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

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Executive Summary

This chapter covers the Eastern Bering Sea (EBS) region—the Aleutian Islands region (Chapter 1A) and the Bogoslof Island area (Chapter 1B) are presented separately.

Summary of changes in assessment inputs
The primary changes include:

- The summer bottom-trawl survey (BTS) biomass and abundance at age estimates from 1982-2005 were revised (slightly) and used. The change in data was attributed to dropping a fishing power correction (by vessel) that was applied with little current justification.
- The 2015 NMFS BTS biomass and abundance at age estimates were included.
- The 2014 and 2015 acoustic vessels-of-opportunity (AVO) data were processed and made available.
- The estimated *age* compositions from the 2014 NMFS summer acoustic-trawl (AT) survey were updated
- Observer data for catch-at-age and average weight-at-age from the 2014 fishery were finalized and included.
- Total catch as reported by NMFS Alaska Regional office was updated and included through 2015.

Changes in the assessment methods
The general modeling approach remained the same. A more fully developed treatment of uncertainty in current-year fishery mean weights-at-age and those used for near term projections was included. This approach estimated the variability of cohort-effects and year-effects using a simple model developed separately from the assessment (where the year and cohort effects are treated as random variables). This model was tuned to the observed fishery mean weights-at-age with observation variances estimated from a bootstrap resampling of fishery observer data. These same data were then included within the assessment model with the year and cohort effects estimated (but here as "fixed effects") setting the variance terms to the values estimated externally. This allows for a more appropriate accounting for and propagation of uncertainty in values for mean weights used for estimating F_{msy} uncertainty. This resulted in the risk-averse buffer between ABC and OFL (computed as 1-ABC/OFL) changing from 13% to about 22%, depending on selectivity configuration.

Summary of results

EBS pollock results

Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *recommended this* year for: 2016	2017
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)	9,203,000 t	11,000,000 t	11,300,000 t	11,000,000 t
Projected female spawning biomass (t)	**2,850,000 t**	**2,950,000 t**	**3,540,000 t**	**3,500,000 t**
B_0	5,162,000 t	5,162,000 t	5,676,000 t	5,676,000 t
B_{MSY}	1,948,000 t	1,948,000 t	1,984,000 t	1,984,000 t
F_{OFL}	0.587	0.587	0.514	0.514
$maxF_{ABC}$	0.512	0.512	0.401	0.401
F_{ABC}	0.24	0.25	0.27	0.26
OFL (t)	3,330,000 t	3,490,000 t	3,910,000 t	3,540,000 t
maxABC (t)	2,900,000 t	3,040,000 t	3,050,000 t	2,760,000 t
ABC (t)	1,637,000 t	1,554,000 t	2,090,000 t	2,019,000 t
Status	2013	2014	2014	2015
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 2016 and 2017.

New data presented in this assessment suggests that the above-average 2008 year class is slightly higher than before and that the 2012 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 (2,090,000 t) which is well below the maximum permissible (Tier 1a) value of 3,050,000 t. The Tier 1a overfishing level (OFL) is estimated to be 3,910,000 t.

Response to SSC and Plan Team comments

General comments:

Comments specific to this assessment

The BSAI Plan Team highlighted research priorities relative to how environmental factors affect the stock-recruitment relationship estimation and on further developments on combining acoustic and bottom trawl indices in a more integrated way

Some treatment of temperature effects is evaluated in the current assessment and research continues on ways to improve abundance indices from bottom trawls and mid-water acoustics. For example, in this assessment two years of acoustic data collected opportunistically from the BT survey fishing vessels have been added. This extends the AVO time series to 10 years, and methods to net-sample the acoustic backscatter for species and length composition have been developed and initiated.

The BSAI Team (2013 minutes) recommended the authors explore the use of a matrix of cohort-specific weights at age for making projections

As described above, a method for incorporating year and cohort-effect uncertainty into weight-at-age projections was developed and is presented in this assessment.

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 and it is presented here as Appendix 1.1 for review of stock structure issues. 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 been continually refined and improved. 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. Typically TACs have been set well below the ABC value and catches have usually stayed within these constraints (Table 1.2)

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 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. From 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, 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 49% (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. Since 2005 the annual proportion of catch within the SCA has dropped considerably (on average) with about 30% of the catch taken in this area. However, the proportion taken in the A-season reached 57% in 2007, the highest level since 1998, but in 2013 only 22% of the A-season catch occurred within the SCA (Table 1.3). In 2015 it decreased to 15% during the A season but was at 45% during B season.

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.

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. 1.2).

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 limits were reached but the fishery itself could continue to be prosecuted outside of those closed areas. The new program imposes a dual cap system which is divided by sector and season. Annual bycatch is intended to remain below the lower cap to avoid a penalty. In order to fish under the dual cap system (as opposed to solely the lower cap) sectors must participate in incentive program agreements (IPAs) that 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 - 2013, 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.

Measures to reduce salmon bycatch in the pollock fishery continue to be considered. The Council took action on amendment 110 to the BSAI Groundfish FMP in April 2015 to provide additional protection for Chinook salmon by imposing more restrictive PSC limits in times of low western Alaskan Chinook salmon abundance. Additional provisions were imposed on the IPAs that reduce fishing in months of higher bycatch encounters and mandate the use of salmon excluders in the trawl nets. These provisions were also included to manage chum salmon bycatch within the IPAs rather than through Amendment 84 to the FMP. Finally, in order to provide additional flexibility for catching pollock when salmon bycatch rates were low, Amendment 110 also allowed for a seasonal shift in catch to allow for an additional 5 % of the pollock to be caught in the A season while retaining the current provision for a full rollover of any unused TAC to the B season. A summary of some key management measures is provided in Table 1.4.

Fishery characteristics

The "A-season" for directed EBS pollock fishing opens on January 20th and extends into early-mid April. During this season, the fishery is characterized as producing 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 2015 spatial pattern had relatively high concentrations of fishing on the shelf north of Unimak Island, especially compared to the pattern observed in 2013 when most fishing activity occurred further north (Fig. 1.2). 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. 1.3).

The 2015 summer and fall (B-season) fishing continued the trend observed in 2014 with higher concentration of catches closer to Unimak Island and within the CVOA (Fig. 1.4). From 1979-2015 the catch of EBS pollock has averaged 1.189 million t (Table 1.1). Since 2001, the average has been above

1.270 million t. However, the 2009 and 2010 catch dropped to 0.81 million t due to stock declines and concomitant reductions in allowable harvest rates. Since 2011 the TAC (and catch) has averaged 1.26 million t.

Pollock retained and discarded catch (based on NMFS observer estimates) in the Eastern Bering Sea and Aleutian Islands for 1991- 2015 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.

Data

The following data were used in the assessment

Source	Type	Years
Fishery	Catch biomass	1964-2015
Fishery	Catch age composition	1964-2014
Fishery	Japanese trawl CPUE	1965-1976
EBS bottom trawl	Area-swept abundance (numbers) index by age	1982-2015
Acoustic trawl survey	Population abundance (numbers) index by age	1979, 1982, 1985, 1988, 1991, 1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006-2010, 2012, 2014
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 1991-2014 (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 those 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 and 2013 the 2008 year class became prominent as 4- and 5-year olds in the catches (Fig. 1.5; Table 1.6). The sampling effort for age determinations and lengths is shown in Tables 1.7 and 1.8. 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). Regarding the precision of total pollock catch biomass, Miller (2005) estimated the CV to be on the order of 1%.

Surveys

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 1.9. 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.

Bottom trawl surveys (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 consistent areas and gears. 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 abundance levels. Between 1991 and 2015 the BTS biomass estimates ranged from 2.28 to 8.39 million t (Table 1.10; Fig. 1.6). 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 about 3.7 million t—excluding the jump in biomass observed in 2014 and 2015 (which brings the 2004-2015 average to 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 (Fig. 1.7).

