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

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November 28, 2017

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 (this year only updates–"full" assessments expected in 2018).

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 2017 NMFS bottom-trawl survey (BTS) biomass and abundance at age estimates were included.
2. The 2016 NMFS acoustic-trawl survey (ATS) biomass and abundance at age estimates were updated based on age data collected from the ATS sampling (in 2016 the BTS age-length key was used).
3. The ATS age data from 1994-2016 that includes the bottom layer analysis (0.5-3m from bottom) was completed and used in the base/reference model (last year the accompanying biomass time series for these data were evaluated but the full set of age data was unavailable).
4. Two additional years of opportunistic acoustic data from vessels transiting the EBS shelf region were processed and the time series now extends from 2006-2017. This provides an alternative index of pollock biomass in mid-water.
5. Observer data for catch-at-age and average weight-at-age from the 2016 fishery were finalized and included.

6. Total catch as reported by NMFS Alaska Regional office was updated and included through 2017.

Changes in the assessment methods

There were no changes to the assessment methods.

Summary of EBS pollock results

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2017	2018	2018	2019
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)	13,000,000 t	12,100,000 t	10,965,000 t	10,117,000 t
Projected female spawning biomass (t)	4,600,000 t	4,500,000 t	3,678,000 t	3,365,000 t
B_0	5,700,000 t	5,700,000 t	5,394,000 t	5,394,000 t
B_{msy}	2,165,000 t	2,165,000 t	2,042,000 t	2,042,000 t
F_{OFL}	0.465	0.465	0.621	0.621
$maxF_{ABC}$	0.398	0.398	0.466	0.466
F_{ABC}	0.36	0.37	0.336	0.336
OFL	3,640,000 t	4,360,000 t	4,795,000 t	4,589,000 t
$maxABC$	3,120,000 t	3,740,000 t	3,603,000 t	3,448,000 t
ABC	2,800,000 t	2,979,000 t	2,592,000 t	2,467,000 t
Status	2015	2016	2016	2017
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

The Plan Teams noted that a compilation of responses to CIE reviews be included in order to maximise their benefit and to promote transparency.

A table summarizing key aspects from the three reviews conducted in 2016 and responses is provided.

Comments specific to this assessment

In the September 2016 minutes, the BSAI Plan Team recommended: " . . . that the authors develop a better prior for steepness, or at least a better rationale, and perhaps consider a meta-analytic approach.
. . . In the long term, the Team recommends evaluating the sample sizes used for the data weighting and pursuing other CIE suggestions.

Input sample size estimates for fishery and surveys were re-evaluated in 2016 and used in the recommended model below (treated as changes to the input data specification).

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 "iterative" 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). Pollock as feeders in the ecosystem have been considered to impact their forage with relatively high consumption rates as young-of-the year (e.g., 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 a pattern of movement to the southeast occurs 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). Their diets with age become more piscivorous and cannibalism has been commonly observed for 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

New information available from ecosystem survey work in the Northern Bering Sea (NBS) region (north of Nunivak Island to the Russian convention line and into Norton Sound) suggests considerably more pollock present there compared to the 2010 survey (1.3 million t in 2017 compared to 11 kt in 2010). Although the 2017 bottom temperatures were colder than recent years, the warm conditions in 2016 may have caused a portion of the pollock stock to move into this region. A loose

relationship was determined (R^2 of 0.43) between mean bottom temperature in the US zone on the EBS shelf and subsequent biomass estimates in the Navarin basin (the Russian area adjacent to the Convention Line; Ianelli et al. 2011). However, the extent that this may occur between years is unknown and more detailed evaluation of the NBS data will be forthcoming. Fortunately, genetic samples were taken from pollock and pending funding availability, should help to ascertain the extent that these fish are related to those observed in the normal EBS shelf survey area. Genetic samples taken from 2017 RACE summer survey from the Northern Bering Sea can be compared with samples from the standard Bering Sea Unimak, Pribilof, and Zhemchug, to ascertain the extent that these fish are related.

Fishery

Description of the directed fishery

Since the late 1970s, the average EBS pollock catch has been about 1.2 million t, ranging from 0.815 million t in 2009 to nearly 1.5 million t during 2003-2006 (Table 1). 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 was enacted in 1993 and only trace amounts of pollock have been harvested from the Aleutian Basin region since then. United States vessels began fishing for pollock in 1980 and by 1987 they were able to take 99% of the quota. Since 1988, only U.S. vessels have been operating in this fishery. Observers collected data aboard the foreign vessels since the late 1970s. The current observer program for the domestic fishery formally began in 1991 and has since then regularly re- evaluated the sampling protocol and making adjustments where needed to improve efficiency. Since 2011, regulations require that all vessels participating in the pollock fishery carry at least one observer. Prior to this time about 70-80% of the catch was observed at sea or during dockside offloading. 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. 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 extends into early-mid April. During this season, the fishery produces highly valued 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 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 occuring in the southeast portion of the shelf (east of 170°W longitude; Fig. 1). Since 2011, regulations and industry-based measures to reduce 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 2017 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 2015 when most fishing activity occurred farther north (Fig. 3). The 2017 A-season catch rates continued to be high following the good conditions observed in the 2016 summer-fall period (Fig. 4). Also of note for this year was that, due to a regulatory change, up to 45% of the TAC could be taken in the A-season. 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 2017 summer and fall (B-season) fishing had a pattern that seems intermediate to 2016 and 2015 (Fig. 6). The fleet-wide catch per hour fished was lower than that observed in 2016 for the B-season but was still quite good compared to other recent years (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 1991-2017 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 Council's 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 incidental catch of pollock that were below marketable sizes. 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. TACs have commonly been set well below the ABC value and catches have usually 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 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^2 inside the EEZ), the Eastern Bering Sea (968,600 km^2), and the Gulf of Alaska (1,156,100 km^2). The marine portion of Steller sea lion critical habitat in Alaska west of 150 ° W encompasses 386,770 km^2 of ocean surface, or 12% of the fishery management regions.

Prior to 1999, 84,100 km^2, or 22% of 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^2, or 13% of critical habitat). The remainder was largely management area 518 (35,180 km^2, 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^2 (21%) of critical habitat in the Aleutian Islands was closed to pollock fishing along with 43,170 km^2 (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^2 (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 38% annually. During the A-season, the average is about 42% (in part because pre-spawning pollock are more concentrated in this area during this period). The proportion of pollock caught within the SCA varies considerably, presumably due to temperature regimes and 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 followed by a preliminary value of 53% in 2017 (Table 4). The high values in recent years was 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 (~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 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 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 Groundfish 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. 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 manage chum salmon bycatch within the IPAs rather than through 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 2016

Alaska pollock is the dominant species in terms of catch in the Bering Sea & Aleutian Island (BSAI) region. In 2016 they accounted for 69% of the BSAI's FMP groundfish harvest and 88% of the total pollock harvest in Alaska. Retained catch of pollock increased 2.4% to 1.35 million t in 2016. BSAI pollock first-wholesale value was $1.35 billion 2016, which was up from $1.27 billion in 2015 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.

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,[1] 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.[2] 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 7). 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,

[1] The AFA was implemented in 1999 for catcher/processors, and in 2000 for catcher vessel and motherships.

[2] 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%).

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.[3] Additionally, pollock more broadly competes with other whitefish that, to varying degrees, can serve as substitutes 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 2.5% increase to 704 kt. The value of these deliveries (shore-based ex-vessel value) totaled $209.4 million in 2016, which was down 7.9% from the ex-vessel value in 2015, as the increased catch was offset by a 9.7% decrease in the ex-vessel price (Table 6). The first-wholesale value of pollock products was $808 million for the at-sea sector and $543 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 2016 increased for the at-sea sector and shore-based sectors, which was largely attributable to an increase in the price of roe products, though prices increased for fillets and surimi products as well.

[3] 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.

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. The price of fillets produced at-sea tend to be about 6% higher, surimi prices tend to be about 20% higher and the price of roe about 45% 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 since 2011, in part, because the shore-based sector increased their relative share of surimi production.[4]

Pollock fillets

A variety of different fillets are produced from pollock, with pin-bone-out (PBO) and deep-skin fillets accounting for approximately 70% and 30% of production in the BSAI, respectively. Total fillet production decreased 3.4% to 161 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 increased 4% to $1.41 per pound and is below the inflation adjusted average price of fillets in 2005-2007 of $1.46 per pound. Media reports indicate that headed-and-gutted (H&G) and fillet prices tended to be low throughout the year. The small size of fish in the catch, significant inventories, and insolvency of a major international pollock trader 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.[5] As recent fillet markets 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.

Surimi seafood

Surimi production continued an increasing trend through 2016, but at a more moderate rate of 1.6% to 190.8 kt which is above the 2005-2007 average. Prices have increased since 2013 to $1.19 per pound in the BSAI in 2016 (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. Industry news indicated the average size of fish caught is down, which incentivizes surimi production because it yields a higher value than fillets. Additionally, the supply of raw surimi material continues to be

[4]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.

[5]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.

constrained in Japan. The high volume of surimi production has raised concerns that prices may begin to plateau or fall, but the more favorable exchange rate with Japan in 2016 may have helped to shore up prices.

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 14.3 kt in 2016, which is 24% below production in 2015 (Fig. 8). Prices peaked in the mid-2000s and have followed a decreasing trend over the last decade which continued until 2015. In 2016 roe production from the U.S. and Russia were low as a result of a smaller average size of fish caught, which also reduced average grade of roe sold. Lower production and tight inventories put upward pressure on roe prices. Additionally, the Yen to U.S. Dollar exchange rate was more favorable in the 2016 than 2015. The net result in the BSAI was a 24% price increase in 2016 to $2.84 per pound, and value was down only 6% to $89 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 according to available records. 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	1964-2017
Fishery	Catch age composition	1964-2016
Fishery	Japanese trawl CPUE	1965-1976
EBS bottom trawl	Area-swept biomass and age-specific proportions	1982-2017
Acoustic trawl survey	Biomass index and age-specific proportions	1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006-2010, 2012, 2014, 2016
Acoustic vessels of opportunity (AVO)	Biomass index	2006-2017

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 1991-2016 (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 - 2016) 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 (~0.02%) they are ignored as a contributor to the catches as modeled 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 meth-

ods. 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 2017 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 2014-2015 bottom temperatures increased along with surface temperatures reached a new high in 2016 and dropped to more average values this year (Fig. 11) [6].

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% (Table 16). 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 2017 biomass estimate (design-based, area swept) was 4.81 million t, slightly below the average for this survey (4.84 million t). Pollock were distributed more widely in 2017 compared to recent years and were abundant in locales cooler than 2°C bottom temperatures (Fig. 12). The extent of distribution within the middle domain is more apparent in Figure 13 which shows that the split in densities observed in the 2016 survey was absent in 2017.

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 2017 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.

[6] The traditional area-swept design-based index is reported in some tables along with the density-dependent corrected index (Kotwicki et al. 2014) presented in past assessments used here.

The level of sampling for lengths and ages in the BTS is shown in (Table 17). 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 18 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 19).

As in previous assessments, a descriptive evaluation of the BTS data alone was conducted to examine mortality patterns similar to those proposed in Cotter et al. (2004). The idea is to evaluate survey data independently from the assessment model for trends. The log-abundance of age 5 and older pollock was regressed against age by cohort. The negative values estimated for the slope are estimates of total annual mortality. Age-5 was selected because younger pollock appear to still be recruiting to the bottom trawl survey gear (based on qualitative evaluation of age composition patterns). A key assumption of this analysis is that all ages are equally available to the gear. Total mortality by cohort seems to be variable (unlike the example in Cotter et al., 2004). Cohorts from the early 1990s appear to have lower total mortality than cohorts since the mid-1990s, which average around 0.4. Total mortality estimates by cohort represent lifetime averages since harvest rates (and actual natural mortality) vary from year to year. The low values estimated for some year classes (e.g., the 1991 cohort) could be because these age groups only become available to the survey at a later age (i.e., that the availability/selectivity to the survey gear changed for these cohorts). Alternatively, it may suggest some net immigration into the survey area or a period of lower natural mortality. In general, these values are consistent with the values obtained within the assessment models.

As described in the 2015 assessment, an alternative index that accounts for the efficiency of bottom-trawl gear for estimating pollock densities was used (Kotwicki et al. 2014). Based on comments from the CIE review, this index was provided in biomass units in this assessment (previously the index was for abundance). This biomass index was shown in Table 15 as noted above (the column labelled "DDC").

Other time series used in the assessment

Acoustic trawl (AT) surveys

The AT surveys are conducted biennially (most recently in 2016) 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 midwater pollock biomass (to 3m from bottom) for the shelf was above 4 million tons in the early years of the time series (Table 15). It dipped below 2 million t in 1991, and then increased and remained between 2.5 and 4 million t for about a decade (1994-2004). The early 2000s (the 'warm' period mentioned above) were characterized by low pollock recruitment, which was subsequently reflected in lower midwater biomass estimates between 2006 and 2012 (the recent 'cold' period; Honkalehto and McCarthy 2015). The midwater pollock biomass estimate from the 2016 AT survey of 4.06 million is above the average (2.76 million t; Table 21). Relative estimation errors for the total biomass were derived from a one-dimensional (1D) geostatistical method (Petitgas 1993, Walline 2007, Williamson and Traynor 1996) and account for observed spatial structure for sampling along transects. As in previous assessments, the other sources of error (e.g., target strength, trawl sampling) were accounted for by inflating the annual error estimates to have an overall average CV

of 25% for application within the assessment model (based on judgement relative to other indices). The portion of shelf-wide biomass (from surface to 3m off-bottom) estimated to be east of 170°W was 37%, compared to an average of 24% since 1994 (Table 21). Also, the distribution of pollock biomass within the SCA was similar to that found in 2014 at 13% compared to the 2007-2012 average of 7% (and 1994-2016 average of 10%).

The 2016 EBS acoustic-trawl survey estimates of population numbers at age were updated based on age-length keys from the AT survey (Fig. 15). Additionally, historical data were updated to account for the layer of pollock detected between 0.5 and 3m from the bottom (previous estimates had use pollock estimates between the surface down to 3m from the bottom only). This affected the age compositions but differences were relatively minor (Fig. 16). As noted last year, the 2016 survey observed relatively few age 1 pollock whereas age 3 (the 2013 year class) was the most abundant age group followed by four year olds (Table 22).

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) are used to compute a midwater abundance index for pollock can be found in Honkalehto et al. (2011). This index was updated this year since there was no directed acoustic-trawl survey in the EBS. This biomass series shows a steady increase for the period 2009-2015 with a slight drop in 2016 that continues in 2017 (Table 23).

A spatial comparison between the BTS data and AVO survey transects in 2016 and 2017 shows differences in the locales and densities of pollock both between years and in their vertical densities within years (Fig. 17). This figure also shows that in both years the AVO survey detects 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 1964-2017. 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 2017 EBS bottom trawl survey estimates of population numbers-at- age and biomass were added.
- The 2016 EBS acoustic-trawl survey estimate of population numbers- at-age based on the actual age data (and age-length keys) from the AT survey
- The 2016 fishery age composition data were added.

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 in 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

Based on recent reviews and feedback from the SSC and Plan Team, a few model configuration options were developed and implemented in 2016 and the main model proposed here is based on the accepted model from last year.

At the September 2016 Plan Team meetings and subsequent SSC, presentations were made describing preliminary results using the ATS data that covered the water column down to 0.5m from the bottom. Due to issues with compiling the age compositions for the new series, the plan was to incorporate and present these results in the 2017 assessment. This was completed and now, based on SSC, Plan Team, and CIE review recommendations, the time series where the acoustic return covers the bottom layer between 0.5 and 3m from bottom is included in the ATS data.

Input sample size

In 2016 we reevaluated specified sample sizes and the trade-offs with flexibility in time and age varying selectivity. This resulted in tuning the recent era (1991-present year) to average sample sizes of 350 and then 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 16.0 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., 2015 for the assessment conducted in 2016). 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. 18). 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 2017-2019 (Table 25).

Parameters estimated within the assessment model

For the selected model, 929 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment, and stock- recruitment parameters account for 77 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 1964-2016 and projected recruitment variability (using the variance of past recruitments) for five years (2018-2022). 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 2014 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 10x54 matrix of 540 parameters bringing the total fishing mortality parameters to 595. The rationale for including time- varying selectivity has recently been supported as a means to improve retrospective patterns (Szuwalksi, 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 0.25; while for the AVO data, a value relative to the AT index was estimated and gave a mean of about 0.30).
- Fishery and survey proportions-at-age estimates (multinomial with effective sample sizes presented 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 1991-2016 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

The limited models presented (with and without the revised acoustic survey biomass estimates and age compositions compared to last year's selected model, here denoted 16.0) shows a slight drop in spawning biomass estimates relative to last year (Fig. 19). The recent recruitment pattern (at age 1) shows an increase in the 2014 value (representing the 2013 year-class) but was otherwise quite similar (Fig. 20). Based on past recommendations by the CIE, SSC, and Plan Team, the model using the acoustic trawl survey data extending from the surface to 0.5m from the bottom (16.0a) was selected for this year's reference/base model.

The fits to the bottom-trawl survey biomass (the density-dependent corrected series) appears to be reasonable (Fig. 21). Similarly, the fits to the acoustic-trawl survey biomass series is consistent with the specified observation uncertainty (Fig. 22).

The estimated parameters and standard errors are provided online and summary model results are given in Table 26. The code for the model (with dimensions and links to parameter names) and input files are available upon 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. 23; 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. 24). The model fits the fishery age- composition data quite well under this form of selectivity (Fig. 25). The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) is consistent with the population trends

for this period (Fig. 26). The fit to the fishery- independent index from the 2006-2017 AVO data shows a relatively stable trend in recent years (Fig. 27).

Bottom-trawl survey selectivity (Fig. 28) 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. 21). 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. 29). In 2017 the model predicted higher proportions of age 5 and age 9 than observed whereas the survey observations indicated a higher-than-expected proportion of 4-year olds (the 2013 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. 22). The AT age compositions consistently track large year classes through the population and the model fits these patterns reasonably well (Fig. 30).

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 totalled 5,000). A pairwise comparison for some key parameters could be evaluated (along with their marginal distributions; Fig. 31). To compare the point estimates (highest posterior density) with the mean of the posterior marginal distribution, overplotting the former on the latter for the 2017 spawning biomass estimate were nearly identical (Fig. 32).

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 1981-88, with estimates ranging from 8 to 12 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 following the low in 2008 of 4.9 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. 33). 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. 34). The estimates of age 3+ pollock biomass were mostly higher than the estimates from previous years (Fig. 35, Table 31).

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. 36).

Recruitment

Model estimates indicate that both the 2008 and 2012 year classes are well above average (Fig. 37). 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. 38). 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. 39).

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. 40) Although the variability is high, the average bias appears to be low with Mohn's ρ equal to -0.01 for the 10 year retrospective and 0.015 if extended back 20-years.

Harvest recommendations

The estimate of B_{MSY} is 2,042 kt (with a CV of 23%) which is less than the projected 2018 spawning biomass of 3,700 kt; (Table 26). For 2017, the Tier 1 levels of yield are 3,603,000 t from a fishable biomass estimated at around 7,724 kt (Table 27). Estimated numbers-at-age are presented

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

Model results indicate that spawning biomass will be above $B_{40\%}$ (3,700 kt) in 2018 and about 180% of the B_{MSY} level. The probability that the current stock size is below 20% of B_0 (based on estimation uncertainty alone) is <0.1% for 2018 and 2019.

A diagnostic (see appendix on model details) on the impact of fishing shows that the 2017 spawning stock size is about 68% of the predicted value had no fishing occurred since 1978 (Table 26). This compares with the 63% of B_{100}% (based on the SPR expansion using mean recruitment from 1978-2015) and 190% 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.

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 (FABC) 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:

B_{MSY} = 2,042 kt female spawning biomass
B_0 = 5,394 kt female spawning biomass
$B_{100\%}$ = 6,137 kt female spawning biomass
$B_{40\%}$ = 2,455 kt female spawning biomass
$B_{35\%}$ = 2,148 kt female spawning biomass

Specification of OFL and Maximum Permissible ABC

Assuming the stock-recruit relationship the 2018 spawning biomass is estimated to be 3,678,000 t (at the time of spawning, assuming the stock is fished at about recent catch levels). This is above the B_{MSY} value of 2,042,000 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 2018 female spawning biomass is estimated to be above the B_{MSY} level (2,042 kt) and the $B_{40\%}$ value (2,455 kt) in 2018 and if the 2017 catch is as specified above, then the OFL and

maximum permissible ABC values by the different Tiers would be:

Tier	Year	MaxABC	OFL
1a	2018	3,603,000	4,795,000
1a	2019	3,448,000	4,589,000
3a	2018	2,592,000	3,189,000
3a	2019	2,467,000	3,028,000

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. 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 2017 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2018 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year- end) catch assumed for 2017. 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 follow ("$maxFABC$" refers to the maximum permissible value of FABC under Amendment 56):

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

Scenario 2: In 2019 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 2016 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 2017 or 2) below half of its MSY level in 2017 or below its MSY level in 2027 under this scenario, then the stock is overfished.)

Scenario 7: In 2018 and 2019, F is set equal to $maxFABC$, 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 2019 or 2) below 1/2 of its MSY level in 2019 and expected to be below its MSY level in 2029 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. These two scenarios are as follow (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 max FABC value and use $F_{35\%}$ as a proxy for F_{MSY}. Scenarios 1 through 7 were projected 14 years from 2017 (Tables 32 through 35). Under the maximum permissible catch level in Tier 3, the expected spawning biomass will decline until 2020 and stabilize slightly above $B_{40\%}$ (in expectation, Fig. 41).

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 2017:

- If spawning biomass for 2017 is estimated to be below 1/2 $B_{35\%}$ the stock is below its MSST.
- If spawning biomass for 2017 is estimated to be above $B_{35\%}$, the stock is above its MSST.
- If spawning biomass for 2017 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 32 through 35). If the mean spawning biomass for 2027 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 2019 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 2029 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 2017, and it is not expected to be approaching an overfished condition based on Scenario 7 (the mean spawning biomass in 2017 is above the $B_{35\%}$ level; (Table 35). Based on this, the EBS pollock stock is being fish below the overfishing level and the stock size is above the overfished level and projected to stay above based on the national status determination criteria.

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 2017 spawning biomass (3,870 kt) which is about 190% of B_{MSY} (2,042 kt). The replacement yield—defined as the catch next year that is expected to achieve a 2018 spawning biomass estimate equal to that from 2017–is estimated to be about 560 t.

The EBS pollock stock appears to have rebounded from the 2008 low point and shows significant increases due to two strong year classes (2008 and 2012). However, there remain several concerns about the medium-term stock conditions. Namely,

1. The conditions in summer 2017 followed a warm period, precaution may be warranted since warm conditions are thought to negatively affect the survival of larval and juvenile pollock.
2. The near-term prognosis for survey found very few one-year-old pollock in summer 2016 and 2017 (the BTS data show below average 1-year olds).
3. The recent BTS data continue to show low abundances of pollock aged 10 and older (Table 18). 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. There is apparently a considerable amount of pollock showing up in the northern part of the shelf beyond the traditional survey area (on the order of 1.3 million t). The extent that these fish are related to those that might move back to the normal fishing areas is unknown (in 2010 the ecosystem survey of the NBS showed very few pollock).
5. The multispecies model suggests that the B_{MSY} level is around 3.6 million t instead of the ~2 million t estimated in the current assessment (noting that the total natural mortality is higher in the multispecies model).
6. Pollock are an important prey species for the ecosystem and apparent changes in the distribution may shift their availability as prey.
7. Whilst outside of ABC considerations, it seems that maintaining the stock at relatively high levels and achieving fishery catch rates observed since 2016 may help with keeping Chinook and other salmon bycatch impacts at their esimated low levels.

8. Finally, given the same estimated aggregate fishing effort in 2017, the estimated stock trend is downwards except at low catch levels (a replacement yield of 560 kt is the amount that would maintain the spawning stock constant). Furthermore, the ability to catch the same amount as in 2017 through to 2021 will require about 25% more effort with a decline in spawning biomass of about 20% compared to the current level (based on expected average recruitment; Fig. 42).

Given these factors, a 2018 ABC of 2,592,000 t is recommended based on the Tier 3 estimates as conservatively selected by the SSC since 2014. We recognize that the actual catch will be constrained by other factors (the 2 million t OY BSAI groundfish catch limit; bycatch avoidance measures). The alternative maximum permissible Tier 1a ABC seems clearly risky. Such high catches would result in unprecedented variability and removals from the stock (and considerably more capacity and effort). Adopting a more stable catch system would also result in less spawning stock variability.

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 39). Unlike the food-web models discussed above, examining predators and prey in isolation may overly simplify relationships. This table serves to highlight the main connections and the status of our understanding or lack thereof.

Ecosystem effects on the EBS pollock stock

The pollock stock condition appears to have benefitted 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 abudance 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 37). 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 represent less than 1% of the total pollock catch. Incidental catch of Pacific cod has increased since 1999 but remains below the 1997 levels (Table 36). The incidental catch of flatfish was variable over time and has increased, particularly for yellowfin sole. Proportionately, the incidental catch has decreased since the overall levels of pollock catch have increased. In fact, the bycatch of pollock in other target fisheries is more than double the bycatch of target species in the pollock fishery (Table 38).

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 (more than double the 2003-2017 average of 227 thousand fish; Table 39). Chinook salmon bycatch has also increased steadily since 2012 with the 2017 counts at just over 30,000 (which is 18% below the 2003-2017 mean value). However, this is the highest value since the implementation of Amendment 91 in 2011 (Table 39). 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 will be provided in the future.

Data gaps and research priorities

The available data for EBS pollock are extensive yet many processes behind the observed patterns are poorly understood. For example, the northern Bering Sea ecosystem survey conducted in 2017 found substantial amounts of pollock compared to the previous survey done in 2010. Research on developing and testing plausible hypotheses about the underlying processes that cause such observations is needed. This should include examining potential effects of temporal changes in survey stations and using spatial processes for estimation purposes (e.g., combining acoustic and bottom trawl survey data). The application of the geostatistical methods (presented for comparative purposes in the 2016 assessment) seems like a reasonable approach to statistically model disparate data sources for generating better abundance indices.

More studies on spatial dynamics, including 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.

Many studies have found inconclusive evidence for genetic population structure in walleye pollock.

Knowledge of stock structure is particularly important for this species, given its commercial importance and continued questions about geographic extent into the Russian zone and the northern Bering Sea. Therefore, **funding for a large scale study using the highest resolution genetic tools available is recommended.** Samples have been coordinated and are continuing with plans for samples from the February 2018 Bogoslof Island region survey. This study is occurring at a criticul juncture and funding for processing these samples is needed.

Acknowledgements

We thank the staff of the AFSC age-and-growth department for their continued excellence in promptly processing the samples used in this assessment. The work of many individuals involved in collecting and processing survey and observer data is greatly appreciated. Finally, thanks to the many colleagues who provided edits and suggestions to improve this document.

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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, 1979-2017 (2017 values through October 25th 2017). The southeast area refers to the EBS region east of 170W; the Northwest is west of 170W. Note: 1979-1989 data are from Pacfin, 1990-2017 data are from NMFS Alaska Regional Office, and include discards. The 2017 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	255,131	555,075	810,206	1,235		176
2011	747,890	451,151	1,199,041	1,208		173
2012	618,869	586,343	1,205,212	975		71
2013	695,669	575,099	1,270,768	2,964		57
2014	858,240	439,180	1,297,420	2,375		427
2015	696,249	625,332	1,321,581	915		733
2016	1,167,140	185,567	1,352,707	1,257		1,005
2017	1,164,848	178,370	1,343,217	1,384		186
Avg.	782,618	416,552	1,199,169	26,084	697,696	31,484

Table 2: Time series of 1964-1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977-2017 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports. Note that the 2017 value is based on catch reported to October 25th 2017 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	3,640,000	2,800,000	1,343,217
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, 1991-2017. SE represents the EBS east of 170W, NW is the EBS west of 170W, source: NMFS Blend and catch-accounting system database. 2017 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%)	57,578 (10%)	71,194 (9%)	131,998 (9%)	52,362	241	559,741	830,559	1,442,902
1993	1,740 (3%)	308 (35%)	26,100 (11%)	83,986 (8%)	112,135 (8%)	57,138	886	232,173	1,094,429	1,384,627
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%)	94,219 (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	971,388	1,125,965
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 (63%)	20 (67%)	1,942 (1%)	19,678 (2%)	22,429 (2%)	1,244	29	293,532	839,177	1,133,984
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 (%)	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%)	17,242 (1%)	1,649	24	557,588	933,191	1,492,452
2004	287 (25%)	(100%)	2,781 (1%)	20,380 (2%)	23,448 (2%)	1,158	0	390,544	1,090,008	1,481,710
2005	324 (20%)	(89%)	2,586 (%)	14,838 (2%)	17,747 (1%)	1,621	0	680,868	802,154	1,484,643
2006	311 (18%)	(50%)	3,677 (1%)	11,877 (1%)	15,865 (1%)	1,745	0	660,824	827,207	1,489,776
2007	425 (17%)	(tr)	3,769 (1%)	12,334 (2%)	16,529 (1%)	2,519	0	626,253	728,249	1,357,021
2008	81 (6%)	(tr)	1,643 (%)	5,968 (1%)	7,692 (1%)	1,278	9	507,880	482,698	991,865
2009	395 (24%)	6 (8%)	1,936 (%)	4,014 (1%)	6,351 (1%)	1,662	73	452,532	358,252	812,520
2010	142 (12%)	53 (30%)	1,197 (%)	2,510 (1%)	3,903 (tr)	1,235	176	555,075	255,131	811,618
2011	75 (6%)	23 (13%)	1,332 (%)	3,444 (tr)	4,873 (tr)	1,208	173	451,151	747,890	1,200,422
2012	95 (10%)	(tr)	1,186 (%)	4,187 (1%)	5,468 (tr)	975	71	586,343	618,869	1,206,258
2013	108 (4%)	(1%)	1,227 (%)	4,145 (1%)	5,480 (tr)	2,964	57	575,099	695,669	1,273,788
2014	138 (6%)	54 (13%)	1,787 (%)	12,568 (1%)	14,546 (1%)	2,375	427	439,180	858,240	1,300,222
2015	19 (2%)	138 (19%)	2,419 (%)	7,062 (1%)	9,639 (1%)	915	733	625,332	696,249	1,323,229
2016	59 (5%)	7 (1%)	993 (1%)	8,197 (1%)	9,256 (1%)	1,257	1,005	185,567	1,167,140	1,354,968
2017	17 (1%)	2 (1%)	1,083 (1%)	5,911 (1%)	7,013 (1%)	1,384	186	178,370	1,164,848	1,344,787

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), 1998-2017. The 2017 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 (4%)	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%)

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 https://alaskafisheries.noaa.gov/fisheries/chinook-salmon-bycatch-management for update and general information)
2016	Measures of amendment 110 go into effect for 2017 fishing season; Chinook salmon runs above the 3-run index value so bycatch limits stay the same
2017	Due to amendment 110 about 45% of the TAC is taken in the A-season (traditionally only 40% was allowed).

