1. Assessment of the walleye pollock stock in the Eastern Bering Sea

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Executive Summary

This chapter covers the Eastern Bering Sea (EBS) region—the Aleutian Islands region (Chapter 1A) and the Bogoslof Island area (Chapter 1B) are presented separately. This year a more comprehensive summary of economic performance is provided in the "Fishery characteristics" section.

Summary of changes in assessment inputs
The primary changes include:

- The 2016 NMFS bottom-trawl survey (BTS) biomass and abundance at age estimates were included.
- The 2016 NMFS acoustic-trawl survey (ATS) biomass and abundance at age estimates were included.
- Observer data for catch-at-age and average weight-at-age from the 2015 fishery were finalized and included.
- Total catch as reported by NMFS Alaska Regional office was updated and included through 2016.

Changes in the assessment methods
Several modifications to the methods were adopted based on a review by the Center for Independent Experts (CIE) and feedback from September/October 2016 presentations to the NPFMC's Plan Team and SSC. This included changes to the treatment of uncertainty in current-year fishery mean weights-at-age and those used for near term projections. The surveys were fitted to biomass estimates instead of abundance. Sample sizes specified for the robust-multinomial likelihood were re-evaluated based on CIE comments and selectivity variability examined. The method of estimating current and future year mean body weight at age was updated (as presented in September/October of 2016) and used. An alternative for specifying the stock-recruit relationship for projection purposes was evaluated due to CIE concerns about the prior distribution as applied. The latter increased the risk-averse buffer between ABC and OFL (computed as 1-ABC/OFL) slightly (13% to 14%) with most of the change in value arising from the lower estimate of stock-recruit relationship steepness parameter.

Summary of results

EBS pollock results

Quantity	As estimated or *specified last* year for: 2016	2017	As estimated or *recommended this* year for: 2017	2018
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)	11,300,000 t	11,000,000 t	13,000,000 t	12,100,000 t
Projected female spawning biomass (t)	**3,540,000 t**	**3,500,000 t**	**4,600,000 t**	**4,500,000 t**
B_0	5,676,000 t	5,676,000 t	5,700,000 t	5,700,000 t
B_{MSY}	1,984,000 t	1,984,000 t	2,165,000 t	2,165,000 t
F_{OFL}	0.514	0.514	0.465	0.465
$maxF_{ABC}$	0.401	0.401	0.398	0.398
F_{ABC}	0.27	0.26	0.36	0.37
OFL (t)	3,910,000 t	3,540,000 t	3,640,000 t	4,360,000 t
maxABC (t)	3,050,000 t	2,760,000 t	3,120,000 t	3,740,000 t
ABC (t)	2,090,000 t	2,019,000 t	2,800,000 t	2,979,000 t
Status	2014	2015	2015	2016
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on estimated catches assuming 1,350,000 t used in place of maximum permissible ABC for 2017 and 2018.

New data presented in this assessment suggests that the above average 2008 year-class is slightly higher than before and that the 2012 year-class also appears to be above average. As such, the maximum permissible Tier 1a ABC remains high. Tier 3 estimates of ABC are also quite high; however, besides adding stability in catch rates and effort, an ABC based on the Tier 3 values is recommended (2,800,000 t) which is well below the maximum permissible (Tier 1a) value of 3,120,000 t. The Tier 1a overfishing level (OFL) is estimated to be 3,640,000 t.

Response to SSC and Plan Team comments

General comments

From the December 2015 SSC minutes: The SSC reminds the authors and PTs to follow the model-numbering scheme adopted at the December 2014 meeting.

We followed the model-numbering scheme described in the most recent version of the SAFE Guidelines (Option D).

The SSC encourages the authors and PTs to refer to the forthcoming CAPAM data-weighting workshop report.

Sample sizes for the fishery data were re-evaluated to obtain alternative time-varying inputs—these were rescaled according to estimated “Francis weights” (method TA1.8; Francis 2011) from model fits and evaluated against alternative levels of flexibility in time and age-varying selectivity.

The SSC recommends that assessment authors work with AFSC's survey program scientist to develop some objective criteria to inform the best approaches for calculating Q with respect to information provided by previous survey trawl performance studies (e.g. Somerton and Munro 2001), and fish-temperature relationships which may impact Q.

The survey catchability was freely estimated in this model and values are examined for general consistency with biological aspects of pollock (which are known to vary in proximity to the bottom with age and between years).

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. The Team recommends using biomass in the AT and BTS (his Model 4 in the presentation), which also includes the bottom 2.5 m of the acoustic biomass. In the long term, the Team recommends evaluating the sample sizes used for the data weighting and pursuing other CIE suggestions.

The AT and BTS data are treated as biomass indices in this assessment. Sample size estimates were re-evaluated and used in the recommended model below. An alternative degree of uncertainty, which notes differences from the CEATTLE stock-recruit relationship was provided as an alternative (but is unfortunately lacking in meta-analytic rigor). The age compositions for including the bottom 2.5 meters from the acoustic data were unavailable in time for this assessment and will be applied in the coming year.

Introduction

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 marketed under the name Alaska pollock, this species continues to represent over 40% of the global whitefish production, with the market disposition split fairly evenly between fillets, whole fish (headed and gutted), and surimi (Fissel et al. 2014). An important component of the commercial production is the sale of roe from pre-spawning pollock. Pollock are considered a relatively fast growing and short-lived species. They play an important role in the Bering Sea ecosystem.

Stock structure

A summary of EBS pollock stock structure was presented at the September 2015 BSAI Plan Team meetings. From that review the Team and SSC concurred that the current stock structure hypothesis for management purposes was of *little or no concern.*

Fishery

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 (Fig. 1.1). Following the peak catch in 1972, bilateral agreements with Japan and the USSR resulted in reductions. Since 1977 (when the U.S. EEZ was declared) the annual 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 (Fig. 1.1). 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. 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 1.1). A fishing moratorium was enacted in 1993 and only trace amounts of pollock have been harvested from the Aleutian Basin region since then.

Management measures/units

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 1.2). 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. In recent studies, Haynie (2014) characterized the CDQ program and Seung and Ianelli (2016) combine a fish population dynamics model with an economic model to evaluate regional impacts.

Due to concerns over possible impacts groundfish fisheries may have on rebuilding populations of Steller sea lions, a number of management measures have been implemented. 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 51% in 2016 (Table 1.3). This high value was due to B-season conditions which had 62% of the catch taken in this region.

The 1998 American Fisheries Act (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. 1.3).

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 2011imposing prohibited species catch (PSC) limits that when reached would 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 new program imposes a dual cap system broken out by fishing sector and season. The management measure was designed to keep the annual bycatch below the lower cap by providing incentives to avoid bycatch. Additionally, in order to participate, vessels must take part in an incentive program agreement (IPA). These IPAs are approved by NMFS and are designed for further bycatch reduction and individual vessel accountability. The fishery has been operating under rules to implement this program since January 2011. During 2008 - 2016, bycatch levels for Chinook salmon have been well below average following record high levels in 2007. This is likely due to industry-based restrictions on areas where pollock fishing may occur, environmental conditions, Amendment 91 measures, and salmon abundance.

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%). These measures are all part of Amendment 110 and a summary of this and other key management measures is provided in Table 1.4.

Fishery characteristics

General 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 100 m contour (and deeper) between Unimak Island and the Pribilof Islands. 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 A-season compared to estimates for the entire season indicate that over time, the number of males and females has been fairly equal (Fig. 1.2). The 2016 and 2014 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. 1.3).

The 2016 summer and fall (B-season) fishing continued the trend of fleet-wide higher catch per hour fished (Fig. 1.4). Compared to 2011 B-season, the combined fleet took about one third of the actual fishing time to reach 600 kt. Spatially, the 2016 B-season was much more concentrated around the "horseshoe," near the shelf break west of the Pribilof Islands and extending north and west from Amak Island (Fig. 1.5). 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 1.1

Pollock retained and discarded catch (based on NMFS observer estimates) in the Eastern Bering Sea and Aleutian Islands for 1991- 2016 are shown in Table 1.5. 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 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.

Economic conditions as of 2015

Alaska pollock is the dominant species in terms of catch in the Bering Sea and Aleutian Island (BSAI) region. It accounted for 69% of the BSAI's FMP groundfish harvest and 89% of the total pollock harvest in Alaska. Retained catch of pollock increased 2.2% to 1.3 million t in 2015. BSAI pollock first-wholesale value was $1.28 billion 2015, which was down slightly from $1.3 billion in 2014 but 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 below 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 American Fisheries Act (AFA) in 1998, which, among other things, established a proportional allocation of the total allowable catch (TAC) among vessels in sectors which could form into cooperatives. Alaska-caught pollock in the BSAI became certified by the Marine Stewardship Council (MSC) in 2005, a 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 (Tables 1.6). The U.S. accounted for over 50% of the global pollock catch (Table 1.7). Between 2008-2010 conservation reductions in the pollock total allowable catch (TAC) trimmed catches to an average 867 thousand t. The supply reduction resulted in price increases for most pollock products, which mitigated the short-term revenue loss (Table 1.8). 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 some major retailer in the

U.S. later began to follow suit. Asian markets, an important export destination for several 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. Most pollock are exported; consequently, exchange rates can have a significant impact on market dynamics, particularly the Dollar-Yen and Dollar-Euro. 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%. Within the U.S. the 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. 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 3% increase to 687 thousand t. The value of these deliveries (shore-based ex-vessel value) totaled $227.3 million in 2015, which was roughly equal to the shore-based ex-vessel value in 2014, as the increased catch was offset by similar decrease in the ex-vessel price. The first-wholesale value of pollock products was $768 million for the at-sea sector and $516 million for the shore-based sector. The higher revenue in recent years is largely the result of increased catch levels as the average price of pollock products have declined since peaking in 2008-2010 and since 2013 have been below the 2005-2007 average, though this varies across products types. The average price of pollock products in 2015 increased slightly for the at-sea sector and decreased slightly for the shore-based sector, which was attributable to sectoral differences in price change of fillet and surimi products.

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. 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 10% higher, surimi prices tend to be about 20% higher and the price of roe about 40% 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 $0.19 per pound since 2011, in part, because the shore-based sector increased their relative share of surimi production.[*]

[*] 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.

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 5% to 167 thousand t in 2015, but since 2010 has increased with aggregate production and catch and has been higher than the 2005-2007 average. The average price of fillet products in the BSAI decreased 1% to $1.35 per pound and is below the inflation adjusted average price of fillets in 2005-2007 of $1.44 per pound. Price negotiations with European buyers in 2015 were difficult with buyers citing exchange rates as an impediment. While still a small portion of their primary production, Russia producers increased fillet production in 2015 and report plans to upgrade their production capacity in the near future. 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.[*] 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 2015, rising 10% to 187.7 thousand t which is above the 2005-2007 average. Prices have increased since 2013 to an average of $1.14 per pound in the BSAI in 2015. The production and price increase in 2015 were attributable to a reduction in the international supply of surimi, particularly from Thailand, that reduced Japanese inventories. Because surimi and fillets are both made from pollock meat, activity in the fillet market can influence the decision of processors to produce surimi. The difficulties in the European fillet market in 2015 further incentivized the shift in production from fillets to surimi. Additionally, industry news indicated a decrease in the average size of fish caught, which yield higher value when processed as surimi than fillets.

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 thousand t annually, production averaged 27 thousand t in 2005-2007 and was 19 thousand t in 2015 (Fig. 1.6). Prices peaked in the mid-2000s prices and have decreased over the last decade through 2015 (prices dropped 21% to $2.30 per pound). The weakness in the Yen against the U.S. Dollar has been cited as a factor in the 2015 price drop. Additionally, the Japanese Yen has remained strong against the Russian Ruble, which makes Russian products relatively cheaper than U.S. products for Japanese buyers. Also, the production volume from Russia has contributed to a carryover of roe inventory in Asian markets, which puts downward pressure on prices. Industry reports further indicate that harvests yielded comparatively more over-mature lower grade roe in 2015 which also contributed to low prices. In terms of recent trends, overall roe production declined with the catch limits during 2007-2010 while the B-season production remained relatively flat until 2015 and 2016 (Fig. 1.6). This is likely due to the fish size and perhaps warmer conditions.

Fish oil

Using oil production per ton as a basic index (tons of oil per ton of 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 around 2010 with a little over 1.5% of the catch being converted to fish oil (Table 1.9). This represents about a 5-fold

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[*] 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 that are also imported into the domestic market. Current data collection does not allow us to estimate the share of U.S. returning imports

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 data were used in the assessment

Source	Type	Years
Fishery	Catch biomass	1964-2016
Fishery	Catch age composition	1964-2015
Fishery	Japanese trawl CPUE	1965-1976
EBS bottom trawl	Area-swept abundance (numbers) index by age	1982-2016
Acoustic trawl survey near surface – 3m from bottom	Population abundance (numbers) index by age	1979, 1982, 1985, 1988, 1991, 1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006-2010, 2012, 2014, 2016
Acoustic vessels of opportunity (AVO)	Population abundance (numbers) index	2006-2015

Fishery

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 1991-2015 (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 - 2015 the 2008 year class been prominent in the catches with 2015 showing the first signs of the 2012 year-class as three year-olds in the catch (Fig. 1.7; Table 1.10). The sampling effort for age determinations and lengths is shown in Tables 1.11 and 1.12. 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). As part of the re-evaluation of sample sizes assumed within the assessment, the number of ages and lengths (and number of hauls from which samples were collected) show significant changes over time (Fig. 1.8). This information was used to inform periods from which input sample size re-weighting was appropriate for modeling (between-year variability was maintained based on the bootstrap variance estimates of catch-at-age). Regarding the precision of total pollock catch biomass, Miller (2005) estimated the CV to be on the order of 1%.

Scientific research catches are reported to fulfill requirements of the Magnuson-Stevens Fisheries Conservation and Management Act. The annual estimated research catches (1963 - 2015) from NMFS surveys in the Bering Sea and Aleutian Islands Region are given in Table 1.13. 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 methods. For pollock, this survey has been instrumental in providing an abundance index and information on the population age structure. This survey is complemented by the acoustic trawl (AT) surveys that sample mid-water components of the pollock stock. Between 1991 and 2016 the BTS biomass estimates ranged from 2.28 to 8.39 million t (Table 1.14; Fig. 1.9). 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 have increased along with surface temperatures and have reached a new high in 2016 (Fig. 1.10).

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 this year (2016) slightly below the average (5%) at 4% (Table 1.15). In some years (e.g., 1997 and 1998) some stations had high catches of pollock in that region and this resulted in high estimates of sampling uncertainty (CVs of 95% and 65% for 1997 and 1998 respectively). This region is contiguous with the Russian border and these strata seem to improve coverage over the range of the exploited pollock stock.

The 2016 biomass estimate (design-based, area swept) was 4.91 million t, slightly above the average for this survey (4.84 million t). Pollock were distributed more patchily in 2016 than in recent years and were most concentrated in the outer domain, relatively unconstrained by the warmer bottom temperatures (Fig. 1.11). The spatial distribution of pollock densities in the 2016 survey appeared to be split with high densities in the southeast and northwest of the main survey area with a gap about one third of the distance from north to south (Fig. 1.12).

The BTS abundance-at-age estimates shows variability in year-class strengths with substantial consistency over time (Fig. 1.13). 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 due to off-bottom distributions. 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 that the catchability of either 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 2016 survey age compositions were developed from age-structures collected during the survey (June-July) and processed at the AFSC labs within a few weeks after the survey was completed. The level of sampling for lengths and ages in the BTS is shown in Table 1.16. The estimated numbers-at-age from the BTS for strata (1-9 except for 1982-84 and 1986, when only strata 1-6 were surveyed) are presented in Table 1.17. Table 1.18 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 1.19.

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 (Fig. 1.14). 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).

Other time series used in the assessment

Acoustic trawl (AT) surveys

The AT surveys are conducted biennially and are designed to estimate the off-bottom component of the pollock stock (compared to the BTS which are conducted annually and provide an abundance index of the near-bottom pollock). The number of trawl hauls, lengths, and ages sampled from the AT survey are presented in Table 1.20. Estimated midwater pollock biomass for the shelf was above 4 million tons in the early years of the time series (Table 1.14). 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). Previously relative estimation errors for the total biomass were derived from a one-dimensional (1D) geostatistical method (Petitgas 1993, Walline 2007, Williamson and Traynor 1996). This method accounts 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 2016 summer AT survey age compositions were developed using an age-length key from the BTS supplemented with a sample of 100 AT survey juveniles (<38 cm fork length) to fill in size classes not well sampled by the BTS (Fig. 1.15; Table 1.21). Of particular note was very few age 1 pollock were found whereas age 3 (the 2013 year class) was the most abundant age group followed by four year olds. Spatially, the 2016 mid-water pollock distribution was somewhat consistent with recent years. The portion of shelf-wide biomass estimated to be east of 170º W was 37%, compared to an average of 24% since 1994 (Table 1.22). 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%).

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 (BT) survey are used to compute a midwater abundance index for pollock can be found in Honkalehto et al. 2011. This index is updated during years when a directed acoustic-trawl survey is *not* carried out in the EBS to provide an additional source of information on pollock found in mid-water. The most recent update was in 2015 when opportunistic data in 2014 and 2015 were compiled and used within the assessment (due to research staff issues when a full AT survey is conducted, the AVO data are processed in years when the RV Oscar Dyson is working in other regions, i.e., in “off years” for the AT survey). The series used for this assessment shows a steady increase for the period 2009-2015 (Table 1.23; Honkalehto et al. in review).

A spatial comparison between the BTS data and AT survey transects in 2014 and 2016 shows differences in the locales and densities of pollock both between years and in their vertical densities within years (Fig. 1.16). This figure also shows that in 2016, the AT survey densities were higher over a larger area than in 2014 while for the BTS data, there appears to be more of a distinct separation between the southeast aggregation and the northeast portion of the shelf. Also, an unusual occurrence of good pollock densities was found in the inner domain into Bristol Bay and nearer Nunivak Island than usual.

Analytic approach

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 1964-2016. A technical description is presented in the Model Details section. 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 2016 EBS bottom trawl survey estimates of population numbers-at-age was added and biomass.
- The 2016 EBS acoustic-trawl survey estimate of population numbers-at-age based on the age data from the BTS survey for the age-length key for the AT survey.
- The 2015 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. Importantly, it allows for trophic interactions with key predators for pollock and can be used to evaluate age and time-varying natural mortality estimates in addition to alternative catch scenarios and management targets (see this volume: http://www.afsc.noaa.gov/refm/stocks/plan_team/EBSmultispp.pdf).

Description of alternative models

Based on the CIE review, a few model configuration options were developed and implemented. To match these features with model names the following table is for descriptive purposes. Note that Models 16.0x were considered preliminary for investigation and sensitivity to changes. 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 is to incorporate and present these results in the 2017 assessment.

	BTS				ATS		Fishery				
Models	Standard survey method	Dens. Dep. Correction	Numbers	Biomass	Numbers	Biomass	15.1 Input sample sizes	Revised input sample sizes	Weight-age as 15.1	Revised weight age	Description
14.1	x		x		x		x		x		2014 model
15.1		x	x		x		x		x		2015 model (alternative BTS abundance index)
16.01	x			x		x	x		x		Transition to biomass (standard indices)
16.02		x		x		x	x		x		Alternative BTS biomass index
16.03		x		x		x		x	x		Input sample size adjustment
16.1		x		x		x		X		x	Proposed model

Input sample size

As part of the CIE review recommendation, the assessment was reevaluated against specified sample sizes and flexibility of time and age varying selectivity. The first phase proceeded as in the past to specify that the fishery average input sample size was equivalent to about 350 fish for the recent era (since 1991) and lower values for the intermediate and earliest period (as shown in Table 1.24). We assumed average values of 100 and 50 for the BTS and ATS data, respectively and modified so that the inter-annual variability reflected the variability in the number of hauls sampled. For model 16.03, effective sample size weights were estimated following Francis 2011 (equation TA1.8, hereafter referred to as Francis weights) computed for the BTS and ATS composition data and over three stanzas of fishery data: from 1964-1976, 1977-1998, and 1999-2015. The justification for breaking the fishery estimates into these periods reflects the different data sources and/or sampling programs from which catch-age information was compiled. Under these assumptions, we modified the sample sizes for the recent two periods according to the estimated Francis weights. The estimated multipliers for the early period suggested increasing the sample size. However, since these data occur prior to survey or other competing age composition information the values were left at relatively low values to reflect the uncertainty of the early period age composition information. The sample sizes for the start and final model are shown in Table 1.24.

Parameters estimated outside of the assessment model

Natural mortality and maturity at age

For all models, fixed natural mortality rates at age were assumed (M=0.9, 0.45, and 0.3 for ages 1, 2, and 3+ respectively; 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. 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
Model 1.0 M	0.900	0.450	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
Prop. Mature	0.000	0.008	0.290	0.642	0.842	0.902	0.948	0.964	0.970	1.000	1.000	1.000	1.000	1.000	1.000

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. As a sensitivity, a profile of different fixed age 3+ values of natural mortality showed that given the assessment model configuration outlined below (for Model 16.1) survey age compositions favored lower values of M while the fishery age composition favored higher values (Fig. 1.17). This is somewhat unsurprising since in recent years the BTS data 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 have been 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. Trends in roe production suggest some possible differences in the warm conditions observed in 2016 and current research is underway to evaluate potential consequences (S. Neidetcher AFSC, pers. Comm.).

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 sex, 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 1.25). 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 refined due to comments from the Plan Team, CIE and SSC. For details of this approach (presented in September and October to the Plan Team and SSC) refer to appendix 1A of this chapter. Results of this method show the relative variability between years and cohorts and provide estimates (and uncertainty) for 2016-2018 (Fig. 1.18; Table 1.25).

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 76 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 (2016-2021). 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 2013 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 relatively availability to the fishery with age). The annual components of fishing mortality result in 54 parameters and the age-time selectivity schedule forms a 10x53 matrix of 530 parameters bringing the total fishing mortality parameters to 584.

Selectivity-at-age estimates for the bottom trawl survey are specified with age and year specific deviations in the average selectivity-at-age. For the AT survey, which began in 1979, parameters are used to specify age-time specific availability. Time-varying survey selectivity is estimated to account for the changes in availability of pollock to the survey gear and is constrained by pre-specified variance terms. 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. No prior distribution was used for any of the indices. The selectivity parameters for the 2 main indices total 132 (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, σ=0.05)
- Log-normal indices of pollock biomass; bottom trawl surveys assume annual estimates of sampling error, as represented in Fig. 1.9; for the AT index the annual errors were specified to have a mean of 0.20; while for the AVO data, a value relative to the AT index was estimated and gave a mean of about 0.32).
- Fishery and survey proportions-at-age estimates (robust quasi-multinomial with effective sample sizes presented in Table 1.24).
- 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 1991-2015 and externally estimated variance terms as described in Appendix 1A.

Work evaluating temperature and predation-dependent effects on the stock-recruitment estimates has begun (Spencer et al. 2016). His approach modified the estimation the 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

Incremental updates and additions of new data to the model 15.1 accepted last year suggests that most of the changes in results are due to the data added rather than the modifications to tuning to biomass versus numbers and to the re-tuning adjustments for sample size estimates (Fig. 1.19). Subsequent model evaluations and sensitivities were focused on assumptions relative to projections (average weight, selectivity, and stock recruitment estimates) and these had little or no bearing on fitting historical data. For Model 16.1, four sub-models were run to show the effect of adding data to the model this year. The addition of age composition data from the fishery and different surveys shows that the proportion of 3-year old pollock in the 2015 fishery was much higher than expected whereas that same year class (2012) was slightly less than expected in the BTS data (Fig. 1.20). A similar effect can be observed in the incremental fitting of new data for the AT and BTS time series (Fig. 1.21). In particular, the BTS biomass estimate reduces the upward trend predicted when those data are excluded. As part of the sample size re-weighting process, a diagnostic for evaluating Francis weight performance compares observed versus model predicted mean age by different composition datasets. The fits for Model 16.1 appear to be reasonable (Fig. 1.22) and compare favorably with Model 15.1 (Table 1.26). However, comparisons between these models are difficult based on goodness of fit alone since different indices are used for tuing and statistical weights for the for composition data differ.

Relative to the average weights-at-age projected for the fishery and alternative assumptions about how to estimate "future selectivity" Ianelli et al. (2015) showed how the buffer between ABC and OFL (computed as 1-ABC/OFL) for Tier 1 varies as well as the relative value of the maximum permissible ABC. The uncertainty in future mean weights-at-age had a relatively large impact and the selectivity estimation (based on the number of recent years over which to average selectivity) also affected variability in results.

The estimated parameters and standard errors are provided in Table 1.27 and summary model results are given in (Table 1.28). The code for the model (with dimensions and links to parameter names) and input files are available upon request to the lead author.

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. 1.23). The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 1.24). The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) is consistent with the population trends for this period (Fig. 1.25). The fit to the fishery-independent index from the 2006-2015 AVO data shows a slightly declining rather than increasing trend to 2015 (Fig. 1.26).

Bottom-trawl survey selectivity 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 2016 surveys even though the model is tuned to biomass rather than numbers as depicted in Fig. 1.27). 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. 1.28).

The AT survey selectivity estimates could differ in the 1979 survey; (Fig. 1.29; top panel). 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 20%) with a reasonable pattern of residuals (Fig. 1.29, bottom panel). The AT age compositions consistently track large year classes through the population and the model fits these patterns reasonably well (Fig. 1.30).

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 1.29). 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. 1.31). 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. 1.32). The estimates of age 3+ pollock biomass were mostly higher than the estimates from previous years (Fig. 1.33, Table 1.29).

To evaluate past management and assessment performance it can be useful to plot estimated fishing mortality relative to some reference values. For EBS pollock, we computed the reference fishing mortality from Tier 1 (unadjusted) and calculated 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. 1.34).

Recruitment

Model estimates indicate that both the 2008 and 2012 year classes are well above the average level (Fig. 1.35). 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. 1.36). Note that the 2014 and 2015 year classes (as age 1 recruits in 2015 and 2016) 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. 1.37).

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. More recently, 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.

Considering the factors affecting recruitment, including the probability that stationarity in the stock-recruit relationship is unlikely, a subjective approach to accounting for additional uncertainty was developed. As a first step, and failing development of a comprehensive ensemble of models which could somehow be more objective, two alternatives to the base-case stock-recruit relationship scenarios were included: one that reduced the influence of the internal model estimates of stock and recruitment in specifying the stock-recruit relationship (so-called "low conditioned" model) and a second one that was intermediate to the base-case scenario and the low conditioned option. For illustration, the 3 cases are shown in two panels (Fig. 1.38. The 1-ABC/OFL buffer for the cases result in: 17%, 14%, and 12%, respectively. Also the values for steepness (and hence point estimates of Fmsy) change in these scenarios (0.568, 0.618, and 0.685, respectively).   In lieu of eliciting a suite of models to capture structural uncertainty, the moderate condition specification was selected for ABC/OFL recommendations. Future research will attempt to more fully support and characterize the range applicable.

Retrospective analysis
Model 16.1, as with past model evaluations, indicate retrospective sensitivity to data available (Fig. 1.39). On balance, for 10 years of retrospective analysis, even though the variability was high, the average bias was low with Mohn's rho near zero (-0.004).

Harvest recommendations

The estimate of B_{MSY} is 2,165,000 t (with a CV of 20%) which is less than the projected 2017 spawning biomass of 4,600,000 t; Table 1.29). For 2016, the Tier 1 levels of yield are 3,120,000 t from a fishable biomass estimated at around 7,830,000 t (Table 1.30). Estimated numbers-at-age are presented in Table 1.31 and estimated catch-at-age is presented in Table 1.32. Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment are given in Table 1.33.

Model results indicate that spawning biomass will be above $B_{40\%}$ (2,643,000 t) in 2017 and about 212% 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 2016 and 2017.

A diagnostic (see Eq. 14 in appendix) on the impact of fishing shows that the 2016 spawning stock size is about 66% of the predicted value had no fishing occurred since 1978 (Table 1.29). This compares with the 62% of $B_{100\%}$ (based on the SPR expansion using mean recruitment from 1978-2012) and 71% 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 (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Estimates of reference points related to maximum sustainable yield (MSY) are currently available. However, their reliability is questionable. We therefore present both reference points for pollock in the BSAI to retain the option for classification in either Tier 1 or Tier 3 of Amendment 56. These Tiers require reference point estimates for biomass level determinations. Consistent with other groundfish stocks, the following values are based on recruitment estimates from post-1976 spawning events:

B_{MSY} = 2,165 thousand t female spawning biomass

B_0 = 5,700 thousand t female spawning biomass

$B_{100\%}$ = 6,608 thousand t female spawning biomass

$B_{40\%}$ = 2,643 thousand t female spawning biomass

$B_{35\%}$ = 2,313 thousand t female spawning biomass

Specification of OFL and Maximum Permissible ABC

Assuming the moderately diffuse stock-recruit relationship the 2017 spawning biomass is estimated to be 4,600,000 t (at the time of spawning, assuming the stock is fished at recommended ABC level). This is above the B_{MSY} value of 2,165,000 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.

Since the 2017 female spawning biomass is estimated to be above the B_{MSY} level (2,165,000 t) and the $B_{40\%}$ value (2,643,000 t) in 2017 and if the 2016 catch equals 1.35 million t, the OFL and maximum permissible ABC values by the different Tiers would be:

Tier	Year	MaxABC	OFL
1a	2017	3,120,000 t	3,640,000 t
1a	2018	3,740,000 t	4,360,000 t

Tier	Year	MaxABC	OFL
3a	2017	2,800,000 t	2,970,000 t
3a	2018	2,979,000 t	3,430,000 t

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 2016 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2017 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2016. 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 recruitments are simulated from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch 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 2017 and 2018, are as follows (*max* F_{ABC} refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In 2017 and 2018 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 estimated to be the level of catch where the spawning biomass in 2016 would equal the 2014 estimate).

Scenario 3: In all future years, F is set equal to the 2012-2016 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: 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. This was requested by public comment for the DSEIS developed in 2006)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2016 or 2) above ½ of its MSY level in 2016 and above its MSY level in 2026 under this scenario, then the stock is not overfished.)

Scenario 7: In 2017 and 2018, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2018 or 2) above 1/2 of its MSY level in 2018 and expected to be above its MSY level in 2028 under this scenario, then the stock is not approaching an overfished condition).

Projections and status determination

For the purposes of these projections, we present results based on selecting the $F_{40\%}$ harvest rate as the max F_{ABC} value and use $F_{35\%}$ as a proxy for F_{MSY}. Scenarios 1 through 7 were projected 14 years from

2016 (Table 1.34). 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. 1.40).

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 2016:

> If spawning biomass for 2016 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.
>
> If spawning biomass for 2016 is estimated to be above $B_{35\%}$, the stock is above its MSST.
>
> If spawning biomass for 2016 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest scenario 6 (Table 1.34). If the mean spawning biomass for 2026 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 ½ $B_{35\%}$, 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 2018 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2028. If the mean spawning biomass for 2028 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 not below MSST for the year 2016, nor is it expected to be approaching an overfished condition based on Scenario 7 (the mean spawning biomass in 2016 is above the $B_{35\%}$ level; Table 1.34). Tier 1 calculations for ABC and OFL values in 2017 and 2018 (assuming catch is 1,350,000 t in 2017 are given in Table 1.35. Based on this, the EBS pollock stock is not being subjected to overfishing, is not overfished, and not approaching a condition of being overfished

ABC Recommendation

ABC levels are affected by estimates of F_{MSY} (which depends principally on the stock-recruitment relationship and demographic schedules such as selectivity-at-age, maturity, growth), the B_{MSY} level, and current stock size (both spawning and fishable). Updated data and analysis result in an estimate of 2016 spawning biomass (4,070 kt) that is about 212% of B_{MSY} (2,165 kt). The replacement yield—defined as the catch next year that is expected to achieve a 2018 spawning biomass estimate equal to that from 2016—is estimated to be about 2,500,000 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 2016 were the **warmest recorded** over the period 1982-2016; additional precaution may be warranted since warm conditions are thought to negatively affect the survival of larval and juvenile pollock.
2. The acoustic survey found very **few one-year-old pollock** in summer 2016 (the BTS data show about average 1-year olds).
3. The current BTS data show **low abundances of pollock aged 10 and older**. Historically there had been good representation of older fish in data from this survey. This is somewhat expected given the poor year-classes observed during the period 2000-2005.
4. The BTS showed **patchier concentrations** of pollock compared to recent years. This can result in increased uncertainty in the estimates. This patchier distribution may also reflect somewhat better nominal fishery catch rates.
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. **Roe production has dropped** in 2015 in the B-season. Recent data show that ~15% of annual roe production has occurred from June-October whereas in 2015 and 2016 the production is ~5%.
7. The selection of a single model, though attempting to account for uncertainties due to process errors, **ignores structural uncertainty** in model specification. Including such structural uncertainties may reflect the type of variability in stock-recruit relationship depicted in the scenario where conditioning the curve on the assessment results is lowered.
8. The **euphausiid index** (see Ecosystem considerations, this volume) decreased from the 2014 estimates and has declined since the 2009 peak. This may negatively affect survival rates of juvenile pollock prior to recruiting to the fishery.
9. Pollock are an important prey species for the ecosystem; there's been a 12% decline in St. Paul Island pup production from 2014-2016 which, when combined information on the other fur seal population components (Bogoslof and St. George Islands), indicates an estimated **2.5% decline in the overall Eastern Stock fur seal population.** Maintaining prey availability may provide better foraging opportunities for the fur seal stock to minimize further declines.
10. Whilst outside of ABC considerations, it seems that maintaining the stock at relatively high levels and achieving fishery catch rates observed in 2016 B-season may help to minimize Chinook salmon bycatch (noting that the total effort required to catch 600 kt in the 5 most recent B-seasons was substantially smaller this year)

Given these factors, a 2017 ABC of 2,800,000 t is recommended based on the Tier 3 estimates as conservatively selected by the SSC in 2014 and 2015. 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 1.36. 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 conditions for 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 extensive survey data. They noted that during cold years, age-0 pollock were distributed primarily in the outer domain in waters greater than 1ºC 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, while uncertain, appears to be also high creating a favorable stock trend in the near term.

A separate section presented this year updates 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., no time varying selectivity in the fishery and only design-based survey indices). However, that model mimics the pattern and abundances 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, 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). Buckley et al. (2016) showed spatial patterns of pollock foraging by size of predators. For example, the northern part of the outer domain (closest to the shelf break) tends to be more piscivorous than counterparts in other areas (Fig. 1.41). This figure also shows that euphausiids make up a larger component of the diet in the southern areas. The euphausiid abundance on the Bering Sea shelf is presented as a section of the 2016 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 1.37). Jellyfish represent the largest component of the bycatch of non-target species and had averaged around 5-6 thousand tons per year but more than doubled in 2014 but has dropped in 2015. 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 1.38). 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 1.39).

A high number of non-Chinook salmon (nearly all made up of chum salmon) was observed in 2014 and 2015 (about 13% above the 2003-2013 average) after the low level observed in 2012 (Table 1.40). Chinook salmon bycatch in 2015 was 54% of the 2003-2015 mean value consistent with the magnitude of bycatch since the implementation of Amendment 91 in 2011. Ianelli and Stram (2014) provide 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%.

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 recent bottom trawl surveys found abundance levels for the 2008 and now 2012 year class appear to be estimated at high levels. 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 above) seem 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. Therefore, a large scale study using the highest resolution genetic tools available is recommended. Such a study would incorporate samples throughout the range of walleye pollock, including North America, Japan, and Russia, if possible. Data from thousands of SNP loci should be screened, using next generation sequencing.

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Tables

Table 1.1 Catch from the Eastern Bering Sea by area, the Aleutian Islands, the Donut Hole, and the Bogoslof Island area, 1979-2016 (2016 values through October 25th 2016). The southeast area refers to the EBS region east of 170W; the Northwest is west of 170W.

	Eastern Bering Sea			Aleutians	Donut Hole	Bogoslof I.
Year	Southeast	Northwest	Total			
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	52,352	10,000	241
1993	1,094,429	232,173	1,326,602	57,132	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	969,644	132,515	1,102,159	22,054		136
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	555,076	810,207	1,285		176
2011	747,890	451,151	1,199,041	1,208		173
2012	618,869	586,343	1,205,212	975		71
2013	695,669	575,099	1,270,768	2,964		57
2014	858,239	439,180	1,297,420	2,375		427
2015	696,247	625,332	1,321,579	897		733
2016	1,163,945	184,030	1,347,974			
Average	772,429	422,779	1,195,208	26,702		

1979-1989 data are from Pacfin.
1990-2016 data are from NMFS Alaska Regional Office, and include discards.
The 2016 EBS catch estimates are preliminary

Table 1.2. Time series of 1964-1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977-2016 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports. Note that the 2016 value is based on catch reported to October 25th 2016 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	1,019,082
		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	990,629
		2009	815,000	815,000	810,784
		2010	813,000	813,000	810,215
		2011	1,270,000	1,252,000	1,199,214
		2012	1,220,000	1,200,000	1,205,283
		2013	1,375,000	1,247,000	1,270,824
		2014	1,369,000	1,267,000	1,297,846
		2015	1,637,000	1,310,000	1,322,312
		2016	2,090,000	1,340,000	1,348,979
	1977-2016 average		1,401,300	1,202,032	1,182,379

Table 1.3. Total EBS shelf pollock catch recorded by observers (rounded to nearest 1,000 t) by year and season with percentages indicating the proportion of the catch that came from within the Steller sea lion conservation area (SCA), 1998-2016. The 2016 data are preliminary.

	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%)

Table 1.4. Highlights of some management measures affecting the pollock fishery.

Year	Management
1977	Preliminary BSAI FMP implemented with several closure areas
1982	FMP implement for the BSAI
1982	Chinook salmon bycatch limits established for foreign trawlers
1984	2 million t groundfish OY limit established
1984	Limits on Chinook salmon bycatch reduced
1990	New observer program established along with data reporting
1992	Pollock CDQ program commences
1994	NMFS adopts minimum mesh size requirements for trawl codends
1994	Voluntary retention of salmon for foodbank donations
1994	NMFS publishes individual vessel bycatch rates on internet
1995	Trawl closures areas and trigger limits established for chum and Chinook salmon
1998	Improved utilization and retention in effect (reduced discarded pollock)
1998	American Fisheries Act (AFA) passed
1999	The AFA was implemented for catcher/processors
1999	Additional critical habitat areas around sea lion haulouts in the GOA and Eastern Bering Sea are closed.
2000	AFA implemented for remaining sectors (catcher vessel and motherships)
2001	Pollock industry adopts voluntary rolling hotspot program for chum salmon
2002	Pollock industry adopts voluntary rolling hotspot program for Chinook salmon
2005	Rolling hotspot program adopted in regulations to exempt fleet from triggered time/area closures for Chinook and chum salmon
2011	Amendment 91 enacted, Chinook salmon management under hard limits
2015	Amendment 110 (BSAI) Salmon prohibited species catch management in the Bering Sea pollock fishery (additional measures that change limits depending on Chinook salmon run-strength indices) and includes additional provisions for reporting requirements (see https://alaskafisheries.noaa.gov/fisheries/chinook-salmon-bycatch-management for update and general information)
2016	Measures of amendment 110 go into effect for 2017 fishing season; Chinook salmon runs above the 3-run index value so bycatch limits stay the same

Table 1.5. Estimates of discarded pollock (t), percent of total (in parentheses; "tr" if <0.5%) and total catch for the Aleutians, Bogoslof, Northwest and Southeastern Bering Sea, 1991-2016. SE represents the EBS east of 170° W, NW is the EBS west of 170° W, source: NMFS Blend and catch-accounting system database. 2016 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)				
	Aleutian Is.	Bogoslof	NW	SE	Total	Aleutian Is.	Bogoslof	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 (tr)	5,968 (1%)	7,692 (1%)	1,278	9	507,880	482,698	991,865
2009	395 (24%)	6 (8%)	1,936 (tr)	4,014 (1%)	6,351 (1%)	1,662	73	452,532	358,252	812,520
2010	142 (12%)	53 (30%)	1,197 (tr)	2,510 (1%)	3,903 (tr)	1,235	176	555,076	255,131	811,619
2011	75 (6%)	23 (13%)	1,331 (tr)	3,444 (%)	4,872 (tr)	1,208	173	451,151	747,890	1,200,422
2012	95 (10%)	(tr)	1,186 (tr)	4,187 (1%)	5,468 (tr)	975	71	586,343	618,869	1,206,258
2013	107 (4%)	(1%)	1,227 (tr)	4,145 (1%)	5,480 (tr)	2,964	57	575,099	695,669	1,273,788
2014	137 (6%)	54 (13%)	1,787 (tr)	12,568 (1%)	14,546 (1%)	2,375	427	439,180	858,239	1,300,221
2015	20 (2%)	138 (19%)	2,419 (tr)	7,060 (1%)	9,636 (1%)	915	733	625,332	696,247	1,323,227
2016	59 (5%)	7 (1%)	811 (tr)	7,670 (1%)	8,547 (1%)	1,244	1,005	184,030	1,163,945	1,350,223

Table 1.6. Pollock in the Bering Sea & Aleutian Islands catch and ex-vessel data. Total and retained catch (thousand metric tons), number of vessel, catcher vessel total and retained catch (thousand metric tons), ex-vessel value (million US$), price (US$ per pound), catcher vessel share of retained catch and number of catcher vessels; 2005-2007 average, 2010-2010 average, and 2011-2015.

	Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015
	All sectors						
Catch K mt	1,440.3	867.0	1195.0	1201.0	1267.0	1293.0	1316.0
Retained Catch K mt	1,423.63	861.00	1190.1	1195.5	1261.5	1278.5	1306.4
Vessels #	109.3	121	117	122	119	121	119
	Catcher Vessels (Trawl)						
Catch K mt	772	461	632.0	634.0	662.0	670.0	688.0
Retained Catch K mt	767.02	457.68	631.5	632.7	661.3	667.1	687.3
Ex-vessel Value M $	$ 213.5	$ 183.6	$ 229.7	$ 241.3	$ 218.7	$ 226.5	$ 227.3
Ex-vessel Price/lb $	$ 0.126	$ 0.180	$ 0.165	$ 0.173	$ 0.150	$ 0.154	$ 0.150
CV share of Retained Catch	53.9%	53.1%	53.0%	52.9%	52.4%	52.2%	52.6%
Vessels #	89	89.3	86	90	87	87	87

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 1.7. Alaska pollock in the Bering Sea & Aleutian Islands first-wholesale market data. First-wholesale production (thousand metric tons), value (million US$), price (US$ per pound), and head and gut, fillet, surimi, and roe production volume (thousand metric tons) value share and price (US$ per pound); 2005-2007 average, 2008-2010 average, and 2011-2015.

		Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015
		BSAI						
All Products	Volume K mt	498.44	355.99	483.11	472.72	506.84	525.46	521.17
All Products	Value M $	$ 1,246.6	$ 1,133.4	$1,351.1	$1,381.0	$1,242.1	$ 1,301.1	$ 1,284.2
All Products	Price lb $	$ 1.13	$ 1.44	$ 1.27	$ 1.33	$ 1.11	$ 1.12	$ 1.12
Fillets	Volume K mt	162.70	113.90	161.22	146.55	170.87	175.77	167.01
Fillets	Price lb $	$ 1.24	$ 1.73	$ 1.55	$ 1.55	$ 1.44	$ 1.37	$ 1.35
Fillets	Value share	36%	38%	41%	36%	44%	41%	39%
Surimi	Volume K mt	173.05	100.99	141.00	157.15	161.66	171.32	187.74
Surimi	Price lb $	$ 0.96	$ 1.63	$ 1.28	$ 1.43	$ 1.00	$ 1.10	$ 1.14
Surimi	Value share	29%	32%	29%	36%	29%	32%	37%
Roe	Volume K mt	27.03	17.63	18.03	16.48	13.91	20.60	18.75
Roe	Price lb $	$ 4.84	$ 4.14	$ 3.63	$ 4.32	$ 3.33	$ 2.92	$ 2.30
Roe	Value share	23%	14%	11%	11%	8%	10%	7%
At-sea price premium ($/lb)		$ 0.30	$ 0.32	$ 0.20	$ 0.25	$ 0.12	$ 0.15	$ 0.23

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 1.8. Alaska pollock U.S. trade and global market data. Global production (thousand metric tons), U.S. share of global production, Russian share of global production, U.S. export volume (thousand metric tons), U.S. export value (million US$), U.S. export price (US$ per pound), the share of U.S. export volume and value with Japan, China and Germany, the share of U.S. export volume and value of meats (including H&G and fillets), surimi and roe; 2005-2007 average, 2008-2010 average, and 2011-2015.

