

# Chapter 1: Assessment of the Walleye Pollock Stock in the Eastern Bering Sea

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## **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.

### *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.

### *Changes in the data*

1. The 2018 NMFS bottom-trawl survey (BTS) biomass and abundance at age estimates were included.
2. The 2018 NMFS acoustic-trawl survey (ATS) biomass and abundance were included (using mainly samples from the BTS survey for age-length keys)
3. The 2018 opportunistic acoustic data from vessels (AVO) conducting the bottom trawl survey was used as an added index of pollock biomass in mid-water.
4. Observer data for catch-at-age and average weight-at-age from the 2016 fishery were finalized and included.
5. Total catch as reported by NMFS Alaska Regional office was updated and included through 2018.

### *Changes in the assessment methods*

There were no changes to the assessment model. An example application of a spatial temporal model for creating an alternative index (including the broader region of the northern Bering Sea (NBS) was developed and presented as a sensitivity).

### *Summary of EBS pollock results*

| Quantity                              | As estimated or <i>specified</i> last year for: |              | As estimated or <i>recommended</i> this year for: |             |
|---------------------------------------|---|--------------|---|-------------|
|                                       | 2018  | 2019         | 2019  | 2020        |
| 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)  | 10,965,000 t                                    | 10,117,000 t | 9,110,000 t                                       | 8,156,000 t |
| Projected female spawning biomass (t) | 3,678,000 t                                     | 3,365,000 t  | 3,127,000 t                                       | 2,765,000 t |
| $B_0$                                 | 5,394,000 t                                     | 5,394,000 t  | 5,866,000 t                                       | 5,866,000 t |
| $B_{msy}$                             | 2,042,000 t                                     | 2,042,000 t  | 2,280,000 t                                       | 2,280,000 t |
| $F_{OFL}$                             | 0.621   | 0.621        | 0.645   | 0.645       |
| $\max F_{ABC}$                        | 0.466   | 0.466        | 0.51  | 0.51        |
| $F_{ABC}$                             | 0.336   | 0.336        |   |             |
| $OFL$                                 | 4,797,000 t                                     | 4,592,000 t  | 3,914,000 t                                       | 3,082,000 t |
| $\max ABC$                            | 3,603,000 t                                     | 3,448,000 t  | 3,096,000 t                                       | 2,437,000 t |
| $ABC$                                 | 2,592,000 t                                     | 2,467,000 t  | 2,631,000 t                                       | 2,072,000 t |
| Status                                | 2016  | 2017         | 2017  | 2018        |
| Overfishing                           | No  | n/a          | No  | n/a         |
| Overfished                            | n/a   | No           | n/a   | No          |
| Approaching overfished                | n/a   | No           | n/a   | No          |

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

#### *General comments*

In the November 2017 Plan Team minutes: "The Team recommends that more NBS surveys be conducted in the near future, as a time series of such data may be essential for understanding changes in the abundance of some individual stocks as well as the overall ecosystem. Some species, such as pollock and Pacific cod, exhibited enormous changes in NBS survey biomass between 2010 and 2017, both in absolute terms and relative to the NBS+EBS total, while others, such as Alaska plaice, exhibited very little change. The Team also recommends that assessment authors evaluate data from the NBS survey to determine if they should be included in their respective assessment models, particularly if more surveys are conducted, recognizing that it may be appropriate to include these data in some assessments but not others, and that the methods used to include these data may vary between assessments."

*In this assessment, a complete time series approach using a spatio temporal model for survey observations outside the standard area was developed and applied. This approach used the spatio-temporal model's estimated covariance matrix over time to fit the survey data (similar to the way*

*the current, density-dependent correction is applied for survey data from the standard bottom trawl survey area).*

*Relative to the ecosystem status report... the Team recommends that assessment authors be more fully integrated into the prioritization of AFSC ecosystem research, in order to: 1) develop methods and approaches (where appropriate) of linking ecosystem indicators to individual species; 2) identify species-specific ecosystem “red-flags;” and 3) track indicator performance retrospectively, as is done for some of the pollock recruitment indicators.*

*A more formal qualitative risk table as developed by the Plan Team and a working group was used and is presented below in discussing ABC considerations*

#### *Comments specific to this assessment*

SSC and Plan Team 2017 minutes:

*...request that the authors develop a better prior for steepness, or at least a better rationale, and perhaps consider a meta-analytic approach.*

*A method outlined in a new meta-analytic paper on steepness using life history characteristics was evaluated using a Beverton-Holt stock recruitment relationship. This is presented as a model alternative.*

The Team requests that the “year class diversity” index that had been reported in previous assessments be included in future assessments.

*This is standard output from the assessment model and a time series of the estimate is provided.*

The Team recommends that the authors compare fishery CPUE and survey CPUE in the core fishery area.

*A more fully developed evaluation of fishery CPUE has yet to begin.*

The Team recommends that next year’s assessment include additional projections based on fixed levels of catch rather than fixed levels of fishing mortality, with the number of additional projections and the levels of fixed catch to be chosen by the author.

*An array of fixed future catches has been included as part of the decision table.*

## **Introduction**

### ***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.

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

In the EBS pollock spawn generally in the period 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 (Jung et al. 2006, Bacheler et al. 2010).

Females are batch spawners with up to 10 batches of eggs per female per year. 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 et al. 2011, Ciannelli et al. 2004). Duffy-Anderson et al. (2015) provide a review of the early life history of EBS pollock.

Throughout their range juvenile pollock feed on a variety of planktonic crustaceans, including calanoid copepods and euphausiids. In the EBS shelf region, one-year-old pollock are found throughout the water column, but also commonly occur in the NMFS bottom trawl survey. Ages 2 and 3 year old pollock are rarely caught in summer bottom trawl survey gear and are more common in the midwater zone as detected by mid-water acoustic trawl surveys. Younger pollock are generally found in the more northern parts of the survey area and appear to move to the southeast as they age (Buckley et al. 2009). Euphausiids, principally *Thysanoessa inermis* and *T. raschii*, are among the most important prey items for pollock in the Bering Sea (Livingston, 1991; Lang et al., 2000; Brodeur et al., 2002; Cianelli et al., 2004; Lang et al., 2005). Pollock diets become more piscivorous with age, and cannibalism has been commonly observed in this region. However, Buckley et al. (2016) showed spatial patterns of pollock foraging by size of predators. For example, the northern part of the the shelf region between the 100 and 200 m isobaths (closest to the shelf break) tends to be more piscivorous than counterparts in other areas.

### ***Stock structure***

Data from the survey work in the Northern Bering Sea (NBS) region (north of Nunivak Island to the Russian convention line and into Norton Sound) from 2017 and 2018, as shown below and evaluated in the appendix, suggests that there are concentrations of pollock present which contrasts with the 2010 survey when relatively few pollock were present. The pattern of temperatures in the region likely affect the pollock distribution in ways that likely vary over time. However, there is evidence of a relationship between mean bottom temperatures in the US zone on the EBS shelf and subsequent biomass estimates in the Navarin basin (the Russian area adjacent to the Convention Line; e.g., Stepanenko and Gritsay 2018, Ianelli et al. 2015). Some genetic samples were taken from pollock and collections continue. Pending funding availability, analysis of these samples could help ascertain the extent that these fish are related to those observed in the normal EBS shelf survey area. Genetic samples taken from the 2017 summer bottom trawl survey from the Northern Bering Sea can be compared with samples from the standard Bering Sea Unimak, Pribilof, Bogoslof, and Zhemchug. This planned study should help improve stock structure evaluation (last done in Ianelli et al. 2015).

### **Fishery**

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

Historically, EBS pollock catches were low until directed foreign fisheries began in 1964. Catches increased rapidly during the late 1960s and reached a peak in 1970–75 when they ranged from 1.3 to 1.9 million t annually. Following the peak catch in 1972, bilateral agreements with Japan and the USSR resulted in reductions. During a 10-year period, catches by foreign vessels operating in the “Donut Hole” region of the Aleutian Basin were substantial totaling nearly 7 million t (Table

[1](#)). A fishing moratorium for this area was enacted in 1993 and only trace amounts of pollock have been harvested from the Aleutian Basin region since then. Since the late 1970s, the average EBS pollock catch has been about 1.2 million t, ranging from 0.810 million t in 2009 to nearly 1.5 million t during 2003– 2006 (Table [1](#)). United States vessels began fishing for pollock in 1980 and by 1987 they were able to take 99% of the quota. Since 1988, U.S. flagged vessels have been operating in this fishery. The current observer program for the domestic fishery formally began in 1991 and prior to that, observers were deployed aboard the foreign vessels since the late 1970s. From the period 1991 to 2011 about 80% of the catch was observed at sea or during dockside offloading. Since 2011, regulations require that all vessels participating in the pollock fishery carry at least one observer so nearly 100% of the pollock fishing operations are monitored by scientifically trained observers. Historical catch estimates used in the assessment, along with management measures (i.e., ABCs and TACs) are shown in Table [2](#).

#### *Catch patterns*

The "A-season" for directed EBS pollock fishing opens on January 20th and fishing typically extends into early-mid April. During this season the fishery targets pre-spawning pollock and produces pollock roe that, under optimal conditions, can comprise over 4% of the catch in weight. The second, 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; Fig. [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).

The catch estimates by sex for the seasons indicate that over time, the number of males and females has been fairly equal (Fig. [2](#)). The 2018 A-season fishery spatial pattern had relatively high concentrations of fishing on the shelf north of Unimak Island, especially compared to the pattern observed in 2016 when the fishing activity extended farther north (Fig. [3](#)). The 2018 A-season catch rates continued to be high improving even on the good conditions observed in 2016 and 2017 A (and B) seasons (Fig. [4](#)). 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. To date, it appears that the pollock fleet as a whole took advantage of this added flexibility (Fig. [5](#)).

The fishing in summer-fall 2018 was again concentrated in the south eastern area near the shelf break but also showed more catches in the northwestern part compared to 2016 and 2017 (Fig. [6](#)). The 2018 summer and fall (B-season) catch per hour fished was lower than the last few years and fishing began slowly and improved to be about average (since 2011; Fig. [7](#)). Since 1979 the catch of EBS pollock has averaged 1.19 million t with the lowest catches occurring in 2009 and 2010 when the limits were set to 0.81 million t due to stock declines (Table [2](#)). Pollock retained and discarded catch (based on NMFS observer estimates) in the Eastern Bering Sea and Aleutian Islands for 1991–2018 are shown in Table [3](#). Since 1991, estimates of discarded pollock have ranged from a high of 9.1% of total pollock catch in 1992 to recent lows of around 0.6%. These low values reflect the implementation of the NMFS' Improved Retention /Improved Utilization program. Prior

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

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

From 1995XX–1999 84,100 km<sup>2</sup>, or 22% of the Steller sea lion critical habitat was closed to the pollock fishery. Most of this closure consisted of the 10 and 20 nm radius all-trawl fishery exclusion zones around sea lion rookeries (48,920 km<sup>2</sup>, or 13% of critical habitat). The remainder was largely management area 518 (35,180 km<sup>2</sup>, or 9% of critical habitat) that was closed pursuant to an international agreement to protect spawning stocks of central Bering Sea pollock. In 1999, an additional 83,080 km<sup>2</sup> (21%) of critical habitat in the Aleutian Islands was closed to pollock fishing along with 43,170 km<sup>2</sup> (11%) around sea lion haulouts in the GOA and Eastern Bering Sea. In 1998, over 22,000 t of pollock were caught in the Aleutian Island region, with over 17,000 t taken within

critical habitat region. Between 1999 and 2004 a directed fishery for pollock was prohibited in this region. Subsequently, 210,350 km<sup>2</sup> (54%) of critical habitat 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 within the SCA varies and has ranged from an annual low of 11% in 2010 to high of 60% in 1998—the 2018 annual value was 54% but was quite high in the A-season (63%; Table 4). The higher values in recent years were likely due to good fishing conditions close to the main port.

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 (Fig. 3).

The majority (about 56%) of Chinook salmon caught as bycatch in the pollock fishery originate from western Alaskan rivers. An Environmental Impact Statement (EIS) was completed in 2009 in conjunction with the Council's recommended bycatch management approach. This EIS evaluated the relative impacts of different bycatch management approaches as well as estimated the impact of bycatch levels on adult equivalent salmon (AEQ) returning to river systems (NMFS/NPFMC 2009). As a result, revised Chinook salmon bycatch management measures went into effect in 2011 which imposed new 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 Fig. 5). These measures are all part of Amendment 110 and a summary of this and other key management measures is provided in Table 5.

### ***Economic conditions as of 2017***

Alaska pollock is the dominant species in terms of catch in the Bering Sea & Aleutian Island (BSAI) region. In 2017 pollock accounted for 70% of the BSAI's FMP groundfish harvest and 88% of the total pollock harvest in Alaska. Retained catch of pollock increased 0.5% to 1.36 million t in 2017. BSAI pollock first-wholesale value was \$1.355 billion 2017, which was roughly equal to the value in 2016 and above the 2005–2007 average of \$1.25 billion. The higher revenue in recent years is largely the result of increased catch and production levels as the average first-wholesale price of pollock products have declined since peaking in 2008–2010 and since 2013 have been close to the 2005–2007 average, though this varies across products types. The marginal increases in the average first-wholesale price of pollock products in 2016 and 2017 are largely due to increases the price of surimi products.

Pollock is targeted exclusively with pelagic trawl gear. The catch of pollock in the BSAI was rationalized with the passage of the AFA in 1998,<sup>1</sup> which, among other things, established a proportional allocation of the total allowable catch (TAC) among vessels in sectors which were allowed to form into cooperatives.<sup>2</sup> Alaska caught pollock in the BSAI became certified by the Marine Stewardship Council (MSC) in 2005, an NGO based third-party sustainability certification, which some buyers seek. In 2015 the official U.S. market name changed from “Alaska pollock” to “pollock” enabling U.S. retailers to differentiate between pollock caught in Alaska and Russia.

Prior to 2008 pollock catches were high at approximately 1.4 million t in the BSAI for an extended period (Table 6). The U.S. accounted for over 50% of the global pollock catch (Table 8). Between 2008–2010 conservation reductions in the pollock total allowable catch (TAC) trimmed catches to an average 867 kt. The supply reduction resulted in price increases for most pollock products, which mitigated the short-term revenue loss (Table 8). Over this same period, the pollock catch in Russia increased from an average of 1 million t in 2005–2007 to 1.4 million t in 2008–2010 and Russia’s share of global catch increased to over 50% and the U.S. share decreased to 35%. Russia lacks the primary processing capacity of the U.S. and much of their catch is exported to China and is re-processed as twice-frozen fillets. Around the mid- to late- 2000s, buyers in Europe, an important segment of the fillet market, started to source fish products with the MSC sustainability certification, and retailers in the U.S. later began to follow suit. Asian markets, an important export destination for a number of pollock products, have shown less interest in requiring MSC certification. The U.S. was the only producer of MSC certified pollock until 2013 when roughly 50% of the Russian catch became MSC certified. Since 2010 the U.S. pollock stock rebounded with catches in the BSAI ranging from 1.2–1.3 million t and Russia’s catch has stabilized at 1.5 to 1.6 million t. The majority of pollock is exported; consequently exchange rates can have a significant impact on market dynamics, particularly the Dollar-Yen and Dollar-Euro.<sup>3</sup> Additionally, pollock more broadly competes with other whitefish that, to varying degrees, can serve as substitutes

<sup>1</sup>The AFA was implemented in 1999 for catcher/processors, and in 2000 for catcher vessel and motherships.

<sup>2</sup>The BSAI pollock TAC is divided between Community Development Program (10% off the top), with the remaining amount split among shore-based catcher vessels (50%), at-sea catcher/processors (40%) and motherships (10%).

<sup>3</sup>Aggregate exports in Table 8 may not fully account for all pollock exports as products such as meal, minced fish and other ancillary product may be coded as generic fish type for export purposes.

depending on the product.

This market environment accounts for some of the major trends in prices and production across product types. Fillet prices peaked in 2008–2010 but declined afterwards because of the greater supply from U.S. and Russia. The 2013 MSC certification of Russian-caught pollock enabled access to segments of European and U.S. fillet markets, which has put continued downward pressure on prices. Pollock roe prices and production have declined steadily over the last decade as international demand has waned with changing consumer preferences in Asia. Additionally, the supply of pollock roe from Russia has increased with catch. The net effect has been not only a reduction in the supply of roe from the U.S. industry, but also a significant reduction in roe prices which are roughly half pre-2008 levels. Prior to 2008, roe comprised 23% of the U.S. wholesale value share, and since 2011 it has been roughly 10%. With the U.S. supply reduction in 2008–2010, surimi production from pollock came under increased pressure as U.S. pollock prices rose and markets sought cheaper sources of raw materials (see Guenneugues and Ianelli 2013 for a global review of surimi resources and market). This contributed to a growth in surimi from warm-water fish of southeast Asia. Surimi prices spiked in 2008–2010 and have since tapered off as production from warm-water species increased (as has pollock). A relatively small fraction of pollock caught in Russian waters is processed as surimi. Surimi is consumed globally, but Asian markets dominate the demand for surimi and demand has remained strong.

The catch of pollock can be broadly divided between the shore-based sector where catcher vessels make deliveries to inshore processors, and the at-sea sector where catch is processed at-sea by catcher/processors and motherships before going directly to the wholesale markets. The retained catch of the shore-based sector increased 1% increase to 710 kt. The value of these deliveries (shore-based ex-vessel value) totaled \$205.1 million in 2017, which was down 1.8% from the ex-vessel value in 2016, as the increased catch was offset by a decrease in the ex-vessel price (Table 6). The first-wholesale value of pollock products was \$841 million for the at-sea sector and \$513 million for the shore-based sector (Table 7). The higher revenue in recent years is largely the result of increased catch levels as the average price of pollock products has declined since peaking in 2008–2010 and since 2013 has been close to the 2005–2007 average, though this varies across products types. The average price of pollock products in 2017 increased for the at-sea sector and decreased for the shore-based sectors. The increase in the at-sea sector revenues was largely due to an increase in surimi prices, an increase which was not observed for the shore-based processors. Fillet product prices declined in 2017 while roe prices increased, however both remain low relative to levels roughly a decade ago.

The portfolios of products shore-based and at-sea processors produce are similar. In both sectors the primary products processed from pollock are fillets, surimi and roe, with each accounting for approximately 40%, 35%, and 10% of first-wholesale value (Table 7). The price of products produced at-sea tend to be higher than comparable products produced shore-based because of the shorter time span between catch, processing and freezing. Since 2014 the price of fillets produced at-sea tend to be about 10% higher, surimi prices tend to be about 35% higher and the price of roe about 50% higher. Average prices for fillets produced at-sea also tend to be higher because they produce proportionally more higher-priced fillet types (like deep-skin fillets). The at-sea price first wholesale premium averaged roughly \$0.30 per pound between 2005–2010 but has decreased to an average of \$0.20 per pound between 2011–2016, in part, because the shore-based sector increased their relative share of surimi production.<sup>4</sup> The at-sea price first wholesale premium increased to

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<sup>4</sup>The at-sea price premium is the difference between the average price of first-wholesale products at-sea and the average price of first-wholesale products shore-based.

\$0.37 in 2017 because of the difference in surimi prices between sectors.

#### *Pollock fillets*

A variety of different fillets are produced from pollock, with pin-bone-out (PBO) and deep-skin fillets typically accounting for approximately 70% and 30% of production in the BSAI, respectively. Deep-skin fillet's share of production increased to 37% in 2017. Total fillet production decreased 2.7% to 157 kt in 2016, but since 2010 has increased with aggregate production and catch and has been higher than the 2005–2007 average (Table 7). The average price of fillet products in the BSAI decreased 8% to \$1.30 per pound and is below the inflation adjusted average price of fillets in 2005–2007 of \$1.49 per pound (2017 dollars). Media reports indicate that headed-and-gutted (H&G) and fillet prices tended to be low throughout much of the year. High inventories, particularly early in the year, were cited as contributing factors. Low H&G prices incentivize Russia producers to upgrade their fillet production capacity in the near future, though fillets are a small portion of their primary production. Much of the Russian catch already goes to China for secondary processing into fillets so this would do little to increase the overall volume, however, increased primary fillet processing in Russia could increase competition with U.S. produced single-frozen fillet products. Approximately 30% of the fillets produced in Alaska are estimated to remain in the domestic market, which accounts for roughly 45% of domestic pollock fillet consumption (AFSC 2016).<sup>5</sup> As fillet markets in recent years have become increasingly tight, the industry has tried to maintain value by increasing domestic marketing for fillet based product and creating product types that are better suited to the American palette, in addition to increased utilization of by-products. Reductions in whitefish supplies in 2018 has put upward pressure on pollock prices, however, U.S.-China trade policy uncertainty could negatively affect the market.

#### *Surimi seafood*

Surimi production continued an increasing trend through 2017, but at a rate of 3.1% to 196.7 kt which is above the 2005–2007 average. Prices have increased since 2013 to \$1.35 per pound in the BSAI in 2017 (Table 7). Because surimi and fillets are both made from pollock meat, activity in the fillet market can influence the decision of processors to produce surimi as smaller average size of fish can incentivize surimi production, particularly it yields a higher value than fillets. Additionally, the supply of raw surimi material in Japan has been limited (and is expected to be the case through 2018). Increasing Atka mackerel prices (another source of raw material for surimi) could also increase demand for pollock based surimi.

#### *Pollock roe*

Roe is a high priced product that is the focus of the A season catch destined primarily for Asian markets. Roe production in the BSAI tapered off in the late–2000s and since has generally fluctuated at under 20 kt annually, production averaged 27 kt in 2005–2007 and was 18.4 kt in 2017, which is up 29% from 2016 (Fig. 8). Prices peaked in the mid-2000s and have followed a decreasing trend over the last decade which continued until 2015. The Yen to U.S. Dollar exchange rate can

<sup>5</sup> Additionally, roughly 10% of the at-sea BSAI production is processed as H&G which is mostly exported, primarily to China, where is reprocessed as fillets and some share of which returns to the U.S.. China also processes H&G from Russia into fillets which are also imported into the domestic market. Current data collection does not allow us to estimate the share of U.S. returning imports.

influence prices and has varied. The average roe price in the BSAI was up 2.2% in 2017 to \$2.91 per pound, with a 32% increase in value to \$118 million (Table 7).

### *Fish oil*

Using oil production per 100 tons as a basic index (tons of oil per ton retained catch) shows increases for the at-sea sector. In 2005–2007 it was 0.3% and starting in 2008 it increased and leveled off after 2010 with over 1.5% of the catch being converted to fish oil (Table 9). This represents about a 5-fold increase in recorded oil production during this period. Oil production from the shore-based fleet was somewhat higher than the at-sea processors prior to 2008 but has been relatively stable. Oil production estimates from the shore-based fleet may be biased low because some production occurs at secondary processors (fishmeal plants) in Alaska. The increased production of oil beginning in 2008 can be attributed to the steady trend to add more value per ton of fish landed.

## **Data**

The following lists the data used in this assessment:

| Source                                | Type  | Years   |
|---------------------------------------|---|---|
| Fishery                               | Catch biomass                                   | 1964–2018   |
| Fishery                               | Catch age composition                           | 1964–2017   |
| Fishery                               | Japanese trawl CPUE                             | 1965–1976   |
| EBS bottom trawl                      | Area-swept biomass and age-specific proportions | 1982–2018   |
| Acoustic trawl survey                 | Biomass index and age-specific proportions      | 1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006–2010, 2012, 2014, 2016, 2018 |
| Acoustic vessels of opportunity (AVO) | Biomass index                                   | 2006–2018   |

### *Fishery*

#### *Catch*

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 within each stratum to arrive at an overall age composition for each year. Data were collected through shore-side sampling and at-sea observers. 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 1991–2017 (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 effective sample size for

fitting fishery age composition data within the assessment model. In addition, estimates of stratum-specific fishery mean weights-at-age (and variances) are provided which are useful for evaluating general patterns in growth and growth variability. For example, Ianelli et al. (2007) showed that seasonal aspects of pollock condition factor could affect estimates of mean weight-at-age. They showed that within a year, the condition factor for pollock varies by more than 15%, with the heaviest pollock caught late in the year from October–December (although most fishing occurs during other times of the year) and the thinnest fish at length tending to occur in late winter. They also showed that spatial patterns in the fishery affect mean weights, particularly when the fishery is shifted more towards the northwest where pollock tend to be smaller at age. 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 (Fig. 9; Table 10). The sampling effort for age determinations, weight-length measurements, and length frequencies is shown in Tables 11, 12, and 13. Sampling for pollock lengths and ages by area has been shown to be relatively proportional to catches (e.g., Fig. 1.8 in Ianelli et al. 2004). 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 (1963–2018) from NMFS surveys in the Bering Sea and Aleutian Islands Region are given in (Table 14). Since these values represent extremely small fractions of the total removals (about 0.02%) they are ignored for assessment purposes.

## ***Surveys***

### ***Bottom trawl survey (BTS)***

Trawl surveys have been conducted annually by the AFSC to assess the abundance of crab and groundfish in the Eastern Bering Sea since 1979 and since 1982 using standardized gear and methods. For pollock, this survey has been instrumental in providing an abundance index and information on the population age structure. This survey is complemented by the acoustic trawl (AT) surveys that sample mid-water components of the pollock stock. Between 1991 and 2018 the BTS biomass estimates ranged from 2.28 to 8.39 million t (Table 15; Fig. 10). 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. These surveys 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. However, 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 C; Fig. 11).

Beginning in 1987 NMFS expanded the standard survey area farther to the northwest. The pollock

biomass levels found in the two northern strata were highly variable, ranging from 1% to 22% of the total biomass; whereas the 2014 estimate was 12%, 2015 was 7%, and in the past two years is slightly below the average (5%) at 4% and 3%–4% (Table 15). In some years (e.g., 1997 and 1998) some stations had high catches of pollock in that region and this resulted in high estimates of sampling uncertainty (CVs of 95% and 65% for 1997 and 1998 respectively). This region is contiguous with the Russian border and these strata seem to improve coverage over the range of the exploited pollock stock.

The 2018 bottom-trawl survey biomass estimate (design-based, area swept) was 3.11 million t, below the average for this survey (4.7 million t). Particularly unusual this year was the complete lack of cold water on the bottom throughout the survey area (Fig. 12). Pollock appeared to be distributed more northerly in 2018 again (as was the case in 2017 (Fig. 13)). These figures also show that the highest densities of pollock were at stations near Zhemchug Canyon.

The BTS abundance-at-age estimates show variability in year-class strengths with substantial consistency over time (Fig. 14). 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). Age 2 or 3 pollock (lengths around 20–29 cm and 30–39 cm, respectively) are relatively rare in this survey presumably because they are more pelagic as juveniles. Observed fluctuations in survey estimates may be attributed to a variety of sources including unaccounted-for variability in natural mortality, survey catchability, and migrations. As an example, some strong year classes appear in the surveys over several ages (e.g., the 1989 year class) while others appear only at older ages (e.g., the 1992 and 2008 year class). Sometimes initially strong year classes appear to wane in successive assessments (e.g., the 1996 year class estimate (at age 1) dropped from 43 billion fish in 2003 to 32 billion in 2007 (Ianelli et al. 2007). Retrospective analyses (e.g., Parma 1993) have also highlighted these patterns, as presented in Ianelli et al. (2006, 2011). Kotwicki et al. (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 2018 survey age compositions were developed from age-structures collected during the survey (June-July) and processed at the AFSC labs within a few weeks after the survey was completed. The level of sampling for lengths and ages in the BTS is shown in (Table 16). The estimated numbers-at-age from the BTS for strata (1–9 except for 1982–84 and 1986, when only strata 1–6 were surveyed) are presented in Table 17 and contains the values used for the index which accounts for density-dependence in bottom trawl tows (Kotwicki et al. 2014). Mean body mass at ages from the survey are shown in (Table 18).

The bottom trawl survey has extended to the north in 2010, 2017, and again this year (but was limited to 49 stations). 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 included the NBS area is to use observed spatial and temporal correlations. We used the vector-autoregressive spatial temporal (VAST) model of Thorson (2018b) together with the density-dependent corrected CPUE values from each station (including stations where pollock were absent; Table 19). Please refer to the appendix for further details on the implementation. The appendix also shows 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. Application of this index within the stock assessment model requires accounting for the temporal covariation. Since this has been part of the assessment for the time series of biomass used in past years, including the

covariance specification was simple to implement and required no changes to the assessment model code.

#### *Acoustic trawl (AT) surveys*

The AT surveys are conducted biennially 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 20). Estimated pollock biomass (to 3m from bottom) for the shelf was above 4 million tons in the early years of the time series (Table 19). It dipped below 2 million t in 1991. Since 1994, the years for which AT survey estimates are available to within 0.5 m of bottom, the biomass increased and remained between about 3 and 4.5 million t for a decade (1994–2004). 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 (the ‘cold’ period; Honkalehto and McCarthy 2015). In 2014 and 2016 (another ‘warm’ period) with the growth of the strong 2012 year class, AT biomass estimates increased to over 4 million t, exceeding levels observed in 1994–2004 (Tables 19 and 21).

The 2018 AT survey began on 6 June. Unfortunately, permission to extend the AT survey into the Russian Cape Navarin area was denied. Instead, the survey plan was to extend several tracklines north of the normal (‘core’) survey area between approximately 170°W and west of St. Matthew Island, based on 2016 and 2017 observations of more pollock than usual in that area. Due to an unforeseen ship failure mid-way through the survey the planned northern extension was reduced (trackline spacing increased). Due to another failure at the end of the survey, the final 3 transects of the AT survey core area were missed. (red transects in Fig. 16). The survey ended about 2 weeks later than planned on 26 August. About 6.1% (~6,016 nmi<sup>2</sup>) of the normal core survey area was unsampled.

Estimates of pollock by length and age for the surveyed area in 2018 were made using routine AT survey methods (e.g., Honkalehto and McCarthy, 2015). Estimates for pollock from the midwater layer between the surface and 3m were combined with those from the bottom layer between 0.5 and 3m depth, as adopted in 2016. The pollock biomass estimate to within 0.5 m of the seafloor was 2.321 million t for the sampled ‘core’ area, which encompassed 92,283 nmi<sup>2</sup> in 2018 was 2.321 million t. The pollock biomass estimate was 237,722 t for the northern extension area, which encompassed 6,900 nmi<sup>2</sup> outside of the traditional AT survey area, pollock biomass was estimated to be 237,722 t. A spatial comparison of these AT survey biomass estimates with the BTS biomass is shown in Fig. 17.

The amount of pollock in the vicinity of the three unsampled transects at the survey end was estimated using acoustic data collected in that area by the RACE BTS vessels (see Honkalehto et al., 2011 for details, and McCarthy et al. in prep.) and AT survey trawl data. That is, BTS backscatter data in the unsampled area and the AT survey trawl data from the two adjacent transects surveyed by the RV Oscar Dyson were used to estimate pollock abundance and biomass by length and age in that area. The deeper shelf break portion (> 200 m) of the unsampled area normally covered by the AT survey was omitted as this relatively small area was not occupied by the BTS vessels. The estimates for the unsampled area (16m from sea surface to 0.5 m above sea floor) were 616 million pollock with a biomass of 178,194 t. These estimates represent 7.1% of the total biomass and 11.1% of total abundance for the entire core AT survey area (i.e. the traditional survey area excluding the northern extension).

The combined biomass estimates (sampled plus unsampled areas to within 0.5 m of seafloor, excluding northern extension area) for the 2018 AT survey is 2.50 million t. This is below average for the time series since 1994 (Table 21).

Relative estimation errors for the total biomass were derived from a one-dimensional (1D) geostatistical method, and accounts for observed spatial structure for sampling along transects (Table 21; Petitgas 1993, Walline 2007, Williamson and Traynor 1996). 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 25% for application within the assessment model.

The 2018 EBS acoustic-trawl survey estimates of population numbers at age were developed based primarily on the BT survey age samples, and supplemented with a small set of juvenile samples from the AT survey. These samples were used to develop age-length keys, which were applied to the population size composition estimates from the AT survey (Fig. 15). Interestingly, the 2018 data support the observation in 2016 that the 2013 year class was relatively abundant (along with the 2012 year class; Table 22).

### ***Other time series used in the assessment***

#### *Japanese fishery CPUE index*

An available time series relating the abundance of pollock during the period 1965–1976 was included. This series is based on Japanese fishery catch rates which used the same size class of trawl vessels as presented in Low and Ikeda (1980). A coefficient of variation of 20% was applied.

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

The details of how acoustic backscatter data from the two commercial fishing vessels chartered for the eastern Bering Sea bottom trawl survey (BTS) were used to compute a midwater abundance index for pollock can be found in Honkalehto et al. (2011). This index was updated this year and shows acoustic-trawl survey in the EBS. This biomass series shows a steady decrease since 2015 (Table 23).

A spatial comparison between the BTS data and AVO survey transects in 2018 suggests differences in the locales and densities of pollock (Fig. 18). This figure also shows that the AVO survey detected densities that were less apparent in the BTS data.

## **Analytic approach**

### ***General model structure***

A statistical age-structured assessment model conceptually outlined in Fournier and Archibald (1982) and like Methot's (1990) stock synthesis model was applied over the period 1964–2018. A technical description is presented in the Model Details section attached. The analysis was first introduced in the 1996 SAFE report and compared to the cohort analyses that had been used previously and was document Ianelli and Fournier 1998). The model was implemented using automatic differentiation software developed as a set of libraries under the C++ language (“ADMB,” Fournier et al. 2012). The data updated from last year’s analyses include:

- The 2018 EBS bottom trawl survey estimates of population numbers-at- age and biomass were added
- The 2018 AVO acoustic backscatter data (as collected from the EBS bottom trawl survey vessels) as a biomass index was added
- The 2018 EBS acoustic-trawl survey estimates of population numbers-at- age and biomass were added
- The 2017 fishery age composition data were added
- The catch biomass estimates were updated through to the current year

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](#)).

### ***Description of alternative models***

Model configuration options developed this year relate primarily to alternative data treatment and a separate re-evaluation of the steepness prior and stock recruitment relationship. The two model alternatives (treated as sensitivities) includes one which incorporates a spatio-temporal model fit to BTS CPUE data *including stations from the NBS*. This survey data model applies the VAST (Thorson 2018) approach and due to allowing for spatial and temporal correlation, is well suited to having missing stations in some areas and years (and adjusts uncertainty accordingly). The second data treatment simply increased the weight on the final two survey data points (by reducing the CVs by a factor of 2). This was done because initial model runs indicated relatively poor fits to these data and by adding some constraint, it was hoped that structural aspects (and/or data conflicts) could be revealed. Finally, the fourth model involved revisiting prior distribution on steepness for the stock recruitment relationship (a response to Plan Team and SSC requests). This included comparing a Beverton-Holt model with some recent meta-analyses on priors for the steepness parameter based on Thorson et al. (2018) approach.

### ***Input sample size***

Sample sizes assumed were re-evaluated in 2016 against the trade-off with flexibility in time and age varying selectivity. This resulted in tuning the recent era (1991-present year) to average sample sizes of 350 for the fishery and then using estimated values for the intermediate and earliest period (Table 24). We assumed average values of 100 and 50 for the BTS and ATS data, respectively with inter-annual variability reflecting the variability in the number of hauls sampled for ages. The tuning aspects for these effective sample size weights were estimated following Francis 2011 (equation TA1.8, hereafter referred to as Francis weights).

## *Parameters estimated outside of the assessment model*

### *Natural mortality and maturity at age*

The baseline 16.1 model specification has been to use constant natural mortality rates at age ( $M=0.9$ , 0.45, and 0.3 for ages 1, 2, and 3+ respectively based on earlier work of Wespestad and Terry 1984). These values have been applied to catch-age models and forecasts since 1982 and appear reasonable for pollock. When predation was explicitly considered estimates tend to be higher and more variable (Holsman et al. 2015; Livingston and Methot 1998; Hollowed et al. 2000). Clark (1999) noted 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. 2015). In the 2014 assessment different natural mortality vectors were evaluated in which the “Lorenzen” approach and that of Gislason et al (2010) were tested. The values assumed for pollock natural mortality-at-age and maturity-at-age (for all models; Smith 1981) consistent with previous assessments were:

| 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 |

In the supplemental multi-species assessment model alternative values of age and time-varying natural mortality are presented. Those estimates indicate higher values than used here. In last year’s evaluation of natural mortality 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 above).

Maturity-at-age values used for the EBS pollock assessment are originally based on Smith (1981) and were reevaluated (e.g., Stahl 2004; Stahl and Kruse 2008a; and Ianelli et al. 2005). These studies found inter-annual variability but general consistency with the current assumed schedule of proportion mature at age.

### *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., 2017 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, these estimates can have large impacts on recommendations (e.g., ABC and OFL).

The mean weight at age in the fishery can vary due to environmental conditions in addition to spatial and temporal patterns of the fishery. Bootstrap distributions of the within-year sampling variability indicate it is relatively small compared to between-year variability in mean weights-at-age. This implies that processes determining mean weights in the fishery cause more variability than sampling (Table 25). 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., Fig. 19). 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 (and uncertainty) for 2018–2020 (Table 25). The changes in weight-at-age in the fishery are substantial, especially for the apparent abundant year-classes (e.g., the 4–9 year-olds from 2012–2017 representing the 2008 year class; Fig. 19.) 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 (Fig. 20). Breaking this further by year and strata for recent years shows variability in the relative body mass at age between strata and years (Fig. 21). In summary, these figures support that accounting for year and cohort effects is important in projecting body mass-at-age forward.

Extensive fishery observer data were available for examining patterns in length-weight condition (standardized for length over all years and areas, 1991–2018). The process for these data were:

1. extract 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. compute the mean value of body mass (weight) for each cm length bin over all areas and time
3. divide each weight measurement by that mean cm-specific value (the “standardization” step)
4. plot 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 (Fig. 22). As the summer/fall progresses, fish were at their heaviest given length (Fig. 22). 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 (Fig. 23 and 24). Differences in seasons were most apparent. The A-season data indicated that most pollock were below the global mean except for a few years whereas in the southeast the B-season were mostly above average in all years. Computing just the mean standardized value for each strata and year shows this pattern more clearly (Fig. 25). Of particular concern is that in the A-season, which is primarily focused on pre-spawning fish, the condition of pollock appears to have been the skinniest (given length) for the past four years in a row (Fig. 25).

#### ***Parameters estimated within the assessment model***

For the selected model, 936 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment, and stock- recruitment parameters account for 78

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 1964–2017 and projected recruitment variability (using the variance of past recruitments) for five years (2019–2024). The two-parameter stock-recruitment curve 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 1978 year-class through to the 2016 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 55 parameters and the age-time selectivity schedule forms a 10x55 matrix of 550 parameters bringing the total fishing mortality parameters to 605. The rationale for including time-varying selectivity has recently been supported as a means to improve retrospective patterns (Szuwalski, Ianelli, and Punt 2017) and as best practice (Martell and Stewart, 2013).

For surveys and indices, the treatment of the catchability coefficient, and interactions with age-specific selectivity require consideration. For the BTS index, selectivity-at-age is estimated with a logistic curve in which year specific deviations in the parameters is allowed. Such time-varying survey selectivity is estimated to account for changes in the availability of pollock to the survey gear and is constrained by pre-specified variance terms. For the AT survey, which originally began in 1979 (the current series including data down to 0.5m 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, five catchability coefficients were estimated: one each for the early fishery catch-per-unit effort (CPUE) data (from Low and Ikeda, 1980), the early bottom trawl survey data (where only 6 strata were surveyed), the main bottom trawl survey data (including all strata surveyed), 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 total 135 (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 Fig. 10; for the AT index the annual errors were specified to have a mean of 0.20; while for the AVO data, a value relative to the AT index was estimated and gave a mean of about 0.25).
- Fishery and survey proportions-at-age estimates (multinomial with effective sample sizes pre-

sented Table 24).

- 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 1991-2017 and externally estimated variance terms as described in Appendix 1A of Ianelli et al. (2016).

Work evaluating temperature and predation-dependent effects on the stock- recruitment estimates continues (Spencer et al. 2016). This approach modified the estimation of the stock-recruitment relationship by including the effect of temperature and predation mortality. A relationship between recruitment residuals and temperature was noted (similar to that found in Mueter et al., 2011) and 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). The extent that such relationships affect the stock-recruitment estimates (and future productivity) is a continuing area of research.

## Results

### *Model evaluation*

A sequential sensitivity of available new data showed that adding the 2017 fishery catch-at-age data and the 2018 catch biomass information resulted in an increase in spawning biomass estimates (Fig. 26). As survey data were added to the model, the results become more similar to last year’s estimate (for 2017 spawning biomass) and shows a lower biomass estimate for 2018 (Fig. 26). Additional models for evaluations were

0. Last year’s model (“Model 16.1”) without any data update
1. The same as last year but with all data time series updated through the most recently available information
2. The same as last year but with the survey time series including an alternative treatment of the NBS indicative biomass (application of the VAST model for the bottom trawl survey index)
  - The rationale for considering this is the likelihood that pollock in the NBS are related and contribute to the EBS fishery
3. The same as Model 16.1 but with the coefficient of variations reduced by half in the terminal year

- This was done as a sensitivity since three observations indicated a decline yet the structural aspects of the model seem to constrain the extent of the decline given past trends in the indices.
4. The same as Model 16.1 but with a Beverton-Holt stock recruitment relationship and steepness from a meta-analysis.
- This was brought forward as a sensitivity in trying alternative prior distributions for steepness.

The reference model (Model 16.1) when compared to the two with different data treatments showed different patterns but ended up with similar model predictions for 2018 (Fig. 27). The spawning biomass estimates and age compositions indicates a slight shift in the scale of spawning biomass estimates relative to last year (Fig. 28). The recent recruitment pattern (at age 1) shows an increase in the 2014 value (representing the 2013 year-class) and a decline in the 2013 estimate (the 2012 year-class; Fig. 29). Diagnostics of model fits between the set evaluated are given in Table 26.

The model with a prior distribution based on meta-analysis (see section below on model description for details) using the Beverton-Holt stock recruitment estimation had very minor impact on the historical biomass and numbers at age, but did influence the shape of the stock-recruitment curve (Fig. 30). Also, it affected management quantities (Table 27).

The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) is consistent with the estimated population trends for this period (Fig. 31). The model fits the fishery-independent index from the 2006–2018 AVO data well indicating a downward trend since 2016 (Fig. 32). The fits to the bottom-trawl survey biomass (the density-dependent corrected series) appear to be reasonable (Fig. 33). Similarly, the fits to the acoustic-trawl survey biomass series is consistent with the specified observation uncertainty (Fig. 34).

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 on request.

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 (Fig. 35; 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 (Fig. 36). The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 37).

Bottom-trawl survey selectivity (Fig. 38) and fits to the numbers of age 2 and older pollock indicate that the model predicts fewer pollock than observed in the 2014 and 2015 survey but slightly more than observed in the 2012, 2013 and in 2016–17 (Fig. 33). The pattern of bottom trawl survey age composition data in recent years shows a decline in the abundance of older pollock since 2011. The 2006 year-class observations are below model expectations in 2012 and 2013, partly due to the fact that in 2010 the survey estimates are greater than the model predictions (Fig. 39). The model predicted much higher proportions of age 6 (2012 year class) than observed in the 2018 survey data whereas the expectations of 5-year old pollock was much lower than observations (both surveys indicated that the 2013 year class was more abundant than the 2012 year-class).

The fit to the numbers of age 2 and older pollock in the AT survey generally falls within the confidence bounds of the survey sampling distributions (here assumed to have an average CV of 25%) with a reasonable pattern of residuals (Fig. 34). The AT age compositions consistently track

large year classes through the population and the model fits these patterns reasonably well (Fig. 40).

As in past assessments, an evaluation of the multivariate posterior distribution was performed by running a chain of 3 million Monte-Carlo Markov chain (MCMC) simulations and saving every 600th iteration (final posterior draws totaled 5,000). A pairwise comparison for some key parameters could be evaluated (along with their marginal distributions; Fig. 41). To compare the point estimates (highest posterior density) with the mean of the posterior marginal distribution, overplotting the former on the latter for the 2018 spawning biomass estimate were similar (Fig. 42).

### ***Time series results***

The time series of begin-year biomass estimates (ages 3 and older) suggests that the abundance of Eastern Bering Sea pollock remained at a high level from 1982–88, with estimates ranging from 8 to 11 million t (Table 31). 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 new highs over 13 million t in 2016 following the low in 2008 of 4.6 million t. The estimate for 2018 is trending downward and is at just over 10 million t.

The level of fishing relative to biomass estimates show 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 (Fig. 43). During 2006 and 2007 the rate averaged more than 20% and the average fishing mortality for ages 3–8 increased during the period of stock decline. The estimate for 2009 through 2016 was below 20% due to the reductions in TACs relative to the maximum permissible ABC values and increased in the spawning biomass. The average F (ages 3–8) increased in 2011 to above 0.25 when the TAC increased but has dropped since then and in 2016 is estimated at about 0.16. Age specific fishing mortality rates reflect these patterns and show some increases in the oldest ages from 2011–2013 but also indicate a decline in recent years (Fig. 44). The estimates of age 3+ pollock biomass were mostly higher than the estimates from previous years (Fig. 45, Table 31).

Estimated numbers-at-age are presented in (Table 28) and estimated catch-at-age values are presented in (Table 29). Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment are given in (Table 30).

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 (Fig. 46).

### ***Recruitment***

Model estimates indicate that both the 2008 and 2012 year classes are well above average (Fig. 47). The stock-recruitment curve as fit within the integrated model shows a fair amount of variability both in the estimated recruitments and in the uncertainty of the curve (Fig. 48). Note that the 2015 and 2016 year classes (as age 1 recruits in 2016 and 2017) are excluded from the stock-recruitment

curve estimation. 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 (Fig. 49).

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

### ***Retrospective analysis***

Running the assessment model over a grid with progressively fewer years included (going back to 20 years, i.e., assuming the data extent ended in 1997) results in a fair amount of variability in both spawning biomass and recruitment (Fig. 50) Although the variability is high, the average bias appears to be low with Mohn's  $\rho$  equal to 0.025 for the 10 year retrospective and 0.05 if extended back 20-years.

### **Harvest recommendations**

#### ***Status summary***

The estimate of  $B_{MSY}$  is 2,280 kt (with a CV of 29%) which is less than the projected 2019 spawning biomass of 3,200 kt; (Table 32). For 2018, the Tier 1 levels of yield are 3,096,000 t from a fishable biomass estimated at around 6,073 kt (Table 33; about 137% of the  $B_{MSY}$  level). A diagnostic (see section below on model details) on the impact of fishing shows that the 2018 spawning stock size is about 62% of the predicted value had no fishing occurred since 1978 (Table 32). This compares with the 60% of  $B_{100\%}$  (based on the SPR expansion using mean recruitment from 1978–2016) and 156% of  $B_0$  (based on the estimated stock-recruitment curve). The latter two values are based on expected recruitment from the mean value since 1978 or from the estimated stock recruitment relationship.

Relative to Tier 3 indicators, the model indicates that spawning biomass will be above  $B_{40\%}$  (3,200 kt) in 2019. 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 2019 and 2020.

### ***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, their reliability is questionable. We therefore present both reference points for pollock in the BSAI to retain the option for classification in either Tier 1 or Tier 3 of 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:

$$\begin{aligned}B_{MSY} &= 2,280 \text{ kt female spawning biomass} \\B_0 &= 5,866 \text{ kt female spawning biomass} \\B_{100\%} &= 5,920 \text{ kt female spawning biomass} \\B_{40\%} &= 2,368 \text{ kt female spawning biomass} \\B_{35\%} &= 2,072 \text{ kt female spawning biomass}\end{aligned}$$

### ***Specification of OFL and Maximum Permissible ABC***

Assuming the stock-recruit relationship the 2019 spawning biomass is estimated to be 3,127,000 t (at the time of spawning, assuming the stock is fished at about recent catch levels). This is above the  $B_{MSY}$  value of 2,280,000 t. Under Amendment 56, this stock has qualified under Tier 1 and the harmonic mean value is considered a risk-averse policy since reliable estimates of  $F_{MSY}$  and its pdf are available (Thompson 1996). The exploitation- rate type value that corresponds to the  $F_{MSY}$  level was applied to the fishable biomass for computing ABC levels. 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 (normalized to the value at age 6) and mean body mass. The uncertainty in the average weights-at-age projected for the fishery and “future selectivity” has been demonstrated to affect the buffer between ABC and OFL (computed as 1-ABC/OFL) for Tier 1 maximum permissible ABC (Ianelli et al. 2015). The uncertainty in future mean weights-at-age had a relatively large impact as did the selectivity estimation.

Since the 2019 female spawning biomass is estimated to be above the  $B_{MSY}$  level (2,280 kt) and the  $B_{40\%}$  value (2,368 kt) in 2019 and if the 2018 catch is as specified above, then the OFL and maximum permissible ABC values by the different Tiers would be:

| Tier | Year | MaxABC    | OFL       |
|------|------|-----------|-----------|
| 1a   | 2019 | 3,096,000 | 3,914,000 |
| 1a   | 2020 | 2,437,000 | 3,082,000 |
| 3a   | 2019 | 2,163,000 | 2,660,000 |
| 3a   | 2020 | 1,792,000 | 2,208,000 |

### ***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 2018 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2019 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2018. 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 will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2018, 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 2020 the catch is set equal to 1.35 million t and in future years  $F$  is set equal to the Tier 3 estimate (Rationale: this was has been about equal to the catch level in recent years).

**Scenario 3:** In all future years,  $F$  is set equal to the 2017 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:** 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:** 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 2018 or 2) below half of its MSY level in 2018 or below its MSY level in 2028 under this scenario, then the stock is overfished.)

**Scenario 7:** In 2019 and 2020,  $F$  is set equal to  $\max F_{ABC}$ , and in all subsequent years,  $F$  is set equal to  $F_{OFL}$ . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) below its MSY level in 2020 or 2) below 1/2 of its MSY level in 2020 and expected to be below its MSY level in 2030 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  $B_{35\%}$ ).

