

1. Assessment of walleye pollock in the eastern Bering Sea

Draft for November 2024 Plan Team review

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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. A list of this document’s contents, including tables and figures is provided in Section [18](#).

1.0.1 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 2024 NMFS bottom-trawl survey (BTS) covering the EBS (but no new data from the NBS). As before, these data were treated with a spatio temporal model for index standardization. Note that while data from the NBS were missing this year, the spatio-temporal model allows estimates based on adjacent observations. We note that this inflates the variance of this year’s estimate. Age data from this survey effort were compiled and included (also with an extensive spatio-temporal model treatment). Preliminary estimates of the 2024 NMFS acoustic-trawl survey (ATS) age composition data was developed using the age-length key from the BTS survey. The BTS-chartered boats also collected acoustic data and the series was updated this year (AVO).

Changes in the data

1. Observer data for catch-at-age and average weight-at-age from the 2023 fishery were finalized and included.
2. Total catch as reported by NMFS Alaska Regional office was updated and included through 2024.
3. In summer 2024, 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 updated estimates of weight-at-age data used to compute spawning biomass as presented to the Plan Team and SSC in September/October 2023 (see J. Ianelli (2023) for details) including estimates to 2024.

5. We added a 2024 estimate to the time series from the acoustic data collected from the bottom trawl survey covering 2006-2024 (except for 2020). This represents the updated “AVO” data (as presented in J. Ianelli (2023)).
6. We added a 2024 estimated biomass and preliminary age-composition from the 2024 ATS survey. The age-composition estimate was based on the BTS age-length key data.

1.0.2 Changes in the assessment methods

The assessment method was the same as presented in December of 2023 (J. Ianelli et al. (2023)). Based on results shown in September 2024 (J. Ianelli and McGilliard (2024a)) some alternative consideration of Tier level is provided.

1.1 Summary of EBS pollock results

Results from integrating the survey and fishery observer data indicate that in 2022 the stock reached about 92% of the all-time peak female spawning biomass estimated from 1987. The values for the recent years continue to remain above B_{MSY} due to the strength of the 2018 year-class.

The following tables are based on results from last year’s selected model (“Model 23.0”). The first table has the ABC recommendation based on Tier 3 calculation as a proxy reduction from the maximum permissible under Tier 1. The second table repeats the result but is simply as a reclassified Tier 3 table. We provide these as options to guide the SSC in their decisions. We also recall the work presented at their October 2024 meeting which indicated the very high value of F_{MSY} estimates when alternative (i.e., less prior influence) assumptions about the stock-recruitment relationship were examined (J. Ianelli and McGilliard (2024a)).

Tier 1 version

Quantity	As estimated or <i>specified</i> last year for:		As estimated or <i>recommended</i> this year for:	
	2024	2025	2025	2026
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)	10,184,000 t	9,437,000 t	8,526,000 t	8,075,000 t
Projected female spawning biomass (t)	3,518,000 t	3,255,000 t	3,118,000 t	3,342,000 t
B_0	6,728,000 t	6,728,000 t	5,975,000 t	5,975,000 t
B_{msy}	2,689,000 t	2,689,000 t	2,310,000 t	2,310,000 t
F_{OFL}	0.422	0.422	0.523	0.523
$maxF_{ABC}$	0.379	0.379	0.443	0.443
F_{ABC}	0.33	0.33	0.402	0.402
OFL	3,162,000 t	3,449,000 t	4,383,000 t	3,785,000 t
$maxABC$	2,837,000 t	3,095,000 t	3,715,000 t	3,209,000 t
ABC	2,313,000 t	2,401,000 t	2,417,000 t	2,036,000 t
Status	2022	2023	2023	2024
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Tier 3 version

Quantity	As estimated or <i>specified</i> last year for:		As estimated or <i>recommended</i> this year for:	
	2024	2025	2025	2026
M (natural mortality rate, ages 3+)	0.3	0.3	0.3	0.3
Tier	1a	1a	3a	3a
Projected total (age 3+) biomass (t)	10,184,000 t	9,437,000 t	8,526,000 t	8,075,000 t
Projected female spawning biomass (t)	3,518,000 t	3,255,000 t	3,118,000 t	3,342,000 t
B_0	6,728,000 t	6,728,000 t	5,902,000 t	5,902,000 t
B_{msy}	2,689,000 t	2,689,000 t	2,066,000 t	2,066,000 t
F_{OFL}	0.422	0.422	0.513	0.513
$maxF_{ABC}$	0.379	0.379	0.394	0.394
F_{ABC}	0.33	0.33	0.394	0.394
OFL	3,162,000 t	3,449,000 t	2,957,000 t	2,496,000 t
$maxABC$	2,837,000 t	3,095,000 t	2,417,000 t	2,036,000 t
ABC	2,313,000 t	2,401,000 t	2,417,000 t	2,036,000 t
Status	2022	2023	2023	2024
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

1.2 Response to SSC and Plan Team comments

Please see the [Sept. 2024 document](#) for a more comprehensive response to the SSC and Plan Team comments.

- The SSC recommends that Tier 1, 2 and 3 harvest recommendations be presented in December. The SSC welcomes other recommendations for consideration that could result in a more stable approach. Since the author and BSAI GPT did not recommend any specific model changes, the SSC expects any new analyses for the final assessment to be focused on justifications for tier designation.
 - *As with past assessments, we include the Tier 1, 2 and 3 harvest recommendations in this assessment.*
- the SSC requests that the author document the method used for determining the selectivity in the forward projections, and that an objective method be applied each year rather than an ad hoc choice of selectivity based on a previous year.
 - *As with past assessments, we document how we chose a selectivity to assume for projection purposes and provide more rationale and objectives in making this choice (see Section 5.4.1).*

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 spawn in batches 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, Brodeur, and Napp (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, Greig, and Boldt (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, Brodeur, and Napp (2004); Lang, Livingston, and Dodd (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 James Ianelli, Kotwicki, and Honkalehto (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 J. Ianelli et al. (2021). Relative to genetics research pursued at the AFSC, we presented in J. Ianelli et al. (2023) noted that the genetic groups mostly aligned with the current stock-management delineations. However, the Aleutian Islands and Bogoslof “stocks” showed subtle differentiation from the GOA management group.

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 (e.g., see James, Ianelli, and Williamson (2007)). A fishing moratorium for this area was enacted in 1993, and only trace amounts of pollock have been caught in the Aleutian Basin region since then. The management framework has two main seasons (A and B) and generally fishing concentrations that separate out by region. Generally speaking, the southeast part of the management area (east of 170°W) is where most of the catch comes from while by season, roughly 55-60% is taken in the summer B-season (Table 1). Since the late 1970s, the average EBS pollock catch has been about 1.2 million t, ranging from a low of 0.810 million t in 2009 to nearly 1.5 million t annually 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. Starting in 2021, an increasing proportion of shore-based catcher vessels have adopted electronic monitoring devices. This has replaced at-sea observers on these boats. However, the biological sampling continues to occur at about the same rate as previously but with samples obtained during the offloading. Work continues on linking the log-book data with the EM data so that tow-by-tow estimates can be obtained. Historical catch estimates used in the assessment, along with management measures (i.e., OFLs, ABCs and TACs) are shown in (Table 2).

3.1.1 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 1).

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 in 2023 but was down in 2024 (Figure 2). The nominal catch rate of sablefish in the pollock fishery also dropped substantially in 2024 after a period of historically high averages (Figure 2). 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. However, in the period 2017-2023, 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 3). 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 2024 A-season fishery spatial pattern had a relatively more catch around the Pribilof Islands compared to 2022 and 2023 (Figure 4). 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 (bottom panel, Figure 2). 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 5). This figure shows that the proportion of the TAC has been consistent over time. Pollock roe production recovered from a low level but increased 2024 (Figure 6).

The summer-fall fishing conditions for 2024 were similar to 2022 (bottom panel, Figure 2). In the B-season catches in the northwestern area increased relative to the previous two years (Figure 7). 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 in 2023 and 2024. For the B-season in 2024, the fleet dispersion was about average and up series low value (since 2000) estimated for 2023 (Figure 8).

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 and 2024 A-season size was consistent with the expectation of the 2018 year class predominating the catch (Figure 9). However, the 2023 B-season mode was small and the weight frequency for 2024 suggested growth of the 2018 year-class. 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 10).

The catch of EBS pollock has averaged 1.21 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 (2020-2024) catch has been 1.292 million t. Pollock catches that are retained or discarded (based on NMFS observer estimates) in the Eastern Bering Sea and Aleutian Islands for 1991–2024 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 1.3%. 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 outside of 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 km² inside the EEZ), the Eastern Bering Sea (968,600 km²), and the Gulf of Alaska (1,156,100 km²). The marine portion of Steller sea lion critical habitat in Alaska west of 150°W encompasses 386,770 km² of ocean surface, or 12.5% of the fishery management regions.

From 1995–1999 84,100 km², 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 km², or 13% of critical habitat). The remainder was largely management area 518 (35,180 km², 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 km² (21%) of critical habitat in the Aleutian Islands was closed to pollock fishing along with 43,170 km² (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 km² (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 our ability 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 4).

The majority (about 56%) of Chinook salmon caught as bycatch in the pollock fishery originate from western Alaskan rivers. The impact of these removals updated and presented at the June 2022 Council meeting. It was updated again in 2024 and will be presented as an appendix to the Chum DEIS that the Council is undertaking. For details, please see ([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 5). 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 table below lists the data and periods covered for this assessment.

Source	Type	Years
Fishery	Catch biomass	1964–2024
Fishery	Catch age composition	1964–2023
Fishery	Japanese trawl CPUE	1965–1976
EBS bottom trawl	Area-swept biomass and age-specific proportions	1982–2019, 2021–2024
Acoustic trawl survey	Biomass index and age-specific proportions	1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006–2010, 2012, 2014, 2016, 2018, 2020, 2022, 2024
Acoustic vessels of opportunity (AVO)	Biomass index	2006–2019, 2021–2024

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

4.1 Fishery

4.1.1 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 1991–2023 (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, James, Ianelli, and Williamson (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 12; 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. As noted previously, 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 12). For the period 2021 through 2023 the predominance of the 2018 year-class has persisted. 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 13).

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

4.2.1 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 2024 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 14. 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 15, Rohan, Barnett, and Charriere (2022)). For the period 2022-2024, the bottom temperatures have been near 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 2024 about 0.9% 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 research of the extent stock shifts between regions continues (e.g., C. A. O’Leary et al. (2021), R. M. Levine et al. (2024)).

The 2024 survey estimate is about 1.66 times higher than the mean since 1982. The 2024 pollock density by station increased relative to 2023, with the largest increases along the shelfbreak (Figure 16). 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

shifted south in 2022 and is slightly farther south in 2024, after a northward shift in 2023. The stock center of gravity also moved east from 2010 to about 2017, then shifted west. The 2024 estimate is farther west than in 2023 (Figure 17).

The BTS abundance-at-age estimates show variability in year-class strengths with substantial consistency over time (Figure 18). The abundance of the 2018 year-class decreased from 2022 to 2023, but increased again in 2024 and represents the most abundant year class. The abundance of age-1 pollock in 2024 appears to be slightly above average and is the highest since 2019.

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, pollock lengthened around 20–25 and 40–45 cm were more abundant in 2024. The size compositions were consistent with the age data (Figure 19).

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 (Cole C. Monnahan et al. (2021); Cecilia A. 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 (James, Ianelli, and Williamson (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 2024 survey age compositions were developed from age-structures collected during the survey (June-August) 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, Ianelli, and Punt (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 (see J. Ianelli (2023)).

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 (see Indivero et al. (2023) for details). 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.

4.2.2 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). The number of trawl hauls, lengths, and ages sampled from the AT survey are presented in Table 15. Estimated pollock biomass for the EBS shelf has averaged 3.2 million t since the time-series was revised to include the water column to 0.5 m (previously the estimates were from 3 m off bottom to the surface) 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; T. 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 16). These surveys have also provided insight on the relative abundance of pollock in areas considered critical to Steller sea lions (the “SCA”; Table 16).

The 2024 AT survey was conducted over the EBS shelf between ~60 m depth and the shelf break during Leg 1 (11-24 June) and Leg 2 (30th June through the 19th of July). Survey transects were spaced at 40 nmi (rather than the normal 20 nmi) with fewer sea days available due to limited funding (usually we have 9 weeks, in 2024 we were initially allotted 6). Survey timing was similar to the survey timing in 2018 and 2022, though survey duration was shorter in 2024. The 5-day delayed start to Leg 1 due to ship staffing issues, a 1-day delayed start to Leg 2 due to flight delays, and an outbreak of COVID-19 onboard during Leg 2 contributed to loss of sea days. After the survey area coverage was completed at 40 nmi transect resolution, there was sufficient time to add transects on the northwestern shelf where historically most juveniles have been observed. This resulted in transects at 20 nmi spacing between 172° W

and the US-Russia maritime boundary. The area east of 170°W was surveyed from 11-22 June and west of 170°W was surveyed from the 23rd of June through July 17. The survey estimated densities by area are shown in [?@fig-ATS_maps](#).

The survey estimate of pollock for 2024 was 11.4 billion fish with a biomass of 2.87 million t (Figure 21). This represents a 25% decrease in biomass from the 2022 estimate of 3.8 million t (with the abundance estimate at 9.67 billion fish). The 2024 biomass estimate is 10% below the survey mean of 3.2 million tons for all surveys from 1994-2022. Preliminary population age estimates from 2024 using the length compositions applied to the BTS age-length key (Table 17, Figure 22). Six-year-old pollock (2018 year class) dominated the estimated population numbers and comprised 47% of the biomass. The 5-year-olds (2019 year class) represented 15% of the biomass estimate. The age-1+ walleye pollock biomass in midwater was concentrated primarily between the 100 m contour and the shelf break, particularly north and west of Unimak Pass, and between Zhemchug Canyon and Pervenets Canyon. Presumed age 1 pollock (<20 cm FL) were found both east of the Pribilofs, near Unimak Pass, which is unusual, and on the northwestern shelf, which is more common. The majority of the biomass in 2024 was presumed age-4+ fish, with 40% of that biomass found east of 170° W, and 60% found west of 170° W.

Relative estimation errors for the total biomass for the ATS time series 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 2024 relative estimation error for the core survey area was 0.056, slightly higher than the time series mean of 0.045, 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.

4.3 Other time series used in the assessment

4.3.1 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.

4.3.2 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 2024 bottom trawl surveys (F/V Alaska Knight, F/V Northwest Explorer). We processed these Acoustic Vessels of Opportunity (AVO) data each year since 2006

to provide an index of age-1+ midwater pollock abundance. As with last year, we implemented a new subsampling methodology (M. 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 (Figure 23). The new methods were applied to reanalyze years 2009, 2010, 2012, 2014-2019, and 2021-2024. For the remaining 5 years of the time series, the original AVO index (T. Honkalehto et al. (2011), Stienessen et al. (2020)) was rescaled to match the mean of the new AVO time series (Figure 23). For 2024 the AVO data were processed (Lauffenburger et al. (2024)) to provide an index of age-1+ midwater pollock abundance in each year. These pre-publication results are given below (noting that the final results are unlikely to change):

- 1) The 2024 AVO index of midwater pollock abundance on the EBS shelf was 2.01 million t, which decreased 19% from 2023 and 31% from 2022. Although not the lowest estimate in the time series, it is the lowest estimate since 2012. This compares with the 2024 AFSC biennial acoustic-trawl survey (ATS) conducted using NOAA Ship Oscar Dyson decreased 25% from 2022 (Figure 23, Table 18).
- 2) The correlation between the AVO index and the AT survey biomass remained the same ($r^2 = 0.895$, $n = 9$ surveys).
- 3) The distribution of pollock backscatter east and west of the Pribilof Islands was average since 2009 (33%).
- 4) The strongest pollock backscatter during the AVO and AT surveys was measured along the southern portion of the EBS shelf. The center of gravity estimate for the 2024 AVO index was similar to that of the AVO 2022 and 2023 estimates, whereas the center of gravity estimate for the 2024 AT survey was shifted southeast compared to the AT 2022 estimate, and more similar to the AVO 2022-2024 center of gravity estimates (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). 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° south of St. Matthew Island close to (58°N , 172°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 D. 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 (J. N. Ianelli and Fournier (1998)). The model was written in ADMB—a library for non-linear estimation and statistical applications (David a. Fournier et al. (2012)). The data updated from last year’s analyses include:

- The 2023 fishery age composition data
- The catch biomass estimates through the current year
- The 2024 bottom-trawl survey index, weight, and age composition data
- The 2024 acoustic-trawl survey index, weight, and age composition data. Note that the 2024 acoustic-trawl age composition are preliminary and based on the BTS age-length key and the ATS abundance-at-length estimates.

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 J. Ianelli (2023).

By the SSC’s numbering scheme, last year’s model was designated Model 23, which here we contrast with the impact of new data made available in this year.

m23.ly The model selected "last year" with last year's data

m23 The same model as last year but with all new data updated (AVO, BTS, ATS, and fishery catch and fishery 2023 age-composition data)

m1 as m23.0 but with new BTS data (age and biomass index estimates) excluded

m2 as m1 but with new ATS data (age and biomass index estimates) excluded

m3 as m2 but with new AVO data (biomass index estimates) excluded

As noted in J. Ianelli and McGilliard (2024b), we continue to provide some facility to test different stock assessment software (as noted in Li et al. (2021)).

5.2.1 Input sample size

Sample sizes for age-composition data were re-evaluated in J. 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 size of 350 for the fishery and then using estimated values for the period 1978-1990 and 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 (using R. I. C. Chris Francis (2011), equation TA1.8). 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 P.-J. F. Hulson et al. (2023) (with the time series updated this year P. Hulson and Williams (2024)).

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, Hicks, and Methot (2015)) or adnnts (C. C. Monnahan and Kristensen (2018)) should be implemented (e.g., as shown by Xu, Thorson, and Methot (2020)). Progress this year has lagged on this and measures to adopt an alternative software approach (e.g., Kaskr (2024)) would help to ease implementation of this and other features (e.g., that of Cheng et al. (2023)).

5.3 Parameters estimated outside of the assessment model

5.3.1 Natural mortality and maturity at age

The M23 model specification used 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, Ianelli, and Livingston (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 J. Ianelli and McGilliard (2024a) a research model with the estimated M at-age and year matrix was applied. The SSC noted that further refinements to the CEATTLE model may hold promise for future application and sensitivities.

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., J. Stahl (2004); J. P. Stahl and Kruse (2008), J. N. 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 James N. 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

5.3.2 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 2024–2026 (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 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, 1366 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 1964–2024 and projected recruitment variability (using the variance of past recruitments) for five years (2025–2030). 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 2022 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 61 parameters and the age-time selectivity schedule forms a 10x61 matrix of 610 parameters bringing the total fishing mortality parameters to 671. The rationale for including time- varying selectivity has recently been supported as a means to improve retrospective patterns (Szuwalski, Ianelli, and Punt (2018)) 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 352 (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 14 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 1991-2023 from the fishery (and 1982-2024 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)) and was presented in the [Sept. 2024 document](#). 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, Cheng, et al. (2020)) 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, Adams, et al. (2020)), such that a fall (but not spring) survey of copepod densities is also associated with cold conditions and elevated recruitment (Eisner et al. (2020)).

5.4.1 Fishery selectivity for projections

The SSC requested a clear development on the assumptions of what selectivity estimates should be used for projections. The model estimates vary by year and this can affect recommendations for ABC and OFL. For example, in 2021, the selectivity estimates shifted dramatically towards younger fish due to the appearance of two-year old pollock in 2020. In such cases, the estimate of F_{MSY} (or proxy) will generally be lower since the basis is on the conservation of reproductive biomass. To evaluate the impact of choice in selecting the selectivity estimates to use for projection purposes, we tested the following scenarios:

1. The selectivity estimates from the most recent year was used for projections. (**most-recent**)
2. The selectivity estimates from the most recent 2-year mean was used for projections. (**2-yr-avg**)
3. The selectivity estimates from the most recent 3-year mean was used for projections. (**3-yr-avg**)
4. The selectivity estimates from the most recent 4-year mean was used for projections. (**4-yr-avg**)
5. The selectivity estimates from the most recent 5-year mean was used for projections. (**5-yr-avg**)

To judge which of these is most appropriate, we compute Mohn's ρ and compare the projected $F_{35\%}$ rate with the annual estimates in later years. For example, in the terminal (retrospective) year 2015 we have estimates of $F_{35\%}$ based on the 2016 expected selectivity (using the above scenarios). We can then compare the "final" estimate of the 2016 selectivity as estimated this year (2024) and go back and compute the $F_{35\%}$ using that year's selectivity. We do that for each retrospective projection $\sum(F_{35\%}^{proj,i} - F_{35\%}^{full,i})^2$ given each of the five scenarios outlined above.

6 Results

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 33; R. I. C. Chris 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 34). The model fits the fishery age-composition data quite well under this form of selectivity (Figure 35).

Bottom-trawl survey selectivity estimates are shown in Figure 36. 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 37). 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 37). The ATS selectivity varies slightly among ages and years (Figure 38). This enhances the fit to the age composition data while still tracking the large year classes through the population (Figure 39). Overall fits to the composition data (appropriately weighted by the effective sample sizes) are shown in Figure 40. The general fit to the age composition data was good, despite some occasional outlier residuals (Figure 41).

6.1 Evaluation of Model(s) and Associated Uncertainty

6.1.1 Sensitivity to model specification

In the [September 2024 assessment evaluation](#) a detailed set of sensitivities were presented regarding assumptions about the stock-recruitment relationship (SRR). Additionally, an alternative natural mortality-at-age and year matrix (from the CEATTLE model results) was tested along with some preliminary model applications using alternative software platforms and a number of SSC requests. Please refer to that work and that from 2023 for recent sensitivities.

A sensitivity of dropping new survey data sequentially from the updated model 23 indicated relative minor changes regarding impact on spawning biomass (Figure 42). From this we conclude that the key change from the 2023 *assessment result* (Figure 42; top panel) is due to the updated new information on the fishery catch-at-age from 2023. Diagnostics comparing changes relative to model fits are given in Table 21. A comparison of management quantities for the recommended 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 43). The model fits the fishery-independent index from the 2006–2024 AVO data well through most of the period but the model predicts lower biomass than the index data indicate in 2022 but a bit higher than the 2024 estimate (Figure 44). The model fits to the bottom-trawl survey biomass (the density-dependent corrected series) were reasonable and within the observation error bounds (Figure 45). 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 45). The fit to the acoustic-trawl survey biomass series (including the USV data from 2020) was consistent with the specified observation uncertainty (Figure 46).

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](#).

6.1.2 Convergence status and criteria

Convergence status was based on the maximum gradient being less than 1e-3 and evaluated using MCMC criteria for finding the modes for key parameters. The MCMC results indicated that all of the $Rhat < 1.01$ and $ESS > 400$ using the R package ‘adnuts’ were satisfactory (Cole C. Monnahan (2024)).

As in past assessments, we evaluated the multivariate posterior distribution using Monte-Carlo Markov chain (MCMC) simulation methods. This year we adopted the no-uturn sampling approach from ADMB but upgraded and packaged within R (adnuts, C. C. Monnahan 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 47). As before, we evaluated how selected parameters relate by doing a pairwise (along with their marginal distributions; Figure 48). 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 2024 spawning biomass. This showed that the point

estimate was similar to the mean of the marginal posterior distribution (Figure 49). As an additional part of the Tier 1 consideration, we evaluated the posterior density of F_{MSY} and it is provided in Figure 50 for reference.

For the main model fits, we produced posterior predictive distributions (e.g., for the two acoustic indices in Figure 51. 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 52).

6.1.3 Likelihood profile

Near term stock projection magnitude depends largely on the estimate of the 2018 year class. As such we profiled model fits for 33 fixed values of that year-class and examined the negative log-likelihood components (Figure 53). Most of the data components were consistent with global estimate of the 2018 year-class.

6.1.4 Retrospective analysis (within model)

We ran a twenty-year retrospective analysis by sequential removal of all data annually beginning with 2024 and ending in 2005 (Figure 54). While variable, the confidence bounds of the retrospective patterns overlapped in all years reflecting the general model uncertainty rather than a consistent retrospective pattern. In 2023, the lower than expected survey biomass estimate followed by lower acoustic estimates in 2024 has created a significant retrospective pattern (Mohn's ρ equal to 0.388 for the 10 year retrospective). This pattern can be explained by the very optimistic estimates of the 2018 year class which has declined somewhat.

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 55). 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 56 and Figure 57 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 58). 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 59).

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 34). 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 60). This figure reveals how shifts in the relative age of fish selected impact F_{MSY} estimates.

Examining the retrospective projections of $F_{35\%}$ based on projected method of specifying selectivity (e.g., using a recent 2 or 5 year mean) was completed. The results showed that the 5-year average was the most consistent with the final estimates of $F_{35\%}$ in the terminal year. However, none of the methods were particularly good at predicting the final values (based on comparing 190 estimates with predictions:

Years averaged	Sums of squares
1	23.28
2	22.72
3	22.35
4	22.07
5	22.05
—	—

An example depiction of predicted versus current estimated values is shown in Figure 61. We therefore selected the 5-year average as the most appropriate.

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 4.35 million t. The estimate for 2024 is trending downward and at 9.41 million t with 2025 estimated at 8.53 million t.

6.1.5 Historical retrospectives

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 62, Table 23).

6.2 Population trends

6.2.1 Fishing intensity

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 63). 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 64).

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 65). Projections of spawning stock biomass given the 2025 estimate of fishing mortality rate given catches equal to the 2024 values shows some variability in the near-term but generally stable; albeit with considerable uncertainty due to uncertainty in recruitment (Figure 66).

6.2.2 Recruitment

Model estimates indicate that the 2008, 2012, 2013, and the 2018 year classes are above average (Figure 67). The 2018 year class is nearly 4 times bigger than average with a CV of about 10%. The stock-recruitment curve as fit within the integrated model shows the variability of the estimated curve (Figure 68). Note that the 2022 and 2023 year classes (as age 1 recruits in 2023 and 2024) 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 69).

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, Swartzman, and Ciannelli (2005)). J. N. 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 70). 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 2,310 kt (with a CV of 30%) which is less than the projected 2025 spawning biomass of 3,100 kt; (Table 27). For 2025, the estimates put the stock in Tier 1a. The corresponding maximum permissible ABC would thus be 3,715,000 t with a fishable biomass estimated at around 8,378 kt (Table 28). For the current year spawning biomass this corresponds to 147% of the B_{MSY} level. A diagnostic (see Section 14) on the impact of fishing shows that the 2024 spawning stock size is about 61% 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 2025 and 2026.

In response to the SSC, we 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 2025 the Tier 2a ABC would be 3,365,000 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 2,853,000 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. Given the priors assumed for the SRR, and the fact that the results are largely similar to the Tier 3 proxy for F_{MSY} (i.e., the $F_{SPR\%}$ at F_{MSY} is close to $F_{35\%}$), **we recommend adopting Tier 3 for this stock until a more detailed management strategy evaluation can be pursued**. 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} .

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):

$$\begin{aligned} B_{MSY} &= 2,310 \text{ kt female spawning biomass} \\ B_0 &= 5,975 \text{ kt female spawning biomass} \\ B_{100\%} &= 5,902 \text{ kt female spawning biomass} \\ B_{40\%} &= 2,361 \text{ kt female spawning biomass} \\ B_{35\%} &= 2,066 \text{ kt female spawning biomass} \end{aligned}$$

7.3 Specification of OFL and Maximum Permissible ABC

Under Amendment 56 of the [BSAI Groundfish FMP](#), the SSC has historically 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 (James Ianelli, Kotwicki, and Honkalehto (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 60).

Since the 2025 female spawning biomass is estimated to be above the B_{MSY} level (2,310 kt) and above the $B_{40\%}$ value (2,361 kt) in 2025 and if the 2024 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	2025	3,715,000	4,383,000
1a	2026	3,209,000	3,785,000
2a	2025	3,364,950	4,383,000
2a	2026	2,906,180	3,785,000
3a	2025	2,417,000	2,957,000
3a	2026	2,036,000	2,496,000

Note that the values presented for 2026 assumed a catch of 1,350,000 t in 2025.

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 2024 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2025 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2024. 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 2025, 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 2025 and 2026 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 2023 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 2024 or 2) below half of its MSY level in 2024 or below its MSY level in 2034 under this scenario, then the stock is overfished.)

Scenario 7: In 2025 and 2026, F is set equal to $\max FABC$, 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 2026 or 2) below 1/2 of its MSY level in 2026 and expected to be below its MSY level in 2036 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 2025 (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 72 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 2024:

- If spawning biomass for 2024 is estimated to be below 1/2 $B_{35\%}$ the stock is below its MSST.
- If spawning biomass for 2024 is estimated to be above $B_{35\%}$, the stock is above its MSST.
- If spawning biomass for 2024 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 2034 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 2024 is below $1/2 B_{35\%}$, the stock is approaching an overfished condition.
- If the mean spawning biomass for 2024 is above $B_{35\%}$, the stock is not approaching an overfished condition.
- If the mean spawning biomass for 2026 is above $1/2 B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2036. If the mean spawning biomass for 2036 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 2024, and it is expected to be above the “overfished condition” based on Scenario 7 (the mean spawning biomass in 2024 is between the $1/2 B_{35\%}$ and $B_{35\%}$ estimate but by 2036 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 (2023). This hypothetical 2023 F_{OFL} from this year’s model was estimated to be 0.375 for EBS pollock (assuming this year’s estimated selectivity and weight-at-age for 2023).

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 2024 spawning biomass (3,390 kt) which is about 147% of B_{MSY} (2,310 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 (81,100 age 1 numbers), but with considerable uncertainty.

Given the same estimated aggregate fishing effort as in 2024, the stock trend would be stable and yield about 1.3 million t (Table 34).

7.6.1 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 adopting Tier 3 projections for management until a full management procedure evaluation can be undertaken.

		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 2024 two surveys showed decreases from the previous estimates (the ATS and AVO indices). The BTS index showed a substantive increase from 2023 estimate. For the three new age-composition estimates available this year, they all indicated persistence in the 2018 year class. While the stock trends and age composition seems to be robustly estimated, we note that in the analyses presented in Sept 2024 (J. Ianelli and McGilliard (2024a)), the robustness of stock-productivity estimates was questioned, especially for the stock-recruitment relationship. **Therefore we rated the assessment-related concern as Level 2, Major concern (if Tier 1), Level 1, no concern (if Tier 3).**

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 70). 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 71). **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):

- **Environment:** The EBS shelf experienced oceanographic conditions that were largely average based on historical time series of multiple metrics over the past year (August 2023 - August 2024).
- **Prey:** Trends of prey for pollock were mostly low in 2024, with prey conditions over the SEBS shelf being potentially more limiting while prey conditions over the NBS shelf appear limiting for age-0 and juvenile pollock, but sufficient for adult fish. The spatial distribution of adult pollock appears to have overlapped with large ‘oceanic’ copepods, while rates of cannibalism indicate reduced overlap with juvenile pollock.
- **Competitors:** Trends in potential competitors were mixed over the shelf, with pollock representing the greatest increase in biomass and potential competitive pressure.
- **Predators:** Trends in potential predators increased over the shelf, though spatial mismatch may mitigate realized predation pressure. Rates of cannibalism remained low in 2024.

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

Fishery performance

As noted above, the 2024 fishery again experienced good nominal fishing rates though dropped slightly from the 2023 indicator. The 2024 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 or average (indicating relatively good fishing; Figure 8).

The CPUE of PSC species and other bycatch declined in 2024. Sablefish, herring and Chinook salmon bycatch rates (per hour of fishing) continued to decrease from 2021 (except for a slight increase in herring CPUE during the B season from low levels; Figure 2).

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 2: Major concern (contingent on Tier designation)	Level 1: No concern	Level 1: No concern	Level 1: No concern

We generally strive to present two key types of information within a fisheries stock assessment. First, we compile all available fishery dependent and fishery independent data to evaluate trends in stock biomass and abundance. Second, we attempt to provide stock productivity estimates. For the latter, age-specific biological data are used to estimate growth, mortality, and reproductive potential. Such information provides guidelines to avoid growth overfishing. An added productivity estimate, that following estimates of the stock recruitment relationship (SRR), can contribute to advice that avoids so called “recruitment” overfishing. This latter point is a key contrast that distinguishes Tiers 1 and 2 within our FMP system from Tier 3 stock classifications.

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 yield (lower overall variability in ABC/yields; Figure 73).

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; J. N. 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 18% 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 -2% lower than the mean value or a target female spawning biomass at 2.772 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 2025 catch values. These indicators and rationale for including them are summarized in Table 33. Model 23 results for these indicators are provided in Table 34. Each column of this table uses a fixed 2025 catch and assumes the same effort for the four additional projection years (2026–2029). 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 2025 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 2026 spawning stock estimates being below the long term mean (but above B_{MSY}).

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 and fishery effects on the ecosystem.

These two topics are combined here noting that the presentation in J. Ianelli (2023) is unchanged and updated summary of current conditions is provided in an appendix. Relative to habitat, Hollowed et al. (2012) provided an extensive review of habitat and density for age-0 and age-1 pollock based on survey data. 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).

The pollock fishery is executed using pelagic fishing gear. This is one reason that 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. J. N. 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

We note that in early 2025, the AFSC has applied for a review of the EBS pollock assessment by the “Center for Independent Experts” NOAA Fisheries (2024).

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., Recattle, 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 2024). 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	529,917	297,202	356,353	542,109	653,555	309,393	886,271	1,195,664
1992	101,597	458,143	454,947	375,612	559,741	830,559	556,544	833,755	1,390,299
1993	93,013	139,160	475,143	619,287	232,173	1,094,429	568,156	758,446	1,326,602
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	604,129	660,117	1,264,247
1996	1,804	104,135	549,297	537,545	105,939	1,086,843	551,101	641,680	1,192,781
1997	2,363	302,180	557,106	262,784	304,544	819,889	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	206,698	782,983	418,169	571,511	989,680
2000	19,363	274,170	439,023	400,154	293,532	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	283,749	561,061	599,272	320,442	1,160,334	597,754	883,022	1,480,776
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	1,090,008	607,130	873,422	1,480,552
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	660,824	827,207	604,297	883,734	1,488,031
2007	62,504	563,748	505,306	222,943	626,253	728,249	567,811	786,691	1,354,502
2008	44,801	463,079	358,936	123,762	507,880	482,698	403,738	586,840	990,578
2009	81,575	370,957	247,944	110,307	452,532	358,252	329,520	481,264	810,784
2010	199,011	356,061	124,670	130,443	555,072	255,114	323,681	486,505	810,186
2011	102,252	348,897	401,755	346,128	451,149	747,882	504,007	695,024	1,199,031
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	695,667	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	539,576	813,106	1,352,681
2017	37,730	143,430	544,028	633,993	181,159	1,178,021	581,758	777,423	1,359,181
2018	3,842	326,753	598,533	450,160	330,595	1,048,692	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	1,409,346
2020	85,717	421,102	560,438	299,978	506,820	860,416	646,156	721,080	1,367,236
2021	56,779	295,470	554,774	469,234	352,249	1,024,009	611,554	764,704	1,376,258
2022	9,018	197,610	487,216	411,573	206,629	898,790	496,235	609,184	1,105,419
2023	11,335	411,552	568,454	319,251	422,887	887,704	579,788	730,803	1,310,591
2024	51,606	353,141	523,585	330,355	404,747	853,940	575,191	683,496	1,258,687

Table 2: Time series of 1964–1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977–2024 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports. Note that the 2024 value is based on catch reported to October 25th 2024 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	1,310,716
		2024	3,162,000	2,313,000	1,300,000	1,300,000
	1977–2024 mean		2,489,455	1,512,708	1,222,888	1,206,496

Table 3: Estimates of discarded and retained pollock (t) for the Northwest and Southeastern Bering Sea, 1991–2024. SE represents the EBS east of 170W, NW is the EBS west of 170W, source: NMFS Blend and catch-accounting system database. 2024 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	1,084,813	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	872,276	1,019,082	1.6%
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	9,363	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	9,899	203,091	888,891	1,105,419	1.2%
2023	4,685	10,218	418,201	877,486	1,310,591	1.1%
2024	3,809	12,090	400,938	841,850	1,258,687	1.3%
Mean	7,323	25,006	386,417	844,747	1,263,493	2.6%

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 https://alaskafisheries.noaa.gov/fisheries/chinook-salmon-bycatch-management 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.
2024	The Council received analyses on 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, 1979–2023.
Units are in millions of fish.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Sum
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	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	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	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	1,745
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	1,938
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	1,920
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	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	1,379
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	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	1,784
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	1,746
1991	0.7	112.9	43.8	90.3	153.9	184.4	497.5	78.1	288.0	28.9	144.1	18.7	91.2	22.8	1,755
1992	1.1	84.7	675.8	130.1	79.6	108.7	133.8	253.6	102.3	147.0	58.0	46.3	13.4	43.8	1,878
1993	0.1	7.4	260.5	1146.7	103.0	66.2	66.4	56.5	86.2	21.2	32.7	12.4	13.5	6.8	1,879
1994	0.7	30.2	55.1	361.2	1059.7	175.7	53.5	19.1	13.1	20.2	9.7	9.4	7.6	4.0	1,819
1995	0.0	0.5	72.9	146.8	395.5	761.1	136.3	34.6	12.3	7.5	17.5	5.0	5.8	1.7	1,597
1996	0.0	21.7	48.1	71.8	161.0	361.9	481.7	184.6	33.6	13.4	7.9	8.8	4.3	5.8	1,405
1997	1.0	77.7	40.3	119.0	455.1	289.0	256.4	198.6	64.0	13.3	6.0	4.6	2.9	4.8	1,533
1998	0.3	42.0	84.5	70.5	153.4	702.8	199.6	131.7	110.7	27.8	6.1	5.6	2.6	2.5	1,540
1999	0.2	10.3	298.7	225.0	103.0	157.0	469.7	131.0	56.5	33.2	4.0	2.2	0.9	0.5	1,492
2000	0.0	16.1	82.4	428.5	346.5	106.7	168.4	357.7	84.9	29.7	22.0	5.2	1.4	0.6	1,650
2001	0.0	3.2	42.8	154.5	581.0	415.0	137.2	129.0	157.2	57.9	33.6	16.2	5.5	3.1	1,736
2002	0.8	47.0	108.1	217.8	287.6	606.3	268.0	98.5	85.9	93.9	34.6	14.4	11.0	3.0	1,877
2003	0.0	14.5	411.8	324.1	360.4	301.5	337.6	158.6	49.4	39.3	35.7	22.9	6.6	3.6	2,066
2004	0.0	0.5	89.6	831.1	480.6	236.8	169.3	156.3	65.0	16.1	17.1	25.3	9.4	5.9	2,103
2005	0.0	4.8	52.2	392.9	863.8	484.6	159.5	68.1	66.6	30.1	10.0	9.1	3.2	2.5	2,147
2006	0.0	9.9	84.2	295.8	619.6	597.6	278.6	107.3	48.0	38.4	17.7	8.2	8.3	5.3	2,119
2007	1.7	15.7	59.2	139.2	389.4	512.0	300.8	137.1	47.6	27.5	21.9	8.9	6.5	3.4	1,671
2008	0.0	25.2	58.8	79.2	147.0	309.7	242.3	148.7	84.3	22.2	17.6	14.4	8.6	2.8	1,161
2009	0.0	1.3	175.5	200.6	82.6	114.4	124.3	104.3	66.6	40.2	23.5	7.6	7.5	2.7	951
2010	1.1	26.5	31.8	559.4	220.5	54.7	43.0	57.7	51.8	31.8	16.0	8.6	6.0	4.4	1,113
2011	0.4	10.4	193.3	115.4	809.2	284.7	63.6	37.5	38.5	41.4	25.8	12.5	1.8	4.0	1,638
2012	0.0	22.3	116.7	946.7	172.8	432.6	141.6	36.7	17.4	14.6	15.9	13.5	7.4	6.1	1,944
2013	1.8	1.0	64.0	342.4	955.9	194.4	156.5	70.0	20.7	12.8	12.8	10.9	7.8	4.8	1,856
2014	0.0	39.2	31.0	167.8	399.3	751.8	210.2	86.2	29.8	9.0	4.5	4.5	4.6	2.8	1,741
2015	0.0	15.5	632.4	196.4	228.6	384.3	510.1	88.8	42.1	17.7	2.9	2.1	3.1	2.7	2,127
2016	0.0	0.5	90.6	1390.3	159.9	174.5	174.8	224.7	34.1	13.8	8.0	0.5	1.2	0.7	2,273
2017	0.0	2.2	28.2	549.1	899.0	215.5	147.6	122.1	97.3	21.8	7.2	5.6	0.5	0.2	2,096
2018	0.0	1.3	13.8	115.0	1216.1	506.6	104.8	82.0	60.6	25.9	4.3	1.1	0.4	0.6	2,132
2019	0.7	10.9	12.3	18.4	157.6	916.8	422.5	93.2	52.1	53.0	10.1	2.9	0.8	0.0	1,751
2020	3.5	247.7	85.5	101.1	135.2	551.1	597.8	124.0	52.8	38.6	27.3	6.8	1.8	1.1	1,974
2021	0.0	111.5	1297.0	144.2	110.1	107.2	309.6	296.0	72.1	26.5	16.2	8.5	2.1	0.0	2,501
2022	0.0	62.3	174.5	1035.4	183.7	70.4	79.5	141.9	81.1	16.3	11.3	4.1	6.0	1.0	1,867
2023	0.0	25.2	86.6	263.0	1473.1	227.2	29.4	45.4	63.6	42.6	18.8	5.4	8.6	2.6	2,292
Mean	3.4	57.3	215.9	367.2	409.8	331.0	213.1	116.3	65.1	33.3	22.1	10.8	7.5	5.1	1,857.7

Table 6: Numbers of pollock NMFS observer samples measured for fishery catch length frequency (by sex and strata), 1977–2023.

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	114,918	93,686	86,598	94,900	33,622	36,012	459,736	
2023	73,284	54,056	38,537	42,259	38,222	37,101	283,459	
2024	71,834	60,398	36,811	41,855	29,604	29,581	270,083	

Table 7: Number of EBS pollock measured for weight and length by sex and strata as collected by the NMFS observer program, 1977-2023

	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	4,890	5,847	1,705	1,566	4,899	4,364	23,271	
2023	10,676	14,487	6,171	6,173	5,911	5,436	48,854	

Table 8: Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977–2023, 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	609	777	209	212	616	563	2,986
2023	452	633	350	313	399	342	2,489

Table 9: NMFS total pollock research catch by year in t, 1964–2023.

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
				2023	119

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 1982–2024 .

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	3,210,402	416,291	3,626,694	11.5%
2022	5,286,911	167,616	5,454,528	3.1%
2023	3,748,408	140,380	3,888,788	3.6%
2024	7,885,512	73,237	7,958,749	0.9%
Average	4,543,531	264,534	4,789,169	5.5%

Table 11: Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982–2024.

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	376	24,819	1,342
1993	375	43,278	1,385	2010	517	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	519	47,873	1,623
				2018	376	48,673	1,486
				2019	520	42,382	1,519
				—	—	—	—
				2021	520	53,545	2,050
				2022	520	36,687	1,980
				2023	492	38,618	1,677
				2024	350	36,137	1,526

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 VAST estimation procedures.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1982	1,095	2,766	3,222	4,353	1,475	197	127	61	38	24	15	9	3	1	1	13,388
1983	4,535	1,072	2,920	4,557	9,382	2,708	459	208	95	85	61	22	8	7	3	26,124
1984	481	395	798	2,244	2,485	5,288	936	200	91	31	21	8	5	6	3	12,993
1985	4,933	790	3,899	1,380	4,540	2,795	1,848	351	86	73	25	8	8	1	1	20,738
1986	2,949	977	791	3,351	1,708	2,579	2,140	1,787	532	82	37	16	1	5	2	16,957
1987	490	688	1,175	924	5,568	1,456	1,329	516	1,611	254	78	30	6	3	3	14,130
1988	1,572	777	2,431	4,764	2,054	6,339	1,698	1,203	668	1,610	155	91	20	24	14	23,422
1989	905	545	959	3,053	6,767	1,276	4,503	632	700	262	820	140	125	59	92	20,838
1990	2,223	276	110	1,139	2,570	8,317	1,530	3,632	344	591	89	832	72	52	72	21,850
1991	3,230	928	357	140	984	842	2,514	875	1,691	427	570	117	343	52	59	13,128
1992	1,559	438	2,930	436	526	851	757	1,055	454	839	289	359	153	121	97	10,862
1993	2,683	443	1,151	5,126	1,066	811	405	531	673	411	355	258	205	112	136	14,365
1994	1,630	725	532	2,064	6,011	977	235	181	196	362	221	305	116	114	192	13,862
1995	1,617	216	477	2,004	2,928	5,104	1,872	405	235	148	272	110	202	82	130	15,801
1996	1,951	428	200	409	1,137	1,509	1,290	425	103	111	74	142	48	85	123	8,036
1997	2,332	406	220	269	3,078	1,412	829	1,066	184	93	67	72	123	39	147	10,337
1998	871	688	371	267	557	3,058	784	474	360	93	41	14	32	34	83	7,726
1999	991	1,113	1,297	1,234	685	1,260	2,949	757	360	333	124	53	22	32	115	11,324
2000	1,045	376	691	2,150	2,160	1,199	954	2,895	1,096	572	245	157	49	22	99	13,709
2001	1,987	1,222	726	703	1,689	1,656	690	335	996	711	271	211	73	30	81	11,381
2002	1,364	395	795	1,240	1,368	1,772	884	428	572	1,068	532	245	146	46	54	10,908
2003	574	166	1,066	1,828	2,160	1,800	2,258	1,166	486	635	1,237	560	232	95	102	14,366
2004	397	266	189	1,614	1,589	1,178	657	694	344	217	217	398	176	46	38	8,020
2005	401	148	220	1,104	3,239	2,179	1,141	455	387	270	78	160	266	106	114	10,267
2006	816	75	113	519	1,400	1,645	967	440	244	204	98	61	87	118	121	6,908
2007	2,734	68	221	707	2,218	2,508	1,673	1,166	462	198	174	157	72	87	180	12,625
2008	503	123	136	264	784	1,553	1,132	708	431	156	128	96	43	24	158	6,238
2009	842	211	433	490	332	502	708	538	385	176	110	35	35	18	79	4,895
2010	480	135	305	4,051	1,669	469	374	383	384	263	224	81	49	29	67	8,960
2011	1,292	136	342	426	2,153	1,043	295	160	243	240	204	157	68	32	95	6,887
2012	1,297	209	493	4,249	965	1,444	459	172	115	157	127	110	94	34	64	9,989
2013	1,252	133	272	1,131	5,459	1,232	751	263	89	80	104	79	76	44	61	11,024
2014	2,538	488	279	494	2,300	7,748	3,821	802	436	158	62	88	92	45	136	19,486
2015	1,457	929	2,767	741	1,516	2,736	5,151	1,522	385	191	27	26	49	30	68	17,595
2016	794	493	728	4,023	1,699	1,200	1,768	2,692	542	222	80	18	18	7	14	14,299
2017	784	321	545	2,648	3,496	1,597	1,231	1,155	1,476	424	163	55	8	5	16	13,923
2018	1,129	473	251	364	2,502	1,538	533	388	398	327	91	14	2	0	6	8,016
2019	2,680	713	593	615	1,760	6,277	2,507	596	430	254	134	61	24	7	3	16,652
2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2021	1,032	798	1,964	753	689	502	1,279	1,477	392	152	127	83	18	13	4	9,284
2022	812	351	600	4,006	1,872	730	811	1,142	856	272	116	97	37	21	2	11,726
2023	1,114	382	342	636	2,750	808	445	443	703	497	106	44	27	11	12	8,320
2024	1,626	1,096	975	662	2,078	6,804	1,509	470	443	399	273	103	32	12	4	16,487
Mean	1,548	557	926	1,741	2,413	2,307	1,386	830	493	325	196	135	78	41	68	13,044

Table 13: Mean EBS pollock body mass (kg) at age as estimated for the summer NMFS bottom trawl survey, 1982–2024.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	0.026	0.077	0.180	0.367	0.540	0.891	1.204	1.365	1.503	1.670	1.821	1.872	2.152	1.825	2.663
1983	0.016	0.105	0.185	0.361	0.521	0.716	1.020	1.307	1.511	1.578	1.631	1.571	1.813	1.556	1.986
1984	0.016	0.068	0.196	0.307	0.485	0.598	0.930	1.378	1.514	1.731	1.870	1.852	1.970	1.745	2.125
1985	0.017	0.082	0.213	0.336	0.473	0.681	0.891	1.232	1.649	1.608	1.721	2.016	2.105	1.802	2.490
1986	0.013	0.063	0.145	0.327	0.420	0.611	0.819	1.030	1.310	1.625	1.735	1.940	2.221	2.282	2.431
1987	0.026	0.106	0.246	0.294	0.426	0.523	0.692	0.826	0.974	1.181	1.494	1.517	1.928	2.229	2.373
1988	0.016	0.095	0.275	0.323	0.426	0.501	0.661	0.877	0.890	1.108	1.344	1.384	1.905	1.160	1.744
1989	0.019	0.090	0.168	0.305	0.391	0.505	0.710	0.804	1.100	1.089	1.226	1.312	1.290	1.290	1.481
1990	0.014	0.171	0.181	0.352	0.433	0.545	0.623	0.762	0.896	1.105	1.142	1.311	1.376	1.487	1.778
1991	0.021	0.136	0.199	0.354	0.564	0.638	0.720	0.817	0.982	1.080	1.328	1.414	1.571	1.815	1.980
1992	0.017	0.130	0.300	0.409	0.505	0.589	0.778	0.870	0.972	1.080	1.226	1.472	1.676	1.730	1.693
1993	0.012	0.103	0.289	0.470	0.525	0.645	0.739	0.866	1.062	1.099	1.293	1.408	1.608	1.689	1.811
1994	0.018	0.089	0.228	0.414	0.573	0.709	0.747	1.087	1.303	1.236	1.346	1.440	1.492	1.671	1.743
1995	0.017	0.063	0.145	0.340	0.480	0.657	0.680	0.897	1.075	1.363	1.308	1.401	1.517	1.511	1.766
1996	0.019	0.080	0.151	0.300	0.509	0.634	0.780	0.871	1.027	1.167	1.387	1.503	1.664	1.692	1.822
1997	0.015	0.083	0.201	0.300	0.370	0.606	0.750	0.868	1.144	1.217	1.349	1.532	1.602	1.622	1.796
1998	0.015	0.076	0.195	0.316	0.457	0.525	0.840	0.939	1.012	1.087	1.263	1.397	1.519	1.897	1.909
1999	0.013	0.091	0.206	0.363	0.420	0.572	0.685	0.900	1.109	1.161	1.301	1.374	1.823	1.790	2.086
2000	0.012	0.090	0.231	0.432	0.472	0.567	0.706	0.800	0.947	1.194	1.428	1.470	1.714	1.767	2.016
2001	0.015	0.076	0.180	0.375	0.549	0.692	0.805	0.873	0.958	1.099	1.323	1.535	1.615	1.814	1.969
2002	0.013	0.094	0.259	0.387	0.533	0.679	0.746	0.920	1.033	1.127	1.146	1.445	1.631	1.796	1.979
2003	0.021	0.114	0.288	0.451	0.645	0.754	0.837	0.964	1.039	1.211	1.219	1.401	1.592	1.528	1.868
2004	0.019	0.104	0.281	0.450	0.592	0.725	0.847	0.966	1.076	1.147	1.192	1.305	1.507	1.807	1.827
2005	0.020	0.107	0.238	0.412	0.554	0.670	0.843	0.958	1.019	1.082	1.336	1.280	1.305	1.483	1.604
2006	0.009	0.100	0.189	0.438	0.612	0.689	0.824	0.901	1.049	1.177	1.260	1.378	1.448	1.436	1.509
2007	0.013	0.103	0.290	0.515	0.639	0.803	0.905	1.028	1.122	1.392	1.349	1.385	1.699	1.594	1.658
2008	0.013	0.061	0.255	0.474	0.610	0.742	0.864	0.995	1.066	1.200	1.478	1.431	1.650	1.792	1.877
2009	0.011	0.066	0.250	0.504	0.697	0.791	0.994	1.107	1.179	1.443	1.525	1.687	1.943	2.227	2.317
2010	0.018	0.084	0.266	0.519	0.690	0.888	1.084	1.181	1.224	1.311	1.431	1.599	1.818	2.139	2.444
2011	0.015	0.082	0.230	0.512	0.662	0.775	0.924	1.097	1.232	1.277	1.426	1.489	1.611	1.757	2.058
2012	0.013	0.079	0.202	0.421	0.611	0.774	0.921	1.133	1.309	1.379	1.418	1.481	1.544	1.839	2.071
2013	0.015	0.081	0.212	0.505	0.582	0.736	0.977	1.164	1.324	1.415	1.515	1.542	1.693	1.913	1.996
2014	0.017	0.114	0.258	0.451	0.582	0.729	0.803	1.114	1.246	1.462	1.706	1.619	1.712	1.933	1.997
2015	0.017	0.087	0.332	0.449	0.590	0.689	0.795	0.922	1.216	1.243	1.584	1.527	1.493	1.555	1.811
2016	0.022	0.082	0.299	0.530	0.605	0.701	0.779	0.836	0.941	1.000	1.214	1.594	1.401	1.682	1.471
2017	0.021	0.104	0.254	0.472	0.634	0.673	0.757	0.821	0.904	0.922	1.077	1.031	1.274	1.148	1.549
2018	0.022	0.095	0.226	0.435	0.600	0.696	0.777	0.826	0.937	0.958	1.084	0.936	1.507	1.215	1.519
2019	0.022	0.113	0.297	0.501	0.637	0.741	0.831	0.946	0.960	1.044	1.012	1.056	1.042	1.283	1.451
2020	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2021	0.022	0.102	0.239	0.447	0.585	0.713	0.804	0.856	0.980	1.150	1.065	1.151	1.313	1.026	1.382
2022	0.017	0.117	0.267	0.443	0.591	0.709	0.781	0.881	0.976	1.070	1.327	1.305	1.356	1.239	1.862
2023	0.016	0.117	0.271	0.417	0.533	0.660	0.803	0.935	0.963	1.010	1.150	1.140	1.463	1.893	1.507
2024	0.018	0.095	0.329	0.476	0.578	0.619	0.704	0.945	1.005	1.041	1.138	1.206	1.314	1.436	1.791
Mean	0.017	0.095	0.234	0.411	0.545	0.675	0.819	0.973	1.113	1.227	1.362	1.445	1.616	1.669	1.886

Table 14: Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1982–2024 (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	—	—	—	3,617
2021	3,505	4,154	4,886	
2022	4,549	5,891	6,532	3,834
2023	3,519	4,279	4,934	
2024	5,476	7,958		2,871
Avg.	4,749	6,667	6,864	2,991

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	
2024	13	41	55		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, 1994–2024 (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) ²	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%
2024	11 Jun- 19 Jul	100,365	0.488	0.583	1.799		2.871	0.056	26%

Table 17: AT survey estimates of EBS pollock abundance-at-age (millions), 1979–2024. Age-1s were modeled as a separate index, ages 2+ were modeled as proportions at age. The 2024 numbers-at-age estimates are preliminary, and based on the bottom trawl survey age-length-key.