		Avg 05-07	Avg 08-10	2011	2012	2013	2014	2015	2016 (thru June)
Global Pollock Catch K mt		2,854	2,662	3,211	3,272	3,239	3,214	-	-
U.S. Share of Global Catch		52%	35%	39.7%	39.8%	42.1%	44.4%	-	-
Russian Share of global catch		37%	53%	49%	50%	48%	47%	-	-
Export Volume K mt		278.9	192.2	303.5	314.7	360.4	395.0	377.8	157.6
Export Value M US$		$ 867.4	$ 635.2	$ 924.3	$ 938.4	$ 968.1	$ 1,081.7	$ 1,038.2	$ 459.6
Export Price lb US$		1.41	1.50	$ 1.38	$ 1.35	$ 1.22	$ 1.24	$ 1.25	$ 1.32
Japan	**Volume Share**	34.4%	26.6%	20.6%	24.0%	18.2%	22.1%	25.0%	21.8%
	Value share	38.1%	26.3%	18.7%	22.1%	17.2%	21.7%	25.5%	23.2%
China	**Volume Share**	3.1%	9.0%	13.1%	11.2%	14.7%	14.7%	12.7%	11.1%
	Value share	2.2%	6.9%	10.8%	9.0%	11.8%	12.0%	10.5%	8.4%
Germany	**Volume Share**	16.7%	19.9%	20.6%	22.2%	22.8%	23.4%	21.4%	15.8%
	Value share	14.5%	21.2%	21.1%	22.8%	24.2%	24.3%	21.3%	14.7%
Meat/Fillets	**Volume Share**	32.7%	52.2%	50.5%	47.0%	51.2%	53.8%	49.2%	43.7%
	Value share	27.2%	48.5%	48.8%	45.4%	50.8%	51.6%	46.2%	37.4%
Surimi	**Volume Share**	56.9%	45.7%	43.8%	48.0%	44.6%	40.7%	45.4%	47.7%
	Value share	37.5%	32.7%	34.1%	42.1%	37.4%	34.3%	39.2%	39.4%
Roe	**Volume Share**	10.4%	8.2%	5.8%	5.1%	4.2%	5.5%	5.4%	8.5%
	Value share	35.3%	22.8%	17.1%	12.6%	11.8%	14.1%	14.6%	23.2%

Notes: 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 1.9. BSAI pollock fish oil production index (Alaska pollock U.S. trade and global market data).

Sector	2005-2007 average	2008-2010 average	2011	2012	2013	2014	2015
All Sectors	1.26	2.04	1.79	1.61	1.90	2.20	1.85
Shoreside	2.07	2.58	2.00	1.89	2.11	2.42	1.94
At-sea	0.31	1.42	1.54	1.30	1.67	1.95	1.73

Table 1.10. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2015. 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	719.8	420.1	392.5	215.5	56.3	25.7	35.9	27.5	17.6	7.9	3	1.1	2,567
1980	9.8	462.2	822.9	443.3	252.1	210.9	83.7	37.6	21.7	23.9	25.4	15.9	7.7	3.7	2,421
1981	0.6	72.2	1012.7	637.9	227	102.9	51.7	29.6	16.1	9.3	7.5	4.6	1.5	1	2,175
1982	4.7	25.3	161.4	1172.2	422.3	103.7	36	36	21.5	9.1	5.4	3.2	1.9	1	2,004
1983	5.1	118.6	157.8	312.9	816.8	218.2	41.4	24.7	19.8	11.1	7.6	4.9	3.5	2.1	1,745
1984	2.1	45.8	88.6	430.4	491.4	653.6	133.7	35.5	25.1	15.6	7.1	2.5	2.9	3.7	1,938
1985	2.6	55.2	381.2	121.7	365.7	321.5	443.2	112.5	36.6	25.8	24.8	10.7	9.4	9.1	1,920
1986	3.1	86	92.3	748.6	214.1	378.1	221.9	214.3	59.7	15.2	3.3	2.6	0.3	1.2	2,041
1987	0	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	0	10.7	454	421.6	252.1	544.3	224.8	104.9	39.2	96.8	18.2	10.2	3.8	11.7	2,192
1989	0	4.8	55.1	149	451.1	166.7	572.2	96.3	103.8	32.4	129	10.9	4	8.5	1,784
1990	1.3	33	57	219.5	200.7	477.7	129.2	368.4	65.7	101.9	9	60.1	8.5	13.9	1,746
1991	0.7	111.8	39.9	86.5	139.2	152.8	386.2	51.9	218.4	21.8	115.0	13.8	72.6	59.0	1,469
1992	0.0	93.5	674.9	132.8	79.5	114.2	134.3	252.2	100.1	155.1	54.3	43.1	12.5	74.2	1,921
1993	0.2	8.1	262.7	1146.2	102.1	65.8	63.7	53.3	91.2	20.5	32.3	11.7	12.5	23.2	1,893
1994	1.6	36.0	56.8	359.6	1066.7	175.8	54.5	20.2	13.4	20.7	8.6	9.4	7.0	11.3	1,842
1995	0.0	0.5	81.3	151.7	397.5	761.2	130.6	32.2	11.1	8.5	18.2	5.5	6.3	10.6	1,615
1996	0.0	23.2	56.2	81.8	166.4	368.5	475.1	185.6	31.4	13.4	8.8	8.6	4.8	11.0	1,435
1997	2.4	83.6	37.8	111.7	478.6	288.3	251.3	196.7	61.6	13.6	6.4	5.0	3.5	15.9	1,556
1998	0.6	51.1	89.8	72.0	156.9	686.9	199.0	128.3	108.7	29.5	6.3	5.8	2.9	8.7	1,547
1999	0.4	11.6	295.0	227.7	105.3	155.7	473.7	132.7	57.5	32.9	3.5	2.2	0.7	2.3	1,501
2000	0.0	17.4	80.2	423.2	343.0	105.4	169.1	359.5	86.0	29.6	24.4	5.7	1.6	2.3	1,647
2001	0.0	3.7	56.8	162.0	574.8	405.8	136.1	129.2	158.3	57.5	35.1	16.0	5.9	5.1	1,746
2002	0.9	56.7	111.1	214.8	284.1	602.2	267.2	99.3	87.4	95.6	34.9	14.5	12.6	4.4	1,886
2003	0.0	17.3	402.2	320.8	366.8	305.2	332.1	157.3	53.0	40.2	36.5	23.7	7.0	7.0	2,069
2004	0.0	1.1	90.0	829.6	479.7	238.2	168.7	156.9	64.0	16.9	18.9	26.1	10.6	13.6	2,114
2005	0.0	3.1	53.7	391.2	861.8	489.1	156.4	67.5	67.1	33.7	11.2	10.2	3.4	5.5	2,154
2006	0.0	12.2	84.2	290.1	622.8	592.2	279.9	108.9	49.6	38.4	16.4	9.6	9.5	13.1	2,127
2007	1.8	19.5	57.2	124.2	374.0	514.7	306.3	139.0	50.2	28.0	23.3	9.4	6.5	16.3	1,671
2008	0.0	26.9	58.6	78.6	147.7	307.4	242.3	149.1	83.3	22.3	19.1	14.5	8.6	15.4	1,174
2009	0.8	3.4	151.8	188.8	73.4	102.0	126.9	106.9	85.7	40.7	26.4	10.5	9.0	19.7	946
2010	2.3	31.4	31.8	560.1	222.3	53.7	44.3	55.8	49.3	34.7	13.9	9.1	5.7	13.3	1,128
2011	0.9	14.7	191.6	117.7	807.6	283.8	64.1	39.4	38.3	40.1	25.3	13.3	1.7	10.4	1,649
2012	0.0	28.3	120.5	942.7	173.0	432.8	138.3	37.9	17.8	13.4	15.9	16.0	8.3	11.5	1,956
2013	3.4	1.7	70.2	342.2	944.4	187.9	154.7	68.5	20.6	17.7	13.6	12.4	9.0	13.2	1,860
2014	0.0	42.2	31.3	170.9	399.0	751.4	210.4	88.2	29.1	9.1	4.8	5.0	4.3	11.8	1,757
2016	0.0	18.7	634.3	195.4	228.3	384.8	509.8	87.0	42.5	18.6	2.9	2.7	3.1	5.2	2,133
Average	3.9	57.8	208.9	339.0	371.0	317.5	200.0	107.6	62.5	33.8	23.2	12.4	8.4	12.3	1802.9

Table 1.11. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2015, as sampled by the NMFS observer program.

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

Table 1.11. (continued) Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2015, as sampled by the NMFS observer program.

Length – weight 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

Table 1.12. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2015, as sampled by the NMFS observer program.

	Number of samples aged						
	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

Table 1.13. NMFS total pollock research catch by year in t, 1964-2015.

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	124
1976	122	1994	267	2012	207
1977	35	1995	249	2013	179
1978	94	1996	206	2014	347
1979	458	1997	262	2015	250
1980	139	1998	121	2016	208
1981	466	1999	299		

Table 1.14. Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979-2016 (**millions** of metric tons). 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. Also, the 1979 - 1981 bottom trawl survey data were omitted from the model since the survey gear differed.

Year	Bottom trawl Survey	AT Survey	AT % age 3+	Total*	Near bottom biomass
1979		7.458	22%		
1980					
1981					
1982	2.856	4.901	95%	7.757	37%
1983	6.258				
1984	4.894				
1985	5.955	4.799	97%	10.754	55%
1986	4.897				
1987	5.498				
1988	7.289	4.675	97%	11.964	61%
1989	6.550				
1990	7.316				
1991	5.130	1.454	46%	6.584	78%
1992	4.583				
1993	5.631				
1994	5.027	2.886	85%	7.913	64%
1995	5.478				
1996	3.415	2.311	97%	5.726	60%
1997	3.800	2.591	70%	6.391	59%
1998	2.781				
1999	3.798	3.285	95%	7.083	54%
2000	5.281	3.049	95%	8.330	63%
2001	4.197				
2002	5.033	3.622	82%	8.655	58%
2003	8.392				
2004	3.863	3.307	99%	7.170	54%
2005	5.321				
2006	3.045	1.560	98%	4.605	66%
2007	4.338	1.769	89%	6.107	71%
2008	3.023	0.997	76%	4.020	75%
2009	2.282	0.924	78%	3.206	71%
2010	3.738	2.323	65%	6.061	62%
2011	3.112				
2012	3.487	1.843	71%	5.330	65%
2013	4.575				
2014	7.430	3.439	65%	10.869	68%
2015	6.390				
2016	4.910	4.063	97%	8.973	55%
Average	4.843	2.763	85%	7.140	62%

* Although the two survey estimates are added in this table, the stock assessment model treats them as separate, independent indices (survey *q*'s are estimated).

Table 1.15. Survey biomass estimates (age 1+, t) of Eastern Bering Sea pollock based on area-swept expansion methods from NMFS bottom trawl surveys 1982-2016.

Year	Survey biomass estimates in strata 1-6	Survey biomass estimates in strata 8 and 9	All area Total	NW %Total
1982	2,858,400	54,469	2,912,869	2%
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%
Avg.	4,520,274	252,308	4,718,247	5%

Table 1.16. Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982-2016. Years where only strata 1-6 were surveyed are shown in italics.

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

Table 1.17. Bottom-trawl survey design-based estimated numbers (millions) at age, 1982-2016, based on strata 1-9. Shaded cells represent years where only strata 1-6 were surveyed. Standard errors and CVs are based on design-based sampling errors.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	StdErr	CV
1982	802	1,982	2,351	3,203	1,051	147	101	49	32	17	9	7	2	1	0	9,753	1,270	13%
1983	333	487	1,194	2,220	4,824	1,427	266	142	56	51	40	13	7	5	1	11,066	1,128	10%
1984	248	238	325	1,118	1,295	3,237	630	142	62	23	15	6	3	4	1	7,348	739	10%
1985	1,718	245	935	548	2,104	1,501	1,164	235	64	46	13	5	5	0	0	8,584	1,727	20%
1986	1,748	251	282	1,404	780	1,448	1,196	1,030	354	58	24	11	0	2	-	8,591	826	10%
1987	194	441	582	374	3,463	719	851	333	1,114	170	63	23	4	1	0	8,332	1,119	13%
1988	436	398	875	2,223	911	3,231	1,041	813	464	1,054	107	60	11	19	4	11,647	1,443	12%
1989	513	192	296	1,017	2,430	617	2,449	373	497	190	497	93	74	41	16	9,295	940	10%
1990	961	204	59	534	955	3,523	782	2,015	221	372	65	510	38	46	23	10,307	1,363	13%
1991	2,205	728	93	54	449	418	1,374	521	1,205	295	412	86	230	33	12	8,115	824	10%
1992	1,111	298	1,520	325	327	517	427	562	267	604	224	270	118	84	54	6,708	798	12%
1993	1,241	223	765	2,791	504	385	228	353	473	295	268	193	126	84	57	7,985	858	11%
1994	806	405	386	1,157	2,890	563	139	145	138	255	150	222	78	68	53	7,456	973	13%
1995	954	56	243	1,154	1,627	2,709	972	216	170	146	200	94	145	53	30	8,769	1,807	21%
1996	1,141	255	89	196	700	960	947	293	77	71	59	112	31	65	17	5,013	448	9%
1997	2,065	230	62	67	1,034	707	573	715	116	40	49	60	69	25	31	5,843	743	13%
1998	505	500	182	115	248	1,342	408	294	232	59	23	9	20	20	14	3,970	446	11%
1999	759	638	572	676	393	636	1,837	500	278	237	97	34	16	21	15	6,709	829	12%
2000	816	254	247	1,117	1,120	685	521	1,890	687	372	145	113	22	11	24	8,025	1,003	12%
2001	1,368	755	393	400	976	1,117	432	235	747	549	196	164	63	24	11	7,430	695	9%
2002	569	290	495	723	863	1,129	630	326	408	823	397	181	107	31	5	6,978	740	11%
2003	270	101	380	1,359	1,401	1,284	1,532	849	355	521	1,108	457	170	62	35	9,884	1,862	19%
2004	275	179	102	881	1,043	769	449	492	233	148	144	271	116	26	14	5,142	494	10%
2005	259	79	128	746	1,986	1,472	775	341	262	195	53	105	187	66	34	6,691	694	10%
2006	736	29	25	195	681	926	627	296	173	150	74	43	65	86	41	4,147	413	10%
2007	1,621	29	68	300	967	1,162	874	622	268	114	110	99	43	57	51	6,384	643	10%
2008	422	64	44	100	368	793	597	432	288	110	98	74	36	21	28	3,475	421	12%
2009	660	103	297	341	179	270	396	334	262	119	80	27	24	14	12	3,119	415	13%
2010	362	59	102	1,860	933	281	254	263	267	193	164	61	36	19	13	4,866	700	14%
2011	912	77	156	263	1,315	677	191	122	181	177	139	114	44	23	28	4,419	430	10%
2012	918	133	234	2,189	534	921	294	136	86	114	101	85	75	27	20	5,867	582	10%
2013	909	57	89	634	3,394	823	531	191	59	58	75	58	55	28	16	6,976	614	9%
2014	1,588	350	63	176	962	3,868	2,030	502	258	107	40	49	44	27	20	10,082	738	7%
2015	765	465	1,546	412	776	1,513	3,078	935	230	105	16	12	28	11	8	9,899	670	7%
2016	507	242	452	2,358	968	668	957	1,351	262	99	33	7	6	4	3	7,916	747	9%
Avg	877	315	447	949	1,270	1,213	844	516	310	227	151	107	60	32	20	7,337	861	12%

Table 1.18. Bottom-trawl efficiency **"corrected"** survey estimated numbers (millions) at age used for the stock assessment model, 1982-2016 based on strata 1-9. Shaded cells represent years where only strata 1-6 were surveyed. Standard errors and CVs are based on design-based sampling errors.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1982	1,287	3,059	3,356	4,377	1,505	206	143	68	43	27	17	10	4	1	1
1983	5,235	782	1,756	3,171	7,134	2,185	399	215	97	84	62	22	9	7	3
1984	496	395	564	1,633	2,073	4,890	935	208	97	34	23	9	5	6	3
1985	6,146	1,033	3,976	1,260	4,145	2,508	1,709	336	85	71	24	8	9	1	0
1986	2,820	694	515	1,907	1,154	1,920	1,680	1,523	477	73	34	15	1	4	1
1987	440	794	1,082	817	4,956	1,371	1,313	519	1,640	253	74	29	5	3	2
1988	1,655	855	1,977	3,752	1,633	5,298	1,571	1,191	687	1,627	154	91	19	25	13
1989	1,051	347	672	2,218	4,981	989	3,761	571	687	267	837	145	128	64	90
1990	2,376	403	145	928	1,853	6,213	1,247	3,068	311	551	85	792	69	51	69
1991	3,184	913	326	106	643	600	1,986	747	1,606	420	568	117	353	50	45
1992	1,637	461	2,399	404	451	756	664	952	424	809	284	354	152	120	95
1993	2,912	433	969	4,095	886	710	369	509	693	428	375	273	214	118	142
1994	1,690	750	573	1,631	4,413	774	202	175	196	369	225	314	119	114	190
1995	2,236	221	427	1,995	2,654	4,323	1,835	483	296	185	349	140	258	102	147
1996	1,779	424	194	389	1,071	1,513	1,386	472	118	127	86	161	53	95	126
1997	2,751	424	221	285	3,408	1,490	883	1,066	181	92	69	76	123	40	138
1998	758	664	348	249	486	2,775	705	446	345	86	39	13	30	33	77
1999	1,137	1,044	968	1,050	599	1,069	2,691	725	350	326	119	50	20	29	98
2000	1,187	441	549	1,861	1,862	962	817	2,674	1,043	547	232	157	48	21	92
2001	1,832	1,057	571	546	1,381	1,444	621	308	918	659	252	201	80	29	77
2002	836	426	877	1,261	1,308	1,695	880	426	576	1,082	539	239	140	42	46
2003	558	171	1,045	1,752	2,078	1,908	2,555	1,445	660	861	1,752	758	286	148	108
2004	406	287	182	1,372	1,338	1,018	598	648	321	200	200	361	154	37	29
2005	448	168	266	1,174	3,328	2,245	1,176	535	407	300	81	170	277	108	110
2006	878	81	125	408	1,023	1,299	831	400	228	197	95	59	85	114	113
2007	2,359	67	169	483	1,511	1,768	1,275	920	388	174	161	140	64	80	155
2008	528	130	108	198	565	1,135	889	618	392	154	128	98	44	24	153
2009	800	221	463	498	290	421	569	445	323	157	104	34	34	18	72
2010	511	144	278	2,985	1,337	417	359	380	399	272	234	85	51	29	63
2011	1,160	125	272	372	1,859	910	267	151	237	236	197	151	64	30	80
2012	1,187	242	455	3,256	761	1,228	421	168	127	176	144	127	106	38	67
2013	1,234	133	256	1,008	5,012	1,162	725	254	86	78	102	77	71	39	52
2014	2,261	612	281	369	1,705	6,257	3,255	693	381	139	53	75	76	36	94
2015	1,205	828	2,332	586	1,222	2,276	4,434	1,293	306	147	19	18	31	18	39
2016	768	484	695	3,330	1,365	922	1,301	1,919	377	148	49	12	12	4	8
Avg	1,650	552	840	1,478	2,057	1,905	1,270	759	443	324	222	154	91	48	74

Table 1.19. Mean EBS pollock body mass (kg) at age as observed in the summer NMFS bottom trawl survey, 1982-2016.

	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15
1982	0.033	0.067	0.167	0.350	0.429	0.669	1.004	1.128	1.202	1.420	1.597	1.624	1.786	2.142	2.673
1983	0.016	0.106	0.169	0.360	0.494	0.576	0.739	1.069	1.145	1.013	1.100	1.149	1.898	1.107	2.730
1984	0.017	0.063	0.193	0.359	0.485	0.616	0.751	1.011	1.220	1.369	1.679	1.656	1.400	1.463	2.505
1985	0.021	0.083	0.174	0.398	0.489	0.629	0.960	1.010	1.365	1.064	1.378	1.771	1.581	2.189	2.753
1986	0.017	0.084	0.145	0.358	0.462	0.642	0.720	0.844	0.996	1.355	1.472	1.471	2.558	2.127	2.833
1987	0.024	0.088	0.188	0.353	0.434	0.530	0.703	0.795	0.888	0.986	1.194	1.367	1.724	2.057	2.700
1988	0.021	0.081	0.210	0.356	0.460	0.521	0.602	0.760	0.851	0.992	1.201	1.209	1.534	1.051	2.444
1989	0.021	0.071	0.174	0.370	0.441	0.534	0.628	0.683	0.935	0.928	1.048	1.066	1.108	1.138	2.167
1990	0.019	0.086	0.155	0.377	0.503	0.573	0.619	0.722	0.796	1.051	1.106	1.128	1.108	1.294	2.294
1991	0.018	0.085	0.151	0.365	0.486	0.580	0.696	0.744	0.877	0.918	1.095	1.202	1.241	1.398	2.525
1992	0.029	0.093	0.205	0.373	0.522	0.623	0.778	0.844	0.897	0.988	1.123	1.241	1.390	1.360	2.484
1993	0.018	0.076	0.253	0.453	0.504	0.563	0.664	0.806	0.977	1.026	1.148	1.264	1.391	1.539	2.502
1994	0.021	0.081	0.190	0.474	0.576	0.638	0.713	0.969	1.170	1.126	1.226	1.326	1.432	1.490	2.279
1995	0.019	0.064	0.114	0.377	0.485	0.629	0.655	0.840	0.967	1.181	1.163	1.330	1.398	1.479	2.234
1996	0.020	0.066	0.116	0.313	0.497	0.596	0.733	0.815	0.971	1.062	1.306	1.395	1.468	1.549	2.151
1997	0.017	0.069	0.208	0.322	0.499	0.598	0.789	0.934	0.964	1.035	1.169	1.295	1.273	1.494	2.080
1998	0.021	0.060	0.134	0.341	0.477	0.520	0.679	0.829	0.910	1.010	1.071	1.331	1.396	1.770	2.176
1999	0.018	0.062	0.157	0.357	0.425	0.561	0.634	0.780	0.981	1.011	1.101	1.200	1.627	1.768	2.232
2000	0.016	0.059	0.168	0.377	0.458	0.531	0.659	0.709	0.784	0.957	1.184	1.214	1.355	1.493	2.211
2001	0.020	0.062	0.129	0.374	0.535	0.618	0.774	0.821	0.855	0.948	1.103	1.201	1.411	1.417	1.917
2002	0.019	0.076	0.223	0.393	0.533	0.646	0.810	0.943	0.897	0.963	1.047	1.094	1.208	1.389	1.957
2003	0.024	0.083	0.237	0.435	0.567	0.672	0.734	0.832	0.884	0.961	0.991	1.029	1.040	1.142	2.218
2004	0.026	0.079	0.210	0.476	0.555	0.680	0.765	0.793	0.941	0.963	1.058	1.052	1.120	1.426	2.426
2005	0.023	0.069	0.213	0.403	0.517	0.609	0.703	0.816	0.888	0.960	1.072	1.112	1.124	1.195	1.998
2006	0.023	0.073	0.166	0.364	0.518	0.607	0.721	0.807	0.910	1.048	1.274	1.209	1.279	1.252	2.098
2007	0.021	0.079	0.280	0.422	0.547	0.672	0.782	0.844	0.925	1.098	1.131	1.112	1.341	1.305	2.071
2008	0.024	0.054	0.186	0.416	0.523	0.642	0.756	0.860	0.924	1.076	1.217	1.206	1.386	1.586	2.064
2009	0.020	0.078	0.165	0.408	0.572	0.669	0.884	1.009	0.955	1.119	1.192	1.440	1.437	1.540	1.928
2010	0.025	0.070	0.237	0.402	0.549	0.679	0.894	0.982	1.033	1.123	1.168	1.258	1.446	1.535	2.202
2011	0.024	0.086	0.169	0.425	0.539	0.647	0.933	1.006	1.108	1.114	1.243	1.304	1.435	1.463	2.115
2012	0.021	0.069	0.204	0.358	0.533	0.671	0.807	0.948	1.212	1.237	1.322	1.360	1.417	1.640	2.071
2013	0.023	0.063	0.167	0.420	0.492	0.623	0.834	0.976	1.079	1.235	1.319	1.366	1.466	1.608	2.128
2014	0.023	0.081	0.162	0.353	0.474	0.604	0.657	0.895	0.987	1.115	1.401	1.350	1.386	1.505	2.043
2015	0.023	0.076	0.206	0.389	0.574	0.627	0.806	0.941	1.046	1.066	1.306	1.610	1.412	1.611	2.220
2016	0.024	0.071	0.198	0.436	0.506	0.619	0.699	0.782	0.844	0.928	1.102	1.485	1.360	1.741	2.218
Average	0.021	0.075	0.184	0.386	0.505	0.612	0.751	0.873	0.982	1.07	1.209	1.298	1.427	1.522	2.276

Table 1.20. 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 170°W (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		-	-	-	-

Table 1.21. AT survey estimates of EBS pollock abundance-at-age (millions), 1979-2016. Age 2+ totals and age-1s were modeled as separate indices. CV's were based on relative error estimates and assumed to average 20% (since 1982).

	Age											
Year	1	2	3	4	5	6	7	8	9	10+	Age 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	453	3,906	1,127	1,670	1,908	293	69	67	30	59	9,130	19%	9,582
1996	972	446	520	2,686	821	509	434	85	17	34	5,553	16%	6,524
1997	12,384	2,743	385	491	1,918	384	205	143	33	18	6,319	15%	18,704
1999	112	1,588	3,597	1,684	583	274	1,169	400	105	90	9,489	23%	9,602
2000	258	1,272	1,185	2,480	900	244	234	725	190	141	7,372	13%	7,629
2002	561	4,188	3,841	1,295	685	593	288	100	132	439	11,561	13%	12,122
2004	16	275	1,189	2,929	1,444	417	202	193	68	101	6,819	15%	6,834
2006	456	209	282	610	695	552	320	110	53	110	2,940	16%	3,396
2007	5,589	1,026	320	430	669	589	306	166	60	52	3,618	18%	9,207
2008	36	2,905	1,032	144	107	170	132	71	58	48	4,668	31%	4,704
2009	5,128	797	1,674	199	31	34	51	38	21	25	2,870	36%	7,997
2010	2,526	6,395	973	2,183	384	46	6	7	7	21	10,023	25%	12,549
2012	67	1,963	1,641	2,444	203	246	64	13	8	19	6,600	25%	6,667
2014	4,438	8,615	941	1,101	892	975	317	67	21	16	12,945	25%	17,384
2016	83	1,017	4,293	3,745	884	254	234	210	36	20	10,692	25%	10,776
Avg.*	1,890	2,565	2,095	1,932	898	494	306	152	59	97	8,599	21%	10,489
Median*	456	1588	1185	1670	739	293	234	110	37	52	7730	20%	9,582

*Average and median values exclude 1979 values.

Table 1.22. Mid-water pollock biomass (near surface down to 3 m from the bottom) by area as estimated from summer acoustic-trawl surveys on the U.S. EEZ portion of the Bering Sea shelf, 1994-2016 (as described in Honkalehto et al. 2015). CVs for biomass estimates were assumed to be 25% for use within the assessment model.

Year	**Date**	**Area** (nmi)^2	**Biomass (1st row) and percent of total (2nd row)** SCA	E170-SCA	W170	**Total biomass**
1994	9 Jul-19 Aug	78,251	0.312 11%	0.399 14%	2.176 75%	2.886
1996	20 Jul-30 Aug	93,810	0.215 9%	0.269 12%	1.826 79%	2.311
1997	17 Jul-4 Sept	102,770	0.246 9%	0.527 20%	1.818 70%	2.592
1999	7 Jun-5 Aug	103,670	0.299 9%	0.579 18%	2.408 73%	3.285
2000	7 Jun-2 Aug	106,140	0.393 13%	0.498 16%	2.158 71%	3.049
2002	4 Jun -30 Jul	99,526	0.647 18%	0.797 22%	2.178 60%	3.622
2004	4 Jun -29 Jul	99,659	0.498 15%	0.516 16%	2.293 69%	3.307
2006	3 Jun -25 Jul	89,550	0.131 8%	0.254 16%	1.175 75%	1.560
2007	2 Jun -30 Jul	92,944	0.084 5%	0.168 10%	1.517 86%	1.769
2008	2 Jun -31 Jul	95,374	0.085 9%	0.029 3%	0.883 89%	0.997
2009	9 Jun -7 Aug	91,414	0.070 8%	0.018 2%	0.835 90%	0.924
2010	5 Jun -7 Aug	92,849	0.067 3%	0.113 5%	2.143 92%	2.323
2012	7 Jun -10 Aug	96,852	0.142 8%	0.138 7%	1.563 85%	1.843
2014	12 Jun -13 Aug	94,361	0.426 12%	1.000 29%	2.014 59%	3.439
2016	12 Jun-17 Aug	100,053	0.516 13%	1.005 25%	2.542 63%	4.063

Key: SCA = Sea lion Conservation Area
E170 - SCA = East of 170 W minus SCA
W170 = West of 170 W

Table 1.23. 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. $CV_{AVO'}$ was assumed to have a mean value of 0.32 for model fitting purposes (scaling relative to the AT and BTS indices).

	AT scaled biomass index	AVO index	$CV_{AVO'}$
2006	0.470 (3.9%)	0.555 (5.1%)	23%
2007	0.534 (4.5%)	0.638 (8.7%)	39%
2008	0.301 (7.6%)	0.316 (6.4%)	29%
2009	0.279 (8.8%)	0.285 (12.0%)	54%
2010	0.701 (6.0%)	0.679 (8.6%)	39%
2011	*-no survey-*	0.543 (5.7%)	26%
2012	0.556 (4.2%)	0.661 (6.2%)	28%
2013	*-no survey-*	0.696 (3.9%)	18%
2014	1.037 (4.6%)	0.900 (4.3%)	19%
2015	*-no survey-*	0.953 (4.6%)	21%
2016		Na	Na

Table 1.24. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964-2016 for model 15.1 and as revised for Model 16.1.

	Fishery		BTS		ATS	
Year	15.1	16.1 Tuned	15.1	16.1 Tuned	15.1	16.1 Tuned
1964-1977	10	10		-	6	
1978	50	39				
1979	50	39			16	10
1980	50	39				
1981	50	39				
1982	50	39	100	105	30	20
1983	50	39	100	126		
1984	50	39	100	118		
1985	50	39	100	125	46	30
1986	50	39	100	88		
1987	50	39	100	105		
1988	50	39	100	76	16	10
1989	50	39	100	80		
1990	50	39	100	82		
1991	174	134	100	71	39	26
1992	200	155	100	82		
1993	273	211	100	90		
1994	108	83	100	74	48	31
1995	138	107	100	75		
1996	149	115	100	90	36	24
1997	256	198	100	78	55	35
1998	270	208	100	82		
1999	456	730	100	90	75	49
2000	452	725	100	101	79	51
2001	292	467	100	107		
2002	435	697	100	110	80	52
2003	389	623	100	107		
2004	332	532	100	108	57	37
2005	399	638	100	109		
2006	328	525	100	102	53	34
2007	408	654	100	97	44	28
2008	341	545	100	82	39	26
2009	232	371	100	87	29	19
2010	239	383	100	90	37	24
2011	447	716	100	113		
2012	411	659	100	116	49	32
2013	390	624	100	120		
2014	394	631	100	137	88	57
2015	337	539	100	151		
2016	na	na	100	115	96	62

Table 1.25. Mean weight-at-age (kg) estimates from the fishery (1991-2015) showing the between-year variability (middle row) and sampling error (bottom panel) based on bootstrap resampling of observer data. Italicized values for 2016 are estimates from the cohort- and year- random effects model. Bolded values represent either the 1992 or 2008 year-class for comparison to averages.

Mean body mass at age (kg) in fishery **Age**

	3	4	5	6	7	8	9	10	11	12	13	14	15
1964-1990	0.303	0.447	0.589	0.722	0.840	0.942	1.029	1.102	1.163	1.212	1.253	1.286	1.312
1991	0.287	0.479	0.608	0.727	0.848	0.887	1.006	1.127	1.125	1.237	1.242	1.279	1.244
1992	0.398	0.468	0.645	0.712	0.814	0.983	1.028	1.224	1.234	1.270	1.175	1.353	1.441
1993	0.495	0.613	0.656	0.772	0.930	1.043	1.196	1.230	1.407	1.548	1.650	1.688	1.635
1994	0.394	0.649	0.730	0.746	0.706	1.010	1.392	1.320	1.339	1.417	1.374	1.310	1.386
1995	**0.375**	0.502	0.730	0.843	0.856	0.973	1.224	1.338	1.413	1.497	1.395	1.212	1.363
1996	0.322	**0.428**	0.680	0.790	0.946	0.949	1.021	1.090	1.403	1.497	1.539	1.750	1.536
1997	0.323	0.466	**0.554**	0.742	0.888	1.071	1.088	1.240	1.410	1.473	1.724	1.458	1.423
1998	0.372	0.588	0.627	**0.623**	0.779	1.034	1.177	1.243	1.294	1.417	1.559	1.556	1.720
1999	0.400	0.502	0.638	0.701	**0.727**	0.901	1.039	1.272	1.207	1.415	1.164	1.141	1.319
2000	0.351	0.524	0.630	0.732	0.782	**0.805**	0.972	1.018	1.268	1.317	1.320	1.665	1.738
2001	0.324	0.497	0.669	0.787	0.963	0.995	**1.062**	1.137	1.327	1.451	1.585	1.466	1.665
2002	0.380	0.508	0.669	0.795	0.908	1.024	1.117	**1.096**	1.300	1.430	1.611	1.319	1.636
2003	0.484	0.550	0.650	0.768	0.862	0.954	1.085	1.224	**1.213**	1.227	1.445	1.340	1.721
2004	0.404	0.580	0.640	0.770	0.890	0.928	1.026	1.207	1.159	**1.179**	1.351	1.292	1.232
2005	0.353	0.507	0.639	0.739	0.880	0.948	1.063	1.094	1.267	1.312	**1.313**	1.164	1.419
2006	0.305	0.448	0.604	0.754	0.855	0.958	1.055	1.126	1.219	1.283	1.306	**1.399**	1.453
2007	0.338	0.509	0.642	0.782	0.960	1.104	1.196	1.276	1.328	1.516	1.416	1.768	**1.532**
2008	0.329	0.521	0.652	0.772	0.899	1.042	1.114	1.204	1.309	1.404	1.513	1.599	1.506
2009	0.345	0.548	0.687	0.892	1.020	1.153	1.407	1.486	1.636	1.637	1.817	2.176	2.292
2010	0.379	0.489	0.665	0.916	1.107	1.255	1.342	1.595	1.613	1.844	1.945	2.049	2.197
2011	**0.290**	0.508	0.666	0.807	0.973	1.222	1.337	1.507	1.578	1.614	2.114	1.731	2.260
2012	0.271	**0.410**	0.641	0.824	0.973	1.173	1.307	1.523	1.614	1.648	1.721	2.020	2.105
2013	0.290	0.443	**0.566**	0.783	1.117	1.275	1.429	1.702	1.850	1.819	1.935	2.115	2.071
2014	0.349	0.504	0.643	**0.761**	0.889	1.031	1.141	1.251	1.343	1.437	1.499	1.494	1.549
2015	0.325	0.489	0.640	0.803	**0.967**	1.116	1.239	1.376	1.476	1.552	1.658	1.752	1.838
2016	*0.344*	*0.522*	*0.642*	*0.804*	***0.933***	*0.986*	*1.140*	*1.176*	*1.265*	*1.365*	*1.357*	*1.356*	*1.351*
2017	*0.205*	*0.531*	*0.712*	*0.812*	***0.947***	*1.048*	*1.075*	*1.208*	*1.228*	*1.303*	*1.393*	*1.378*	*1.372*
Stdev	0.055	0.056	0.040	0.059	0.101	0.117	0.139	0.172	0.173	0.170	0.246	0.301	0.314
CV	16%	11%	6%	8%	11%	11%	12%	13%	13%	12%	16%	19%	19%
Mean	0.355	0.509	0.647	0.774	0.902	1.033	1.163	1.276	1.373	1.458	1.535	1.564	1.651
						Sampling CV (from bootstrap)							
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%

Table 1.26. Goodness of fit (root-mean square log errors) for EBS pollock comparing Models 15.1 and 16.1. Numbers in bold indicate that that index was used in tuning (otherwise is just for comparing).

Model	BTS Biomass	BTS Abundance	ATS Biomass	ATS Abundance
15.1	0.3471	**0.8377**	0.3441	**0.3594**
16.1	**0.2451**	0.8465	**0.3103**	0.308

Table 1.27. Parameter estimates and their standard errors. (details at github.com/jimianelli/EBSpollock)