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%, the 2015 estimate is 7%, closer to the overall average of 6% (Table 1.11). 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 improve coverage over the range of the exploited pollock stock. The use of the additional strata was evaluated in 2006 and accepted as appropriate by the Council's SSC.

The 2015 biomass estimate was 6.39 million t, about 32% more than the average for this survey (4.84 million t). This survey estimate ranks 5th out of the 28 estimates since 1987, following the 2003, 2014, 1988 and 1989 estimates (8.39, 7.43, 7.29, and 6.55 million t, respectively). Pollock were distributed throughout the shelf region, with the biggest concentrations in the middle and outer domains, relatively unconstrained by the warmer bottom temperatures (Fig. 1.8). In the 2015 survey, as in 2014, pollock appeared to occur in higher densities at most stations than in 2013 and previous years (Fig. 1.9).

In general, much of the inter-annual variability of survey estimates is due to the effect of year class variability. Survey abundance-at-age estimates reflect the impact of this variability (Fig. 1.10). The BTS operations regularly catch pollock above 40 cm in length, and in some years include many 1-year olds (with modal lengths around 10-19 cm) but infrequently age 2 or 3 pollock (lengths around 20-29 cm and 30-39 cm, respectively). Other sources of variability may be unaccounted-for variability in natural mortality, survey catchability, and migration. For 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 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 2015 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 1.12. 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 1.13. Table 1.14 contains the values used for the efficiency “corrected” index. Mean body mass at ages from the survey are shown in Table 1.15.

As in previous assessments, a descriptive evaluation of the BTS data alone was conducted to examine mortality patterns similar to that 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 are still recruiting to the bottom trawl survey gear. 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. 1.11). 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. The low values for the most recent cohorts are due to the increased abundances observed since 2013

New studies on the efficiency of bottom-trawl gear for estimating pollock densities have been completed (Kotwicki et al. 2014). They found that bottom-trawl efficiency decreased with increasing bottom trawl catches, resulting in hyper-stability (under-estimates during high abundance levels) of the index of abundance derived from bottom trawl survey. They developed a method for correcting these density-dependent effects to avoid potential issues associated with hyper-stability. Since these factors can span years in the way they are modeled, the assessment model was modified to accept an estimated covariance matrix so that the BTS abundance data could be modeled following a multivariate normal distribution (see Model Details section below). This “corrected index” (normalized to have the same mean) shows a slight departure from the current BTS values and the estimated uncertainty is greater (Fig. 1.12). The input covariance matrix ($\mathbf{\Sigma}$) can be provided from the authors upon request.

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 1.16. . Estimated midwater pollock biomass for the shelf was above 4 million tons in the early years of the time series (Table 1.10). 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). The most recent midwater pollock biomass estimate from the 2014 AT survey, 3.44 million t, rose to within 1994-2004 levels, supported largely by the 2012, 2008, and 2010 year classes (Honkalehto and McCarthy 2015). Relative estimation errors for the total biomass (presented as CVs) were derived from a one-dimensional (1D) geostatistical method (Petitgas 1993, Walline 2007, Williamson and Traynor 1996; Table 1.17. 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 20% for application within the assessment model.

The updated numbers at age for the 2014 summer AT survey differed slightly over those based on the BTS age-length key used in Ianelli et al. (2014; Fig. 1.13; Table 1.17). In particular the estimates of 4 year olds (2010 year class) increased and the numbers of 6 year olds decreased slightly.

Spatially, the 2014 mid-water pollock distribution differed from recent years. The portion of shelf-wide biomass estimated to be east of 170º W was 41%, compared to an average of 26% since 1994 (Table 1.18). Also, the distribution of pollock biomass within the SCA rose to 12% compared to the 2007-2012 average of 7% (and 1994-2014 average of 9%).

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

In 2014 and 2015 acoustic data were collected from the two commercial fishing vessels chartered for the eastern Bering Sea bottom trawl (BT) survey as before (e.g.,von Szalay et al. 2007, Kotwicki et al. 2009, Honkalehto et al. 2011). Since 2006, these integrated 38 kHz backscatter acoustic data have provided a spatially explicit, annual index of midwater pollock that tracks the biennial midwater pollock biomass time series from the AT survey. The AVO index was first tried in the stock assessment in 2010, and was improved and more formally incorporated in 2011 (Ianelli et al. 2011). The data were processed according to Honkalehto et al. (2011) to provide an index of midwater pollock abundance in each year (Fig. 1.14). In summary:

1. The AVO index of midwater pollock abundance on the eastern Bering Sea shelf increased 29% from 2013 to 2014 and 6% from 2014 to 2015 (Table 1.19; Fig. 1.15).
2. With the addition of another annual comparison between results from AVO and the AFSC biennial acoustic-trawl survey conducted using NOAA Ship *Oscar Dyson* in summer 2014, the AVO index continues to be well correlated with pollock biomass from AT surveys conducted in the same year (r^2= 0.90; Honkalehto et al. in prep.).
3. The percentage of pollock backscatter east of the Pribilof Islands was 24% in 2014 and 25% in 2015. This is similar to the percentage in 2013 (26%) but much greater than the percentage in summers 2010-2012 (range 4-9%), implying more midwater pollock biomass east of the Pribilof Islands region in recent years. The increased percentage of pollock biomass east of the Pribilofs was also observed in the 2014 AT survey and largely attributed to dense aggregations of the 2012 year class.

Analytic approach

Model structure

A statistical age-structured assessment model conceptually outlined in Fournier and Archibald (1982) and similar to Methot's (1990) stock synthesis model was applied over the period 1964-2015. 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. The current model also was documented in an Academy of Sciences National Research Council report (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 main changes from last year's analyses include:

- The 2015 EBS bottom trawl survey estimate of population numbers-at-age was added.
- The 2014 EBS AT survey estimate of population numbers-at-age was updated using the age data from the AT survey (in 2014 the age data from the BTS survey was used to estimate the age-length key for the AT survey).
- The 2014 fishery age composition data were added.
- The 2014 and 2015 AVO index estimates of midwater pollock backscatter were added.

Parameters estimated outside of the assessment model

Natural mortality and maturity at age

For Model 1, 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

Maturity-at-age values were reevaluated based on the studies of Stahl (2004; subsequently Stahl and Kruse 2008a). Ianelli et al. (2005) investigated the inter-annual variability found by Stahl (2004). This involved using the fixed maturity-at-age levels presented above (for Model 1) to estimate total mature and immature numbers at age and then converting those to values at length using female mean-lengths at age (with an assumed natural variability about these means). Expected proportion mature-at-length for 2002 matched Stahl's data whereas for 2003, the model's expected values for maturity-at-length were shifted towards larger pollock. This result suggests that younger-than-currently-assumed pollock may contribute to the spawning stock. This minor change may be due to time varying effects on maturity and since this result was consistent, the maturity-at-age schedule was left at the same values used in all recent assessments (Smith 1981).

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). Regular age-determination methods coupled with extensive length and weight data collections show that growth may differ by sex, area, and year class. Pollock in the northwest area typically are 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.

Stock assessment models for groundfish in Alaska typically track numbers of individuals in the population. 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, these are typically only available up until the most recent completed calendar year of fishing (i.e., 2014 for the assessment conducted in 2015). 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 since age-composition data are unavailable).

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 1.20). The coefficients of variation between years are on the order of 6% to 9% (for the ages that are targeted) whereas the sampling variability is generally around 1% or 2%.