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, and annual from 2011-2016.

	Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015	2016
				All Sectors				
Catch kt	1,444	872	1,200	1,206	1,274	1,300	1,323	1,355
Retained Catch kt	1,427	866	1,195	1,200	1,267	1,285	1,314	1,346
Vessels	110	121	118	122	121	121	120	121
				Catcher Vessels (Trawl)				
Retained Catch kt	768.67	459	630	632	661	668	687	704
Ex-vessel Value M $	$213.60	$183.80	$229.40	$241.30	$218.70	$226.50	$227.40	$209.40
Ex-vessel Price/lb $	$0.13	$0.18	$0.16	$0.17	$0.15	$0.16	$0.15	$0.14
CV ret. catch share	53.90%	53.00%	52.70%	52.70%	52.20%	52.00%	52.30%	52.30%
Vessels	89	89	86	90	87	87	87	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, and annual from 2011-2016.

	Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015	2016
				BSAI				
All Products Volume kt	498.25	355.99	483.11	472.72	506.84	525.54	520.94	534.89
All Products Value M$	$1,246.4	$1,133.4	$1,351.1	$1,381.0	$1,242.1	$1,301.2	$1,272.5	$1,351.5
All Products Price lb $	$1.13	$1.44	$1.27	$1.33	$1.11	$1.12	$1.11	$1.15
Fillets Volume kt	162.70	113.90	161.22	146.55	170.87	175.78	167.01	161.29
Fillets Price lb $	$1.24	$1.73	$1.55	$1.55	$1.44	$1.37	$1.35	$1.41
Fillets Value share	36%	38%	41%	36%	44%	41%	39%	37%
Surimi Volume kt	173.05	100.99	141.00	157.15	161.66	171.33	187.74	190.82
Surimi Price lb $	$0.96	$1.63	$1.28	$1.43	$1.00	$1.10	$1.14	$1.19
Surimi Value share	29%	32%	29%	36%	29%	32%	37%	37%
Roe Volume kt	27.03	17.63	18.03	16.48	13.91	20.60	18.75	14.26
Roe Price lb $	$4.84	$4.14	$3.63	$4.32	$3.33	$2.92	$2.29	$2.84
Roe Value share	23%	14%	11%	11%	8%	10%	7%	7%
At-sea price premium ($/lb)	$0.30	$0.32	$0.20	$0.25	$0.13	$0.15	$0.25	$0.25

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, and annual from 2011-2016.

	Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015	2016	2017
Global Pollock Catch kt	2,854	2,662	3,211	3,272	3,239	3,245	3,373	-	-
US Share	52%	35%	40%	40%	42%	44%	44%	-	-
Russian	37%	53%	49%	50%	48%	47%	48%	-	-
Export Volume kt	278.9	192.2	303.5	314.7	360.4	395.0	377.8	378.6	222.5
Export Value M $	$867.4	$635.2	$924.3	$938.4	$968.1	$1,081.7	$1,038.2	$988.8	$594.5
Export Price/lb $	1.41	1.50	$1.38	$1.35	$1.22	$1.24	$1.25	$1.18	$1.21
Japan Volume Share	34.4%	26.6%	20.6%	24.0%	18.2%	22.1%	25.0%	20.1%	23.0%
Japan Value share	38.1%	26.3%	18.7%	22.1%	17.2%	21.7%	25.5%	20.3%	25.6%
China Volume Share	3.1%	9.0%	13.1%	11.2%	14.7%	14.7%	12.7%	11.7%	15.0%
China Value share	2.2%	6.9%	10.8%	9.0%	11.8%	12.0%	10.5%	9.7%	12.5%
Germany Volume Share	16.7%	19.9%	20.6%	22.2%	22.8%	23.4%	21.4%	19.3%	11.1%
Germany Value share	14.5%	21.2%	21.1%	22.8%	24.2%	24.3%	21.3%	19.2%	11.0%
Fish Volume Share	32.7%	52.2%	50.5%	47.0%	51.2%	53.8%	49.2%	49.3%	45.3%
Fish Value share	27.2%	48.5%	48.8%	45.4%	50.8%	51.6%	46.2%	46.3%	41.9%
Surimi Volume Share	56.9%	45.7%	43.8%	48.0%	44.6%	40.7%	45.4%	47.0%	46.7%
Surimi Value share	37.5%	32.7%	34.1%	42.1%	37.4%	34.3%	39.2%	42.4%	39.8%
Roe Volume Share	10.4%	8.2%	5.8%	5.1%	4.2%	5.5%	5.4%	3.7%	8.0%
Roe Value share	35.3%	22.8%	17.1%	12.6%	11.8%	14.1%	14.6%	11.2%	18.2%

Notes: 2017 data thru July; Exports are from the US and are note specific to the BSAI region. 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, 2008-2010 average, and 2011-2016.

	Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015	2016
All Sectors	1.26	2.04	1.79	1.61	1.90	2.20	1.85	2.07
Shoreside	2.07	2.57	2.00	1.89	2.11	2.42	1.94	2.28
At-sea	0.31	1.42	1.55	1.31	1.67	1.96	1.74	1.84

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 10: Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2016. 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
Avg.	3.7	55.9	210.7	375.4	376.7	323.6	207.8	114.0	64.7	33.8	23.8	12.0	8.3	11.7	1,822

Table 11: Numbers of pollock NMFS observer samples measured for fishery catch length frequency (by sex and strata), 1977-2016.

Length Frequency samples							
	A Season		B Season SE		B Season NW		
Year	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

Table 12: Number of EBS pollock measured for weight and length by sex and strata as collected by the NMFS observer program, 1977-2016

	Weight-length samples						
	A Season		B Season SE		B Season NW		
	Males	Females	Males	Females	Males	Females	Total
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	4,826	5,128	5,950	5,674	920	784	23,282

Table 13: Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2016, as sampled by the NMFS observer program.

	A Season		B Season SE		B Season NW		
	Males	Females	Males	Females	Males	Females	Total
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

Table 14: NMFS total pollock research catch by year in t, 1964-2017.

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	213
1981	466	1999	299		

Table 15: Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979 - 2017 (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 (the column labelled DDC contains the values obtained from the Kotwicki et al. density-dependence correction method.

	Bottom trawl survey		AT	AT %		Near bottom
Year	Design-based	DDC	Survey	age 3+	Total	biomass
1979			7.458	22%		
1980						
1981						
1982	2.856	4.069	4.901	95%	7.757	37%
1983	6.258	8.409				
1984	4.894	6.409				
1985	5.955	8.250	4.799	97%	10.754	55%
1986	4.897	6.826				
1987	5.498	7.892				
1988	7.289	11.088	4.675	97%	11.964	61%
1989	6.55	9.796				
1990	7.316	11.900				
1991	5.13	7.390	1.454	46%	6.584	78%
1992	4.583	6.211				
1993	5.631	7.089				
1994	5.027	7.100	2.886	85%	7.913	64%
1995	5.478	9.107				
1996	3.415	4.080	2.311	97%	5.726	60%
1997	3.8	5.019	2.591	70%	6.391	59%
1998	2.781	3.510				
1999	3.798	5.455	3.285	95%	7.083	54%
2000	5.281	7.355	3.049	95%	8.33	63%
2001	4.197	5.440				
2002	5.033	6.771	3.622	82%	8.655	58%
2003	8.392	13.508				
2004	3.863	5.106	3.307	99%	7.17	54%
2005	5.321	6.696				
2006	3.045	3.886	1.56	98%	4.605	66%
2007	4.338	6.145	1.769	89%	6.107	71%
2008	3.023	3.994	0.997	76%	4.02	75%
2009	2.282	2.990	0.924	78%	3.206	71%
2010	3.738	5.132	2.323	65%	6.061	62%
2011	3.112	3.949				
2012	3.487	4.614	1.843	71%	5.33	65%
2013	4.575	6.115				
2014	7.43	10.331	3.439	65%	10.869	68%
2015	6.394	8.587				
2016	4.91	6.608	4.063	97%	8.973	55%
2017	4.814	6.256				
Average	4.843	6.752	2.763	85%	7.14	62%

Table 16: Survey biomass estimates (age 1+, t) of Eastern Bering Sea pollock based on area-swept expansion methods from NMFS bottom trawl surveys 1982 - 2017.

	Survey biomass			
Year	Strata 1-6	Strata 8-9	Total	%NW
1982	2,858,400	54,469	2,912,869	98%
1983	5,921,380			
1984	4,542,405			
1985	4,560,122	637,881	5,198,003	12%
1986	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	137,547	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%
Avg.	4,524,947	248,476	4,721,160	5%

Table 17: Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982-2017.

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

Table 18: 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.

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	10,764
Avg	1,427	496	803	1,470	2,030	1,844	1,241	746	450	317	215	147	86	45	68	11,387

Table 19: Mean EBS pollock body mass (kg) at age as observed in the summer NMFS bottom trawl survey, 1982-2017.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1982	0.031	0.072	0.164	0.343	0.420	0.652	1.019	1.123	1.192	1.334	1.571	1.582	1.766	1.588	2.458
1983	0.017	0.140	0.239	0.360	0.493	0.585	0.720	1.073	1.177	1.055	1.121	1.174	1.487	1.018	1.699
1984	0.015	0.063	0.249	0.358	0.476	0.615	0.754	1.003	1.213	1.390	1.507	1.664	1.346	1.422	2.117
1985	0.018	0.084	0.192	0.385	0.468	0.626	0.763	0.864	1.361	1.155	1.286	1.659	1.579	1.600	2.565
1986	0.012	0.091	0.184	0.348	0.465	0.636	0.714	0.857	1.005	1.258	1.281	1.084	2.164	2.090	2.408
1987	0.017	0.109	0.217	0.335	0.424	0.531	0.699	0.798	0.874	0.993	1.131	1.393	1.697	1.965	2.251
1988	0.017	0.098	0.276	0.344	0.437	0.512	0.588	0.735	0.829	0.995	1.135	1.227	1.643	0.860	1.573
1989	0.016	0.089	0.173	0.368	0.431	0.522	0.619	0.684	0.932	0.922	1.052	1.044	1.102	1.155	1.229
1990	0.014	0.099	0.153	0.382	0.493	0.569	0.592	0.713	0.737	1.039	1.046	1.108	1.175	1.241	1.399
1991	0.019	0.121	0.164	0.323	0.492	0.577	0.690	0.732	0.874	0.911	1.084	1.184	1.211	1.302	1.694
1992	0.014	0.114	0.283	0.365	0.509	0.616	0.764	0.850	0.899	0.975	1.082	1.231	1.302	1.331	1.292
1993	0.014	0.058	0.319	0.462	0.517	0.580	0.679	0.802	0.985	1.024	1.145	1.259	1.347	1.523	1.594
1994	0.013	0.069	0.227	0.473	0.566	0.638	0.720	0.915	1.155	1.122	1.189	1.293	1.373	1.534	1.522
1995	0.013	0.068	0.138	0.379	0.492	0.639	0.639	0.769	0.913	1.148	1.174	1.282	1.340	1.391	1.528
1996	0.017	0.070	0.140	0.298	0.498	0.600	0.742	0.806	0.970	1.021	1.335	1.387	1.427	1.540	1.539
1997	0.016	0.069	0.230	0.337	0.403	0.543	0.699	0.792	0.993	1.016	1.137	1.287	1.249	1.501	1.580
1998	0.016	0.069	0.184	0.337	0.473	0.515	0.671	0.797	0.882	0.918	1.091	1.311	1.290	1.721	1.759
1999	0.015	0.074	0.182	0.335	0.392	0.554	0.621	0.769	0.937	0.956	1.099	1.184	1.554	1.724	1.853
2000	0.011	0.062	0.208	0.357	0.444	0.518	0.637	0.703	0.776	0.919	1.135	1.177	1.347	1.396	1.818
2001	0.015	0.074	0.165	0.368	0.493	0.595	0.682	0.748	0.839	0.885	1.096	1.201	1.395	1.345	1.645
2002	0.012	0.075	0.231	0.365	0.512	0.626	0.653	0.798	0.879	0.905	0.934	1.076	1.145	1.409	1.809
2003	0.022	0.095	0.303	0.429	0.571	0.660	0.748	0.846	0.873	0.969	0.974	1.002	1.010	1.170	1.218
2004	0.020	0.092	0.270	0.470	0.547	0.676	0.757	0.785	0.937	0.938	1.043	1.044	1.103	1.351	1.402
2005	0.019	0.078	0.192	0.398	0.522	0.600	0.701	0.807	0.885	0.913	1.011	1.065	1.089	1.189	1.294
2006	0.009	0.078	0.135	0.368	0.517	0.605	0.726	0.804	0.912	1.039	1.097	1.174	1.265	1.242	1.343
2007	0.012	0.091	0.301	0.446	0.549	0.671	0.773	0.848	0.928	1.054	1.124	1.093	1.297	1.282	1.391
2008	0.014	0.050	0.225	0.421	0.527	0.638	0.759	0.859	0.929	1.060	1.214	1.190	1.336	1.506	1.563
2009	0.011	0.070	0.215	0.410	0.584	0.689	0.846	0.908	0.954	1.156	1.186	1.439	1.412	1.548	1.776
2010	0.019	0.072	0.244	0.402	0.541	0.675	0.908	0.975	1.012	1.110	1.141	1.267	1.423	1.529	1.927
2011	0.015	0.106	0.238	0.445	0.553	0.647	0.804	0.989	1.108	1.160	1.247	1.303	1.429	1.448	1.643
2012	0.014	0.075	0.214	0.357	0.530	0.669	0.812	0.885	1.212	1.246	1.302	1.333	1.424	1.636	1.860
2013	0.017	0.061	0.239	0.418	0.492	0.617	0.829	0.966	1.087	1.239	1.295	1.352	1.447	1.584	1.607
2014	0.016	0.097	0.264	0.352	0.476	0.603	0.660	0.891	0.981	1.121	1.280	1.308	1.397	1.459	1.656
2015	0.019	0.087	0.288	0.379	0.510	0.592	0.717	0.804	1.056	1.071	1.306	1.630	1.304	1.469	1.624
2016	0.022	0.080	0.225	0.437	0.513	0.606	0.694	0.774	0.842	0.915	1.039	0.911	1.328	1.564	1.540
2017	0.022	0.093	0.204	0.402	0.534	0.607	0.695	0.758	0.827	0.836	0.958	0.804	1.198	1.319	1.593

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.

	Hauls				Lengths				Otoliths				Number aged			
Year	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	

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, 1994-2016 (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).

		Area			Biomass		
Year	Date	(nmi)^2	SCA	E170-SCA	W170	3m total	0.5m total
1994	9 Jul - 19 Aug	78,251	0.312	0.399	2.176	2.886	3.640
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	4.330
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	100,053	0.516	1.005	2.542	4.063	4.829

Table 22: AT survey estimates of EBS pollock abundance-at-age (millions), 1979-2016. Age 2+ totals and age-1s were modeled as separate indices. CVs were based on relative error estimates and assumed to average 20% (since 1982; note also that this applies to abundance totals, currently the model is tuned to ATS biomass with CV assumption of 25% based on reviews and relative errors compared to the BTS).

	Age										Age		
Year	1	2	3	4	5	6	7	8	9	10+	2+	CV	Total
1979	69,110	41,132	3,884	413	534	128	30	4	28	161	46,314	250%	115,424
1982	108	3,401	4,108	7,637	1,790	283	141	178	90	177	17,805	20%	17,913
1985	2,076	929	8,149	898	2,186	1,510	1,127	130	21	15	14,965	20%	17,041
1988	11	1,112	3,586	3,864	739	1,882	403	151	130	414	12,280	20%	12,292
1991	639	5,942	967	215	224	133	120	39	37	53	7,730	20%	8,369
1994	983	4,094	1,216	1,833	2,262	386	107	97	54	193	10,242	18%	11,225
1996	1,800	567	552	2,741	915	634	585	142	39	140	6,314	15%	8,114
1997	13,251	2,879	440	536	2,327	546	313	291	75	178	7,584	14%	20,834
1999	607	1,780	3,717	1,810	652	398	1,548	526	180	233	10,844	22%	11,451
2000	460	1,322	1,230	2,588	1,012	327	308	950	278	246	8,260	12%	8,721
2002	723	4,281	3,931	1,435	839	772	389	149	184	641	12,621	12%	13,344
2004	83	313	1,216	3,118	1,637	568	291	281	121	265	7,809	14%	7,892
2006	525	217	291	654	783	659	390	145	75	166	3,380	15%	3,904
2007	5,775	1,041	345	478	794	729	407	241	98	126	4,258	17%	10,034
2008	71	2,915	1,047	166	161	288	235	136	102	107	5,156	30%	5,227
2009	5,197	816	1,733	277	68	84	117	93	65	89	3,341	34%	8,538
2010	2,568	6,404	984	2,295	446	73	33	37	38	85	10,395	24%	12,963
2012	177	1,989	1,693	2,710	280	367	113	36	25	98	7,309	24%	7,487
2014	4,751	8,655	969	1,161	1,119	1,770	740	170	79	87	14,750	24%	19,501
2016	353	1,185	4,546	4,439	1,194	487	557	650	130	119	13,307	24%	13,660
Avg.	2,488	2,564	1,594	1,749	966	539	409	263	103	185	8,371	20%	10,860
Med.	723	1,780	1,216	1,810	839	487	313	149	79	140	7,809	18%	10,034

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 (5%)	25%
2007	1.769 (4%)	0.638 (9%)	43%
2008	0.997 (8%)	0.316 (6%)	32%
2009	0.924 (9%)	0.285 (12%)	60%
2010	2.323 (6%)	0.679 (9%)	43%
2011	$-no\,survey-$	0.543 (6%)	29%
2012	1.843 (4%)	0.661 (6%)	31%
2013	$-no\,survey-$	0.694 (4%)	19%
2014	3.439 (5%)	0.897 (4%)	21%
2015	$-no\,survey-$	0.953 (5%)	23%
2016	4.063 (2%)	0.750 (3%)	16%
2017	$-no\,survey-$	0.730 (3%)	17%

Table 24: Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964-2017. 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		105	

Table 25: Mean weight-at-age (kg) estimates from the fishery (1991-2016) showing the between-year variability (middle row) and sampling error (bottom panel) based on bootstrap resampling of observer data.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1964-90	0.007	0.170	0.303	0.447	0.589	0.722	0.84	0.942	1.029	1.102	1.163	1.212	1.253	1.286	1.312
1991	0.007	0.150	0.286	0.476	0.604	0.728	0.839	0.873	1.014	1.127	1.129	1.251	1.240	1.308	1.249
1992	0.007	0.179	0.394	0.462	0.647	0.701	0.812	0.982	1.031	1.210	1.226	1.272	1.199	1.340	1.430
1993	0.007	0.331	0.497	0.610	0.650	0.754	0.904	1.039	1.211	1.232	1.391	1.538	1.610	1.646	1.584
1994	0.007	0.233	0.405	0.651	0.728	0.747	0.707	1.057	1.395	1.347	1.347	1.391	1.394	1.301	1.341
1995	0.007	0.153	0.377	0.498	0.735	0.840	0.856	0.986	1.220	1.315	1.388	1.477	1.390	1.297	1.341
1996	0.007	0.293	0.323	0.427	0.679	0.794	0.949	0.953	1.020	1.096	1.362	1.500	1.520	1.710	1.598
1997	0.007	0.187	0.315	0.471	0.559	0.747	0.893	1.072	1.091	1.243	1.346	1.443	1.668	1.423	1.383
1998	0.007	0.191	0.368	0.589	0.627	0.621	0.775	1.029	1.169	1.253	1.327	1.452	1.414	1.523	1.537
1999	0.007	0.188	0.405	0.507	0.643	0.701	0.728	0.891	1.037	1.250	1.248	1.431	0.990	0.516	1.236
2000	0.007	0.218	0.353	0.526	0.629	0.731	0.782	0.806	0.966	1.007	1.242	1.321	1.101	1.165	1.466
2001	0.007	0.227	0.327	0.503	0.669	0.788	0.958	0.987	1.063	1.115	1.314	1.435	1.563	1.433	1.467
2002	0.007	0.231	0.386	0.509	0.666	0.795	0.910	1.029	1.104	1.095	1.288	1.448	1.597	1.343	1.683
2003	0.007	0.276	0.489	0.547	0.649	0.767	0.862	0.953	1.081	1.200	1.200	1.206	1.362	1.377	1.699
2004	0.007	0.135	0.409	0.583	0.640	0.758	0.889	0.924	1.035	1.162	1.110	1.160	1.333	1.281	1.213
2005	0.007	0.283	0.346	0.508	0.642	0.741	0.882	0.954	1.062	1.096	1.225	1.276	1.251	1.174	1.373
2006	0.007	0.174	0.305	0.447	0.606	0.755	0.853	0.952	1.065	1.114	1.219	1.234	1.282	1.399	1.462
2007	0.007	0.155	0.346	0.506	0.641	0.781	0.962	1.098	1.182	1.275	1.304	1.477	1.500	1.738	1.520
2008	0.007	0.208	0.330	0.520	0.652	0.774	0.903	1.049	1.119	1.282	1.421	1.524	1.553	1.921	1.660
2009	0.007	0.136	0.340	0.526	0.704	0.879	1.002	1.125	1.399	1.490	1.563	1.614	1.814	1.996	2.230
2010	0.050	0.175	0.383	0.489	0.664	0.915	1.119	1.261	1.371	1.587	1.659	1.924	1.923	2.079	2.316
2011	0.031	0.205	0.290	0.509	0.665	0.808	0.976	1.225	1.346	1.518	1.585	1.621	2.176	1.754	2.287
2012	0.029	0.142	0.270	0.410	0.643	0.824	0.974	1.172	1.306	1.519	1.614	1.644	1.717	2.040	2.086
2013	0.095	0.144	0.289	0.442	0.564	0.782	1.131	1.284	1.426	1.692	1.834	1.806	1.960	2.187	2.207
2014	0.014	0.193	0.316	0.455	0.617	0.751	0.894	1.154	1.310	1.370	1.692	1.815	1.733	1.658	2.236
2015	0.025	0.181	0.403	0.463	0.571	0.690	0.786	0.887	1.145	1.201	1.378	1.892	1.452	1.603	2.627
2016	0.025	0.181	0.407	0.531	0.557	0.648	0.732	0.801	0.943	1.047	1.201	0.637	1.088	1.870	1.638
Avg	0.015	0.199	0.360	0.506	0.640	0.762	0.888	1.021	1.158	1.263	1.370	1.453	1.493	1.542	1.687
CV	NA	26%	16%	11%	7%	8%	12%	13%	13%	14%	13%	18%	19%	23%	24%
Sampling CV (from bootstrap), ages 1 and 2 were excluded															
1991			2%	2%	2%	2%	1%	4%	2%	7%	3%	7%	4%	7%	5%
1992			1%	2%	3%	2%	2%	2%	4%	3%	4%	5%	14%	8%	9%
1993			1%	0%	2%	3%	3%	4%	3%	5%	6%	10%	11%	16%	12%
1994			3%	1%	1%	2%	5%	13%	7%	7%	6%	7%	8%	15%	8%
1995			2%	2%	1%	1%	2%	4%	7%	8%	7%	14%	8%	53%	9%
1996			2%	4%	2%	1%	1%	2%	4%	6%	18%	11%	9%	12%	13%
1997			3%	1%	1%	1%	2%	2%	4%	8%	14%	14%	23%	9%	9%
1998			2%	3%	2%	1%	2%	3%	2%	6%	11%	13%	18%	24%	22%
1999			0%	1%	1%	1%	1%	2%	3%	5%	15%	27%	43%	57%	27%
2000			1%	1%	1%	2%	1%	1%	3%	6%	6%	13%	52%	76%	70%
2001			2%	1%	1%	1%	3%	3%	2%	5%	7%	9%	13%	14%	47%
2002			1%	1%	1%	1%	1%	3%	3%	3%	6%	7%	11%	34%	35%
2003			1%	1%	1%	1%	1%	2%	4%	6%	5%	7%	14%	36%	22%
2004			2%	1%	1%	2%	2%	2%	3%	8%	6%	6%	14%	18%	11%
2005			2%	1%	0%	1%	2%	3%	3%	5%	8%	8%	25%	37%	28%
2006			1%	1%	1%	1%	1%	3%	4%	4%	9%	14%	12%	19%	11%
2007			1%	1%	1%	1%	1%	2%	4%	5%	7%	13%	14%	12%	10%
2008			1%	1%	1%	1%	1%	2%	3%	6%	7%	7%	8%	22%	8%
2009			1%	1%	3%	2%	2%	3%	4%	6%	10%	12%	9%	30%	16%
2010			2%	0%	1%	3%	3%	4%	4%	5%	7%	10%	15%	13%	11%
2011			1%	1%	0%	1%	3%	4%	5%	5%	6%	9%	29%	16%	21%
2012			1%	0%	1%	1%	2%	5%	8%	11%	9%	10%	13%	21%	45%
2013			1%	0%	0%	2%	3%	4%	8%	9%	10%	12%	13%	18%	16%
2014			2%	1%	1%	1%	2%	3%	6%	14%	16%	19%	16%	22%	17%
2015			2%	1%	1%	0%	2%	3%	5%	13%	16%	20%	15%	23%	16%
2016			2%	1%	1%	0%	2%	3%	5%	13%	16%	20%	15%	23%	16%

Table 26: Summary model results showing the stock condition for EBS pollock. Values in parentheses are coefficients of variation (CVs) of values immediately above.

Biomass	2016 Assessment	2017 Assessment
Year 2018 spawning biomass	4,600,000 t	3,678,000 t
(CV)	(14%)	(13%)
2017 spawning biomass	4,070,000 t	3,870,000 t
B_{MSY}	2,165,000 t	2,042,000 t
(CV)	(20%)	23%
SPR%F_{MSY}	30%	29%
$B_{40\%}$	2,643,000 t	2,455,000 t
$B_{35\%}$	2,313,000 t	2,148,000 t
B_0 (stock-recruitment curve)	5,700,000 t	5,394,000 t
2017 Percent of B_{MSY} spawning biomass	212%	190%
Estimated B_{2017} over B_{2017} without fishing mortality	0.66	0.68
Recruitment (millions of pollock at age 1)		
Steepness parameter (h)	0.686	0.653
Average recruitment (all yrs)	24,350	23,840
2000 year class	35,844	34,900
2006 year class	25,928	25,600
2008 year class	56,100	53,800
2012 year class	63,900	60,200
Natural Mortality (age 3 and older)	0.3	0.3

Table 27: Summary results of Tier 1 2017 yield projections for EBS pollock.

Description	Value
2018 fishable biomass (GM)	7,724,000 t
Equilibrium fishable biomass at MSY	4,016,000 t
$MSYR$ (HM)	0.466
2018 Tier 1 ABC	3,603,000 t
OFL	
$MSYR$ (AM)	0.621
2018 Tier 1 OFL	4,795,000 t
Recommended F_{ABC}	0.336 t
Recommended ABC	2,592,000 t

Table 28: Estimated billions of EBS pollock at age (columns 2-11) from the 2017 model.