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	
2024	5,075	1,146	681	379	820	2,485	450	110	86	127	6,284	11,359	
Mean	2,390	2,325	1,413	1,873	985	653	384	232	103	171	8,139	10,529	
Median	702	1,234	1,015	1,552	807	472	311	143	91	131	7,722	9,858	

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 et al. 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%
2024	2.87	2.007	0.0272	13%
Mean	2.850	2.180	5%	23%

Table 19: Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964–‘r thisyr’. Note fishery sample size for 1964–1977 was fixed at 10 and that the fishery mean sample size is from 1991–2023.

Year	Fishery	BTS	ATS
1978	39		
1979	39		
1980	39		
1981	39		
1982	39	162	
1983	39	131	
1984	39	63	
1985	39	74	
1986	39	152	
1987	39	61	
1988	39	82	
1989	39	53	
1990	39	48	
1991	260	79	
1992	228	85	
1993	344	92	
1994	286	87	43
1995	257	105	
1996	189	226	32
1997	319	73	49
1998	355	65	
1999	476	95	67
2000	482	91	70
2001	328	183	
2002	487	186	72
2003	441	126	
2004	391	189	51
2005	494	194	
2006	506	330	47
2007	500	193	39
2008	524	235	35
2009	420	145	26
2010	549	108	34
2011	728	165	
2012	607	107	44
2013	753	67	
2014	606	118	79
2015	821	104	
2016	704	123	61
2017	607	235	
2018	668	158	50
2019	701	121	
2020	565		
2021	818	149	
2022	641	173	52
2023	443	127	
2024		64	79
Mean	500	139	52

Table 20: Annual mean weight-at-age (kg) estimates from the fishery (1991–2023; plus projections 2024–2026) 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	0.285	0.482	0.604	0.73	0.844	0.882	1.02	1.123	1.135	1.237	1.236	1.296	1.247
1992	0.007	0.179	0.397	0.465	0.651	0.714	0.819	0.986	1.03	1.2	1.236	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	1.402	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	1.359	0.701	1.54
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	1.359	1.402	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	1.402	1.54
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	1.54
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	1.402	1.54
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	1.54
2023	0.025	0.186	0.492	0.482	0.524	0.606	0.796	0.92	0.955	1.046	1.088	1.267	1.355	1.325	0.951
2024	0.025	0.186	0.401	0.667	0.663	0.72	0.791	0.905	1.009	1.061	1.138	1.257	1.267	1.29	1.368
2025	-	-	0.382	0.526	0.796	0.791	0.845	0.912	1.02	1.117	1.161	1.231	1.342	1.344	1.36
2026	-	-	0.382	0.506	0.654	0.924	0.917	0.966	1.027	1.128	1.217	1.254	1.315	1.419	1.414
Mean	0.007	0.18	0.318	0.462	0.603	0.731	0.844	0.954	1.052	1.126	1.195	1.249	1.285	1.307	1.33
CV	-	-	18%	13%	8%	9%	12%	13%	14%	16%	17%	19%	22%	25%	28%

Table 21: Goodness-of-fit measures to primary data for different new-data models. See text for incremental model descriptions. 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	Model 23	Drop new	BTS	and ATS	and AVO
RMSE BTS	0.16		0.16	0.16	0.16
RMSE ATS	0.18		0.18	0.18	0.18
RMSE AVO	0.23		0.23	0.23	0.23
RMSE CPUE	0.09		0.09	0.09	0.09
SDNR BTS	0.95		0.98	0.98	0.98
SDNR ATS	1.00		1.00	1.02	1.02
SDNR AVO	0.98		0.97	0.97	0.99
Eff. N Fishery	1181.83		1199.44	1198.62	1198.98
Eff. N BTS	247.73		248.25	250.86	251.14
Eff. N ATS	268.76		268.12	258.78	259.11
Catch NLL	3.13		2.98	2.94	2.95
BTS NLL	30.74		30.83	30.87	30.89
ATS NLL	8.86		8.78	8.66	8.71
AVO NLL	8.70		8.57	8.55	8.34
Fish Age NLL	167.30		166.18	166.31	166.20
BTS Age NLL	194.12		191.91	190.91	190.75
ATS Age NLL	30.33		30.55	29.90	30.00
NLL selectivity	196.16		193.34	193.10	193.00
NLL Priors	20.17		20.16	20.17	20.18
Data NLL	465.36		461.71	459.35	459.16
Total NLL	717.52		711.20	708.02	707.67

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
B_{2025}	3,300	3,100
$CV_{B_{2025}}$	0.15	0.13
B_{MSY}	2,403	2,310
$CV_{B_{MSY}}$	0.33	0.3
B_{2025}/B_{MSY}	139%	135%
B_0	6,068	5,975
$B_{35\%}$	2,052	2,066
SPR rate at F_{MSY}	33%	31%
Steepness	0.61	0.62
Est. $B_{2024}/B_{2024, no fishing}$	0.61	0.61
B_{2024}/B_{MSY}	147%	147%

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 2016–2023 assessments for EBS pollock.

Component	Last year	Model 23
B_{2025}	3,300	3,100
$CV_{B_{2025}}$	0.15	0.13
B_{MSY}	2,403	2,310
$CV_{B_{MSY}}$	0.33	0.3
B_{2025}/B_{MSY}	139%	135%
B_0	6,068	5,975
$B_{35\%}$	2,052	2,066
SPR rate at F_{MSY}	33%	31%
Steepness	0.61	0.62
Est. $B_{2024}/B_{2024, no fishing}$	0.61	0.61
B_{2024}/B_{MSY}	147%	147%

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

Year	1	2	3	4	5	6	7	8	9	10+
1964	6.36	3.40	2.10	0.45	0.20	0.39	0.18	0.06	0.04	0.22
1965	20.92	2.58	2.14	1.48	0.28	0.12	0.24	0.11	0.04	0.16
1966	15.02	8.49	1.62	1.50	0.91	0.17	0.08	0.15	0.07	0.13
1967	25.46	6.09	5.33	1.14	0.95	0.58	0.11	0.05	0.10	0.13
1968	22.07	10.31	3.78	3.48	0.65	0.54	0.33	0.06	0.03	0.13
1969	26.10	8.93	6.37	2.46	2.01	0.38	0.32	0.19	0.04	0.09
1970	23.46	10.55	5.49	4.03	1.44	1.18	0.22	0.19	0.11	0.08
1971	14.39	9.45	6.34	3.27	2.29	0.79	0.65	0.12	0.10	0.10
1972	11.75	5.78	5.53	3.55	1.71	1.13	0.39	0.32	0.05	0.08
1973	26.72	4.72	3.28	2.87	1.71	0.80	0.53	0.18	0.14	0.06
1974	19.45	10.76	2.60	1.57	1.27	0.74	0.35	0.23	0.07	0.07
1975	16.41	7.84	5.70	1.10	0.66	0.53	0.31	0.14	0.09	0.05
1976	12.62	6.63	4.41	2.52	0.49	0.30	0.24	0.14	0.06	0.06
1977	13.29	5.11	3.82	2.16	1.16	0.23	0.14	0.11	0.07	0.05
1978	24.35	5.39	2.97	2.06	1.07	0.56	0.11	0.07	0.06	0.06
1979	57.03	9.87	3.16	1.60	1.01	0.50	0.26	0.05	0.03	0.05
1980	27.26	23.14	5.95	1.79	0.80	0.45	0.22	0.11	0.02	0.03
1981	31.89	11.07	14.32	3.70	0.93	0.36	0.20	0.09	0.05	0.03
1982	18.24	12.95	6.95	9.68	2.16	0.47	0.18	0.10	0.05	0.04
1983	51.08	7.41	8.19	4.94	6.22	1.26	0.27	0.10	0.06	0.05
1984	14.02	20.76	4.69	5.89	3.33	3.88	0.75	0.16	0.06	0.06
1985	32.53	5.70	13.16	3.38	4.02	2.08	2.35	0.46	0.10	0.07
1986	12.52	13.22	3.61	9.43	2.32	2.61	1.25	1.42	0.28	0.10
1987	7.07	5.09	8.39	2.59	6.45	1.53	1.62	0.76	0.88	0.23
1988	5.42	2.88	3.23	6.05	1.82	4.38	1.00	1.06	0.49	0.71
1989	11.37	2.20	1.83	2.26	4.15	1.18	2.76	0.61	0.65	0.74
1990	49.40	4.62	1.40	1.30	1.53	2.68	0.73	1.64	0.37	0.85
1991	26.39	20.08	2.93	1.00	0.84	0.89	1.52	0.40	0.89	0.68
1992	22.65	10.73	12.73	2.11	0.67	0.51	0.51	0.78	0.21	0.80
1993	44.72	9.21	6.79	8.84	1.40	0.41	0.27	0.23	0.34	0.44
1994	15.21	18.18	5.85	4.83	5.61	0.92	0.24	0.14	0.12	0.41
1995	10.64	6.18	11.57	4.28	3.28	3.28	0.54	0.14	0.08	0.31
1996	22.04	4.32	3.93	8.49	3.05	2.09	1.77	0.30	0.08	0.22
1997	29.73	8.96	2.74	2.87	6.16	2.08	1.21	0.87	0.15	0.16
1998	14.52	12.09	5.67	2.00	2.04	4.19	1.29	0.66	0.45	0.16
1999	15.78	5.90	7.67	4.11	1.41	1.38	2.52	0.78	0.37	0.33
2000	24.29	6.41	3.75	5.46	2.86	0.95	0.89	1.49	0.46	0.42
2001	34.20	9.87	4.08	2.71	3.68	1.82	0.61	0.52	0.82	0.52

2002	22.71	13.91	6.28	2.97	1.86	2.21	0.99	0.33	0.29	0.77
2003	14.10	9.23	8.84	4.55	2.01	1.13	1.10	0.50	0.17	0.59
2004	6.34	5.73	5.87	6.23	3.07	1.18	0.58	0.52	0.24	0.42
2005	4.46	2.58	3.65	4.25	3.90	1.84	0.66	0.29	0.26	0.37
2006	11.23	1.81	1.64	2.65	2.81	2.12	0.96	0.35	0.16	0.36
2007	24.50	4.56	1.15	1.16	1.71	1.56	1.03	0.48	0.18	0.28
2008	13.01	9.96	2.90	0.81	0.74	0.95	0.73	0.50	0.24	0.24
2009	48.56	5.29	6.34	2.09	0.53	0.42	0.44	0.34	0.24	0.24
2010	22.41	19.74	3.37	4.55	1.37	0.32	0.21	0.21	0.17	0.23
2011	13.62	9.11	12.57	2.46	2.89	0.82	0.18	0.11	0.11	0.21
2012	11.80	5.54	5.80	9.14	1.70	1.42	0.38	0.09	0.05	0.15
2013	42.75	4.80	3.52	4.20	5.96	1.10	0.66	0.18	0.04	0.09
2014	49.04	17.38	3.05	2.55	2.81	3.57	0.65	0.34	0.08	0.06
2015	21.23	19.94	11.06	2.22	1.74	1.73	1.98	0.32	0.17	0.07
2016	8.02	8.63	12.70	7.67	1.46	1.08	0.95	0.99	0.16	0.11
2017	8.02	3.26	5.50	9.31	4.48	0.92	0.65	0.55	0.52	0.14
2018	16.50	3.26	2.08	4.04	6.40	2.49	0.51	0.36	0.30	0.35
2019	81.11	6.71	2.08	1.53	2.89	3.71	1.39	0.29	0.20	0.37
2020	20.41	32.98	4.27	1.53	1.11	2.00	1.95	0.64	0.14	0.31
2021	11.33	8.30	20.83	3.08	1.05	0.71	1.04	0.94	0.32	0.22
2022	11.49	4.61	5.21	14.33	2.13	0.68	0.43	0.53	0.45	0.28
2023	16.76	4.67	2.90	3.70	9.72	1.42	0.43	0.25	0.29	0.41
2024	18.29	6.81	2.95	2.07	2.51	5.93	0.87	0.27	0.15	0.41

Table 25: Estimated millions of EBS pollock caught at age (columns 2–11) from the selected assessment model (continues on following page).

Year	1	2	3	4	5	6	7	8	9	10+
1964	8.47	38.31	89.73	63.17	27.13	51.85	22.58	6.97	4.28	24.62
1965	28.54	29.80	93.75	211.22	39.46	16.86	32.04	14.05	4.39	18.84
1966	20.40	101.49	77.32	196.46	117.20	21.49	9.20	17.74	7.95	13.86
1967	64.36	140.34	550.11	219.00	185.44	110.88	21.10	9.26	18.29	23.43
1968	63.37	262.82	392.87	669.11	123.30	100.01	60.87	11.72	5.22	24.16
1969	90.33	256.77	807.94	452.47	362.79	67.65	56.79	36.64	7.19	18.36
1970	139.98	492.33	938.72	813.29	319.48	261.65	52.51	48.31	30.48	21.34
1971	120.53	624.23	1352.81	841.54	672.25	229.97	193.13	41.26	34.96	35.97
1972	87.98	516.51	1446.48	1077.21	542.54	357.89	126.55	115.98	21.35	33.54
1973	177.38	529.38	1011.31	1008.56	622.99	294.53	194.38	73.88	58.51	24.39
1974	112.48	1475.19	977.51	599.51	492.17	286.15	133.73	95.36	32.42	32.91
1975	62.94	745.46	2006.58	376.79	221.66	176.86	102.98	50.65	33.71	20.73
1976	35.09	521.14	1309.94	840.77	159.70	94.79	76.03	45.26	21.96	21.16
1977	26.93	358.79	907.07	617.47	352.19	68.95	41.74	33.84	20.86	17.97
1978	41.64	348.29	712.41	601.51	353.39	182.71	36.69	22.47	19.23	20.06
1979	80.58	437.01	645.09	446.24	353.15	179.31	92.67	18.50	11.73	18.48
1980	27.29	550.09	831.59	468.20	273.30	164.33	77.25	40.28	8.05	12.28
1981	18.54	138.05	1077.25	682.19	255.54	104.72	56.00	26.74	14.05	7.05
1982	5.68	89.21	241.35	1113.92	395.53	93.90	35.78	19.35	9.28	7.38
1983	10.83	44.69	207.39	389.65	858.56	211.32	44.54	17.11	9.36	8.15
1984	2.40	99.67	117.13	403.93	452.09	608.97	120.08	25.49	9.95	10.14
1985	4.68	27.98	368.38	210.07	431.34	341.59	380.99	73.33	15.62	12.31
1986	1.40	57.40	99.63	629.13	225.00	368.04	189.59	203.51	41.28	15.80
1987	0.48	14.62	187.48	115.03	460.25	152.31	164.61	91.05	104.33	26.94
1988	0.42	10.22	156.83	386.00	199.57	565.64	156.28	156.68	72.20	101.40
1989	0.75	7.24	60.61	168.69	469.06	163.28	482.07	98.75	98.12	110.28
1990	3.98	20.83	47.09	141.32	283.99	540.27	170.99	380.10	80.35	181.99
1991	2.05	94.87	71.45	83.29	132.99	177.34	410.39	93.60	233.35	194.28
1992	2.05	64.54	688.22	184.43	102.09	127.86	172.86	281.65	78.97	291.99
1993	2.31	22.38	236.76	1102.25	145.75	71.65	69.61	60.89	87.87	106.77
1994	0.56	33.55	71.50	347.58	1031.25	157.54	49.65	28.32	23.57	77.77
1995	0.35	12.42	95.82	143.04	396.15	776.40	117.06	28.93	16.21	56.88
1996	0.77	16.09	47.60	143.51	200.03	396.33	522.22	91.23	20.42	49.02
1997	1.01	52.34	43.05	103.22	441.33	300.25	276.43	220.96	43.07	40.68
1998	0.38	41.55	101.29	78.39	152.82	678.34	207.85	140.34	109.80	34.56
1999	0.31	12.03	269.03	219.71	106.48	157.30	448.19	131.03	61.79	53.92
2000	0.47	12.21	83.28	423.92	348.10	119.06	166.75	332.63	84.84	70.18
2001	0.69	16.55	62.28	169.93	609.14	423.27	137.10	113.47	164.98	95.23

2002	0.51	33.21	123.83	218.85	297.43	630.73	279.76	90.40	70.26	159.73	
2003	0.32	17.48	376.07	348.16	363.39	303.92	348.56	151.99	45.79	123.06	
2004	0.12	8.20	113.58	836.21	505.27	257.06	163.15	145.40	59.89	78.88	
2005	0.08	3.74	66.66	398.47	897.36	474.49	161.02	67.27	59.12	65.92	
2006	0.22	3.68	66.23	290.56	612.80	641.38	275.55	97.60	40.84	81.85	
2007	0.48	10.14	46.80	136.30	377.57	496.11	315.82	133.71	47.10	68.85	
2008	0.25	20.73	69.30	84.44	153.63	312.11	237.16	153.84	73.18	66.90	
2009	0.85	7.25	169.15	209.64	90.61	121.61	128.02	99.70	67.80	70.45	
2010	0.32	23.70	39.98	562.35	223.18	61.82	48.05	56.52	44.25	59.39	
2011	0.25	13.42	201.11	140.46	848.31	270.30	58.24	37.13	36.61	69.22	
2012	0.22	10.14	113.67	950.71	193.82	465.02	124.93	29.39	17.65	50.30	
2013	0.73	6.53	64.53	353.62	988.91	195.09	178.43	59.59	13.40	31.30	
2014	0.79	26.26	51.39	179.54	407.54	784.85	186.34	96.92	24.67	19.18	
2015	0.38	20.45	613.89	211.09	241.53	392.14	553.04	91.98	51.58	23.57	
2016	0.11	5.52	117.35	1407.89	192.17	182.64	183.37	257.13	39.01	27.57	
2017	0.11	2.28	36.12	577.26	971.14	201.39	143.20	126.73	132.91	35.17	
2018	0.19	2.23	11.78	119.35	1207.39	542.49	103.52	75.37	60.65	67.28	
2019	1.11	10.92	14.99	26.36	165.64	935.01	458.68	83.58	51.44	80.26	
2020	0.57	254.26	102.25	94.46	132.42	517.82	601.36	176.49	43.91	86.79	
2021	0.32	104.31	1282.87	167.59	116.56	114.73	288.77	292.30	92.58	59.76	
2022	0.24	50.62	181.63	1051.93	193.43	79.48	76.12	121.38	90.13	52.53	
2023	0.34	34.71	90.91	269.14	1483.99	208.04	57.18	48.23	55.07	78.23	
2024	0.40	54.73	100.11	182.48	362.90	848.14	123.82	54.62	29.01	85.83	

Table 26: Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964–2024. 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	530	27	6,362	38	1,777	22
1965	621	22	20,924	25	2,159	20
1966	718	21	15,021	32	2,311	19
1967	903	19	25,464	26	3,562	17
1968	1,120	19	22,070	28	4,072	17
1969	1,371	19	26,095	26	5,171	16
1970	1,530	18	23,463	27	5,580	15
1971	1,673	17	14,389	33	6,174	13
1972	1,590	17	11,752	33	5,907	12
1973	1,364	18	26,724	19	4,816	14
1974	1,026	22	19,449	19	3,619	16
1975	966	21	16,414	18	3,934	13
1976	926	16	12,615	17	3,778	10
1977	1,111	13	13,292	15	4,112	9
1978	989	12	24,349	10	3,569	9
1979	906	11	57,027	6	3,342	8
1980	1,071	9	27,259	9	4,341	7
1981	1,653	6	31,885	8	7,632	5
1982	2,310	6	18,243	11	8,350	5
1983	3,121	5	51,081	6	10,491	5
1984	3,252	5	14,020	11	9,922	5
1985	3,778	5	32,534	7	13,125	4
1986	3,727	4	12,523	10	11,045	4
1987	3,794	4	7,072	11	11,607	3
1988	3,607	3	5,423	11	10,237	3
1989	3,130	3	11,365	8	8,294	3
1990	2,648	3	49,400	4	6,994	3
1991	2,119	4	26,389	5	5,950	4
1992	2,019	4	22,654	6	8,227	3
1993	2,682	3	44,718	4	9,766	3
1994	3,127	3	15,205	6	10,136	3
1995	3,344	3	10,637	7	11,479	3
1996	3,282	3	22,035	5	10,023	3
1997	3,185	3	29,734	4	9,019	3
1998	2,699	3	14,519	5	8,079	3
1999	2,821	3	15,776	5	9,072	3
2000	2,722	3	24,285	4	8,107	3
2001	2,762	3	34,202	3	8,214	3
2002	2,566	3	22,705	4	8,224	3
2003	2,602	3	14,098	5	9,169	2
2004	2,898	3	6,340	6	9,534	2
2005	2,551	3	4,462	7	7,724	2
2006	2,326	3	11,228	5	6,685	3
2007	1,893	3	24,504	4	5,282	3
2008	1,432	3	13,012	6	4,354	3
2009	1,515	3	48,558	3	5,609	3
2010	1,554	3	22,411	5	5,068	3
2011	1,916	3	13,623	6	7,382	3
2012	2,345	3	11,795	6	8,079	3
2013	2,675	3	42,753	3	8,255	3
2014	2,620	3	49,038	4	7,878	3
2015	2,447	3	21,229	6	9,227	3
2016	2,716	3	8,015	10	10,314	3
2017	3,165	3	8,016	12	10,381	3
2018	3,025	4	16,501	11	8,762	3
2019	2,938	4	81,112	10	8,322	4
2020	2,258	5	20,413	15	6,909	5
2021	2,464	7	11,331	20	10,759	8
2022	3,406	9	11,485	25	11,494	9
2023	3,333	10	16,759	29	9,695	10
2024	3,389	12	18,286	55	9,415	12

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

Component	Model 23
B_{2025}	3,100
$CV_{B_{2025}}$	0.13
B_{MSY}	2,310
$CV_{B_{MSY}}$	0.3
B_{2025}/B_{MSY}	135%
B_0	5,975
$B_{35\%}$	2,066
SPR rate at F_{MSY}	31%
Steepness	0.62
Est. $B_{2024}/B_{2024, no fishing}$	0.61
B_{2024}/B_{MSY}	147%

Table 28: Summary results of Tier 1 2024 yield projections for EBS pollock.

Component	Model 23
2025 fishable biomass (GM)	8,378,000
Equilibrium fishable biomass at MSY	4,656,000
MSY R (HM)	0.443
2025 Tier 1 ABC	3,715,000
2025 Tier 1 F_{OFL} unadjusted	0.523
2025 Tier 1 OFL	4,383,000
Recommended ABC	2,417,000

Table 29: For the configuration named Model 23, 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
2025	1,350	1,350	1,350	1,350	1,350	1,350	1,350
2026	1,350	1,350	1,350	1,350	1,350	2,377	1,964
2027	1,793	1,793	1,123	812	0	1,648	1,556
2028	1,614	1,614	1,120	846	0	1,609	1,825
2029	1,604	1,604	1,214	943	0	1,682	1,761
2030	1,570	1,570	1,247	992	0	1,669	1,697
2031	1,591	1,591	1,292	1,046	0	1,696	1,704
2032	1,598	1,598	1,318	1,083	0	1,700	1,702
2033	1,587	1,587	1,320	1,094	0	1,682	1,682
2034	1,581	1,581	1,323	1,103	0	1,674	1,674
2035	1,567	1,567	1,314	1,101	0	1,658	1,658
2036	1,560	1,560	1,311	1,102	0	1,649	1,649
2037	1,555	1,555	1,308	1,100	0	1,646	1,646
2038	1,551	1,551	1,303	1,097	0	1,643	1,643

Table 30: For the configuration named Model 23, Tier 3 projections of EBS pollock ABC for the 7 scenarios. Note: scenario 2 results for 2025 and 2026 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
2025	2,145	2,145	1,352	980	0	2,603	2,603
2026	1,964	1,964	1,243	903	0	2,377	2,377
2027	1,793	1,793	1,123	812	0	1,648	1,871
2028	1,614	1,614	1,120	846	0	1,609	1,825
2029	1,604	1,604	1,214	943	0	1,682	1,761
2030	1,570	1,570	1,247	992	0	1,669	1,697
2031	1,591	1,591	1,292	1,046	0	1,696	1,704
2032	1,598	1,598	1,318	1,083	0	1,700	1,702
2033	1,587	1,587	1,320	1,094	0	1,682	1,682
2034	1,581	1,581	1,323	1,103	0	1,674	1,674
2035	1,567	1,567	1,314	1,101	0	1,658	1,658
2036	1,560	1,560	1,311	1,102	0	1,649	1,649
2037	1,555	1,555	1,308	1,100	0	1,646	1,646
2038	1,551	1,551	1,303	1,097	0	1,643	1,643

Table 31: For the configuration named Model 23, 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
2025	0.213	0.213	0.213	0.213	0.213	0.213	0.213
2026	0.235	0.235	0.235	0.235	0.235	0.463	0.364
2027	0.364	0.364	0.214	0.150	0.000	0.407	0.349
2028	0.362	0.362	0.214	0.150	0.000	0.420	0.444
2029	0.347	0.347	0.214	0.150	0.000	0.413	0.420
2030	0.339	0.339	0.214	0.150	0.000	0.406	0.408
2031	0.337	0.337	0.214	0.150	0.000	0.405	0.405
2032	0.335	0.335	0.214	0.150	0.000	0.404	0.404
2033	0.334	0.334	0.214	0.150	0.000	0.401	0.401
2034	0.333	0.333	0.214	0.150	0.000	0.399	0.399
2035	0.333	0.333	0.214	0.150	0.000	0.399	0.399
2036	0.332	0.332	0.214	0.150	0.000	0.398	0.397
2037	0.331	0.331	0.214	0.150	0.000	0.397	0.397
2038	0.331	0.331	0.214	0.150	0.000	0.396	0.396

Table 32: For the configuration named Model 23, 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
2025	2,955	2,955	2,955	2,955	2,955	2,955	2,955
2026	2,635	2,635	2,635	2,635	2,635	2,484	2,548
2027	2,483	2,483	2,568	2,604	2,694	2,103	2,274
2028	2,469	2,469	2,781	2,931	3,339	2,186	2,329
2029	2,483	2,483	2,934	3,172	3,878	2,239	2,296
2030	2,488	2,488	3,019	3,329	4,319	2,251	2,271
2031	2,496	2,496	3,075	3,440	4,691	2,257	2,262
2032	2,504	2,504	3,111	3,517	5,004	2,260	2,261
2033	2,504	2,504	3,125	3,560	5,252	2,258	2,257
2034	2,486	2,486	3,112	3,566	5,422	2,240	2,240
2035	2,474	2,474	3,100	3,565	5,550	2,230	2,230
2036	2,460	2,460	3,084	3,556	5,644	2,217	2,217
2037	2,453	2,453	3,073	3,548	5,712	2,213	2,213
2038	2,466	2,466	3,082	3,559	5,777	2,227	2,227

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
$P[F_{2025} > F_{MSY}]$	Probability that the fishing mortality in 2025 exceeds F_{MSY}	OFL definition is based on F_{MSY}
$P[F_{2025} > F_{35\%}]$	Probability that the fishing mortality in 2025 exceeds $F_{35\%}$	OFL definition is based on F_{MSY} or proxy (here for Tier 3)
$P[B_{2026} < B_{MSY}]$	Probability that the spawning biomass in 2026 is less than B_{MSY}	B_{MSY} is a reference point target and biomass in 2021 provides an indication of the impact of 2025 fishing
$P[B_{2027} < B_{MSY}]$	Probability that the spawning biomass in 2027 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 2025 and 2026
$P[B_{2026} < \bar{B}]$	Probability that the spawning biomass in 2026 is less than the 1978–2024 mean	To provide some perspective of what the stock condition might be relative to historical estimates after fishing in 2025.
$P[B_{2029} < \bar{B}]$	Probability that the spawning biomass in 2029 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 2025.
$P[B_{2029} < B_{2025}]$	Probability that the spawning biomass in 2029 is less than that estimated for 2025	To provide a medium term expectation of stock status relative to 2025 levels
$P[B_{2027} < B_{20\%}]$	Probability that the spawning biomass in 2027 is less than $B_{20\%}$	$B_{20\%}$ had been selected as a Steller Sea Lion lower limit for allowing directed fishing
$P[p_{a_5,2027} > \bar{p}_{a_5}]$	Probability that in 2027 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.
$P[D_{2026} < D_{1994}]$	Probability that the diversity of ages represented in the spawning biomass (by weight) in 2026 is less than the value estimated for 1994	To provide a relative index on the abundance of different age classes in the 2026 population relative to 1994 (a year identified as having low age composition diversity)
$P[D_{2029} < D_{1994}]$	Probability that the diversity of ages represented in the spawning biomass (by weight) in 2029 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)
$P[E_{2025} > E_{2024}]$	Probability that the theoretical fishing effort in 2025 will be greater than that estimated in 2024.	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 2025 catches (first row, in kt). Note that for the 2022 and later year-classes average values were assumed. Constant Fs based on the 2025 catches were used for subsequent years.

	10	325	650	975	1300	1625	1950	2600
$P[F_{2025} > F_{MSY}]$	0	0	0	0	0	0	1	13
$P[F_{2025} > F_{35\%}]$	0	0	0	0	0	0	0	13
$P[B_{2026} < B_{MSY}]$	17	20	24	28	33	39	45	59
$P[B_{2027} < B_{MSY}]$	12	16	20	26	32	40	48	65
$P[B_{2026} < \bar{B}]$	4	8	16	26	39	53	66	86
$P[B_{2029} < \bar{B}]$	2	5	9	15	21	28	36	51
$P[B_{2029} < B_{2023}]$	7	12	18	25	32	40	47	60
$P[B_{2027} < B_{20\%}]$	1	1	2	3	4	5	7	12
$P[p_{a_5, 2027} > \bar{p}_{a_5}]$	18	30	42	53	62	68	74	80
$P[D_{2026} < D_{1994}]$	0	0	0	0	0	0	0	0
$P[D_{2029} < D_{1994}]$	0	1	2	5	10	16	24	46
$P[E_{2025} > E_{2024}]$	0	0	0	8	38	64	78	91

Table 35: Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 2003–2024 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	0	2
2004	6,590	89	7	14	21	0	0	0	1	1
2005	5,196	157	9	14	12	1	0	0	1	9
2006	2,716	154	11	15	99	21	0	0	1	16
2007	2,397	204	5	27	138	118	0	0	3	12
2008	4,183	120	19	27	4	8	0	0	1	10
2009	8,115	135	9	4	5	4	1	0	2	5
2010	2,516	149	12	2	0	0	2	0	2	10
2011	8,232	277	27	1	1	1	1	0	2	9
2012	3,518	142	7	2	1	1	1	0	3	4
2013	5,294	121	15	0	0	1	2	0	2	10
2014	12,767	44	29	10	1	7	1	0	3	9
2015	4,950	90	41	4	24	10	2	0	2	5
2016	2,203	75	54	4	5	22	0	0	1	3
2017	6,152	48	12	2	3	18	1	0	0	2
2018	8,251	52	24	9	0	4	0	0	0	3
2019	7,778	146	101	17	1	4	0	3	1	8
2020	6,299	187	122	85	2	12	11	41	2	13
2021	15,660	70	39	109	0	1	6	0	3	8
2022	15,218	45	369	19	0	0	2	0	2	21
2023	14,093	73	55	172	0	1	6	0	3	13
2024	4,399	41	13	15	0	2	3	0	0	2

- [1] “Pollock - bottom” “Pacific Cod”
- [3] “Other Flatfish - BSAI” “Other Species”
- [5] “Pollock - midwater” “Rock Sole - BSAI”
- [7] “Arrowtooth Flounder” “Greenland Turbot - BSAI”
- [9] “Atka Mackerel” “Rockfish”
- [11] “Sablefish” “Yellowfin Sole - BSAI”
- [13] “No retained catch” “Flathead Sole”
- [15] “Halibut” “Alaska Plaice - BSAI”
- [17] “Kamchatka Flounder - BSAI”

Table 36: Bycatch estimates (t) of other target species caught in the BSAI directed pollock fishery, 1991–2024 based on then NMFS Alaska Regional Office reports from observers (2024 data are preliminary).

Year	P.cod	Rock.Sole	Flathead	Arrowtooth	POP	Yellowfin	Sablefish	Shark	Atka.Mkrl	Skates	Other
1991	24,309	5,120	0	5,693	388	417	7	0	24	0	10,889
1992	24,005	7,233	2	4,311	173	892	7	0	260	0	15,559
1993	20,930	8,713	0	1,222	282	1,102	1	0	39	0	8,127
1994	14,404	3,006	0	2,010	170	1,207	1	0	43	0	4,434
1995	19,776	2,179	2,175	1,177	142	675	12	0	210	0	1,908
1996	15,173	2,042	3,207	1,844	303	1,797	7	0	384	0	3,724
1997	8,262	1,522	2,350	984	428	605	2	0	83	0	3,188
1998	6,255	770	2,047	1,712	616	1,744	2	0	10	0	2,451
1999	3,220	1,058	1,885	272	120	349	7	0	157	0	1,884
2000	3,432	2,687	2,510	978	21	1,465	12	0	1	0	6,418
2001	3,879	1,672	2,199	529	574	594	21	0	40	0	5,699
2002	5,883	1,885	1,843	607	542	768	34	0	221	0	3,714
2003	5,967	1,418	1,501	617	935	209	48	0	762	0	2,060
2004	6,436	2,553	2,104	556	393	841	16	0	1,052	0	1,689
2005	7,413	1,125	2,351	651	652	63	11	0	677	0	1,620
2006	7,291	1,360	2,862	1,088	735	256	8	0	788	0	2,703
2007	5,629	510	4,225	2,795	624	85	11	0	315	0	2,574
2008	6,971	2,149	4,315	1,715	335	552	4	0	14	0	3,770
2009	7,875	7,591	4,665	2,202	114	270	2	0	25	0	4,762
2010	6,907	2,239	4,356	1,453	230	1,057	1	0	54	0	2,602
2011	10,041	8,480	4,885	1,591	658	1,082	0	65	899	2,352	1,135
2012	10,065	6,701	3,968	745	705	1,516	0	54	263	2,018	1,481
2013	8,954	6,379	3,146	965	610	2,096	0	43	70	1,750	745
2014	5,241	4,360	2,553	737	1,300	1,953	0	75	116	808	2,436
2015	8,302	1,709	2,259	402	2,525	863	0	51	202	823	2,874
2016	4,978	1,094	1,553	276	3,189	870	18	59	68	422	1,706
2017	6,150	1,707	908	204	4,438	577	95	91	60	447	2,215
2018	4,270	1,077	973	270	3,803	743	396	61	543	507	2,443
2019	6,213	1,117	1,087	421	7,971	443	1,236	100	367	508	2,026
2020	9,184	865	1,970	687	5,969	1,211	3,452	132	569	827	4,917
2021	9,103	830	1,531	413	2,468	753	1,105	172	544	911	1,671
2022	3,785	677	948	241	1,445	887	320	55	156	560	677
2023	3,820	549	843	245	1,344	749	486	270	39	400	945
2024	2,945	886	962	339	1,862	519	125	130	39	362	657

Table 37: Bycatch estimates (t) of pollock caught in the other non-pollock EBS directed fisheries, 1991–2024 based on then NMFS Alaska Regional Office reports from observers.

Year	NRock.sole	Other.flats	Other.spp	P.cod	Yellowfin.sole	Total
1991	9,711	6,824	755	10,669	NA	27,961
1992	9,824	1,371	514	20,651	13,100	45,462
1993	18,582	2,581	390	31,252	15,253	68,060
1994	15,784	6,770	89	26,584	33,200	82,429
1995	7,766	5,211	26	25,464	27,041	65,509
1996	7,698	5,456	802	22,377	22,254	58,590
1997	9,123	3,480	14	33,645	24,100	70,364
1998	3,960	3,010	941	10,460	15,339	33,711
1999	5,207	4,771	1,193	21,106	8,701	40,980
2000	5,480	7,067	520	14,480	13,425	40,974
2001	4,577	4,707	488	11,540	16,502	37,816
2002	9,942	2,220	51	15,234	14,489	41,938
2003	4,924	3,672	235	15,926	11,578	36,337
2004	8,975	6,396	194	18,650	10,383	44,599
2005	7,235	5,057	201	14,109	10,312	36,917
2006	6,986	3,826	142	15,168	5,966	32,090
2007	3,245	4,353	276	20,319	4,020	32,214
2008	4,930	4,813	17	9,533	9,827	29,122
2009	6,171	3,432	13	7,875	7,036	24,529
2010	6,074	3,140	85	6,575	5,179	21,055
2011	6,931	2,150	300	8,977	8,673	27,033
2012	6,703	1,685	412	8,377	11,197	28,377
2013	7,326	3,991	238	9,801	20,171	41,529
2014	11,258	6,051	202	11,502	24,712	53,727
2015	9,386	4,266	429	9,062	21,281	44,426
2016	11,850	2,717	449	9,070	22,306	46,394
2017	5,616	3,428	507	8,319	23,414	41,286
2018	5,182	3,516	952	8,008	28,235	45,894
2019	3,176	7,968	1,362	7,593	23,153	43,254
2020	6,401	2,367	724	5,511	31,651	46,656
2021	2,398	5,124	1,381	4,315	24,844	38,065
2022	2,976	5,249	2,623	6,260	26,514	43,625
2023	11,047	4,478	3,059	7,181	22,347	48,113
2024	15,035	4,190	1,463	5,117	13,179	38,985

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	2,156	NA	3,158	28,658	4,378,008	17,777	NA	NA
1992	1,500,765	33,672	2,220	NA	647	40,187	4,569,662	43,874	NA	NA
1993	1,649,087	36,615	1,326	NA	527	241,972	738,250	58,140	NA	NA
1994	371,214	31,880	963	689	1,627	91,764	811,734	42,361	NA	NA
1995	153,993	13,403	492	397	905	17,755	206,651	4,644	NA	NA
1996	89,416	55,468	382	321	1,242	77,174	63,398	5,934	NA	NA
1997	17,046	44,313	257	200	1,135	65,415	216,152	137	NA	NA
1998	57,071	51,245	353	278	801	60,677	123,758	14,287	NA	NA
1999	7,549	11,978	154	125	800	45,169	20,386	92	NA	NA
2000	1,517	4,961	110	91	483	58,568	6,580	0	NA	NA
2001	5,146	33,441	243	200	225	57,002	5,709	106	NA	NA
2002	2,172	34,474	165	138	109	80,630	2,908	20	NA	NA
2003	771	45,661	89	74	967	188,339	750	52	8	NA
2004	1,139	51,751	96	82	1,096	442,148	712	27	4	1
2005	631	68,126	120	100	594	703,080	2,260	0	NA	1
2006	1,345	82,653	132	111	434	305,793	2,796	289	NA	3
2007	1,497	121,956	312	270	352	86,380	3,165	8	NA	3
2008	9,179	21,242	373	312	128	15,133	9,327	676	8	33
2009	6,204	12,731	541	436	65	45,960	7,392	1,137	19	NA
2010	12,846	9,835	335	267	349	13,734	10,291	1,124	28	NA
2011	10,986	25,499	460	378	377	193,754	6,584	577	25	NA
2012	5,621	11,343	463	388	2,353	22,297	6,250	344	NA	NA
2013	12,427	13,091	334	272	959	125,525	8,704	508	34	107
2014	12,522	15,135	239	200	160	219,837	19,455	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	103	1,431	343,208	1,166	440	NA	26
2017	7,270	30,079	97	89	964	467,750	3,407	203	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	1,709	546,472	4,668	52	-	115
2022	4,758	6,415	170	156	1,708	242,375	1,952	311	59	88
2023	11,997	11,874	88	67	3,087	112,512	4,100	54	-	132
2024	9,744	7,948	77	6,281	1,281	35,117	9,275	230	1	4

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

Indicator	Observation	Interpretation	Evaluation
Ecosystem effects on EBS pollock			
<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	Fairly stable nutrient flow from upwelled BS Basin	Inter-annual variability low	No concern
Fishery effects on ecosystem			
<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

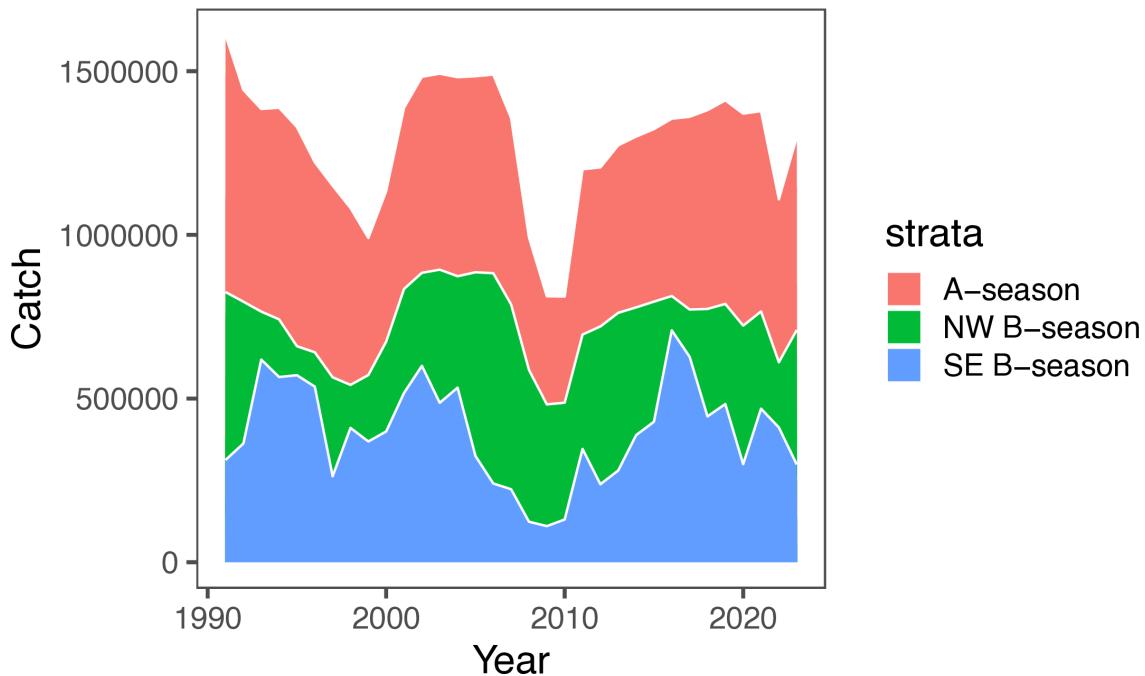


Figure 1: Pollock catch estimates (t) from the Eastern Bering Sea by season and region. The A-season is defined as from Jan-May and B-season from June-October.

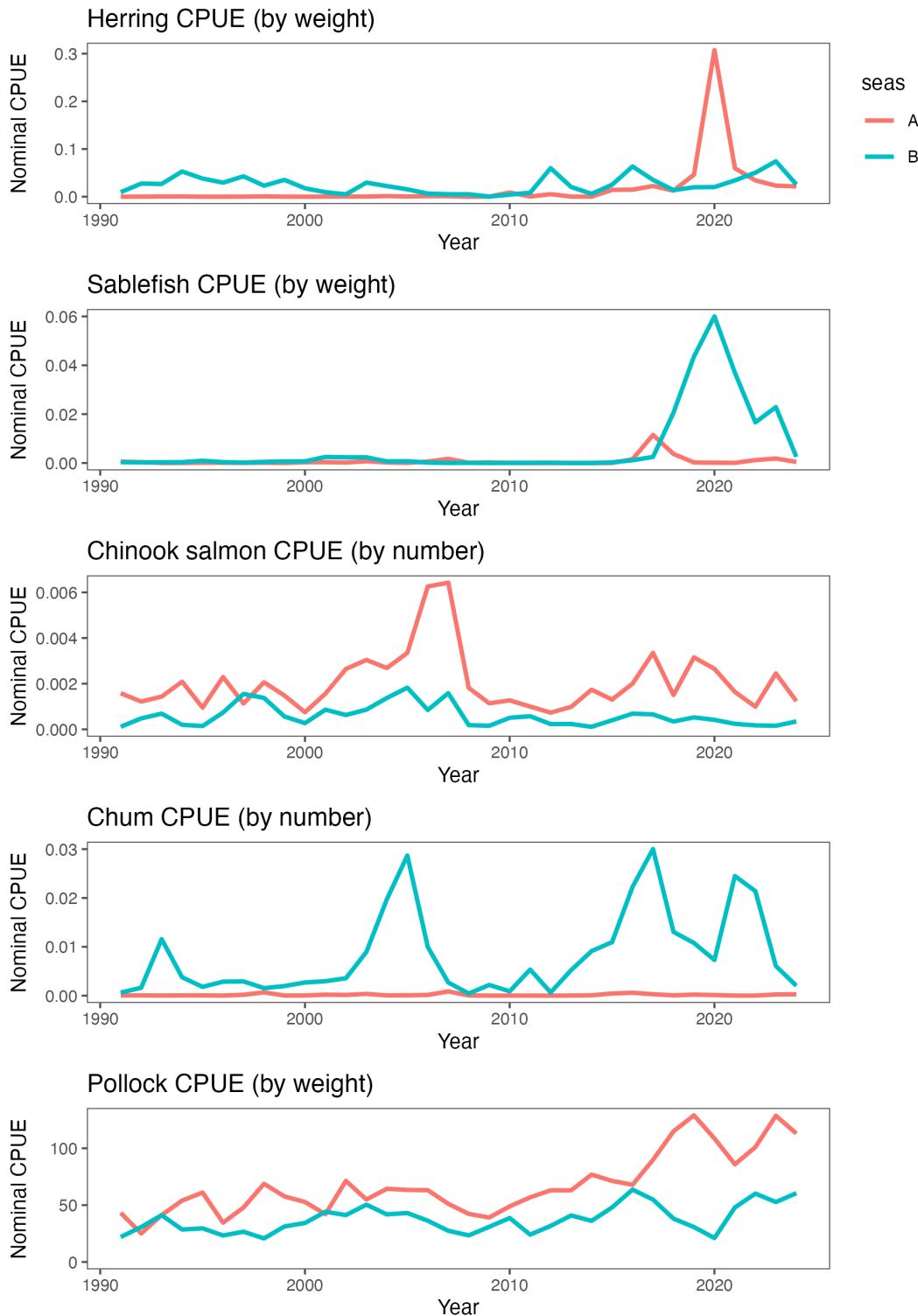


Figure 2: Nominal catch divided by effort (hours towed) for selected bycatch species and pollock for the EBS pollock fleet (sectors combined) by season

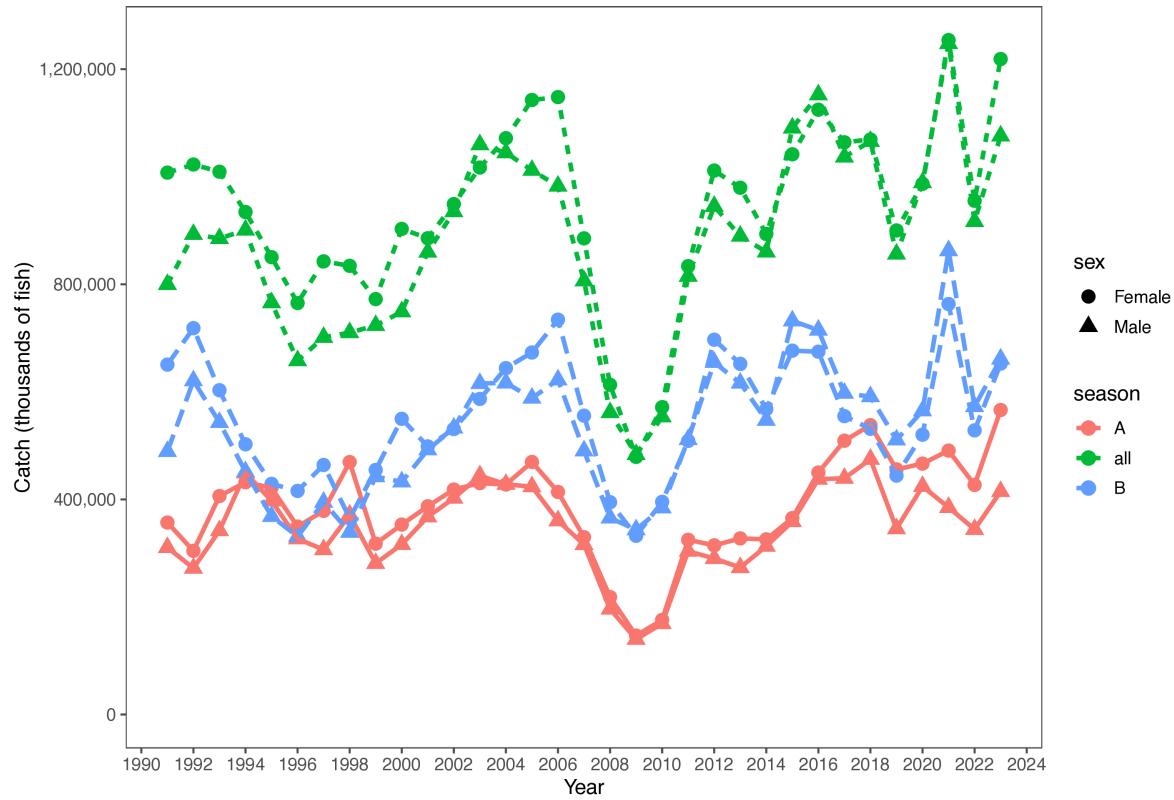


Figure 3: Estimate of EBS pollock catch numbers by sex for the A season (January-May) and B seasons (June-October) and total.