As requested, alternative approaches to account for the identified mean weight-at-age having clear year and cohort effects were developed with an objective to characterize the uncertainty due to observation and “process” variability (i.e., year-to-year variability in mean body weight at age). Fishery data from 1991-2014 collected by NMFS observers provide estimates and observation variances (shown as CVs) using the same bootstrap procedures used for catch-at-age estimation (Table 1.20). These summarized data were then modeled to estimate expected mean weights by age (*a*) over time (*t*) as

$$\hat{w}_{at} = \mu_a e^{\varepsilon_t^y + \varepsilon_a^c},\ \varepsilon_t^y \sim N\left(0, \sigma_y^2\right),\ \varepsilon_a^c \sim N\left(0, \sigma_c^2\right)$$

where the ε_t^y and ε_a^c terms are random effects representing year and cohort effects on mean fishery weights at age. The age range was restricted from 3 to 15 since the fishery has negligible catches and therefore data on younger pollock. Parameters estimated in this separate model thus include 13 for the mean ages (μ_a), the two variance terms, and the 66 random effects, counting the 13 cohorts represented by ages 3-15 starting in 1991, then the subsequent 26 more cohorts represented from 1992-2017 plus 27 year-effects. Results showing the data and model depiction indicate that the year and cohort effect does reasonably well at representing the pattern of mean body weights at age and also provides estimates of uncertainty for 2015-2017 that reflect the process (and observation) variability (CV of about 11% on average; Fig. 1.16). Since these data and processes can be considered separate from other aspects of the stock assessment model, the estimated cohort and year-effects variance estimates can translate this level of variability to the main stock assessment model. This was done by treating the cohort and year effects as new parameters in the assessment with their values conditioned on these same data as shown in Fig. 1.16 *and assuming the variance terms as estimated in the random effects model.* Tests evaluating the model predictions (using historical data and step-ahead predictions) show that these estimates outperformed a simple mean weight at age. Perhaps more importantly, having the variability reflected in future yet unobserved fishery mean-weights-at-age propagates uncertainty in estimates of F_{MSY} rates.

Parameters estimated inside the assessment model

For the selected model, 852 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment, and stock-recruitment parameters account for 75 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 1964-2015 and projected recruitment variability (using the variance of past recruitments) for five years (2015-2020). 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.

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. The annual components of fishing mortality result in 52 parameters and the age-time selectivity schedule forms a 10x51 matrix of 510 parameters bringing the total fishing mortality parameters to 562.

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 which scales 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. The selectivity parameters for the 2 main indices total 126 (the CPUE and AVO data mirror the fishery and AT survey selectivities, respectively).

Based on the work of von Szalay et al. (2007) prior distributions on the sum of the AT and BTS catchability coefficients were introduced in Ianelli et al. (2007). This simply allows an evaluation of the extent that the BTS covers the bottom-dwelling pollock (up to ~3 m above the bottom) and the AT survey covers the remainder of the water column. Conceptually, the catchabilities from both surveys could sum to unity (assuming fish lack behavioral responses to survey gear—e.g., herding or diving). Values of this sum that are less than one could imply that there are spatial aspects of the pollock stock that are missed whereas values greater than one could imply that there are pollock on the shelf during the summer that could be considered as visitors perhaps originating (and returning to) other areas such as the Russian zone.

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:

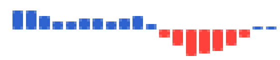
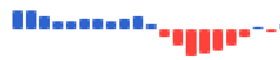
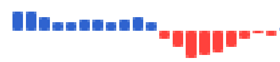
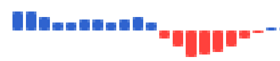
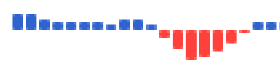
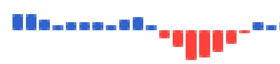
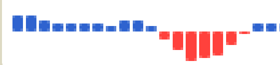
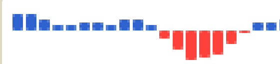
- Total catch biomass (log-normal, σ=0.05)
- Log-normal indices of abundance (numbers of fish; bottom trawl surveys assume annual estimates of sampling error, as represented in Fig. 1.6; for the AT index the annual errors were specified to have a mean of 0.20; while for the AVO data, a relative value was assumed which gave a mean of about 0.32).
- Fishery and survey proportions-at-age estimates (robust quasi-multinomial with effective sample sizes presented in Table 1.21).
- 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 1991-2014 and externally estimated variance terms as described in previous section.

Work evaluating temperature and predation-dependent effects on the stock-recruitment estimates has begun (Spencer et al. In Review). His approach modified the estimation the of the stock-recruitment relationship by including the effect of temperature and predation mortality. A quadratic pattern in recruitment residuals was noted (similar to that found in Mueter et al., 2011) which may result in lower expected pollock recruitment in the EBS under warmer conditions. Similar results relating summer temperature conditions to subsequent pollock recruitment for recent years were also found by Yasumiishi et al. (2015). The extent that such relationships affect the stock-recruitment estimates (and future productivity) is a continuing area of research.

Results

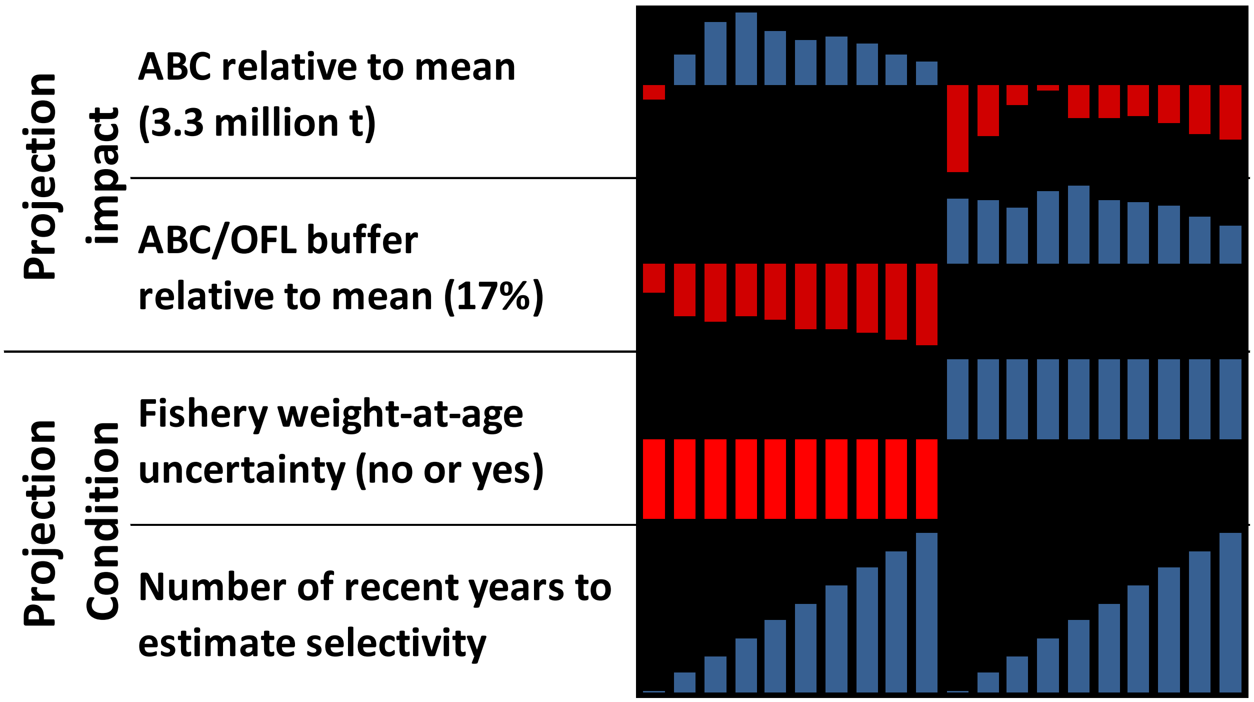
Model evaluation

A sequence of models were developed that evaluated sensitivities to new data which included updating the catch biomass for 2014 and estimated levels for 2015 along with the 2014 fishery mean weights-at-age. As in past years, a set of models showing the impact of new data was constructed, this year with a summary of the impact of these changes on the relative spawning biomass (last column):

Model		2015 catch	AT Age revised	2014 Fish Ages	BTS Std Index	BTS Alt Index	AVO Update	Spawning biomass relative to the average from 1995-2015
0.0	2014 assessment							
0.1	With updated catch and extended to 2015	X						
0.2	As 0.1 but with updated AT Age data	X	X					
0.3	As 0.2 but with 2014 fishery age	X	X	X				
0.4	As 0.3 but with standard BTS data added	X	X	X	X			
0.5	As 0.3 but with corrected BTS index data added	X	X	X		X		
0.6	As 0.4 but with AVO data added	X	X	X	X		X	
0.7	As 0.5 but with AVO data added	X	X	X		X	X	

Incremental updates and additions of new data to the model accepted last year show that the update of the AT age data relative to last year slightly reduced the trend in spawning biomass relative to the average from 1995-2015 (Model 0.2; right most column of table above) and adding the 2014 fishery age composition data (Model 0.3) tended to offset the slight reduction. The new 2015 BTS data changed the trend and the effect of the alternative BTS index and AVO data had minor impact (Models 0.4 – 0.7). Overall, the addition of the new data introduced in this assessment increased the spawning biomass estimates (Fig. 1.17). 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.

