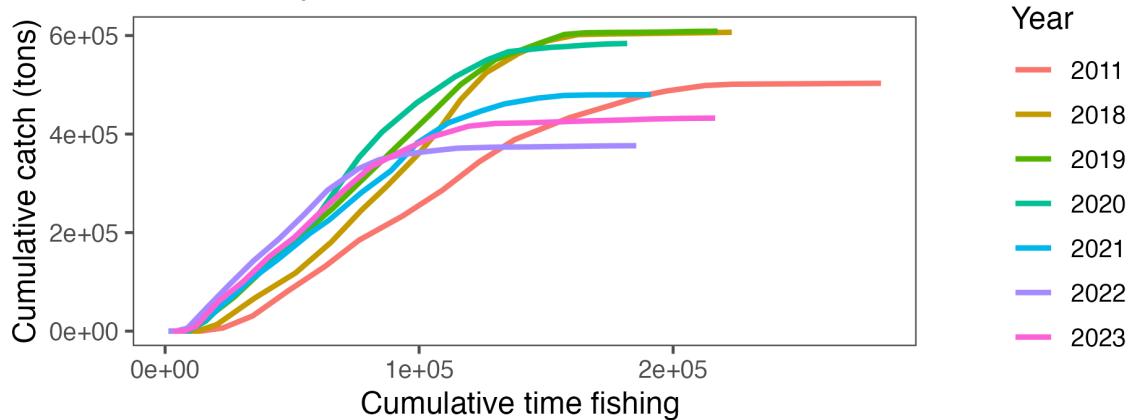
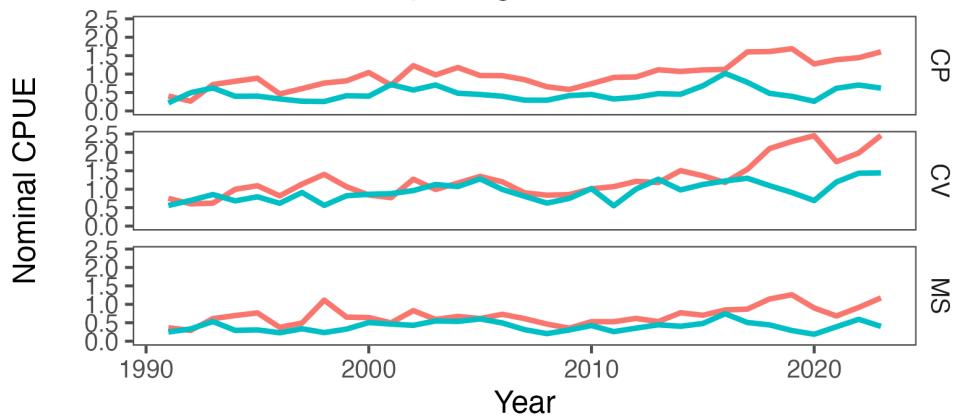


Figure 5: EBS pollock catch distribution during A-season, 2021–2023. Column height is proportional to total catch.

### A-season pollock



### Pollock CPUE (by weight)



### B-season pollock

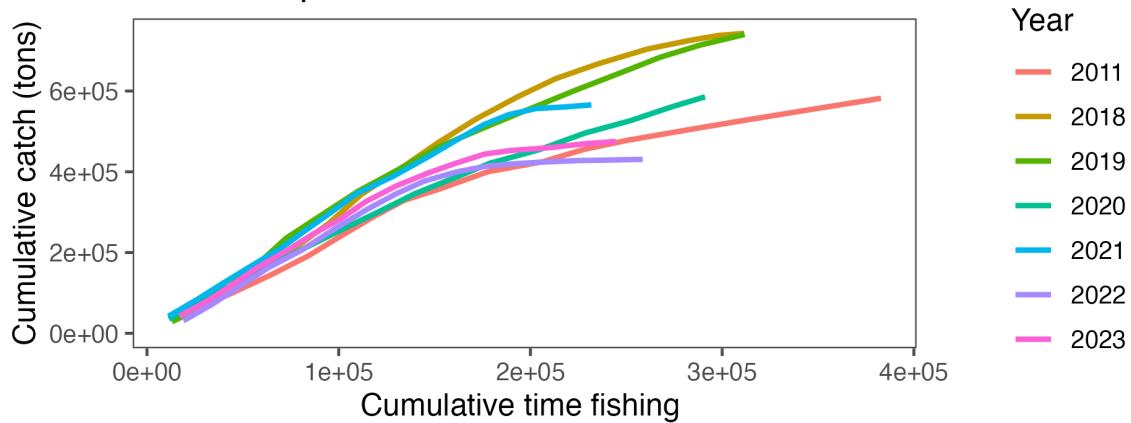


Figure 6: A-season (top) and B-season (bottom) EBS fleet-wide cumulative catch by hours observed fishing and relative pollock catch per hour of fishing (by sector)

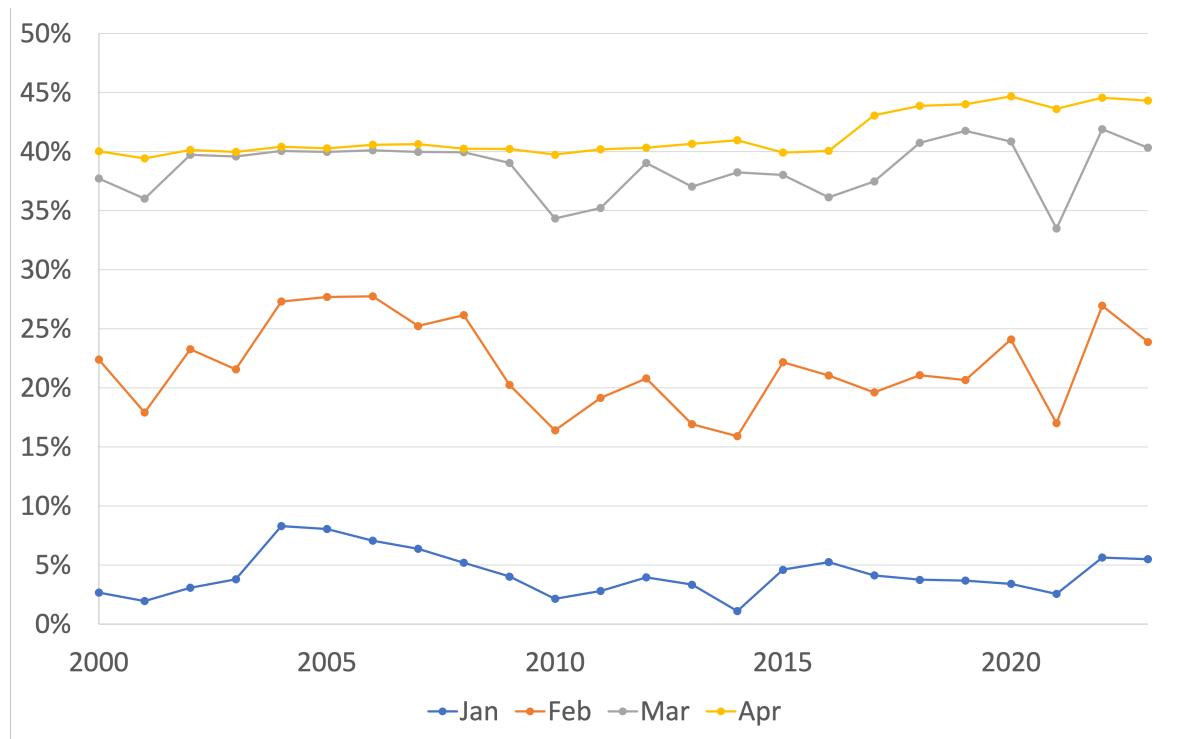


Figure 7: Proportion of the annual EBS pollock TAC by month during the A-season, 2000–2023. The higher value observed since 2017 was due to Amendment 110 of the FMP to allow greater flexibility to avoid Chinook salmon.

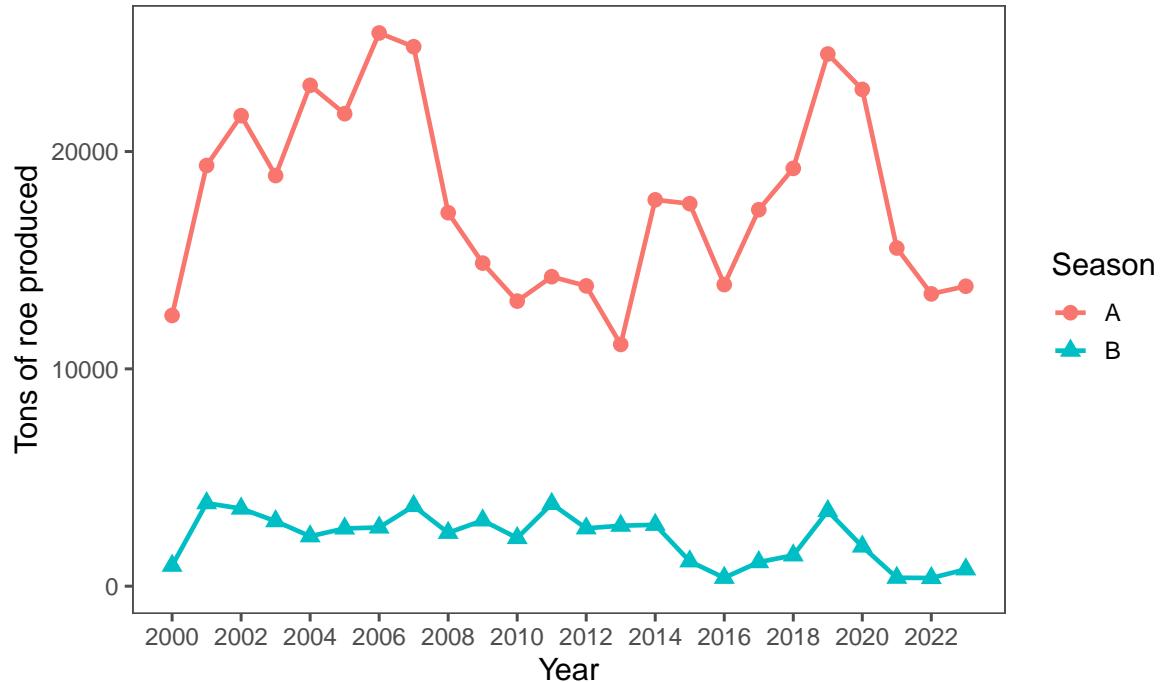


Figure 8: EBS pollock roe production in A and B seasons , 2000-2023.

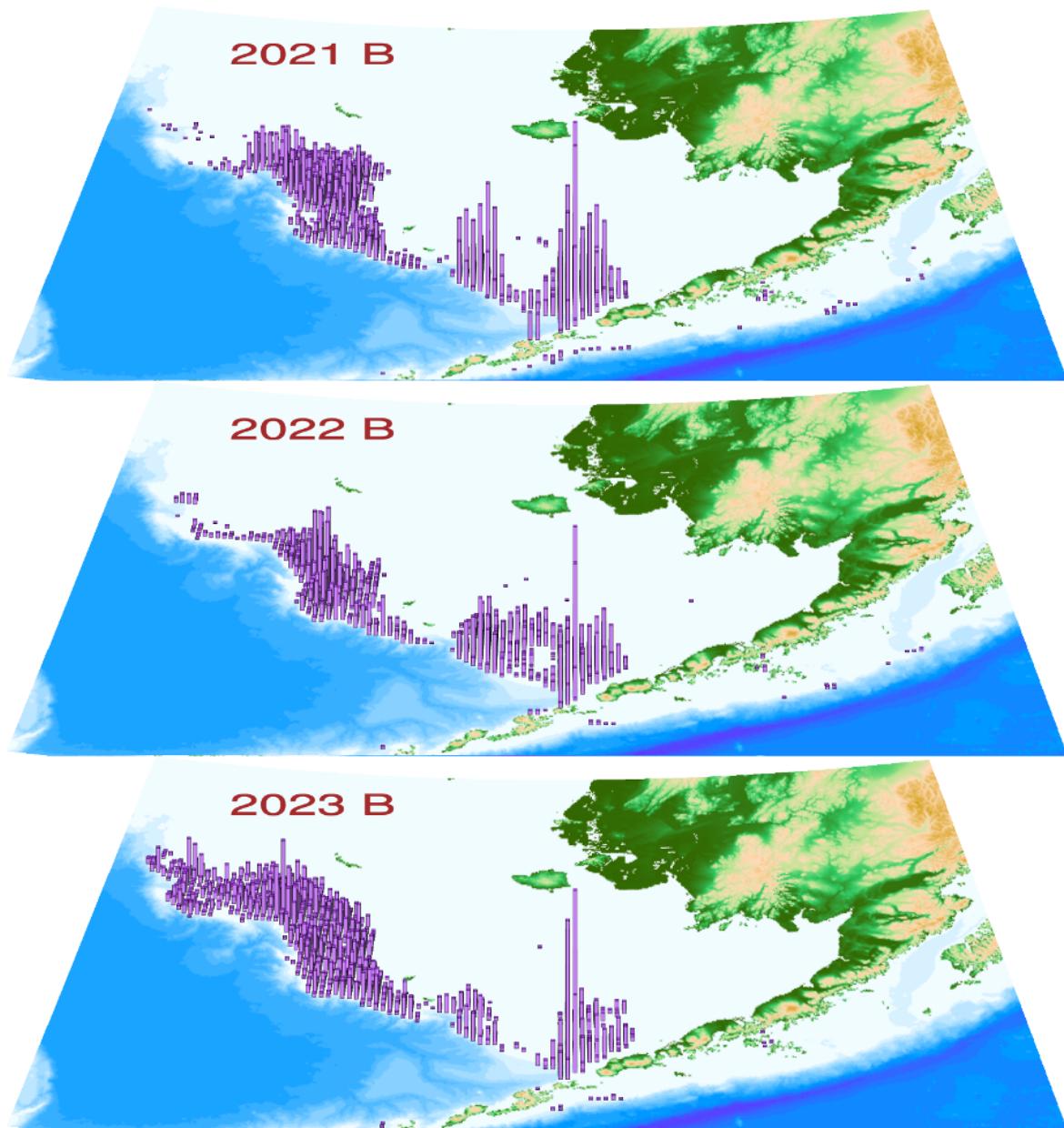


Figure 9: EBS pollock catch distribution during B-season, 2021–2023. Column height is proportional to total catch. Note that directed fishery for pollock generally is finished prior to October; the labels are indicative full-year catches.

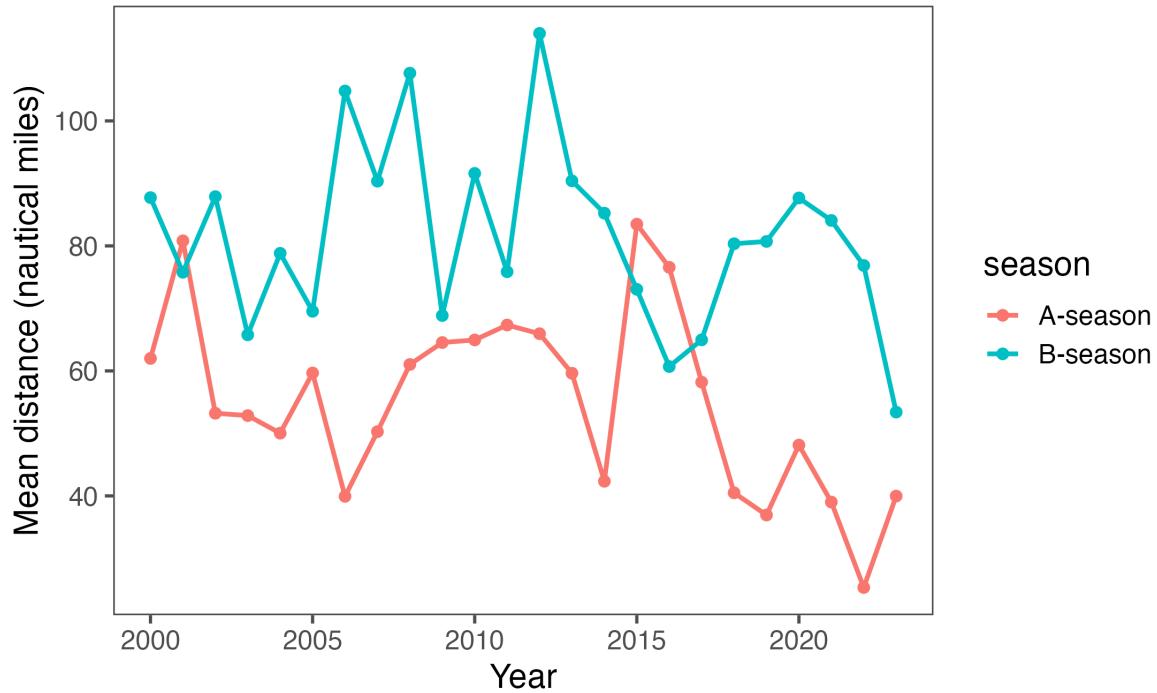


Figure 10: Estimated mean daily distance between operations, 2000-2023.

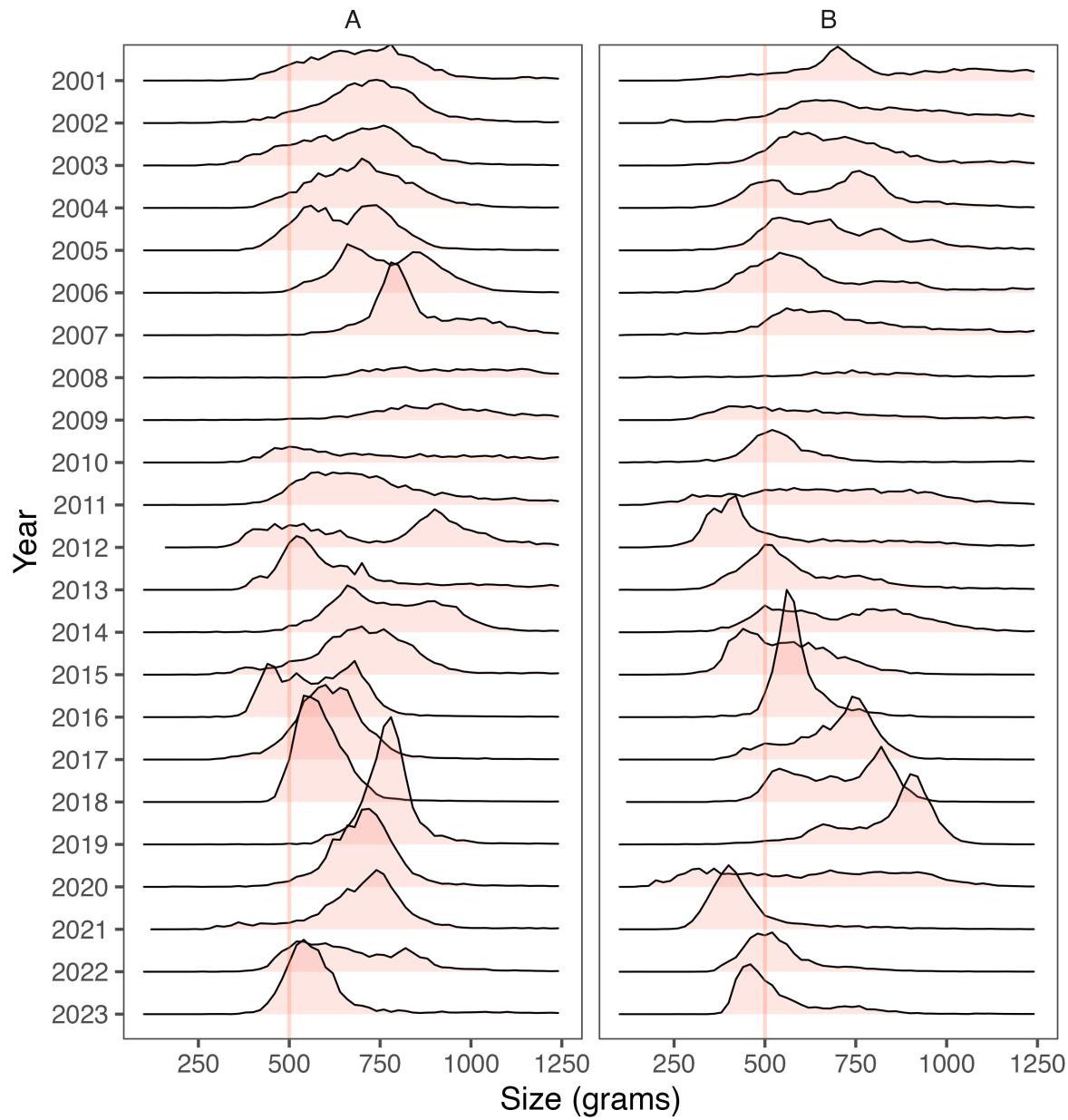


Figure 11: Pollock fishery data showing the frequency of mean pollock weight within a tow (in 50 g increments) by year and season.

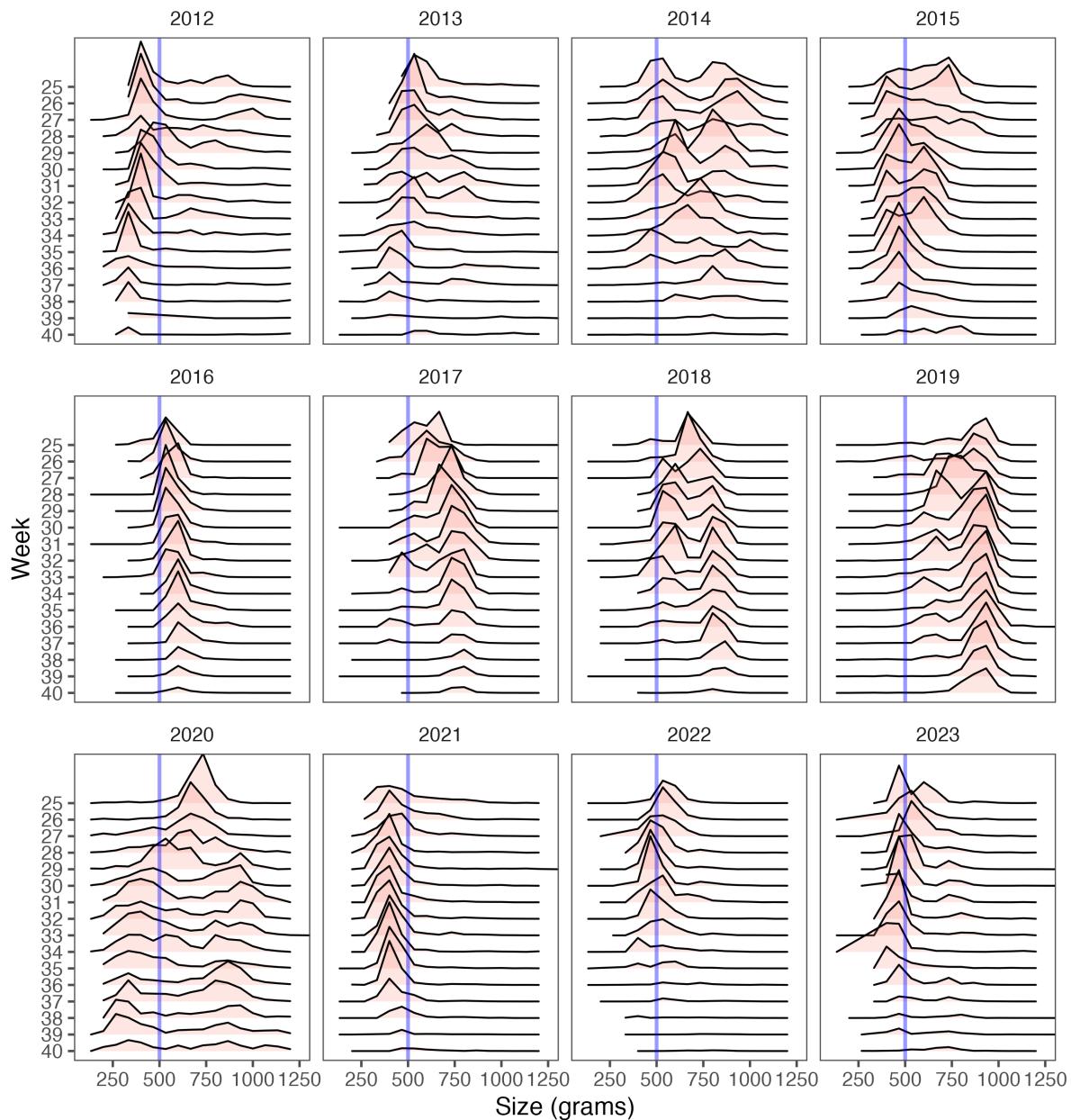


Figure 12: Pollock fishery data showing the frequency of mean pollock weight within a tow (in 50 g increments) by recent years and weeks of the B-season.

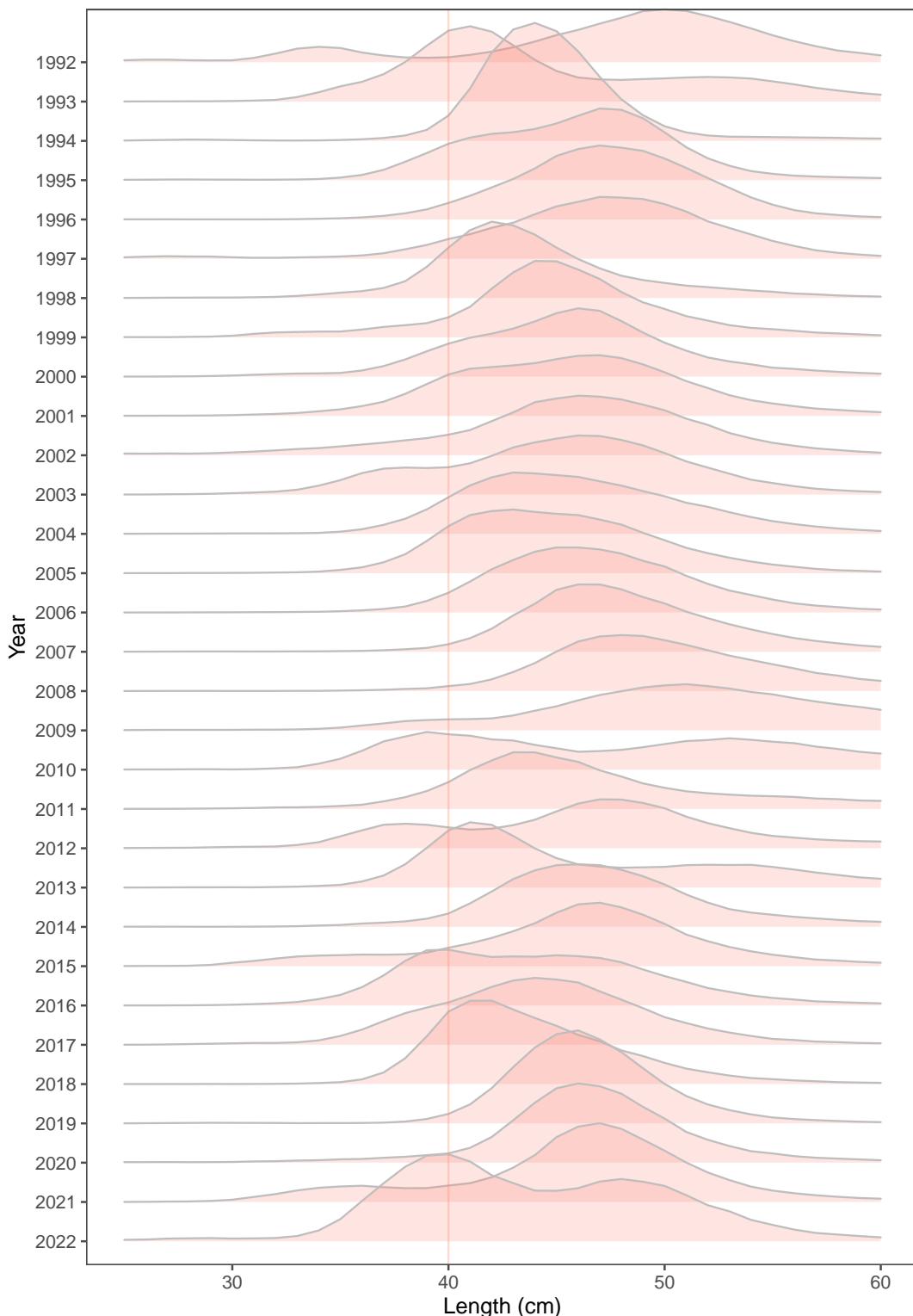


Figure 13: Fishery catch-at-length (cm) by the pollock fishery, 1992-2023.

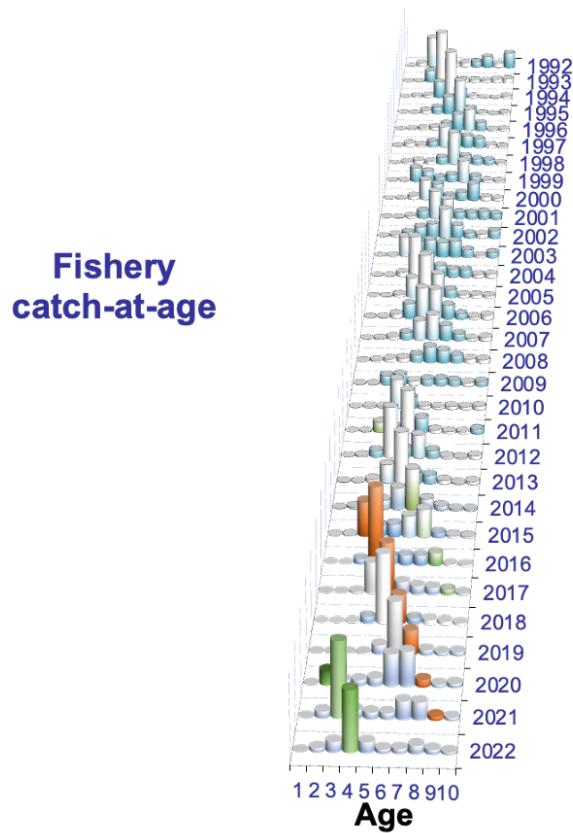


Figure 14: EBS pollock fishery estimated catch-at-age data (in number) for 1992–2022. Age 10 represents pollock age 10 and older. The 2012 year-class is shaded in orange.

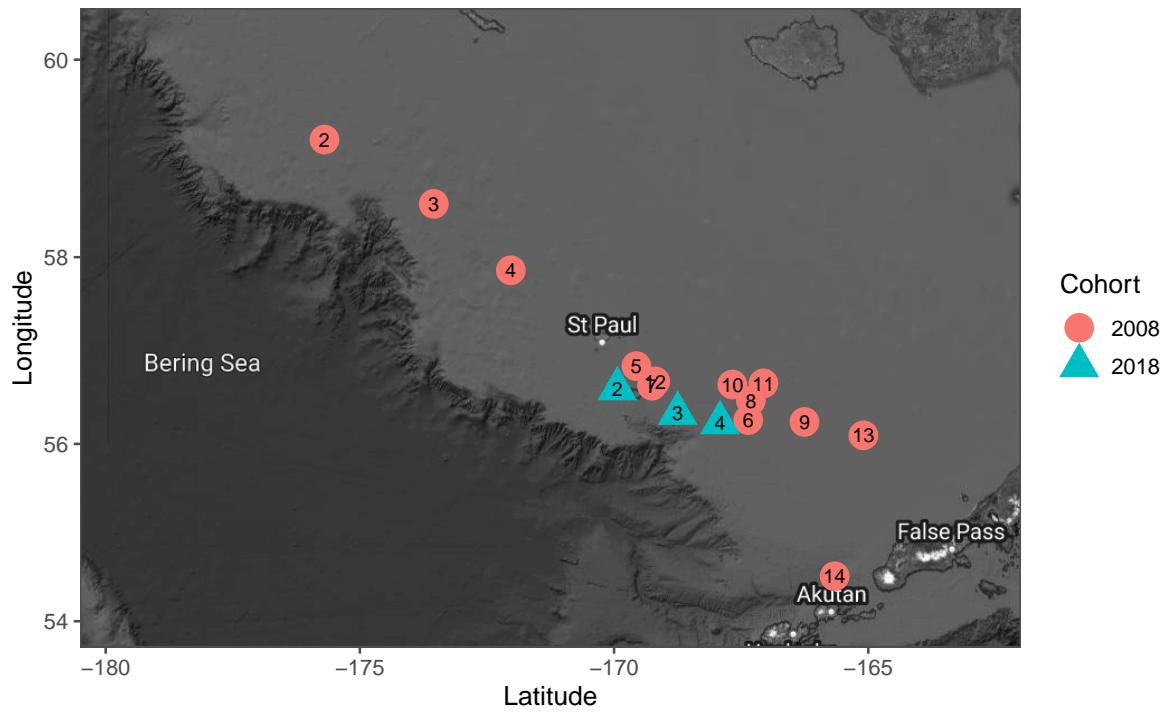


Figure 15: Pollock age sample mean locales for two cohorts representing the 2008 and 2018 year-classes (from data through 2022).