name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev
log_avgrec	9.93	0.1	log_F_dev	0.69	0.18	sel_dev_fsh	0.13	0.42	sel_dev_fsh	0.06	0.3	sel_dev_fsh	-0.14	0.43	sel_dev_fsh	0.16	0.34	sel_dev_fsh	-0.08	0.42
log_avginit	4.86	0.7	log_F_dev	0.82	0.18	sel_dev_fsh	0.07	0.4	sel_dev_fsh	0.06	0.32	sel_dev_fsh	-0.03	0.4	sel_dev_fsh	0.07	0.31	sel_dev_fsh	-0.43	0.35
log_avg_F	-1.5	0.07	log_F_dev	0.88	0.18	sel_dev_fsh	0.16	0.39	sel_dev_fsh	0.04	0.4	sel_dev_fsh	0.08	0.38	sel_dev_fsh	0.06	0.29	sel_dev_fsh	0.72	0.27
q_offset	-0.15	0.12	log_F_dev	0.69	0.17	sel_dev_fsh	-0.1	0.32	sel_dev_fsh	0.04	0.42	sel_dev_fsh	0.15	0.36	sel_dev_fsh	0.05	0.29	sel_dev_fsh	-0.05	0.27
log_q_eit	-1.07	0.1	log_F_dev	0.57	0.16	sel_dev_fsh	-0.09	0.3	sel_dev_fsh	0.05	0.3	sel_dev_fsh	-0.03	0.36	sel_dev_fsh	0.07	0.27	sel_dev_fsh	0.1	0.27
log_Rzero	9.9	0.18	log_F_dev	0.44	0.18	sel_dev_fsh	-0.08	0.3	sel_dev_fsh	-0.21	0.42	sel_dev_fsh	-0.04	0.35	sel_dev_fsh	-0.01	0.43	sel_dev_fsh	-0.15	0.26
steepness	0.69	0.07	log_F_dev	0.52	0.18	sel_dev_fsh	-0.07	0.32	sel_dev_fsh	-0.13	0.39	sel_dev_fsh	0.02	0.33	sel_dev_fsh	0.17	0.39	sel_dev_fsh	0.01	0.26
log_q_cpue	0.04	0.18	log_F_dev	0.55	0.18	sel_dev_fsh	-0.02	0.41	sel_dev_fsh	-0.02	0.37	sel_dev_fsh	-0.06	0.36	sel_dev_fsh	-0.29	0.36	sel_dev_fsh	0	0.26
log_q_avo	-9.62	0.12	log_F_dev	0.45	0.19	sel_dev_fsh	-0.01	0.41	sel_dev_fsh	-0.01	0.37	sel_dev_fsh	0.03	0.4	sel_dev_fsh	-0.61	0.34	sel_dev_fsh	-0.04	0.27
log_initdev	3.31	0.77	log_F_dev	0.14	0.2	sel_dev_fsh	0.02	0.3	sel_dev_fsh	0.05	0.32	sel_dev_fsh	0.01	0.3	sel_dev_fsh	-0.28	0.31	sel_dev_fsh	-0.08	0.26
log_initdev	2.85	0.77	log_F_dev	-0.25	0.21	sel_dev_fsh	0.2	0.42	sel_dev_fsh	0.06	0.3	sel_dev_fsh	-0.13	0.43	sel_dev_fsh	0.48	0.3	sel_dev_fsh	0	0.42
log_initdev	1.32	0.87	log_F_dev	-0.39	0.21	sel_dev_fsh	0.15	0.4	sel_dev_fsh	0.07	0.3	sel_dev_fsh	-0.05	0.41	sel_dev_fsh	0.15	0.3	sel_dev_fsh	-0.18	0.38
log_initdev	0.48	1	log_F_dev	-0.39	0.2	sel_dev_fsh	-0.02	0.39	sel_dev_fsh	0.07	0.33	sel_dev_fsh	0.12	0.38	sel_dev_fsh	0.15	0.29	sel_dev_fsh	-0.68	0.29
log_initdev	1.14	0.88	log_F_dev	-0.38	0.18	sel_dev_fsh	-0.23	0.37	sel_dev_fsh	0.07	0.42	sel_dev_fsh	-0.07	0.37	sel_dev_fsh	0.13	0.29	sel_dev_fsh	0.8	0.26
log_initdev	0.35	1.03	log_F_dev	-0.45	0.17	sel_dev_fsh	-0.11	0.33	sel_dev_fsh	0.07	0.3	sel_dev_fsh	0.02	0.36	sel_dev_fsh	0.12	0.27	sel_dev_fsh	0.04	0.26
log_initdev	-0.78	1.39	log_F_dev	-0.76	0.13	sel_dev_fsh	-0.09	0.33	sel_dev_fsh	-0.16	0.41	sel_dev_fsh	-0.07	0.37	sel_dev_fsh	-0.03	0.43	sel_dev_fsh	-0.09	0.28
log_initdev	-1.24	1.54	log_F_dev	-0.47	0.13	sel_dev_fsh	-0.04	0.4	sel_dev_fsh	-0.36	0.37	sel_dev_fsh	-0.07	0.35	sel_dev_fsh	0.38	0.39	sel_dev_fsh	0.03	0.27
log_initdev	-1.23	1.55	log_F_dev	-0.45	0.11	sel_dev_fsh	0.02	0.42	sel_dev_fsh	-0.15	0.36	sel_dev_fsh	0.14	0.36	sel_dev_fsh	0.22	0.36	sel_dev_fsh	0.02	0.26
log_initdev	-1.24	1.55	log_F_dev	-0.08	0.11	sel_dev_fsh	0.04	0.42	sel_dev_fsh	-0.02	0.36	sel_dev_fsh	0.07	0.38	sel_dev_fsh	-0.62	0.34	sel_dev_fsh	0.02	0.27
log_initdev	-1.24	1.55	log_F_dev	0.06	0.1	sel_dev_fsh	0.09	0.3	sel_dev_fsh	0.1	0.36	sel_dev_fsh	0.03	0.3	sel_dev_fsh	-0.61	0.32	sel_dev_fsh	0.05	0.26
log_initdev	-1.24	1.54	log_F_dev	0.35	0.1	sel_dev_fsh	0.02	0.42	sel_dev_fsh	0.14	0.31	sel_dev_fsh	-0.19	0.43	sel_dev_fsh	-0.24	0.29	sel_dev_fsh	-0.05	0.42
log_initdev	-1.24	1.54	log_F_dev	-0.05	0.12	sel_dev_fsh	0.03	0.4	sel_dev_fsh	0.12	0.3	sel_dev_fsh	-0.1	0.41	sel_dev_fsh	0.3	0.28	sel_dev_fsh	0.1	0.39
log_initdev	-1.24	1.54	log_F_dev	-0.11	0.14	sel_dev_fsh	-0.07	0.39	sel_dev_fsh	0.12	0.33	sel_dev_fsh	0.46	0.38	sel_dev_fsh	0.29	0.28	sel_dev_fsh	0.02	0.31
log_rec_dev	-1.13	0.38	log_F_dev	-0.14	0.13	sel_dev_fsh	-0.04	0.38	sel_dev_fsh	0.11	0.41	sel_dev_fsh	0.02	0.37	sel_dev_fsh	0.2	0.29	sel_dev_fsh	-0.34	0.26
log_rec_dev	0.04	0.27	log_F_dev	0.01	0.13	sel_dev_fsh	0.01	0.33	sel_dev_fsh	0.09	0.3	sel_dev_fsh	0.11	0.36	sel_dev_fsh	0.13	0.27	sel_dev_fsh	0.43	0.26
log_rec_dev	-0.29	0.33	log_F_dev	0.02	0.14	sel_dev_fsh	0	0.34	sel_dev_fsh	-0.16	0.42	sel_dev_fsh	-0.09	0.36	sel_dev_fsh	-0.12	0.43	sel_dev_fsh	0.26	0.27
log_rec_dev	0.23	0.28	log_F_dev	-0.14	0.13	sel_dev_fsh	-0.04	0.4	sel_dev_fsh	-0.46	0.36	sel_dev_fsh	0.09	0.35	sel_dev_fsh	0.27	0.38	sel_dev_fsh	-0.11	0.27
log_rec_dev	0.08	0.3	log_F_dev	-0.45	0.11	sel_dev_fsh	0.01	0.42	sel_dev_fsh	-0.25	0.35	sel_dev_fsh	-0.09	0.36	sel_dev_fsh	0.13	0.36	sel_dev_fsh	-0.17	0.27
log_rec_dev	0.24	0.28	log_F_dev	-0.33	0.1	sel_dev_fsh	0.03	0.42	sel_dev_fsh	0.09	0.36	sel_dev_fsh	-0.1	0.32	sel_dev_fsh	0.5	0.33	sel_dev_fsh	-0.09	0.27
log_rec_dev	0.13	0.29	log_F_dev	-0.17	0.1	sel_dev_fsh	0.05	0.29	sel_dev_fsh	0.12	0.37	sel_dev_fsh	-0.11	0.28	sel_dev_fsh	-0.01	0.31	sel_dev_fsh	-0.06	0.27
log_rec_dev	-0.35	0.34	log_F_dev	-0.02	0.09	sel_dev_fsh	-0.23	0.42	sel_dev_fsh	0.15	0.32	sel_dev_fsh	-0.14	0.43	sel_dev_fsh	-0.38	0.3	sel_dev_fsh	-0.08	0.42
log_rec_dev	-0.54	0.34	log_F_dev	0.01	0.1	sel_dev_fsh	0.19	0.4	sel_dev_fsh	0.15	0.3	sel_dev_fsh	-0.03	0.41	sel_dev_fsh	-0.31	0.29	sel_dev_fsh	0.18	0.39
log_rec_dev	0.27	0.22	log_F_dev	-0.11	0.1	sel_dev_fsh	0.11	0.39	sel_dev_fsh	0.14	0.33	sel_dev_fsh	-0.31	0.39	sel_dev_fsh	-0.15	0.3	sel_dev_fsh	0.57	0.32
log_rec_dev	-0.03	0.22	log_F_dev	-0.18	0.1	sel_dev_fsh	0.08	0.39	sel_dev_fsh	0.11	0.41	sel_dev_fsh	0.19	0.37	sel_dev_fsh	0.02	0.3	sel_dev_fsh	-0.09	0.27
log_rec_dev	-0.18	0.2	log_F_dev	0.03	0.1	sel_dev_fsh	-0.02	0.34	sel_dev_fsh	0.11	0.3	sel_dev_fsh	0.04	0.36	sel_dev_fsh	0.06	0.27	sel_dev_fsh	-0.3	0.26
log_rec_dev	-0.45	0.19	log_F_dev	0.08	0.1	sel_dev_fsh	-0.01	0.34	sel_dev_fsh	-0.13	0.42	sel_dev_fsh	0.09	0.36	sel_dev_fsh	-0.15	0.43	sel_dev_fsh	-0.11	0.26
log_rec_dev	-0.38	0.17	log_F_dev	0.16	0.09	sel_dev_fsh	-0.02	0.4	sel_dev_fsh	-0.24	0.38	sel_dev_fsh	0.11	0.32	sel_dev_fsh	-0.31	0.36	sel_dev_fsh	-0.06	0.26
log_rec_dev	0.28	0.14	log_F_dev	0.11	0.1	sel_dev_fsh	-0.03	0.42	sel_dev_fsh	-0.28	0.35	sel_dev_fsh	0.09	0.32	sel_dev_fsh	0.29	0.35	sel_dev_fsh	-0.02	0.27
log_rec_dev	1.12	0.12	log_F_dev	-0.09	0.1	sel_dev_fsh	-0.02	0.42	sel_dev_fsh	0	0.36	sel_dev_fsh	-0.02	0.31	sel_dev_fsh	0.3	0.33	sel_dev_fsh	-0.06	0.27
log_rec_dev	0.29	0.13	log_F_dev	0.21	0.1	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	0.13	0.37	sel_dev_fsh	-0.01	0.28	sel_dev_fsh	0.14	0.3	sel_dev_fsh	-0.02	0.27
log_rec_dev	0.41	0.13	log_F_dev	0.18	0.12	sel_dev_fsh	-0.25	0.42	sel_dev_fsh	0.09	0.33	sel_dev_fsh	-0.15	0.43	sel_dev_fsh	0.19	0.29	sel_dev_fsh	-0.03	0.42
log_rec_dev	-0.23	0.15	log_F_dev	0.12	0.14	sel_dev_fsh	0.1	0.4	sel_dev_fsh	0.1	0.33	sel_dev_fsh	0	0.41	sel_dev_fsh	-0.27	0.3	sel_dev_fsh	0.09	0.39
log_rec_dev	0.93	0.12	log_F_dev	0.02	0.16	sel_dev_fsh	0.06	0.39	sel_dev_fsh	0.11	0.39	sel_dev_fsh	-0.25	0.39	sel_dev_fsh	-0.09	0.31	sel_dev_fsh	-0.05	0.32
log_rec_dev	-0.42	0.15	log_F_dev	-0.03	0.19	sel_dev_fsh	0.04	0.39	sel_dev_fsh	0.11	0.33	sel_dev_fsh	0.1	0.38	sel_dev_fsh	-0.05	0.3	sel_dev_fsh	-0.05	0.28
log_rec_dev	0.51	0.12	log_F_dev	-0.11	0.24	sel_dev_fsh	0.04	0.37	sel_dev_fsh	0.11	0.29	sel_dev_fsh	0.19	0.36	sel_dev_fsh	-0.05	0.27	sel_dev_fsh	-0.03	0.26
log_rec_dev	-0.36	0.14	sel_dev_fsh	-0.02	0.43	sel_dev_fsh	0.04	0.36	sel_dev_fsh	-0.1	0.42	sel_dev_fsh	0.07	0.36	sel_dev_fsh	-0.23	0.43	sel_dev_fsh	0.08	0.26
log_rec_dev	-0.98	0.16	sel_dev_fsh	0.03	0.42	sel_dev_fsh	0.03	0.4	sel_dev_fsh	-0.08	0.39	sel_dev_fsh	-0.05	0.34	sel_dev_fsh	-0.44	0.36	sel_dev_fsh	0.01	0.26
log_rec_dev	-1.32	0.17	sel_dev_fsh	0.15	0.41	sel_dev_fsh	0	0.42	sel_dev_fsh	-0.28	0.36	sel_dev_fsh	0.03	0.3	sel_dev_fsh	0.72	0.3	sel_dev_fsh	-0.04	0.27
log_rec_dev	-0.63	0.14	sel_dev_fsh	0.04	0.41	sel_dev_fsh	-0.01	0.42	sel_dev_fsh	-0.06	0.35	sel_dev_fsh	0.04	0.29	sel_dev_fsh	0.43	0.31	sel_dev_fsh	0	0.27
log_rec_dev	0.86	0.11	sel_dev_fsh	0	0.32	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	0.03	0.37	sel_dev_fsh	0.01	0.28	sel_dev_fsh	0.14	0.3	sel_dev_fsh	0.03	0.26
log_rec_dev	0.21	0.12	sel_dev_fsh	-0.04	0.3	sel_dev_fsh	-0.21	0.42	sel_dev_fsh	0.08	0.33	sel_dev_fsh	-0.08	0.43	sel_dev_fsh	-0.23	0.28	sel_dev_fsh	0.03	0.42
log_rec_dev	0.1	0.12	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	0.14	0.4	sel_dev_fsh	0.08	0.33	sel_dev_fsh	0.05	0.4	sel_dev_fsh	0.23	0.28	sel_dev_fsh	-0.11	0.36
log_rec_dev	0.82	0.11	sel_dev_fsh	-0.04	0.3	sel_dev_fsh	0.17	0.39	sel_dev_fsh	0.1	0.4	sel_dev_fsh	-0.24	0.38	sel_dev_fsh	-0.12	0.3	sel_dev_fsh	-0.53	0.31
log_rec_dev	-0.26	0.12	sel_dev_fsh	-0.03	0.3	sel_dev_fsh	0.02	0.39	sel_dev_fsh	0.11	0.33	sel_dev_fsh	-0.18	0.37	sel_dev_fsh	-0.26	0.28	sel_dev_fsh	-0.04	0.29
log_rec_dev	-0.64	0.12	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	0	0.37	sel_dev_fsh	0.11	0.29	sel_dev_fsh	-0.11	0.36	sel_dev_fsh	-0.24	0.27	sel_dev_fsh	-0.03	0.27
log_rec_dev	0.11	0.11	sel_dev_fsh	0.05	0.42	sel_dev_fsh	-0.01	0.33	sel_dev_fsh	-0.12	0.42	sel_dev_fsh	0.01	0.34	sel_dev_fsh	-0.1	0.42	sel_dev_fsh	0.09	0.26
log_rec_dev	0.42	0.11	sel_dev_fsh	0.1	0.41	sel_dev_fsh	-0.01	0.34	sel_dev_fsh	0.1	0.4	sel_dev_fsh	0.15	0.34	sel_dev_fsh	-0.12	0.36	sel_dev_fsh	0.14	0.26
log_rec_dev	-0.28	0.11	sel_dev_fsh	0.12	0.4	sel_dev_fsh	-0.03	0.42	sel_dev_fsh	-0.08	0.37	sel_dev_fsh	0.01	0.31	sel_dev_fsh	-0.6	0.28	sel_dev_fsh	0.13	0.26
log_rec_dev	-0.2	0.11	sel_dev_fsh	-0.05	0.32	sel_dev_fsh	-0.02	0.42	sel_dev_fsh	-0.15	0.35	sel_dev_fsh	0.18	0.29	sel_dev_fsh	0.27	0.26	sel_dev_fsh	0.18	0.27
log_rec_dev	0.23	0.11	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	-0.05	0.3	sel_dev_fsh	-0.11	0.35	sel_dev_fsh	0.21	0.27	sel_dev_fsh	0.4	0.27	sel_dev_fsh	0.15	0.26
log_rec_dev	0.56	0.11	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	-0.19	0.42	sel_dev_fsh	0.06	0.33	sel_dev_fsh	-0.12	0.42	sel_dev_fsh	-0.01	0.28	sel_dev_fsh	0.04	0.42
log_rec_dev	0.15	0.11	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	-0.17	0.39	sel_dev_fsh	0.06	0.33	sel_dev_fsh	-0.07	0.36	sel_dev_fsh	-0.06	0.27	sel_dev_fsh	-0.26	0.36
log_rec_dev	-0.35	0.11	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	0.13	0.38	sel_dev_fsh	0.05	0.4	sel_dev_fsh	0.34	0.34	sel_dev_fsh	0.22	0.26	sel_dev_fsh	0.11	0.29
log_rec_dev	-1.14	0.12	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	0.08	0.38	sel_dev_fsh	0.07	0.4	sel_dev_fsh	-0.21	0.35	sel_dev_fsh	0.03	0.27	sel_dev_fsh	0.05	0.29
log_rec_dev	-1.47	0.13	sel_dev_fsh	-0.02	0.28	sel_dev_fsh	0.05	0.32	sel_dev_fsh	0.1	0.3	sel_dev_fsh	-0.27	0.35	sel_dev_fsh	-0.03	0.26	sel_dev_fsh	-0.2	0.29
log_rec_dev	-0.54	0.11	sel_dev_fsh	0.06	0.42	sel_dev_fsh	0.04	0.31	sel_dev_fsh	-0.11	0.43	sel_dev_fsh	0	0.34	sel_dev_fsh	-0.03	0.42	sel_dev_fsh	-0.18	0.28
log_rec_dev	0.23	0.11	sel_dev_fsh	0.1	0.4	sel_dev_fsh	0.04	0.33	sel_dev_fsh	-0.16	0.4	sel_dev_fsh	0.01	0.32	sel_dev_fsh	-0.22	0.36	sel_dev_fsh	0	0.27
log_rec_dev	-0.36	0.12	sel_dev_fsh	0.23	0.4	sel_dev_fsh	0	0.42	sel_dev_fsh	0.04	0.38	sel_dev_fsh	0.19	0.31	sel_dev_fsh	-0.37	0.31	sel_dev_fsh	0.09	0.27
log_rec_dev	1	0.11	sel_dev_fsh	-0.13	0.37	sel_dev_fsh	0.01	0.42	sel_dev_fsh	-0.06	0.36	sel_dev_fsh	0.07	0.3	sel_dev_fsh	-0.3	0.27	sel_dev_fsh	0.14	0.27
log_rec_dev	0.08	0.12	sel_dev_fsh	-0.1	0.31	sel_dev_fsh	0.02	0.3	sel_dev_fsh	0.07	0.35	sel_dev_fsh	0.06	0.27	sel_dev_fsh	0.23	0.26	sel_dev_fsh	0.21	0.26
log_rec_dev	-0.43	0.15	sel_dev_fsh	-0.07	0.29	sel_dev_fsh	-0.19	0.42	sel_dev_fsh	0	0.34	sel_dev_fsh	-0.13	0.42	sel_dev_fsh	0.61	0.27	sel_dev_fsh	0.01	0.43
log_rec_dev	-0.61	0.18	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	-0.07	0.39	sel_dev_fsh	0.06	0.35	sel_dev_fsh	-0.43	0.37	sel_dev_fsh	0.12	0.27	sel_dev_fsh	0.05	0.36
log_rec_dev	1.13	0.16	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	-0.08	0.35	sel_dev_fsh	0.05	0.39	sel_dev_fsh	-0.07	0.31	sel_dev_fsh	-0.13	0.26	sel_dev_fsh	-0.49	0.31
log_rec_dev	0.45	0.15	sel_dev_fsh	-0.02	0.29	sel_dev_fsh	0.09	0.31	sel_dev_fsh	0.05	0.4	sel_dev_fsh	0.63	0.31	sel_dev_fsh	0.01	0.26	sel_dev_fsh	0.48	0.27
log_rec_dev	-0.12	0.17	sel_dev_fsh	0	0.28	sel_dev_fsh	0.07	0.3	sel_dev_fsh	0.06	0.3	sel_dev_fsh	0	0.33	sel_dev_fsh	0.07	0.26	sel_dev_fsh	0.25	0.29
log_rec_dev	-0.08	0.19	sel_dev_fsh	0.12	0.42	sel_dev_fsh	0.06	0.3	sel_dev_fsh	-0.12	0.43	sel_dev_fsh	0	0.35	sel_dev_fsh	-0.08	0.42	sel_dev_fsh	-0.15	0.31
repl_F	0.28	0.14	sel_dev_fsh	0.1	0.4	sel_dev_fsh	0.05	0.32	sel_dev_fsh	0.05	0.4	sel_dev_fsh	0.06	0.32	sel_dev_fsh	0.34	0.35	sel_dev_fsh	-0.09	0.31
log_F_dev	-0.61	0.27	sel_dev_fsh	0	0.39	sel_dev_fsh	0.02	0.41	sel_dev_fsh	0.1	0.38	sel_dev_fsh	-0.01	0.31	sel_dev_fsh	-0.01	0.3	sel_dev_fsh	0.02	0.28
log_F_dev	-0.62	0.2	sel_dev_fsh	-0.01	0.36	sel_dev_fsh	0.02	0.42	sel_dev_fsh	-0.09	0.37	sel_dev_fsh	-0.02	0.29	sel_dev_fsh	-0.05	0.28	sel_dev_fsh	-0.03	0.28
log_F_dev	-0.69	0.19	sel_dev_fsh	-0.04	0.31	sel_dev_fsh	0.02	0.3	sel_dev_fsh	-0.2	0.36	sel_dev_fsh	-0.04	0.27	sel_dev_fsh	-0.25	0.26	sel_dev_fsh	-0.03	0.26
log_F_dev	-0.16	0.18	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	-0.17	0.42	sel_dev_fsh	0.1	0.34	sel_dev_fsh	-0.02	0.43	sel_dev_fsh	0.04	0.26	sel_dev_fsh	0.02	0.43
log_F_dev	-0.17	0.18	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	0.03	0.39	sel_dev_fsh	0.03	0.33	sel_dev_fsh	0.01	0.38	sel_dev_fsh	0.04	0.26	sel_dev_fsh	0.09	0.35
log_F_dev	-0.13	0.18	sel_dev_fsh	-0.04	0.3	sel_dev_fsh	-0.12	0.37	sel_dev_fsh	0.05	0.37	sel_dev_fsh	-0.63	0.35	sel_dev_fsh	0.03	0.27	sel_dev_fsh	0	0.31
log_F_dev	0.24	0.18	sel_dev_fsh	-0.02	0.32	sel_dev_fsh	-0.03	0.36	sel_dev_fsh	0.03	0.4	sel_dev_fsh	-0.43	0.31	sel_dev_fsh	0.02	0.27	sel_dev_fsh	-1.06	0.27
log_F_dev	0.58	0.18	sel_dev_fsh	-0.02	0.3	sel_dev_fsh	0.05	0.32	sel_dev_fsh	0.05	0.3	sel_dev_fsh	0.67	0.3	sel_dev_fsh	-0.08	0.26	sel_dev_fsh	0.42	0.27

Table 1.27. (continued) Parameter estimates and their standard errors.

name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev	name	value	std.dev
sel_dev_fsh	0.38	0.29	sel_coffs_eit	-1.4	1.31	sel_bts1_dev	0.1	0.09	coh_eff	4.67	0.08	log_F_dev	0.52	0.18	sel_dev_fsh	-0.08	0.3	sel_dev_fsh	-0.21	0.42
sel_dev_fsh	0.14	0.3	sel_coffs_eit	-1.83	1.91	sel_bts1_dev	-0.18	0.1	coh_eff	5	0	log_F_dev	0.55	0.18	sel_dev_fsh	-0.07	0.32	sel_dev_fsh	-0.13	0.39
sel_dev_fsh	0.02	0.28	sel_coffs_eit	-1.94	1.89	sel_bts1_dev	-0.04	0.1	coh_eff	3.85	0.1	log_F_dev	0.45	0.19	sel_dev_fsh	-0.02	0.41	sel_dev_fsh	-0.02	0.37
sel_dev_fsh	0.01	0.28	sel_coffs_eit	-2.09	0.71	sel_bts1_dev	0.02	0.08	coh_eff	0.1	0.12	log_F_dev	0.14	0.2	sel_dev_fsh	-0.01	0.41	sel_dev_fsh	-0.01	0.37
sel_dev_fsh	-0.01	0.26	sel_slp_bts	1.03	0.02	sel_bts1_dev	-0.12	0.11	coh_eff	0.71	0.11	log_F_dev	-0.25	0.21	sel_dev_fsh	0.02	0.3	sel_dev_fsh	0.05	0.32
sel_dev_fsh	-0.04	0.43	sel_a50_bts	6	0	sel_bts1_dev	-0.15	0.12	coh_eff	3.52	0.1	log_F_dev	-0.39	0.21	sel_dev_fsh	0.2	0.42	sel_dev_fsh	0.06	0.3
sel_dev_fsh	0.27	0.37	sel_age_one	-2.98	0.06	sel_bts1_dev	-0.03	0.09	coh_eff	1.91	0.1	log_F_dev	-0.39	0.2	sel_dev_fsh	0.15	0.4	sel_dev_fsh	0.07	0.3
sel_dev_fsh	0.35	0.29	sel_bts_dev	-0.36	0.12	sel_bts1_dev	-0.02	0.09	coh_eff	3.68	0.06	log_F_dev	-0.38	0.18	sel_dev_fsh	-0.02	0.39	sel_dev_fsh	0.07	0.33
sel_dev_fsh	0.54	0.27	sel_bts_dev	-0.19	0.11	sel_bts1_dev	0.08	0.1	coh_eff	2.8	0.1	log_F_dev	-0.45	0.17	sel_dev_fsh	-0.23	0.37	sel_dev_fsh	0.07	0.42
sel_dev_fsh	-1.1	0.27	sel_bts_dev	-0.11	0.1	sel_bts1_dev	0.02	0.1	coh_eff	1.79	0.1	log_F_dev	-0.76	0.13	sel_dev_fsh	-0.11	0.33	sel_dev_fsh	0.07	0.3
sel_dev_fsh	-0.07	0.27	sel_bts_dev	-0.28	0.09	sel_bts1_dev	0.14	0.09	coh_eff	4.27	0.09	log_F_dev	-0.47	0.13	sel_dev_fsh	-0.09	0.33	sel_dev_fsh	-0.16	0.41
sel_dev_fsh	0.01	0.27	sel_bts_dev	-0.23	0.09	sel_bts1_dev	0.11	0.08	coh_eff	5	0	log_F_dev	-0.45	0.11	sel_dev_fsh	-0.04	0.4	sel_dev_fsh	-0.36	0.37
sel_dev_fsh	0.03	0.28	sel_bts_dev	-0.22	0.1	sel_bts1_dev	0.24	0.09	coh_eff	4.64	0.08	log_F_dev	-0.08	0.11	sel_dev_fsh	0.02	0.42	sel_dev_fsh	-0.15	0.36
sel_dev_fsh	0.01	0.28	sel_bts_dev	-0.19	0.1	sel_bts1_dev	0.34	0.1	coh_eff	3.41	0.09	log_F_dev	0.06	0.1	sel_dev_fsh	0.04	0.42	sel_dev_fsh	-0.02	0.36
sel_dev_fsh	0.02	0.26	sel_bts_dev	-0.1	0.1	sel_bts1_dev	0.08	0.11	coh_eff	2.6	0.1	log_F_dev	0.35	0.1	sel_dev_fsh	0.09	0.3	sel_dev_fsh	0.1	0.36
sel_dev_fsh	0.03	0.43	sel_bts_dev	0.01	0.1	sel_bts1_dev	-0.02	0.13	coh_eff	4.42	0.09	log_F_dev	-0.05	0.12	sel_dev_fsh	0.02	0.42	sel_dev_fsh	0.14	0.31
sel_dev_fsh	-0.28	0.38	sel_bts_dev	0.05	0.09	sel_bts1_dev	-0.05	0.09	coh_eff	2.64	0.11	log_F_dev	-0.11	0.14	sel_dev_fsh	0.03	0.4	sel_dev_fsh	0.12	0.3
sel_dev_fsh	0.12	0.31	sel_bts_dev	0.07	0.09	sel_bts1_dev	-0.05	0.08	coh_eff	2.91	0.1	log_F_dev	-0.14	0.13	sel_dev_fsh	-0.07	0.39	sel_dev_fsh	0.12	0.33
sel_dev_fsh	0.07	0.27	sel_bts_dev	0.1	0.09	sel_bts1_dev	0.16	0.09	coh_eff	3.97	0.1	log_F_dev	0.01	0.13	sel_dev_fsh	-0.04	0.38	sel_dev_fsh	0.11	0.41
sel_dev_fsh	0.46	0.27	sel_bts_dev	0.1	0.09	sel_bts1_dev	0.35	0.07	coh_eff	2.31	0.09	log_F_dev	0.02	0.14	sel_dev_fsh	0.01	0.33	sel_dev_fsh	0.09	0.3
sel_dev_fsh	-0.59	0.28	sel_bts_dev	0.08	0.08	sel_bts1_dev	0.28	0.09	coh_eff	2.8	0.08	log_F_dev	-0.14	0.13	sel_dev_fsh	0	0.34	sel_dev_fsh	-0.16	0.42
sel_dev_fsh	-0.17	0.29	sel_bts_dev	-0.05	0.08	sel_bts1_dev	-0.05	0.09	coh_eff	2.53	0.09	log_F_dev	-0.45	0.11	sel_dev_fsh	-0.04	0.4	sel_dev_fsh	-0.46	0.36
sel_dev_fsh	0.08	0.28	sel_bts_dev	-0.19	0.08	sel_bts1_dev	-0.1	0.1	coh_eff	2.47	0.11	log_F_dev	-0.33	0.1	sel_dev_fsh	0.01	0.42	sel_dev_fsh	-0.25	0.35
sel_dev_fsh	0.13	0.28	sel_bts_dev	-0.3	0.08	sel_bts1_dev	0.28	0.08	coh_eff	4.15	0.11	log_F_dev	-0.17	0.1	sel_dev_fsh	0.03	0.42	sel_dev_fsh	0.09	0.36
sel_dev_fsh	0.15	0.27	sel_bts_dev	-0.34	0.08	sel_bts1_dev	0.07	0.09	coh_eff	3.76	0.14	log_F_dev	-0.02	0.09	sel_dev_fsh	0.05	0.29	sel_dev_fsh	0.12	0.37
sel_dev_fsh	-0.04	0.43	sel_bts_dev	-0.28	0.08	sel_bts1_dev	0.07	0.1	coh_eff	0	1	log_F_dev	0.01	0.1	sel_dev_fsh	-0.23	0.42	sel_dev_fsh	0.15	0.32
sel_dev_fsh	0	0.37	sel_bts_dev	-0.28	0.08	sel_bts1_dev	0.13	0.12	coh_eff	0	1	log_F_dev	-0.11	0.1	sel_dev_fsh	0.19	0.4	sel_dev_fsh	0.15	0.3
sel_dev_fsh	-0.12	0.33	sel_bts_dev	-0.15	0.08	rec_dev_fut	0	0.66	yr_eff	0	1	log_F_dev	-0.18	0.1	sel_dev_fsh	0.11	0.39	sel_dev_fsh	0.14	0.33
sel_dev_fsh	-0.08	0.29	sel_bts_dev	-0.03	0.08	rec_dev_fut	0	0.66	yr_eff	0.06	1	log_F_dev	0.03	0.1	sel_dev_fsh	0.08	0.39	sel_dev_fsh	0.11	0.41
sel_dev_fsh	0.14	0.27	sel_bts_dev	0	0.08	rec_dev_fut	0	0.66	yr_eff	0.26	1.01	log_F_dev	0.08	0.1	sel_dev_fsh	-0.02	0.34	sel_dev_fsh	0.11	0.3
sel_dev_fsh	0.24	0.28	sel_bts_dev	0.05	0.09	rec_dev_fut	0	0.66	yr_eff	0.04	0.93	log_F_dev	0.16	0.09	sel_dev_fsh	-0.01	0.34	sel_dev_fsh	-0.13	0.42
sel_dev_fsh	0.17	0.28	sel_bts_dev	0.06	0.09	rec_dev_fut	0	0.66	yr_eff	0.5	0.91	log_F_dev	0.11	0.1	sel_dev_fsh	-0.02	0.4	sel_dev_fsh	-0.24	0.38
sel_dev_fsh	-0.15	0.3	sel_bts_dev	0.16	0.09	L1	27.21	0.02	yr_eff	0.19	0.82	log_F_dev	-0.09	0.1	sel_dev_fsh	-0.03	0.42	sel_dev_fsh	-0.28	0.35
sel_dev_fsh	-0.13	0.33	sel_bts_dev	0.27	0.09	L2	49.87	0.08	yr_eff	0.12	0.74	log_F_dev	0.21	0.1	sel_dev_fsh	-0.02	0.42	sel_dev_fsh	0	0.36
sel_dev_fsh	-0.03	0.29	sel_bts_dev	0.31	0.09	log_K	-0.32	0	yr_eff	-0.15	0.67	log_F_dev	0.18	0.12	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	0.13	0.37
sel_dev_fsh	-0.04	0.44	sel_bts_dev	0.43	0.08	d_scale	0.57	0	yr_eff	-0.05	0.6	log_F_dev	0.12	0.14	sel_dev_fsh	-0.25	0.42	sel_dev_fsh	0.09	0.33
sel_dev_fsh	-0.13	0.38	sel_bts_dev	0.43	0.08	d_scale	0.81	0	yr_eff	1.7	0.31	log_F_dev	0.02	0.16	sel_dev_fsh	0.1	0.4	sel_dev_fsh	0.1	0.33
sel_dev_fsh	0.75	0.32	sel_bts_dev	0.27	0.08	d_scale	0.79	0	yr_eff	1.1	0.32	log_F_dev	-0.03	0.19	sel_dev_fsh	0.06	0.39	sel_dev_fsh	0.11	0.39
sel_dev_fsh	0.13	0.31	sel_bts_dev	0.28	0.08	d_scale	0.78	0	yr_eff	-0.59	0.54	log_F_dev	-0.11	0.24	sel_dev_fsh	0.04	0.39	sel_dev_fsh	0.11	0.33
sel_dev_fsh	-0.16	0.3	sel_bts_dev	0.31	0.08	d_scale	0.81	0	yr_eff	0.43	0.3	sel_dev_fsh	-0.02	0.43	sel_dev_fsh	0.04	0.37	sel_dev_fsh	0.11	0.29
sel_dev_fsh	0.13	0.27	sel_bts_dev	0.19	0.09	d_scale	0.85	0.01	yr_eff	-0.08	0.08	sel_dev_fsh	0.03	0.42	sel_dev_fsh	0.04	0.36	sel_dev_fsh	-0.1	0.42
sel_dev_fsh	-0.29	0.28	sel_bts_dev	0.15	0.12	d_scale	0.88	0.01	yr_eff	-0.09	0.08	sel_dev_fsh	0.15	0.41	sel_dev_fsh	0.03	0.4	sel_dev_fsh	-0.08	0.39
sel_dev_fsh	-0.17	0.29	sel_bts2_dev	-0.12	0.08	d_scale	0.9	0.01	yr_eff	-0.17	0.09	sel_dev_fsh	0.04	0.41	sel_dev_fsh	0	0.42	sel_dev_fsh	-0.28	0.36
sel_dev_fsh	-0.2	0.34	sel_bts2_dev	-0.15	0.06	d_scale	0.98	0.02	yr_eff	-1.32	0.13	sel_dev_fsh	0	0.32	sel_dev_fsh	-0.01	0.42	sel_dev_fsh	-0.06	0.35
sel_dev_fsh	-0.02	0.29	sel_bts2_dev	0	0.05	d_scale	1.02	0.02	yr_eff	-0.52	0.09	sel_dev_fsh	-0.04	0.3	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	0.03	0.37
sel_dev_fsh	0.01	0.44	sel_bts2_dev	0.03	0.04	d_scale	1.08	0.04	yr_eff	-0.68	0.1	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	-0.21	0.42	sel_dev_fsh	0.08	0.33
sel_dev_fsh	0.01	0.44	sel_bts2_dev	0.07	0.05	d_scale	1.09	0.06	yr_eff	-1.02	0.11	sel_dev_fsh	-0.04	0.3	sel_dev_fsh	0.14	0.4	sel_dev_fsh	0.08	0.33
sel_dev_fsh	-0.05	0.43	sel_bts2_dev	-0.02	0.05	d_scale	1.71	0.07	yr_eff	-0.25	0.08	sel_dev_fsh	-0.03	0.3	sel_dev_fsh	0.17	0.39	sel_dev_fsh	0.1	0.4
sel_dev_fsh	-0.04	0.43	sel_bts2_dev	-0.14	0.06	coh_eff	0	1	yr_eff	-0.37	0.08	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	0.02	0.39	sel_dev_fsh	0.11	0.33
sel_dev_fsh	-0.07	0.43	sel_bts2_dev	-0.17	0.05	coh_eff	0	1	yr_eff	-0.01	0.07	sel_dev_fsh	0.05	0.42	sel_dev_fsh	0	0.37	sel_dev_fsh	0.11	0.29
sel_dev_fsh	-0.01	0.36	sel_bts2_dev	-0.15	0.06	coh_eff	0	1	yr_eff	0.18	0.06	sel_dev_fsh	0.1	0.41	sel_dev_fsh	-0.01	0.33	sel_dev_fsh	-0.12	0.42
sel_dev_fsh	0.05	0.35	sel_bts2_dev	-0.05	0.06	coh_eff	0	1	yr_eff	-0.51	0.07	sel_dev_fsh	0.12	0.4	sel_dev_fsh	-0.01	0.34	sel_dev_fsh	0.1	0.4
sel_dev_fsh	0.04	0.36	sel_bts2_dev	-0.08	0.05	coh_eff	0	1	yr_eff	-1.57	0.12	sel_dev_fsh	-0.05	0.32	sel_dev_fsh	-0.03	0.42	sel_dev_fsh	-0.08	0.37
sel_dev_fsh	0.04	0.36	sel_bts2_dev	-0.1	0.04	coh_eff	0	1	yr_eff	-0.65	0.07	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	-0.02	0.42	sel_dev_fsh	-0.15	0.35
sel_dev_fsh	0.01	0.3	sel_bts2_dev	-0.04	0.04	coh_eff	0	1	yr_eff	0.22	0.05	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	-0.05	0.3	sel_dev_fsh	-0.11	0.35
sel_dev_fsh	0	0.71	sel_bts2_dev	0.07	0.05	coh_eff	0	1	yr_eff	-2.01	0.13	sel_dev_fsh	-0.04	0.29	sel_dev_fsh	-0.19	0.42	sel_dev_fsh	0.06	0.33
sel_dev_fsh	0	0.71	sel_bts2_dev	0.18	0.03	coh_eff	0	1	yr_eff	0	0.05	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	-0.17	0.39	sel_dev_fsh	0.06	0.33
sel_dev_fsh	0	0.71	sel_bts2_dev	0.17	0.04	coh_eff	0	1	yr_eff	-0.56	0.06	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	0.13	0.38	sel_dev_fsh	0.05	0.4
sel_dev_fsh	0	0.71	sel_bts2_dev	0.25	0.04	coh_eff	0	1	yr_eff	-0.51	0.07	sel_dev_fsh	-0.02	0.28	sel_dev_fsh	0.08	0.38	sel_dev_fsh	0.07	0.4
sel_dev_fsh	0	0.71	sel_bts2_dev	0.12	0.05	coh_eff	0	1	yr_eff	0.38	0.05	sel_dev_fsh	0.06	0.42	sel_dev_fsh	0.05	0.32	sel_dev_fsh	0.1	0.3
sel_dev_fsh	0	0.71	sel_bts2_dev	0.09	0.05	coh_eff	0	1	yr_eff	-0.37	0.07	sel_dev_fsh	0.1	0.4	sel_dev_fsh	0.04	0.31	sel_dev_fsh	-0.11	0.43
sel_dev_fsh	0	0.71	sel_bts2_dev	0.13	0.04	coh_eff	0	1	yr_eff	-0.5	0.05	sel_dev_fsh	0.23	0.4	sel_dev_fsh	0.04	0.33	sel_dev_fsh	-0.16	0.4
sel_dev_fsh	0	0.71	sel_bts2_dev	0.1	0.04	coh_eff	0	1	yr_eff	-1.53	0.1	sel_dev_fsh	-0.13	0.37	sel_dev_fsh	0	0.42	sel_dev_fsh	0.04	0.38
sel_dev_fsh	0	0.71	sel_bts2_dev	0.15	0.05	coh_eff	0	1	yr_eff	-1.09	0.08	sel_dev_fsh	-0.1	0.31	sel_dev_fsh	0.01	0.42	sel_dev_fsh	-0.06	0.36
sel_dev_fsh	0	0.71	sel_bts2_dev	0.09	0.04	coh_eff	0.07	1	yr_eff	0.45	0.05	sel_dev_fsh	-0.07	0.29	sel_dev_fsh	0.02	0.3	sel_dev_fsh	0.07	0.35
sel_dev_eit	-0.9	1.17	sel_bts2_dev	0.01	0.04	coh_eff	-0.07	0.99	yr_eff	-0.52	0.08	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	-0.19	0.42	sel_dev_fsh	0	0.34
sel_dev_eit	1	1.52	sel_bts2_dev	0.12	0.03	coh_eff	0.16	1	yr_eff	0.4	0.06	sel_dev_fsh	-0.03	0.29	sel_dev_fsh	-0.07	0.39	sel_dev_fsh	0.06	0.35
sel_dev_eit	2.38	1.74	sel_bts2_dev	-0.03	0.04	coh_eff	-0.08	0.97	yr_eff	0.04	0.06	sel_dev_fsh	-0.02	0.29	sel_dev_fsh	-0.08	0.35	sel_dev_fsh	0.05	0.39
sel_dev_eit	2.4	1.74	sel_bts2_dev	-0.03	0.04	coh_eff	-0.01	0.97	yr_eff	-0.19	0.06	sel_dev_fsh	0	0.28	sel_dev_fsh	0.09	0.31	sel_dev_fsh	0.05	0.4
sel_dev_eit	2.67	2.22	sel_bts2_dev	-0.06	0.04	coh_eff	-0.09	0.94	yr_eff	-0.72	0.06	sel_dev_fsh	0.12	0.42	sel_dev_fsh	0.07	0.3	sel_dev_fsh	0.06	0.3
sel_dev_eit	2.79	2.21	sel_bts2_dev	-0.14	0.04	coh_eff	0.05	0.93	yr_eff	-0.39	0.05	sel_dev_fsh	0.1	0.4	sel_dev_fsh	0.06	0.3	sel_dev_fsh	-0.12	0.43
sel_dev_eit	2.86	1.3	sel_bts2_dev	-0.01	0.03	coh_eff	0.36	0.96	yr_eff	-0.2	0.05	sel_dev_fsh	0	0.39	sel_dev_fsh	0.05	0.32	sel_dev_fsh	0.05	0.4
sel_coffs_fsh	-4	0.81	sel_bts2_dev	-0.04	0.03	coh_eff	-0.07	0.97	yr_eff	0.08	0.05	sel_dev_fsh	-0.01	0.36	sel_dev_fsh	0.02	0.41	sel_dev_fsh	0.1	0.38
sel_coffs_fsh	-2.14	0.62	sel_bts2_dev	-0.05	0.03	coh_eff	-0.48	0.88	yr_eff	-0.4	0.1	sel_dev_fsh	-0.04	0.31	sel_dev_fsh	0.02	0.42	sel_dev_fsh	-0.09	0.37
sel_coffs_fsh	-0.92	0.53	sel_bts2_dev	-0.08	0.04	coh_eff	0.5	0.88	yr_eff	0	1	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	0.02	0.3	sel_dev_fsh	-0.2	0.36
sel_coffs_fsh	0.35	0.43	sel_bts2_dev	-0.07	0.04	coh_eff	2.11	0.13	yr_eff	0	1	sel_dev_fsh	-0.05	0.29	sel_dev_fsh	-0.17	0.42	sel_dev_fsh	0.1	0.34
sel_coffs_fsh	0.36	0.3	sel_bts2_dev	-0.04	0.05	coh_eff	2.39	0.12	yr_eff	0	1	sel_dev_fsh	-0.04	0.3	sel_dev_fsh	0.03	0.39	sel_dev_fsh	0.03	0.33
sel_coffs_fsh	0.36	0.27	sel_bts1_dev	-0.12	0.13	coh_eff	2.96	0.13	yr_eff	0	1	sel_dev_fsh	-0.02	0.32	sel_dev_fsh	-0.12	0.37	sel_dev_fsh	0.05	0.37
sel_coffs_fsh	0.32	0.27	sel_bts1_dev	-0.15	0.09	coh_eff	3	0.12	yr_eff	0	1	sel_dev_fsh	-0.02	0.3	sel_dev_fsh	-0.03	0.36	sel_dev_fsh	0.03	0.4
sel_coffs_fsh	0.27	0.27	sel_bts1_dev	0.01	0.12	coh_eff	1.98	0.12	log_F_dev	0.69	0.18	sel_dev_fsh	0.13	0.42	sel_dev_fsh	0.05	0.32	sel_dev_fsh	0.05	0.3
sel_coffs_fsh	0.23	0.28	sel_bts1_dev	-0.3	0.09	coh_eff	3.03	0.12	log_F_dev	0.82	0.18	sel_dev_fsh	0.13	0.42	sel_dev_fsh	0.06	0.3			
sel_coffs_fsh	0.2	0.3	sel_bts1_dev	-0.44	0.12	coh_eff	3.62	0.12	log_F_dev	0.88	0.18	sel_dev_fsh	0.07	0.4	sel_dev_fsh	0.06	0.32			
sel_coffs_eit	1.63	0.32	sel_bts1_dev	-0.21	0.14	coh_eff	2.5	0.12	log_F_dev	0.69	0.17	sel_dev_fsh	0.16	0.39	sel_dev_fsh	0.04	0.4			
sel_coffs_eit	-0.09	1.01	sel_bts1_dev	-0.34	0.15	coh_eff	2.1	0.12	log_F_dev	0.57	0.16	sel_dev_fsh	-0.1	0.32	sel_dev_fsh	0.04	0.42			
sel_coffs_eit	-1.4	1.31	sel_bts1_dev	-0.13	0.13	coh_eff	1.84	0.12	log_F_dev	0.44	0.18	sel_dev_fsh	-0.09	0.3	sel_dev_fsh	0.05	0.3			

Table 1.28. Summary model results showing the stock condition for EBS pollock. Values in parentheses are coefficients of variation (CV's) of values immediately above.

	2015 Assessment	2016 **Assessment**
Biomass		
Year 2017 spawning biomass*	3,540,000 t	4,600,000 t
(CV)	(14%)	(14%)
2016 spawning biomass	3,483,000 t	4,070,000 t
B_{MSY}	1,984,000 t	2,165,000 t
(CV)	(20%)	(20%)
$SPR\vert F_{MSY}$	30%	30%
$B_{40\%}$	2,813,000 t	2,643,000 t
$B_{35\%}$	2,461,000 t	2,313,000 t
B_0 (stock-recruitment curve)	5,676,000 t	5,700,000 t
2016 Percent of B_{MSY} spawning biomass	176%	188%
2017 Percent of B_{MSY} spawning biomass	178%	212%
Ratio of B_{2016} over B_{2016} under no fishing since 1978	0.59	0.66
Recruitment (millions of pollock at age 1)		
Steepness parameter (*h*)	0.671	0.686
Average recruitment (all yrs)	23,100	24,350
2000 year class	36,321	35,844
2006 year class	27,094	25,928
2008 year class	62,011	56,100
2012 year class	Na	63,900
Natural Mortality (age 3 and older)	0.3	0.3

*Assuming 2017 catch will be 1,350,000 t

Table 1.29. Summary results of Tier 1 2017 yield projections for EBS pollock.

Description	Value
Tier 1 maximum permissible ABC	
2017 fishable biomass (GM)	7,830,000 t
MSYR (HM)	0.398
Adjustment factor	1.0
Adjusted ABC rate	0.398
2017 MSYR yield (Tier 1 ABC)	3,120,000 t
OFL	
MSYR (AM)	0.465
2017 MSYR OFL	3,640,000 t
Recommended F_{ABC}	0.36
Recommended ABC	2,800,000 t
Fishable biomass at *MSY*	3,991,000 t

Notes: MSYR = exploitation rate relative to begin-year age fishable biomass corresponding to F_{MSY}. F_{MSY} yields calculated within the model (i.e., including uncertainty in both the estimate of F_{MSY} and in projected stock size). HM = Harmonic mean, GM = Geometric mean, AM = Arithmetic mean

Table 1.30 Estimates millions of EBS pollock at age from the 2016 model.