Year	1	2	3	4	5	6	7	8	9	10+
1964	6.43	3.46	2.19	0.47	0.20	0.39	0.18	0.06	0.04	0.22
1965	21.16	2.61	2.18	1.55	0.29	0.13	0.25	0.11	0.04	0.16
1966	15.16	8.59	1.64	1.53	0.96	0.18	0.08	0.16	0.07	0.13
1967	25.65	6.15	5.40	1.15	0.97	0.61	0.12	0.05	0.10	0.13
1968	22.19	10.39	3.81	3.52	0.67	0.56	0.36	0.07	0.03	0.14
1969	26.18	8.98	6.42	2.49	2.04	0.39	0.33	0.21	0.04	0.10
1970	23.52	10.59	5.52	4.06	1.46	1.21	0.23	0.20	0.12	0.08
1971	14.46	9.47	6.36	3.29	2.32	0.81	0.67	0.13	0.10	0.10
1972	11.83	5.80	5.55	3.57	1.73	1.15	0.40	0.33	0.06	0.09
1973	26.95	4.75	3.30	2.89	1.73	0.82	0.55	0.19	0.15	0.06
1974	19.77	10.85	2.62	1.59	1.29	0.76	0.36	0.24	0.08	0.08
1975	16.77	7.97	5.76	1.12	0.67	0.54	0.32	0.15	0.10	0.06
1976	12.90	6.78	4.49	2.59	0.51	0.31	0.25	0.15	0.07	0.07
1977	13.38	5.22	3.91	2.22	1.21	0.24	0.15	0.12	0.07	0.06
1978	24.61	5.42	3.05	2.13	1.12	0.60	0.12	0.07	0.06	0.06
1979	59.44	9.98	3.19	1.65	1.07	0.54	0.29	0.06	0.04	0.06
1980	26.54	24.11	6.02	1.82	0.85	0.49	0.24	0.13	0.03	0.04
1981	30.73	10.77	14.94	3.77	0.96	0.40	0.22	0.11	0.06	0.03
1982	16.90	12.48	6.77	10.15	2.22	0.50	0.20	0.12	0.06	0.05
1983	50.85	6.87	7.89	4.81	6.57	1.31	0.29	0.12	0.07	0.06
1984	14.31	20.67	4.35	5.67	3.24	4.13	0.79	0.17	0.07	0.08
1985	34.42	5.82	13.10	3.13	3.87	2.03	2.52	0.48	0.11	0.09
1986	14.22	13.99	3.69	9.40	2.15	2.51	1.22	1.52	0.29	0.11
1987	7.65	5.78	8.87	2.65	6.44	1.42	1.54	0.74	0.94	0.24
1988	5.75	3.11	3.67	6.41	1.86	4.39	0.93	1.00	0.47	0.75
1989	11.05	2.34	1.97	2.57	4.41	1.21	2.78	0.56	0.62	0.74
1990	48.53	4.49	1.48	1.40	1.74	2.86	0.76	1.66	0.34	0.83
1991	25.25	19.73	2.85	1.05	0.91	1.03	1.64	0.42	0.91	0.66
1992	22.23	10.26	12.50	2.04	0.70	0.56	0.59	0.85	0.23	0.82
1993	45.92	9.04	6.49	8.68	1.34	0.43	0.30	0.28	0.39	0.48
1994	15.39	18.67	5.74	4.63	5.52	0.87	0.25	0.16	0.15	0.47
1995	10.52	6.26	11.87	4.18	3.15	3.25	0.51	0.14	0.09	0.34
1996	22.66	4.28	3.98	8.69	2.97	2.00	1.77	0.29	0.08	0.24
1997	30.96	9.21	2.72	2.90	6.29	2.02	1.15	0.87	0.14	0.17
1998	15.26	12.59	5.84	1.97	2.07	4.27	1.25	0.63	0.45	0.16
1999	16.42	6.20	7.99	4.23	1.39	1.40	2.59	0.75	0.34	0.33
2000	25.51	6.67	3.95	5.69	2.94	0.94	0.90	1.52	0.44	0.40
2001	34.91	10.37	4.25	2.85	3.85	1.88	0.60	0.52	0.83	0.50
2002	23.45	14.19	6.60	3.09	1.97	2.33	1.04	0.33	0.29	0.76
2003	14.41	9.53	9.02	4.79	2.11	1.21	1.19	0.53	0.17	0.57
2004	6.57	5.86	6.07	6.36	3.25	1.25	0.63	0.59	0.26	0.41
2005	4.72	2.67	3.73	4.40	4.00	1.97	0.70	0.33	0.31	0.38
2006	11.90	1.92	1.70	2.71	2.91	2.21	1.06	0.39	0.18	0.40
2007	25.62	4.84	1.22	1.20	1.76	1.64	1.10	0.54	0.20	0.32
2008	14.01	10.42	3.08	0.86	0.77	0.98	0.79	0.55	0.28	0.28
2009	53.82	5.69	6.62	2.22	0.57	0.44	0.46	0.38	0.27	0.28
2010	21.63	21.88	3.62	4.76	1.47	0.34	0.23	0.24	0.20	0.29
2011	12.78	8.79	13.93	2.65	3.05	0.89	0.20	0.13	0.13	0.27
2012	11.06	5.20	5.60	10.14	1.84	1.54	0.43	0.10	0.06	0.20
2013	60.22	4.50	3.31	4.05	6.70	1.20	0.74	0.21	0.05	0.13
2014	39.88	24.48	2.86	2.39	2.70	4.13	0.72	0.40	0.10	0.09
2015	17.26	16.21	15.59	2.08	1.62	1.65	2.39	0.38	0.21	0.10
2016	18.24	7.02	10.32	11.02	1.37	1.00	0.90	1.31	0.20	0.16
2017	18.47	7.42	4.47	7.56	6.98	0.88	0.59	0.52	0.77	0.22

Table 29: Estimated millions of EBS pollock caught at age (columns 2-11) from the 2017 model.

Year	1	2	3	4	5	6	7	8	9	10+
1964	8.93	37.80	85.33	62.32	27.24	52.60	22.95	7.08	4.32	25.20
1965	28.96	29.34	98.54	214.65	39.58	16.30	30.53	13.40	4.21	18.43
1966	20.79	101.32	79.64	193.77	119.24	21.79	9.14	17.37	7.75	13.63
1967	65.21	139.80	556.37	215.18	182.93	113.22	21.55	9.28	18.07	23.01
1968	64.42	263.02	396.25	661.75	122.45	100.42	63.25	12.18	5.32	24.08
1969	91.54	256.42	809.68	447.69	361.32	67.77	57.37	38.21	7.51	18.49
1970	141.65	490.07	937.67	808.65	317.90	262.46	52.70	48.85	32.05	22.12
1971	122.39	619.64	1347.28	838.16	668.80	230.90	194.25	41.57	35.93	39.03
1972	89.84	513.47	1437.50	1072.60	540.00	359.44	127.79	117.54	22.04	36.09
1973	182.03	526.17	1004.02	1002.63	619.68	295.21	196.60	75.08	60.69	26.12
1974	116.63	1466.57	968.47	596.50	489.58	286.83	135.48	97.02	33.72	34.93
1975	65.81	746.37	1986.01	375.90	222.12	177.93	104.41	51.70	35.06	22.30
1976	36.63	523.15	1302.04	834.60	159.95	95.48	76.93	46.08	22.77	22.52
1977	27.47	358.99	904.18	614.24	350.62	69.32	42.20	34.36	21.52	19.06
1978	42.35	343.38	709.60	599.53	350.54	184.71	37.38	23.02	19.99	21.34
1979	84.00	429.88	634.96	443.52	351.27	181.06	95.71	19.31	12.47	19.98
1980	26.76	550.26	817.69	458.94	270.70	166.20	81.08	43.28	8.84	13.72
1981	18.34	131.31	1076.08	670.10	248.61	106.63	59.66	29.69	16.09	8.21
1982	5.62	86.11	234.51	1113.05	385.29	94.78	38.56	22.02	11.13	9.06
1983	12.07	42.11	204.74	377.79	856.59	214.44	46.93	19.51	11.42	10.45
1984	2.85	100.71	109.29	391.49	432.58	630.93	127.34	27.90	12.02	13.06
1985	5.88	28.98	357.19	191.94	415.50	335.08	409.98	77.76	17.83	15.45
1986	1.94	62.13	99.71	610.74	206.58	368.82	187.36	219.32	46.61	18.94
1987	0.65	17.17	193.04	114.60	448.26	141.07	162.37	89.33	119.03	30.00
1988	0.56	11.62	176.16	396.12	198.88	548.93	145.45	150.84	74.95	115.32
1989	0.92	8.21	69.08	187.33	478.69	162.64	471.85	90.78	94.55	113.10
1990	4.87	21.46	56.19	152.31	306.29	554.94	168.53	369.14	73.64	172.73
1991	2.36	96.06	84.38	90.03	137.54	198.18	426.51	98.24	236.95	166.26
1992	2.44	63.73	678.11	194.59	109.66	135.00	191.59	288.25	76.42	274.43
1993	2.99	25.73	216.11	1069.63	149.42	75.97	72.89	67.68	94.58	112.48
1994	0.81	45.45	90.93	321.96	980.64	150.44	55.45	34.81	32.27	99.64
1995	0.46	15.24	122.42	142.04	385.62	756.21	110.15	30.11	18.61	70.88
1996	0.99	15.23	53.49	170.04	207.65	389.07	517.11	82.30	20.14	58.04
1997	1.25	45.43	44.78	96.24	455.35	291.73	269.52	232.08	39.93	45.06
1998	0.47	39.71	112.80	79.70	155.46	674.47	210.60	140.34	109.02	36.88
1999	0.34	10.94	275.92	221.45	103.35	158.12	462.20	128.44	58.00	53.19
2000	0.52	11.44	81.50	425.25	349.41	112.63	168.19	346.32	83.39	67.85
2001	0.75	15.55	60.81	167.73	610.01	419.10	133.12	115.09	170.43	96.15
2002	0.55	34.10	121.70	215.65	296.64	625.95	279.46	90.58	72.61	164.23
2003	0.34	16.66	382.52	343.95	370.42	308.69	345.18	152.56	43.70	124.86
2004	0.13	7.49	109.45	834.74	508.45	256.17	164.22	150.59	60.12	80.71
2005	0.08	3.59	62.98	405.55	884.62	479.37	160.44	69.94	62.91	67.05
2006	0.24	3.91	66.52	290.25	610.26	627.75	287.03	102.08	44.71	89.38
2007	0.51	11.31	49.70	135.90	381.62	495.34	313.33	140.90	49.68	76.50
2008	0.27	21.87	69.09	84.48	154.79	309.80	239.97	157.33	77.24	71.91
2009	0.89	7.71	167.81	209.03	90.25	118.89	124.94	101.13	70.48	75.97
2010	0.29	25.54	41.53	557.45	225.62	63.79	48.62	55.15	45.69	65.12
2011	0.22	13.89	205.56	142.15	854.12	277.84	59.76	37.31	37.12	75.36
2012	0.19	10.46	113.79	950.47	193.65	464.43	130.36	29.55	18.25	56.74
2013	0.88	6.23	63.90	351.23	982.97	194.02	180.07	59.68	13.43	36.37
2014	0.53	33.07	46.95	179.27	405.78	780.85	184.57	97.47	25.41	22.89
2015	0.24	17.95	614.39	195.19	238.70	382.89	540.08	88.72	51.29	27.42
2016	0.17	3.48	100.13	1387.79	165.65	174.20	167.39	236.88	36.33	28.55
2017	0.16	3.50	41.28	909.28	802.93	146.54	105.07	90.33	130.69	36.35

Table 30: Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2017. Biomass units are thousands of t, age-1 recruitment is in millions of pollock.

Year	SSB	CV%	Biomass 3+	CV%	Rec	CV%
1964	528	27	1,779	22	6,434	38
1965	625	23	2,165	20	21,164	25
1966	727	22	2,326	20	15,163	32
1967	916	20	3,566	17	25,647	26
1968	1,135	19	4,082	17	22,188	28
1969	1,390	19	5,174	16	26,178	26
1970	1,623	18	5,820	15	23,515	27
1971	1,714	17	6,260	13	14,457	33
1972	1,623	17	5,940	13	11,825	33
1973	1,360	19	4,765	14	26,950	19
1974	1,006	22	3,510	16	19,769	19
1975	853	20	3,611	12	16,771	18
1976	862	15	3,538	10	12,898	17
1977	890	13	3,446	9	13,383	15
1978	890	11	3,273	8	24,614	10
1979	844	11	3,116	8	59,440	6
1980	935	9	3,896	7	26,538	9
1981	1,543	6	7,453	5	30,727	8
1982	2,372	6	8,645	5	16,900	11
1983	2,981	6	9,849	5	50,853	6
1984	3,245	5	9,731	5	14,310	11
1985	3,545	5	11,887	4	34,423	7
1986	3,808	5	11,278	4	14,216	10
1987	3,966	4	11,922	3	7,654	13
1988	3,979	4	11,291	3	5,753	13
1989	3,590	4	9,568	3	11,046	10
1990	2,899	4	7,671	4	48,531	4
1991	2,177	5	6,054	4	25,245	6
1992	2,276	4	9,276	3	22,230	6
1993	3,125	3	11,427	3	45,919	4
1994	3,443	3	11,188	3	15,386	6
1995	3,626	3	12,757	3	10,520	7
1996	3,625	3	10,979	3	22,656	5
1997	3,432	3	9,603	3	30,960	4
1998	3,164	3	9,609	3	15,255	5
1999	3,189	3	10,561	3	16,418	5
2000	3,214	3	9,735	3	25,509	4
2001	3,237	3	9,479	3	34,907	3
2002	3,050	3	9,811	3	23,450	4
2003	3,208	3	11,750	2	14,414	5
2004	3,306	3	11,073	2	6,566	7
2005	3,036	3	9,272	3	4,718	8
2006	2,493	3	7,110	3	11,901	6
2007	2,072	3	5,762	3	25,621	4
2008	1,551	4	4,726	3	14,006	7
2009	1,650	4	5,943	3	53,821	5
2010	1,907	4	6,327	4	21,630	7
2011	2,325	4	9,107	4	12,784	11
2012	2,706	5	9,051	4	11,062	14
2013	3,004	5	8,873	5	60,223	12
2014	2,858	6	8,143	6	39,877	17
2015	2,973	8	11,913	9	17,259	17
2016	3,658	10	13,549	11	18,238	20
2017	3,870	12	12,049	11	18,465	22

Table 31: Estimates of begin-year age 3 and older biomass (thousands of tons) and coefficients of variation (CV) for the current assessment compared to 2010-2017 assessments for EBS pollock.

Year	Current	CV	2016	CV	2015	CV	2014	CV	2013	CV	2012	CV	2011	CV
1964	1,779	22	1,834	22	1,869	24	1,622	21	1,602	21	1,608	21	1,601	21
1965	2,165	20	2,229	20	2,324	22	2,076	19	2,051	19	2,059	19	2,050	19
1966	2,326	19	2,404	19	2,563	22	2,186	19	2,149	19	2,157	19	2,158	20
1967	3,566	17	3,667	17	3,888	19	3,397	16	3,344	16	3,352	16	3,364	16
1968	4,082	17	4,198	17	4,495	18	3,870	16	3,800	16	3,808	16	3,838	16
1969	5,174	15	5,294	15	5,690	16	5,220	15	5,145	16	5,154	16	5,187	16
1970	5,820	14	5,936	14	6,424	15	6,252	15	6,178	15	6,187	15	6,221	15
1971	6,260	13	6,360	13	6,858	14	6,945	13	6,884	13	6,893	13	6,917	13
1972	5,940	12	6,024	12	6,431	13	6,353	13	6,299	13	6,308	13	6,328	13
1973	4,765	13	4,845	13	5,161	14	4,748	16	4,692	16	4,700	16	4,727	16
1974	3,510	16	3,589	16	3,846	17	3,348	19	3,291	20	3,298	20	3,329	19
1975	3,611	12	3,679	12	3,868	13	3,554	13	3,515	13	3,523	13	3,533	13
1976	3,538	10	3,608	10	3,872	11	3,609	10	3,577	10	3,587	10	3,580	10
1977	3,446	8	3,535	8	3,939	10	3,642	9	3,612	9	3,623	9	3,598	9
1978	3,273	8	3,375	8	3,888	9	3,556	9	3,524	9	3,537	9	3,496	8
1979	3,116	8	3,239	8	3,859	9	3,426	8	3,386	8	3,402	8	3,342	8
1980	3,896	6	4,068	6	4,887	8	4,372	7	4,307	7	4,332	7	4,229	7
1981	7,453	5	7,813	4	9,054	6	8,527	5	8,320	6	8,363	6	8,159	5
1982	8,645	5	9,056	4	10,289	5	9,766	5	9,496	5	9,548	5	9,313	5
1983	9,849	4	10,240	4	11,383	5	10,911	4	10,560	5	10,621	5	10,340	5
1984	9,731	4	10,033	4	11,040	5	10,601	4	10,239	5	10,300	5	10,031	5
1985	11,887	4	12,237	3	12,951	4	12,838	4	12,409	4	12,478	4	12,186	4
1986	11,278	4	11,531	3	12,019	4	12,036	4	11,621	4	11,685	4	11,426	4
1987	11,922	3	12,143	3	12,334	4	12,615	3	12,243	3	12,308	3	12,063	3
1988	11,291	3	11,497	3	11,536	4	11,906	3	11,583	3	11,642	3	11,424	3
1989	9,568	3	9,755	3	9,700	4	10,128	3	9,860	3	9,912	3	9,723	3
1990	7,671	3	7,812	3	7,701	4	8,101	3	7,891	4	7,935	4	7,764	4
1991	6,054	4	6,183	4	6,063	5	6,331	4	6,170	4	6,209	4	6,048	4
1992	9,276	3	9,476	3	9,472	3	9,704	3	9,561	3	9,601	3	9,411	3
1993	11,427	2	11,627	2	11,712	3	11,840	3	11,712	3	11,754	3	11,543	3
1994	11,188	2	11,313	2	11,418	3	11,402	3	11,306	3	11,341	3	11,146	3
1995	12,757	2	13,000	2	13,177	3	13,135	3	13,074	3	13,109	3	12,883	3
1996	10,979	2	11,239	2	11,358	3	11,235	3	11,198	3	11,229	3	11,019	3
1997	9,603	2	9,837	2	9,940	3	9,816	3	9,801	3	9,828	3	9,626	3
1998	9,609	2	9,908	2	9,990	3	9,906	3	9,902	3	9,929	3	9,721	3
1999	10,561	2	10,751	2	10,853	3	10,799	3	10,791	3	10,819	3	10,607	3
2000	9,735	2	9,955	2	10,068	3	10,031	3	10,020	3	10,044	3	9,840	3
2001	9,479	2	9,702	2	9,854	3	9,818	3	9,802	3	9,829	3	9,615	3
2002	9,811	2	10,025	2	10,276	3	10,221	3	10,182	3	10,230	3	9,987	3
2003	11,750	2	12,080	2	12,365	3	12,278	2	12,211	2	12,269	2	11,974	3
2004	11,073	2	11,401	2	11,591	3	11,493	2	11,416	2	11,491	2	11,178	3
2005	9,272	2	9,598	2	9,705	3	9,601	3	9,521	3	9,608	3	9,298	3
2006	7,110	2	7,390	2	7,446	3	7,343	3	7,261	3	7,348	3	7,059	3
2007	5,762	3	6,046	3	6,045	4	5,932	4	5,840	4	5,953	4	5,633	4
2008	4,726	3	4,945	3	4,849	4	4,721	4	4,607	4	4,724	4	4,392	5
2009	5,943	3	6,374	3	6,331	5	6,068	4	5,879	5	6,069	5	6,172	8
2010	6,327	3	6,657	3	6,680	5	5,936	5	5,622	6	5,768	6	6,094	9
2011	9,107	3	9,637	3	10,053	7	8,895	6	7,927	7	7,780	9	7,823	10
2012	9,051	4	9,626	4	10,164	8	8,822	7	7,853	9	7,866	10	8,340	12
2013	8,873	4	9,504	5	10,337	9	9,540	8	8,261	10	8,138	NA	NA	NA
2014	8,143	5	8,947	6	9,805	10	8,960	9	8,045	11	7,946	NA	NA	NA
2015	11,913	8	12,407	10	10,970	11	9,203	9	7,778	12	NA	NA	NA	NA
2016	13,549	10	13,495	12	11,292	12	NA	NA	NA	NA	NA	NA	NA	NA
2017	12,049	11	13,033	13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 32: 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
2017	1,350	1,350	1,350	1,350	1,350	1,350	1,350
2018	2,591	1,390	1,726	1,168	0	3,188	2,591
2019	2,154	1,390	1,589	1,144	0	2,456	2,154
2020	1,729	2,209	1,388	1,050	0	1,751	2,114
2021	1,540	1,879	1,330	1,034	0	1,590	1,727
2022	1,518	1,687	1,320	1,041	0	1,603	1,655
2023	1,555	1,636	1,343	1,069	0	1,657	1,676
2024	1,579	1,616	1,357	1,087	0	1,685	1,692
2025	1,593	1,611	1,369	1,100	0	1,697	1,699
2026	1,582	1,588	1,363	1,100	0	1,679	1,679
2027	1,586	1,589	1,364	1,105	0	1,680	1,680
2028	1,568	1,570	1,354	1,099	0	1,659	1,659
2029	1,560	1,561	1,350	1,097	0	1,652	1,652
2030	1,569	1,569	1,355	1,101	0	1,665	1,665

Table 33: Tier 3 projections of EBS pollock ABC (given catches in Table 32) for the 7 scenarios.

ABC	Scenario.1	Scenario.2	Scenario.3	Scenario.4	Scenario.5	Scenario.6	Scenario.7
2017	2,443	2,443	1,616	1,089	0	3,021	3,021
2018	2,591	2,591	1,726	1,168	0	3,188	3,188
2019	2,154	2,467	1,589	1,144	0	2,456	2,645
2020	1,729	2,209	1,388	1,050	0	1,751	2,114
2021	1,540	1,879	1,330	1,034	0	1,590	1,727
2022	1,518	1,688	1,320	1,041	0	1,603	1,655
2023	1,555	1,637	1,343	1,069	0	1,657	1,676
2024	1,579	1,617	1,357	1,087	0	1,685	1,692
2025	1,593	1,612	1,369	1,100	0	1,697	1,699
2026	1,582	1,590	1,363	1,100	0	1,679	1,679
2027	1,586	1,590	1,364	1,105	0	1,680	1,680
2028	1,568	1,570	1,354	1,099	0	1,659	1,659
2029	1,560	1,561	1,350	1,097	0	1,652	1,652
2030	1,569	1,569	1,355	1,101	0	1,665	1,665

Table 34: 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
2017	0.197	0.197	0.197	0.197	0.197	0.197	0.197
2018	0.380	0.189	0.240	0.157	0.000	0.487	0.380
2019	0.380	0.199	0.240	0.157	0.000	0.487	0.380
2020	0.377	0.380	0.240	0.157	0.000	0.444	0.479
2021	0.355	0.376	0.240	0.157	0.000	0.421	0.435
2022	0.350	0.362	0.240	0.157	0.000	0.420	0.425
2023	0.349	0.355	0.240	0.157	0.000	0.422	0.424
2024	0.350	0.352	0.240	0.157	0.000	0.424	0.425
2025	0.349	0.350	0.240	0.157	0.000	0.423	0.423
2026	0.349	0.349	0.240	0.157	0.000	0.422	0.422
2027	0.350	0.350	0.240	0.157	0.000	0.422	0.422
2028	0.348	0.349	0.240	0.157	0.000	0.420	0.420
2029	0.348	0.348	0.240	0.157	0.000	0.420	0.420
2030	0.347	0.347	0.240	0.157	0.000	0.419	0.419

Table 35: 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
2017	3,888	3,888	3,888	3,888	3,888	3,888	3,888
2018	3,611	3,750	3,713	3,774	3,894	3,535	3,611
2019	2,967	3,485	3,343	3,592	4,132	2,716	2,967
2020	2,586	3,165	3,092	3,461	4,347	2,296	2,537
2021	2,505	2,840	3,056	3,502	4,679	2,243	2,343
2022	2,523	2,697	3,077	3,574	5,001	2,275	2,316
2023	2,549	2,636	3,098	3,630	5,263	2,303	2,319
2024	2,573	2,615	3,115	3,663	5,437	2,327	2,332
2025	2,575	2,593	3,112	3,669	5,541	2,326	2,327
2026	2,568	2,577	3,113	3,689	5,711	2,315	2,315
2027	2,563	2,568	3,113	3,707	5,873	2,308	2,309
2028	2,547	2,550	3,097	3,696	5,945	2,294	2,294
2029	2,548	2,550	3,094	3,693	5,982	2,297	2,297
2030	2,558	2,559	3,100	3,698	6,019	2,308	2,308

Table 36: Bycatch estimates (t) of FMP species caught in the BSAI directed pollock fishery, 1997-2017 based on then NMFS Alaska Regional Office reports from observers (2017 data are preliminary).

Year	Pacific.Cod	Flathead.Sole	Rock.Sole	Yellowfin.Sole	Arrowtooth.Flounder	Pacific.Ocean.Perch	Atka.Mackerel	Sablefish	Greenland.Turbot	Alaska.Plaice	Skates	Squid	Sharks	Sculpin	All.other	Total
1997	8,262	2,350	1,522	606	985	428	83	2	123	1	NA	NA	NA	NA	879	15,241
1998	6,559	2,118	779	1,762	1,762	682	91	2	178	14	NA	NA	NA	NA	805	14,751
1999	3,220	1,885	1,058	350	273	121	161	7	30	3	NA	NA	NA	NA	249	7,357
2000	3,432	2,510	2,688	1,466	979	22	2	12	52	147	NA	NA	NA	NA	306	11,615
2001	3,878	2,199	1,673	594	529	574	41	21	68	14	NA	NA	NA	NA	505	10,098
2002	5,925	1,843	1,885	768	606	544	221	34	70	50	NA	NA	NA	NA	267	12,214
2003	5,968	1,706	1,419	210	618	935	762	48	40	7	571	1,226	294	81	327	14,213
2004	6,437	2,009	2,554	841	557	394	1,053	17	18	8	841	977	187	150	436	16,477
2005	7,413	2,319	1,125	63	651	653	678	11	31	45	732	1,150	169	131	490	15,661
2006	7,291	2,837	1,361	256	1,089	736	789	9	65	11	1,308	1,399	512	169	620	18,450
2007	5,630	4,203	510	86	2,795	625	315	12	107	3	1,287	1,169	245	190	726	17,902
2008	6,965	4,288	2,123	516	1,711	336	15	5	85	49	2,756	1,452	144	281	438	21,164
2009	7,878	4,602	7,602	271	2,203	114	25	3	44	176	3,856	209	100	292	305	27,682
2010	6,987	4,309	2,330	1,057	1,502	231	57	2	26	126	1,886	277	26	258	375	19,448
2011	10,041	4,886	8,481	1,083	1,600	660	894	1	29	74	2,353	178	66	315	560	31,219
2012	10,062	3,968	6,701	1,496	749	713	263	1	53	137	2,018	495	55	286	509	27,507
2013	8,958	3,147	6,320	2,088	965	611	70	0	21	148	1,751	117	43	219	241	24,698
2014	5,213	2,554	4,359	1,954	758	1,300	117	1	41	318	813	1,478	75	191	497	19,669
2015	8,303	2,260	1,709	863	403	2,519	195	0	41	99	824	2,206	52	187	342	20,002
2016	4,982	1,641	1,150	885	295	3,280	69	19	29	40	467	1,160	57	126	545	14,743

Table 37: Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 2003-2017, 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
2,003	5,591	98	9	88	1	20	0	0	0	1
2,004	6,490	87	20	7	0	14	0	0	0	1
2,005	5,084	146	12	9	1	14	1	0	6	2
2,006	2,657	147	92	8	20	15	1	9	0	6
2,007	2,150	198	136	4	118	27	3	5	0	6
2,008	3,711	103	4	6	7	27	1	0	0	6
2,009	3,703	58	4	4	2	3	1	0	0	1
2,010	2,153	116	0	4	0	1	1	0	0	1
2,011	6,571	216	2	18	0	1	2	0	0	1
2,012	2,454	124	1	3	0	0	2	0	0	1
2,013	4,734	101	0	2	0	0	1	0	0	2
2,014	11,036	40	2	5	2	0	3	0	0	4
2,015	4,748	87	21	28	9	1	2	0	0	2
2,016	2,185	70	5	48	22	3	1	0	0	2
2,017	5,776	46	3	4	18	2	0	0	0	0

Table 38: Bycatch estimates (t) of pollock caught in the other non-pollock EBS directed fisheries, 2003-2017 based on then NMFS Alaska Regional Office reports from observers.

Year	Scypho.jellies	Misc.fish	Eulachon.Osmerid	Sea.star	Eelpouts	Grenadier	Sea.pen	Lanternfish	Snails	All.other
2,003	5,591	98	9	88	1	20	0	0	0	1
2,004	6,490	87	20	7	0	14	0	0	0	1
2,005	5,084	146	12	9	1	14	1	0	6	2
2,006	2,657	147	92	8	20	15	1	9	0	6
2,007	2,150	198	136	4	118	27	3	5	0	6
2,008	3,711	103	4	6	7	27	1	0	0	6
2,009	3,703	58	4	4	2	3	1	0	0	1
2,010	2,153	116	0	4	0	1	1	0	0	1
2,011	6,571	216	2	18	0	1	2	0	0	1
2,012	2,454	124	1	3	0	0	2	0	0	1
2,013	4,734	101	0	2	0	0	1	0	0	2
2,014	11,036	40	2	5	2	0	3	0	0	4
2,015	4,748	87	21	28	9	1	2	0	0	2
2,016	2,185	70	5	48	22	3	1	0	0	2
2,017	5,776	46	3	4	18	2	0	0	0	0

Table 39: Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997-2017 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 2017 are preliminary.