Relative to the average weights-at-age projected for the fishery and alternative assumptions about how to estimate "future selectivity" the following graphic shows the conditions (bottom two rows) and the impact on the buffer between ABC and OFL (computed as 1-ABC/OFL) for Tier 1 and the relative value of the maximum permissible ABC. The uncertainty in future mean weights-at-age has a relatively large impact and the selectivity estimation (based on the number of recent years over which to average selectivity) also affects results variably. For the subsequent ABC computations the conditions reflected in the 16th column were used; namely the setting that accounts for future uncertainty in mean weights-at-age in the fishery and using the most recent 6-year average (which was accepted and used in the past assessments). Note that this indicates that 5 years of fishery age composition data contribute to the estimated selectivity (i.e., data from the 2010-2014 fishery).



In the 2013 preliminary models (and again in the 2014 assessment), using an alternative index (Kotwicki et al. 2014) derived from the BTS data was tested. This index treats variability in survey efficiency depending on near-bottom fish density, and uses a different likelihood form and involves a multivariate covariance matrix spanning over years in the model fitting (see appendix for details). Results showed that adding the efficiency-corrected index resulted in generally better fits to other data components and also led to a slightly higher degree of uncertainty associated with the 2015 spawning biomass estimate in 2014 (Ianelli et al. 2014). Comparisons of this index with the standard were conducted again in 2015 and the results were similar; for brevity only the revised index data were used for further model presentations. The estimated parameters and standard errors are provided in Table 1.22 and summary model results are given in (Table 1.23).

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. 1.18). The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 1.19). The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) is consistent with the population trends for this period (Fig. 1.20). The fit to the fishery-independent index from the 2006-2015 AVO data differed with a poor fit to the most recent two index values (Fig. 1.21). This poorer fit in the index could be attributed lack of corroborating signals from other sources of data and their relatively high observation CVs.

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 and 2013 surveys (Fig. 1.22). 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. 1.23).

The AT survey selectivity estimates were allowed to differ in the 1979 survey; (Fig. 1.24; 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 fairly reasonable pattern of residuals (Fig. 1.24, bottom panel). The AT age compositions consistently track large year classes through the population and the model fits these patterns reasonably well (Fig. 1.25). The AT age-1 index is generally fit poorly but with residuals that appear to be reasonably random (Fig. 1.25, bottom panel).

Time series results

The estimate of B_{MSY} is 1,984,000 t (with a CV of 20%) which is less than the projected 2016 spawning biomass of 3,540,000 t; Table 1.23). For 2015, the Tier 1 levels of yield are 3,050,000 t from a fishable biomass estimated at around 7,610,000 t (Table 1.24). Estimated numbers-at-age are presented in Table 1.25 and estimated catch-at-age is presented in Table 1.26. Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment are given in Table 1.27.

Model results indicate that spawning biomass will be above $B_{40\%}$ (2,813,000 t) in 2016 and about 178% 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 2015 and 2016 (Fig. 1.26).

Another diagnostic (see Eq. 14 in appendix) on the impact of fishing shows that the 2015 spawning stock size is about 59% of the predicted value had no fishing occurred since 1978 (Table 1.23). This compares with the 50% of $B_{100\%}$ (based on the SPR expansion using mean recruitment from 1978-2012) and 61% 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.

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 1.28). 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 stabilized around 10 million t since 2011 following a low in 2008 at 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 a given spawning year) has been mostly below 20% since 1980 (Fig. 1.27). During 2006-2008 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 2014 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 nearly 0.3 when the TAC increased but has dropped since then and in 2014 was estimated at about 0.2. Age specific fishing mortality rates reflect these patterns and show some increases in the oldest ages from 2011-2013 but a decline recent years (Fig. 1.28). The proportion of the catch that was estimated to be immature has dropped in recent years but varies between 15% to above 30% (with the 1964-2015 total estimated at over 35%; (Fig. 1.29). The estimates of age 3+ pollock biomass were mostly higher than the estimates from previous years, especially the past 4 assessments (Fig. 1.30, Table 1.28).

One way to evaluate past management and assessment performance is 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. 1.31).

Recruitment

Model estimates indicate that the 2008 year class is well above the average level (Fig. 1.32) and shows a general increase relative to the 2014 assessment. 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. 1.33). Note that the 2013 and 2014 year classes (as age 1 recruits in 2014 and 2015) are excluded from estimating the stock-recruitment curve.

Environmental factors affecting recruitment

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, 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 average catches.

Retrospective analysis

As requested by the SSC and Plan Team, retrospective analyses were again conducted with results that differed considerably from previous years. The model runs indicate that the 2014 and 2015 data affect the overall historical biomass trajectory (Fig. 1.34). Previous results indicated a slight tendency for over-estimation of spawning biomass when it is declining and a slight tendency for underestimation during increases. The data from 2014 and 2015 made the retrospective pattern (for the 10-year period) appear as mainly underestimates with Mohn's rho equal to -0.14. However, the retrospective estimates still fall well within the bounds of uncertainty (Figs. 1.34).

Harvest recommendations

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} = 1,984 thousand t female spawning biomass

B_0 = 5,676 thousand t female spawning biomass

$B_{100\%}$ = 7,032 thousand t female spawning biomass

$B_{40\%}$ = 2,813 thousand t female spawning biomass

$B_{35\%}$ = 2,461 thousand t female spawning biomass

Specification of OFL and Maximum Permissible ABC

The 2016 spawning biomass is estimated to be 3,540,000 t (at the time of spawning, assuming the stock is fished at recommended ABC level). This is above the B_{MSY} value of 1,984,000 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 2016 female spawning biomass is estimated to be above the B_{MSY} level (1,984,000 t) and the $B_{40\%}$ value (2,813,000 t) in 2016 and assuming that the 2015 catch equals 1.35 million t, the OFL and maximum permissible ABC values by the different Tiers would be:

Tier	Year	MaxABC	OFL
1a	2016	3,050,000 t	3,910,000 t
1a	2017	2,760,000 t	2,760,000 t

Tier	Year	MaxABC	OFL
3a	2016	2,090,000 t	2,580,000 t
3a	2017	2,019,000 t	2,320,000 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 2015 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2016 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2015. 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 2016 and 2017, 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 2016 and 2017 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 is in 2016 would equal the 2014 estimate).

Scenario 3: In all future years, *F* is set equal to the 2011-2015 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 2015 or 2) above ½ of its MSY level in 2015 and above its MSY level in 2025 under this scenario, then the stock is not overfished.)

Scenario 7: In 2016 and 2017, *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 2017 or 2) above 1/2 of its MSY level in 2017 and expected to be above its MSY level in 2027 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 2015 (Table 1.29). 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. 1.35).

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 2015:

If spawning biomass for 2015 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.

If spawning biomass for 2015 is estimated to be above $B_{35\%}$, the stock is above its MSST.