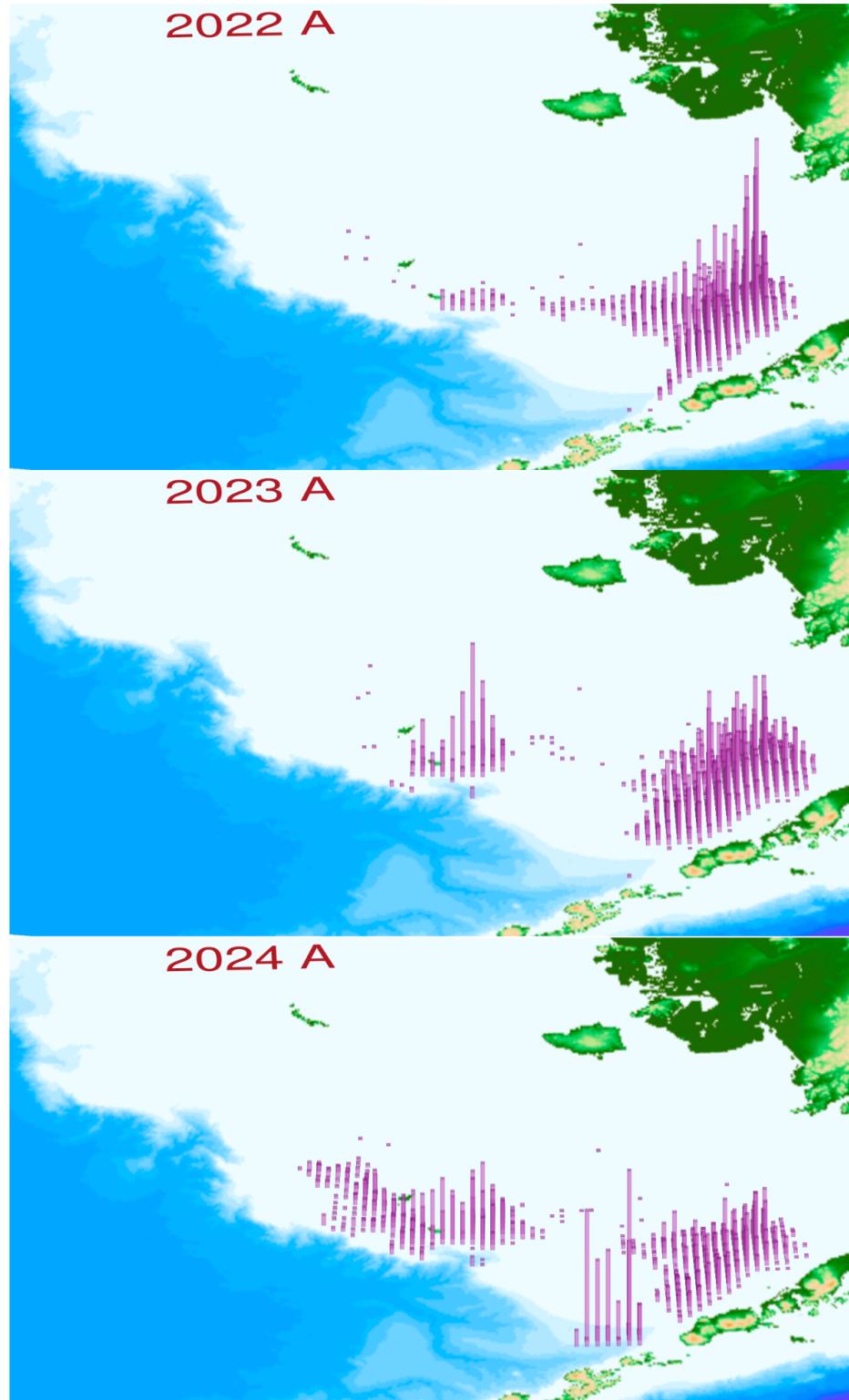


Figure 4: EBS pollock catch distribution during A-season, 2022–2024. Column height is proportional to total catch.

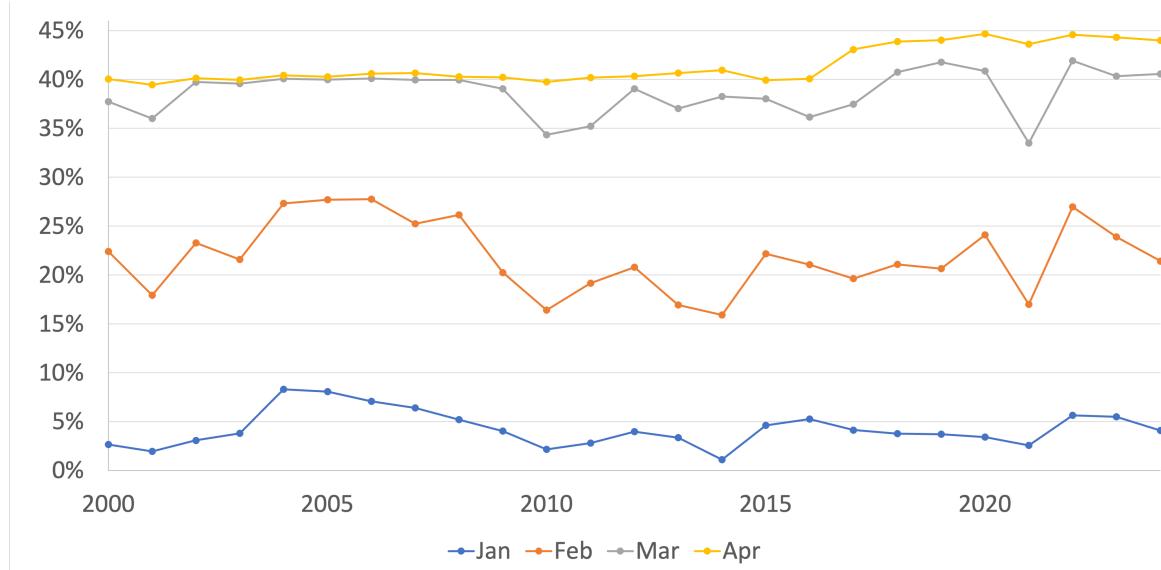


Figure 5: Proportion of the annual EBS pollock TAC by month during the A-season, 2000–2024. The higher value observed since 2017 was due to Amendment 110 of the FMP to allow greater flexibility to avoid Chinook salmon.

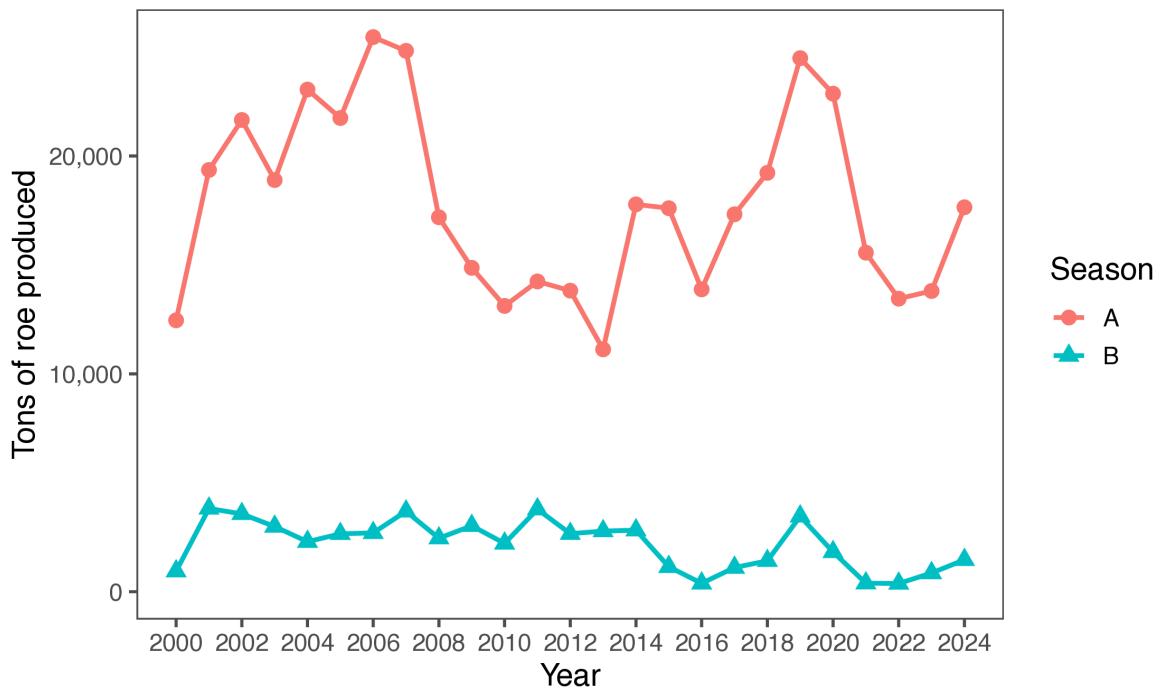


Figure 6: EBS pollock roe production in A and B seasons, 2000–2024.

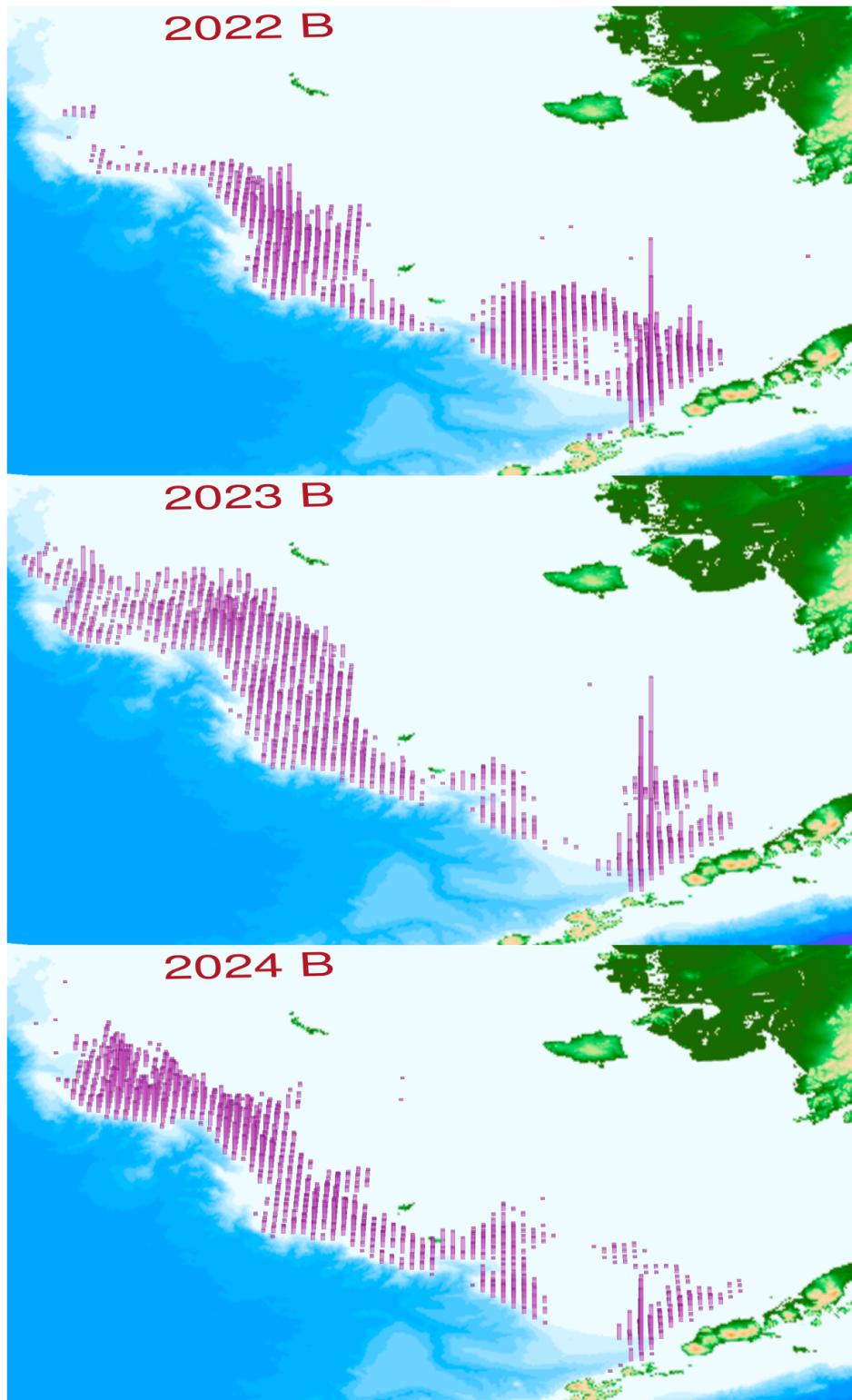


Figure 7: EBS pollock catch distribution during B-season, 2022–2024. Column height is proportional to total catch. Note that directed fishery for pollock generally is finished prior to October; the labels are indicative full-year catches.

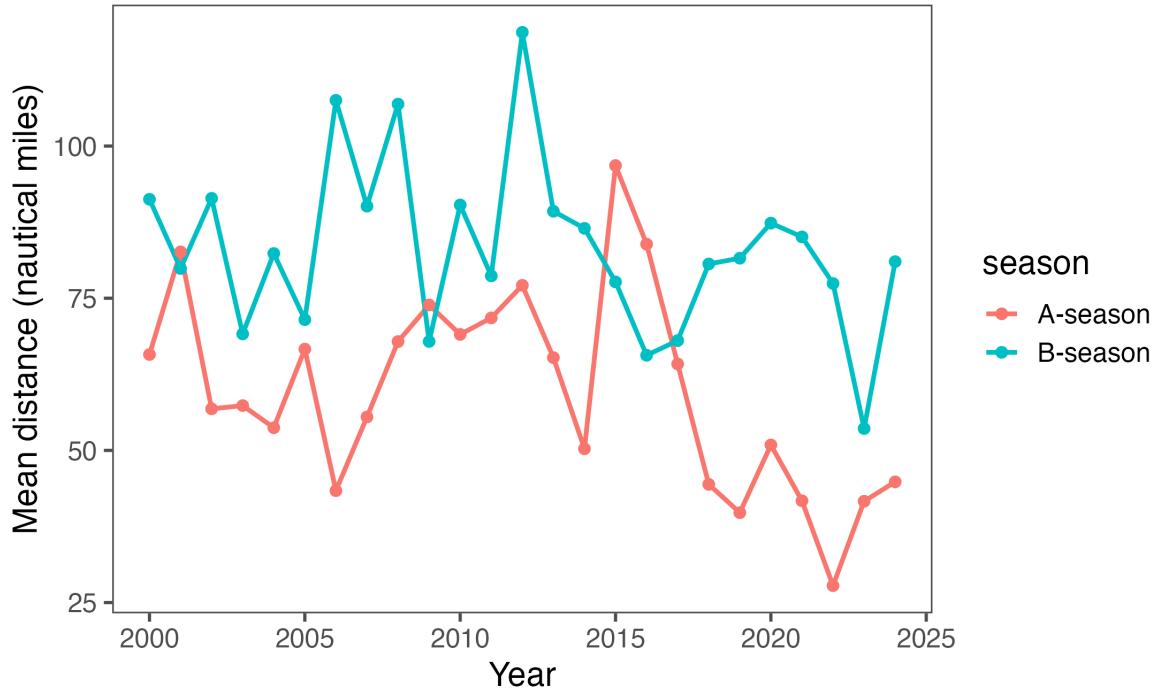


Figure 8: Estimated mean daily distance between operations, 2000-2024.

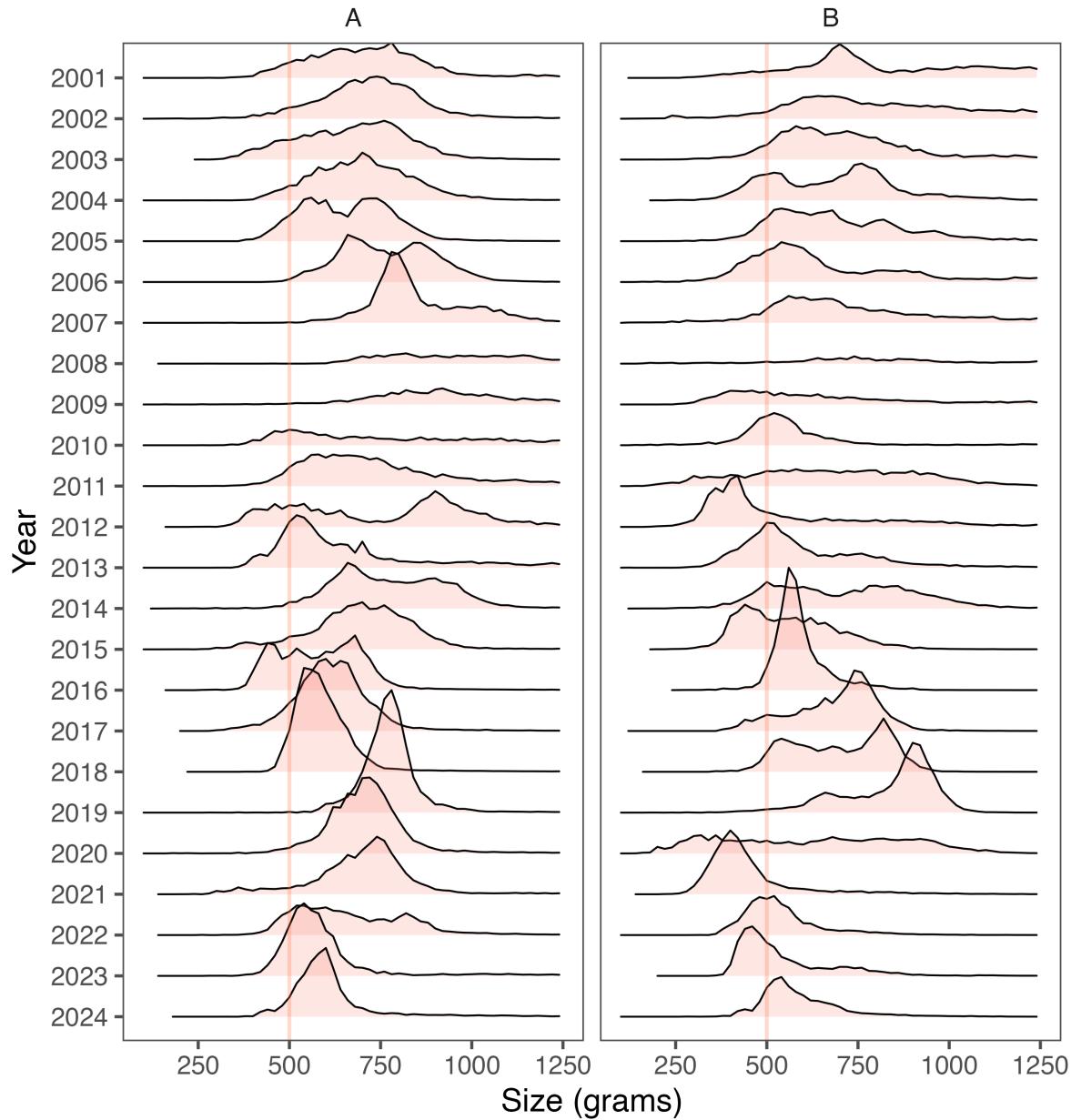


Figure 9: Pollock fishery data showing the frequency of mean pollock weight within a tow (in 50 g increments, vertical line at 500 g is for reference) by year and season.

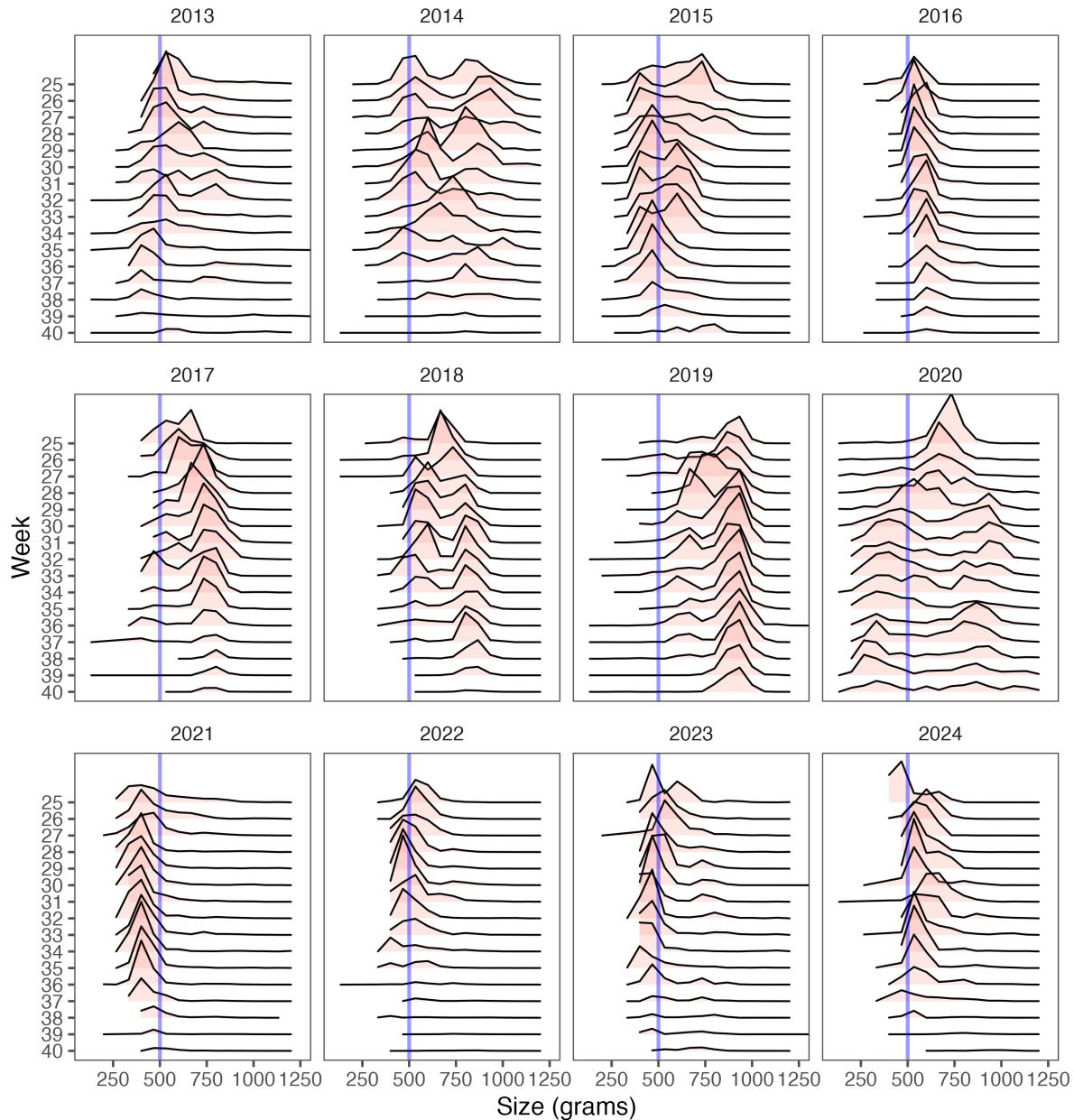


Figure 10: Pollock fishery data showing the frequency of mean pollock weight within a tow (in 50 g increments, vertical line at 500 g is for reference) by recent years and week-of-the-year, B-season.

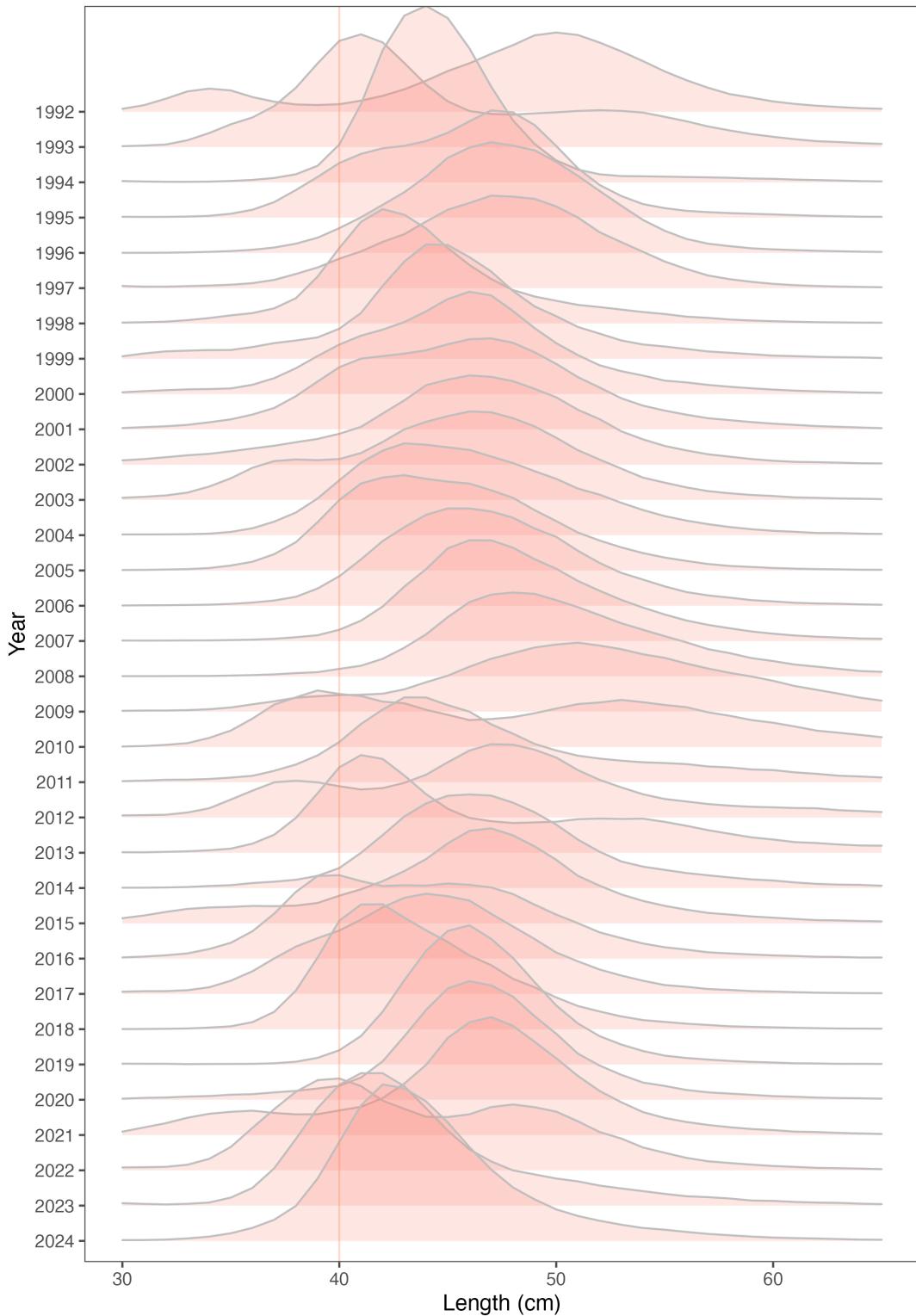


Figure 11: Fishery catch-at-length (cm) by the pollock fishery, 1992-2024.

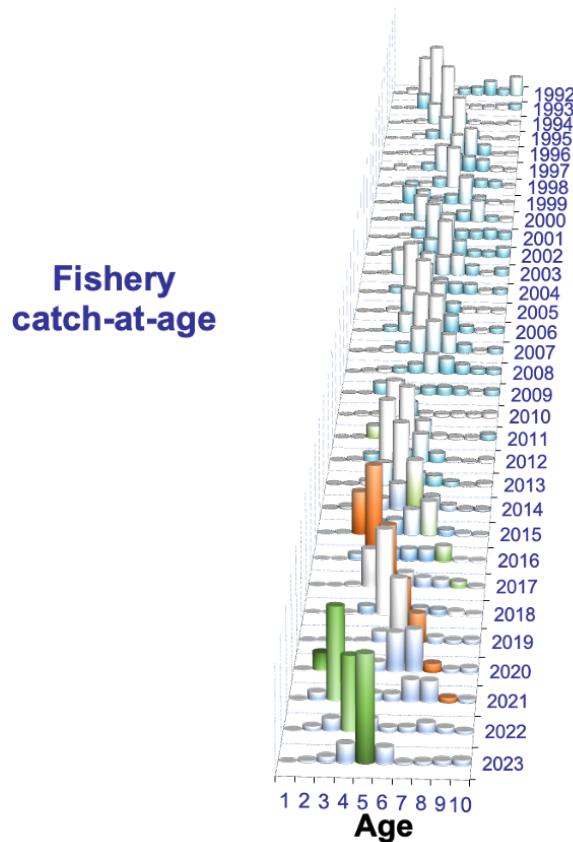


Figure 12: EBS pollock fishery estimated catch-at-age data (in number) for 1992–2023. Age 10 represents pollock age 10 and older. The 2012 year-class is shaded in orange and the 2018 year-class is shaded in green.

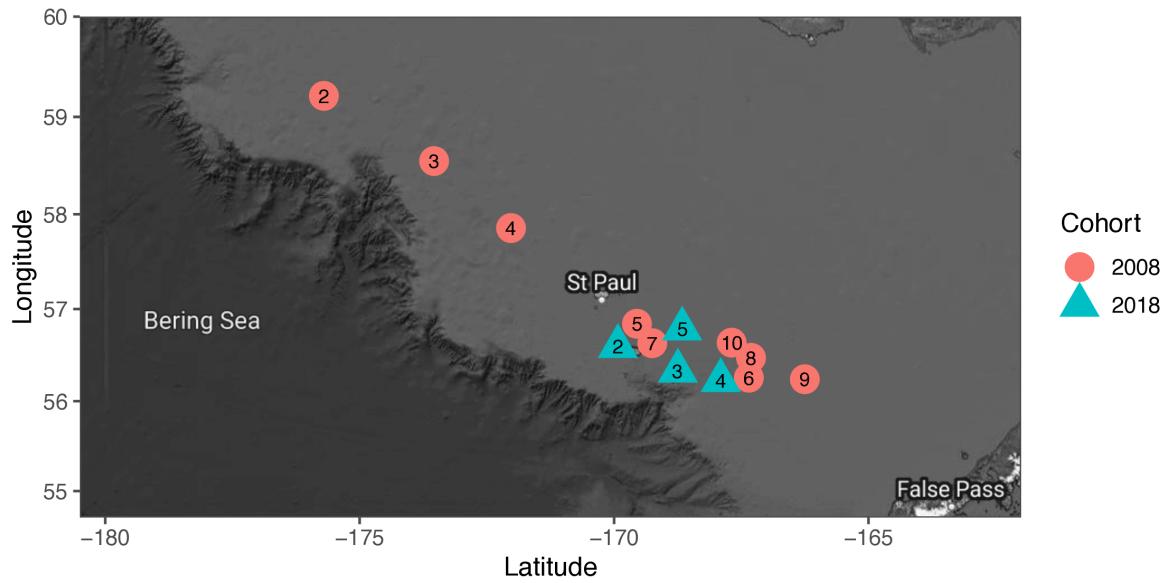


Figure 13: Pollock age sample mean locales for two cohorts representing the 2008 and 2018 year-classes (from data through 2023).

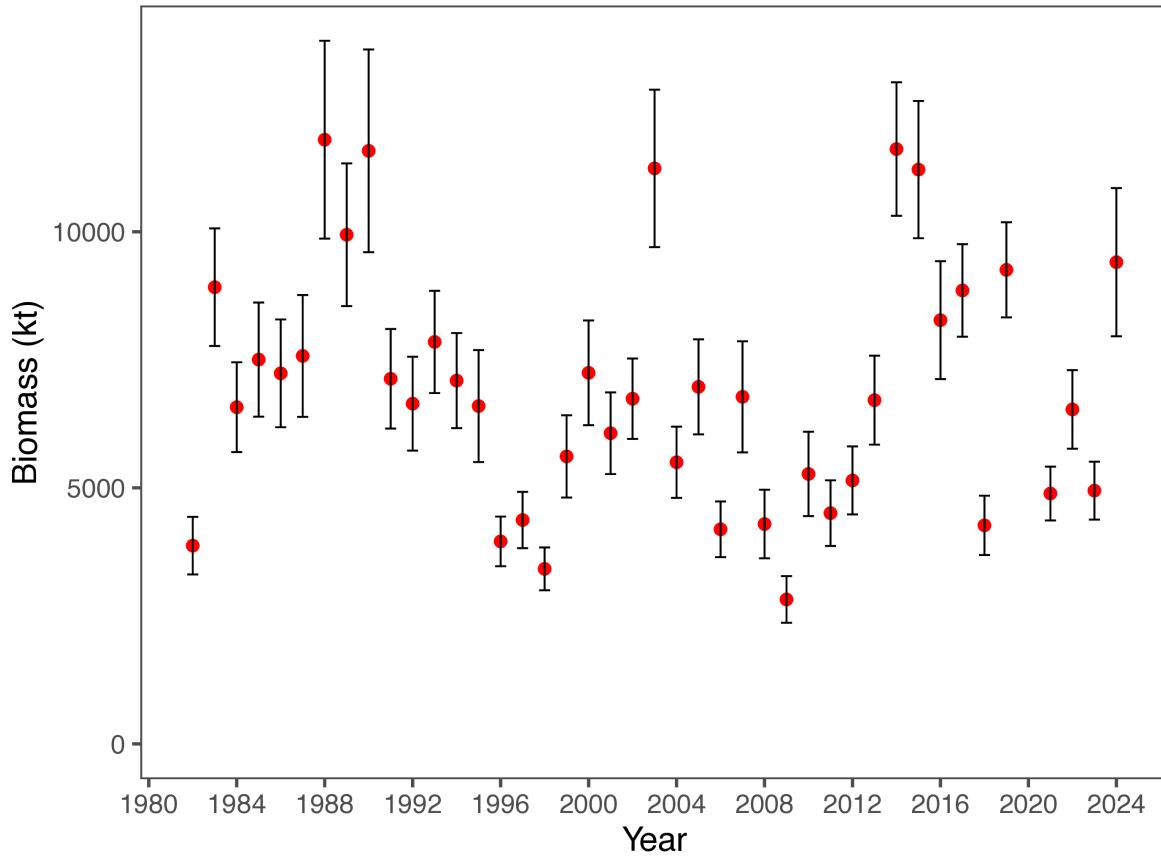


Figure 14: Bottom-trawl survey biomass estimates with error bars representing 95% confidence intervals for the VAST model-based methods for EBS pollock.

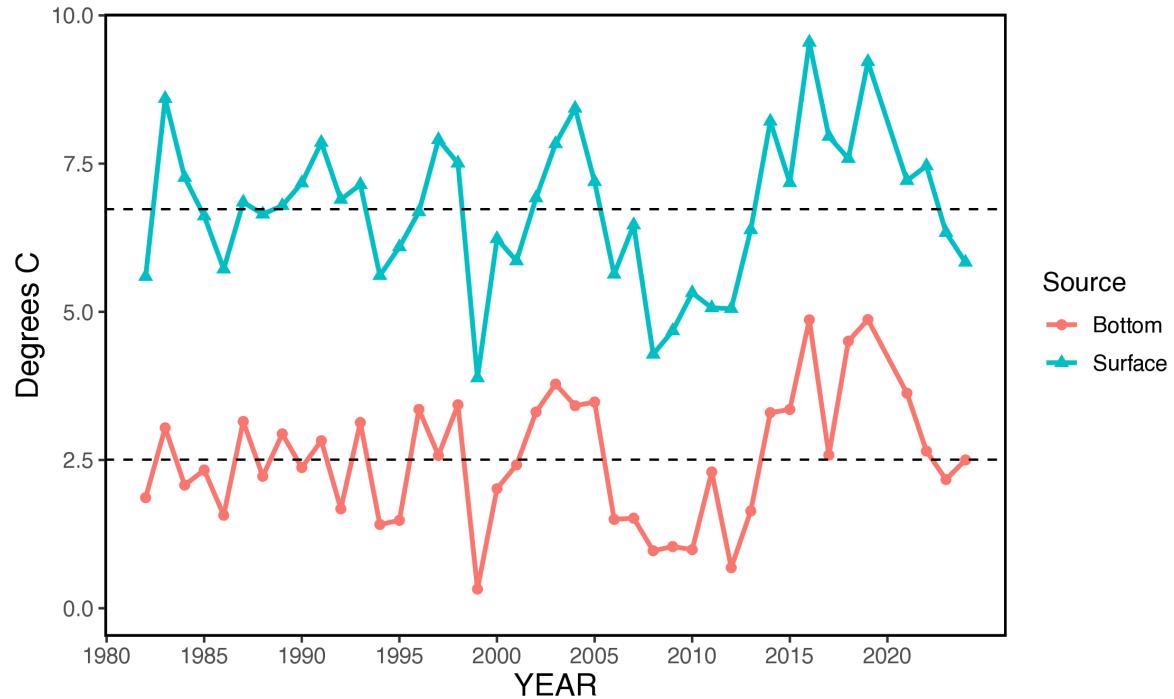


Figure 15: Bottom and surface temperatures for the Bering Sea from the NMFS summer bottom-trawl surveys (1982–2019, 2021–2024). Dashed lines represent mean values.

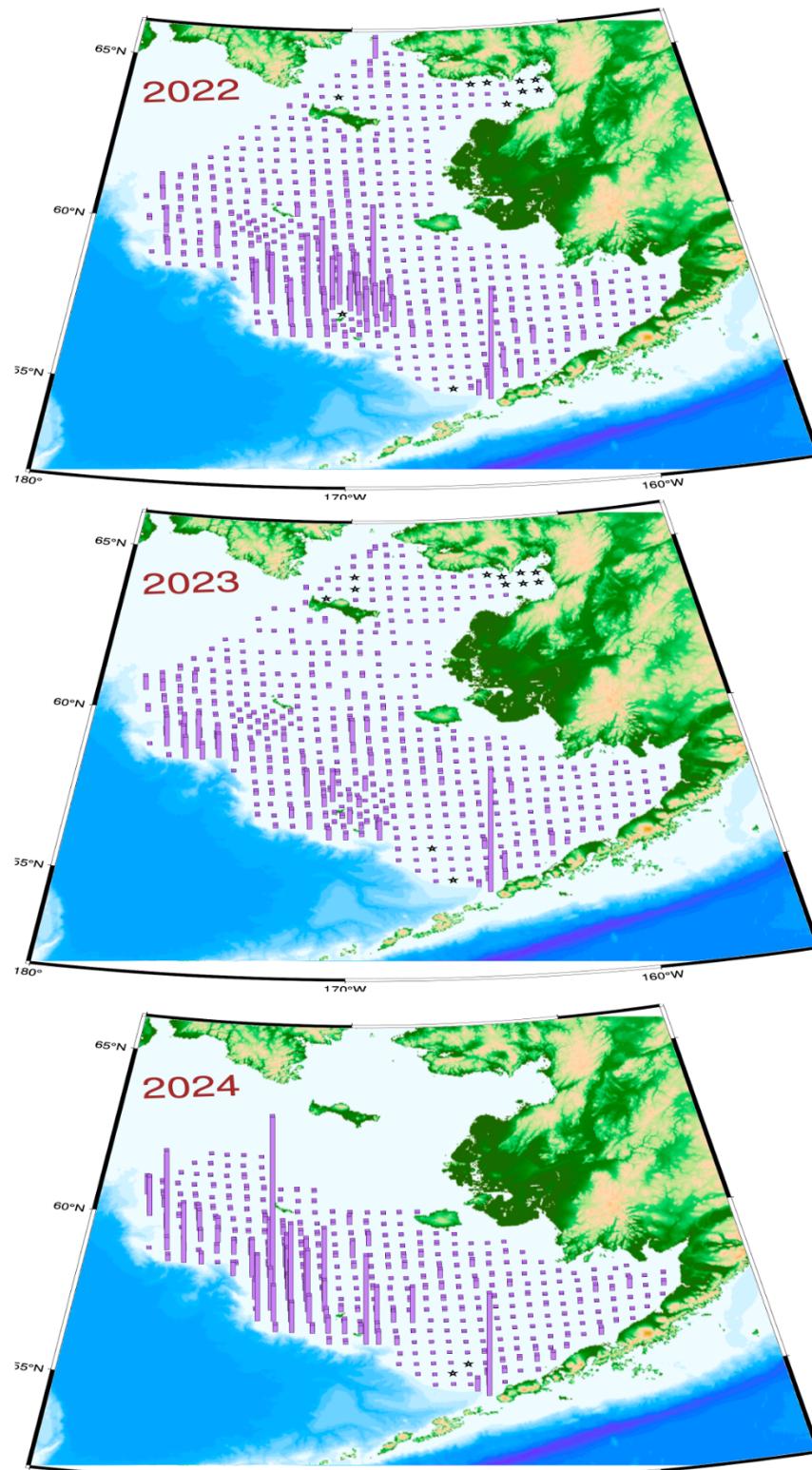


Figure 16: Bottom trawl survey pollock catch in kg per hectare for 2021-2024. Height of vertical lines are proportional to station-specific pollock densities by weight (kg per hectare) with constant scales for all years (red stars indicate tows where pollock were absent from the catch).

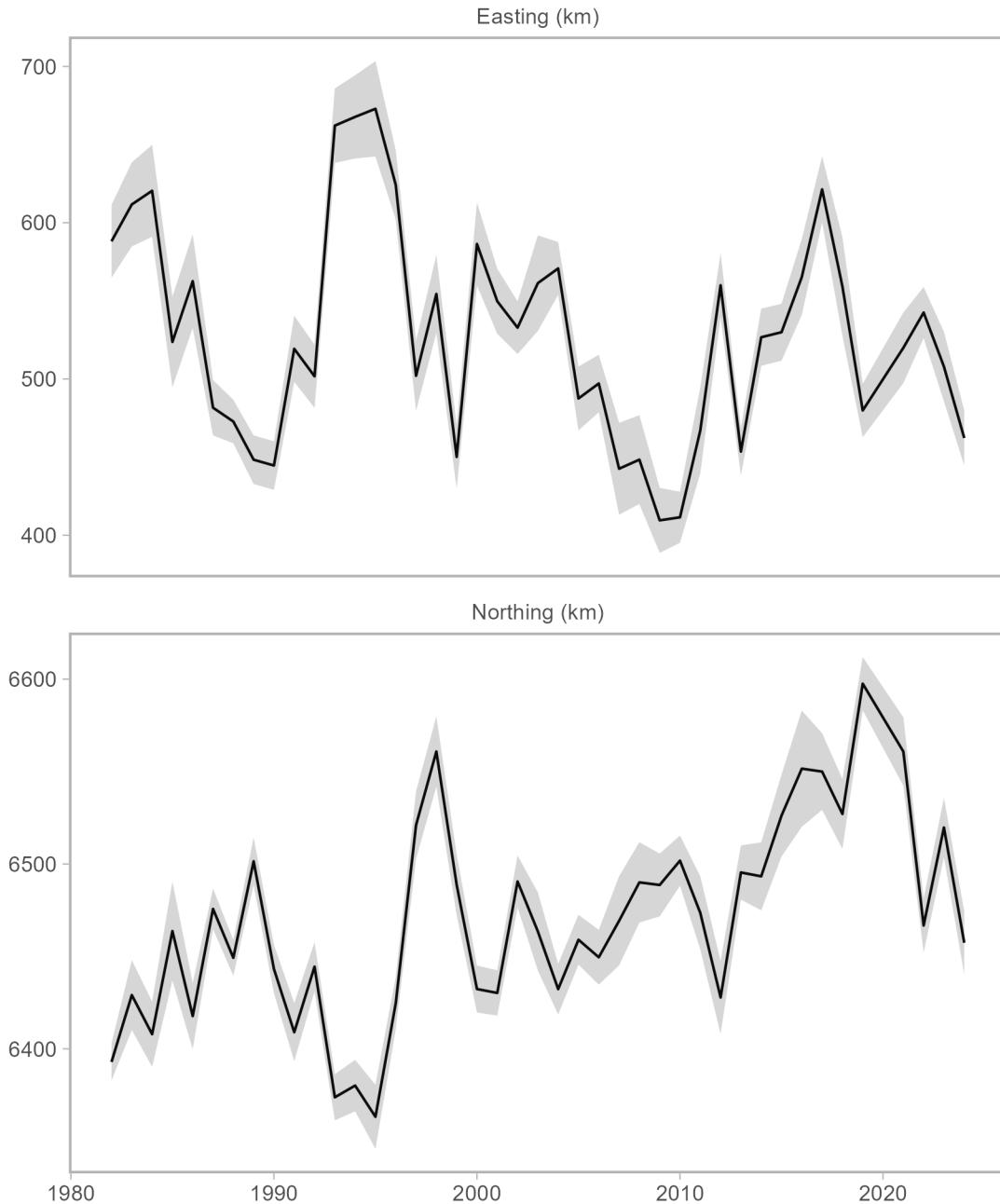


Figure 17: The EBS pollock stock center of gravity as estimated over time using VAST

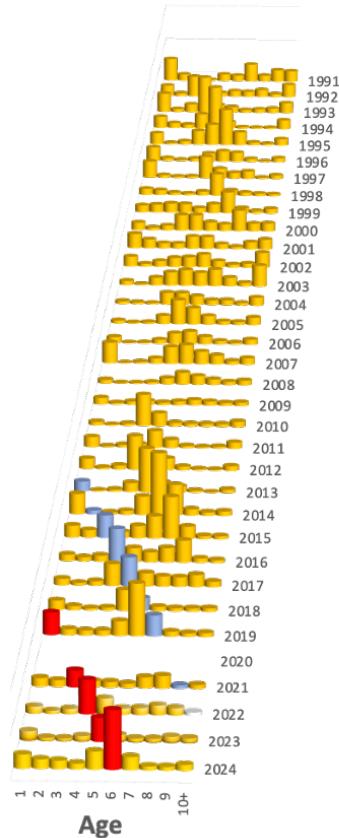


Figure 18: Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1990–2019, 2021–2024). The 2012 and 2018 year-classes are shaded differently.

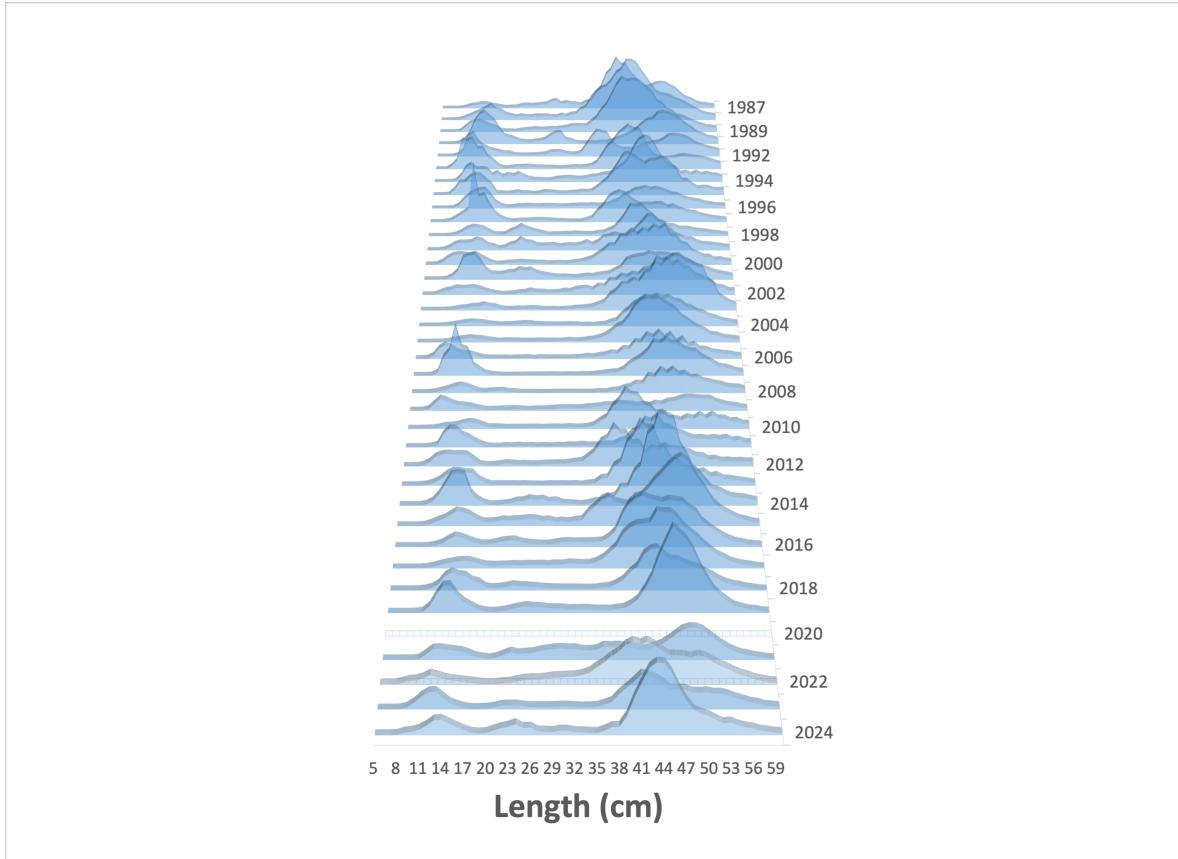


Figure 19: Pollock abundance levels by size and year as estimated from the NMFS bottom-trawl surveys (1990–2019 and 2021–2024).