Year	Bairdi.Crab.	Blue.King.Crab	Chinook.Salmon	Golden.King.Crab	Halibut.catch	Halibut.Mort	Herring	Non.Chinook.Salmon	Opilio.Crab	Other.King.Crab	Red.King.Crab.
1991	1,398,112	0	40,906	0	2,159	0	3,159	28,951	4,380,025	33,431	17,777
1992	1,501,801	0	35,950	0	2,221	0	647	40,274	4,570,741	20,387	43,874
1993	1,649,104	0	38,516	0	1,326	0	527	242,191	738,260	1,926	58,140
1994	371,238	0	33,136	0	963	689	1,626	92,672	811,758	514	42,361
1995	153,995	0	14,984	0	492	398	904	19,264	206,654	941	4,646
1996	89,416	0	55,623	0	382	321	1,241	77,236	63,398	215	5,934
1997	17,248	0	44,909	0	260	203	1,134	65,988	216,152	393	137
1998	57,042	0	51,322	0	353	278	800	64,042	123,405	5,093	14,287
1999	2,397	0	10,381	0	153	125	799	44,610	15,830	7	91
2000	1,485	0	4,242	0	110	91	482	56,867	6,481	121	0
2001	5,061	0	30,937	0	265	200	225	53,904	5,653	5,139	106
2002	2,113	0	32,402	0	199	168	108	77,178	2,698	194	17
2003	733	9	43,021	0	113	96	909	180,782	609	0	52
2004	1,189	4	51,700	2	108	93	1,104	440,475	743	0	27
2005	659	0	67,362	1	146	113	610	704,587	2,300	0	0
2006	1,657	0	82,750	3	156	122	435	306,047	2,909	0	203
2007	1,522	0	122,255	3	360	292	353	93,201	3,220	0	8
2008	8,839	8	21,398	33	424	334	127	15,555	9,428	0	576
2009	6,120	20	12,743	0	588	458	64	46,893	7,428	0	1,137
2010	12,884	28	9,847	0	334	266	351	13,665	9,433	0	1,050
2011	10,964	25	25,499	0	458	377	376	193,753	6,471	0	577
2012	5,547	0	11,344	0	462	388	2,352	22,390	6,188	0	343
2013	12,424	34	13,109	107	333	271	958	125,525	8,587	316	315
2014	12,522	0	15,129	147	239	199	159	219,823	19,456	348	368
2015	8,872	0	18,329	0	152	130	1,488	237,802	8,339	0	0
2016	2,293	0	22,197	106	105	92	1,422	343,158	1,165	0	439
2017	331	0	30,058	0	80	80	964	467,666	334	0	23

Indicator	Observation	Interpretation	Evaluation
Ecosystem effects on EBS pollock			
Prey availability or abundance trends			
Zooplankton	Stomach contents, AT and ichthyoplankton surveys, changes mean wt-at-age	Data improving, indication of increases from 2004-2009 and subsequent decreasees (for euphausiids in 2012 and 2014)	Variable abundanceindicates important recruitment (for prey)
Predator population trends			
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	
Changes in habitat quality			
Temperature regime	Cold years pollock distribution towards NW on average	Likely to affect surveyed stock	Some concern, the distribution of pollock availability to different surveys may change systematically
Winter-spring environmental conditions	Affects pre-recruit survival	Probably a number of factors	Causes natural variability
Production	Fairly stable nutrient flow from upwelled BS Basin	Inter-annual variability low	No concern
Fishery effects on ecosystem			
Fishery contribution to bycatch			
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 40: Summary of 2016 CIE reviewer comments and responses to date

Issue	Response
Natural mortality is assumed known exactly despite being quite uncertain.	Prior has been applied, examined in retrospective runs.
The stock recruitment relationship is very uncertain and although it is estimated it is done so with an artificial and very constraining prior.	2016 greater evaluation of unconstrained prior used
Uncertain future fishery selectivity is not properly modelled. A well-estimated average is used, whereas a random choice of previous estimated selectivities could be modelled.	Untrue, miscommunication. Evaluations of historical selectivities for projections has been done
The pdf of FMSY is not well determined as FMSY depends strongly on the stock recruitment relationship, fishery selectivity, and natural mortality	PDF is well determined, within alternative structural models uncertainty
Technically correct Bayesian model be developed with a view to replacing the existing model.	Posterior distributions added across several models created
Ultimately, a multi-species trophic interaction model may be used for stock assessment, but this should wait until an improved single-species stock assessment model is fully implemented. At that stage, the trophic interaction model and the single-species model could be tested (using an operating model) to see which is likely to provide better stock assessment estimates.	This work is ongoing
Ageing: perhaps 1 in 10 of surface-read otoliths should be broken and burnt to confirm that the same reading is obtained.	underway
Investigate the trawl survey time series to see if vessel effects can be estimated (using a multiple regression with other explanatory variables, e.g., year, stratum, time-of-day, weather conditions).	underway
The 3 m cutoff for the acoustic survey should be dispensed with and pollock biomass should be estimated over most of the water column.	Done
An analysis of mark types should be undertaken to better understand the length/age composition of pollock marks (which could perhaps lead to a better survey design).	Research at MACE on multi-frequency approach to help w/ species classification
More in situ target strength data should be collected for pollock to better define the length-target strength relationship.	Research at MACE ongoing
It may not be appropriate to include the AVO index in the base model but it should certainly be included in a sensitivity.	Done
It is probably better to fit to total biomass rather than total numbers for the trawl survey.	Done
For ages 2 years and older, it is better to fit to total biomass rather than total numbers for the acoustic survey.	Done
Annual mean weight-at-age: the shrinkage of fish should not be allowed to occur, and this may be best achieved by modelling increments in mean fish weight rather than the mean weights.	Done
Tighten the random walk and the parameterization on the fishery selectivities and then apply the data weighting methods of Francis (2011).	2017
Incorporate the uncertainty associated with unknown future selectivities into the pdfs of quantities of interest (e.g., FMSY).	Done, revisited 2017
There is clearly some uncertainty associated with M and this needs to be propagated through into the pdf of FMSY and other quantities of interest (i.e., estimate M).	2017
The uncertainty associated with the stock-recruitment relationship needs to be propagated through into the pdf of FMSY and other quantities of interest (i.e., estimate h with a justifiable prior).	Done in 2016
Perform a detailed historical analysis of the length/age composition of the catch in relationship to possible explanatory variables to enable the fishery to be split fisheries into multiple components for the purposes of stock assessment. The minimum split will be into A and B seasons with a processor and catcher fleet to mimic the reality of the fishery.	Future project
The information that is known about the survey qs should be included in the stock assessment model through informed priors.	Implemented via Kotwicki et al.
The objective function, for a Bayesian stock assessment, can and should be derived purely from likelihood components (generated by statistical assumptions with regard to data), prior distributions, and an occasional penalty function (if absolutely necessary).	Agreed
Incorporation of cannibalism explicitly in the modelling and in the forecasting. Disentangling cannibalism from environmental and climate effects on recruitment hold the most potential for improving knowledge of the stock and the ecosystem functioning	CEATTLE 2016

Figures

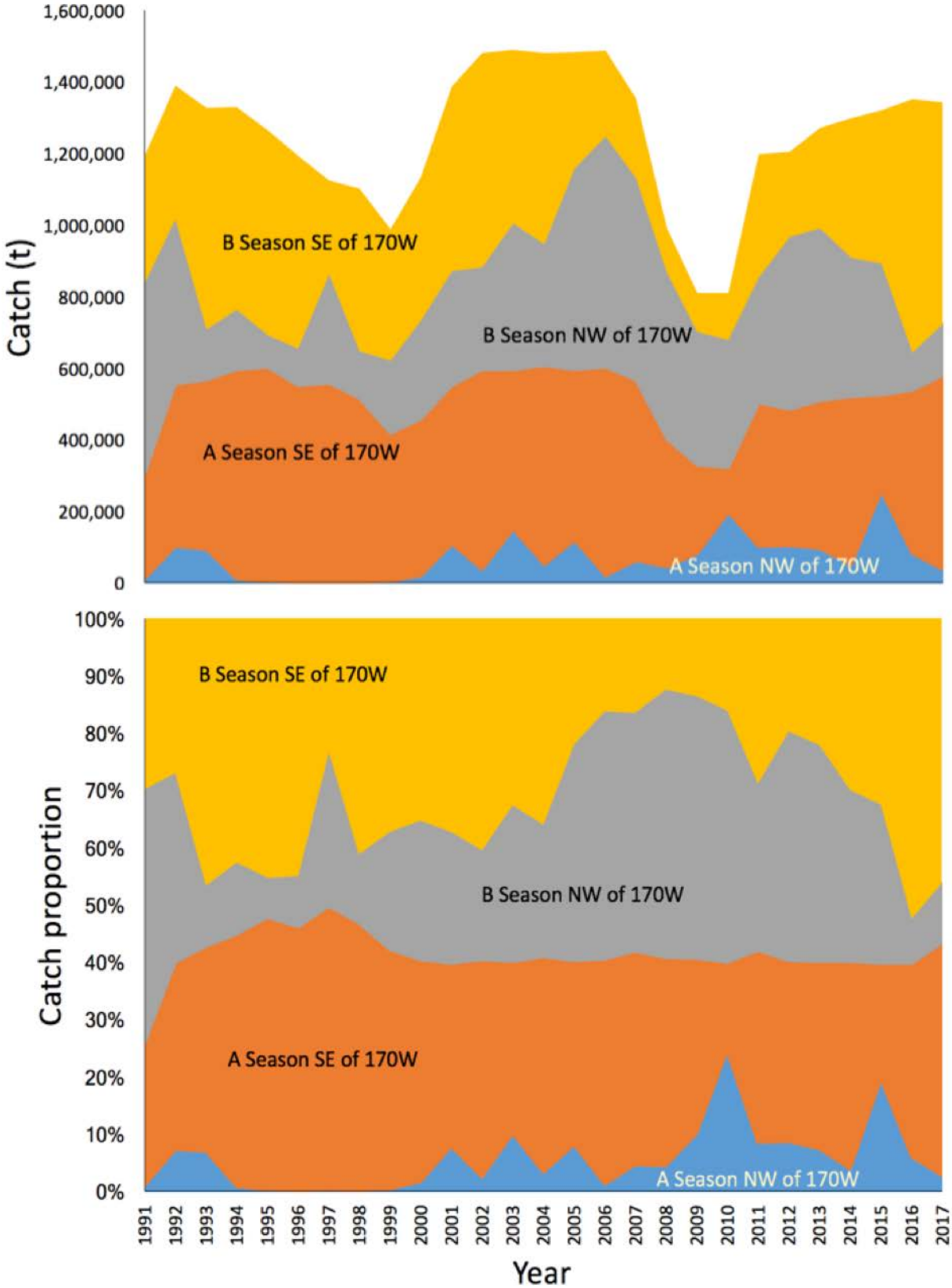

Figure 1: Pollock catch estimates (t) from the Eastern Bering Sea by season and region (top) and in proportion (bottom). The A-season is defined as from Jan-May and B-season from June-October.

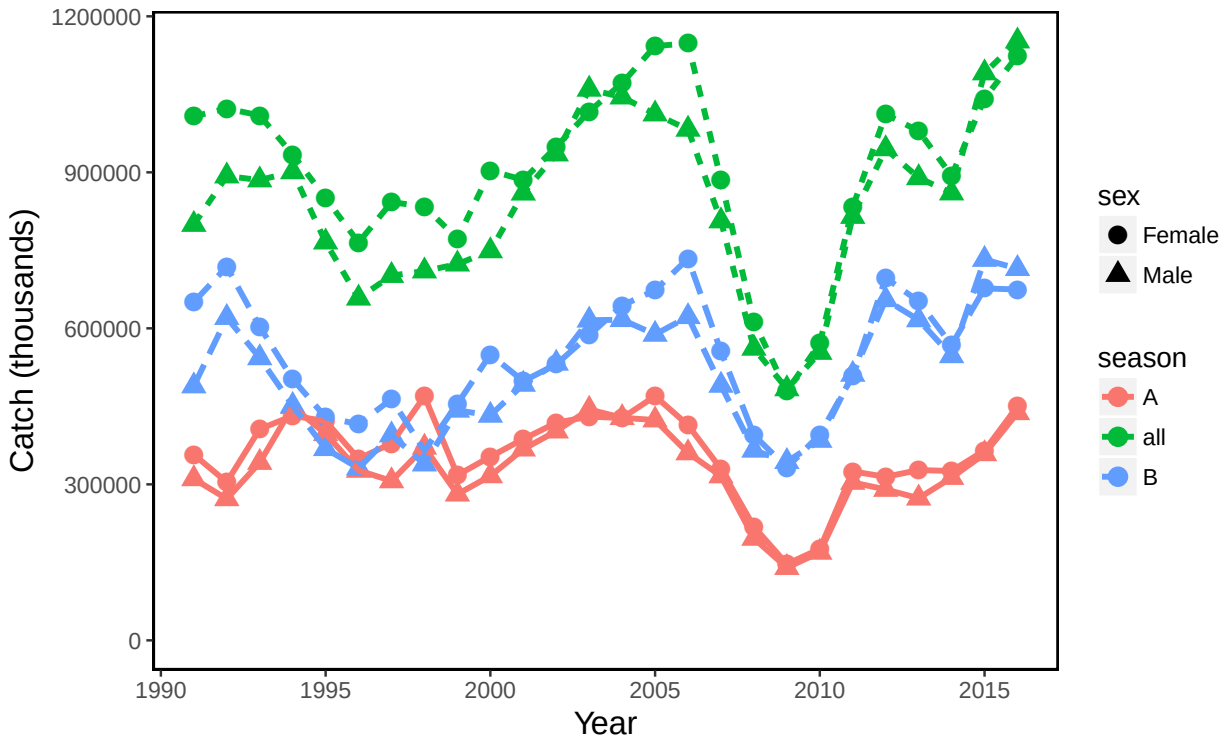

Figure 2: Estimate of EBS pollock catch numbers by sex for the A season (January-May) and B seasons (June-October) and total.

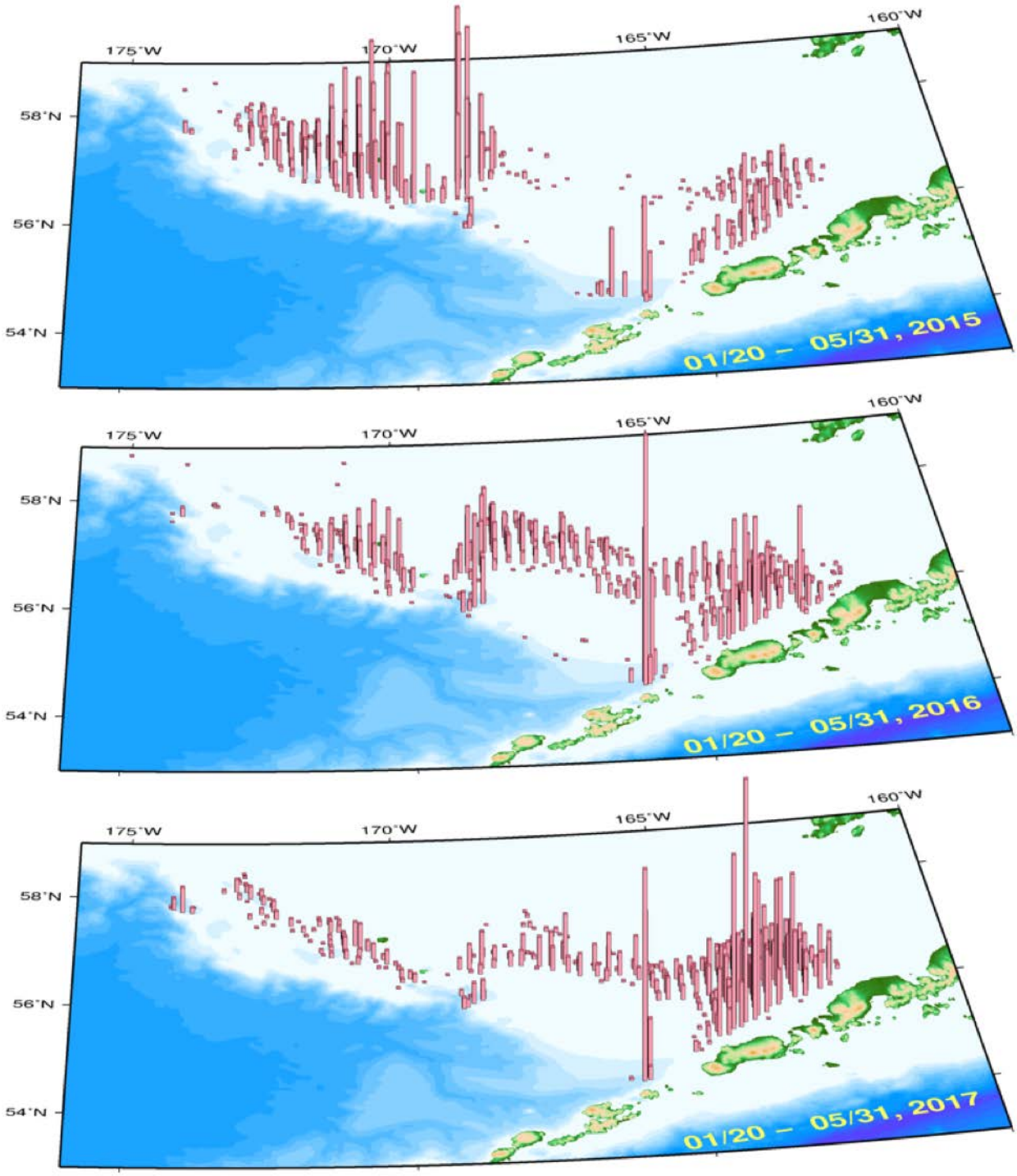

Figure 3: EBS pollock catch distribution during A-season, 2015-2017. Column height is proportional to total catch.

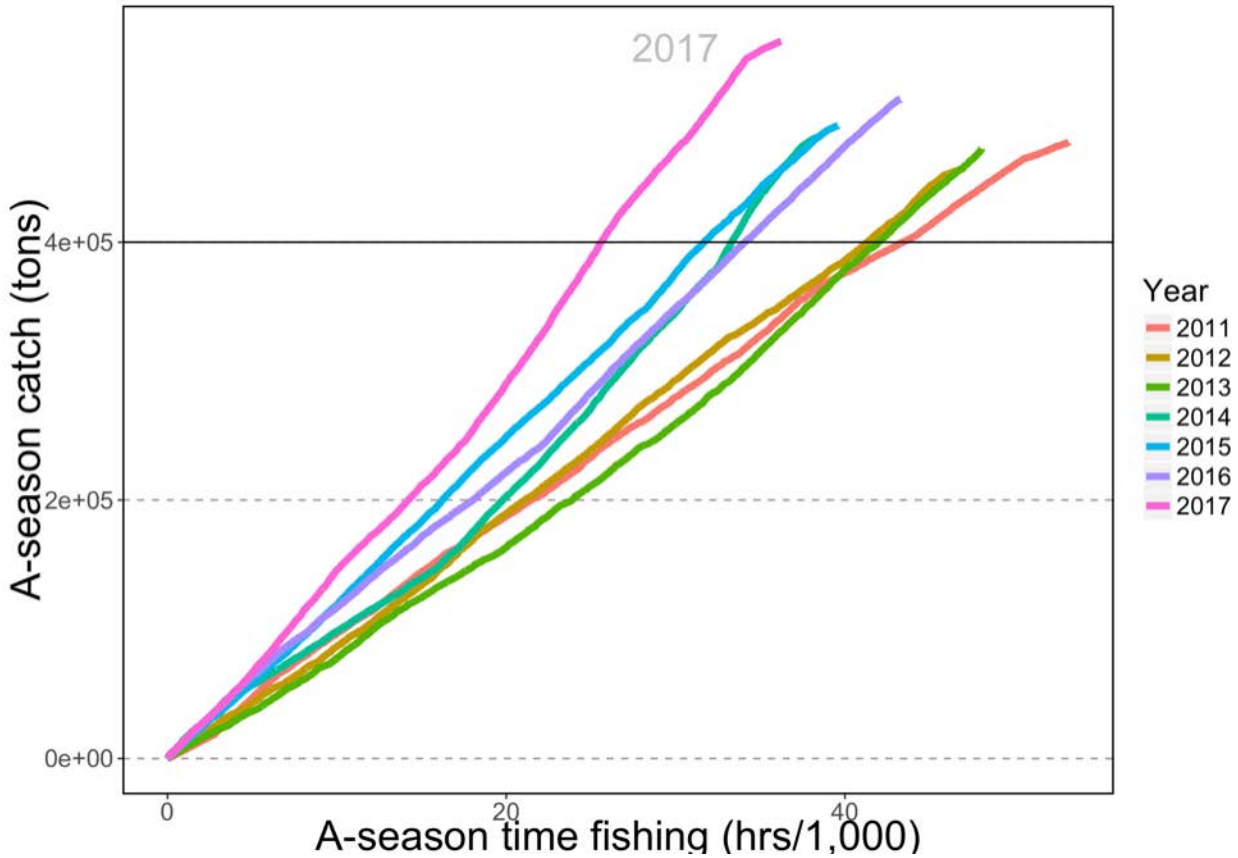

Figure 4: A-season EBS fleet-wide nominal pollock catch (kg) per hour of fishing recorded by NMFS scientific observers.

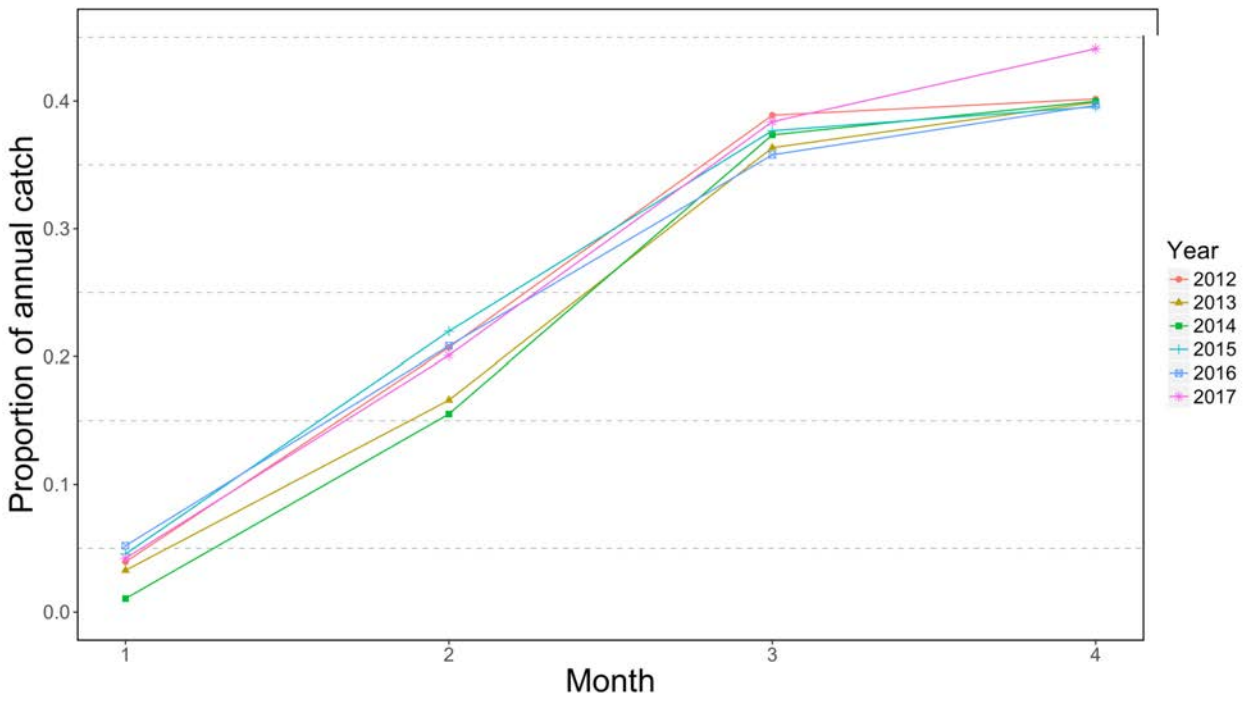

Figure 5: Proportion of the annual EBS pollock catch by month during the A-season, 2012-2017. The higher value observed in 2017 is due to Amendment 110 of the FMP to allow greater flexibility to avoid Chinook salmon.

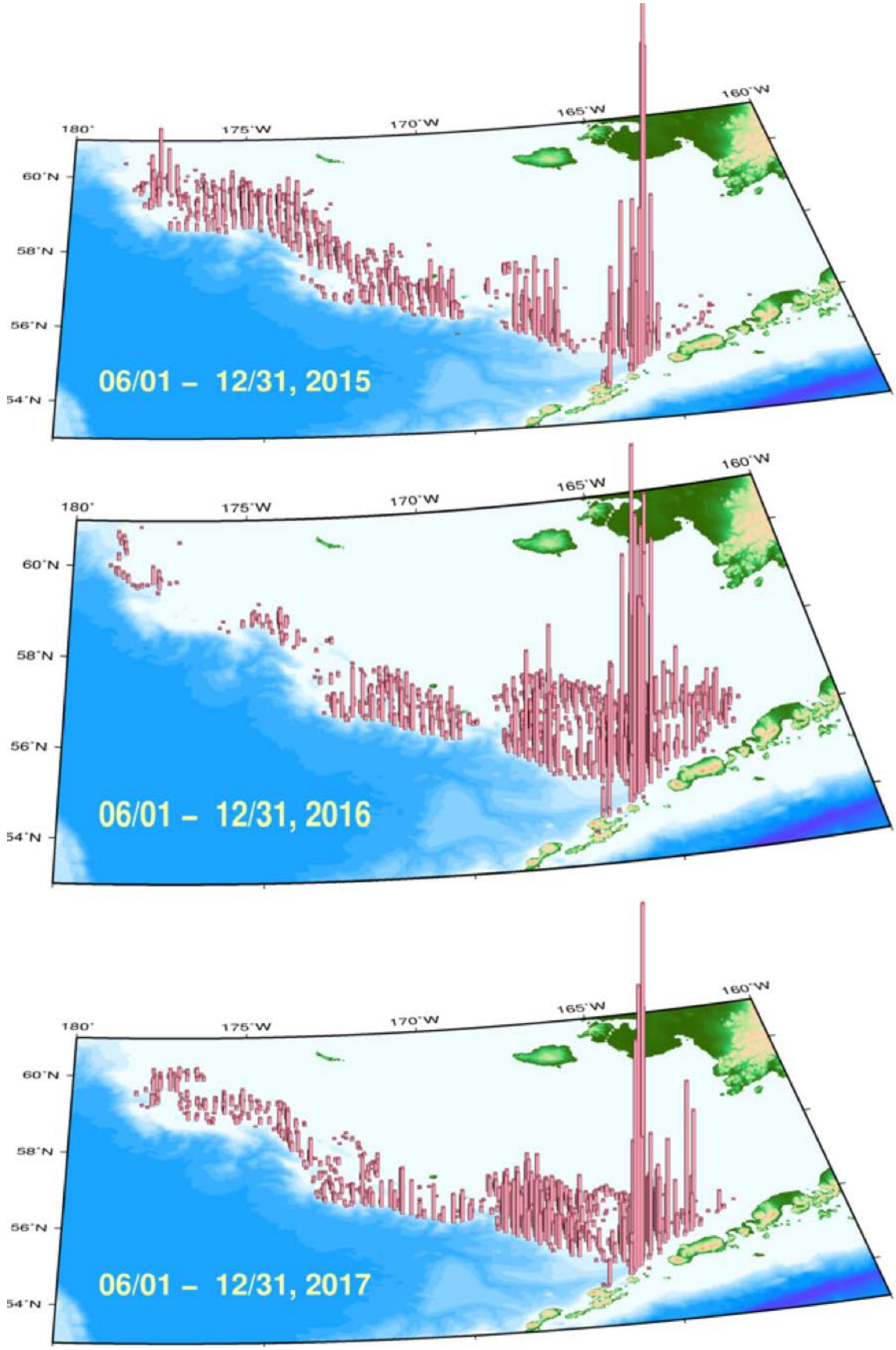

Figure 6: EBS pollock catch distribution during B-season, 2015-2017. Column height is proportional to total catch.

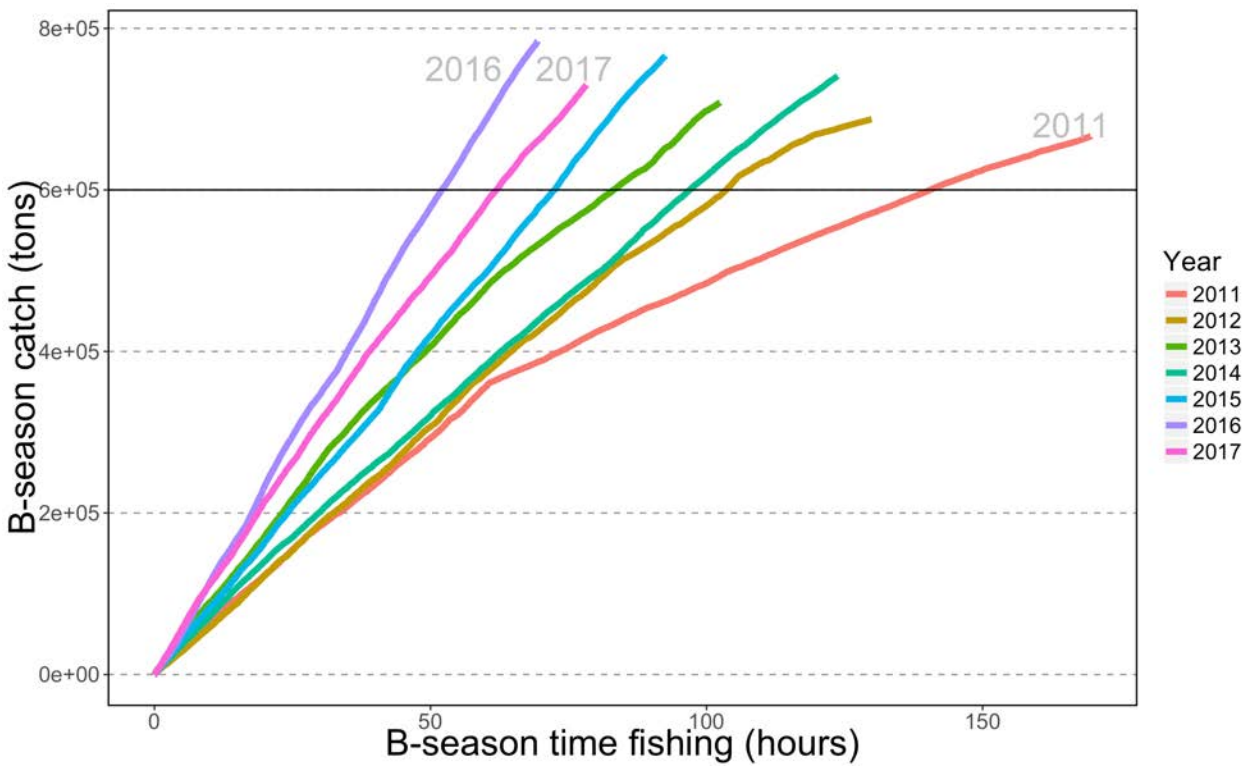

Figure 7: B-season EBS fleet-wide nominal pollock catch (kg) per hour of fishing recorded by NMFS scientific observers.