	1	2	3	4	5	6	7	8	9	10+	Total
1964	6,670	3,534	2,242	483	209	406	183	59	37	225	14,048
1965	21,535	2,706	2,223	1,588	304	131	256	116	38	169	29,067
1966	15,437	8,737	1,702	1,563	994	192	83	163	75	134	29,079
1967	25,796	6,263	5,491	1,191	994	634	123	54	106	136	40,789
1968	22,271	10,448	3,883	3,593	698	582	373	73	32	144	42,097
1969	26,141	9,015	6,455	2,536	2,103	411	345	222	43	105	47,377
1970	23,500	10,572	5,546	4,094	1,500	1,250	246	206	131	87	47,133
1971	14,578	9,468	6,356	3,312	2,351	840	701	136	110	114	37,967
1972	11,964	5,851	5,550	3,570	1,747	1,178	424	351	64	100	30,800
1973	26,909	4,808	3,324	2,898	1,744	839	567	203	158	69	41,519
1974	19,909	10,829	2,649	1,612	1,306	773	372	251	85	91	37,877
1975	17,094	8,023	5,763	1,144	691	558	331	159	102	68	33,934
1976	13,138	6,909	4,528	2,610	527	322	262	155	73	75	28,599
1977	13,755	5,318	3,990	2,256	1,234	254	156	128	75	69	27,236
1978	25,352	5,575	3,108	2,186	1,154	619	128	79	65	71	38,337
1979	61,943	10,281	3,283	1,700	1,111	560	302	63	39	64	79,344
1980	27,184	25,131	6,215	1,891	885	526	262	142	29	47	62,313
1981	30,738	11,036	15,585	3,908	1,013	428	248	125	68	36	63,186
1982	16,305	12,486	6,934	10,619	2,329	541	227	132	66	55	49,695
1983	52,162	6,626	7,895	4,938	6,913	1,400	320	135	78	71	80,539
1984	13,573	21,200	4,193	5,678	3,340	4,387	855	196	82	90	53,593
1985	34,632	5,517	13,436	3,017	3,881	2,113	2,704	522	120	104	66,045
1986	14,545	14,077	3,496	9,644	2,079	2,533	1,282	1,645	318	134	49,752
1987	7,835	5,912	8,925	2,509	6,610	1,375	1,572	790	1,026	275	36,830
1988	5,561	3,185	3,756	6,446	1,765	4,510	905	1,030	508	829	28,496
1989	11,103	2,261	2,021	2,628	4,432	1,149	2,868	555	636	820	28,472
1990	48,848	4,513	1,435	1,436	1,780	2,873	721	1,723	337	896	64,563
1991	25,581	19,857	2,859	1,015	926	1,050	1,658	404	959	700	55,009
1992	22,781	10,399	12,572	2,042	670	559	604	884	223	882	51,614
1993	46,863	9,260	6,575	8,723	1,342	406	300	293	416	521	74,699
1994	15,943	19,051	5,883	4,675	5,550	869	242	164	160	517	53,054
1995	10,905	6,481	12,108	4,277	3,181	3,283	518	136	92	384	41,365
1996	22,878	4,433	4,119	8,861	3,044	2,034	1,794	290	76	271	47,800
1997	31,178	9,301	2,812	3,003	6,417	2,075	1,174	896	146	187	57,190
1998	15,483	12,675	5,889	2,044	2,140	4,359	1,285	643	469	174	45,162
1999	16,827	6,295	8,045	4,264	1,445	1,450	2,663	774	360	351	42,473
2000	25,850	6,841	4,004	5,724	2,968	980	942	1,579	463	431	49,783
2001	35,963	10,510	4,351	2,895	3,880	1,905	630	555	873	532	62,094
2002	23,952	14,621	6,687	3,166	1,997	2,364	1,061	352	311	811	55,322
2003	14,626	9,738	9,289	4,848	2,160	1,230	1,224	552	184	627	44,478
2004	6,640	5,946	6,193	6,560	3,301	1,287	653	617	281	454	31,932
2005	4,832	2,700	3,785	4,495	4,149	2,020	738	346	330	421	23,815
2006	12,208	1,964	1,718	2,748	2,991	2,322	1,090	411	197	443	26,093
2007	26,391	4,963	1,249	1,216	1,792	1,692	1,190	568	218	359	39,638
2008	14,622	10,729	3,154	884	795	1,014	831	611	302	317	33,261
2009	56,931	5,945	6,822	2,278	584	459	489	411	316	328	74,562
2010	22,500	23,146	3,784	4,932	1,523	364	250	256	217	339	57,310
2011	13,479	9,148	14,734	2,768	3,181	936	216	143	143	313	45,061
2012	11,201	5,480	5,819	10,740	1,928	1,638	459	109	73	237	37,685
2013	63,522	4,554	3,484	4,212	7,150	1,264	825	230	55	160	85,456
2014	31,883	25,825	2,898	2,522	2,820	4,467	775	459	118	111	71,879
2015	18,180	12,962	16,436	2,107	1,715	1,746	2,653	420	255	126	56,598
2016	18,951	7,391	8,251	11,696	1,415	1,090	1,003	1,552	244	217	51,810
Median	19,430	7,707	4,440	2,896	1,773	1,070	585	273	137	187	45,162
Average	22,993	9,255	5,727	3,807	2,316	1,401	794	435	226	289	47,242

Table 1.31. Assessment model-estimated catch-at-age of EBS pollock (millions; 1964-2016).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	9.2	38.0	85.7	62.3	27.2	52.6	22.9	7.1	4.3	25.1	334.3
1965	29.1	30.0	98.6	213.6	39.6	16.4	30.7	13.5	4.2	18.5	494.1
1966	21.0	101.7	80.9	191.9	119.1	21.9	9.2	17.5	7.8	13.7	584.7
1967	64.9	140.3	555.2	216.1	181.4	113.3	21.7	9.4	18.3	23.3	1,343.8
1968	64.2	262.1	397.5	655.1	124.2	100.7	64.0	12.4	5.4	24.6	1,710.2
1969	90.9	255.5	805.5	444.3	360.9	69.4	58.1	38.9	7.7	19.0	2,150.3
1970	140.9	486.8	933.8	799.7	318.2	264.8	54.4	49.7	32.9	23.0	3,104.4
1971	123.0	616.6	1,337.5	831.7	663.6	234.2	197.8	43.3	37.0	41.0	4,125.7
1972	90.7	515.6	1,428.3	1,061.5	536.0	361.0	130.9	120.9	23.3	38.4	4,306.6
1973	181.1	529.0	1,002.9	992.2	612.3	295.6	199.2	77.4	63.3	28.5	3,981.4
1974	116.7	1,451.2	967.3	594.7	484.3	286.0	137.3	98.9	35.3	37.9	4,209.7
1975	66.8	744.9	1,958.7	378.1	223.8	179.0	105.9	52.9	36.4	24.5	3,771.1
1976	37.1	526.4	1,293.9	825.0	161.6	96.9	78.0	46.9	23.5	24.4	3,113.7
1977	27.9	359.2	904.8	609.3	347.5	70.3	43.0	35.0	22.0	20.5	2,439.6
1978	42.9	344.6	707.5	598.8	347.4	184.5	38.1	23.6	20.4	22.7	2,330.7
1979	85.5	430.3	634.5	440.7	350.3	180.3	96.2	19.9	12.9	21.3	2,271.8
1980	26.6	555.0	815.6	456.7	267.6	166.3	81.8	44.1	9.3	14.8	2,437.8
1981	17.7	130.0	1,083.2	664.1	246.1	105.8	61.1	30.6	16.9	9.0	2,364.4
1982	5.3	83.9	232.1	1,116.2	381.1	94.7	39.5	23.2	11.9	9.9	1,997.8
1983	12.2	40.1	199.9	372.0	859.4	213.7	48.6	20.6	12.5	11.6	1,790.6
1984	2.7	102.8	104.0	380.4	423.2	640.0	130.1	29.6	13.1	14.8	1,840.7
1985	6.0	27.7	361.8	182.4	400.3	332.0	419.7	81.1	19.3	17.5	1,847.7
1986	2.0	63.7	94.0	623.9	193.5	356.5	187.2	225.9	49.0	21.2	1,816.9
1987	0.7	18.2	193.8	109.1	452.4	132.6	157.7	90.2	124.2	32.6	1,311.6
1988	0.6	12.6	180.1	401.2	186.3	553.9	135.7	148.1	76.9	122.8	1,818.2
1989	1.0	8.7	71.3	194.5	480.5	151.7	471.2	86.2	94.3	120.5	1,679.9
1990	5.2	24.3	55.6	161.5	315.4	551.8	153.3	372.1	70.5	180.5	1,890.1
1991	2.5	113.5	88.7	96.6	149.3	204.0	404.5	89.4	236.3	171.8	1,556.6
1992	2.6	70.6	689.9	200.0	105.2	133.9	182.5	281.5	71.5	279.3	2,017.1
1993	3.1	27.7	229.0	1,067.1	146.3	68.6	68.1	66.4	94.3	114.2	1,884.8
1994	0.9	49.5	94.8	329.6	971.8	147.6	51.2	34.5	33.3	105.3	1,818.6
1995	0.5	17.4	127.5	145.6	377.6	749.9	109.8	28.7	18.9	76.7	1,652.7
1996	1.1	18.2	56.5	171.7	210.5	390.3	509.7	81.1	19.3	62.8	1,521.3
1997	1.4	52.2	45.8	99.2	461.1	295.4	266.2	228.8	39.0	47.4	1,536.5
1998	0.5	46.6	114.8	81.5	158.3	663.9	208.0	137.4	109.2	38.1	1,558.4
1999	0.4	12.8	275.1	223.0	105.5	154.1	462.3	129.1	58.1	53.8	1,474.3
2000	0.6	13.5	82.4	422.2	344.2	112.8	167.6	347.8	83.8	69.8	1,644.6
2001	0.9	18.0	67.4	172.9	597.4	411.4	133.8	117.6	171.8	98.4	1,789.4
2002	0.7	42.3	124.0	216.6	291.5	620.6	275.2	90.3	73.8	166.0	1,901.0
2003	0.4	19.7	375.8	338.8	367.6	303.9	341.4	151.0	45.0	128.1	2,071.7
2004	0.2	8.5	108.8	832.2	498.7	253.0	161.9	149.4	60.2	83.5	2,156.2
2005	0.1	4.0	64.5	396.5	882.2	478.1	159.5	69.2	62.6	70.2	2,187.0
2006	0.3	4.6	66.4	285.1	614.9	623.7	280.9	101.5	44.6	91.6	2,113.7
2007	0.7	13.1	47.5	123.9	368.1	497.7	318.6	139.7	50.6	78.6	1,638.4
2008	0.4	24.3	68.3	82.9	152.8	309.5	240.9	160.9	78.5	76.0	1,194.5
2009	1.3	8.9	142.0	192.6	81.1	105.3	124.6	102.6	80.6	82.1	921.0
2010	0.4	30.5	40.4	553.5	224.9	62.1	50.2	55.4	46.1	70.4	1,133.9
2011	0.3	17.0	204.0	143.4	844.9	276.0	60.5	38.8	37.8	80.1	1,703.0
2012	0.3	13.5	115.4	943.2	192.1	457.6	129.6	30.5	19.4	61.8	1,963.3
2013	1.4	7.4	68.3	351.2	971.4	189.4	178.8	61.4	14.5	42.3	1,886.2
2014	0.6	39.1	46.4	179.7	402.5	770.4	181.4	99.7	25.8	26.3	1,771.8
2015	0.3	17.4	560.9	170.7	211.7	340.4	484.4	78.3	46.8	29.3	1,940.3
2016	0.3	9.2	247.2	836.4	151.3	195.8	178.7	277.8	43.4	47.7	1,987.7
Median	1.7	38.5	161.1	345.0	331.2	208.9	134.7	73.3	36.7	41.0	1,847.7
Average	24.4	162.2	391.2	419.5	358.2	276.3	168.0	93.7	47.5	60.6	2,001.7

Table 1.32. Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2016. Biomass units are thousands of t, age-1 recruitment is in millions of pollock.

Year	Age 3+ biomass	Spawning biomass	Age 1 Rec.	Year	Age 3+ biomass	Spawning biomass	Age 1 Rec.
1964	1,834	543	6,670	1990	7,812	2,974	48,848
1965	2,230	643	21,535	1991	6,184	2,235	25,581
1966	2,404	749	15,437	1992	9,477	2,334	22,781
1967	3,667	944	25,796	1993	11,627	3,183	46,863
1968	4,199	1,170	22,271	1994	11,313	3,474	15,943
1969	5,295	1,429	26,141	1995	13,000	3,678	10,905
1970	5,936	1,663	23,500	1996	11,239	3,688	22,878
1971	6,360	1,751	14,578	1997	9,837	3,489	31,178
1972	6,025	1,655	11,964	1998	9,909	3,258	15,483
1973	4,846	1,388	26,909	1999	10,751	3,264	16,827
1974	3,590	1,033	19,909	2000	9,955	3,296	25,850
1975	3,679	877	17,094	2001	9,702	3,323	35,963
1976	3,609	885	13,138	2002	10,025	3,136	23,952
1977	3,536	917	13,755	2003	12,080	3,313	14,626
1978	3,376	923	25,352	2004	11,401	3,417	6,640
1979	3,239	890	61,943	2005	9,599	3,142	4,832
1980	4,069	1,019	27,184	2006	7,391	2,592	12,208
1981	7,814	1,702	30,738	2007	6,047	2,173	26,391
1982	9,057	2,606	16,305	2008	4,946	1,616	14,622
1983	10,240	3,249	52,162	2009	6,374	1,763	56,931
1984	10,033	3,499	13,573	2010	6,658	1,985	22,500
1985	12,237	3,774	34,632	2011	9,638	2,426	13,479
1986	11,531	4,005	14,545	2012	9,627	2,841	11,201
1987	12,143	4,123	7,835	2013	9,504	3,171	63,522
1988	11,497	4,102	5,561	2014	8,948	3,079	31,883
1989	9,756	3,688	11,103	2015	12,407	3,394	18,180
				2016	13,495	4,067	18,951

Table 1.33. Estimates of begin-year age 3 and older biomass (thousands of tons) and coefficients of variation (CV) for the current assessment compared to 2009-2015 assessments for EBS pollock.

	Current		2015		2014		2013		2012		2011		2010		2009	
	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV
1964	1,834	22%	1,869	24%	1,622	21%	1,602	21%	1,608	21%	1,602	21%	1,589	21%	1,564	22%
1965	2,230	20%	2,324	22%	2,077	20%	2,051	20%	2,059	20%	2,050	20%	2,008	19%	2,008	20%
1966	2,404	20%	2,563	22%	2,186	20%	2,150	20%	2,157	20%	2,159	20%	1,944	21%	1,947	22%
1967	3,667	17%	3,888	19%	3,397	16%	3,344	16%	3,353	16%	3,365	16%	3,140	17%	3,149	17%
1968	4,199	17%	4,495	18%	3,871	17%	3,800	17%	3,809	17%	3,838	17%	3,486	18%	3,510	19%
1969	5,295	16%	5,690	16%	5,220	16%	5,145	16%	5,154	16%	5,187	16%	4,879	17%	5,007	17%
1970	5,936	15%	6,424	15%	6,253	15%	6,179	15%	6,188	15%	6,221	15%	5,974	16%	6,159	15%
1971	6,360	13%	6,858	14%	6,946	14%	6,884	14%	6,894	14%	6,918	14%	6,785	13%	6,949	13%
1972	6,025	13%	6,431	13%	6,353	14%	6,299	14%	6,308	14%	6,329	14%	6,277	13%	6,444	13%
1973	4,846	14%	5,161	14%	4,749	16%	4,692	16%	4,700	16%	4,728	16%	4,547	16%	4,696	16%
1974	3,590	16%	3,846	17%	3,348	20%	3,291	20%	3,298	20%	3,329	20%	3,085	20%	3,196	20%
1975	3,679	12%	3,868	13%	3,554	14%	3,516	14%	3,523	14%	3,533	14%	3,366	13%	3,384	13%
1976	3,609	10%	3,872	11%	3,609	11%	3,578	11%	3,587	11%	3,580	11%	3,460	10%	3,431	11%
1977	3,536	9%	3,939	10%	3,643	10%	3,613	9%	3,624	10%	3,598	9%	3,500	9%	3,457	9%
1978	3,376	8%	3,888	9%	3,557	9%	3,524	9%	3,537	9%	3,497	9%	3,390	9%	3,340	9%
1979	3,239	8%	3,859	9%	3,426	9%	3,387	9%	3,403	9%	3,343	9%	3,267	9%	3,212	9%
1980	4,069	7%	4,887	8%	4,372	7%	4,307	7%	4,333	7%	4,230	7%	4,203	7%	4,124	8%
1981	7,814	5%	9,054	6%	8,528	6%	8,321	6%	8,364	6%	8,160	6%	8,190	6%	8,031	6%
1982	9,057	5%	10,289	5%	9,767	5%	9,497	6%	9,549	6%	9,313	6%	9,349	6%	9,165	6%
1983	10,240	5%	11,383	5%	10,911	5%	10,560	5%	10,621	5%	10,340	5%	10,376	5%	10,168	5%
1984	10,033	5%	11,040	5%	10,601	5%	10,239	5%	10,300	5%	10,031	5%	10,060	5%	9,857	5%
1985	12,237	4%	12,951	4%	12,838	4%	12,409	4%	12,478	4%	12,186	4%	12,246	4%	12,027	4%
1986	11,531	4%	12,019	4%	12,036	4%	11,621	4%	11,685	4%	11,426	4%	11,471	4%	11,269	4%
1987	12,143	3%	12,334	4%	12,615	4%	12,243	4%	12,308	4%	12,063	4%	12,111	4%	11,915	4%
1988	11,497	3%	11,536	4%	11,906	3%	11,583	4%	11,642	4%	11,424	4%	11,402	4%	11,227	4%
1989	9,756	3%	9,700	4%	10,128	4%	9,861	4%	9,913	4%	9,724	4%	9,671	4%	9,521	4%
1990	7,812	4%	7,701	4%	8,102	4%	7,891	4%	7,936	4%	7,764	4%	7,681	4%	7,558	4%
1991	6,184	4%	6,063	5%	6,331	4%	6,171	5%	6,209	5%	6,049	5%	5,911	5%	5,811	5%
1992	9,477	3%	9,472	3%	9,705	3%	9,562	3%	9,602	3%	9,411	3%	9,316	3%	9,211	4%
1993	11,627	3%	11,712	3%	11,840	3%	11,712	3%	11,754	3%	11,543	3%	11,493	3%	11,388	3%
1994	11,313	3%	11,418	3%	11,402	3%	11,306	3%	11,341	3%	11,146	3%	11,077	3%	10,990	4%
1995	13,000	3%	13,177	3%	13,135	3%	13,074	3%	13,109	3%	12,883	3%	12,779	3%	12,699	3%
1996	11,239	3%	11,358	3%	11,235	3%	11,198	3%	11,229	3%	11,019	3%	10,903	4%	10,843	4%
1997	9,837	3%	9,940	3%	9,816	4%	9,801	4%	9,828	4%	9,627	4%	9,485	4%	9,440	4%
1998	9,909	3%	9,990	3%	9,907	3%	9,903	4%	9,929	3%	9,722	4%	9,584	4%	9,538	4%
1999	10,751	3%	10,853	3%	10,799	3%	10,791	3%	10,819	3%	10,607	3%	10,509	3%	10,421	3%
2000	9,955	3%	10,068	3%	10,031	3%	10,020	3%	10,044	3%	9,841	3%	9,747	3%	9,632	3%
2001	9,702	3%	9,854	3%	9,819	3%	9,803	3%	9,830	3%	9,616	3%	9,506	3%	9,341	4%
2002	10,025	3%	10,276	3%	10,221	3%	10,182	3%	10,230	3%	9,988	3%	9,842	3%	9,595	4%
2003	12,080	2%	12,365	3%	12,278	3%	12,211	3%	12,269	3%	11,974	3%	11,805	3%	11,453	3%
2004	11,401	2%	11,591	3%	11,493	3%	11,416	3%	11,491	3%	11,178	3%	10,974	3%	10,606	4%
2005	9,599	2%	9,705	3%	9,602	3%	9,522	3%	9,608	3%	9,299	3%	9,079	4%	8,736	4%
2006	7,391	3%	7,446	3%	7,343	3%	7,262	4%	7,349	4%	7,060	4%	6,839	4%	6,543	5%
2007	6,047	3%	6,045	4%	5,933	4%	5,840	4%	5,954	4%	5,633	5%	5,386	5%	5,090	6%
2008	4,946	3%	4,849	4%	4,722	5%	4,607	5%	4,724	5%	4,393	6%	4,146	7%	3,809	8%
2009	6,374	3%	6,331	5%	6,069	5%	5,880	5%	6,069	6%	6,172	8%	6,225	10%	4,762	11%
2010	6,658	4%	6,680	5%	5,937	5%	5,622	6%	5,769	7%	6,095	10%	6,582	12%	4,616	13%
2011	9,638	4%	10,053	7%	8,895	6%	7,928	8%	7,781	9%	7,823	11%	9,620	15%		
2012	9,627	5%	10,164	8%	8,823	8%	7,853	10%	7,867	10%	8,341	12%				
2013	9,504	5%	10,337	9%	9,541	8%	8,261	11%	8,138	12%						
2014	8,948	7%	9,805	10%	8,960	9%	8,045	12%								
2015	12,407	10%	10,970	11%	9,203	10%										
2016	13,495	12%	11,292	12%												
2017	13,033	13%														

Table 1.34 Tier 3 projections of catch, fishing mortality, and spawning biomass (thousands of tons) for EBS pollock for the 7 scenarios. Note that the values for $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 6,608, 2,643 and 2,313 thousand t, respectively.

Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2016	1,350	1,350	1,350	1,350	1,350	1,350	1,350
2017	2,803	1,350	1,783	1,263	0	3,433	2,803
2018	2,540	2,979	1,826	1,372	0	2,869	2,540
2019	2,087	2,350	1,666	1,320	0	2,158	2,542
2020	1,730	1,906	1,518	1,247	0	1,686	1,873
2021	1,604	1,672	1,437	1,196	0	1,652	1,708
2022	1,633	1,657	1,434	1,202	0	1,716	1,732
2023	1,660	1,667	1,437	1,206	0	1,756	1,760
2024	1,679	1,681	1,443	1,213	0	1,775	1,775
2025	1,676	1,673	1,442	1,213	0	1,763	1,763
2026	1,670	1,669	1,438	1,211	0	1,755	1,755
2027	1,661	1,663	1,431	1,207	0	1,744	1,744
2028	1,651	1,652	1,424	1,201	0	1,733	1,733
2029	1,653	1,653	1,424	1,201	0	1,736	1,736
Fishing M.	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2016	0.226	0.226	0.226	0.226	0.226	0.226	0.226
2017	0.438	0.193	0.262	0.180	0.000	0.560	0.438
2018	0.438	0.438	0.262	0.180	0.000	0.560	0.438
2019	0.438	0.438	0.262	0.180	0.000	0.542	0.560
2020	0.416	0.428	0.262	0.180	0.000	0.482	0.503
2021	0.399	0.404	0.262	0.180	0.000	0.474	0.480
2022	0.399	0.400	0.262	0.180	0.000	0.480	0.481
2023	0.400	0.400	0.262	0.180	0.000	0.484	0.484
2024	0.400	0.400	0.262	0.180	0.000	0.484	0.484
2025	0.399	0.398	0.262	0.180	0.000	0.481	0.481
2026	0.399	0.398	0.262	0.180	0.000	0.481	0.481
2027	0.399	0.398	0.262	0.180	0.000	0.480	0.480
2028	0.398	0.398	0.262	0.180	0.000	0.479	0.479
2029	0.398	0.397	0.262	0.180	0.000	0.478	0.478
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2016	4,067	4,067	4,067	4,067	4,067	4,067	4,067
2017	4,360	4,557	4,501	4,568	4,721	4,265	4,360
2018	3,603	4,149	4,136	4,416	5,122	3,286	3,603
2019	2,971	3,279	3,710	4,142	5,362	2,588	2,898
2020	2,721	2,875	3,505	4,014	5,621	2,382	2,507
2021	2,688	2,750	3,424	3,956	5,804	2,409	2,448
2022	2,722	2,748	3,421	3,972	6,034	2,458	2,469
2023	2,754	2,765	3,431	3,987	6,192	2,490	2,492
2024	2,778	2,784	3,447	4,009	6,328	2,509	2,509
2025	2,764	2,769	3,432	3,998	6,415	2,491	2,491
2026	2,752	2,757	3,417	3,985	6,465	2,480	2,480
2027	2,742	2,746	3,404	3,972	6,494	2,470	2,470
2028	2,730	2,732	3,388	3,956	6,508	2,461	2,461
2029	2,744	2,746	3,398	3,965	6,541	2,476	2,476

Table 1.35 Maximum permissible Tier 1a EBS pollock ABC and OFL projections for 2017 and 2018.

Year	Catch	ABC	OFL
2017	1,350,000 t	3,120,000 t	3,640,000 t
2018	1,350,000 t	3,740,000 t	4,360,000 t

Table 1.36. Analysis of ecosystem considerations for BSAI pollock and the pollock fishery.

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 abundance—indicates 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 1.37 Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 1997-2002 based on observer data, 2003-2016 based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska).

Group	1997	1998	1999	2000	2001	2002
Jellyfish	6,632	6,129	6,176	9,361	3,095	1,530
Squid	1,487	1,210	474	379	1,776	1,708
Skates	348	406	376	598	628	870
Misc Fish	207	134	156	236	156	134
Sculpins	109	188	67	185	199	199
Sleeper shark	105	74	77	104	206	149
Smelts	19.5	30.2	38.7	48.7	72.5	15.3
Grenadiers	19.7	34.9	79.4	33.2	11.6	6.5
Salmon shark	6.6	15.2	24.7	19.5	22.5	27.5
Starfish	6.5	57.7	6.8	6.2	12.8	17.4
Shark	15.6	45.4	10.3	0.1	2.3	2.3
Benthic inverts.	2.5	26.3	7.4	1.7	0.6	2.1
Sponges	0.8	21	2.4	0.2	2.1	0.3
Octopus	1	4.7	0.4	0.8	4.8	8.1
Crabs	1	8.2	0.8	0.5	1.8	1.5
Anemone	2.6	1.8	0.3	5.8	0.1	0.6
Tunicate	0.1	1.5	1.5	0.4	3.7	3.8
Unident. inverts	0.2	2.9	0.1	4.4	0.1	0.2
Echinoderms	0.8	2.6	0.1	0	0.2	0.1
Seapen/whip	0.1	0.2	0.5	0.9	1.5	2.1
Other	0.8	2.9	1.1	0.8	1.2	3.7

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Scypho jellies	5,644	6,590	5,196	2,716	2,398	4,183	8,115	2,661	8,893	3,878	6,117	12,712	4,924	2,192
Misc fish	101.3	89.8	157.9	154.1	202.9	120.2	135.1	173.0	325.8	163.0	151.0	43.6	89.9	75.0
Sea star	89.4	7.2	9.5	11.3	5.3	18.7	9.8	13.2	37.5	8.1	14.8	29.9	41.6	54.3
Eulachon	2.5	19.3	9.2	93.6	100.8	2.4	5.3	0.7	3.3	1.7	0.8	1.9	19.3	5.1
Eelpouts	7.0	0.7	1.3	21.0	118.7	8.9	4.3	2.1	1.3	1.3	1.8	7.7	10.6	22.7
osmerids	7.5	2.0	3.4	5.8	37.5	2.0	0.1	0.1	0.3	0.2	0.2	0.3	2.6	0.6
Sea pens	0.6	1.0	1.7	2.0	4.0	1.1	2.6	3.1	2.9	3.9	2.3	3.4	2.1	1.1
Sponge	0.1	0.0	0.0	0.0	1.4	0.2	0.5	4.9	3.9	0.5	6.6	2.3	0.4	0.3
Snails	1.3	1.0	6.9	0.2	0.5	1.9	1.5	1.4	1.4	1.5	1.1	1.6	1.3	0.4
Lanternfishes	0.3	0.1	0.6	9.6	5.8	1.5	0.4	0.0	0.0	0.1	0.0	0.0	0.2	0.6
Sea anemone	0.4	0.4	0.3	0.6	0.3	0.9	1.3	2.4	2.0	1.7	2.4	1.7	2.4	1.0
Brittle star	0.3	0.0	0.0	2.6	0.2	3.6	0.1	0.3	0.2	0.1	0.1	1.6	0.2	0.1
urochordata	0.0	0.0	0.5	0.0	0.0	0.8	0.7	3.1	0.9	0.1	1.9	1.8	1.5	0.9
Invertebrate	0.0	0.1	0.1	0.2	0.8	0.3	0.3	1.0	0.7	2.2	0.2	1.1	0.3	0.0
Misc crabs	0.7	0.0	0.3	0.1	1.3	0.6	0.2	0.1	0.3	0.2	0.6	0.5	0.2	0.4
All other	0.3	0.7	3.5	3.9	5.1	2.1	1.9	2.0	1.8	0.6	0.8	0.8	0.9	1.2

Table 1.38 Bycatch estimates (t) of other **target species** caught in the BSAI directed pollock fishery, 1997-2015 based on then NMFS Alaska Regional Office reports from observers (*2015 data are preliminary*).

	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					879	15,241
1998	6,559	2,118	779	1,762	1,762	682	91	2	178	14					805	14,751
1999	3,220	1,885	1,058	350	273	121	161	7	30	3					249	7,357
2000	3,432	2,510	2,688	1,466	979	22	2	12	52	147					306	11,615
2001	3,878	2,199	1,673	594	529	574	41	21	68	14					505	10,098
2002	5,925	1,843	1,885	768	606	544	221	34	70	50					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 1.39 Bycatch estimates (t) of **pollock** caught in the other non-pollock EBS directed fisheries, 2003-2015 based on then NMFS Alaska Regional Office reports from observers.

	Fishery						
	Pacific cod	Yellowfin sole	Rock sole	Flathead sole	Other flatfish	Others	**Total**
2003	15,926	11,579	4,925	2,984	689	260	36,362
2004	18,650	10,384	8,976	5,163	1,233	194	44,600
2005	14,110	10,313	7,235	3,663	1,395	201	36,917
2006	15,168	5,967	6,986	2,664	1,163	143	32,091
2007	20,320	4,021	3,245	3,418	936	276	32,215
2008	9,534	9,828	4,931	4,103	720	17	29,132
2009	7,876	7,037	6,172	3,161	345	14	24,603
2010	6,410	5,179	6,074	2,997	320	86	21,066
2011	8,987	8,674	6,931	1,474	828	302	27,196
2012	8,381	11,199	6,704	903	849	413	28,450
2013	9,096	20,172	7,328	2,010	2,037	238	40,881
2014	11,509	24,713	11,259	4,106	2,298	202	54,086
2015	9,076	21,282	9,382	2,633	2,360	429	45,162
2016	7,583	19,809	11,656	1,556	1,899	195	42,699
Average	11,616	12,154	7,272	2,917	1,219	212	35,390

Table 1.40 Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997-2012 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 2016 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		40,906		2,160		3,159	28,951	4,380,025	33,431	17,777
1992	1,501,801		35,950		2,221		647	40,274	4,570,741	20,387	43,874
1993	1,649,104		38,516		1,326		527	242,191	738,260	1,926	58,140
1994	371,238		33,136		963	689	1,627	92,672	811,758	514	42,361
1995	153,995		14,984		492	398	905	19,264	206,654	941	4,646
1996	89,416		55,623		382	321	1,242	77,236	63,398	215	5,934
1997	17,248		44,909		261	203	1,135	65,988	216,152	393	137
1998	57,042		51,322		353	278	801	64,042	123,405	5,093	14,287
1999	2,397		10,381		154	125	800	44,610	15,830	7	91
2000	1,485		4,242		110	91	483	56,867	6,481	121	0
2001	5,061		30,937		266	200	225	53,904	5,653	5,139	106
2002	2,113		32,402		199	168	109	77,178	2,698	194	17
2003	733	9	43,021		113	96	909	180,782	609		52
2004	1,189	4	51,700	2	109	93	1,104	440,475	743		27
2005	659	0	67,362	1	147	113	610	704,587	2,300		0
2006	1,657	0	82,750	3	157	122	436	306,047	2,909		203
2007	1,522	0	122,255	3	360	292	354	93,201	3,220		8
2008	8,839	8	21,398	33	424	334	128	15,555	9,428		576
2009	6,120	20	12,743	0	588	458	65	46,893	7,428		1,137
2010	12,884	29	9,847	0	335	267	351	13,665	9,433		1,051
2011	10,965	26	25,499	0	459	378	377	193,754	6,471		577
2012	5,548	0	11,344	0	463	388	2,353	22,390	6,189		344
2013	12,424	34	13,109	107	334	271	959	125,525	8,588	316	316
2014	12,522	0	15,129	148	239	200	159	219,823	19,456	348	368
2015	8,873	0	18,329	0	152	130	1,489	237,803	8,340	0	0
2016	2,293	0	22,197	106	106	92	1,423	343,158	1,165	0	439

Figures

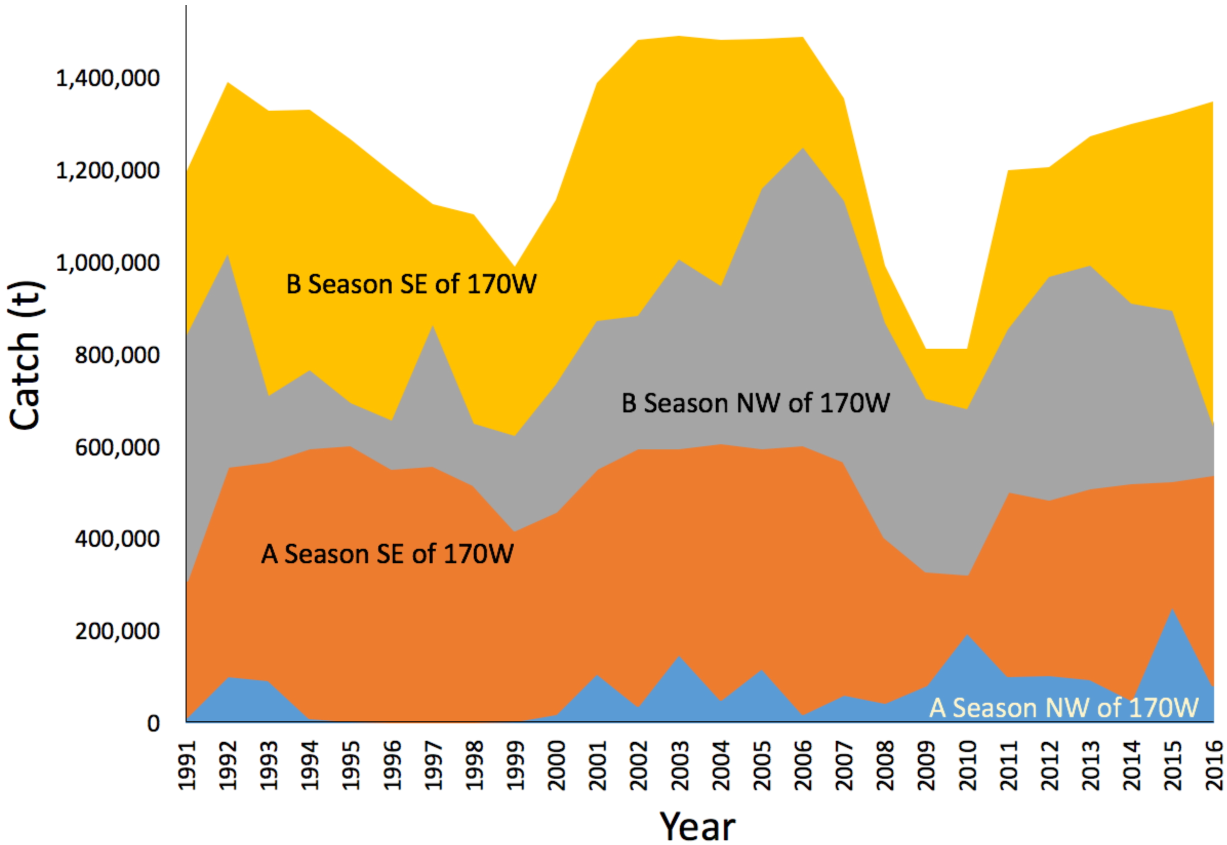


Figure 1.1. Pollock catch estimates from the Eastern Bering Sea overall (top) and by season and region (bottom) in metric t. The A-season is defined as from Jan-May and B-season from June-October.

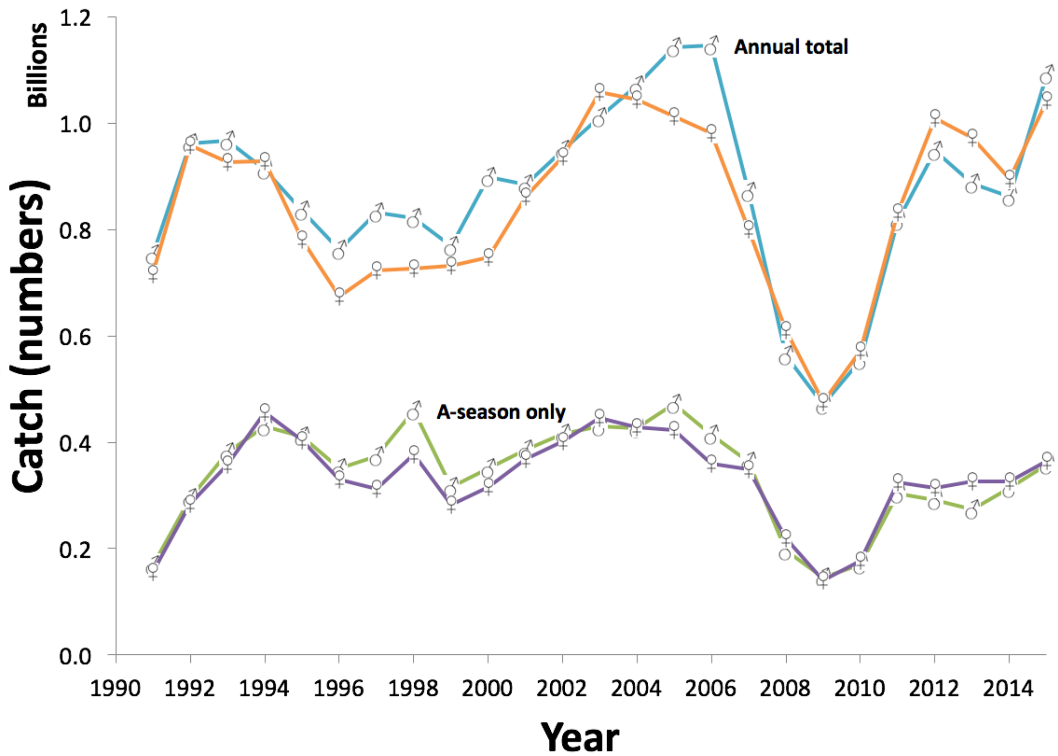


Figure 1.2. Estimate of EBS pollock catch numbers by sex for the A season (January-May) and for the entire annual fishery, 1991-2015.

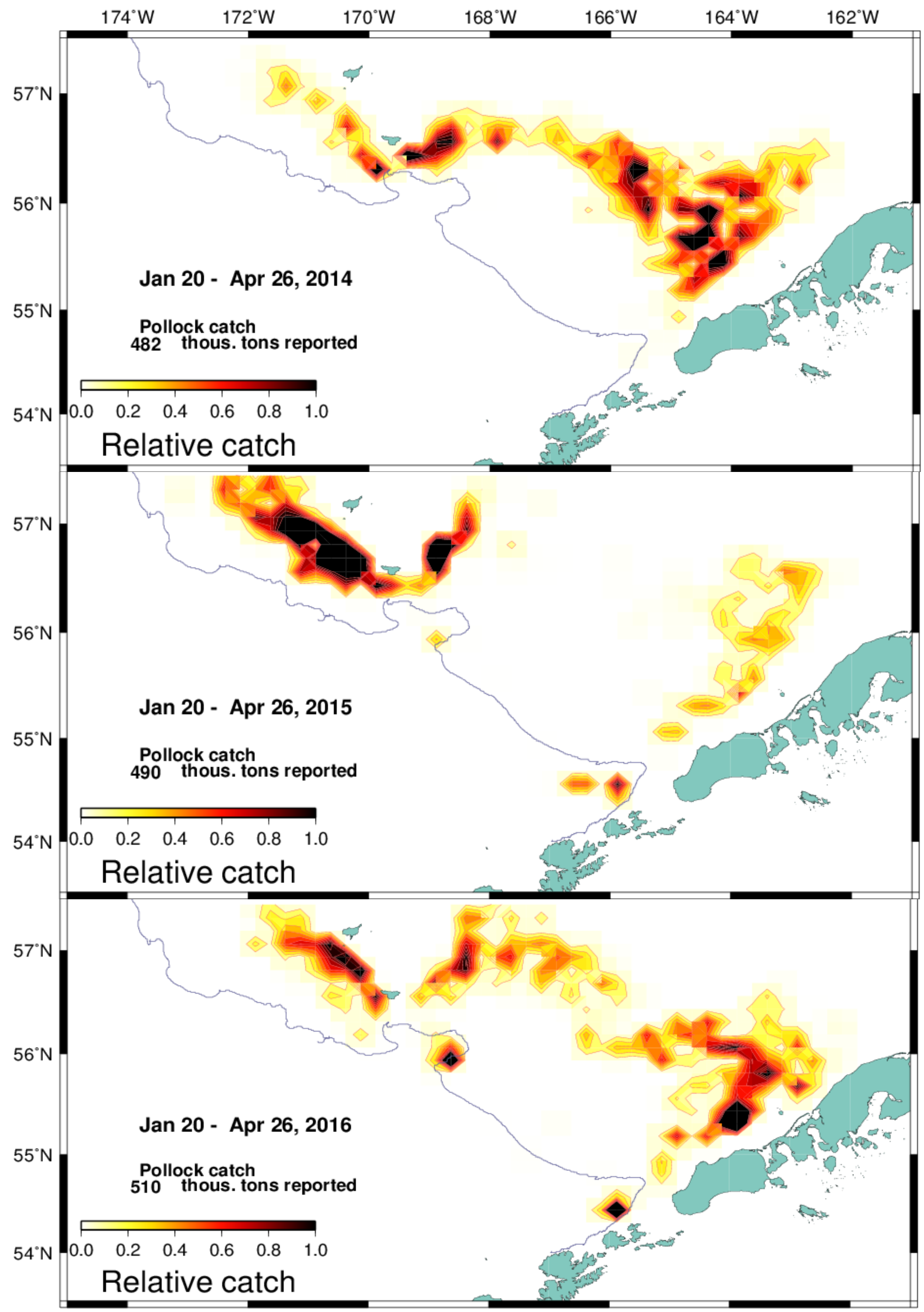


Figure 1.3. Pollock catch distribution 2014-2016, for the A-season on the EBS shelf.