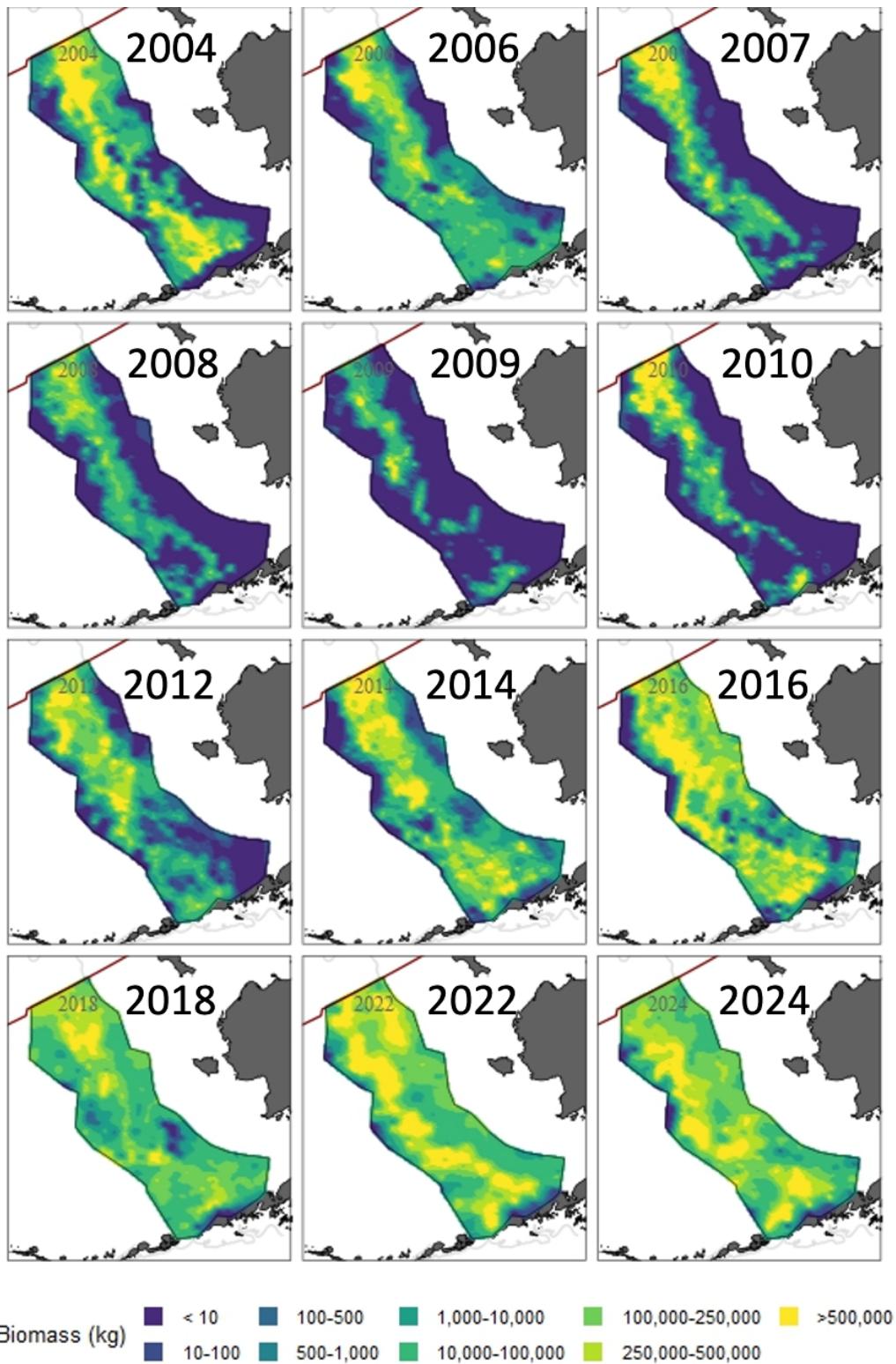


Figure 20: Heat map of acoustic-trawl survey relative pollock biomass, 2004-2024.

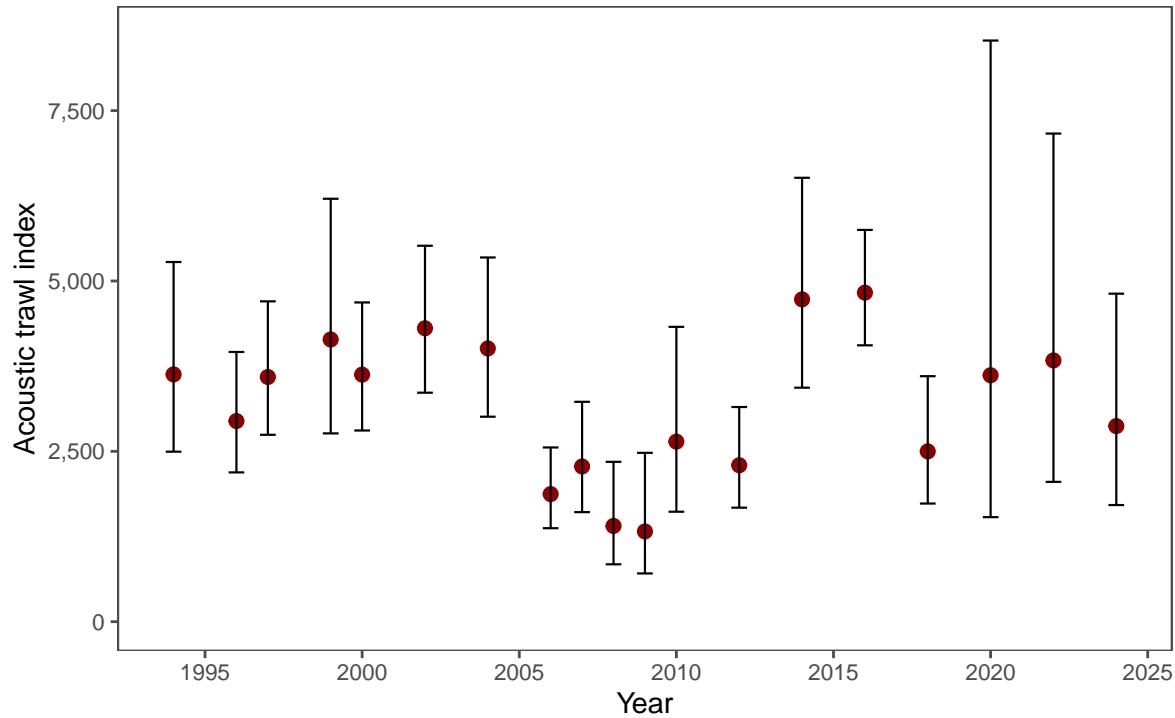


Figure 21: Acoustic-trawl EBS pollock biomass estimates by year used in this assessment.
Error bars represent approximate 95% confidence bounds.

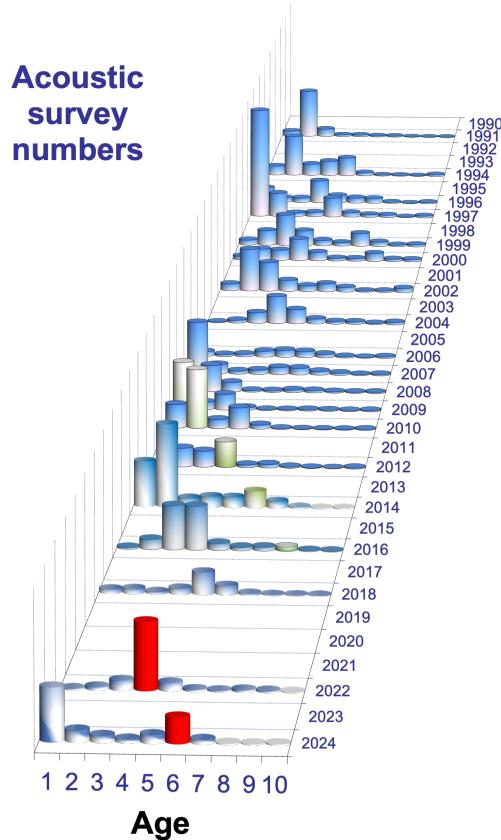


Figure 22: Acoustic-trawl survey pollock numbers-at-age estimates, 1991-2024. The 2018 and 2008 year classes are shaded differently. Note that the series used in the model starts in 1994.

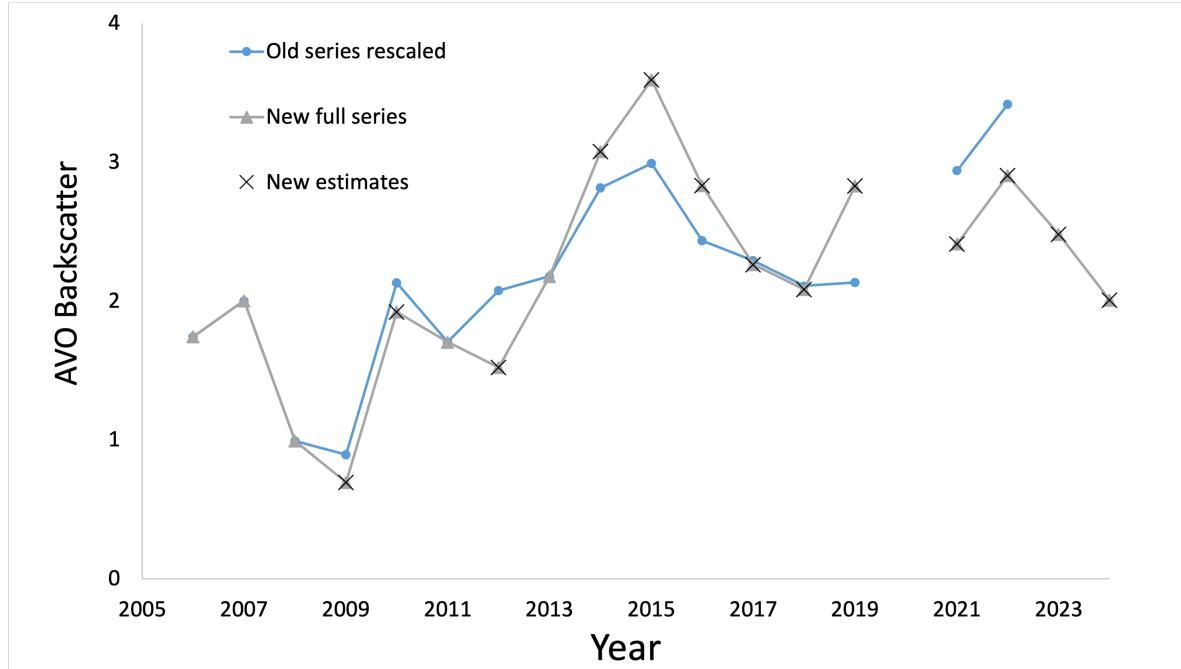


Figure 23: Time series of EBS pollock data from the acoustic vessels of opportunity (AVO) showing the years of new data compared to previous series and the full series.

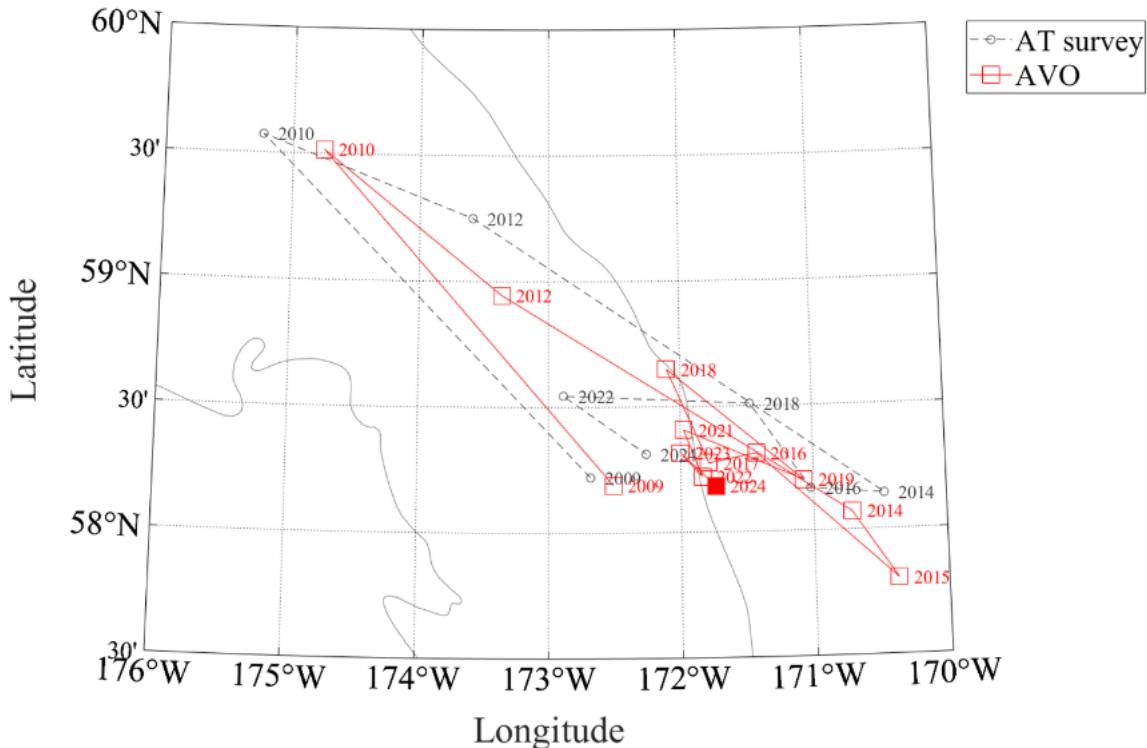


Figure 24: Geographic center of gravity estimates derived from pollock sA ($\text{m}^2 \text{ nmi}^{-2}$) from acoustic-trawl (AT) survey (gray circles) and the acoustic vessel-of-opportunity index (red squares). The point with a filled red square is to highlight the new AVO estimate (2024). The 100 and 200 m bathymetric contours are indicated in gray. The 2018 AT survey did not complete the last 3 transects (i.e., the western-most transects) due to vessel mechanical problems, and the omission of sA from this area will bias the 2018 AT data point to the southeast.

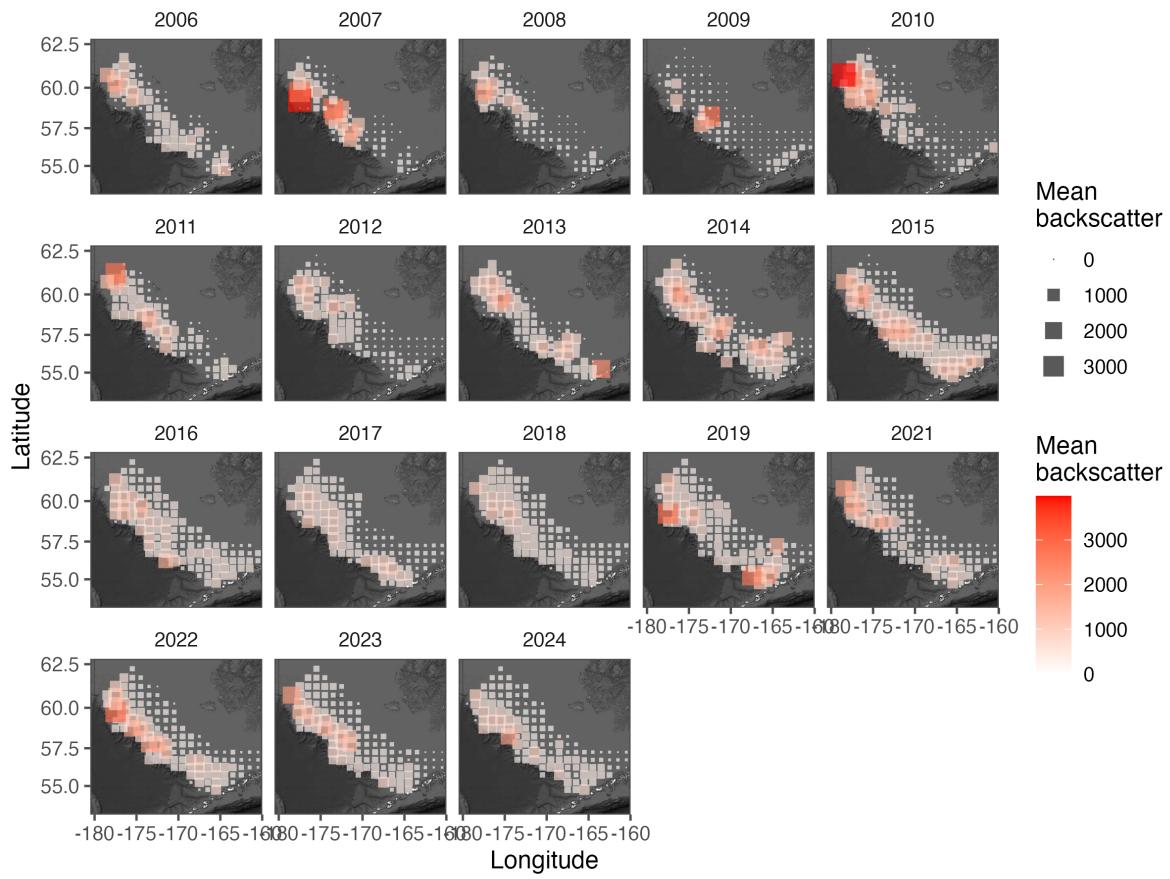


Figure 25: Maps of acoustic vessel-of-opportunity (AVO) index data 2006-2024. Grid cell size and shading is proportional to pollock backscatter.

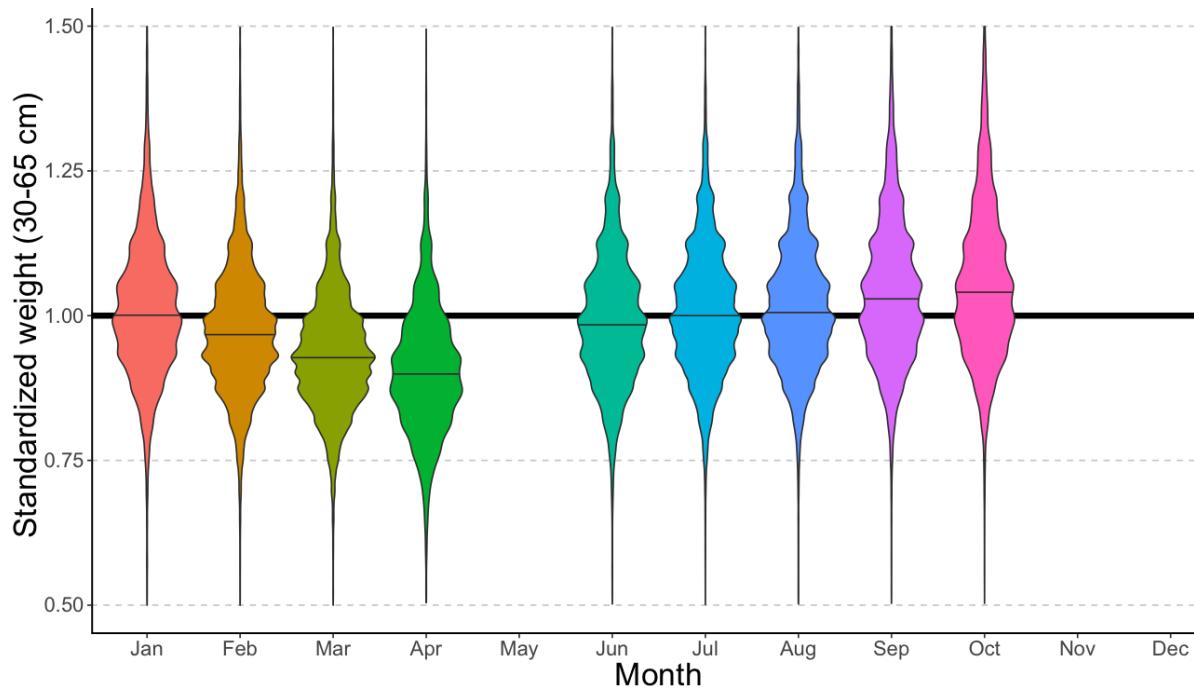


Figure 26: EBS pollock fishery body mass (given length) anomaly (standardized by overall mean body mass at each length) by month based on some over 700 thousand fish measurements from 1991–2024.

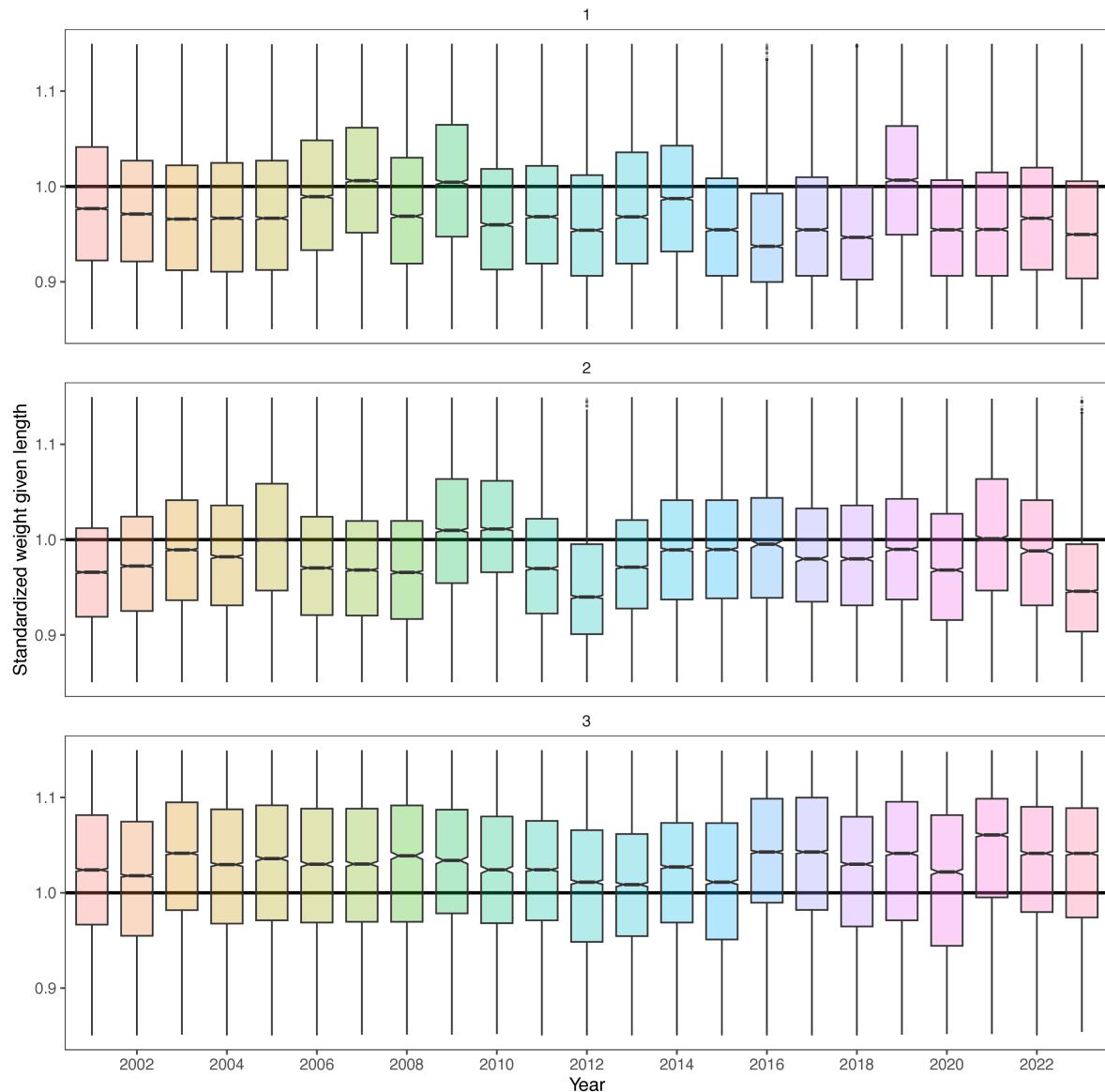


Figure 27: EBS pollock fishery body mass (given length) anomaly (standardized by overall mean body mass at each length) by year and season/area strata, 1991–2024. Strata are defined as A-season (top), and B-season west of 170W (middle) and east of 170W (bottom)

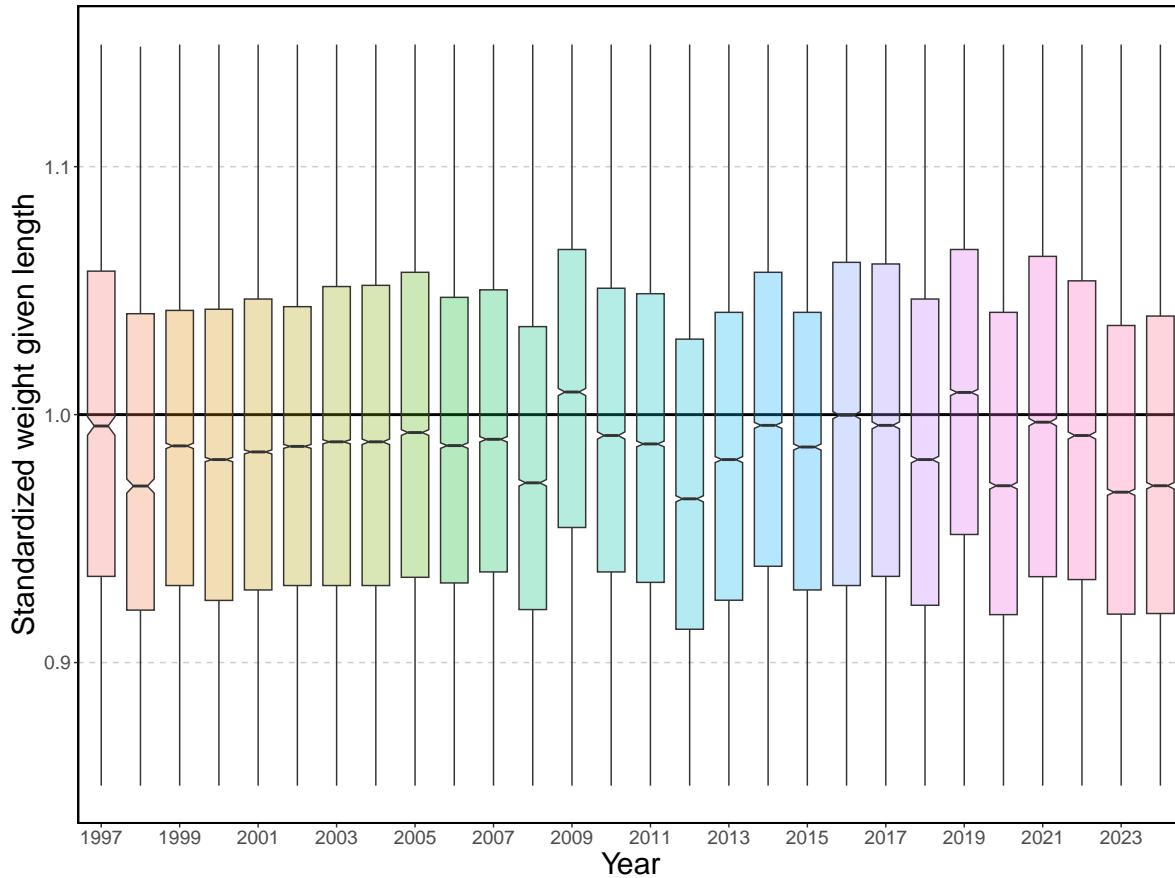


Figure 28: EBS pollock body mass (given length) anomaly (standardized by overall mean body mass at each length) by year, 1991–2024.

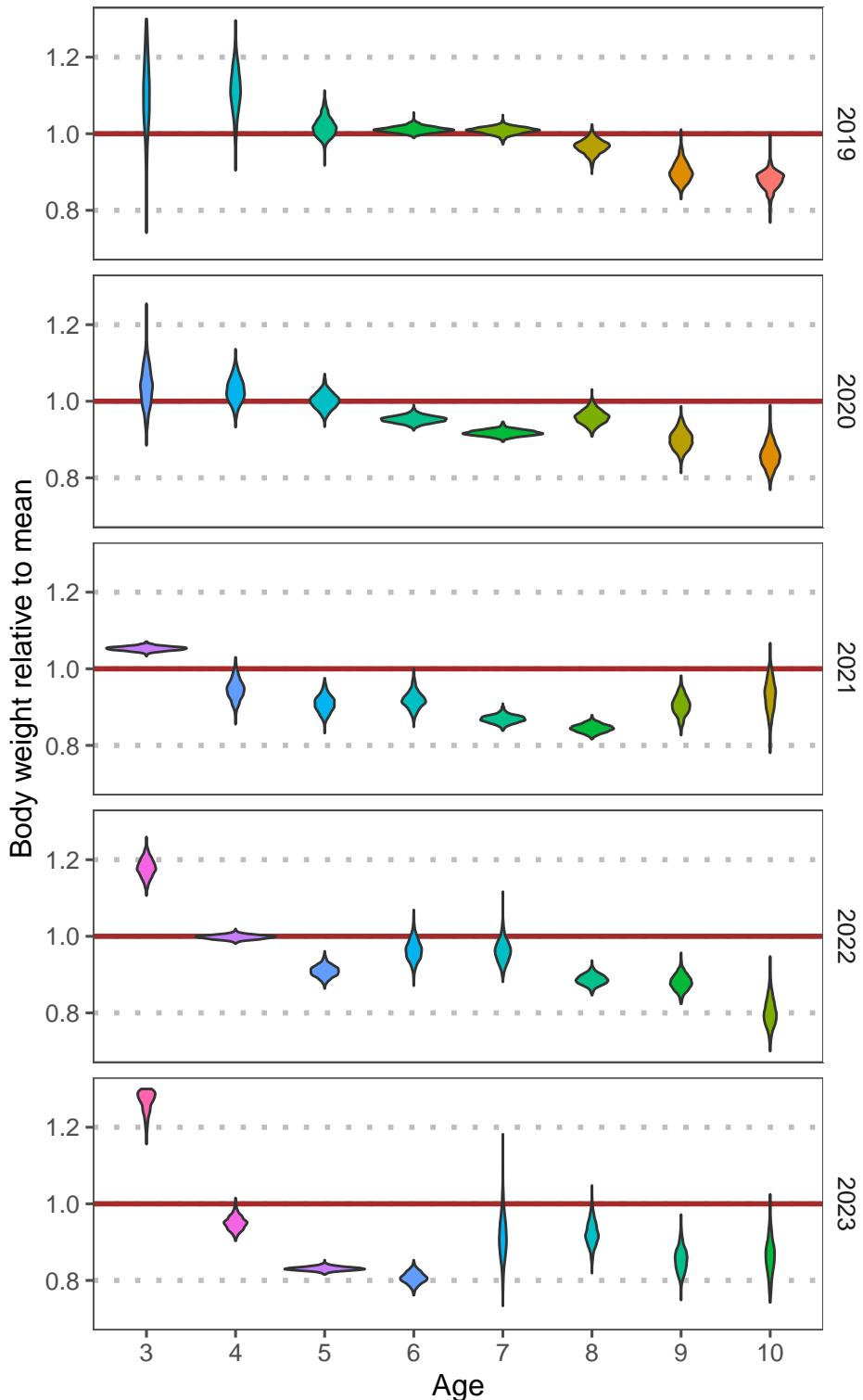
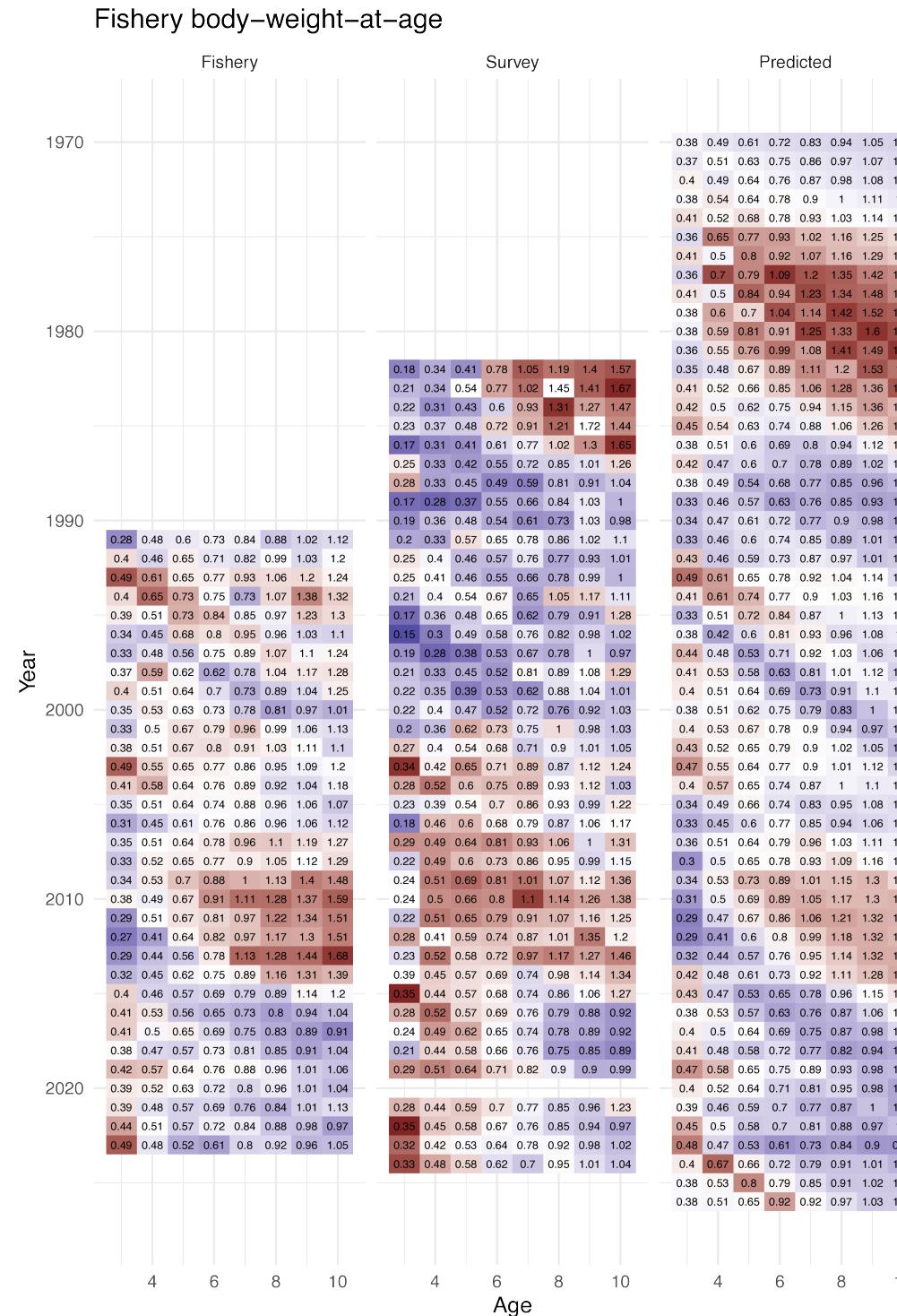


Figure 29: Recent fishery average weight-at-age anomaly (relative to the mean) by strata for ages 3–10, 2019–2023. Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.



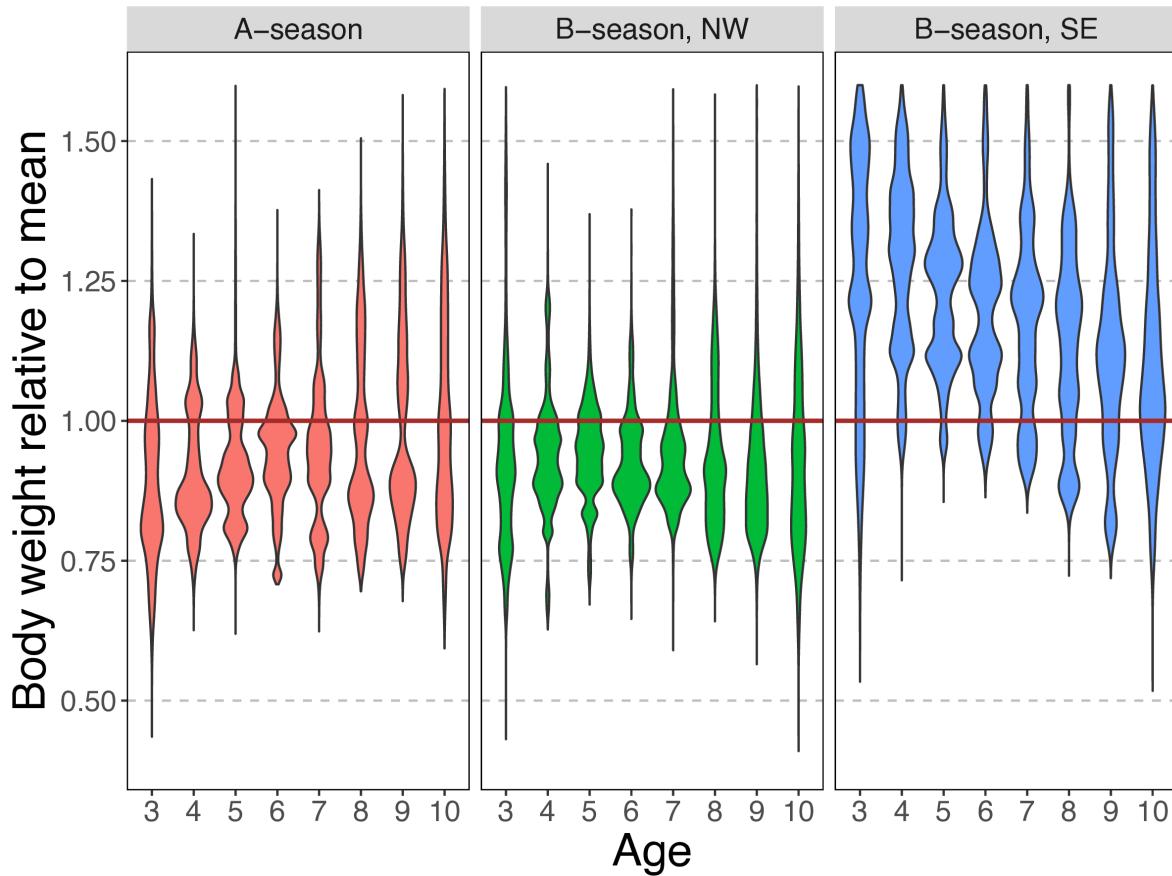


Figure 31: Fishery average weight-at-age anomaly (relative to the mean) across strata and combined for all ages (3–10), and available years (1991–2023). Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

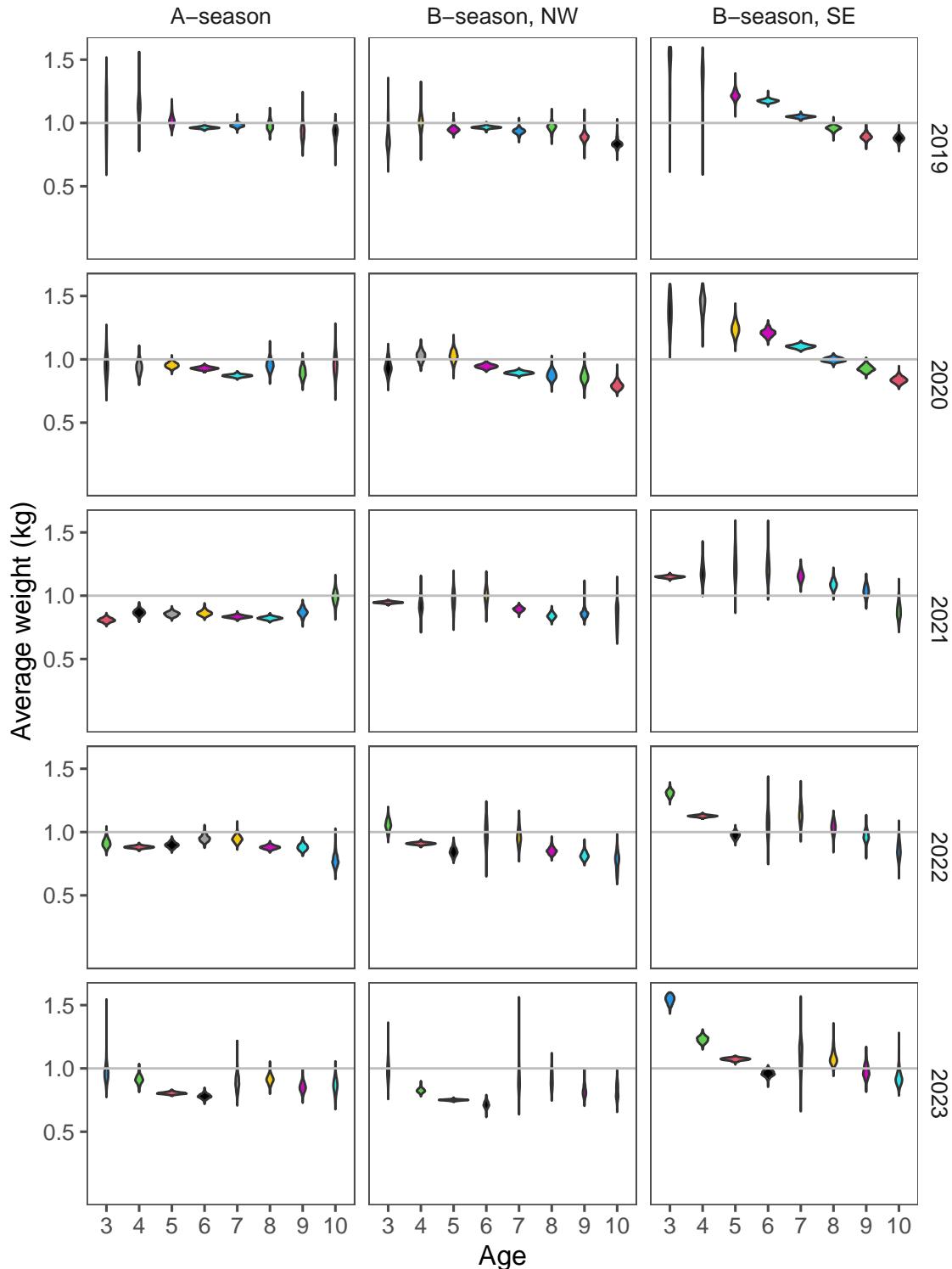


Figure 32: Recent fishery average weight-at-age anomaly (relative to the mean) by strata for ages 3–10, 2019–2023. Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

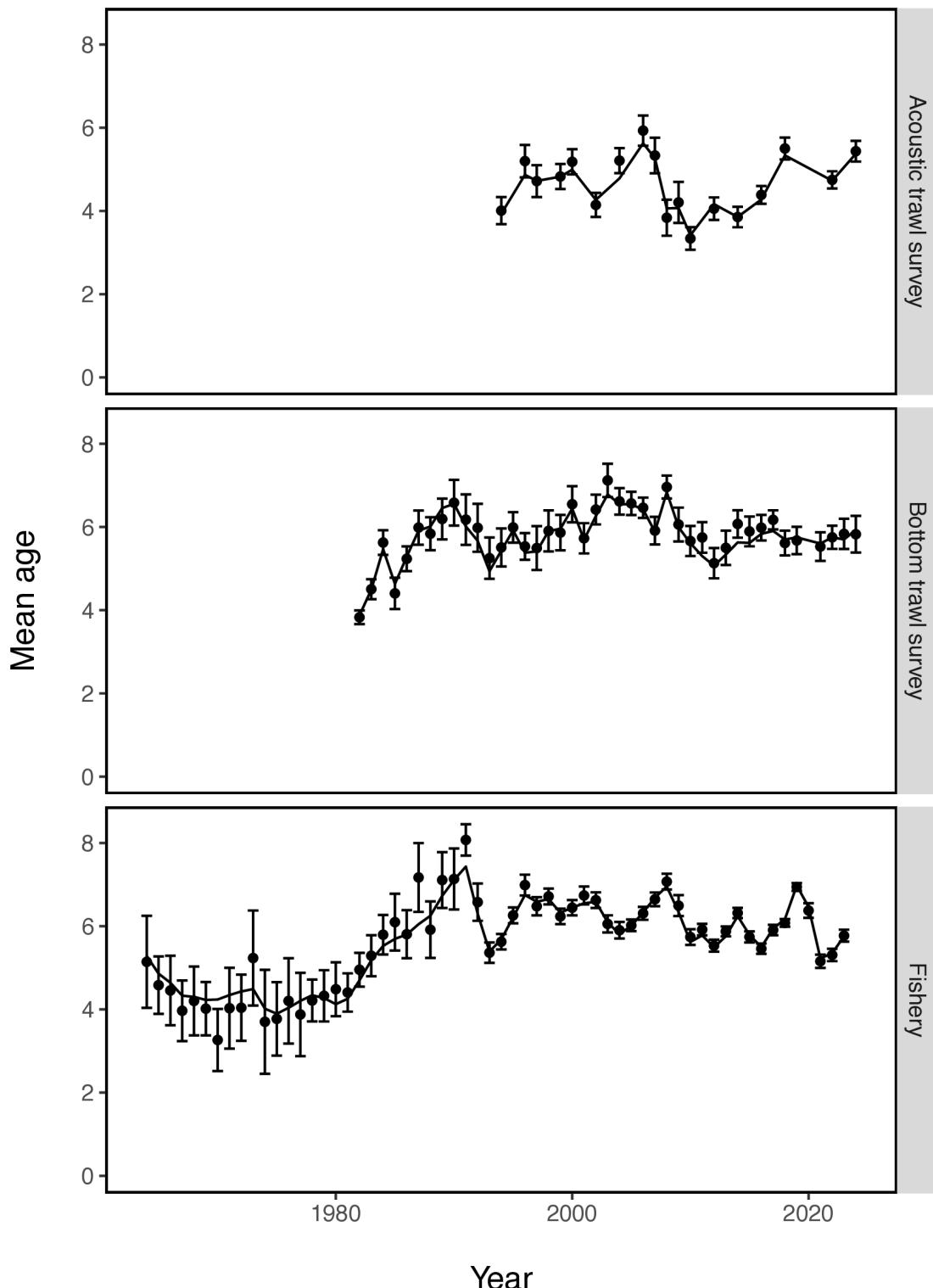


Figure 33: EBS pollock model fits to observed mean age for the Acoustic trawl survey (top), the bottom trawl survey (middle) and fishery (bottom)

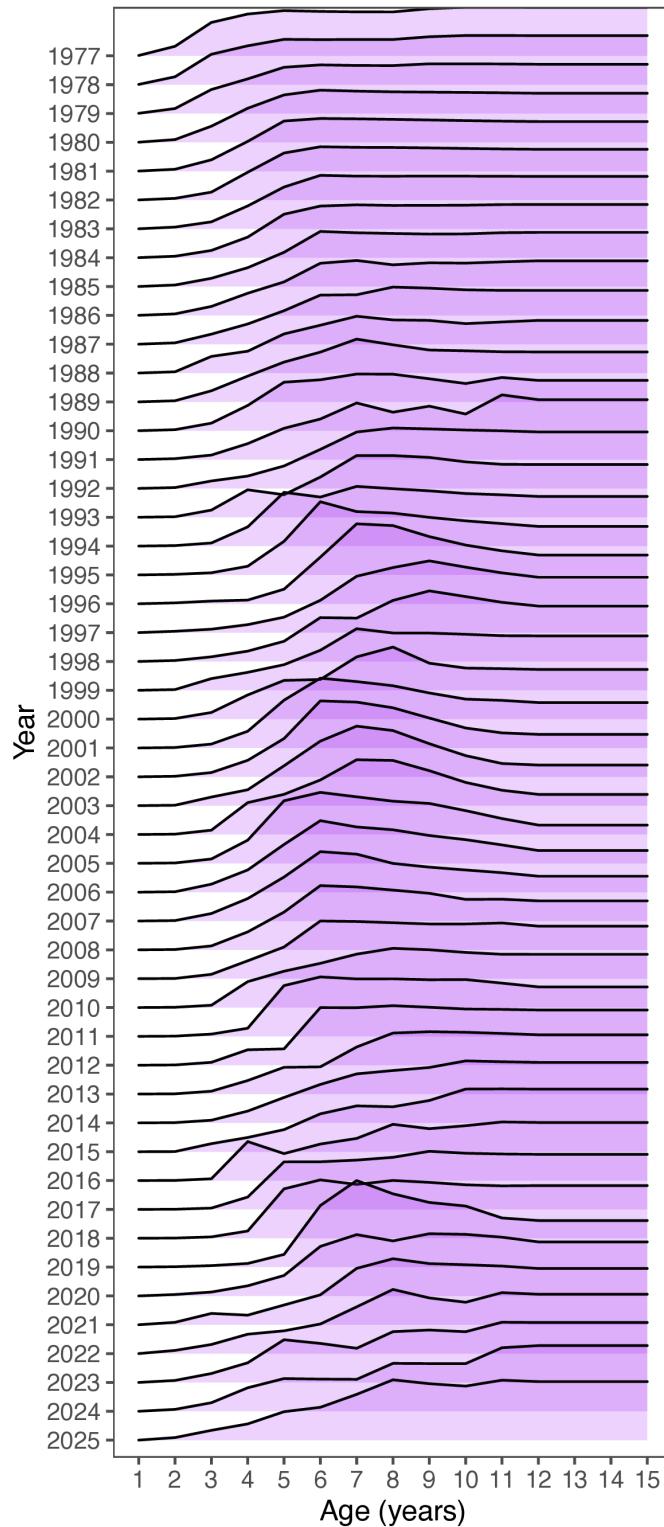


Figure 34: Selectivity at age estimates for the EBS pollock fishery; note that the values for the terminal year is used for ABC and OFL projections.