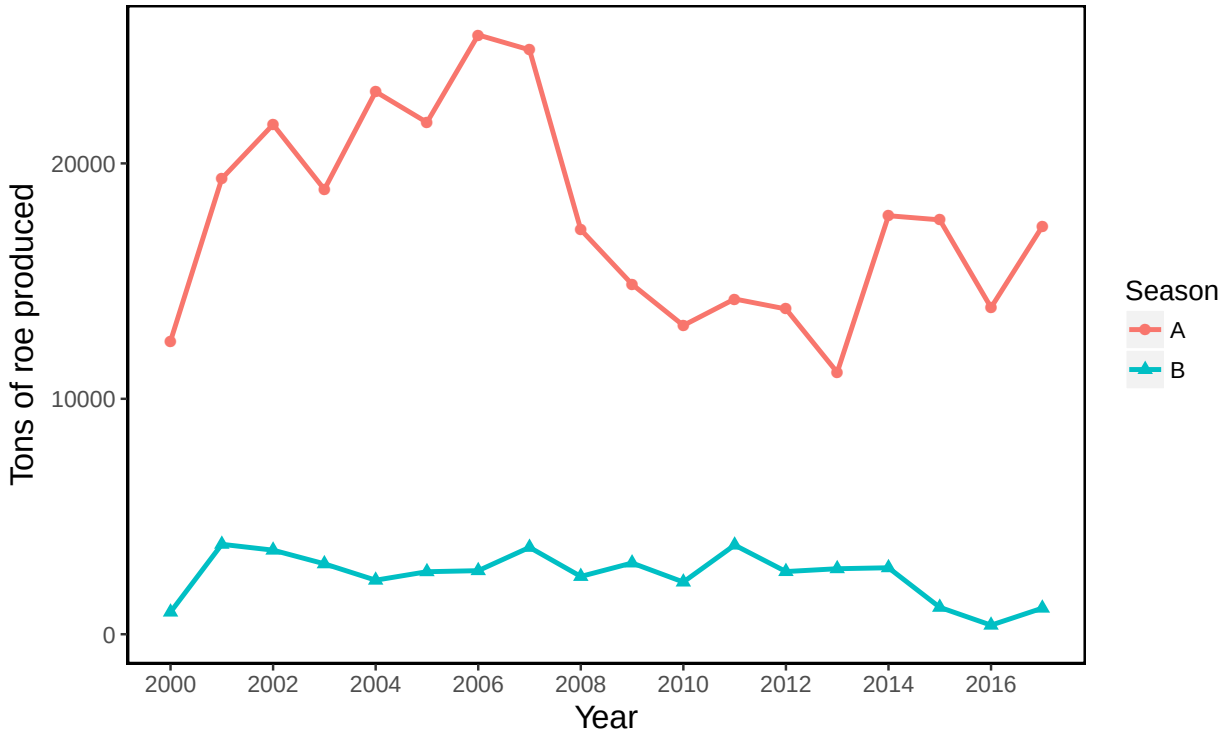

Figure 8: EBS pollock roe production in A and B seasons compared to overall landed catch.

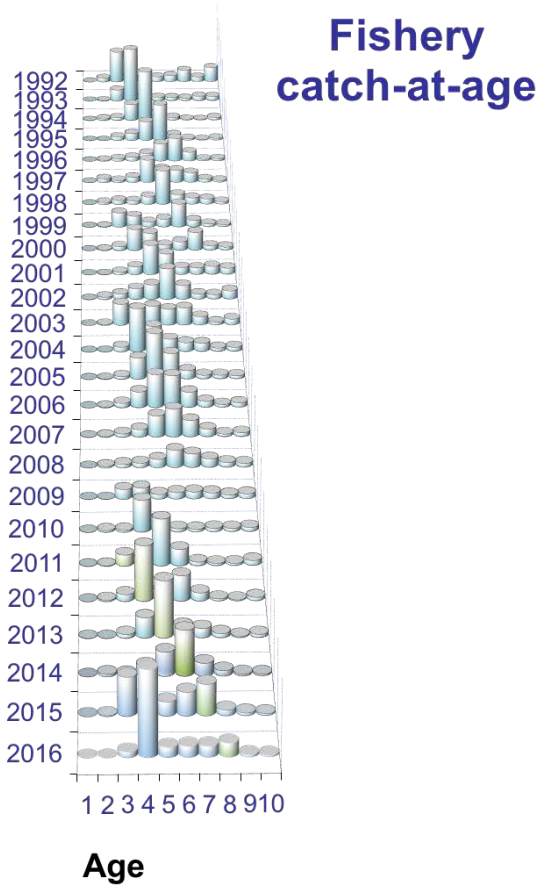

Figure 9: EBS pollock fishery estimated catch-at-age data (in number) for 1991-2016. Age 10 represents pollock age 10 and older. The 2008 year-class is shaded in green.

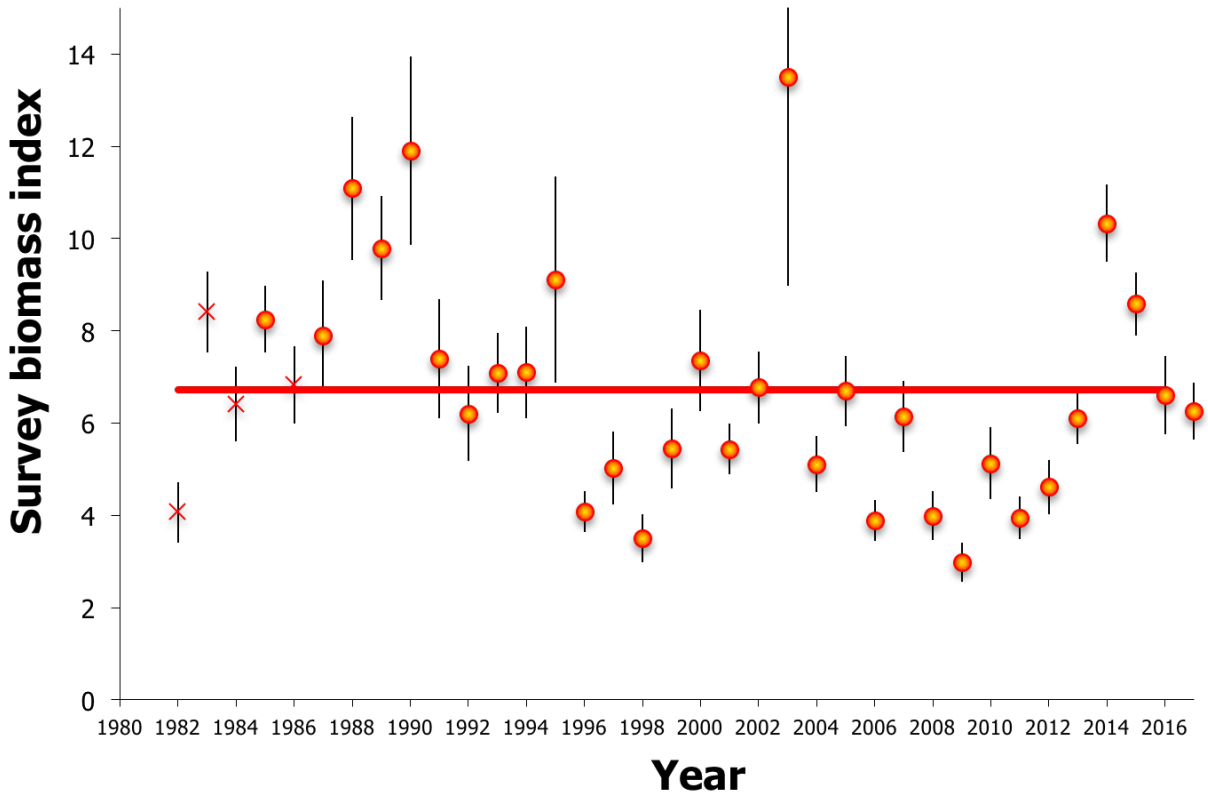

Figure 10: Bottom-trawl survey biomass estimates with error bars representing 1 standard deviation (density-dependent correction method; DDC) for EBS pollock. Horizontal line represents the long-term mean. Note these values differ from the design-based versions in Table 15.

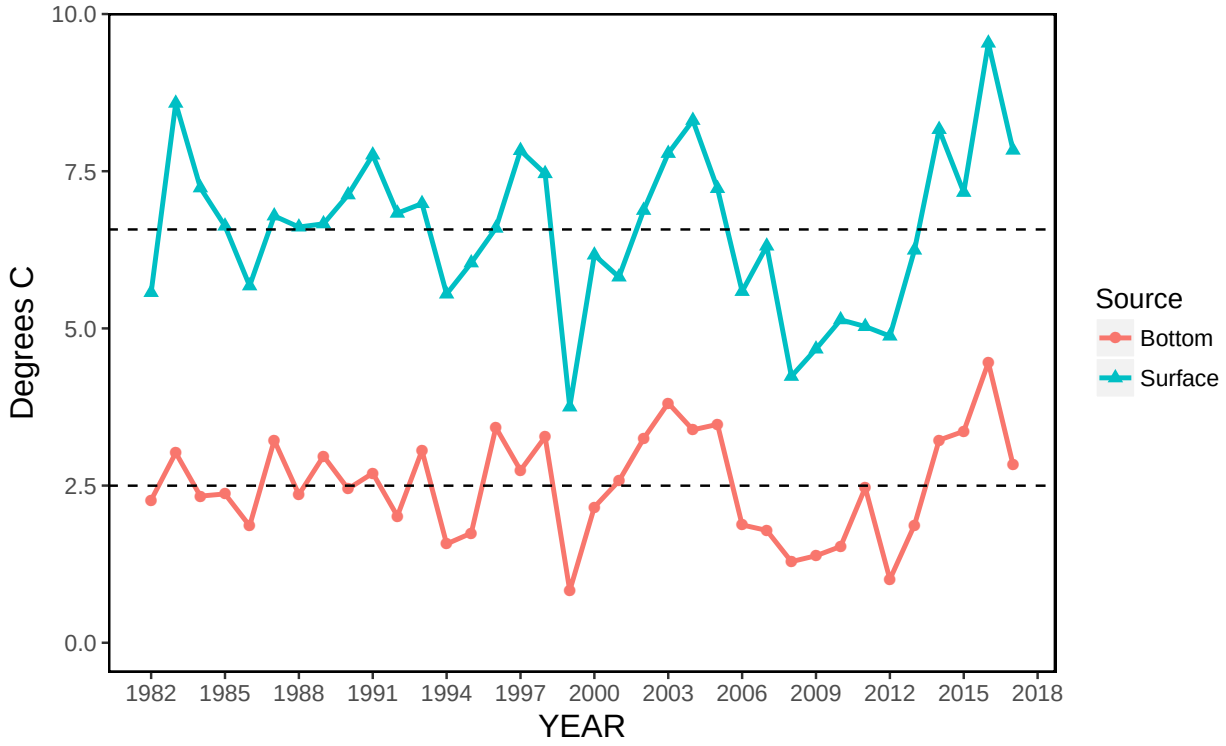

Figure 11: Bottom and surface temperatures for the Bering Sea from the NMFS summer bottom-trawl surveys (1982-2017). Dashed lines represent mean values.

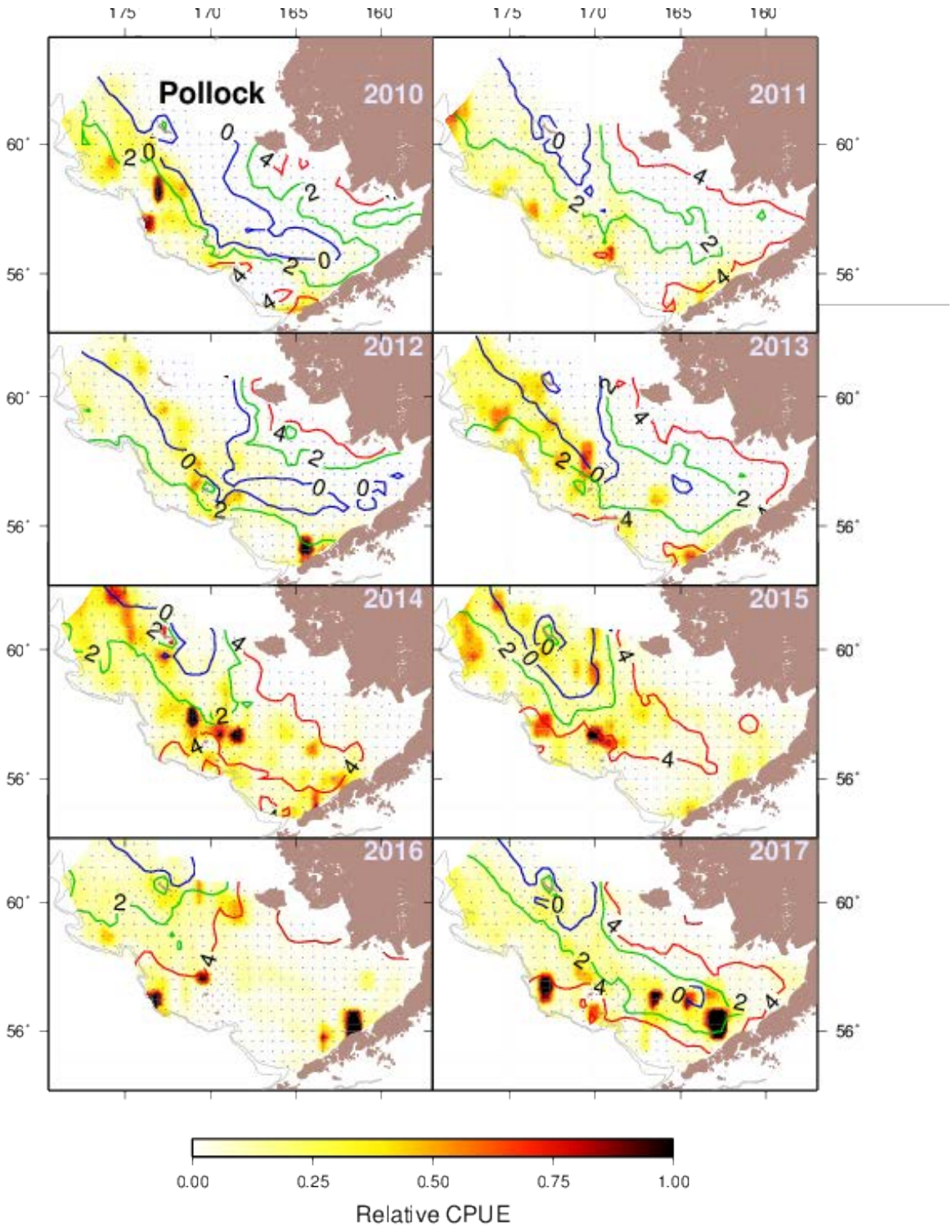

Figure 12: EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms in degrees C; 2010-2017.

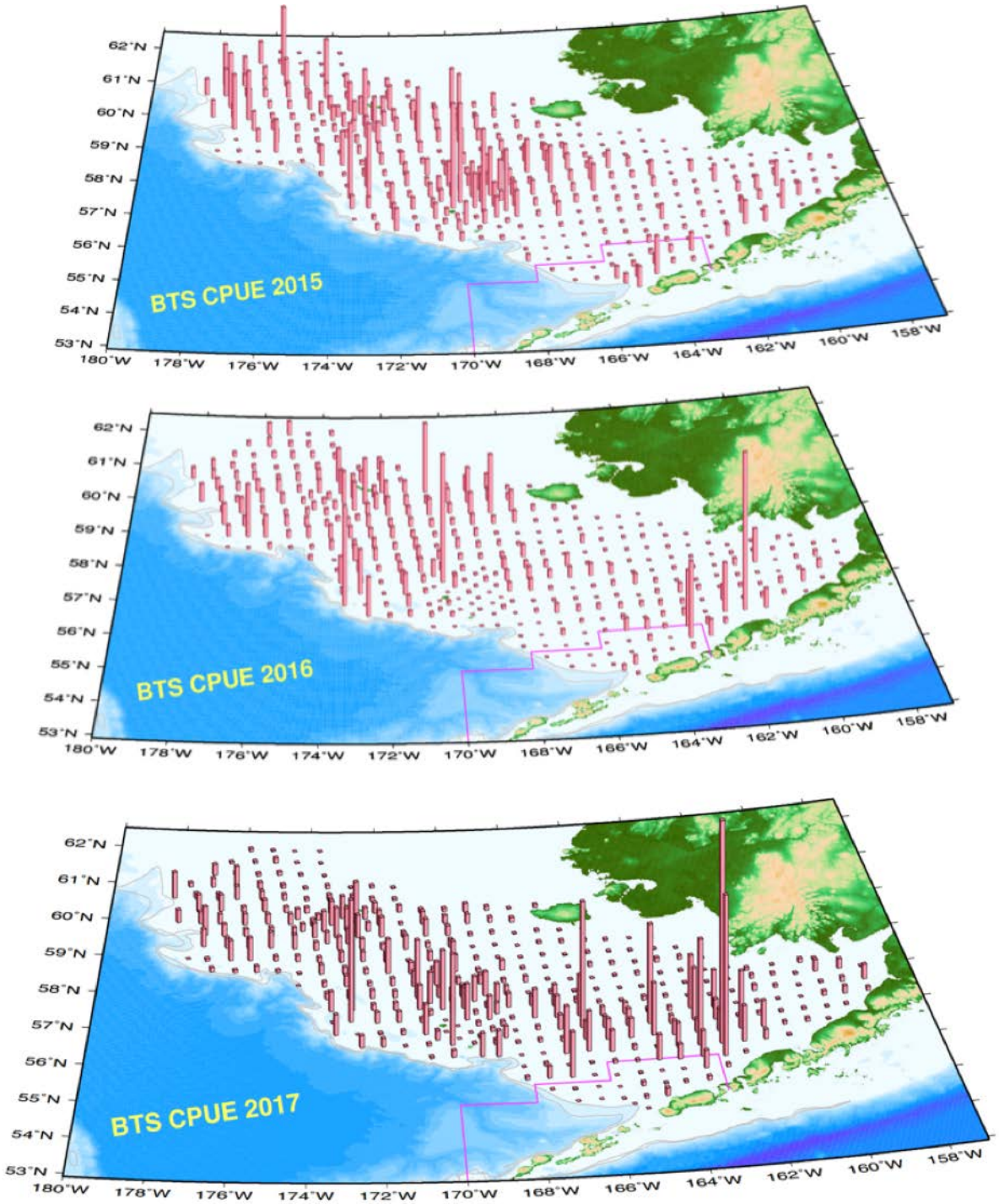

Figure 13: Bottom trawl survey pollock catch in kg per hectare for 2015 - 2017. Height of vertical lines are proportional to station-specific pollock densities by weight (kg per hectare) with constant scales for all years.

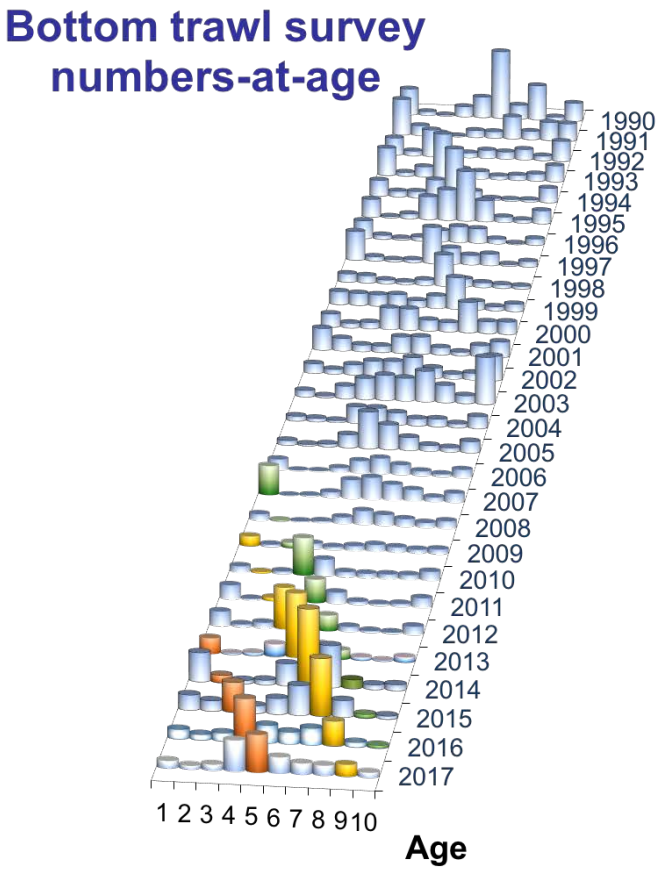

Figure 14: Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1990-2017). The 2006 and 2008 year-classes are shaded differently.

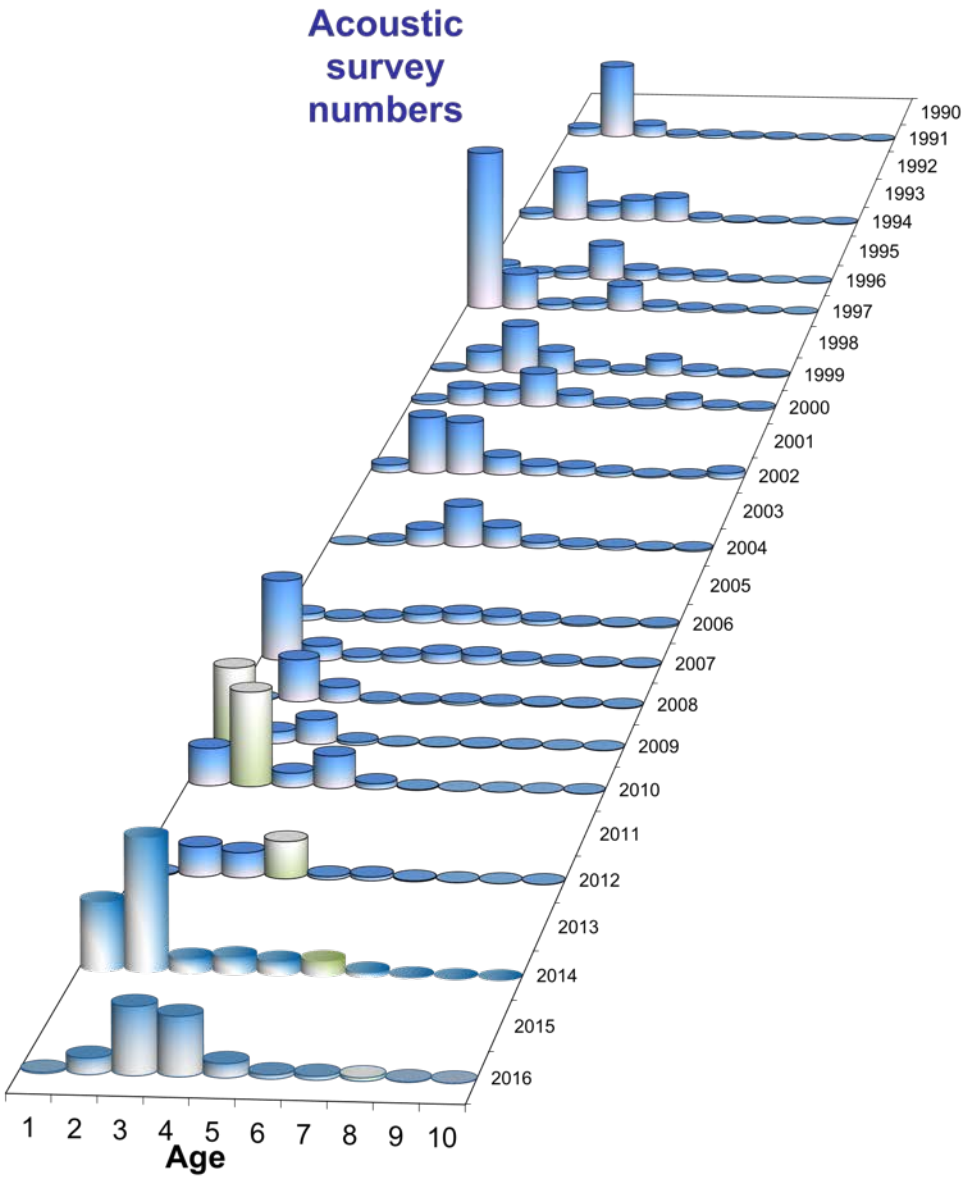

Figure 15: Pollock abundance at age estimates from the AT survey, 1979-2016.

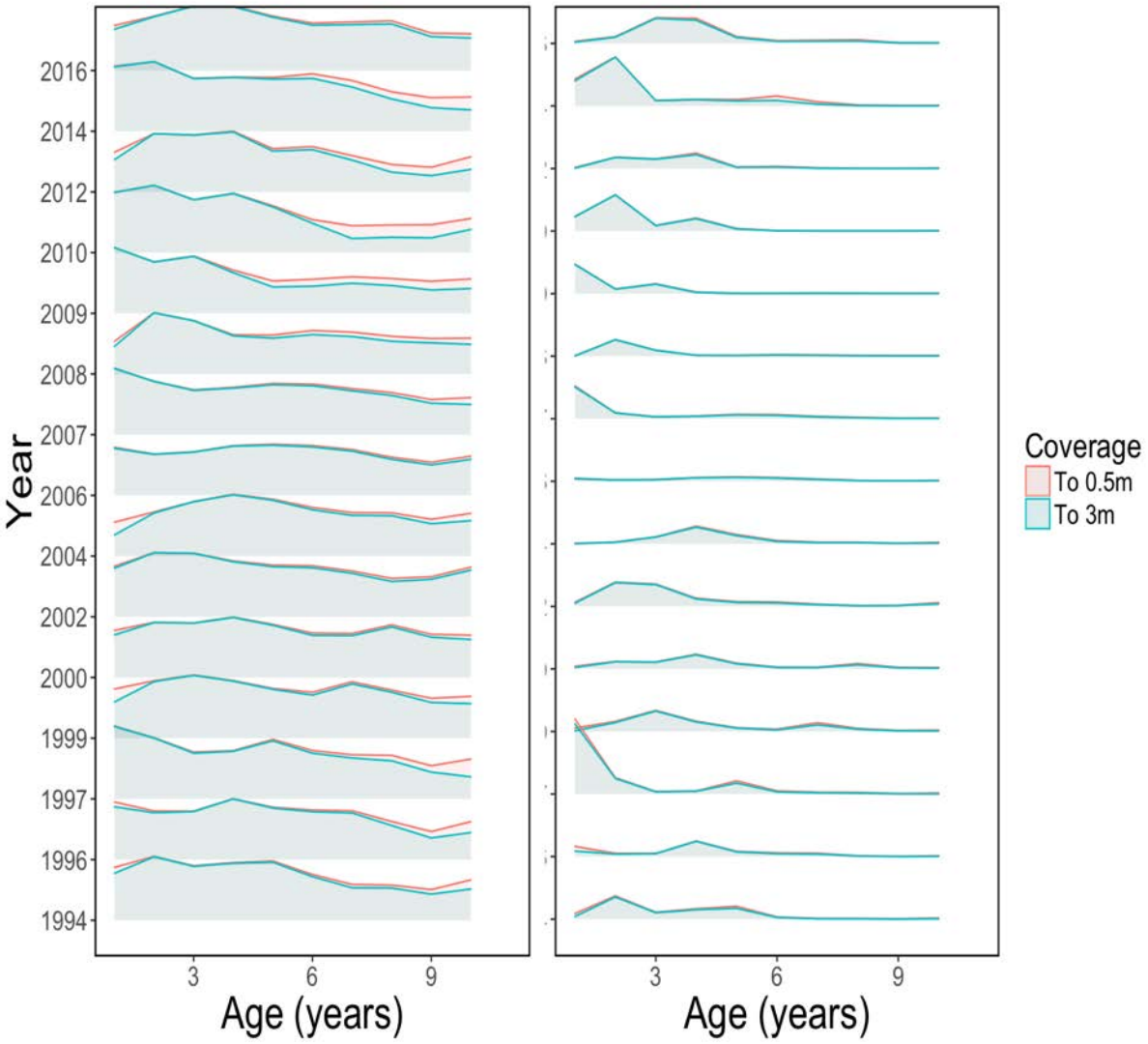

Figure 16: Pollock abundance at age estimates from the AT survey showing revisions including the bottom layer (0.5-3m) on log scale (left) and arithmetic scale (right) 1994-2016.