### ***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 2018 (Tables 34 through 37). Under the catch set to Tier 3 ABC estimates, the expected spawning biomass will decline until 2020 and stabilize slightly above  $B_{40\%}$  (in expectation, Fig. 51).

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 2018:

- If spawning biomass for 2018 is estimated to be below  $1/2 B_{35\%}$  the stock is below its MSST.
- If spawning biomass for 2018 is estimated to be above  $B_{35\%}$ , the stock is above its MSST.
- If spawning biomass for 2018 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 ((Tables 34 through 37)). If the mean spawning biomass for 2028 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 2018 is below  $1/2 B_{35\%}$ , the stock is approaching an overfished condition.
- If the mean spawning biomass for 2018 is above  $B_{35\%}$ , the stock is not approaching an overfished condition.
- If the mean spawning biomass for 2020 is above  $1/2 B_{35\%}$  but below  $B_{35\%}$ , the determination depends on the mean spawning biomass for 2028. If the mean spawning biomass for 2030 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 2018, and it is expected to be above the "overfished condition" based on Scenario 7 (the mean spawning biomass in 2018 is above the  $B_{35\%}$  estimate; (Table 37)). Based on this, the EBS pollock stock is being fished below the overfishing level and the stock size is estimated to be above, and stay above the overfished level.

### ***ABC Recommendation***

ABC levels are affected by estimates of  $F_{MSY}$  which depends 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 at above-average levels and projections indicate declines. Updated data and analysis result in an estimate of 2018 spawning biomass (3,550 kt) which is about 156% of  $B_{MSY}$  (2,280 kt). The replacement yield—defined as the catch next year that is expected to achieve a 2019 spawning biomass estimate equal to that from 2018—is estimated to be about -340 t. Note that the negative value for replacement yield suggests that the stock will decline even in the absence of any fishing. This follows a period of increases from 2008–2017 and is expected. The extent that the stock will exhibit declines into the future depends on future recruitment, which is always uncertain. Some issues to consider in the medium-term are that

1. The conditions in summer 2018 were exceptional in the complete absence of a “cold pool” and being a second consecutive year with significant abundances found outside of the standard survey area.
2. There were relatively few juvenile pollock observed in the surveys during the summers of 2016–2018.
3. The recent BTS data continue to show low abundances of pollock aged 10 and older (Table 17). Historically there had been good representation of older fish in data from this survey. This is somewhat expected given the poor year-classes observed during the period 2000–2005.
4. The multispecies model suggests that the  $B_{MSY}$  level is around 2.9 million t instead of the 2.3 million t estimated in the current assessment (noting that the total natural mortality is higher in the multispecies model).
5. Pollock are an important prey species for other species in the ecosystem and apparent changes in the distribution may shift their availability as prey.
6. Finally, given the same estimated aggregate fishing effort in 2018, the estimated stock trend is downwards except at low catch levels (a replacement yield of -340 kt is the amount that would maintain the spawning stock constant). Being a negative value means that even without any fishing, the stock is projected to decline. Furthermore, the ability to catch roughly the same amount as in 2018 through to 2022 will require about *75% more effort* (effectively) with a decline in spawning biomass of about 30% compared to the current level (based on expected average recruitment; Fig. 52).

#### *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 matrix table below when determining whether to recommend an ABC lower than the maximum permissible. This was implemented for this year’s recommendation.

| Considerations                           |   |  |  |
|--|---|--|--|
|  | Assessment-related  | Population dynamics  | Environmental & ecosystem  |
| Level 1 Normal                           | 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   |
| Level 2 Substantially increased concerns | Substantially increased assessment uncertainty unresolved issues.   | Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.   | Some indicators showing an adverse signals but the pattern is inconsistent across all indicators.  |
| Level 3 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) |
| Level 4 Extreme concern                  | Severe problems with the stock assessment, severe retrospective bias.<br>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     |

The table is applied by evaluating the severity of three 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—adverse trends in environmental/ecosystem indi-

cators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.

*Assessment considerations* The EBS pollock assessment model appears to track the stock from year based on retrospective analysis (the pattern lacks tendency to over or under estimate the stock trend. The model tracks the available data well including multiple abundance indices. Of minor concern (presently) is the fact that the model estimate of declining abundance is somewhat less than that suggested by the survey data. The data and model appear to be consistent without big surprises relative to the ability to fit the information and provide a trade-off between process and observation errors (which combined, provide relatively high estimates of uncertainty). **We therefore rated the assessment-related concern as level 1, normal.**

*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 and 2012 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. There also are clear density-dependent effects on growth, in particular, the 2012 year class. The stock is estimated to be well above  $B_{msy}$  at present, but projections indicate a decline given recent catch levels and future trends will depend on pollock survival at egg, larval, and juvenile stages which may be compromised given the lack of a cold pool and a considerable redistribution into the northern part of the Bering Sea. It seems likely that recruitment in the near term will be below average yet the population dynamics, being data driven, projects recruitment to be average. Additional age-specific aspects of the spawning population indicates that the stock is at a low diversity of ages and the mean age of the spawning stock (weighted by spawning output) are both at relatively low levels (Fig. 53). **We therefore rated the population-dynamic concern as level 2, a substantially increased concern.**

*Environmental/Ecosystem considerations* 2018 was unprecedented (for the period of our observations) with near- complete lack of sea ice in the Northern Bering Sea and complete lack of sea ice (and resulting cold pool) over the southeastern Bering Sea shelf. The ecosystem responses indicate potential concerns for pollock, as both prey resources and predator dynamics were impacted. Over the southern shelf, a weak, delayed bloom provided reduced phytoplankton biomass which likely impacted the zooplankton prey base.

Small copepod production in the spring of 2018 was apparently above average, but decreased nauplii survival is predicted based on reduced phytoplankton. Both acoustic and RZA (rapid zooplankton assessment) estimates indicate low euphausiid abundance; both indicators suggest this high-quality prey has become less available since 2012. Over the northern shelf, large copepods were an order of magnitude less abundant than a previous survey conducted in 2007; euphausiids were also several orders of magnitude lower. Larval pollock production appears high (comparable to 2014 and 2016), which is expected in warm years, but larval survival is expected to be low due to degraded prey resources and reduced energy transfer.

Fish condition (based on weight/length residuals) show that adult pollock condition was negative in both the SEBS and NBS, which continues a declining trend since 2012. The biomass of the pelagic forager guild, which includes pollock, remains below the long-term mean with pollock declining 59% since 2014 and 38% since 2017. Total CPUE of groundfish estimated from the bottom trawl survey showed a sharp decline in 2018, primarily due to a decrease in pollock, Pacific cod, and several flatfish species.

A seabird die-off event, unprecedented in terms of spatial and temporal scale, combined with broad

reproductive failures and/or late breeding success indicate, in part, a lack of sufficient prey resources (emaciation and starvation are the only identified causes of mortality to date). In addition to several of these species preying on juvenile pollock, they also rely on the same zooplankton as pollock for survival. The die-offs may be indicative of poor juvenile pollock survival and/or available prey for juvenile pollock. Some outstanding ecosystem questions are whether Pacific cod and pollock remained in the NBS over winter 2017–2018. Given the warm water temperatures (and lack of sea ice), over-winter feeding to meet their metabolic demands may have reduced the prey base and shifted the food-web balance in the NBS.

There were also unusual observations of adult pollock behavior in Bristol Bay and these may be indicative of (i) a distribution shift in response to warm temperatures (although temperatures SEBS shelf were similar to a ‘typical’ warm year), (ii) looking for adequate prey (although stomachs were not empty and contents were ‘typical’), or (iii) potential harmful algal bloom event (samples still being processed).

In summary,

- Unprecedented warm conditions in 2018 resulted in reduced primary and secondary production
- The cold pool prediction for summer 2019 is for continued warm conditions and reduced cold pool extent
- Weak, delayed phytoplankton bloom, reduced biomass, and reduced energy transfer to upper trophic levels (i.e., zooplankton prey base and juvenile pollock)
- Zooplankton prey base reduced (small, lipid-poor taxa, few euphausiids)
- Adult pollock condition index is negative in both SEBS and NBS and has been trending downwards in SEBS since 2010.
- Unprecedented seabird die-off event and broad reproductive failures indicate, in part, a lack of sufficient prey resources

**We therefore rated the Ecosystem concern as Level 2, substantially increased concern.**  
These results are summarized as:

| Considerations      |   |   |   |
|---------------------|---|---|---|
| Assessment-related  | Population dynamics                       | Environmental or ecosystem                | Score (max of individual)                 |
| Level 1: No concern | Level 2: Substantially increased concerns | Level 2: Substantially increased concerns | Level 2: Substantially increased concerns |

The overall score is level 2, the maximum of the individual scores, suggests that setting an ABC below the maximum permissible is warranted. The SSC recommended against using a table that showed example alternatives to select buffers based on that risk level. Thompson (unpublished Sept 2018 plan team document) tabulated the magnitude of buffers applied by the Plan Teams for the period 2003–2017, and found that the mode of the buffers recommended was 10–20%. Using this as a guideline, a buffer of 15% would give an ABC as  $0.85 \times \text{ABC}_{\max} = 2,631 \text{ kt}$ ). In the past, the SSC has considered factors similar to those presented above and selected an ABC based on

Tier 3 estimates. We recommend this added precaution again again this year, (i.e., ABC = 2,163 kt) which implies a buffer of 30%.

Recognizing that the actual catch will be constrained by other factors (the 2 million t BSAI ground-fish catch limit and bycatch avoidance measures), applying the maximum permissible Tier 1a ABC seems clearly risky. Such high catches would result in unprecedented variability and removals from the stock (and require considerably more capacity and effort). Less variability in catch would also result in less spawning stock variability (and reduce risks to the fishery should another period of poor recruitments occur). 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 2019 catch values. These indicators and rationale for including them are summarized in Table 43). Model 16.1 results for these indicators are provided in Table 44. Each column of this table uses a fixed 2019 catch and assumes the same effort for the four additional projection years (2020–2023). 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 2020 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. However, for catch to equal the 2018 value, more fishing effort will likely be required and there is an good chance that the proportion of the stock less than age 6 will be greater than the historical average. In terms of catch advice, aiming for a catch between 1.25 and 1.374 million t results in a roughly even chance that the stock in 2020 will be equal to the long term mean.

## 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 (see Appendix 1 of the Ecosystem Considerations chapter for methods), 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 (see Sterling and Ream 2004, Zeppelin and Ream 2006) will require careful monitoring and evaluation.

A brief summary of these two perspectives (ecosystem effects on pollock stock and pollock fishery effects on ecosystem) is given in (Table 41). 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.

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

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

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. In this approach, 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).

Euphausiids make up a large component of the pollock diet. The euphausiid abundance on the Bering Sea shelf is presented as a section of the 2017 Ecosystem Considerations Chapter of the SAFE report and shows a continued decline in abundance since the peak in 2009 (for details see De Robertis et al. (2010) and Ressler et al. (2012). The role that the apparent recent 2009 peak abundance had in the survival of the 2008 year class of EBS pollock is interesting. Contrasting this with how the feeding ecology of the 2012 year class (also apparently well above average) may differ is something to evaluate in the future.

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

Since the pollock fishery is primarily pelagic in nature, the bycatch of non-target species is small relative to the magnitude of the fishery (Table 40). 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 but has dropped in 2015 and been about average since then. 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 less than 1% of the total pollock catch. Incidental catch of Pacific cod has varied but in the past three years it is about half of the 2011 and 2012 levels (Table 38). There has been a marked increase in the incidental catch of Pacific ocean perch, sablefish, and Atka mackerel and a decrease in flatfish species. Proportionately, the incidental catch decreased since the overall levels of pollock catch have increased since 2008. In fact, the bycatch of pollock in other target fisheries is more than double the bycatch of target species in the pollock fishery (Table 39).

The number of non-Chinook salmon (nearly all made up of chum salmon) taken incidentally has steadily increased since 2014 with 2017 number in excess of 465 thousand fish but the 2018 level was slightly more than the 2003–2017 average of 227 thousand fish; Table 41). Chinook salmon bycatch has also increased steadily since 2012 with the 2017 counts at just below 30,000 (which was 18% below the 2003–2017 mean value). In 2018 the bycatch dropped back down to 13.5 thousand fish (Table 41). 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 were provided to the Council in 2018 and impact levels remain low.

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

The available data for EBS pollock are extensive yet many processes behind the observed patterns continue to be poorly understood.

The recent patterns of abundance observed in the northern Bering Sea provide an example. As such, we recommend the following research priorities:

- Investigate using spatial processes for estimation purposes (e.g., combining acoustic and bot-

tom trawl survey data). The application of the geostatistical methods (presented for comparative purposes in this assessment) 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.

- Develop methods to use spatio-temporal models to estimate composition information (i.e., length and age).
- Study the relationship between climate and recruitment and trophic interactions of pollock within the ecosystem would be useful for improving ways to evaluate the current and alternative fishery management system. In particular, studies investigating the processes affecting recruitment of pollock in the different regions of the EBS (including potential for influx from the GOA) should be pursued.
- Apply new technologies (e.g., bottom-moored echosounders) to evaluate pollock movement between regions.
- Expand genetic sample collections for pollock (and process available samples) and apply high resolution genetic tools for stock structure analyses.

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## Tables

Table 1: Catch from the Eastern Bering Sea by area, the Aleutian Islands, the Donut Hole, and the Bogoslof Island area, 1979–2018 (2018 values through October 15th 2018). The southeast area refers to the EBS region east of 170W; the Northwest is west of 170W. Note: 1979–1989 data are from Pacfin, 1990–2018 data are from NMFS Alaska Regional Office, and include discards. The 2018 EBS catch estimates are preliminary.

| Eastern Bering Sea |           |           |           |           |            |             |
|--------------------|-----------|-----------|-----------|-----------|------------|-------------|
| Year               | Southeast | Northwest | Total     | Aleutians | Donut Hole | Bogoslof I. |
| 1979               | 368,848   | 566,866   | 935,714   | 9,446     |            |             |
| 1980               | 437,253   | 521,027   | 958,280   | 58,157    |            |             |
| 1981               | 714,584   | 258,918   | 973,502   | 55,517    |            |             |
| 1982               | 713,912   | 242,052   | 955,964   | 57,753    |            |             |
| 1983               | 687,504   | 293,946   | 981,450   | 59,021    |            |             |
| 1984               | 442,733   | 649,322   | 1,092,055 | 77,595    | 181,200    |             |
| 1985               | 604,465   | 535,211   | 1,139,676 | 58,147    | 363,400    |             |
| 1986               | 594,997   | 546,996   | 1,141,993 | 45,439    | 1,039,800  |             |
| 1987               | 529,461   | 329,955   | 859,416   | 28,471    | 1,326,300  | 377,436     |
| 1988               | 931,812   | 296,909   | 1,228,721 | 41,203    | 1,395,900  | 87,813      |
| 1989               | 904,201   | 325,399   | 1,229,600 | 10,569    | 1,447,600  | 36,073      |
| 1990               | 640,511   | 814,682   | 1,455,193 | 79,025    | 917,400    | 151,672     |
| 1991               | 653,555   | 542,109   | 1,195,664 | 98,604    | 293,400    | 316,038     |
| 1992               | 830,559   | 559,741   | 1,390,299 | 52,362    | 10,000     | 241         |
| 1993               | 1,094,429 | 232,173   | 1,326,602 | 57,138    | 1,957      | 886         |
| 1994               | 1,152,575 | 176,777   | 1,329,352 | 58,659    |            | 556         |
| 1995               | 1,172,306 | 91,941    | 1,264,247 | 64,925    |            | 334         |
| 1996               | 1,086,843 | 105,939   | 1,192,781 | 29,062    |            | 499         |
| 1997               | 819,889   | 304,544   | 1,124,433 | 25,940    |            | 163         |
| 1998               | 971,388   | 132,515   | 1,103,903 | 22,054    |            | 8           |
| 1999               | 782,983   | 206,698   | 989,680   | 1,010     |            | 29          |
| 2000               | 839,177   | 293,532   | 1,132,710 | 1,244     |            | 29          |
| 2001               | 961,977   | 425,220   | 1,387,197 | 825       |            | 258         |
| 2002               | 1,160,334 | 320,442   | 1,480,776 | 1,177     |            | 1,042       |
| 2003               | 933,191   | 557,588   | 1,490,779 | 1,649     |            | 24          |
| 2004               | 1,090,008 | 390,544   | 1,480,552 | 1,158     |            | 0           |
| 2005               | 802,154   | 680,868   | 1,483,022 | 1,621     |            | 0           |
| 2006               | 827,207   | 660,824   | 1,488,031 | 1,745     |            | 0           |
| 2007               | 728,249   | 626,253   | 1,354,502 | 2,519     |            | 0           |
| 2008               | 482,698   | 507,880   | 990,578   | 1,278     |            | 9           |
| 2009               | 358,252   | 452,532   | 810,784   | 1,662     |            | 73          |
| 2010               | 255,132   | 555,075   | 810,207   | 1,285     |            | 176         |
| 2011               | 747,890   | 451,151   | 1,199,041 | 1,208     |            | 173         |
| 2012               | 618,869   | 586,343   | 1,205,212 | 975       |            | 71          |
| 2013               | 695,667   | 575,098   | 1,270,765 | 2,964     |            | 57          |
| 2014               | 858,240   | 439,180   | 1,297,419 | 2,375     |            | 427         |
| 2015               | 696,249   | 625,331   | 1,321,581 | 915       |            | 733         |
| 2016               | 1,167,088 | 185,571   | 1,352,659 | 1,257     |            | 1,005       |
| 2017               | 1,178,112 | 181,162   | 1,359,274 | 1,507     |            | 186         |
| 2018               | 1,020,904 | 325,711   | 1,346,615 | 1,778     |            | 133         |
| Avg.               | 788,905   | 414,351   | 1,203,256 | 25,481    | 697,696    | 30,505      |

Table 2: Time series of 1964–1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977–2018 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports. Note that the 2018 value is based on catch reported to October 25th 2018 plus an added component due to bycatch of pollock in other fisheries.

| Year | Catch          | Year | 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 | 1,490,000 | 1,300,000 | 1,390,299 |
|      |                | 1993 | 1,340,000 | 1,300,000 | 1,326,602 |
|      |                | 1994 | 1,330,000 | 1,330,000 | 1,329,352 |
|      |                | 1995 | 1,250,000 | 1,250,000 | 1,264,247 |
|      |                | 1996 | 1,190,000 | 1,190,000 | 1,192,781 |
|      |                | 1997 | 1,130,000 | 1,130,000 | 1,124,433 |
|      |                | 1998 | 1,110,000 | 1,110,000 | 1,102,159 |
|      |                | 1999 | 992,000   | 992,000   | 989,680   |
|      |                | 2000 | 1,139,000 | 1,139,000 | 1,132,710 |
|      |                | 2001 | 1,842,000 | 1,400,000 | 1,387,197 |
|      |                | 2002 | 2,110,000 | 1,485,000 | 1,480,776 |
|      |                | 2003 | 2,330,000 | 1,491,760 | 1,490,779 |
|      |                | 2004 | 2,560,000 | 1,492,000 | 1,480,552 |
|      |                | 2005 | 1,960,000 | 1,478,500 | 1,483,022 |
|      |                | 2006 | 1,930,000 | 1,485,000 | 1,488,031 |
|      |                | 2007 | 1,394,000 | 1,394,000 | 1,354,502 |
|      |                | 2008 | 1,000,000 | 1,000,000 | 990,578   |
|      |                | 2009 | 815,000   | 815,000   | 810,784   |
|      |                | 2010 | 813,000   | 813,000   | 810,206   |
|      |                | 2011 | 1,270,000 | 1,252,000 | 1,199,041 |
|      |                | 2012 | 1,220,000 | 1,200,000 | 1,205,212 |
|      |                | 2013 | 1,375,000 | 1,247,000 | 1,270,768 |
|      |                | 2014 | 1,369,000 | 1,267,000 | 1,297,420 |
|      |                | 2015 | 1,637,000 | 1,310,000 | 1,321,581 |
|      |                | 2016 | 2,090,000 | 1,340,000 | 1,352,707 |
|      |                | 2017 | 2,800,000 | 1,345,000 | 1,343,217 |
|      |                | 2018 | 2,592,000 | 1,364,341 | 1,346,615 |
|      | 1977–2017 mean |      | 1,455,902 | 1,241,006 | 1,188,382 |

Table 3: Estimates of discarded pollock (t), percent of total (in parentheses) and total catch for the Aleutians, Bogoslof, Northwest and Southeastern Bering Sea, 1991–2018. SE represents the EBS east of 170W, NW is the EBS west of 170W, source: NMFS Blend and catch-accounting system database. 2018 data are preliminary. Note that the higher discard rates in the Aleutian Islands and Bogoslof region reflect the lack of directed pollock fishing.

|      | Discarded pollock |             |              |              | Total (retained plus discard) |            |         |         |           |           |
|------|-------------------|-------------|--------------|--------------|-------------------------------|------------|---------|---------|-----------|-----------|
|      | Aleut. Is.        | Bog.        | NW           | SE           | Total                         | Aleut. Is. | Bog.    | NW      | SE        | Total     |
| 1991 | 5,231 (5%)        | 20,327 (6%) | 48,257 (9%)  | 66,792 (10%) | 140,607 (9%)                  | 98,604     | 316,038 | 542,109 | 653,555   | 1,610,306 |
| 1992 | 2,986 (6%)        | 240 (100%)  | 57,581 (10%) | 71,194 (9%)  | 132,002 (9%)                  | 52,362     | 241     | 559,750 | 830,559   | 1,442,912 |
| 1993 | 1,740 (3%)        | 308 (35%)   | 26,107 (11%) | 83,986 (8%)  | 112,141 (8%)                  | 57,138     | 886     | 232,180 | 1,094,429 | 1,384,633 |
| 1994 | 1,373 (2%)        | 11 (2%)     | 16,084 (9%)  | 88,098 (8%)  | 105,566 (8%)                  | 58,659     | 556     | 176,777 | 1,152,575 | 1,388,567 |
| 1995 | 1,380 (2%)        | 267 (80%)   | 9,715 (11%)  | 87,492 (7%)  | 98,855 (7%)                   | 64,925     | 334     | 91,941  | 1,172,306 | 1,329,506 |
| 1996 | 994 (3%)          | 7 (1%)      | 4,838 (5%)   | 71,368 (7%)  | 77,208 (6%)                   | 29,062     | 499     | 105,939 | 1,086,843 | 1,222,342 |
| 1997 | 618 (2%)          | 13 (8%)     | 22,557 (7%)  | 71,032 (9%)  | 94,220 (8%)                   | 25,940     | 163     | 304,544 | 819,889   | 1,150,536 |
| 1998 | 162 (1%)          | 3 (39%)     | 1,581 (1%)   | 14,291 (1%)  | 16,037 (1%)                   | 22,054     | 8       | 132,515 | 969,644   | 1,124,221 |
| 1999 | 480 (48%)         | 11 (39%)    | 1,912 (1%)   | 26,912 (3%)  | 29,315 (3%)                   | 1,010      | 29      | 206,698 | 782,983   | 990,719   |
| 2000 | 790 (64%)         | 20 (67%)    | 1,942 (1%)   | 19,678 (2%)  | 22,430 (2%)                   | 1,244      | 29      | 293,532 | 839,177   | 1,133,983 |
| 2001 | 380 (46%)         | 28 (11%)    | 2,450 (1%)   | 14,874 (2%)  | 17,732 (1%)                   | 825        | 258     | 425,220 | 961,977   | 1,388,280 |
| 2002 | 779 (66%)         | 12 (1%)     | 1,441 (tr)   | 19,430 (2%)  | 21,661 (1%)                   | 1,177      | 1,042   | 320,442 | 1,160,334 | 1,482,995 |
| 2003 | 468 (28%)         | 19 (79%)    | 2,959 (1%)   | 13,795 (1%)  | 17,241 (1%)                   | 1,649      | 24      | 557,588 | 933,191   | 1,492,453 |
| 2004 | 287 (25%)         | 0 (100%)    | 2,781 (1%)   | 20,380 (2%)  | 23,448 (2%)                   | 1,158      | 0       | 390,544 | 1,090,008 | 1,481,710 |
| 2005 | 324 (20%)         | 0 (89%)     | 2,586 (tr)   | 14,838 (2%)  | 17,748 (1%)                   | 1,621      | 0       | 680,868 | 802,154   | 1,484,643 |
| 2006 | 311 (18%)         | 0 (50%)     | 3,677 (1%)   | 11,877 (1%)  | 15,865 (1%)                   | 1,745      | 0       | 660,824 | 827,207   | 1,489,776 |
| 2007 | 425 (17%)         | 0 (%)       | 3,769 (1%)   | 12,334 (2%)  | 16,528 (1%)                   | 2,519      | 0       | 626,253 | 728,249   | 1,357,021 |
| 2008 | 81 (6%)           | 0 (%)       | 1,643 (tr)   | 5,968 (1%)   | 7,692 (1%)                    | 1,278      | 9       | 507,880 | 482,698   | 991,865   |
| 2009 | 395 (24%)         | 6 (8%)      | 1,936 (tr)   | 4,014 (1%)   | 6,352 (1%)                    | 1,662      | 73      | 452,532 | 358,252   | 812,519   |
| 2010 | 142 (12%)         | 53 (30%)    | 1,271 (tr)   | 2,511 (1%)   | 3,976 (tr)                    | 1,235      | 176     | 555,075 | 255,132   | 811,618   |
| 2011 | 75 (6%)           | 23 (13%)    | 1,378 (tr)   | 3,456 (tr)   | 4,932 (tr)                    | 1,208      | 173     | 451,151 | 747,890   | 1,200,422 |
| 2012 | 95 (10%)          | 0 (%)       | 1,191 (tr)   | 4,187 (1%)   | 5,473 (tr)                    | 975        | 71      | 586,343 | 618,869   | 1,206,258 |
| 2013 | 108 (4%)          | 0 (1%)      | 1,226 (tr)   | 4,144 (1%)   | 5,478 (tr)                    | 2,964      | 57      | 575,098 | 695,667   | 1,273,786 |
| 2014 | 138 (6%)          | 54 (13%)    | 1,787 (tr)   | 12,568 (1%)  | 14,547 (1%)                   | 2,375      | 427     | 439,180 | 858,240   | 1,300,221 |
| 2015 | 19 (2%)           | 138 (19%)   | 2,419 (tr)   | 7,062 (1%)   | 9,638 (1%)                    | 915        | 733     | 625,331 | 696,249   | 1,323,228 |
| 2016 | 59 (5%)           | 7 (1%)      | 998 (1%)     | 8,145 (1%)   | 9,209 (1%)                    | 1,257      | 1,005   | 185,571 | 1,167,088 | 1,354,921 |
| 2017 | 17 (1%)           | 2 (1%)      | 1,357 (1%)   | 6,944 (1%)   | 8,321 (1%)                    | 1,384      | 186     | 181,162 | 1,178,112 | 1,360,844 |
| 2018 |                   | 2 (21%)     | 1,779 (1%)   | 8,261 (1%)   | 10,042 (1%)                   |            | 9       | 328,722 | 1,045,138 | 1,373,868 |

Table 4: Total EBS shelf pollock catch recorded by observers (rounded to nearest 100 t) by year and season with percentages indicating the proportion of the catch that came from within the Steller sea lion conservation area (SCA), 1998–2018. The 2018 data are preliminary.

| Year | A season        | B-season        | Total             |
|------|-----------------|-----------------|-------------------|
| 1998 | 385,000 t (82%) | 403,000 t (38%) | 788,000 t (60%)   |
| 1999 | 339,000 t (54%) | 468,000 t (23%) | 807,000 t (36%)   |
| 2000 | 375,000 t (36%) | 572,000 t (44%) | 947,000 t (16%)   |
| 2001 | 490,000 t (27%) | 674,000 t (46%) | 1,164,000 t (38%) |
| 2002 | 512,200 t (56%) | 689,100 t (42%) | 1,201,200 t (48%) |
| 2003 | 532,400 t (47%) | 737,400 t (40%) | 1,269,800 t (43%) |
| 2004 | 532,600 t (45%) | 710,800 t (34%) | 1,243,300 t (38%) |
| 2005 | 530,300 t (45%) | 673,200 t (17%) | 1,203,500 t (29%) |
| 2006 | 533,400 t (51%) | 764,300 t (14%) | 1,297,700 t (29%) |
| 2007 | 479,500 t (57%) | 663,200 t (11%) | 1,142,700 t (30%) |
| 2008 | 341,700 t (46%) | 498,800 t (12%) | 840,500 t (26%)   |
| 2009 | 282,700 t (39%) | 388,800 t (13%) | 671,500 t (24%)   |
| 2010 | 269,800 t (15%) | 403,100 t (9%)  | 672,900 t (11%)   |
| 2011 | 477,600 t (54%) | 666,600 t (32%) | 1,144,200 t (41%) |
| 2012 | 457,100 t (52%) | 687,500 t (17%) | 1,144,600 t (31%) |
| 2013 | 472,200 t (22%) | 708,100 t (19%) | 1,180,300 t (20%) |
| 2014 | 482,800 t (38%) | 741,200 t (37%) | 1,224,000 t (37%) |
| 2015 | 490,400 t (15%) | 765,900 t (45%) | 1,256,300 t (33%) |
| 2016 | 510,700 t (35%) | 784,000 t (62%) | 1,294,700 t (51%) |
| 2017 | 555,300 t (51%) | 750,800 t (54%) | 1,306,100 t (53%) |
| 2018 | 573,000 t (63%) | 746,500 t (46%) | 1,319,500 t (54%) |

Table 5: Highlights of some management measures affecting the pollock fishery.

| Year | Management   |
|------|--|
| 1977 | Preliminary BSAI FMP implemented with several closure areas  |
| 1982 | FMP implement for the BSAI   |
| 1982 | Chinook salmon bycatch limits established for foreign trawlers   |
| 1984 | 2 million t groundfish OY limit established  |
| 1984 | Limits on Chinook salmon bycatch reduced   |
| 1990 | New observer program established along with data reporting   |
| 1992 | Pollock CDQ program commences  |
| 1994 | NMFS adopts minimum mesh size requirements for trawl codends   |
| 1994 | Voluntary retention of salmon for foodbank donations   |
| 1994 | NMFS publishes individual vessel bycatch rates on internet   |
| 1995 | Trawl closures areas and trigger limits established for chum and Chinook salmon  |
| 1998 | Improved utilization and retention in effect (reduced discarded pollock)   |
| 1998 | American Fisheries Act (AFA) passed  |
| 1999 | The AFA was implemented for catcher/processors   |
| 1999 | Additional critical habitat areas around sea lion haulouts in the GOA and Eastern Bering Sea are closed.   |
| 2000 | AFA implemented for remaining sectors (catcher vessel and motherships)   |
| 2001 | Pollock industry adopts voluntary rolling hotspot program for chum salmon  |
| 2002 | Pollock industry adopts voluntary rolling hotspot program for Chinook salmon   |
| 2005 | Rolling hotspot program adopted in regulations to exempt fleet from triggered time/area closures for Chinook and chum salmon   |
| 2011 | Amendment 91 enacted, Chinook salmon management under hard limits  |
| 2015 | Amendment 110 (BSAI) Salmon prohibited species catch management in the Bering Sea pollock fishery (additional measures that change limits depending on Chinook salmon run-strength indices) and includes additional provisions for reporting requirements (see <a href="https://alaskafisheries.noaa.gov/fisheries/chinook-salmon-bycatch-management">https://alaskafisheries.noaa.gov/fisheries/chinook-salmon-bycatch-management</a> for update and general information) |
| 2016 | Measures of amendment 110 go into effect for 2017 fishing season; Chinook salmon runs above the 3-run index value so bycatch limits stay the same  |
| 2017 | Due to amendment 110 about 45% of the TAC is taken in the A-season (traditionally only 40% was allowed).   |
| 2018 | In-river estimates of Chinook salmon (three river index) fell below the threshold and therefore a lower PSC limit applies (from a performance standard of 47,491 to 33,318 and a PSC limit from 60,000 to 45,000 Chinook salmon overall). Additionally, squid have been recategorized as an ecosystem component.   |

Table 6: BSAI pollock catch and ex-vessel data showing the total and retained catch (in kt), the number of vessels for all sectors and for trawl catcher vessels including ex-vessel value (million US\$), price (US\$ per pound), and catcher vessel shares. Years covered include the 2005–2007 average, the 2008–2010 average, the 2011–2013 average, and annual from 2014–2017.

|                            | Avg 05–07 | Avg 08–10 | Avg 11–13 | 2014    | 2015    | 2016    | 2017    |
|----------------------------|-----------|-----------|-----------|---------|---------|---------|---------|
| All sectors                |           |           |           |         |         |         |         |
| Catch kt                   | 1,444     | 872       | 1,227     | 1,300   | 1,323   | 1,355   | 1,361   |
| Retained Catch kt          | 1,427     | 866       | 1,221     | 1,285   | 1,314   | 1,346   | 1,353   |
| Vessels #                  | 110       | 121       | 120       | 121     | 120     | 121     | 119     |
| Catcher Vessels (Trawl)    |           |           |           |         |         |         |         |
| Retained Catch kt          | 768.3     | 458.9     | 640.8     | 668.5   | 687.1   | 703.9   | 710.4   |
| Ex-vessel Value M \$       | \$214.2   | \$184.9   | \$229.6   | \$226.3 | \$226.7 | \$208.9 | \$205.1 |
| Ex-vessel Price/lb \$      | \$0.13    | \$0.18    | \$0.16    | \$0.16  | \$0.15  | \$0.14  | \$0.14  |
| CV share of Retained Catch | 53.84%    | 53.00%    | 52.49%    | 52.03%  | 52.31%  | 52.31%  | 52.52%  |
| Vessels #                  | 89        | 89        | 88        | 87      | 87      | 88      | 88      |

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 7: BSAI pollock first-wholesale market data including production (kt), value (million US\$), price (US\$ per pound) for all products and then separately for other categories (head and gut, fillet, surimi, and roe production). Years covered include the 2005–2007 average, the 2008–2010 average, the 2011–2013 average, and annual from 2014–2017.

|                              | Avg 05–07 | Avg 08–10 | Avg 11–13 | 2014      | 2015      | 2016      | 2017      |
|------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| <b>All Products</b>          |           |           |           |           |           |           |           |
| Volume kt                    | 498.25    | 355.99    | 487.56    | 525.54    | 520.94    | 534.89    | 523.94    |
| Value M\$                    | \$1,246.4 | \$1,133.4 | \$1,324.7 | \$1,301.2 | \$1,272.5 | \$1,351.5 | \$1,355.0 |
| At-sea sector value share    | 59%       | 58%       | 59%       | 58%       | 60%       | 60%       | 62%       |
| Price per lb \$              | \$1.13    | \$1.44    | \$1.23    | \$1.12    | \$1.11    | \$1.15    | \$1.17    |
| <b>Fillets</b>               |           |           |           |           |           |           |           |
| Volume kt                    | 162.70    | 113.90    | 159.55    | 175.78    | 167.01    | 161.29    | 156.95    |
| Price lb \$                  | \$1.24    | \$1.73    | \$1.51    | \$1.37    | \$1.35    | \$1.41    | \$1.30    |
| Value share                  | 36%       | 38%       | 40%       | 41%       | 39%       | 37%       | 33%       |
| <b>Surimi</b>                |           |           |           |           |           |           |           |
| Volume kt                    | 173.05    | 100.99    | 153.27    | 171.33    | 187.74    | 190.82    | 196.73    |
| Price lb \$                  | \$0.96    | \$1.63    | \$1.23    | \$1.10    | \$1.14    | \$1.19    | \$1.35    |
| Value share                  | 29%       | 32%       | 32%       | 32%       | 37%       | 37%       | 43%       |
| <b>Roe</b>                   |           |           |           |           |           |           |           |
| Volume kt                    | 27.03     | 17.63     | 16.14     | 20.60     | 18.75     | 14.26     | 18.43     |
| Price lb \$                  | \$4.84    | \$4.14    | \$3.78    | \$2.92    | \$2.29    | \$2.84    | \$2.91    |
| Value share                  | 23%       | 14%       | 10%       | 10%       | 7%        | 7%        | 9%        |
| At-sea price premium (\$/lb) | \$0.30    | \$0.32    | \$0.19    | \$0.15    | \$0.25    | \$0.25    | \$0.37    |

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 8: Alaska pollock U.S. trade and global market data showing global production (in kt) and the U.S. and Russian shares followed by U.S. export volumes (kt), values (million US\$), and export prices (US\$ per pound). Subsequent rows show the breakout of import shares (of U.S. pollock) by country (Japan, China and Germany) and the share of U.S. export volume and value of fish (i.e., H&G and fillets), and other product categories (surimi and roe). Years covered include the 2005–2007 average, the 2008–2010 average, the 2011–2013 average, and annual from 2014–2018.

|                               | Avg 05-07 | Avg 08-10 | Avg 11-13 | 2014      | 2015      | 2016    | 2017      | 2018 thru July |
|-------------------------------|-----------|-----------|-----------|-----------|-----------|---------|-----------|----------------|
| Global Pollock Catch kt       | 2,854     | 2,662     | 3,241     | 3,245     | 3,373     | 3,476   | -         | -              |
| U.S. Share of Global Catch    | 52%       | 35%       | 40%       | 44%       | 44%       | 44%     | -         | -              |
| Russian Share of global catch | 37%       | 53%       | 49%       | 47%       | 48%       | 50%     | -         | -              |
| BSAI share of global          | 51%       | 33%       | 38%       | 40%       | 39%       | 39%     | -         | -              |
| Export Volume kt              | 278.9     | 192.2     | 326.2     | 395.0     | 377.8     | 379.6   | 398.0     | 243.8          |
| Export Value M \$             | \$867.4   | \$635.2   | \$943.6   | \$1,081.7 | \$1,038.2 | \$990.5 | \$1,007.6 | \$671.5        |
| Export Price/lb \$            | \$1.41    | \$1.50    | \$1.31    | \$1.24    | \$1.25    | \$1.18  | \$1.15    | \$1.25         |
| Japan Volume Share            | 34.4%     | 26.6%     | 20.8%     | 22.1%     | 25.0%     | 20.1%   | 21.7%     | 23.4%          |
| Japan Value share             | 38.1%     | 26.3%     | 19.3%     | 21.7%     | 25.5%     | 20.2%   | 22.9%     | 29.4%          |
| China Volume Share            | 3.1%      | 9.0%      | 13.1%     | 14.7%     | 12.7%     | 11.9%   | 14.8%     | 13.8%          |
| China Value share             | 2.2%      | 6.9%      | 10.5%     | 12.0%     | 10.5%     | 9.9%    | 12.6%     | 9.9%           |
| Germany Volume Share          | 16.7%     | 19.9%     | 21.9%     | 23.4%     | 21.4%     | 19.3%   | 10.9%     | 8.0%           |
| Germany Value share           | 14.5%     | 21.2%     | 22.7%     | 24.3%     | 21.3%     | 19.2%   | 11.0%     | 7.6%           |
| Meat Volume Share             | 32.7%     | 46.1%     | 49.6%     | 53.8%     | 49.2%     | 49.4%   | 48.8%     | 48.6%          |
| Meat Value share              | 27.2%     | 44.5%     | 48.3%     | 51.6%     | 46.2%     | 46.4%   | 46.6%     | 40.2%          |
| Surimi Volume Share           | 56.9%     | 45.7%     | 45.4%     | 40.7%     | 45.4%     | 46.9%   | 46.6%     | 42.9%          |
| Surimi Value share            | 37.5%     | 32.7%     | 37.9%     | 34.3%     | 39.2%     | 42.4%   | 42.3%     | 39.3%          |
| Roe Volume Share              | 10.4%     | 8.2%      | 4.9%      | 5.5%      | 5.4%      | 3.7%    | 4.6%      | 8.5%           |
| Roe Value share               | 35.3%     | 22.8%     | 13.8%     | 14.1%     | 14.6%     | 11.2%   | 11.1%     | 20.5%          |

Notes: 2018 data thru July; Exports are from the US and are note specific to the BSAI region.

'Meat' includes fillets, H&G, minced and other non-surimi meat based products.

Source: FAO Fisheries & Aquaculture Dept. Statistics <http://www.fao.org/fishery/statistics/en>.

NOAA Fisheries, Fisheries Statistics Division, Foreign Trade Division of the U.S. Census Bureau,  
<http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/index>. U.S. Department of Agriculture <http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx>.

Table 9: BSAI pollock fish oil production index (tons of oil per 100 tons of retained catch); 2005–2007 average, the 2008–2010 average, the 2011–2013 average, and annual from 2014–2017.

| sector      | Avg 05–07 | Avg 08–10 | Avg 11–13 | 2014 | 2015 | 2016 | 2017 |              |
|-------------|-----------|-----------|-----------|------|------|------|------|--------------|
| All Sectors | 1.25      | 2.03      | 1.76      | 2.19 | 1.84 | 2.06 | 1.92 |              |
| Shoreside   | 2.07      | 2.58      | 2.00      | 2.42 | 1.94 | 2.28 | 2.09 | Source: NMFS |
| At Sea      | 0.30      | 1.41      | 1.50      | 1.94 | 1.72 | 1.82 | 1.74 |              |

Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 10: Eastern Bering Sea pollock catch at age estimates based on observer data, 1979–2017.  
 Units are in millions of fish.

| Year | 1     | 2     | 3       | 4       | 5       | 6     | 7     | 8     | 9     | 10    | 11    | 12   | 13   | 14+  | Total |
|------|-------|-------|---------|---------|---------|-------|-------|-------|-------|-------|-------|------|------|------|-------|
| 1979 | 101.4 | 543.0 | 719.8   | 420.1   | 392.5   | 215.5 | 56.3  | 25.7  | 35.9  | 27.5  | 17.6  | 7.9  | 3.0  | 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  | 1,012.7 | 637.9   | 227.0   | 102.9 | 51.7  | 29.6  | 16.1  | 9.3   | 7.5   | 4.6  | 1.5  | 1.0  | 2,175 |
| 1982 | 4.7   | 25.3  | 161.4   | 1,172.2 | 422.3   | 103.7 | 36.0  | 36.0  | 21.5  | 9.1   | 5.4   | 3.2  | 1.9  | 1.0  | 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   | 86.0  | 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  | 454.0   | 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    | 149.0   | 451.1   | 166.7 | 572.2 | 96.3  | 103.8 | 32.4  | 129.0 | 10.9 | 4.0  | 8.5  | 1,784 |
| 1990 | 1.3   | 33.0  | 57.0    | 219.5   | 200.7   | 477.7 | 129.2 | 368.4 | 65.7  | 101.9 | 9.0   | 60.1 | 8.5  | 13.9 | 1,746 |
| 1991 | 0.4   | 113.2 | 44.4    | 88.9    | 151.8   | 181.9 | 509.7 | 81.5  | 292.9 | 29.5  | 143.9 | 18.2 | 88.3 | 71.8 | 1,816 |
| 1992 | 2.0   | 88.2  | 670.8   | 130.3   | 82.9    | 110.2 | 136.2 | 254.8 | 102.7 | 152.5 | 57.9  | 45.4 | 13.7 | 75.5 | 1,923 |
| 1993 | 0.1   | 6.9   | 243.6   | 1,144.4 | 108.0   | 73.9  | 68.5  | 53.1  | 91.6  | 20.5  | 35.2  | 10.9 | 13.5 | 23.3 | 1,894 |
| 1994 | 1.2   | 35.6  | 58.6    | 347.4   | 1,067.2 | 180.5 | 57.7  | 18.7  | 12.4  | 20.2  | 9.2   | 10.2 | 7.6  | 12.1 | 1,839 |
| 1995 | -     | 0.4   | 77.1    | 148.5   | 406.8   | 767.1 | 121.9 | 32.0  | 11.2  | 8.1   | 17.7  | 5.2  | 6.7  | 10.4 | 1,613 |
| 1996 | -     | 16.7  | 51.9    | 82.6    | 161.5   | 362.8 | 481.6 | 186.0 | 32.6  | 14.1  | 8.4   | 8.7  | 4.5  | 11.0 | 1,422 |
| 1997 | 1.6   | 77.9  | 39.2    | 107.6   | 472.7   | 282.6 | 252.6 | 200.1 | 65.4  | 14.0  | 5.9   | 5.3  | 3.3  | 14.4 | 1,543 |
| 1998 | 0.2   | 42.3  | 85.6    | 70.9    | 154.8   | 697.0 | 202.0 | 131.0 | 107.5 | 29.1  | 6.1   | 6.2  | 2.4  | 9.2  | 1,544 |
| 1999 | 0.2   | 9.6   | 294.4   | 224.6   | 102.3   | 159.7 | 470.8 | 130.7 | 56.3  | 34.1  | 3.7   | 2.3  | 0.8  | 2.2  | 1,492 |
| 2000 | -     | 15.3  | 80.3    | 425.8   | 347.0   | 105.2 | 170.4 | 357.6 | 86.0  | 29.5  | 22.3  | 5.3  | 1.3  | 1.6  | 1,648 |
| 2001 | -     | 3.1   | 46.9    | 154.7   | 582.6   | 410.5 | 135.9 | 127.0 | 157.3 | 59.0  | 34.4  | 16.0 | 5.4  | 5.7  | 1,738 |
| 2002 | 0.9   | 47.0  | 108.6   | 213.4   | 287.4   | 602.3 | 270.2 | 100.6 | 86.3  | 96.8  | 33.9  | 15.3 | 11.0 | 4.5  | 1,878 |
| 2003 | -     | 14.1  | 408.6   | 323.5   | 367.2   | 307.1 | 331.2 | 158.8 | 49.5  | 38.4  | 36.1  | 22.7 | 6.8  | 6.7  | 2,071 |
| 2004 | -     | 0.5   | 90.1    | 825.4   | 483.7   | 239.0 | 168.5 | 155.2 | 63.2  | 15.5  | 18.6  | 26.8 | 8.9  | 14.0 | 2,109 |
| 2005 | -     | 4.1   | 51.1    | 399.4   | 859.1   | 483.5 | 157.6 | 68.7  | 68.3  | 30.8  | 9.6   | 8.9  | 3.0  | 5.0  | 2,149 |
| 2006 | -     | 10.0  | 83.2    | 293.3   | 615.3   | 592.6 | 283.6 | 109.9 | 49.5  | 40.7  | 17.0  | 8.3  | 8.4  | 11.6 | 2,123 |
| 2007 | 1.6   | 16.9  | 60.5    | 137.5   | 388.6   | 508.7 | 300.1 | 139.5 | 47.6  | 27.4  | 24.2  | 9.5  | 6.1  | 14.2 | 1,683 |
| 2008 | -     | 25.9  | 57.6    | 79.4    | 148.8   | 308.4 | 242.0 | 149.3 | 82.5  | 21.8  | 18.4  | 14.0 | 8.9  | 15.7 | 1,173 |
| 2009 | -     | 1.3   | 175.9   | 199.9   | 82.4    | 112.9 | 123.4 | 104.0 | 65.9  | 40.5  | 23.9  | 7.6  | 8.2  | 12.3 | 958   |
| 2010 | 1.0   | 27.2  | 30.8    | 557.9   | 220.6   | 55.0  | 42.5  | 56.6  | 52.9  | 31.8  | 16.0  | 8.8  | 6.2  | 10.3 | 1,118 |
| 2011 | 0.4   | 11.4  | 192.8   | 115.6   | 809.5   | 284.4 | 64.1  | 37.7  | 38.3  | 40.2  | 25.3  | 12.8 | 1.8  | 8.3  | 1,643 |
| 2012 | -     | 23.7  | 117.8   | 943.8   | 173.7   | 433.1 | 139.9 | 37.0  | 17.6  | 14.7  | 16.2  | 13.8 | 7.8  | 8.9  | 1,948 |
| 2013 | 1.7   | 0.8   | 65.3    | 342.1   | 955.5   | 195.2 | 155.9 | 69.1  | 20.1  | 13.3  | 12.5  | 12.0 | 7.9  | 10.4 | 1,862 |
| 2014 | -     | 39.6  | 31.4    | 168.6   | 397.4   | 752.2 | 210.3 | 86.3  | 29.2  | 9.0   | 4.6   | 4.7  | 4.5  | 9.0  | 1,747 |
| 2015 | -     | 15.7  | 633.2   | 194.8   | 229.1   | 385.2 | 509.4 | 88.2  | 43.0  | 17.2  | 3.2   | 2.2  | 3.3  | 4.0  | 2,128 |
| 2016 | -     | 0.5   | 91.7    | 1,389.7 | 159.3   | 175.3 | 175.5 | 223.1 | 34.7  | 13.2  | 7.9   | 0.5  | 1.3  | -    | 2,273 |
| 2017 | 0.0   | 2.0   | 29.8    | 551.4   | 894.6   | 214.7 | 147.5 | 123.2 | 96.3  | 21.5  | 7.8   | 6.3  | 0.6  | 0.4  | 2,096 |
| Avg. | 6.5   | 54.5  | 206.0   | 379.9   | 390.0   | 320.8 | 206.3 | 114.3 | 65.5  | 33.5  | 23.4  | 11.9 | 8.1  | 11.7 | 1,829 |

Table 11: Numbers of pollock NMFS observer samples measured for fishery catch length frequency (by sex and strata), 1977–2017.