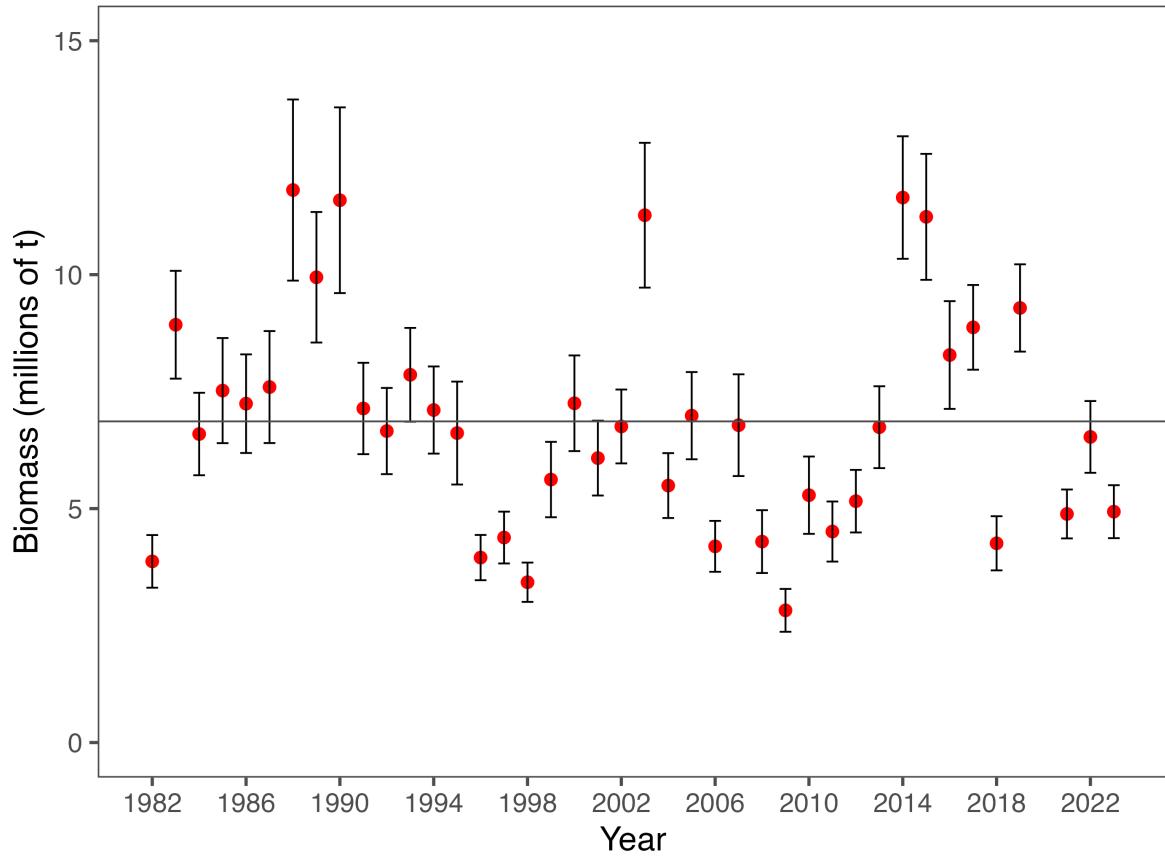


Figure 16: Bottom-trawl survey biomass estimates with error bars representing 95% confidence intervals for the VAST model-based methods for EBS pollock.

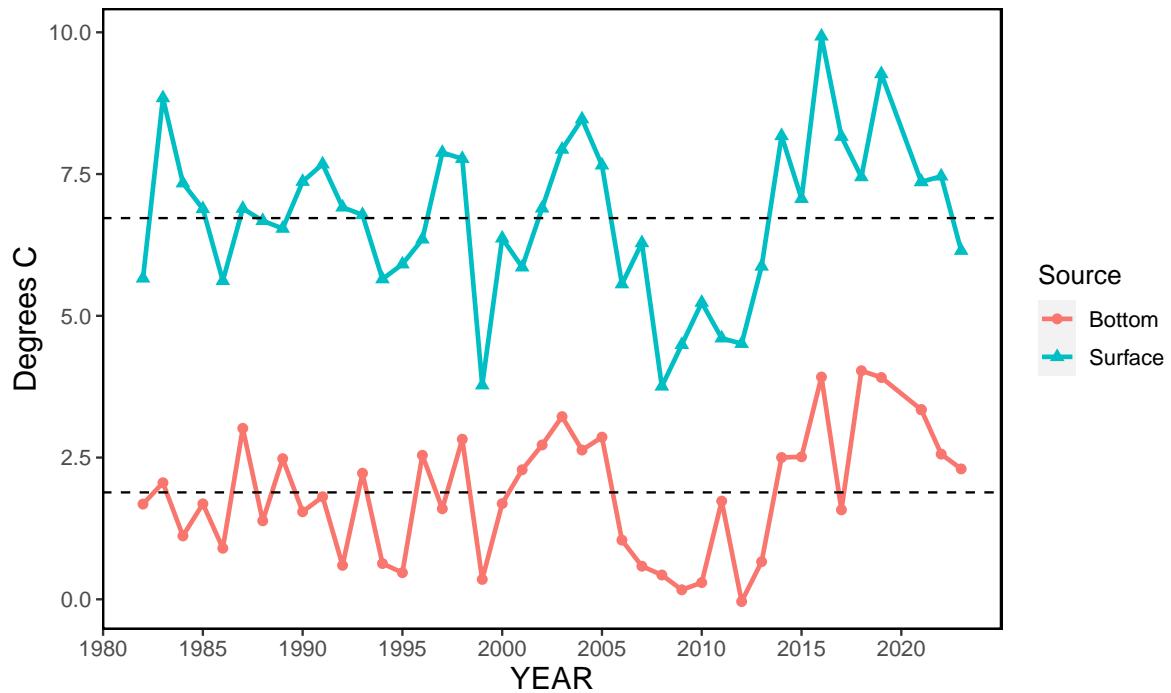


Figure 17: Bottom and surface temperatures for the Bering Sea from the NMFS summer bottom-trawl surveys (1982–2019, 2021–2023). Dashed lines represent mean values.

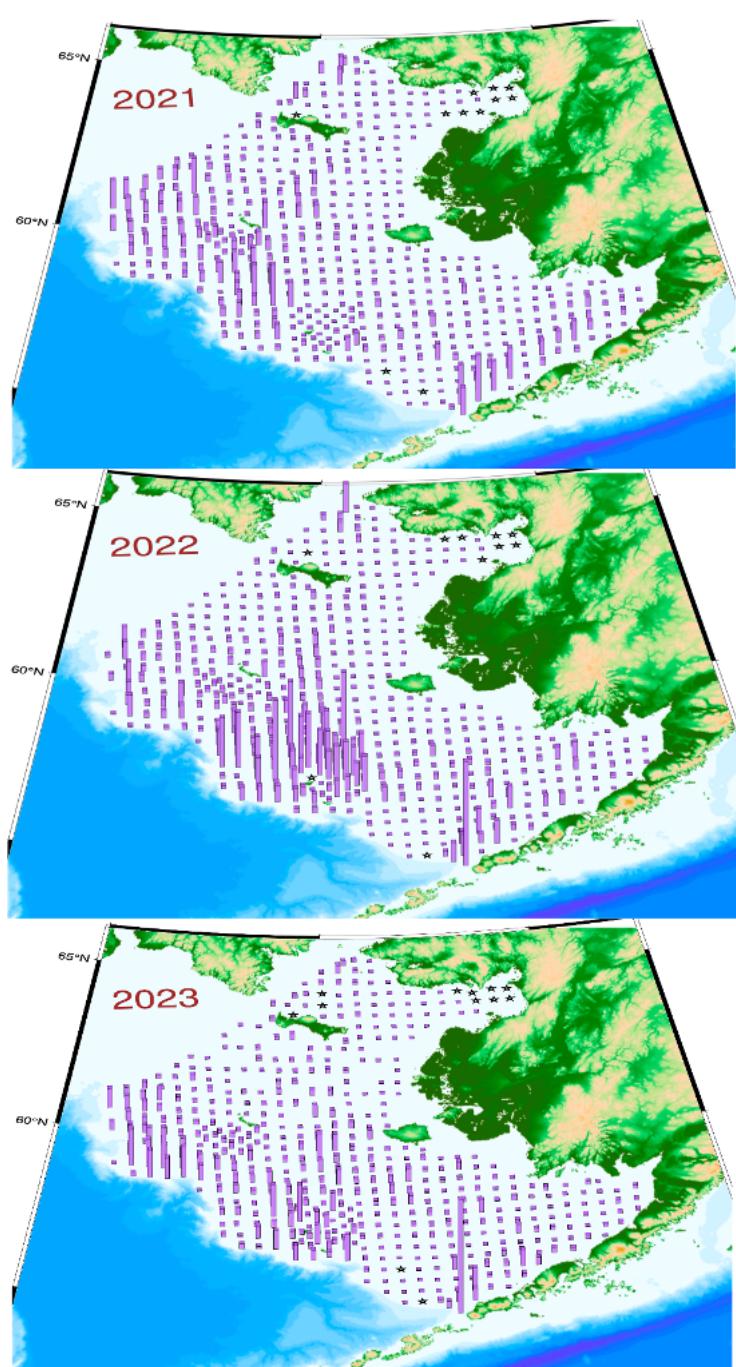


Figure 18: Bottom trawl survey pollock catch in kg per hectare for 2021-2023. Height of vertical lines are proportional to station-specific pollock densities by weight (kg per hectare) with constant scales for all years (red stars indicate tows where pollock were absent from the catch).

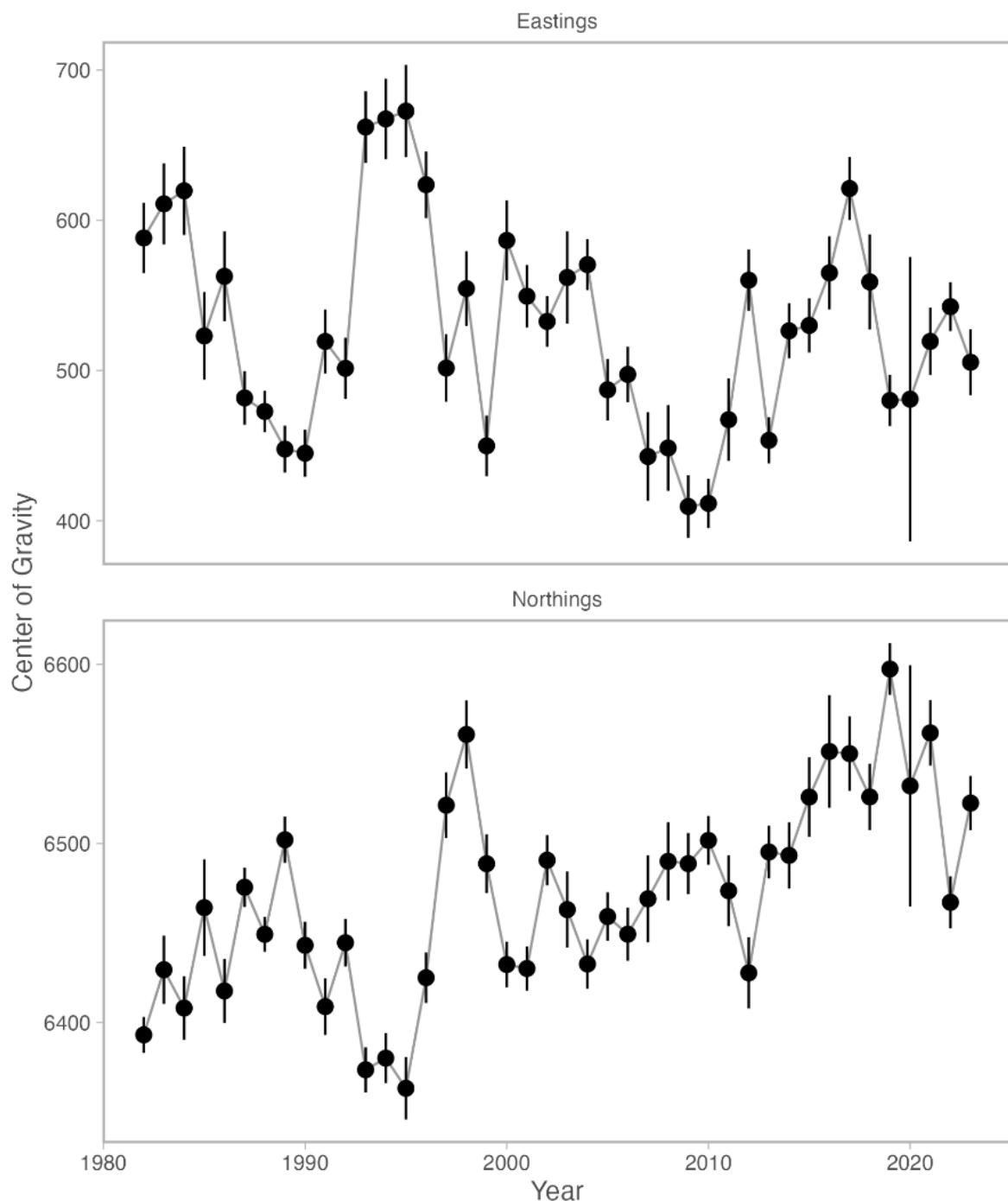


Figure 19: The EBS pollock stock center of gravity as estimated over time using VAST

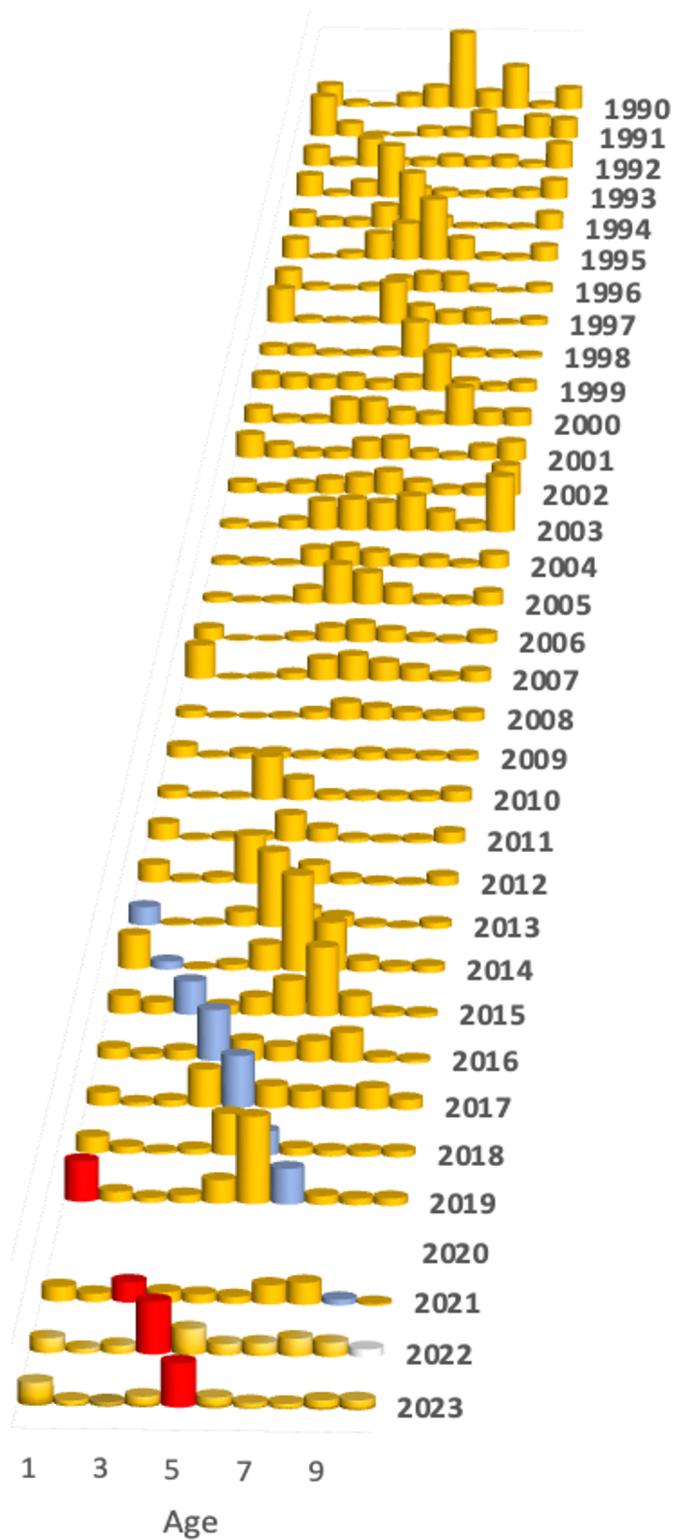


Figure 20: Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1990–2019, 2021–2023). The 2012 and 2018 year-classes are shaded differently.

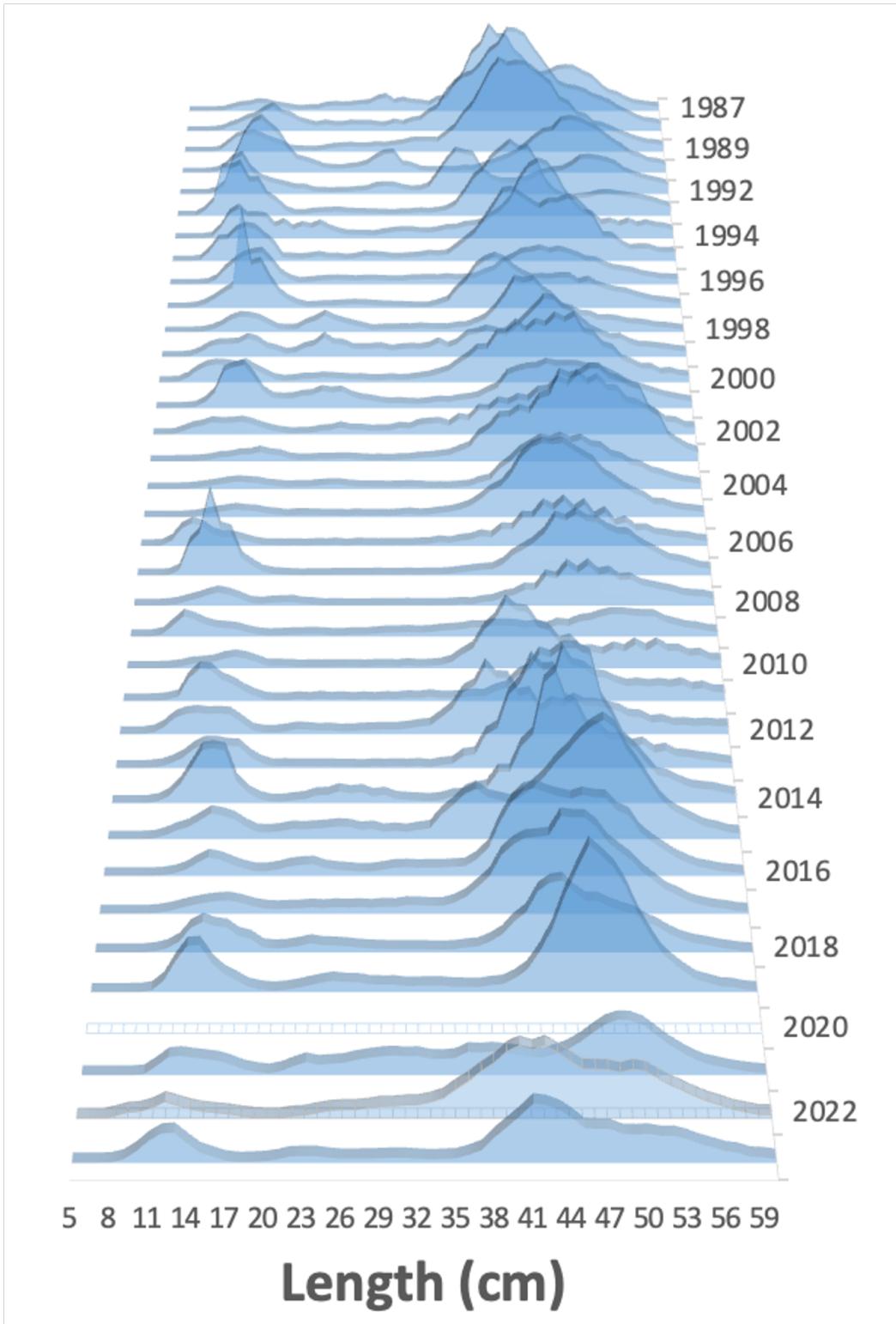


Figure 21: Pollock abundance levels by size and year as estimated from the NMFS bottom-trawl surveys (1990–2019 and 2021–2023).

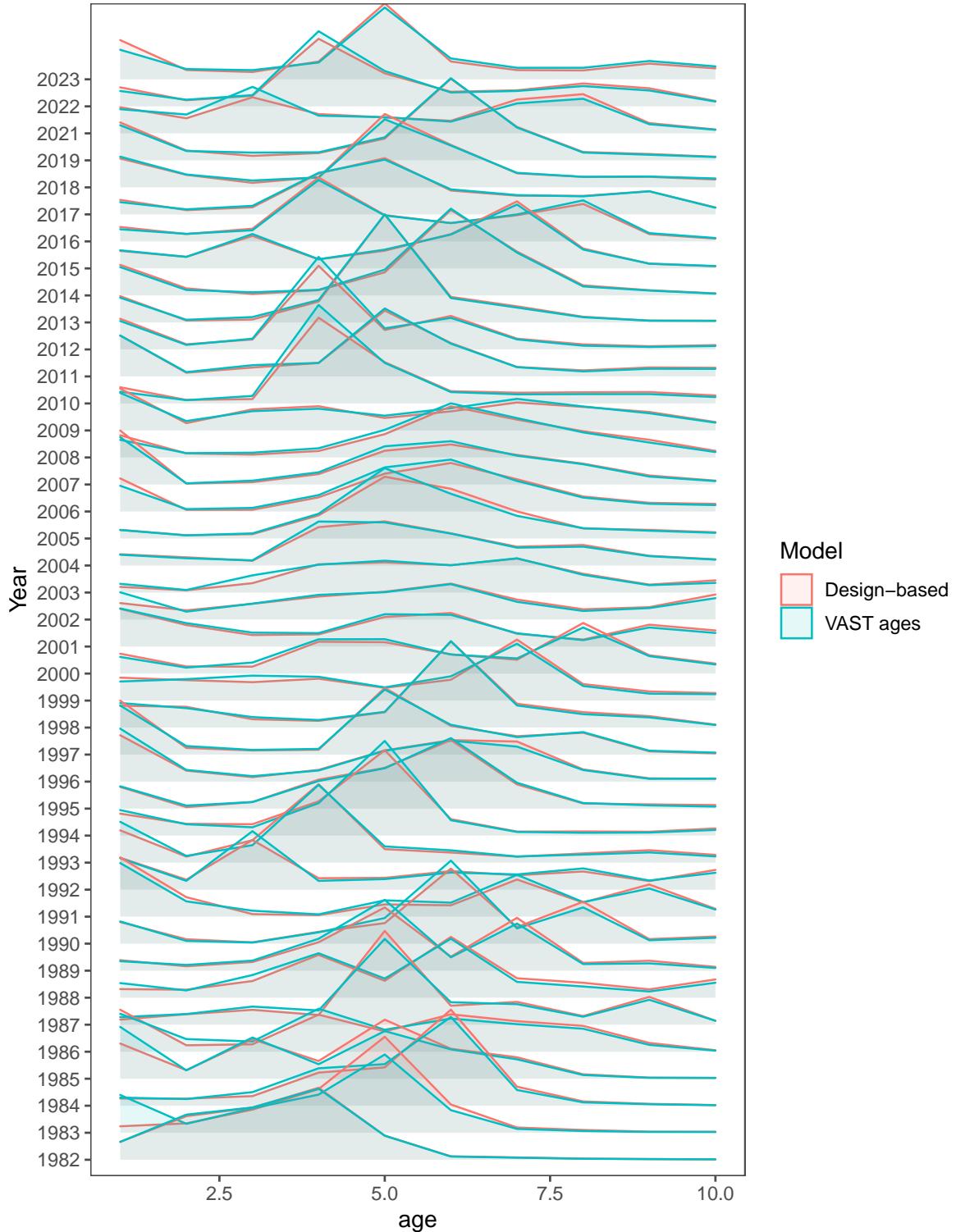


Figure 22: Comparison of EBS pollock estimated proportions-at-age from the bottom trawl surveys using the standard design-based estimates and those using the VAST spatio-temporal model, 1982-2023 (no data from 2020).

# Acoustic survey numbers

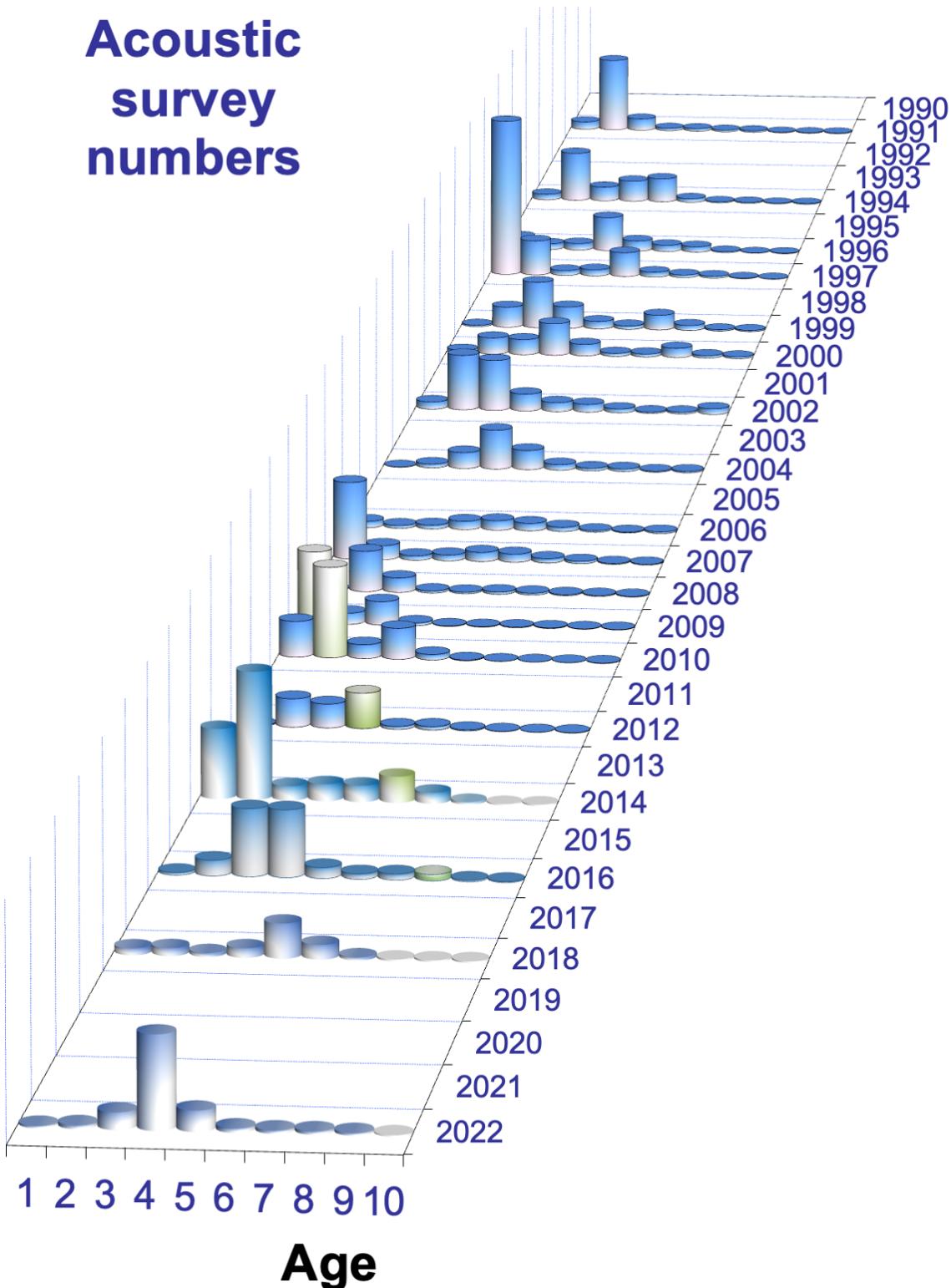


Figure 23: Acoustic-trawl survey pollock numbers-at-age estimates, 1991-2022. Note that the series used in the model starts in 1994.

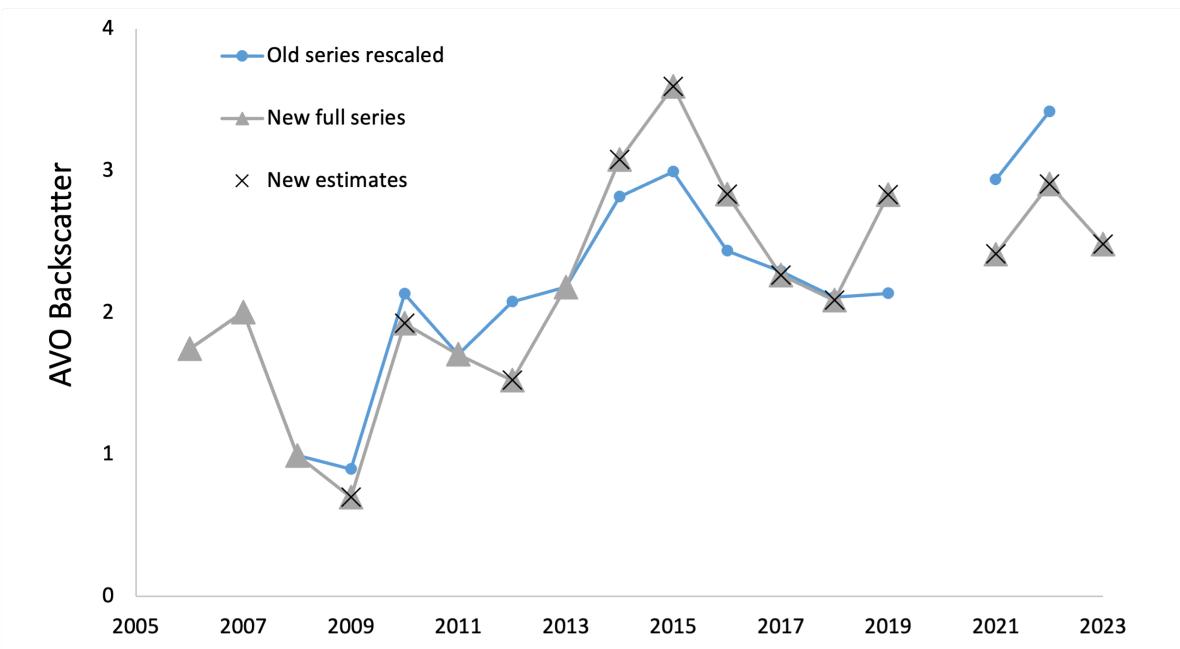


Figure 24: Time series of EBS pollock data from the acoustic vessels of opportunity (AVO) showing the years of new data compared to previous series and the full series.