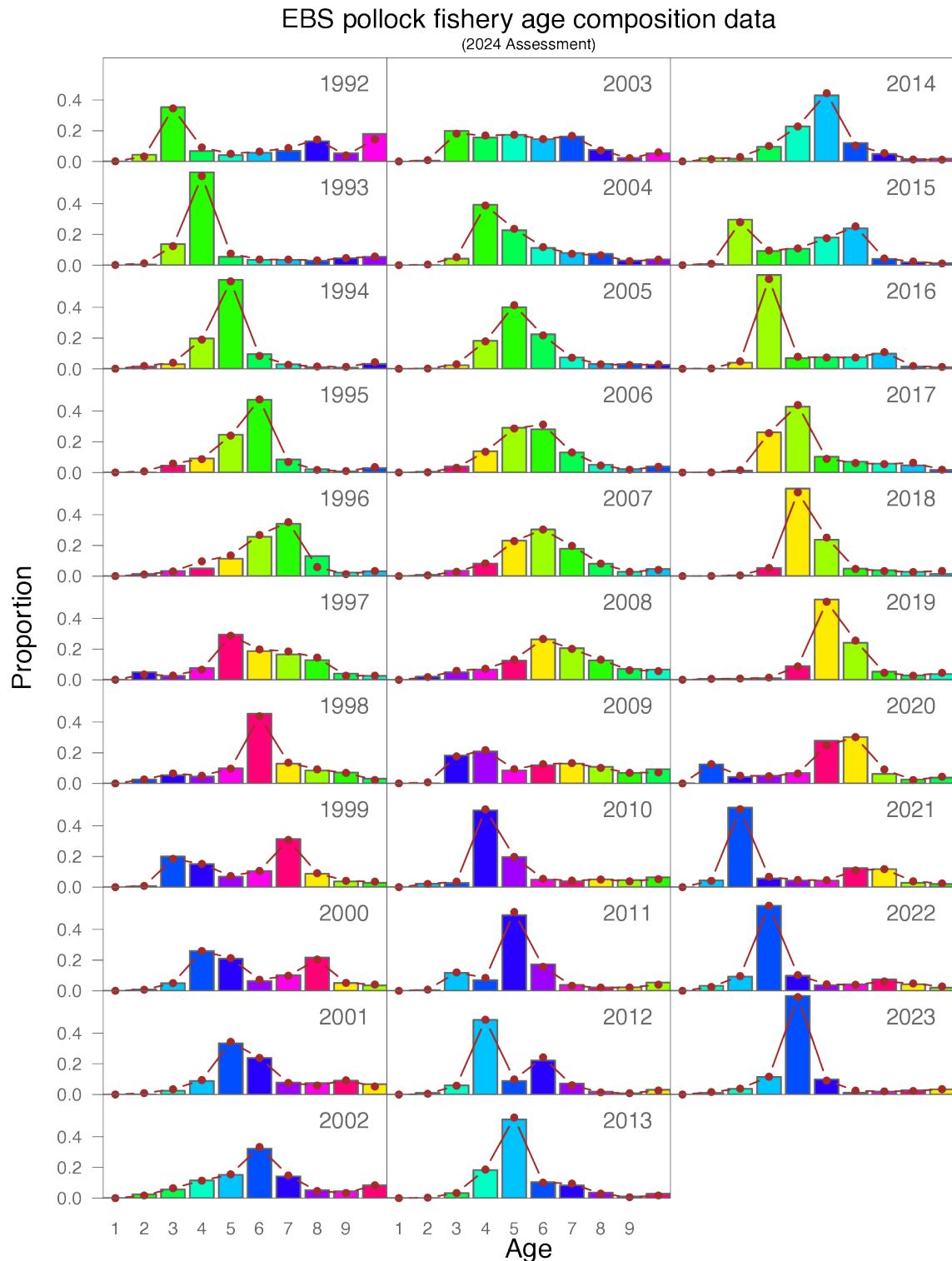


Figure 35: Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1992–2023). The 2023 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

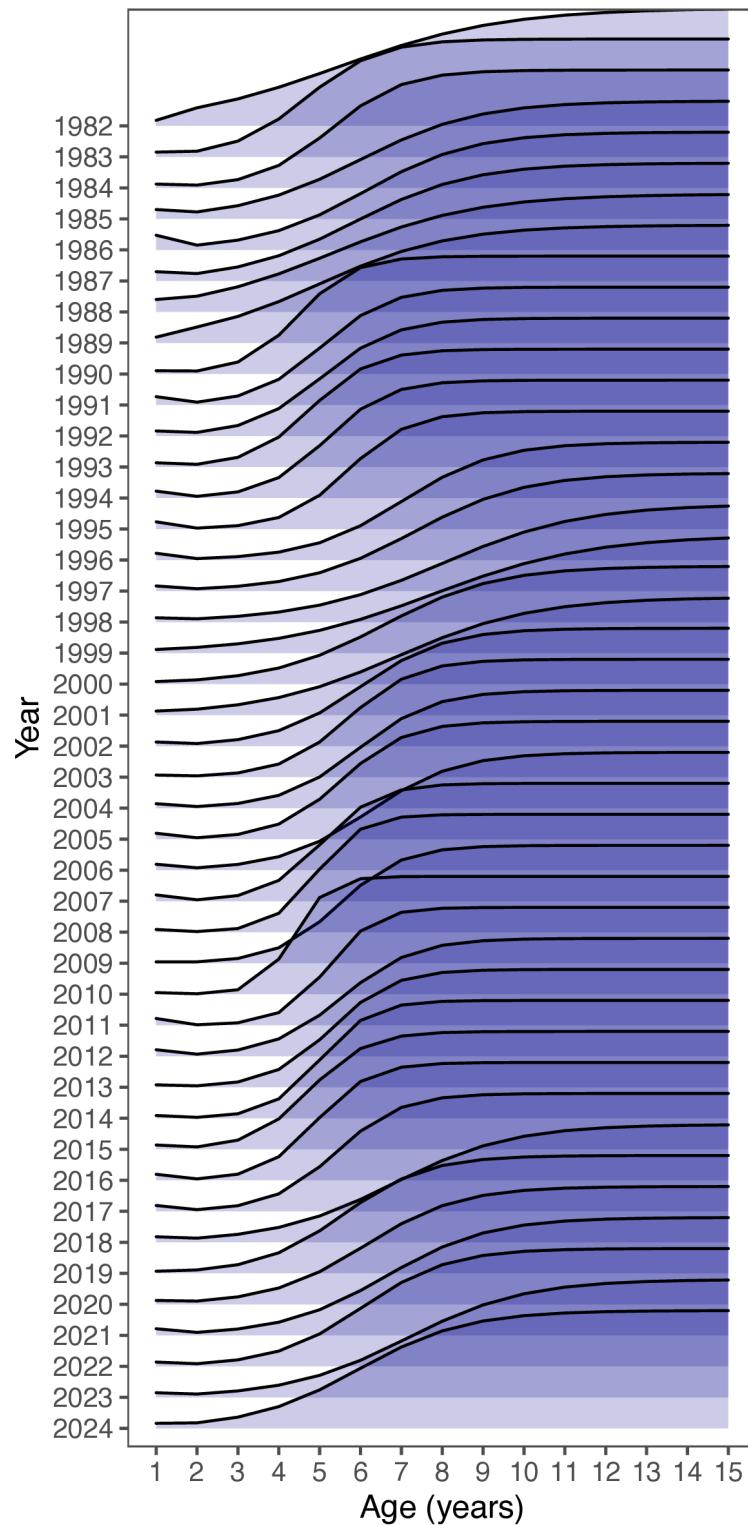


Figure 36: Model estimates of bottom-trawl survey selectivity, 1982–2024.

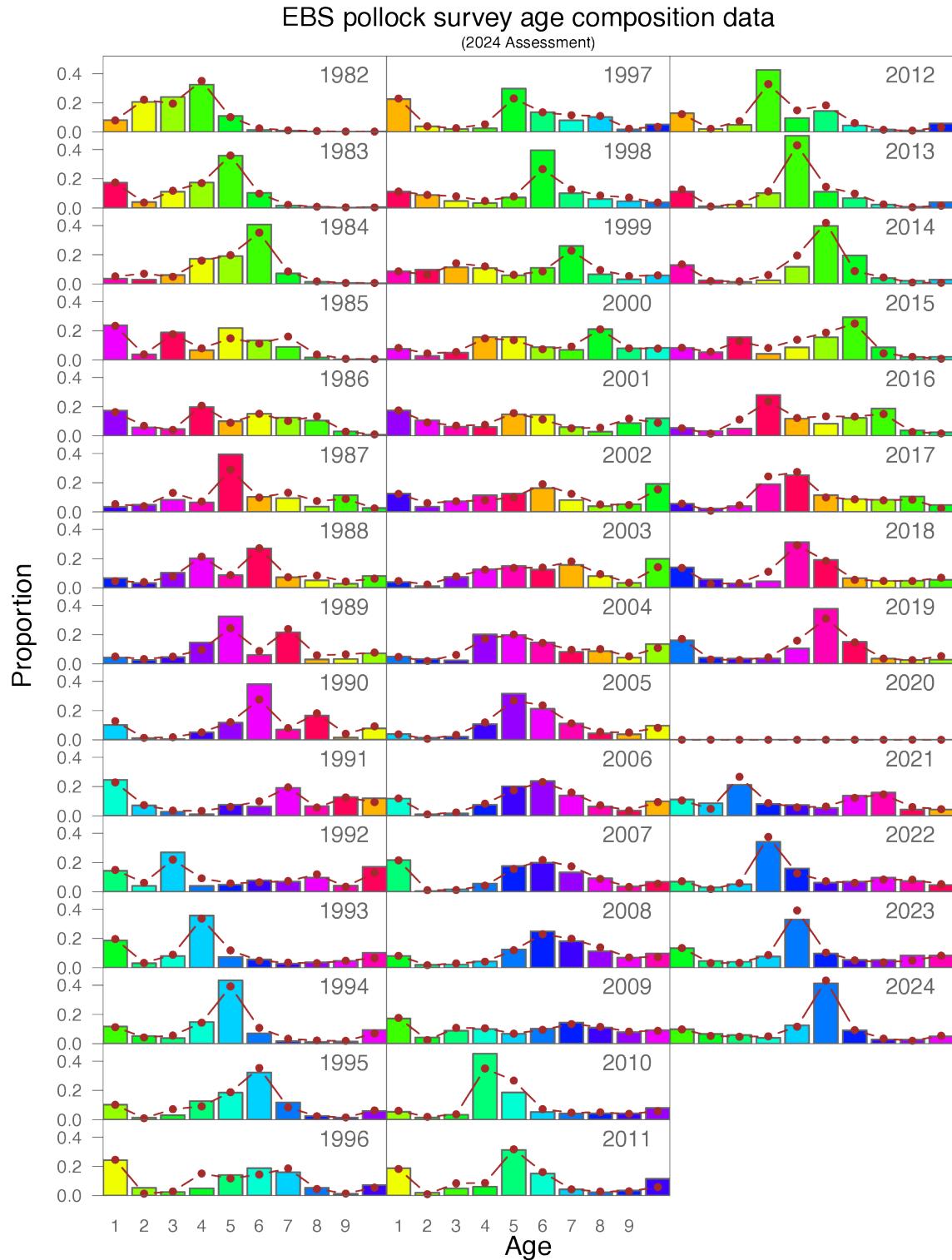


Figure 37: Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time.

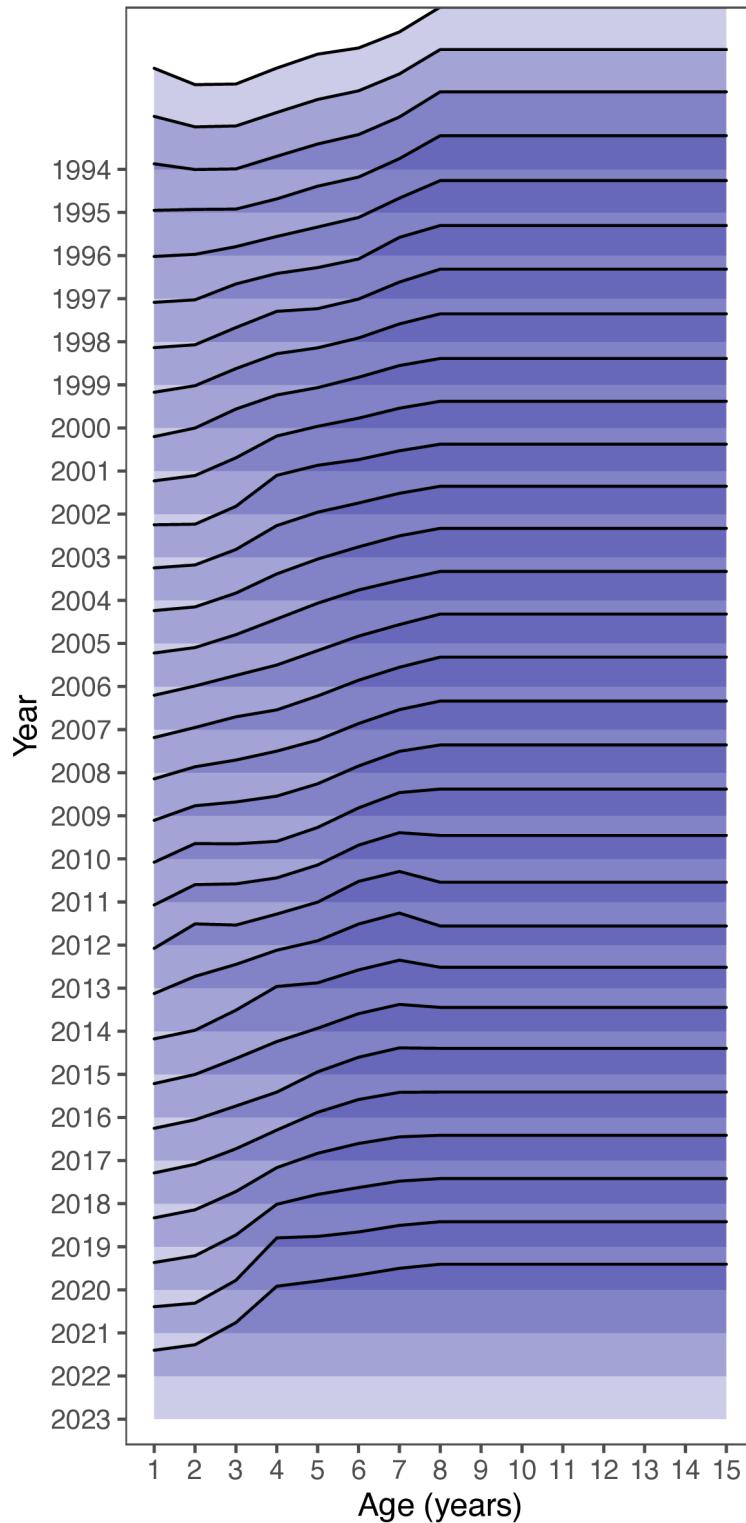


Figure 38: Estimates of AT survey numbers selectivity-at-age (with mean value equal to 1.0) over time for EBS pollock age 2 and older.

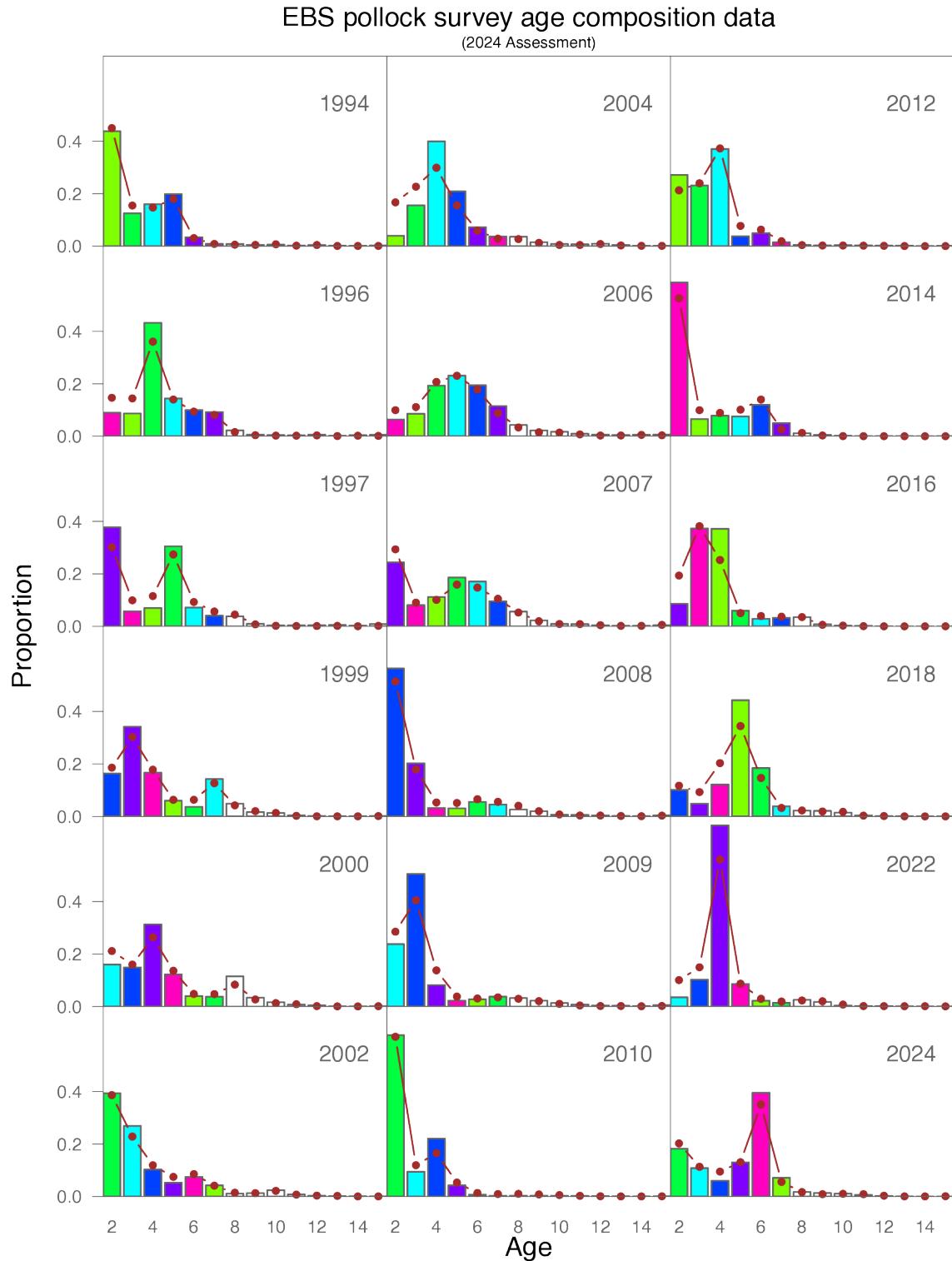


Figure 39: Model fit (dots) to the acoustic-trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time (for years with consecutive surveys).

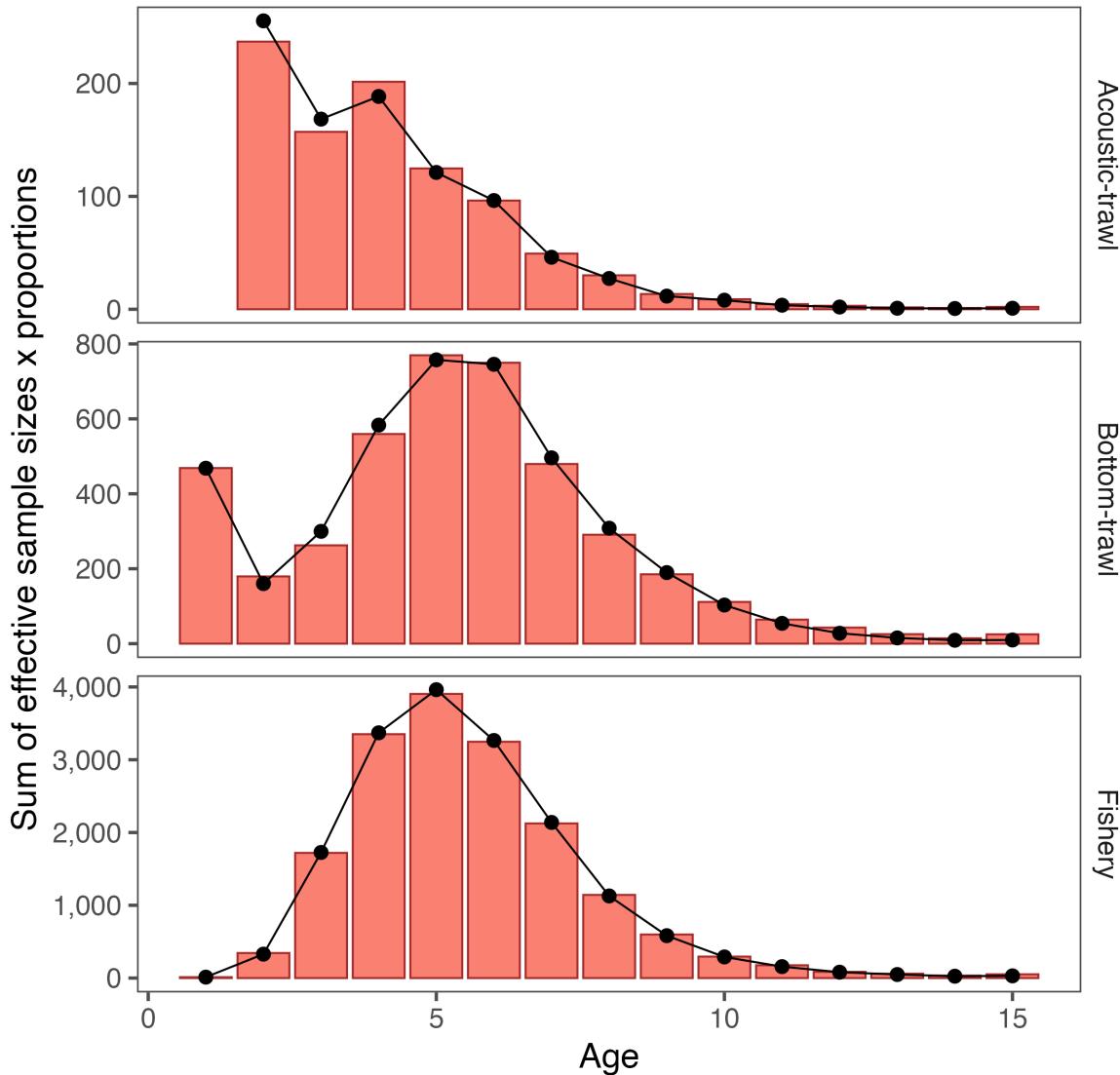


Figure 40: Aggregate fit to composition data where the columns represent the sum over years of the observed proportions multiplied by the effective sample size whereas the lines with dots are the model predictions by different gear types.

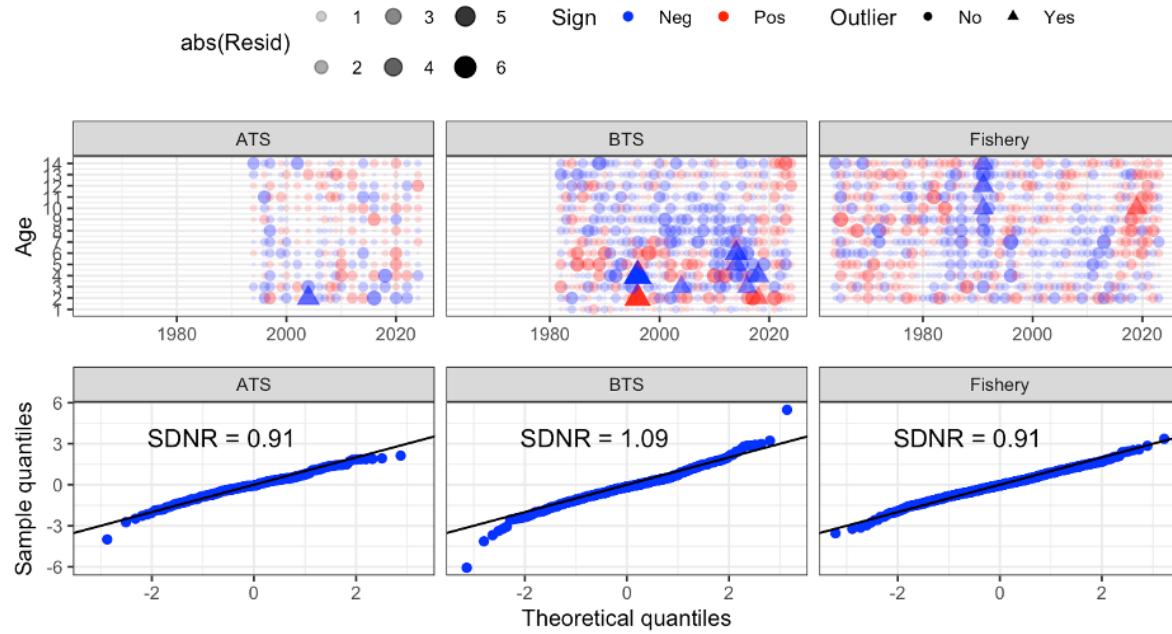


Figure 41: One-step-ahead residual plots (top row) and Q-Q plots of residuals (showing the standard-deviation of normalized residuals—SDNR; bottom row) for the fishery, acoustic-trawl survey (ATS) and bottom trawl survey (BTS) age composition data for EBS pollock

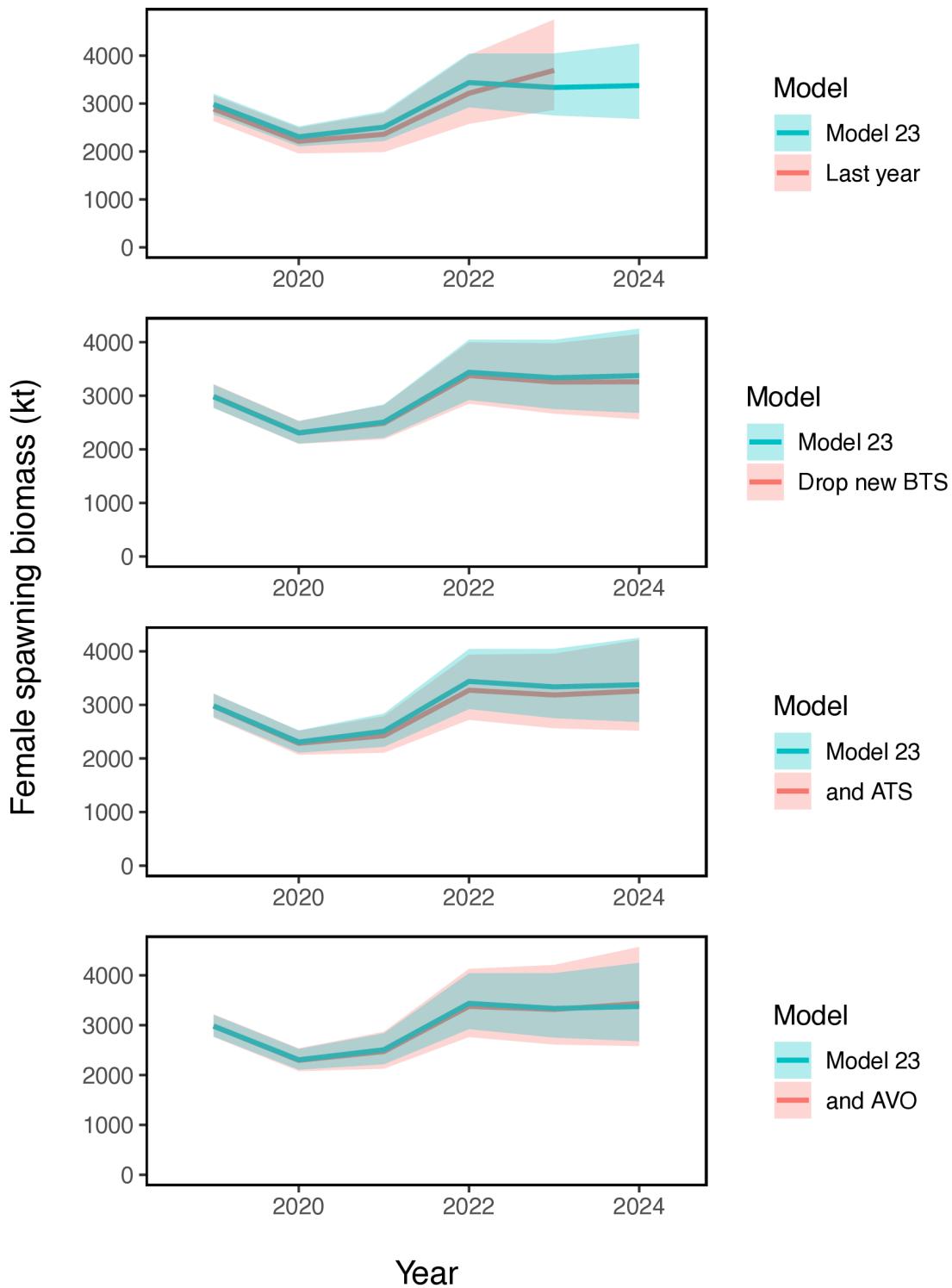


Figure 42: Model runs comparing last year's assessment with all the data updated in 2024 (top). Subsequent panels (from 2nd to bottom) illustrate the cumulative impact of removing new 2024 data. The second panel shows the impact of removing the 2024 bottom trawl survey (BTS) data, then the acoustic-trawl (ATS) and finally the AVO data.

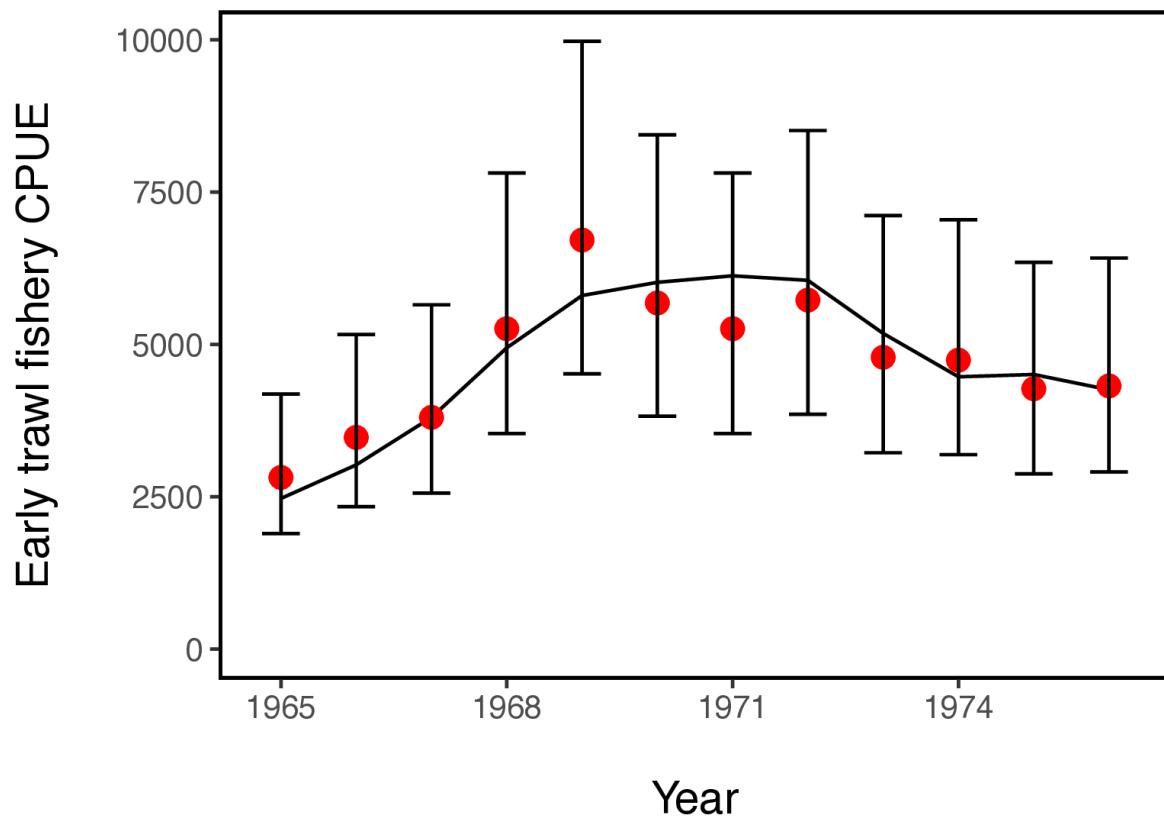


Figure 43: EBS pollock model fits to the Japanese fishery CPUE.

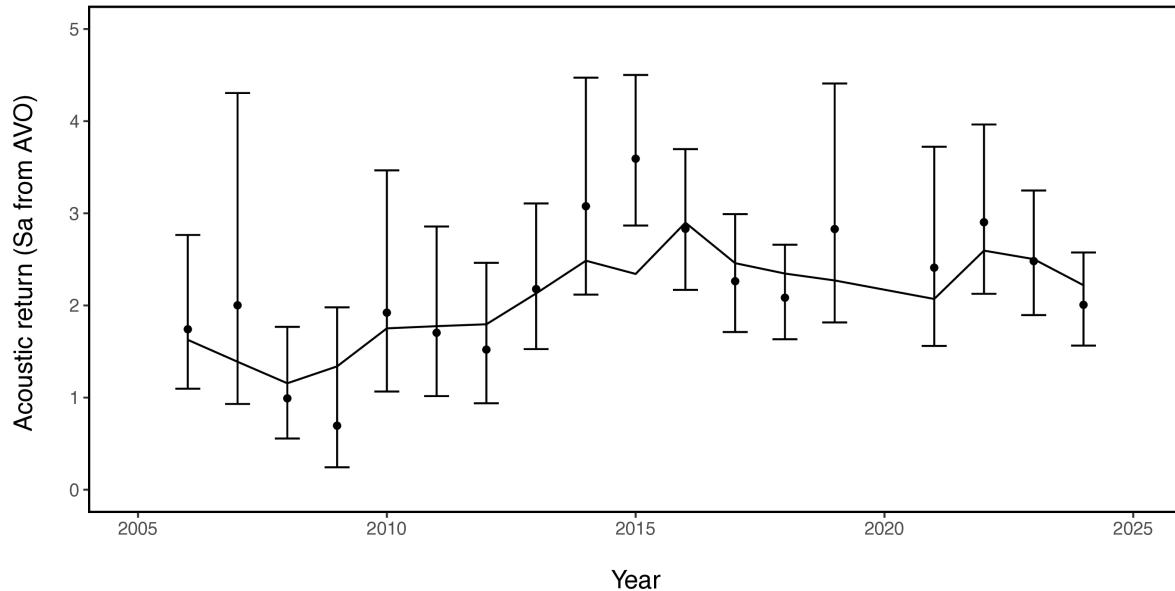


Figure 44: Model results of predicted and observed AVO index. Error bars represent assumed 95% confidence bounds of the input series.

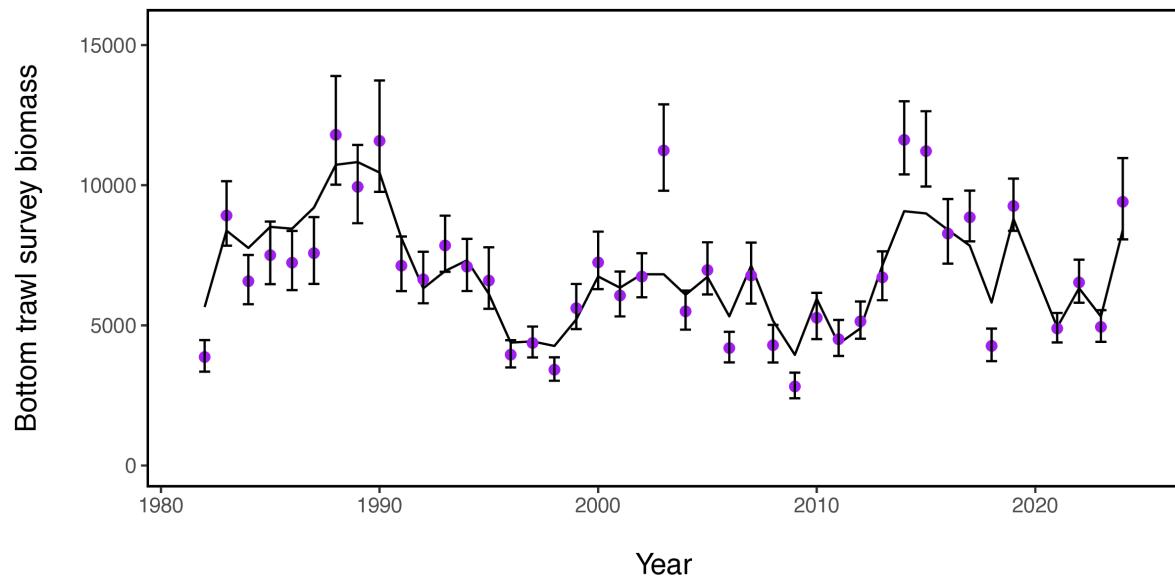


Figure 45: EBS pollock model fit to the BTS survey data (VAST estimates based on density dependence-corrected CPUE by station), 1982–2019, 2021–2024. Units are relative biomass.

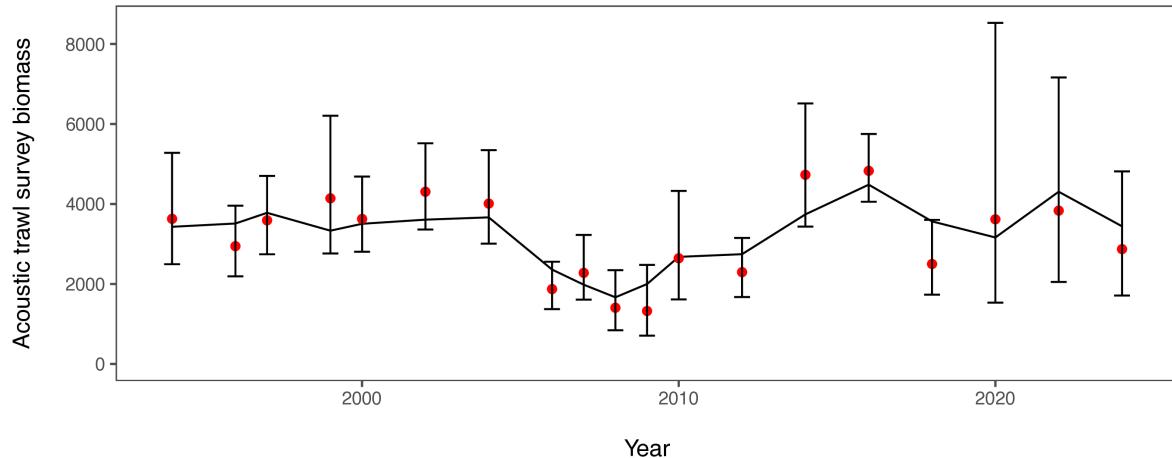


Figure 46: EBS pollock model fit to the ATS biomass index, 1994–2024.

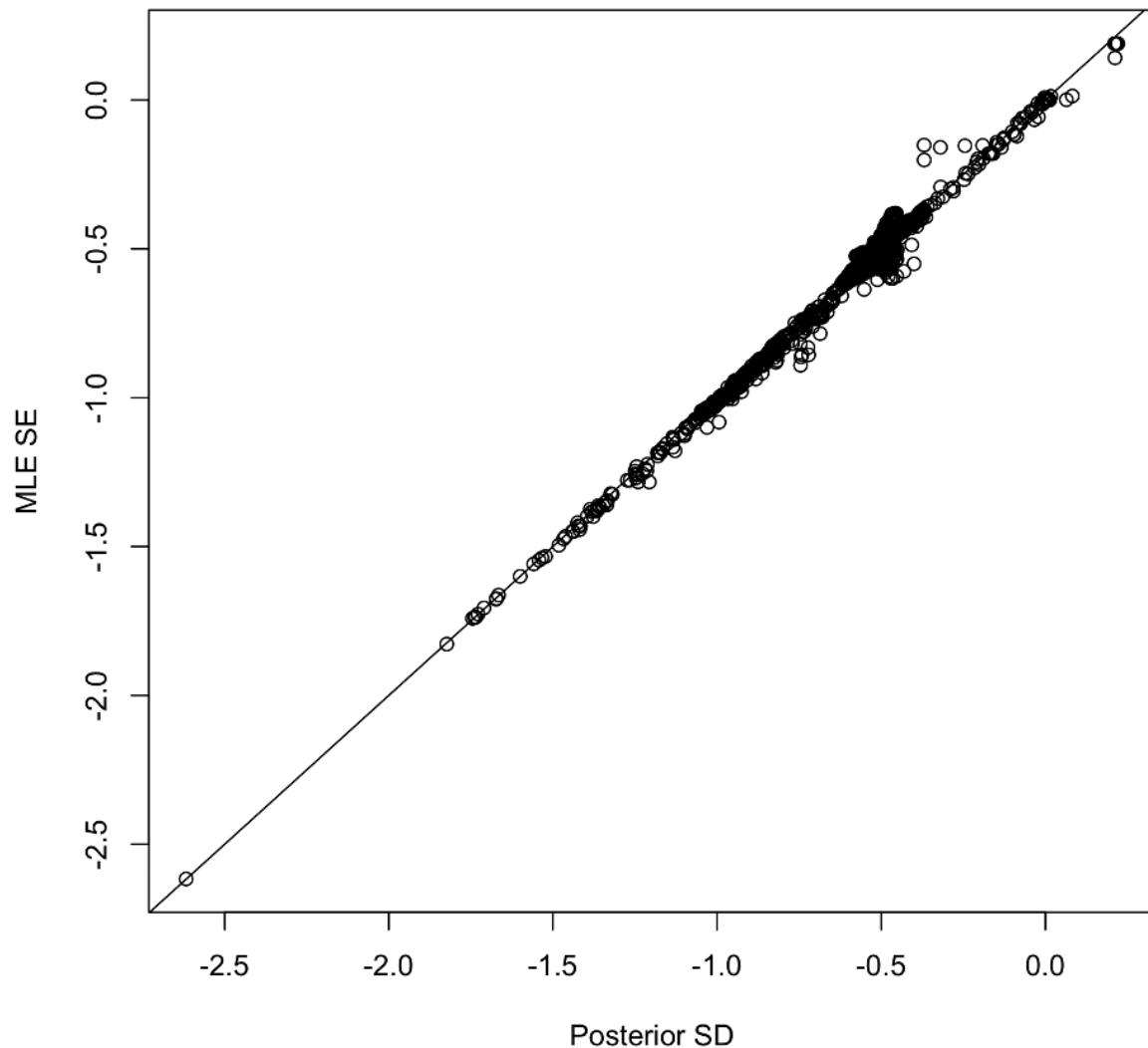
Comparing Bayesian vs frequentist uncertainty estimates

Figure 47: Comparison of the asymptotic parameter standard errors (from inverting the Hessian; vertical axis) with the marginals from the MCMC draws (horizontal axis).

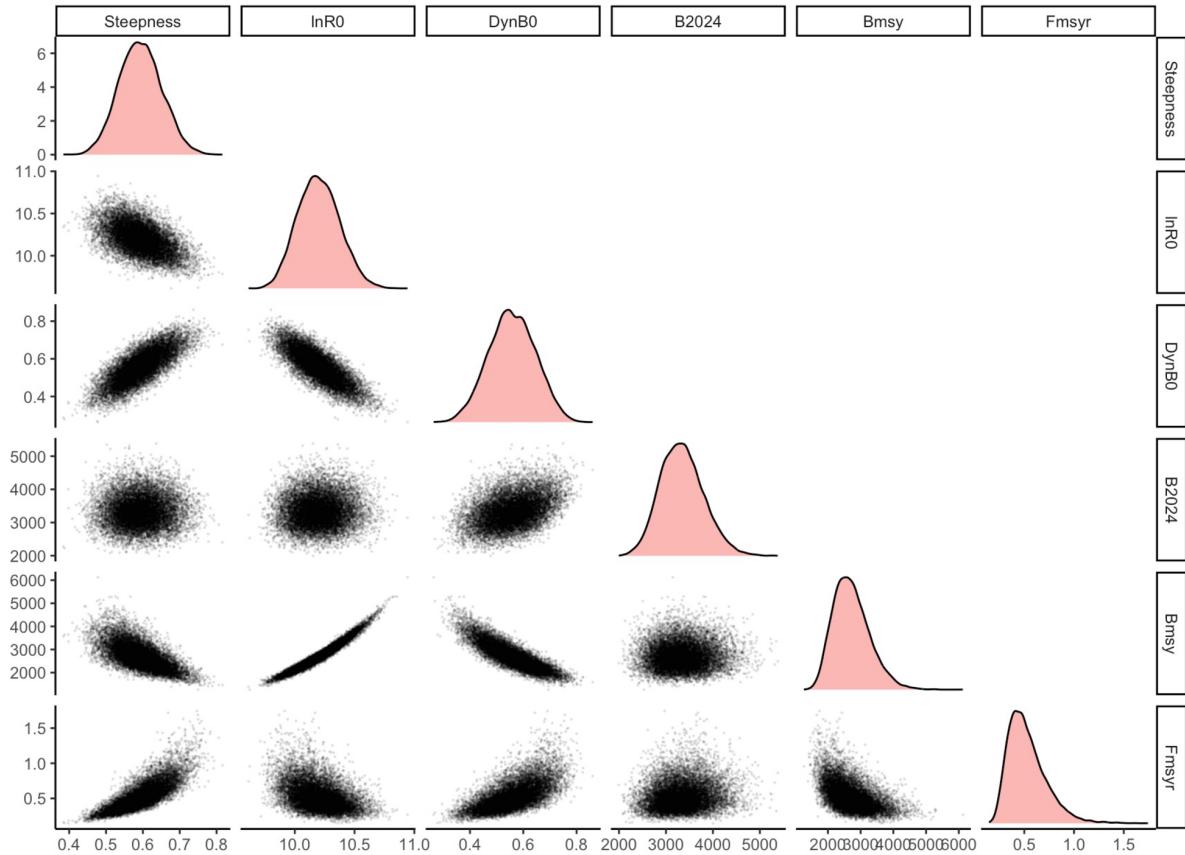


Figure 48: Pairwise plot of selected EBS pollock parameters and output from MCMC to approximate the multivariate posterior distribution. Note that the figures on the diagonal represent the marginal posterior distributions. Key: steepness and lnR0 are stock-recruitment parameters, DynB0 is the ratio of spawning biomass estimated for in 2024 over the value estimated that would occur if there had been no fishing, B2025 is the spawning biomass in 2025 and Fmsyr is the rate at which MSY would be achieved on average.

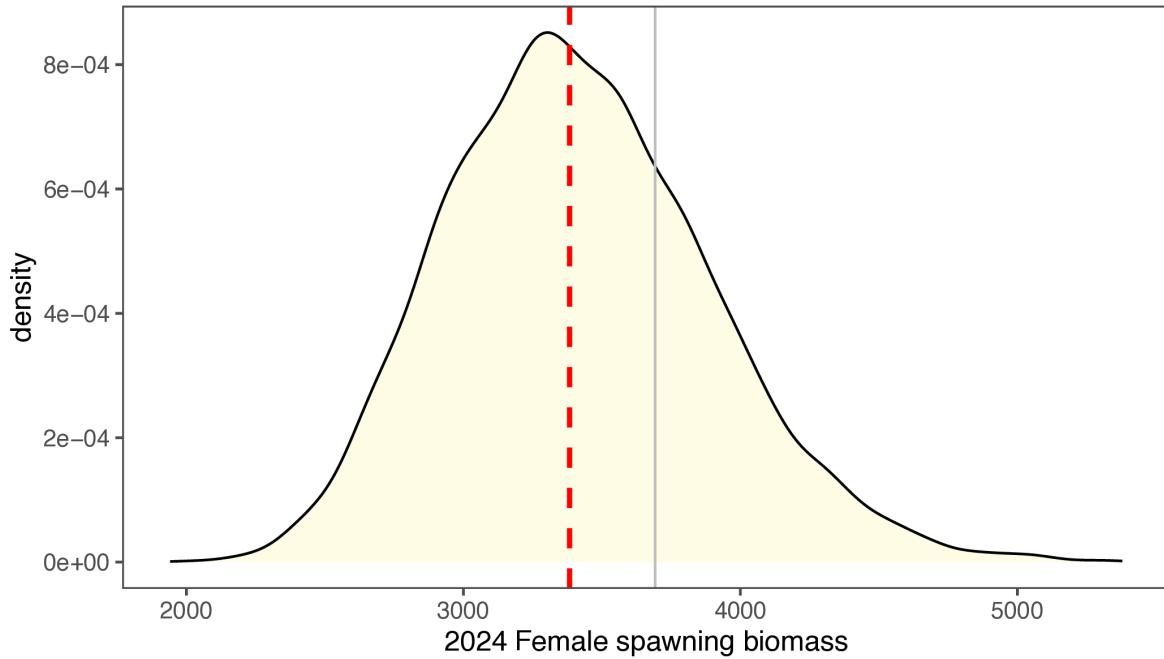


Figure 49: Integrated marginal posterior density (based on MCMC results) for the 2024 EBS pollock female spawning biomass compared to the point estimate (grey line).

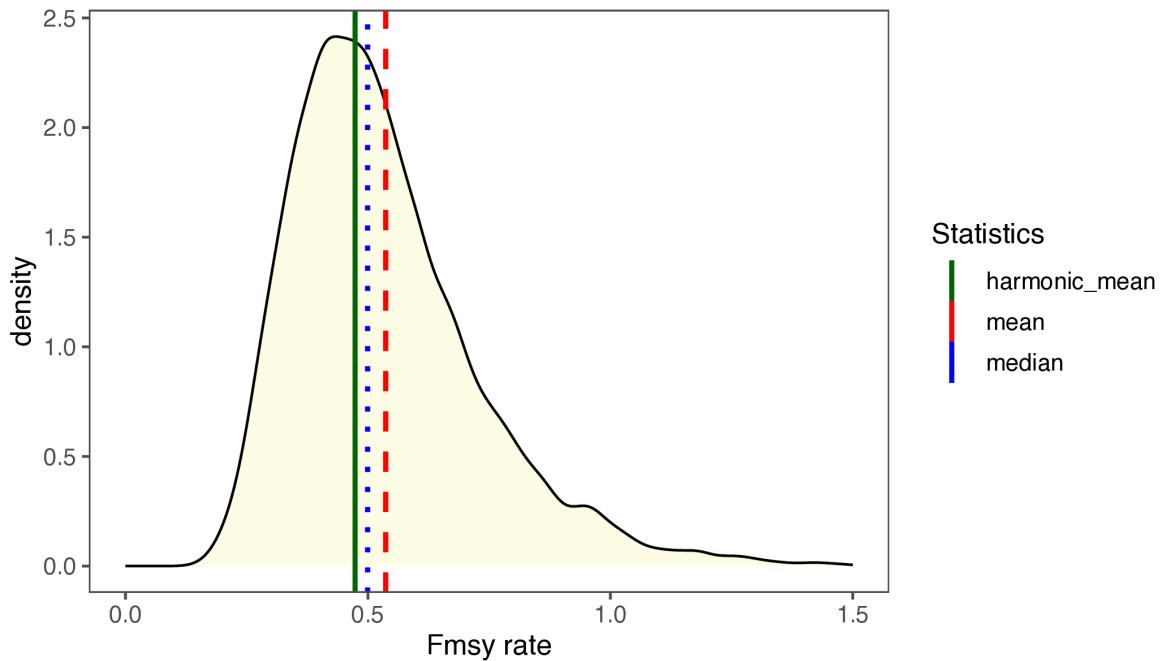


Figure 50: Integrated marginal posterior density (based on MCMC results) for the F_{MSY} for EBS pollock and different central tendency values.