| Year | Length Frequency samples |         |             |         |             |         |         |
|------|--------------------------|---------|-------------|---------|-------------|---------|---------|
|      | A Season                 |         | B Season SE |         | B Season NW |         |         |
|      | Males                    | Females | Males       | Females | Males       | Females | Total   |
| 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 | 160,491                  | 148,236 | 166,117     | 150,261 | 141,085     | 139,852 | 906,042 |
| 1992 | 158,405                  | 153,866 | 163,045     | 164,227 | 101,036     | 102,667 | 843,244 |
| 1993 | 143,296                  | 133,711 | 148,299     | 140,402 | 27,262      | 28,522  | 621,490 |
| 1994 | 139,332                  | 147,204 | 159,341     | 153,526 | 28,015      | 27,953  | 655,370 |
| 1995 | 131,287                  | 128,389 | 179,312     | 154,520 | 16,170      | 16,356  | 626,032 |
| 1996 | 149,111                  | 140,981 | 200,482     | 156,804 | 18,165      | 18,348  | 683,890 |
| 1997 | 124,953                  | 104,115 | 116,448     | 107,630 | 60,192      | 53,191  | 566,527 |
| 1998 | 136,605                  | 110,620 | 208,659     | 178,012 | 32,819      | 40,307  | 707,019 |
| 1999 | 36,258                   | 32,630  | 38,840      | 35,695  | 16,282      | 18,339  | 178,044 |
| 2000 | 64,575                   | 58,162  | 63,832      | 41,120  | 40,868      | 39,134  | 307,689 |
| 2001 | 79,333                   | 75,633  | 54,119      | 51,268  | 44,295      | 45,836  | 350,483 |
| 2002 | 71,776                   | 69,743  | 65,432      | 64,373  | 37,701      | 39,322  | 348,347 |
| 2003 | 74,995                   | 77,612  | 49,469      | 53,053  | 51,799      | 53,463  | 360,390 |
| 2004 | 75,426                   | 76,018  | 63,204      | 62,005  | 47,289      | 44,246  | 368,188 |
| 2005 | 76,627                   | 69,543  | 43,205      | 33,886  | 68,878      | 63,088  | 355,225 |
| 2006 | 72,353                   | 63,108  | 28,799      | 22,363  | 75,180      | 65,209  | 327,010 |
| 2007 | 62,827                   | 60,522  | 32,945      | 25,518  | 75,128      | 69,116  | 326,054 |
| 2008 | 46,125                   | 51,027  | 20,493      | 23,503  | 61,149      | 64,598  | 266,894 |
| 2009 | 46,051                   | 44,080  | 19,877      | 18,579  | 50,451      | 53,344  | 232,379 |
| 2010 | 39,495                   | 41,054  | 19,194      | 20,591  | 40,449      | 41,323  | 202,106 |
| 2011 | 58,822                   | 62,617  | 60,254      | 65,057  | 51,137      | 48,084  | 345,971 |
| 2012 | 53,641                   | 57,966  | 45,044      | 46,940  | 50,167      | 53,224  | 306,982 |
| 2013 | 52,303                   | 62,336  | 37,434      | 44,709  | 49,484      | 49,903  | 296,168 |
| 2014 | 55,954                   | 58,097  | 46,568      | 51,950  | 46,643      | 46,202  | 305,414 |
| 2015 | 55,646                   | 56,507  | 45,074      | 41,218  | 46,237      | 43,084  | 287,766 |
| 2016 | 57,478                   | 59,000  | 10,264      | 9,016   | 72,973      | 69,669  | 278,400 |
| 2017 | 55,965                   | 64,728  | 15,871      | 14,136  | 70,285      | 66,026  | 287,011 |

Table 12: Number of EBS pollock measured for weight and length by sex and strata as collected by the NMFS observer program, 1977-2017

|      | 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 | 2,712                 | 2,781   | 2,339       | 2,496   | 1,065       | 1,169   | 12,562 |
| 1992 | 1,517                 | 1,582   | 1,911       | 1,970   | 588         | 566     | 8,134  |
| 1993 | 1,201                 | 1,270   | 1,448       | 1,406   | 435         | 450     | 6,210  |
| 1994 | 1,552                 | 1,630   | 1,569       | 1,577   | 162         | 171     | 6,661  |
| 1995 | 1,215                 | 1,259   | 1,320       | 1,343   | 223         | 232     | 5,592  |
| 1996 | 2,094                 | 2,135   | 1,409       | 1,384   | 1           | 1       | 7,024  |
| 1997 | 628                   | 627     | 616         | 665     | 511         | 523     | 3,570  |
| 1998 | 1,852                 | 1,946   | 959         | 923     | 327         | 350     | 6,357  |
| 1999 | 5,318                 | 4,798   | 7,797       | 7,054   | 3,532       | 3,768   | 32,267 |
| 2000 | 12,421                | 11,318  | 12,374      | 7,809   | 7,977       | 7,738   | 59,637 |
| 2001 | 14,882                | 14,369  | 10,778      | 10,378  | 8,777       | 9,079   | 68,263 |
| 2002 | 14,004                | 13,541  | 12,883      | 12,942  | 7,202       | 7,648   | 68,220 |
| 2003 | 14,780                | 15,495  | 9,401       | 10,092  | 9,994       | 10,261  | 70,023 |
| 2004 | 7,690                 | 7,890   | 6,819       | 6,847   | 4,603       | 4,321   | 38,170 |
| 2005 | 7,390                 | 7,033   | 5,109       | 4,115   | 6,927       | 6,424   | 36,998 |
| 2006 | 7,324                 | 6,989   | 5,085       | 4,068   | 6,842       | 6,356   | 36,664 |
| 2007 | 6,681                 | 6,635   | 4,278       | 3,203   | 7,745       | 7,094   | 35,636 |
| 2008 | 4,256                 | 4,787   | 2,056       | 2,563   | 5,950       | 6,316   | 25,928 |
| 2009 | 4,470                 | 4,199   | 2,273       | 2,034   | 5,004       | 5,187   | 23,167 |
| 2010 | 4,536                 | 5,272   | 2,261       | 2,749   | 4,125       | 4,618   | 23,561 |
| 2011 | 6,772                 | 6,388   | 6,906       | 6,455   | 5,809       | 4,634   | 36,964 |
| 2012 | 5,500                 | 5,981   | 4,508       | 4,774   | 4,928       | 5,348   | 31,039 |
| 2013 | 6,525                 | 5,690   | 4,313       | 3,613   | 4,920       | 4,849   | 29,910 |
| 2014 | 5,675                 | 5,871   | 4,753       | 5,180   | 4,785       | 4,652   | 30,916 |
| 2015 | 5,310                 | 5,323   | 4,645       | 4,188   | 4,337       | 4,011   | 27,766 |
| 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 |

Table 13: Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977–2017, 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 | 420      | 423     | 272         | 265     | 320         | 341     | 2,041  |
| 1992 | 392      | 392     | 371         | 386     | 178         | 177     | 1,896  |
| 1993 | 444      | 473     | 503         | 493     | 124         | 122     | 2,159  |
| 1994 | 201      | 202     | 570         | 573     | 131         | 141     | 1,818  |
| 1995 | 298      | 316     | 436         | 417     | 123         | 131     | 1,721  |
| 1996 | 468      | 449     | 442         | 433     | 1           | 1       | 1,794  |
| 1997 | 433      | 436     | 284         | 311     | 326         | 326     | 2,116  |
| 1998 | 592      | 659     | 307         | 307     | 216         | 232     | 2,313  |
| 1999 | 540      | 500     | 730         | 727     | 306         | 298     | 3,100  |
| 2000 | 666      | 626     | 843         | 584     | 253         | 293     | 3,265  |
| 2001 | 598      | 560     | 724         | 688     | 178         | 205     | 2,951  |
| 2002 | 651      | 670     | 834         | 886     | 201         | 247     | 3,489  |
| 2003 | 583      | 644     | 652         | 680     | 260         | 274     | 3,092  |
| 2004 | 560      | 547     | 599         | 697     | 244         | 221     | 2,867  |
| 2005 | 611      | 597     | 613         | 489     | 419         | 421     | 3,149  |
| 2006 | 608      | 599     | 590         | 457     | 397         | 398     | 3,048  |
| 2007 | 639      | 627     | 586         | 482     | 583         | 570     | 3,485  |
| 2008 | 492      | 491     | 313         | 356     | 541         | 647     | 2,838  |
| 2009 | 488      | 416     | 285         | 325     | 400         | 434     | 2,346  |
| 2010 | 624      | 545     | 504         | 419     | 465         | 414     | 2,971  |
| 2011 | 581      | 808     | 579         | 659     | 404         | 396     | 3,427  |
| 2012 | 517      | 571     | 480         | 533     | 485         | 579     | 3,165  |
| 2013 | 703      | 666     | 517         | 402     | 568         | 526     | 3,381  |
| 2014 | 609      | 629     | 475         | 553     | 413         | 407     | 3,086  |
| 2015 | 653      | 642     | 502         | 509     | 511         | 491     | 3,308  |
| 2016 | 488      | 599     | 929         | 969     | 157         | 125     | 3,267  |
| 2017 | 604      | 778     | 777         | 753     | 179         | 163     | 3,254  |

Table 14: NMFS total pollock research catch by year in t, 1964–2018.

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

Table 15: Survey biomass estimates (age 1+, t) of Eastern Bering Sea pollock based on design-based area-swept expansion methods from NMFS bottom trawl surveys 1982–2018.

| Year    | Survey biomass |            |           |     |
|---------|----------------|------------|-----------|-----|
|         | Strata 1-6     | Strata 8-9 | Total     | %NW |
| 1982    | 2,858,400      | 54,469     | 2,912,869 | 2%  |
| 1983    | 5,921,380      | -          | 5,921,380 | -   |
| 1984    | 4,542,405      | -          | 4,542,405 | -   |
| 1985    | 4,560,122      | 637,881    | 5,198,003 | 12% |
| 1986    | 4,835,722      | -          | 4,835,722 | -   |
| 1987    | 5,111,645      | 386,788    | 5,498,433 | 7%  |
| 1988    | 7,003,983      | 179,980    | 7,183,963 | 3%  |
| 1989    | 5,906,477      | 643,938    | 6,550,415 | 10% |
| 1990    | 7,107,218      | 189,435    | 7,296,653 | 3%  |
| 1991    | 5,067,092      | 62,446     | 5,129,538 | 1%  |
| 1992    | 4,316,660      | 209,493    | 4,526,153 | 5%  |
| 1993    | 5,196,453      | 98,363     | 5,294,816 | 2%  |
| 1994    | 4,977,639      | 49,686     | 5,027,325 | 1%  |
| 1995    | 5,409,297      | 68,541     | 5,477,838 | 1%  |
| 1996    | 2,981,680      | 143,573    | 3,125,253 | 5%  |
| 1997    | 2,868,734      | 693,429    | 3,562,163 | 19% |
| 1998    | 2,137,049      | 550,706    | 2,687,755 | 20% |
| 1999    | 3,598,688      | 199,786    | 3,798,474 | 5%  |
| 2000    | 4,985,064      | 118,565    | 5,103,629 | 2%  |
| 2001    | 4,145,746      | 51,108     | 4,196,854 | 1%  |
| 2002    | 4,755,668      | 197,770    | 4,953,438 | 4%  |
| 2003    | 8,106,358      | 285,902    | 8,392,261 | 3%  |
| 2004    | 3,744,501      | 118,473    | 3,862,974 | 3%  |
| 2005    | 4,731,068      | 137,548    | 4,868,616 | 3%  |
| 2006    | 2,845,553      | 199,827    | 3,045,380 | 7%  |
| 2007    | 4,158,234      | 179,986    | 4,338,220 | 4%  |
| 2008    | 2,834,093      | 189,174    | 3,023,267 | 6%  |
| 2009    | 2,231,225      | 51,185     | 2,282,410 | 2%  |
| 2010    | 3,550,981      | 186,898    | 3,737,878 | 5%  |
| 2011    | 2,945,641      | 166,672    | 3,112,312 | 5%  |
| 2012    | 3,281,223      | 206,005    | 3,487,229 | 6%  |
| 2013    | 4,297,970      | 277,433    | 4,575,403 | 6%  |
| 2014    | 6,552,849      | 877,104    | 7,429,952 | 12% |
| 2015    | 5,944,325      | 450,034    | 6,394,359 | 7%  |
| 2016    | 4,698,430      | 211,650    | 4,910,080 | 4%  |
| 2017    | 4,688,500      | 125,873    | 4,814,373 | 3%  |
| 2018    | 3,015,612      | 97,185     | 3,112,797 | 3%  |
| Average | 4,484,154      | 224,241    | 4,708,394 | 5%  |

Table 16: Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982–2018.

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

Table 17: Bottom-trawl survey estimated numbers *millions* at age used for the stock assessment model. Note that in 1982–84 and 1986 only strata 1–6 were surveyed. Note these estimates are based on design-based procedures.

| Year | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12  | 13  | 14  | 15  | Total  |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|-----|-----|-----|--------|
| 1982 | 1,281 | 2,986 | 3,356 | 4,377 | 1,505 | 206   | 143   | 68    | 43    | 27    | 17    | 10  | 3   | 1   | 0   | 14,024 |
| 1983 | 1,810 | 681   | 1,655 | 2,980 | 6,690 | 2,042 | 371   | 198   | 89    | 77    | 58    | 20  | 8   | 7   | 2   | 16,688 |
| 1984 | 431   | 348   | 537   | 1,535 | 1,905 | 4,451 | 853   | 189   | 88    | 31    | 21    | 8   | 5   | 6   | 3   | 10,411 |
| 1985 | 5,919 | 959   | 3,844 | 1,222 | 4,031 | 2,455 | 1,678 | 331   | 84    | 69    | 23    | 8   | 9   | 1   | 0   | 20,634 |
| 1986 | 2,690 | 428   | 499   | 1,875 | 1,135 | 1,889 | 1,653 | 1,501 | 470   | 72    | 33    | 15  | 1   | 4   | -   | 12,266 |
| 1987 | 379   | 779   | 1,082 | 817   | 4,956 | 1,371 | 1,313 | 519   | 1,640 | 253   | 74    | 29  | 5   | 2   | 2   | 13,222 |
| 1988 | 1,225 | 715   | 1,943 | 3,692 | 1,606 | 5,209 | 1,544 | 1,169 | 673   | 1,596 | 150   | 89  | 18  | 24  | 10  | 19,662 |
| 1989 | 917   | 342   | 672   | 2,218 | 4,981 | 989   | 3,761 | 571   | 686   | 266   | 836   | 144 | 126 | 63  | 83  | 16,656 |
| 1990 | 2,335 | 354   | 120   | 924   | 1,847 | 6,193 | 1,243 | 3,058 | 310   | 549   | 84    | 789 | 68  | 51  | 67  | 17,992 |
| 1991 | 3,161 | 885   | 319   | 94    | 639   | 600   | 1,986 | 746   | 1,606 | 420   | 568   | 116 | 352 | 49  | 40  | 11,580 |
| 1992 | 1,512 | 416   | 2,361 | 398   | 445   | 745   | 655   | 939   | 418   | 798   | 280   | 349 | 149 | 118 | 93  | 9,675  |
| 1993 | 2,417 | 338   | 898   | 3,844 | 833   | 667   | 345   | 474   | 643   | 396   | 347   | 252 | 198 | 109 | 128 | 11,890 |
| 1994 | 1,404 | 508   | 552   | 1,631 | 4,413 | 774   | 201   | 173   | 192   | 366   | 220   | 309 | 113 | 109 | 165 | 11,129 |
| 1995 | 1,571 | 137   | 426   | 1,995 | 2,654 | 4,322 | 1,834 | 483   | 294   | 184   | 347   | 137 | 255 | 100 | 137 | 14,877 |
| 1996 | 1,552 | 369   | 175   | 348   | 964   | 1,363 | 1,245 | 424   | 105   | 113   | 76    | 143 | 47  | 84  | 110 | 7,119  |
| 1997 | 2,490 | 383   | 201   | 259   | 3,109 | 1,383 | 828   | 997   | 169   | 84    | 64    | 70  | 114 | 37  | 127 | 10,314 |
| 1998 | 727   | 639   | 336   | 240   | 468   | 2,674 | 680   | 429   | 332   | 83    | 37    | 13  | 28  | 31  | 73  | 6,789  |
| 1999 | 1,109 | 1,018 | 967   | 1,050 | 599   | 1,069 | 2,691 | 725   | 350   | 326   | 119   | 50  | 19  | 28  | 96  | 10,217 |
| 2000 | 1,120 | 410   | 535   | 1,825 | 1,814 | 932   | 783   | 2,564 | 999   | 523   | 221   | 150 | 46  | 20  | 86  | 12,027 |
| 2001 | 1,829 | 1,052 | 571   | 546   | 1,381 | 1,444 | 621   | 308   | 918   | 659   | 252   | 201 | 80  | 28  | 77  | 9,967  |
| 2002 | 811   | 408   | 851   | 1,231 | 1,272 | 1,656 | 862   | 417   | 565   | 1,060 | 528   | 234 | 137 | 42  | 45  | 10,118 |
| 2003 | 549   | 165   | 1,045 | 1,752 | 2,078 | 1,908 | 2,555 | 1,445 | 660   | 860   | 1,752 | 758 | 285 | 148 | 108 | 16,068 |
| 2004 | 395   | 286   | 182   | 1,372 | 1,338 | 1,018 | 598   | 648   | 321   | 200   | 200   | 361 | 154 | 37  | 28  | 7,137  |
| 2005 | 397   | 151   | 247   | 1,073 | 3,008 | 2,023 | 1,055 | 479   | 364   | 268   | 72    | 152 | 248 | 96  | 98  | 9,732  |
| 2006 | 872   | 45    | 61    | 381   | 1,016 | 1,298 | 831   | 400   | 228   | 196   | 94    | 59  | 85  | 114 | 111 | 5,790  |
| 2007 | 2,353 | 45    | 118   | 445   | 1,501 | 1,767 | 1,275 | 920   | 388   | 174   | 161   | 140 | 63  | 80  | 152 | 9,582  |
| 2008 | 516   | 97    | 85    | 169   | 548   | 1,131 | 889   | 618   | 392   | 154   | 128   | 98  | 44  | 24  | 152 | 5,045  |
| 2009 | 798   | 219   | 431   | 444   | 248   | 393   | 558   | 443   | 323   | 155   | 103   | 34  | 34  | 18  | 71  | 4,271  |
| 2010 | 511   | 130   | 249   | 2,966 | 1,332 | 416   | 359   | 380   | 399   | 272   | 234   | 85  | 50  | 29  | 63  | 7,475  |
| 2011 | 1,115 | 119   | 268   | 360   | 1,855 | 908   | 266   | 151   | 237   | 236   | 197   | 151 | 63  | 30  | 80  | 6,036  |
| 2012 | 1,170 | 235   | 442   | 3,254 | 761   | 1,228 | 421   | 168   | 127   | 176   | 144   | 127 | 106 | 38  | 67  | 8,465  |
| 2013 | 1,227 | 104   | 217   | 974   | 5,002 | 1,161 | 725   | 254   | 86    | 78    | 102   | 77  | 71  | 39  | 51  | 10,167 |
| 2014 | 2,256 | 580   | 272   | 366   | 1,705 | 6,257 | 3,255 | 693   | 381   | 139   | 53    | 75  | 76  | 36  | 93  | 16,237 |
| 2015 | 1,183 | 809   | 2,296 | 583   | 1,221 | 2,276 | 4,433 | 1,292 | 305   | 145   | 17    | 16  | 29  | 17  | 36  | 14,659 |
| 2016 | 749   | 437   | 630   | 3,323 | 1,364 | 922   | 1,301 | 1,919 | 376   | 147   | 48    | 10  | 11  | 3   | 5   | 11,244 |
| 2017 | 586   | 289   | 460   | 2,367 | 2,863 | 1,247 | 861   | 774   | 919   | 262   | 93    | 32  | 4   | 1   | 5   | 10,763 |
| 2018 | 978   | 456   | 195   | 394   | 2,741 | 1,487 | 491   | 359   | 362   | 279   | 87    | 14  | 2   | 0   | 5   | 9,869  |
| Avg  | 1,415 | 495   | 786   | 1,441 | 2,049 | 1,834 | 1,221 | 736   | 447   | 316   | 212   | 144 | 84  | 44  | 69  | 11,346 |

Table 18: Mean EBS pollock body mass (kg) at age as observed in the summer NMFS bottom trawl survey, 1982–2018.

| Year | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15+   |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1982 | 0.032 | 0.075 | 0.168 | 0.349 | 0.425 | 0.644 | 0.999 | 1.086 | 1.166 | 1.354 | 1.552 | 1.610 | 1.806 | 1.703 | 2.557 |
| 1983 | 0.017 | 0.141 | 0.242 | 0.360 | 0.490 | 0.572 | 0.714 | 1.057 | 1.101 | 0.990 | 1.075 | 1.084 | 1.494 | 1.074 | 1.721 |
| 1984 | 0.014 | 0.072 | 0.251 | 0.362 | 0.489 | 0.623 | 0.759 | 1.000 | 1.192 | 1.389 | 1.482 | 1.675 | 1.328 | 1.446 | 2.072 |
| 1985 | 0.014 | 0.104 | 0.235 | 0.394 | 0.486 | 0.616 | 0.752 | 0.869 | 1.400 | 1.092 | 1.246 | 1.744 | 1.615 | 1.600 | 2.562 |
| 1986 | 0.012 | 0.102 | 0.195 | 0.345 | 0.453 | 0.636 | 0.716 | 0.845 | 0.995 | 1.237 | 1.275 | 1.093 | 2.164 | 2.123 | 2.342 |
| 1987 | 0.017 | 0.110 | 0.271 | 0.356 | 0.435 | 0.525 | 0.696 | 0.777 | 0.869 | 0.956 | 1.134 | 1.369 | 1.680 | 2.007 | 2.122 |
| 1988 | 0.018 | 0.108 | 0.300 | 0.347 | 0.446 | 0.513 | 0.589 | 0.740 | 0.839 | 0.978 | 1.171 | 1.190 | 1.645 | 0.892 | 1.579 |
| 1989 | 0.016 | 0.092 | 0.177 | 0.363 | 0.432 | 0.514 | 0.617 | 0.655 | 0.894 | 0.889 | 1.006 | 1.027 | 1.069 | 1.118 | 1.133 |
| 1990 | 0.013 | 0.102 | 0.160 | 0.385 | 0.503 | 0.568 | 0.605 | 0.714 | 0.776 | 1.024 | 1.038 | 1.088 | 1.019 | 1.205 | 1.271 |
| 1991 | 0.019 | 0.108 | 0.156 | 0.371 | 0.492 | 0.581 | 0.689 | 0.731 | 0.859 | 0.890 | 1.055 | 1.145 | 1.216 | 1.325 | 1.816 |
| 1992 | 0.014 | 0.113 | 0.284 | 0.385 | 0.550 | 0.647 | 0.784 | 0.828 | 0.880 | 0.964 | 1.067 | 1.200 | 1.301 | 1.279 | 1.248 |
| 1993 | 0.012 | 0.072 | 0.323 | 0.448 | 0.493 | 0.540 | 0.644 | 0.778 | 0.963 | 1.017 | 1.130 | 1.235 | 1.342 | 1.493 | 1.597 |
| 1994 | 0.015 | 0.086 | 0.242 | 0.479 | 0.570 | 0.630 | 0.707 | 0.944 | 1.121 | 1.075 | 1.152 | 1.277 | 1.337 | 1.422 | 1.501 |
| 1995 | 0.013 | 0.088 | 0.170 | 0.371 | 0.474 | 0.627 | 0.652 | 0.784 | 0.900 | 1.099 | 1.045 | 1.221 | 1.220 | 1.338 | 1.544 |
| 1996 | 0.017 | 0.081 | 0.154 | 0.327 | 0.496 | 0.576 | 0.696 | 0.779 | 0.939 | 1.021 | 1.271 | 1.377 | 1.414 | 1.550 | 1.638 |
| 1997 | 0.016 | 0.053 | 0.237 | 0.337 | 0.406 | 0.537 | 0.677 | 0.769 | 0.937 | 1.013 | 1.123 | 1.269 | 1.227 | 1.462 | 1.569 |
| 1998 | 0.016 | 0.070 | 0.184 | 0.343 | 0.467 | 0.509 | 0.660 | 0.804 | 0.894 | 0.958 | 1.057 | 1.348 | 1.345 | 1.764 | 1.810 |
| 1999 | 0.014 | 0.080 | 0.216 | 0.354 | 0.417 | 0.557 | 0.631 | 0.762 | 0.961 | 0.986 | 1.075 | 1.162 | 1.519 | 1.725 | 1.869 |
| 2000 | 0.010 | 0.063 | 0.240 | 0.375 | 0.447 | 0.518 | 0.643 | 0.701 | 0.769 | 0.944 | 1.127 | 1.189 | 1.300 | 1.436 | 1.810 |
| 2001 | 0.016 | 0.069 | 0.166 | 0.376 | 0.502 | 0.598 | 0.670 | 0.764 | 0.852 | 0.906 | 1.093 | 1.193 | 1.402 | 1.384 | 1.680 |
| 2002 | 0.011 | 0.097 | 0.256 | 0.379 | 0.512 | 0.634 | 0.663 | 0.798 | 0.891 | 0.928 | 0.939 | 1.100 | 1.195 | 1.401 | 1.864 |
| 2003 | 0.021 | 0.106 | 0.341 | 0.431 | 0.568 | 0.688 | 0.745 | 0.849 | 0.904 | 0.964 | 0.969 | 1.019 | 1.025 | 1.120 | 1.187 |
| 2004 | 0.019 | 0.099 | 0.305 | 0.480 | 0.554 | 0.676 | 0.752 | 0.783 | 0.934 | 0.941 | 1.028 | 1.035 | 1.107 | 1.320 | 1.376 |
| 2005 | 0.018 | 0.079 | 0.241 | 0.391 | 0.510 | 0.583 | 0.688 | 0.792 | 0.862 | 0.901 | 1.006 | 1.058 | 1.090 | 1.187 | 1.317 |
| 2006 | 0.009 | 0.081 | 0.149 | 0.375 | 0.515 | 0.605 | 0.717 | 0.803 | 0.896 | 1.027 | 1.070 | 1.153 | 1.255 | 1.231 | 1.329 |
| 2007 | 0.012 | 0.095 | 0.312 | 0.443 | 0.548 | 0.668 | 0.771 | 0.838 | 0.915 | 1.060 | 1.108 | 1.089 | 1.276 | 1.267 | 1.373 |
| 2008 | 0.014 | 0.054 | 0.229 | 0.427 | 0.530 | 0.643 | 0.757 | 0.858 | 0.919 | 1.060 | 1.205 | 1.187 | 1.344 | 1.506 | 1.534 |
| 2009 | 0.010 | 0.113 | 0.222 | 0.411 | 0.563 | 0.687 | 0.845 | 0.915 | 0.956 | 1.166 | 1.165 | 1.432 | 1.431 | 1.529 | 1.761 |
| 2010 | 0.018 | 0.078 | 0.244 | 0.403 | 0.541 | 0.670 | 0.893 | 0.978 | 1.016 | 1.113 | 1.146 | 1.259 | 1.424 | 1.527 | 1.935 |
| 2011 | 0.015 | 0.112 | 0.233 | 0.426 | 0.548 | 0.641 | 0.795 | 0.995 | 1.094 | 1.140 | 1.229 | 1.279 | 1.400 | 1.447 | 1.617 |
| 2012 | 0.013 | 0.080 | 0.207 | 0.361 | 0.535 | 0.663 | 0.794 | 0.916 | 1.191 | 1.216 | 1.272 | 1.318 | 1.406 | 1.642 | 1.899 |
| 2013 | 0.017 | 0.069 | 0.225 | 0.424 | 0.492 | 0.617 | 0.824 | 0.970 | 1.079 | 1.212 | 1.288 | 1.335 | 1.450 | 1.603 | 1.707 |
| 2014 | 0.016 | 0.100 | 0.219 | 0.360 | 0.477 | 0.601 | 0.653 | 0.881 | 0.966 | 1.105 | 1.288 | 1.301 | 1.356 | 1.455 | 1.624 |
| 2015 | 0.019 | 0.093 | 0.288 | 0.392 | 0.518 | 0.595 | 0.718 | 0.803 | 1.037 | 1.069 | 1.305 | 1.575 | 1.343 | 1.557 | 1.756 |
| 2016 | 0.023 | 0.083 | 0.242 | 0.434 | 0.508 | 0.603 | 0.690 | 0.775 | 0.837 | 0.916 | 1.062 | 0.968 | 1.334 | 1.577 | 1.584 |
| 2017 | 0.022 | 0.098 | 0.198 | 0.398 | 0.528 | 0.595 | 0.686 | 0.737 | 0.818 | 0.819 | 0.947 | 0.816 | 1.183 | 1.319 | 1.578 |
| 2018 | 0.020 | 0.073 | 0.206 | 0.374 | 0.495 | 0.603 | 0.697 | 0.744 | 0.839 | 0.878 | 0.959 | 0.935 | 1.018 | 1.069 | 1.121 |
| Avg  | 0.016 | 0.089 | 0.229 | 0.387 | 0.498 | 0.603 | 0.719 | 0.833 | 0.958 | 1.035 | 1.139 | 1.226 | 1.353 | 1.435 | 1.676 |

Table 19: Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979–2018 (millions 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 columns are for the standard survey area including the Northern Bering Sea (NBS) extension. AT survey data prior to 1994 represent estimates from the surface to 3m off bottom.

| Year | Bottom trawl survey |        |            | AT     |        |
|------|---------------------|--------|------------|--------|--------|
|      | DDC                 | VAST   | VAST + NBS | Survey | age 3+ |
| 1979 |                     |        |            | 7.458  | 22%    |
| 1980 |                     |        |            |        |        |
| 1981 |                     |        |            |        |        |
| 1982 | 4.069               | 3.802  | 3.819      | 4.901  | 95%    |
| 1983 | 8.409               | 9.601  | 9.825      |        |        |
| 1984 | 6.409               | 6.927  | 6.986      |        |        |
| 1985 | 8.25                | 7.828  | 8.199      | 4.799  | 97%    |
| 1986 | 6.826               | 7.275  | 7.399      |        |        |
| 1987 | 7.892               | 7.708  | 7.787      |        |        |
| 1988 | 11.088              | 10.901 | 10.922     | 4.675  | 97%    |
| 1989 | 9.796               | 10.34  | 10.482     |        |        |
| 1990 | 11.9                | 11.615 | 11.674     |        |        |
| 1991 | 7.39                | 7.336  | 7.515      | 1.454  | 46%    |
| 1992 | 6.211               | 6.625  | 6.699      |        |        |
| 1993 | 7.089               | 7.777  | 7.937      |        |        |
| 1994 | 7.1                 | 7.348  | 7.432      | 3.640  | 85%    |
| 1995 | 9.107               | 6.481  | 6.544      |        |        |
| 1996 | 4.08                | 3.916  | 4.067      | 2.955  | 97%    |
| 1997 | 5.019               | 4.834  | 5.031      | 3.591  | 70%    |
| 1998 | 3.51                | 3.648  | 4.038      |        |        |
| 1999 | 5.455               | 5.129  | 5.185      | 4.202  | 95%    |
| 2000 | 7.355               | 7.937  | 8.024      | 3.614  | 95%    |
| 2001 | 5.44                | 6.035  | 6.106      |        |        |
| 2002 | 6.771               | 6.842  | 7.028      | 4.330  | 82%    |
| 2003 | 13.508              | 10.846 | 11.468     |        |        |
| 2004 | 5.106               | 5.423  | 5.743      | 4.016  | 99%    |
| 2005 | 6.696               | 6.905  | 7.018      |        |        |
| 2006 | 3.886               | 4.004  | 4.016      | 1.887  | 98%    |
| 2007 | 6.145               | 6.411  | 6.438      | 2.288  | 89%    |
| 2008 | 3.994               | 4.246  | 4.258      | 1.407  | 76%    |
| 2009 | 2.99                | 2.929  | 2.934      | 1.323  | 78%    |
| 2010 | 5.132               | 5.174  | 5.183      | 2.651  | 65%    |
| 2011 | 3.949               | 4.539  | 4.604      |        |        |
| 2012 | 4.614               | 4.729  | 4.771      | 2.299  | 71%    |
| 2013 | 6.115               | 6.096  | 6.166      |        |        |
| 2014 | 10.331              | 11.889 | 12.508     | 4.727  | 65%    |
| 2015 | 8.587               | 9.604  | 10.878     |        |        |
| 2016 | 6.608               | 7.216  | 9.776      | 4.829  | 97%    |
| 2017 | 6.256               | 6.941  | 8.694      |        |        |
| 2018 | 4.187               | 4.002  | 5.596      | 2.499  |        |
| Avg  | 6.683               | 6.780  | 7.101      | 3.141  |        |

Table 20: 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    | 55 | 91  |    | 11,031  | 18,654 | 29,685 |       | 1,105    | 1,515 | 2,620 |       | —           | —     | —     | —   |

Table 21: Mid-water pollock biomass (near surface down to 3m from the bottom unless otherwise noted) by area as estimated from summer acoustic-trawl surveys on the U.S. EEZ portion of the Bering Sea shelf, 1994–2018 (Honkalehto et al. 2015). CVs for biomass estimates were assumed to average 25% (inter-annual variability arises from the 1-dimensional variance estimation method). Note last column reflects biomass to 0.5m from bottom (as used in the model).

| Year | Date            | Area               |       | Biomass  |       |          |            |
|------|-----------------|--------------------|-------|----------|-------|----------|------------|
|      |                 | (nmi) <sup>2</sup> | SCA   | E170-SCA | W170  | 3m total | 0.5m total |
| 1994 | 9 Jul - 19 Aug  | 78,251             | 0.312 | 0.399    | 2.176 | 2.886    | 3.64       |
| 1996 | 20 Jul - 30 Aug | 93,810             | 0.215 | 0.269    | 1.826 | 2.311    | 2.955      |
| 1997 | 17 Jul - 4 Sept | 102,770            | 0.246 | 0.527    | 1.818 | 2.592    | 3.591      |
| 1999 | 7 Jun - 5 Aug   | 103,670            | 0.299 | 0.579    | 2.408 | 3.285    | 4.202      |
| 2000 | 7 Jun - 2 Aug   | 106,140            | 0.393 | 0.498    | 2.158 | 3.049    | 3.614      |
| 2002 | 4 Jun - 30 Jul  | 99,526             | 0.647 | 0.797    | 2.178 | 3.622    | 4.33       |
| 2004 | 4 Jun - 29 Jul  | 99,659             | 0.498 | 0.516    | 2.293 | 3.307    | 4.016      |
| 2006 | 3 Jun - 25 Jul  | 89,550             | 0.131 | 0.254    | 1.175 | 1.560    | 1.887      |
| 2007 | 2 Jun - 30 Jul  | 92,944             | 0.084 | 0.168    | 1.517 | 1.769    | 2.288      |
| 2008 | 2 Jun - 31 Jul  | 95,374             | 0.085 | 0.029    | 0.883 | 0.997    | 1.407      |
| 2009 | 9 Jun - 7 Aug   | 91,414             | 0.070 | 0.018    | 0.835 | 0.924    | 1.323      |
| 2010 | 5 Jun - 7 Aug   | 92,849             | 0.067 | 0.113    | 2.143 | 2.323    | 2.651      |
| 2012 | 7 Jun - 10 Aug  | 96,852             | 0.142 | 0.138    | 1.563 | 1.843    | 2.299      |
| 2014 | 12 Jun - 13 Aug | 94,361             | 0.426 | 1.000    | 2.014 | 3.439    | 4.727      |
| 2016 | 12 Jun - 17 Aug | 100,674            | 0.516 | 1.005    | 2.542 | 4.063    | 4.829      |
| 2018 | 12 Jun - 22 Aug | 98,300             | 0.218 | 0.462    | 1.439 | 2.120    | 2.499      |

Table 22: AT survey estimates of EBS pollock abundance-at-age (millions), 1979–2018. Age 2+ totals and age-1s were modeled as separate indices.

| 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 | 983    | 4,094  | 1,216 | 1,833 | 2,262 | 386   | 107   | 97  | 54  | 175 | 10,224 | 11,207  |  |
| 1996 | 1,800  | 567    | 552   | 2,741 | 915   | 634   | 585   | 142 | 39  | 129 | 6,303  | 8,103   |  |
| 1997 | 13,251 | 2,879  | 440   | 536   | 2,327 | 546   | 313   | 291 | 75  | 152 | 7,557  | 20,808  |  |
| 1999 | 607    | 1,780  | 3,717 | 1,810 | 652   | 398   | 1,548 | 526 | 180 | 228 | 10,839 | 11,446  |  |
| 2000 | 460    | 1,322  | 1,230 | 2,588 | 1,012 | 327   | 308   | 950 | 278 | 241 | 8,256  | 8,716   |  |
| 2002 | 723    | 4,281  | 3,931 | 1,435 | 839   | 772   | 389   | 149 | 184 | 637 | 12,617 | 13,340  |  |
| 2004 | 83     | 313    | 1,216 | 3,118 | 1,637 | 568   | 291   | 281 | 121 | 255 | 7,800  | 7,883   |  |
| 2006 | 525    | 217    | 291   | 654   | 783   | 659   | 390   | 145 | 75  | 149 | 3,364  | 3,888   |  |
| 2007 | 5,775  | 1,041  | 345   | 478   | 794   | 729   | 407   | 241 | 98  | 114 | 4,246  | 10,021  |  |
| 2008 | 71     | 2,915  | 1,047 | 166   | 161   | 288   | 235   | 136 | 102 | 98  | 5,147  | 5,218   |  |
| 2009 | 5,197  | 816    | 1,733 | 277   | 68    | 84    | 117   | 93  | 65  | 84  | 3,337  | 8,533   |  |
| 2010 | 2,568  | 6,404  | 984   | 2,295 | 446   | 73    | 33    | 37  | 38  | 81  | 10,390 | 12,958  |  |
| 2012 | 177    | 1,989  | 1,693 | 2,710 | 280   | 367   | 113   | 36  | 25  | 93  | 7,305  | 7,482   |  |
| 2014 | 4,751  | 8,655  | 969   | 1,161 | 1,119 | 1,770 | 740   | 170 | 79  | 80  | 14,743 | 19,494  |  |
| 2016 | 353    | 1,185  | 4,546 | 4,439 | 1,194 | 487   | 557   | 650 | 130 | 114 | 13,302 | 13,655  |  |
| 2018 | 424    | 535    | 314   | 570   | 2,338 | 843   | 199   | 134 | 103 | 107 | 5,145  | 5,568   |  |
| Avg. | 2,359  | 2,437  | 1,514 | 1,676 | 1,052 | 558   | 396   | 255 | 103 | 171 | 8,161  | 10,520  |  |
| Med. | 665    | 1,551  | 1,131 | 1,622 | 877   | 516   | 311   | 147 | 88  | 121 | 7,679  | 9,369   |  |

Table 23: An abundance index derived from acoustic data collected opportunistically aboard bottom-trawl survey vessels (AVO index; Honkalehto et al. 2014). Note values in parentheses are the coefficients of variation from using 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 assumed to have a mean value of 0.30 for model fitting purposes (scaling relative to the AT and BTS indices).

| Year | AT scaled biomass index | AVO index | $CV_{AVO}$ |
|------|-------------------------|-----------|------------|
| 2006 | 1.560 (4%)              | 0.555 9%  | 26%        |
| 2007 | 1.769 (4%)              | 0.638 14% | 44%        |
| 2008 | 0.997 (8%)              | 0.316 20% | 33%        |
| 2009 | 0.924 (9%)              | 0.285 42% | 62%        |
| 2010 | 2.323 (6%)              | 0.679 13% | 44%        |
| 2011 | —no survey—             | 0.543 11% | 29%        |
| 2012 | 1.843 (4%)              | 0.661 9%  | 32%        |
| 2013 | —no survey—             | 0.694 6%  | 20%        |
| 2014 | 3.439 (5%)              | 0.897 5%  | 22%        |
| 2015 | —no survey—             | 0.953 5%  | 23%        |
| 2016 | 4.063 (2%)              | 0.776 5%  | 19%        |
| 2017 | —no survey—             | 0.730 5%  | 18%        |
| 2018 | 2.499 (2%)              | 0.672 5%  | 17%        |

Table 24: Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964–2018. Note fishery sample size for 1964–1977 was fixed at 10.

| Year | Fishery | BTS | ATS |
|------|---------|-----|-----|
| 1978 | 39      |     |     |
| 1979 | 39      |     |     |
| 1980 | 39      |     |     |
| 1981 | 39      |     |     |
| 1982 | 39      | 105 |     |
| 1983 | 39      | 126 |     |
| 1984 | 39      | 118 |     |
| 1985 | 39      | 125 |     |
| 1986 | 39      | 88  |     |
| 1987 | 39      | 105 |     |
| 1988 | 39      | 76  |     |
| 1989 | 39      | 80  |     |
| 1990 | 39      | 82  |     |
| 1991 | 134     | 71  |     |
| 1992 | 155     | 82  |     |
| 1993 | 211     | 90  |     |
| 1994 | 83      | 74  | 43  |
| 1995 | 107     | 75  |     |
| 1996 | 115     | 90  | 32  |
| 1997 | 198     | 78  | 49  |
| 1998 | 208     | 82  |     |
| 1999 | 730     | 90  | 67  |
| 2000 | 725     | 101 | 70  |
| 2001 | 467     | 107 |     |
| 2002 | 697     | 110 | 72  |
| 2003 | 623     | 107 |     |
| 2004 | 532     | 108 | 51  |
| 2005 | 638     | 109 |     |
| 2006 | 525     | 102 | 47  |
| 2007 | 654     | 97  | 39  |
| 2008 | 545     | 82  | 35  |
| 2009 | 371     | 87  | 26  |
| 2010 | 383     | 90  | 34  |
| 2011 | 716     | 113 |     |
| 2012 | 659     | 116 | 44  |
| 2013 | 624     | 120 |     |
| 2014 | 631     | 137 | 79  |
| 2015 | 539     | 151 |     |
| 2016 | 510     | 115 | 61  |
| 2017 | 500     | 105 |     |
| 2018 |         | 100 | 25  |



Table 26: Goodness of fit to primary data used for assessment model parameter estimation for different model configurations, EBS pollock.

| Component      | Model 16.1 | Include NBS | Fit 2018 surveys |
|----------------|------------|-------------|------------------|
| RMSE BTS       | 0.240      | 0.100       | 0.240            |
| RMSE ATS       | 0.220      | 0.220       | 0.220            |
| RMSE AVO       | 0.210      | 0.210       | 0.210            |
| RMSE CPUE      | 0.090      | 0.090       | 0.090            |
| Eff. N Fishery | 1438.000   | 1386.000    | 1437.000         |
| Eff. N BTS     | 168.000    | 143.000     | 168.000          |
| Eff. N ATS     | 214.000    | 209.000     | 210.000          |

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

| Component                           | Model 16.1 | Include NBS | Bev-Holt | Fit 2018 surveys |
|-------------------------------------|------------|-------------|----------|------------------|
| $B_{2019}$                          | 3,200      | 3,200       | 3,200    | 2,800            |
| $CV_{B_{2019}}$                     | 0.11       | 0.11        | 0.11     | 0.1              |
| $B_{MSY}$                           | 2,280      | 2,229       | 2,422    | 2,250            |
| $CV_{B_{MSY}}$                      | 0.29       | 0.29        | 0.36     | 0.29             |
| $B_{2019}/B_{MSY}$                  | 137%       | 139%        | 129%     | 119%             |
| $B_0$                               | 5,866      | 5,756       | 9,701    | 5,792            |
| $B_{35\%}$                          | 2,072      | 2,051       | 2,072    | 2,034            |
| SPR rate at $F_{MSY}$               | 30%        | 30%         | 31%      | 30%              |
| Steepness                           | 0.64       | 0.64        | 0.77     | 0.64             |
| Est. $B_{2018}/B_{2018,no fishing}$ | 0.62       | 0.62        | 0.45     | 0.58             |
| $B_{2018}/B_{MSY}$                  | 156%       | 158%        | 147%     | 139%             |

Table 28: Estimated billions of EBS pollock at age (columns 2–11) from the 2018 assessment model.

| Year | 1     | 2     | 3     | 4     | 5    | 6    | 7    | 8    | 9    | 10+  |
|------|-------|-------|-------|-------|------|------|------|------|------|------|
| 1964 | 6.29  | 3.42  | 2.15  | 0.46  | 0.20 | 0.38 | 0.17 | 0.06 | 0.04 | 0.21 |
| 1965 | 20.95 | 2.55  | 2.15  | 1.52  | 0.29 | 0.12 | 0.24 | 0.11 | 0.04 | 0.16 |
| 1966 | 15.01 | 8.50  | 1.61  | 1.51  | 0.94 | 0.18 | 0.08 | 0.15 | 0.07 | 0.12 |
| 1967 | 25.59 | 6.09  | 5.34  | 1.12  | 0.95 | 0.60 | 0.11 | 0.05 | 0.10 | 0.12 |
| 1968 | 22.17 | 10.36 | 3.77  | 3.48  | 0.65 | 0.55 | 0.35 | 0.07 | 0.03 | 0.13 |
| 1969 | 26.24 | 8.97  | 6.40  | 2.46  | 2.01 | 0.38 | 0.32 | 0.20 | 0.04 | 0.09 |
| 1970 | 23.56 | 10.61 | 5.52  | 4.05  | 1.44 | 1.18 | 0.22 | 0.19 | 0.12 | 0.08 |
| 1971 | 14.40 | 9.49  | 6.38  | 3.29  | 2.30 | 0.79 | 0.65 | 0.12 | 0.10 | 0.10 |
| 1972 | 11.76 | 5.78  | 5.56  | 3.57  | 1.72 | 1.14 | 0.39 | 0.32 | 0.06 | 0.08 |
| 1973 | 27.01 | 4.72  | 3.28  | 2.89  | 1.73 | 0.81 | 0.54 | 0.19 | 0.14 | 0.06 |
| 1974 | 19.77 | 10.87 | 2.60  | 1.58  | 1.29 | 0.75 | 0.35 | 0.23 | 0.07 | 0.07 |
| 1975 | 16.76 | 7.97  | 5.77  | 1.11  | 0.67 | 0.54 | 0.32 | 0.15 | 0.09 | 0.05 |
| 1976 | 12.83 | 6.77  | 4.49  | 2.58  | 0.50 | 0.31 | 0.25 | 0.15 | 0.07 | 0.06 |
| 1977 | 13.28 | 5.19  | 3.90  | 2.22  | 1.20 | 0.24 | 0.15 | 0.12 | 0.07 | 0.06 |
| 1978 | 24.46 | 5.38  | 3.03  | 2.12  | 1.12 | 0.59 | 0.12 | 0.07 | 0.06 | 0.06 |
| 1979 | 58.15 | 9.92  | 3.16  | 1.64  | 1.06 | 0.53 | 0.28 | 0.06 | 0.03 | 0.05 |
| 1980 | 25.87 | 23.59 | 5.98  | 1.80  | 0.84 | 0.49 | 0.24 | 0.13 | 0.03 | 0.04 |
| 1981 | 29.48 | 10.50 | 14.61 | 3.73  | 0.94 | 0.39 | 0.22 | 0.11 | 0.06 | 0.03 |
| 1982 | 16.66 | 11.97 | 6.59  | 9.90  | 2.19 | 0.49 | 0.20 | 0.11 | 0.06 | 0.04 |
| 1983 | 50.96 | 6.77  | 7.57  | 4.68  | 6.38 | 1.29 | 0.28 | 0.12 | 0.06 | 0.06 |
| 1984 | 14.28 | 20.71 | 4.28  | 5.43  | 3.14 | 4.00 | 0.77 | 0.17 | 0.07 | 0.07 |
| 1985 | 34.58 | 5.80  | 13.12 | 3.08  | 3.69 | 1.96 | 2.42 | 0.46 | 0.10 | 0.08 |
| 1986 | 14.02 | 14.06 | 3.68  | 9.41  | 2.12 | 2.38 | 1.16 | 1.45 | 0.28 | 0.11 |
| 1987 | 7.52  | 5.70  | 8.91  | 2.64  | 6.44 | 1.39 | 1.46 | 0.70 | 0.89 | 0.23 |
| 1988 | 5.57  | 3.06  | 3.62  | 6.43  | 1.85 | 4.38 | 0.91 | 0.95 | 0.45 | 0.70 |
| 1989 | 10.77 | 2.27  | 1.94  | 2.53  | 4.42 | 1.20 | 2.77 | 0.55 | 0.58 | 0.69 |
| 1990 | 47.66 | 4.38  | 1.44  | 1.38  | 1.71 | 2.86 | 0.75 | 1.65 | 0.33 | 0.77 |
| 1991 | 25.05 | 19.37 | 2.78  | 1.02  | 0.89 | 1.01 | 1.63 | 0.41 | 0.90 | 0.62 |
| 1992 | 22.03 | 10.18 | 12.28 | 1.98  | 0.68 | 0.54 | 0.58 | 0.84 | 0.22 | 0.78 |
| 1993 | 45.35 | 8.95  | 6.44  | 8.52  | 1.30 | 0.41 | 0.29 | 0.27 | 0.38 | 0.44 |
| 1994 | 15.17 | 18.44 | 5.69  | 4.59  | 5.40 | 0.84 | 0.24 | 0.15 | 0.14 | 0.43 |
| 1995 | 10.37 | 6.17  | 11.72 | 4.14  | 3.12 | 3.16 | 0.50 | 0.13 | 0.08 | 0.31 |
| 1996 | 22.52 | 4.22  | 3.92  | 8.58  | 2.94 | 1.98 | 1.70 | 0.27 | 0.07 | 0.21 |
| 1997 | 30.74 | 9.16  | 2.68  | 2.86  | 6.21 | 2.00 | 1.13 | 0.82 | 0.13 | 0.15 |
| 1998 | 15.09 | 12.50 | 5.80  | 1.94  | 2.03 | 4.21 | 1.23 | 0.61 | 0.42 | 0.14 |
| 1999 | 16.35 | 6.13  | 7.94  | 4.20  | 1.37 | 1.37 | 2.54 | 0.73 | 0.33 | 0.29 |
| 2000 | 25.57 | 6.65  | 3.90  | 5.64  | 2.92 | 0.93 | 0.88 | 1.49 | 0.43 | 0.37 |
| 2001 | 34.83 | 10.39 | 4.23  | 2.82  | 3.82 | 1.87 | 0.59 | 0.51 | 0.81 | 0.47 |
| 2002 | 23.41 | 14.16 | 6.61  | 3.08  | 1.95 | 2.31 | 1.03 | 0.33 | 0.28 | 0.72 |
| 2003 | 14.27 | 9.52  | 9.00  | 4.80  | 2.10 | 1.19 | 1.18 | 0.52 | 0.16 | 0.54 |
| 2004 | 6.45  | 5.80  | 6.06  | 6.34  | 3.26 | 1.24 | 0.62 | 0.58 | 0.26 | 0.38 |
| 2005 | 4.63  | 2.62  | 3.69  | 4.39  | 3.98 | 1.98 | 0.70 | 0.32 | 0.30 | 0.36 |
| 2006 | 11.77 | 1.88  | 1.67  | 2.68  | 2.91 | 2.20 | 1.05 | 0.38 | 0.18 | 0.38 |
| 2007 | 25.23 | 4.78  | 1.20  | 1.18  | 1.74 | 1.63 | 1.09 | 0.53 | 0.19 | 0.30 |
| 2008 | 13.62 | 10.26 | 3.04  | 0.84  | 0.76 | 0.96 | 0.79 | 0.54 | 0.28 | 0.26 |
| 2009 | 51.29 | 5.54  | 6.52  | 2.19  | 0.55 | 0.43 | 0.45 | 0.38 | 0.27 | 0.27 |
| 2010 | 21.39 | 20.85 | 3.53  | 4.69  | 1.45 | 0.33 | 0.22 | 0.23 | 0.19 | 0.28 |
| 2011 | 12.83 | 8.70  | 13.28 | 2.58  | 3.00 | 0.88 | 0.19 | 0.12 | 0.12 | 0.25 |
| 2012 | 11.19 | 5.21  | 5.54  | 9.66  | 1.79 | 1.49 | 0.42 | 0.09 | 0.06 | 0.18 |
| 2013 | 56.86 | 4.55  | 3.32  | 4.00  | 6.34 | 1.16 | 0.71 | 0.20 | 0.04 | 0.12 |
| 2014 | 42.24 | 23.12 | 2.90  | 2.40  | 2.66 | 3.86 | 0.69 | 0.37 | 0.09 | 0.08 |
| 2015 | 12.69 | 17.17 | 14.72 | 2.10  | 1.63 | 1.63 | 2.19 | 0.36 | 0.19 | 0.09 |
| 2016 | 14.50 | 5.16  | 10.94 | 10.39 | 1.38 | 1.00 | 0.88 | 1.16 | 0.19 | 0.14 |
| 2017 | 16.71 | 5.90  | 3.29  | 8.00  | 6.50 | 0.88 | 0.59 | 0.50 | 0.66 | 0.19 |
| 2018 | 17.37 | 6.79  | 3.76  | 2.41  | 5.45 | 4.04 | 0.48 | 0.32 | 0.28 | 0.48 |