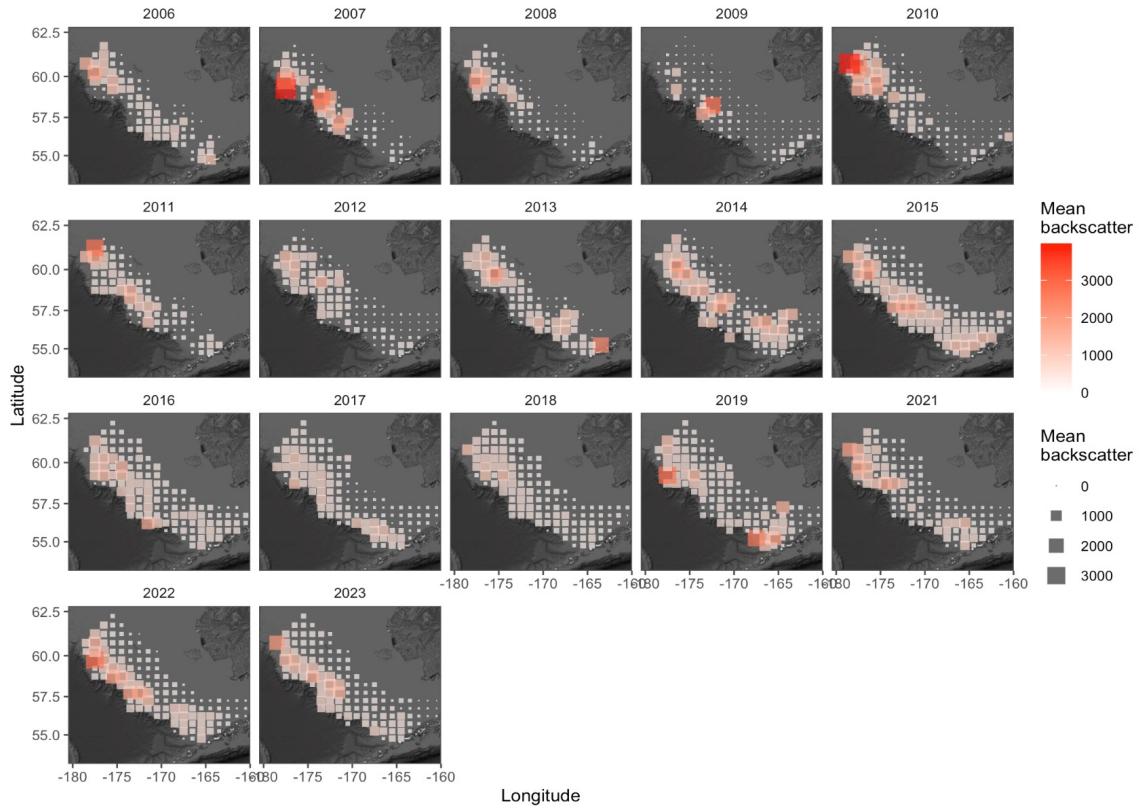


Figure 25: Maps of acoustic vessel-of-opportunity (AVO) index data 2006-2023. Grid cell size and shading is proportional to pollock backscatter.

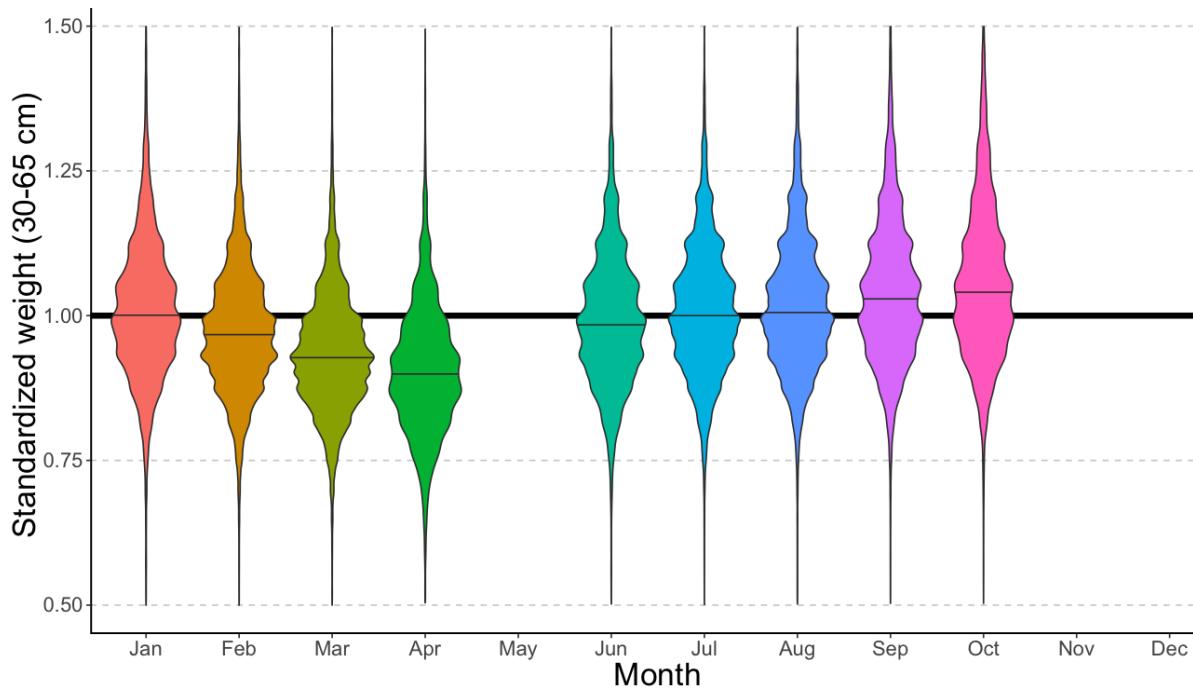


Figure 26: EBS pollock fishery body mass (given length) anomaly (standardized by overall mean body mass at each length) by month based on some over 700 thousand fish measurements from 1991–2023.

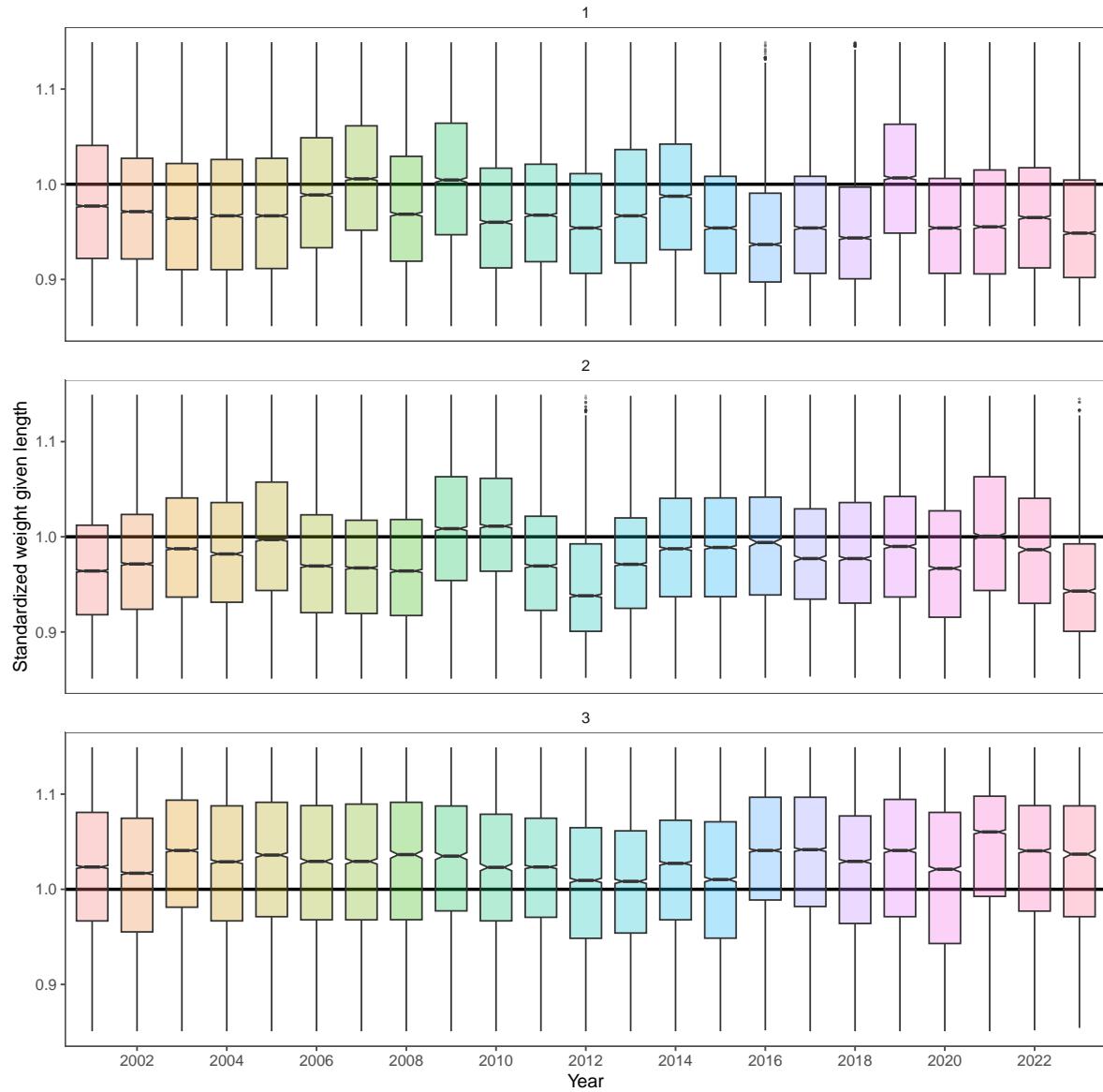


Figure 27: EBS pollock fishery body mass (given length) anomaly (standardized by overall mean body mass at each length) by year and season/area strata, 1991–2023. Strata are defined as A-season (top), and B-season west of 170W (middle) and east of 170W (bottom)

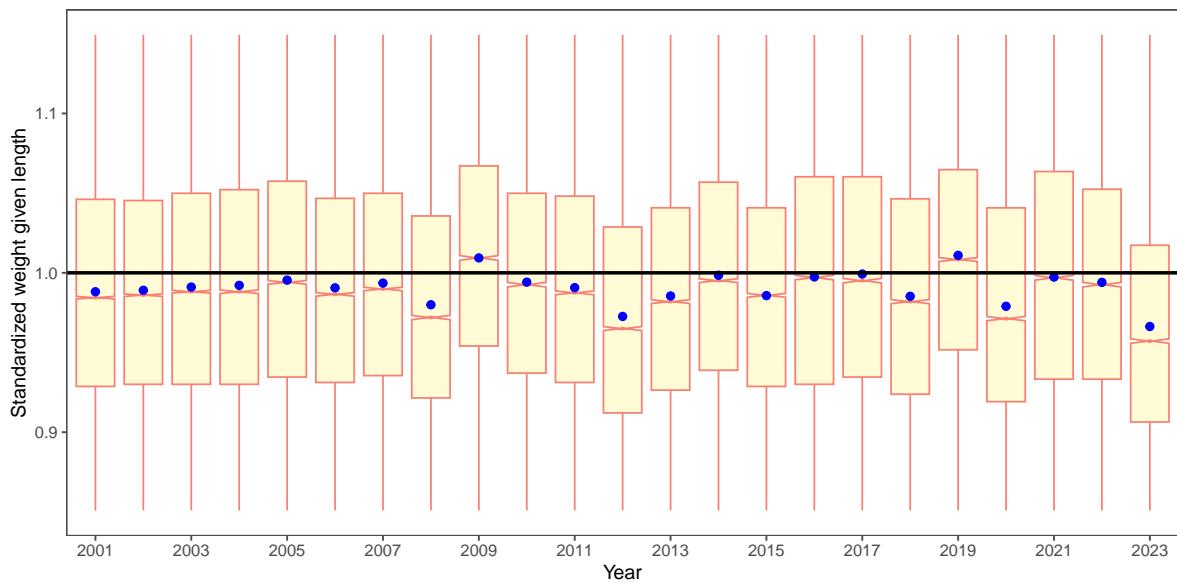


Figure 28: EBS pollock body mass (given length) anomaly (standardized by overall mean body mass at each length) by year, 1991–2023.

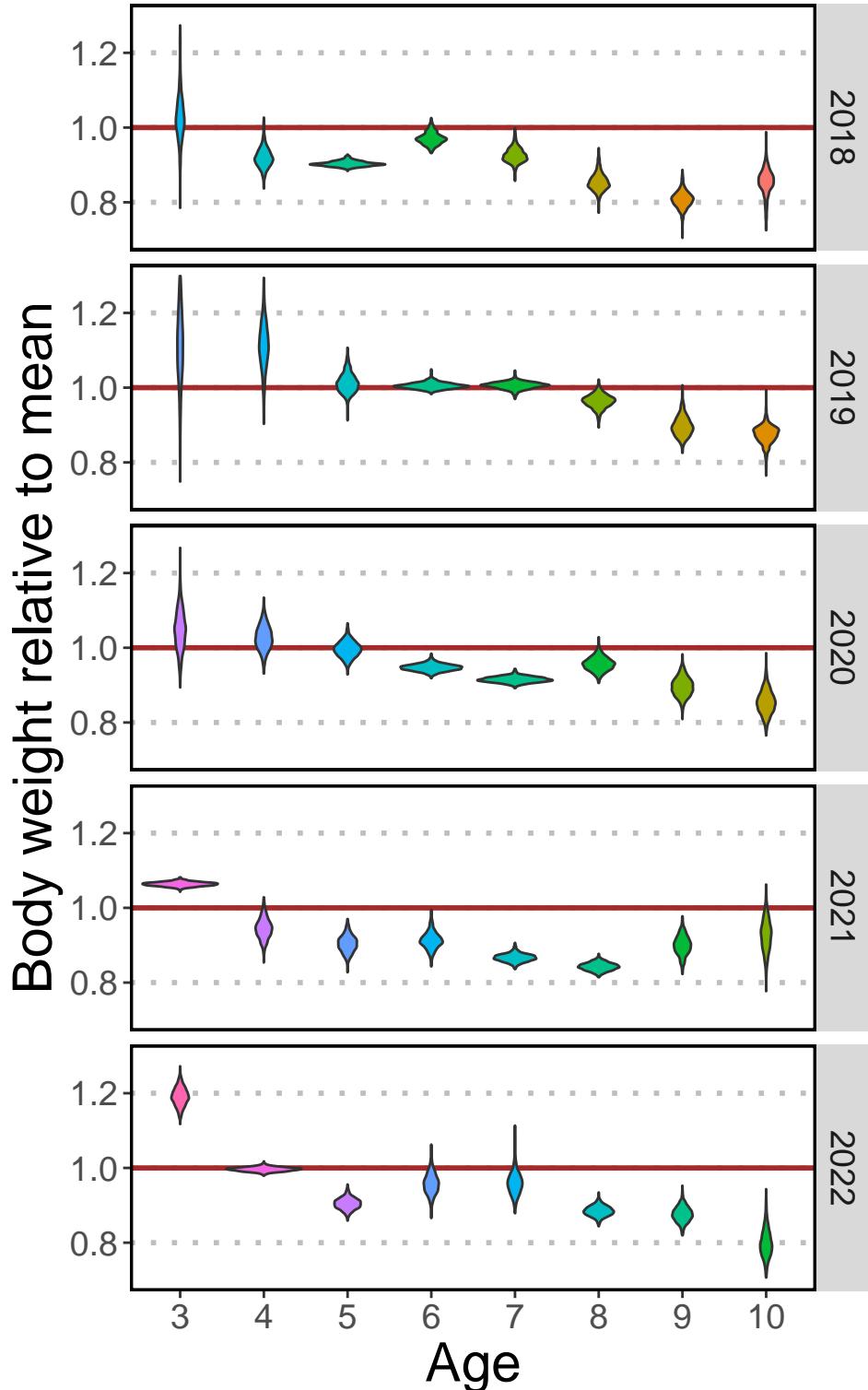


Figure 29: Recent fishery average weight-at-age anomaly (relative to the mean) by strata for ages 3–10, 2017–2021. Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

### Fishery body-weight-at-age

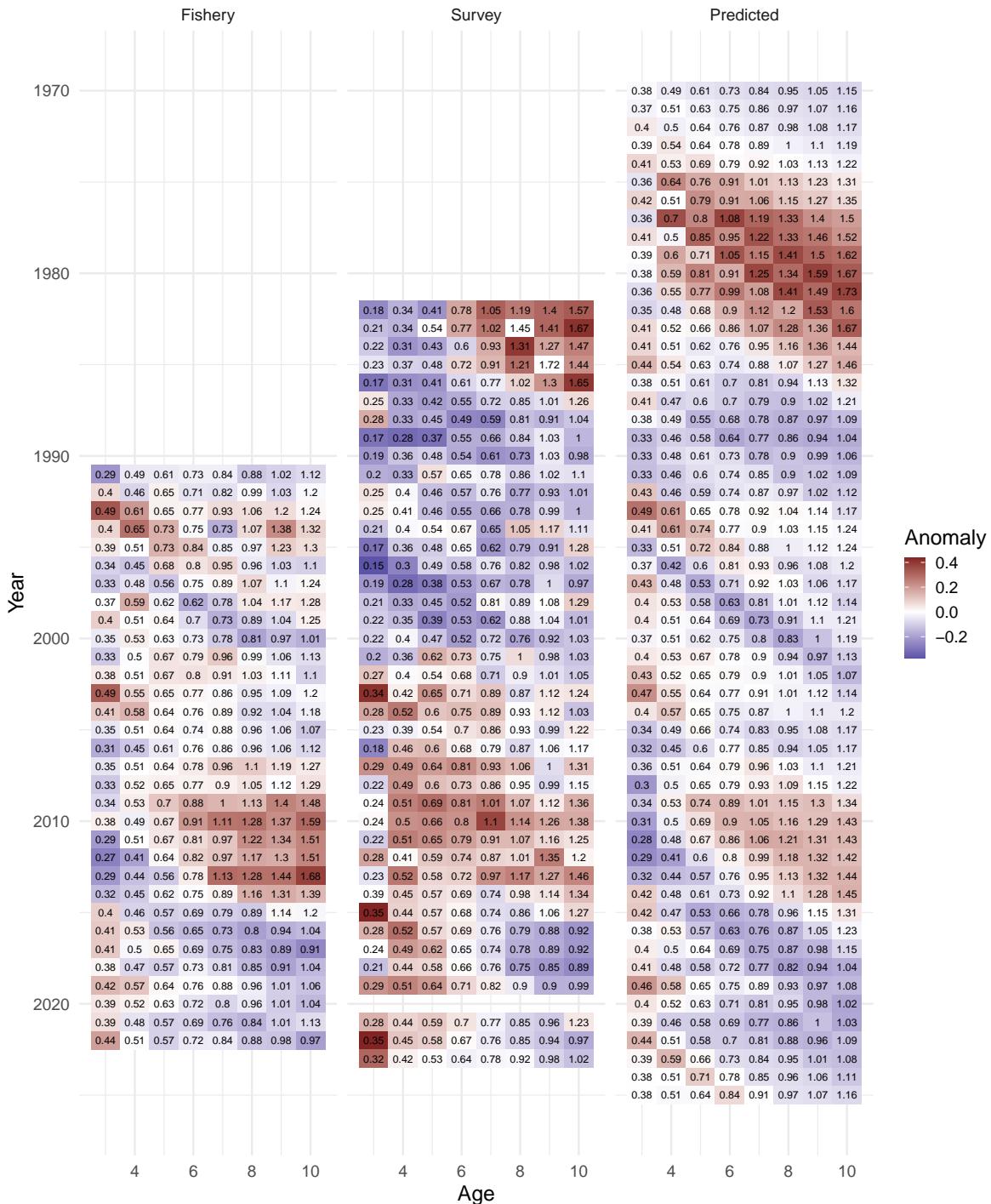


Figure 30: Data input and model predictions for the weight-at-age random-effects model fit separately to obtain variance estimates for cohort and year effect contributions to changes in incremental growth from one age to the next. Shadings reflect the anomaly from the mean while the numbers are the weight-at-age in kg.

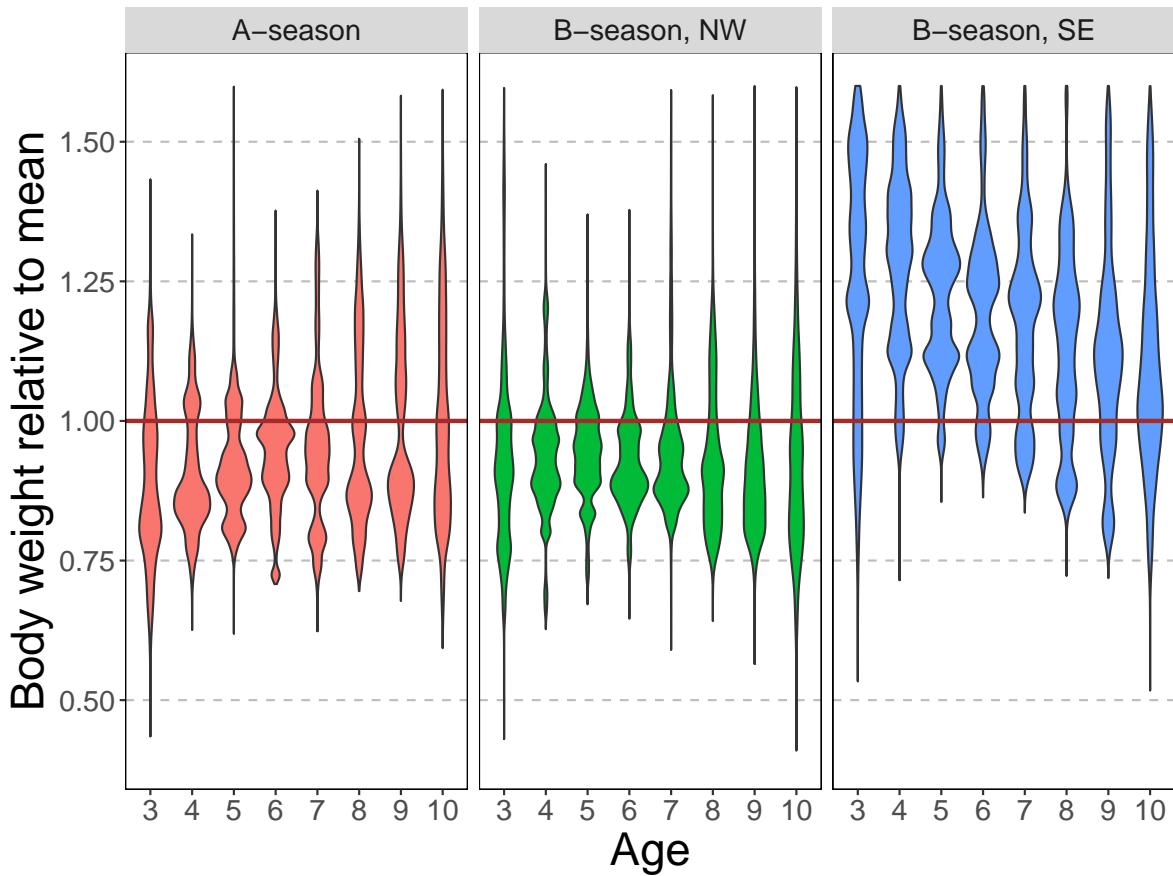


Figure 31: Fishery average weight-at-age anomaly (relative to the mean) across strata and combined for all ages (3–10), and available years (1991–2022). Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

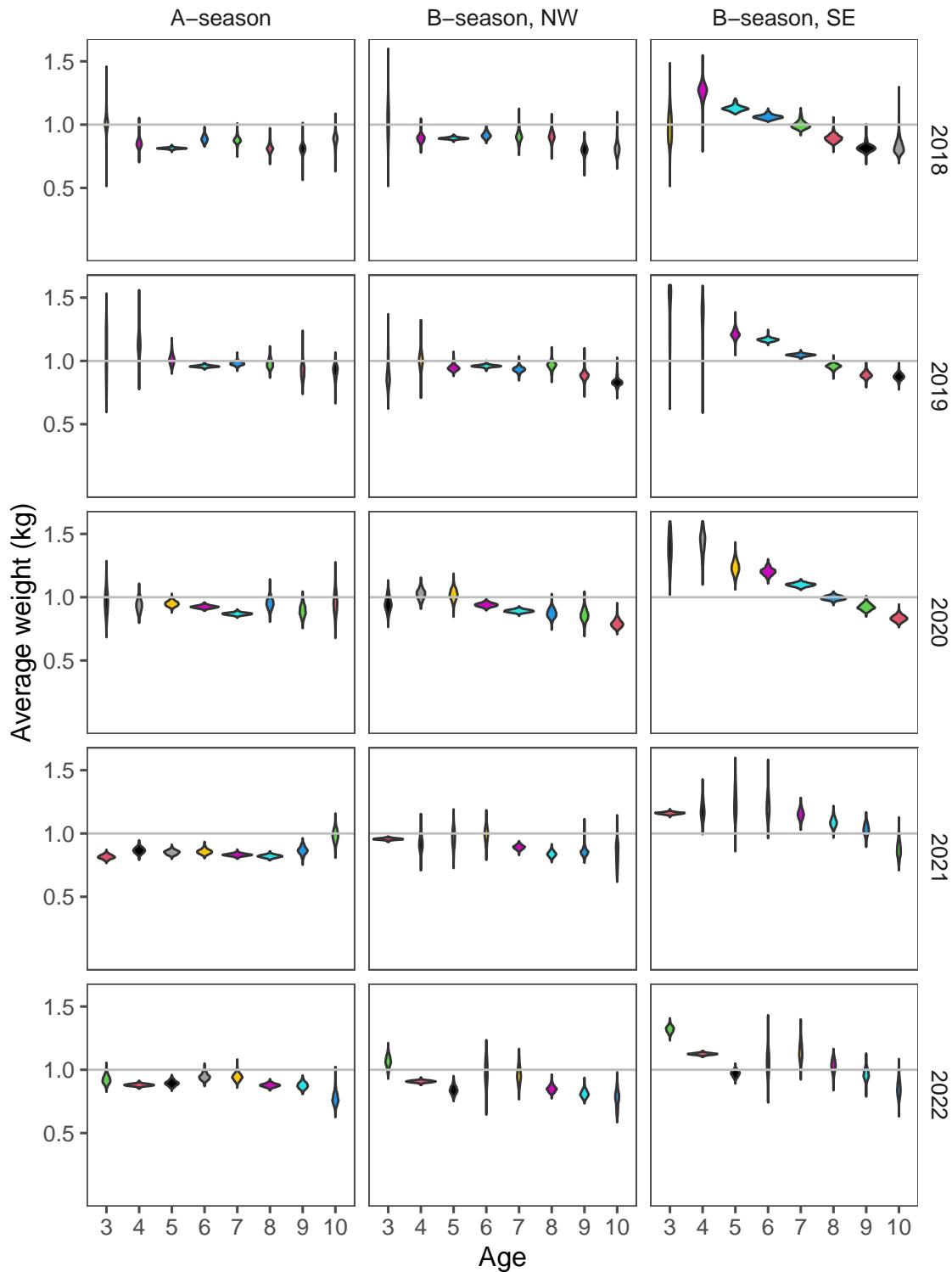


Figure 32: Recent fishery average weight-at-age anomaly (relative to the mean) by strata for ages 3–10, 2018–2022. Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

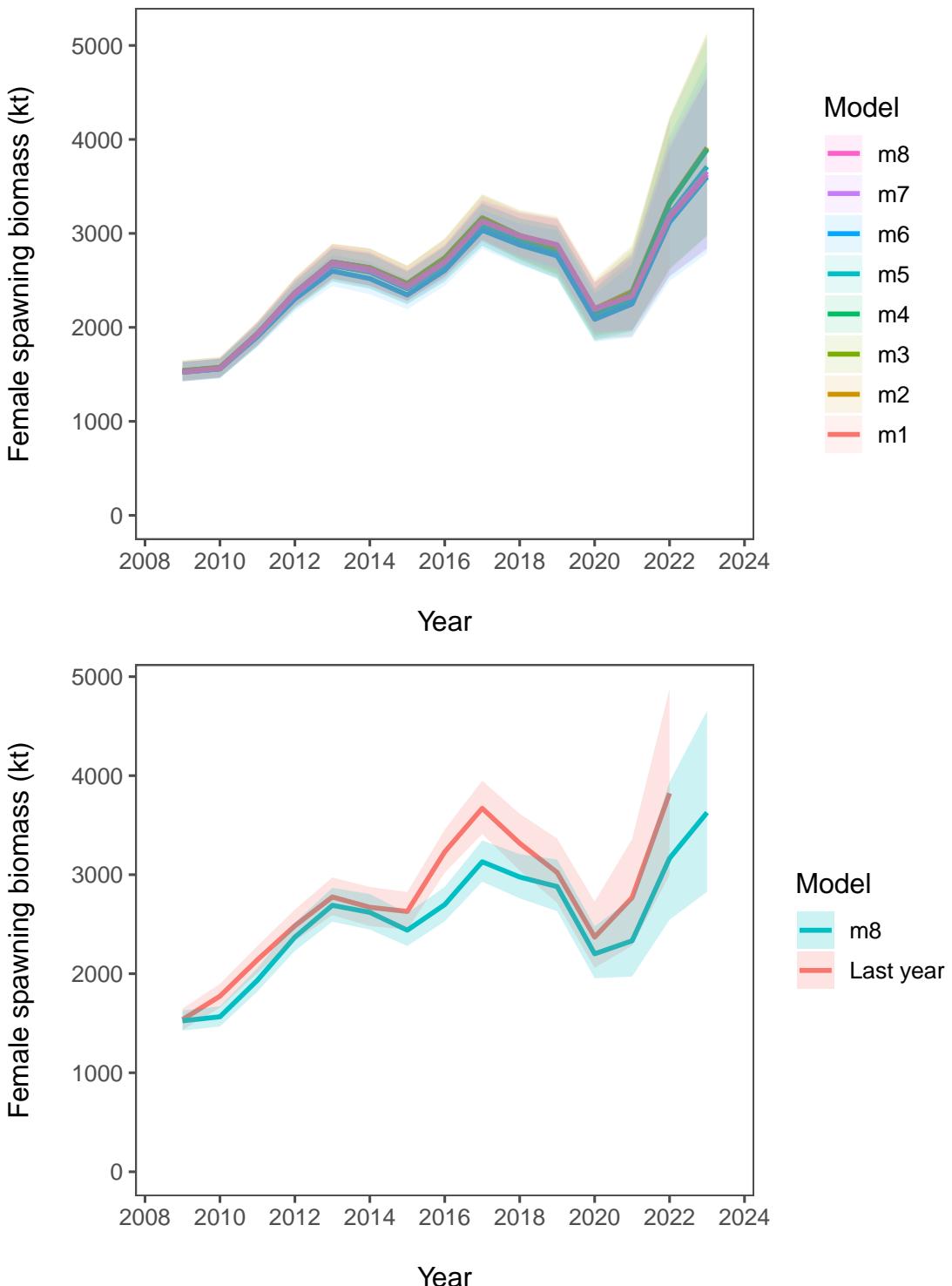


Figure 33: Model runs comparing last year's assessment with the impact of sequentially adding new data (first 2023 catch and 2021 fishery catch-at-age, then the 2023 bottom trawl survey data point, then the acoustic trawl and finally the AVO data).