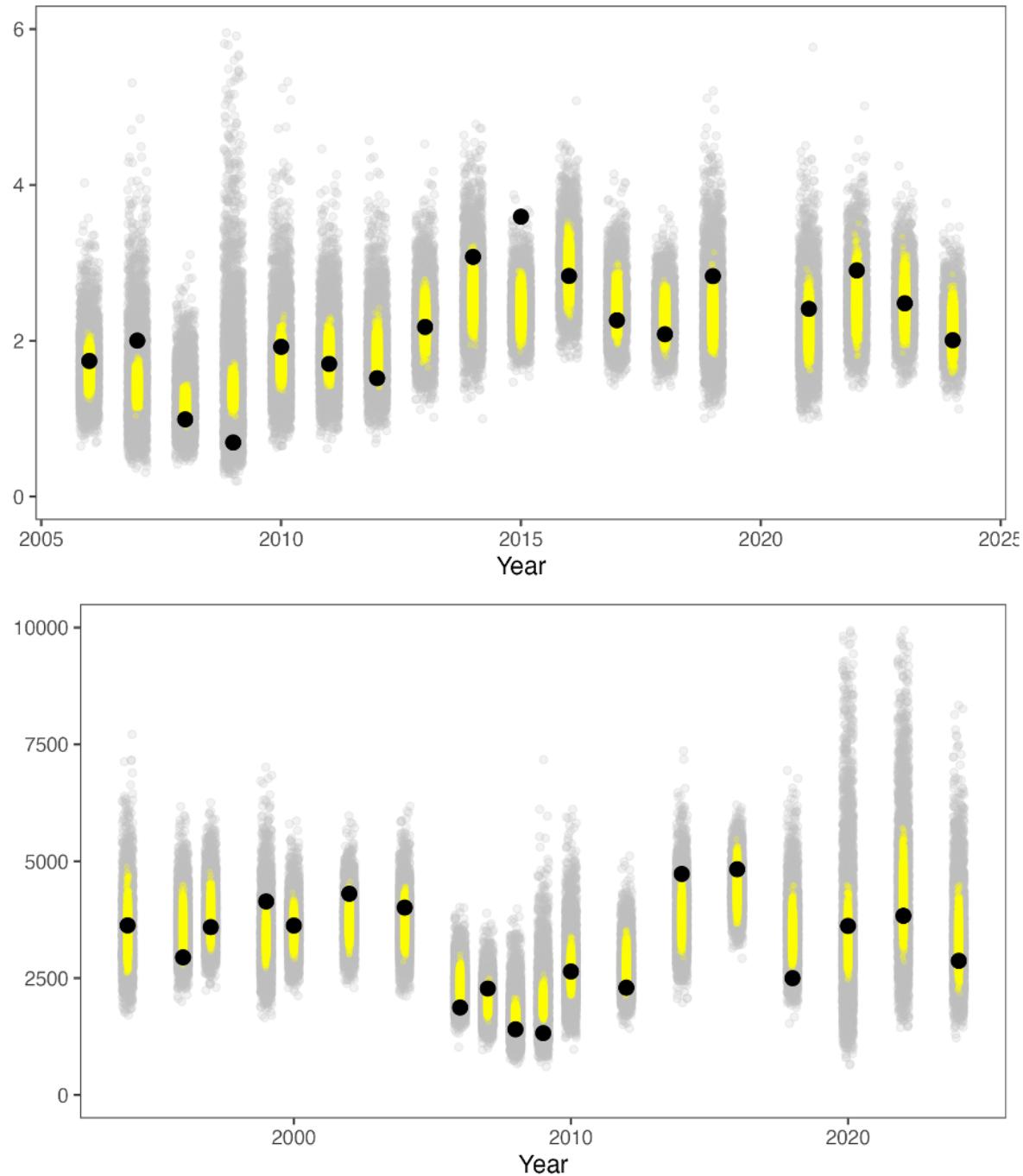


Figure 51: Plot of the observed index values (solid line) for the AVO (top) and ATS (bottom), the distribution of the expected value (yellow dots) and the posterior predictive distribution (grey points).

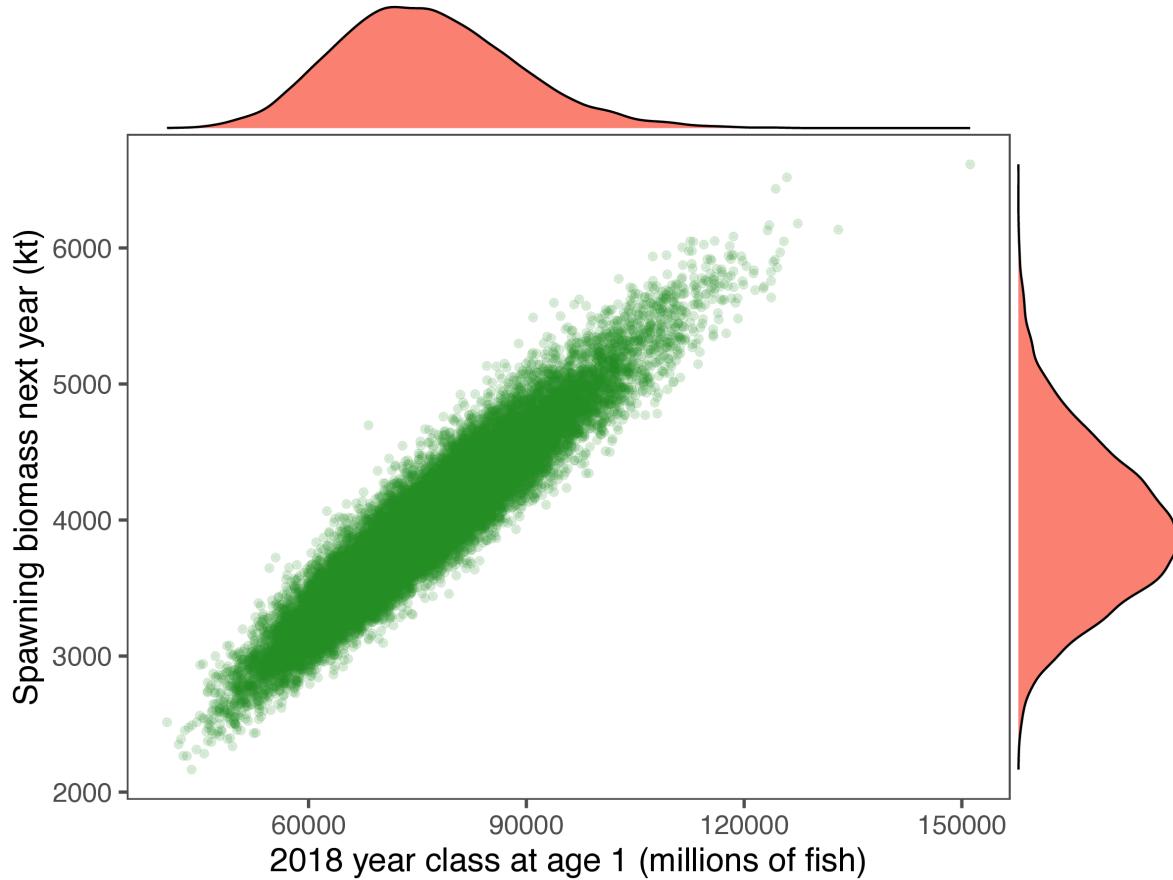


Figure 52: Plot of a representation of the posterior marginal distributions of spawning biomass in 2025 (vertical scale and right-side distribution) versus the size of the 2018 year-class (horizontal scale and the top distribution).

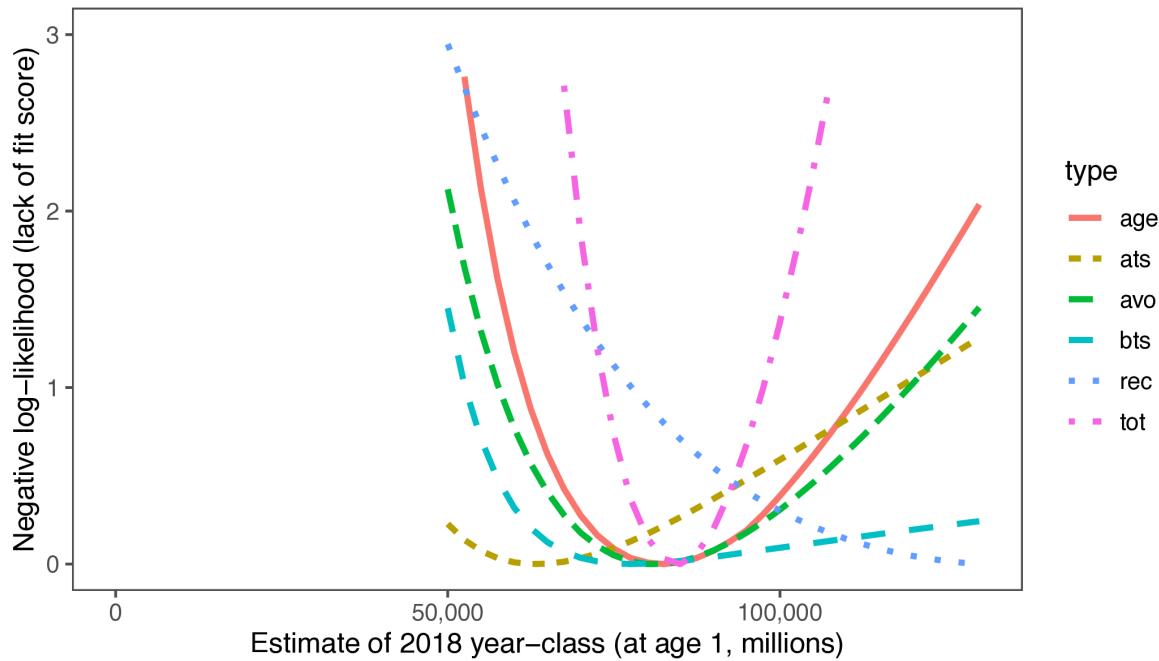


Figure 53: Profile-likelihood depicting the sources of uncertainty in the 2018 year-class. Likelihood component abbreviations: age, ats, avo, bts, rec, and tot represent respectively all the age composition data from the survey and fishery, the three indices, the stock-recruitment relationship, and total negative log-likelihoods, respectively.

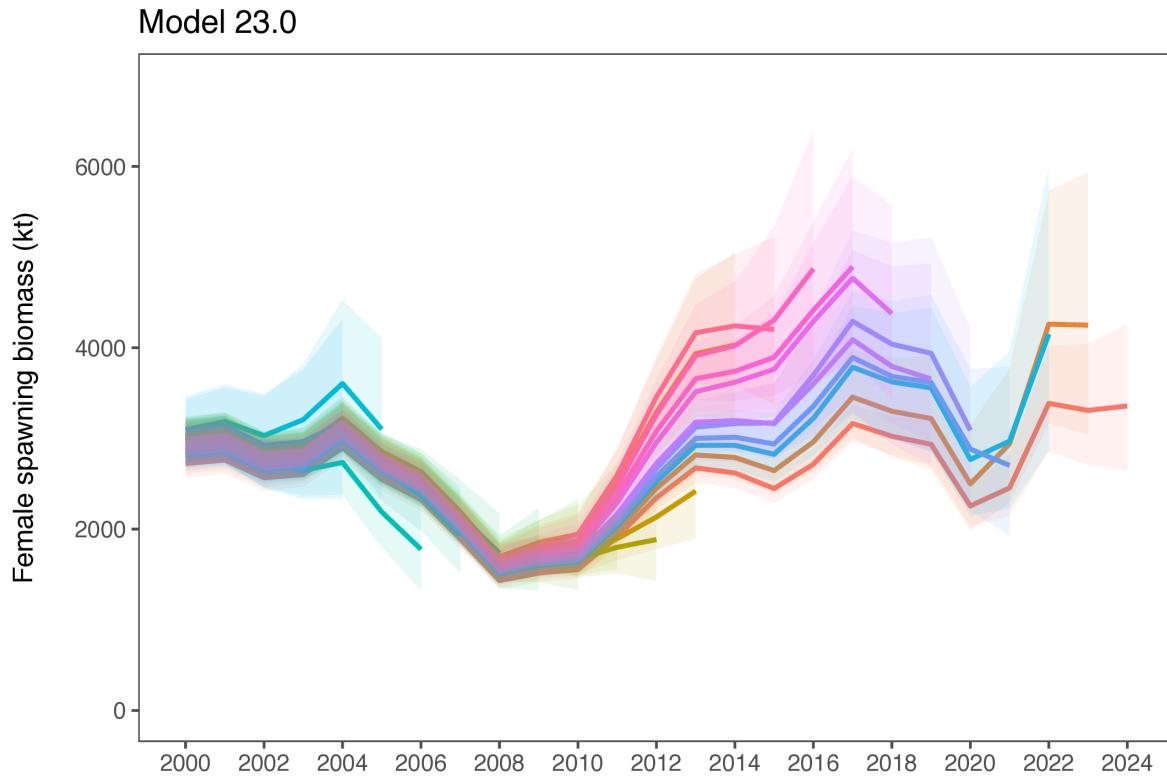


Figure 54: Retrospective patterns for EBS pollock spawning biomass showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations).

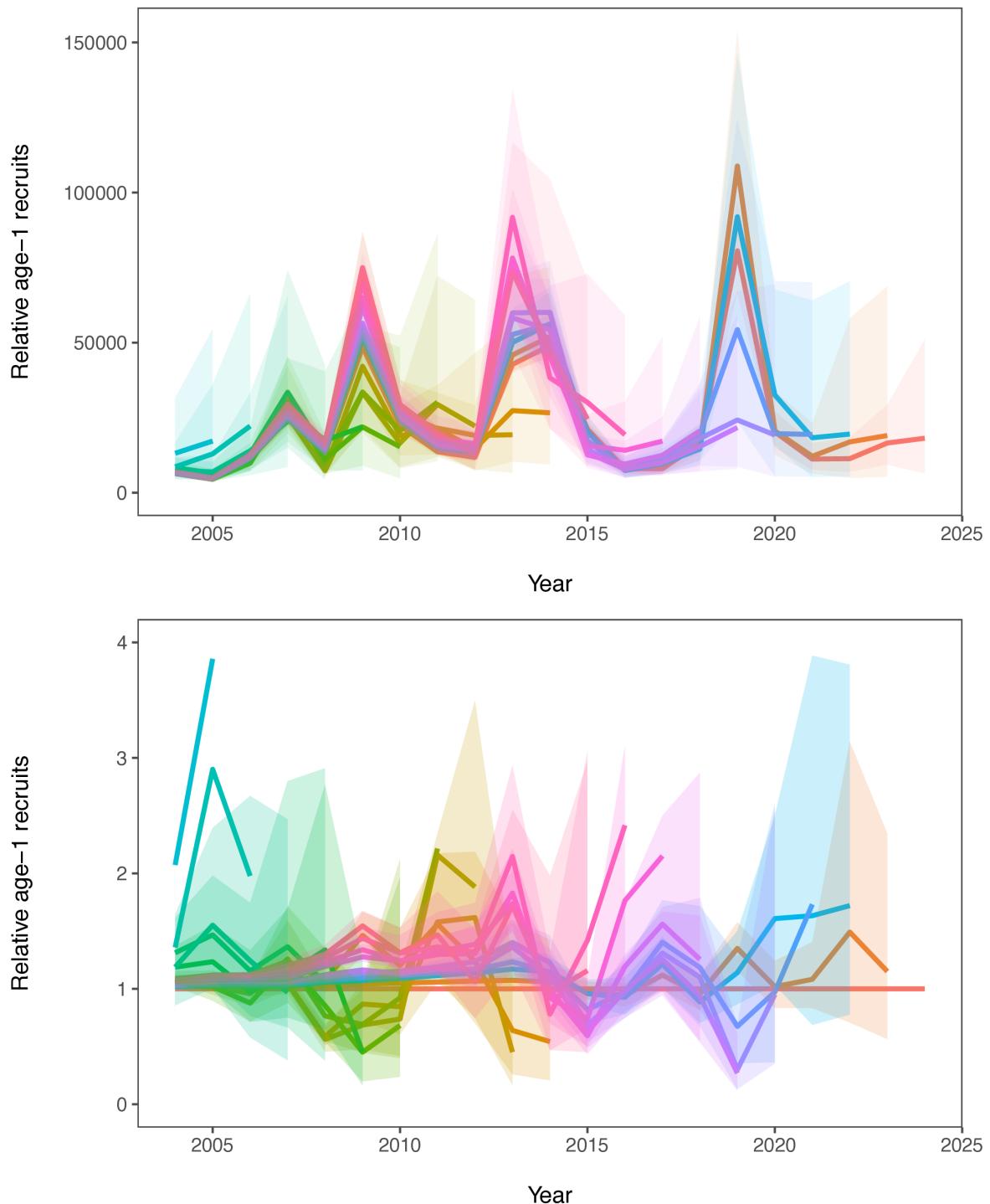


Figure 55: Retrospective patterns for EBS pollock recruitment showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations).

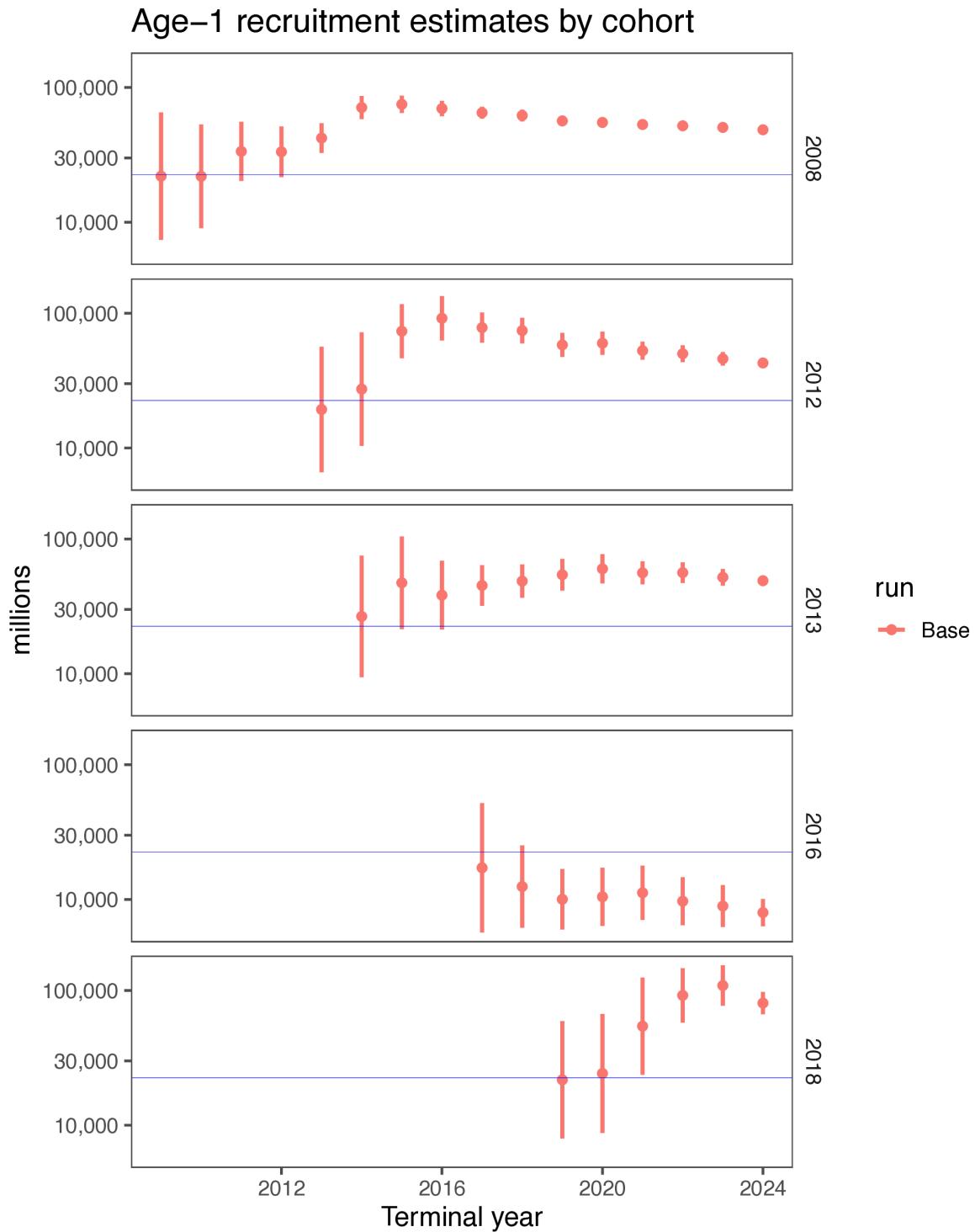


Figure 56: Retrospective evolution of EBS pollock selected year-class estimates as a function of the terminal year of data used in the model (based on retrospectives of Model 23.0).

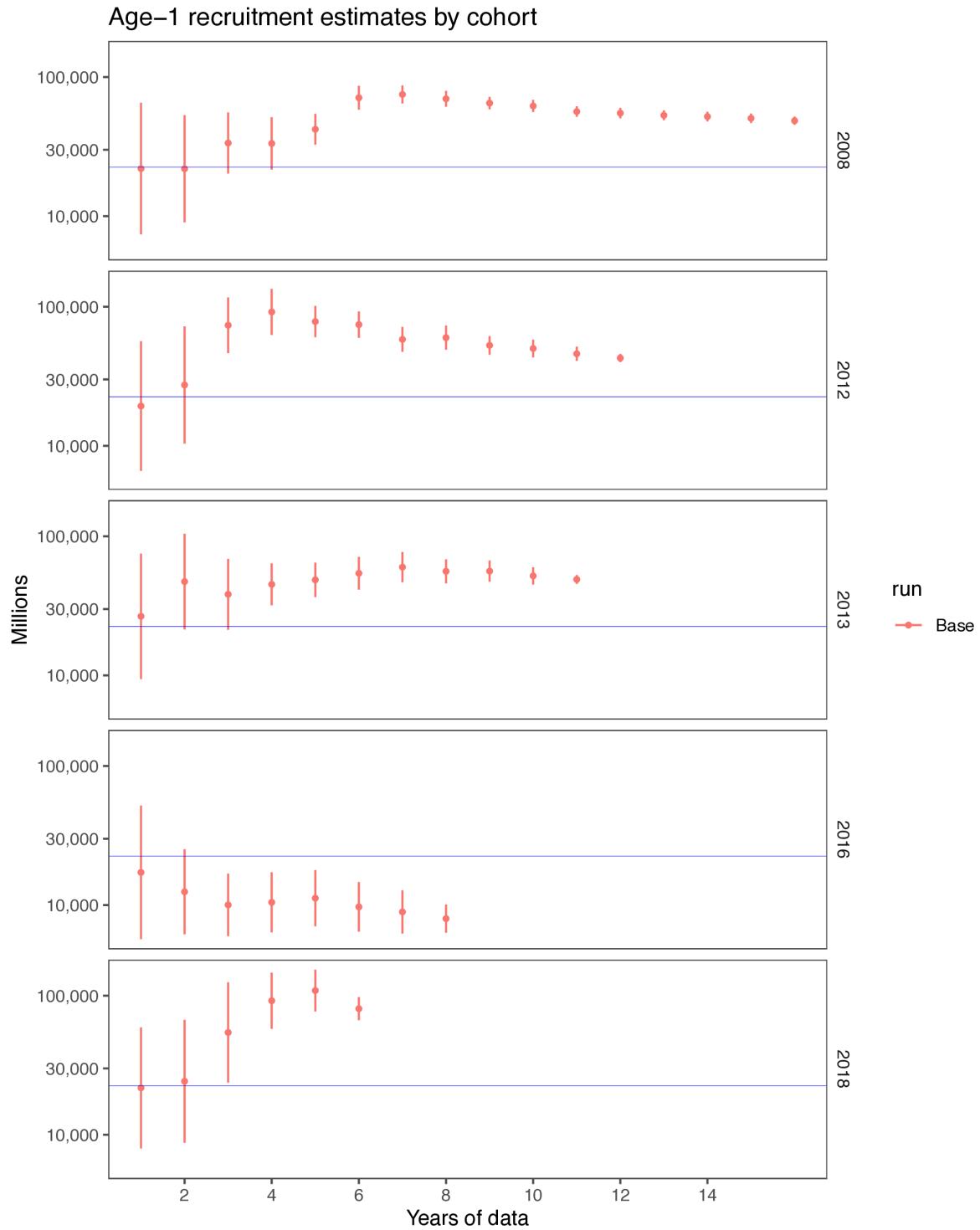


Figure 57: Retrospective evolution of EBS pollock selected year-class estimates as a function of the the number of years the year-class has been in the model (based on retrospectives of Model 23.0).

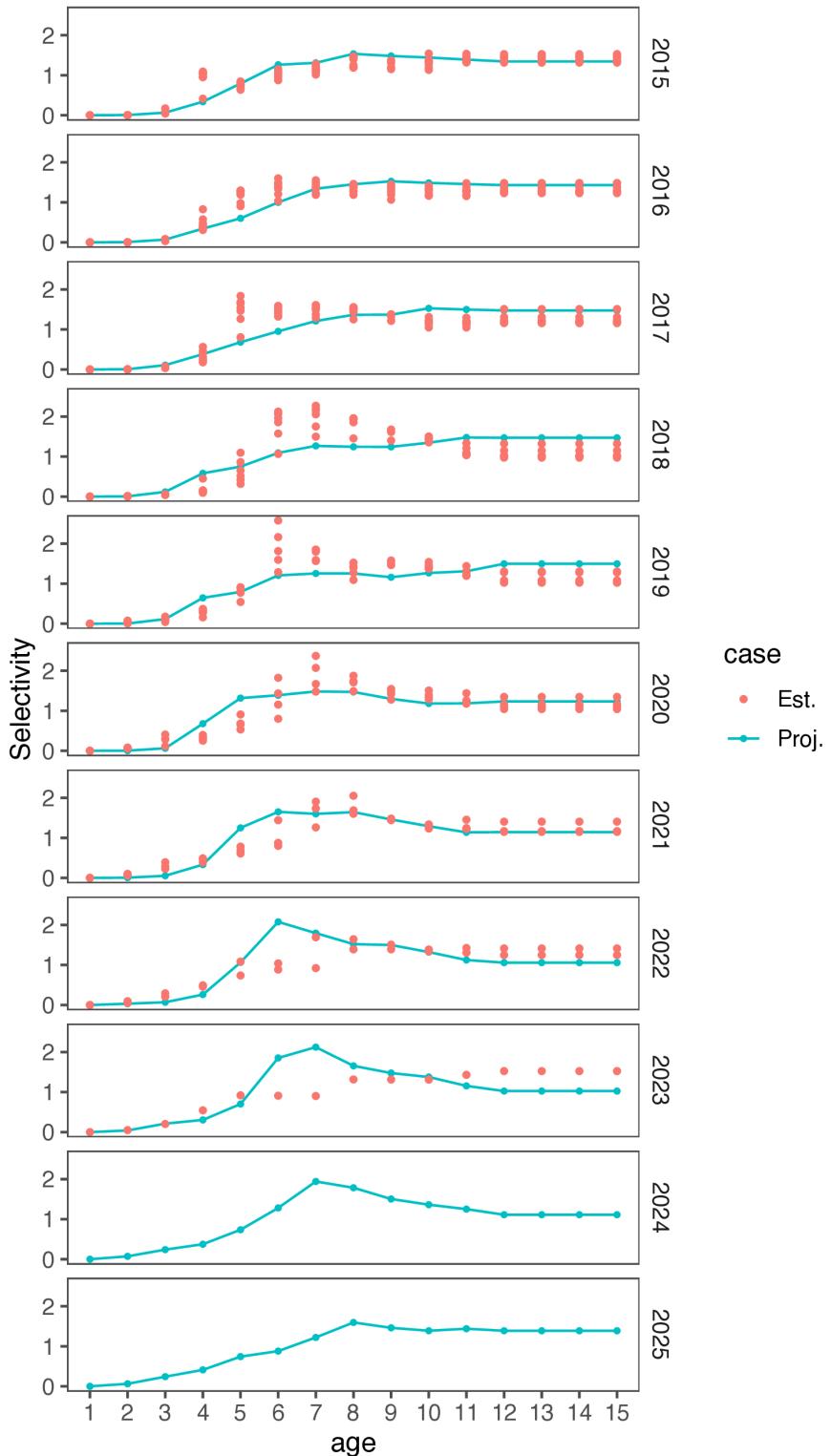


Figure 58: Retrospective pattern for estimated EBS pollock fishery selectivity (dots) compared to the projected selectivity from the year prior (solid line). The multiple dots are from subsequent retrospective runs—e.g., the single set of dots for 2023 are this year's estimate of selectivity in that year (whereas the line is the retrospective estimate as if it was the 2023 ‘assessment’).

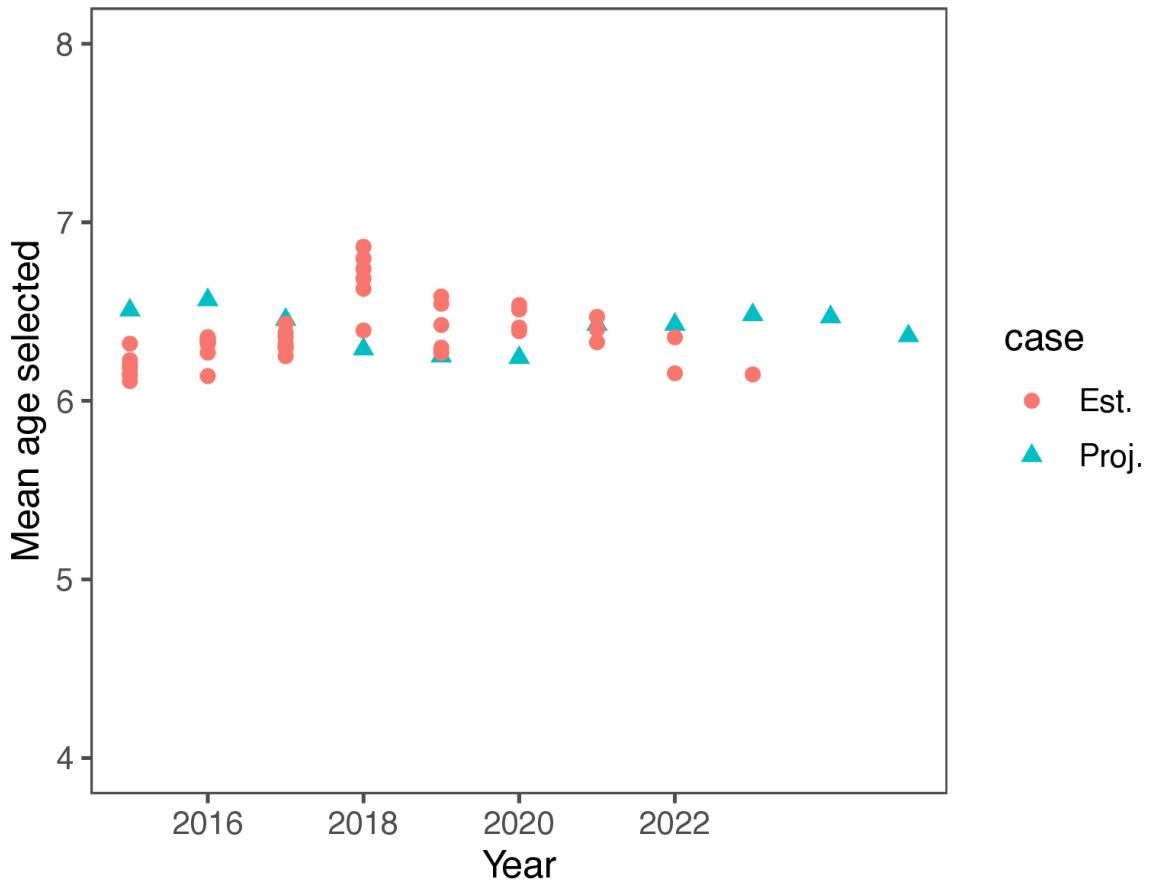


Figure 59: Retrospective pattern for the mean selected age by based on estimated pollock fishery selectivity for a specified peel year (red dots) as compared to the mean selected age of the projected selectivity from the previous peel year. All calculations use the current model configuration.

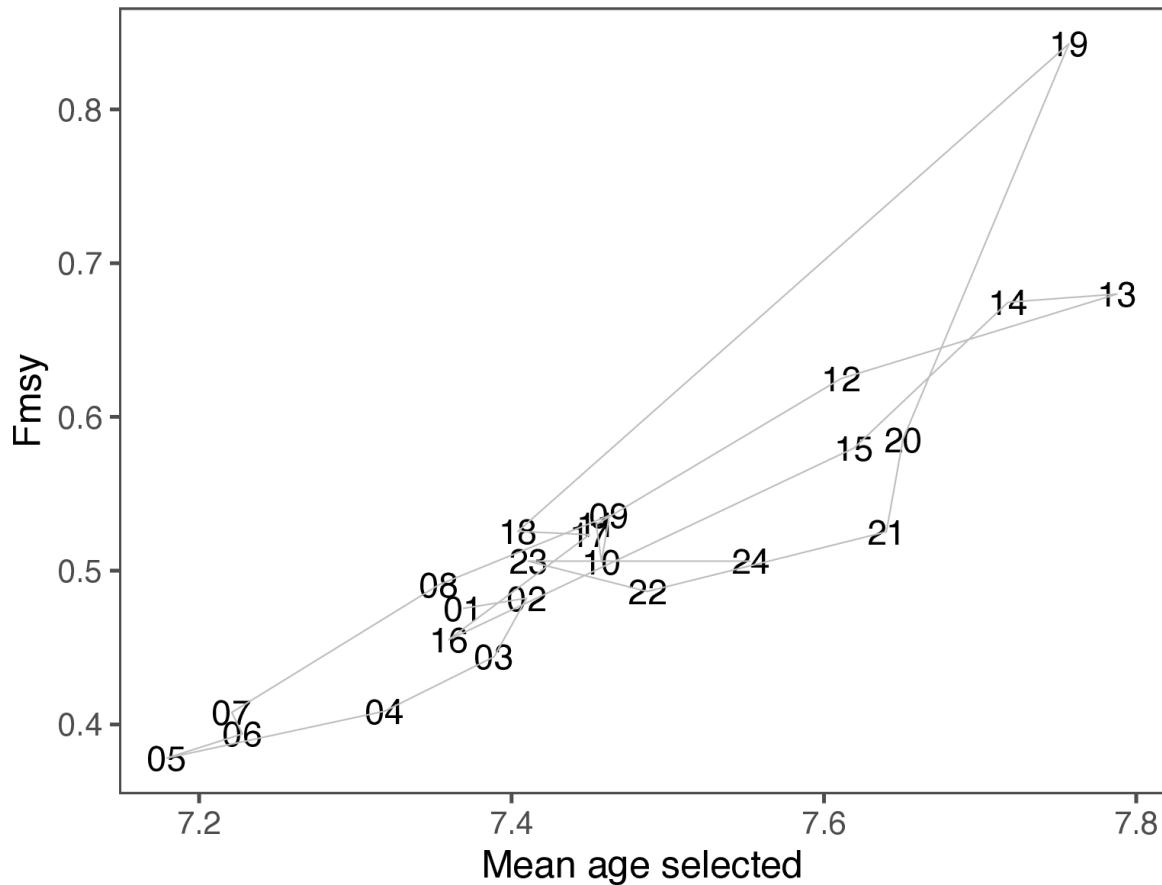


Figure 60: Comparison of F_{MSY} and mean selected age from the current assessment (Model 23.0). The horizontal axis is a way to summarize if selectivity tends towards younger or older fish. Labels (and each point) are from the demographic parameters (weight-at-age, selectivity-at-age) used to compute F_{MSY} .

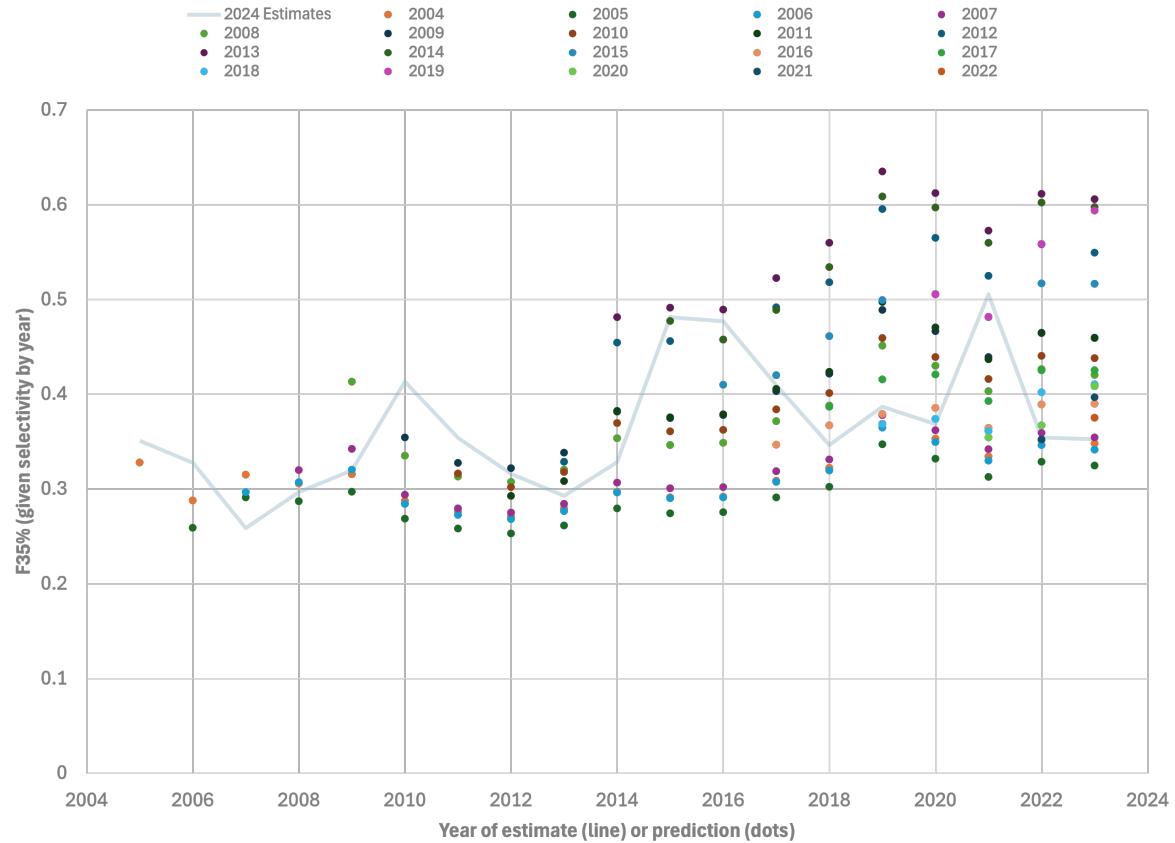


Figure 61: A single case (recent-year selectivity) retrospective predictions of F35% given the current (model 23) 2024 estimates (grey line) compared to each retrospective prediction of that fishing mortality rate (dots).

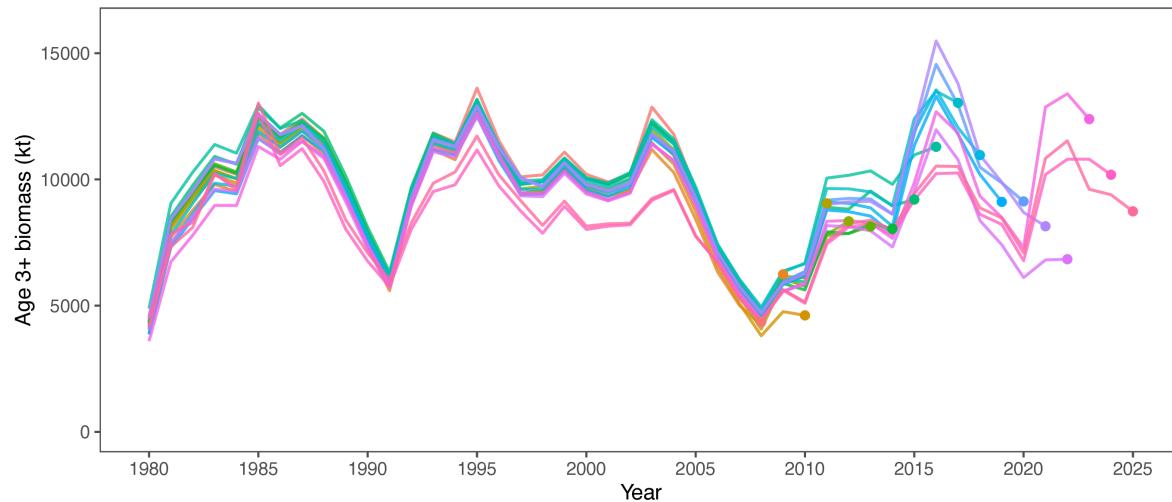


Figure 62: Comparison of the current assessment results with past assessments of begin-year EBS age-3+ pollock biomass.

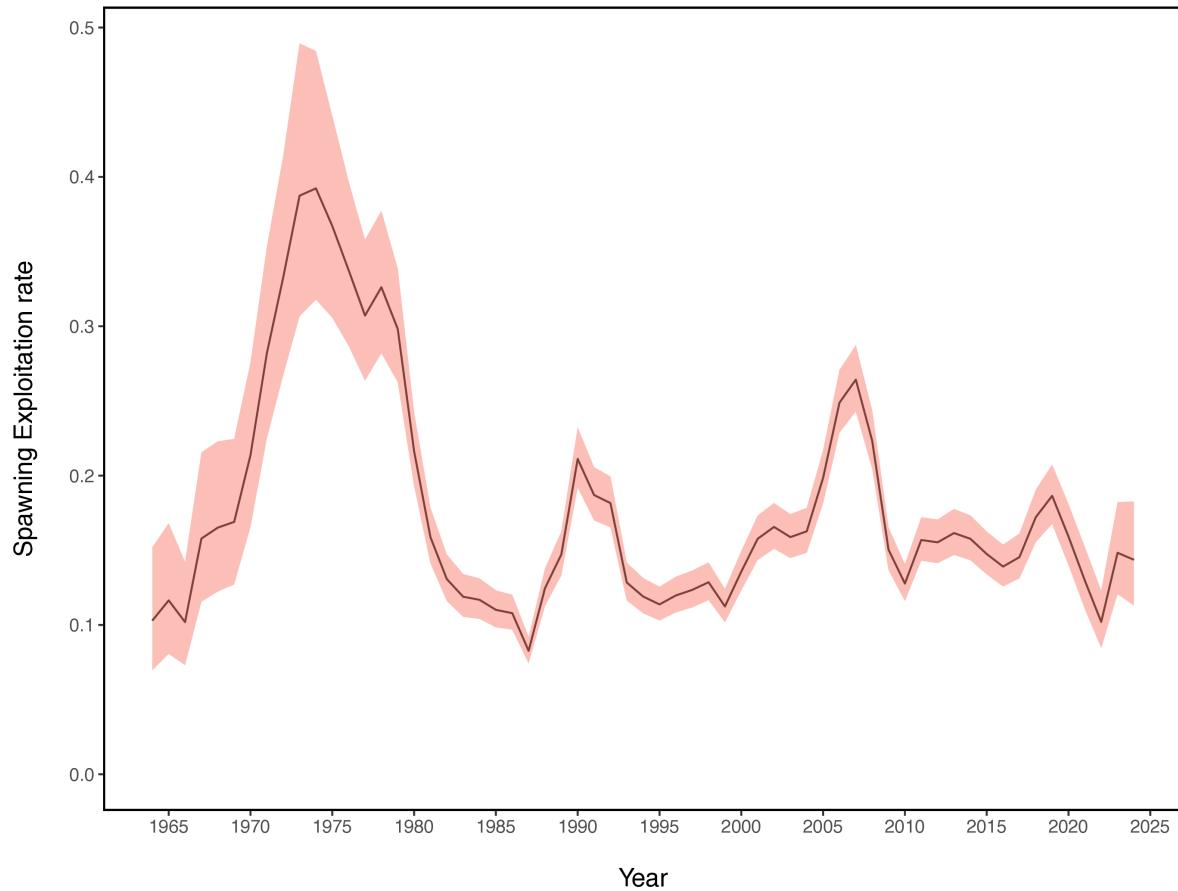


Figure 63: Estimated spawning exploitation rate (defined as the percent removal of egg production in a given spawning year).

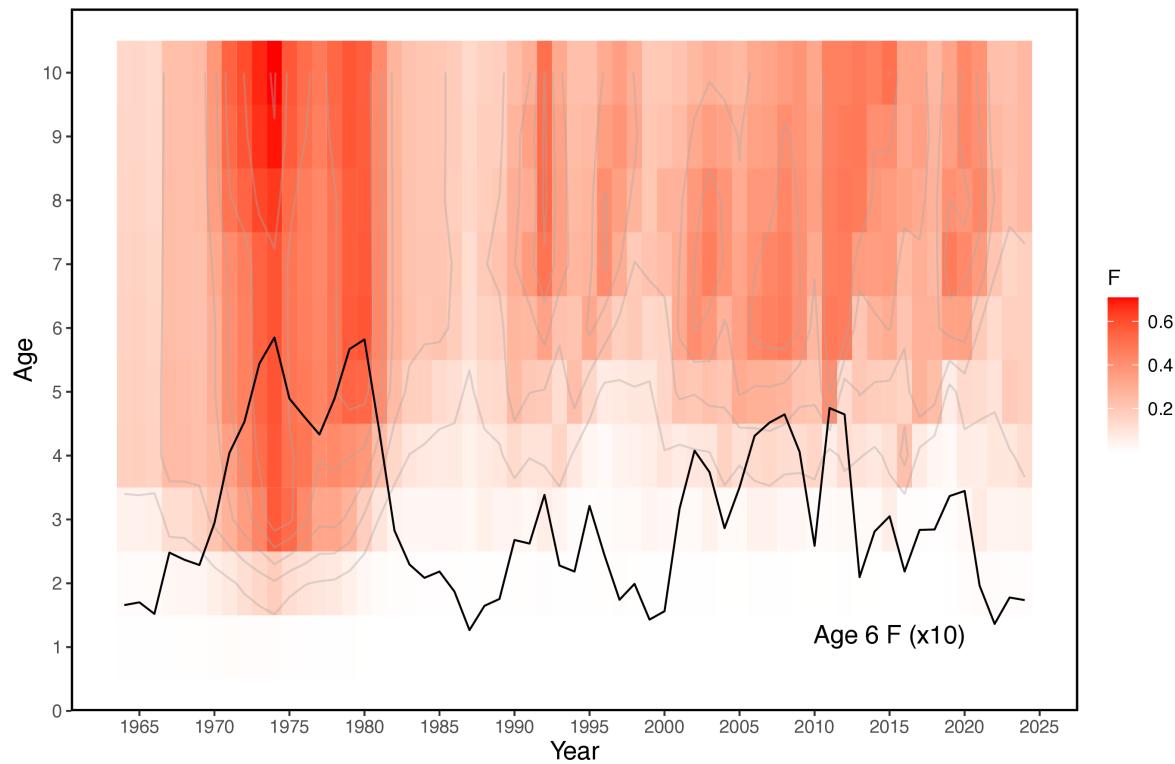


Figure 64: Estimated instantaneous age-specific fishing mortality rates for EBS pollock.

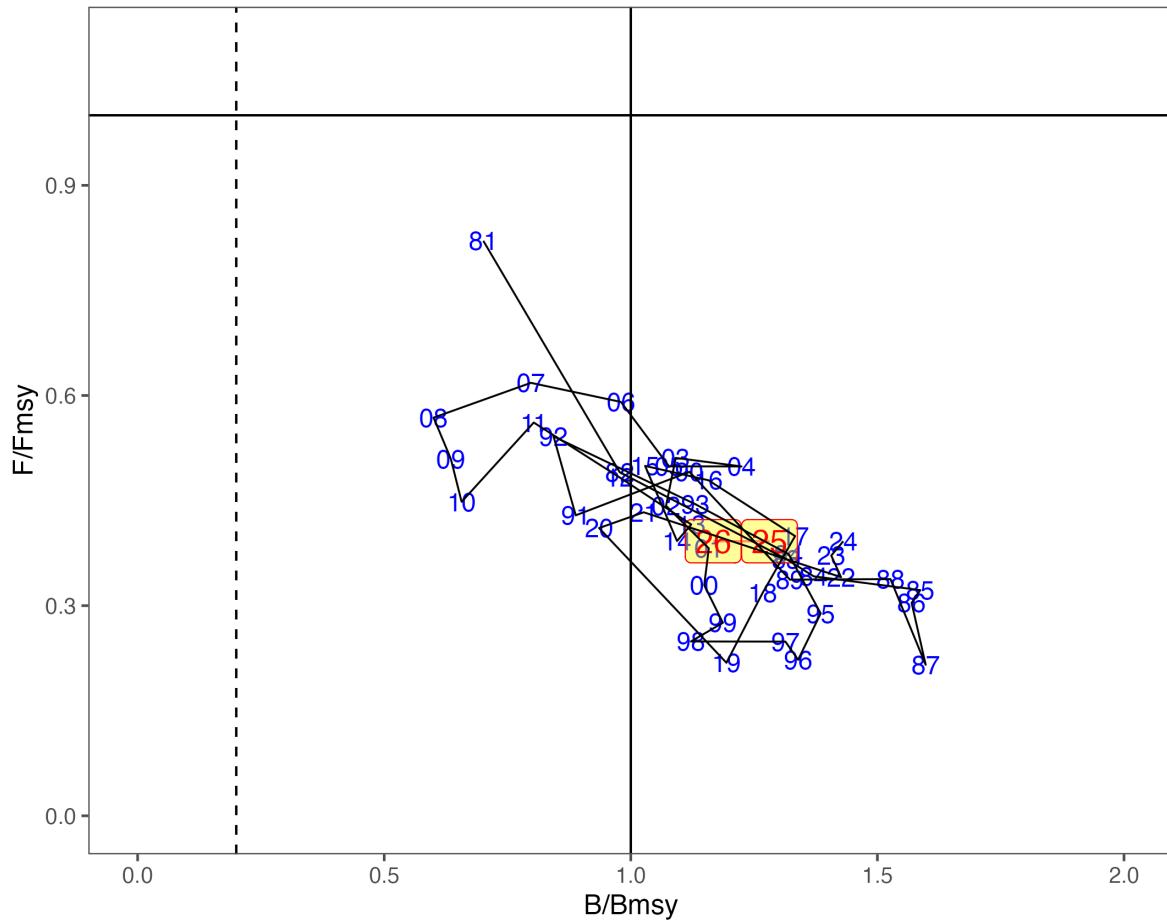


Figure 65: Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock. Two projection years are shaded in yellow.