Table 29: Estimated millions of EBS pollock caught at age (columns 2–11) from the 2018 assessment model.

| Year | 1      | 2       | 3       | 4       | 5      | 6      | 7      | 8      | 9      | 10+    |
|------|--------|---------|---------|---------|--------|--------|--------|--------|--------|--------|
| 1964 | 8.80   | 37.68   | 85.08   | 62.34   | 27.27  | 52.63  | 22.96  | 7.08   | 4.33   | 25.23  |
| 1965 | 28.86  | 28.96   | 98.48   | 215.43  | 39.52  | 16.25  | 30.43  | 13.36  | 4.20   | 18.38  |
| 1966 | 20.71  | 101.09  | 78.85   | 195.07  | 119.35 | 21.70  | 9.08   | 17.27  | 7.70   | 13.55  |
| 1967 | 65.50  | 139.55  | 557.22  | 214.77  | 183.92 | 113.12 | 21.41  | 9.20   | 17.93  | 22.83  |
| 1968 | 64.66  | 263.71  | 395.56  | 666.30  | 121.36 | 100.12 | 62.68  | 12.01  | 5.23   | 23.74  |
| 1969 | 92.11  | 257.11  | 812.62  | 450.02  | 361.56 | 66.72  | 56.84  | 37.68  | 7.38   | 18.13  |
| 1970 | 142.39 | 492.32  | 940.47  | 814.63  | 317.69 | 260.85 | 51.59  | 48.17  | 31.48  | 21.54  |
| 1971 | 122.28 | 621.70  | 1353.63 | 842.52  | 672.08 | 228.80 | 191.89 | 40.44  | 35.22  | 37.81  |
| 1972 | 89.53  | 512.00  | 1442.93 | 1079.70 | 542.56 | 358.48 | 125.87 | 115.39 | 21.30  | 34.64  |
| 1973 | 183.10 | 524.06  | 1003.54 | 1008.89 | 624.37 | 295.12 | 195.07 | 73.68  | 59.29  | 24.71  |
| 1974 | 117.33 | 1474.37 | 967.40  | 597.09  | 493.01 | 287.63 | 134.54 | 96.02  | 32.94  | 33.30  |
| 1975 | 66.12  | 748.37  | 1998.38 | 374.31  | 221.22 | 177.62 | 103.78 | 51.11  | 34.54  | 21.10  |
| 1976 | 36.66  | 524.50  | 1305.78 | 838.34  | 158.81 | 94.70  | 76.44  | 45.71  | 22.53  | 21.56  |
| 1977 | 27.43  | 358.95  | 906.60  | 616.09  | 351.31 | 68.60  | 41.71  | 34.03  | 21.44  | 18.32  |
| 1978 | 42.47  | 343.42  | 710.18  | 601.04  | 351.43 | 184.45 | 36.90  | 22.69  | 19.96  | 20.70  |
| 1979 | 83.18  | 431.99  | 635.51  | 443.76  | 351.98 | 181.10 | 95.34  | 18.99  | 12.40  | 19.42  |
| 1980 | 26.45  | 548.82  | 821.74  | 459.09  | 270.38 | 166.21 | 80.84  | 42.97  | 8.79   | 13.27  |
| 1981 | 17.87  | 130.77  | 1075.62 | 673.12  | 248.08 | 106.06 | 59.53  | 29.53  | 16.19  | 7.93   |
| 1982 | 5.63   | 84.42   | 234.58  | 1113.41 | 386.31 | 94.20  | 38.27  | 21.95  | 11.23  | 8.91   |
| 1983 | 12.31  | 42.30   | 201.95  | 380.23  | 855.45 | 215.13 | 46.63  | 19.39  | 11.54  | 10.37  |
| 1984 | 2.90   | 102.54  | 110.02  | 387.64  | 434.99 | 630.31 | 128.26 | 27.82  | 12.09  | 13.02  |
| 1985 | 6.04   | 29.41   | 363.03  | 194.08  | 410.75 | 335.30 | 409.07 | 78.27  | 17.89  | 15.35  |
| 1986 | 1.95   | 63.29   | 100.82  | 624.76  | 208.61 | 362.29 | 185.32 | 216.28 | 46.75  | 18.69  |
| 1987 | 0.64   | 17.11   | 196.04  | 116.58  | 458.05 | 141.60 | 157.52 | 87.19  | 116.89 | 29.61  |
| 1988 | 0.55   | 11.48   | 175.22  | 404.78  | 202.13 | 557.37 | 144.25 | 144.20 | 72.86  | 111.89 |
| 1989 | 0.89   | 7.95    | 68.36   | 187.80  | 490.05 | 164.07 | 474.00 | 89.49  | 90.23  | 108.22 |
| 1990 | 4.76   | 20.93   | 54.76   | 151.93  | 308.32 | 566.34 | 168.14 | 370.11 | 72.58  | 164.42 |
| 1991 | 2.35   | 95.24   | 83.49   | 88.88   | 137.33 | 198.13 | 430.88 | 98.77  | 240.30 | 161.22 |
| 1992 | 2.46   | 64.01   | 674.88  | 193.41  | 107.72 | 134.32 | 191.43 | 293.43 | 78.64  | 275.83 |
| 1993 | 3.06   | 26.01   | 216.60  | 1066.72 | 148.12 | 74.75  | 73.63  | 68.31  | 98.24  | 113.36 |
| 1994 | 0.83   | 45.97   | 91.29   | 323.58  | 979.32 | 148.90 | 55.24  | 35.67  | 32.77  | 100.17 |
| 1995 | 0.47   | 15.39   | 122.86  | 142.68  | 387.93 | 757.39 | 109.61 | 30.56  | 18.74  | 69.37  |
| 1996 | 1.02   | 15.26   | 53.49   | 170.32  | 209.47 | 393.75 | 516.14 | 82.28  | 19.71  | 54.78  |
| 1997 | 1.27   | 45.67   | 44.68   | 96.36   | 456.99 | 295.57 | 272.99 | 227.11 | 39.26  | 41.30  |
| 1998 | 0.47   | 39.72   | 113.07  | 79.42   | 155.82 | 677.38 | 212.80 | 140.63 | 105.70 | 33.76  |
| 1999 | 0.35   | 10.91   | 275.74  | 221.40  | 103.10 | 157.95 | 461.88 | 128.67 | 57.79  | 50.51  |
| 2000 | 0.52   | 11.41   | 81.20   | 425.07  | 349.51 | 112.26 | 167.62 | 345.13 | 83.28  | 65.15  |
| 2001 | 0.74   | 15.55   | 60.61   | 167.26  | 611.69 | 420.70 | 132.57 | 114.46 | 168.99 | 92.85  |
| 2002 | 0.55   | 34.08   | 121.91  | 215.72  | 296.36 | 626.98 | 280.00 | 90.35  | 72.26  | 160.92 |
| 2003 | 0.33   | 16.71   | 382.77  | 345.50  | 371.76 | 308.28 | 345.25 | 152.93 | 43.40  | 122.04 |
| 2004 | 0.12   | 7.49    | 109.83  | 836.62  | 512.59 | 257.26 | 163.73 | 149.93 | 60.05  | 78.57  |
| 2005 | 0.08   | 3.56    | 63.01   | 406.86  | 887.18 | 483.55 | 160.82 | 69.32  | 62.33  | 65.22  |
| 2006 | 0.23   | 3.86    | 66.26   | 289.89  | 612.73 | 629.30 | 288.96 | 101.81 | 44.01  | 86.57  |
| 2007 | 0.50   | 11.27   | 49.42   | 135.31  | 380.15 | 495.31 | 312.56 | 141.24 | 49.43  | 74.03  |
| 2008 | 0.26   | 21.83   | 69.05   | 84.16   | 154.23 | 308.77 | 240.42 | 157.19 | 77.61  | 70.16  |
| 2009 | 0.86   | 7.72    | 168.71  | 210.04  | 90.25  | 118.73 | 125.23 | 102.25 | 71.01  | 75.83  |
| 2010 | 0.29   | 25.15   | 41.61   | 558.54  | 225.66 | 63.32  | 48.12  | 55.19  | 46.28  | 65.08  |
| 2011 | 0.23   | 14.00   | 204.96  | 142.28  | 855.69 | 277.98 | 59.36  | 36.91  | 37.06  | 75.34  |
| 2012 | 0.19   | 10.65   | 114.20  | 950.27  | 193.70 | 465.94 | 130.40 | 29.49  | 18.00  | 56.05  |
| 2013 | 0.85   | 6.39    | 64.15   | 351.48  | 982.84 | 193.75 | 181.10 | 60.11  | 13.23  | 35.14  |
| 2014 | 0.57   | 31.86   | 47.52   | 179.83  | 405.45 | 781.95 | 185.70 | 97.38  | 25.60  | 21.74  |
| 2015 | 0.18   | 18.26   | 598.99  | 204.60  | 239.46 | 384.61 | 545.81 | 90.69  | 52.62  | 25.85  |
| 2016 | 0.14   | 3.18    | 118.09  | 1395.35 | 166.57 | 177.54 | 174.13 | 240.67 | 37.37  | 28.56  |
| 2017 | 0.16   | 2.87    | 29.68   | 560.96  | 914.93 | 209.34 | 137.36 | 111.51 | 131.83 | 37.47  |
| 2018 | 0.14   | 2.85    | 29.22   | 146.34  | 667.09 | 840.88 | 97.40  | 62.20  | 48.88  | 84.34  |

Table 30: Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964–2018. Biomass units are thousands of t, age-1 recruitment is in millions of pollock.

| Year | SSB   | CV.SSB | Recruitment | CV.Rec... | Age.3..Biomass | CV.. |
|------|-------|--------|-------------|-----------|----------------|------|
| 1964 | 516   | 27     | 6,294       | 38        | 1,744          | 22   |
| 1965 | 612   | 23     | 20,951      | 25        | 2,124          | 20   |
| 1966 | 711   | 22     | 15,011      | 32        | 2,277          | 20   |
| 1967 | 896   | 20     | 25,590      | 26        | 3,504          | 17   |
| 1968 | 1,111 | 19     | 22,171      | 28        | 4,011          | 17   |
| 1969 | 1,364 | 19     | 26,244      | 26        | 5,105          | 16   |
| 1970 | 1,597 | 18     | 23,562      | 27        | 5,757          | 15   |
| 1971 | 1,691 | 18     | 14,401      | 33        | 6,209          | 13   |
| 1972 | 1,605 | 17     | 11,755      | 34        | 5,902          | 13   |
| 1973 | 1,345 | 19     | 27,009      | 19        | 4,729          | 14   |
| 1974 | 993   | 22     | 19,772      | 19        | 3,474          | 16   |
| 1975 | 841   | 20     | 16,758      | 18        | 3,585          | 12   |
| 1976 | 853   | 15     | 12,831      | 17        | 3,515          | 10   |
| 1977 | 882   | 13     | 13,276      | 15        | 3,426          | 9    |
| 1978 | 882   | 11     | 24,458      | 10        | 3,250          | 8    |
| 1979 | 835   | 11     | 58,151      | 6         | 3,087          | 8    |
| 1980 | 923   | 9      | 25,871      | 9         | 3,856          | 7    |
| 1981 | 1,515 | 6      | 29,475      | 8         | 7,314          | 5    |
| 1982 | 2,317 | 6      | 16,662      | 11        | 8,448          | 5    |
| 1983 | 2,896 | 5      | 50,955      | 6         | 9,556          | 5    |
| 1984 | 3,136 | 5      | 14,281      | 11        | 9,428          | 5    |
| 1985 | 3,432 | 5      | 34,580      | 7         | 11,615         | 4    |
| 1986 | 3,706 | 4      | 14,019      | 10        | 11,039         | 4    |
| 1987 | 3,880 | 4      | 7,524       | 13        | 11,734         | 3    |
| 1988 | 3,908 | 4      | 5,573       | 14        | 11,125         | 3    |
| 1989 | 3,530 | 4      | 10,770      | 10        | 9,422          | 3    |
| 1990 | 2,845 | 4      | 47,657      | 4         | 7,536          | 4    |
| 1991 | 2,125 | 5      | 25,052      | 6         | 5,920          | 4    |
| 1992 | 2,212 | 4      | 22,026      | 6         | 9,065          | 3    |
| 1993 | 3,038 | 3      | 45,352      | 4         | 11,181         | 3    |
| 1994 | 3,353 | 3      | 15,169      | 6         | 10,957         | 3    |
| 1995 | 3,537 | 3      | 10,371      | 7         | 12,508         | 3    |
| 1996 | 3,536 | 3      | 22,524      | 5         | 10,751         | 3    |
| 1997 | 3,349 | 3      | 30,739      | 4         | 9,395          | 3    |
| 1998 | 3,089 | 3      | 15,088      | 5         | 9,422          | 3    |
| 1999 | 3,123 | 3      | 16,347      | 5         | 10,390         | 3    |
| 2000 | 3,155 | 3      | 25,565      | 4         | 9,582          | 3    |
| 2001 | 3,178 | 3      | 34,834      | 3         | 9,335          | 3    |
| 2002 | 3,000 | 3      | 23,412      | 4         | 9,698          | 3    |
| 2003 | 3,169 | 3      | 14,270      | 5         | 11,657         | 2    |
| 2004 | 3,274 | 3      | 6,451       | 7         | 10,999         | 2    |
| 2005 | 3,006 | 3      | 4,629       | 8         | 9,197          | 2    |
| 2006 | 2,464 | 3      | 11,769      | 5         | 7,035          | 3    |
| 2007 | 2,042 | 3      | 25,225      | 4         | 5,683          | 3    |
| 2008 | 1,523 | 4      | 13,623      | 6         | 4,651          | 3    |
| 2009 | 1,615 | 4      | 51,287      | 4         | 5,837          | 3    |
| 2010 | 1,861 | 4      | 21,394      | 6         | 6,185          | 3    |
| 2011 | 2,249 | 4      | 12,826      | 9         | 8,788          | 3    |
| 2012 | 2,596 | 4      | 11,188      | 10        | 8,722          | 4    |
| 2013 | 2,873 | 4      | 56,864      | 9         | 8,547          | 4    |
| 2014 | 2,731 | 5      | 42,237      | 12        | 7,855          | 5    |
| 2015 | 2,827 | 6      | 12,693      | 21        | 11,345         | 6    |
| 2016 | 3,511 | 7      | 14,502      | 18        | 13,293         | 8    |
| 2017 | 3,838 | 9      | 16,709      | 19        | 11,785         | 9    |
| 2018 | 3,552 | 10     | 17,373      | 21        | 10,202         | 9    |



Table 32: Summary of model 16.1 results and the stock condition for EBS pollock. Biomass units are thousands of t.

| Component                           | Model 16.1 |
|-------------------------------------|------------|
| $B_{2019}$                          | 3,200      |
| $CV_{B_{2019}}$                     | 0.11       |
| $B_{MSY}$                           | 2,280      |
| $CV_{B_{MSY}}$                      | 0.29       |
| $B_{2019}/B_{MSY}$                  | 137%       |
| $B_0$                               | 5,866      |
| $B_{35\%}$                          | 2,072      |
| SPR rate at $F_{MSY}$               | 30%        |
| Steepness                           | 0.64       |
| Est. $B_{2018}/B_{2018, nofishing}$ | 0.62       |
| $B_{2018}/B_{MSY}$                  | 156%       |

Table 33: Summary results of Tier 1 2018 yield projections for EBS pollock.

| Component                           | Model 16.1 |
|-------------------------------------|------------|
| 2019 fishable biomass (GM)          | 6,073,000  |
| Equilibrium fishable biomass at MSY | 3,830,000  |
| MSY R (HM)                          | 0.51       |
| 2019 Tier 1 ABC                     | 3,096,000  |
| 2019 Tier 1 $F_{OFL}$               | 0.645      |
| 2019 Tier 1 OFL                     | 3,914,000  |
| MSY R (HM)                          | 0.434      |
| Recommended ABC                     | 2,631,000  |

Table 34: 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 |
|-------|------------|------------|------------|------------|------------|------------|------------|
| 2018  | 1,350      | 1,350      | 1,350      | 1,350      | 1,350      | 1,350      | 1,350      |
| 2019  | 2,163      | 1,350      | 1,403      | 976        | 0          | 2,659      | 2,163      |
| 2020  | 1,534      | 1,350      | 1,148      | 855        | 0          | 1,589      | 1,534      |
| 2021  | 1,170      | 1,527      | 1,023      | 795        | 0          | 1,203      | 1,434      |
| 2022  | 1,182      | 1,322      | 1,020      | 808        | 0          | 1,262      | 1,337      |
| 2023  | 1,265      | 1,320      | 1,061      | 847        | 0          | 1,371      | 1,394      |
| 2024  | 1,358      | 1,382      | 1,127      | 904        | 0          | 1,470      | 1,477      |
| 2025  | 1,401      | 1,411      | 1,164      | 940        | 0          | 1,505      | 1,508      |
| 2026  | 1,423      | 1,428      | 1,190      | 966        | 0          | 1,520      | 1,521      |
| 2027  | 1,417      | 1,418      | 1,196      | 976        | 0          | 1,505      | 1,506      |
| 2028  | 1,416      | 1,417      | 1,201      | 984        | 0          | 1,501      | 1,501      |
| 2029  | 1,399      | 1,400      | 1,193      | 981        | 0          | 1,480      | 1,480      |
| 2030  | 1,393      | 1,393      | 1,191      | 981        | 0          | 1,475      | 1,475      |
| 2031  | 1,399      | 1,399      | 1,195      | 985        | 0          | 1,483      | 1,483      |

Table 35: Tier 3 projections of EBS pollock ABC (given catches in Table 34) for the 7 scenarios.

| ABC  | Scenario.1 | Scenario.2 | Scenario.3 | Scenario.4 | Scenario.5 | Scenario.6 | Scenario.7 |
|------|------------|------------|------------|------------|------------|------------|------------|
| 2018 | 2,310      | 2,310      | 1,490      | 1,033      | 0          | 2,853      | 2,853      |
| 2019 | 2,163      | 2,163      | 1,403      | 976        | 0          | 2,659      | 2,659      |
| 2020 | 1,534      | 1,791      | 1,148      | 855        | 0          | 1,589      | 1,859      |
| 2021 | 1,170      | 1,527      | 1,023      | 795        | 0          | 1,203      | 1,434      |
| 2022 | 1,182      | 1,322      | 1,020      | 808        | 0          | 1,262      | 1,337      |
| 2023 | 1,265      | 1,320      | 1,061      | 847        | 0          | 1,371      | 1,394      |
| 2024 | 1,358      | 1,382      | 1,127      | 904        | 0          | 1,470      | 1,477      |
| 2025 | 1,401      | 1,412      | 1,164      | 940        | 0          | 1,505      | 1,508      |
| 2026 | 1,423      | 1,428      | 1,190      | 966        | 0          | 1,520      | 1,521      |
| 2027 | 1,417      | 1,419      | 1,196      | 976        | 0          | 1,505      | 1,506      |
| 2028 | 1,416      | 1,417      | 1,201      | 984        | 0          | 1,501      | 1,501      |
| 2029 | 1,399      | 1,400      | 1,193      | 981        | 0          | 1,480      | 1,480      |
| 2030 | 1,393      | 1,393      | 1,191      | 981        | 0          | 1,475      | 1,475      |
| 2031 | 1,399      | 1,399      | 1,195      | 985        | 0          | 1,483      | 1,483      |

Table 36: 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 |
|------|------------|------------|------------|------------|------------|------------|------------|
| 2018 | 0.251      | 0.251      | 0.251      | 0.251      | 0.251      | 0.251      | 0.251      |
| 2019 | 0.465      | 0.268      | 0.280      | 0.188      | 0.000      | 0.603      | 0.465      |
| 2020 | 0.458      | 0.333      | 0.280      | 0.188      | 0.000      | 0.537      | 0.458      |
| 2021 | 0.414      | 0.460      | 0.280      | 0.188      | 0.000      | 0.487      | 0.527      |
| 2022 | 0.412      | 0.429      | 0.280      | 0.188      | 0.000      | 0.496      | 0.509      |
| 2023 | 0.418      | 0.424      | 0.280      | 0.188      | 0.000      | 0.510      | 0.514      |
| 2024 | 0.423      | 0.426      | 0.280      | 0.188      | 0.000      | 0.520      | 0.521      |
| 2025 | 0.426      | 0.427      | 0.280      | 0.188      | 0.000      | 0.524      | 0.524      |
| 2026 | 0.426      | 0.427      | 0.280      | 0.188      | 0.000      | 0.523      | 0.523      |
| 2027 | 0.426      | 0.426      | 0.280      | 0.188      | 0.000      | 0.521      | 0.521      |
| 2028 | 0.426      | 0.426      | 0.280      | 0.188      | 0.000      | 0.520      | 0.520      |
| 2029 | 0.424      | 0.424      | 0.280      | 0.188      | 0.000      | 0.518      | 0.518      |
| 2030 | 0.424      | 0.424      | 0.280      | 0.188      | 0.000      | 0.517      | 0.517      |
| 2031 | 0.424      | 0.424      | 0.280      | 0.188      | 0.000      | 0.516      | 0.516      |

Table 37: 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 |
|------|------------|------------|------------|------------|------------|------------|------------|
| 2018 | 3,559      | 3,559      | 3,559      | 3,559      | 3,559      | 3,559      | 3,559      |
| 2019 | 3,004      | 3,126      | 3,119      | 3,178      | 3,302      | 2,922      | 3,004      |
| 2020 | 2,346      | 2,708      | 2,715      | 2,931      | 3,445      | 2,134      | 2,346      |
| 2021 | 2,149      | 2,455      | 2,594      | 2,897      | 3,701      | 1,950      | 2,110      |
| 2022 | 2,225      | 2,357      | 2,666      | 3,020      | 4,055      | 2,037      | 2,093      |
| 2023 | 2,345      | 2,403      | 2,793      | 3,186      | 4,422      | 2,148      | 2,167      |
| 2024 | 2,429      | 2,456      | 2,902      | 3,329      | 4,755      | 2,213      | 2,220      |
| 2025 | 2,475      | 2,488      | 2,976      | 3,432      | 5,028      | 2,244      | 2,246      |
| 2026 | 2,490      | 2,496      | 3,015      | 3,494      | 5,240      | 2,249      | 2,250      |
| 2027 | 2,482      | 2,484      | 3,024      | 3,523      | 5,401      | 2,235      | 2,235      |
| 2028 | 2,470      | 2,471      | 3,022      | 3,534      | 5,517      | 2,222      | 2,222      |
| 2029 | 2,455      | 2,455      | 3,012      | 3,533      | 5,599      | 2,208      | 2,208      |
| 2030 | 2,455      | 2,455      | 3,013      | 3,541      | 5,678      | 2,210      | 2,210      |
| 2031 | 2,464      | 2,464      | 3,022      | 3,554      | 5,748      | 2,220      | 2,220      |

Table 38: Bycatch estimates (t) of FMP species caught in the BSAI directed pollock fishery, 1997–2018 based on then NMFS Alaska Regional Office reports from observers (2018 data are preliminary).

| Year | Pacific.Cod | Flathead.Sole | Rock.Sole | Yellowfin.Sole | Arrowtooth.Founder | Pacific.Ocean.Perch | Atka.Mackerel | Sablefish | Greenland.Turbot | Alaska.Plaice | Skates | Squid | Sharks | Sculpin | All.other | Total  |
|------|-------------|---------------|-----------|----------------|--------------------|---------------------|---------------|-----------|------------------|---------------|--------|-------|--------|---------|-----------|--------|
| 1997 | 8,263       | 2,350         | 1,523     | 606            | 985                | 428                 | 83            | 2         | 124              | 0             | NA     | 1,369 | NA     | NA      | 1,693     | 17,426 |
| 1998 | 6,255       | 2,048         | 770       | 1,745          | 1,713              | 617                 | 10            | 2         | 174              | 0             | NA     | 544   | NA     | NA      | 1,732     | 15,609 |
| 1999 | 3,220       | 1,885         | 1,059     | 350            | 273                | 121                 | 158           | 7         | 30               | 0             | NA     | 419   | NA     | NA      | 1,428     | 8,950  |
| 2000 | 3,433       | 2,510         | 2,688     | 1,466          | 979                | 21                  | 2             | 12        | 52               | 0             | NA     | 355   | NA     | NA      | 5,999     | 17,518 |
| 2001 | 3,879       | 2,199         | 1,673     | 594            | 530                | 574                 | 41            | 21        | 68               | 0             | NA     | 1,730 | NA     | NA      | 3,880     | 15,191 |
| 2002 | 5,883       | 1,844         | 1,886     | 768            | 607                | 542                 | 221           | 34        | 70               | 0             | NA     | 1,312 | NA     | NA      | 2,298     | 15,466 |
| 2003 | 5,968       | 1,500         | 1,418     | 210            | 618                | 935                 | 762           | 48        | 40               | 6             | 571    | 788   | 294    | 81      | 1,020     | 14,258 |
| 2004 | 6,437       | 2,104         | 2,554     | 841            | 557                | 394                 | 1,053         | 17        | 18               | 8             | 841    | 977   | 187    | 150     | 469       | 16,605 |
| 2005 | 7,413       | 2,352         | 1,125     | 63             | 651                | 652                 | 678           | 11        | 31               | 45            | 732    | 1,150 | 169    | 131     | 502       | 15,704 |
| 2006 | 7,291       | 2,862         | 1,361     | 256            | 1,089              | 736                 | 789           | 9         | 65               | 11            | 1,308  | 1,399 | 512    | 169     | 630       | 18,486 |
| 2007 | 5,630       | 4,226         | 510       | 86             | 2,795              | 625                 | 315           | 12        | 107              | 3             | 1,287  | 1,169 | 245    | 190     | 731       | 17,929 |
| 2008 | 6,971       | 4,315         | 2,150     | 552            | 1,715              | 336                 | 15            | 5         | 85               | 58            | 2,756  | 1,452 | 144    | 281     | 442       | 21,277 |
| 2009 | 7,875       | 4,666         | 7,591     | 271            | 2,202              | 114                 | 25            | 3         | 44               | 173           | 3,856  | 209   | 100    | 292     | 294       | 27,716 |
| 2010 | 6,965       | 4,358         | 2,242     | 1,056          | 1,466              | 231                 | 57            | 2         | 26               | 119           | 1,886  | 277   | 26     | 258     | 296       | 19,264 |
| 2011 | 10,040      | 4,886         | 8,481     | 1,083          | 1,589              | 660                 | 894           | 1         | 25               | 74            | 2,352  | 177   | 66     | 315     | 544       | 31,186 |
| 2012 | 10,061      | 3,968         | 6,701     | 1,496          | 745                | 712                 | 263           | 1         | 53               | 137           | 2,018  | 495   | 55     | 286     | 507       | 27,502 |
| 2013 | 8,958       | 3,147         | 6,319     | 2,087          | 965                | 611                 | 70            | 0         | 21               | 148           | 1,751  | 117   | 43     | 219     | 241       | 24,697 |
| 2014 | 5,212       | 2,554         | 4,359     | 1,954          | 737                | 1,299               | 117           | 0         | 29               | 318           | 809    | 1,477 | 75     | 190     | 422       | 19,552 |
| 2015 | 8,303       | 2,260         | 1,709     | 863            | 403                | 2,516               | 192           | 0         | 41               | 99            | 824    | 2,206 | 52     | 187     | 342       | 19,995 |
| 2016 | 4,975       | 1,628         | 1,142     | 882            | 282                | 3,272               | 69            | 19        | 29               | 39            | 461    | 1,164 | 58     | 124     | 517       | 14,663 |
| 2017 | 5,951       | 956           | 1,825     | 608            | 208                | 4,818               | 64            | 102       | 18               | 46            | 509    | 1,887 | 93     | 81      | 323       | 17,489 |
| 2018 | 4,264       | 1,038         | 1,145     | 788            | 263                | 4,091               | 546           | 447       | 30               | 104           | 583    | 1,644 | 63     | 58      | 322       | 15,384 |

Table 39: Bycatch estimates (t) of pollock caught in the other non-pollock EBS directed fisheries, 1997–2018 based on then NMFS Alaska Regional Office reports from observers.

| Year | Pacific.Cod | Yellowfin.Sole | Rock.Sole | Flathead.Sole | Other.flatfish | Other.fisheries | Total  |
|------|-------------|----------------|-----------|---------------|----------------|-----------------|--------|
| 1997 | 33,658      | 24,100         | 9,123     | 2,983         | 75             | 14              | 69,955 |
| 1998 | 10,468      | 15,339         | 3,960     | 2,369         | 342            | 941             | 33,421 |
| 1999 | 21,131      | 8,701          | 5,207     | 4,040         | 406            | 1,197           | 40,684 |
| 2000 | 14,508      | 13,425         | 5,480     | 6,467         | 228            | 520             | 40,631 |
| 2001 | 11,570      | 16,502         | 4,577     | 4,337         | 270            | 488             | 37,748 |
| 2002 | 15,255      | 14,489         | 9,942     | 1,934         | 210            | 51              | 41,884 |
| 2003 | 15,926      | 11,578         | 4,924     | 2,983         | 381            | 260             | 36,055 |
| 2004 | 18,650      | 10,383         | 8,975     | 5,162         | 625            | 198             | 43,996 |
| 2005 | 14,109      | 10,312         | 7,235     | 3,662         | 1,133          | 220             | 36,674 |
| 2006 | 15,168      | 5,966          | 6,986     | 2,663         | 1,109          | 144             | 32,038 |
| 2007 | 20,319      | 4,020          | 3,245     | 3,417         | 616            | 276             | 31,895 |
| 2008 | 9,533       | 9,827          | 4,930     | 4,102         | 713            | 17              | 29,124 |
| 2009 | 7,875       | 7,036          | 6,171     | 3,160         | 324            | 13              | 24,582 |
| 2010 | 6,409       | 5,156          | 6,097     | 2,997         | 316            | 85              | 21,062 |
| 2011 | 8,987       | 8,673          | 6,931     | 1,473         | 704            | 306             | 27,077 |
| 2012 | 8,381       | 11,199         | 6,703     | 903           | 824            | 413             | 28,425 |
| 2013 | 9,096       | 20,171         | 7,327     | 2,010         | 1,948          | 238             | 40,792 |
| 2014 | 11,508      | 24,700         | 11,270    | 4,106         | 1,986          | 202             | 53,775 |
| 2015 | 9,076       | 21,281         | 9,381     | 2,632         | 1,615          | 429             | 44,417 |
| 2016 | 9,093       | 22,323         | 11,848    | 1,666         | 1,274          | 450             | 46,657 |
| 2017 | 8,345       | 23,433         | 5,617     | 1,956         | 1,315          | 512             | 41,180 |
| 2018 | 6,262       | 20,371         | 5,182     | 2,608         | 668            | 117             | 35,210 |

Table 40: Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 2003–2018, based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska).

| Year | Scypho.jellies | Misc.fish | Eulachon.Osmerid | Sea.star | Eelpouts | Grenadier | Sea.pen | Lanternfish | Snails | All.other |
|------|----------------|-----------|------------------|----------|----------|-----------|---------|-------------|--------|-----------|
| 2003 | 5,591          | 98        | 9                | 88       | 1        | 20        | 0       | 0           | 0      | 1         |
| 2004 | 6,490          | 87        | 20               | 7        | 0        | 14        | 0       | 0           | 0      | 1         |
| 2005 | 5,084          | 146       | 12               | 9        | 1        | 14        | 1       | 0           | 6      | 2         |
| 2006 | 2,657          | 147       | 92               | 8        | 20       | 15        | 1       | 9           | 0      | 6         |
| 2007 | 2,150          | 198       | 136              | 4        | 118      | 27        | 3       | 5           | 0      | 6         |
| 2008 | 3,711          | 103       | 4                | 6        | 7        | 27        | 1       | 0           | 0      | 6         |
| 2009 | 3,703          | 58        | 4                | 4        | 2        | 3         | 1       | 0           | 0      | 1         |
| 2010 | 2,153          | 116       | 0                | 4        | 0        | 1         | 1       | 0           | 0      | 1         |
| 2011 | 6,571          | 216       | 2                | 18       | 0        | 1         | 2       | 0           | 0      | 1         |
| 2012 | 2,454          | 124       | 1                | 3        | 0        | 0         | 2       | 0           | 0      | 1         |
| 2013 | 4,734          | 101       | 0                | 2        | 0        | 0         | 1       | 0           | 0      | 2         |
| 2014 | 11,036         | 40        | 2                | 5        | 2        | 0         | 3       | 0           | 0      | 4         |
| 2015 | 4,748          | 87        | 21               | 28       | 9        | 1         | 2       | 0           | 0      | 2         |
| 2016 | 2,185          | 70        | 5                | 48       | 22       | 3         | 1       | 0           | 0      | 2         |
| 2017 | 5,776          | 46        | 3                | 4        | 18       | 2         | 0       | 0           | 0      | 0         |

Table 41: Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997–2018 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 2018 are preliminary.

| Year | Bairdi.Crab. | Blue.King.Crab | Chinook.Salmon | Golden.King.Crab | Halibut.catch | Herring | Non.Chin..salmon | Opilio.Crab | Other.King.Crab | Red.King.Crab. |
|------|--------------|----------------|----------------|------------------|---------------|---------|------------------|-------------|-----------------|----------------|
| 1991 | 249,836      | 0              | 31,702         | 0                | 525           | 3,095   | 23,304           | 1,681,668   | 14,937          | 535            |
| 1992 | 1,042,484    | 0              | 28,760         | 0                | 1,651         | 630     | 39,741           | 3,558,922   | 12,675          | 7,885          |
| 1993 | 387,357      | 0              | 32,533         | 0                | 634           | 519     | 239,384          | 215,733     | 394             | 9,342          |
| 1994 | 149,066      | 0              | 29,816         | 0                | 611           | 1,528   | 84,718           | 302,281     | 34              | 666            |
| 1995 | 46,286       | 0              | 8,800          | 0                | 157           | 798     | 14,509           | 59,936      | 521             | 2,013          |
| 1996 | 18,554       | 0              | 50,282         | 0                | 229           | 1,168   | 74,423           | 42,329      | 198             | 2,572          |
| 1997 | 6,525        | 0              | 43,329         | 0                | 160           | 1,088   | 61,504           | 88,589      | 156             | 0              |
| 1998 | 38,100       | 0              | 50,835         | 0                | 200           | 749     | 59,570           | 55,197      | 1,836           | 9,560          |
| 1999 | 1,077        | 0              | 10,331         | 0                | 84            | 784     | 44,586           | 12,783      | 2               | 0              |
| 2000 | 173          | 0              | 3,967          | 0                | 91            | 481     | 56,715           | 1,807       | 103             | 0              |
| 2001 | 86           | 0              | 30,118         | 0                | 195           | 224     | 52,857           | 2,179       | 5,136           | 38             |
| 2002 | 651          | 0              | 32,249         | 0                | 151           | 108     | 77,101           | 1,669       | 81              | 5              |
| 2003 | 723          | 8              | 42,146         | 0                | 86            | 947     | 178,224          | 607         | 0               | 52             |
| 2004 | 1,078        | 4              | 48,171         | 1                | 93            | 1,064   | 439,122          | 633         | 0               | 8              |
| 2005 | 592          | 0              | 64,018         | 1                | 100           | 421     | 695,006          | 1,913       | 0               | 0              |
| 2006 | 964          | 0              | 77,883         | 0                | 119           | 219     | 290,862          | 2,547       | 0               | 25             |
| 2007 | 826          | 0              | 104,078        | 3                | 274           | 345     | 82,410           | 2,713       | 0               | 7              |
| 2008 | 798          | 8              | 18,507         | 3                | 253           | 124     | 13,161           | 4,322       | 0               | 27             |
| 2009 | 849          | 0              | 8,163          | 0                | 254           | 64      | 41,833           | 2,999       | 0               | 34             |
| 2010 | 838          | 28             | 7,320          | 0                | 135           | 189     | 12,731           | 4,337       | 0               | 16             |
| 2011 | 2,929        | 25             | 24,100         | 0                | 258           | 345     | 185,279          | 4,405       | 0               | 3              |
| 2012 | 1,137        | 0              | 9,850          | 0                | 313           | 2,166   | 20,115           | 2,851       | 0               | 2              |
| 2013 | 1,576        | 6              | 11,454         | 4                | 129           | 958     | 123,792          | 3,746       | 0               | 0              |
| 2014 | 885          | 0              | 14,425         | 0                | 134           | 151     | 218,067          | 3,330       | 0               | 7              |
| 2015 | 1,179        | 0              | 17,583         | 0                | 117           | 1,387   | 236,185          | 2,942       | 0               | 0              |
| 2016 | 468          | 0              | 21,222         | 0                | 98            | 1,425   | 338,818          | 833         | 0               | 6              |
| 2017 | 327          | 0              | 29,517         | 0                | 76            | 957     | 466,484          | 288         | 0               | 22             |
| 2018 | 898          | 0              | 13,503         | 0                | 48            | 304     | 280,424          | 276         | 0               | 14             |

Table 42: Ecosystem considerations for BSAI pollock and the pollock fishery.

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

Table 43: 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  |
|------------------------------------|--|--|
| $P [F_{2019} > F_{MSY}]$           | Probability that the fishing mortality in 2019 exceeds $F_{MSY}$   | OFL definition is based on $F_{MSY}$   |
| $P [B_{2020} < B_{MSY}]$           | Probability that the spawning biomass in 2020 is less than $B_{MSY}$   | $B_{MSY}$ is a reference point target and biomass in 2020 provides an indication of the impact of 2019 fishing   |
| $P [B_{2021} < B_{MSY}]$           | Probability that the spawning biomass in 2021 is less than $B_{MSY}$   | $B_{MSY}$ is a reference point target and biomass in 2023 provides an indication of the impact of fishing in 2019 and 2020   |
| $P [B_{2020} < \bar{B}]$           | Probability that the spawning biomass in 2020 is less than the 1978–2018 mean  | To provide some perspective of what the stock condition might be relative to historical estimates after fishing in 2019.   |
| $P [B_{2023} < \bar{B}]$           | Probability that the spawning biomass in 2023 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 2019.   |
| $P [B_{2023} < B_{2019}]$          | Probability that the spawning biomass in 2023 is less than that estimated for 2019   | To provide a medium term expectation of stock status relative to 2019 levels   |
| $P [B_{2021} < B_{20\%}]$          | Probability that the spawning biomass in 2021 is less than $B_{20\%}$  | $B_{20\%}$ had been selected as a Steller Sea Lion lower limit for allowing directed fishing   |
| $P [p_{a_5,2021} > \bar{p}_{a_5}]$ | Probability that in 2023 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.   |
| $P [D_{2020} < D_{1994}]$          | Probability that the diversity of ages represented in the spawning biomass (by weight) in 2020 is less than the value estimated for 1994 | To provide a relative index on the abundance of different age classes in the 2020 population relative to 1994 (a year identified as having low age composition diversity)        |
| $P [D_{2023} < D_{1994}]$          | Probability that the diversity of ages represented in the spawning biomass (by weight) in 2023 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) |
| $P [E_{2019} > E_{2018}]$          | Probability that the theoretical fishing effort in 2019 will be greater than that estimated in 2018.                                     | To provide the relative effort that is expected (and hence some idea of costs).  |

```
## Error in round(M$catch_dec_tab, 0): non-numeric argument to mathematical function
```

Table 44: Outcomes of decision (expressed as chances out of 100) given different 2019 catches (first row, in kt). Note that for the 2017 and later year-classes average values were assumed. Constant Fs based on the 2019 catches were used for subsequent years.

|                                    | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
|------------------------------------|----|----|----|----|----|----|----|----|
| $P[F_{2019} > F_{MSY}]$            | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| $P[B_{2020} < B_{MSY}]$            | 26 | 20 | 21 | 22 | 20 | 23 | 24 | 25 |
| $P[B_{2021} < B_{MSY}]$            | 24 | 17 | 18 | 19 | 16 | 20 | 22 | 23 |
| $P[B_{2020} < \bar{B}]$            | 37 | 17 | 20 | 23 | 14 | 26 | 30 | 33 |
| $P[B_{2023} < \bar{B}]$            | 21 | 12 | 14 | 15 | 11 | 16 | 18 | 19 |
| $P[B_{2023} < B_{2019}]$           | 34 | 24 | 25 | 27 | 22 | 29 | 31 | 32 |
| $P[B_{2021} < B_{20\%}]$           | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  |
| $P[p_{a_5, 2021} > \bar{p}_{a_5}]$ | 58 | 42 | 45 | 48 | 40 | 51 | 54 | 56 |
| $P[D_{2020} < D_{1994}]$           | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| $P[D_{2023} < D_{1994}]$           | 4  | 1  | 2  | 2  | 1  | 2  | 3  | 3  |
| $P[E_{2019} > E_{2018}]$           | 23 | 0  | 0  | 1  | 0  | 4  | 8  | 15 |

## Figures

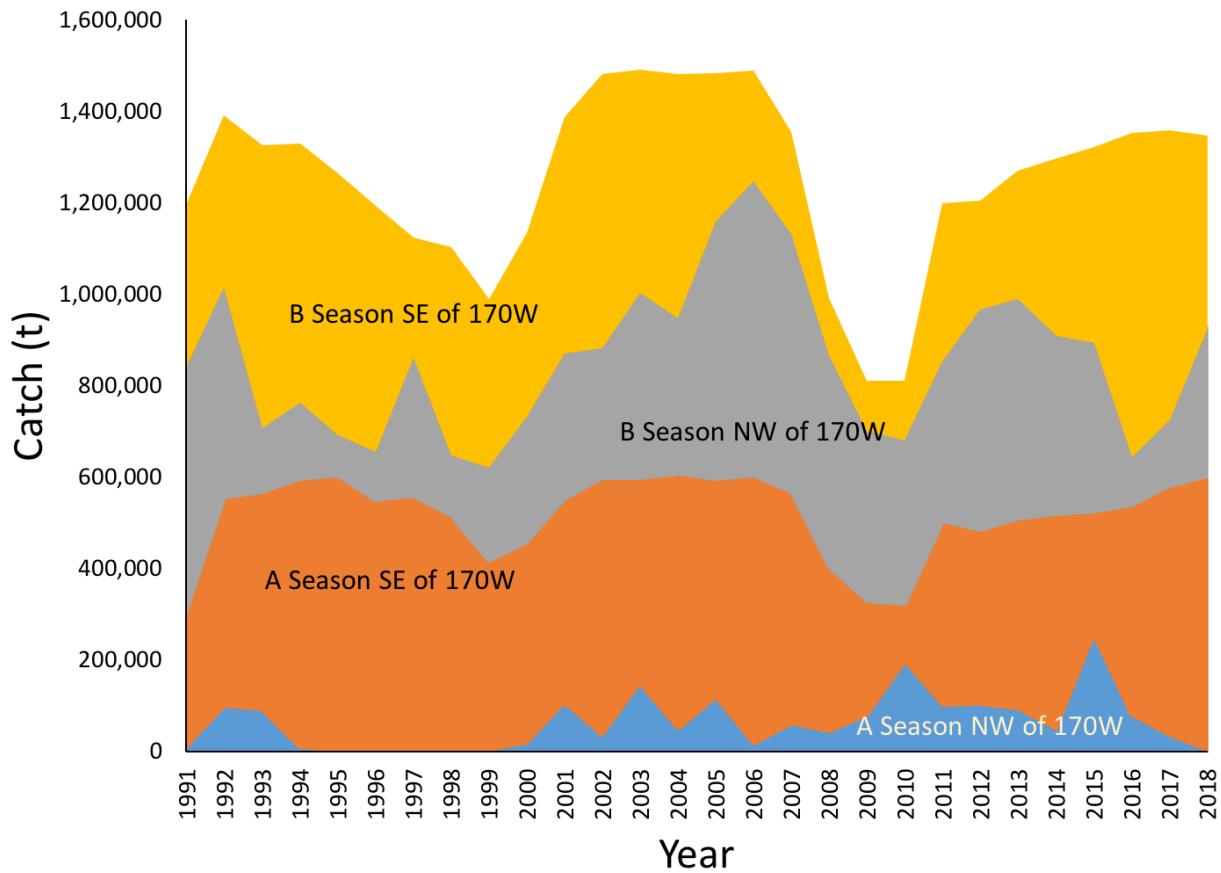


Figure 1: Pollock catch estimates (t) from the Eastern Bering Sea by season and region. The A-season is defined as from Jan-May and B-season from June-October.

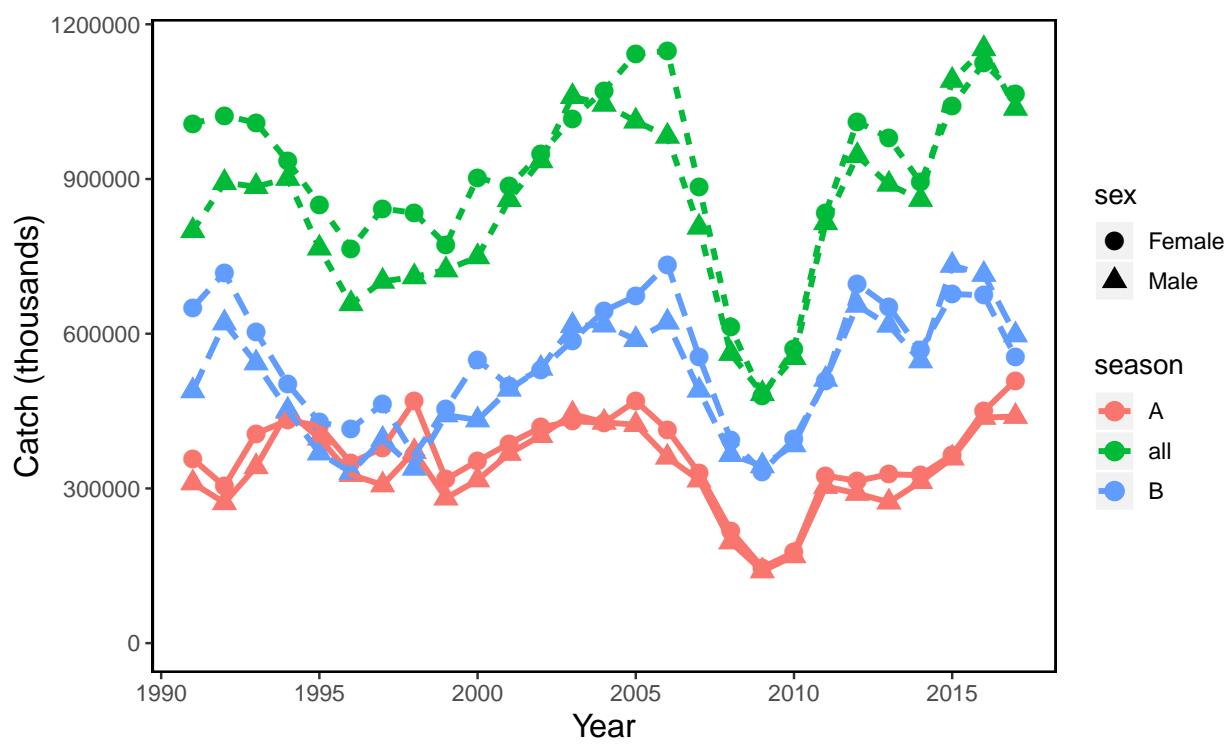


Figure 2: Estimate of EBS pollock catch numbers by sex for the A season (January-May) and B seasons (June-October) and total.