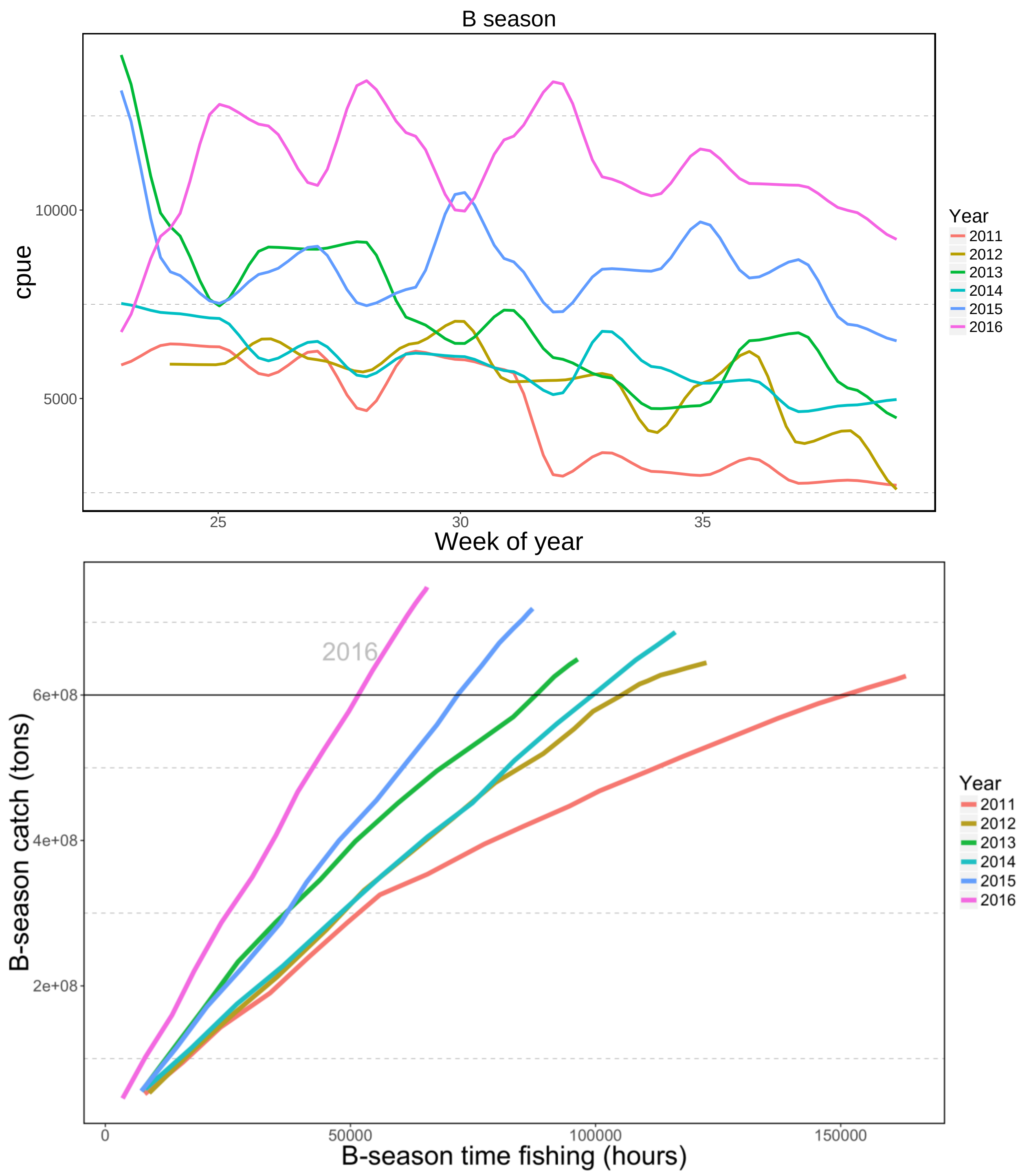


Figure 1.4. B-season EBS fleet-wide nominal pollock catch (kg) per hour of fishing recorded by NMFS scientific observers, 2011-2016 (top) and cumulative catch plotted against hours observed fishing (bottom). The horizontal line represents 600 kt for B-season catch.

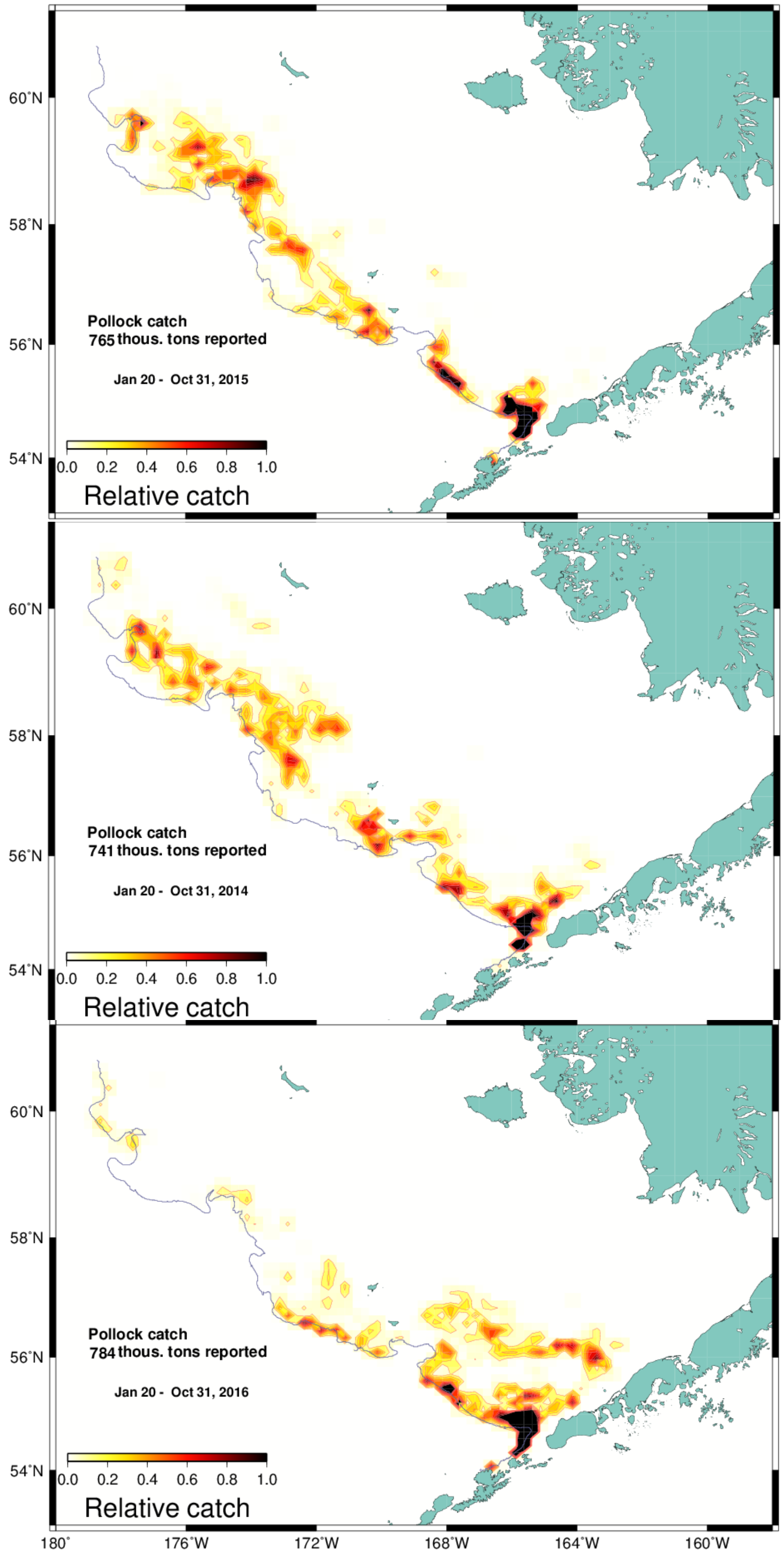


Figure 1.5. Pollock catch distribution during June – October, 2014-2016.

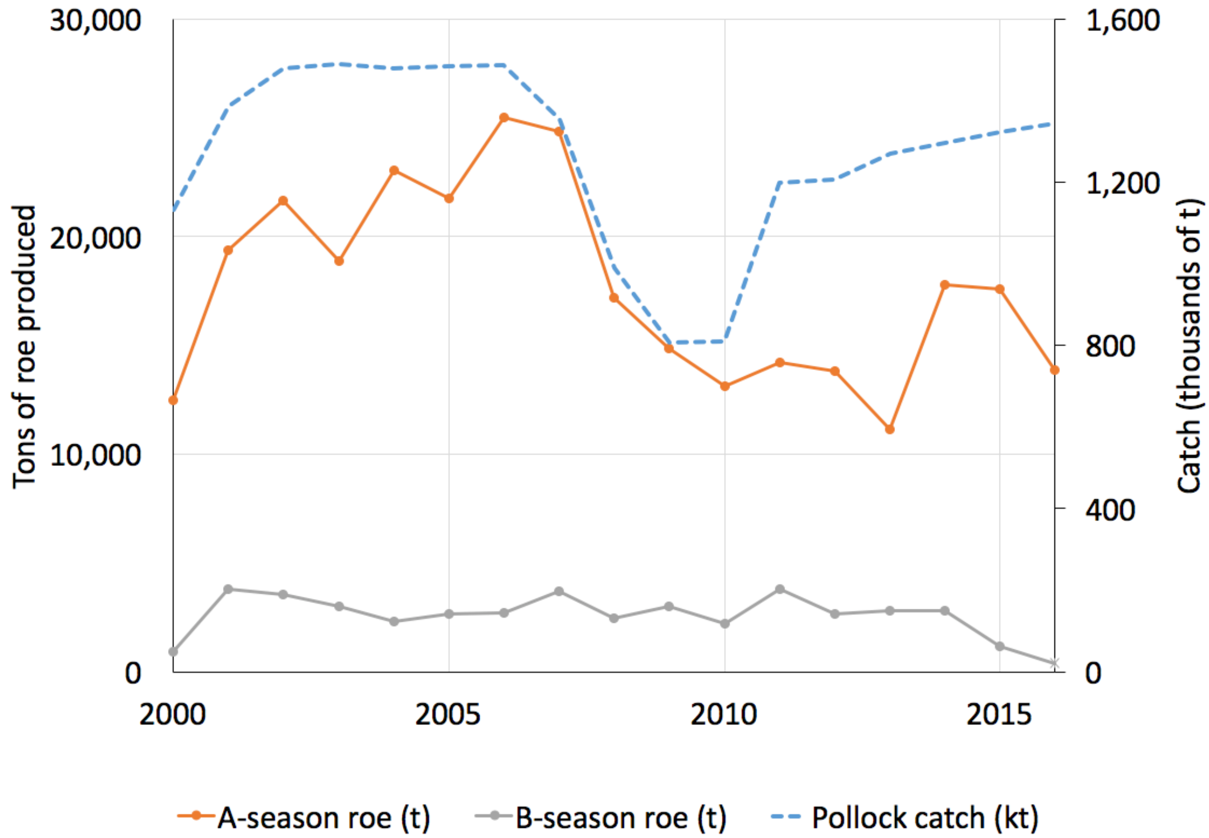


Figure 1.6. EBS pollock roe production in A and B seasons compared to overall landed catch, 2000-2015.

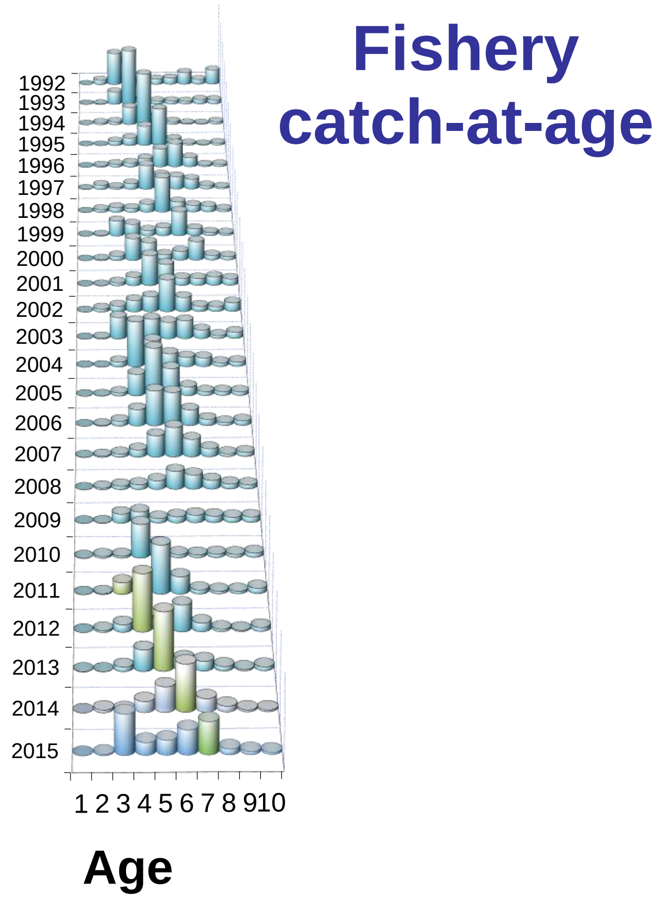


Figure 1.7. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2015. Age 10 represents pollock age 10 and older. The 2008 year-class is shaded in green.

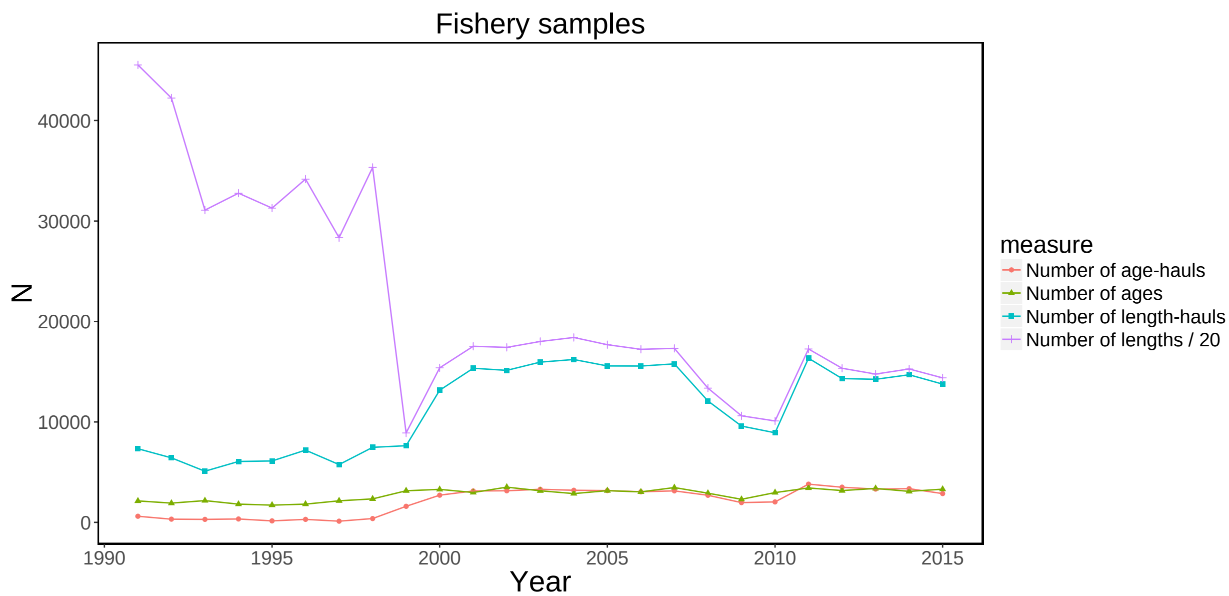


Figure 1.8. EBS pollock observer sampling summarized for number of ages, hauls from which ages were collected, and lengths (total measured and hauls sampled), 1991-2015.

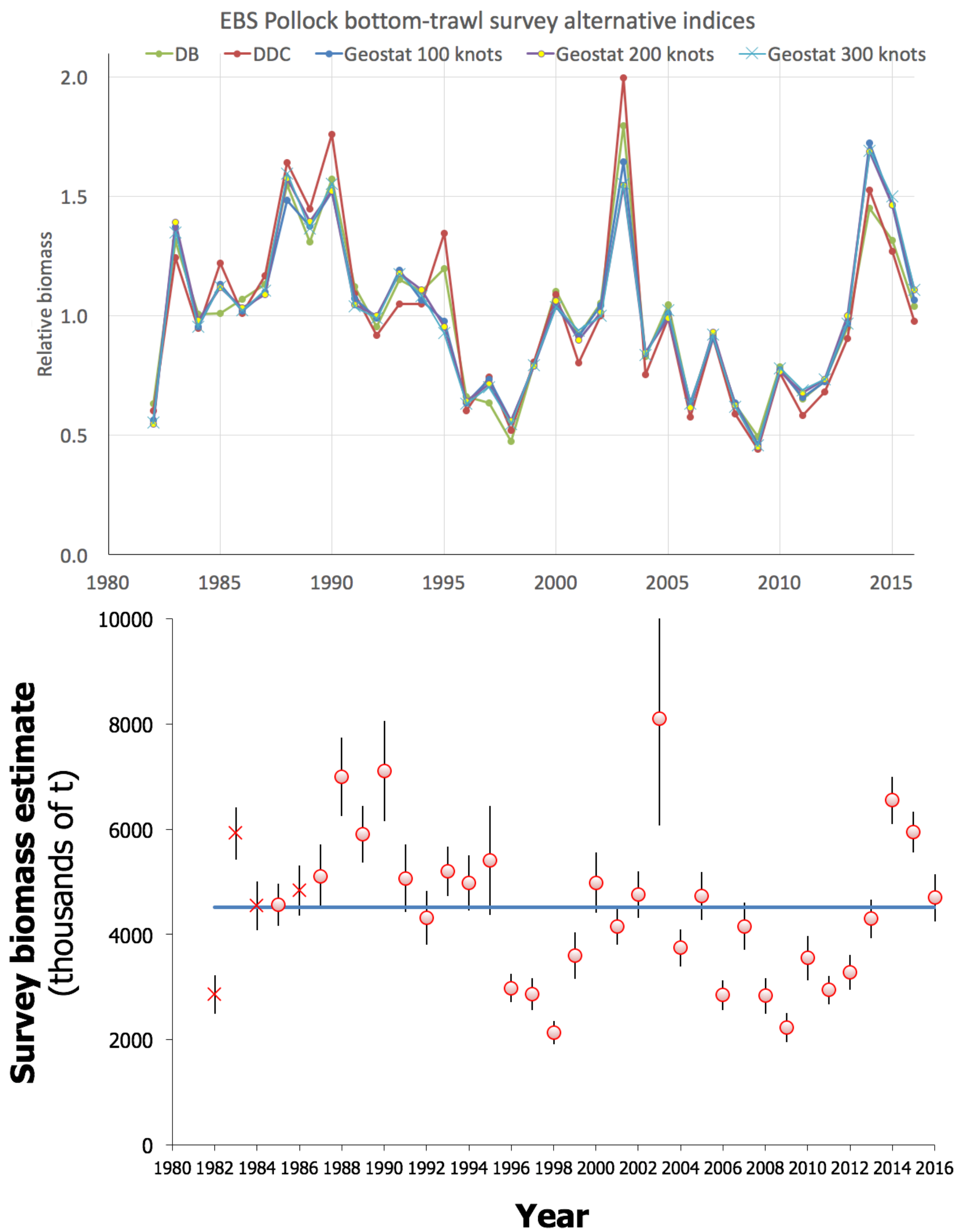


Figure 1.9. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (density-dependent correction method; DDC) for EBS pollock, 1982-2016, bottom panel. These estimates **include** the northern strata except for 1982-84, and 1986. Horizontal line represents the long-term mean. The top panel shows the design-based estimates (DB) together with the density dependence-corrected (DDC) series and three specifications of a random-effects geostatistical approach (Thorson 2016*)

* Based on the tutorial developed by James Thorson at: https://goo.gl/hgMzok as applied to eastern Bering Sea pollock.

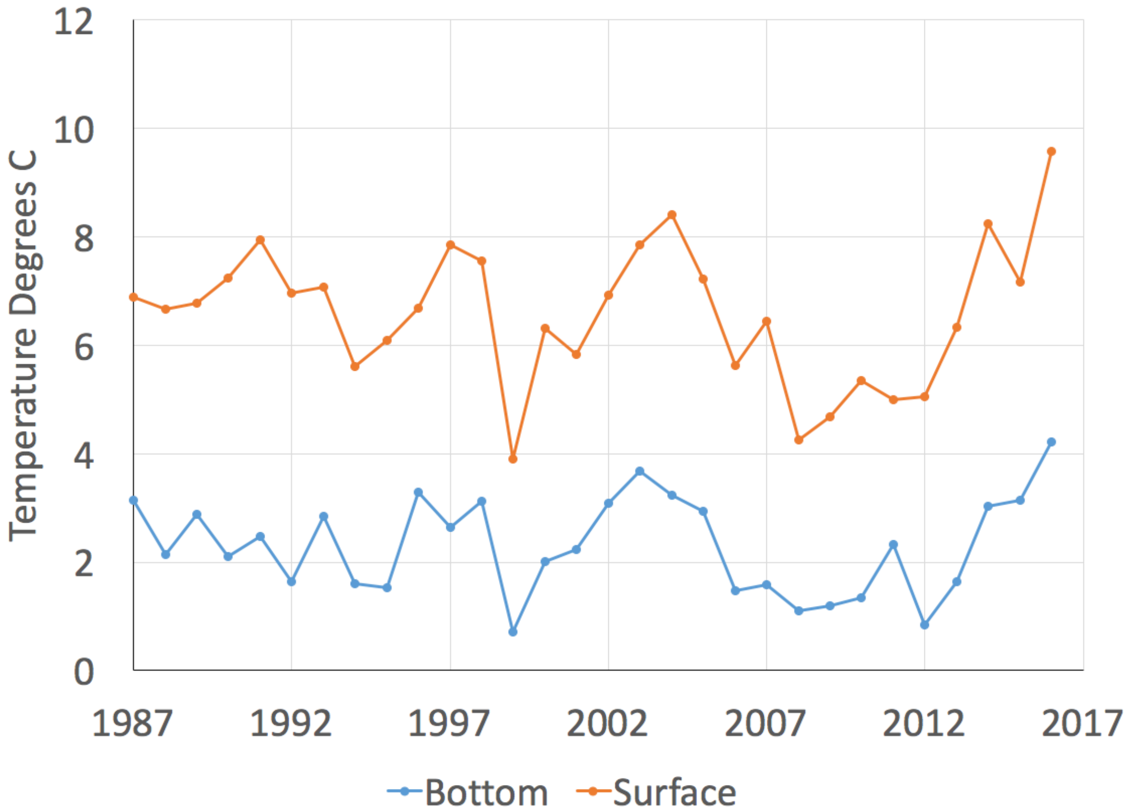


Figure 1.10. Bottom and surface temperatures for the Bering Sea from the NMFS summer bottom-trawl surveys (1987-2016).

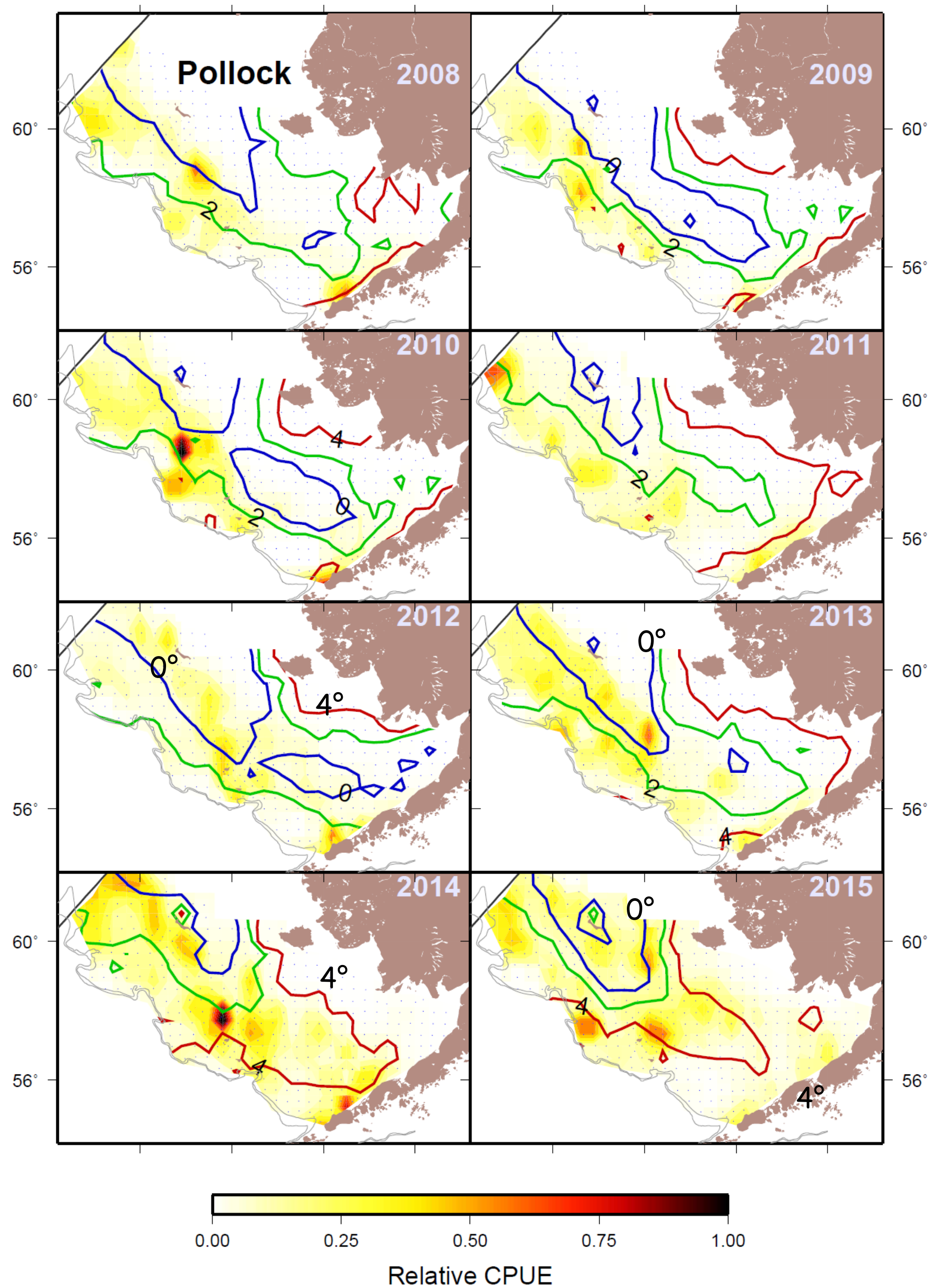


Figure 1.11. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 2007-2016.

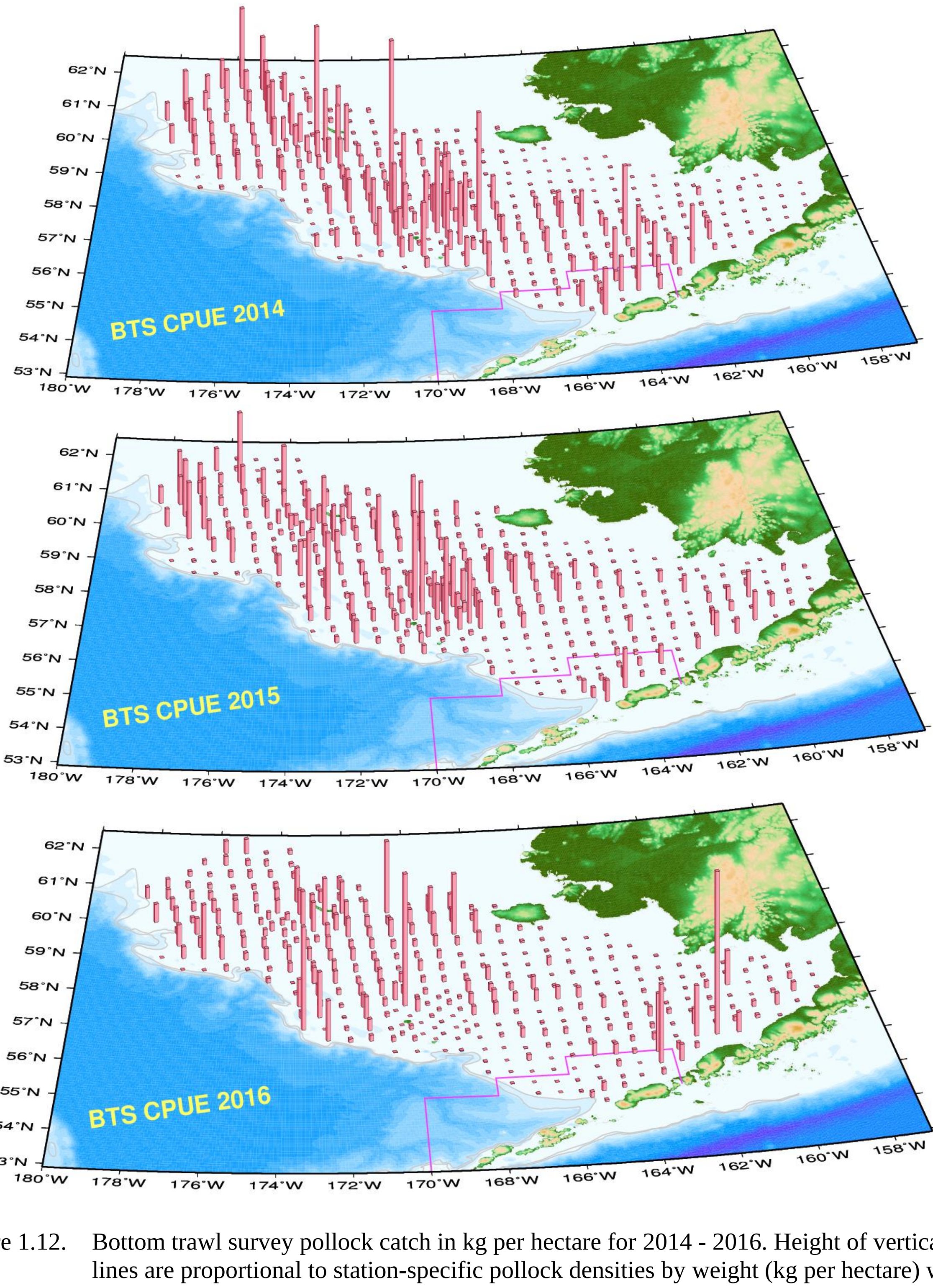


Figure 1.12. Bottom trawl survey pollock catch in kg per hectare for 2014 - 2016. Height of vertical lines are proportional to station-specific pollock densities by weight (kg per hectare) with constant scales for all years.

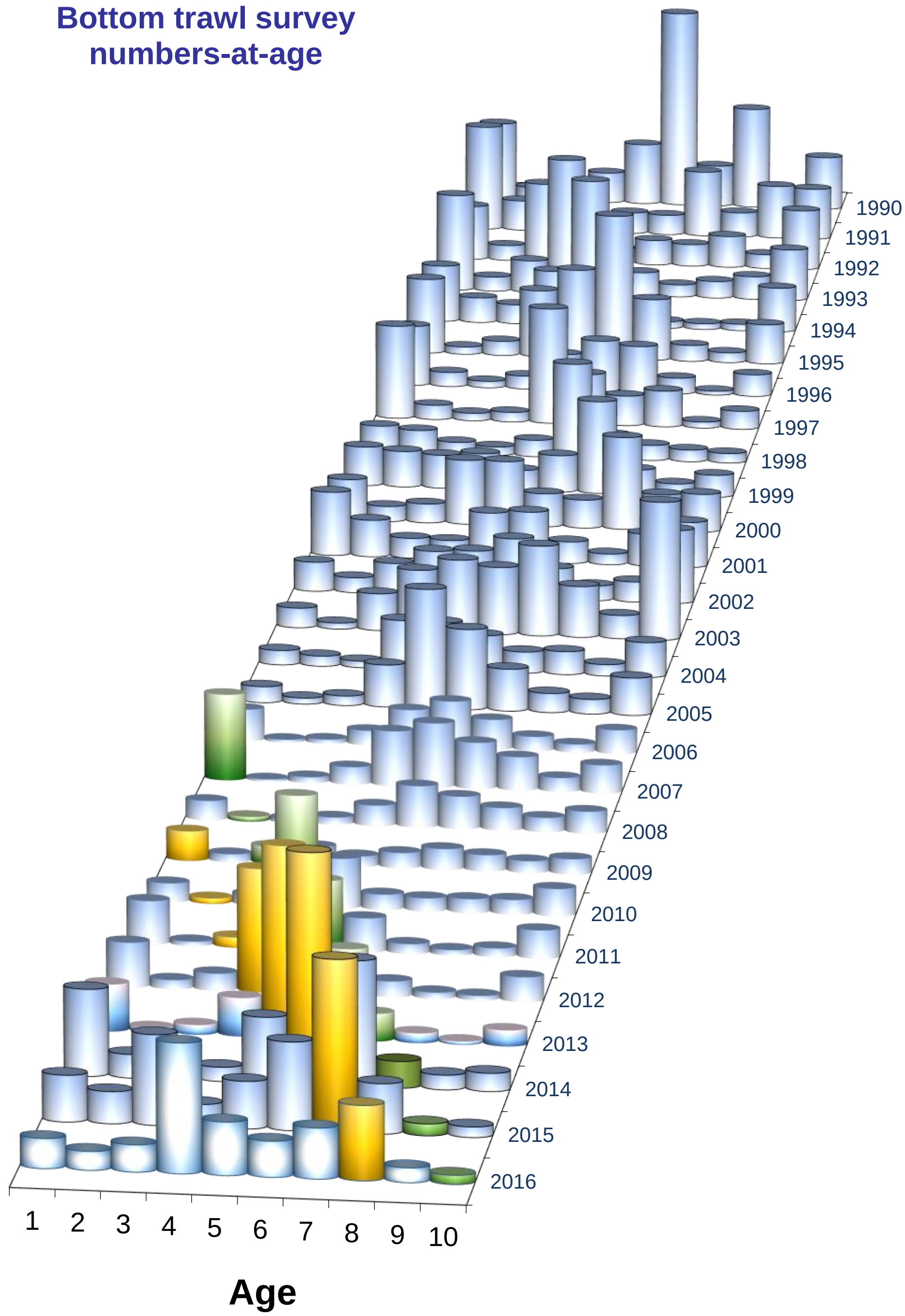


Figure 1.13. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1990-2016). The 2006 and 2008 year-classes are shaded differently.

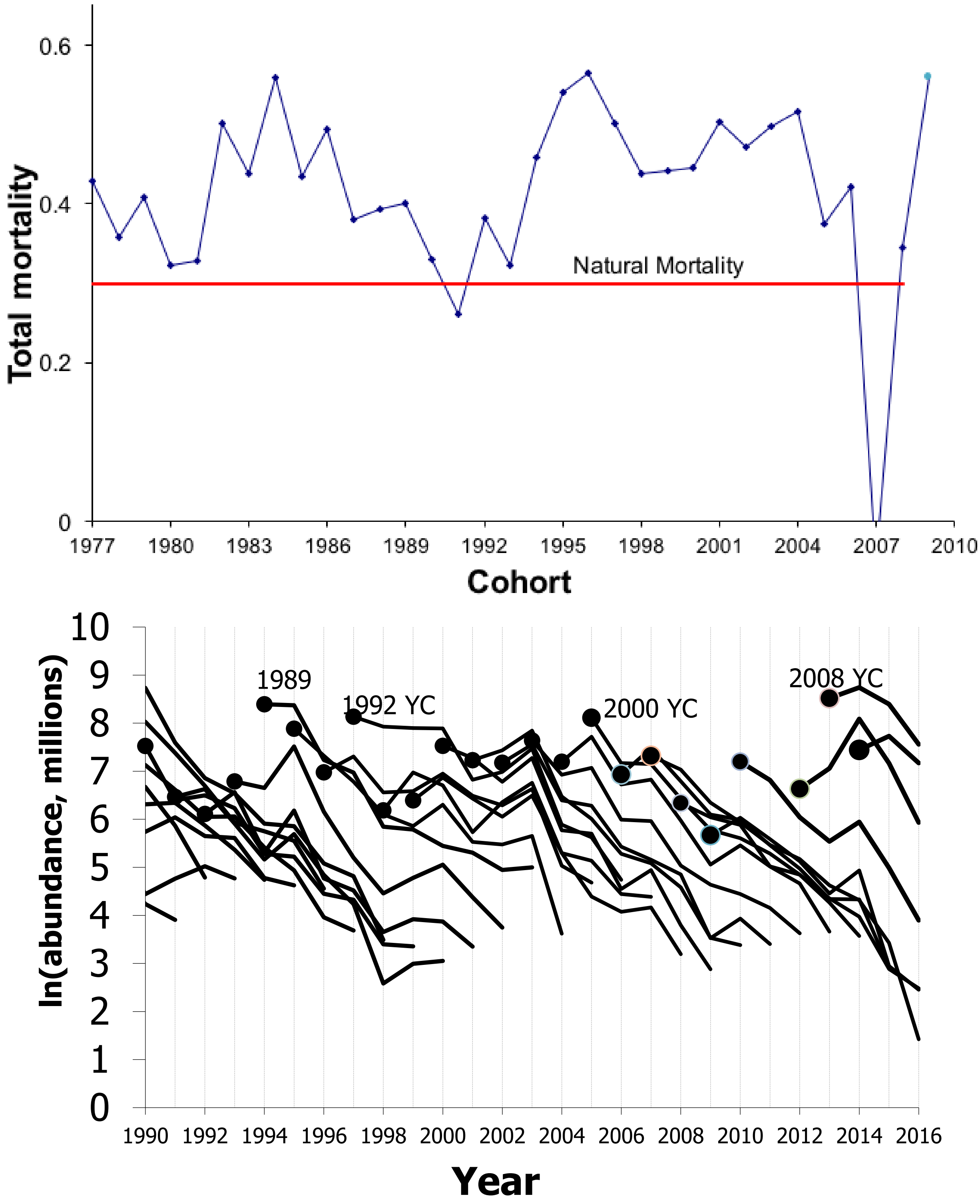


Figure 1.14. Evaluation of EBS pollock cohort abundances as observed for age 5 and older in the NMFS summer bottom trawl surveys, 1982-2016. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort (the 2007 year-class had anomalous increases in abundance from age 5-8).

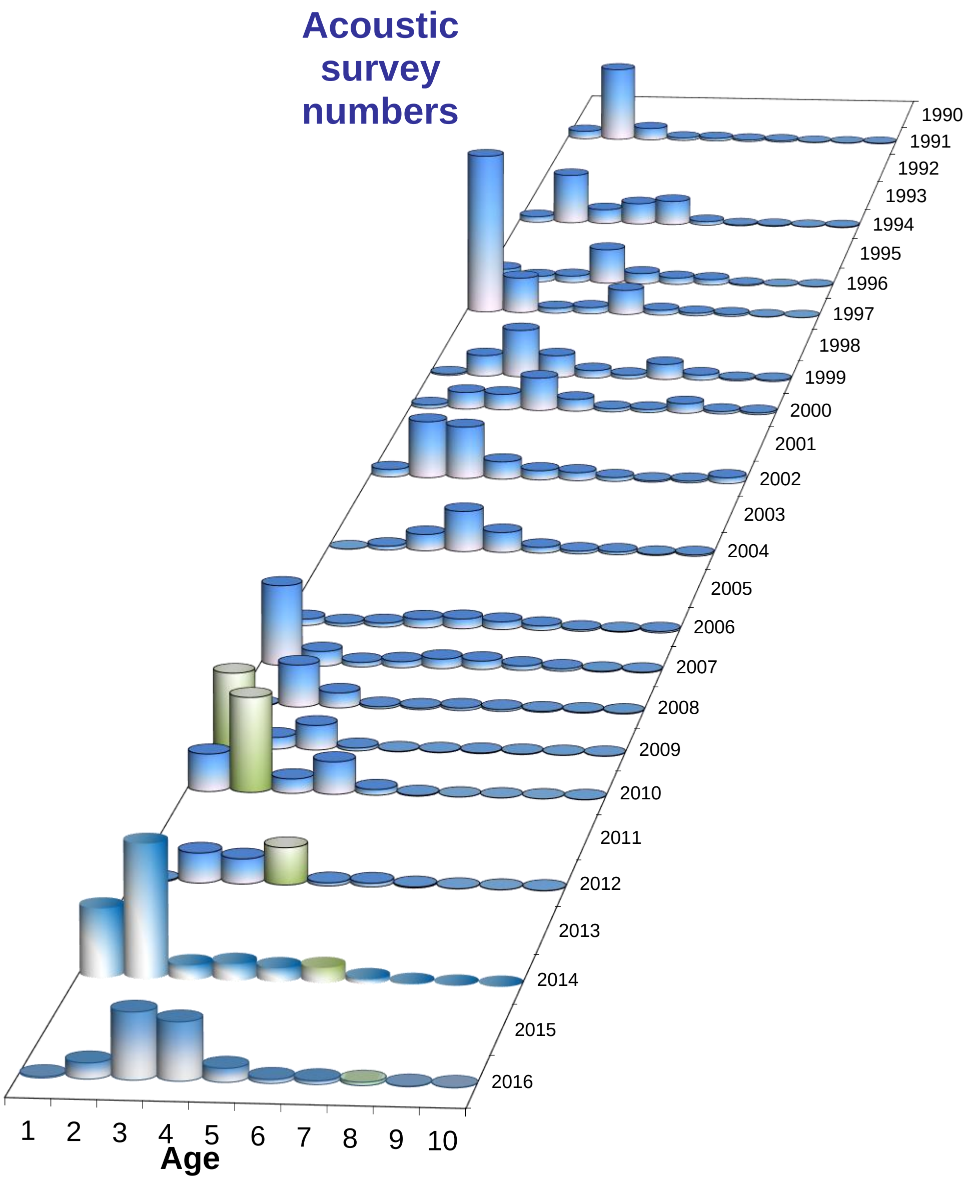


Figure 1.15. Pollock abundance at age estimates from the AT survey, 1991-2016 (note that the 2016 estimates are based on the BTS age length data applied to the ATS length compositions).

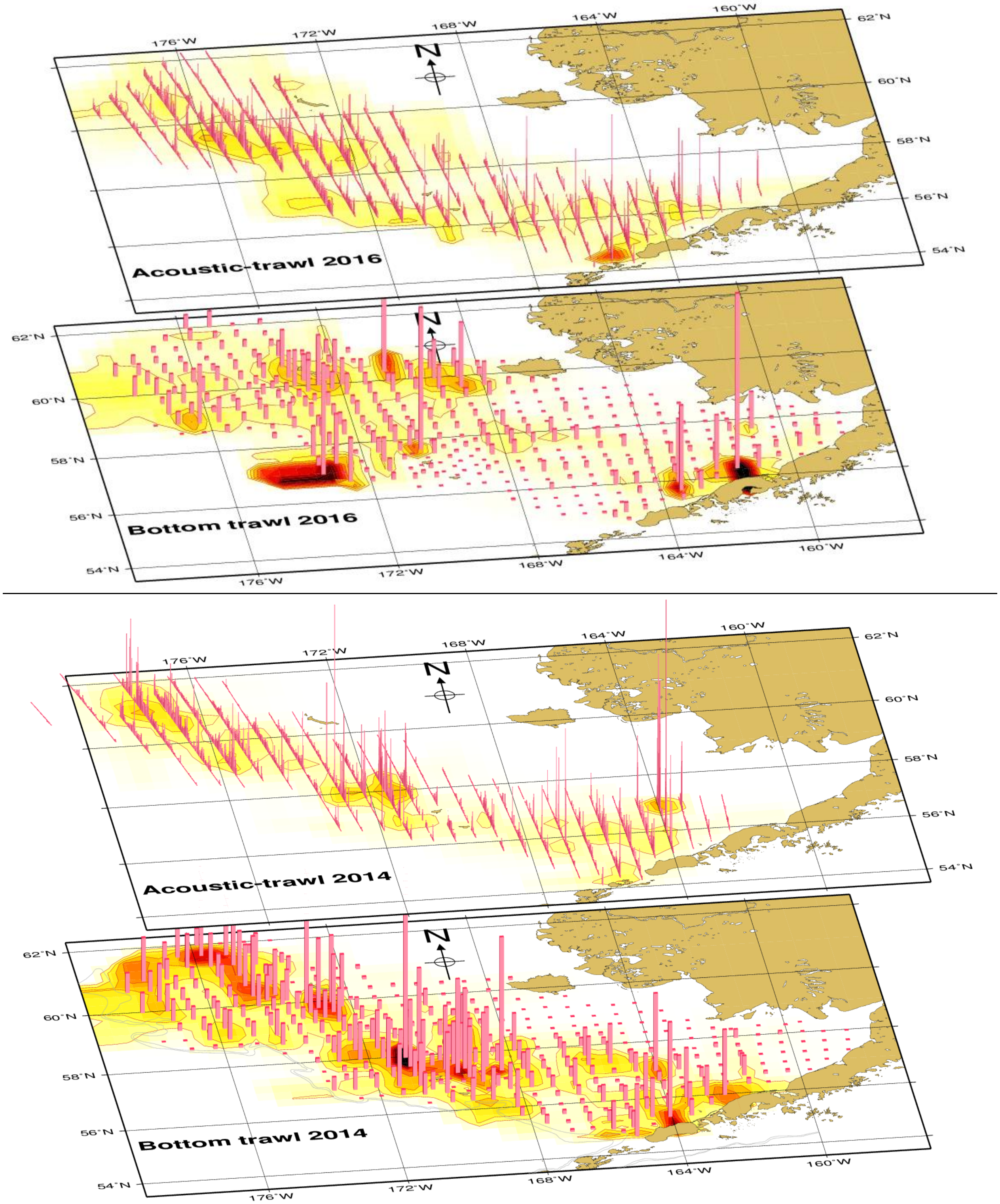


Figure 1.16. EBS pollock acoustic-trawl survey transects (superimposed) over bottom-trawl survey stations and density estimates (in both settings contoured in the yellow-red heat map) comparing 2016 (top) and 2014 (bottom).