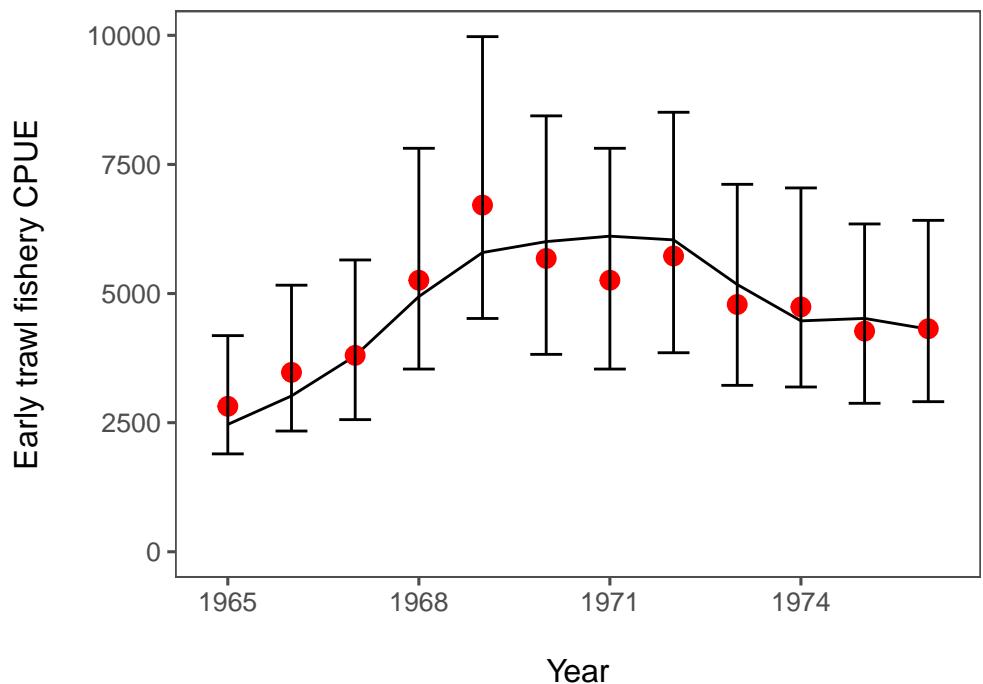


Figure 34: EBS pollock model fits to the Japanese fishery CPUE.

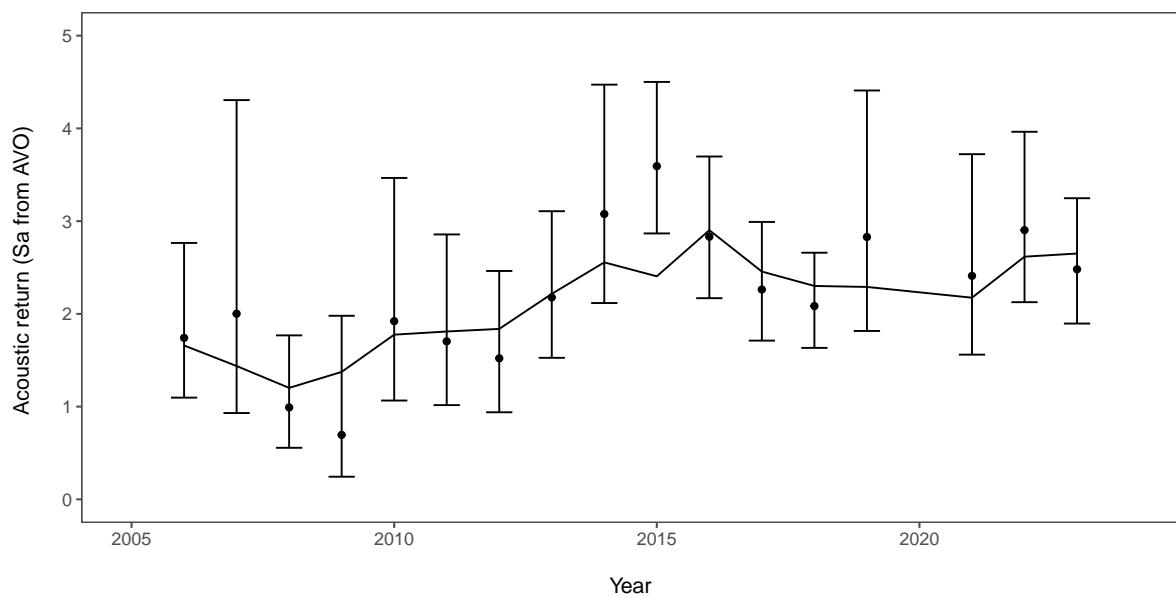


Figure 35: Model results of predicted and observed AVO index. Error bars represent assumed 95% confidence bounds of the input series.

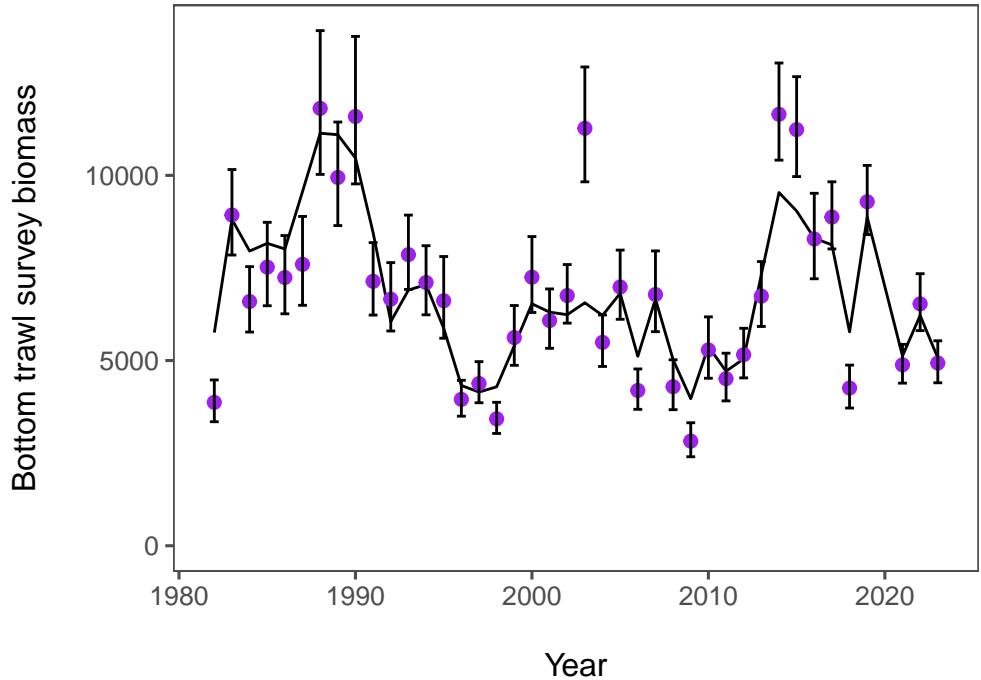


Figure 36: EBS pollock model fit to the BTS survey data (VAST estimates based on density dependence-corrected CPUE by station), 1982–2019, 2021-2023. Units are relative biomass.

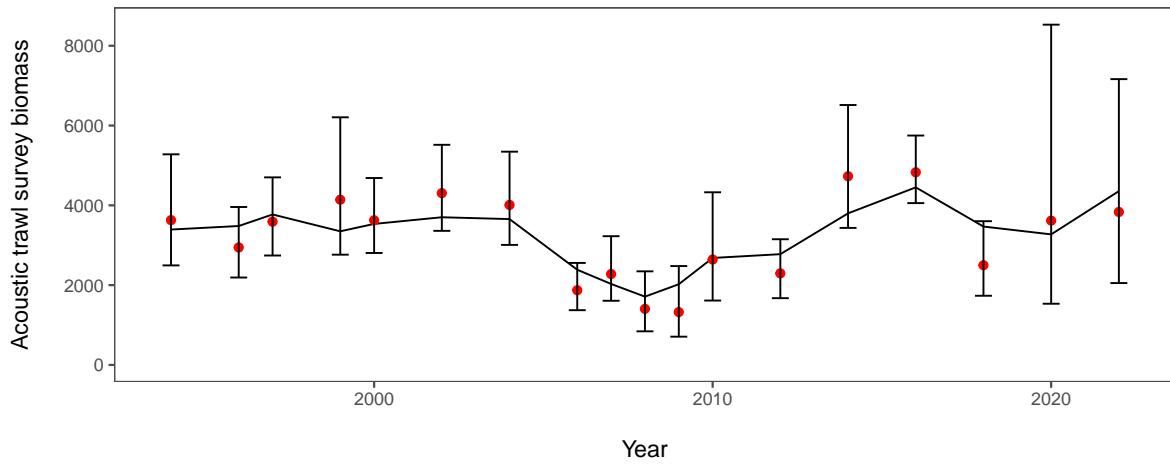


Figure 37: EBS pollock model fit to the ATS biomass index, 1994–2022.

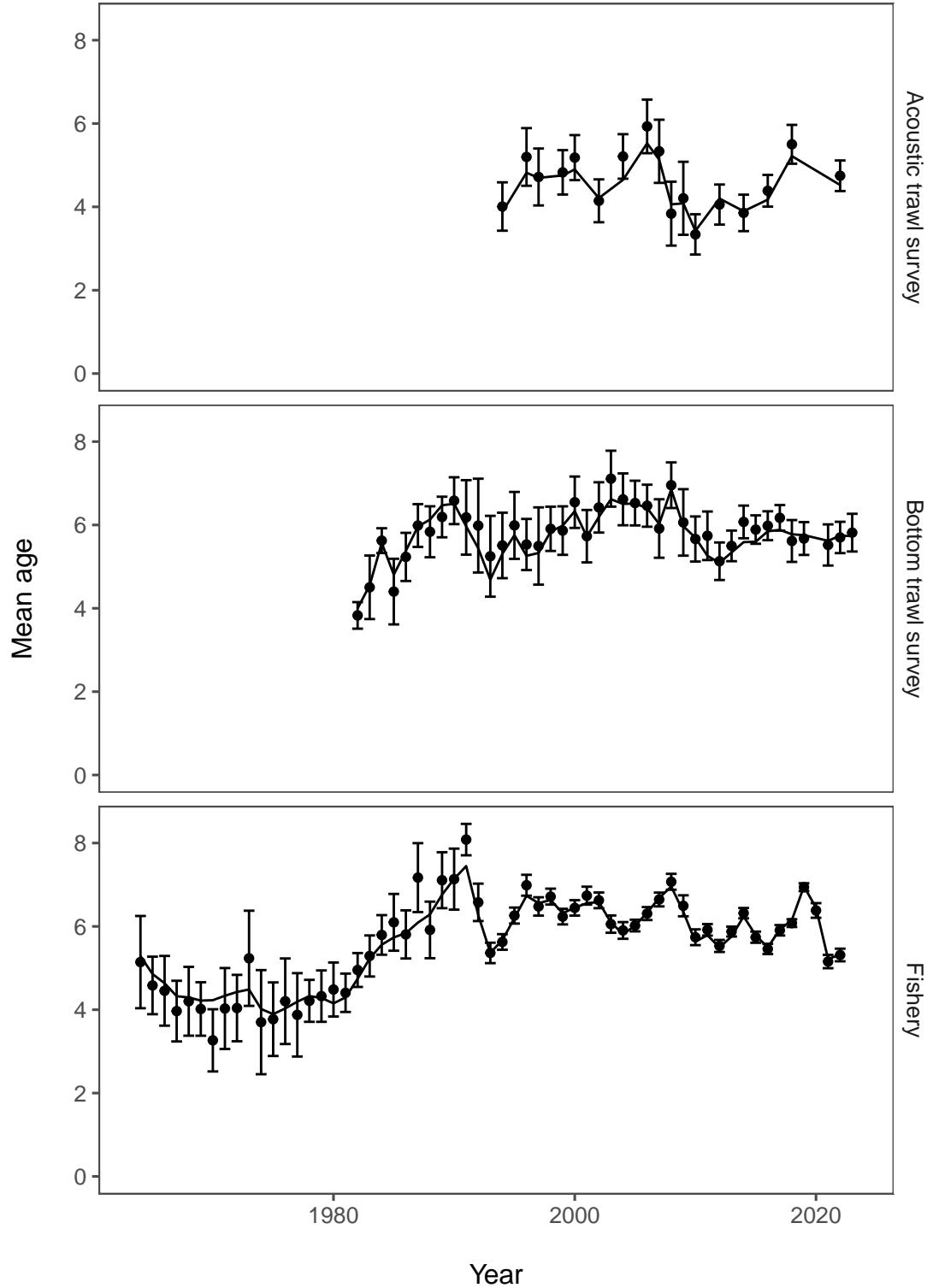


Figure 38: EBS pollock model fits to observed mean age for the Acoustic trawl survey (top), the bottom trawl survey (middle) and fishery (bottom)

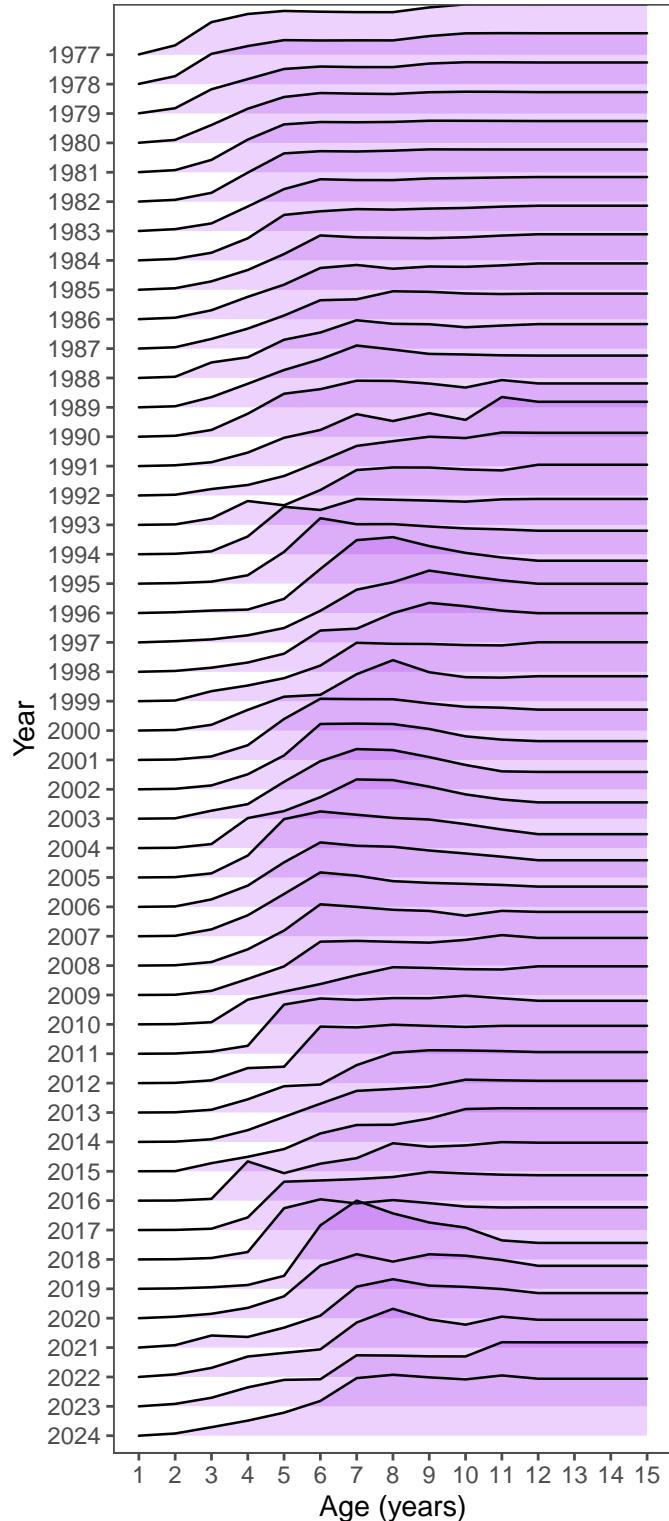


Figure 39: Selectivity at age estimates for the EBS pollock fishery; note that the values for the terminal year is used for ABC and OFL projections.

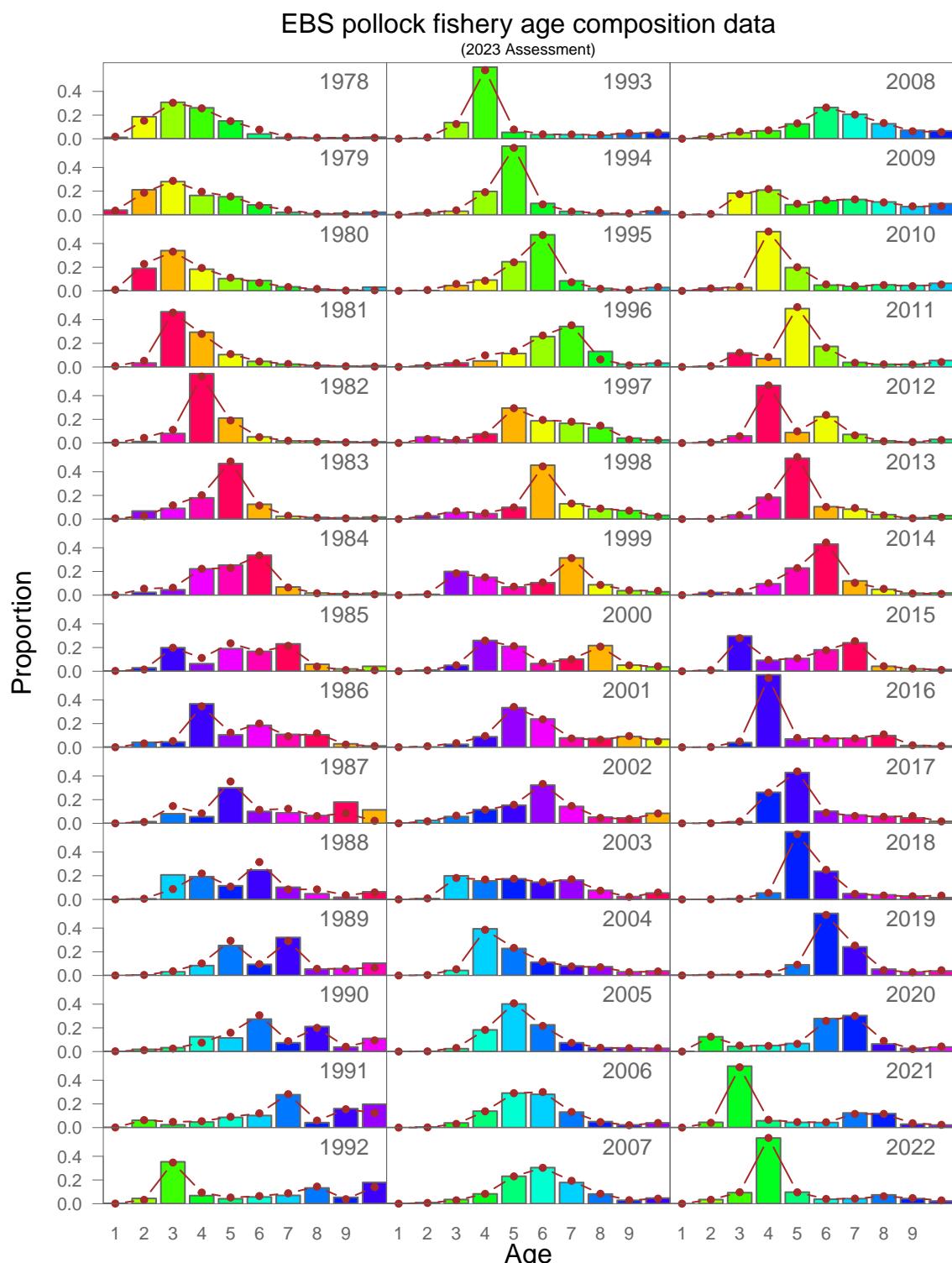


Figure 40: Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1992–2022). The 2022 data are new to this year’s assessment. Colors coincide with cohorts progressing through time. 129

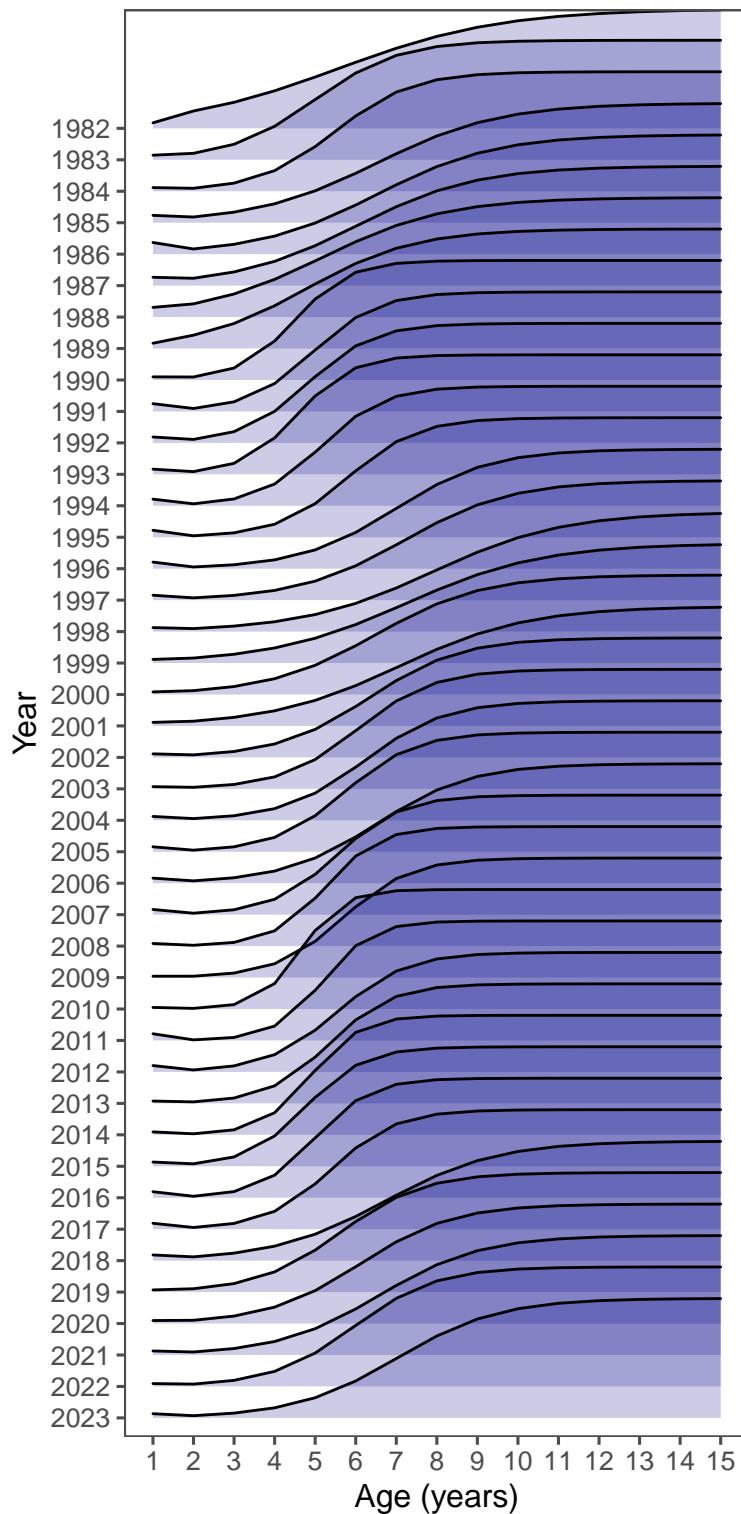


Figure 41: Model estimates of bottom-trawl survey selectivity, 1982–2023.

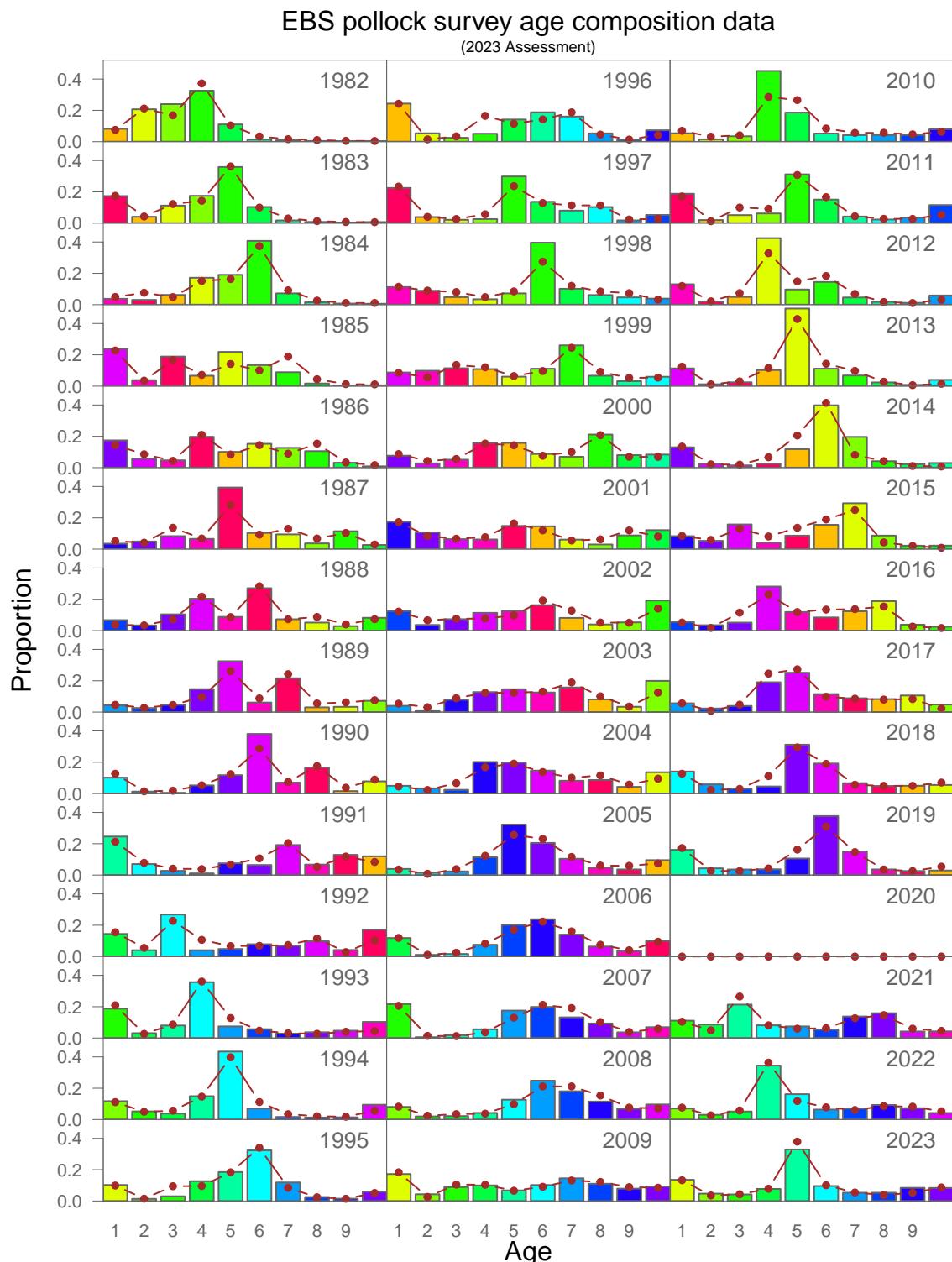


Figure 42: Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time.

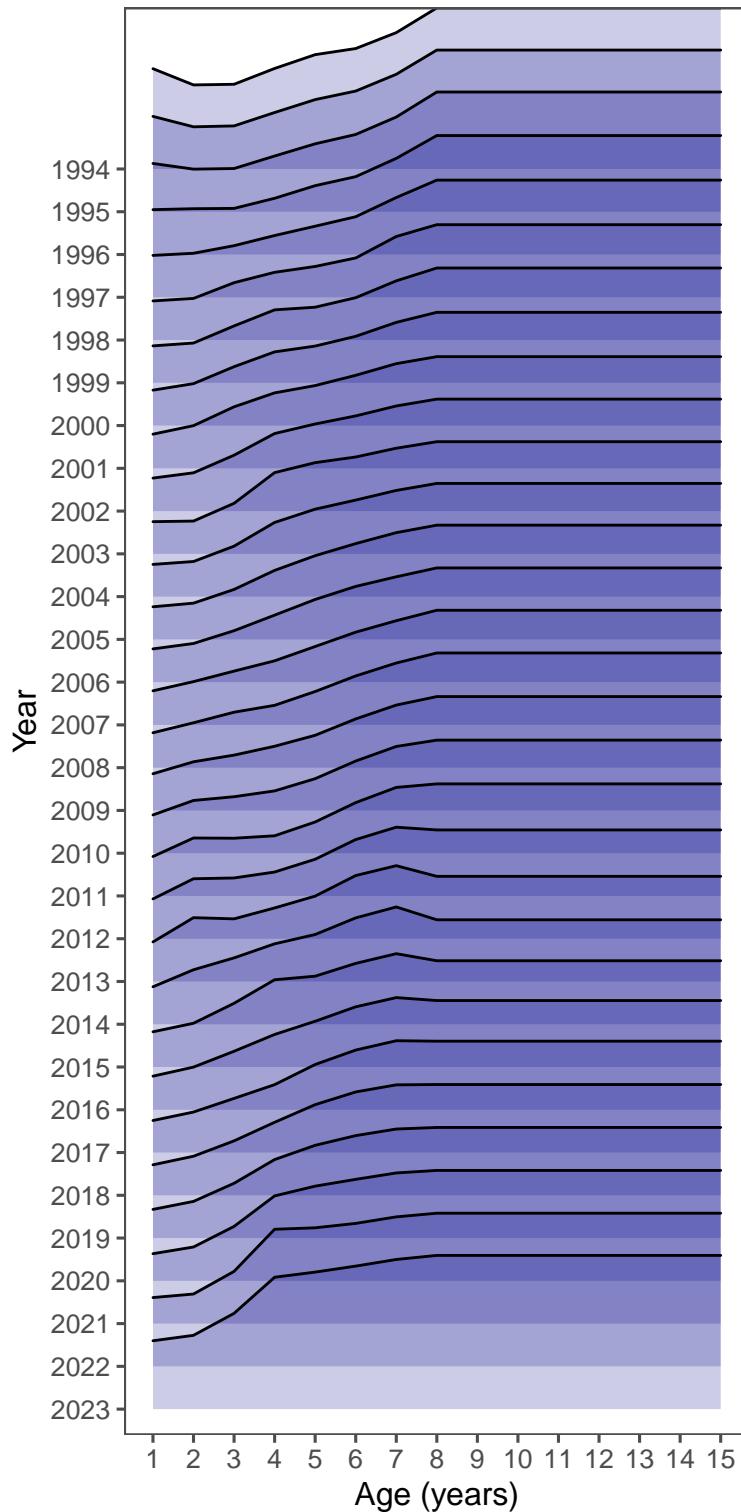


Figure 43: Estimates of AT survey numbers selectivity-at-age (with mean value equal to 1.0) over time for EBS pollock age 2 and older.