If spawning biomass for 2015 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 1.29). If the mean spawning biomass for 2025 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 2017 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
>
> If the mean spawning biomass for 2017 is above $B_{35\%}$, the stock is not approaching an overfished condition.
>
> If the mean spawning biomass for 2017 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2027. If the mean spawning biomass for 2027 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 2015, nor is it expected to be approaching an overfished condition based on Scenario 7 (the mean spawning biomass in 2015 is above the $B_{35\%}$ level; Table 1.29). Tier 1 calculations for ABC and OFL values in 2016 and 2017 (assuming catch is 1,350,000 t in 2016 are given in Table 1.30. Based on this, the EBS pollock stock is not being subjected to overfishing.

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 2015 spawning biomass (3,483 kt) that is about 178% of B_{MSY} (1,984 kt). The replacement yield—defined as the catch next year that is expected to achieve a 2017 spawning biomass estimate equal to that from 2015—is estimated to be about 2,040,000 t.

Even though the EBS pollock stock has appeared to recover from its 2008 low, there remain reasons to specify an ABC below the maximum permissible Tier 1 (or Tier 3) values. For example, the fleet was able to operate with reasonably good catch rates and maintain salmon bycatch at relatively low levels. This includes fishing earlier in the season to avoid the late-season higher chinook bycatch rates.

Given these factors, a 2016 ABC of 2,090,000 t is recommended based on the Tier 3 estimates as conservatively selected by the SSC in 2014, recognizing 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 risky even with the improvements in accounting for future mean weights at age. Also, 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). In terms of magnitude, pollock cannibalism may account for 2.5 million t to nearly 5 million t of pollock consumed (based on uncertainties in diet percentage and total consumption rate; Jurado-Molina et al. 2005).

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 1.31. 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).

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). In the 2009 SAFE report, an analysis of MACE AT survey backscatter as an index of euphausiid abundance on the Bering Sea shelf was presented. The spatial distributions and trends were evaluated using methods described in De Robertis et al. (2010) and Ressler et al. (2012). This information is presented in the Ecosystem Consideration chapter and indicates declines observed in both the 2012 and

2014 surveys relative to the 2009 peak. It is noteworthy that this index shows a peak abundance in 2009 which may have contributed to the survival of the 2008 year class of EBS pollock.

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 1.32). 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 1.33). 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 1.34).

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 1.35). 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 year class to be at record 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).

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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References

Aydin, K. Y., et al.2002. A comparison of the Eastern Bering and western Bering Sea shelf and slope ecosystems through the use of mass-balance food web models. U.S. Department of Commerce, Seattle, WA. (NOAA Technical Memorandum NMFS-AFSC-130) 78p.

Bacheler, N.M., L. Ciannelli, K.M. Bailey, and J.T. Duffy-Anderson. 2010. Spatial and temporal patterns of walleye pollock (*Theragra chalcogramma*) spawning in the eastern Bering Sea inferred from egg and larval distributions. Fish. Oceanogr. 19:2. 107-120.

Bailey, K.M., T.J. Quinn, P. Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, *Theragra chalcogramma*. Advances in Mar. Biol. 37:179-255.

Barbeaux, S. J., S. Gaichas, J. N. Ianelli, and M. W. Dorn. 2005. Evaluation of biological sampling protocols for at-sea groundfish observers in Alaska. Alaska Fisheries Research Bulletin 11(2):82-101.

Barbeaux, S.J., Horne, J., Ianelli, J. 2014. A novel approach for estimating location and scale specific fishing exploitation rate of eastern Bering Sea walleye pollock (*Theragra chalcogramma*). Fish. Res. 153 p. 69 – 82.

Brodeur, R.D.; Wilson, M.T.; Ciannelli, L.; Doyle, M. and Napp, J.M. (2002). Interannual and regional variability in distribution and ecology of juvenile pollock and their prey in frontal structures of the Bering Sea. Deep-Sea Research II. 49: 6051-6067.

Butterworth, D.S., J.N. Ianelli, and R. Hilborn. 2003. A statistical model for stock assessment of southern bluefin tuna with temporal changes in selectivity. Afr. J. mar. Sci. 25: 331-361.

Canino, M.F., P.T. O'Reilly, L. Hauser, and P. Bentzen. 2005. Genetic differentiation in walleye pollock (*Theragra chalcogramma*) in response to selection at the pantophysin (*Pan* I) locus. Can. J. Fish. Aquat. Sci. 62:2519-2529.

Ciannelli, L., B.W. Robson, R.C. Francis, K. Aydin, and R.D. Brodeur 2004a. Boundaries of open marine ecosystems: an application to the Pribilof Archipelago, southeast Bering Sea. *Ecological Applications,* Volume 14, No. 3. pp. 942-953.

Ciannelli, L.; Brodeur, R.D., and Napp, J.M. 2004b. Foraging impact on zooplankton by age-0 walleye pollock (*Theragra chalcogramma)* around a front in the southeast Bering Sea. Marine Biology. 144: 515-525.

Clark, W.G. 1999. Effects of an erroneous natural mortality rate on a simple age-structured model. Can. J. Fish. Aquat. Sci. 56:1721-1731.

Cooper, D. W., Duffy-Anderson, J. T., Norcross, B. L., Holladay, B. A., & Stabeno, P. J. (2014). Nursery areas of juvenile northern rock sole (Lepidopsetta polyxystra) in the eastern Bering Sea in relation to hydrography and thermal regimes. *ICES Journal of Marine Science*, *71*(7), 1683–1695. doi:10.1093/icesjms/fst210

Cotter, A.J.R., L. Burt, C.G.M Paxton, C. Fernandez, S.T. Buckland, and J.X Pan. 2004. Are stock assessment methods too complicated? Fish and Fisheries, 5:235-254.

Cotter, A. J. R., Mesnil, B., and Piet, G. J. 2007. Estimating stock parameters from trawl cpue-at-age series using year-class curves. – ICES Journal of Marine Science, 64: 234–247.

Coyle, K. O., Eisner, L. B., Mueter, F. J., Pinchuk, A. I., Janout, M. A., Cieciel, K. D., … Andrews, A. G. (2011). Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. *Fisheries Oceanography*, *20*(2), 139–156. doi:10.1111/j.1365-2419.2011.00574.x

De Robertis, A., and K. Williams. 2008. Weight-length relationships in fisheries studies: the standard allometric model should be applied with caution. Trans. Am. Fish. Soc. 137:707-719.

De Robertis, A., McKelvey, D.R., and Ressler, P.H. 2010. Development and application of empirical multi-frequency methods for backscatter classification in the North Pacific. Can. J. Fish. Aquat. Sci. 67: 1459-1474.

Dorn, M.W. 1992. Detecting environmental covariates of Pacific whiting *Merluccius productus* growth using a growth-increment regression model. Fish. Bull. 90:260-275.

Fissel, B., M. Dalton, R. Felthoven, B. Garber-Yonts, A. Haynie, A. Himes-Cornell, S. Kasperski, J. Lee, D. Lew, and C. Seung. 2014. Stock assessment and fishery evaluation report for the Groundfish fisheries of the Gulf of Alaska and Bering Sea/Aleutian Islands area: Economic status of the groundfish fisheries off Alaska, 2013.

Fournier, D.A. and C.P. Archibald. 1982. A general theory for analyzing catch-at-age data. Can. J. Fish. Aquat. Sci. 39:1195-1207.

Fournier, D.A., J.R. Sibert, J. Majkowski, and J. Hampton. 1990. MULTIFAN a likelihood-based method for estimating growth parameters and age composition from multiple length frequency samples with an application to southern bluefin tuna (*Thunnus maccoyii*). Can. J. Fish. Aquat. Sci. 47:301-317.

Francis, R.I.C.C., and Shotton, R. 1997. Risk in fisheries management: a review. Can. J. Fish. Aquat. Sci.54: 1699–1715.