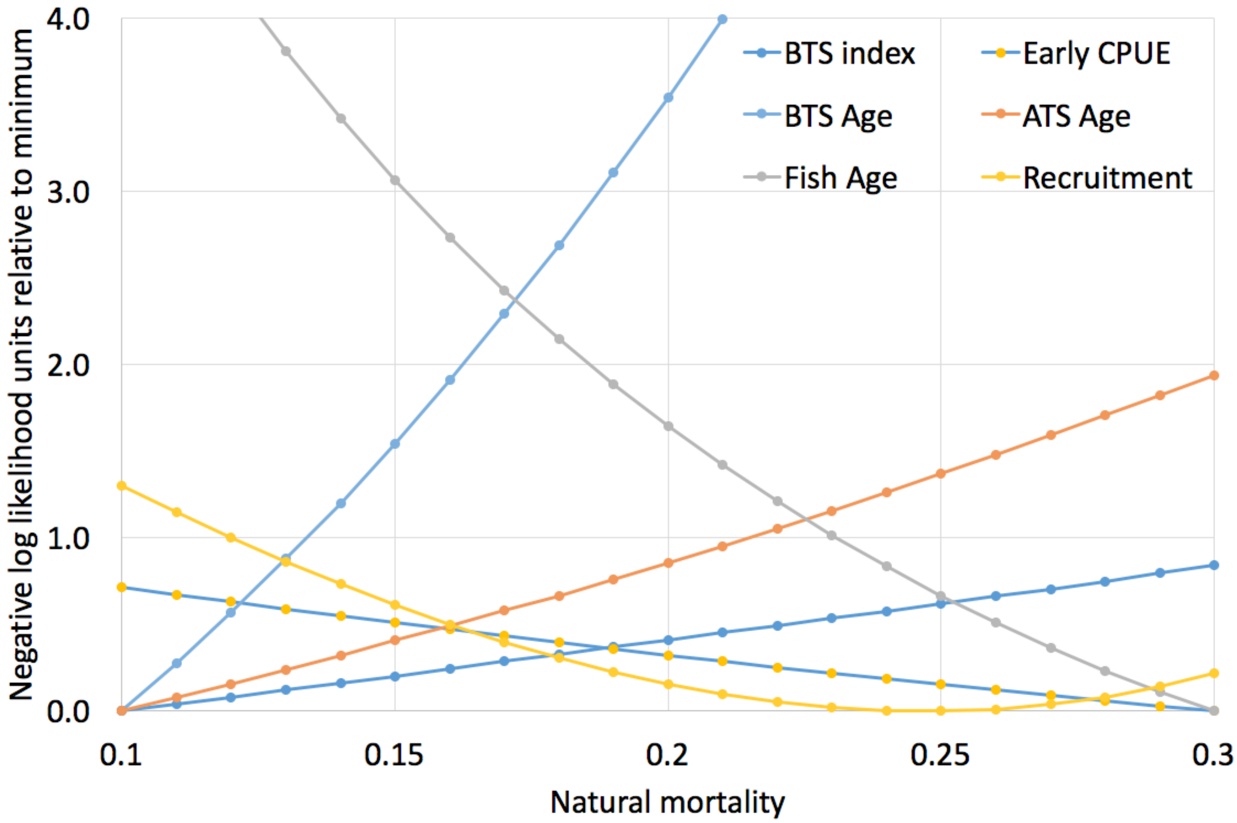


Figure 1.17. EBS pollock profile likelihood over fixed values of age 3+ natural mortality under Model 16.1 showing negative log-likelihood selected components differences relative to the minimum value for the grid of M=0.1 to 0.3. Note that the range was selected based on initial attempts to estimate M within the assessment and that this is for expository purposes only (the fact that the survey age composition favors lower natural mortality is likely due to dynamics affecting availability of pollock in recent years—i.e., movement into the region).

Age

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.29	0.48	0.61	0.73	0.85	0.89	1.01	1.13	1.12	1.24	1.24	1.28	1.24
1992	0.40	0.47	0.65	0.71	0.81	0.98	1.03	1.22	1.23	1.27	1.18	1.35	1.44
1993	0.49	0.61	0.66	0.77	0.93	1.04	1.20	1.23	1.41	1.55	1.65	1.69	1.64
1994	0.39	0.65	0.73	0.75	0.71	1.01	1.39	1.32	1.34	1.42	1.37	1.31	1.39
1995	0.38	0.50	0.73	0.84	0.86	0.97	1.22	1.34	1.41	1.50	1.39	1.21	1.36
1996	0.32	0.43	0.68	0.79	0.95	0.95	1.02	1.09	1.40	1.50	1.54	1.75	1.54
1997	0.32	0.47	0.55	0.74	0.89	1.07	1.09	1.24	1.41	1.47	1.72	1.46	1.42
1998	0.37	0.59	0.63	0.62	0.78	1.03	1.18	1.24	1.29	1.42	1.56	1.56	1.72
1999	0.40	0.50	0.64	0.70	0.73	0.90	1.04	1.27	1.21	1.42	1.16	1.14	1.32
2000	0.35	0.52	0.63	0.73	0.78	0.80	0.97	1.02	1.27	1.32	1.32	1.67	1.74
2001	0.32	0.50	0.67	0.79	0.96	1.00	1.06	1.14	1.33	1.45	1.58	1.47	1.66
2002	0.38	0.51	0.67	0.80	0.91	1.02	1.12	1.10	1.30	1.43	1.61	1.32	1.64
2003	0.48	0.55	0.65	0.77	0.86	0.95	1.09	1.22	1.21	1.23	1.45	1.34	1.72
2004	0.40	0.58	0.64	0.77	0.89	0.93	1.03	1.21	1.16	1.18	1.35	1.29	1.23
2005	0.35	0.51	0.64	0.74	0.88	0.95	1.06	1.09	1.27	1.31	1.31	1.16	1.42
2006	0.30	0.45	0.60	0.75	0.85	0.96	1.06	1.13	1.22	1.28	1.31	1.40	1.45
2007	0.34	0.51	0.64	0.78	0.96	1.10	1.20	1.28	1.33	1.52	1.42	1.77	1.53
2008	0.33	0.52	0.65	0.77	0.90	1.04	1.11	1.20	1.31	1.40	1.51	1.60	1.51
2009	0.35	0.55	0.69	0.89	1.02	1.15	1.41	1.49	1.64	1.64	1.82	2.18	2.29
2010	0.38	0.49	0.67	0.92	1.11	1.26	1.34	1.59	1.61	1.84	1.94	2.05	2.20
2011	0.29	0.51	0.67	0.81	0.97	1.22	1.34	1.51	1.58	1.61	2.11	1.73	2.26
2012	0.27	0.41	0.64	0.82	0.97	1.17	1.31	1.52	1.61	1.65	1.72	2.02	2.10
2013	0.29	0.44	0.57	0.78	1.12	1.27	1.43	1.70	1.85	1.82	1.94	2.12	2.07
2014	0.35	0.50	0.64	0.76	0.89	1.03	1.14	1.25	1.34	1.44	1.50	1.49	1.55
2015	0.32	0.49	0.64	0.80	0.97	1.12	1.24	1.38	1.48	1.55	1.66	1.75	1.84

1982	0.27	0.44	0.57	0.84	1.18	1.27	1.31	1.35	1.38	1.43	1.43	1.45	1.44
1983	0.28	0.46	0.63	0.73	0.98	1.29	1.36	1.38	1.40	1.42	1.46	1.45	1.46
1984	0.31	0.47	0.64	0.79	0.87	1.09	1.38	1.43	1.43	1.44	1.44	1.48	1.46
1985	0.31	0.48	0.64	0.80	0.92	0.97	1.18	1.44	1.47	1.47	1.47	1.46	1.50
1986	0.27	0.42	0.60	0.74	0.88	0.99	1.03	1.22	1.47	1.50	1.48	1.48	1.47
1987	0.31	0.42	0.57	0.73	0.86	0.97	1.06	1.08	1.26	1.50	1.52	1.50	1.49
1988	0.34	0.45	0.57	0.70	0.84	0.95	1.04	1.11	1.12	1.29	1.52	1.53	1.51
1989	0.29	0.46	0.58	0.68	0.80	0.92	1.01	1.09	1.15	1.15	1.31	1.54	1.55
1990	0.27	0.46	0.63	0.73	0.81	0.90	1.00	1.07	1.13	1.18	1.17	1.33	1.55
1991	0.26	0.44	0.62	0.78	0.86	0.91	0.98	1.06	1.11	1.17	1.21	1.19	1.34
1992	0.39	0.45	0.62	0.79	0.92	0.97	1.00	1.05	1.11	1.15	1.20	1.23	1.21
1993	0.41	0.59	0.65	0.81	0.94	1.05	1.07	1.07	1.10	1.15	1.18	1.22	1.25
1994	0.35	0.56	0.75	0.79	0.92	1.04	1.12	1.12	1.11	1.13	1.17	1.20	1.23
1995	0.21	0.45	0.66	0.84	0.87	0.98	1.09	1.15	1.15	1.13	1.15	1.18	1.21
1996	0.23	0.35	0.59	0.79	0.95	0.96	1.05	1.14	1.19	1.18	1.15	1.17	1.20
1997	0.33	0.43	0.56	0.78	0.95	1.07	1.05	1.13	1.19	1.24	1.21	1.18	1.18
1998	0.27	0.42	0.52	0.64	0.84	1.00	1.11	1.08	1.15	1.21	1.25	1.22	1.18
1999	0.34	0.45	0.61	0.69	0.78	0.96	1.09	1.18	1.14	1.19	1.24	1.27	1.24
2000	0.30	0.49	0.61	0.74	0.80	0.87	1.03	1.14	1.22	1.17	1.21	1.26	1.28
2001	0.26	0.45	0.64	0.74	0.86	0.89	0.94	1.08	1.18	1.25	1.19	1.23	1.27
2002	0.37	0.48	0.67	0.84	0.91	0.99	1.00	1.02	1.14	1.23	1.28	1.21	1.25
2003	0.41	0.53	0.64	0.82	0.96	1.01	1.07	1.05	1.07	1.18	1.25	1.30	1.23
2004	0.39	0.56	0.69	0.78	0.94	1.06	1.08	1.12	1.10	1.10	1.20	1.27	1.31
2005	0.33	0.49	0.66	0.78	0.86	1.00	1.11	1.12	1.15	1.12	1.11	1.21	1.28
2006	0.29	0.45	0.61	0.77	0.87	0.93	1.06	1.15	1.15	1.18	1.14	1.13	1.22
2007	0.38	0.52	0.68	0.82	0.94	1.01	1.04	1.14	1.21	1.20	1.21	1.16	1.14
2008	0.29	0.53	0.67	0.81	0.93	1.04	1.08	1.10	1.18	1.24	1.22	1.23	1.17
2009	0.31	0.51	0.75	0.87	0.98	1.06	1.14	1.16	1.16	1.23	1.28	1.25	1.25
2010	0.35	0.50	0.71	0.92	1.02	1.10	1.16	1.21	1.21	1.20	1.25	1.30	1.26
2011	0.28	0.53	0.67	0.86	1.05	1.12	1.18	1.22	1.26	1.25	1.22	1.27	1.31
2012	0.30	0.42	0.67	0.80	0.97	1.14	1.19	1.23	1.26	1.29	1.27	1.24	1.29
2013	0.29	0.46	0.58	0.82	0.92	1.07	1.22	1.25	1.27	1.29	1.31	1.29	1.25
2014	0.29	0.46	0.64	0.74	0.95	1.03	1.15	1.28	1.29	1.31	1.32	1.33	1.30
2015	0.36	0.48	0.66	0.81	0.89	1.06	1.12	1.22	1.33	1.33	1.34	1.34	1.35
2016	*0.34*	*0.52*	*0.64*	*0.80*	*0.93*	*0.99*	*1.14*	*1.18*	*1.26*	*1.36*	*1.36*	*1.36*	*1.35*
2017	*0.21*	*0.53*	*0.71*	*0.81*	*0.95*	*1.05*	*1.07*	*1.21*	*1.23*	*1.30*	*1.39*	*1.38*	*1.37*
2018	*0.21*	*0.39*	*0.72*	*0.88*	*0.95*	*1.06*	*1.14*	*1.14*	*1.26*	*1.27*	*1.33*	*1.41*	*1.39*
2016	*2%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*0%*	*0%*	*1%*	*1%*	*1%*	*1%*
2017	*14%*	*14%*	*11%*	*8%*	*6%*	*4%*	*3%*	*2%*	*2%*	*1%*	*1%*	*1%*	*1%*
2018	*14%*	*20%*	*15%*	*11%*	*9%*	*7%*	*5%*	*4%*	*3%*	*2%*	*2%*	*1%*	*1%*

Figure 1.18. Schematic of EBS pollock fishery data (top) and model fits to estimate mean body weights-at-age (kg; bottom). Ages are in columns, years are in rows. Residuals expressed as (observed-predicted)/observed. Note that the data remain in the model and are used for computing fishery catch biomass, but model predictions for 2016-2018 (and their associated uncertainty shown in last three rows of lower-right table) are used for Tier 1 model projections and ABC/OFL estimates for models using these estimates.

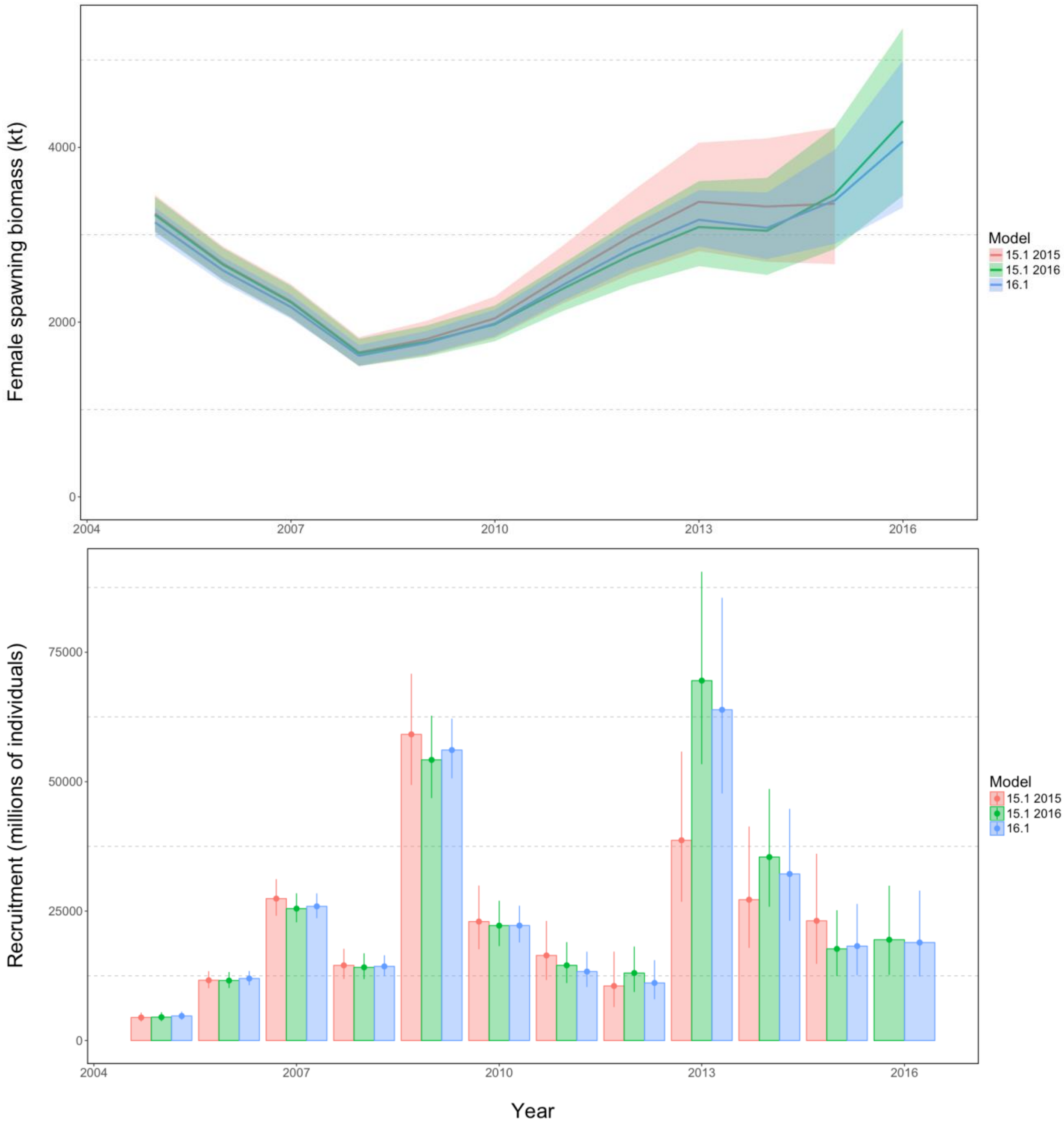
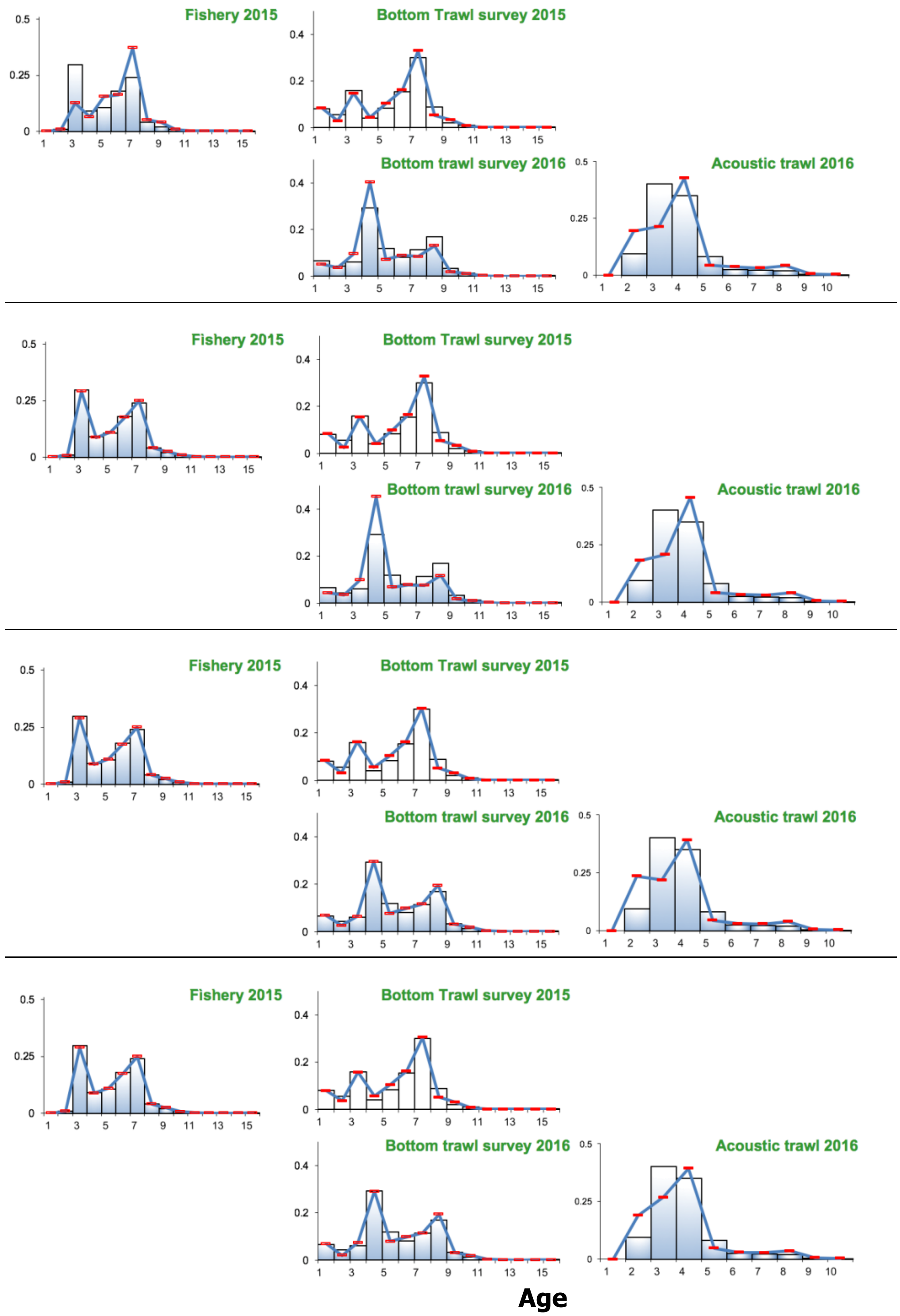


Figure 1.19. EBS pollock results of model evaluations comparing last year's model and results with the same model using updated data and the proposed new model for 2016 (Model 16.1). Female spawning biomass is shown on top panel and recent recruitment at age one in lower panel.



Catch biomass only updated (no new age data in fitting)

Catch and fishery age data updated

Catch and fishery age data updated and bottom trawl survey data updated

Catch and fishery age, bottom trawl survey data, and acoustic-trawl data all included

Figure 1.20. Model 16.1 fits to new EBS pollock age composition data. Captions on right depict data fitted for each row (new data in shaded bars).

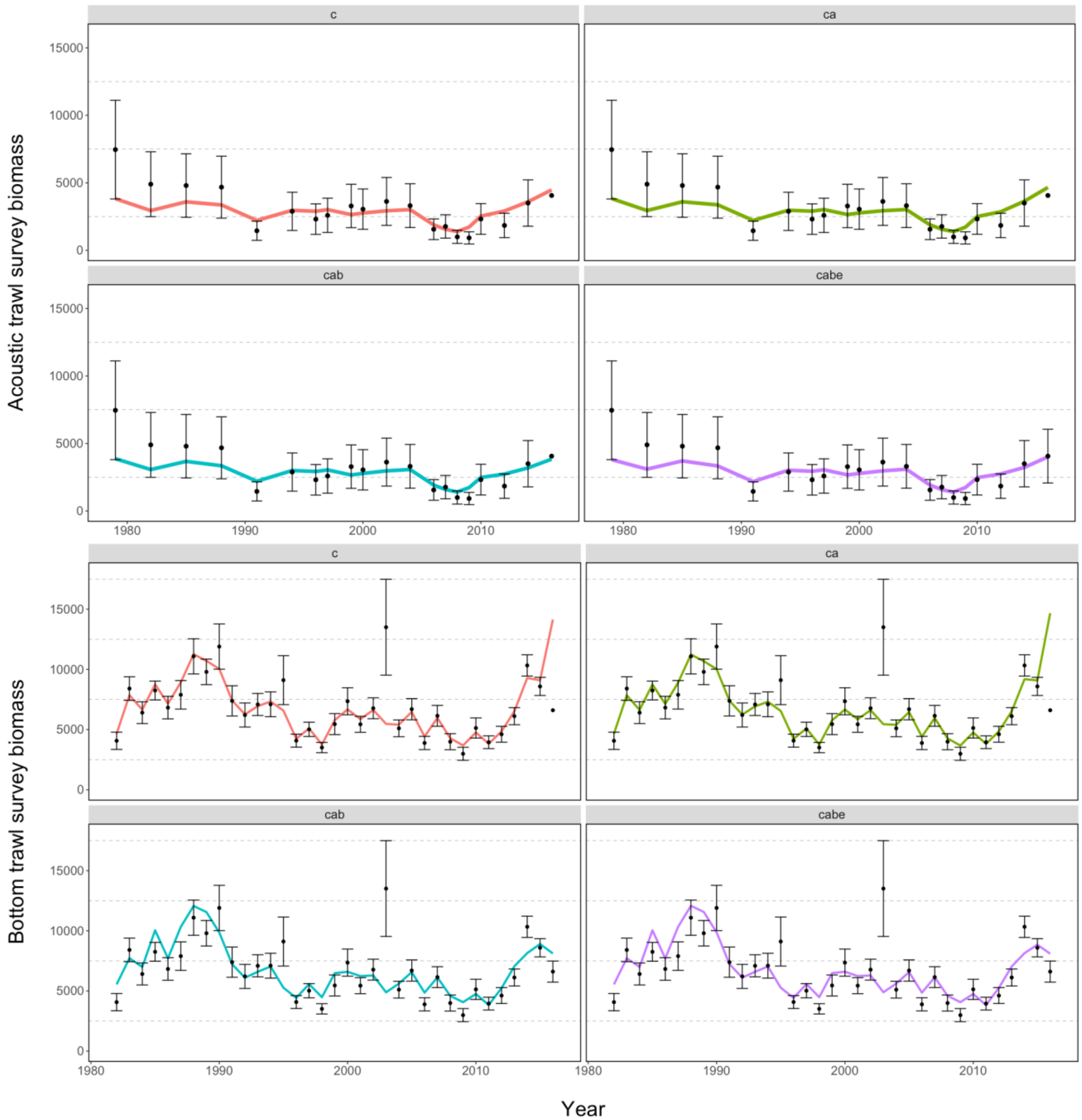


Figure 1.21. EBS pollock Model 16.1 fits to AT biomass estimates (top) and BTS estimates (bottom). The four panels for each survey are for incremental additions of data to the current assessment (C=fishery catch only, CA adds in fishery catch-age data, CAB adds in BTS data, and CABE represents addition of echo integration AT data). Note that dots without error bars means that data point was excluded from estimation.

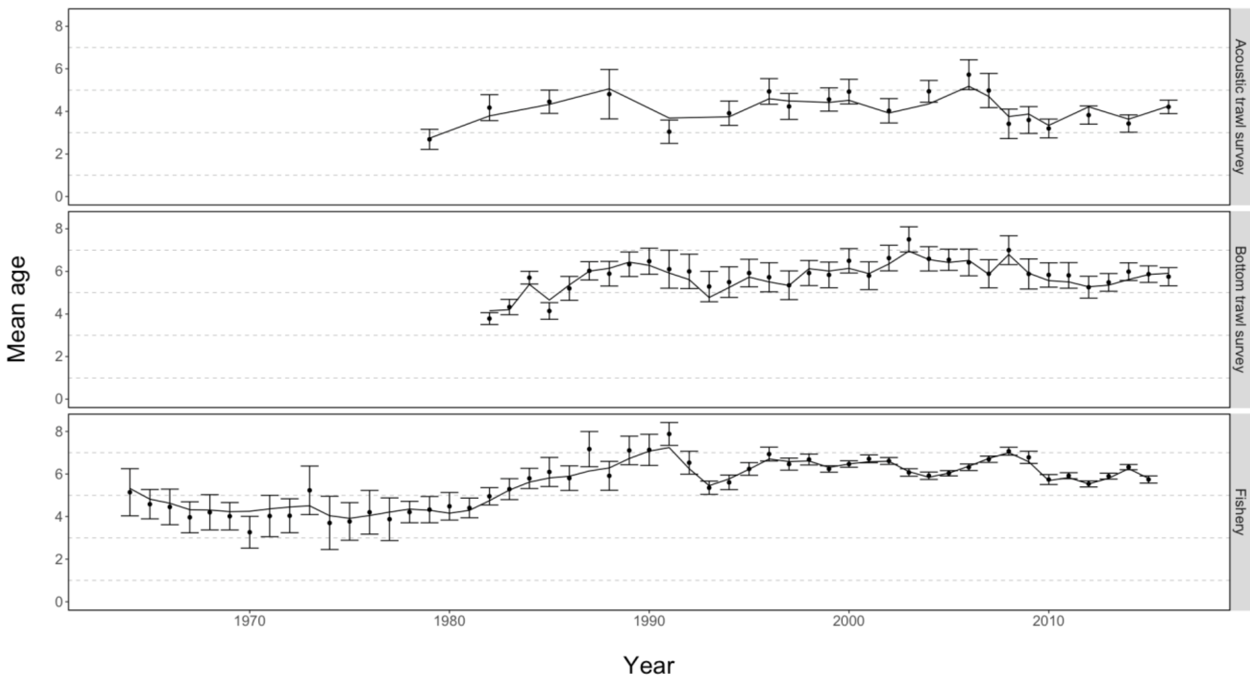


Figure 1.22. Model 16.1 fits to observed mean age for the fishery (bottom) bottom trawl survey (middle) and the Acoustic trawl survey (top) for EBS pollock.

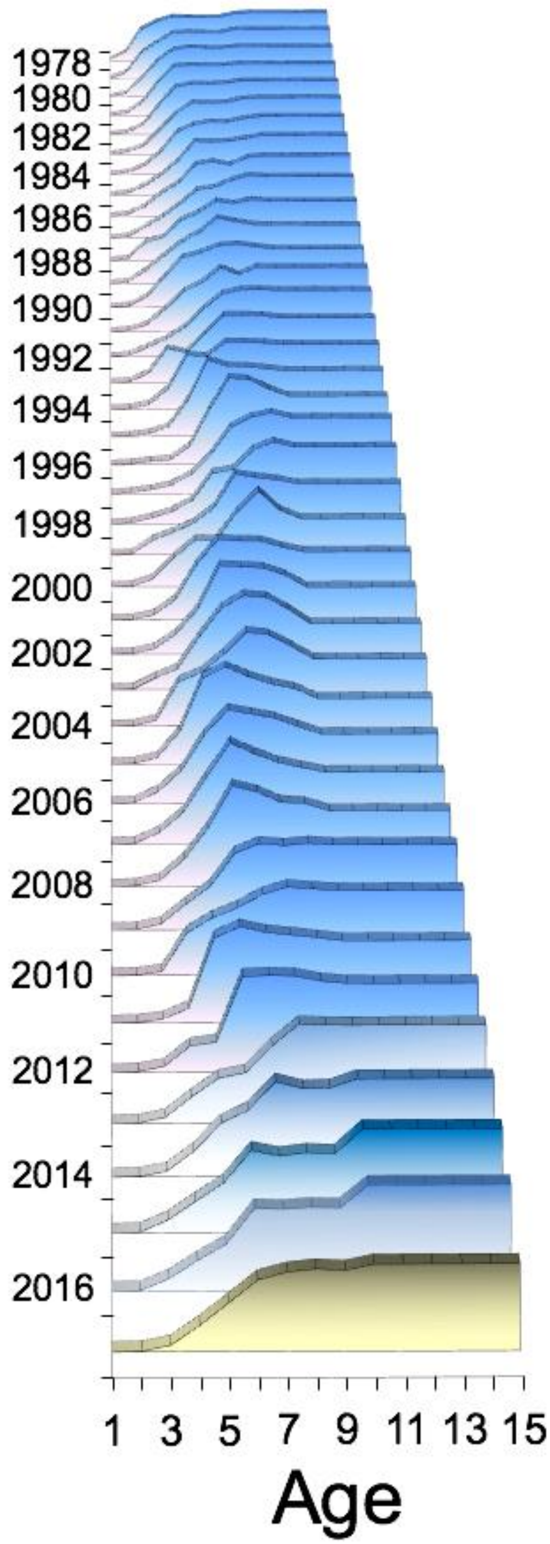


Figure 1.23. Selectivity at age estimates for the EBS pollock fishery, 1978-2016 including the estimates (front-most panel) used for the future yield considerations.

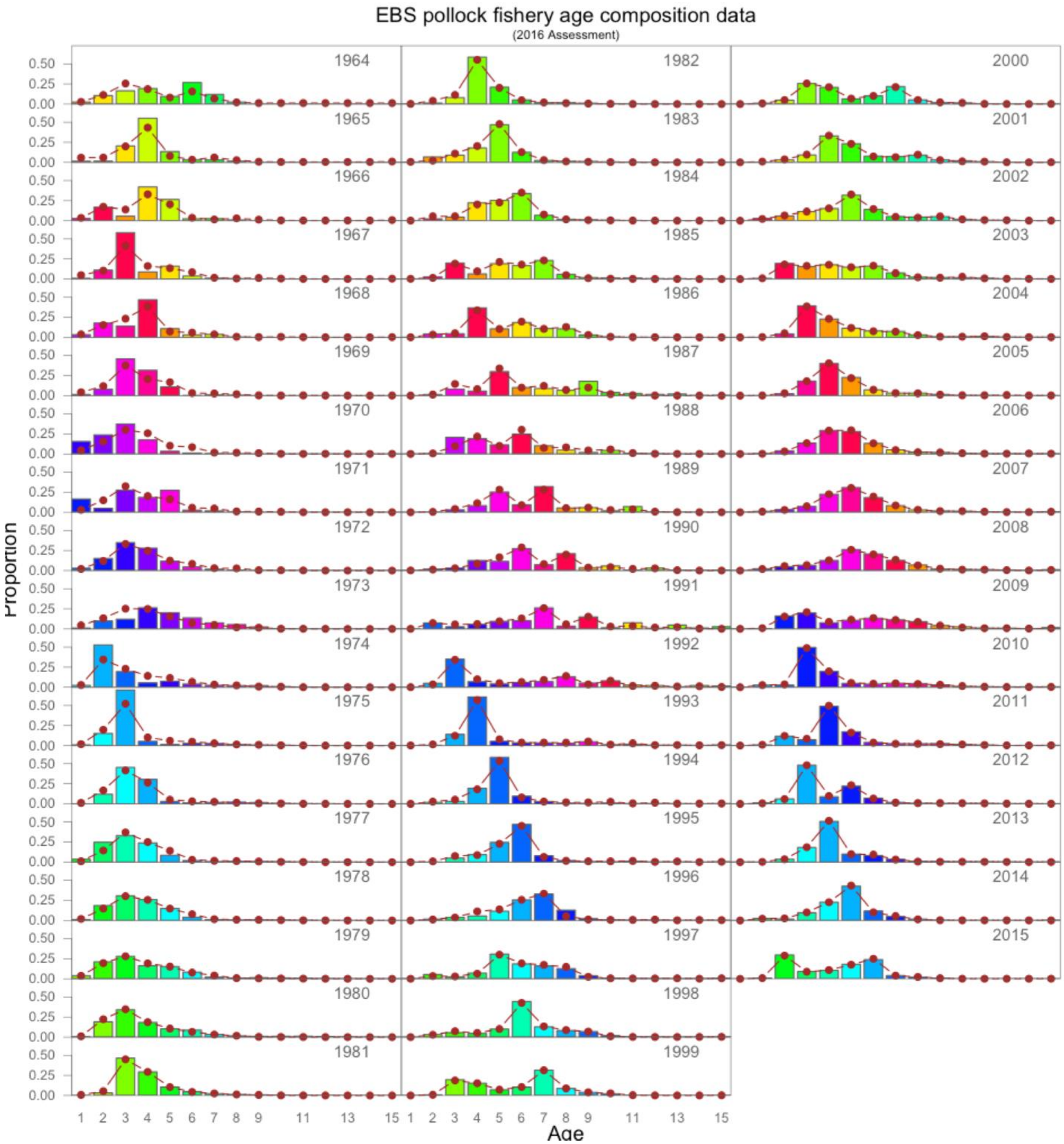


Figure 1.24. Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2015). The 2015 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

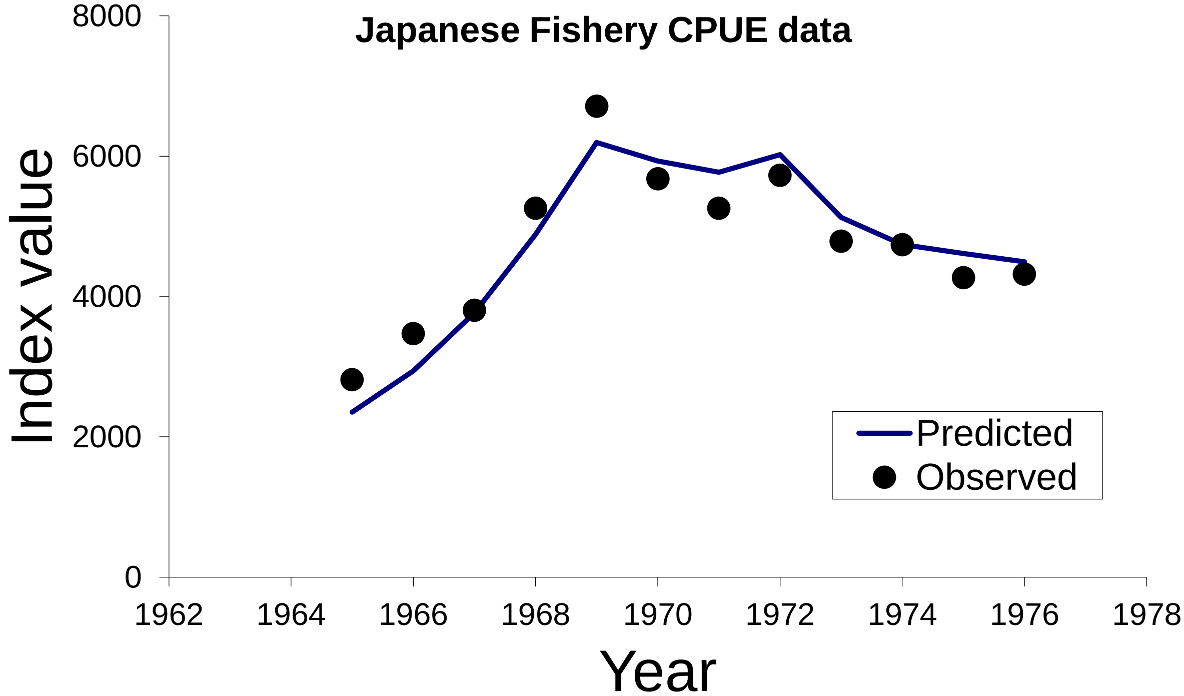


Figure 1.25. Japanese fishery CPUE (Low and Ikeda, 1980) model fits for EBS pollock, 1965-1976.

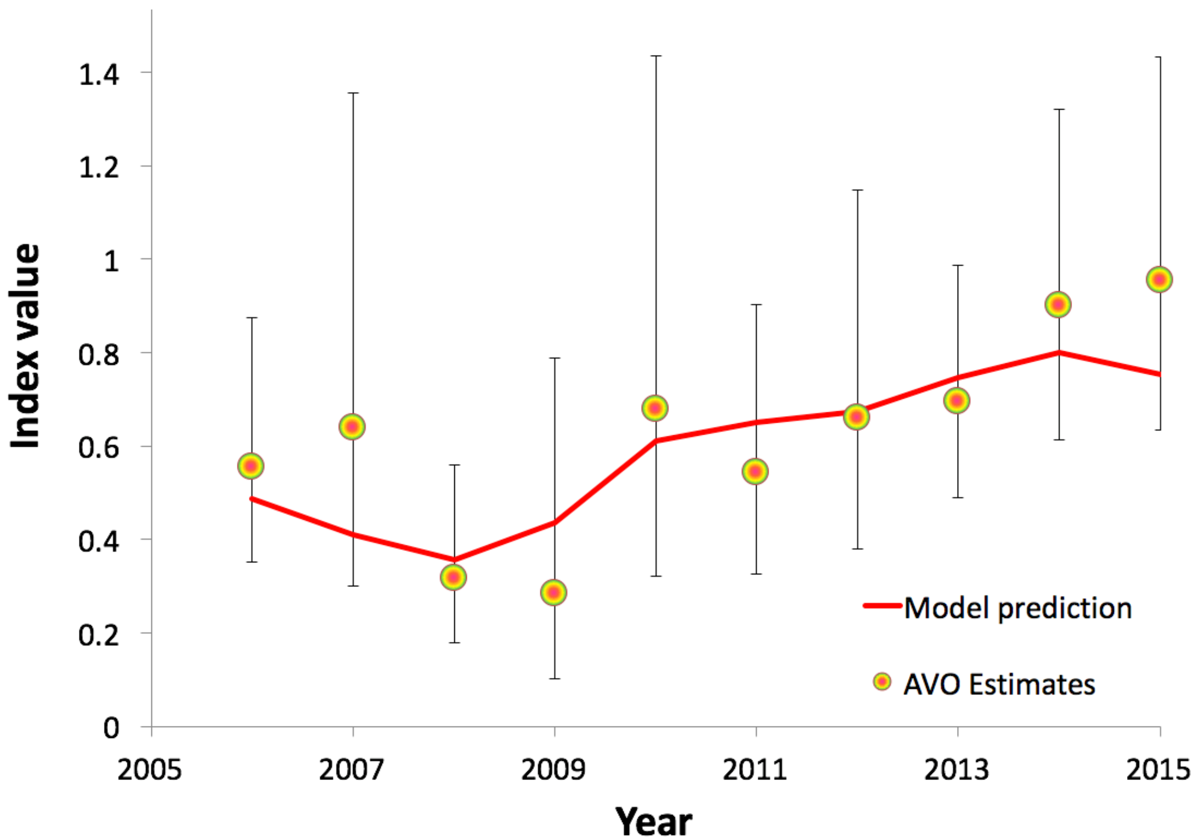


Figure 1.26. Model results of predicted EBS pollock biomass following the AVO index (under model 1.0). Error bars represent assumed 95% confidence bounds.

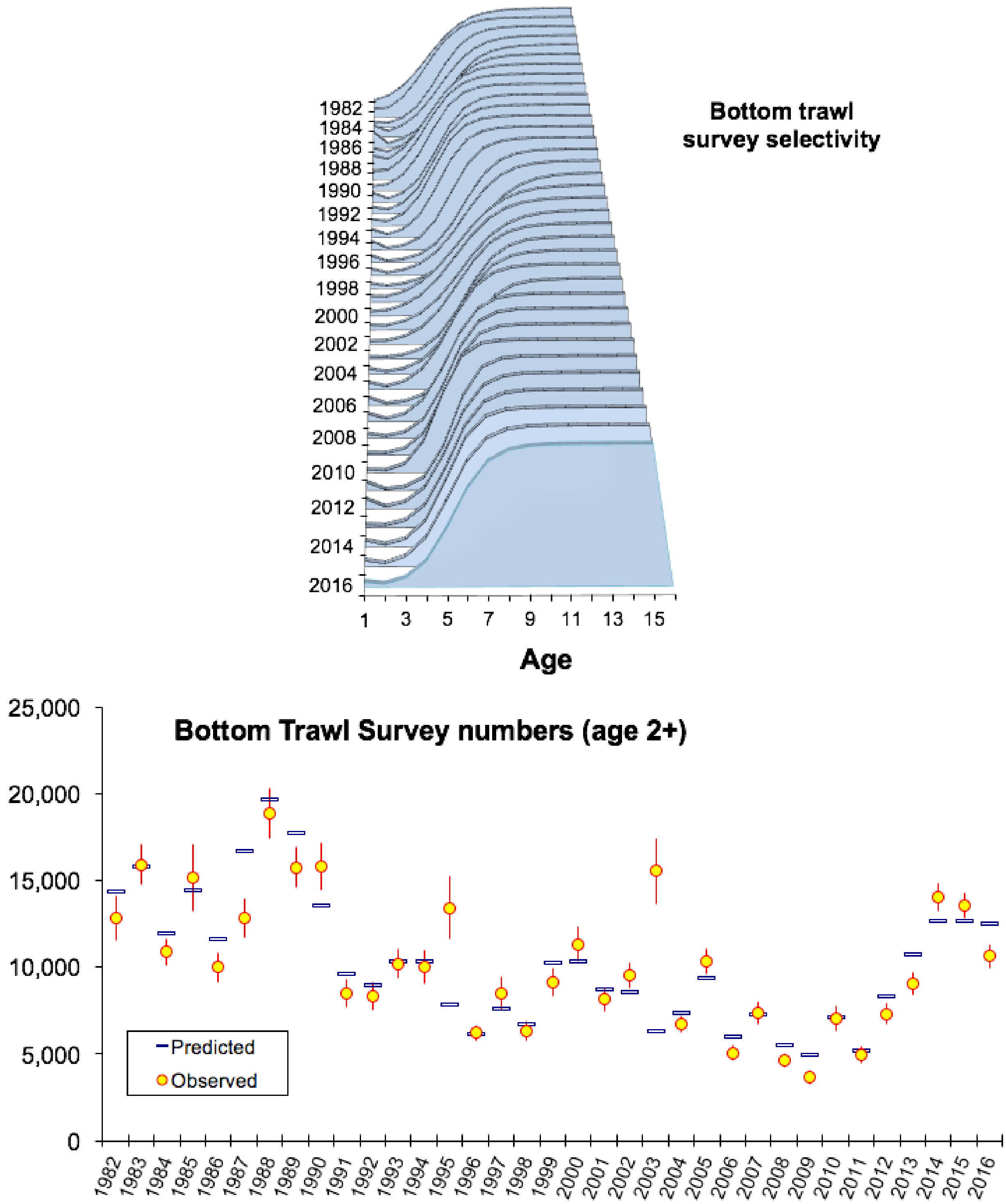


Figure 1.27. Estimates of bottom-trawl survey numbers (millions age 2 and older, lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2016.