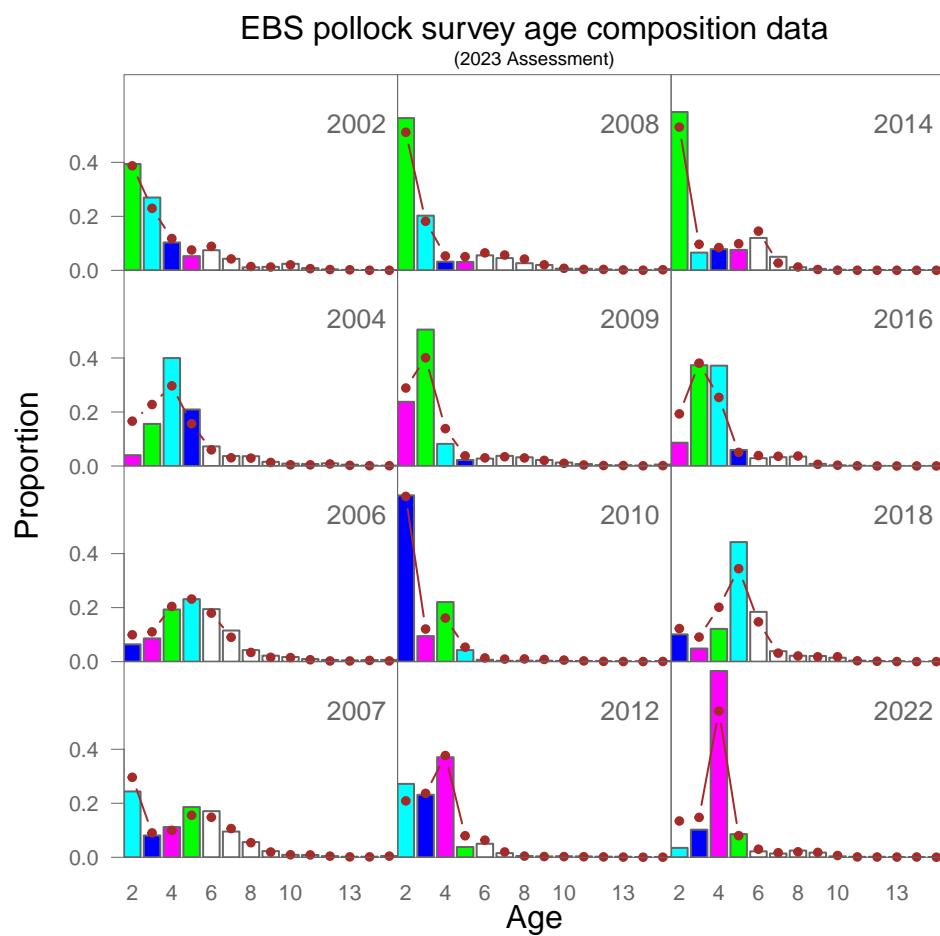


Figure 44: Model fit (dots) to the acoustic-trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time (for years with consecutive surveys).

## Comparing Bayesian vs frequentist uncertainty estimates

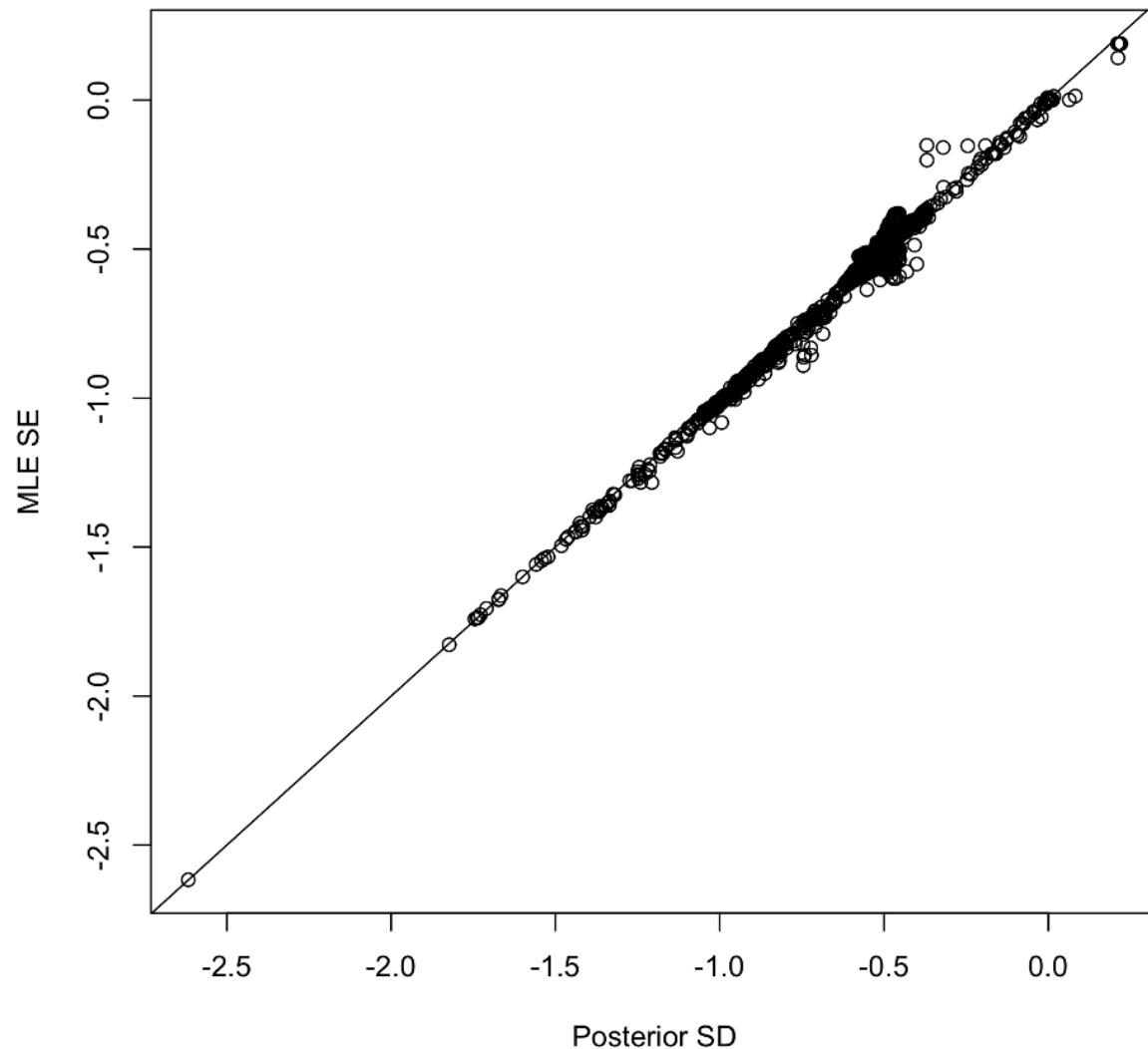


Figure 45: Comparison of the asymptotic parameter standard errors (from inverting the Hessian; vertical axis) with the marginals from the MCMC draws (horizontal axis).

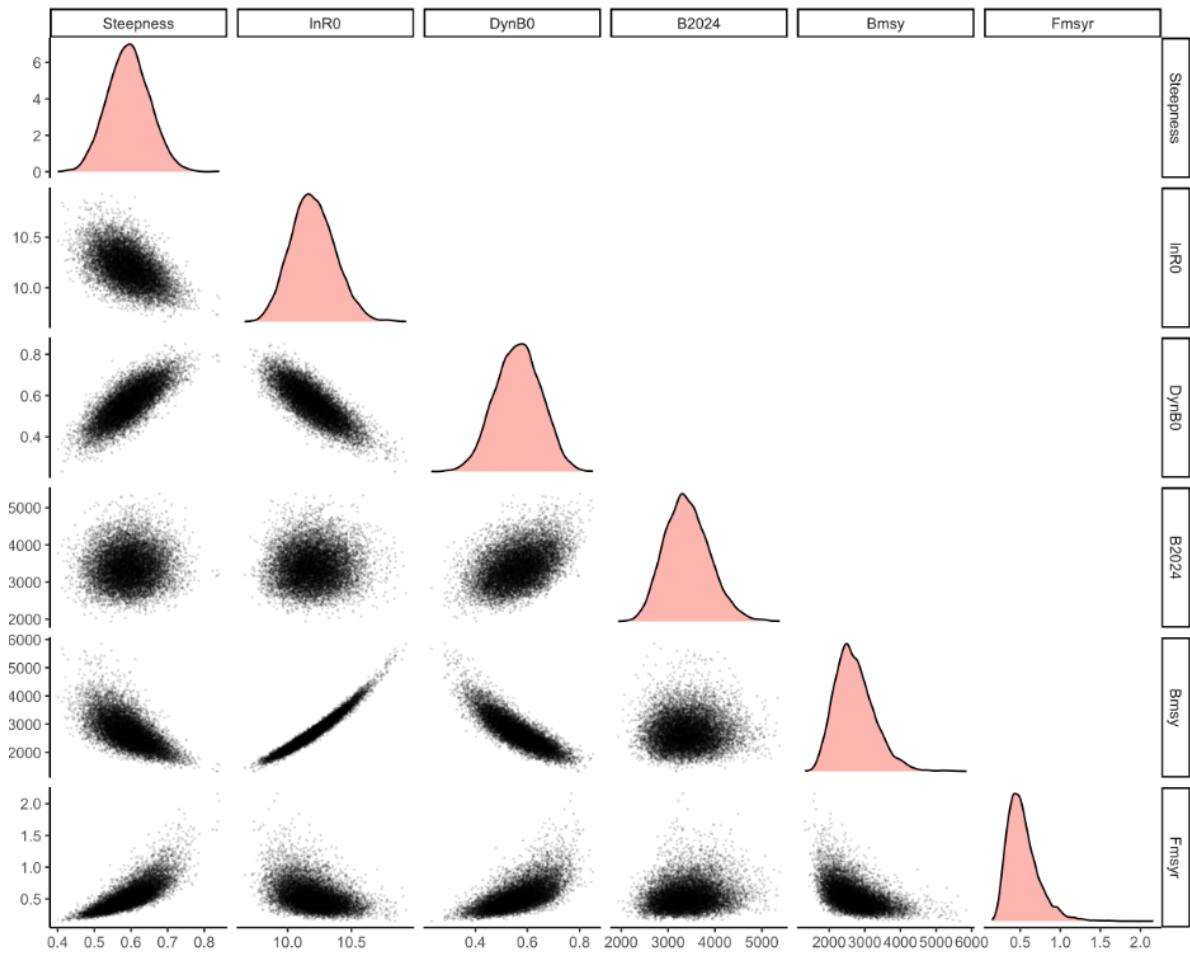


Figure 46: Pairwise plot of selected EBS pollock parameters and output from MCMC 12 thousand draws were saved as an approximation to the multivariate posterior distribution. Note that the figures on the diagonal represent the marginal posterior distributions. Key: steepness and lnR0 are stock-recruitment parameters, DynB0 is the ratio of spawning biomass estimated for in 2023 over the value estimated that would occur if there had been no fishing, B2024 is the spawning biomass in 2024 and Fmsyr is the rate at which MSY would be achieved on average.

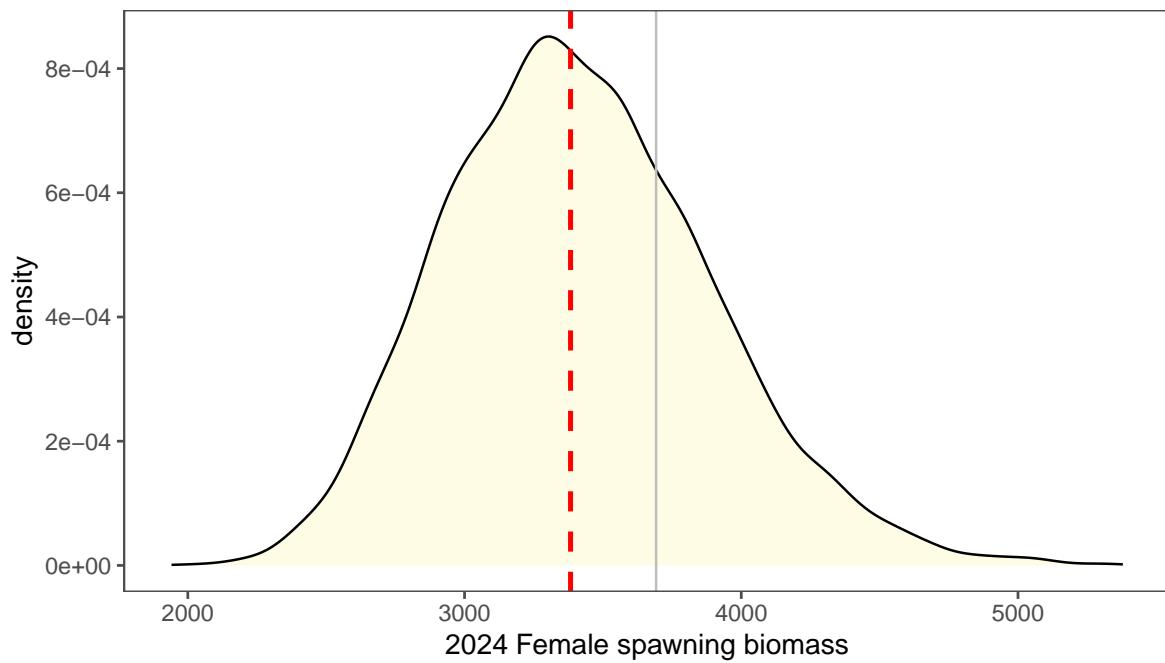


Figure 47: Integrated marginal posterior density (based on MCMC results) for the 2024 EBS pollock female spawning biomass compared to the point estimate (grey line).

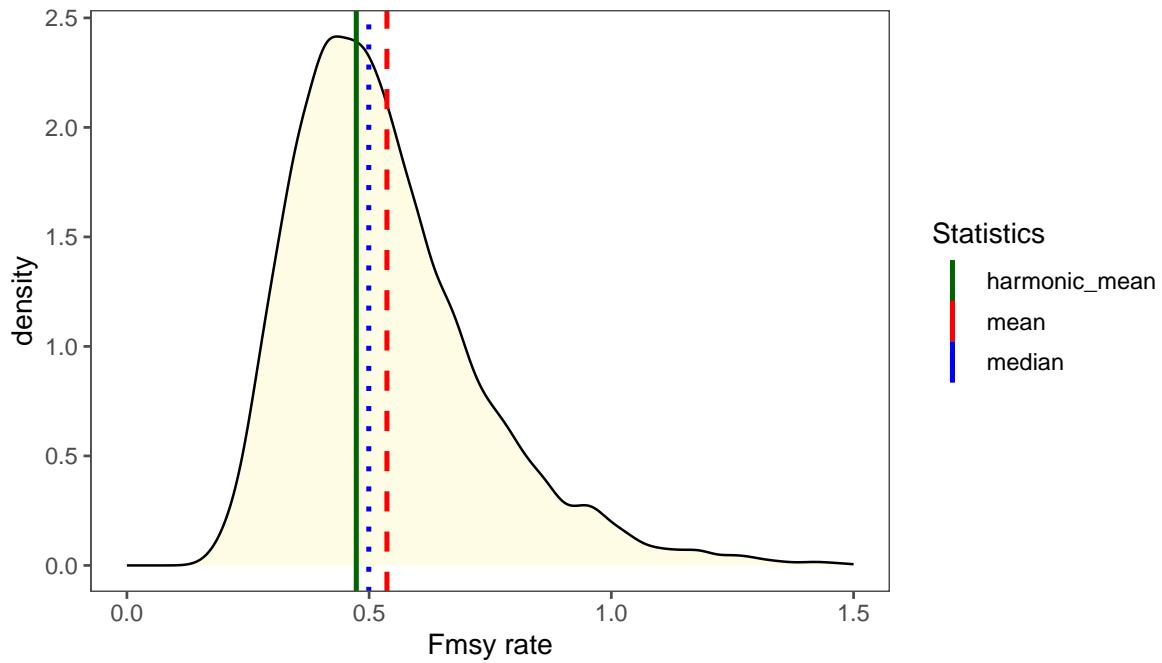


Figure 48: Integrated marginal posterior density (based on MCMC results) for the  $F_{MSY}$  for EBS pollock and different central tendency values.

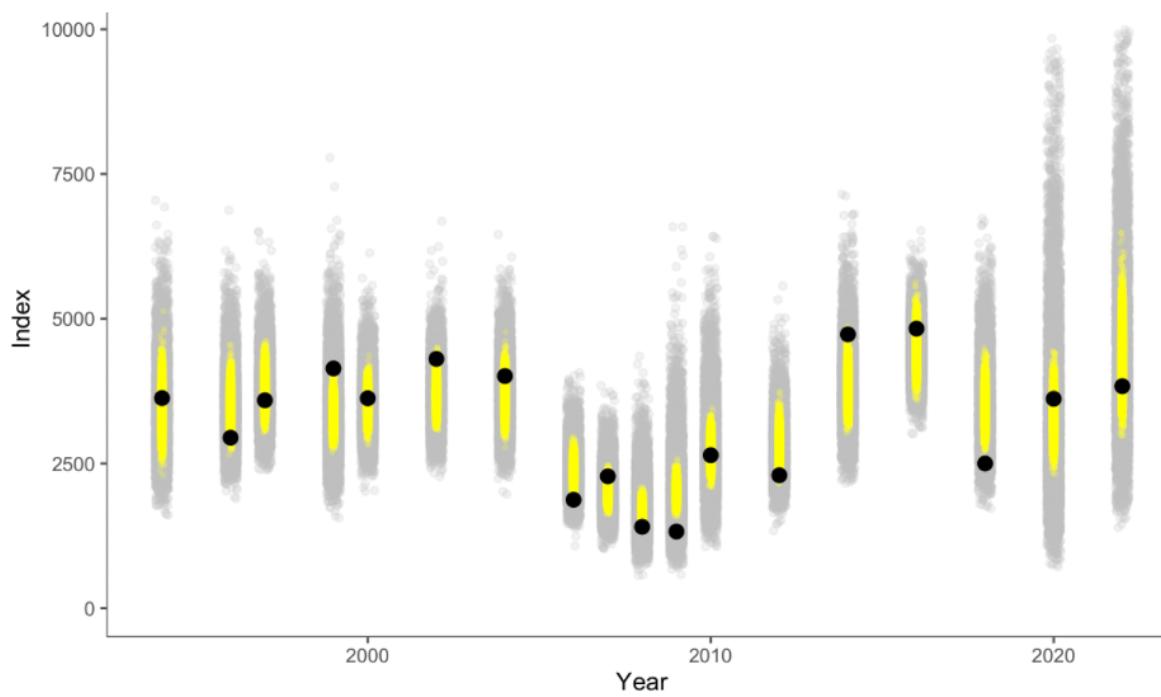
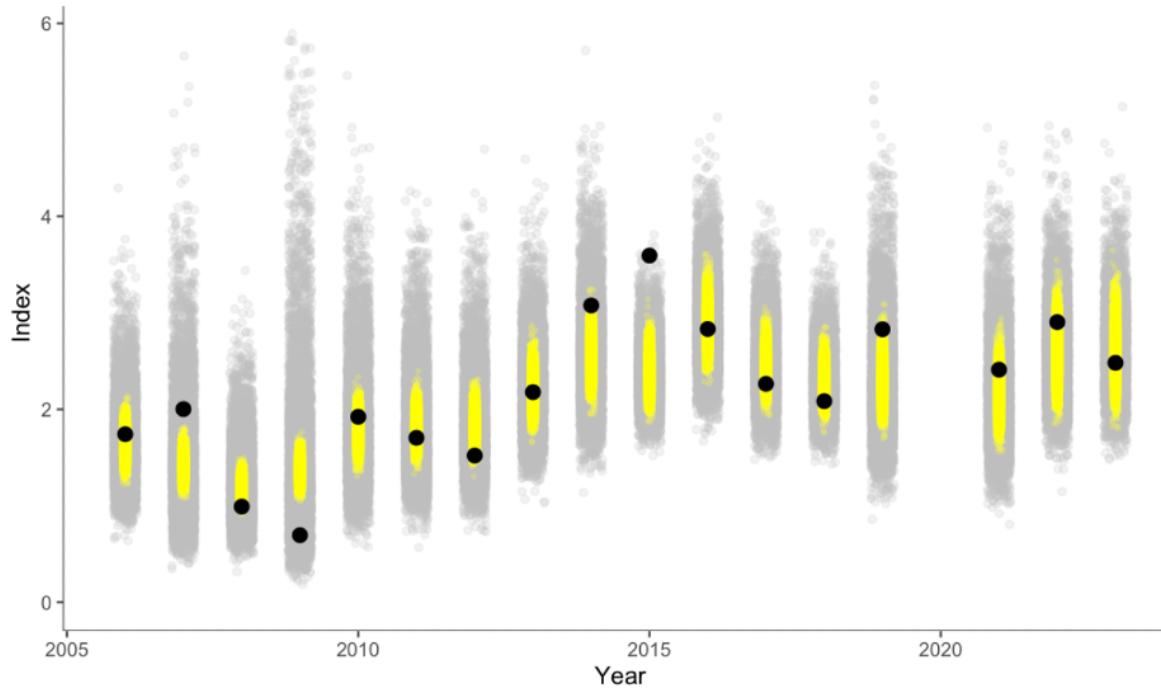


Figure 49: Plot of the observed index values (solid line) for the AVO (top) and ATS (bottom), the distribution of the expected value (yellow dots) and the posterior predictive distribution (grey points).

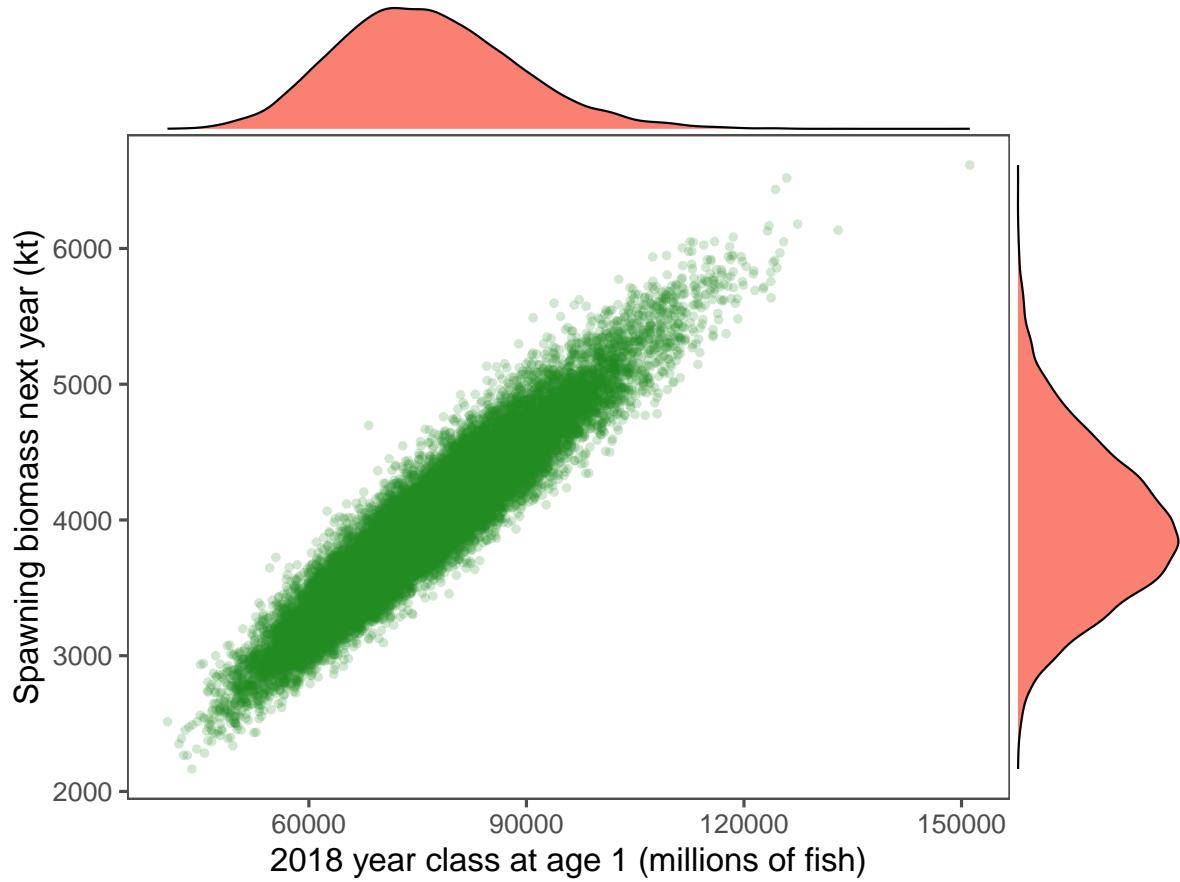


Figure 50: Plot of a representation of the posterior marginal distributions of spawning biomass in 2023 (vertical scale and right-side distribution) versus the size of the 2018 year-class (horizontal scale and the top distribution).

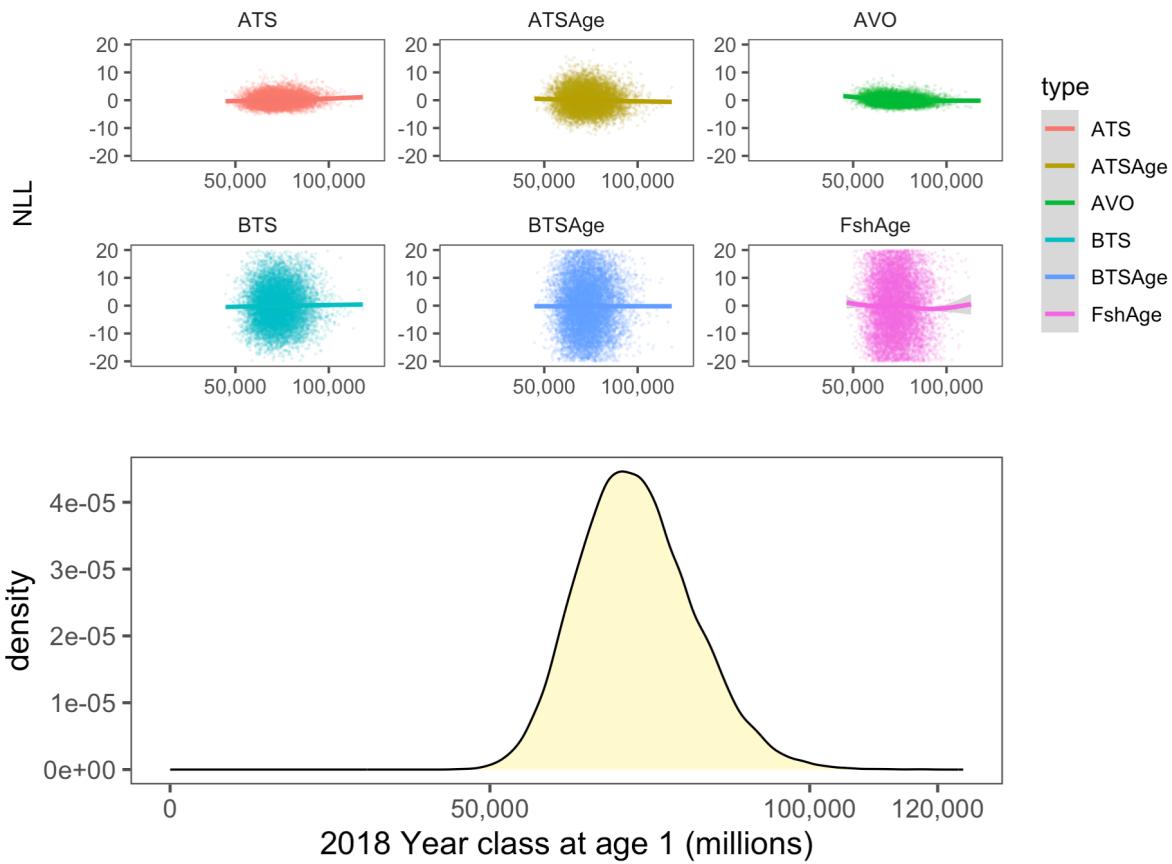


Figure 51: Distribution depicting the uncertainty of the 2018 year-class (bottom) and the scatter of posterior likelihood values (with the mean negative log-likelihood subtracted off).

Base, Model 23.0

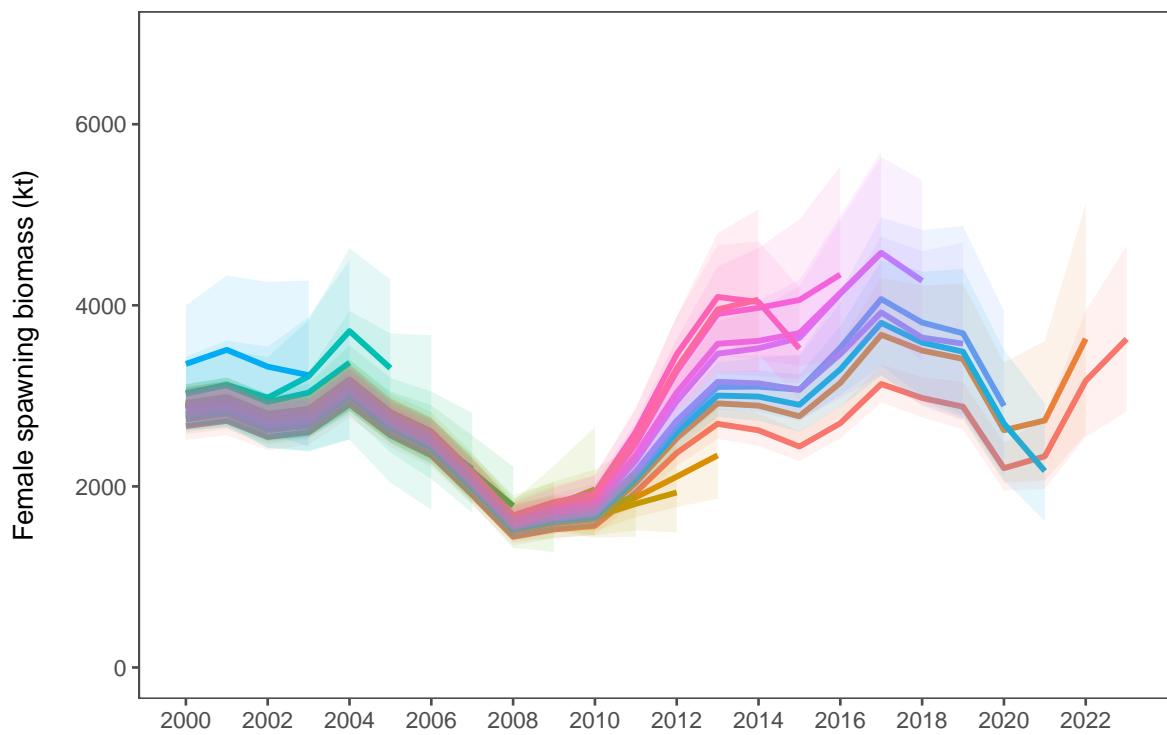


Figure 52: Retrospective patterns for EBS pollock spawning biomass showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations).