Francis, R.I.C.C. 1992. Use of risk analysis to assess fishery management strategies: a case study using orange roughy (*Hoplostethus atlanticus*) on the Chatham Rise, New Zealand. Can. J. Fish. Aquat. Sci. 49: 922-930.

Francis, R I C C 2011. Data weighting in statistical fisheries stock assessment models. Can. Journ. Fish. Aquat. Sci. 1138: 1124-1138.

Gislason, H., Daan, N., Rice, J. C., & Pope, J. G. (2010). Size, growth, temperature and the natural mortality of marine fish. *Fish and Fisheries*, *11*(2), 149–158. doi:10.1111/j.1467-2979.2009.00350.

Grant, W. S., Spies, I., and Canino, M. F. 2010. Shifting-balance stock structure in North Pacific walleye pollock (*Gadus chalcogrammus*). – ICES Journal of Marine Science, 67:1686-1696.

Greiwank, A., and G.F. Corliss (eds.) 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan. 6-8, Breckenridge, CO. Soc. Indust. And Applied Mathematics, Philadelphia.

Hinckley, S. 1987. The reproductive biology of walleye pollock, *Theragra chalcogramma*, in the Bering Sea, with reference to spawning stock structure. Fish. Bull. 85:481-498.

Hollowed, A. B., J. N. Ianelli, and P. A. Livingston. 2000. Including predation mortality in stock assessments: A case study involving Gulf of Alaska walleye pollock. ICES Journal of Marine Science, 57, pp. 279-293.

Hollowed, A. B., Aydin, K. Y., Essington, T. E., Ianelli, J. N., Megrey, B. a, Punt, A. E., & Smith, A. D. M. (2011). Experience with quantitative ecosystem assessment tools in the northeast Pacific. *Fish and Fisheries*, *12*(2), 189–208. doi:10.1111/j.1467-2979.2011.00413.

Hollowed, A. B., Barbeaux, S. J., Cokelet, E. D., Farley, E., Kotwicki, S., Ressler, P. H., … Wilson, C. D. 2012. Effects of climate variations on pelagic ocean habitats and their role in structuring forage fish distributions in the Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, *65-70*, 230–250. doi:10.1016/j.dsr2.2012.02.008

Honkalehto, T., Ressler, P.H., Towler, R.H., Wilson, C.D., 2011.Using acoustic data from fishing vessels to estimate walleye pollock (*Theragra chalcogramma*) abundance in the eastern Bering Sea. 2011. Can. J. Fish. Aquat. Sci. 68: 1231–1242

Honkalehto, T., D. McKelvey, and N. Williamson. 2005. Results of the echo integration-trawl survey of walleye pollock (*Theragra chalcogramma*) on the U.S. and Russian Bering Sea shelf in June and July 2004. AFSC Processed Rep. 2005-02, 43 p.

Honkalehto, T, A. McCarthy, P. Ressler, K. Williams, and D. Jones. 2012. Results of the Acoustic-Trawl Survey of Walleye Pollock (*Theragra chalcogramma*) on the U.S. and Russian Bering Sea Shelf in June - August 2010. AFSC Processed Rep. 2012-01, 57 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Honkalehto, T., A. McCarthy, P. Ressler, and D. Jones, 2013. Results of the acoustic-trawl survey of walleye pollock (*Theragra chalcogramma*) on the U.S., and Russian Bering Sea shelf in June–August 2012 (DY1207). AFSC Processed Rep. 2013-02, 60 p. Alaska Fish. Sci. Cent. NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115. Available from http://www.afsc.noaa.gov/Publications/ProcRpt/PR2013-02.pdf

Honkalehto, T, P. H. Ressler, S. C. Stienessen, Z. Berkowitz, R. H. Towler, a. L. Mccarthy, and R. R. Lauth. 2014. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2012-2013. AFSC Processed Rep. 2014-04, 19 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115. http://www.afsc.noaa.gov/Publications/ProcRpt/PR2013-02.pdf

Honkalehto, T, and A. McCarthy. 2015. Results of the Acoustic-Trawl Survey of Walleye Pollock (*Gaddus chalcogrammus*) on the U.S. and Russian Bering Sea Shelf in June - August 2014. AFSC Processed Rep. 2015-07, 62 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115. Available from: http://www.afsc.noaa.gov/Publications/ProcRpt/ PR2015-07.pdf

Hulson, P.-J.F., Miller, S.E., Ianelli, J.N., and Quinn, T.J., II. 2011. Including mark–recapture data into a spatial age-structured model: walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea. Can. J. Fish. Aquat. Sci. 68(9): 1625–1634. doi:10.1139/f2011-060.

Hulson, P. F., Quinn, T. J., Hanselman, D. H., Ianelli, J. N. (2013). Spatial modeling of Bering Sea walleye pollock with integrated age-structured assessment models in a changing environment. Canadian Journal of Fisheries & Aquatic Sciences, 70(9), 1402-1416. doi:10.1139/cjfas-2013-0020.

Hunt Jr., G.L., K.O. Coyle, L. Eisner, E.V. Farley, R. Heintz, F. Mueter, J.M. Napp, J.E. Overland, P.H. Ressler, S. Salo, and P.J. Stabeno. Climate impacts on eastern Bering Sea food webs: A synthesis of new data and an assessment of the Oscillating Control Hypothesis. Submitted to ICES Journal of Marine Science.

Ianelli, J.N. 2005. Assessment and Fisheries Management of Eastern Bering Sea Walleye Pollock: is Sustainability Luck Bulletin of Marine Science, Volume 76, Number 2, April 2005 , pp. 321-336(16)

Ianelli, J.N. and D.A. Fournier. 1998. Alternative age-structured analyses of the NRC simulated stock assessment data. *In* Restrepo, V.R. [ed.]. Analyses of simulated data sets in support of the NRC study on stock assessment methods. NOAA Tech. Memo. NMFS-F/SPO-30. 96 p.

Ianelli, J.N., L. Fritz, T. Honkalehto, N. Williamson and G. Walters 1998. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 1999. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-79.

Ianelli, J.N., S. Barbeaux, G. Walters, T. Honkalehto, and N. Williamson. 2004. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2005. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:37-126.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, N. Williamson and G. Walters. 2003. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2003. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-101.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin and N. Williamson. 2009. Assessment of the walleye pollock stock in the Eastern Bering Sea. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:49-148.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin and N. Williamson. 2008. Assessment of the walleye pollock stock in the Eastern Bering Sea. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:47-137.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin and N. Williamson. 2007. Eastern Bering Sea walleye pollock. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:41-138.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin, and N. Williamson. 2006. Assessment of Alaska Pollock Stock in the Eastern Bering Sea. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:35-138.

Ianelli, J.N., T. Buckley, T. Honkalehto, G Walters, and N. Williamson 2001. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2002. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/ Aleutian Islands regions. North Pac. Fish. Mgmt. Council Anchorage, AK, Section 1:1-79

Ianelli, J.N., Barbeaux, S., Honkalehto, T., Kotwicki, S., Aydin, K., and Williamson, N. Assessment of the walleye pollock stock in the eastern Bering Sea. 2009. Stock Assessment. NPFMC Bering Sea and Aleutian Islands

Stock Assessment and Fishery Evaluation (SAFE) Report for 2010. Alaska Fisheries Science Center. URL: http://www.afsc.noaa.gov/refm/docs/2009/EBSpollock.pdf

Ianelli, J.N., S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin and N. Williamson. 2010. Assessment of the walleye pollock stock in the Eastern Bering Sea. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:53-156.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin and N. Williamson. 2011. Assessment of the walleye pollock stock in the Eastern Bering Sea. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:58-157.