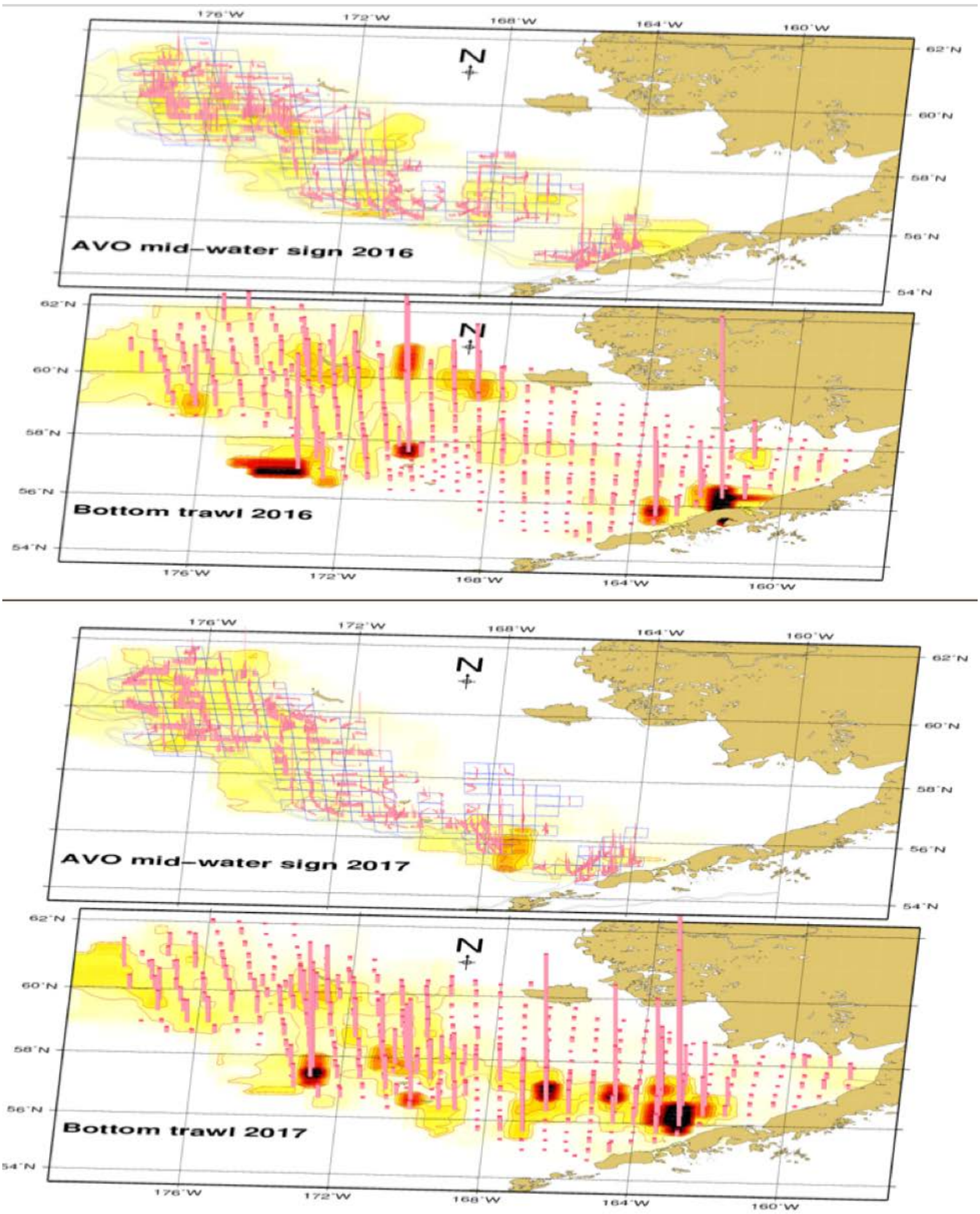

Figure 17: EBS pollock AVO transects (superimposed) over bottom-trawl survey stations and density estimates (in both settings contoured in the yellow-red heat map) comparing 2017 (top) and 2016 (bottom).

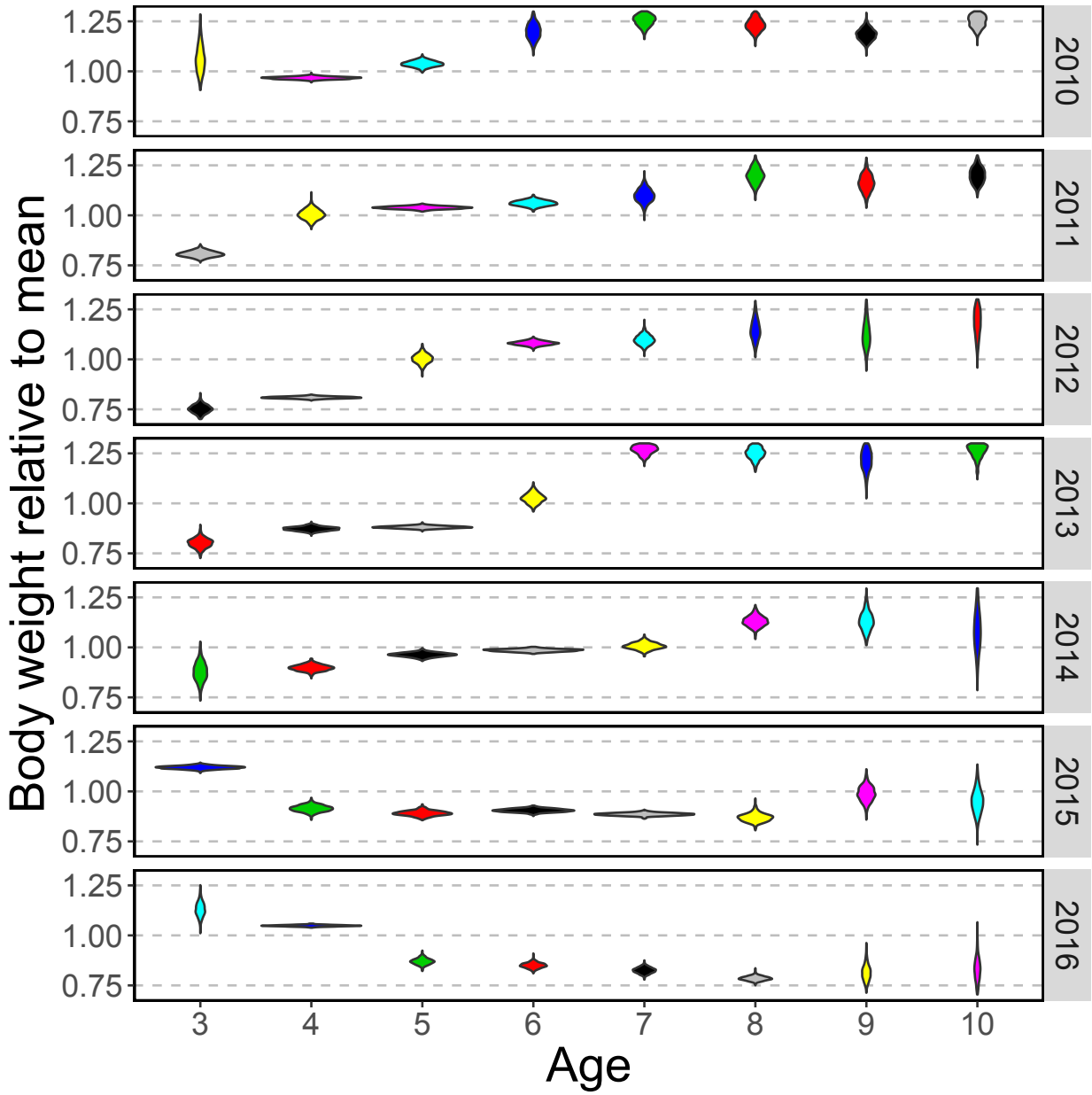

Figure 18: Recent fishery average weight-at-age anomaly (relative to mean) for ages 3-10, 2010-2016. Vertical shape reflects uncertainty in the data (wider shapes being more precise), colors are consistent with cohorts.

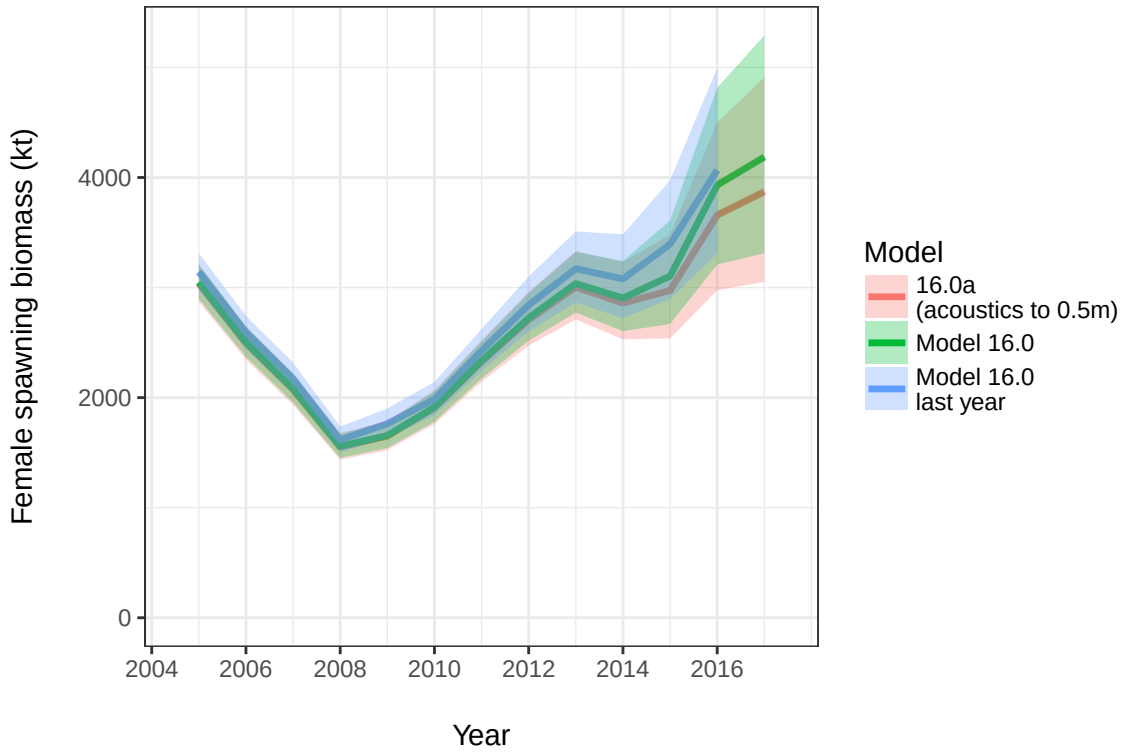

Figure 19: EBS pollock model evaluation results of female spawning biomass comparing last year's model and results with the same model using updated data and then with the updated acoustic-trawl survey data extended to 0.5 m from bottom.

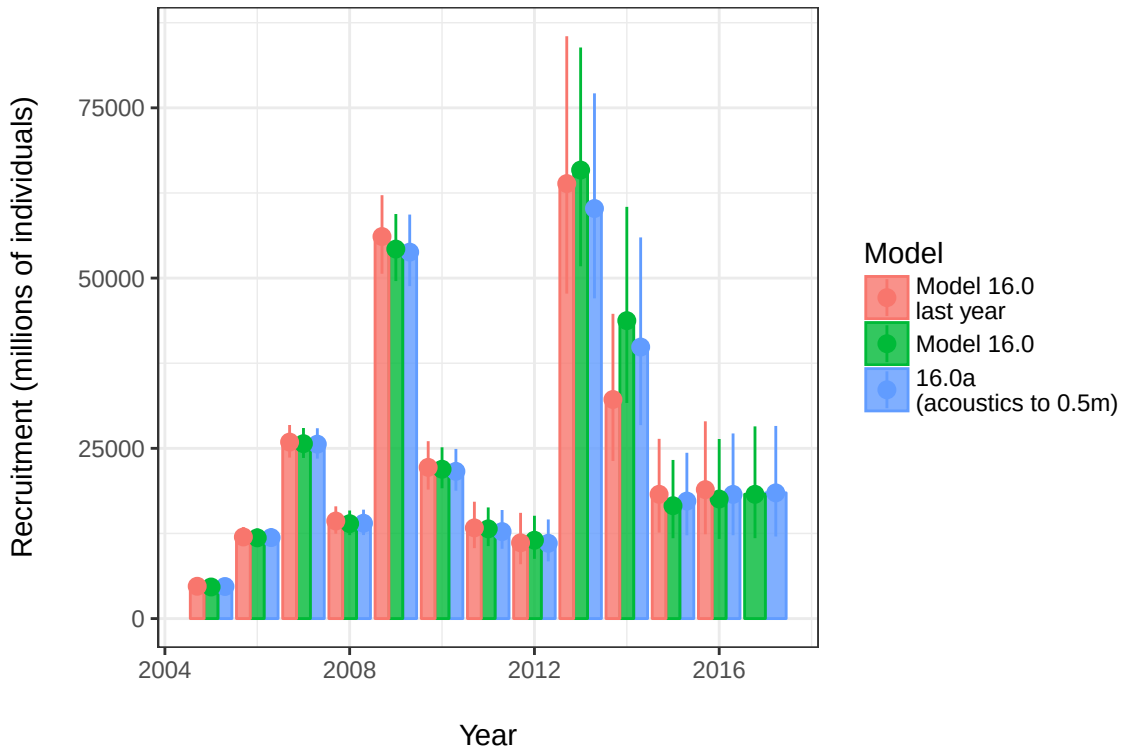

Figure 20: EBS pollock model evaluation results of recruitment comparing last year's model and results with the same model using updated data and then with the updated acoustic-trawl survey data extended to 0.5 m from bottom.

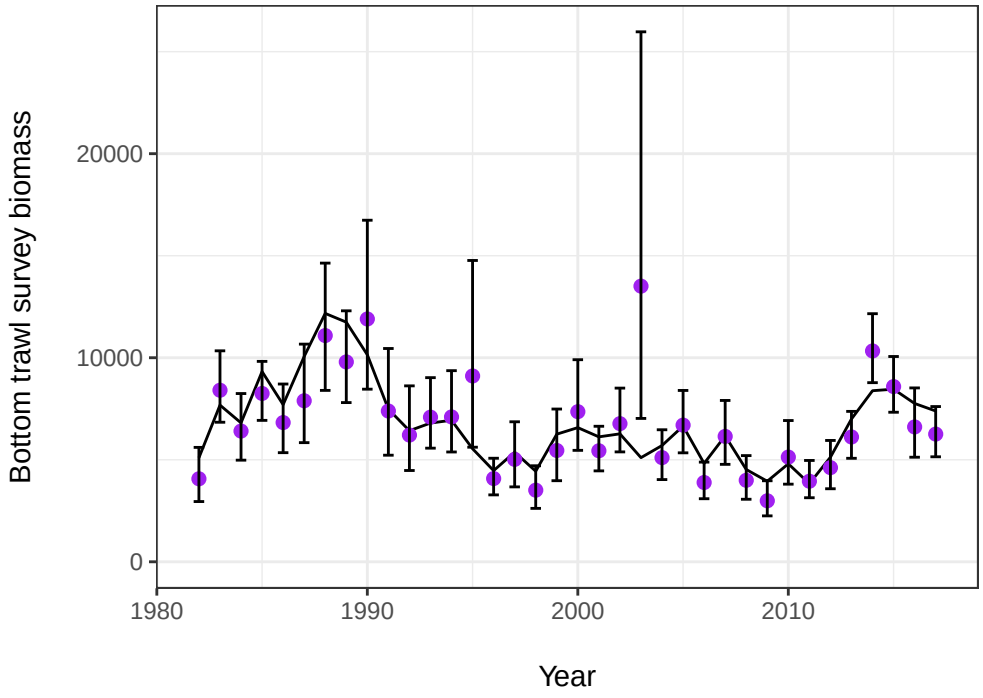

Figure 21: EBS pollock model fit to the BTS biomass data, 1982-2017.

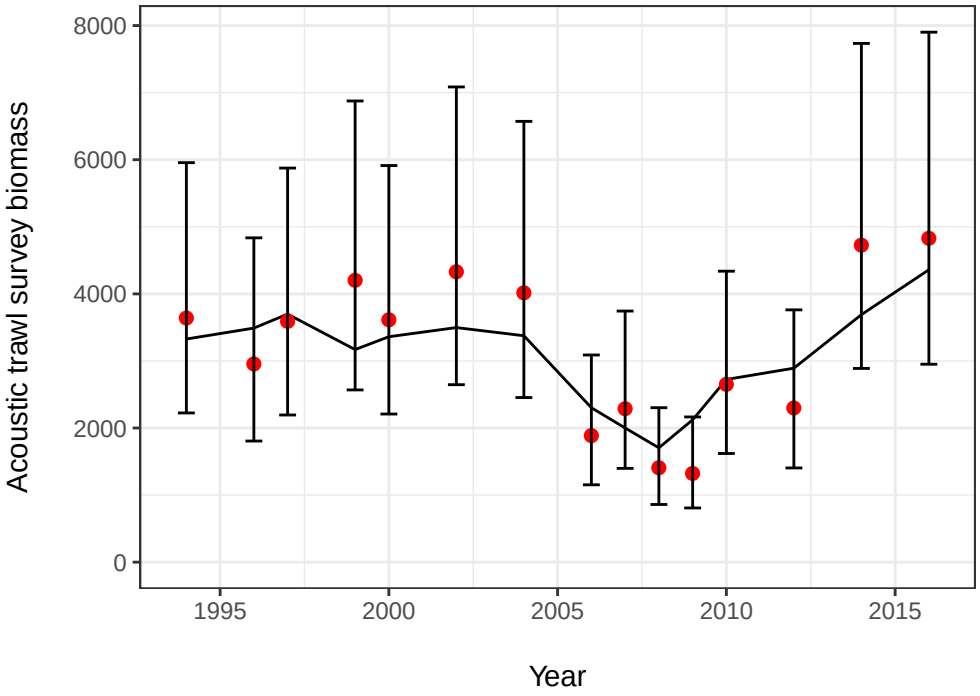

Figure 22: EBS pollock model fit to the ATS biomass data, 1994-2016.

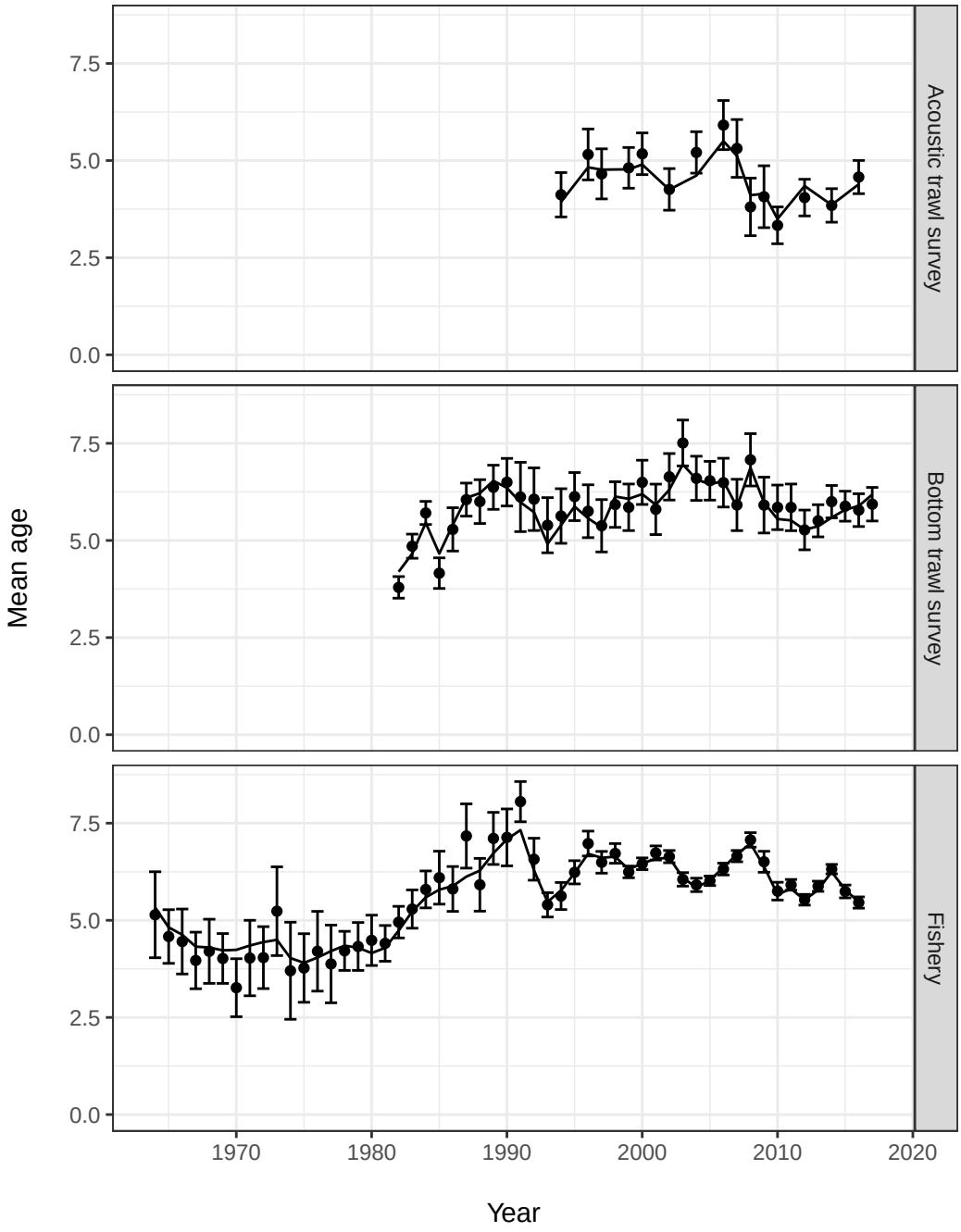

Figure 23: EBS pollock model fits to observed mean age for the fishery (bottom) bottom trawl survey (middle) and the Acoustic trawl survey (top) for EBS pollock.

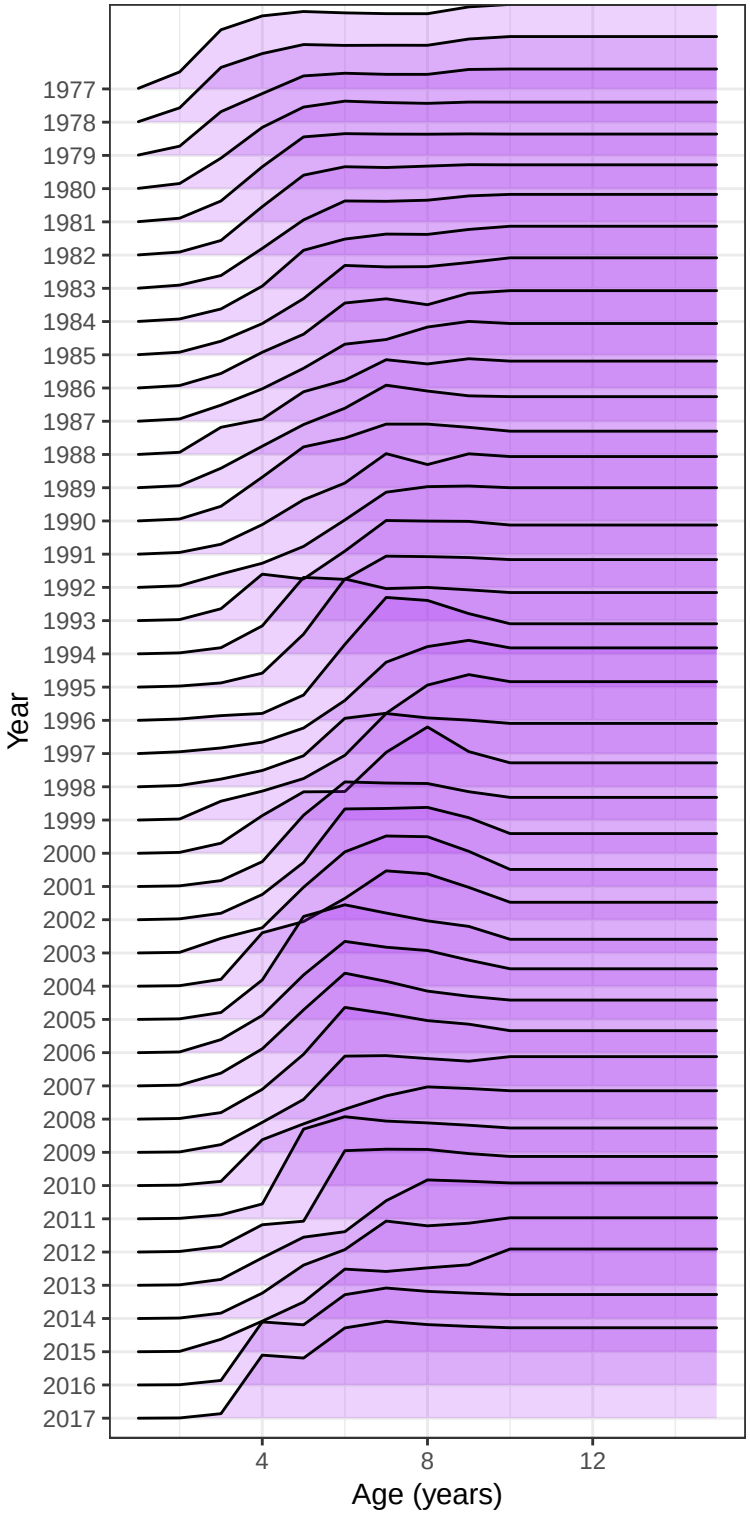

Figure 24: Selectivity at age estimates for the EBS pollock fishery.

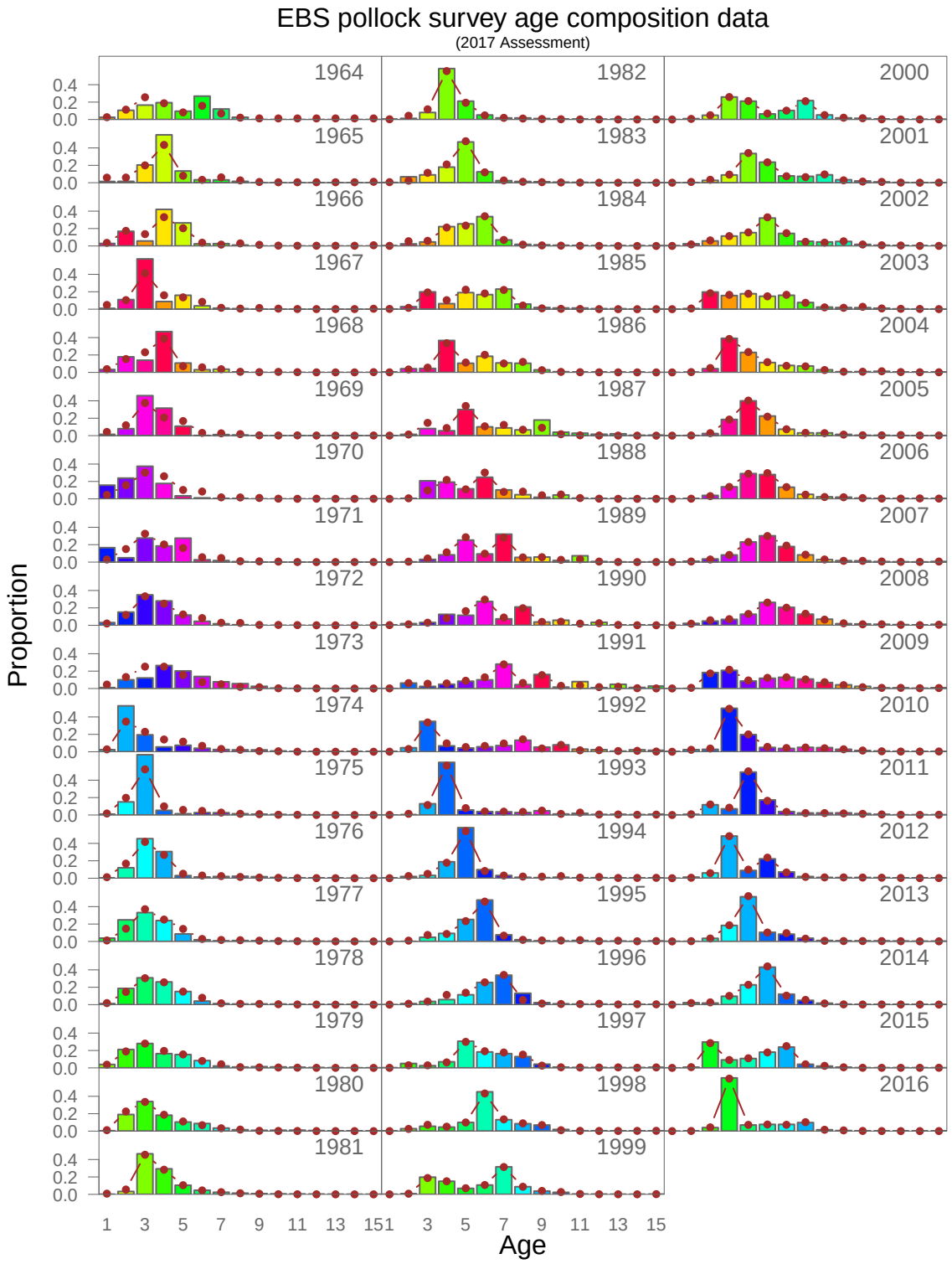

Figure 25: Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2016). The 2016 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

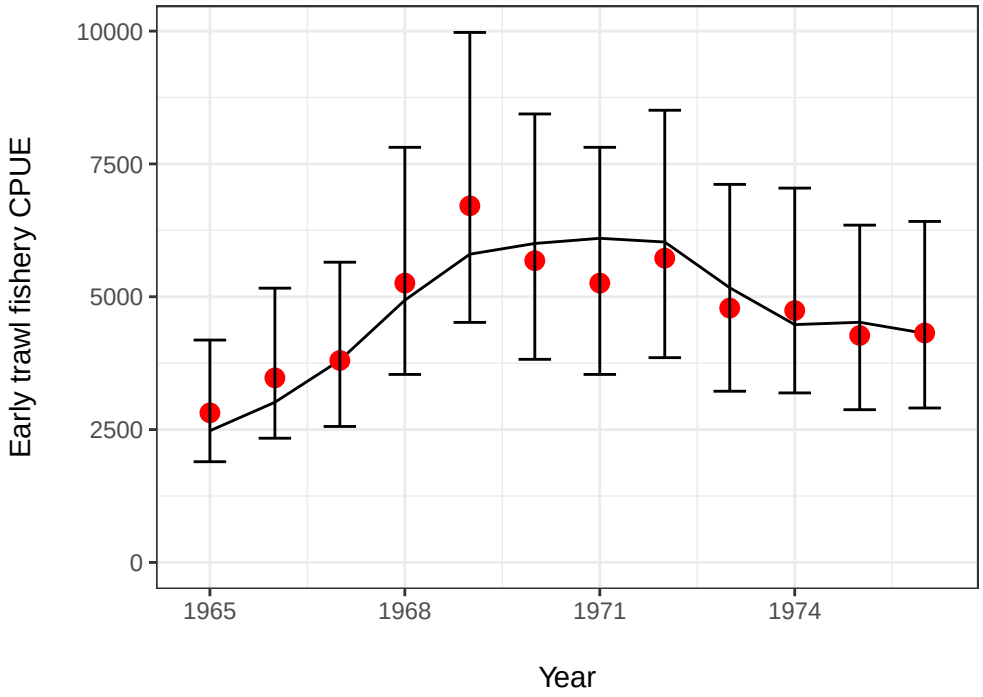

Figure 26: EBS pollock model fits to the Japanese fishery CPUE.