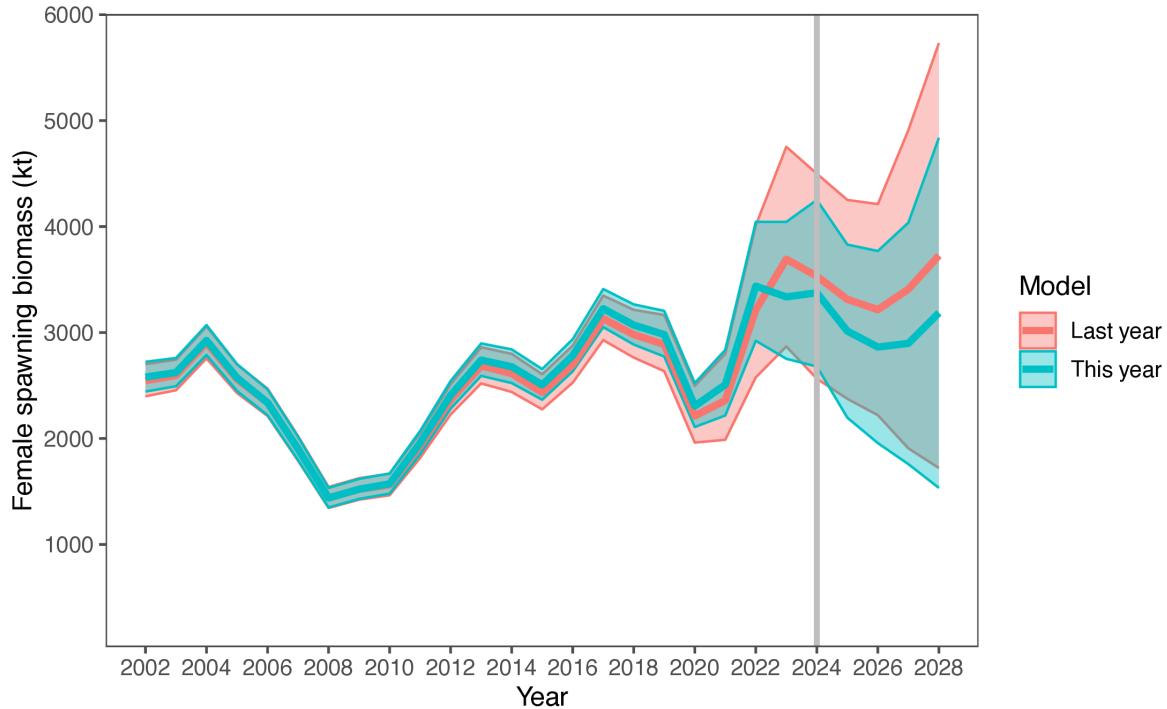


Figure 66: The estimated EBS pollock spawning stock biomass for model 23 last year and this with projections equal to the estimated fishing mortality from 2024.

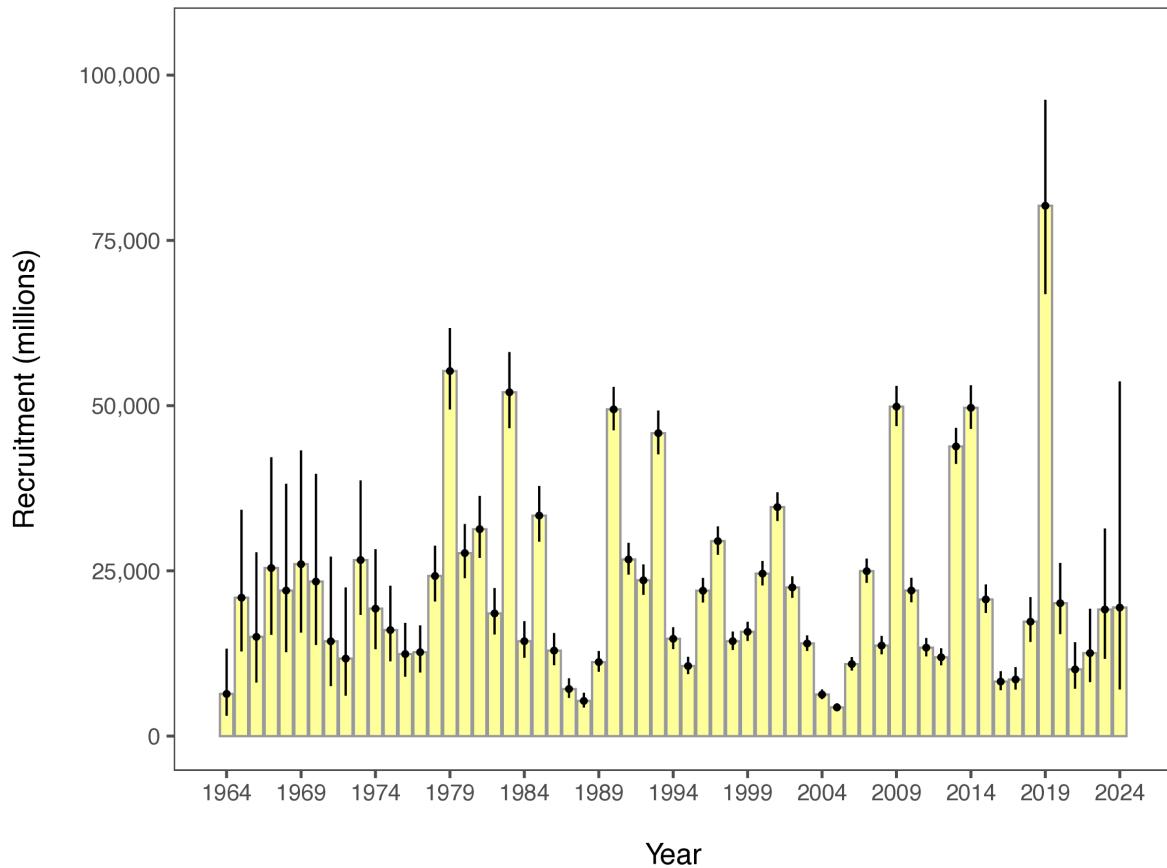


Figure 67: Recruitment estimates (age-1 recruits) for EBS pollock for all years since 1964 (1963–2023 year classes) for Model 23. Error bars reflect 90% credible intervals based on model estimates of uncertainty.

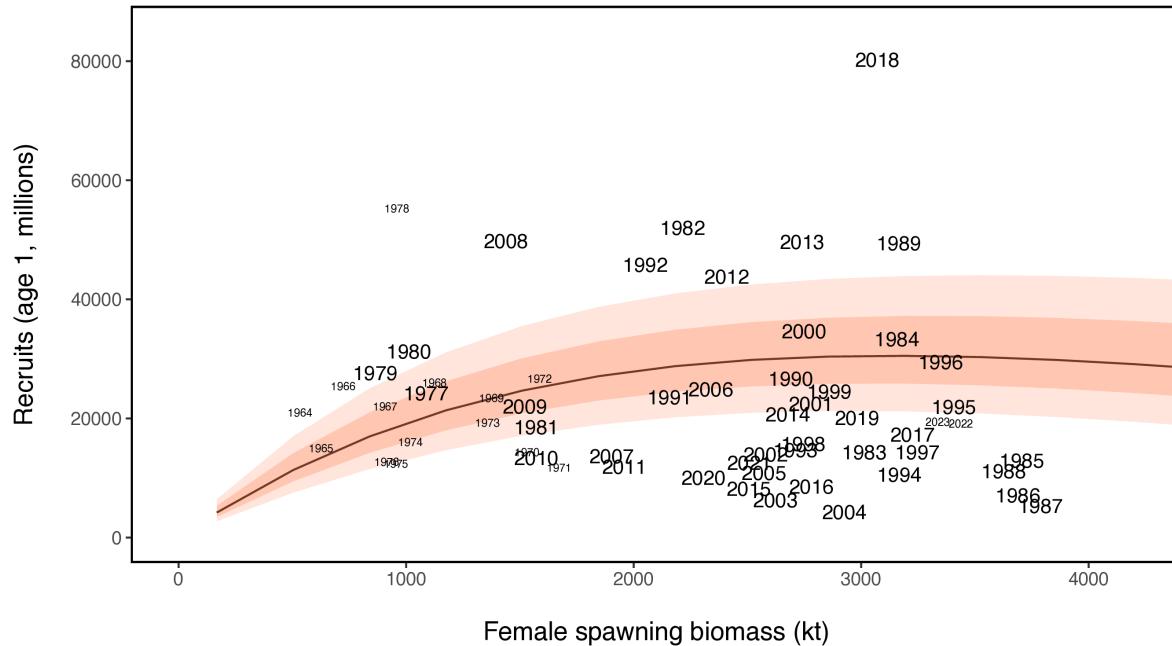


Figure 68: Stock-recruitment estimates (shaded represents structural uncertainty) and age-1 EBS pollock estimates labeled by year-classes.

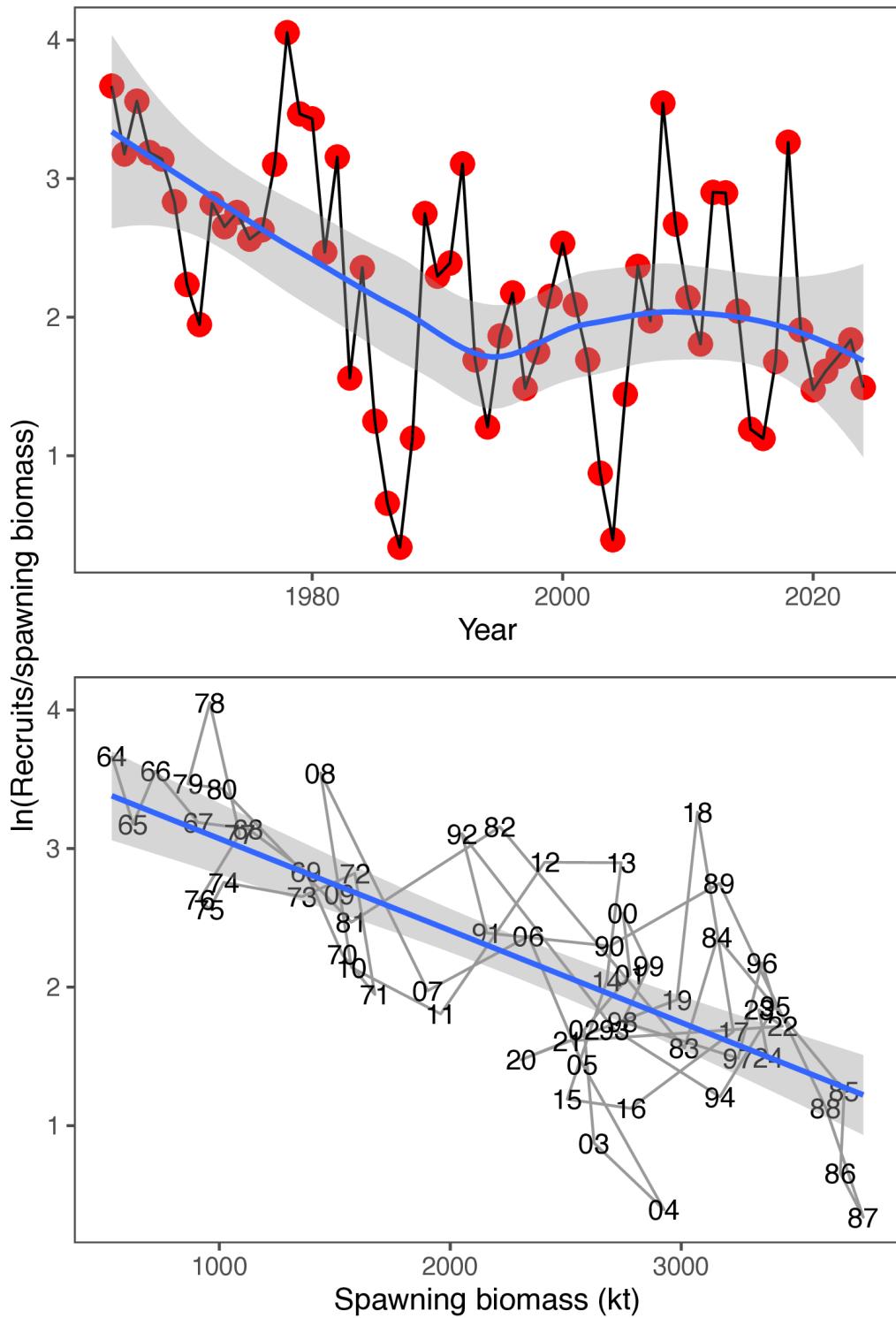


Figure 69: EBS pollock productivity as measured by logged recruits per spawning biomass, $\log(R/S)$, as a function of spawning biomass with a linear fit (bottom) and over time, 1964–2024 with a smooth function overlain (top).

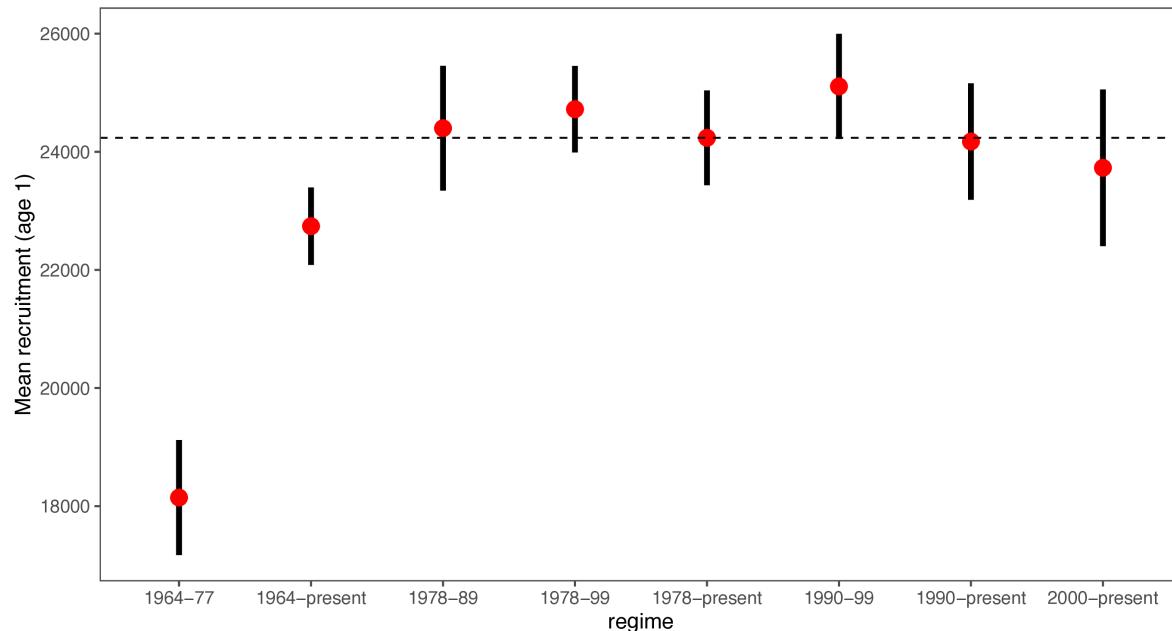


Figure 70: Mean recruitment estimates (age-1) for EBS pollock for different periods with error bars representing 95% credible intervals.

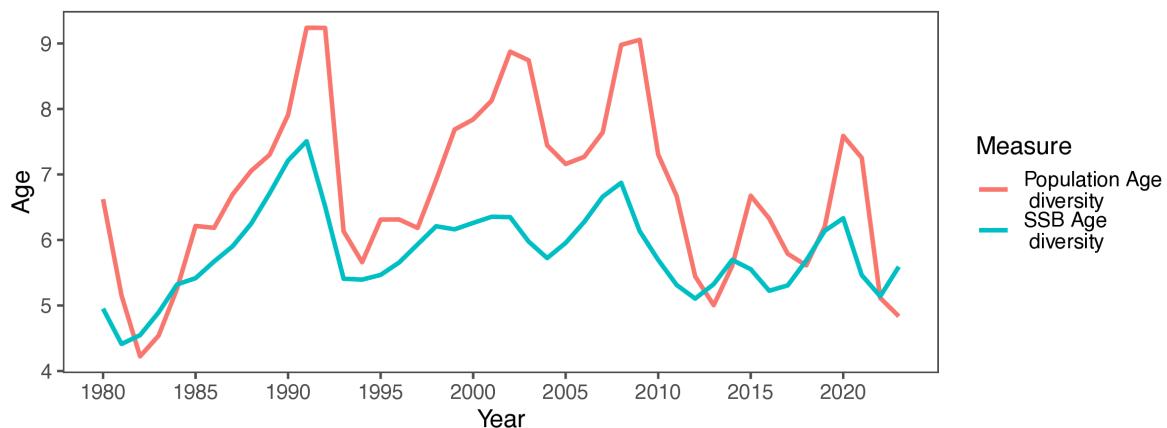


Figure 71: For the mature component of the EBS pollock stock, time series of estimated average age and diversity of ages (using the Shannon-Wiener H statistic), 1980–2024.

Alternative 1

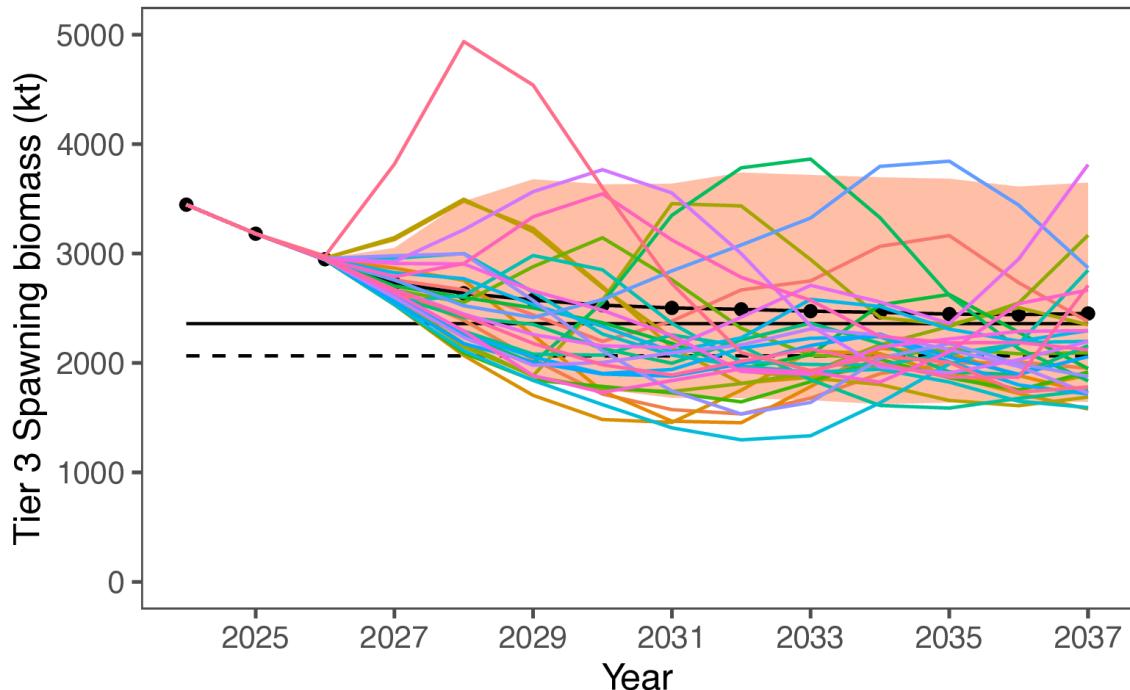
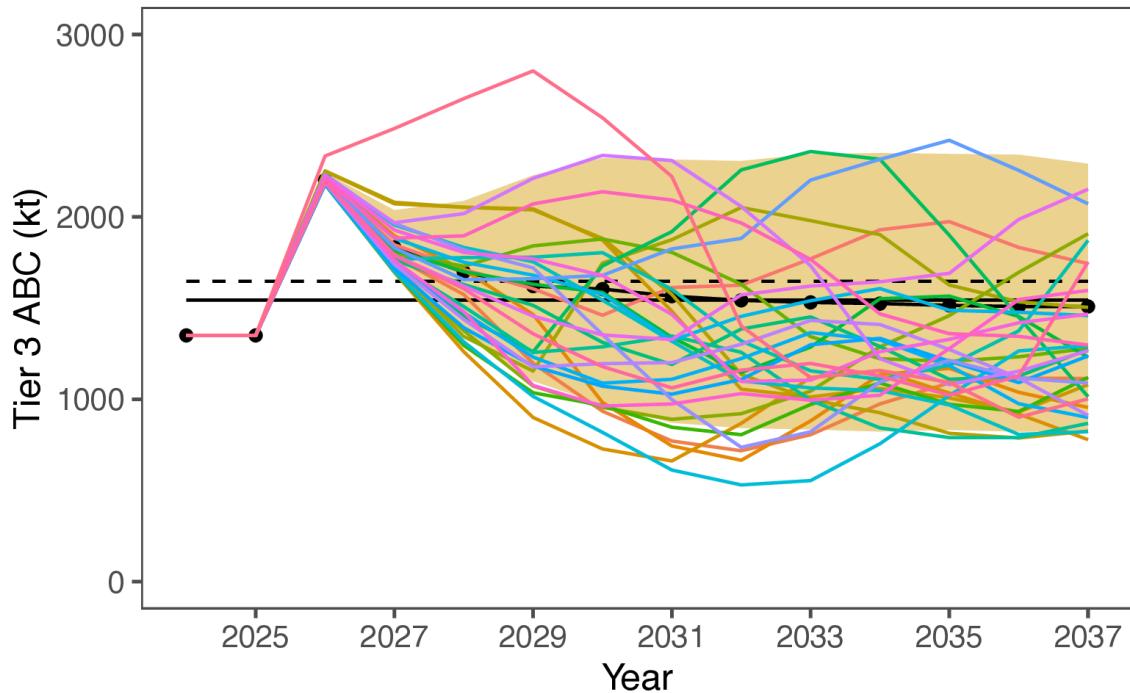


Figure 72: Projected EBS Tier 3 pollock yield (top) and female spawning biomass (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978–2020. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1.

Alt 3, mean F

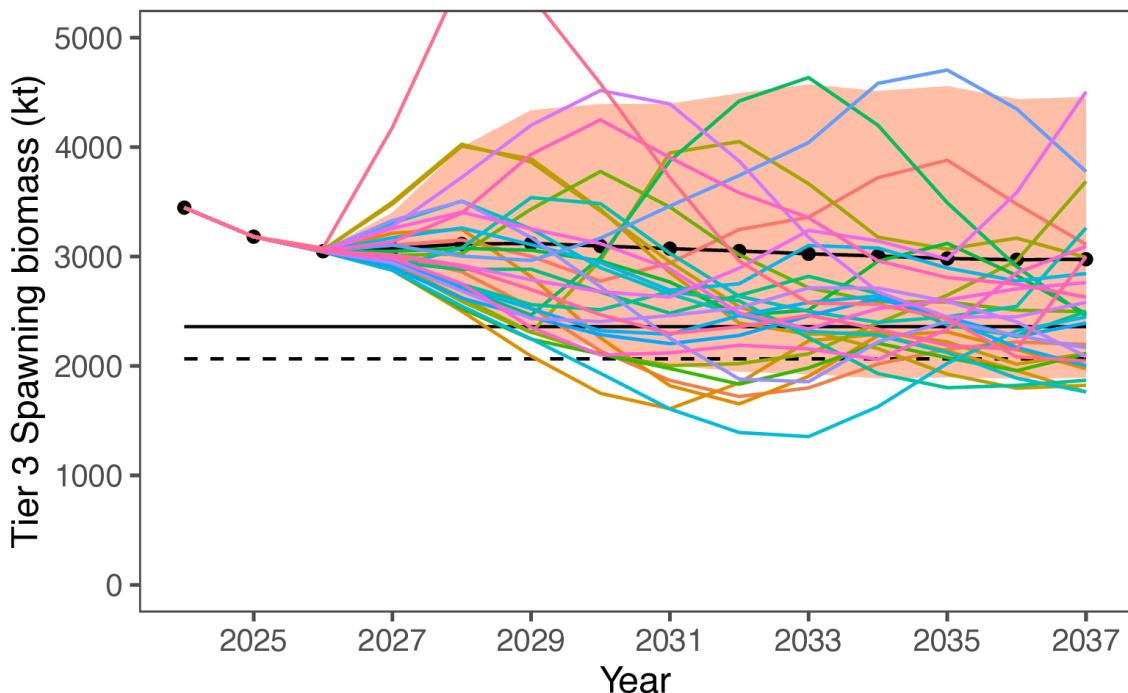
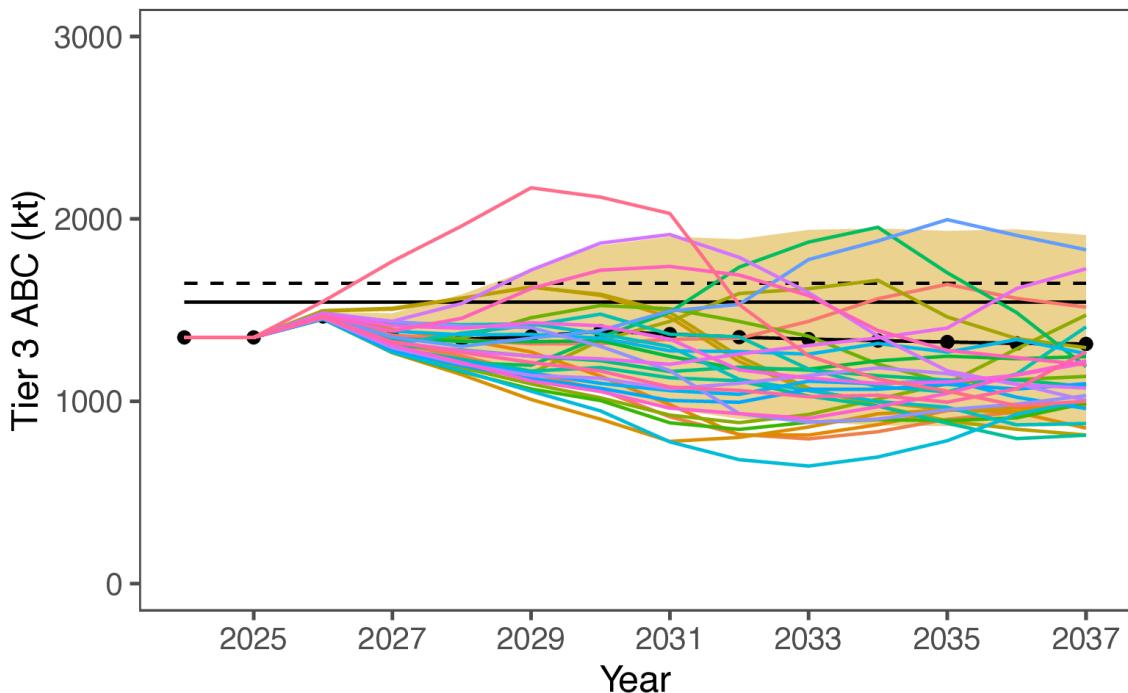


Figure 73: Projected pollock yield (top) and female spawning biomass (bottom) under Alternative 3—fishing under the recent 5-year average fishing mortality. The long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines) $B_{40\%}$ are computed from average recruitment from 1978–2020.

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 D. Fournier and Archibald (1982) and elsewhere (e.g., Hilborn and Walters (1992), Jon T. 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:

$$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}} (1 - e^{-Z_{t,a}}) N_{t,a}, \quad 1 \leq t \leq T, 1 \leq a \leq A \quad (14.1)$$

$$N_{t+1,a+1} = N_{t,a-1} e^{-Z_{t,a-1}} \quad 1 \leq t \leq T, 1 \leq a < A \quad (14.2)$$

$$N_{t+1,A} = N_{t,A-1} e^{-Z_{t,A-1}} + N_{t,A} e^{-Z_{t,A}}, \quad 1 \leq t \leq T \quad (14.3)$$

$$Z_{t,a} = F_{t,a} + M_{t,a} \quad (14.4)$$

$$C_{t,.} = \sum_{a=1}^A C_{t,a} \quad (14.5)$$

$$p_{t,a} = \frac{C_{t,a}}{C_{t,.}} \quad (14.6)$$

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, Ianelli, and Hilborn (2003) :

$$F_{t,a} = s_{t,a} \mu^f e^{\epsilon_t}, \quad \epsilon_t \sim \mathcal{N}(0, \sigma_E^2) \quad (14.7)$$

$$s_{t+1,a} = s_{t,a} e^{\gamma_t}, \quad \gamma_t \sim \mathcal{N}(0, \sigma_s^2) \quad (14.8)$$

where $s_{t,a}$ is the selectivity for age class a in year t , and μ^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:

$$s_{t,a} = [1 + e^{-\alpha_t a - \beta_t}]^{-1}, \quad a > 1 \quad (14.9)$$

$$s_{t,a} = \mu_s e^{-\delta_t^\mu}, \quad a = 1 \quad (14.10)$$

$$\alpha_t = \bar{\alpha} e^{\delta_t^\alpha}, \quad (14.11)$$

$$\beta_t = \bar{\beta} e^{\delta_t^\beta}, \quad (14.12)$$

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

$$\delta_t^\mu - \delta_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\delta^\mu}^2) \quad (14.13)$$

$$\alpha_t^\mu - \alpha_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\alpha^\mu}^2) \quad (14.14)$$

$$\beta_t^\mu - \beta_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\beta^\mu}^2) \quad (14.15)$$

The parameters to be estimated in this part of the model are thus for t=1982 through to 2024. 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.

$$\ln(s_{t,a}) - \ln(s_{t+1,a}) \sim \mathcal{N}(0, \sigma_{sel}^2) \quad (14.16)$$

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 ν 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 ($\hat{\bar{a}}_t$):

$$\nu = \text{var} \left(r_t^a \sqrt{\frac{N_t}{\kappa_t}} \right)^{-1} \quad (14.17)$$

$$r_t^a = \bar{a}_t - \hat{\bar{a}}_t \quad (14.18)$$

$$\kappa_t = \left[\sum_a^A \bar{a}_t - \hat{\bar{a}}_t \right]^{0.5} \quad (14.19)$$

where r_t^a is the residual of mean age and

$$\hat{\bar{a}}_t = \sum_a^A a \hat{p}_{ta} \quad (14.20)$$

$$\bar{a}_t = \sum_a^A a p_{ta} \quad (14.21)$$

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.

$$R_t = f(B_{t-1}) \quad (14.22)$$

with mature spawning biomass during year t was defined as:

$$B_t = \sum_{a=1}^A w_{t,a} \phi_a N_{t,a} \quad (14.23)$$

and, ϕ_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 R. I. C. C. Francis (1992) was used. For the optional Beverton-Holt form (the Ricker form presented in Eq. 12 was adopted for this assessment) we have:

$$R_t = \frac{B_{t-1} e^{\varepsilon_t}}{\alpha + \beta B_{t-1}} \quad (14.24)$$

where

- R_t is recruitment at age 1 in year t ,
- B_t is the biomass of mature spawning females in year t ,
- ε_t is the recruitment anomaly for year t , ($\varepsilon_t \sim \mathcal{N}(0, \sigma_R^2)$)
- α, β 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 R. I. C. C. Francis (1992), so that:

$$\alpha = \tilde{B}_0 \frac{1-h}{4h} \quad (14.25)$$

$$\beta = \frac{5h-1}{4hR_0} \quad (14.26)$$

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 σ_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) :

$$R_t = \frac{B_{t-1} e^{\alpha(1 - B_{t-1} \frac{R_0}{\psi_0})}}{\psi_0} \quad (14.27)$$

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

$$h = \frac{e^\alpha}{e^\alpha + 4} \quad (14.28)$$

so that the prior used on h can be implemented in both the Ricker and Beverton-Holt stock-recruitment forms. Here the term ψ_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:

$$R'_t = \hat{R}_t \frac{f(B'_{t-1})}{f(B_{t-1})} \quad (14.29)$$

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 J. N. 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.

To provide a diagnostic for diversity in the age structure of the spawning biomass, we computed the Shannon entropy in exponential form. Following Jost (2006), and substituting the population's mature age structure in place of species, this provides an estimate of the effective number of ages. This is computed for each year as a measure of different age groups contributing to the spawning population as:

$$H_i = \exp(-\sum p_a \cdot \log(p_a)) \quad (14.30)$$

where p_a is the proportion of mature fish biomass-at-age a in year i .

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):

$$nll(i) = n \sum_{t,a} p_{ta} \ln \hat{p}_{ta} \quad (14.31)$$

$$p_{ta} = \frac{O_{ta}}{\sum_a O_{ta}} \quad \hat{p}_{ta} = \frac{\hat{C}_{ta}}{\sum_a \hat{C}_{ta}} \quad (14.32)$$

$$\mathbf{C} = \mathbf{CE} \quad (14.33)$$

$$\mathbf{E} = \begin{matrix} b_{1,1} & b_{1,2} & \dots & b_{1,15} \\ b_{2,1} & b_{2,2} & & b_{2,15} \\ \vdots & & \ddots & \vdots \\ b_{15,1} & b_{15,2} & \dots & b_{15,15} \end{matrix} \quad (14.34)$$

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 (D. A. Fournier et al. (1990)). Consequently, as the model fit approached a solution, we invoke a robust likelihood function which fit proportions at age as:

$$\prod_{a=1}^A \prod_{t=1}^T \left[\left(\exp \left(-\frac{(p_{ta} - \hat{p}_{ta})^2}{2(\eta_{ta} + 0.1/A)\tau_t^2} \right) + 0.01 \right) \times \frac{1}{\sqrt{2\pi(\eta_{ta} + 0.1/A)\tau_t}} \right] \quad (14.35)$$

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

$$nll(i) = -0.5 \sum_{a=1}^A \sum_{t=1}^T \ln 2\pi (\eta_{ta} + 0.1/A) - \sum_t^T A \ln \tau_t + \sum_{a=1}^A \sum_{t=1}^T \ln \left\{ \exp \left(-\frac{(p_{ta} - \hat{p}_{ta})^2}{(2\eta_{ta} + 0.1/A)\tau_t^2} \right) + 0.01 \right\} \quad (14.36)$$

where

$$\eta_{ta} = p_{ta}(1 - p_{ta}) \quad (14.37)$$

and

$$\tau_t^2 = 1/n_t \quad (14.38)$$

which gives the variance for p_{ta}

$$(\eta_{ta} + 0.1/A)\tau_t^2 \quad (14.39)$$

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:

$$\hat{N}_{ta}^s = e^{-0.5Z_{ta}} N_{ta} q_t^s s_{ta}^S \quad (14.40)$$

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:

$$\hat{N}_{ta}^s = e^{-0.5Z_{ta}} w_{ta} N_{ta} q_t^s s_{ta}^S \quad (14.41)$$

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:

$$nll(i) = \sum_t \frac{\ln(u_t^s / \hat{N}_t^s)^2}{2\sigma_{s,t}^2} \quad (14.42)$$

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:

$$nll(i) = \sum_t \frac{(u_t^s - \hat{N}_t^s)^2}{2\sigma_{s,t}^2}. \quad (14.43)$$

The AT survey and AVO index is modeled using a lognormal distribution whereas for the BTS survey, a multivariate log-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

$$nll_i = 0.5 \mathbf{X} \Sigma^{-1} \mathbf{X}' \quad (14.44)$$

where is a vector of observed minus model predicted values for this index and Σ is the estimated covariance matrix provided from the method provided in Kotwicki, Ianelli, and Punt (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

$$nll_i = 0.5 \sum_t \frac{\ln(C_b^{obs}/\hat{C}_b)^2}{2\sigma_{C_b,t}^2} \quad (14.45)$$

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 '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 J. T. 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 S. B. Ianelli James N. 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 (2024) and future mean weights for each age i , $i= (1, 2,...,15)$, given actual observed mean and variances in weight-at-age over the period 1991-2023. The values of based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

$$w_{ta}^{future} \sim \mathcal{N}(\bar{w}_a, \sigma_{w_a}^2) \quad (14.46)$$

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:

$$\hat{w}_{ta} = \bar{w}_a e^{v_t} \quad a = 1, t \geq 1964 \quad (14.47)$$

$$\hat{w}_{ta} = \hat{w}_{t-1,a-1} + \Delta_a e^{\psi_t} \quad a > 1, t > 1964 \quad (14.48)$$

$$\Delta_a = \bar{w}_{a+1} - \bar{w}_a \quad a < A \quad (14.49)$$

$$\bar{w}_a = \alpha \left\{ L_1 + (L_2 - L_1) \left(\frac{1 - K^{a-1}}{1 - K^{A-1}} \right) \right\}^3 \quad (14.50)$$

where the fixed effects parameters are L_1, L_2, K , and α while the random effects parameters are v_t and ψ_t .

14.6 Tier 1 projections

Tier 1 projections were calculated two ways. First, for 2025 and 2026 ABC and *OFL* levels, the harmonic mean F_{MSY} value was computed and the analogous harvest rate (\bar{u}_{HM}) applied to the estimated geometric mean fishable biomass at B_{MSY} :

$$ABC_t = B_{GM,t}^f \bar{u}_{HM} \zeta_t \quad (14.51)$$

$$B_{GM,t}^f = e^{\ln \hat{B}_t^f - 0.5 \sigma_{B^f}^2} \quad (14.52)$$

$$\bar{u}_{HM,t}^f = e^{\ln \hat{u}_{MSY,t} - 0.5 \sigma_{u_{MSY}}^2} \quad (14.53)$$

$$\zeta_t = \frac{B_t / B_{MSY} - 0.05}{1 - 0.05} \quad B_t < B_{MSY} \quad (14.54)$$

$$\zeta_t = 1.0 \quad B_t \geq B_{MSY} \quad (14.55)$$

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.

14.7 Additional references

15 Appendix Risk table information for environmental/ecosystem considerations

Provided by: Elizabeth Siddon, NOAA/AFSC

15.1 Environmental processes

The eastern Bering Sea (EBS) experienced a prolonged period of above-average thermal conditions from 2014 through 2021. Since 2021, and continuing from August 2023–August 2024, thermal conditions in the EBS have been close to historical baselines of many metrics. There have been no sustained marine heatwaves over the southeastern or northern Bering Sea shelves since January 2021 (Callahan and Lemagie, 2024), and observed (Rohan and Barnett, 2024) and modeled (Kearney, 2024) bottom temperatures were mostly near-normal over the past year. Sea surface temperatures (SSTs) and bottom temperatures were near the long-term means in all regions by summer 2024. Notable deviations include (i) warm SSTs in the outer domain from fall 2023 through spring 2024 and (ii) unusually warm bottom temperatures in the northern outer domain since spring 2024 that may indicate an intrusion of shelf water (Callahan et al., 2024).

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 2023 year class of pollock experienced average late summer temperatures in 2023 during the age-0 stage and cooler spring temperatures in 2024 during the age-1 stage indicating average conditions for the overwintering survival from age-0 to age-1 (Yasumiishi, 2024).

Atmospheric conditions are one of the primary drivers that impact the oceanographic setting in the EBS. Both the North Pacific Index (NPI) and Aleutian Low Index (ALI) provide complementary views of the atmospheric pressure system in the North Pacific. During winter 2023-2024, the NPI was average (Siddon, 2024) and the strength and location of the Aleutian Low Pressure System were both near climatological averages (Overland and Wang, 2024). Thus, despite delayed formation of sea ice in fall 2023 (Thoman, 2024), cold winds from the Arctic helped advance sea ice to near-normal extent by mid-winter. Near-normal sea ice extent and thickness (Thoman, 2024b, 2024c) may have contributed to a cold pool (<2°C water) of average spatial extent (Siddon, 2024), though the footprint of the coldest waters (<0°C) in 2024 was 75% smaller than in 2023 (Rohan and Barnett, 2024b).

December 2023 had significant along-shelf winds (to the southeast) that could have driven offshore Ekman transport. Weaker, but more sustained winds that also favored offshore transport occurred from March to May 2024 (Hennon, 2024). Beginning in May and continuing through summer 2024, persistent storms resulted in a deeper mixed layer, which entrained deeper, cooler water, such that SSTs remained cooler through at least August 2024 (Stabeno, 2024). During the fall BASIS survey, age-0 pollock were found shallower in the water column, more comparable to a warm year (Spear and Andrews, 2024).

For projections into 2025, the National Multi-Model Ensemble (NMME) predicts that SSTs over the EBS are expected to be near normal (anomalies within $<0.5^{\circ}\text{C}$ of the 1982–2010 baseline) (Lemagie, 2024). With the expected transition to La Niña, cooler conditions in the EBS may follow. Relatively cool SSTs may contribute to earlier formation of sea ice than has been observed over the last several years (Thoman, 2024b).

15.2 Prey

Metrics of ocean acidification include Ωarag and pH. Ωarag is important for shell formation in pollock prey items like pteropods. Summer 2024 bottom water Ωarag conditions were similar to 2023; bottom waters remain near threshold levels of biological significance with the most corrosive bottom waters found in slope waters and over the northwest shelf (Pilcher et al., 2024).

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 (SEBS) in spring noted moderate abundance of small copepods, but low abundance of large copepods along the middle shelf (higher in the outer shelf) and near-zero abundance of euphausiids in the RZA, which is typical for the spring. In summer, small copepods remained abundant throughout the region. Large copepods remained in low abundance while euphausiids increased, especially towards the northern portion of the SEBS. Euphausiid density during the summer acoustic survey declined in 2024 to the second-lowest value in the time series (Levine and Ressler, 2024). In fall, both small and large copepods as well as euphausiids were in low abundance, but increased towards the north. In the northern Bering Sea (NBS) in fall, small copepods had moderate and consistent abundances throughout the sampling grid, large copepods were patchy with the highest values north and south of St. Lawrence Island, and euphausiids were very low (Kimmel et al., 2024).

Based on Food Habits Lab stomach content analysis, pollock consumption of copepods increased from 2023 to 2024, replacing euphausiids as the greatest percent by weight in the diets (K. Aydin, pers comm). This may be explained by the spatial distribution of the pollock stock in 2024, which was concentrated over the northwest outer domain (L. Barnett, pers comm), where large ‘oceanic’ copepods occur (euphausiids mainly occur over the middle domain). Additionally,

rates of cannibalism have been low between 2021-2024; the lowest year for cannibalism on record was 2018 (K. Aydin, pers comm).

The estimated abundance of larval pollock sampled in spring increased from near the end of the last cold stanza (2012) through the warm stanza (2014, 2016, 2018) to a time-series maximum in 2024 (Rogers et al., 2024). The condition of those larval pollock was highest over the southeastern shelf and lowest to the northwest of the Pribilof Islands (Porter et al., 2024). By late summer, age-0 pollock CPUE estimates in the middle domain of the SEBS and NBS regions were lower than estimates from the recent warm period (2014–2021) but slightly higher than estimates from the cold period (2007–2013) (Andrews et al., 2024). In the inner domain, pollock were the most numerous non-salmonid species collected in the ADF&G nearshore survey (Garcia et al., 2024). In the NBS, CPUE estimates have remained low compared to the SEBS (Andrews et al., 2024). Since 2022, with cooler SSTs, pollock weights and energy density have been low while % lipid has been average (Page et al., 2024).

In the SEBS, juvenile (100–250 mm) fish condition has shown a declining trend since 2021 while adult (>250 mm) fish condition increased from 2023 to 2024, but remains below the long-term mean. In the NBS (data through 2023), juvenile fish condition has also declined since 2021, but adult fish condition increased since 2021 and was above average in 2023 (Prohaska et al., 2024). The availability of surface silicate, a proxy for phytoplankton growth, serves as an indicator of age-0 pollock condition. Low silicate availability and significant declines in pollock weight observed in 2022 may signal poorer recruitment to age-1 for the 2022 year class (Gann and Eisner, 2024).

15.3 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. The biomass of jellyfish over the southeastern shelf in 2024 remained low (Yasumiishi et al., 2024) to average (Buser and Rohan, 2024) while biomass remained high in the NBS (Yasumiishi et al., 2024). The 2024 forecast for Togiak herring was the fifth highest on record, but was 32% lower than the 2023 forecast (Dressel et al., 2024).

Western Alaska chum salmon showed trends of increasing adult returns, juvenile abundance, and above-average to average juvenile condition in recent years, which indicates potential signs of recovery for these populations. In contrast, western Alaska Chinook salmon do not appear to show signs of recovery in response to the recent cooler conditions observed since 2021. The abundance of Bristol Bay sockeye salmon peaked in 2021–2022, but cooler conditions since then have resulted in run sizes closer to the long-term average in 2023–2024 (DeFilippo, 2024). The condition (based on energy density anomalies) of juvenile pink, chum, coho, and Chinook salmon in the SEBS indicated lower energy stores and reduced capacity for overwinter survival. Juvenile salmon in the NBS had average to positive energy stores, which may contribute to higher overwinter survival (Fergusson et al., 2024).

The biomass of pelagic foragers measured during the standard bottom trawl survey (Jun-Aug; 1982–2024) increased 71% from 2023 to 2024 to just above their long-term mean. The trend is largely driven by pollock, which increased 78% from 2023. Pacific herring decreased 5% from 2023, but remain above their long-term mean (Siddon, 2024). 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.

15.4 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). However, rates of cannibalism have been low between 2021-2024 (K. Aydin, pers comm). In 2024, 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.

Other potential predators of juvenile pollock include arrowtooth flounder, jellyfish and chum salmon. In the SEBS, the biomass of apex predators, which includes arrowtooth flounder, in 2024 remained just below the long term mean of that guild. Within that guild, however, arrowtooth flounder increased 26% from 2023 to 2024 (Siddon, 2024). Arrowtooth were distributed over the southern outer domain while pollock were distributed over the northern outer domain. As stated above, jellyfish biomass in the SEBS in 2024 remained low (Yasumiishi et al., 2024) to average (Buser and Rohan, 2024) while biomass was high in the NBS (Yasumiishi et al., 2024). Western Alaska chum salmon showed trends of increasing adult returns (DeFilippo, 2024).

15.5 Summary for Environmental/Ecosystem considerations:

- **Environment:** The EBS shelf experienced oceanographic conditions that were largely average based on historical time series of multiple metrics over the past year (August 2023 - August 2024).
- **Prey:** Trends of prey for pollock were mostly low in 2024, with prey conditions over the SEBS shelf being potentially more limiting while prey conditions over the NBS shelf appear limiting for age-0 and juvenile pollock, but sufficient for adult fish. The spatial distribution of adult pollock appears to have overlapped with large ‘oceanic’ copepods, while rates of cannibalism indicate reduced overlap with juvenile pollock.
- **Competitors:** Trends in potential competitors were mixed over the shelf, with pollock representing the greatest increase in biomass and potential competitive pressure.
- **Predators:** Trends in potential predators increased over the shelf, though spatial mismatch may mitigate realized predation pressure. Rates of cannibalism remained low in 2024.

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

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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 20232019, 2021–2023 surveys. 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.

16.3.1 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 74). Index values and error terms (based on diagonal of covariance matrix over time) are shown in Figure 75.

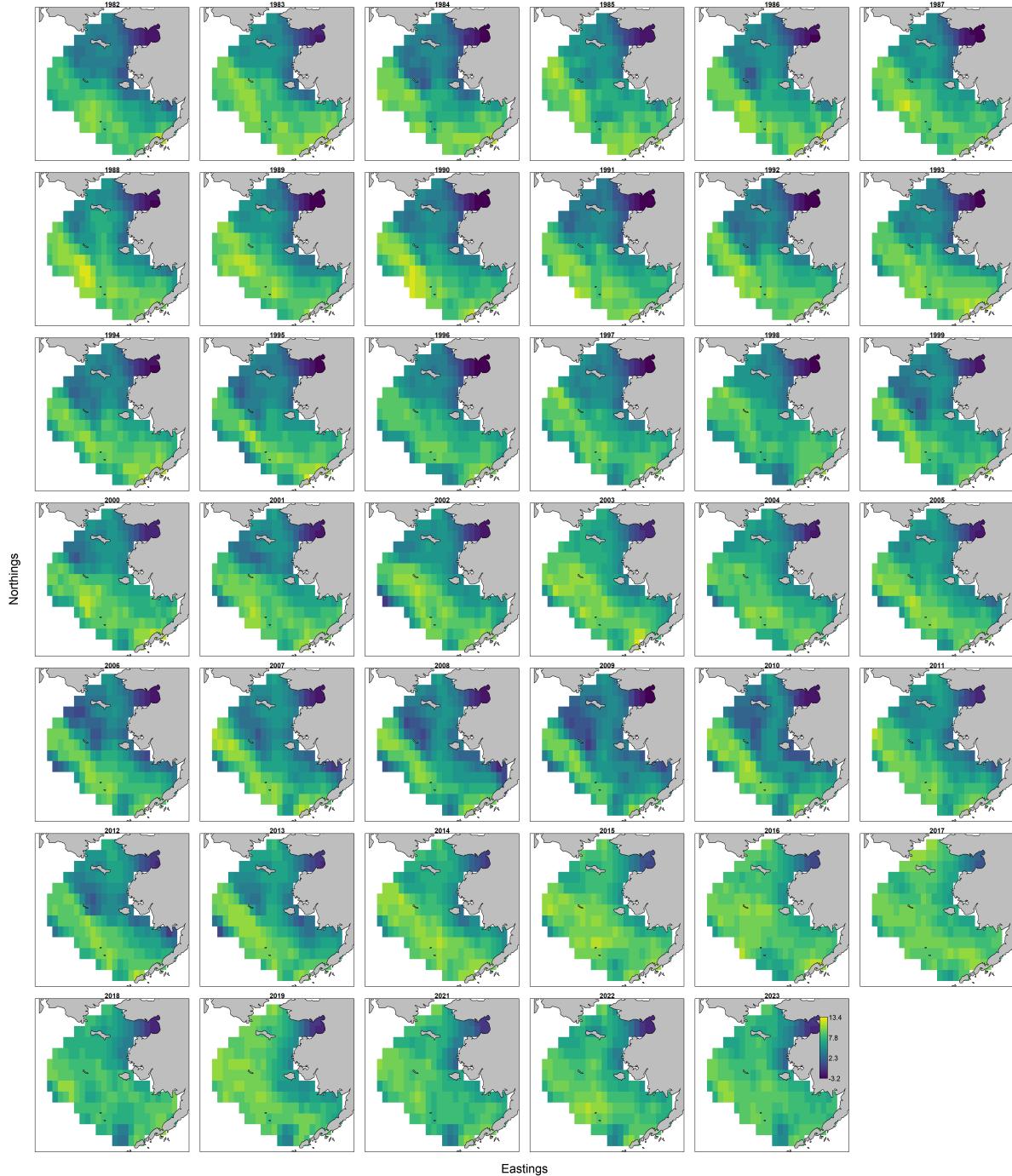


Figure 74: Pollock log density maps of the BTS data using the VAST model approach, 1982-2019, 2021-2023.