Ianelli, J.N., T. Honkalehto, S. Barbeaux, S. Kotwicki, K. Aydin, and N. Williamson, 2012. Assessment of the walleye pollock stock in the Eastern Bering Sea, pp. 51-156. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions for 2013. North Pacific Fishery Management Council, Anchorage, AK. Available from http://www.afsc.noaa.gov/REFM/docs/2012/EBSpollock.pdf

Ianelli, J.N., T. Honkalehto, S. Barbeaux, S. Kotwicki, K. Aydin, and N. Williamson, 2013. Assessment of the walleye pollock stock in the Eastern Bering Sea, pp. 51-156. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions for 2014. North Pacific Fishery Management Council, Anchorage, AK. Available from http://www.afsc.noaa.gov/REFM/docs/2013/EBSpollock.pdf

Ianelli, J.N., A.B. Hollowed, A.C. Haynie, F.J. Mueter, and N.A. Bond. 2011. Evaluating management strategies for eastern Bering Sea walleye pollock (*Theragra chalcogramma*) in a changing environment. ICES Journal of Marine Science, doi:10.1093/icesjms/fsr010.

Ianelli, J.N. and D.L. Stram. 2014. Estimating impacts of the pollock fishery bycatch on western Alaska Chinook salmon. ICES Journal of Marine Science. doi:10.1093/icesjms/fsu173

Jurado-Molina J., P. A. Livingston and J. N. Ianelli. 2005. Incorporating predation interactions to a statistical catch-at-age model for a predator-prey system in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences. 62(8): 1865-1873.

Jensen, A. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences 53, 820–822.

Kastelle, C. R., and Kimura, D. K. 2006. Age validation of walleye pollock (*Theragra chalcogramma*) from the Gulf of Alaska using the disequilibrium of Pb-210 and Ra-226. e ICES Journal of Marine Science, 63: 1520e1529.

Kimura, D.K. 1989. Variability in estimating catch-in-numbers-at-age and its impact on cohort analysis. *In* R.J. Beamish and G.A. McFarlane (eds.), Effects on ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aq. Sci. 108:57-66.

Kimura, D.K., J.J. Lyons, S.E. MacLellan, and B.J. Goetz. 1992. Effects of year-class strength on age determination. Aust. J. Mar. Freshwater Res. 43:1221-8.

Kimura, D.K., C.R. Kastelle , B.J. Goetz, C.M. Gburski, and A.V. Buslov. 2006. Corroborating ages of walleye pollock (*Theragra chalcogramma*), Australian J. of Marine and Freshwater Research 57:323-332.

Kotenev, B.N. and A.I. Glubokov. 2007. Walleye pollock *Theregra chalcogramma* from the Navarin Region and adjacent waters of the Bering Sea: ecology, biology, and stock structure. Moscow VNIRO publishing. 180p.

Kotwicki, S., T.W. Buckley, T. Honkalehto, and G. Walters. 2004. Comparison of walleye pollock data collected on the Eastern Bering Sea shelf by bottom trawl and echo integration trawl surveys. (poster presentation available at: ftp://ftp.afsc.noaa.gov/posters/pKotwicki01 pollock.pdf).

Kotwicki, S., T.W. Buckley, T. Honkalehto, and G. Walters. 2005. Variation in the distribution of walleye pollock (*Theragra chalcogramma*) with temperature and implications for seasonal migration. Fish. Bull 103:574–587.

Kotwicki, S., A. DeRobertis, P. vonSzalay, and R. Towler. 2009. The effect of light intensity on the availability of walleye pollock (*Theragra chalcogramma*) to bottom trawl and acoustic surveys. Can. J. Fisheries and Aquatic Science. 66(6): 983–994.

Kotwicki, S. and Lauth R.R. 2013. Detecting temporal trends and environmentally-driven changes in the spatial distribution of groundfishes and crabs on the eastern Bering Sea shelf. Deep-Sea Research Part II: Topical Studies in Oceanography. 94:231-243.

Kotwicki, S., Ianelli, J. N., & Punt, A. E. 2014. Correcting density-dependent effects in abundance estimates from bottom-trawl surveys. *ICES Journal of Marine Science*, *71*(5), 1107–1116.

Kotwicki, S. JN Ianelli, and André E. Punt. In press. Correcting density-dependent effects in abundance estimates from bottom trawl surveys. ICES Journal of Marine Science.

Lang, G.M., Livingston, P.A., Dodd, K.A., 2005. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1997 through 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-158, 230p. http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-158.pdf

Lang, G.M., R.D. Brodeur, J.M. Napp, and R. Schabetsberger. (2000). Variation in groundfish predation on juvenile walleye pollock relative to hydrographic structure near the Pribilof Islands, Alaska. ICES Journal of Marine Science. 57:265-271.

Lauth, R.R., J.N. Ianelli, and W.W. Wakefield. 2004. Estimating the size selectivity and catching efficiency of a survey bottom trawl for thornyheads, *Sebastolobus spp.* using a towed video camera sled. Fisheries Research. 70:39-48.

Lehodey, P., I. Senina, and R. Murtugudde. 2008. A spatial ecosystem and populations dynamics model (SEAPODYM) – Modeling of tuna and tuna-like populations. Progress in Oceanography 78: 304–318.

Livingston, P. A., and Methot, R. D. (1998). Incorporation of predation into a population assessment model of Eastern Bering Sea walleye pollock. *In* Fishery Stock Assessment Models. NOAA Technical Report 126, *NMFS F/NWC-54*, Alaska Sea Grant Program, 304 Eielson Building, University of Alaska Fairbanks, Fairbanks, AK 99775. pp. 663-678.

Livingston, P.A. (1991). Walleye pollock. Pages 9-30 in: P.A. Livingston (ed.). Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea, 1984-1986. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/NWC-207, 240 p.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. J. Fish. Biol. 49:627-647.

Lorenzen, K. 2000. Allometry of natural mortality as a basis for assessing optimal release size in fish-stocking programmes. Canadian Journal of Fisheries and Aquatic Sciences 57, 2374-2381.

Low, L.L., and Ikeda. 1980. Average density index of walleye pollock in the Bering Sea. NOAA Tech. Memo. SFRF743.

Mace, P., L. Botsford, J. Collie, W. Gabriel, P. Goodyear J. Powers, V. Restrepo, A. Rosenberg, M. Sissenwine, G. Thompson, J. Witzig. 1996. Scientific review of definitions of overfishing in U.S. Fishery Management Plans. NOAA Tech. Memo. NMFS-F/SPO-21. 20 p.

Martinson, E.C., H.H. Stokes and D.L. Scarnecchia. 2012. Use of juvenile salmon growth and temperature change indices to predict groundfish post age-0 yr class strengths in the Gulf of Alaska and eastern Bering Sea. Fisheries Oceanography 21:307-319.

McAllister, M.K. and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Can. J. Fish. Aquat. Sci. 54:284-300.

Merritt, M.F. and T.J. Quinn II. 2000. Using perceptions of data accuracy and empirical weighting of information: assessment of a recreational fish population. Canadian Journal of Fisheries and Aquatic Sciences. 57: 1459-1469.

Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *In* Proceedings of the symposium on applications of stock assessment techniques to Gadids. L. Low [ed.]. Int. North Pac. Fish. Comm. Bull. 50: 259-277.

Miller, T.J. 2005. Estimation of catch parameters from a fishery observer program with multiple objectives. PhD Dissertation. Univ. of Washington. 419p.

Mohn, R. 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. Ices J. Mar Sci. 56, 473-488.

Moss, J.H., E.V. Farley, Jr., A.M. Feldmann, and J.N. Ianelli. (in review). Spatial distribution, energetic status, and food habits of eastern Bering Sea age-0 walleye pollock. Transactions of the American Fisheries Society.

Mueter, F. J., and M. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. Ecological Applications 18:309–320.

Mueter, F. J., C. Ladd, M. C. Palmer, and B. L. Norcross. 2006. Bottom-up and top-down controls of walleye pollock (*Theragra chalcogramma*) on the Eastern Bering Sea shelf. Progress in Oceanography 68:152-183.

Mueter, F. J., N.A. Bond, J.N. Ianelli, and A.B. Hollowed. 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. ICES Journal of Marine Science.