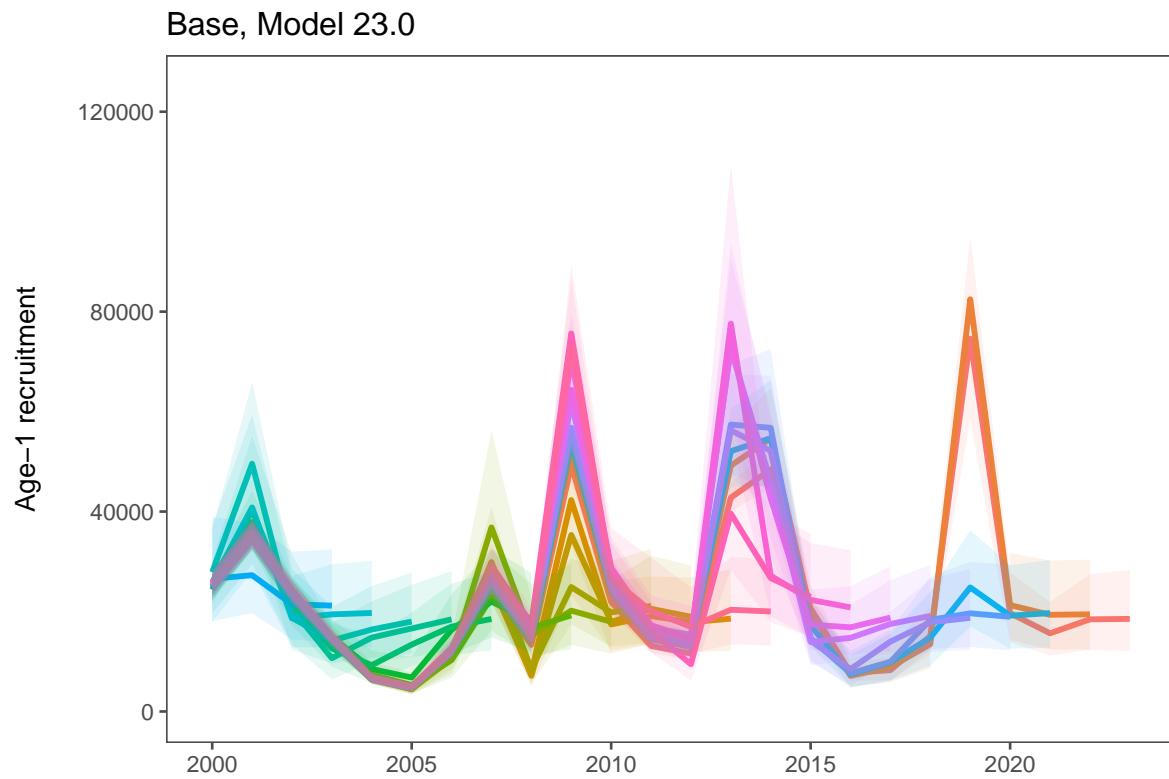


Figure 53: Retrospective patterns for EBS pollock recruitment showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations).

### Age-1 recruitment estimates by cohort

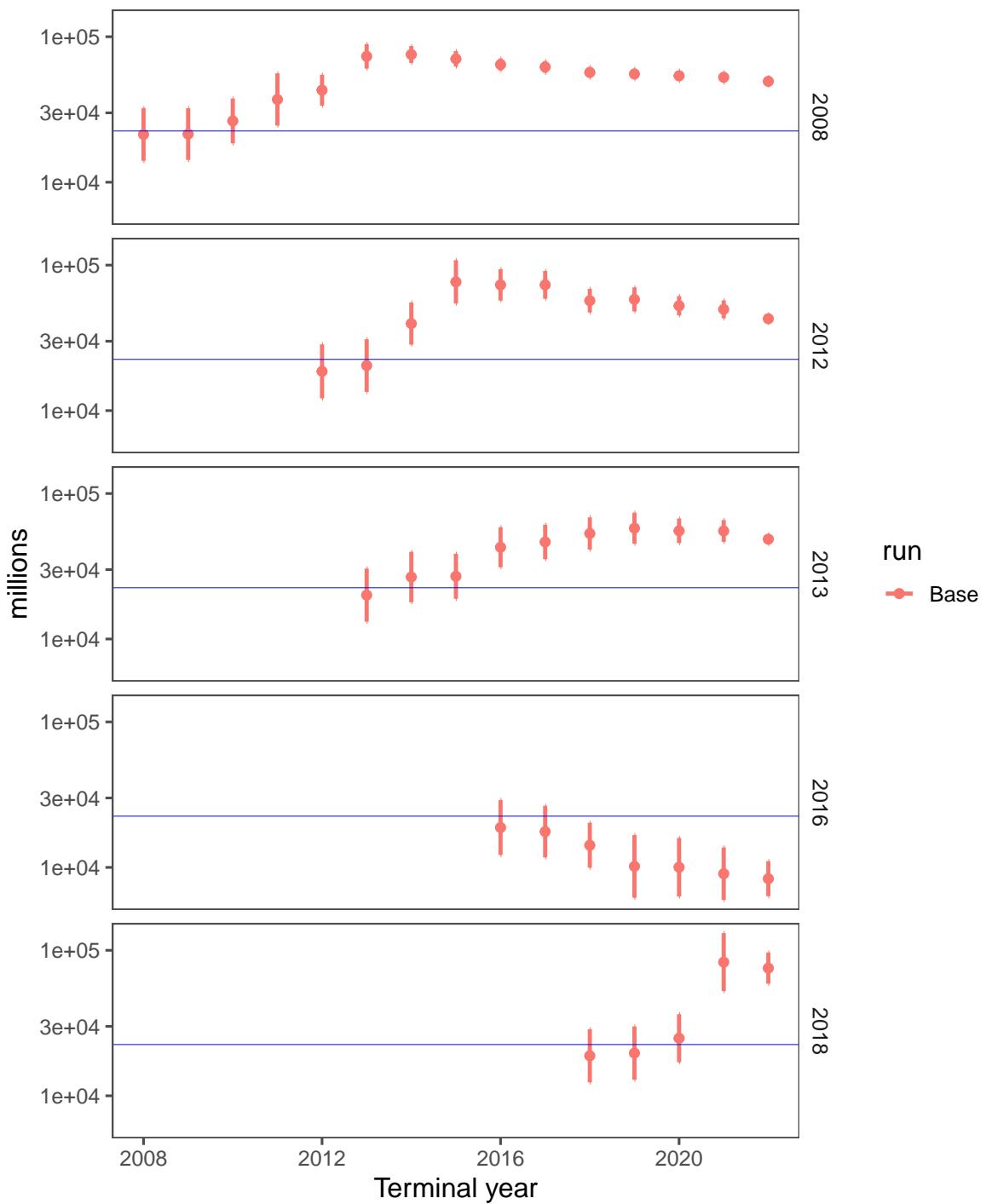


Figure 54: Retrospective evolution of EBS pollock selected year-class estimates as a function of the terminal year of data used in the model (based on retrospectives of Model 23.0).

### Age-1 recruitment estimates by cohort

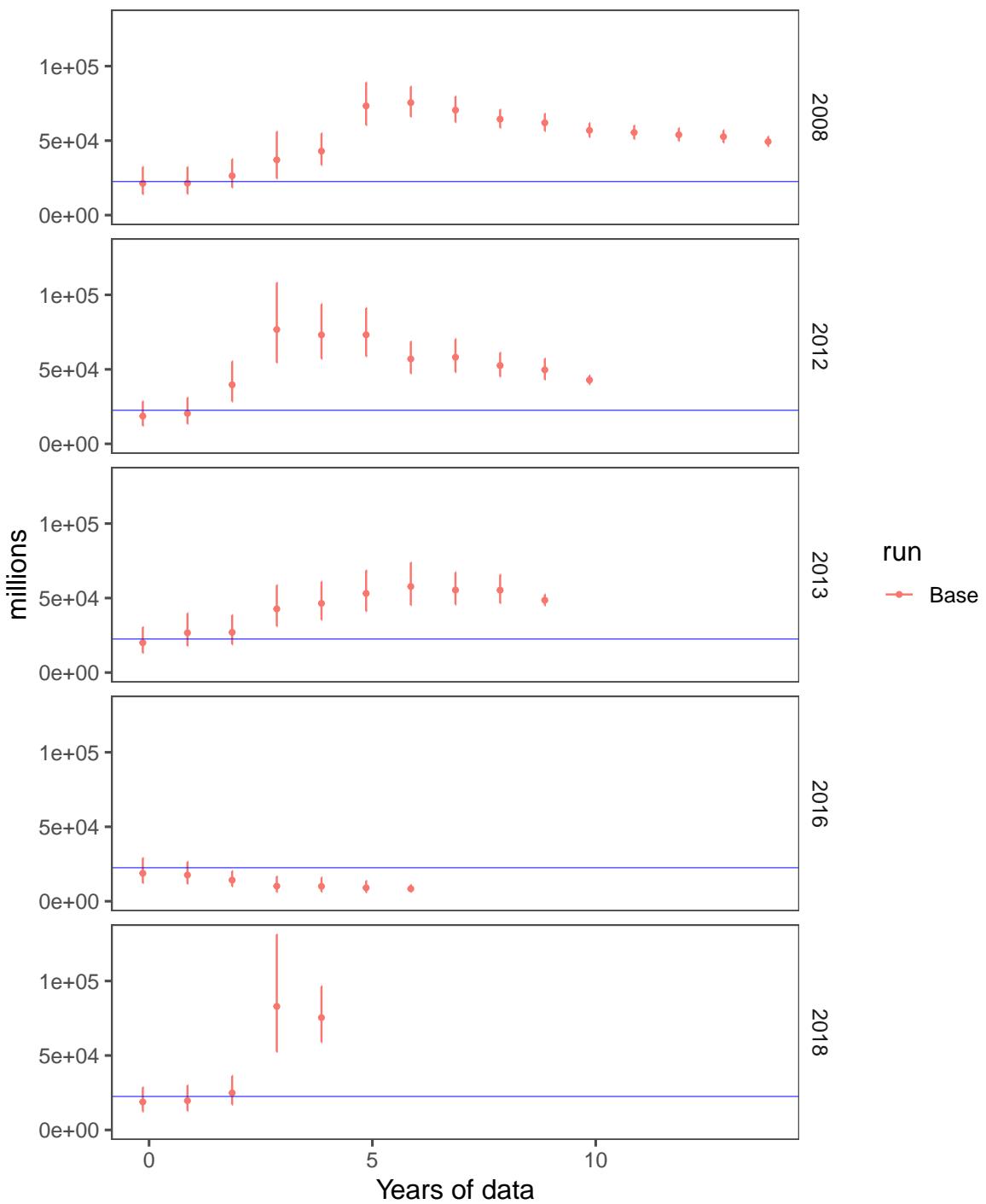


Figure 55: Retrospective evolution of EBS pollock selected year-class estimates as a function of the the number of years the year-class has been in the model (based on retrospectives of Model 23.0).

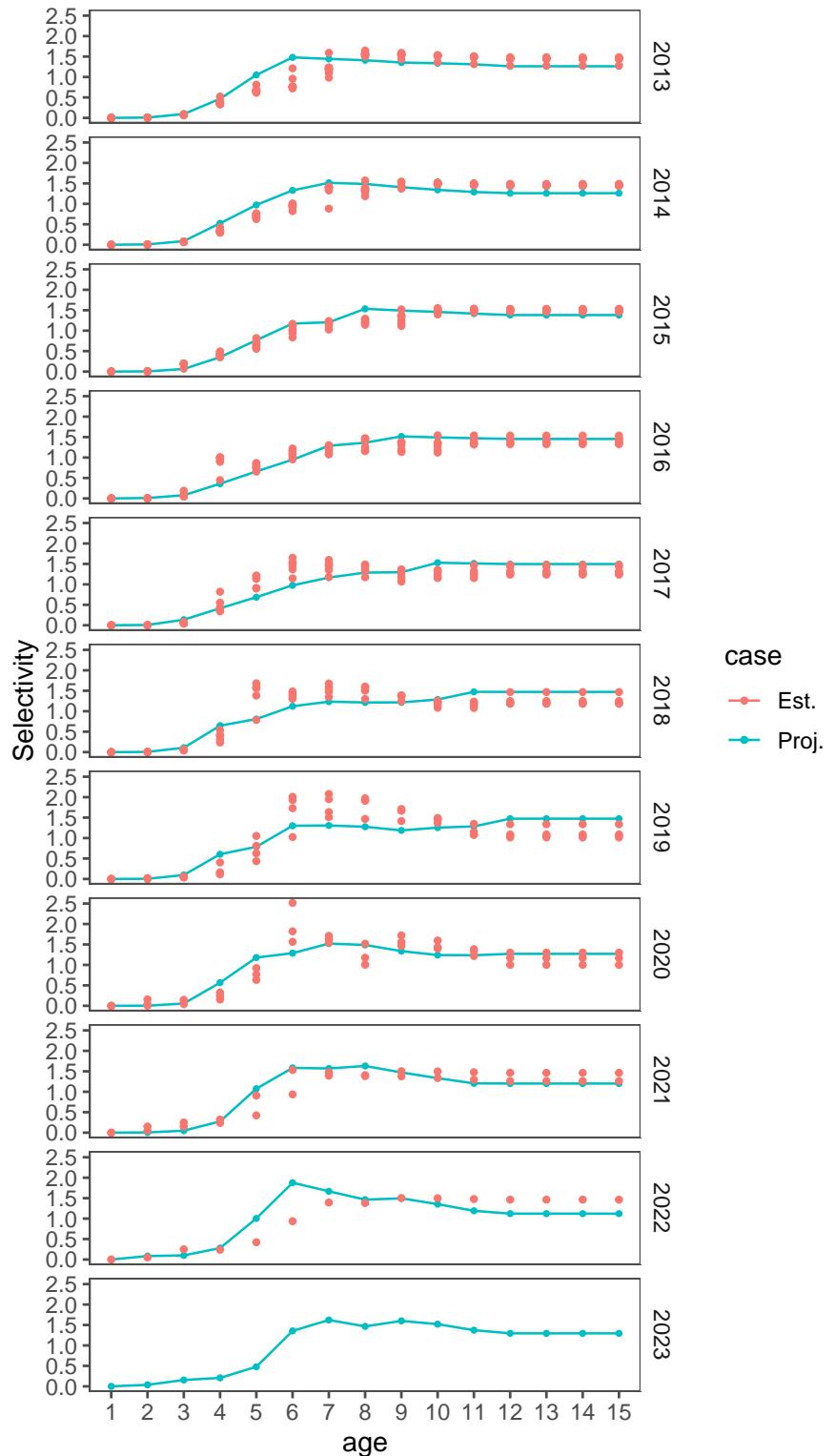


Figure 56: Retrospective pattern for estimated EBS pollock fishery selectivity (dots) compared to the projected selectivity from the year prior (solid line).

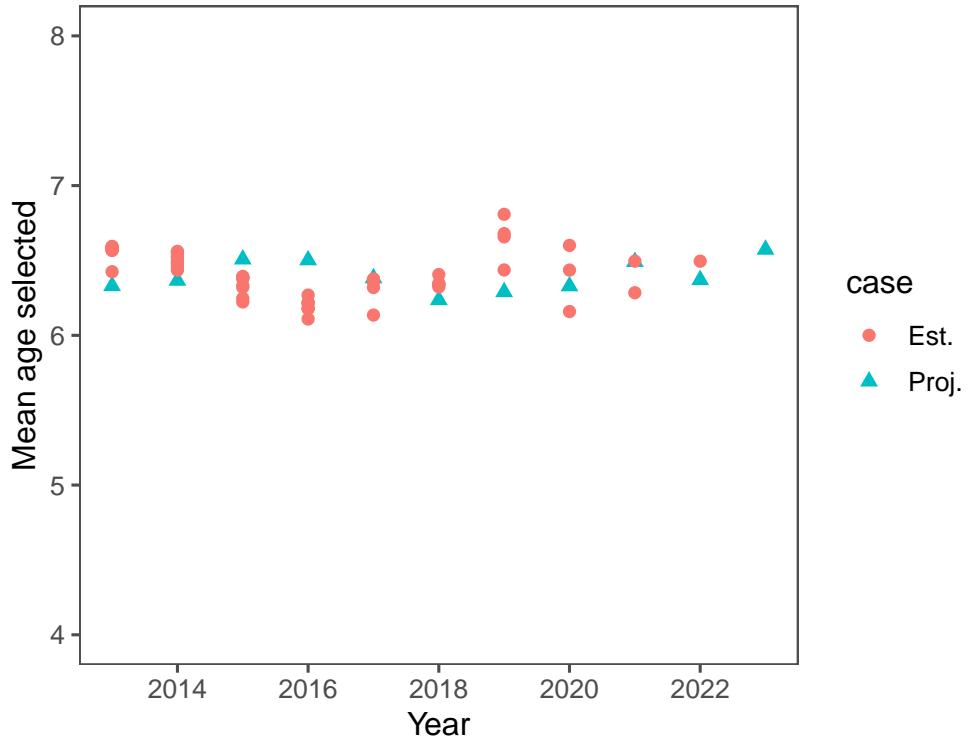


Figure 57: Retrospective pattern for the mean selected age (ages 1-8) based on estimated EBS pollock fishery selectivity compared to the projected selectivity from the year prior.

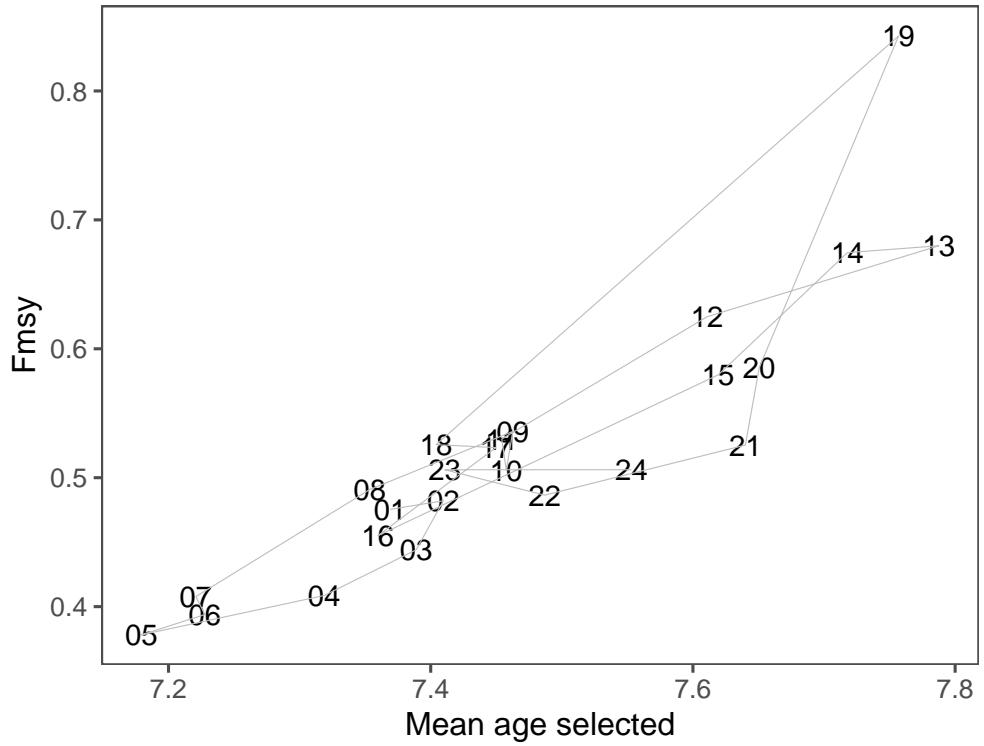


Figure 58: Comparison of  $F_{MSY}$  and mean selected age. The horizontal axis is a way to summarize if selectivity tends towards younger or older fish. Labels indicate the year that demographic parameters (weight-at-age, selectivity-at-age) were used to compute  $F_{MSY}$ .

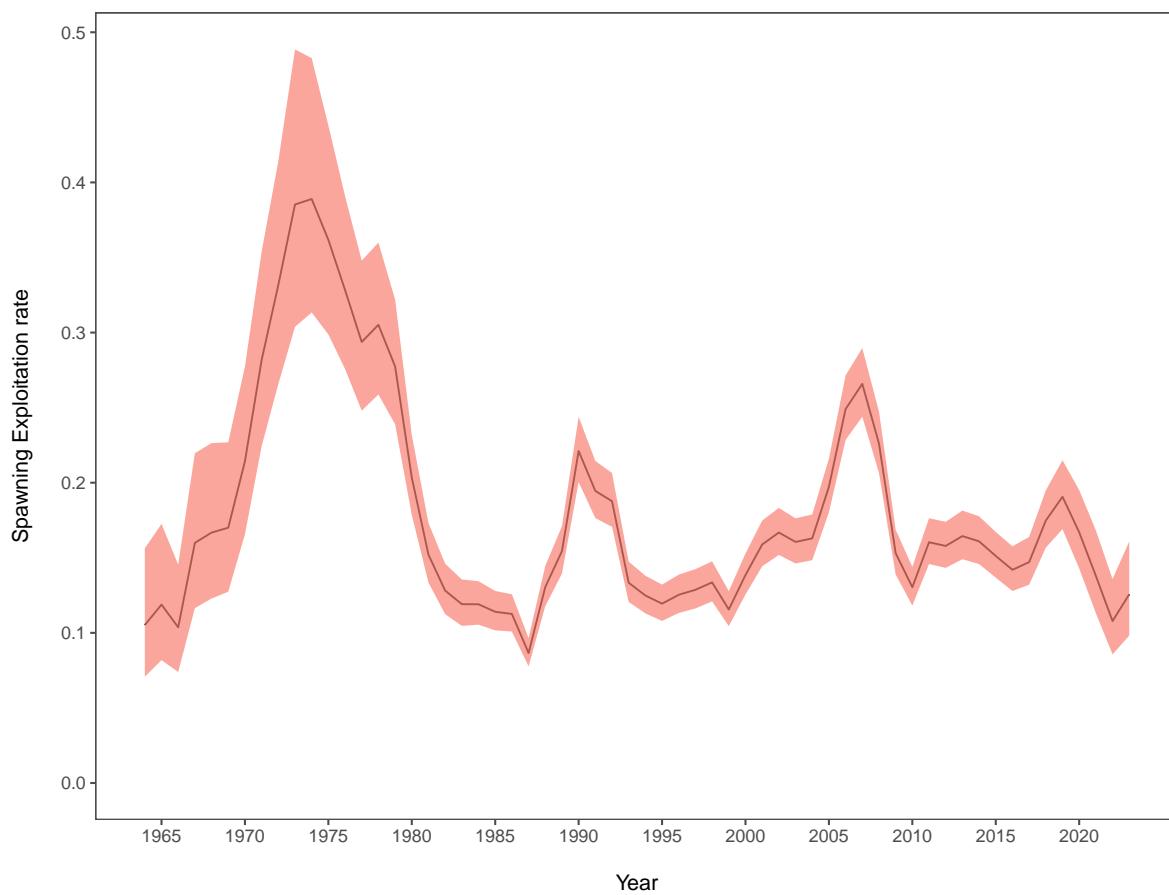


Figure 59: Estimated spawning exploitation rate (defined as the percent removal of egg production in a given spawning year).

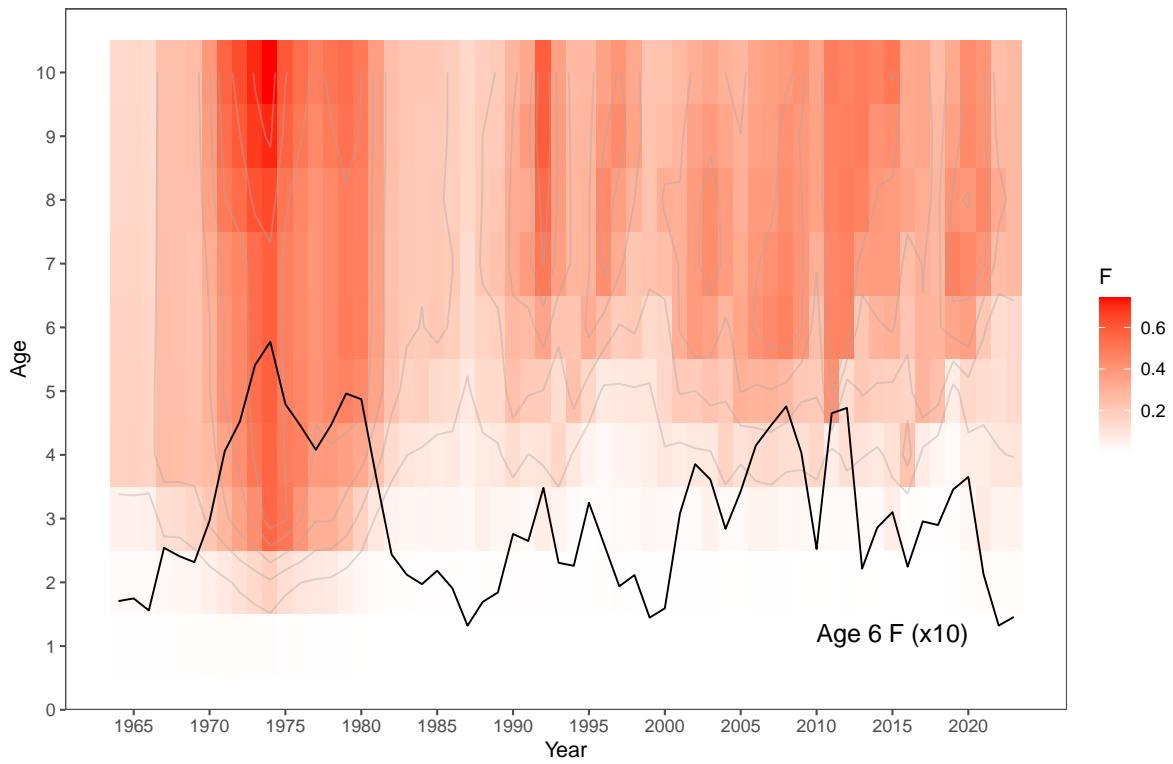


Figure 60: Estimated instantaneous age-specific fishing mortality rates for EBS pollock.

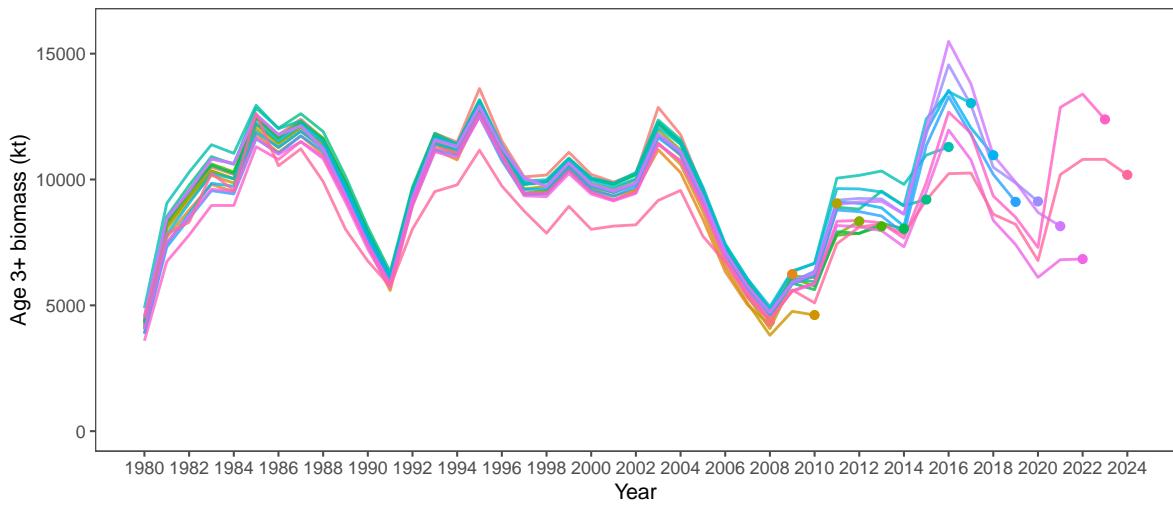


Figure 61: Comparison of the current assessment results with past assessments of begin-year EBS age-3+ pollock biomass.

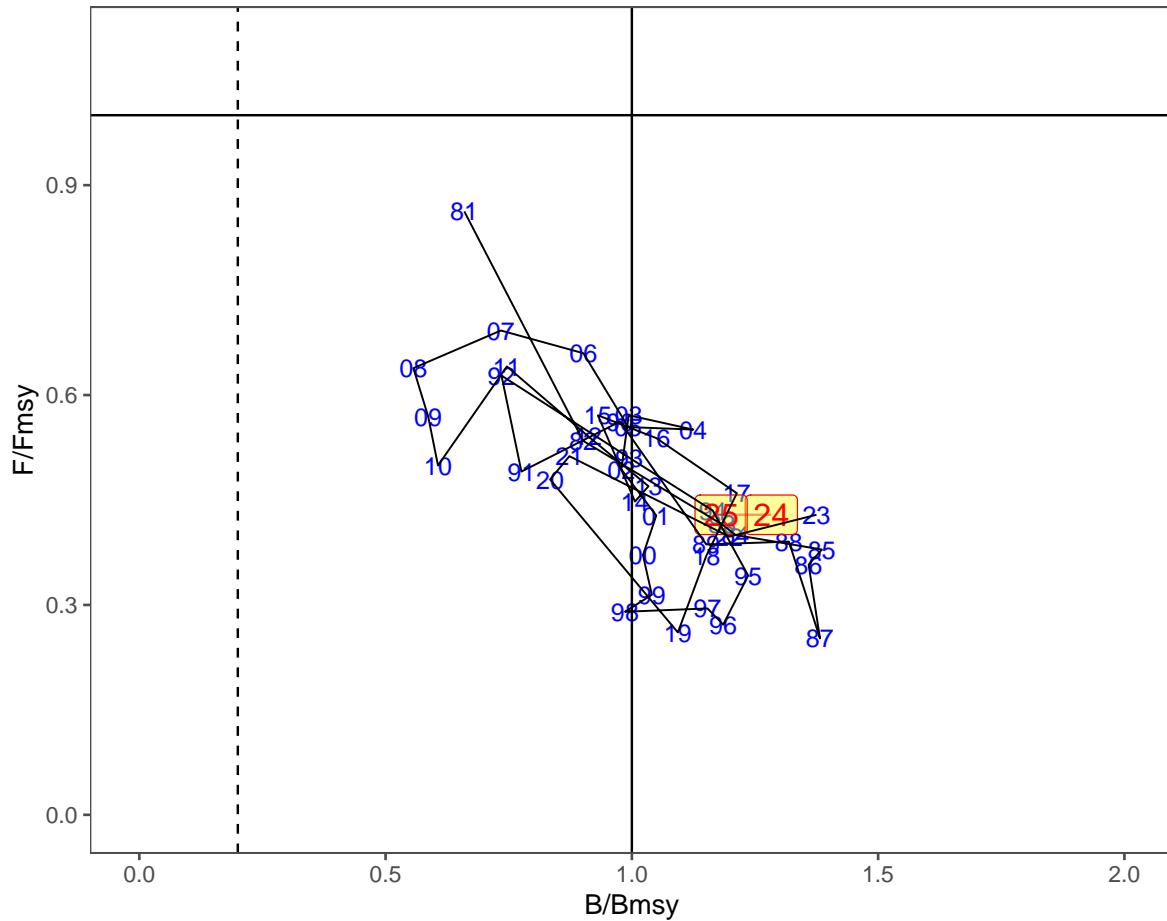


Figure 62: Estimated spawning biomass relative to annually estimated  $F_{MSY}$  values and fishing mortality rates for EBS pollock. Two projection years are shaded in yellow.