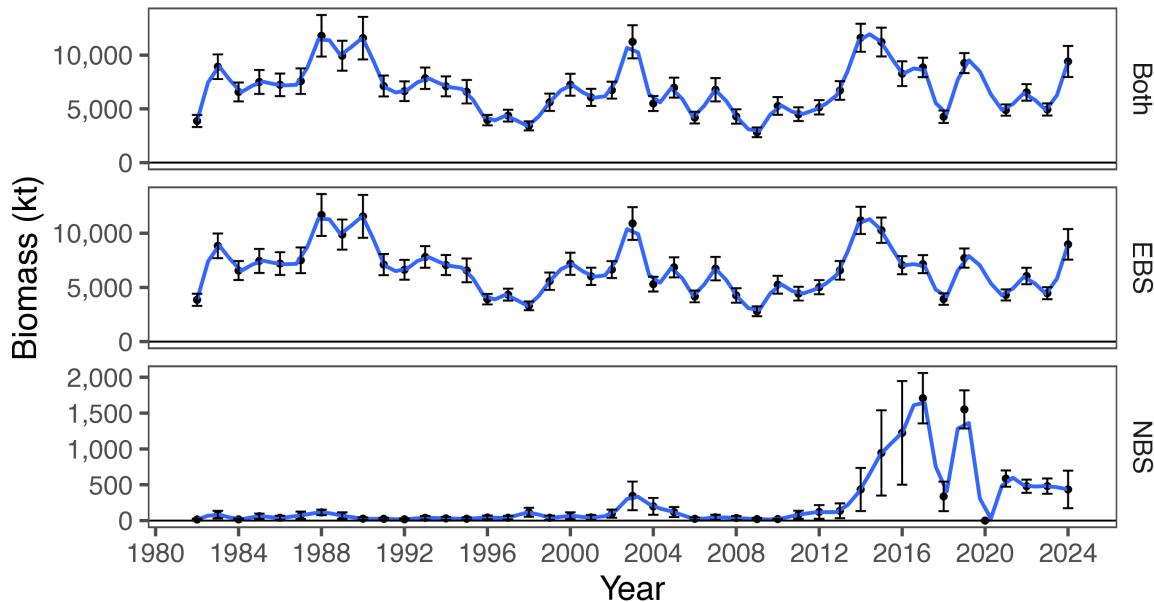


Figure 75: Pollock index values for the standard survey region, the NBS, and combined based on the VAST application to density-dependent corrected CPUE values from the BTS data, 1982–2019, 2021–2024.

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17 Parameter estimates for the EBS pollock reference model

The names and dimensions of parameters used in model 23 are shown in Table 1. The parameter estimates and standard deviations are shown in Table 2.

Table 1: Parameter labels and dimensions used in the EBS pollock model 23.

Number of parameters and dimensions	
Parameter name	N
L1	1
L2	1
coh_eff	72
d_scale	13
log_F_devs	61
log_K	1
log_Rzero	1
log_avg_F	1
log_avginit	1
log_avgrec	1
log_initdevs	14
log_q_ats	1
log_q_avo	1
log_q_cpue	1
log_rec_devs	61
rec_dev_future	5
sel_a50_bts	1
sel_a50_bts_dev	43
sel_age_one_bts	1
sel_age_one_bts_dev	43
sel_coffs_ats	7
sel_coffs_fsh	12
sel_devs_ats	210

sel_devs_fsh	708
sel_slp_bts	1
sel_slp_bts_dev	43
steepness	1
yr_eff	60
sum —	1,366

Table 2: Parameter estimates and standard dfor the EBS pollock Model 23.

List of parameters

Parameter	Est.	Stdev.	Parameter	Est.	Stdev.
log_avgrec	9.827	0.093	sel_devs_fsh	0.056	0.277
log_avginit	4.816	0.692	sel_devs_fsh	0.011	0.420
log_avg_F	-1.419	0.060	sel_devs_fsh	-0.055	0.346
log_q_ats	-0.616	0.066	sel_devs_fsh	0.041	0.285
log_Rzero	10.073	0.269	sel_devs_fsh	-1.072	0.256
steepness	0.622	0.076	sel_devs_fsh	0.420	0.247
log_q_cpue	0.101	0.170	sel_devs_fsh	0.354	0.274
log_q_avo	-8.187	0.077	sel_devs_fsh	0.128	0.293
log_initdevs	3.317	0.765	sel_devs_fsh	0.018	0.279
log_initdevs	2.833	0.767	sel_devs_fsh	0.026	0.275
log_initdevs	1.298	0.858	sel_devs_fsh	0.096	0.274
log_initdevs	0.471	1.002	sel_devs_fsh	0.060	0.283
log_initdevs	1.145	0.877	sel_devs_fsh	-0.027	0.278
log_initdevs	0.351	1.032	sel_devs_fsh	-0.023	0.420
log_initdevs	-0.786	1.385	sel_devs_fsh	0.199	0.366
log_initdevs	-1.243	1.544	sel_devs_fsh	0.186	0.273
log_initdevs	-1.236	1.546	sel_devs_fsh	0.608	0.257
log_initdevs	-1.231	1.548	sel_devs_fsh	-1.089	0.257
log_initdevs	-1.228	1.549	sel_devs_fsh	-0.021	0.250
log_initdevs	-1.229	1.548	sel_devs_fsh	0.007	0.272
log_initdevs	-1.231	1.548	sel_devs_fsh	0.036	0.288
log_initdevs	-1.233	1.547	sel_devs_fsh	0.022	0.283
log_rec_devs	-1.069	0.383	sel_devs_fsh	-0.040	0.298
log_rec_devs	0.121	0.265	sel_devs_fsh	0.032	0.289
log_rec_devs	-0.210	0.326	sel_devs_fsh	0.083	0.269
log_rec_devs	0.318	0.273	sel_devs_fsh	0.012	0.420
log_rec_devs	0.175	0.295	sel_devs_fsh	-0.202	0.371
log_rec_devs	0.342	0.275	sel_devs_fsh	0.025	0.292
log_rec_devs	0.236	0.286	sel_devs_fsh	-0.129	0.249
log_rec_devs	-0.253	0.339	sel_devs_fsh	0.504	0.257
log_rec_devs	-0.455	0.345	sel_devs_fsh	-0.622	0.260
log_rec_devs	0.366	0.212	sel_devs_fsh	-0.138	0.273
log_rec_devs	0.048	0.216	sel_devs_fsh	0.064	0.303
log_rec_devs	-0.121	0.200	sel_devs_fsh	0.130	0.290
log_rec_devs	-0.384	0.190	sel_devs_fsh	0.144	0.291

log_rec_devs	-0.332	0.172	sel_devs_fsh	0.113	0.292
log_rec_devs	0.273	0.133	sel_devs_fsh	0.100	0.269
log_rec_devs	1.124	0.112	sel_devs_fsh	-0.019	0.420
log_rec_devs	0.386	0.127	sel_devs_fsh	0.151	0.362
log_rec_devs	0.543	0.125	sel_devs_fsh	-0.037	0.303
log_rec_devs	-0.016	0.142	sel_devs_fsh	-0.141	0.263
log_rec_devs	1.014	0.111	sel_devs_fsh	-0.100	0.248
log_rec_devs	-0.279	0.142	sel_devs_fsh	0.287	0.256
log_rec_devs	0.563	0.115	sel_devs_fsh	0.124	0.268
log_rec_devs	-0.392	0.136	sel_devs_fsh	-0.145	0.294
log_rec_devs	-0.963	0.145	sel_devs_fsh	-0.121	0.329
log_rec_devs	-1.229	0.145	sel_devs_fsh	0.001	0.300
log_rec_devs	-0.489	0.119	sel_devs_fsh	-0.003	0.282
log_rec_devs	0.981	0.099	sel_devs_fsh	0.003	0.271
log_rec_devs	0.354	0.105	sel_devs_fsh	-0.013	0.421
log_rec_devs	0.201	0.107	sel_devs_fsh	-0.515	0.347
log_rec_devs	0.881	0.100	sel_devs_fsh	1.088	0.283
log_rec_devs	-0.198	0.111	sel_devs_fsh	0.191	0.266
log_rec_devs	-0.555	0.115	sel_devs_fsh	-0.175	0.257
log_rec_devs	0.173	0.103	sel_devs_fsh	-0.094	0.248
log_rec_devs	0.473	0.100	sel_devs_fsh	-0.166	0.255
log_rec_devs	-0.244	0.106	sel_devs_fsh	-0.131	0.283
log_rec_devs	-0.161	0.105	sel_devs_fsh	-0.115	0.334
log_rec_devs	0.270	0.101	sel_devs_fsh	-0.034	0.354
log_rec_devs	0.613	0.098	sel_devs_fsh	-0.021	0.306
log_rec_devs	0.203	0.100	sel_devs_fsh	-0.015	0.276
log_rec_devs	-0.273	0.102	sel_devs_fsh	0.071	0.423
log_rec_devs	-1.073	0.111	sel_devs_fsh	-0.111	0.378
log_rec_devs	-1.424	0.118	sel_devs_fsh	-1.458	0.267
log_rec_devs	-0.501	0.105	sel_devs_fsh	1.073	0.251
log_rec_devs	0.279	0.100	sel_devs_fsh	0.301	0.260
log_rec_devs	-0.354	0.108	sel_devs_fsh	0.029	0.263
log_rec_devs	0.963	0.098	sel_devs_fsh	-0.071	0.262
log_rec_devs	0.190	0.102	sel_devs_fsh	0.233	0.278
log_rec_devs	-0.308	0.108	sel_devs_fsh	0.082	0.312
log_rec_devs	-0.452	0.109	sel_devs_fsh	-0.086	0.360
log_rec_devs	0.836	0.098	sel_devs_fsh	-0.027	0.311
log_rec_devs	0.973	0.098	sel_devs_fsh	-0.035	0.277
log_rec_devs	0.136	0.108	sel_devs_fsh	0.060	0.423
log_rec_devs	-0.838	0.134	sel_devs_fsh	0.144	0.395

log_rec_devs	-0.838	0.145	sel_devs_fsh	-0.289	0.317
log_rec_devs	-0.116	0.138	sel_devs_fsh	-1.106	0.244
log_rec_devs	1.476	0.127	sel_devs_fsh	0.610	0.253
log_rec_devs	0.097	0.167	sel_devs_fsh	0.349	0.272
log_rec_devs	-0.492	0.208	sel_devs_fsh	0.212	0.278
log_rec_devs	-0.478	0.258	sel_devs_fsh	-0.075	0.276
log_rec_devs	-0.100	0.298	sel_devs_fsh	0.105	0.283
log_rec_devs	-0.013	0.551	sel_devs_fsh	0.049	0.340
log_F_devs	-0.652	0.256	sel_devs_fsh	-0.030	0.305
log_F_devs	-0.627	0.203	sel_devs_fsh	-0.028	0.280
log_F_devs	-0.705	0.190	sel_devs_fsh	0.036	0.423
log_F_devs	-0.165	0.187	sel_devs_fsh	0.194	0.400
log_F_devs	-0.179	0.181	sel_devs_fsh	0.069	0.365
log_F_devs	-0.137	0.185	sel_devs_fsh	-0.545	0.272
log_F_devs	0.226	0.181	sel_devs_fsh	0.059	0.245
log_F_devs	0.573	0.178	sel_devs_fsh	0.208	0.261
log_F_devs	0.684	0.179	sel_devs_fsh	0.116	0.280
log_F_devs	0.814	0.180	sel_devs_fsh	0.110	0.283
log_F_devs	0.877	0.183	sel_devs_fsh	-0.050	0.269
log_F_devs	0.684	0.169	sel_devs_fsh	-0.076	0.274
log_F_devs	0.575	0.164	sel_devs_fsh	-0.069	0.304
log_F_devs	0.464	0.179	sel_devs_fsh	-0.051	0.303
log_F_devs	0.558	0.178	sel_devs_fsh	0.097	0.615
log_F_devs	0.609	0.172	sel_devs_fsh	0.771	0.502
log_F_devs	0.547	0.169	sel_devs_fsh	0.146	0.439
log_F_devs	0.243	0.183	sel_devs_fsh	-0.639	0.357
log_F_devs	-0.191	0.199	sel_devs_fsh	-1.369	0.271
log_F_devs	-0.390	0.194	sel_devs_fsh	0.075	0.259
log_F_devs	-0.430	0.185	sel_devs_fsh	0.486	0.273
log_F_devs	-0.434	0.171	sel_devs_fsh	0.273	0.282
log_F_devs	-0.519	0.168	sel_devs_fsh	0.174	0.275
log_F_devs	-0.836	0.153	sel_devs_fsh	0.153	0.283
log_F_devs	-0.529	0.140	sel_devs_fsh	-0.052	0.314
log_F_devs	-0.501	0.113	sel_devs_fsh	-0.113	0.376
log_F_devs	-0.088	0.105	sel_devs_fsh	0.148	0.630
log_F_devs	0.121	0.096	sel_devs_fsh	1.002	0.415
log_F_devs	0.428	0.101	sel_devs_fsh	0.653	0.396
log_F_devs	-0.002	0.116	sel_devs_fsh	0.747	0.365
log_F_devs	-0.249	0.125	sel_devs_fsh	0.215	0.298
log_F_devs	-0.266	0.120	sel_devs_fsh	-0.525	0.256

log_F_devs	-0.094	0.124	sel_devs_fsh	-0.648	0.257
log_F_devs	-0.063	0.132	sel_devs_fsh	-0.608	0.276
log_F_devs	-0.242	0.125	sel_devs_fsh	-0.345	0.288
log_F_devs	-0.476	0.122	sel_devs_fsh	-0.297	0.282
log_F_devs	-0.381	0.105	sel_devs_fsh	-0.146	0.294
log_F_devs	-0.244	0.097	sel_devs_fsh	-0.196	0.326
log_F_devs	-0.079	0.091	sel_devs_fsh	-0.030	0.426
log_F_devs	-0.003	0.091	sel_devs_fsh	0.450	0.285
log_F_devs	-0.105	0.097	sel_devs_fsh	0.925	0.275
log_F_devs	-0.167	0.096	sel_devs_fsh	-0.173	0.291
log_F_devs	0.041	0.096	sel_devs_fsh	-0.119	0.295
log_F_devs	0.124	0.094	sel_devs_fsh	-0.576	0.276
log_F_devs	0.235	0.095	sel_devs_fsh	-0.169	0.253
log_F_devs	0.216	0.102	sel_devs_fsh	0.103	0.259
log_F_devs	0.037	0.110	sel_devs_fsh	-0.121	0.277
log_F_devs	0.346	0.107	sel_devs_fsh	-0.122	0.270
log_F_devs	0.358	0.127	sel_devs_fsh	-0.101	0.273
log_F_devs	0.310	0.144	sel_devs_fsh	-0.066	0.272
log_F_devs	0.257	0.156	sel_devs_fsh	0.000	0.428
log_F_devs	0.338	0.164	sel_devs_fsh	0.173	0.319
log_F_devs	0.021	0.151	sel_devs_fsh	-0.276	0.269
log_F_devs	-0.006	0.137	sel_devs_fsh	0.617	0.252
log_F_devs	-0.223	0.145	sel_devs_fsh	0.092	0.287
log_F_devs	-0.110	0.125	sel_devs_fsh	-0.042	0.304
log_F_devs	0.123	0.131	sel_devs_fsh	-0.201	0.292
log_F_devs	0.065	0.131	sel_devs_fsh	-0.054	0.260
log_F_devs	-0.285	0.151	sel_devs_fsh	-0.106	0.261
log_F_devs	-0.301	0.171	sel_devs_fsh	-0.173	0.288
log_F_devs	-0.197	0.357	sel_devs_fsh	-0.031	0.305
sel_devs_fsh	0.053	0.418	sel_devs_fsh	0.000	0.278
sel_devs_fsh	0.092	0.405	sel_devs_fsh	0.023	0.431
sel_devs_fsh	0.143	0.393	sel_devs_fsh	-0.363	0.364
sel_devs_fsh	-0.041	0.301	sel_devs_fsh	-0.077	0.327
sel_devs_fsh	-0.042	0.277	sel_devs_fsh	0.020	0.285
sel_devs_fsh	-0.056	0.271	sel_devs_fsh	0.591	0.267
sel_devs_fsh	-0.048	0.269	sel_devs_fsh	0.274	0.292
sel_devs_fsh	-0.039	0.269	sel_devs_fsh	-0.302	0.310
sel_devs_fsh	-0.028	0.270	sel_devs_fsh	-0.179	0.335
sel_devs_fsh	-0.018	0.272	sel_devs_fsh	-0.027	0.288
sel_devs_fsh	-0.011	0.274	sel_devs_fsh	0.028	0.303

sel_devs_fsh	-0.006	0.273	sel_devs_fsh	-0.007	0.316
sel_devs_fsh	0.060	0.415	sel_devs_fsh	0.021	0.284
sel_devs_fsh	0.100	0.398	sel_devs_fsh	0.000	0.707
sel_devs_fsh	0.243	0.389	sel_devs_fsh	0.004	0.708
sel_devs_fsh	-0.132	0.358	sel_devs_fsh	0.005	0.708
sel_devs_fsh	-0.095	0.299	sel_devs_fsh	0.129	0.743
sel_devs_fsh	-0.074	0.282	sel_devs_fsh	-0.136	0.429
sel_devs_fsh	-0.052	0.279	sel_devs_fsh	-0.104	0.410
sel_devs_fsh	-0.033	0.278	sel_devs_fsh	0.008	0.432
sel_devs_fsh	-0.019	0.280	sel_devs_fsh	-0.026	0.474
sel_devs_fsh	-0.008	0.281	sel_devs_fsh	-0.029	0.433
sel_devs_fsh	0.001	0.282	sel_devs_fsh	0.008	0.446
sel_devs_fsh	0.009	0.276	sel_devs_fsh	0.034	0.712
sel_devs_fsh	0.125	0.413	sel_devs_fsh	0.107	0.685
sel_devs_fsh	0.100	0.396	sel_devs_ats	0.321	0.244
sel_devs_fsh	0.006	0.383	sel_devs_ats	0.332	0.251
sel_devs_fsh	-0.006	0.356	sel_devs_ats	0.306	0.251
sel_devs_fsh	-0.047	0.304	sel_devs_ats	0.299	0.249
sel_devs_fsh	-0.051	0.286	sel_devs_ats	0.315	0.252
sel_devs_fsh	-0.048	0.290	sel_devs_ats	0.321	0.253
sel_devs_fsh	-0.037	0.313	sel_devs_ats	0.316	0.213
sel_devs_fsh	-0.024	0.404	sel_devs_ats	0.362	0.254
sel_devs_fsh	-0.012	0.402	sel_devs_ats	0.362	0.257
sel_devs_fsh	-0.004	0.315	sel_devs_ats	0.357	0.256
sel_devs_fsh	0.000	0.284	sel_devs_ats	0.350	0.255
sel_devs_fsh	0.132	0.413	sel_devs_ats	0.353	0.256
sel_devs_fsh	0.067	0.395	sel_devs_ats	0.358	0.255
sel_devs_fsh	0.157	0.384	sel_devs_ats	0.361	0.224
sel_devs_fsh	-0.106	0.312	sel_devs_ats	0.433	0.260
sel_devs_fsh	-0.102	0.295	sel_devs_ats	0.426	0.262
sel_devs_fsh	-0.092	0.314	sel_devs_ats	0.396	0.260
sel_devs_fsh	-0.079	0.395	sel_devs_ats	0.409	0.260
sel_devs_fsh	-0.023	0.404	sel_devs_ats	0.397	0.261
sel_devs_fsh	-0.005	0.411	sel_devs_ats	0.401	0.259
sel_devs_fsh	0.011	0.408	sel_devs_ats	0.392	0.232
sel_devs_fsh	0.018	0.404	sel_devs_ats	0.406	0.261
sel_devs_fsh	0.023	0.302	sel_devs_ats	0.488	0.266
sel_devs_fsh	0.188	0.413	sel_devs_ats	0.479	0.265
sel_devs_fsh	0.137	0.395	sel_devs_ats	0.442	0.264
sel_devs_fsh	-0.032	0.382	sel_devs_ats	0.448	0.265

sel_devs_fsh	-0.252	0.365	sel_devs_ats	0.453	0.263
sel_devs_fsh	-0.123	0.321	sel_devs_ats	0.427	0.238
sel_devs_fsh	-0.108	0.328	sel_devs_ats	0.437	0.269
sel_devs_fsh	-0.050	0.402	sel_devs_ats	0.523	0.268
sel_devs_fsh	0.010	0.411	sel_devs_ats	0.518	0.267
sel_devs_fsh	0.037	0.416	sel_devs_ats	0.483	0.267
sel_devs_fsh	0.053	0.412	sel_devs_ats	0.476	0.267
sel_devs_fsh	0.060	0.410	sel_devs_ats	0.491	0.266
sel_devs_fsh	0.080	0.303	sel_devs_ats	0.464	0.242
sel_devs_fsh	0.010	0.414	sel_devs_ats	0.474	0.269
sel_devs_fsh	0.029	0.394	sel_devs_ats	0.497	0.270
sel_devs_fsh	-0.080	0.378	sel_devs_ats	0.554	0.269
sel_devs_fsh	-0.049	0.376	sel_devs_ats	0.518	0.269
sel_devs_fsh	-0.001	0.326	sel_devs_ats	0.524	0.270
sel_devs_fsh	-0.015	0.329	sel_devs_ats	0.495	0.269
sel_devs_fsh	-0.049	0.403	sel_devs_ats	0.500	0.245
sel_devs_fsh	0.007	0.412	sel_devs_ats	0.545	0.268
sel_devs_fsh	0.028	0.416	sel_devs_ats	0.539	0.272
sel_devs_fsh	0.033	0.411	sel_devs_ats	0.522	0.272
sel_devs_fsh	0.038	0.409	sel_devs_ats	0.551	0.272
sel_devs_fsh	0.050	0.299	sel_devs_ats	0.556	0.272
sel_devs_fsh	-0.233	0.414	sel_devs_ats	0.537	0.272
sel_devs_fsh	0.198	0.395	sel_devs_ats	0.522	0.248
sel_devs_fsh	0.117	0.377	sel_devs_ats	0.549	0.274
sel_devs_fsh	0.080	0.378	sel_devs_ats	0.565	0.273
sel_devs_fsh	-0.021	0.326	sel_devs_ats	0.554	0.273
sel_devs_fsh	-0.008	0.329	sel_devs_ats	0.567	0.273
sel_devs_fsh	-0.017	0.401	sel_devs_ats	0.573	0.273
sel_devs_fsh	-0.031	0.413	sel_devs_ats	0.560	0.273
sel_devs_fsh	-0.014	0.416	sel_devs_ats	0.543	0.250
sel_devs_fsh	-0.016	0.411	sel_devs_ats	0.515	0.269
sel_devs_fsh	-0.023	0.408	sel_devs_ats	0.513	0.275
sel_devs_fsh	-0.033	0.299	sel_devs_ats	0.585	0.275
sel_devs_fsh	-0.253	0.414	sel_devs_ats	0.601	0.275
sel_devs_fsh	0.108	0.395	sel_devs_ats	0.585	0.275
sel_devs_fsh	0.070	0.382	sel_devs_ats	0.573	0.275
sel_devs_fsh	0.050	0.379	sel_devs_ats	0.571	0.251
sel_devs_fsh	0.039	0.363	sel_devs_ats	0.511	0.275
sel_devs_fsh	0.049	0.350	sel_devs_ats	0.527	0.276
sel_devs_fsh	0.029	0.395	sel_devs_ats	0.613	0.274

sel_devs_fsh	0.000	0.413	sel_devs_ats	0.614	0.275
sel_devs_fsh	-0.010	0.416	sel_devs_ats	0.596	0.275
sel_devs_fsh	-0.017	0.410	sel_devs_ats	0.588	0.275
sel_devs_fsh	-0.026	0.407	sel_devs_ats	0.585	0.252
sel_devs_fsh	-0.038	0.300	sel_devs_ats	0.614	0.275
sel_devs_fsh	-0.211	0.413	sel_devs_ats	0.580	0.278
sel_devs_fsh	0.146	0.392	sel_devs_ats	0.519	0.278
sel_devs_fsh	0.181	0.380	sel_devs_ats	0.551	0.277
sel_devs_fsh	0.037	0.378	sel_devs_ats	0.582	0.277
sel_devs_fsh	0.008	0.359	sel_devs_ats	0.590	0.276
sel_devs_fsh	-0.003	0.319	sel_devs_ats	0.594	0.254
sel_devs_fsh	-0.003	0.329	sel_devs_ats	0.595	0.279
sel_devs_fsh	-0.028	0.411	sel_devs_ats	0.572	0.279
sel_devs_fsh	-0.021	0.415	sel_devs_ats	0.530	0.278
sel_devs_fsh	-0.025	0.407	sel_devs_ats	0.548	0.277
sel_devs_fsh	-0.032	0.404	sel_devs_ats	0.575	0.276
sel_devs_fsh	-0.049	0.301	sel_devs_ats	0.588	0.276
sel_devs_fsh	-0.194	0.413	sel_devs_ats	0.591	0.255
sel_devs_fsh	-0.175	0.386	sel_devs_ats	0.605	0.279
sel_devs_fsh	0.131	0.368	sel_devs_ats	0.591	0.278
sel_devs_fsh	0.081	0.372	sel_devs_ats	0.560	0.278
sel_devs_fsh	0.044	0.309	sel_devs_ats	0.572	0.277
sel_devs_fsh	0.037	0.296	sel_devs_ats	0.581	0.277
sel_devs_fsh	0.035	0.319	sel_devs_ats	0.571	0.277
sel_devs_fsh	-0.003	0.410	sel_devs_ats	0.577	0.254
sel_devs_fsh	0.006	0.415	sel_devs_ats	0.621	0.277
sel_devs_fsh	0.013	0.320	sel_devs_ats	0.591	0.277
sel_devs_fsh	0.013	0.291	sel_devs_ats	0.542	0.278
sel_devs_fsh	0.013	0.276	sel_devs_ats	0.533	0.278
sel_devs_fsh	-0.192	0.413	sel_devs_ats	0.544	0.278
sel_devs_fsh	-0.072	0.387	sel_devs_ats	0.559	0.277
sel_devs_fsh	-0.084	0.341	sel_devs_ats	0.576	0.254
sel_devs_fsh	0.090	0.300	sel_devs_ats	0.582	0.274
sel_devs_fsh	0.076	0.285	sel_devs_ats	0.577	0.277
sel_devs_fsh	0.063	0.289	sel_devs_ats	0.547	0.277
sel_devs_fsh	0.056	0.315	sel_devs_ats	0.544	0.278
sel_devs_fsh	0.016	0.406	sel_devs_ats	0.554	0.278
sel_devs_fsh	0.012	0.414	sel_devs_ats	0.564	0.277
sel_devs_fsh	0.013	0.318	sel_devs_ats	0.566	0.254
sel_devs_fsh	0.012	0.290	sel_devs_ats	0.587	0.278

sel_devs_fsh	0.011	0.275	sel_devs_ats	0.547	0.280
sel_devs_fsh	-0.183	0.413	sel_devs_ats	0.566	0.280
sel_devs_fsh	0.018	0.387	sel_devs_ats	0.536	0.281
sel_devs_fsh	-0.132	0.366	sel_devs_ats	0.540	0.281
sel_devs_fsh	-0.053	0.354	sel_devs_ats	0.547	0.280
sel_devs_fsh	0.058	0.307	sel_devs_ats	0.538	0.257
sel_devs_fsh	0.062	0.293	sel_devs_ats	0.565	0.278
sel_devs_fsh	0.061	0.312	sel_devs_ats	0.540	0.283
sel_devs_fsh	0.036	0.398	sel_devs_ats	0.511	0.283
sel_devs_fsh	0.028	0.413	sel_devs_ats	0.521	0.283
sel_devs_fsh	0.034	0.321	sel_devs_ats	0.530	0.284
sel_devs_fsh	0.035	0.294	sel_devs_ats	0.536	0.283
sel_devs_fsh	0.036	0.280	sel_devs_ats	0.523	0.260
sel_devs_fsh	-0.224	0.412	sel_devs_ats	0.563	0.285
sel_devs_fsh	-0.141	0.380	sel_devs_ats	0.527	0.285
sel_devs_fsh	-0.044	0.364	sel_devs_ats	0.499	0.284
sel_devs_fsh	-0.030	0.364	sel_devs_ats	0.509	0.286
sel_devs_fsh	0.044	0.314	sel_devs_ats	0.521	0.286
sel_devs_fsh	0.054	0.308	sel_devs_ats	0.528	0.285
sel_devs_fsh	0.068	0.315	sel_devs_ats	0.511	0.263
sel_devs_fsh	0.068	0.326	sel_devs_ats	0.530	0.286
sel_devs_fsh	0.055	0.410	sel_devs_ats	0.542	0.288
sel_devs_fsh	0.049	0.370	sel_devs_ats	0.568	0.288
sel_devs_fsh	0.051	0.310	sel_devs_ats	0.554	0.289
sel_devs_fsh	0.050	0.282	sel_devs_ats	0.548	0.289
sel_devs_fsh	-0.180	0.407	sel_devs_ats	0.533	0.288
sel_devs_fsh	-0.380	0.361	sel_devs_ats	0.496	0.265
sel_devs_fsh	-0.173	0.350	sel_devs_ats	0.551	0.294
sel_devs_fsh	-0.043	0.356	sel_devs_ats	0.537	0.291
sel_devs_fsh	0.082	0.350	sel_devs_ats	0.574	0.290
sel_devs_fsh	0.140	0.326	sel_devs_ats	0.557	0.290
sel_devs_fsh	0.123	0.316	sel_devs_ats	0.556	0.291
sel_devs_fsh	0.123	0.323	sel_devs_ats	0.548	0.291
sel_devs_fsh	0.099	0.405	sel_devs_ats	0.500	0.269
sel_devs_fsh	0.072	0.368	sel_devs_ats	0.460	0.285
sel_devs_fsh	0.068	0.310	sel_devs_ats	0.585	0.293
sel_devs_fsh	0.066	0.282	sel_devs_ats	0.609	0.293
sel_devs_fsh	-0.198	0.409	sel_devs_ats	0.584	0.294
sel_devs_fsh	-0.487	0.353	sel_devs_ats	0.557	0.295
sel_devs_fsh	-0.275	0.343	sel_devs_ats	0.554	0.295

sel_devs_fsh	0.066	0.355	sel_devs_ats	0.537	0.273
sel_devs_fsh	0.115	0.363	sel_devs_ats	0.460	0.296
sel_devs_fsh	0.151	0.309	sel_devs_ats	0.553	0.297
sel_devs_fsh	0.148	0.292	sel_devs_ats	0.632	0.296
sel_devs_fsh	0.139	0.310	sel_devs_ats	0.583	0.298
sel_devs_fsh	0.095	0.397	sel_devs_ats	0.559	0.298
sel_devs_fsh	0.084	0.314	sel_devs_ats	0.548	0.299
sel_devs_fsh	0.082	0.292	sel_devs_ats	0.581	0.279
sel_devs_fsh	0.079	0.280	sel_devs_ats	0.579	0.298
sel_devs_fsh	-0.165	0.413	sel_devs_ats	0.530	0.305
sel_devs_fsh	-0.273	0.370	sel_devs_ats	0.481	0.304
sel_devs_fsh	-0.280	0.338	sel_devs_ats	0.573	0.305
sel_devs_fsh	-0.023	0.348	sel_devs_ats	0.590	0.306
sel_devs_fsh	0.117	0.366	sel_devs_ats	0.585	0.307
sel_devs_fsh	0.085	0.308	sel_devs_ats	0.611	0.287
sel_devs_fsh	0.094	0.284	sel_devs_ats	0.584	0.310
sel_devs_fsh	0.098	0.279	sel_devs_ats	0.554	0.314
sel_devs_fsh	0.092	0.280	sel_devs_ats	0.530	0.314
sel_devs_fsh	0.086	0.281	sel_devs_ats	0.603	0.313
sel_devs_fsh	0.084	0.283	sel_devs_ats	0.609	0.314
sel_devs_fsh	0.085	0.277	sel_devs_ats	0.608	0.315
sel_devs_fsh	-0.130	0.416	sel_devs_ats	0.623	0.295
sel_devs_fsh	-0.102	0.382	sel_devs_ats	0.607	0.316
sel_devs_fsh	-0.301	0.353	sel_devs_ats	0.620	0.322
sel_devs_fsh	-0.021	0.339	sel_devs_ats	0.656	0.324
sel_devs_fsh	0.026	0.360	sel_devs_ats	0.635	0.325
sel_devs_fsh	0.065	0.316	sel_devs_ats	0.631	0.325
sel_devs_fsh	0.065	0.310	sel_devs_ats	0.621	0.324
sel_devs_fsh	0.073	0.300	sel_devs_ats	0.625	0.304
sel_devs_fsh	0.078	0.285	sel_devs_ats	0.619	0.327
sel_devs_fsh	0.080	0.283	sel_devs_ats	0.642	0.332
sel_devs_fsh	0.082	0.284	sel_devs_ats	0.678	0.333
sel_devs_fsh	0.085	0.279	sel_devs_ats	0.654	0.333
sel_devs_fsh	-0.147	0.418	sel_devs_ats	0.643	0.332
sel_devs_fsh	0.103	0.390	sel_devs_ats	0.644	0.332
sel_devs_fsh	-0.085	0.364	sel_devs_ats	0.650	0.314
sel_devs_fsh	-0.162	0.345	sel_devs_ats	0.636	0.339
sel_devs_fsh	-0.076	0.345	sel_devs_ats	0.654	0.343
sel_devs_fsh	0.043	0.314	sel_devs_ats	0.701	0.342
sel_devs_fsh	0.036	0.312	sel_devs_ats	0.673	0.343

sel_devs_fsh	0.033	0.332	sel_devs_ats	0.663	0.342
sel_devs_fsh	0.051	0.381	sel_devs_ats	0.666	0.342
sel_devs_fsh	0.060	0.393	sel_devs_ats	0.670	0.325
sel_devs_fsh	0.069	0.400	sel_devs_ats	0.637	0.354
sel_devs_fsh	0.076	0.306	sel_devs_ats	0.650	0.356
sel_devs_fsh	-0.136	0.420	sel_devs_ats	0.732	0.354
sel_devs_fsh	-0.150	0.391	sel_devs_ats	0.684	0.354
sel_devs_fsh	0.063	0.371	sel_devs_ats	0.679	0.354
sel_devs_fsh	-0.068	0.351	sel_devs_ats	0.683	0.354
sel_devs_fsh	0.062	0.342	sel_devs_ats	0.687	0.338
sel_devs_fsh	0.007	0.324	sel_devs_ats	0.696	0.367
sel_devs_fsh	0.035	0.307	sel_devs_ats	0.684	0.372
sel_devs_fsh	0.027	0.316	sel_devs_ats	0.611	0.372
sel_devs_fsh	0.027	0.384	sel_devs_ats	0.676	0.371
sel_devs_fsh	0.032	0.396	sel_devs_ats	0.698	0.370
sel_devs_fsh	0.047	0.402	sel_devs_ats	0.704	0.371
sel_devs_fsh	0.054	0.306	sel_devs_ats	0.702	0.355
sel_devs_fsh	-0.152	0.420	sel_devs_ats	0.684	0.391
sel_devs_fsh	0.046	0.396	sel_devs_ats	0.681	0.393
sel_devs_fsh	0.139	0.368	sel_devs_ats	0.632	0.391
sel_devs_fsh	-0.078	0.357	sel_devs_ats	0.678	0.390
sel_devs_fsh	-0.230	0.347	sel_devs_ats	0.703	0.388
sel_devs_fsh	0.073	0.322	sel_devs_ats	0.711	0.391
sel_devs_fsh	0.043	0.304	sel_devs_ats	0.704	0.375
sel_devs_fsh	0.042	0.312	sel_coffs_fsh	-4.106	0.736
sel_devs_fsh	0.018	0.379	sel_coffs_fsh	-2.165	0.566
sel_devs_fsh	0.024	0.396	sel_coffs_fsh	-0.883	0.472
sel_devs_fsh	0.033	0.403	sel_coffs_fsh	0.359	0.281
sel_devs_fsh	0.040	0.306	sel_coffs_fsh	0.339	0.266
sel_devs_fsh	-0.159	0.421	sel_coffs_fsh	0.310	0.256
sel_devs_fsh	-0.031	0.398	sel_coffs_fsh	0.270	0.252
sel_devs_fsh	0.078	0.370	sel_coffs_fsh	0.230	0.252
sel_devs_fsh	0.164	0.355	sel_coffs_fsh	0.195	0.256
sel_devs_fsh	-0.016	0.355	sel_coffs_fsh	0.167	0.263
sel_devs_fsh	-0.074	0.332	sel_coffs_fsh	0.145	0.274
sel_devs_fsh	0.022	0.303	sel_coffs_fsh	0.128	0.289
sel_devs_fsh	-0.031	0.300	sel_coffs_ats	-0.156	0.246
sel_devs_fsh	0.023	0.335	sel_coffs_ats	-0.159	0.268
sel_devs_fsh	0.004	0.391	sel_coffs_ats	0.021	0.257
sel_devs_fsh	0.003	0.402	sel_coffs_ats	0.145	0.249

sel_devs_fsh	0.018	0.306	sel_coffs_ats	0.186	0.264
sel_devs_fsh	-0.161	0.421	sel_coffs_ats	0.284	0.264
sel_devs_fsh	-0.078	0.402	sel_coffs_ats	0.417	0.230
sel_devs_fsh	0.122	0.372	sel_slp_bts	0.989	0.034
sel_devs_fsh	-0.084	0.358	sel_a50_bts	6.236	0.119
sel_devs_fsh	0.014	0.354	sel_age_one_bts	-3.194	0.076
sel_devs_fsh	-0.037	0.356	sel_slp_bts_dev	-0.705	0.176
sel_devs_fsh	-0.096	0.340	sel_slp_bts_dev	0.047	0.151
sel_devs_fsh	0.136	0.317	sel_slp_bts_dev	0.009	0.132
sel_devs_fsh	0.087	0.310	sel_slp_bts_dev	-0.401	0.159
sel_devs_fsh	0.064	0.319	sel_slp_bts_dev	-0.343	0.126
sel_devs_fsh	0.028	0.397	sel_slp_bts_dev	-0.442	0.191
sel_devs_fsh	0.006	0.306	sel_slp_bts_dev	-0.545	0.237
sel_devs_fsh	-0.194	0.421	sel_slp_bts_dev	-0.437	0.285
sel_devs_fsh	-0.115	0.403	sel_slp_bts_dev	0.328	0.223
sel_devs_fsh	0.461	0.375	sel_slp_bts_dev	0.222	0.160
sel_devs_fsh	0.045	0.361	sel_slp_bts_dev	0.172	0.156
sel_devs_fsh	0.124	0.354	sel_slp_bts_dev	0.313	0.162
sel_devs_fsh	-0.053	0.354	sel_slp_bts_dev	0.281	0.122
sel_devs_fsh	0.134	0.338	sel_slp_bts_dev	0.234	0.117
sel_devs_fsh	-0.094	0.295	sel_slp_bts_dev	-0.137	0.088
sel_devs_fsh	-0.091	0.282	sel_slp_bts_dev	-0.289	0.127
sel_devs_fsh	-0.112	0.299	sel_slp_bts_dev	-0.510	0.113
sel_devs_fsh	-0.066	0.360	sel_slp_bts_dev	-0.604	0.119
sel_devs_fsh	-0.041	0.305	sel_slp_bts_dev	-0.338	0.139
sel_devs_fsh	-0.163	0.421	sel_slp_bts_dev	-0.480	0.102
sel_devs_fsh	-0.074	0.403	sel_slp_bts_dev	-0.063	0.100
sel_devs_fsh	-0.382	0.383	sel_slp_bts_dev	0.173	0.124
sel_devs_fsh	0.168	0.367	sel_slp_bts_dev	0.082	0.101
sel_devs_fsh	0.036	0.354	sel_slp_bts_dev	0.208	0.115
sel_devs_fsh	0.083	0.353	sel_slp_bts_dev	-0.082	0.099
sel_devs_fsh	0.127	0.298	sel_slp_bts_dev	0.337	0.139
sel_devs_fsh	0.105	0.278	sel_slp_bts_dev	0.542	0.100
sel_devs_fsh	0.026	0.280	sel_slp_bts_dev	0.239	0.113
sel_devs_fsh	0.069	0.295	sel_slp_bts_dev	0.753	0.145
sel_devs_fsh	0.022	0.359	sel_slp_bts_dev	0.550	0.086
sel_devs_fsh	-0.016	0.304	sel_slp_bts_dev	0.205	0.130
sel_devs_fsh	-0.153	0.420	sel_slp_bts_dev	0.298	0.135
sel_devs_fsh	-0.042	0.400	sel_slp_bts_dev	0.530	0.103
sel_devs_fsh	-0.346	0.384	sel_slp_bts_dev	0.433	0.114

sel_devs_fsh	0.038	0.372	sel_slp_bts_dev	0.429	0.135
sel_devs_fsh	0.183	0.353	sel_slp_bts_dev	0.253	0.101
sel_devs_fsh	0.059	0.349	sel_slp_bts_dev	-0.337	0.124
sel_devs_fsh	-0.028	0.295	sel_slp_bts_dev	0.004	0.121
sel_devs_fsh	0.046	0.277	sel_slp_bts_dev	-0.118	0.219
sel_devs_fsh	0.059	0.278	sel_slp_bts_dev	-0.207	0.099
sel_devs_fsh	-0.017	0.291	sel_slp_bts_dev	-0.037	0.133
sel_devs_fsh	0.128	0.298	sel_slp_bts_dev	-0.339	0.128
sel_devs_fsh	0.072	0.275	sel_slp_bts_dev	-0.227	0.190
sel_devs_fsh	-0.081	0.419	sel_a50_bts_dev	-0.010	0.070
sel_devs_fsh	0.003	0.393	sel_a50_bts_dev	-0.157	0.047
sel_devs_fsh	-0.371	0.377	sel_a50_bts_dev	-0.035	0.045
sel_devs_fsh	-0.323	0.360	sel_a50_bts_dev	0.077	0.053
sel_devs_fsh	-0.223	0.350	sel_a50_bts_dev	0.100	0.052
sel_devs_fsh	-0.062	0.323	sel_a50_bts_dev	0.062	0.069
sel_devs_fsh	0.127	0.283	sel_a50_bts_dev	-0.052	0.086
sel_devs_fsh	-0.028	0.279	sel_a50_bts_dev	-0.098	0.077
sel_devs_fsh	0.165	0.275	sel_a50_bts_dev	-0.209	0.065
sel_devs_fsh	0.104	0.295	sel_a50_bts_dev	-0.130	0.063
sel_devs_fsh	0.354	0.299	sel_a50_bts_dev	-0.133	0.058
sel_devs_fsh	0.336	0.266	sel_a50_bts_dev	-0.169	0.047
sel_devs_fsh	-0.156	0.418	sel_a50_bts_dev	-0.088	0.040
sel_devs_fsh	-0.067	0.336	sel_a50_bts_dev	0.003	0.046
sel_devs_fsh	0.503	0.307	sel_a50_bts_dev	0.186	0.034
sel_devs_fsh	-0.262	0.316	sel_a50_bts_dev	0.223	0.051
sel_devs_fsh	-0.344	0.318	sel_a50_bts_dev	0.313	0.044
sel_devs_fsh	-0.043	0.313	sel_a50_bts_dev	0.277	0.056
sel_devs_fsh	-0.028	0.292	sel_a50_bts_dev	0.143	0.062
sel_devs_fsh	0.215	0.287	sel_a50_bts_dev	0.178	0.045
sel_devs_fsh	0.108	0.280	sel_a50_bts_dev	0.055	0.046
sel_devs_fsh	0.233	0.288	sel_a50_bts_dev	0.007	0.051
sel_devs_fsh	-0.113	0.289	sel_a50_bts_dev	0.040	0.036
sel_devs_fsh	-0.046	0.262	sel_a50_bts_dev	-0.019	0.036
sel_devs_fsh	-0.145	0.417	sel_a50_bts_dev	0.089	0.034
sel_devs_fsh	-0.490	0.354	sel_a50_bts_dev	-0.085	0.042
sel_devs_fsh	-0.031	0.274	sel_a50_bts_dev	-0.119	0.034
sel_devs_fsh	0.796	0.280	sel_a50_bts_dev	-0.030	0.041
sel_devs_fsh	0.000	0.307	sel_a50_bts_dev	-0.211	0.039
sel_devs_fsh	0.015	0.325	sel_a50_bts_dev	-0.094	0.028
sel_devs_fsh	0.086	0.324	sel_a50_bts_dev	-0.050	0.041

sel_devs_fsh	0.025	0.291	sel_a50_bts_dev	-0.078	0.030
sel_devs_fsh	-0.013	0.281	sel_a50_bts_dev	-0.161	0.032
sel_devs_fsh	-0.051	0.279	sel_a50_bts_dev	-0.208	0.038
sel_devs_fsh	-0.125	0.302	sel_a50_bts_dev	-0.148	0.039
sel_devs_fsh	-0.069	0.275	sel_a50_bts_dev	-0.071	0.027
sel_devs_fsh	-0.051	0.418	sel_a50_bts_dev	0.153	0.043
sel_devs_fsh	0.009	0.360	sel_a50_bts_dev	-0.020	0.036
sel_devs_fsh	-0.777	0.309	sel_a50_bts_dev	0.059	0.074
sel_devs_fsh	-0.295	0.266	sel_a50_bts_dev	0.130	0.040
sel_devs_fsh	0.908	0.266	sel_a50_bts_dev	0.045	0.048
sel_devs_fsh	0.260	0.308	sel_a50_bts_dev	0.197	0.047
sel_devs_fsh	0.025	0.317	sel_a50_bts_dev	0.038	0.070
sel_devs_fsh	-0.025	0.284	sel_age_one_bts_dev	-0.034	0.098
sel_devs_fsh	-0.033	0.269	sel_age_one_bts_dev	0.005	0.075
sel_devs_fsh	-0.007	0.273	sel_age_one_bts_dev	0.039	0.128
sel_devs_fsh	0.022	0.288	sel_age_one_bts_dev	-0.216	0.099
sel_devs_fsh	-0.036	0.279	sel_age_one_bts_dev	-0.400	0.101
sel_devs_fsh	-0.021	0.419	sel_age_one_bts_dev	-0.236	0.154
sel_devs_fsh	0.186	0.370	sel_age_one_bts_dev	-0.290	0.149
sel_devs_fsh	-0.289	0.323	sel_age_one_bts_dev	-0.053	0.145
sel_devs_fsh	-0.688	0.293	sel_age_one_bts_dev	0.093	0.106
sel_devs_fsh	-0.359	0.267	sel_age_one_bts_dev	-0.168	0.091
sel_devs_fsh	0.466	0.267	sel_age_one_bts_dev	-0.031	0.093
sel_devs_fsh	0.148	0.279	sel_age_one_bts_dev	0.024	0.082
sel_devs_fsh	0.164	0.271	sel_age_one_bts_dev	-0.095	0.105
sel_devs_fsh	0.134	0.272	sel_age_one_bts_dev	-0.120	0.106
sel_devs_fsh	0.116	0.273	sel_age_one_bts_dev	-0.107	0.063
sel_devs_fsh	0.086	0.275	sel_age_one_bts_dev	-0.008	0.087
sel_devs_fsh	0.055	0.269	sel_age_one_bts_dev	0.049	0.102
sel_devs_fsh	-0.035	0.419	sel_age_one_bts_dev	0.101	0.095
sel_devs_fsh	0.516	0.374	sel_age_one_bts_dev	0.182	0.092
sel_devs_fsh	0.280	0.336	sel_age_one_bts_dev	0.066	0.062
sel_devs_fsh	-0.793	0.306	sel_age_one_bts_dev	0.066	0.069
sel_devs_fsh	-0.744	0.287	sel_age_one_bts_dev	0.219	0.096
sel_devs_fsh	-0.357	0.268	sel_age_one_bts_dev	0.043	0.094
sel_devs_fsh	0.275	0.267	sel_age_one_bts_dev	-0.032	0.106
sel_devs_fsh	0.307	0.272	sel_age_one_bts_dev	-0.038	0.061
sel_devs_fsh	0.226	0.272	sel_age_one_bts_dev	-0.062	0.064
sel_devs_fsh	0.154	0.274	sel_age_one_bts_dev	0.161	0.066
sel_devs_fsh	0.100	0.276	sel_age_one_bts_dev	0.338	0.053

sel_devs_fsh	0.071	0.268	sel_age_one_bts_dev	0.304	0.086
sel_devs_fsh	-0.135	0.419	sel_age_one_bts_dev	-0.099	0.073
sel_devs_fsh	0.347	0.364	sel_age_one_bts_dev	-0.085	0.094
sel_devs_fsh	0.155	0.341	sel_age_one_bts_dev	0.178	0.088
sel_devs_fsh	0.659	0.307	sel_age_one_bts_dev	0.138	0.073
sel_devs_fsh	-0.016	0.281	sel_age_one_bts_dev	0.032	0.097
sel_devs_fsh	-0.410	0.276	sel_age_one_bts_dev	-0.072	0.114
sel_devs_fsh	-0.413	0.276	sel_age_one_bts_dev	-0.083	0.094
sel_devs_fsh	-0.302	0.284	sel_age_one_bts_dev	-0.044	0.080
sel_devs_fsh	-0.004	0.280	sel_age_one_bts_dev	0.232	0.065
sel_devs_fsh	0.032	0.275	sel_age_one_bts_dev	0.090	0.183
sel_devs_fsh	0.040	0.276	sel_age_one_bts_dev	-0.052	0.098
sel_devs_fsh	0.047	0.268	sel_age_one_bts_dev	0.016	0.106
sel_devs_fsh	-0.107	0.420	sel_age_one_bts_dev	-0.022	0.112
sel_devs_fsh	-0.382	0.337	sel_age_one_bts_dev	-0.029	0.185
sel_devs_fsh	0.281	0.322	rec_dev_future	0.000	0.664
sel_devs_fsh	0.240	0.307	rec_dev_future	0.000	0.664
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sel_devs_fsh	-0.066	0.289	L1	28.278	0.027
sel_devs_fsh	-0.073	0.282	L2	46.096	0.112
sel_devs_fsh	-0.047	0.274	log_K	-0.128	0.002
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sel_devs_fsh	-0.153	0.420	d_scale	0.766	0.018
sel_devs_fsh	-0.379	0.354	d_scale	0.830	0.018
sel_devs_fsh	0.828	0.283	d_scale	0.870	0.019
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sel_devs_fsh	-0.028	0.260	yr_eff	0.031	0.325
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sel_devs_fsh	-0.010	0.247	yr_eff	0.559	0.078
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sel_devs_fsh	0.127	0.265	yr_eff	-1.022	0.146
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sel_devs_fsh	0.079	0.351	yr_eff	-1.767	0.239
sel_devs_fsh	-0.607	0.286	yr_eff	-1.551	0.212

sel_devs_fsh	0.436	0.249	yr_eff	-0.243	0.063
sel_devs_fsh	0.161	0.271	yr_eff	-3.431	0.284
sel_devs_fsh	-0.251	0.286	yr_eff	0.850	0.739
sel_devs_fsh	-0.066	0.287	yr_eff	0.000	1.000
sel_devs_fsh	0.093	0.261	yr_eff	0.000	1.000
sel_devs_fsh	0.096	0.263	yr_eff	0.000	1.000
sel_devs_fsh	0.029	0.295	yr_eff	0.000	1.000
sel_devs_fsh	-0.031	0.301	yr_eff	0.000	1.000

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