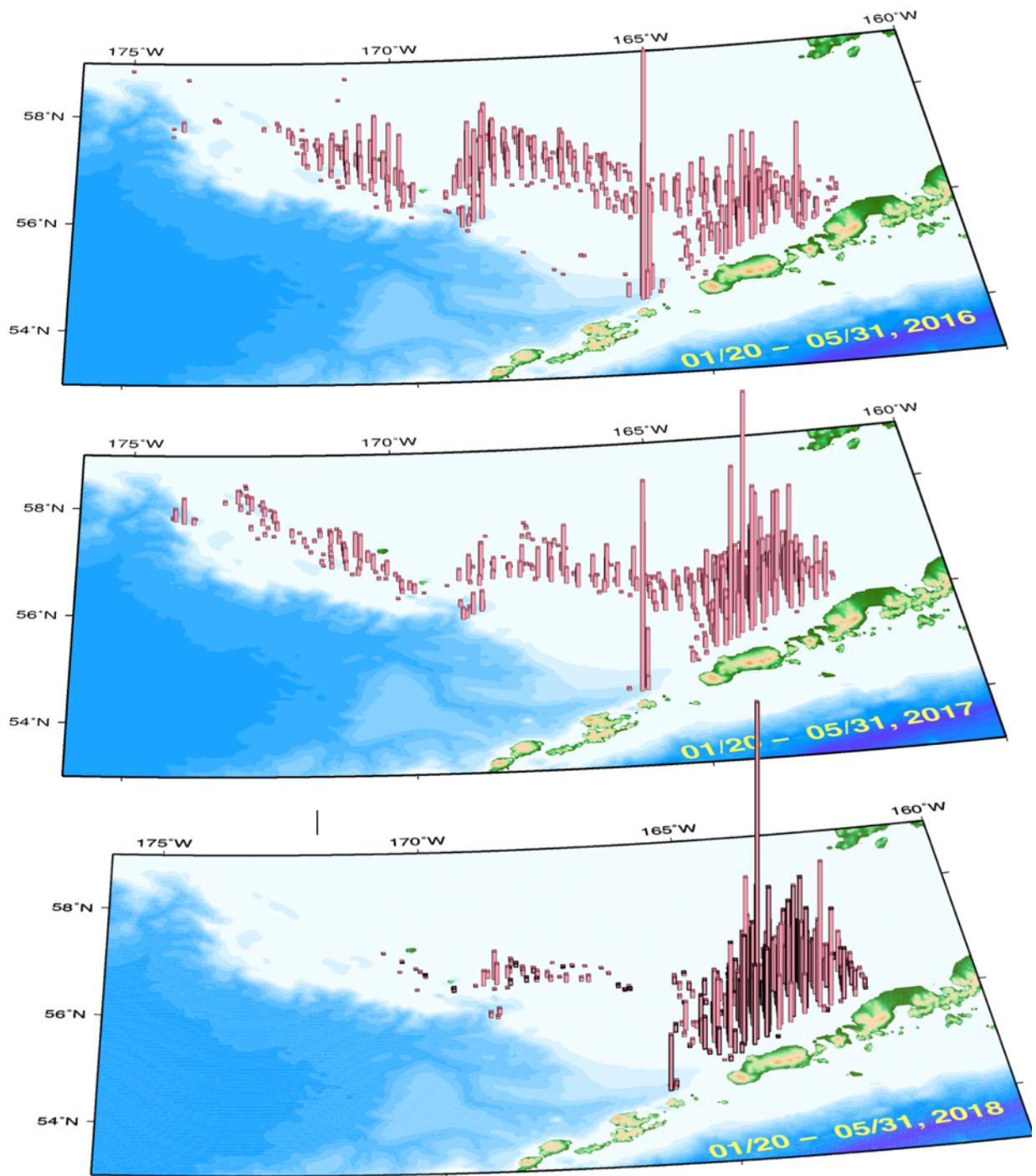


Figure 3: EBS pollock catch distribution during A-season, 2016–2018. Column height is proportional to total catch.

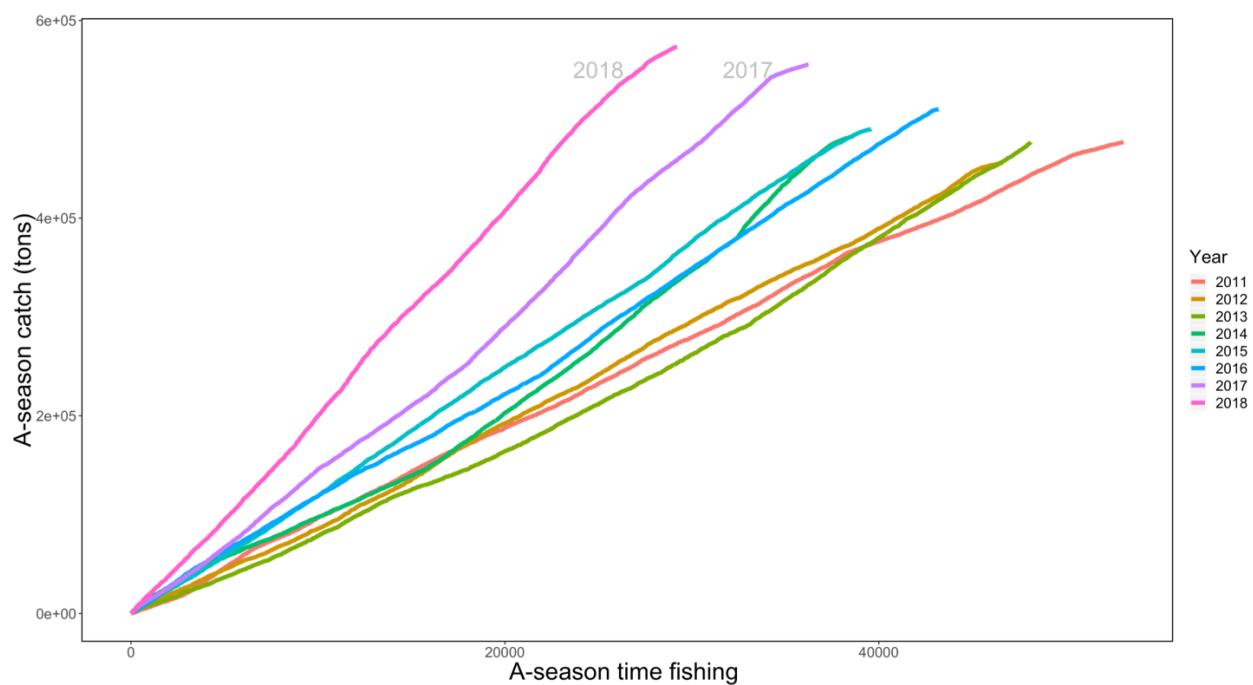


Figure 4: A-season EBS fleet-wide nominal pollock catch (kg) per hour of fishing recorded by NMFS scientific observers.

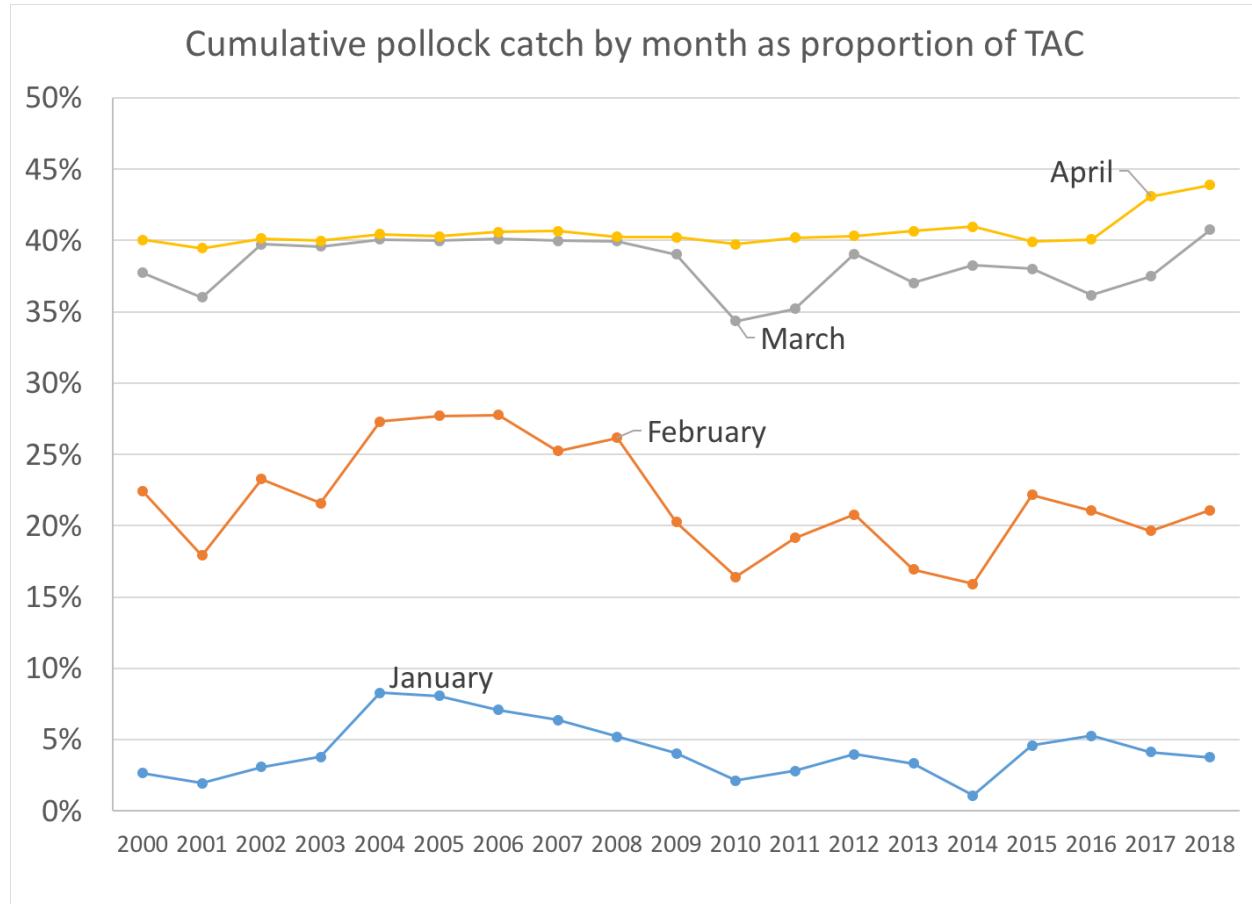


Figure 5: Proportion of the annual EBS pollock TAC by month during the A-season, 2000–2018. The higher value observed since 2017 was due to Amendment 110 of the FMP to allow greater flexibility to avoid Chinook salmon.

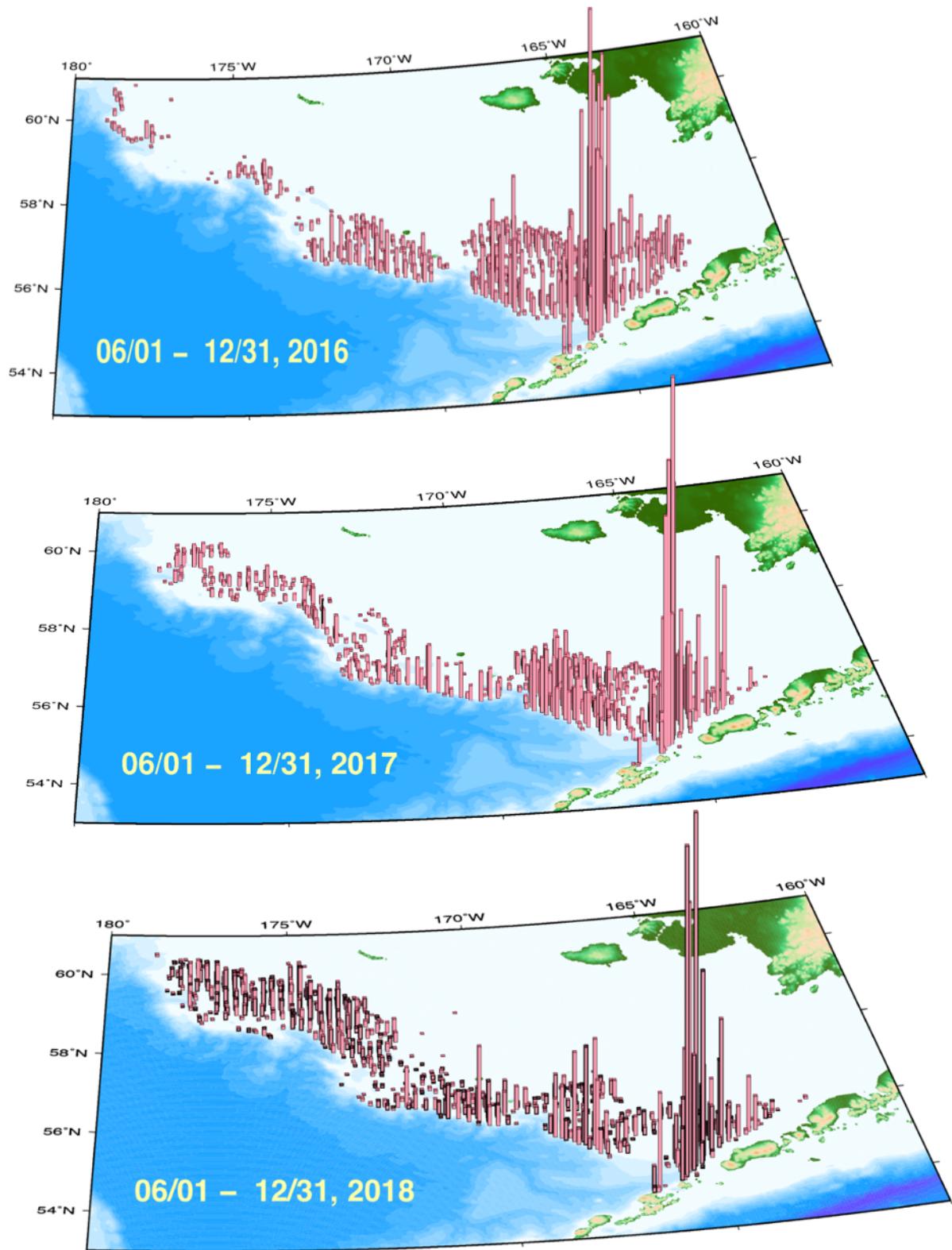


Figure 6: EBS pollock catch distribution during B-season, 2016–2018. Column height is proportional to total catch. Note that directed fishery for pollock generally is finished prior to October; the labels are indicative full-year catches.

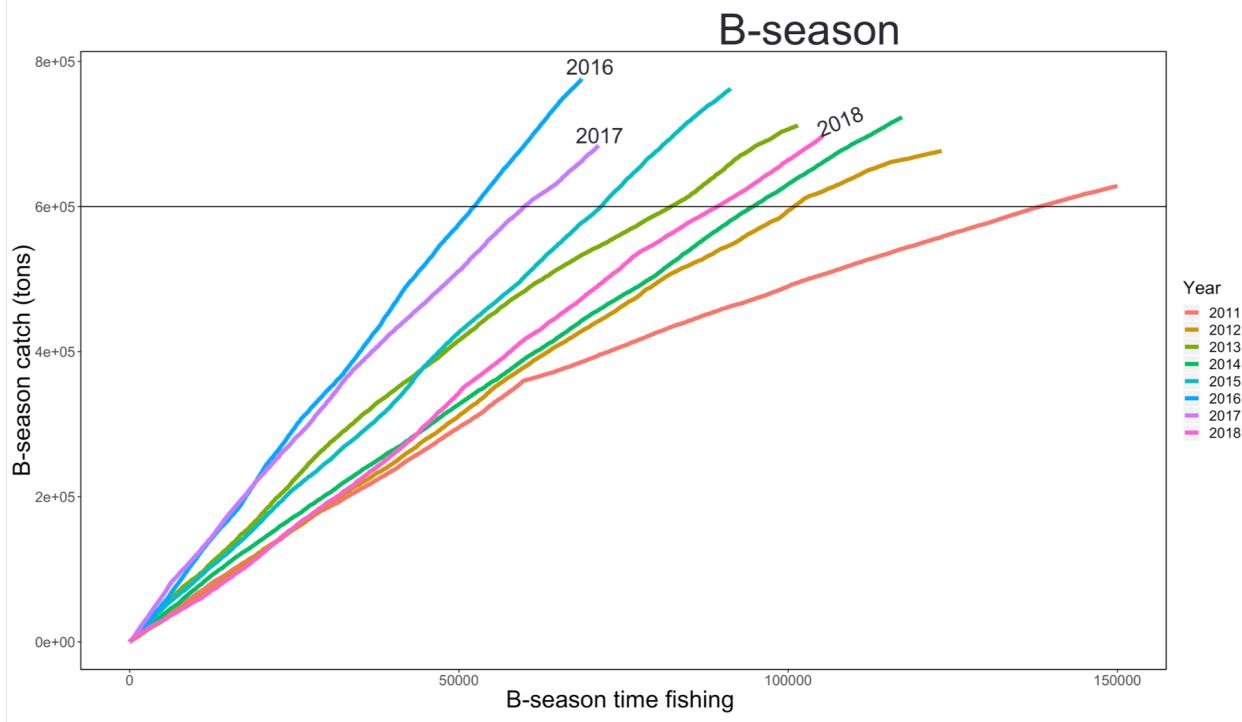


Figure 7: B-season EBS fleet-wide nominal pollock catch (kg) per hour of fishing recorded by NMFS scientific observers.

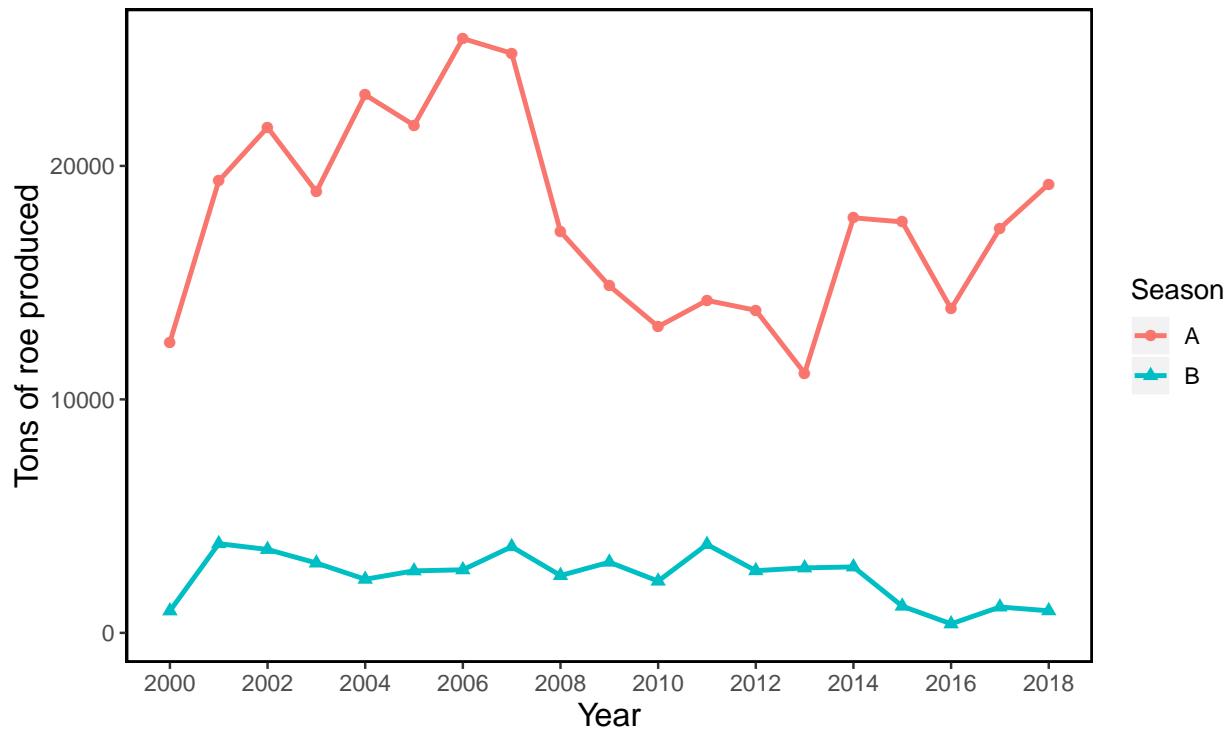


Figure 8: EBS pollock roe production in A and B seasons compared to overall landed catch.

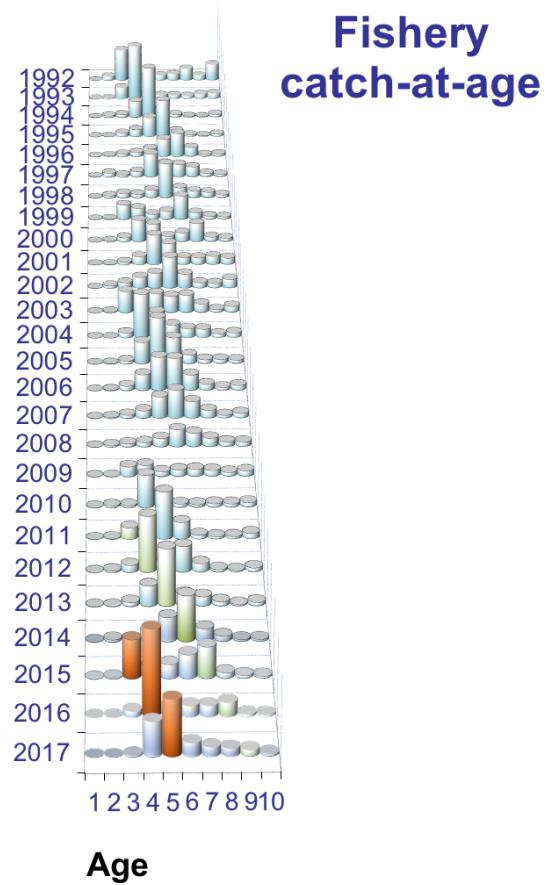


Figure 9: EBS pollock fishery estimated catch-at-age data (in number) for 1992–2017. Age 10 represents pollock age 10 and older. The 2008 year-class is shaded in green.

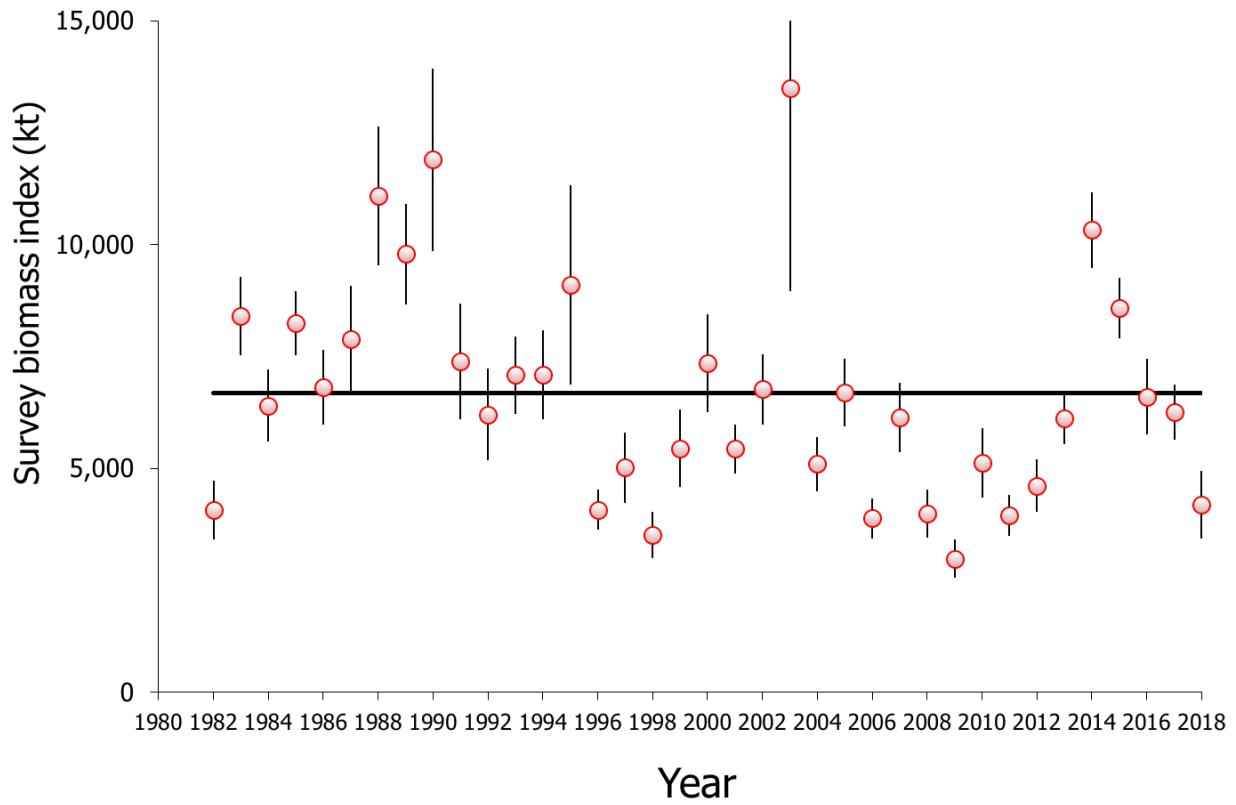


Figure 10: Bottom-trawl survey biomass estimates with error bars representing 1 standard deviation (density-dependent correction method; DDC) for EBS pollock. Horizontal line represents the long-term mean. Note these values differ from the design-based versions in Table 19.

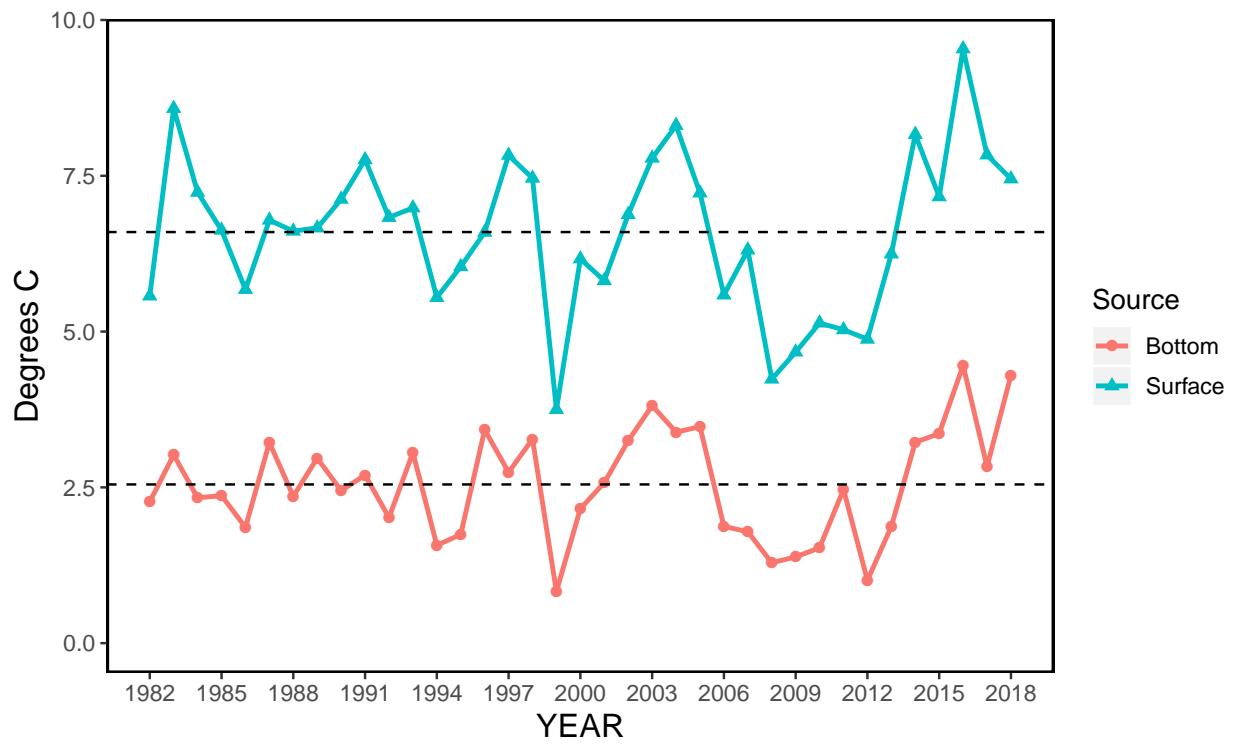


Figure 11: Bottom and surface temperatures for the Bering Sea from the NMFS summer bottom-trawl surveys (1982–2018). Dashed lines represent mean values.

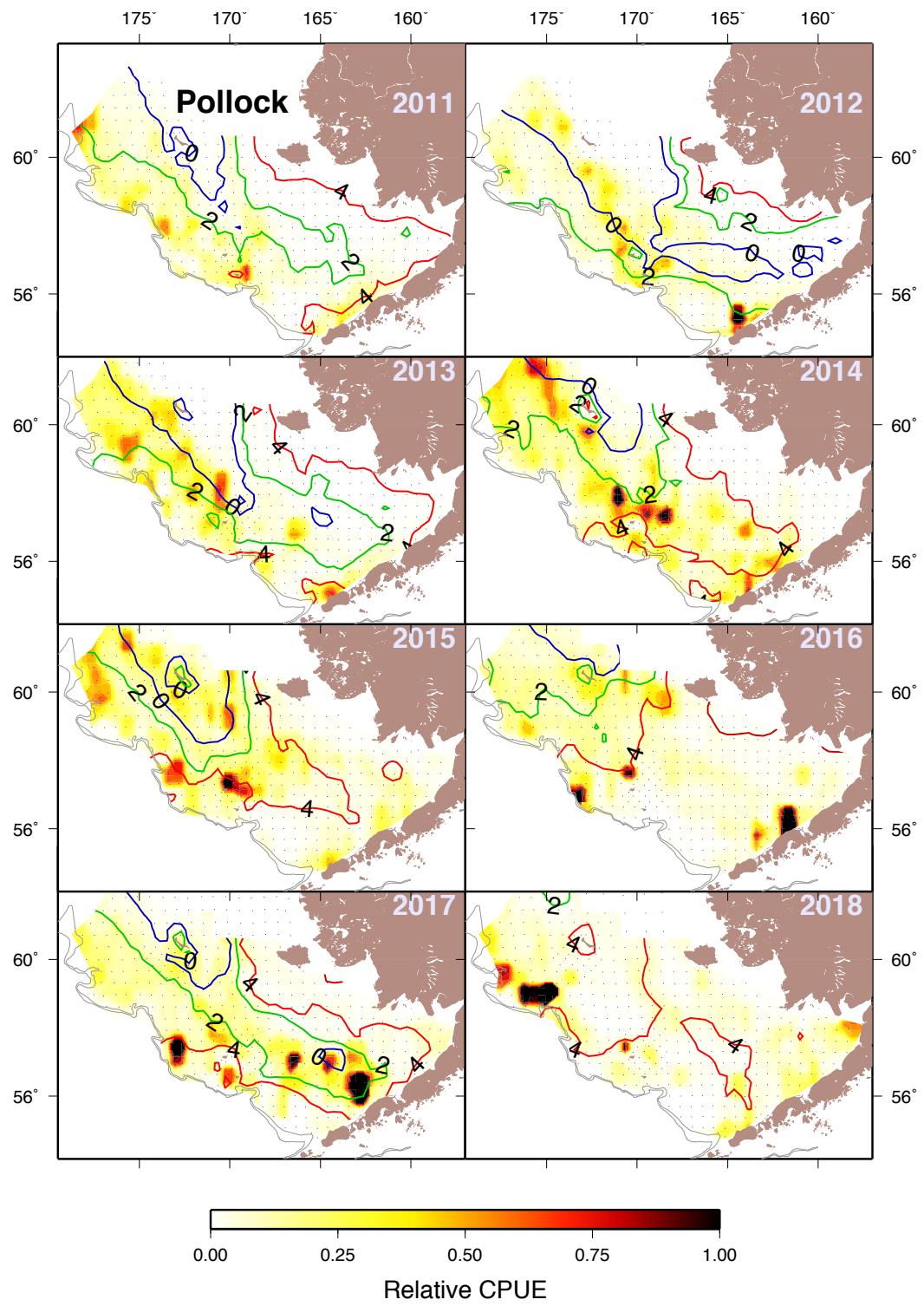


Figure 12: EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms in degrees C; from the bottom trawl survey data 2011–2018.

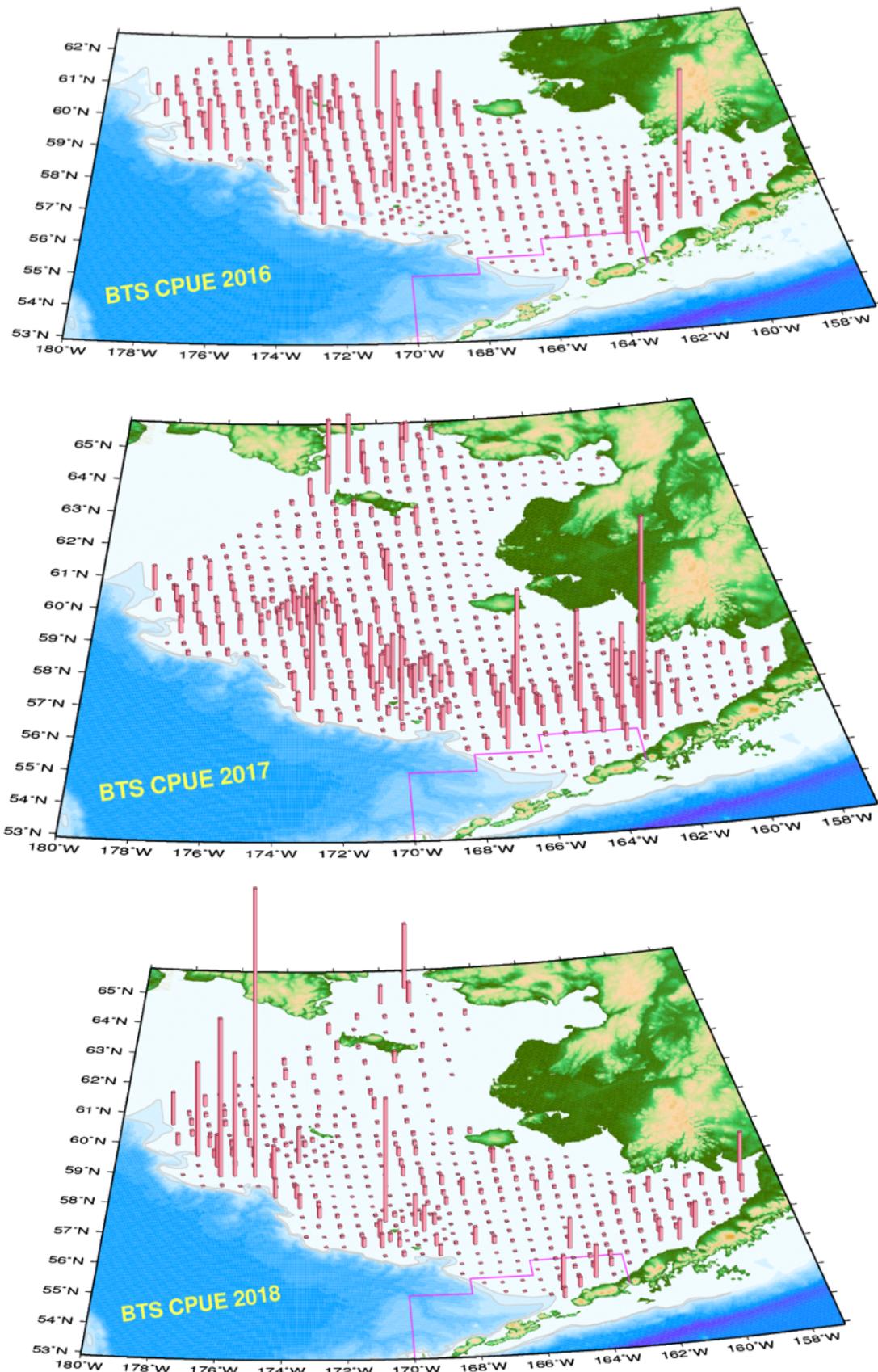


Figure 13: Bottom trawl survey pollock catch in kg per hectare for 2016 - 2018. Height of vertical lines are proportional to station-specific pollock densities by weight (kg per hectare) with constant scales for all years.

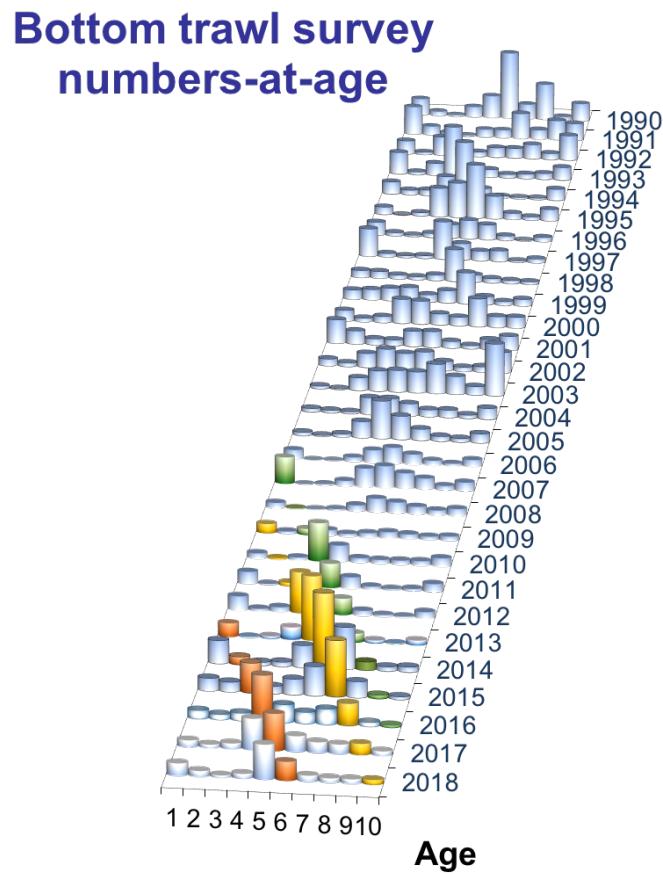


Figure 14: Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1990–2018). The 2006, 2008, and 2012 year-classes are shaded differently.

# Acoustic survey numbers

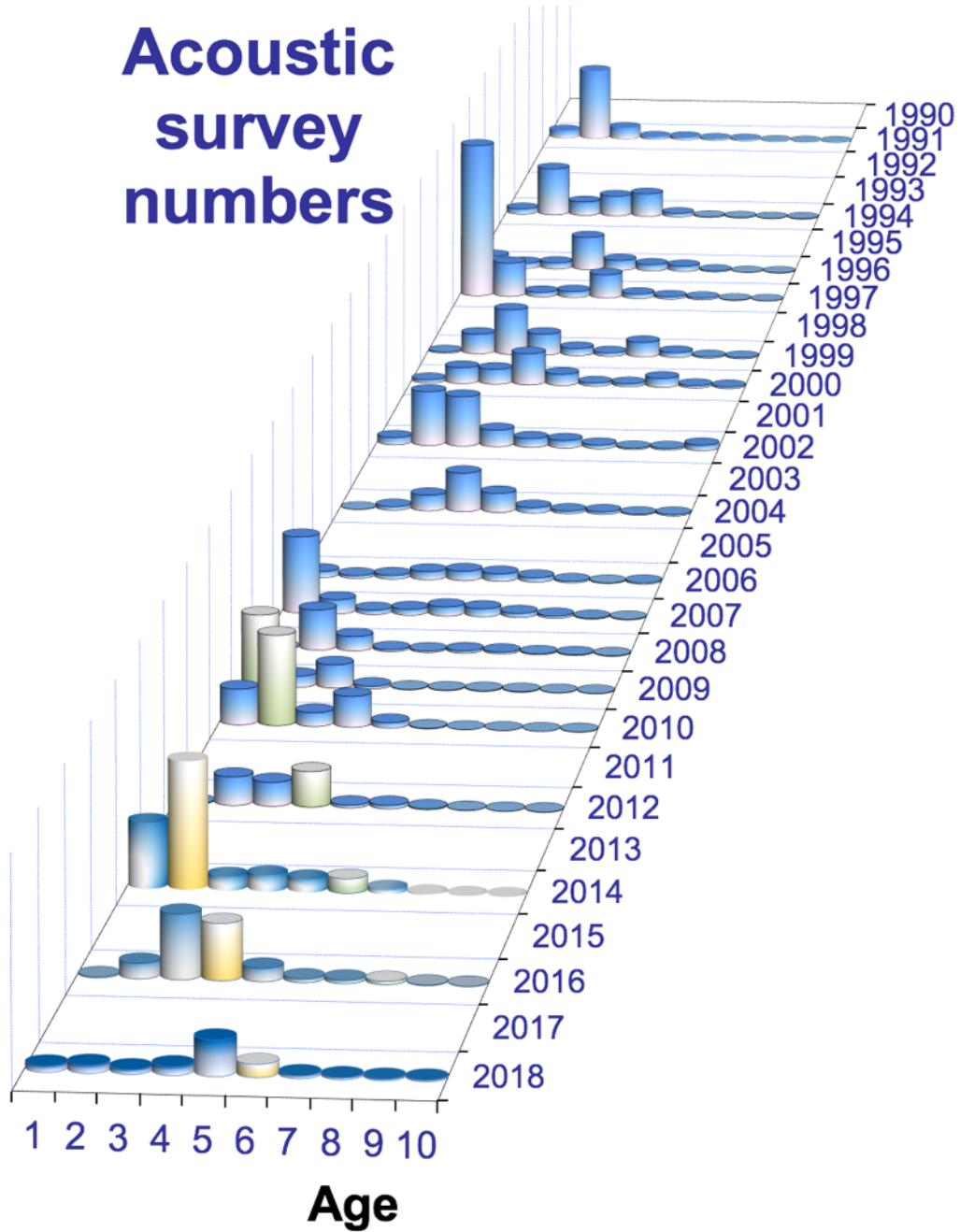


Figure 15: Pollock abundance at age estimates from the AT survey, 1979–2018; 2018 age estimates are preliminary using primarily BTS age data

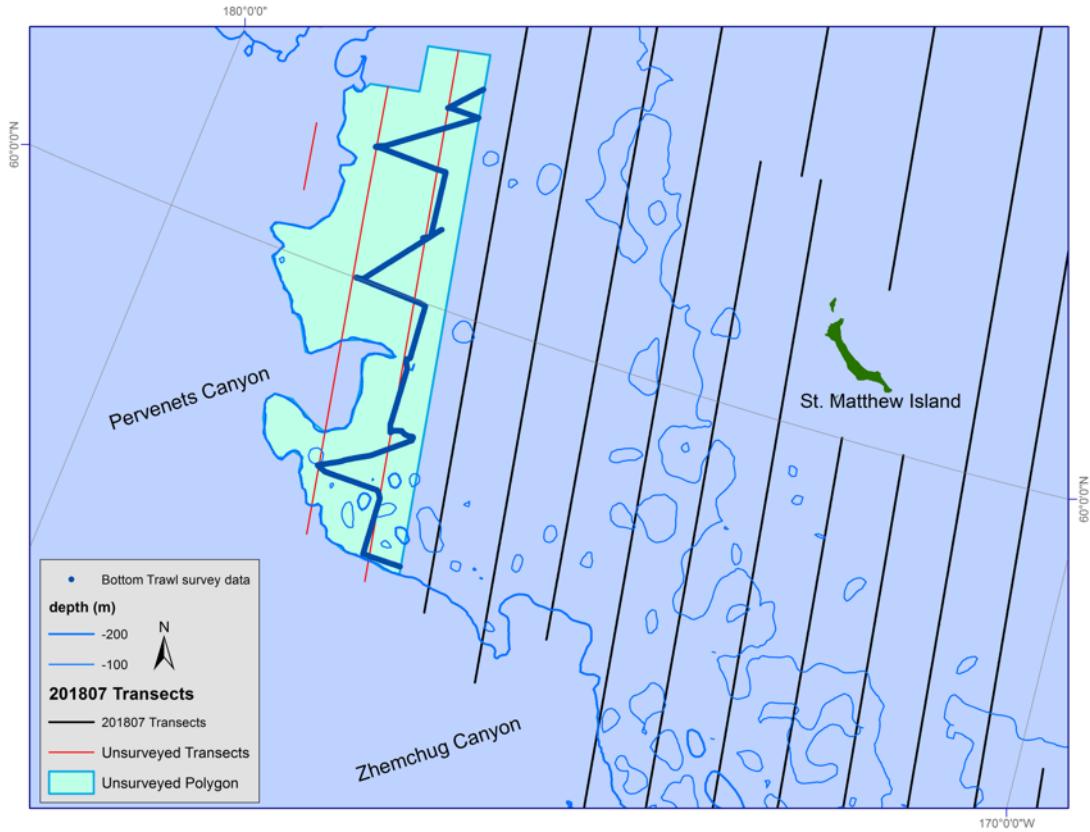


Figure 16: Map of survey area showing completed transects (black lines), unsurveyed transects (red lines), surveyed polygon (green shading), and the tracks of the bottom trawl vessels inside the unsampled area that were used to estimate acoustic backscatter in this area.

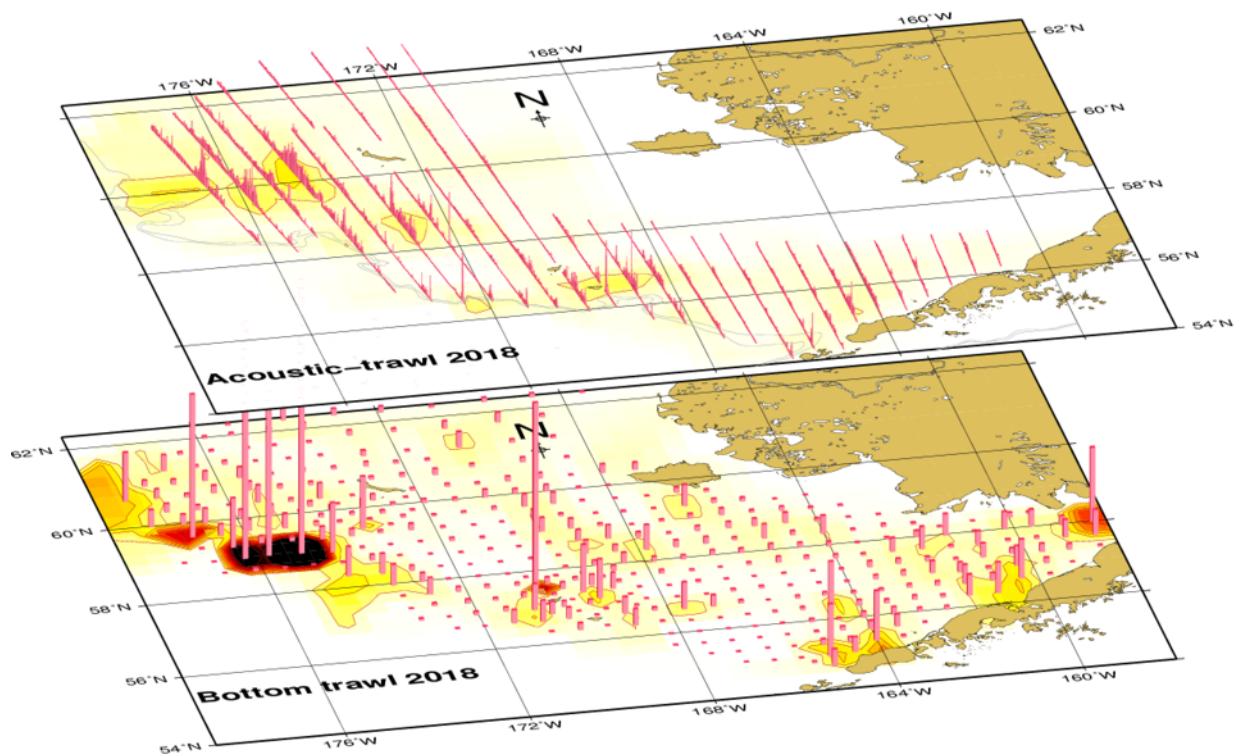


Figure 17: EBS pollock ATS transects (superimposed) over bottom-trawl survey stations and density estimates (in both settings contoured in the yellow-red heat map) for 2018.

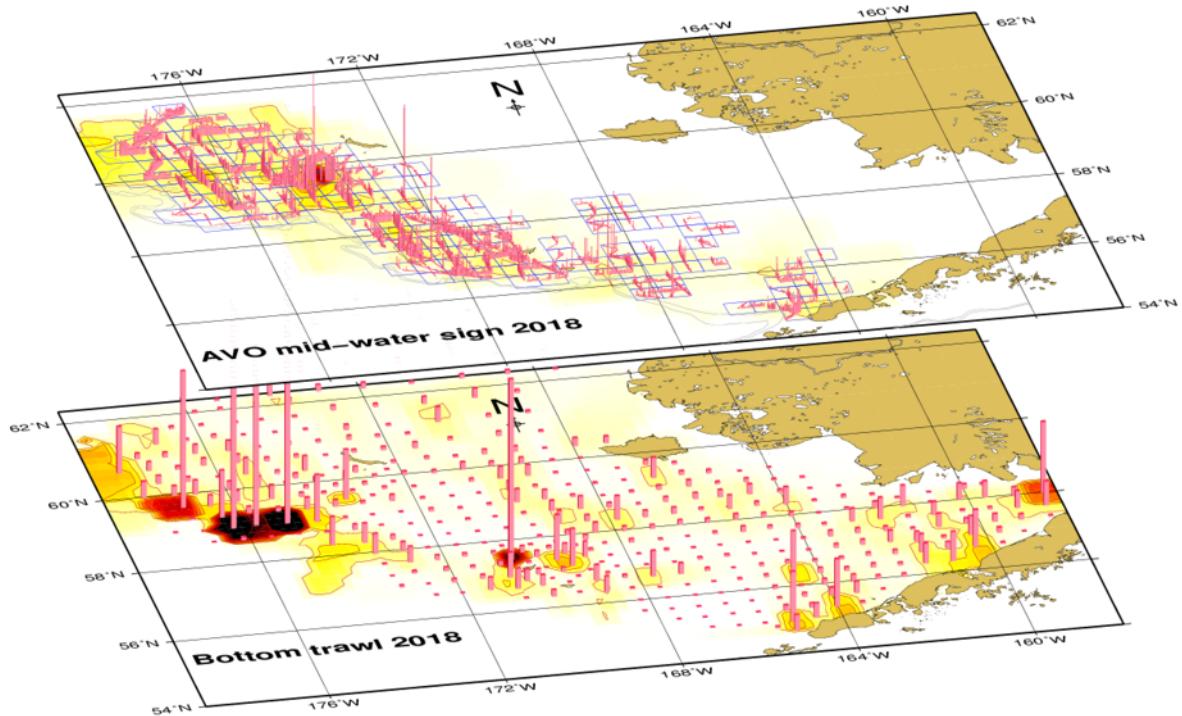


Figure 18: EBS pollock AVO transects (superimposed) over bottom-trawl survey stations and density estimates (in both settings contoured in the yellow-red heat map) for 2018.