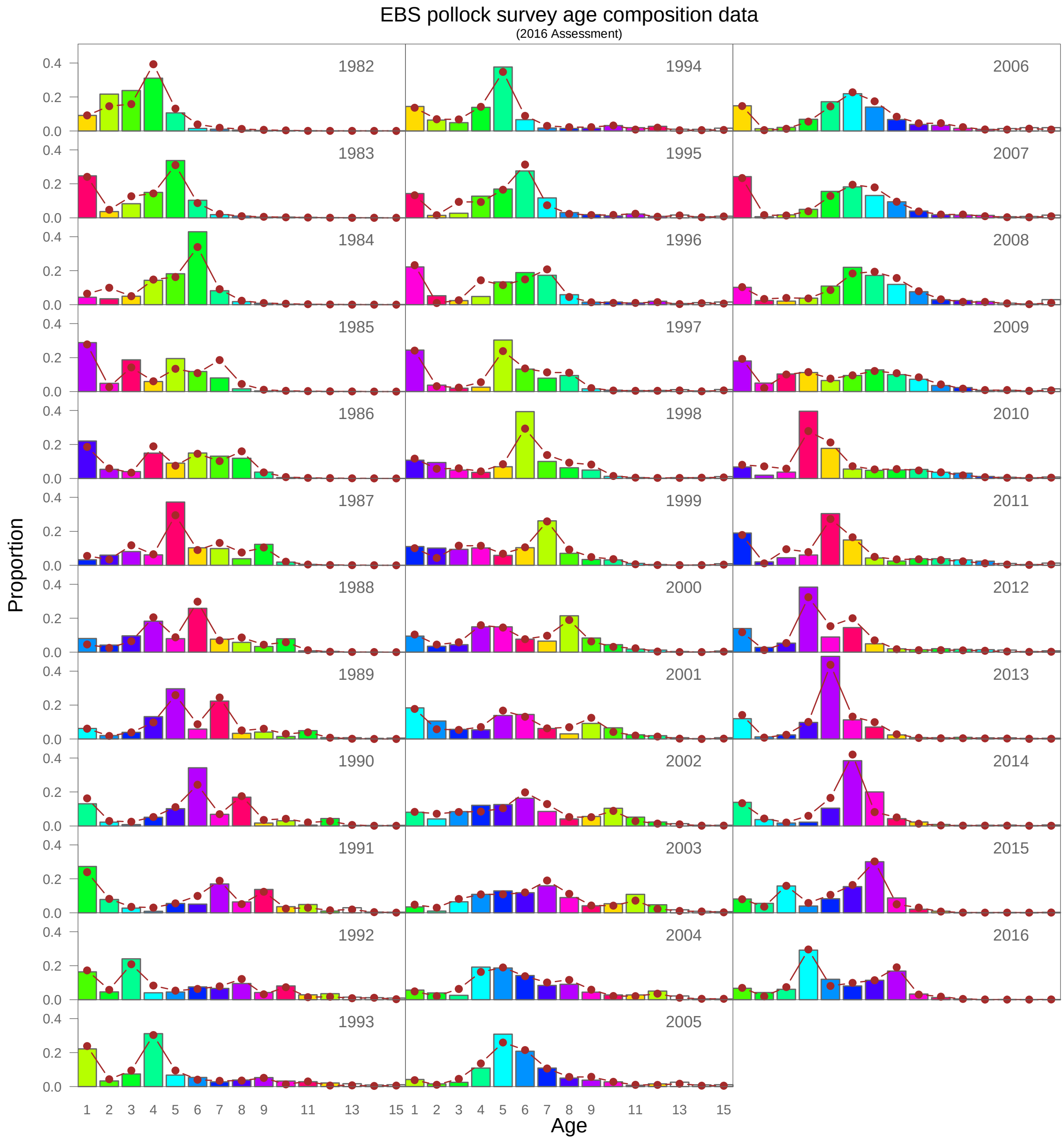
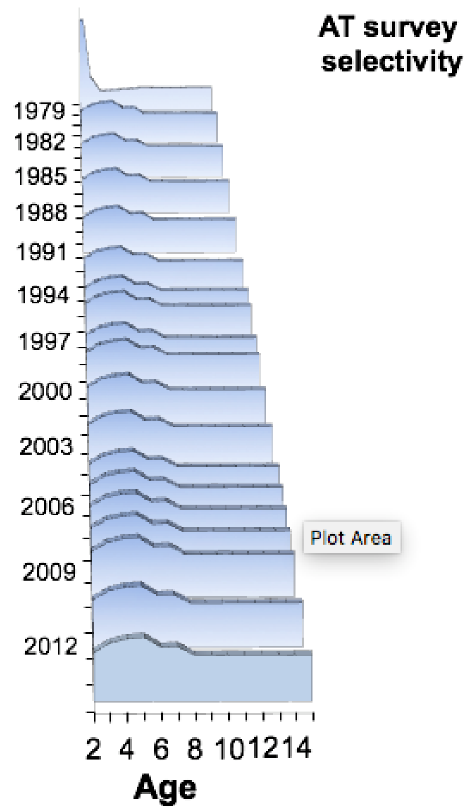


Figure 1.28. Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2016.



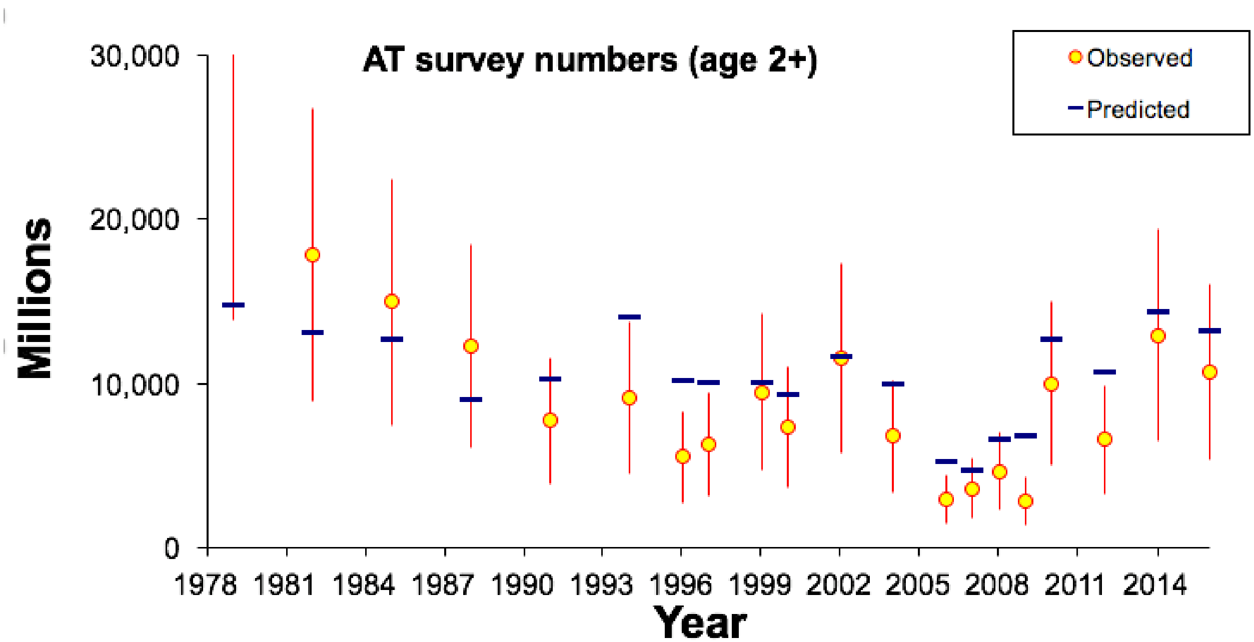


Figure 1.29. Estimates of AT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older, 1979-2016. Note that the 1979 observed value (=46,314) is off the scale of the figure.

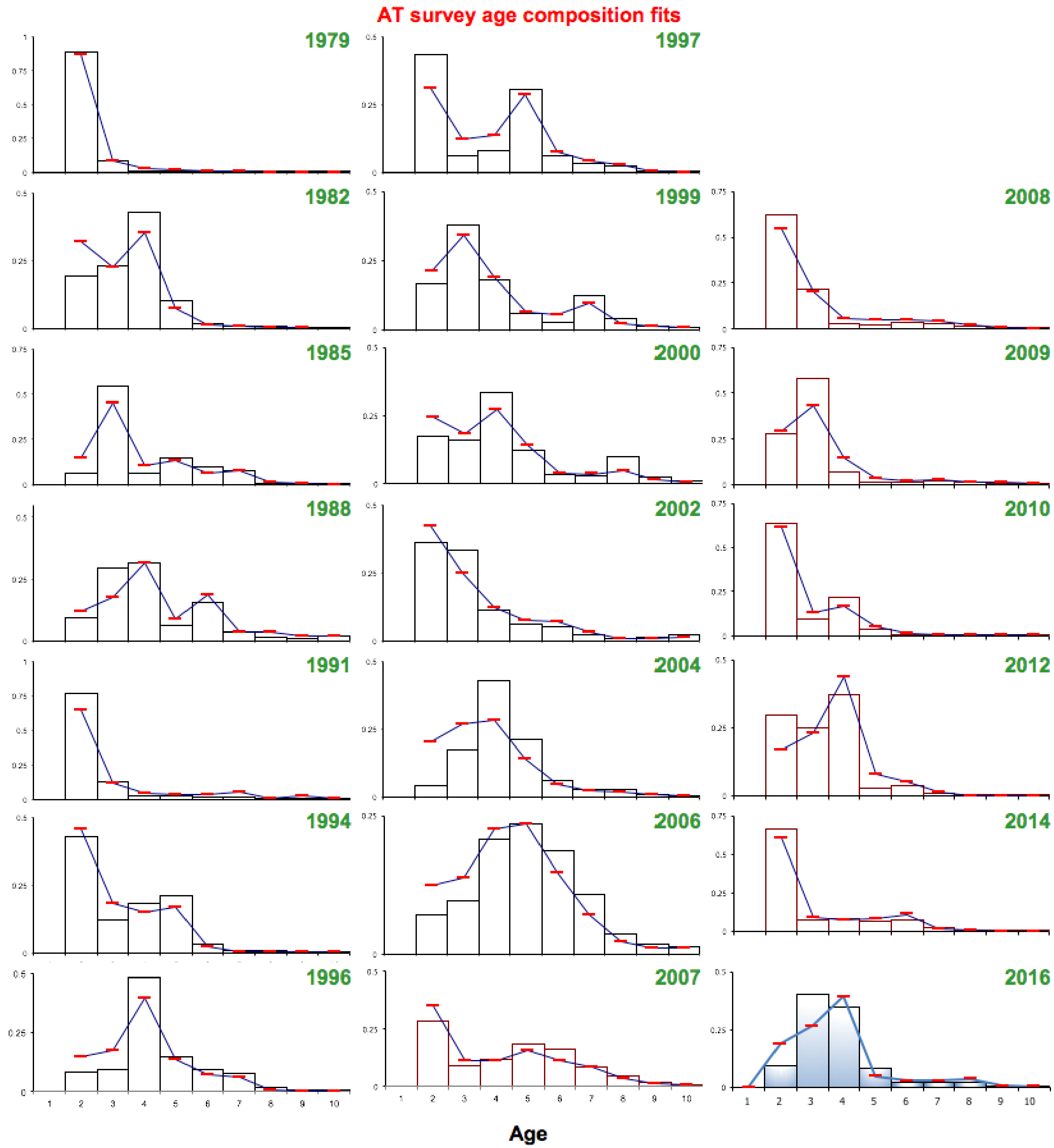


Figure 1.30. Fit to the AT survey EBS pollock age composition data (proportion of numbers). Lines represent model predictions while the vertical columns and dots represent data. The 2016 age composition data were based on age data from the BTS applied to the AT survey length frequency.

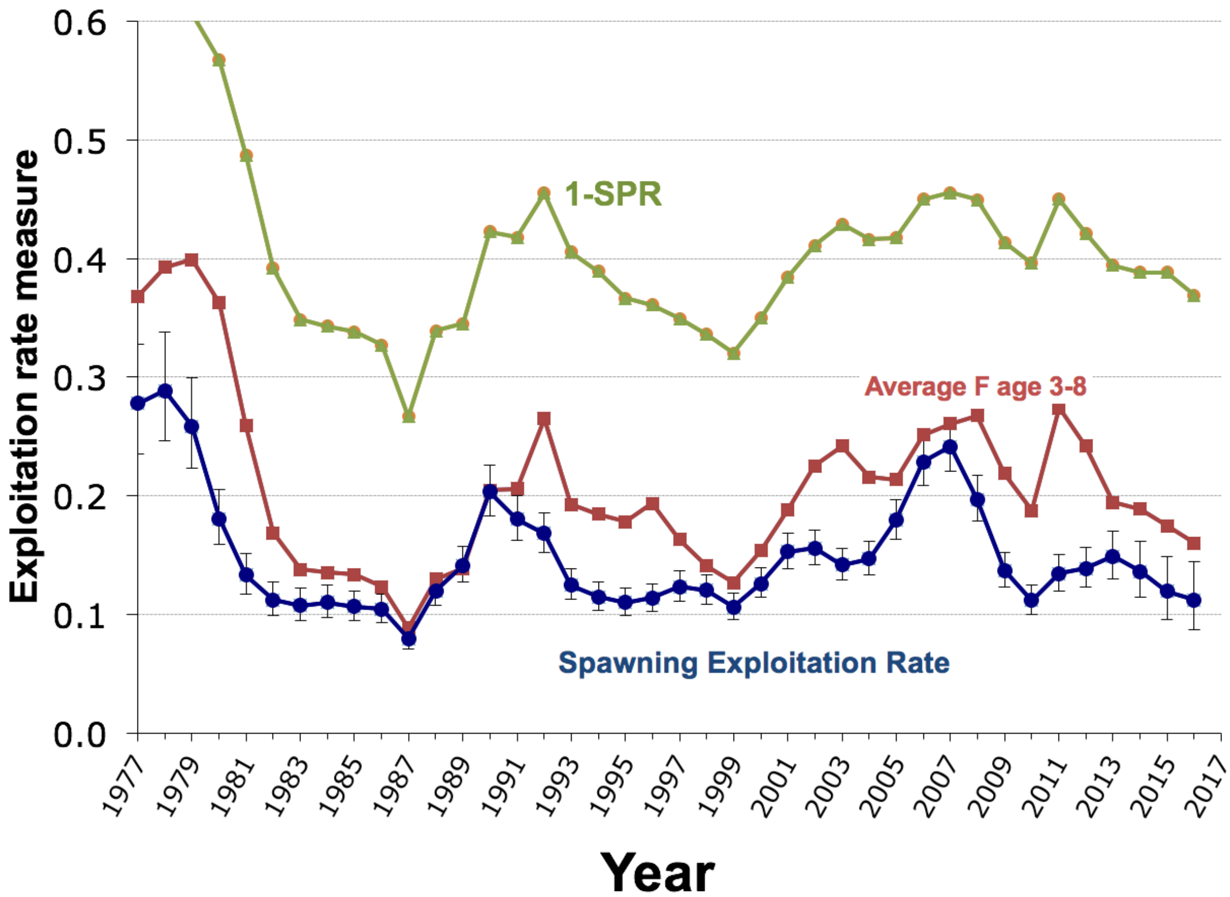


Figure 1.31. Estimated spawning exploitation rate (defined as the percent removal of egg production in a given spawning year), implied SPR rate (actually 1-SPR so that higher values imply more impact on spawning biomass per recruit) and average fishing mortality (ages 3-8) for EBS pollock, 1977-2016. Error bars represent two standard deviations from the estimates.

Year \ Age	2	3	4	5	6	7	8	9	10
1964	0.01	0.05	0.16	0.16	0.16	0.16	0.15	0.14	0.14
1965	0.01	0.05	0.17	0.16	0.16	0.15	0.14	0.14	0.13
1966	0.01	0.06	0.15	0.15	0.14	0.14	0.13	0.13	0.13
1967	0.03	0.12	0.23	0.24	0.23	0.23	0.22	0.22	0.22
1968	0.03	0.13	0.24	0.23	0.22	0.22	0.22	0.22	0.22
1969	0.04	0.16	0.23	0.22	0.22	0.22	0.23	0.23	0.23
1970	0.06	0.22	0.25	0.28	0.28	0.29	0.32	0.34	0.36
1971	0.08	0.28	0.34	0.39	0.38	0.39	0.46	0.48	0.53
1972	0.12	0.35	0.42	0.43	0.43	0.44	0.50	0.54	0.58
1973	0.15	0.42	0.50	0.51	0.51	0.51	0.57	0.61	0.63
1974	0.18	0.54	0.55	0.55	0.55	0.55	0.60	0.64	0.65
1975	0.12	0.49	0.47	0.46	0.46	0.46	0.48	0.52	0.53
1976	0.10	0.40	0.45	0.43	0.42	0.42	0.42	0.46	0.47
1977	0.09	0.30	0.37	0.39	0.38	0.38	0.38	0.41	0.42
1978	0.08	0.30	0.38	0.42	0.42	0.42	0.42	0.45	0.46
1979	0.05	0.25	0.35	0.45	0.46	0.45	0.45	0.48	0.48
1980	0.03	0.16	0.32	0.43	0.45	0.44	0.44	0.45	0.45
1981	0.01	0.08	0.22	0.33	0.33	0.33	0.33	0.34	0.33
1982	0.01	0.04	0.13	0.21	0.22	0.22	0.23	0.23	0.23
1983	0.01	0.03	0.09	0.15	0.19	0.19	0.19	0.20	0.21
1984	0.01	0.03	0.08	0.16	0.18	0.19	0.19	0.20	0.21
1985	0.01	0.03	0.07	0.13	0.20	0.20	0.20	0.21	0.22
1986	0.01	0.03	0.08	0.11	0.18	0.18	0.17	0.20	0.20
1987	0.00	0.03	0.05	0.08	0.12	0.12	0.14	0.15	0.15
1988	0.00	0.06	0.07	0.13	0.15	0.19	0.18	0.19	0.19
1989	0.00	0.04	0.09	0.13	0.17	0.21	0.20	0.19	0.19
1990	0.01	0.05	0.14	0.23	0.25	0.28	0.29	0.27	0.26
1991	0.01	0.04	0.12	0.21	0.25	0.33	0.29	0.33	0.33
1992	0.01	0.07	0.12	0.20	0.32	0.42	0.45	0.46	0.45
1993	0.00	0.04	0.15	0.13	0.22	0.30	0.30	0.30	0.29
1994	0.00	0.02	0.08	0.23	0.22	0.28	0.28	0.27	0.27
1995	0.00	0.01	0.04	0.15	0.30	0.28	0.28	0.27	0.26
1996	0.01	0.02	0.02	0.08	0.25	0.39	0.39	0.34	0.31
1997	0.01	0.02	0.04	0.09	0.18	0.30	0.35	0.37	0.34
1998	0.00	0.02	0.05	0.09	0.19	0.21	0.28	0.31	0.29
1999	0.00	0.04	0.06	0.09	0.13	0.22	0.21	0.21	0.19
2000	0.00	0.02	0.09	0.14	0.14	0.23	0.29	0.23	0.21
2001	0.00	0.02	0.07	0.20	0.29	0.28	0.28	0.26	0.24
2002	0.00	0.02	0.08	0.18	0.36	0.35	0.35	0.32	0.27
2003	0.00	0.05	0.08	0.22	0.33	0.39	0.38	0.33	0.27
2004	0.00	0.02	0.16	0.19	0.26	0.33	0.33	0.28	0.24
2005	0.00	0.02	0.11	0.28	0.32	0.29	0.26	0.25	0.21
2006	0.00	0.05	0.13	0.27	0.37	0.35	0.33	0.30	0.27
2007	0.00	0.04	0.13	0.27	0.41	0.37	0.33	0.31	0.29
2008	0.00	0.03	0.11	0.25	0.43	0.40	0.36	0.35	0.32
2009	0.00	0.02	0.10	0.17	0.31	0.35	0.34	0.35	0.34
2010	0.00	0.01	0.14	0.19	0.22	0.26	0.29	0.28	0.27
2011	0.00	0.02	0.06	0.36	0.41	0.39	0.37	0.36	0.35
2012	0.00	0.02	0.11	0.12	0.39	0.39	0.39	0.37	0.36
2013	0.00	0.02	0.10	0.17	0.19	0.29	0.37	0.36	0.36
2014	0.00	0.02	0.09	0.18	0.22	0.31	0.29	0.29	0.32
2015	0.00	0.04	0.10	0.15	0.25	0.24	0.24	0.24	0.31
2016	0.00	0.04	0.09	0.13	0.23	0.23	0.23	0.23	0.29
5-yr Avera	**0.00**	**0.03**	**0.09**	**0.19**	**0.28**	**0.31**	**0.31**	**0.31**	**0.33**
5-yr Max	**0.00**	**0.04**	**0.11**	**0.18**	**0.39**	**0.39**	**0.39**	**0.37**	**0.36**
5-yr Min	**0.00**	**0.02**	**0.09**	**0.12**	**0.19**	**0.23**	**0.23**	**0.23**	**0.29**

Figure 1.32. Estimated instantaneous age-specific fishing mortality rates for EBS pollock, 1964-2016. (note that these are the continuous form of fishing mortality rate as specified in Eq. 1; colors correspond to low (green) and high (red) values).

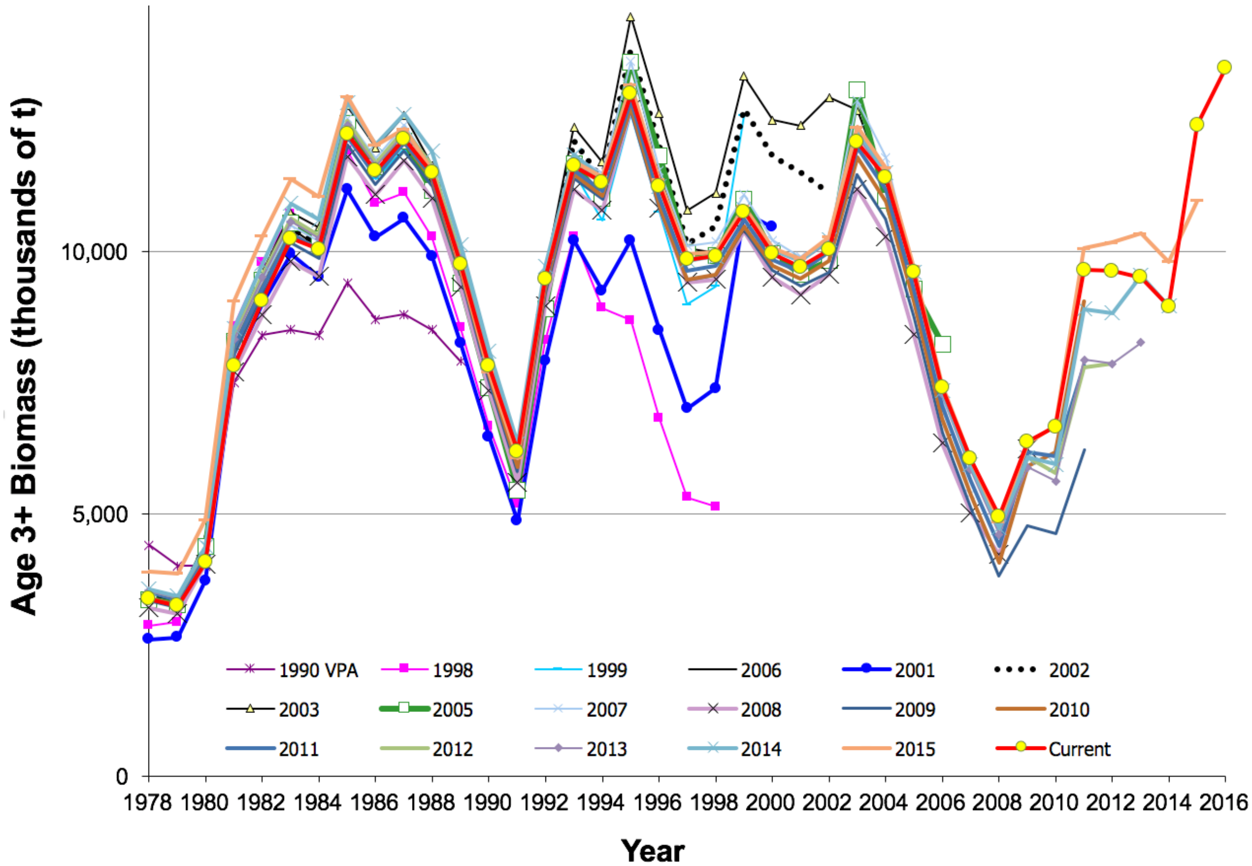


Figure 1.33. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2016.

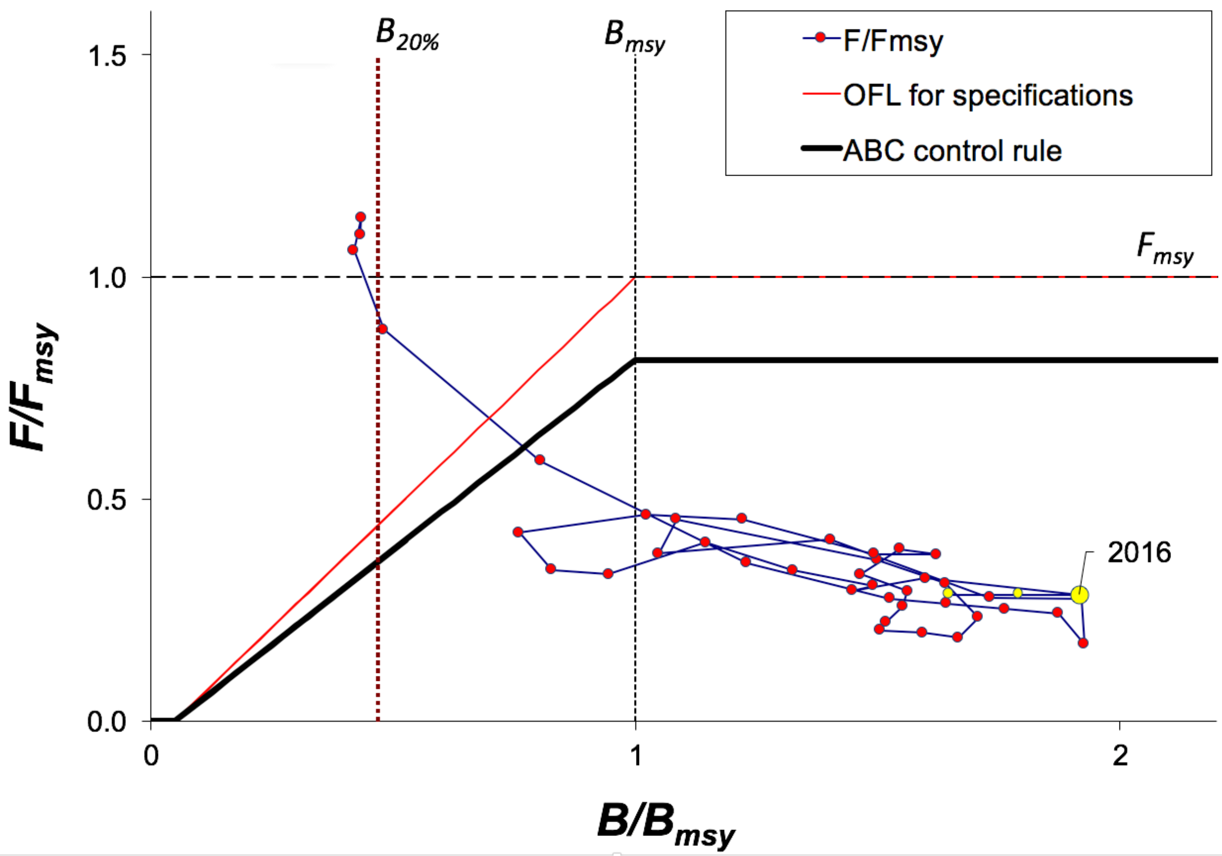


Figure 1.34. Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock, 1977-2016 (plus 2017 and 2018 in highlighted dots). *Note that the control rules for OFL and ABC are designed for setting specifications in future years.*

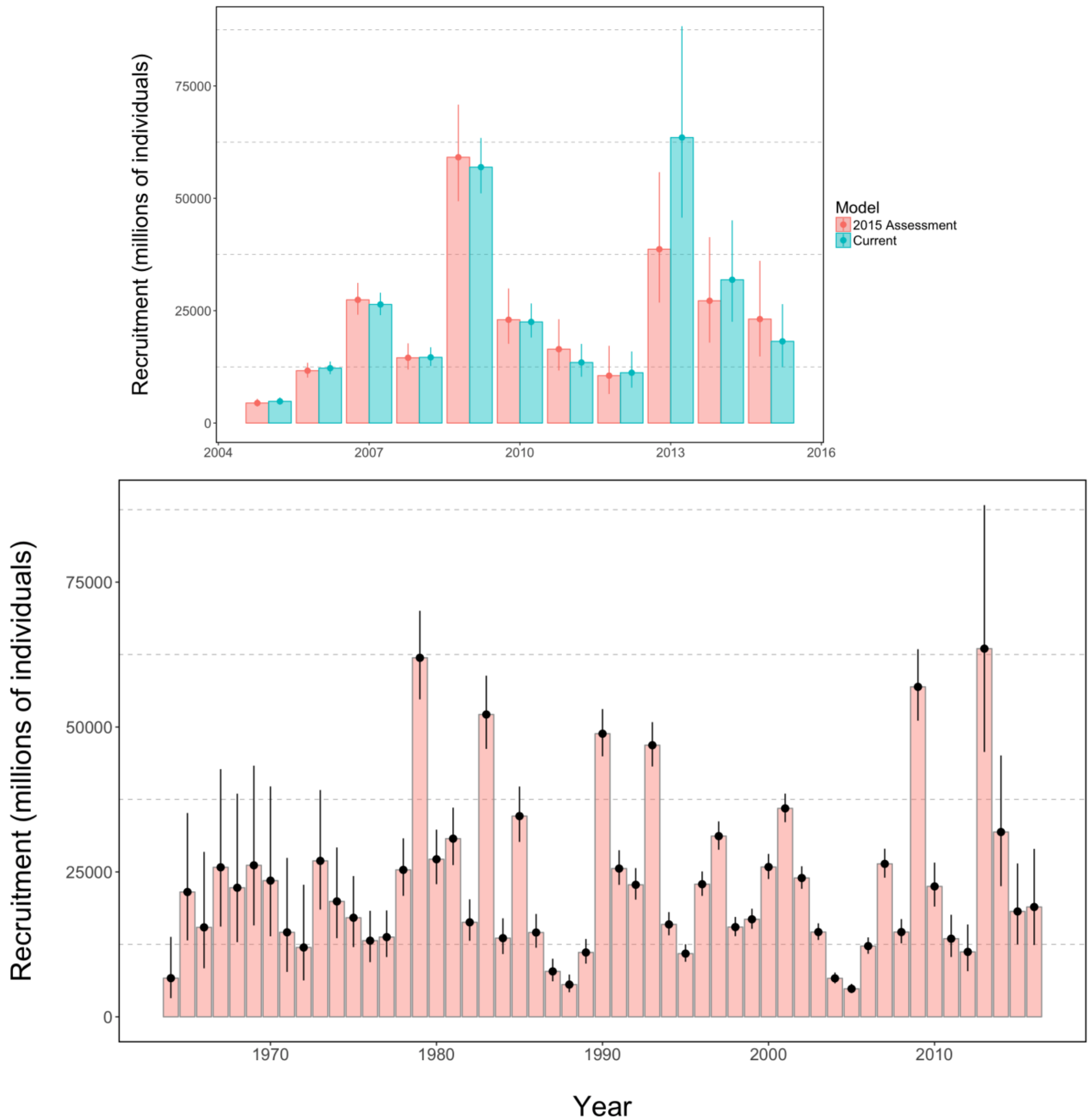


Figure 1.35. Recruitment estimates (age-1 recruits) for EBS pollock from the current model compared with the previous assessment (top) and for all years since 1964 (1963-2015 year classes) for Model 16.1 (bottom panel). Error bars reflect 90% credible intervals based on model estimates of uncertainty.

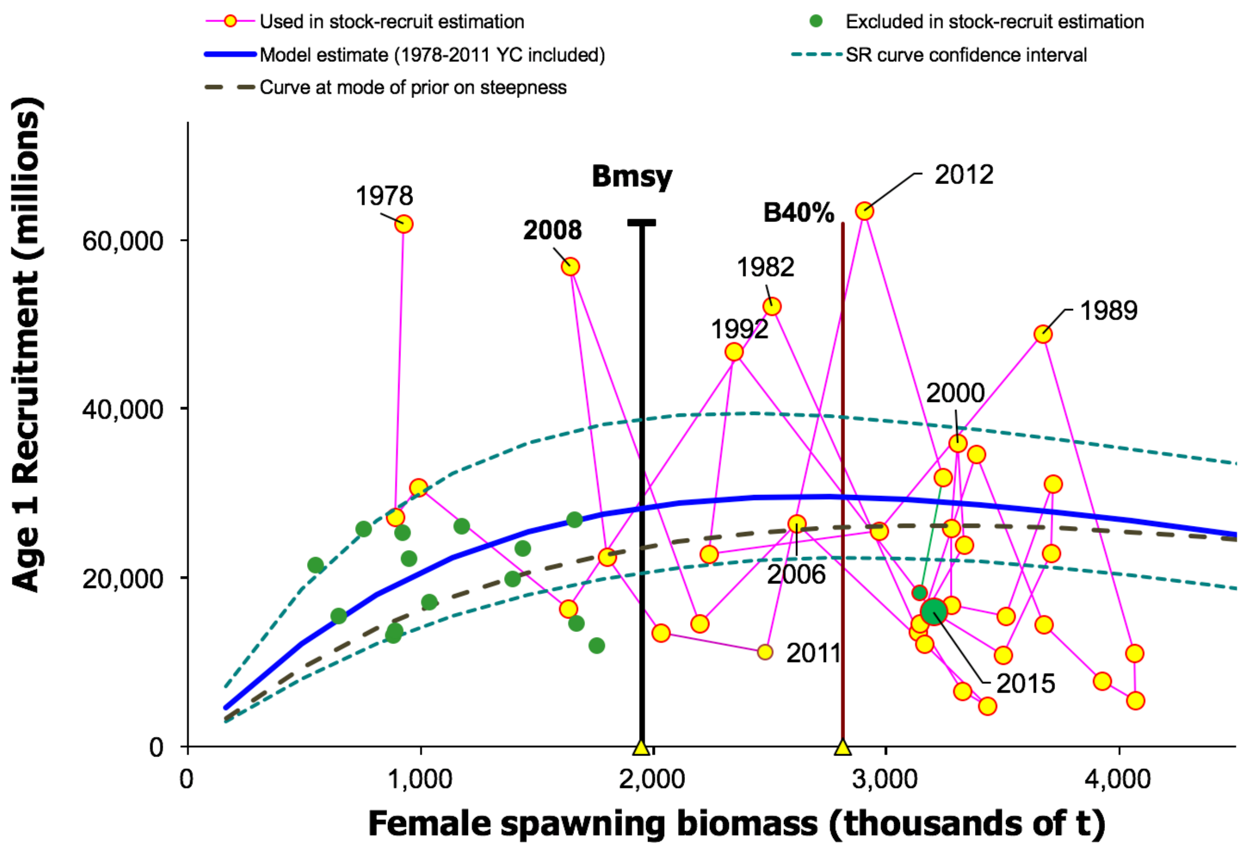


Figure 1.36. Year-class strengths relative to female spawning biomass (thousands of t) for EBS pollock. Labels on points correspond to year classes labels (measured as one-year olds). Vertical lines indicate B_{MSY} and $B_{40\%}$ levels whereas the solid curve represents fitted stock-recruitment relationship (dashed lines represent estimated 90% credible intervals).

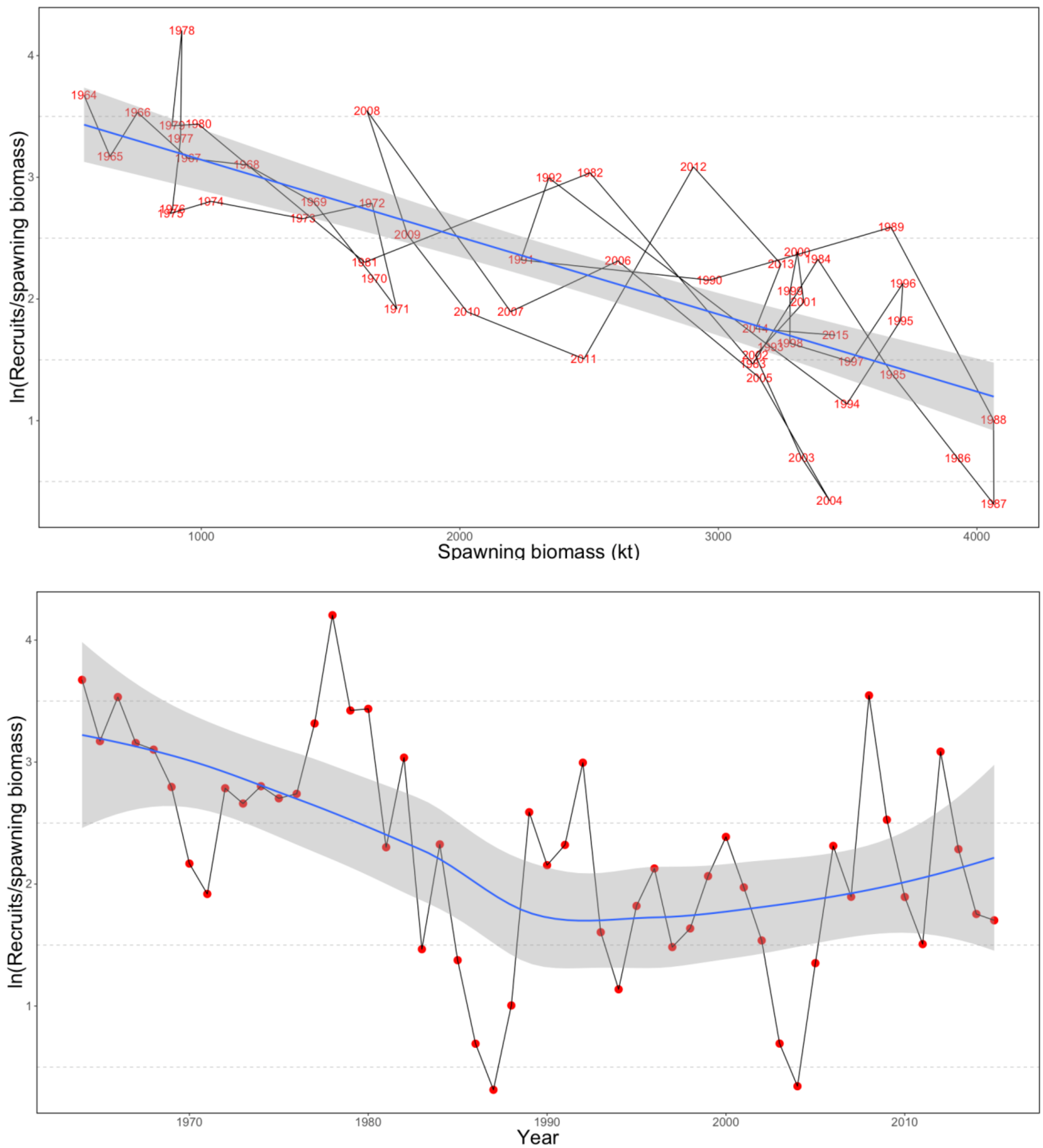


Figure 1.37. EBS pollock productivity, as measured by logged recruits per spawning biomass—log(R/S)—as a function of spawning biomass with a linear fit (top) and over time,1964-2015 (bottom).

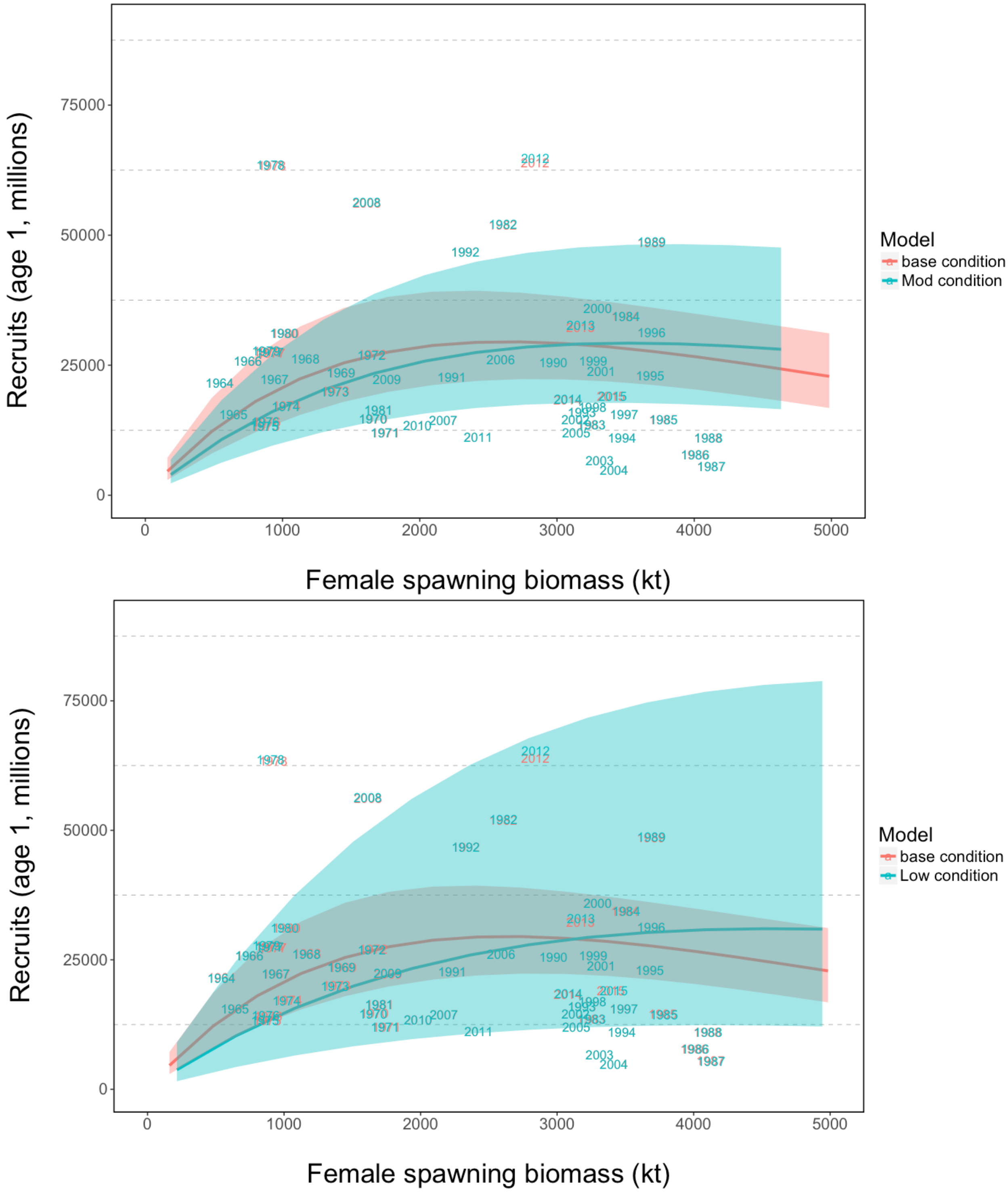


Figure 1.38. EBS pollock stock-recruit relationship with alternative affinities to conditioning within the model for moderate (top) and low conditioned (bottom) scenarios with the "base condition" where the model parameters are fully conditioned on recruit and spawning stock estimates (and related likelihood components).