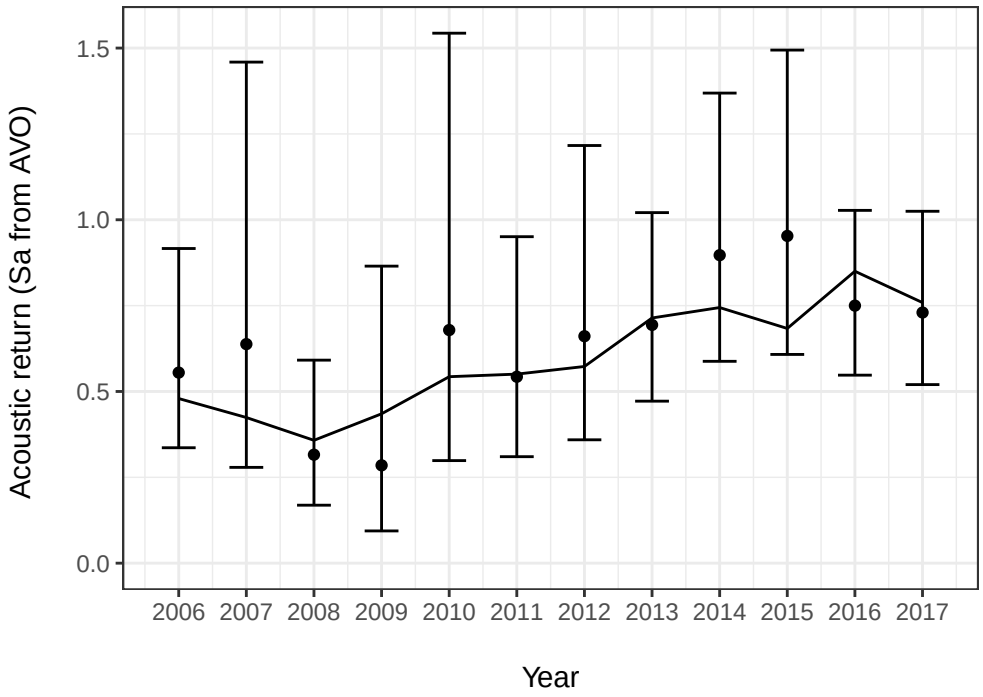

Figure 27: Model results of predicted EBS pollock biomass following the AVO index (under model 1.0). Error bars represent assumed 95% confidence bounds.

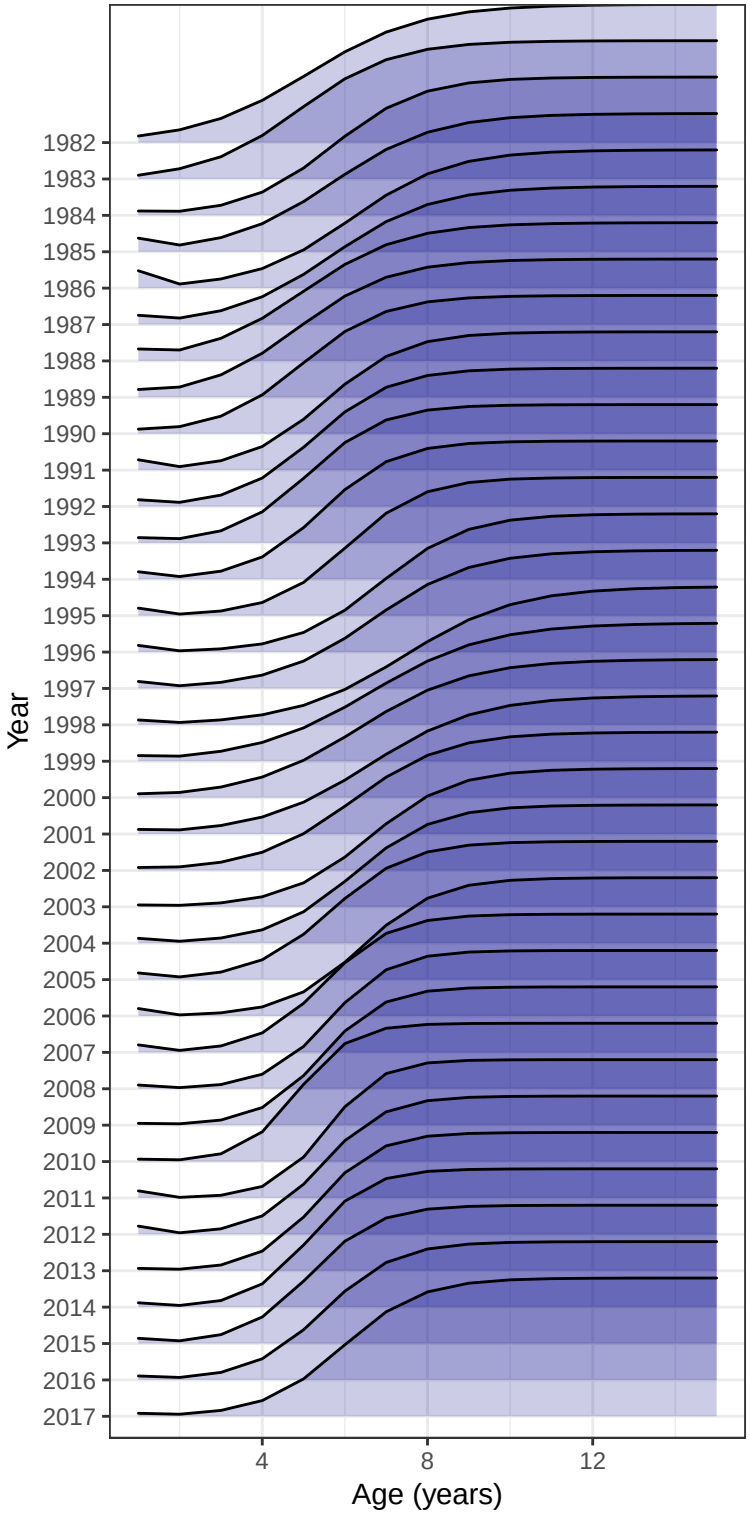

Figure 28: Model estimates of bottom-trawl survey selectivity, 1982-2017.

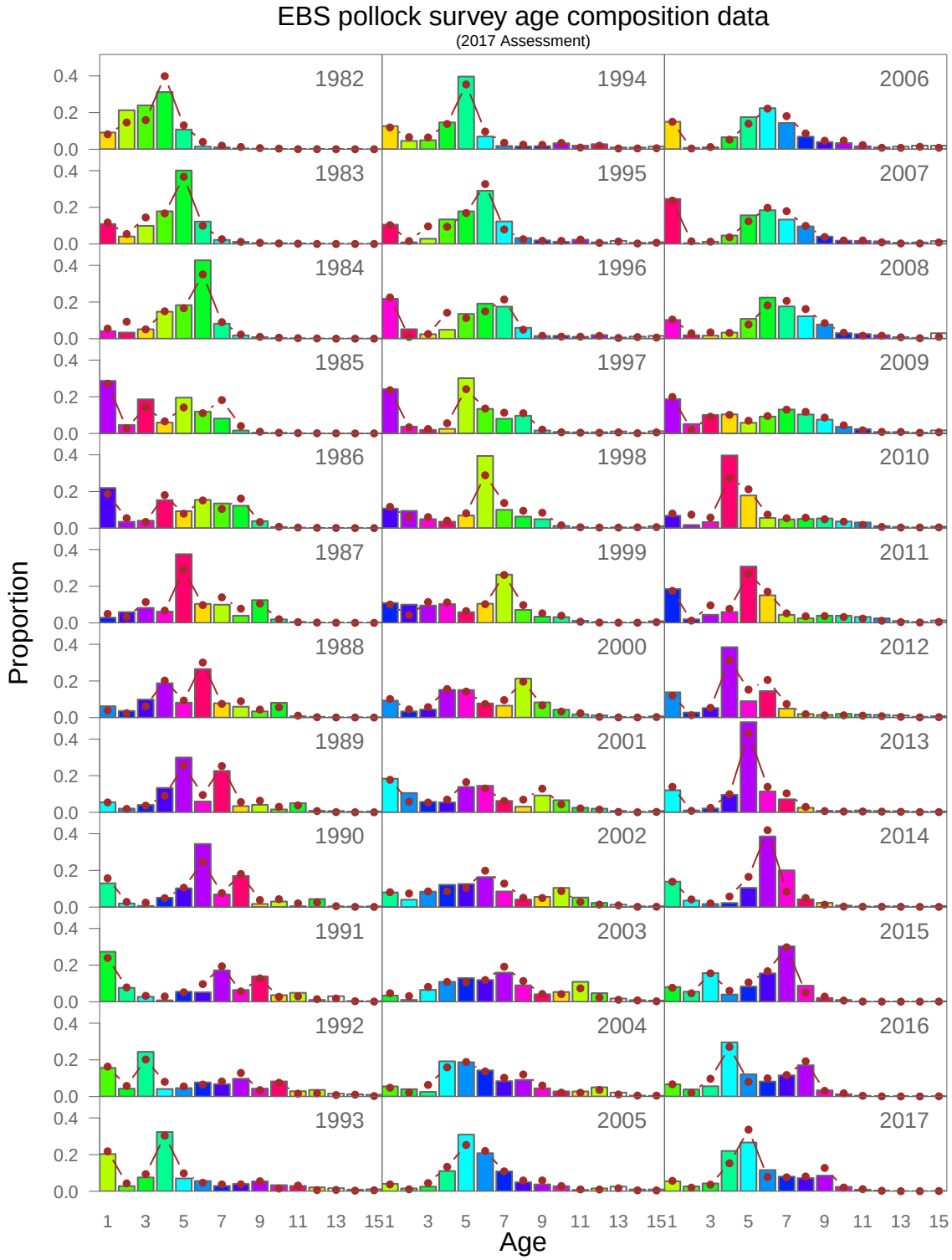

Figure 29: Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2017.

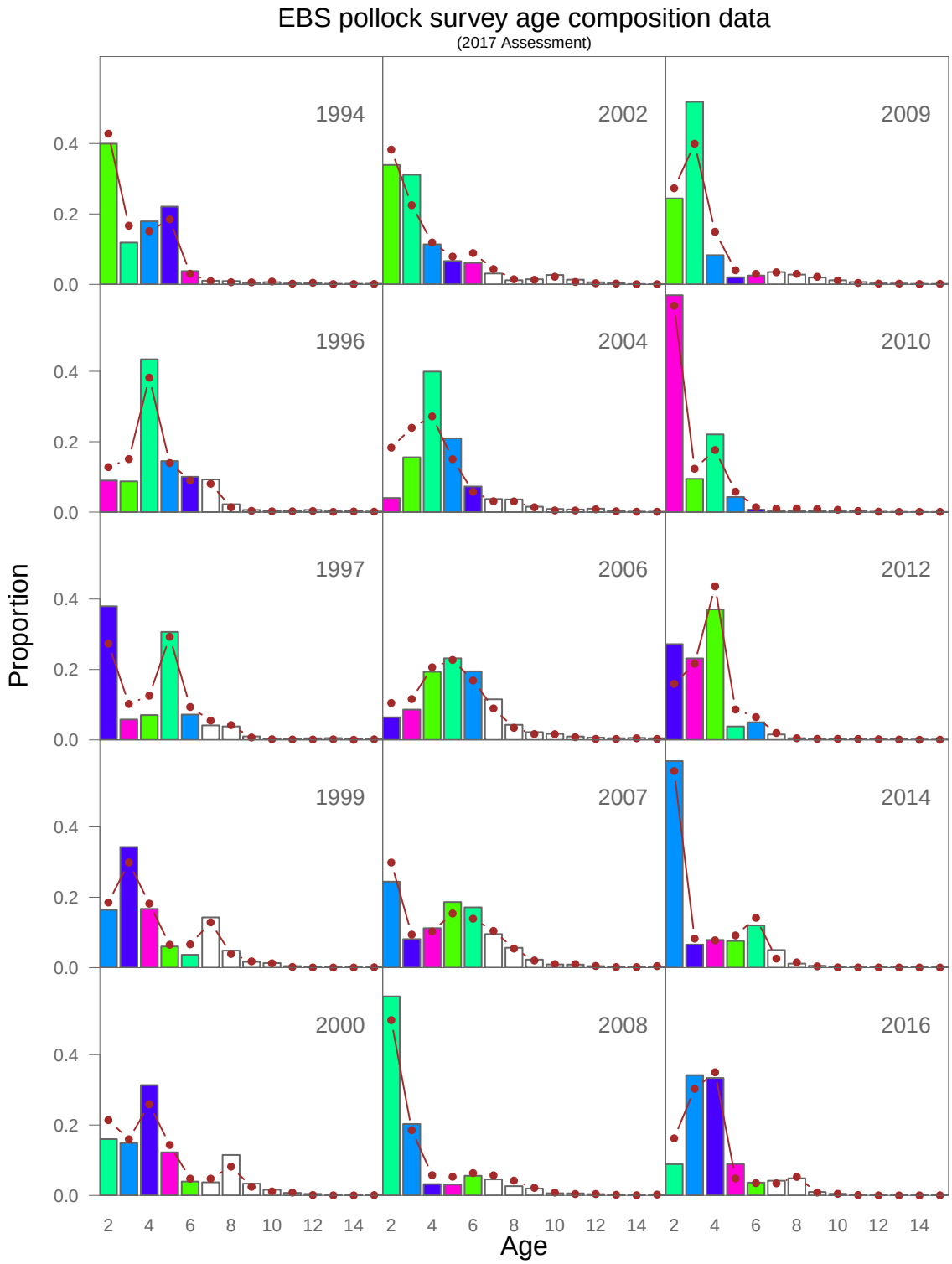

Figure 30: Model fit (dots) to the acoustic-trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time (for years with consecutive surveys).

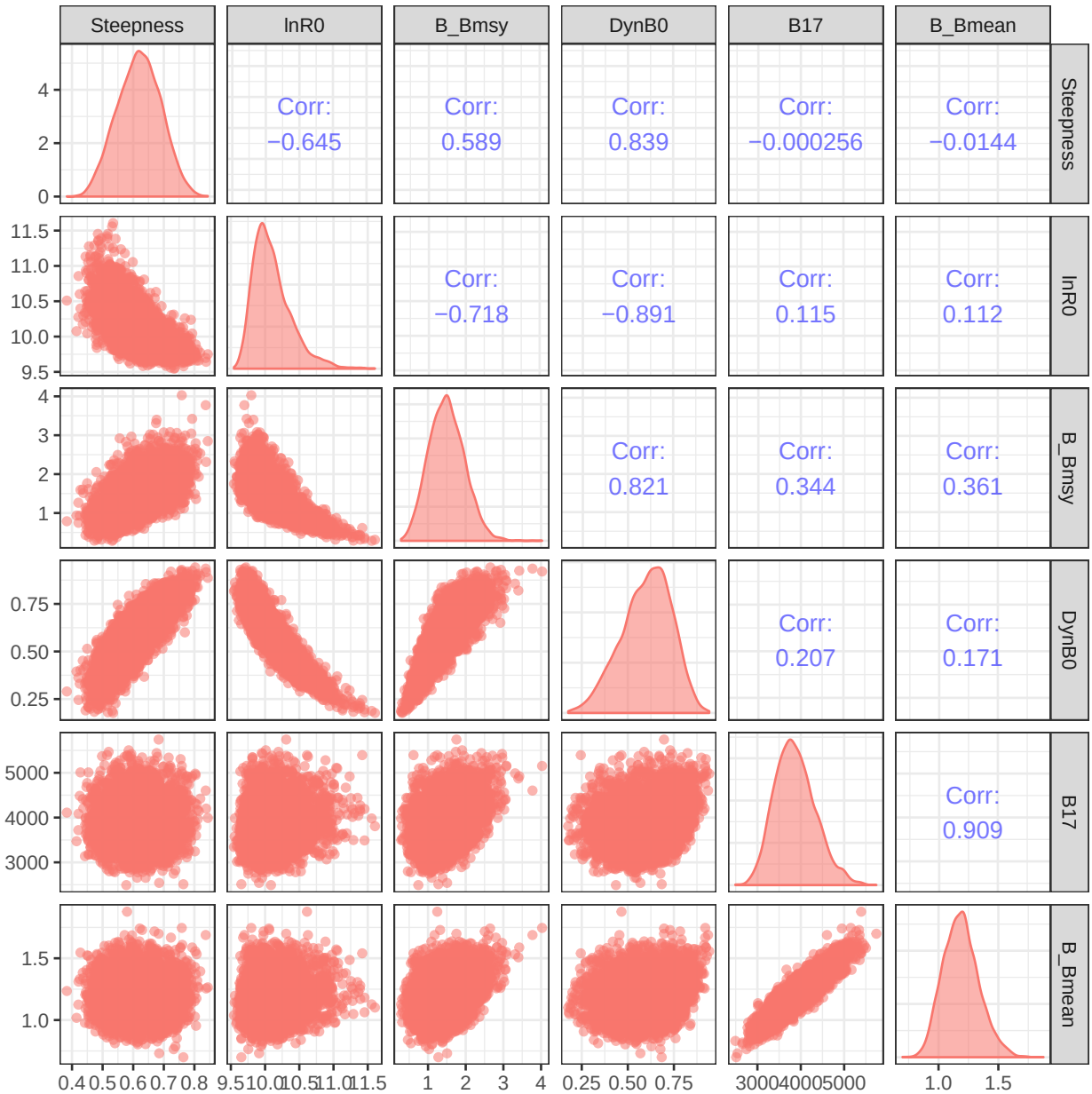

Figure 31: Pairwise plot of selected EBS pollock parameters and output from 3 million MCMC iterations thinned such that 5 thousand draws were saved as an approximation to the multivariate posterior distribution. Note that the figures on the diagonal represent the marginal posterior distributions. Key: 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 2017 over the value estimated that would occur if there had been no fishing, B17 is the spawning biomass in 2017, and B_Bmean is $B_{2017}/\bar{B}$.

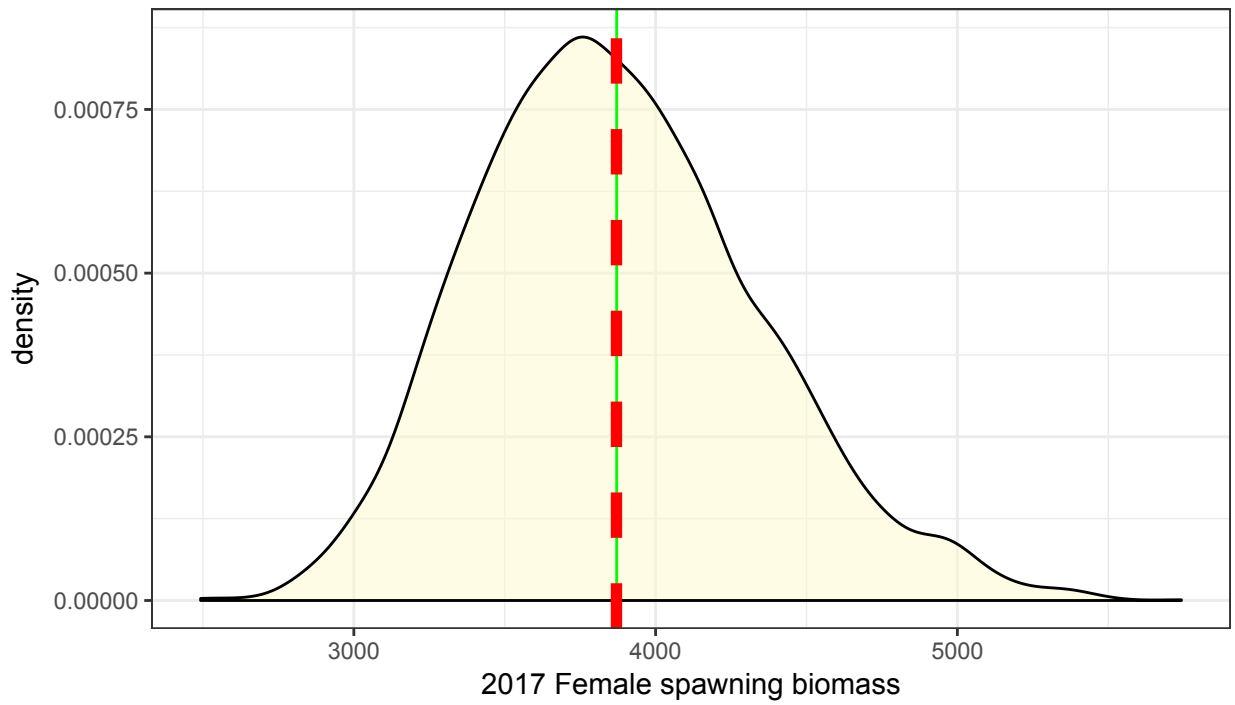

Figure 32: Integrated marginal posterior density (based on MCMC results) for the 2017 EBS pollock female spawning biomass compared to the point estimate (dashed red line). The mean of the posterior is shown in green (under the dashed line).

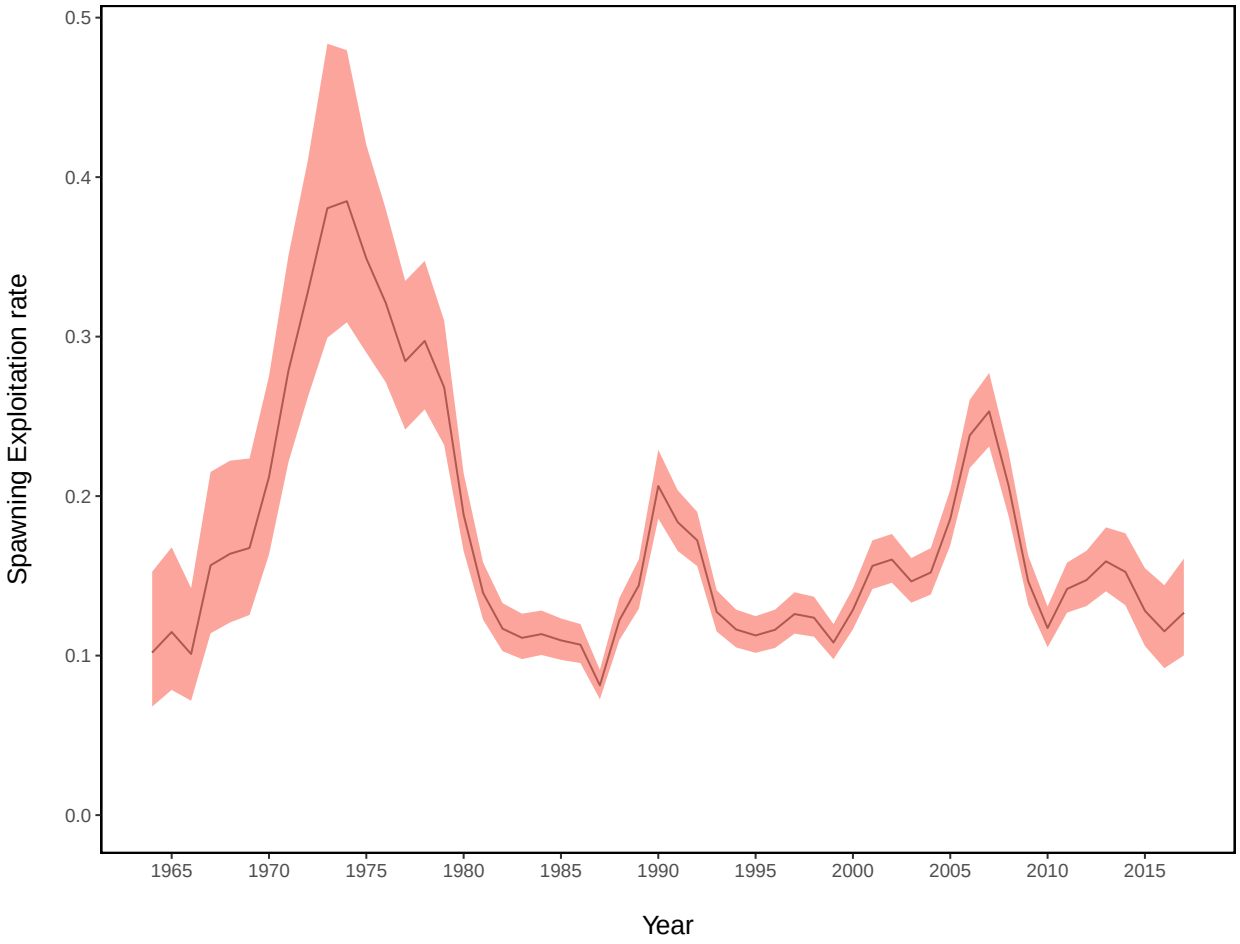

Figure 33: Estimated spawning exploitation rate (defined as the percent removal of egg production in a given spawning year).

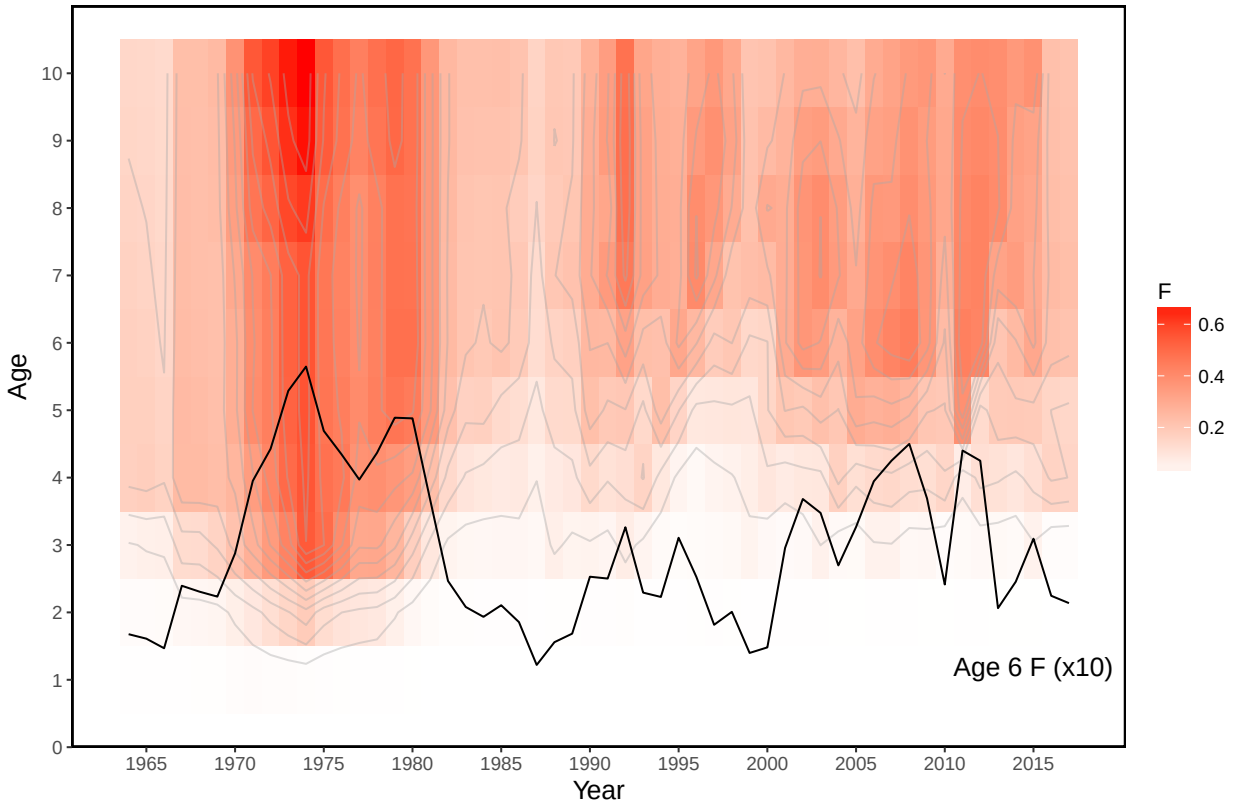

Figure 34: Estimated instantaneous age-specific fishing mortality rates for EBS pollock.