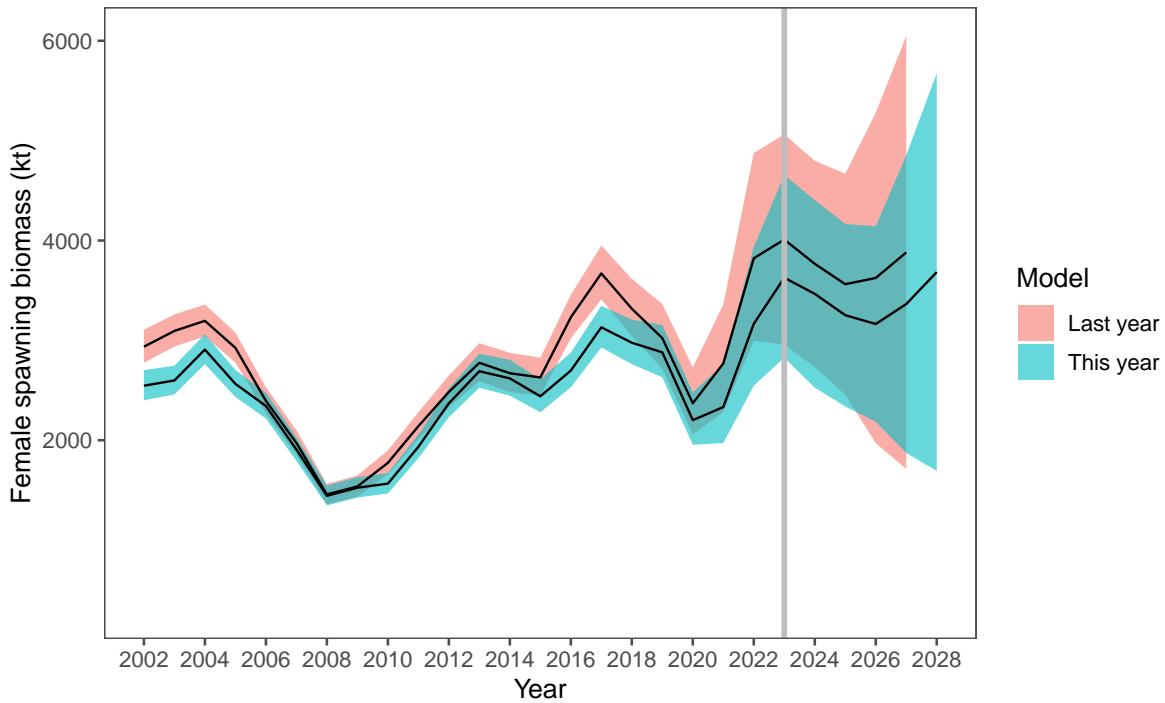


Figure 63: The estimated EBS pollock spawning stock biomass for model 20 last year and this with projections equal to the estimated fishing mortality from 2023.

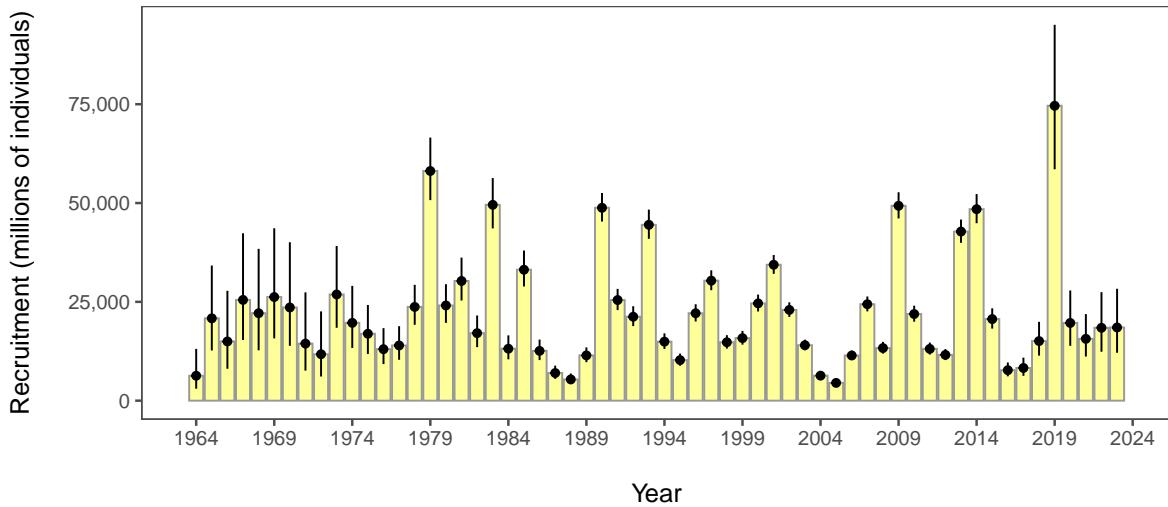


Figure 64: Recruitment estimates (age-1 recruits) for EBS pollock for all years since 1964 (1963–2022 year classes) for Model 20. Error bars reflect 90% credible intervals based on model estimates of uncertainty.

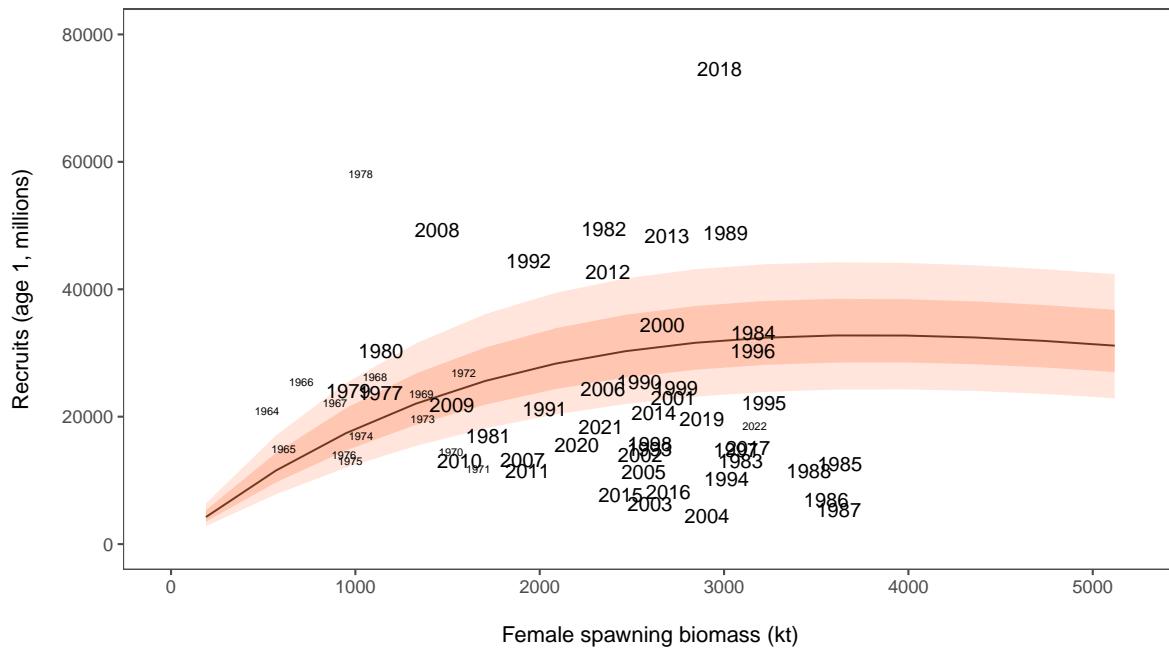


Figure 65: Stock-recruitment estimates (shaded represents structural uncertainty) and age-1 EBS pollock estimates labeled by year-classes.

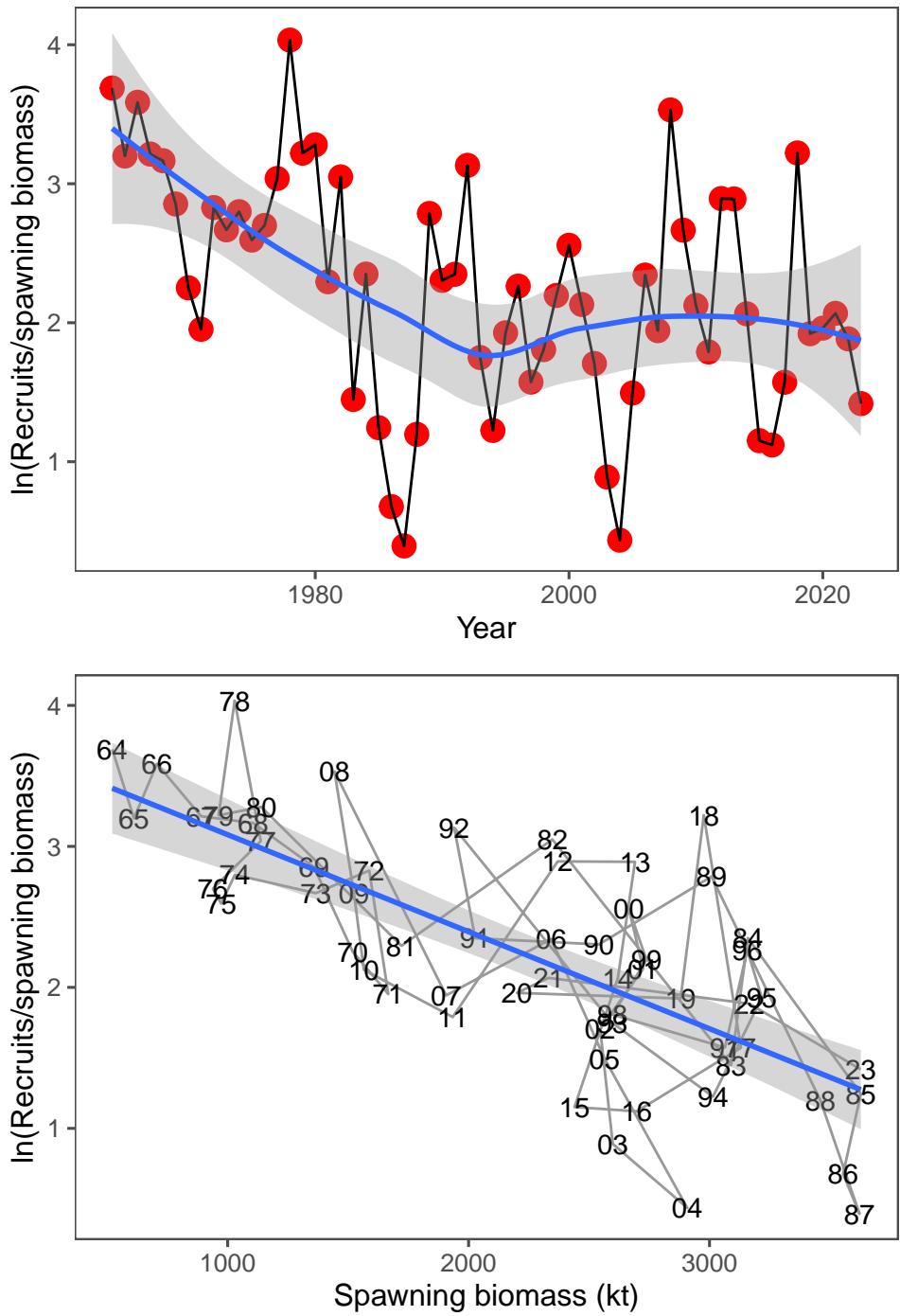


Figure 66: EBS pollock productivity as measured by logged recruits per spawning biomass,  $\log(R/S)$ , as a function of spawning biomass with a linear fit (bottom) and over time, 1964–2023 (top).

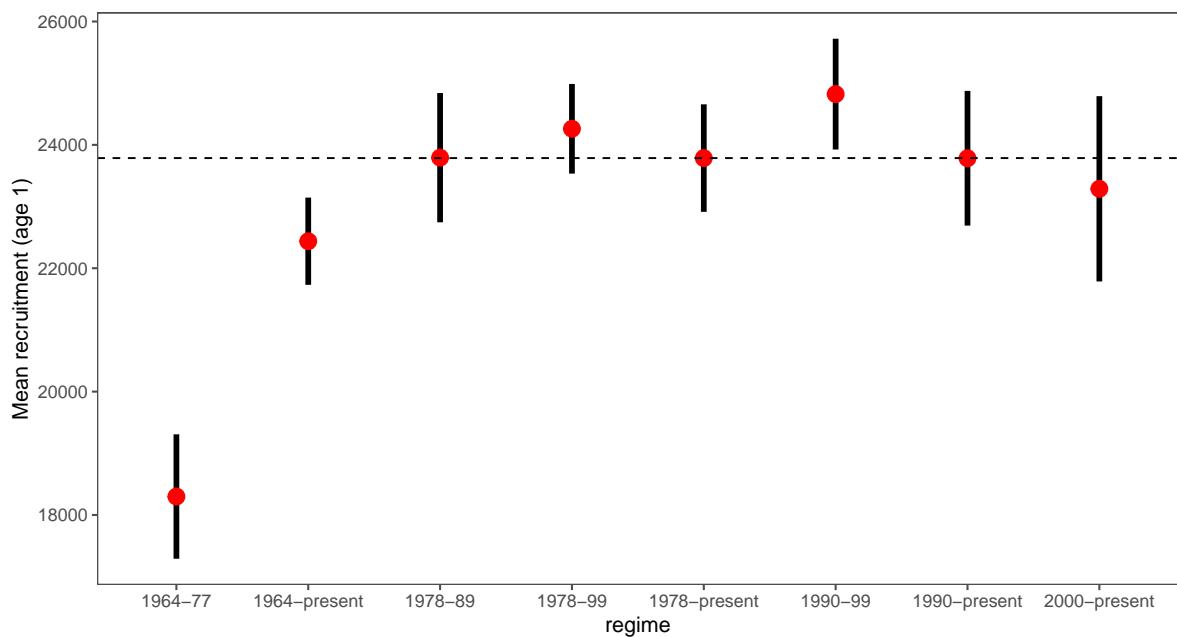


Figure 67: Mean recruitment estimates (age-1) for EBS pollock for different periods with error bars representing 95% credible intervals.

### Alternative 1

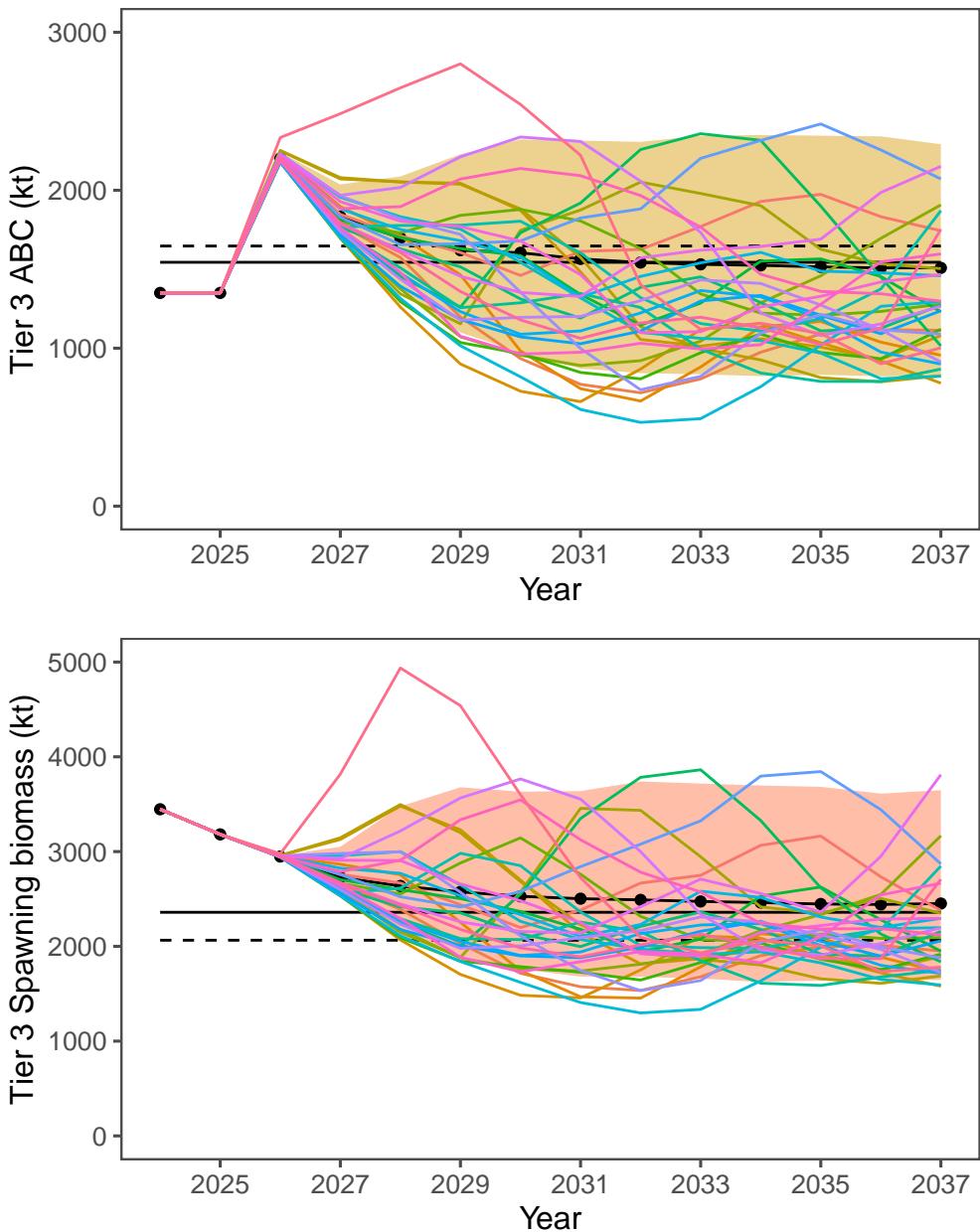


Figure 68: Projected EBS Tier 3 pollock yield (top) and female spawning biomass (bottom) relative to the long-term expected values under  $F_{35\%}$  and  $F_{40\%}$  (horizontal lines).  $B_{40\%}$  is computed from average recruitment from 1978–2020. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1.

Alt 3, mean F

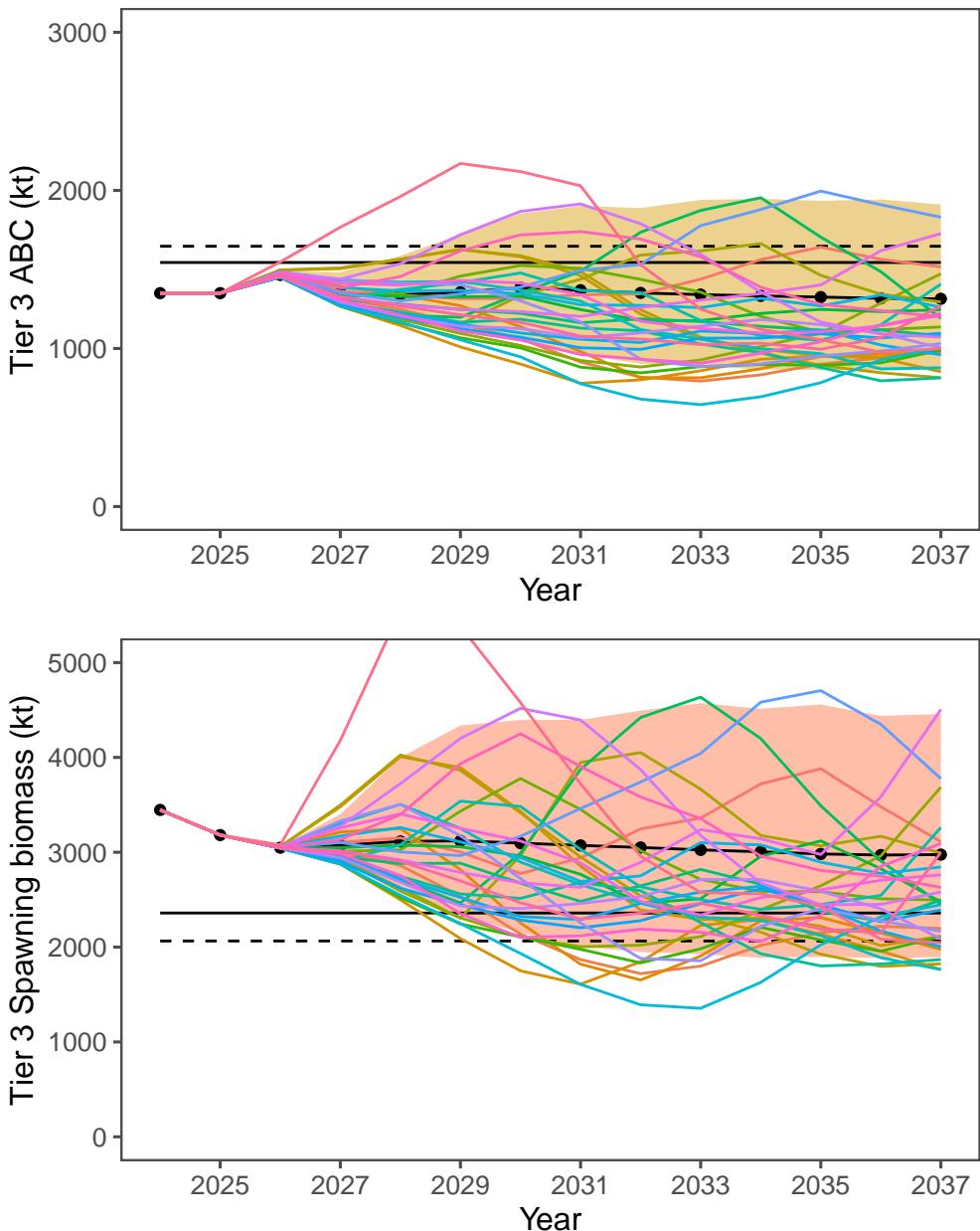


Figure 69: Projected pollock yield (top) and female spawning biomass (bottom) under Alternative 3—fishing under the recent 5-year average fishing mortality. The long-term expected values under  $F_{35\%}$  and  $F_{40\%}$  (horizontal lines)  $B_{40\%}$  are computed from average recruitment from 1978–2020.

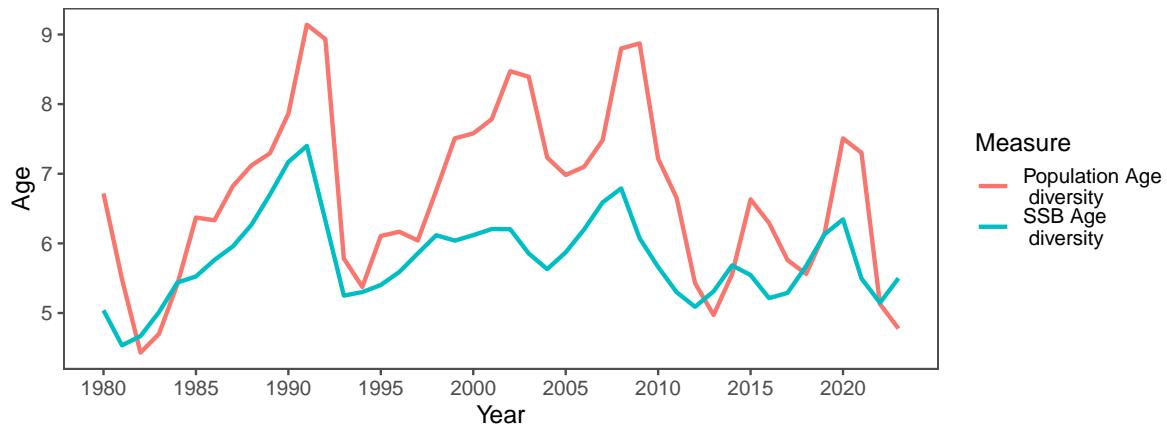


Figure 70: For the mature component of the EBS pollock stock, time series of estimated average age and diversity of ages (using the Shannon-Wiener H statistic), 1980–2023.

## 14 Appendix EBS Pollock Model Description

### 14.1 Dynamics

This assessment is based on a statistical age-structured model with the catch equation and population dynamics model as described in Fournier and Archibald (1982) and elsewhere (e.g., Hilborn and Walters (1992), Schnute and Richards (1995), McAllister and Ianelli (1997)). The catch in numbers at age in year  $t(C_{t,a})$  and total catch biomass ( $Y_t$ ) can be described as:

$$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}} (1 - e^{-Z_{t,a}}) N_{t,a}, \quad 1 \leq t \leq T, 1 \leq a \leq A \quad (1)$$

$$N_{t+1,a+1} = N_{t,a-1} e^{-Z_{t,a-1}} \quad 1 \leq t \leq T, 1 \leq a < A \quad (2)$$

$$N_{t+1,A} = N_{t,A-1} e^{-Z_{t,A-1}} + N_{t,A} e^{-Z_{t,A}}, \quad 1 \leq t \leq T \quad (3)$$

$$Z_{t,a} = F_{t,a} + M_{t,a} \quad (4)$$

$$C_{t,.} = \sum_{a=1}^A C_{t,a} \quad (5)$$

$$p_{t,a} = \frac{C_{t,a}}{C_{t,.}} \quad (6)$$

$$Y_t = \sum_{a=1}^A w_{t,a} C_{t,a} \quad (7)$$

$$(8)$$

where

- $T$  is the number of years,
- $A$  is the number of age classes in the population,
- $N_{t,a}$  is the number of fish age  $a$  in year  $t$ ,
- $C_{t,a}$  is the catch of age class  $a$  in year  $t$ ,
- $p_{t,a}$  is the proportion of the total catch in year  $t$ , that is in age class  $a$ ,
- $C_t$  is the total catch in year  $t$ ,
- $w_a$  is the mean body weight (kg) of fish in age class  $a$ ,
- $Y_t$  is the total yield biomass in year  $t$ ,
- $F_{t,a}$  is the instantaneous fishing mortality for age class  $a$ , in year  $t$ ,
- $M_{t,a}$  is the instantaneous natural mortality in year  $t$  for age class  $a$ , and
- $Z_{t,a}$  is the instantaneous total mortality for age class  $a$ , in year  $t$ .

Fishing mortality ( $F_{t,a}$ ) is specified as being semi-separable and non-parametric in form with restrictions on the variability following Butterworth et al. (2003) :

$$F_{t,a} = s_{t,a} \mu^f e^{\epsilon_t}, \quad \epsilon_t \sim \mathcal{N}(0, \sigma_E^2) \quad (9)$$

$$s_{t+1,a} = s_{t,a} e^{\gamma_t}, \quad \gamma_t \sim \mathcal{N}(0, \sigma_s^2) \quad (10)$$

where  $s_{t,a}$  is the selectivity for age class  $a$  in year  $t$ , and  $\mu^f$  is the median fishing mortality rate over time.

If the selectivities ( $s_{t,a}$ ) are constant over time then fishing mortality rate decomposes into an age component and a year component. A curvature penalty on the selectivity coefficients using the squared second-differences to provide smoothness between ages.

Bottom-trawl survey selectivity was set to be asymptotic yet retain the properties desired for the characteristics of this gear. Namely, that the function should allow flexibility in selecting age 1 pollock over time. The functional form of this selectivity was:

$$s_{t,a} = [1 + e^{-\alpha_t a - \beta_t}]^{-1}, \quad a > 1 \quad (11)$$

$$s_{t,a} = \mu_s e^{-\delta_t^\mu}, \quad a = 1 \quad (12)$$

$$\alpha_t = \bar{\alpha} e^{\delta_t^\alpha}, \quad (13)$$

$$\beta_t = \bar{\beta} e^{\delta_t^\beta}, \quad (14)$$

where the parameters of the selectivity function follow a random walk process as in Dorn et al. (2000):

$$\delta_t^\mu - \delta_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\delta^\mu}^2) \quad (15)$$

$$(16)$$

$$\alpha_t^\mu - \alpha_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\alpha^\mu}^2) \quad (17)$$

$$\beta_t^\mu - \beta_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\beta^\mu}^2) \quad (18)$$

The parameters to be estimated in this part of the model are thus for t=1982 through to 2023. The variance terms for these process error parameters were specified to be 0.04.

In this assessment, the random-walk deviation penalty was optionally shifted to the changes in log-selectivity. that is, for the BTS estimates, the process error was applied to the logistic parameters as above, but the lognormal penalty was applied to the resulting selectivities-at-age directly. The extent of this variability was evaluated in the context of the impact on

age-specific survey catchability/availability and contrasted with an independent estimate of pollock availability to the bottom trawl survey.

$$\ln(s_{t,a}) - \ln(s_{t+1,a}) \sim \mathcal{N}(0, \sigma_{sel}^2) \quad (19)$$

$$(20)$$

In 2008 the AT survey selectivity approach was modified. As an option, the age one pollock observed in this trawl can be treated as an index and are not considered part of the age composition (which then ranges from age 2-15). This was done to improve some interaction with the flexible selectivity smoother that is used for this gear and was compared. Additionally, the annual specification of input observation variance terms was allowed for the AT data.

A diagnostic approach to evaluate input variance specifications (via sample size under multinomial assumptions) was added in the 2018 assessment. This method uses residuals from mean ages together with the concept that the sample variance of mean age (from a given annual data set) varies inversely with input sample size. It can be shown that for a given set of input proportions at age (up to the maximum age  $A$ ) and sample size  $N_t$  for year  $t$ , an adjustment factor  $\nu$  for input sample size can be computed when compared with the assessment model predicted proportions at age ( $\hat{p}_{ta}$ ) and model predicted mean age ( $\hat{\bar{a}}_t$ ):

$$\nu = \text{var} \left( r_t^a \sqrt{\frac{N_t}{\kappa_t}} \right)^{-1} \quad (21)$$

$$r_t^a = \bar{a}_t - \hat{\bar{a}}_t \quad (22)$$

$$\kappa_t = \left[ \sum_a^A \bar{a}_t - \hat{\bar{a}}_t \right]^{0.5} \quad (23)$$

where  $r_t^a$  is the residual of mean age and

$$\hat{\bar{a}}_t = \sum_a^A a \hat{p}_{ta} \quad (24)$$

$$\bar{a}_t = \sum_a^A a p_{ta} \quad (25)$$

Based on previous analyses, we used the above relationship as a diagnostic for evaluating input sample sizes by comparing model predicted mean ages with observed mean ages and the implied 95% confidence bands. This method provided support for modifying the frequency of allowing selectivity changes.

## 14.2 Recruitment

In these analyses, recruitment ( $R_t$ ) represents numbers of age-1 individuals modeled as a stochastic function of spawning stock biomass.

$$R_t = f(B_{t-1}) \quad (26)$$

with mature spawning biomass during year  $t$  was defined as:

$$B_t = \sum_{a=1}^A w_{t,a} \phi_a N_{t,a} \quad (27)$$

and,  $\phi_a$  is the proportion of mature females at age  $a$  as shown in the sub-section titled Natural mortality and maturity at age under “Parameters estimated independently” above.

A reparameterized form for the stock-recruitment relationship following Francis (1992) was used. For the optional Beverton-Holt form (the Ricker form presented in Eq. 12 was adopted for this assessment) we have:

$$R_t = \frac{B_{t-1} e^{\varepsilon_t}}{\alpha + \beta B_{t-1}} \quad (28)$$

where

- $R_t$  is recruitment at age 1 in year  $t$ ,
- $B_t$  is the biomass of mature spawning females in year  $t$ ,
- $\varepsilon_t$  is the recruitment anomaly for year  $t$ , ( $\varepsilon_t \sim \mathcal{N}(0, \sigma_R^2)$ )
- $\alpha, \beta$  are stock recruitment parameters.

Values for the stock-recruitment function parameters are calculated from the values of (the number of 0-year-olds in the absence of exploitation and recruitment variability) and the steepness of the stock-recruit relationship ( $h$ ). The steepness is the fraction of  $R_0$  to be expected (in the absence of recruitment variability) when the mature biomass is reduced to 20% of its pristine level Francis (1992), so that:

$$\alpha = \tilde{B}_0 \frac{1-h}{4h} \quad (29)$$

$$\beta = \frac{5h-1}{4hR_0} \quad (30)$$

where  $\tilde{B}_0$  is the total egg production (or proxy, e.g., female spawning biomass) in the absence of exploitation (and recruitment variability) expressed as a fraction of  $R_0$ .