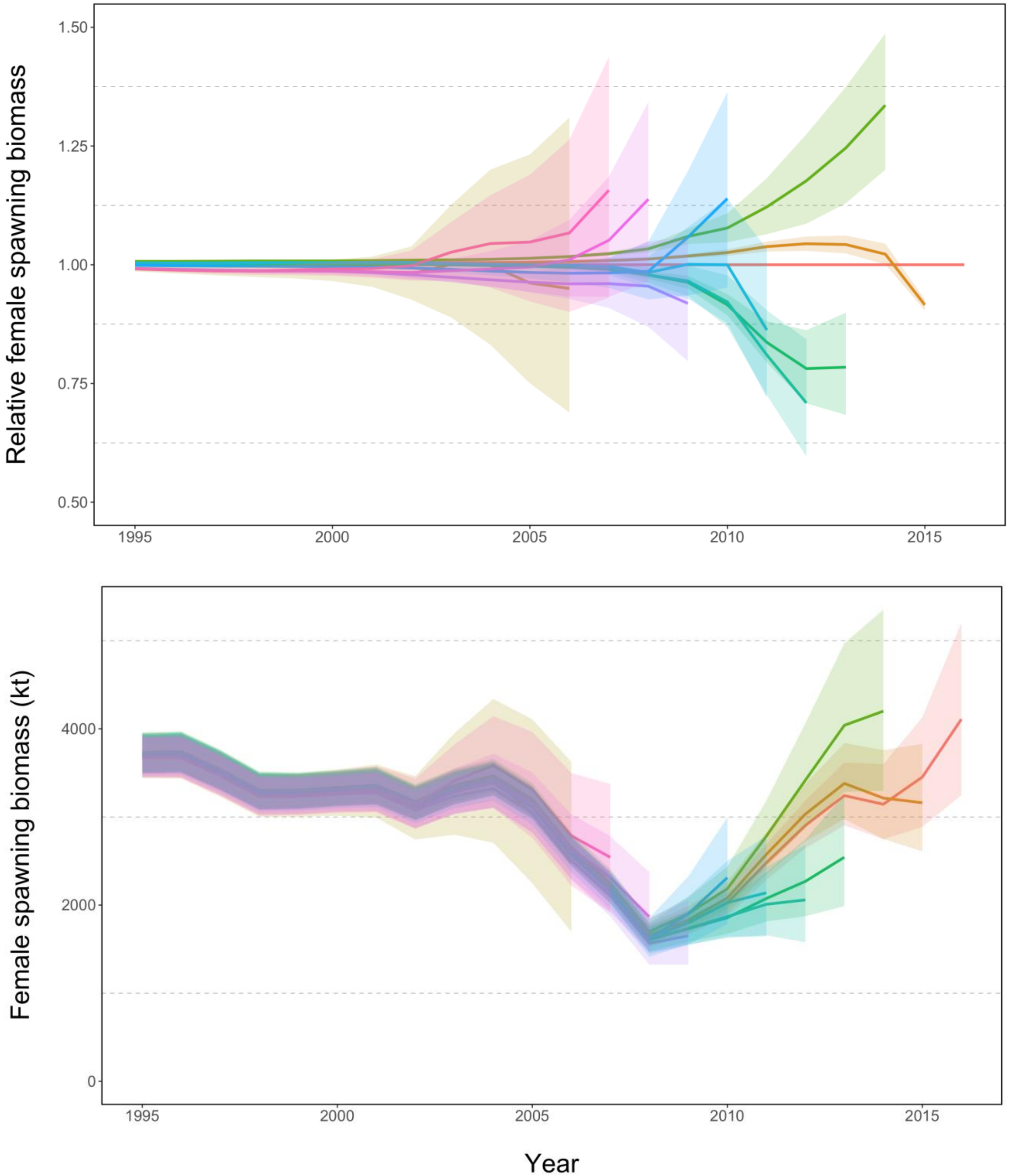


Figure 1.39. Retrospective patterns of model 16.1 for EBS pollock spawning in retrospective year for 2004-2016 showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (±2 standard deviations). Mohn's rho was estimated to be -0.004 for the 10-year period.

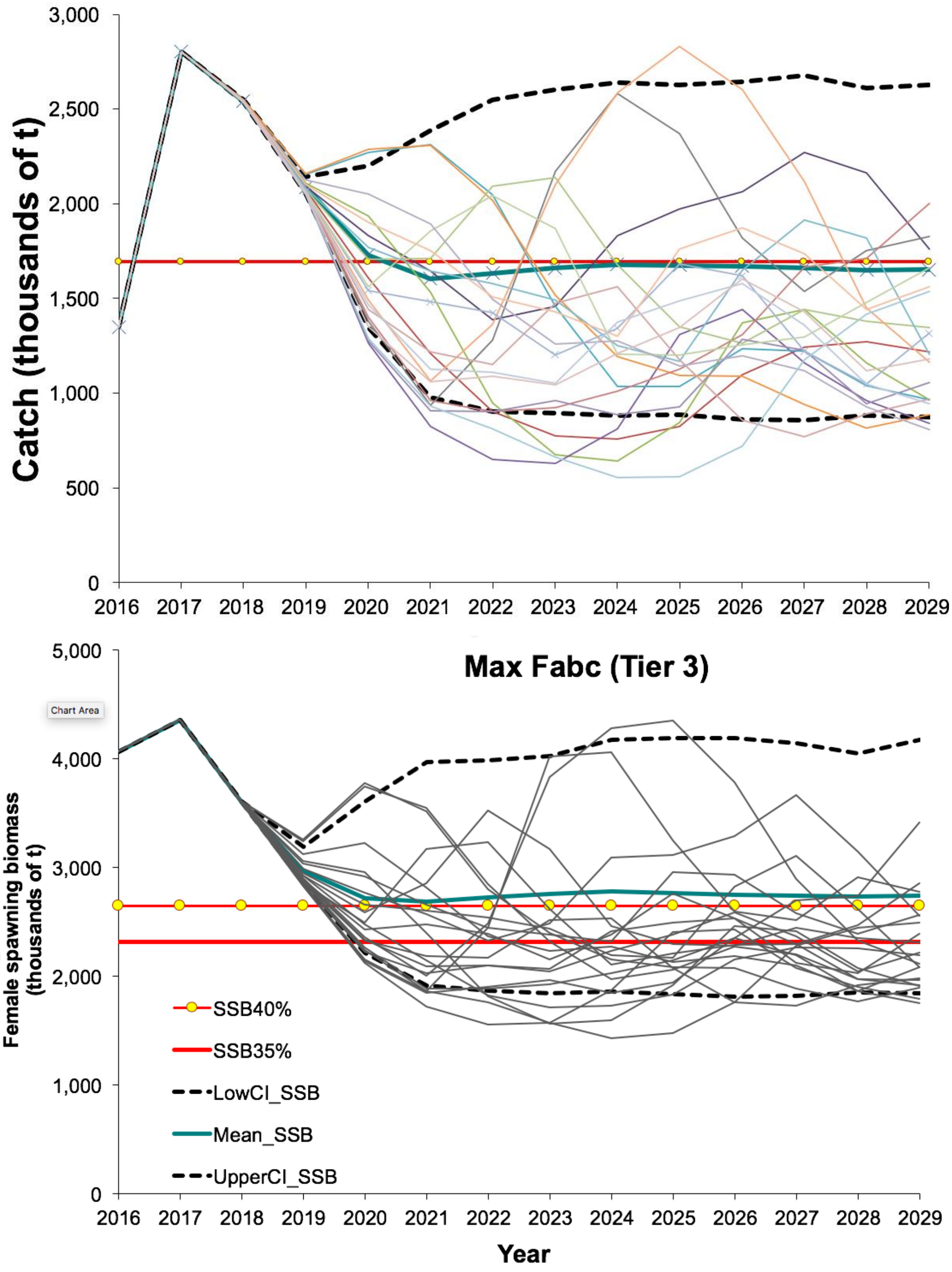


Figure 1.40. Projected EBS **Tier 3** pollock **yield** (top) and **female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2013. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1. The grey lines represent a sub-sample of simulated trajectories. Note that the numbers at age 2 in 2015 were set to their median value.

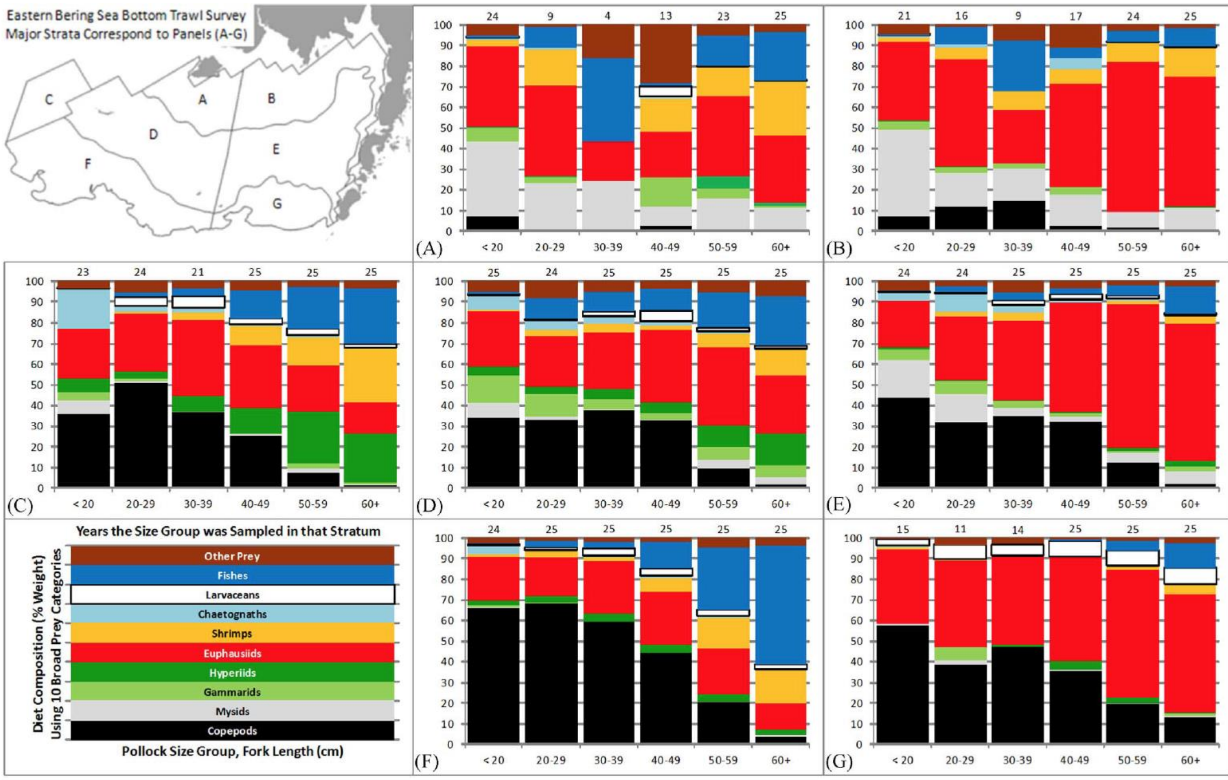


Figure 1.41. Gravimetric composition (%W) of the stomach contents by pollock length categories (cm FL, below column) in each major stratum (A–G) of the eastern Bering Sea bottom trawl surveys, 1987-2011. The number of years each length category was sampled in each stratum is shown above each column. Reproduced with permission from Buckley et al. 2016.

Model details

An explicit age-structured model with the catch equation and population dynamics model as described in Fournier and Archibald (1982) and elsewhere (Hilborn and Walters 1992, Schnute and Richards 1995, McAllister and Ianelli 1997). Catch in numbers at age in year t ($C_{t,a}$) and total catch biomass (Y_t) were

$$
\begin{aligned}
C_{t,a} &= \frac{F_{t,a}}{Z_{t,a}}\ 1 - e^{-Z_{a,t}}\ \ N_{t,a}, & 1 \le t \le T \quad 1 \le a \le A \\
N_{t+1,a+1} &= N_{t,a} e^{-Z_{t,a}} & 1 \le t \le T \quad 1 \le a < A \\
N_{t+1,A} &= N_{t,A-1} e^{-Z_{t,A-1}} + N_{t,A} e^{-Z_{t,A}} & 1 \le t \le T \\
Z_{t,a} &= F_{t,a} + M_{t,a} \\
C_{t\cdot} &= \sum_{a=1}^{A} C_{t,a} \\
p_{t,a} &= C_{t,a} / C_{t\cdot} \\
Y_t &= \sum_{a=1}^{A} w_a C_{t,a}\ \text{, and}
\end{aligned}
$$

.... (Eq. 1)

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,

$C_{t\cdot}$ is the total catch in year t,

w_a is the mean body weight (kg) of fish in age class a,

$Y_{t\cdot}$ is the total yield biomass in year t,

$F_{t,a}$ is the instantaneous fishing mortality for age class a, in year t,

M_{ta} is the instantaneous natural mortality in year t for age class a, and

Z_{ta} is the instantaneous total mortality for age class a, in year t.

We reduced the freedom of the parameters listed above by restricting the variation in the fishing mortality rates ($F_{t,a}$) following Butterworth et al. (2003) by assuming that

$$F_{t,a} = s_{t,a}\mu^f e^{\varepsilon_t} \quad \varepsilon_t \sim N\ 0,\sigma_E^2 \qquad \text{(Eq. 2)}$$

$$S_{t+1,a} = s_{t,a} e^{\gamma_t} \quad \gamma_t \sim N\ 0,\sigma_s^2 \qquad \text{(Eq. 3)}$$

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. This assumption creates what is known as a separable model. If selectivity in fact changes over time, then the separable model can mask important changes in fish abundance. In our analyses, we constrain the variance term σ_s^2 to allow selectivity to change slowly over time–thus improving our ability to estimate γ_t. Also, to provide regularity in the age component, we placed a curvature penalty on the selectivity coefficients using the squared second-differences. We selected a simple random walk as our time-series effect on these quantities. Prior assumptions about the relative variance quantities were made. For example, we assume that the variance of transient effects (e.g., σ_E^2) is large to fit the catch biomass precisely. Perhaps the largest difference between the model presented here and those used for other groundfish stocks is in how we model selectivity of both the fishery and survey gear types. The approach taken here assumes that large differences between a selectivity coefficient in a given year for a given age should not vary too much from adjacent years and ages (unless the data suggest otherwise, e.g., Lauth et al. 2004). The magnitude of these changes is determined by the prior variances as presented above. For the application here selectivity is allowed to change in each year. The basis for this model specification was to better account for the high levels of sampling and to avoid over-simplifying real changes in age-specific fishing mortality. The mean selectivity going forward for projections and ABC deliberations is the simple mean of the estimates from 2010-2014.

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 is:

$$\begin{aligned} s_{t,a} &= \left[1 + e^{-\alpha_t\ a-\beta_t}\ \right]^{-1}, \ a > 1 \\ s_{t,a} &= \mu_s e^{\delta_t^\mu}, \qquad a = 1 \\ \alpha_t &= \bar{\alpha} e^{\delta_t^\alpha} \\ \beta_t &= \bar{\beta} e^{\delta_t^\beta} \end{aligned} \qquad \text{(Eq. 4)}$$

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

$$\delta_t^{\mu} - \delta_{t+1}^{\mu} \sim N\left(0, \sigma_{\delta^{\mu}}^2\right)$$
$$\delta_t^{\alpha} - \delta_{t+1}^{\alpha} \sim N\left(0, \sigma_{\delta^{\alpha}}^2\right)$$
$$\delta_t^{\beta} - \delta_{t+1}^{\beta} \sim N\left(0, \sigma_{\delta^{\beta}}^2\right) \qquad \text{(Eq. 5)}$$

The parameters to be estimated in this part of the model are thus $\bar{\alpha}, \bar{\beta}, \delta_t^{\mu}, \delta_t^{\alpha}$, and δ_t^{β} 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*) $p_{a,i}$ and sample size N_i for year *i*, an adjustment factor *f* for input sample size can be computed when compared with the assessment model predicted proportions at age ($\hat{p}_{ij}$) and model predicted mean age ($\hat{\bar{a}}$):

$$f = \mathrm{var}\left(r_i^a \sqrt{\frac{N_i}{s_i}}\right)^{-1}$$
$$r_i^a = \bar{a}_i - \hat{\bar{a}}_i$$
$$s_i = \left[\sum_j^A \bar{a}_i^2 p_{ij} - \hat{\bar{a}}_i^2\right]^{0.5} \qquad \text{(Eq. 6)}$$

where r_i^a is the residual of mean age and

$$\hat{\bar{a}}_i = \sum_j^A j\hat{p}_{ij}, \qquad \bar{a}_i = \sum_j^A jp_{ij} \qquad \text{(Eq. 7)}$$

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. A further modification made in Ianelli et al. (1998) was to have an environmental component to account for the differential survival attributed to larval drift (e.g., Wespestad et al. 2000). (κ_t):

$$R_t = f\left(B_{t-1}\right)e^{\kappa_t + \tau_t}, \qquad \tau_t \sim N\left(0, \sigma_R^2\right) \qquad \text{(Eq. 8)}$$

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

$$B_t = \sum_{a=1}^{15} w_a \phi_a N_{at} \quad \text{(Eq. 9)}$$

and, ϕ_a 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:

$$R_t = f\left(B_{t-1}\right) = \frac{B_{t-1} e^{\varepsilon_t}}{\alpha + \beta B_{t-1}} \quad \text{(Eq. 10)}$$

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*,

α, β are stock-recruitment function parameters.

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

$$\alpha = \tilde{B}_0 \frac{1-h}{4h}$$
$$\beta = \frac{5h-1}{4hR_0} \quad \text{(Eq. 11)}$$

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. (2001) is shown in Fig. 1.42. 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 σ_R 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):

$$R_t = f(B_{t-1}) = B_{t-1} e^{\alpha(1 - B_{t-1}/\varphi_0 R_0)} / \varphi_0 \quad \text{(Eq. 12)}$$

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

$$h = \frac{e^a}{e^a + 4} \quad \text{(Eq. 13)}$$

so that the prior used on h can be implemented in both the Ricker and Beverton-Holt stock-recruitment forms. Here the term φ_0 represents the equilibrium unfished spawning biomass per-recruit.

Diagnostics

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

$$R_t^{'} = \hat{R}_t \frac{f\left(S_t^{'}\right)}{f\left(\hat{S}_t\right)} \quad \text{(Eq. 14)}$$

where $\hat{R}_t$ is the original recruitment estimate in year t with $f\left(S_t^{'}\right)$ and $f\left(\hat{S}_t\right)$ representing the stock-recruitment function given spawning biomass under no fishing and under the fishing scenario, 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):

$$f = n \cdot \sum_{a,t} p_{at} \ln \ \hat{p}_{at} \quad ,$$
$$p_{at} = \frac{O_{at}}{\sum_a O_{at}}, \qquad \hat{p}_{at} = \frac{\hat{C}_{at}}{\sum_a \hat{C}_{at}}$$
$$\hat{C} = C \cdot E_{ageing}$$
$$E_{ageing} = \begin{pmatrix} b_{1,1} & b_{1,2} & b_{1,3} & \cdots & b_{1,15} \\ b_{2,1} & b_{2,2} & & & \\ b_{3,1} & & \ddots & & \\ \vdots & & & \ddots & \\ b_{15,2} & & & & b_{15,15} \end{pmatrix};$$
....(Eq. 15)

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

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

$$\prod_{a=1}^{A}\prod_{t=1}^{T}\frac{\left(\exp\left\{-\frac{p_{t,a}-\hat{p}_{t,a}\ ^2}{2\ \eta_{t,a}+0.1/T\ \ \tau^2}\right\}+0.01\right)}{\sqrt{2\pi\ \ \eta_{t,a}+0.1/T\ \ \tau}}$$
....(Eq. 16)

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

$$-1/2\sum_{a=1}^{A}\sum_{t=1}^{T}\log_e\ 2\pi\ \ \eta_{t,a}+0.1/T\ \ -\sum_{a=1}^{A}T\log_e\ \tau$$
$$+\sum_{a=1}^{A}\sum_{t=1}^{T}\log_e\left[\exp\left\{-\frac{p_{t,a}-\hat{p}_{t,a}\ ^2}{2\ \eta_{t,a}+0.1/T\ \ \tau^2}\right\}+0.01\right]$$
....(Eq. 17)

where $\eta_{t,a} = p_{t,a}\ \ 1 - p_{t,a}$

and $\tau^2 = 1/n$

gives the variance for $p_{t,a}$

$$\eta_{t,a} + 0.1/T \quad \tau^2 .$$

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:

$$\hat{N}^s_{t,a} = e^{-0.5Z_{t,a}} N_{t,a} q^s_t s^s_{t,a} \quad \text{(Eq. 18)}$$

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:

$$\hat{N}^s_{t,a} = e^{-0.5Z_{t,a}} w_{t,a} N_{t,a} q^s_t s^s_{t,a} \quad \text{(Eq. 19)}$$

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:

$$\sum_t \left(\frac{\ln\left(A^s_t / \hat{N}^s_t \right)^2}{2\sigma^2_{s,t}} \right) \quad \text{(Eq. 20)}$$

where A^s_t is the total (numerical abundance or optionally biomass) estimate with variance $\sigma^2_{s,t}$ from survey *s* in year *t* or optionally, the normal distribution can be selected:

$$\sum_t \left(\frac{\left(A^s_t - \hat{N}^s_t \right)^2}{2\sigma^2_{s,t}} \right).$$

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

$$0.5\mathbf{X}\Sigma^{-1}\mathbf{X}'$$

where $\mathbf{X}$ 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 catches (O_t) by the fishery is given by

$$\sum_t \left(\frac{\ln\left(O_t / \hat{C}_t \right)^2}{2\sigma^2_{c,t}} \right) \quad \text{(Eq. 21)}$$

where $\sigma_{c,t}$ is pre-specified (set to 0.05) affecting 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 $\lambda_\varepsilon \sum_t \varepsilon^2 + \lambda_\gamma \sum_{t,a} \gamma^2_{t,a} + \lambda_\delta \sum_t \delta^2_t$ where the size of the λ'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.

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_i^{future}) on current (2015) 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 1991-2015. The values of $\bar{w}_i, \sigma^2_{w_i}$ based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

$$w_i^{future} \sim N\left(\bar{w}_i, \sigma^2_{w_i}\right) \quad \text{(Eq. 22).}$$

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.

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 ($\hat{u}_{HM}$) applied to the estimated geometric mean fishable biomass at B_{MSY}:

$$\begin{aligned}
ABC &= B'_{GM}\,\hat{u}_{HM}\,\zeta \\
B'_{GM} &= e^{\ln\left(\hat{B}'\right)-0.5\sigma^2_B} \\
\hat{u}_{HM} &= e^{\ln u_{msy}-0.5\sigma^2_{u_{msy}}} \qquad \text{(Eq. 23)} \\
\zeta &= \frac{B_t/B_{msy}-0.05}{1-0.05} \qquad B_t < B_{msy} \\
\zeta &= 1 \qquad B_t \geq B_{msy}
\end{aligned}$$

where $\hat{B}'$ is the point estimate of the fishable biomass defined as (for a given year)

$$\sum_{j=1}^{15} N_j s_j w_j \quad \text{(Eq. 24)}$$

with N_j, s_j and w_j the estimated population numbers (begin year), selectivity and weights-at-age j, 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.

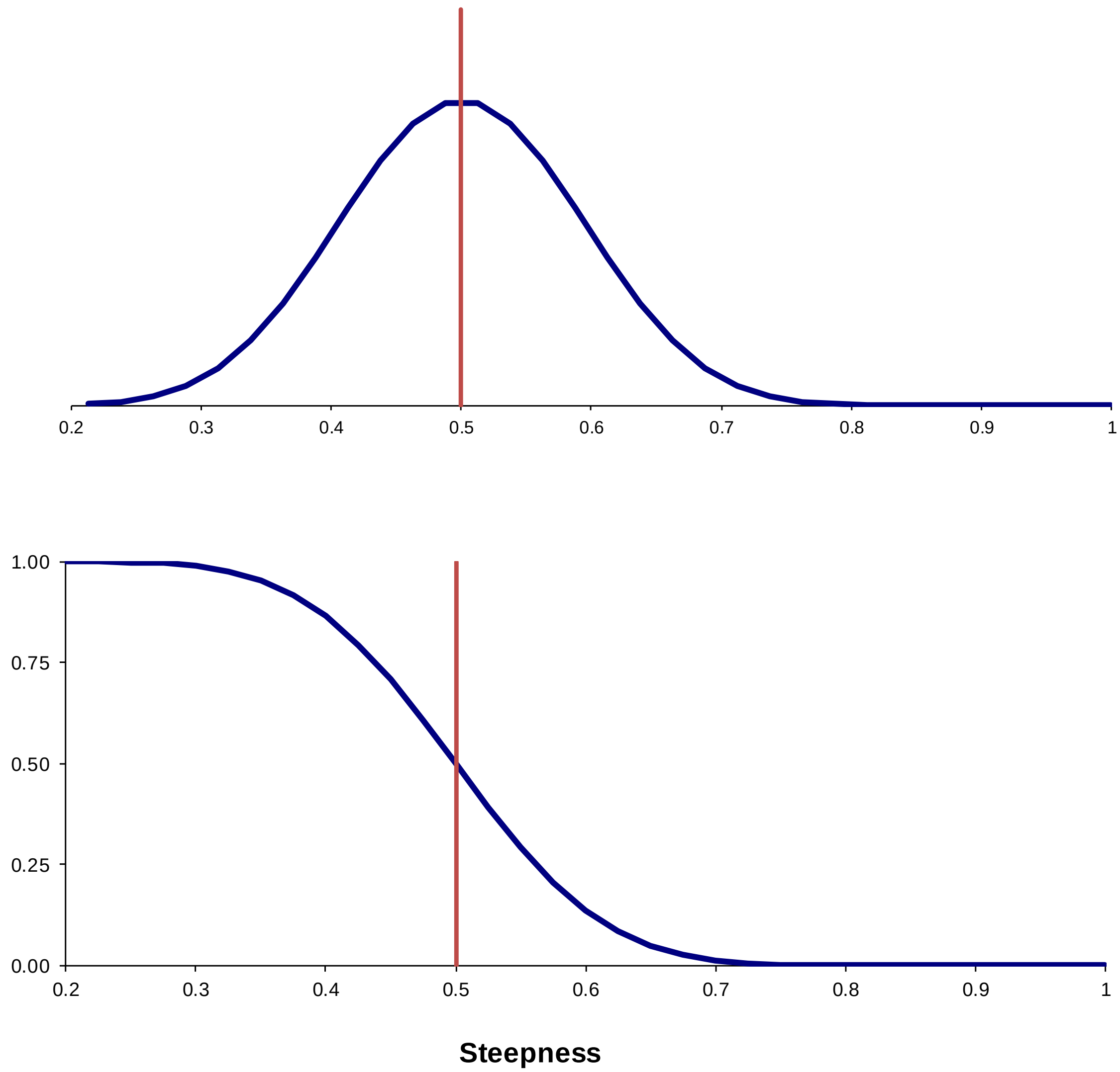


Figure 1.42. Cumulative prior probability distribution of steepness based on the beta distribution with α and β set to values which assume a mean and CV of 0.5 and 0.12, respectively. This prior distribution implies that there is about 14% chance that the value for steepness is greater than 0.6.

Alternative summary

EBS pollock results for Model 15.1.

Quantity	As estimated or *specified last* year for: 2016	2017	As estimated or *recommended this* year for: 2017	2018
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)	11,300,000 t	11,000,000 t	13,900,000 t	12,900,000 t
Projected female spawning biomass (t)	**3,540,000 t**	**3,500,000 t**	**4,830,000 t**	**4,600,000 t**
B_0	5,676,000 t	5,676,000 t	5,820,000 t	5,820,000 t
B_{MSY}	1,984,000 t	1,984,000 t	2,218,000 t	2,218,000 t
F_{OFL}	0.514	0.514	0.61	0.61
$maxF_{ABC}$	0.401	0.401	0.53	0.53
F_{ABC}	0.27	0.26	0.38	0.38
OFL (t)	3,910,000 t	3,540,000 t	4,680,000 t	5,990,000 t
maxABC (t)	3,050,000 t	2,760,000 t	4,100,000 t	5,240,000 t
ABC (t)	2,090,000 t	2,019,000 t	2,950,000 t	3,260,000 t
Status	2014	2015	2015	2016
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on estimated catches assuming 1,350,000 t used in place of maximum permissible ABC for 2017 and 2018.

Appendix 1a. Evaluation of random effect models for mean body weight estimation for EBS pollock

This document summarizes the approach presented to the NPFMC in Sept/Oct of 2016 and based on a review conducted in May 2016. The terms of reference and presentations and subsequent reports from this review can be found at: www.tinyurl.com/pollockCIE2016. This section addresses the approach to selecting body weight estimation for the fishery.

Advice on sustainable fishing practices typically revolves around ensuring that fishing mortality rates are at or below values used as reference points. In most management settings, conservation measures are set based on catch biomass limits with some assumption about expected body mass-at-age (hereafter referred to as weight-at-age) to convert from modeled catch numbers (as specified based on the fishing mortality rates). Typically stock assessment uncertainty presentations focus on absolute values of the population numbers-at-age estimates. Together with uncertainty in stock productivity estimates, risk assessments can be performed on structural models (e.g., Stewart and Martell 2015) but rarely consider uncertainty in expected body weights. While uncertainty in abundance (and productivity) is critical to evaluate risks in management settings, the additional uncertainty due to unknown weight-at-age is typically ignored (Jaworski 2011) and this can result in underestimates of uncertainty. This is exacerbated when stocks depend on one or two year classes?

For many fisheries settings empirical estimates of mean body mass-at-age are quite precise due to sampling design and effort. For example, the uncertainty of estimated mean body mass for the eastern Bering Sea (EBS) walleye pollock (*Gadus chalcogrammus*) for the main fished ages typically has coefficients of variation below 5%.

The model for predicting mean body weight-at-age in the fishery is used only to make predictions of the current year and future year values and their relative uncertainty.

Data

Fishery sampling for EBS pollock is extensive with large numbers of age, weight, and length measures sampled from the catch each year (see Tables 1.11 and 1.12 above). NMFS observer sampling data on catch-at-length and 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 1991-2015 (the period for which all the necessary information is readily available).

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 those sets 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 that could affect estimates of mean weight-at-age vary substantially within years. In 2016, the routine for estimating weights-at-age was updated to be adaptable to other stocks and converted into an R package. The values were re-computed for the period 1991-2014 (and include 2015) and estimated mean body weights-at-age were nearly identical to those previously used. A detailed summary of the relative mean weight-at-age estimates is shown in a series of figures presented as Supplemental material.

Models

The growth model followed the parameterization of Schnute and Fournier (1980), with the addition of cohort effects and annual year effects (Table 1a.1). The years and ages for model application can be specified independently of the data extent. As with Jaworski (2011) a series of prediction methods were evaluated against a measure of predictive performance. These alternative estimators for mean weight-at-age were developed based on evaluating a variety of potentially useful independent variables. Potential explanatory variables were evaluated provided that they would be available at the time of the assessment in each year (e.g., since the bottom trawl survey is used to collect temperature information, this may be useful to predict mean weights in the fishery). The objective function used to evaluate estimator performance was simply examining how well "out-of-sample" data were predicted. For example, for a particular estimator, the first iteration data from 1991-2000 were used to estimate the mean weights in 2001 and 2002. These estimated were then compared to the actual mean weights observed for 2001 and 2002. The second iteration repeated this process but used data from 1991-2001 to estimate 2002 and 2003 data for comparison with actual observations. This sequence was continued through to using data from 1991-2014 to estimate 2015 means (and compared with actual 2015 mean values). Since some age-groups are relatively more important than others to the fishery (in terms of prediction errors), comparisons of estimates with "observed" were weighted by the relative importance of different age-groups. The relative importance of different age-groups was computed by using the mean numbers-at-age estimated in the population from Ianelli *et al.* (2015) and accounting for the fishery selectivity and mean weight over that period. This weighting scheme is intended to favor estimators for age-groups that are most important to the fishery and is computed as:

$$\gamma_a = \frac{\bar{N}_a s_a \bar{w}_a}{\sum \bar{N}_a s_a \bar{w}_a}.$$

Then the estimator that performed best minimizes:

$\sum_{y=2001}^{2014} \sum_{t=y}^{y-1} \sum_{a=3}^{10} \gamma_a \left(w'_{t,a} - \hat{w}^k_{t,a} \right)^2$ where y is the "assessment" year, $\hat{w}^k_{t,a}$ is the k[th] estimator for mean weight-at-age a, in year y, and $w'_{t,a}$ are the actual observations in year t. The vector for the γ_a weighting was based approach defined above results in:

Age	3	4	5	6	7	8	9	10	11	12	13	14	15
γ_a	0.031	0.132	0.227	0.222	0.155	0.089	0.055	0.033	0.022	0.014	0.009	0.005	0.006

Parameter estimation

The estimation configurations tested included simple means to more complex year- and cohort- specific random effects approaches (Table 1a.2) and was coded in both TMB (Kristensen *et al.*, 2016) and ADMB (Fournier *et al.*, 2012). The code used is available at http://goo.gl/h8So5Z .

Results

Seven alternative estimation models were configured for contrast and testing predictability (as depicted by the scoring statistic developed above; Table 1a.3). The projection model for the mean weights-at-age in model testing shows the high level of variability and relatively poor skill in model predictions (Fig. 1a.1). Nonetheless, the performance was substantially improved with the inclusion of current year survey data and modeling the cohort and year effects (Fig. 1a.2).

Summary and conclusion

The addition of survey data to predict mean weights seems to be a significant improvement over methods that just use running means or incorporate cohort effects, at least for the EBS pollock case. The out-of-sample scores where best for the case where survey and cohort effects are included. For situations where uncertainty in mean weight at age is propagated for ABC determinations, having the year-effect process errors seems useful in addition to the cohort-specific terms.

Table 1a.1. Equations and model parameters for growth estimation

Symbol	Description
$\hat{w}_{ij} = \mu_j e^{\delta_i} \quad j=1, \; i \geq 1$ $\hat{w}_{ij} = \hat{w}_{i-1,j-1} + \Delta_j e^{\zeta_i} \quad j>1, \; i>1$ $\Delta_j = \mu_{j-1} - \mu_j \quad j<J$ $\mu_j = \alpha \left[L_1 + \left(L_2 - L_1 \right) \left(\frac{1-K^{j-1}}{1-K^{J-1}} \right) \right]^3$	Growth model
$\hat{w}_{ij}$	Expected mean weight-at-age j in year i
i , j	Index for year and age
μ_j	Mean length age j
Δ_j	Mean growth increment
α	Constant to scale lengths
$\delta_i \, \zeta_i$	Cohort and year effects
K, L_1, and L_2	Parameters of the von Bertalanffy growth

Table 1a.2. Alternative methods evaluated for computing mean weight-at-age for EBS pollock.

Method	Description
Means	Mean fishery weights-at-age of most recent *n* years of data (*n* =1, 3, 5, and 10)
Year and Cohort	Year and cohort effect model
Year and Cohort with scaled survey data	Include scaled survey weights-at-age ($\hat{w}_{i,j}^{k-2} = \lambda_j w_{i,j}^{survey}$)
Year effect only (with scaled survey data)	Year effect model (a random effect parameter for each annual growth increment)

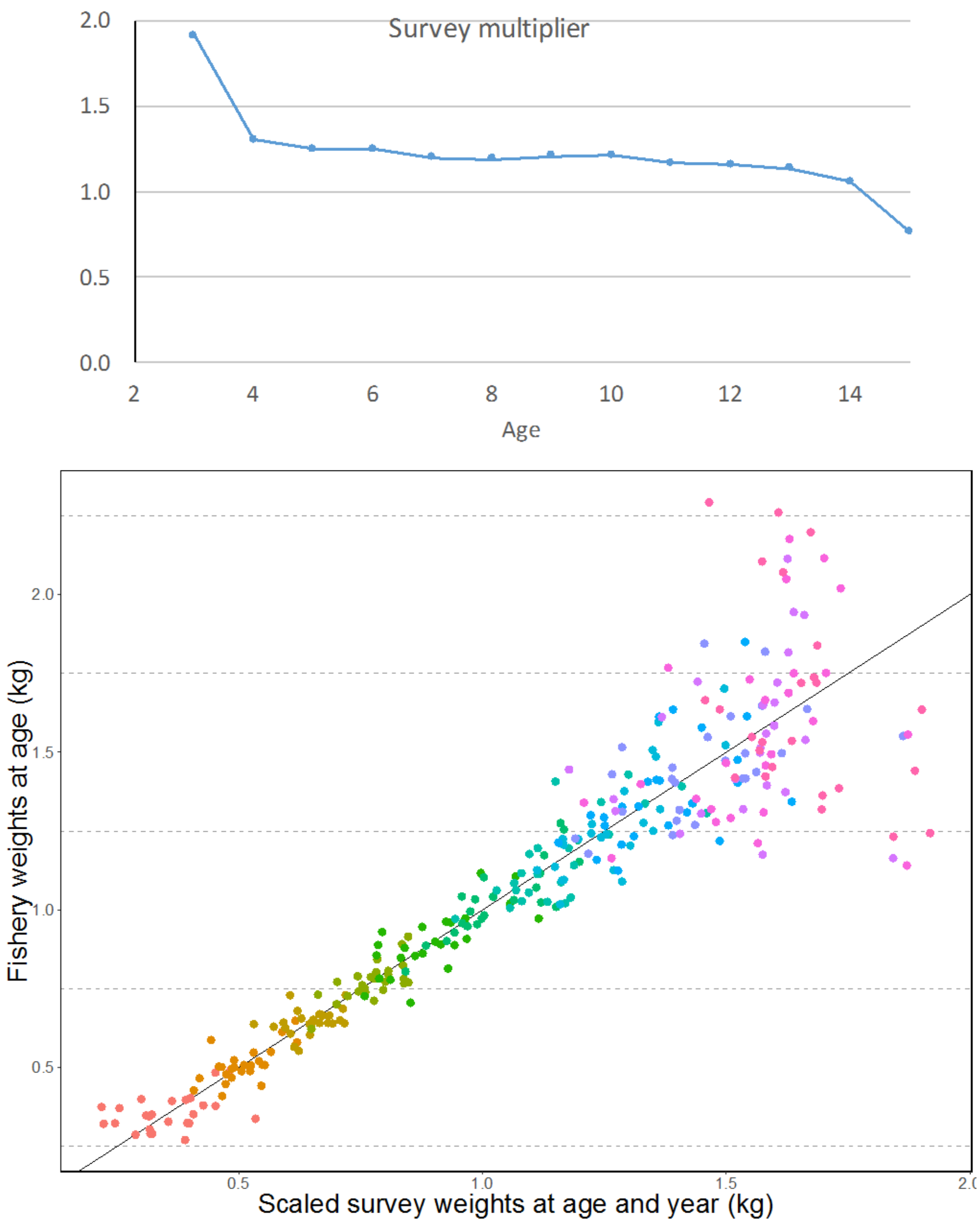


Figure 1a.1. Summary of how summer survey mean weight-at-age data for EBS pollock can be scaled to match reasonably the resulting fishery mean weight-at-age data. The top panel represents the scalars-at-age (here computed but in the model, estimated as free parameters) used to apply the survey data as covariates to the fishery mean-weight estimates.

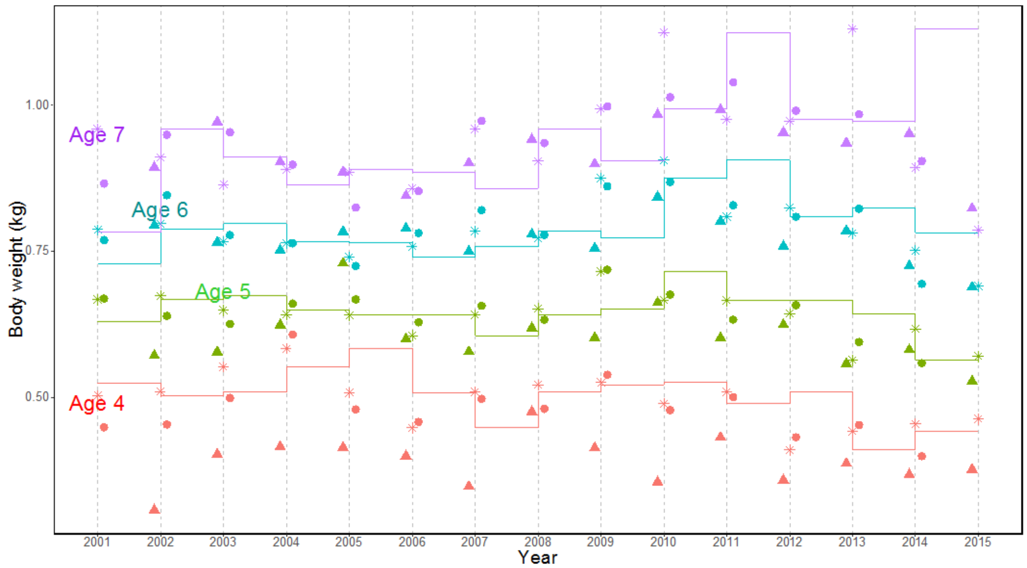


Figure 1a.2. Example projection results compared to data for fishery weights-at-ages 4-7. The lines represent estimates set equal to the most recent value for the current assessment year and next year whereas the solid bullets and triangles represent the modeled estimates for the current assessment year and next year, respectively. The stars represent the final realized estimates based on the observer data.

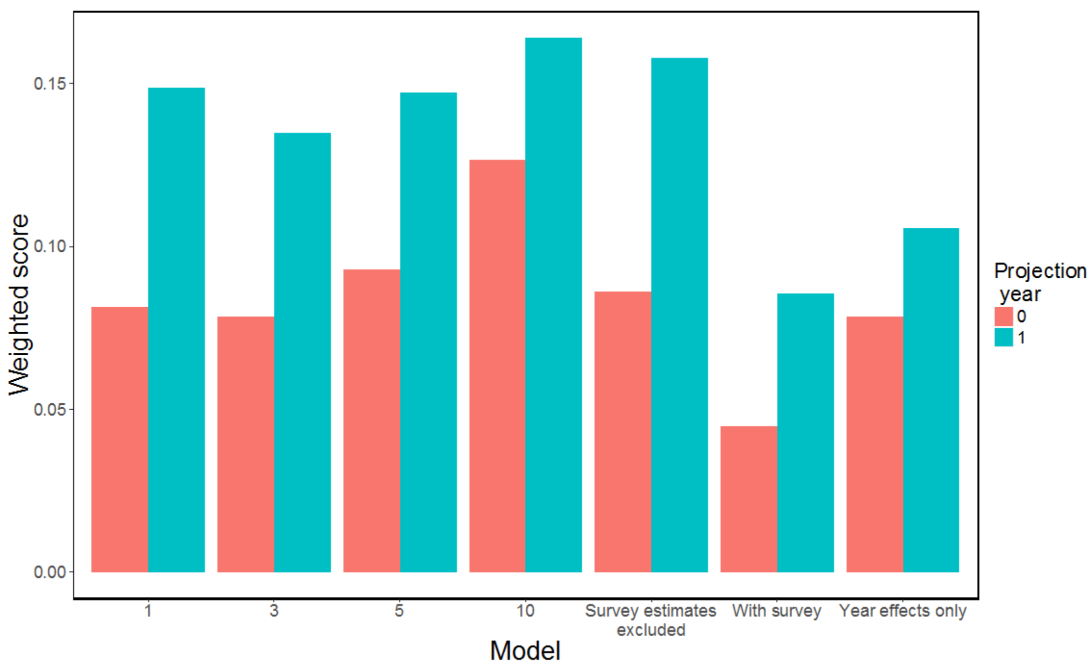


Figure 1a.3. “Out-of-sample” sv cores of performance for different methods for projecting average body weight where projection year of 0 means current (assessment) year and 1 means the coming year used for ABC estimation. Models labeled 1, 3, 5, and 10 represent the means over that many most recent years. The right-most “Models” are random effects approaches with and without survey data included.

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