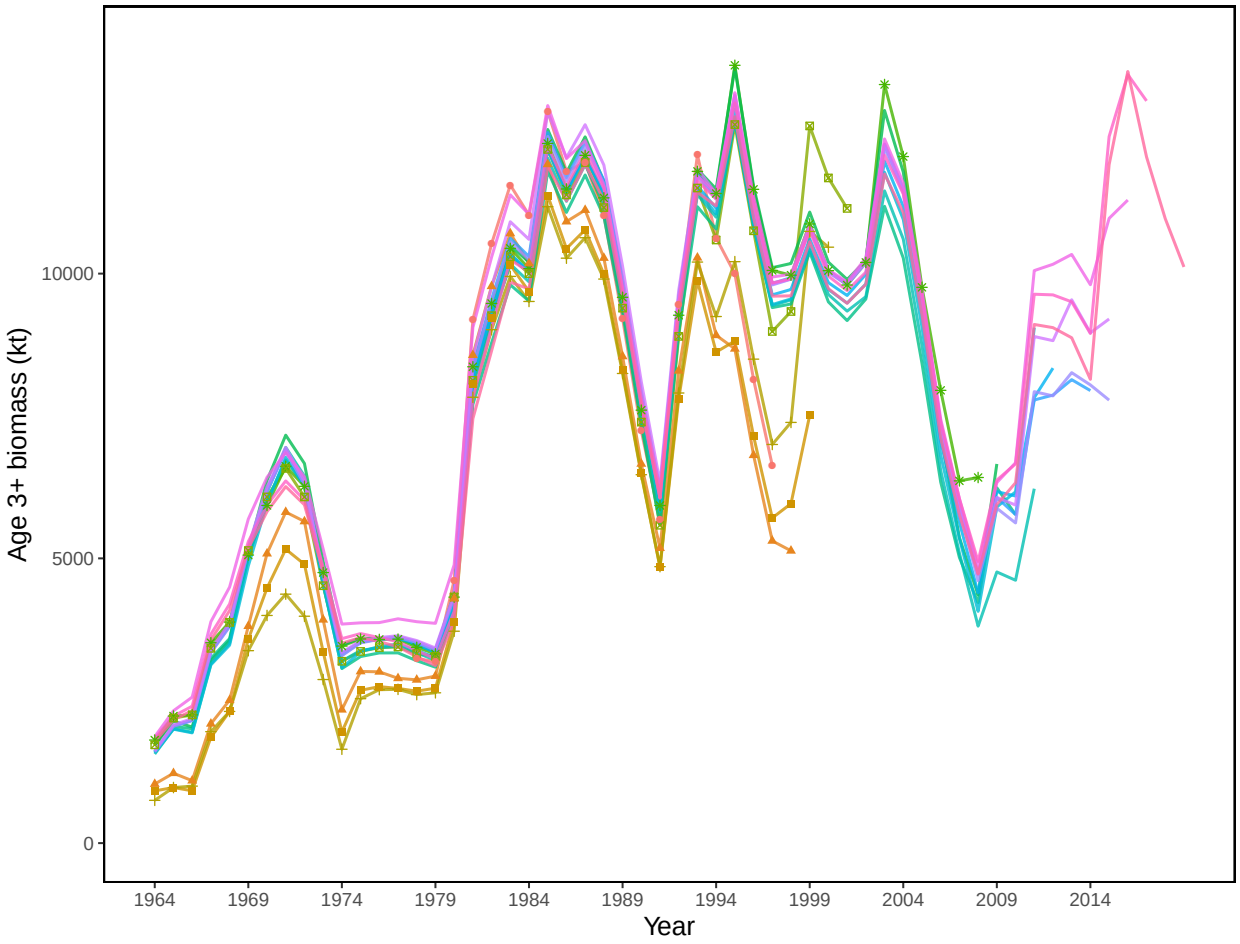

Figure 35: Comparison of the current assessment results with past assessments of begin-year EBS age-3+ pollock biomass.

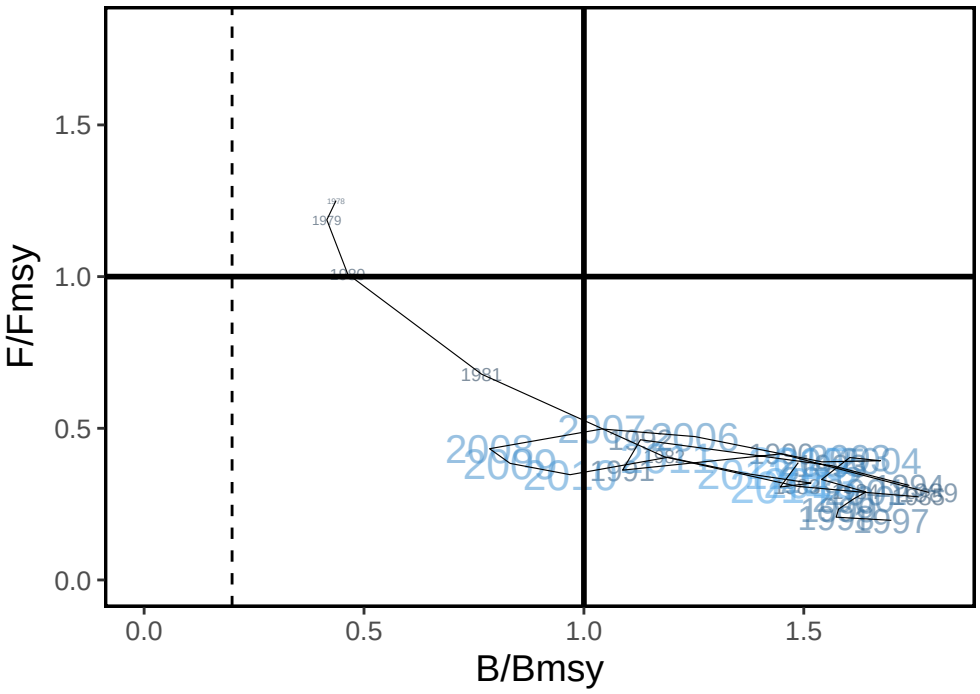

Figure 36: Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock.

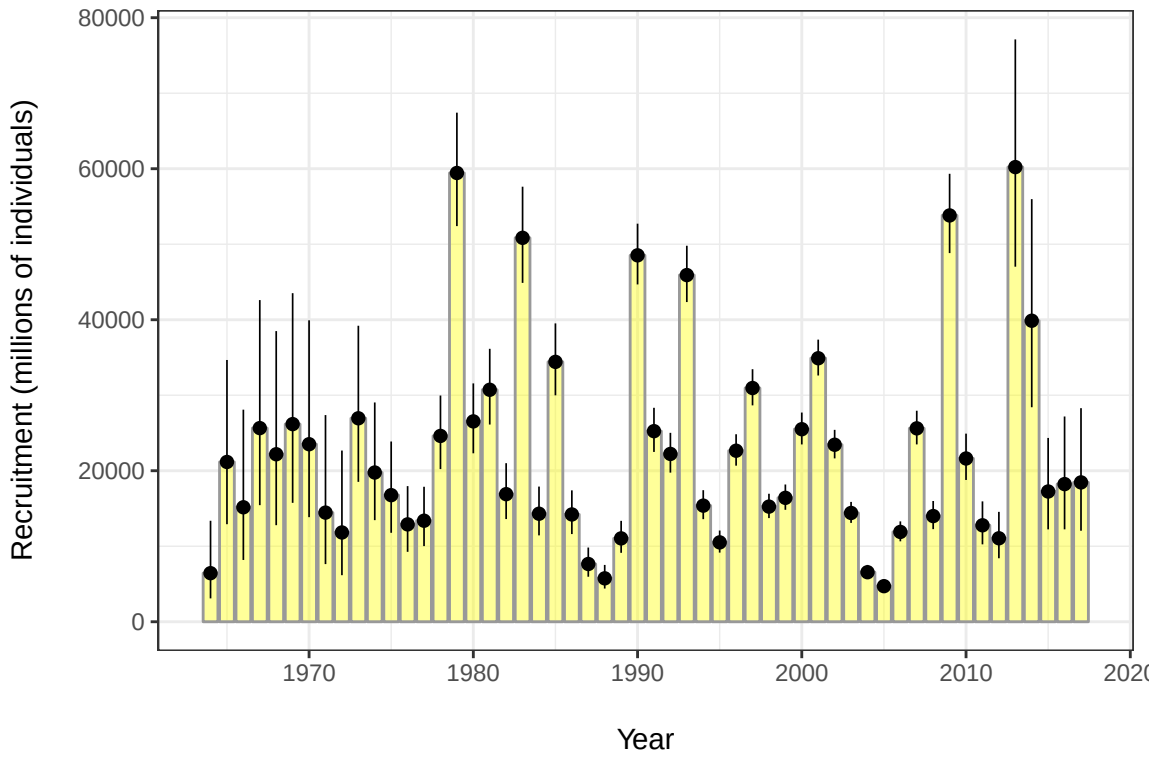

Figure 37: Recruitment estimates (age-1 recruits) for EBS pollock for all years since 1964 (1963-2016 year classes) for Model 16.0. Error bars reflect 90% credible intervals based on model estimates of uncertainty.

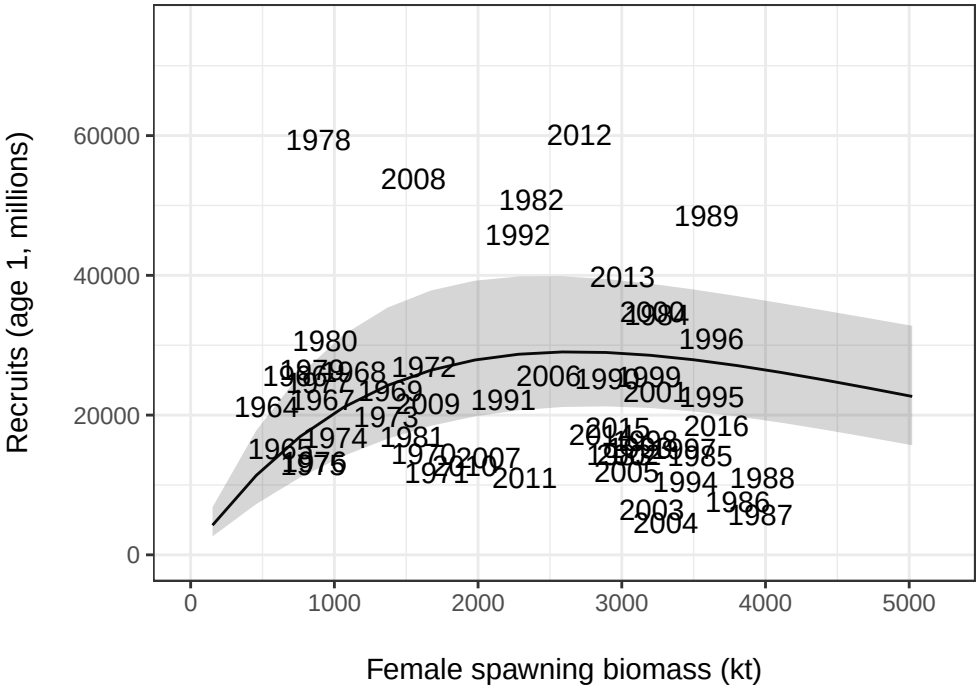

Figure 38: Stock-recruitment estimates (shaded represnts structural uncertainty) and age-1 EBS pollock estimates labeled by year-classes

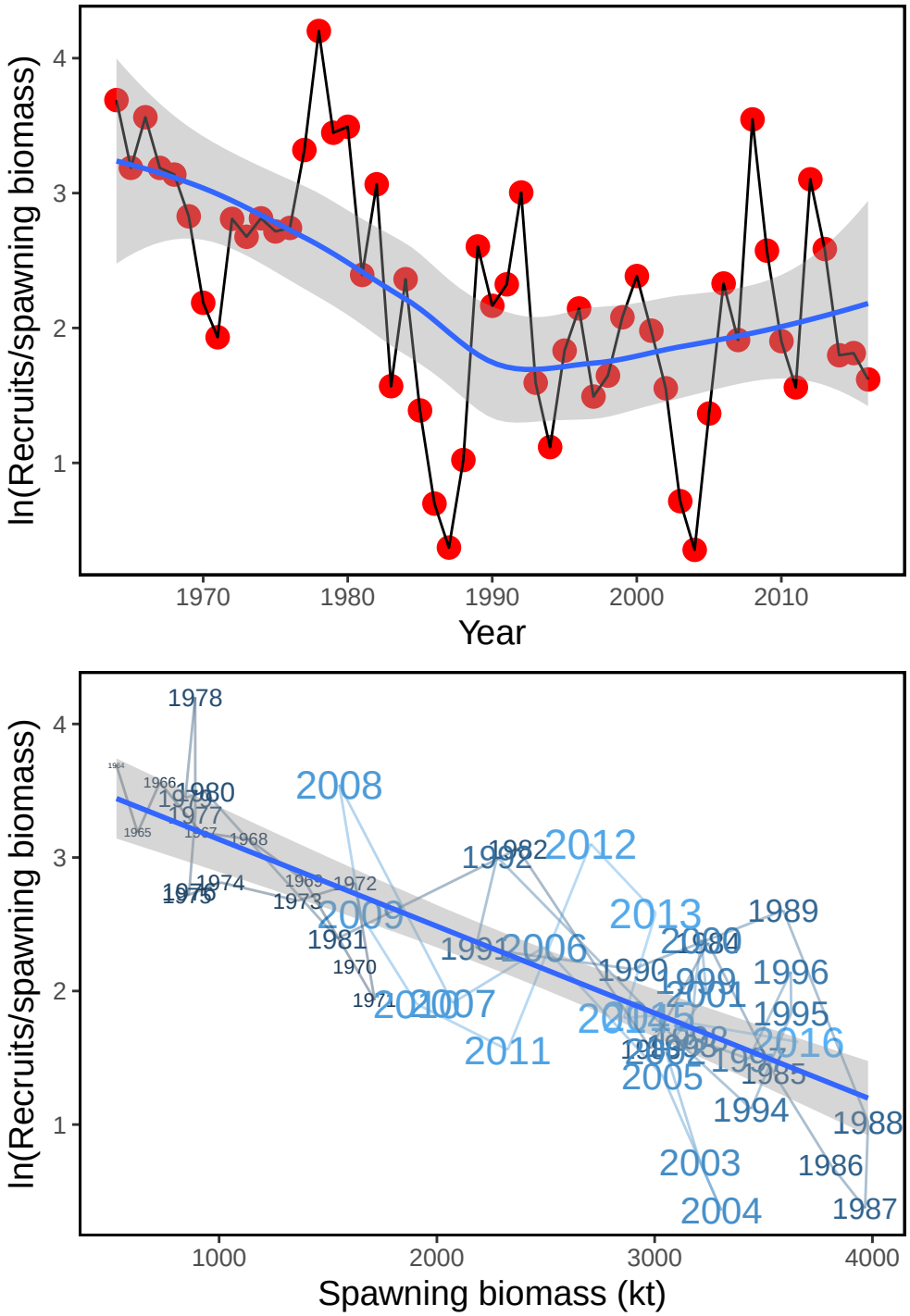

Figure 39: EBS pollock productivity as measured by logged recruits per spawning biomass, log(R/S), as a function of spawning biomass with a linear fit (bottom) and over time, 1964-2017 (top).

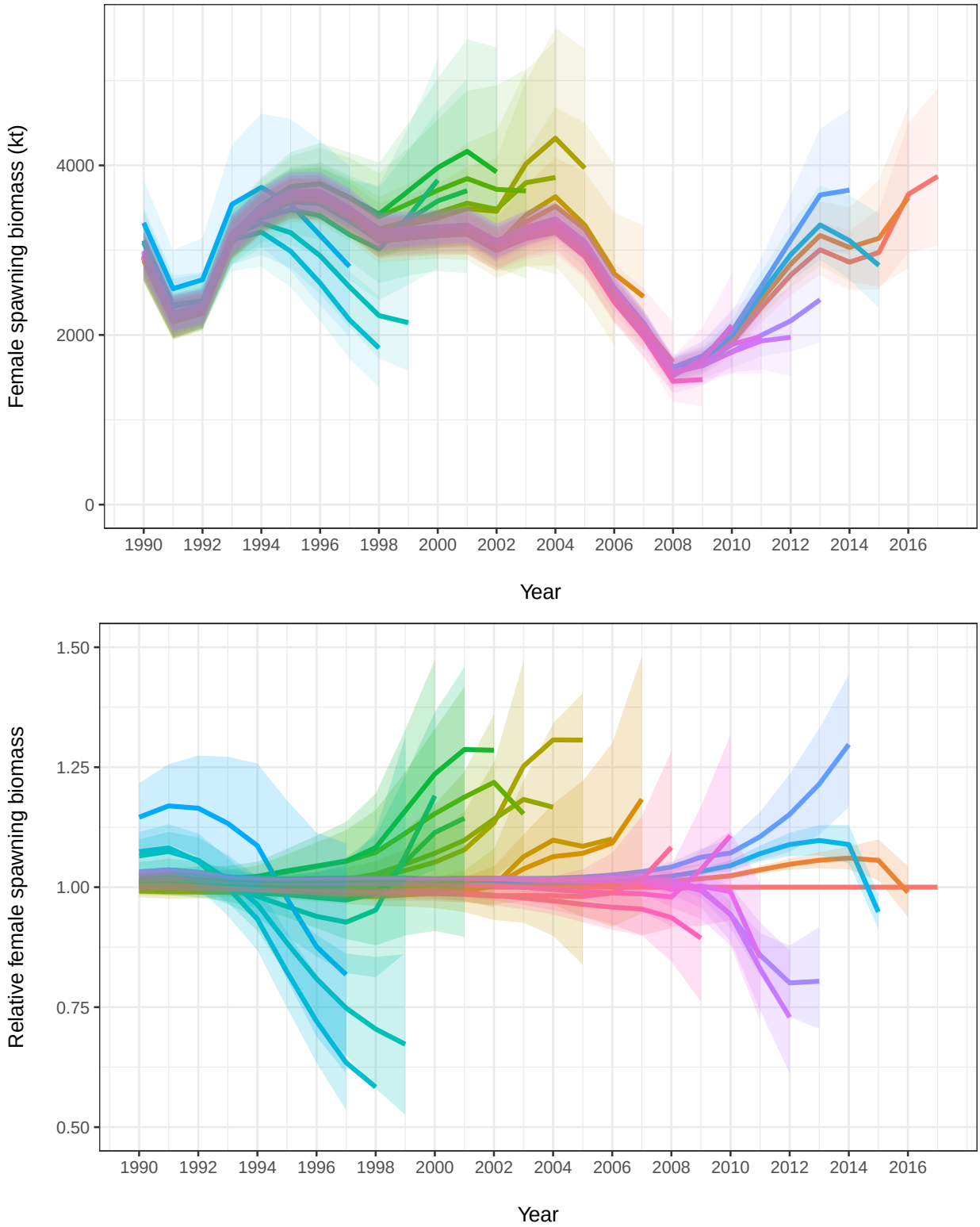

Figure 40: Retrospective patterns for EBS pollock spawning biomass showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations).

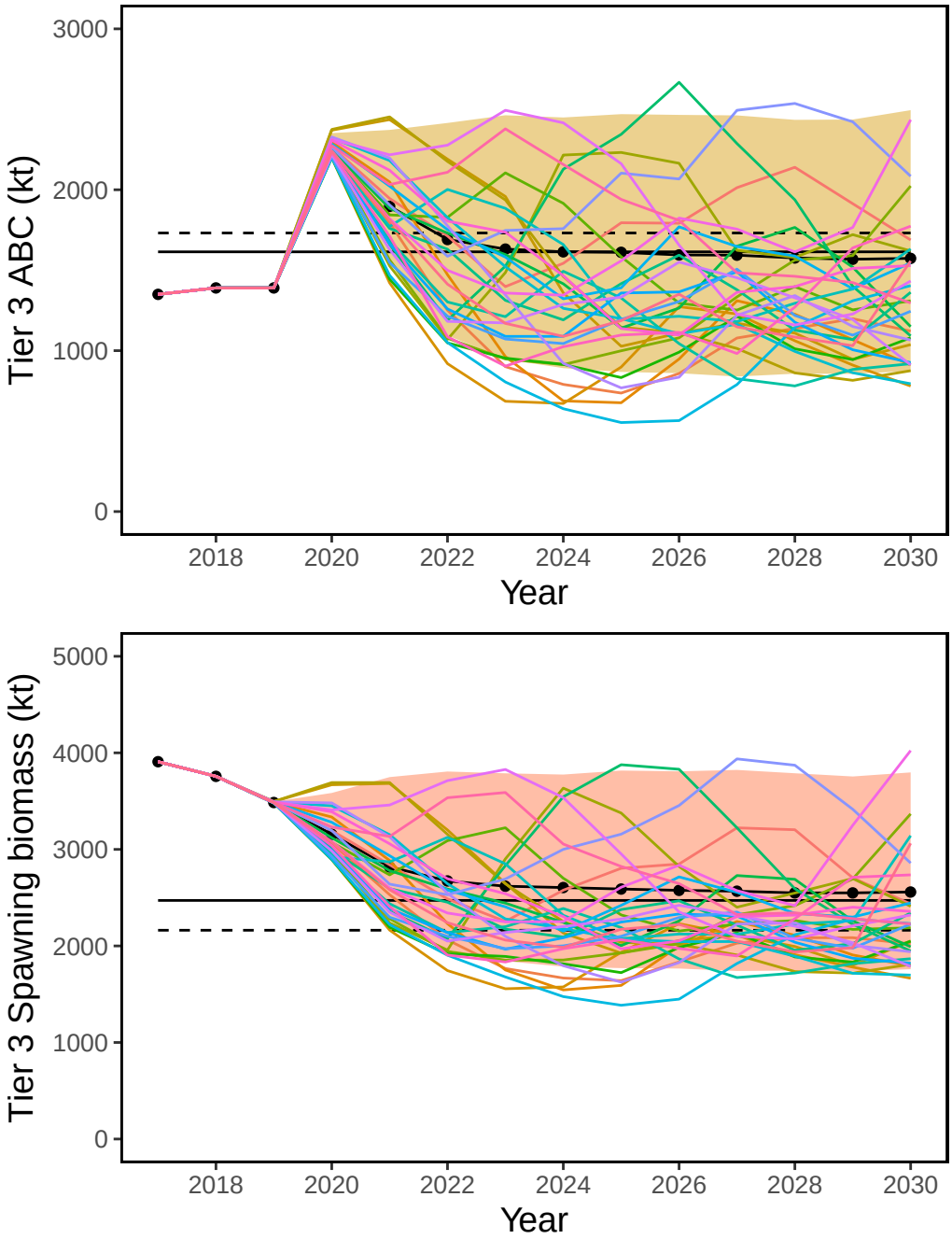

Figure 41: Projected EBS Tier 3 pollock yield (top) and female spawning biomass (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2014. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1.

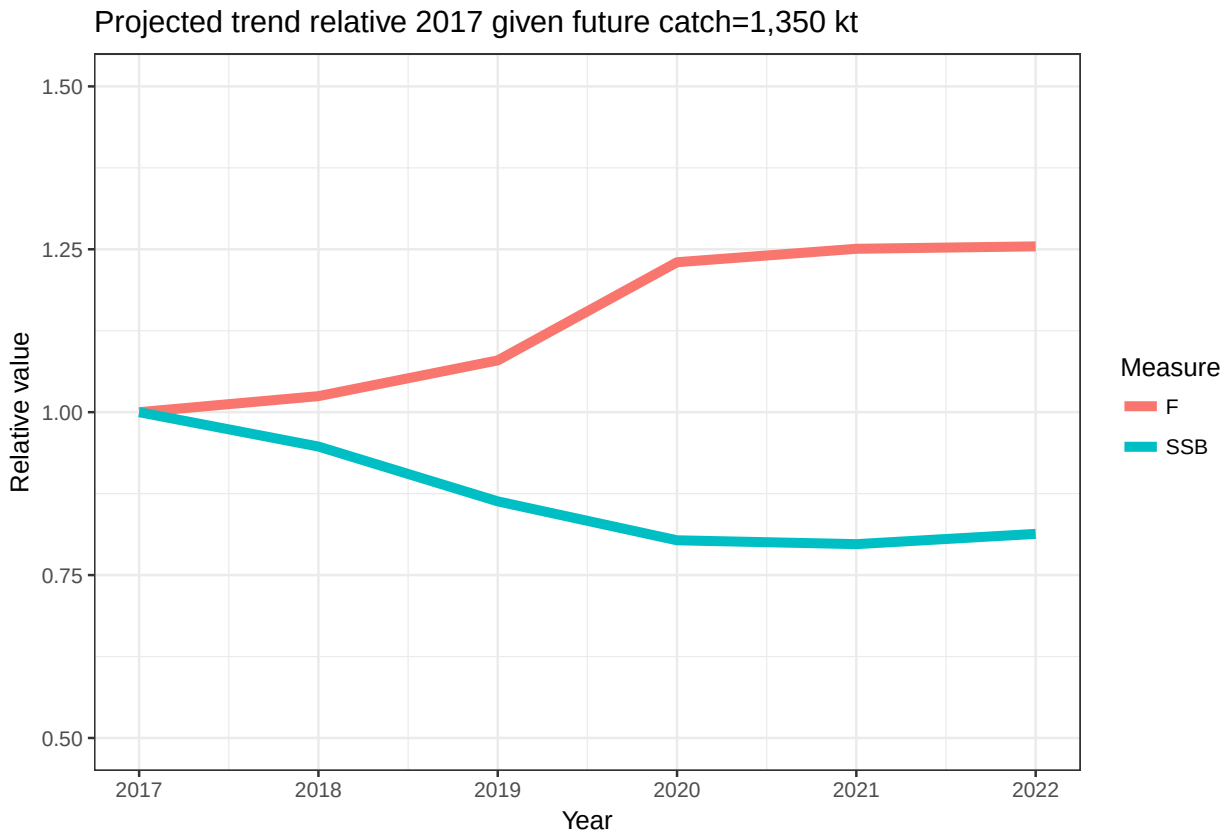

Figure 42: Projected fishing mortality and spawning biomass relative to 2017 values under constant catch of 1.35 million t, 2017-2022.

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:

$$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}\left(1 - e^{-Z_{t,a}}\right) N_{t,a}, \qquad 1 \le t \le T, 1 \le a \le A \tag{1}$$

$$N_{t+1,a+1} = N_{t,a-1} e^{-Z_{t,a-1}} \qquad 1 \le t \le T, 1 \le a < A \tag{2}$$

$$N_{t+1,A} = N_{t,A-1} e^{-Z_{t,A-1}} + N_{t,A} e^{-Z_{t,A}}, \qquad 1 \le t \le T \tag{3}$$

$$Z_{t,a} = F_{t,a} + M_{t,a} \tag{4}$$

$$C_{t,.} = \sum_{a=1}^{A} C_{t,a} \tag{5}$$

$$p_{t,a} = \frac{C_{t,a}}{C_{t,.}} \tag{6}$$

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

$$\tag{8}$$

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):

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

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

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

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

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

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

$$s_{t,a} = \mu_s e^{-\delta_t^{\mu}}, \qquad a = 1 \tag{12}$$

$$\alpha_t = \bar{\alpha} e^{\delta_t^{\alpha}}, \tag{13}$$

$$\beta_t = \bar{\beta} e^{\delta_t^{\beta}}, \tag{14}$$

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

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

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

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

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 ν for input sample size can be computed when compared with the assessment model predicted proportions at age ($\hat{p}_{ta}$) and model predicted mean age ($\hat{\bar{a}}_t$):

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

$$r_t^a = \bar{a}_t - \hat{\bar{a}}_t \tag{19}$$

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

where r_t^a is the residual of mean age and

$$\hat{\bar{a}}_t = \sum_a^A a\hat{p}_{ta} \tag{21}$$

$$\bar{a}_t = \sum_a^A ap_{ta} \tag{22}$$

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.

$$R_t = f\left(B_{t-1}\right) \tag{23}$$

with mature spawning biomass during year t was defined as:

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

and, ϕ_a is the proportion of mature females at age is 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:

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

where

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

Values for the stock-recruitment function parameters and 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 R0 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:

$$\alpha = \tilde{B}_0 \frac{1-h}{4h} \tag{26}$$

$$\beta = \frac{5h-1}{4hR_0} \tag{27}$$

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) are being qualitatively considered. As in past years the value of was set at 0.9 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):

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

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

$$h = \frac{e^a}{e^a + 4} \tag{29}$$

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

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

$$p_{ta} = \frac{O_{ta}}{\sum_a O_{ta}} \qquad \hat{p}_{ta} = \frac{\hat{C}_{ta}}{\sum_a \hat{C}_{ta}} \tag{31}$$

$$\mathbf{C} = \mathbf{CE} \tag{32}$$

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

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 bi,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:

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

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

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

where

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

$$\text{and} \tag{37}$$

$$\tau_t^2 = 1/n_t \tag{38}$$

which gives the variance for p_{ta}

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

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:

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

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:

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

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:

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

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:

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

$$\tag{44}$$

. 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

$$nll_i = 0.5\mathbf{X}\Sigma^{-1}\mathbf{X}' \tag{45}$$

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

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

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 's represent prior assumptions about the variances of these random variables. Most of these parameters are associated with year-to- year and age specific deviations in selectivity coefficients. For a presentation of this type of Bayesian approach to modeling errors-in- variables, the reader is referred to Schnute (1994). To facilitate estimating such a large number of parameters, automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries was used. This software provided the derivative calculations needed for finding the posterior mode via a quasi-Newton function minimization routine (e.g., Press et al. 1992). The model implementation language (ADModel Builder) gave simple and rapid access to these routines and provided the ability estimate the variance-covariance matrix for all dependent and independent parameters of interest.

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,. . . ,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:

$$\hat{w}_{ta} = \bar{w}_a e_t^{\upsilon} \qquad a = 1,\, t \geq 1964 \tag{47}$$

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

$$\Delta_a = \bar{w}_{a+1} - \bar{w}_a \qquad a < A \tag{49}$$

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

$$\tag{51}$$

where the fixed effects parameters are L_1, L_2, K, and α while the random effects parameters are υ_t and ψ_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 ($u_{\bar{H}M}$) applied to the estimated geometric mean fishable biomass at B_{MSY} :

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

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

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

$$\zeta_t = \frac{B_t/B_{MSY} - 0.05}{1 - 0.05} \qquad B_t < B_{MSY} \tag{55}$$

$$\zeta_t = 1.0 \qquad B_t \geq B_{MSY} \tag{56}$$

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.

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