Some interpretation and further explanation follows. For steepness equal 0.2, then recruits are a linear function of spawning biomass (implying no surplus production). For steepness equal to 1.0, then recruitment is constant for all levels of spawning stock size. A value of  $h = 0.9$  implies that at 20% of the unfished spawning stock size will result in an expected value of 90% unfished recruitment level. Steepness of 0.7 is a commonly assumed default value for the Beverton-Holt form (e.g., Kimura (1989)). The prior distribution for steepness used a beta distribution as in Ianelli et al. (2016). The prior on steepness was specified to be a symmetric form of the Beta distribution with  $\alpha = \beta = 14.93$  implying a prior mean of 0.5 and CV of 12% (implying that there is about a 14% chance that the steepness is greater than 0.6). This conservative prior is consistent with previous years' application and serves to constrain the stock-recruitment curve from favoring steep slopes (uninformative priors result in  $F_{MSY}$  values near an  $F_{SPR}$  of about  $F_{18\%}$  a value considerably higher than the default proxy of  $F_{35\%}$ ). The residual pattern for the post-1977 recruits used in fitting the curve with a more diffuse prior resulted in all estimated recruits being below the curve for stock sizes less than  $B_{MSY}$  (except for the 1978 year class). We believe this to be driven primarily by the apparent negative-slope for recruits relative to stock sizes above  $B_{MSY}$  and as such, provides a potentially unrealistic estimate of productivity at low stock sizes. This prior was elicited from the rationale that residuals should be reasonably balanced throughout the range of spawning stock sizes. Whereas this is somewhat circular (i.e., using data for prior elicitation), the point here is that residual patterns (typically ignored in these types of models) were qualitatively considered.

In model 16.1 (from the 2019 assessment), a Beverton Holt stock recruitment form was implemented using the prior value of 0.67 for steepness and a CV of 0.17. This resulted in beta distribution parameters (for the prior) at  $\alpha = 6.339$  and  $\beta = 4.293$ .

The value of  $\sigma_R$  was set at 1.0 to accommodate additional uncertainty in factors affecting recruitment variability.

To have the critical value for the stock-recruitment function (steepness,  $h$ ) on the same scale for the Ricker model, we begin with the parameterization of Kimura (1989) :

$$R_t = \frac{B_{t-1} e^{\alpha(1 - B_{t-1} \frac{R_0}{\psi_0})}}{\psi_0} \quad (31)$$

It can be shown that the Ricker parameter  $a$  maps to steepness as:

$$h = \frac{e^\alpha}{e^\alpha + 4} \quad (32)$$

so that the prior used on  $h$  can be implemented in both the Ricker and Beverton-Holt stock-recruitment forms. Here the term  $\psi_0$  represents the equilibrium unfished spawning biomass per-recruit.

### 14.3 Diagnostics

In 2006 a replay feature was added where the time series of recruitment estimates from a particular model is used to compute the subsequent abundance expectation had no fishing occurred. These recruitments are adjusted from the original estimates by the ratio of the expected recruitment given spawning biomass (with and without fishing) and the estimated stock-recruitment curve. I.e., the recruitment under no fishing is modified as:

$$R'_t = \hat{R}_t \frac{f(B'_{t-1})}{f(B_{t-1})}$$

where  $R_t$  is the original recruitment estimate in year  $t$  with  $B'_{t-1}$  and  $B_{t-1}$  representing the stock-recruitment function given spawning biomass under no fishing and under the estimated fishing intensity, respectively.

The assessment model code allows retrospective analyses (e.g., Parma (1993), and Ianelli and Fournier (1998)). This was designed to assist in specifying how spawning biomass patterns (and uncertainty) have changed due to new data. The retrospective approach simply uses the current model to evaluate how it may change over time with the addition of new data based on the evolution of data collected over the past several years.

### 14.4 Parameter estimation

The objective function was simply the sum of the negative log-likelihood function and logs of the prior distributions. To fit large numbers of parameters in nonlinear models it is useful to be able to estimate certain parameters in different stages. The ability to estimate stages is also important in using robust likelihood functions since it is often undesirable to use robust objective functions when models are far from a solution. Consequently, in the early stages of estimation we use the following log- likelihood function for the survey and fishery catch at age data (in numbers):

$$nll(i) = n \sum_{t,a} p_{ta} \ln \hat{p}_{ta} \quad (33)$$

$$p_{ta} = \frac{O_{ta}}{\sum_a O_{ta}} \quad \hat{p}_{ta} = \frac{\hat{C}_{ta}}{\sum_a \hat{C}_{ta}} \quad (34)$$

$$\mathbf{C} = \mathbf{CE} \quad (35)$$

$$\mathbf{E} = \begin{matrix} b_{1,1} & b_{1,2} & \dots & b_{1,15} \\ b_{2,1} & b_{2,2} & & b_{2,15} \\ \vdots & & \ddots & \vdots \\ b_{15,1} & b_{15,2} & \dots & b_{15,15} \end{matrix} \quad (36)$$

where  $A$ , and  $T$ , represent the number of age classes and years, respectively,  $n$  is the sample size, and represent the observed and predicted numbers at age in the catch. The elements  $b_{i,j}$  represent ageing mis-classification proportions are based on independent agreement rates between otolith age readers. For the models presented this year, the option for including aging errors was re-evaluated.

Sample size values were revised and are shown in the main document. Strictly speaking, the amount of data collected for this fishery indicates higher values might be warranted. However, the standard multinomial sampling process is not robust to violations of assumptions (Fournier et al. (1990)). Consequently, as the model fit approached a solution, we invoke a robust likelihood function which fit proportions at age as:

$$\prod_{a=1}^A \prod_{t=1}^T \left[ \left( \exp \left( -\frac{(p_{ta} - \hat{p}_{ta})^2}{2(\eta_{ta} + 0.1/A) \tau_t^2} \right) + 0.01 \right) \times \frac{1}{\sqrt{2\pi(\eta_{ta} + 0.1/A) \tau_t}} \right] \quad (37)$$

Taking the logarithm we obtain the log-likelihood function for the age composition data:

$$nll(i) = -0.5 \sum_{a=1}^A \sum_{t=1}^T \ln 2\pi (\eta_{ta} + 0.1/A) - \sum_t^T A \ln \tau_t + \sum_{a=1}^A \sum_{t=1}^T \ln \left\{ \exp \left( -\frac{(p_{ta} - \hat{p}_{ta})^2}{(2\eta_{ta} + 0.1/A) \tau_t^2} \right) + 0.01 \right\} \quad (38)$$

where

$$\eta_{ta} = p_{ta}(1 - p_{ta}) \quad (39)$$

$$\text{and} \quad (40)$$

$$\tau_t^2 = 1/n_t \quad (41)$$

which gives the variance for  $p_{ta}$

$$(\eta_{ta} + 0.1/A) \tau_t^2 \quad (42)$$

Completing the estimation in this fashion reduces the model sensitivity to data that would otherwise be considered outliers.

Within the model, predicted survey abundance accounted for within-year mortality since surveys occur during the middle of the year. As in previous years, we assumed that removals by the survey were insignificant (i.e., the mortality of pollock caused by the survey was considered insignificant). Consequently, a set of analogous catchability and selectivity terms were estimated for fitting the survey observations as:

$$\hat{N}_{ta}^s = e^{-0.5Z_{ta}} N_{ta} q_t^s s_{ta}^S \quad (43)$$

where the superscript  $s$  indexes the type of survey (AT or BTS). For the option to use the survey predictions in biomass terms instead of just abundance, the above was modified to include observed survey biomass weights-at-age:

$$\hat{N}_{ta}^s = e^{-0.5Z_{ta}} w_{ta} N_{ta} q_t^s s_{ta}^S \quad (44)$$

For the AVO index, the values for selectivity were assumed to be the same as for the AT survey and the mean weights at age over time was also assumed to be equal to the values estimated for the AT survey.

For these analyses we chose to keep survey catchabilities constant over time (though they are estimated separately for the AVO index and for the AT and bottom trawl surveys). The contribution to the negative log-likelihood function (ignoring constants) from the surveys is given by either the lognormal distribution:

$$nll(i) = \sum_t \frac{\ln(u_t^s / \hat{N}_t^s)^2}{2\sigma_{s,t}^2} \quad (45)$$

where  $u_t^s$  is the total (numerical abundance or optionally biomass) estimate with variance  $\sigma_{s,t}$  from survey  $s$  in year  $t$  or optionally, the normal distribution can be selected:

$$nll(i) = \sum_t \frac{(u_t^s - \hat{N}_t^s)^2}{2\sigma_{s,t}^2}. \quad (46)$$

(47)

The AT survey and AVO index is modeled using a lognormal distribution whereas for the BTS survey, a normal distribution was applied.

For model configurations in which the BTS data are corrected for estimated efficiency, a multivariate lognormal distribution was used. For the negative- log likelihood component this was modeled as

$$nll_i = 0.5\mathbf{X}\Sigma^{-1}\mathbf{X}' \quad (48)$$

where  $\mathbf{X}$  is a vector of observed minus model predicted values for this index and  $\Sigma$  is the estimated covariance matrix provided from the method provided in Kotwicki et al. (2014). For the VAST estimates, the supplied covariance matrix was used in the same way.

The contribution to the negative log-likelihood function for the observed total catch biomass ( $C_b^{obs}, \hat{C}_b$ ) by the fishery is given by

$$nll_i = 0.5 \sum_t \frac{\ln(C_b^{obs}/\hat{C}_b)^2}{2\sigma_{C_b,t}^2} \quad (49)$$

where  $\sigma_{C_b,t}$  is pre-specified (set to 0.05) reflecting the accuracy of the overall observed catch in biomass. Similarly, the contribution of prior distributions (in negative log-density) to the log-likelihood function include  $\lambda_\varepsilon \sum_t \varepsilon_t^2 + \lambda_\gamma \sum_{ta} \gamma^2 + \lambda_\delta \sum_t \delta_t^2$  where the size of the  $\lambda$ 's represent prior assumptions about the variances of these random variables. Most of these parameters are associated with year-to-year and age specific deviations in selectivity coefficients. For a presentation of this type of Bayesian approach to modeling errors-in-variables, the reader is referred to Schnute (1994). To facilitate estimating such a large number of parameters, automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries was used. This software provided the derivative calculations needed for finding the posterior mode via a quasi-Newton function minimization routine (e.g., Press et al. (1992)). The model implementation language (ADModel Builder) gave simple and rapid access to these routines and provided the ability estimate the variance-covariance matrix for all dependent and independent parameters of interest.

## 14.5 Uncertainty in mean body mass

The approach we use to solve for  $F_{MSY}$  and related quantities (e.g.,  $B_{MSY}$ ,  $MSY$ ) within a general integrated model context was shown in Ianelli and Williamson (2001). In 2007 this was modified to include uncertainty in weight-at-age as an explicit part of the uncertainty for  $F_{MSY}$  calculations. This involved estimating a vector of parameters ( $w_{ta}^{future}$ ) on current (2023) and future mean weights for each age  $i$ ,  $i = (1, 2, \dots, 15)$ , given actual observed mean and variances in weight-at-age over the period 1991-2022. The values of based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

$$w_{ta}^{future} \sim \mathcal{N}(\bar{w}_a, \sigma_{w_a}^2)$$

Note that this converges to the mean values over the time series of data (no other likelihood component within the model is affected by future mean weights-at-age) while retaining the natural uncertainty that can propagate through estimates of  $F_{MSY}$  uncertainty. This latter point is essentially a requirement of the Tier 1 categorization.

Subsequently, this method was refined to account for current-year survey data and both cohort and year effects. The model for this is:

$$\hat{w}_{ta} = \bar{w}_a e^{v_t} \quad a = 1, t \geq 1964 \quad (50)$$

$$\hat{w}_{ta} = \hat{w}_{t-1,a-1} + \Delta_a e^{\psi_t} \quad a > 1, t > 1964 \quad (51)$$

$$\Delta_a = \bar{w}_{a+1} - \bar{w}_a \quad a < A \quad (52)$$

$$\bar{w}_a = \alpha \left\{ L_1 + (L_2 - L_1) \left( \frac{1 - K^{a-1}}{1 - K^{A-1}} \right) \right\}^3 \quad (53)$$

$$(54)$$

where the fixed effects parameters are  $L_1, L_2, K$ , and  $\alpha$  while the random effects parameters are  $v_t$  and  $\psi_t$ .

## 14.6 Tier 1 projections

Tier 1 projections were calculated two ways. First, for 2024 and 2025 ABC and *OFL* levels, the harmonic mean  $F_{MSY}$  value was computed and the analogous harvest rate ( $u_{HM}^-$ ) applied to the estimated geometric mean fishable biomass at  $B_{MSY}$ :

$$ABC_t = B_{GM,t}^f \hat{u}_{HM} \zeta_t \quad (55)$$

$$B_{GM,t}^f = e^{\ln \hat{B}_t^f - 0.5 \sigma_{B^f}^2} \quad (56)$$

$$u_{HM,t}^f = e^{\ln \hat{u}_{MSY,t} - 0.5 \sigma_{u_{MSY}}^2} \quad (57)$$

$$\zeta_t = \frac{B_t / B_{MSY} - 0.05}{1 - 0.05} \quad B_t < B_{MSY} \quad (58)$$

$$\zeta_t = 1.0 \quad B_t \geq B_{MSY} \quad (59)$$

where  $\hat{B}_t^f$  is the point estimate of the fishable biomass defined (for a given year):  $\sum_a N_{ta} s_{ta} w_{ta}$  with  $N_{ta}$ ,  $s_{ta}$ , and  $w_{ta}$  the estimated population numbers (begin year), selectivity and weights-at-age, respectively.  $B_{MSY}$  and  $B_t$  are the point estimates spawning biomass levels at equilibrium  $F_{MSY}$  and in year  $t$  (at time of spawning). For these projections, catch must be specified (or solved for if in the current year when  $B_t < B_{MSY}$ ). For longer term projections a form of operating model (as has been presented for the evaluation of  $B_{20\%}$ ) with feedback (via future catch specifications) using the control rule and assessment model would be required.

## **15 Appendix 1. Risk Table information for Environmental/Ecosystem considerations**

Provided by: Elizabeth Siddon, NOAA/AFSC

### **15.1 Environmental processes**

The recent warm stanza in the eastern Bering Sea (EBS) persisted from approximately 2014 through 2021. Since 2021, the EBS has experienced cooler oceanographic conditions with the most recent year's metrics of sea surface and bottom temperatures, sea ice, and cold pool extent being near their respective time series averages. Regional sea surface and bottom temperature trends were largely at or near the long-term average in 2023. Exceptions include (i) slightly warmer than average sea surface temperature (SST) over the outer domain (southern and northern shelf) and over the southern middle domain from approximately December 2022 through April 2023 and (ii) slightly cooler than average bottom temperature over the outer domain of the southern shelf from August 2022 through August 2023. Due to these exceptions, the outer domain may have been a more strongly vertically stratified system during late winter/early spring 2022-2023. During the standard bottom trawl survey in summer 2023, bottom temperatures were slightly cooler than the time series average with the coldest bottom temperatures in the southern inner domain since 2013. Marine heatwaves based on SSTs have been brief and infrequent in the EBS since January 2021 (Hennon et al., 2023).

Age-0 fish experiencing warm temperatures during late summer followed by relatively cooler temperatures in spring of age-1 are thought to have below average survival. Based on this Temperature Change index, the 2022 year class is predicted to have average recruitment to age-4 in 2026 (Yasumiishi, 2023).

Sea ice metrics, such as early season (Oct. - Dec.) ice extent, annual ice extent, and sea ice thickness were all near their respective time series averages. The 2023 cold pool extent was also near its historical average. Broad-scale climate indices, like the North Pacific Index, reflected a transition from La Niña conditions to developing El Niño conditions in the tropic Pacific; the National Multi-Model Ensemble predicts SST anomalies of +0.5-1°C over the SEBS shelf through May 2024 (Hennon et al., 2023).

The center of gravity estimate for pollock has moved steadily north since approximately 2000, but shifted fairly south in 2022, and then north again in 2023 (though not to the most northward position). The stock center of gravity also moved east from 2010 through 2017, then shifted west to approximately its time series average in 2023. The area occupied by the stock steadily expanded since 2010, with the exception of 2018, and has since decreased since 2019 but remains above the time series average in 2023 (Figure 19).

## **Prey**

Chlorophyll-a biomass was among the lowest in every sub-region over the southern and northern shelf and slope for 2023 (Nielsen et al., 2023). Additionally, in 2023, the coccolithophore index for both the inner and middle shelf was among the highest ever observed in the timeseries. The striking milky aquamarine color of the water during a coccolithophore bloom can reduce foraging success for visual predators, such as fish and surface-feeding seabirds (Nielsen and Eisner, 2023). Modeled bottom pH and Ωarag (important for pteropod shell formation) both improved this year compared to lowest to near-lowest values for the model hindcast in 2022, though both remain near threshold levels of biological significance (Pilcher et al., 2023).

Small copepods form the prey base for larval to early juvenile pollock during spring. Late juvenile pollock feed on a variety of planktonic crustaceans, including large calanoid copepods and euphausiids. The Rapid Zooplankton Assessment in the southeastern Bering Sea in spring noted a moderate abundance of small copepods, but low abundance and low lipid content of large copepods and euphausiids. In fall, the moderate abundance of small copepods continued, and while the abundance of large copepods and euphausiids remained low, abundances increased from south to north. In the northern Bering Sea in fall, small copepods were ubiquitous and increased in abundance from south to north, while hot spots of large copepods and euphausiids were observed around St. Lawrence Island (Kimmel et al. 2023).

A significant relationship exists between the abundance of large, lipid-rich copepods and the recruitment and survival of juvenile pollock to age-3 (Eisner et al., 2020). Low availability of large copepod prey in 2020 and 2022 may result in reduced overwinter survival and recruitment to age-3 (in 2023 and 2025) (Yasumiishi et al., 2023b).

Age-0 fish condition (samples collected during southern and northern Bering Sea surface trawl surveys), measured by length-weight residuals, % lipid content, and energy density residuals, were all below their respective time series averages in 2023. Length-weight and energy density residuals show decreasing trends since 2021 while the mean % lipid has been below average (time series 2002-2023) since the beginning of the recent warm stanza in 2014 (Page et al., 2023). Juvenile (100-250 mm) fish condition in the southern Bering Sea decreased since 2021 while adult fish condition has decreased since 2019 with 2023 being the second lowest in the time series (1997-2023). Juvenile fish condition in the northern Bering Sea has decreased since 2021 while adult fish condition has increased since 2021 with 2023 being the highest in the time series (2010, 2017, 2019, 2021-2023) (Prohaska and Rohan, 2023).

## **Competitors**

Jellyfish feed primarily on zooplankton and small fish, and therefore may compete for prey resources for both juvenile and adult life stages of pollock. Jellyfish abundance over the southeastern Bering Sea shelf was average over the time series (1982-2023; Buser, 2023), whereas abundance increased over the northern Bering Sea shelf (Buser, 2023; Yasumiishi et al., 2022c).

Togiak herring biomass has been increasing in recent years as a result of strong 2016 and 2017 year classes that have also contributed to high Prohibited Species Catch in the EBS pollock fishery (Joy et al., 2023).

Yukon and Kuskokwim River salmon runs have experienced precipitous declines in recent years (Whitworth et al., 2023), leading to potential reduced competition for prey resources where these stocks overlap, though slight increases were observed in juvenile Chinook and chum salmon indices in 2023 (Murphy et al., 2023). In 2023, returns of Bristol Bay sockeye salmon remained exceptionally high relative to the long-term average, but lower than the recent record high numbers observed in 2021 and 2022 (Cunningham and Vega, 2023). Juvenile sockeye salmon feed on zooplankton (competitors with age-0 pollock) and age-0 pollock (competitors with adult pollock) in warm years; adults feed on zooplankton and krill. Juvenile salmon condition in 2022, measured by energy density anomalies, was negative for all species (except neutral for Chinook salmon) in the southeastern Bering Sea and positive for all species (except neutral for sockeye salmon) in the northern Bering Sea (Fergusson et al., 2023).

The biomass of pelagic foragers measured during the standard EBS bottom trawl survey decreased 34% from 2022 to 2023 and is below the long-term mean (1982-2023) and is now at its third lowest value. The guild is largely driven by walleye pollock that decreased 25% from 2022. Pacific herring decreased 75% from a time series high in 2022, but remain above their long-term mean (Siddon, 2023). The impacts of recent large year classes of sablefish to the EBS ecosystem (as prey, predators, and competitors) remain largely unknown at this time, but may compete with pollock for prey resources as juveniles.

## Predators

Pollock are cannibalistic and rates of cannibalism might be expected to increase as the biomass of older, larger fish increases (i.e., the aging of the large 2018 year class). In 2023, with an average cold pool extent over the shelf, predation pressure from cannibalism may have been mitigated by this thermal barrier as adult pollock tend to avoid the cold bottom waters. However, the biomass of pelagic foragers, including adult pollock, dropped to their third lowest value over the time series in 2023 (Siddon, 2023). Fur seal consumption of adult pollock generally increases in years when juvenile pollock are less abundant (Kuhn et al., 2019). However, Northern fur seal pup production at St. Paul Island in 2022 continued a declining trend since 1998 that may be partially attributed to low pup growth rates. Other potential predators of juvenile pollock include jellyfish and chum salmon. Jellyfish abundance over the southeastern Bering Sea shelf was average over the time series (1982-2023; Buser, 2023), whereas abundance increased over the northern Bering Sea shelf (Buser, 2023; Yasumiishi et al., 2022c). Chum salmon abundance has been declining in the Yukon and Kuskokwim Rivers since 2017 (Whitworth et al., 2023), a trend also reflected in the commercial harvest data (Whitehouse, 2023).

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## **16 Appendix on model-based methods on bottom-trawl survey biomass trends**

### **16.1 Overview**

These applications of VAST were configured to model NMFS/AFSC bottom trawl survey (BTS) data and for acoustic backscatter data (next section). For the BTS, the station-specific CPUEs (kg per hectare) for pollock were compiled from 1982-2023. Further details can be found at the [GitHub repo](#) mainpage, wiki, and glossary. The R help files, e.g., `?make_data` for explanation of data inputs, or `?make_settings` for explanation of settings.

The software versions of dependent programs used to generate VAST estimates were:

- R (4.3.0)
- MKL libraries via Microsoft R Open (4.0.2)
- INLA (21.11.22)
- Matrix (1.4-0)
- TMB (1.9.6)
- TMBhelper (1.4.0)
- VAST (3.10.1)
- FishStatsUtils (2.12.1)

For these model-based index time series, we used the same VAST model run settings.

### **16.2 Spatio-temporal treatment of survey data on pollock density**

For EBS pollock we used data on biomass per unit area from all grid cells and corner stations in the 83-112 bottom trawl survey of the EBS, 1982-2023, including exploratory northern extension samples in 2001, 2005, and 2006, as well as 83-112 samples available in the NBS in 1982, 1985, 1988, 1991, 2010, and 2017-2023 (except 2020). NBS samples collected prior to 2010 and in 2018 did not follow the 20 nautical mile sampling grid used in 2010, 2017, 2019, 2021, and 2023. Assimilating these data therefore required extrapolating into unsampled areas. As before, we included a spatially varying covariate of the cold-pool extent (Thorson 2019, (O’Leary et al. 2020)). All environmental data used as covariates were computed within the R package `coldpool` (Rohan et al., 2022).

We used a Poisson-link delta-model (Thorson 2018) involving two linear predictors and a gamma distribution to model positive catch rates. We extrapolated population density to the entire EBS and NBS in each year, using extrapolation grids that are available within [FishStatsUtils] (<https://github.com/James-Thorson-NOAA/FishStatsUtils>). These extrapolation grids were defined using 3705 m (2 nmi)  $\times$  3705 m (2 nmi) cells; this results in 36,690 extrapolation-grid cells for the eastern Bering Sea and 15,079 in the northern Bering Sea. We used bilinear interpolation to interpolate densities from 750 “knots” to these extrapolation grid

cells; knots were approximately evenly distributed over space, in proportion to the dimensions of the extrapolation grid. We estimated geometric anisotropy (how spatial autocorrelation declines with differing rates over distance in some cardinal directions than others), and included a spatial and spatio-temporal term for both linear predictors. To facilitate interpolation of density between unsampled years, we specified that the spatio-temporal fields were structured over time as an AR(1) process (where the magnitude of autocorrelation was estimated as a fixed effect for each linear predictor). However, we did not include any temporal correlation for intercepts, which we treated as fixed effects for each linear predictor and year. Finally, we used epsilon bias-correction to correct for retransformation bias (Thorson and Kristensen 2016).

We checked model fits for evidence of non-convergence by confirming that (1) the derivative of the marginal likelihood with respect to each fixed effect was sufficiently small (less than ~0.001) and (2) that the Hessian matrix was positive definite. We then checked for evidence of model fit by computing Dunn-Smyth randomized quantile residuals (Dunn and Smyth 1996) and visualizing these using a quantile-quantile plot within the DHARMA R package. We also evaluated the distribution of these residuals over space in each year, and inspected them for evidence of residual spatio-temporal patterns.

### **16.3 Spatio-temporal treatment of survey age composition data**

For model-based estimation of age compositions in the Bering Sea, we fitted observations of numerical abundance-at-age at each sampling location. This was made possible by applying a year-specific, region-specific (EBS and NBS) age-length key to records of numerical abundance and length-composition. We computed these estimates in VAST, assuming a Poisson-link delta-model (Thorson 2018) involving two linear predictors, and a gamma distribution to model positive catch rates. We did not include any density covariates in estimation of age composition for consistency with models used in the previous assessment, and due to computational limitations. We used the same extrapolation grid as implemented for abundance indices, but here we modeled spatial and spatiotemporal fields with a mesh with coarser spatial resolution than the index model, here using 50 “knots”. This reduction in the spatial resolution of the model, relative to that used abundance indices, was necessary due to the increased computational load of fitting multiple age categories and using epsilon bias-correction. We implemented the same diagnostics to check convergence and model fit as those used for abundance indices.

#### **Densities and biomass estimates**

Relative densities over time suggests that the biomass of pollock can reflect abundances in the NBS even in years where samples are unavailable (all years except 2010, 2017–2019 and 2021–2023; (Figure 71). Index values and error terms (based on diagonal of covariance matrix over time) are shown in Figure 72.

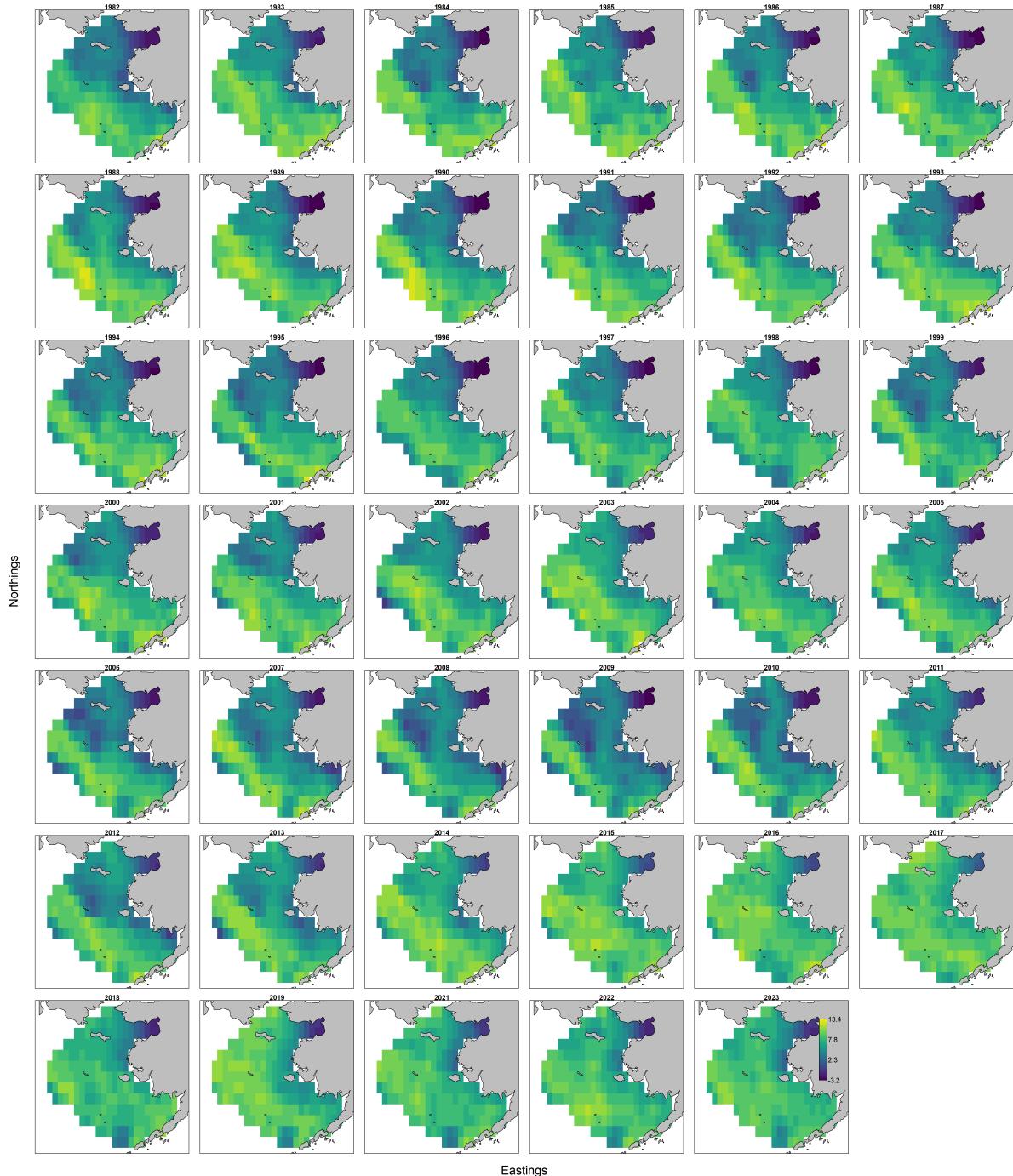


Figure 71: Pollock log density maps of the BTS data using the VAST model approach, 1982-2019, 2021-2023.

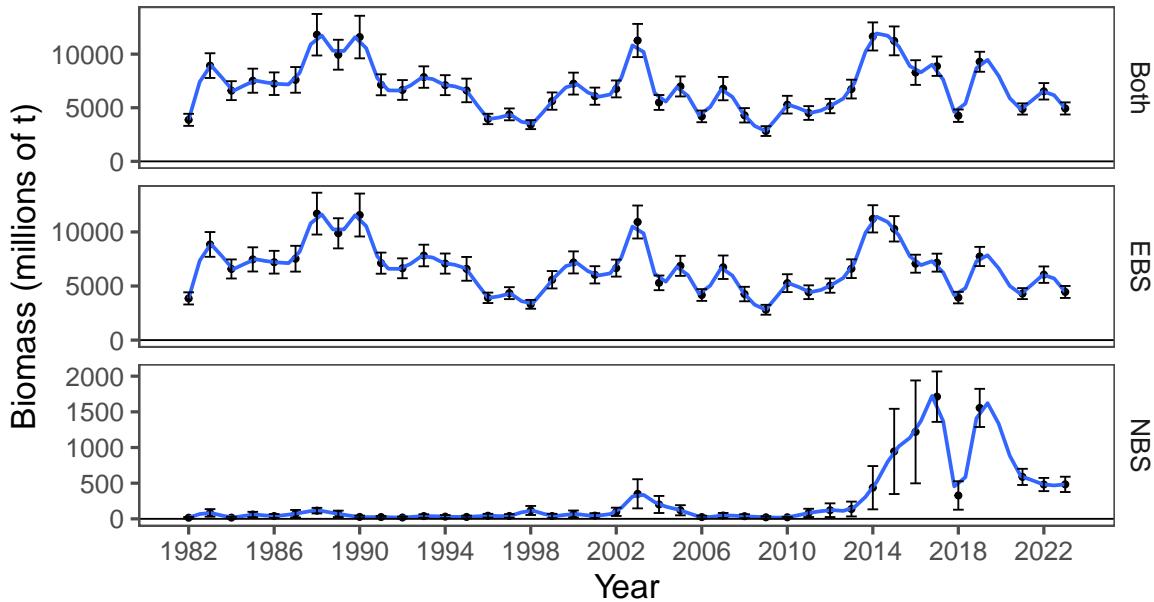


Figure 72: Pollock index values for the standard survey region, the NBS, and combined based on the VAST application to density-dependent corrected CPUE values from the BTS data, 1982–2019, 2021-2023.

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