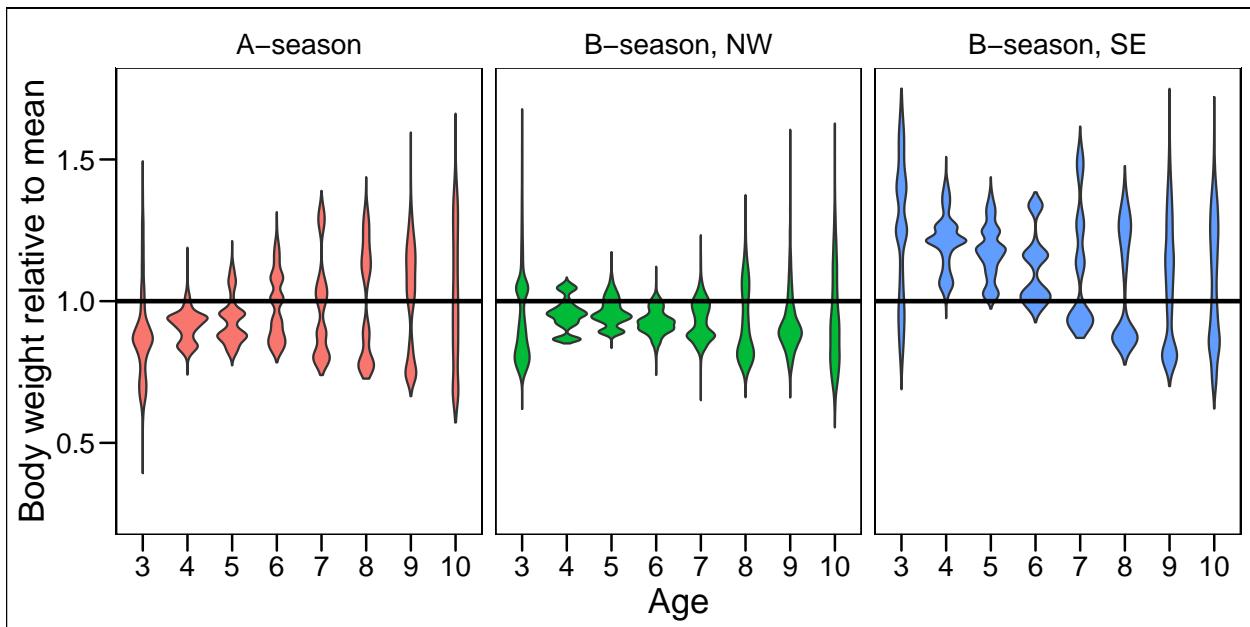


Figure 19: Fishery average weight-at-age anomaly (relative to mean) across strata and combined for all ages (3–10), and available years (1991–2017). Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

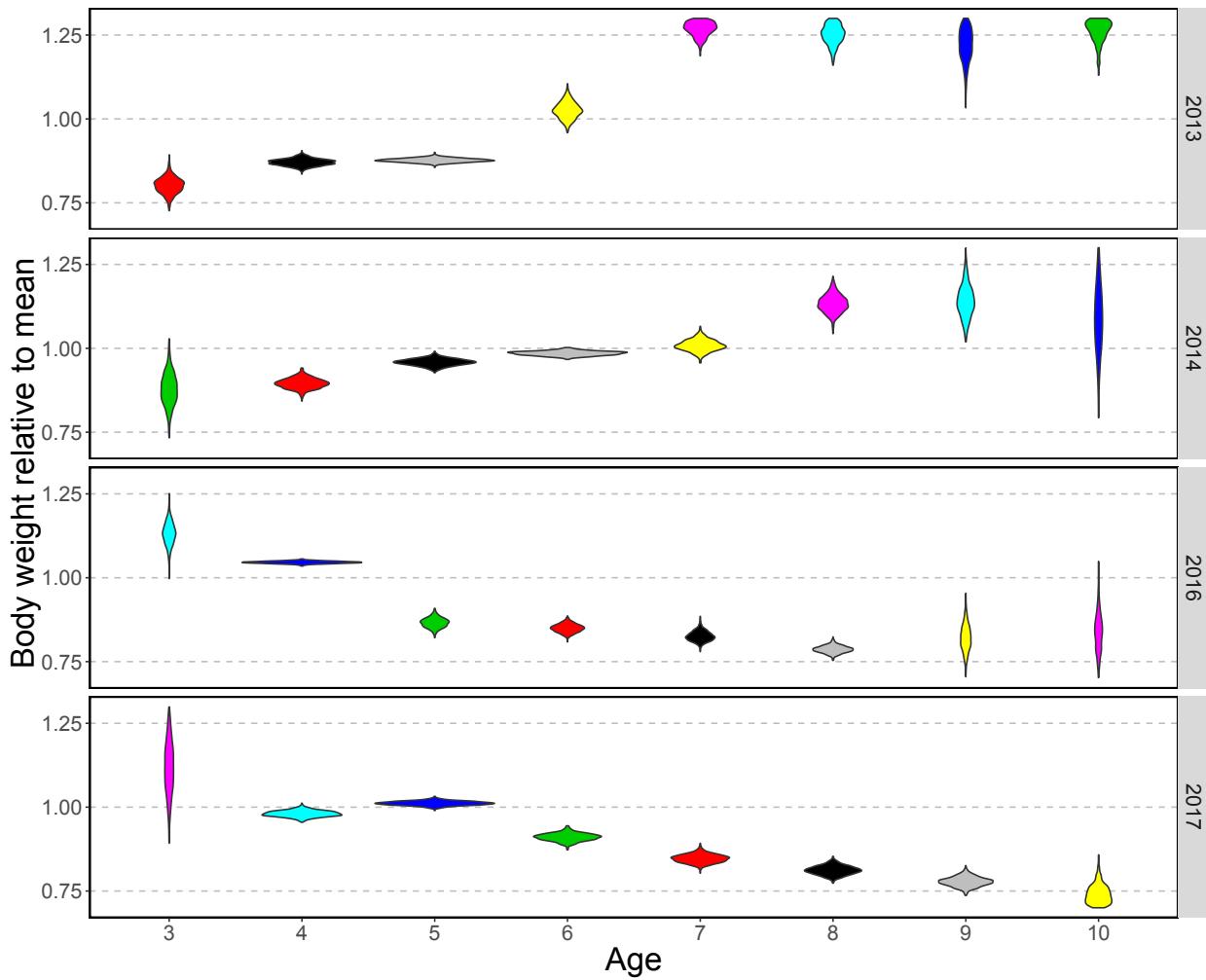


Figure 20: Recent fishery average weight-at-age anomaly (relative to mean) for ages 3–10 by strata (years 1991–2017 combined). Vertical shape reflects uncertainty in the data (wider shapes being more precise).

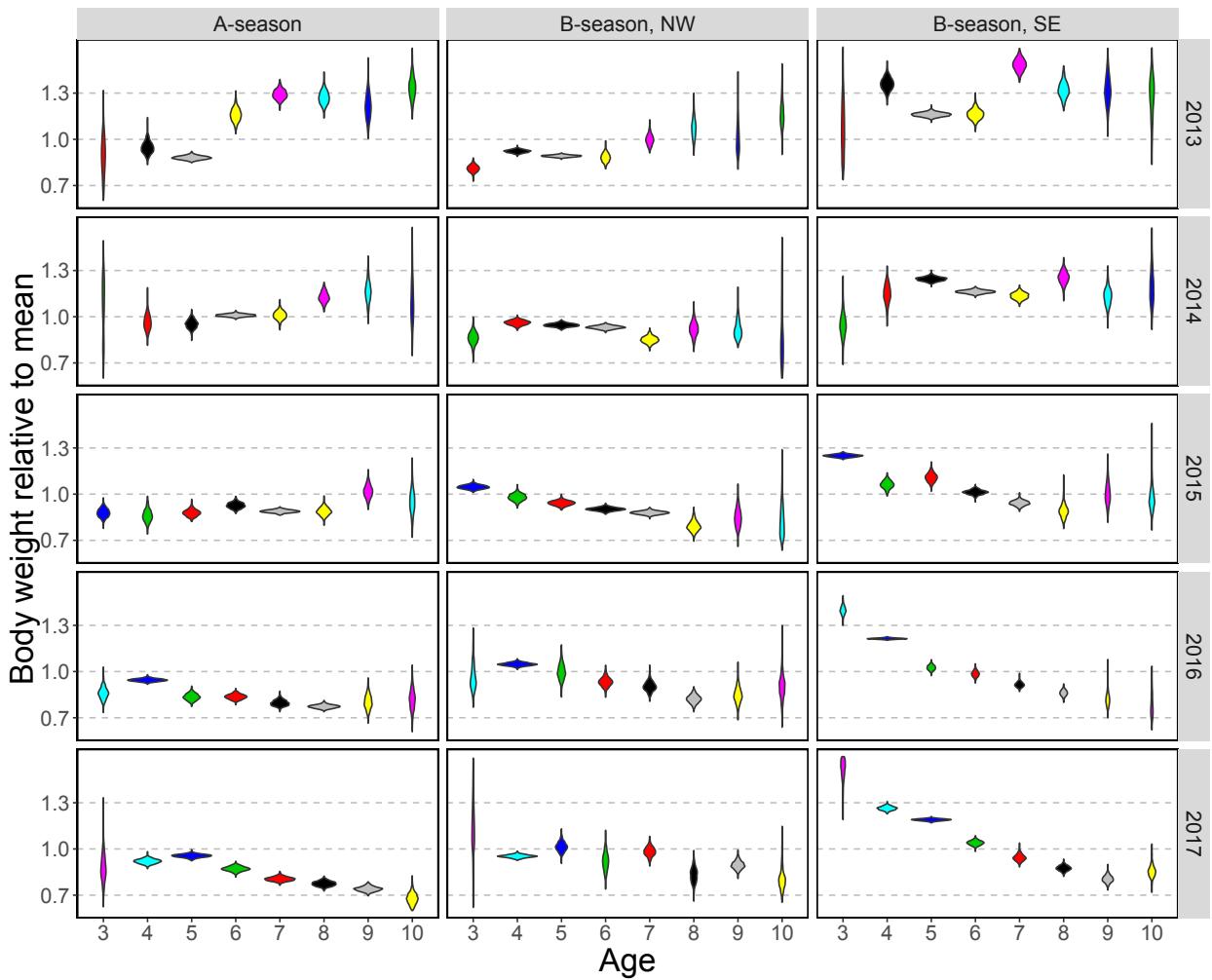


Figure 21: Recent fishery average weight-at-age anomaly (relative to mean) by strata for ages 3–10, 2013–2017. Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

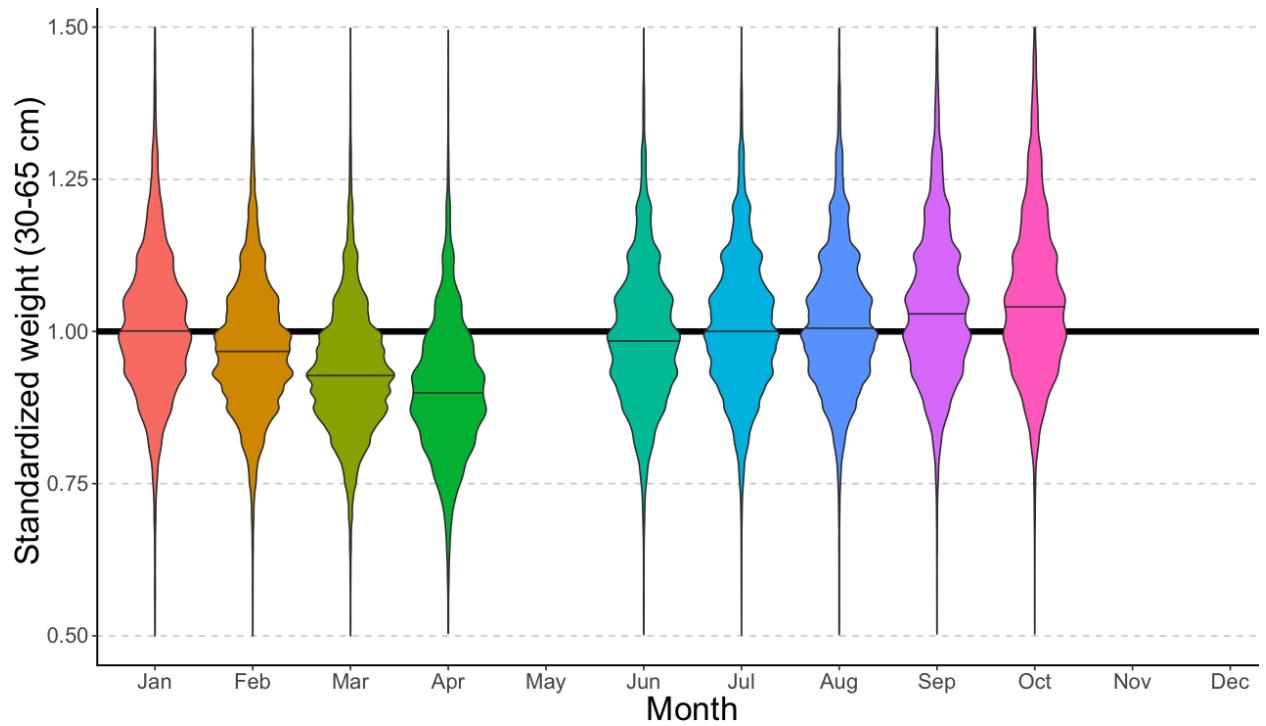


Figure 22: EBS pollock fishery body mass (given length) anomaly (standardized by overall mean body mass at each length) by month based on some over 700 thousand fish measurements from 1991–2018.

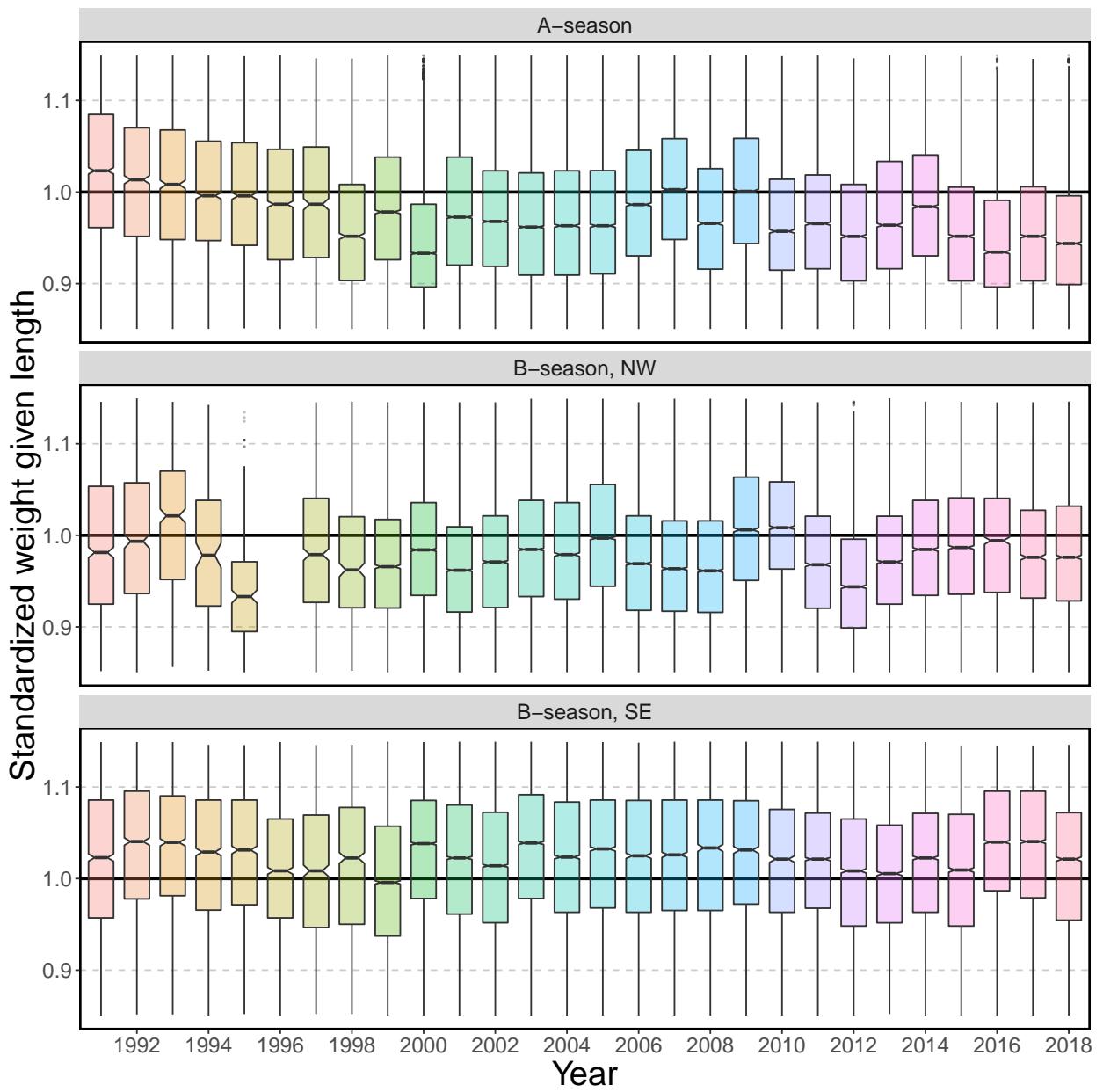


Figure 23: EBS pollock fishery body mass (given length) anomaly (standardized by overall mean body mass at each length) by year and season/area strata, 1991–2018.

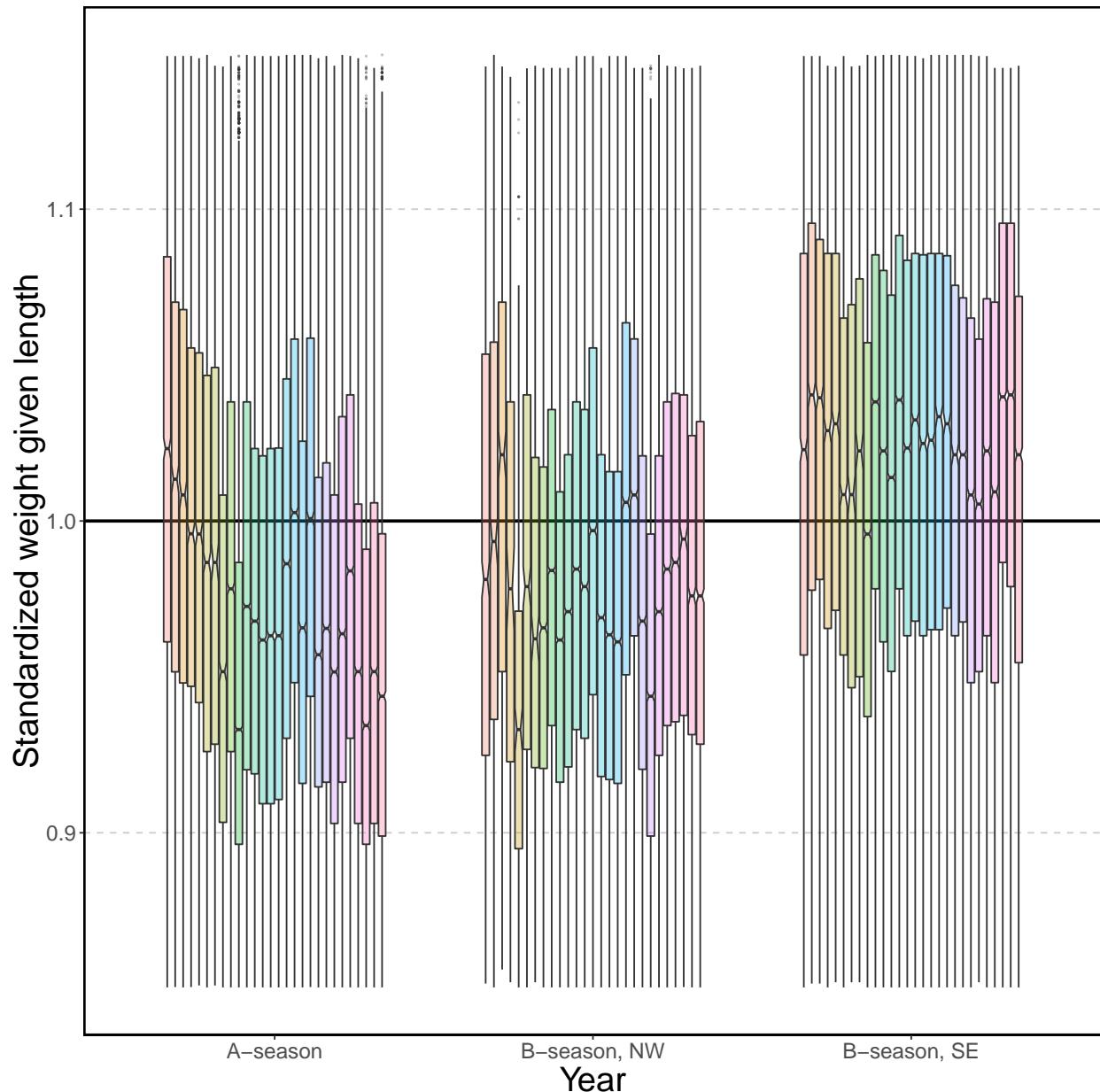


Figure 24: EBS pollock body mass (given length) anomaly (standardized by overall mean body mass at each length) by year and season/area strata, 1991–2018, aggregated by strata.

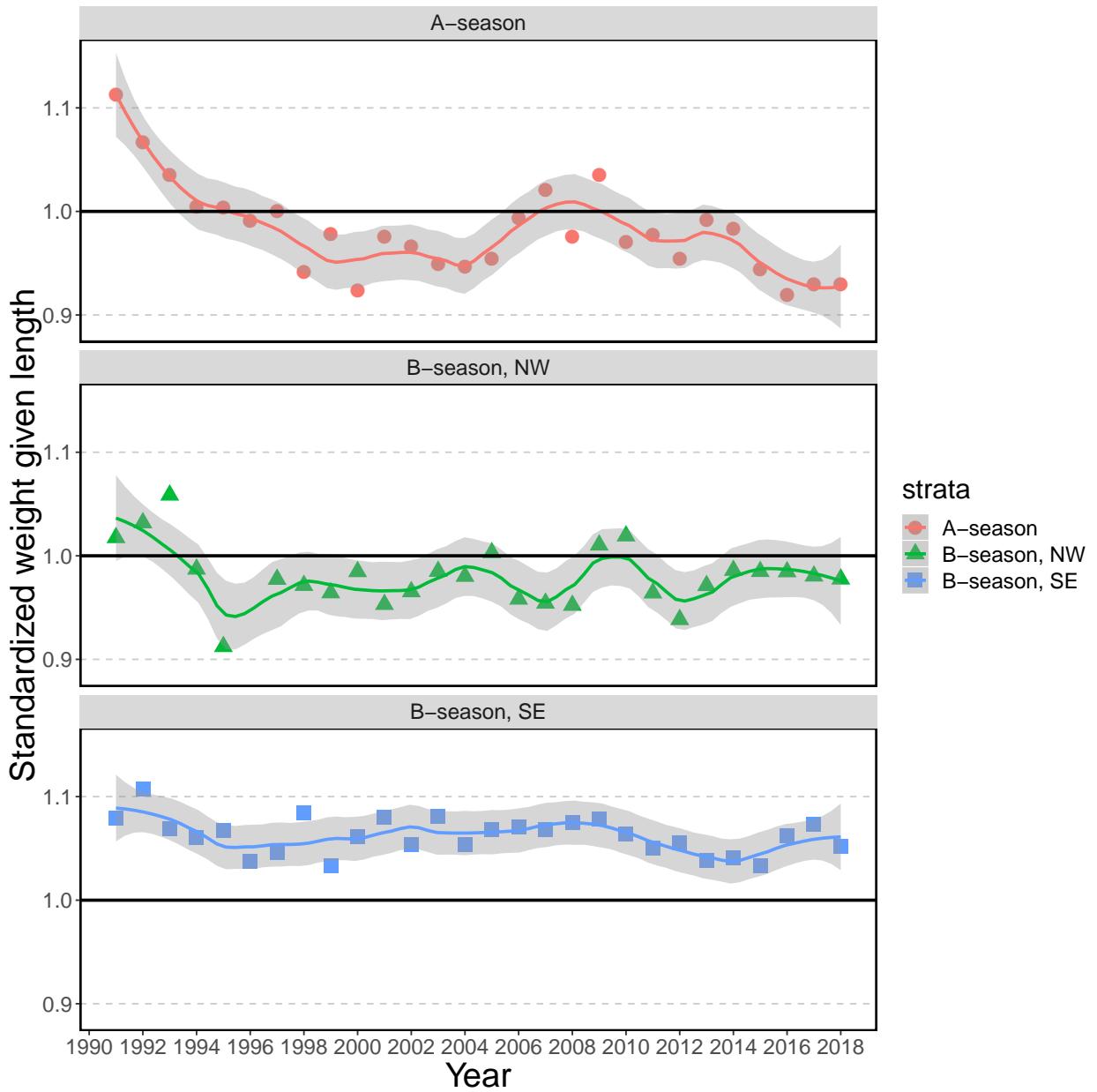


Figure 25: EBS pollock body mass (given length) anomaly (standardized by overall mean body mass at each length) by year and season/area strata shown as mean values with a fitted loess smooth trend, 1991–2018.

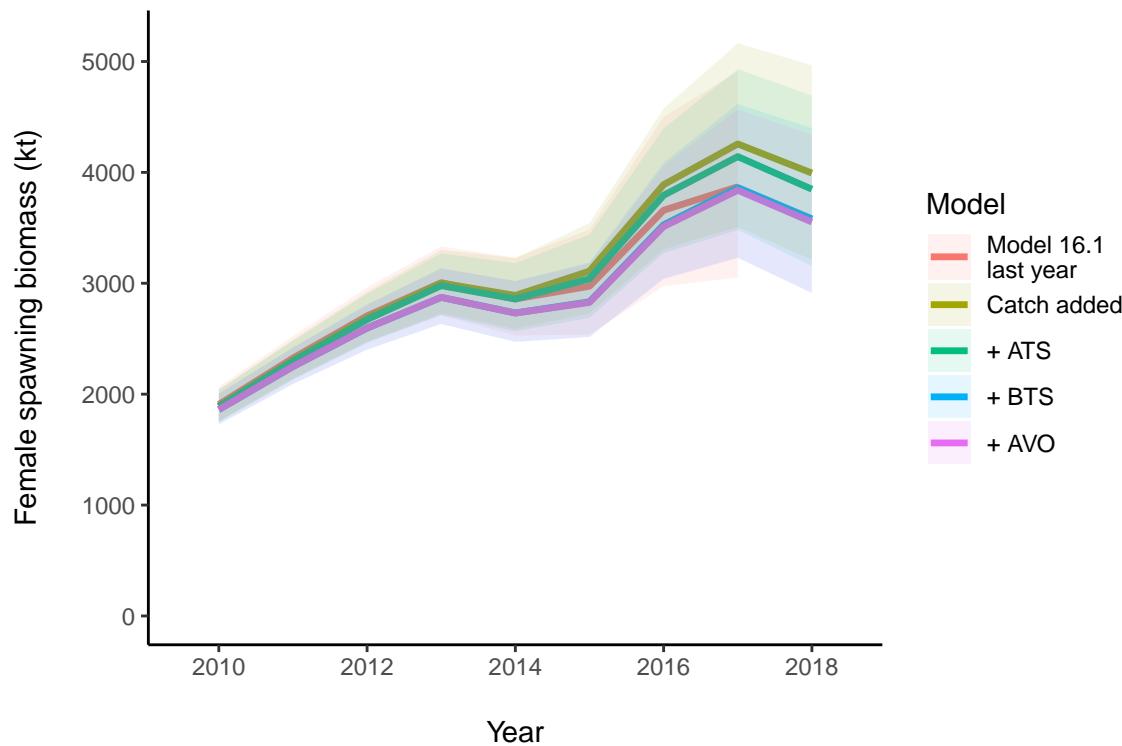


Figure 26: Model runs comparing last year's assessment with the impact of sequentially addint new data (first 2018 catch and 2017 fishery catch-at-age, then the acoustic trawl survey (ATS), bottom trawl survey (BTS) and the acoustic AVO data for model 16.1.

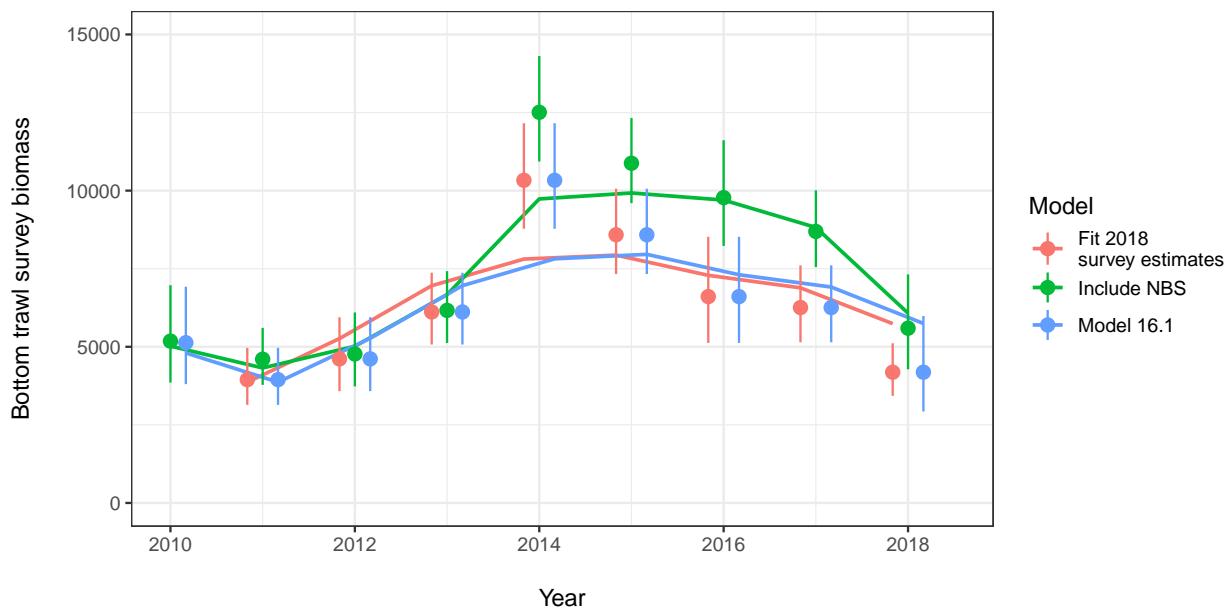


Figure 27: EBS pollock model evaluation results of three model fits to different treatment of bottom trawl survey sampling.

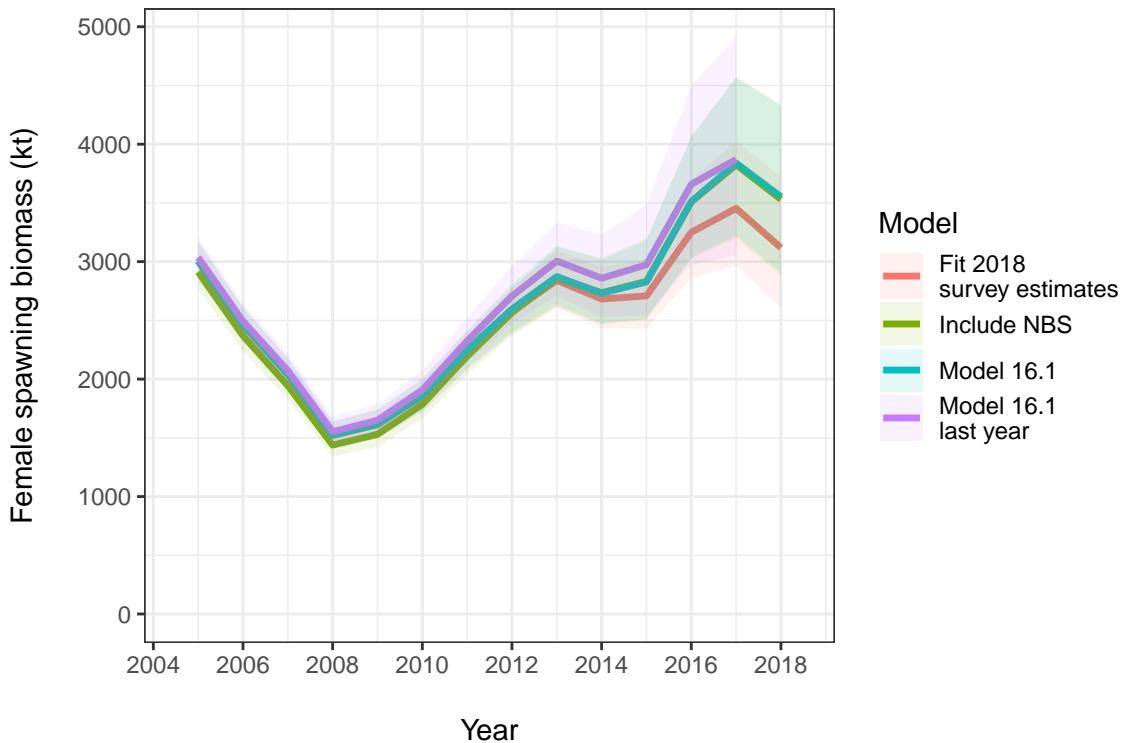


Figure 28: EBS pollock model evaluation results of female spawning biomass comparing model (and data) alternatives. Note that the ‘with NBS’ model is almost identical to model 16.1.

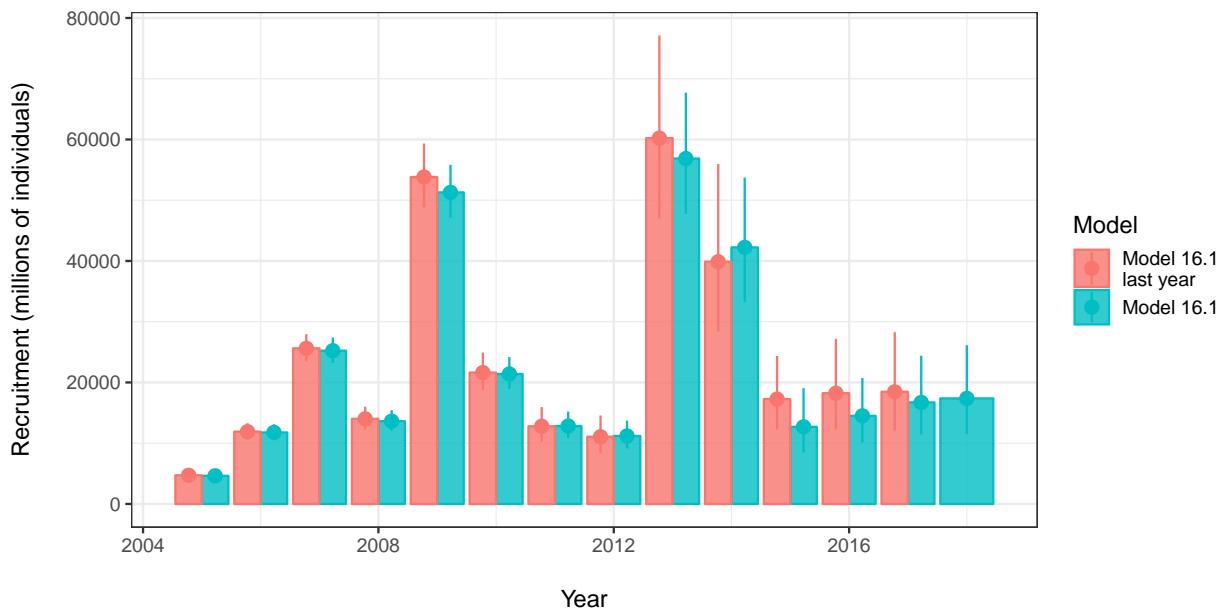


Figure 29: EBS pollock model evaluation results of recruitment comparing last year’s model with this year.

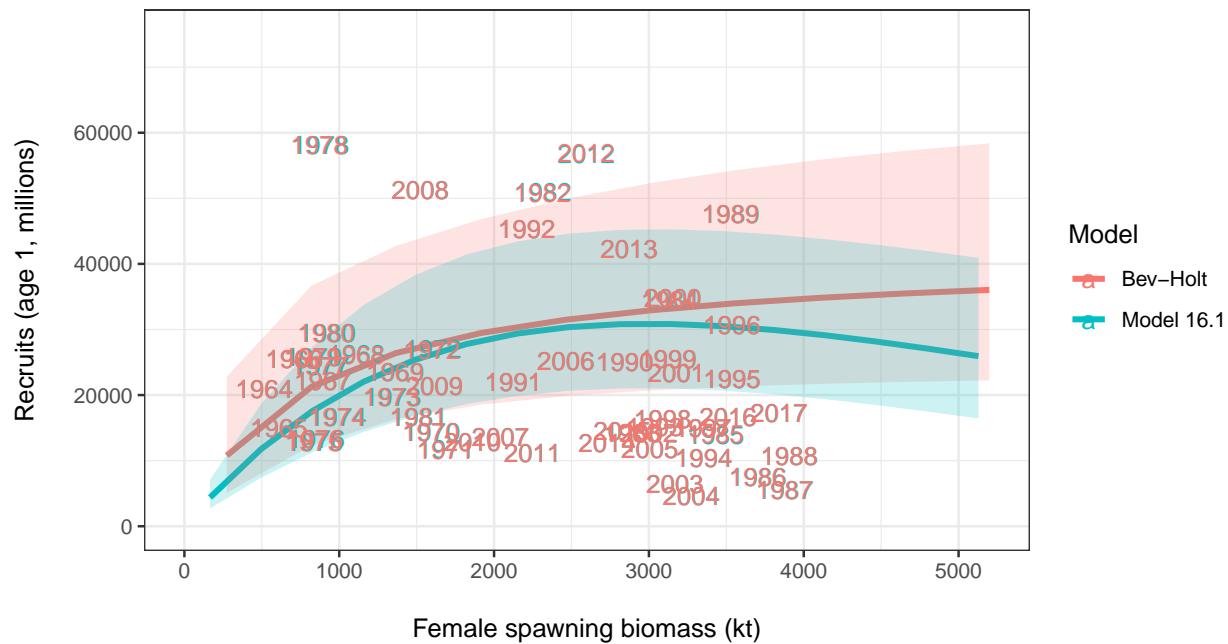


Figure 30: EBS pollock model evaluation results comparing model 16.1 (which assumes a Ricker stock-recruitment relationship) with that where a prior mean steepness of 0.67 and CV of 15% applied to a Beverton-Holt stock recruit relationship.

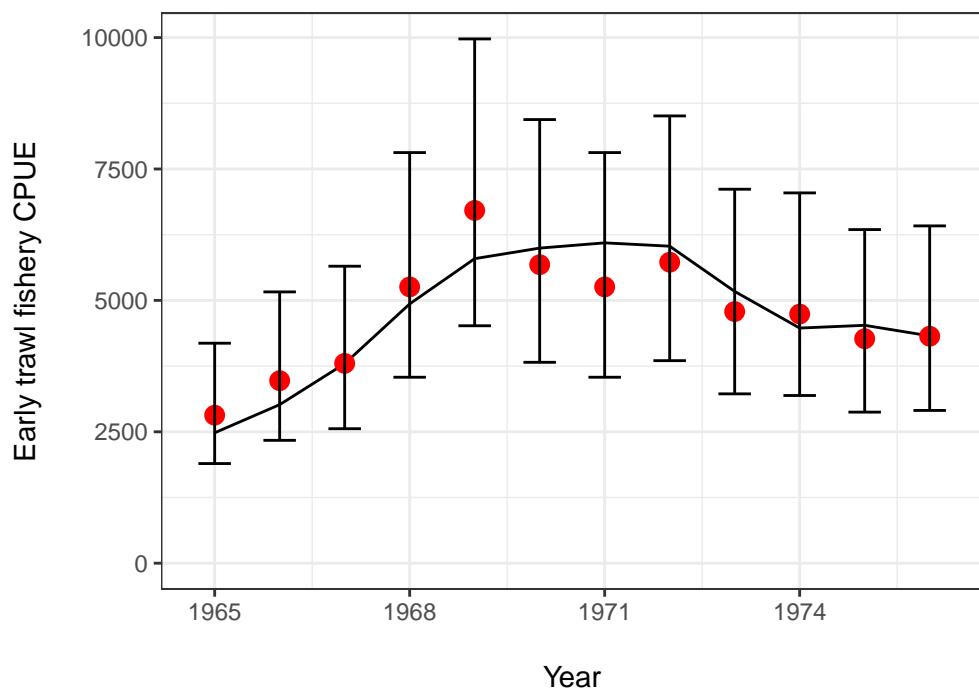


Figure 31: EBS pollock model fits to the Japanese fishery CPUE.

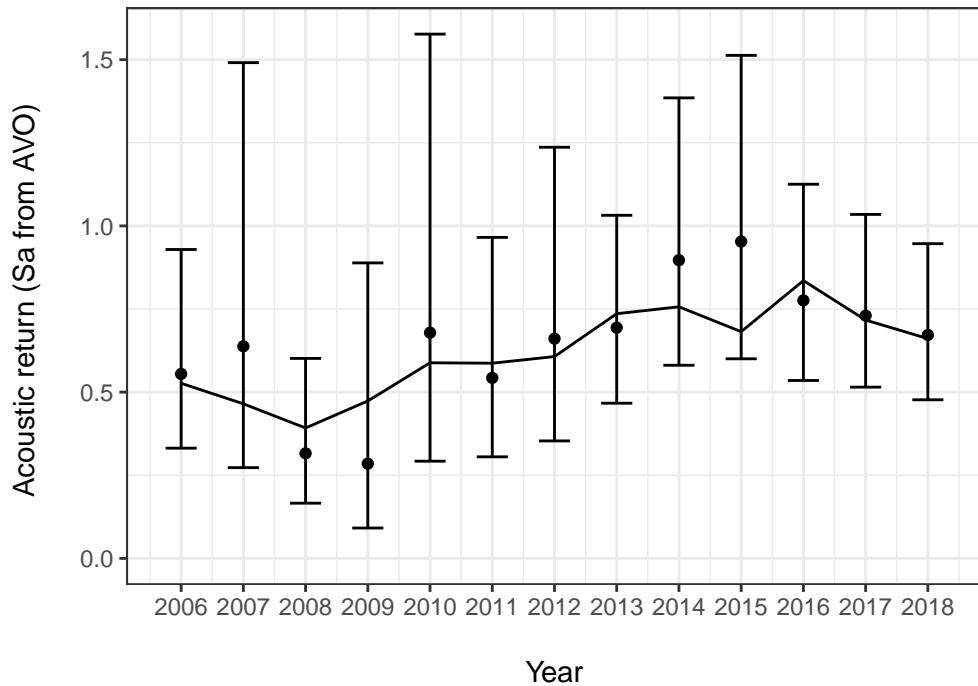


Figure 32: Model results of predicted and observed AVO index. Error bars represent assumed 95% confidence bounds of the input series.

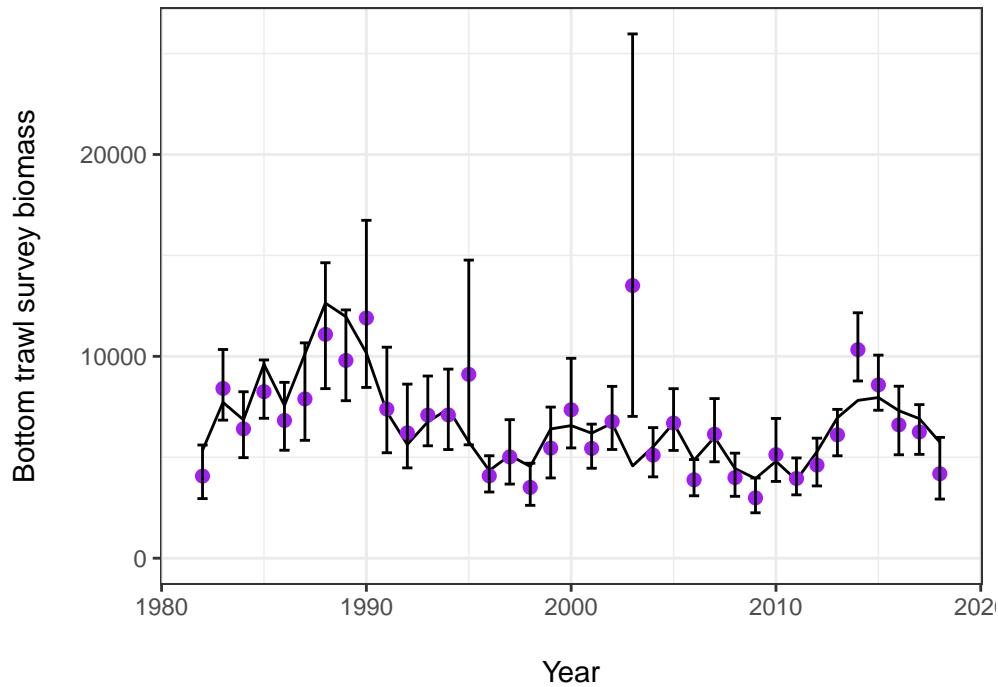


Figure 33: EBS pollock model fit to the BTS biomass data (density dependence corrected estimates), 1982–2018.

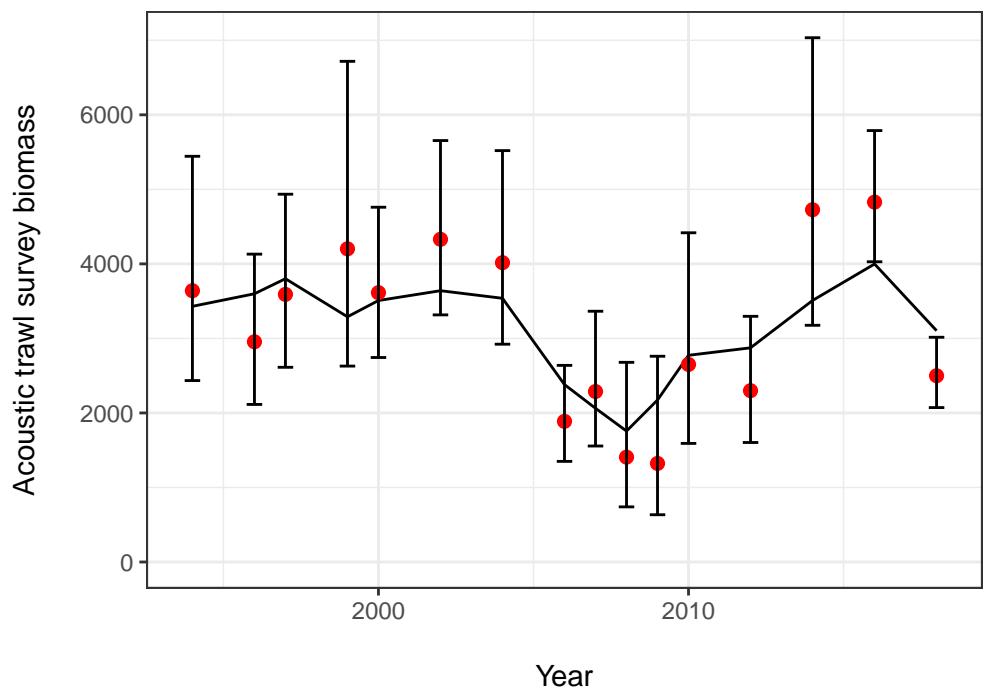


Figure 34: EBS pollock model fit to the ATS biomass data, 1994–2018.

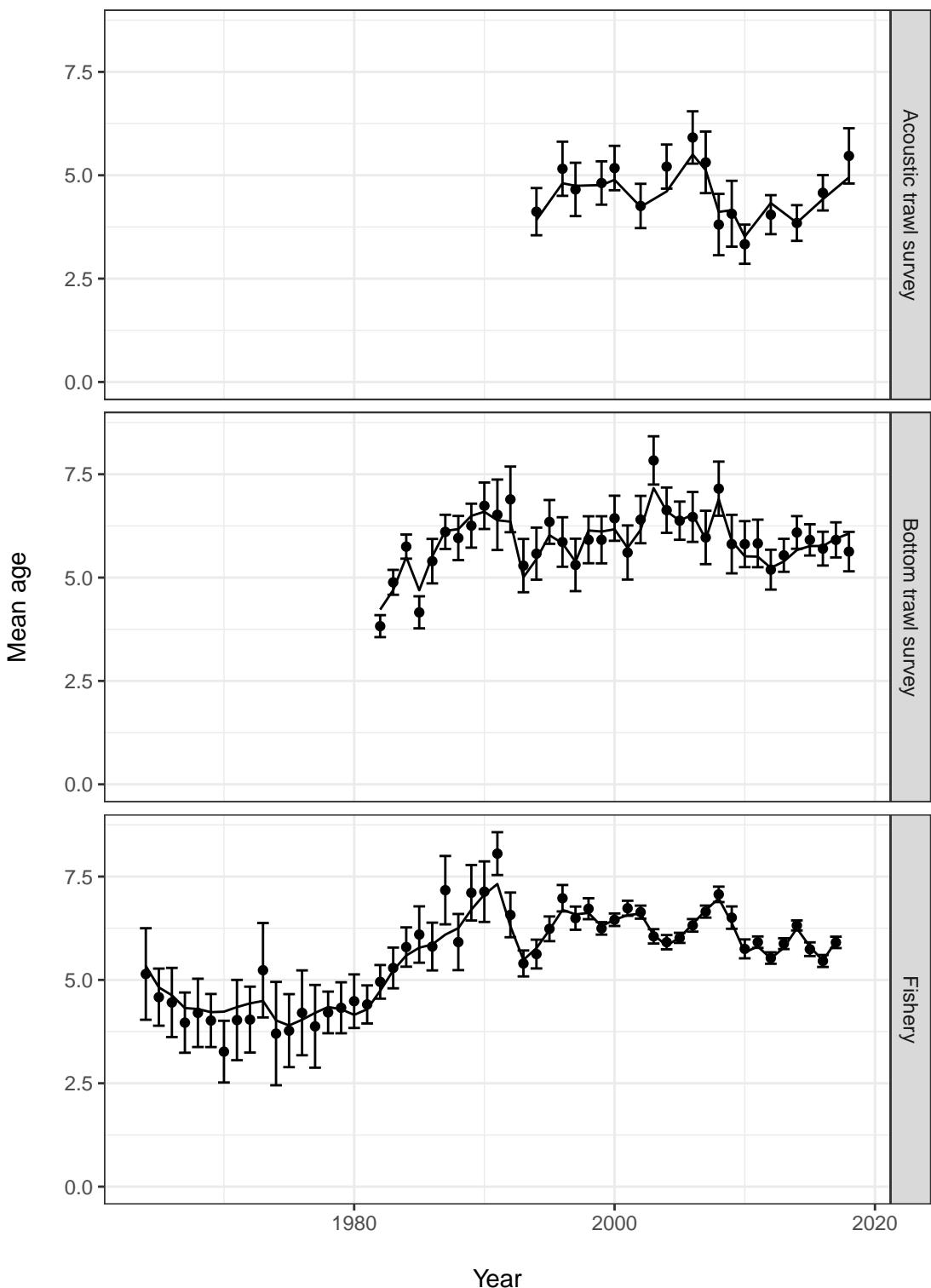


Figure 35: EBS pollock model fits to observed mean age for the Acoustic trawl survey (top), the bottom trawl survey (middle), and the fishery (bottom) for EBS pollock.

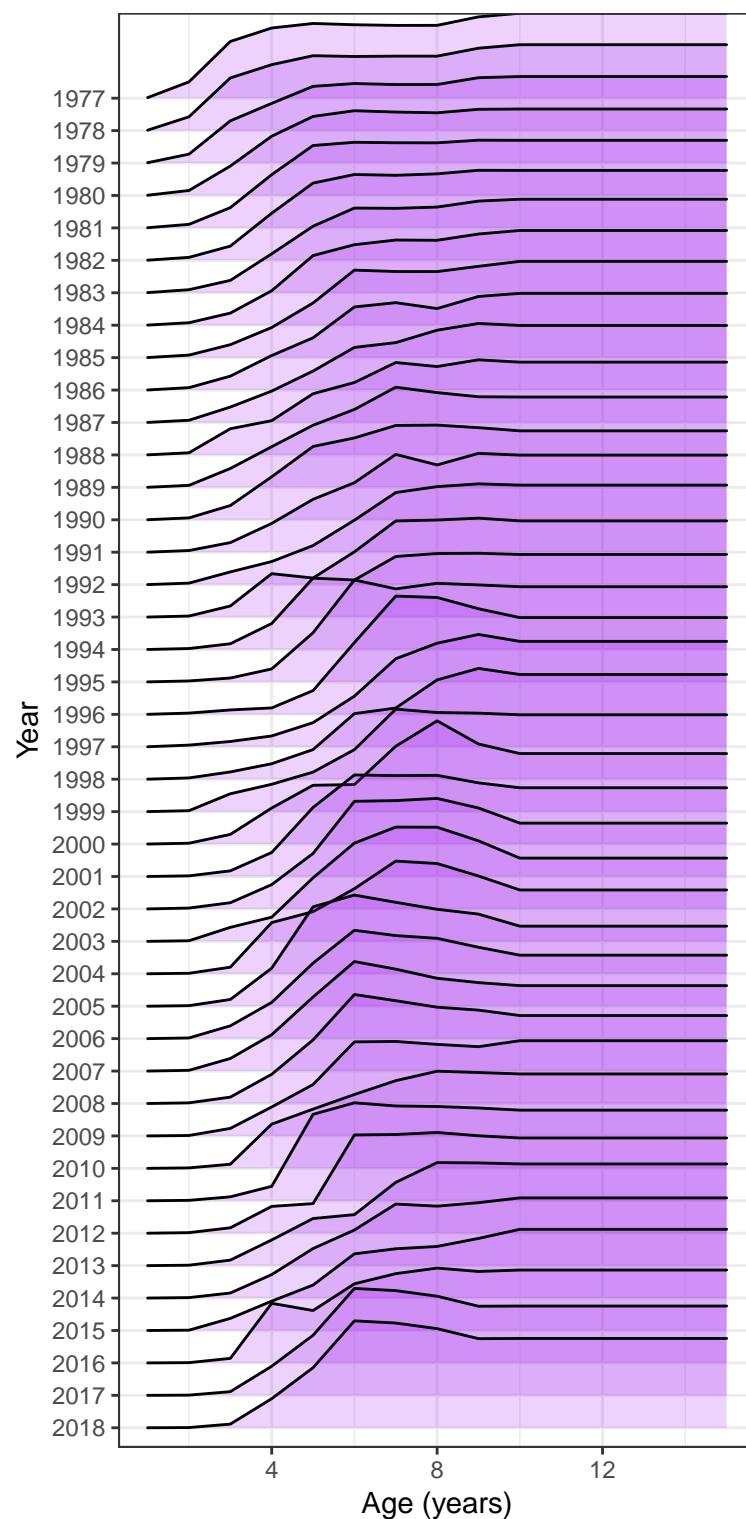


Figure 36: Selectivity at age estimates for the EBS pollock fishery.

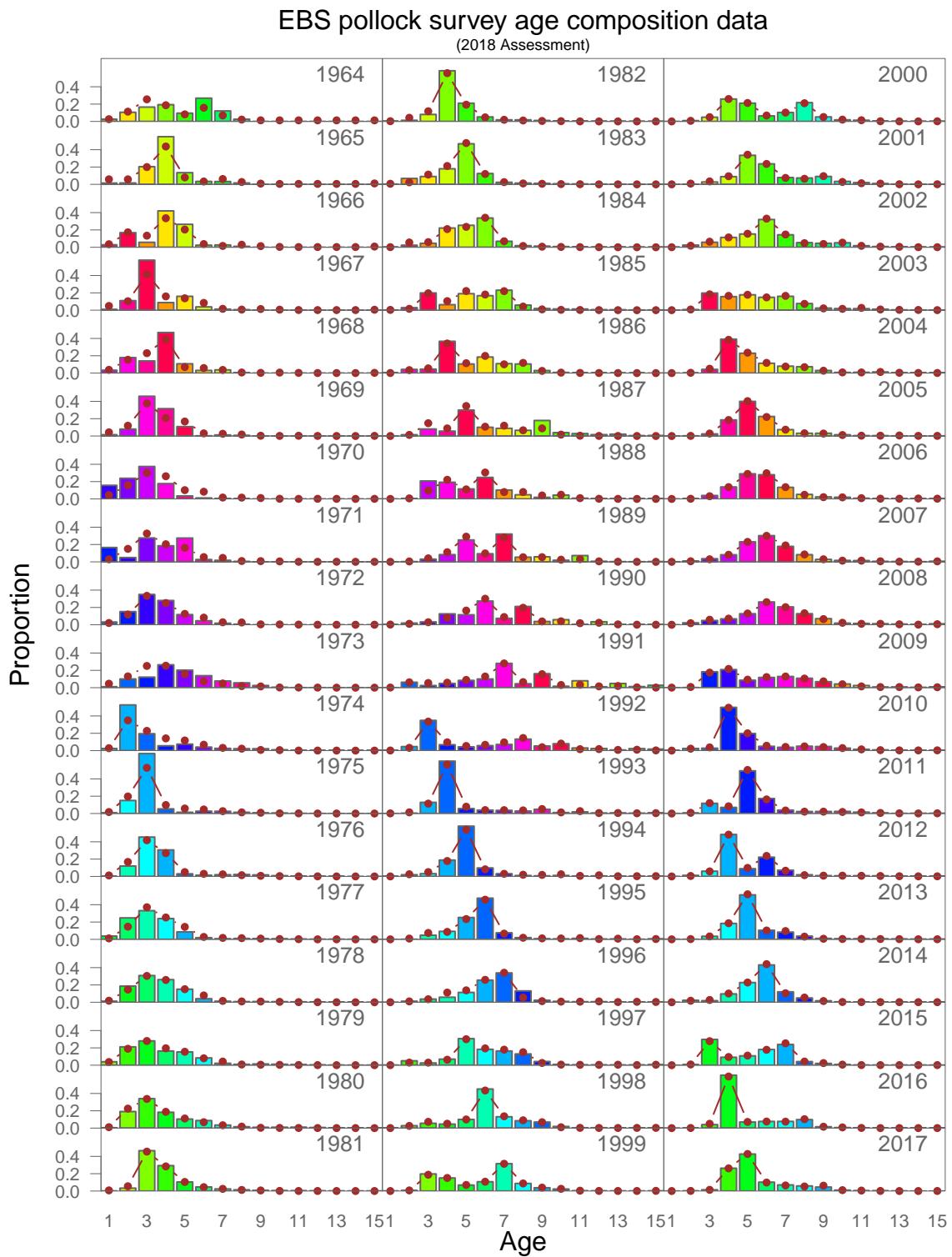


Figure 37: Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964–2017). The 2017 data are new to this year’s assessment. Colors coincide with cohorts progressing through time.

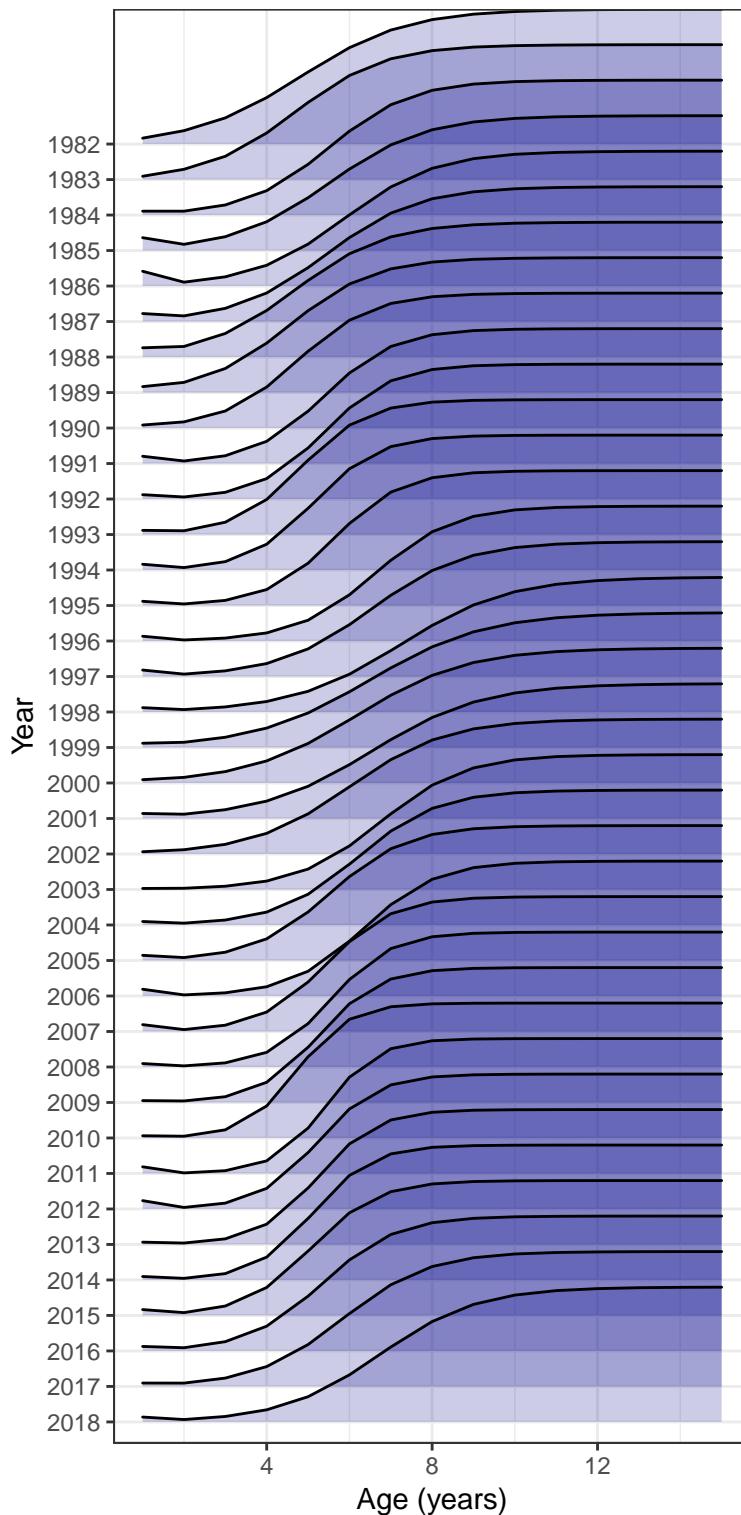


Figure 38: Model estimates of bottom-trawl survey selectivity, 1982–2018.

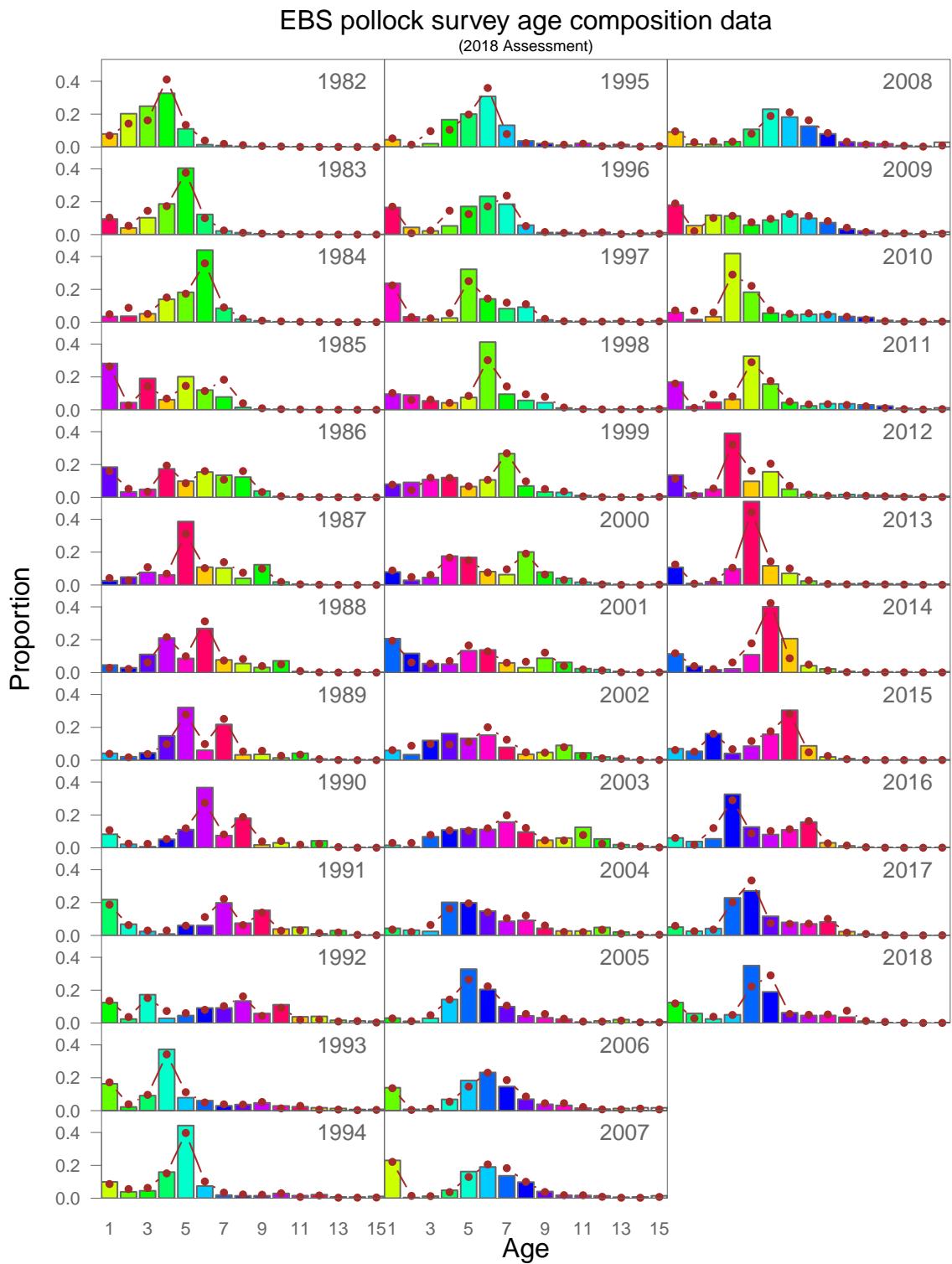


Figure 39: Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2018.

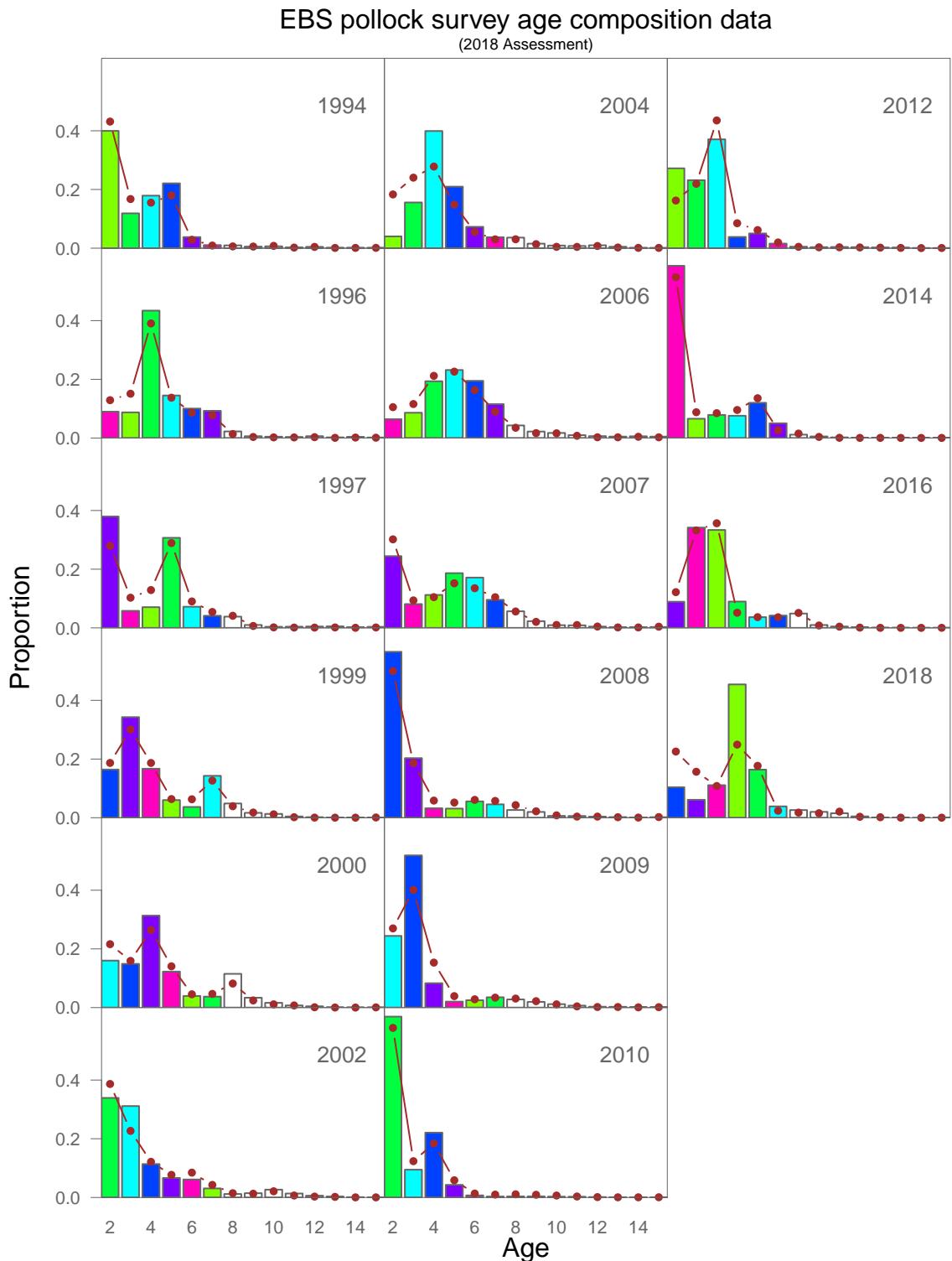


Figure 40: Model fit (dots) to the acoustic-trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time (for years with consecutive surveys).

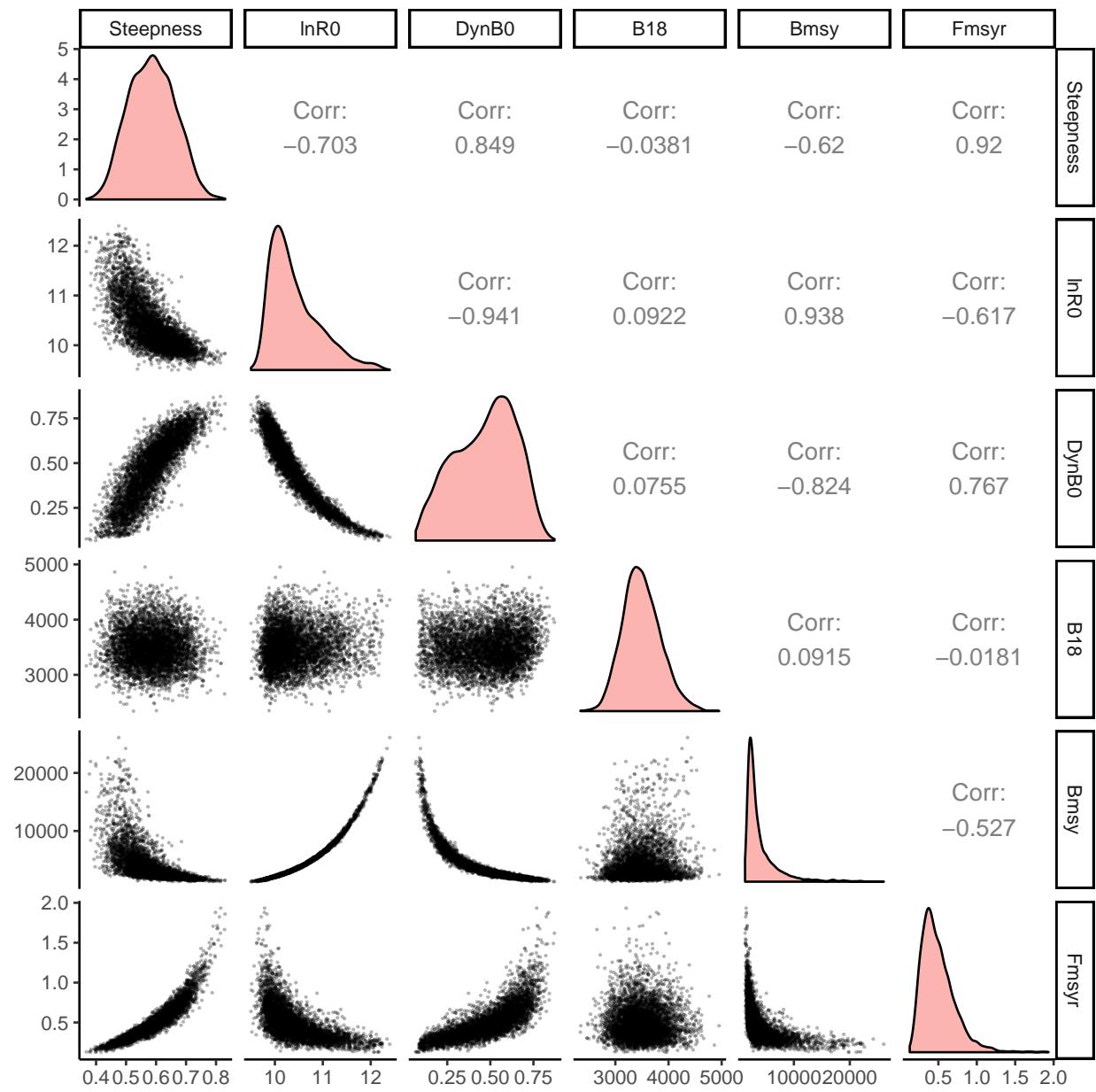


Figure 41: Pairwise plot of selected EBS pollock parameters and output from 3 million MCMC iterations thinned such that 5 thousand draws were saved as an approximation to the multivariate posterior distribution. Note that the figures on the diagonal represent the marginal posterior distributions. Key: lnR0 is the parameter that scales the stock-recruit relationship, B\_Bmsy is estimated  $B_{2017}/B_{MSY}$ , DynB0 is the ratio of spawning biomass estimated for in 2018 over the value estimated that would occur if there had been no fishing, B18 is the spawning biomass in 2018, and B\_Bmean is  $B_{2018}/\bar{B}$ .

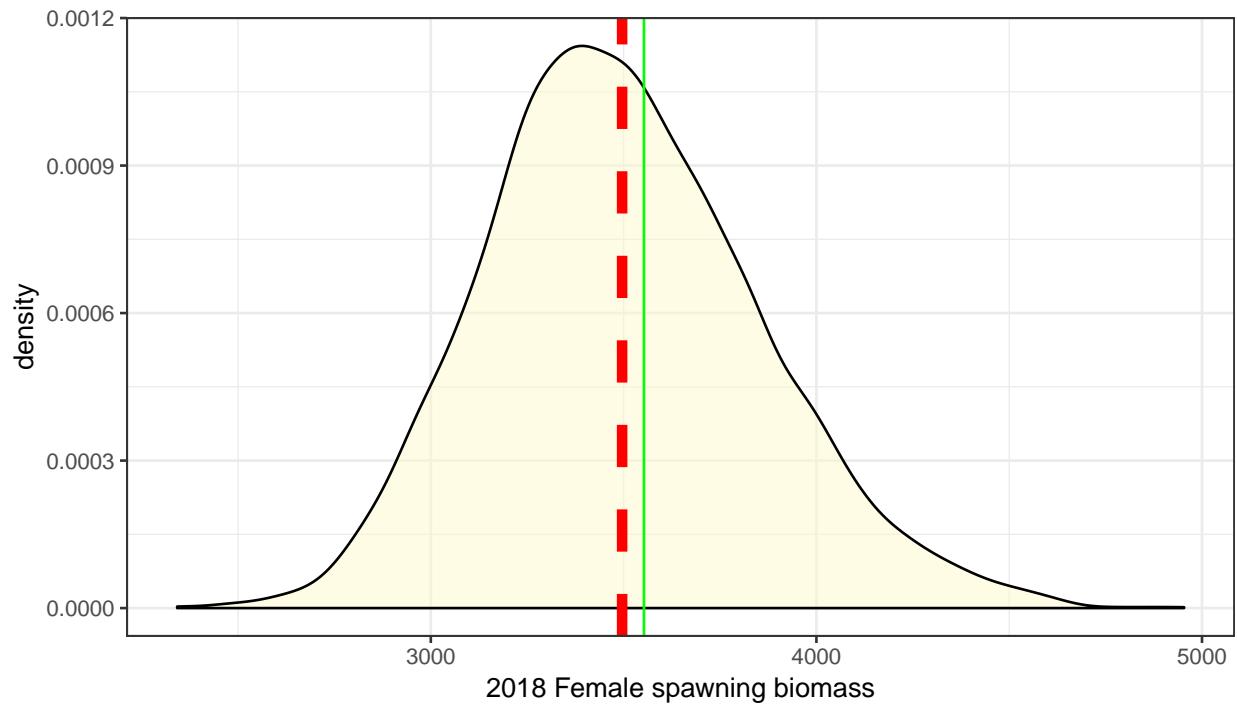


Figure 42: Integrated marginal posterior density (based on MCMC results) for the 2018 EBS pollock female spawning biomass compared to the point estimate (dashed red line). The mean of the posterior is shown in green (under the dashed line).

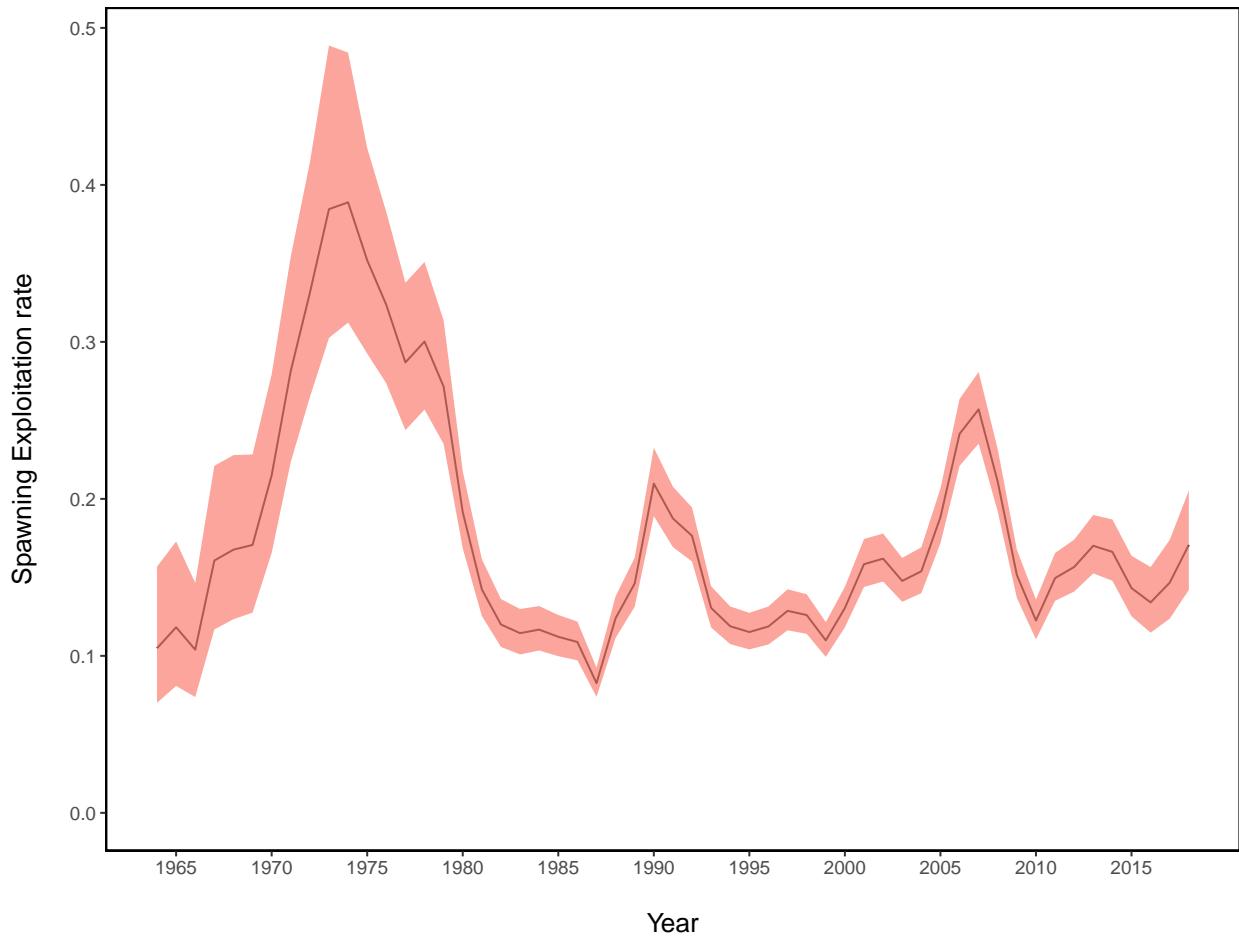


Figure 43: Estimated spawning exploitation rate (defined as the percent removal of egg production in a given spawning year).

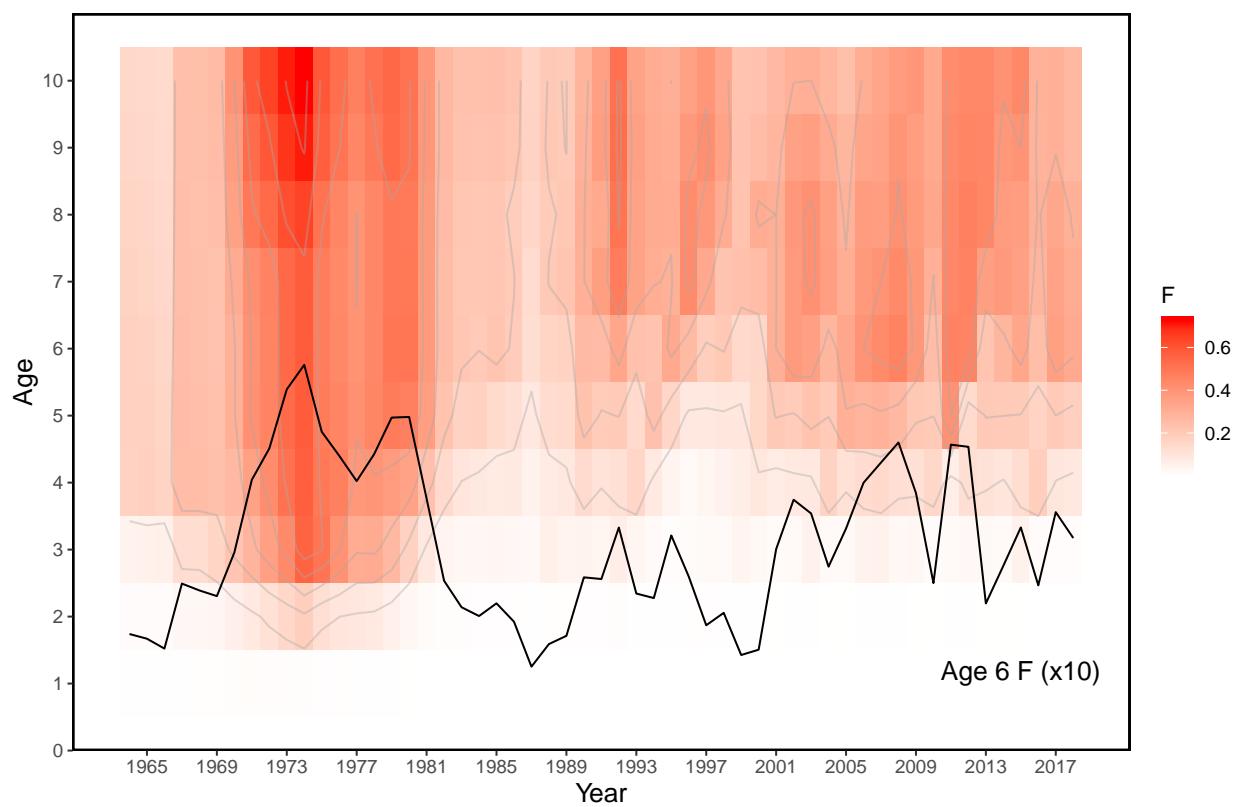


Figure 44: Estimated instantaneous age-specific fishing mortality rates for EBS pollock.

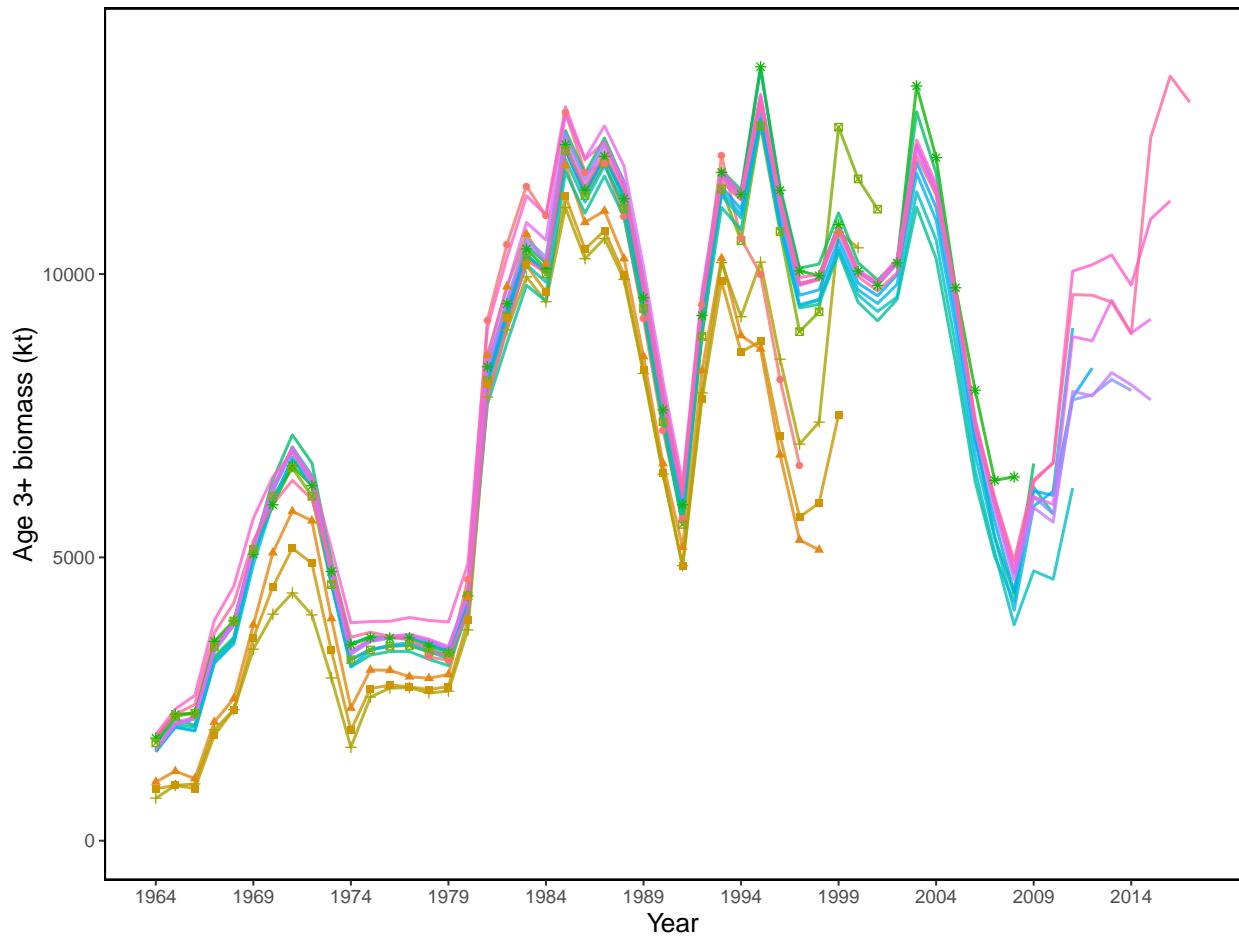


Figure 45: Comparison of the current assessment results with past assessments of begin-year EBS age-3+ pollock biomass.

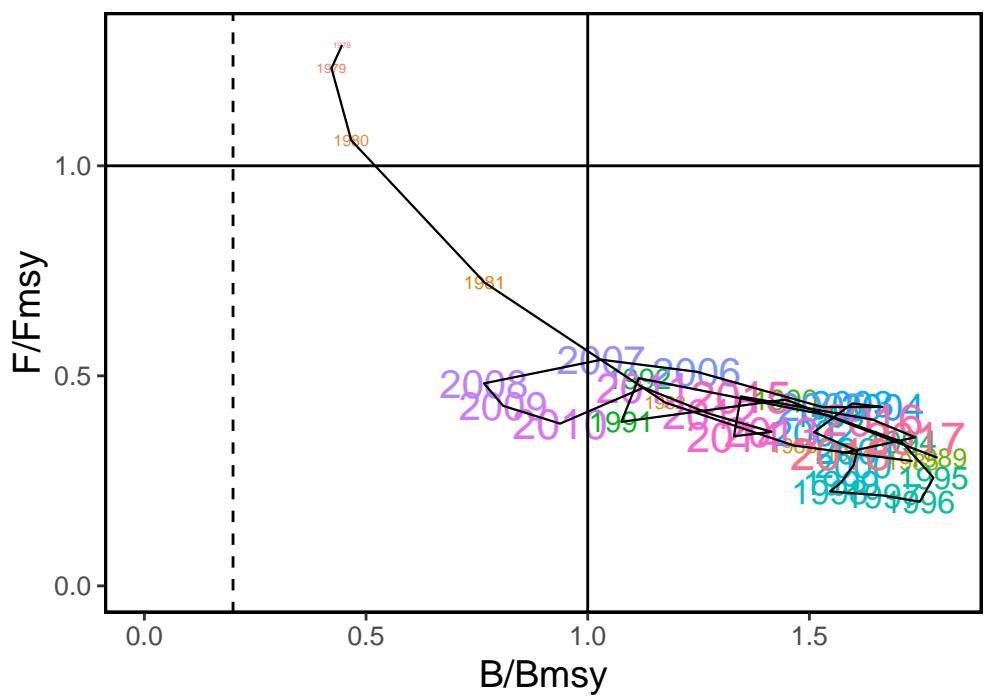


Figure 46: Estimated spawning biomass relative to annually estimated  $F_{MSY}$  values and fishing mortality rates for EBS pollock.

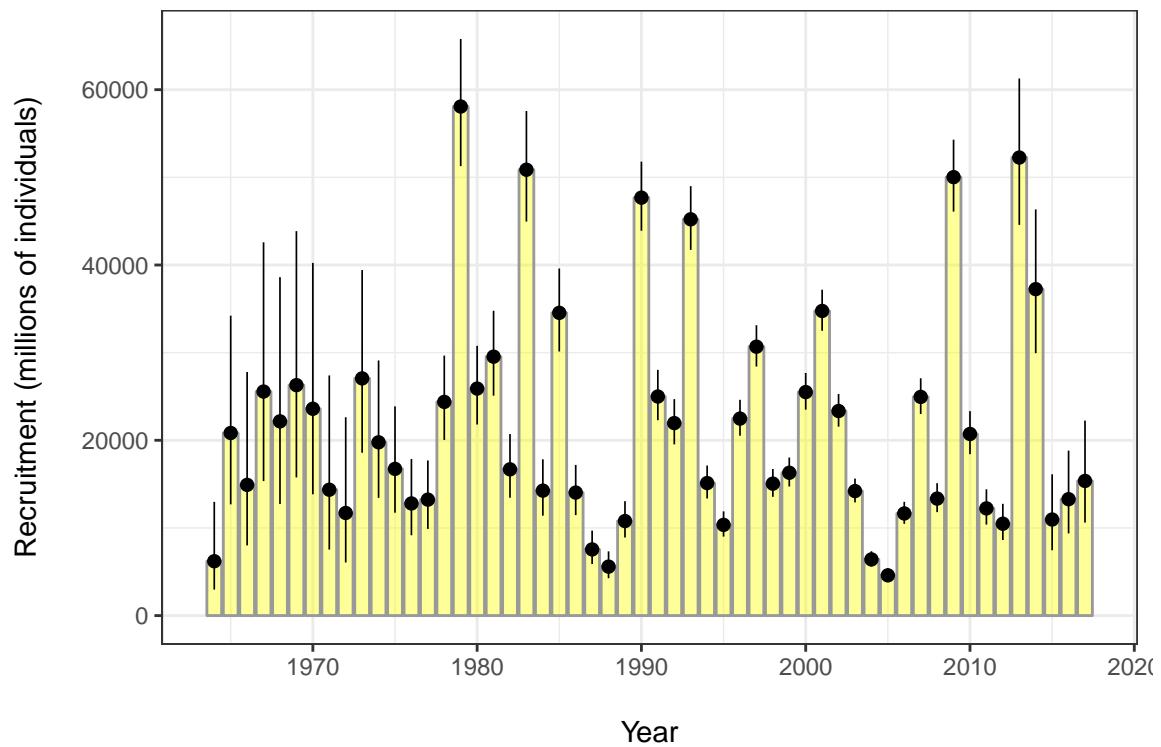


Figure 47: Recruitment estimates (age-1 recruits) for EBS pollock for all years since 1964 (1963–2017 year classes) for Model 16.1. Error bars reflect 90% credible intervals based on model estimates of uncertainty.

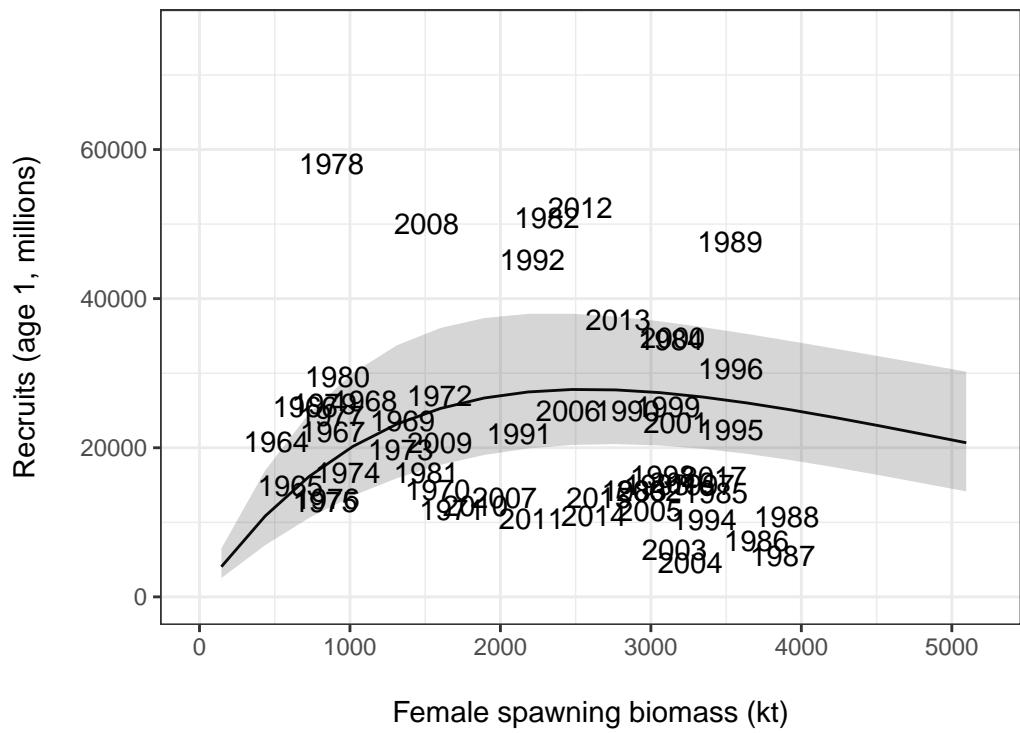


Figure 48: Stock-recruitment estimates (shaded represents structural uncertainty) and age-1 EBS pollock estimates labeled by year-classes

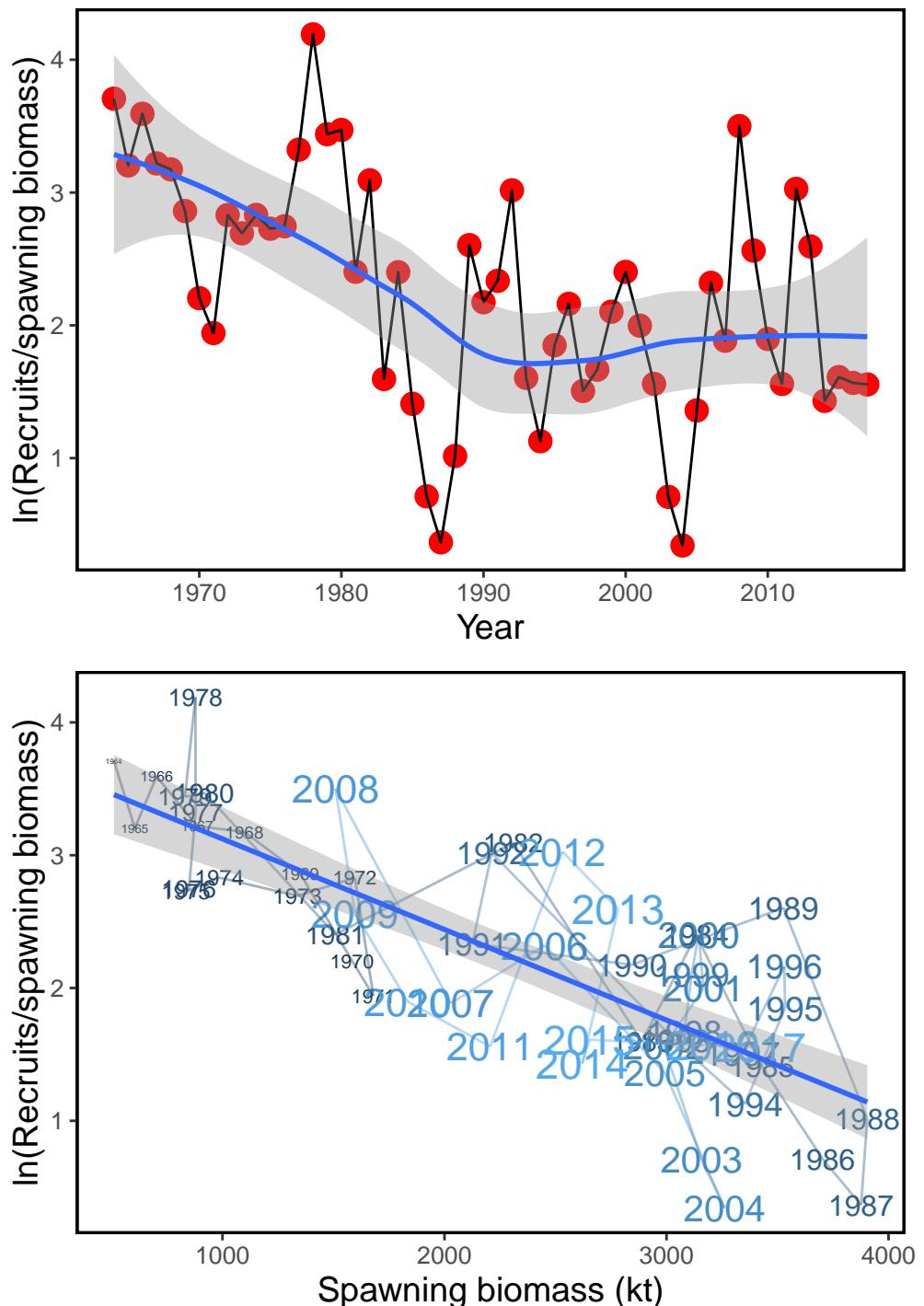


Figure 49: EBS pollock productivity as measured by logged recruits per spawning biomass,  $\log(R/S)$ , as a function of spawning biomass with a linear fit (bottom) and over time, 1964–2018 (top).

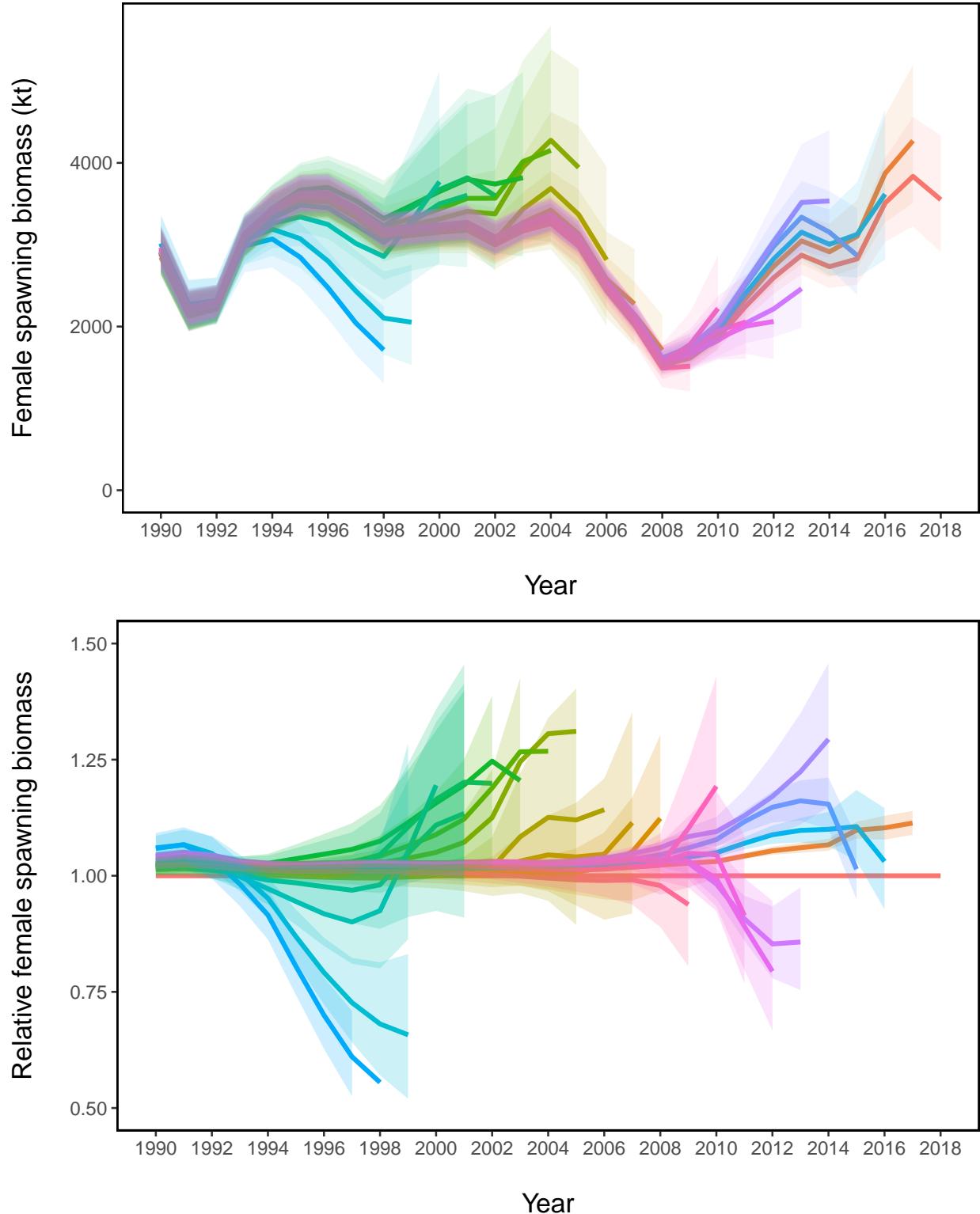


Figure 50: Retrospective patterns for EBS pollock spawning biomass showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations).

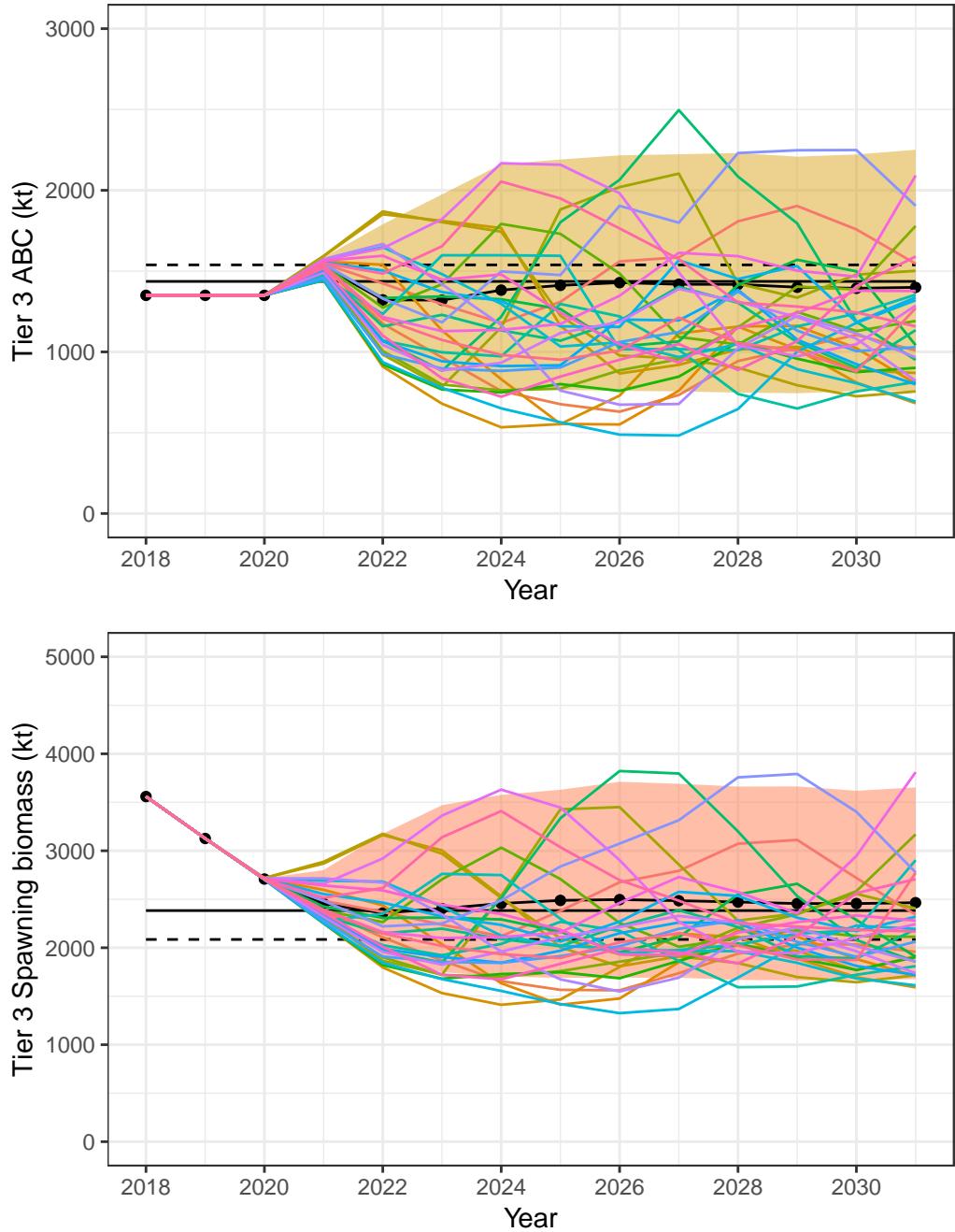


Figure 51: Projected EBS Tier 3 pollock yield (top) and female spawning biomass (bottom) relative to the long-term expected values under  $F_{35\%}$  and  $F_{40\%}$  (horizontal lines).  $B_{40\%}$  is computed from average recruitment from 1978–2015. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1.

Projected trend relative to 2018 given future catch=1,350 kt

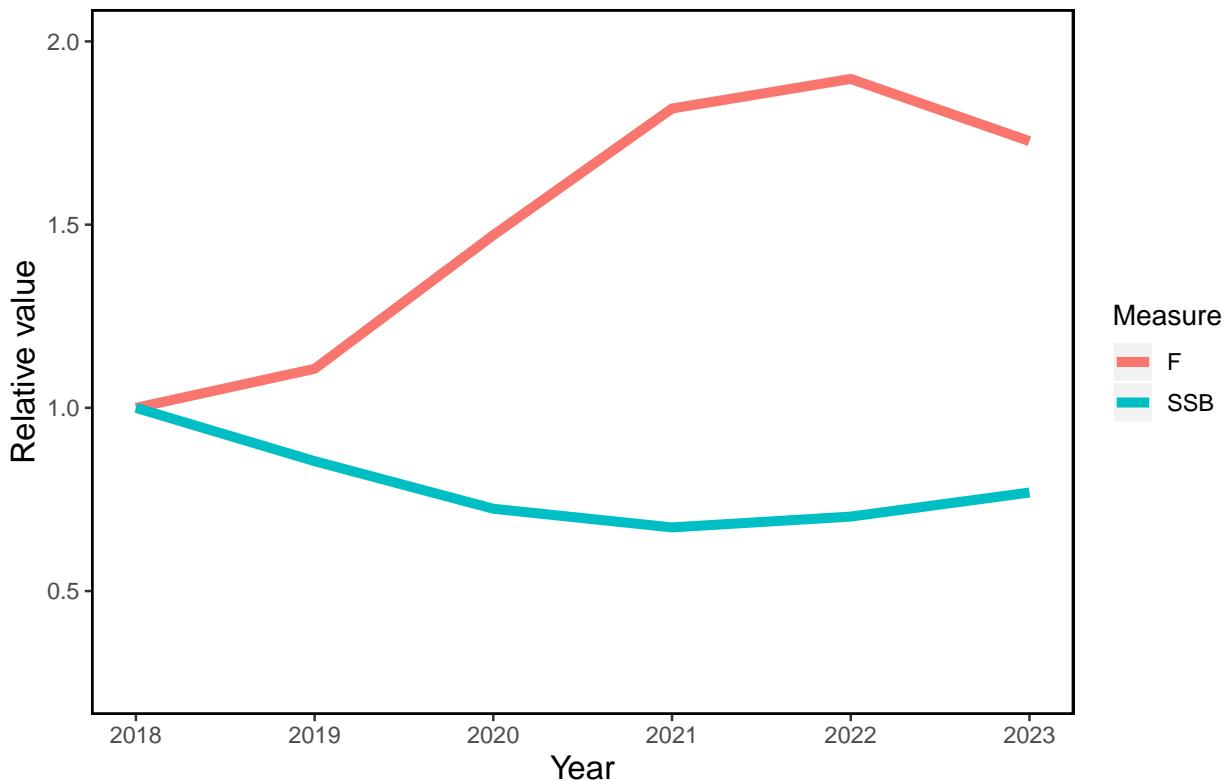


Figure 52: Projected fishing mortality and spawning biomass relative to 2018 values under constant catch of 1.35 million t, 2019–2023.

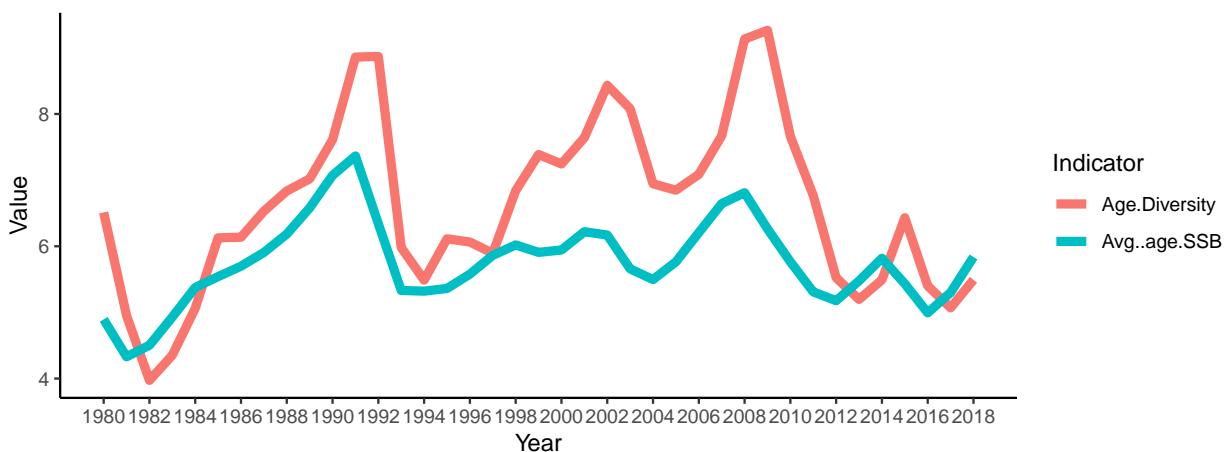


Figure 53: For the mature component of the EBS pollock stock, time series of estimated average age and diversity of ages (using the Shannon-Wiener H statistic), 1980–2018.

## EBS Pollock Model Description

### Dynamics

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

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

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

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

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

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

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

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

$$(8)$$

where

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\alpha_t^\mu - \alpha_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\alpha^\mu}^2) \quad (16)$$

$$\beta_t^\mu - \beta_{t+1}^\mu \sim \mathcal{N}(0, \sigma_{\beta^\mu}^2) \quad (17)$$

The parameters to be estimated in this part of the model are thus for  $t=1982, 1983, 2016$ . The variance terms for these process error parameters were specified to be 0.04.

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

$$\nu = \text{var} \left( r_t^a \sqrt{\frac{N_t}{\kappa_t}} \right)^{-1} \quad (18)$$

$$r_t^a = \bar{a}_t - \hat{a}_t \quad (19)$$

$$\kappa_t = \left[ \sum_a^A \bar{a}_t - \hat{a}_t \right]^{0.5} \quad (20)$$

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

$$\hat{a}_t = \sum_a^A a \hat{p}_{ta} \quad (21)$$

$$\bar{a}_t = \sum_a^A a p_{ta} \quad (22)$$

For this assessment, we use 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.

### **Recruitment**

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

$$R_t = f(B_{t-1}) \quad (23)$$

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

$$B_t = \sum_{a=1}^A w_{t,a} \phi_a N_{t,a} \quad (24)$$

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

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

$$R_t = \frac{B_{t-1} e^{\varepsilon_t}}{\alpha + \beta B_{t-1}} \quad (25)$$

where

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

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

$$\alpha = \tilde{B}_0 \frac{1-h}{4h} \quad (26)$$

$$\beta = \frac{5h-1}{4hR_0} \quad (27)$$

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 1988). 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, “Bholt”, a Beverton Holt stock recruitment form was implemented using the prior value of 0.67 for steepness and a CV of 0.17. This resulted in beta distribution parameters (for the prior) at  $\alpha = 6.339$  and

$$\beta = 4.293.$$

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

To have the critical value for the stock-recruitment function (steepness,  $h$ ) on the same scale for the Ricker model, we begin with the parameterization of Kimura (1990):

$$R_t = \frac{B_{t-1} e^{\alpha \left(1 - B_{t-1} \frac{R_0}{\psi_0}\right)}}{\psi_0} \quad (28)$$

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

$$h = \frac{e^\alpha}{e^\alpha + 4} \quad (29)$$

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

## Diagnostics

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

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

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

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

## 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):

$$nll(i) = n \sum_{t,a} p_{ta} \ln \hat{p}_{ta} \quad (30)$$

$$p_{ta} = \frac{O_{ta}}{\sum_a O_{ta}} \quad \hat{p}_{ta} = \frac{\hat{C}_{ta}}{\sum_a \hat{C}_{ta}} \quad (31)$$

$$\mathbf{C} = \mathbf{CE} \quad (32)$$

$$\mathbf{E} = \begin{matrix} b_{1,1} & b_{1,2} & \dots & b_{1,15} \\ b_{2,1} & b_{2,2} & & b_{2,15} \\ \vdots & & \ddots & \vdots \\ b_{15,1} & b_{15,2} & \dots & b_{15,15} \end{matrix} \quad (33)$$

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

Sample size values were revised and are shown in the main document. Strictly speaking, the amount of data collected for this fishery indicates higher values might be warranted. However, the standard multinomial sampling process is not robust to violations of assumptions (Fournier et al. 1990).

Consequently, as the model fit approached a solution, we invoke a robust likelihood function which fit proportions at age as:

$$\prod_{a=1}^A \prod_{t=1}^T \left[ \left( \exp \left( -\frac{(p_{ta} - \hat{p}_{ta})^2}{2(\eta_{ta} + 0.1/A) \tau_t^2} \right) + 0.01 \right) \times \frac{1}{\sqrt{2\pi (\eta_{ta} + 0.1/A) \tau_t}} \right] \quad (34)$$

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

$$nll(i) = -0.5 \sum_{a=1}^A \sum_{t=1}^T \ln 2\pi (\eta_{ta} + 0.1/A) - \sum_t^T A \ln \tau_t + \sum_{a=1}^A \sum_{t=1}^T \ln \left\{ \exp \left( -\frac{(p_{ta} - \hat{p}_{ta})^2}{(2\eta_{ta} + 0.1/A) \tau_t^2} \right) + 0.01 \right\} \quad (35)$$

where

$$\eta_{ta} = p_{ta}(1 - p_{ta}) \quad (36)$$

$$\text{and} \quad (37)$$

$$\tau_t^2 = 1/n_t \quad (38)$$

which gives the variance for  $p_{ta}$

$$(\eta_{ta} + 0.1/A) \tau_t^2 \quad (39)$$

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:

$$\hat{N}_{ta}^s = e^{-0.5Z_{ta}} N_{ta} q_t^s s_{ta}^S \quad (40)$$

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:

$$\hat{N}_{ta}^s = e^{-0.5Z_{ta}} w_{ta} N_{ta} q_t^s s_{ta}^S \quad (41)$$

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:

$$nll(i) = \sum_t \frac{\ln(u_t^s / \hat{N}_t^s)^2}{2\sigma_{s,t}^2} \quad (42)$$

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:

$$nll(i) = \sum_t \frac{(u_t^s - \hat{N}_t^s)^2}{2\sigma_{s,t}^2}. \quad (43)$$

(44)

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

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

$$nll_i = 0.5 \mathbf{X} \Sigma^{-1} \mathbf{X}' \quad (45)$$

where  $\mathbf{X}$  is a vector of observed minus model predicted values for this index and  $\Sigma$  is the estimated covariance matrix provided from the method provided in Kotwicki et al. 2014.

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

$$nll_i = 0.5 \sum_t \frac{\ln(C_b^{obs} / \hat{C}_b)^2}{2\sigma_{C_b,t}^2} \quad (46)$$

where  $\sigma_{C_b,t}$  is pre-specified (set to 0.05) reflecting the accuracy of the overall observed catch in biomass. Similarly, the contribution of prior distributions (in negative log-density) to the log-likelihood function include  $\lambda_\varepsilon \sum_t \varepsilon_t^2 + \lambda_\gamma \sum_{ta} \gamma^2 + \lambda_\delta \sum_t \delta_t^2$  where the size of the  $\lambda$ 's represent prior assumptions about the variances of these random variables. Most of these parameters are associated with year-to- year and age specific deviations in selectivity coefficients. For a presentation of this type of Bayesian approach to modeling errors-in- variables, the reader is referred to Schnute (1994). To facilitate estimating such a large number of parameters, automatic differentiation software extended from Griewank 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.

### ***Uncertainty in mean body mass***

The approach we use to solve for  $F_{MSY}$  and related quantities (e.g.,  $B_{MSY}$   $MSY$ ) within a general integrated model context was shown in Ianelli et al. (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 (2017) and future mean weights for each age  $i$ ,  $i = (1, 2, \dots, 15)$ , given actual observed mean and variances in weight-at-age over the period 1991-2017. The values of based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

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

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

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

$$\hat{w}_{ta} = \bar{w}_a e_t^\psi \quad a = 1, t \geq 1964 \quad (47)$$

$$\hat{w}_{ta} = \hat{w}_{t-1,a-1} + \Delta_a e_t^\psi \quad a > 1, t > 1964 \quad (48)$$

$$\Delta_a = \bar{w}_{a+1} - \bar{w}_a \quad a < A \quad (49)$$

$$\bar{w}_a = \alpha \left\{ L_1 + (L_2 - L_1) \left( \frac{1 - K^{a-1}}{1 - K^{A-1}} \right) \right\}^3 \quad (50)$$

(51)

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

### **Tier 1 projections**

Tier 1 projections were calculated two ways. First, for 2017 and 2018 ABC and *OFL* levels, the harmonic mean  $F_{MSY}$  value was computed and the analogous harvest rate ( $u_{HM}$ ) applied to the estimated geometric mean fishable biomass at  $B_{MSY}$ :

$$ABC_t = B_{GM,t}^f \hat{u}_{HM} \zeta_t \quad (52)$$

$$B_{GM,t}^f = e^{\ln \hat{B}_t^f - 0.5 \sigma_{Bf}^2} \quad (53)$$

$$u_{HM,t}^f = e^{\ln \hat{u}_{MSY,t} - 0.5 \sigma_{u_{MSY}}^2} \quad (54)$$

$$\zeta_t = \frac{B_t / B_{MSY} - 0.05}{1 - 0.05} \quad B_t < B_{MSY} \quad (55)$$

$$\zeta_t = 1.0 \quad B_t \geq B_{MSY} \quad (56)$$

where  $\hat{B}_t^f$  is the point estimate of the fishable biomass defined (for a given year):  $\sum_a N_a s_{ta} w_{ta}$  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.

## Appendix on spatio-temporal analysis of NMFS bottom-trawl survey data

### Overview

This application of VAST was configured to model a subset of NMFS/AFSC bottom trawl survey data. Specifically, the station-specific CPUE (kg per hectare) for pollock were compiled from 1982-2018. Further details can be found at the [GitHub repo](#) mainpage, wiki, and glossary. The R help files, e.g., `?Data_Fn` for explanation of data inputs, or `?Param_Fn` for explanation of parameters. VAST has involved many publications for developing individual features (see references section below). What follows is intended as a step by step documentation of applying the model to these data.

Settings and configurations are available here (link to come...). The location by year for the stations used are shown in Figure 54.

### Diagnostic plots

#### Encounter-probability component

One can check to ensure that observed encounter frequencies for either low or high probability samples are within the 95% predictive interval for predicted encounter probability (Figure 55). Diagnostics for positive-catch-rate component was evaluated using a standard Q-Q plot. Qualitatively, the fits to pollock data are reasonable (Figures 56 and 57).

#### Pearson residuals

Spatially the residual pattern can be evaluated over time. Results for pollock data shows that consistent positive or negative residuals across or within years is limited for the encounter probability component of the model and for the positive catch rate component (Figures 58 and 59, respectively).

#### 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, and 2018; (Figure 60)). Index values and error terms (based on diagonal of covariance matrix over time) are shown in Figure 61

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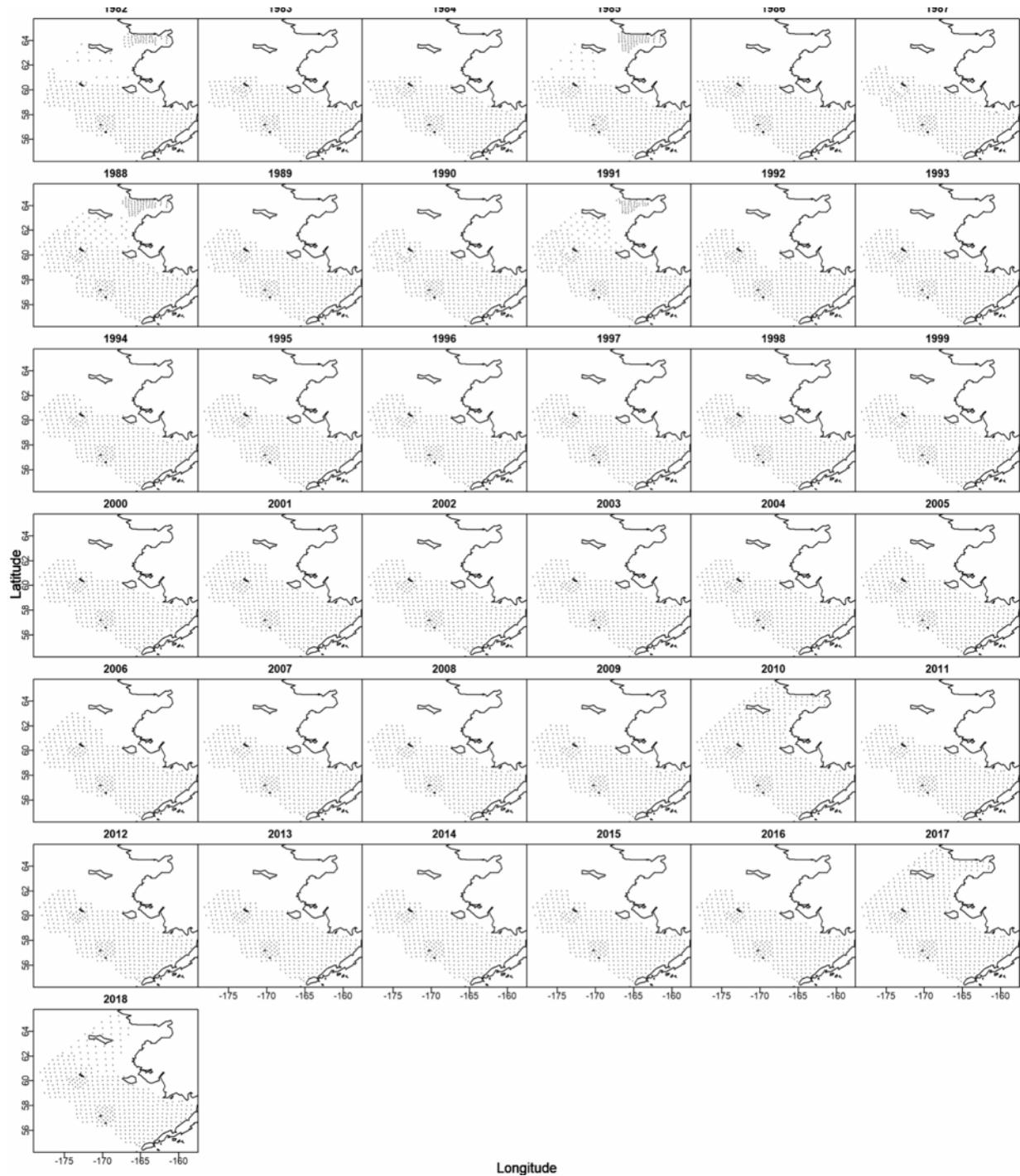


Figure 54: Locations of stations used for the VAST moldel, 1982–2018.

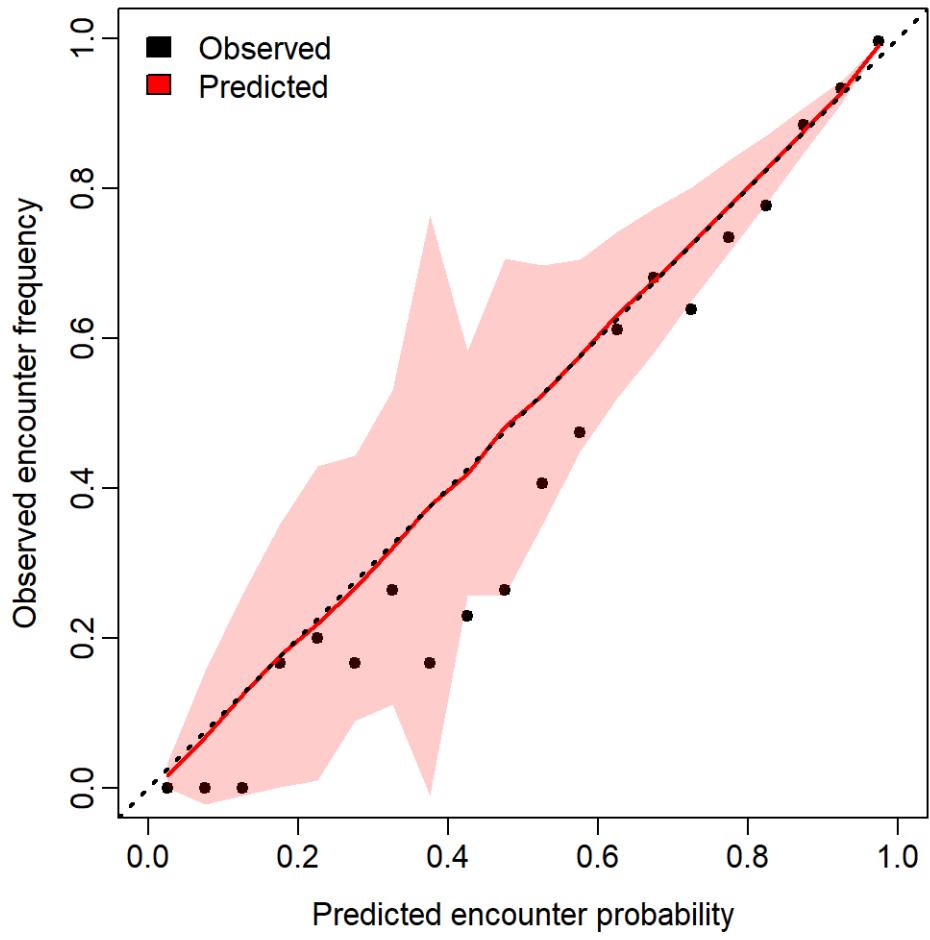


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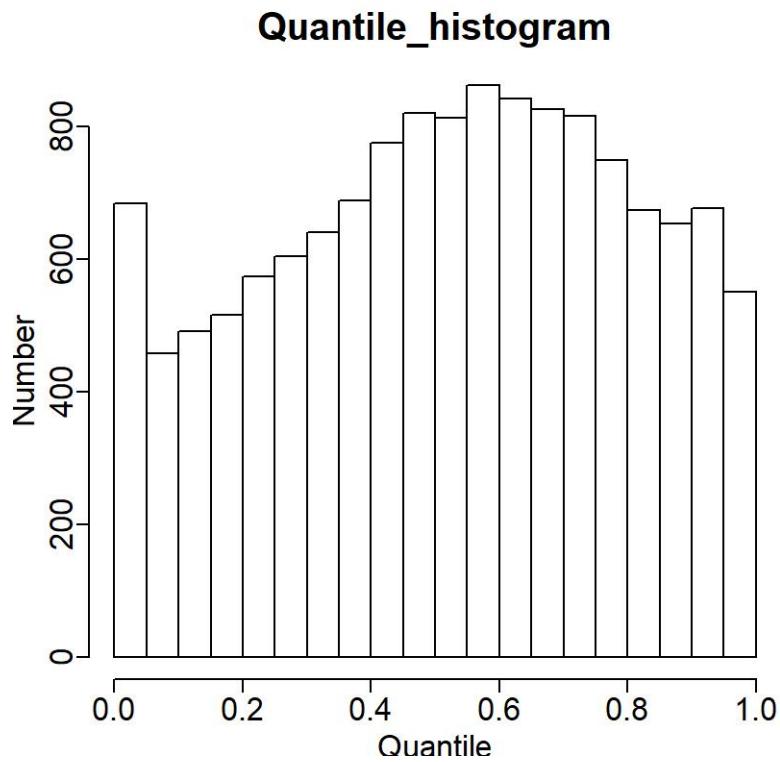


Figure 56: Plot indicating distribution of quantiles for “positive catch rate” component.

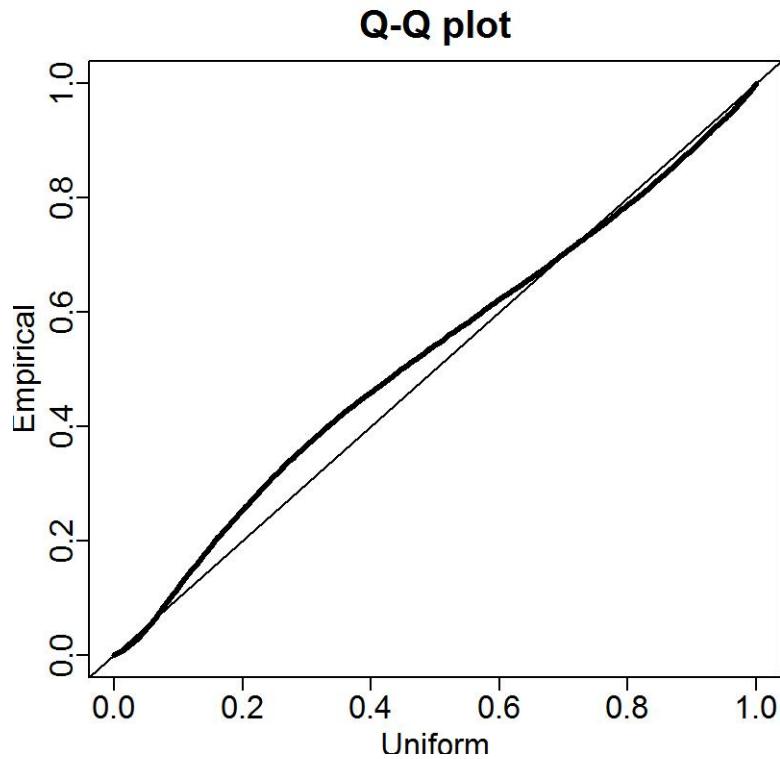


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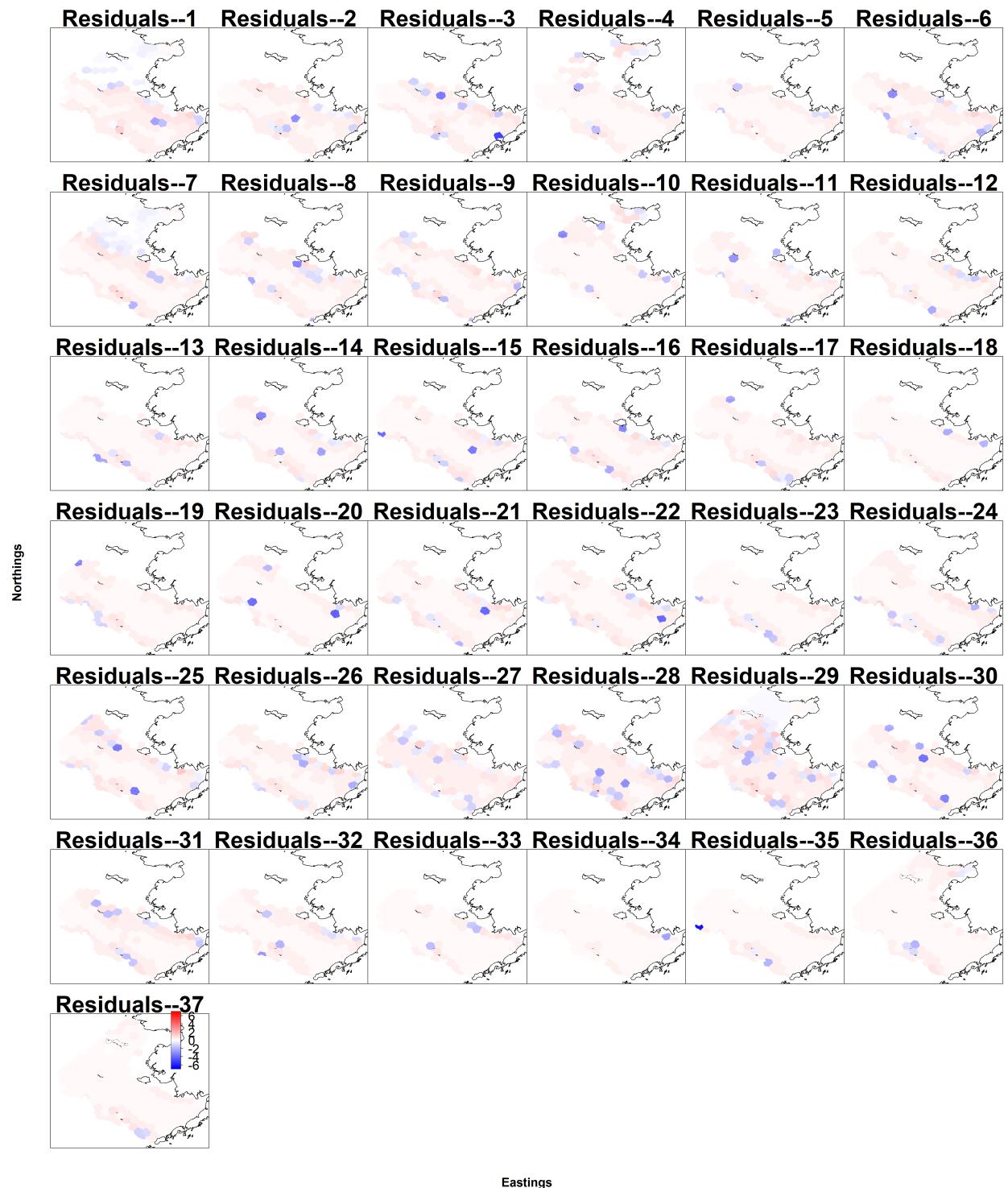


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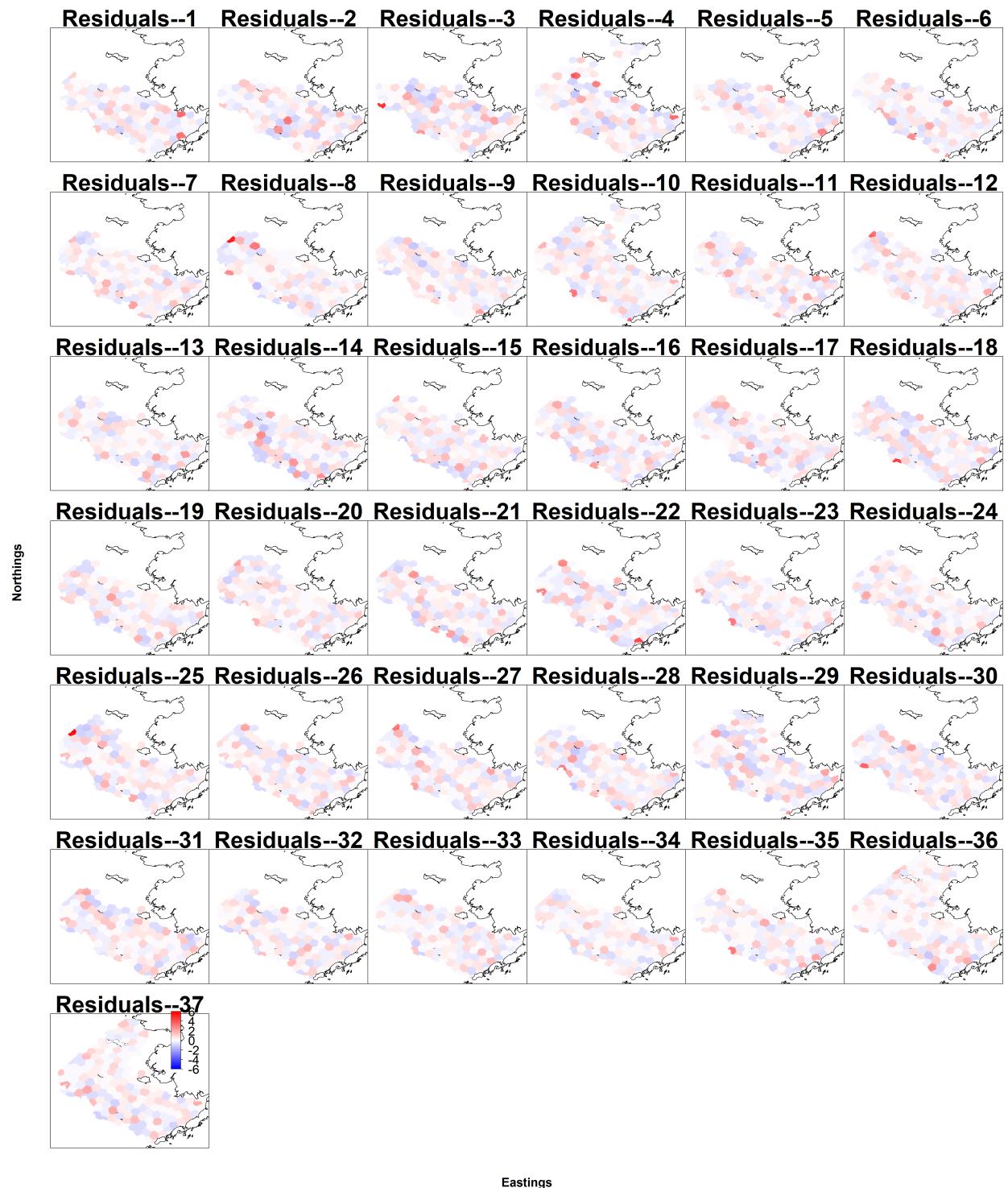


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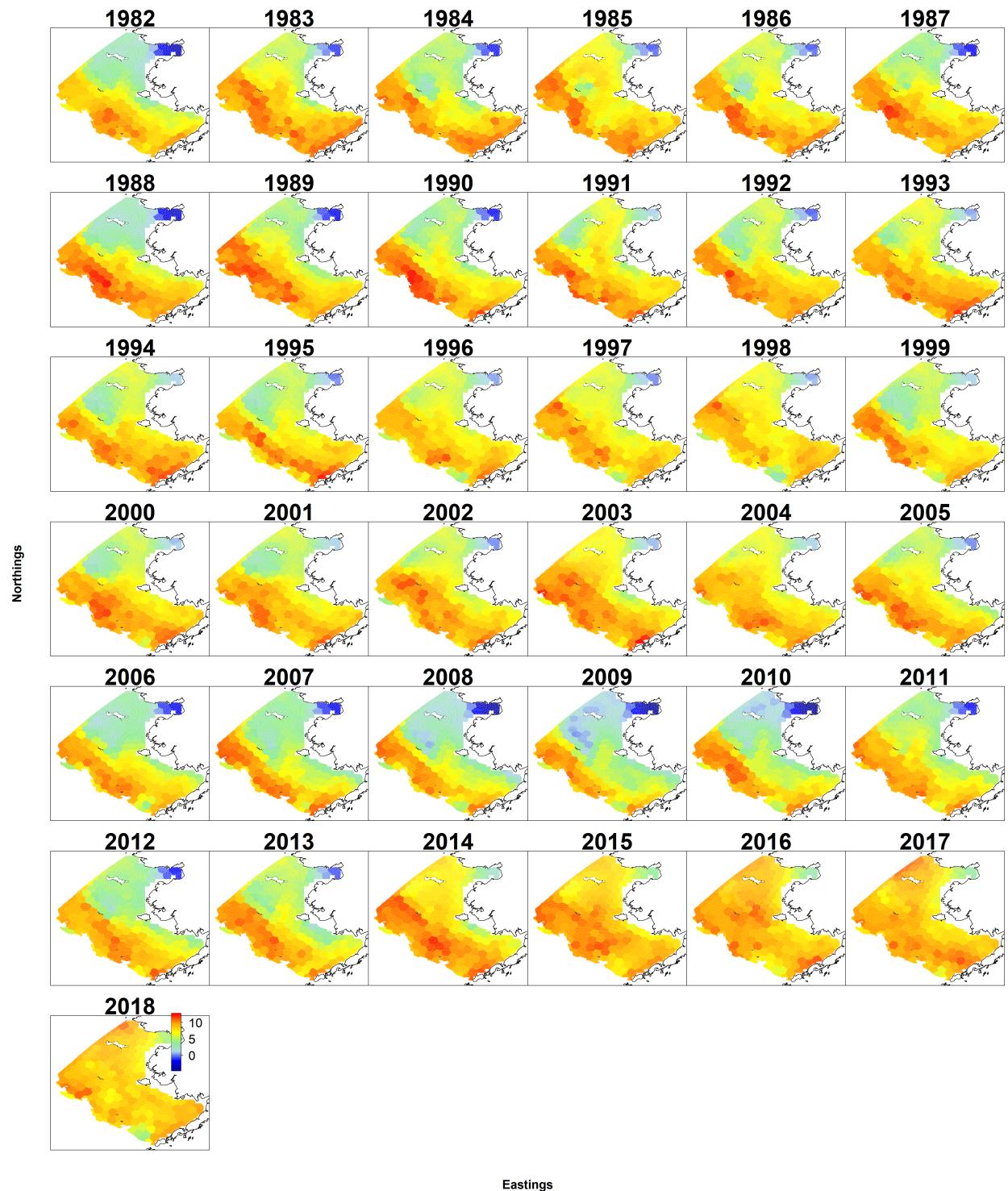


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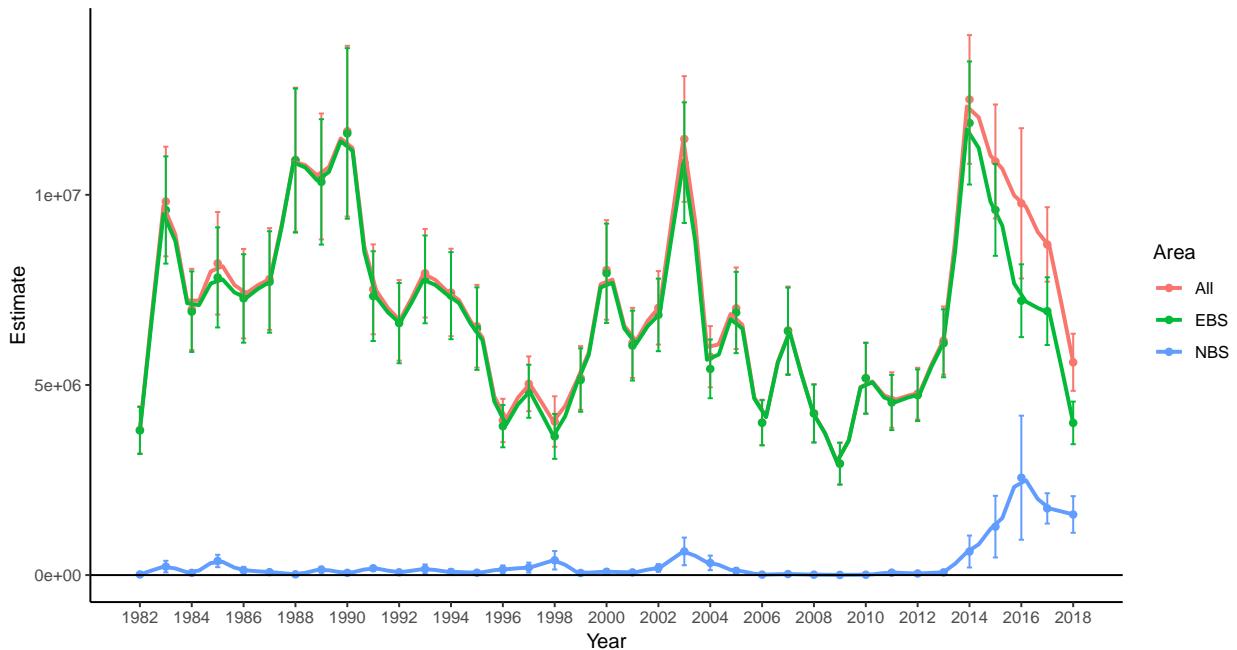


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the marginal posterior distributions. Key: lnR0 is the parameter that scales the  
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spawning biomass estimated for in 2018 over the value estimated that would occur  
if there had been no fishing, B18 is the spawning biomass in 2018, and B\_Bmean is  
 $B_{2018}/\bar{B}$ . . . . .
- 42 Integrated marginal posterior density (based on MCMC results) for the 2018 EBS  
pollock female spawning biomass compared to the point estimate (dashed red line).  
The mean of the posterior is shown in green (under the dashed line). . . . .

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| 43 | Estimated spawning exploitation rate (defined as the percent removal of egg production in a given spawning year). . . . .   |
| 44 | Estimated instantaneous age-specific fishing mortality rates for EBS pollock. . . . .   |
| 45 | Comparison of the current assessment results with past assessments of begin-year EBS age-3+ pollock biomass. . . . .  |
| 46 | Estimated spawning biomass relative to annually estimated $F_{MSY}$ values and fishing mortality rates for EBS pollock. . . . .   |
| 47 | Recruitment estimates (age-1 recruits) for EBS pollock for all years since 1964 (1963–2017 year classes) for Model 16.1. Error bars reflect 90% credible intervals based on model estimates of uncertainty. . . . .   |
| 48 | Stock-recruitment estimates (shaded represents structural uncertainty) and age-1 EBS pollock estimates labeled by year-classes . . . . .  |
| 49 | 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, 1964–2018 (top). . . . .  |
| 50 | 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). . . . .   |
| 51 | 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 1978–2015. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1. . . . . |
| 52 | Projected fishing mortality and spawning biomass relative to 2018 values under constant catch of 1.35 million t, 2019–2023. . . . .   |
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| 59 | Pearson residuals of the positive catch rate component for the combined survey area, 1982–2018. . . . .   |
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| 61 | 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, 1982–2018. . . . .   |