O'Reilly, P.T., M.F. Canino, K.M. Bailey and P. Bentzen. 2004. Inverse relationship between F_{ST} and microsatellite polymorphism in the marine fish, walleye pollock (*Theragra chalcogramma*): implications for resolving weak population structure. *Molecular Ecology (2004) 13, 1799–1814*

Parma, A.M. 1993. Retrospective catch-at-age analysis of Pacfic halibut: implications on assessment of harvesting policies. *In* Proceedings of the International Symposium on Management Strategies of Exploited Fish Populations. Alaska Sea Grant Rep. No. 93-02. Univ. Alaska Fairbanks.

Petitgas, P. 1993. Geostatistics for fish stock assessments: a review and an acoustic application. ICES J. Mar. Sci. 50: 285-298.

Powers, J. E. 2014. Age-specific natural mortality rates in stock assessments: size-based vs. density-dependent. *ICES Journal of Marine Science*, *71*(7), 1629–1637.

Press, W.H., S.A. Teukolsky, W.T. Vetterling, B.P. Flannery. 1992. Numerical Recipes in C. Second Ed. Cambridge University Press. 994 p.

Punt, A.E., Smith, D.C., KrusicGolub, K. and Robertson, S. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia's Southern and Eastern Scalefish and Shark Fishery. *Can. J. Fish. Aquat. Sci.* 65:1991-2005.

Ressler, P.H., De Robertis, A., Warren, J.D., Smith, J.N., and Kotwicki, S. (2012). Using an acoustic index of euphausiid abundance to understand trophic interactions in the Bering Sea ecosystem. Deep-Sea Res. II. 0967-0645,

Restrepo, V.R., G.G. Thompson, P.M Mace, W.L Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade, and J.F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Tech. Memo. NMFS-F/SPO-31. 54 p.

Schnute, J.T. 1994. A general framework for developing sequential fisheries models. Can. J. Fish. Aquat. Sci. 51:1676-1688.

Schnute, J.T. and Richards, L.J. 1995. The influence of error on population estimates from catch-age models. Can. J. Fish. Aquat. Sci. 52:2063-2077.

Smith, G.B. 1981. The biology of walleye pollock. *In* Hood, D.W. and J.A. Calder, The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I. U.S. Dep. Comm., NOAA/OMP 527-551.

Stahl, J. 2004. Maturation of walleye pollock, *Theragra chalcogramma*, in the Eastern Bering Sea in relation to temporal and spatial factors. Masters thesis. School of Fisheries and Ocean Sciences, Univ. Alaska Fairbanks, Juneau. 000p.

Stahl, J., and G. Kruse. 2008a. Spatial and temporal variability in size at maturity of walleye pollock in the eastern Bering Sea. Transactions of the American Fisheries Society 137:1543–1557.

Stahl, J., and G. Kruse. 2008b. Classification of Ovarian Stages of Walleye Pollock (*Theragra chalcogramma*). In Resiliency of Gadid Stocks to Fishing and Climate Change. Alaska Sea Grant College Program • AK-SG-08-01.

Sterling, J. T. and R. R. Ream 2004. At-sea behavior of juvenile male northern fur seals (*Callorhinus ursinus*). Canadian Journal of Zoology 82: 1621-1637.

Stram, D. L., and Ianelli, J. N. 2014. Evaluating the efficacy of salmon bycatch measures using fishery-dependent data. *ICES Journal of Marine Science, 3*(2). doi:10.1093/icesjms/fsu168

Swartzman, G.L., A.G. Winter, K.O. Coyle, R.D. Brodeur, T. Buckley, L. Ciannelli, G.L. Hunt, Jr., J. Ianelli, and S.A. Macklin (2005). Relationship of age-0 pollock abundance and distribution around the Pribilof Islands with other shelf regions of the Eastern Bering Sea. Fisheries Research, Vol. 74, pp. 273-287.

Takahashi, Y, and Yamaguchi, H. 1972. Stock of the Alaska pollock in the eastern Bering Sea. Bull. Jpn. Soc. Sci. Fish. 38:418-419.

Thompson, G.G. 1996. Risk-averse optimal harvesting in a biomass dynamic model. Unpubl. Manuscr., 54 p. Alaska Fisheries Science Center, 7600 Sand Pt. Way NE, Seattle WA, 98115. Distributed as Appendix B to the Environmental Analysis Regulatory Impact Review of Ammendments 44/44 to the Fishery Management Plans for the Groundfish Fisheries of the Bering Sea and Aleutian Islands Area and the Gulf of Alaska.

von Szalay PG, Somerton DA, Kotwicki S. 2007. Correlating trawl and acoustic data in the Eastern Bering Sea: A first step toward improving biomass estimates of walleye pollock (*Theragra chalcogramma*) and Pacific cod (*Gadus macrocephalus*)? Fisheries Research 86(1) 77-83.

Walline, P. D. 2007. Geostatistical simulations of eastern Bering Sea walleye pollock spatial distributions, to estimate sampling precision. ICES J. Mar. Sci. 64:559-569.

Walters, C. J., and J. F. Kitchell. 2001. Cultivation/depensation effects on juvenile survival and recruitment. Can. J. Fish. Aquat. Sci. 58:39-50.

Wespestad, V. G. and J. M. Terry. 1984. Biological and economic yields for Eastern Bering Sea walleye pollock under differing fishing regimes. N. Amer. J. Fish. Manage., 4:204-215.

Wespestad, V. G., J. Ianelli, L. Fritz, T. Honkalehto, G. Walters. 1996. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 1997. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-73.

Wespestad, V. G., L. W. Fritz, W. J. Ingraham, and B. A. Megrey. 2000. On relationships between cannibalism, climate variability, physical transport, and recruitment success of Bering Sea walleye pollock (*Theragra chalcogramma*). ICES Journal of Marine Science **57**:272-278.

Williamson, N., and J. Traynor. 1996. Application of a one-dimensional geostatistical procedure to fisheries acoustic surveys of Alaskan pollock. ICES J. Mar. Sci. 53:423-428.

Winter, A.G., G.L. Swartzman, and L. Ciannelli (2005). Early- to late-summer population growth and prey consumption by age-0 pollock (*Theragra chalcogramma*), in two years of contrasting pollock abundance near the Pribilof Islands, Bering Sea. /Fisheries Oceanography/, Vol. 14, No. 4, pp. 307-320.

Yasumiishi, E. M., K. R. Criddle, N. Hillgruber, F. J. Mueter, and J. H. Helle. 2015. Chum salmon (Oncorhynchus keta) growth and temperature indices as indicators of the year–class strength of age-1 walleye pollock (*Gadus chalcogrammus*) in the eastern Bering Sea. Fish. Oceanogr. 24:242-256.

Zeppelin, T. K. and R.R. Ream. 2006. Foraging habitats based on the diet of female northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, Alaska. Journal of Zoology 270(4): 565-576.

Tables

Table 1.1 Catch from the Eastern Bering Sea by area, the Aleutian Islands, the Donut Hole, and the Bogoslof Island area, 1979-2015 (2015 values through October 25th 2015). 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	886,567	132,515	1,019,082	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	255,024	555,189	810,213	1,285		176
2011	747,893	451,150	1,199,044	1,208		173
2012	618,863	586,343	1,205,205	975		71
2013	695,667	575,099	1,270,766	2,964		57
2014	858,239	439,180	1,297,419	2,375		427
2015	692,308	623,419	1,315,727	897		733
Average	759,493	429,183	1,188,676	27,423		

1979-1989 data are from Pacfin.
1990-2015 data are from NMFS Alaska Regional Office, and include discards.
The 2015 EBS catch estimates are preliminary

Table 1.2. Time series of 1964-1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977-2014 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports. Note that the 2015 value is based on catch reported to October 25th 2015 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	1,199,069
		2012	1,220,000	1,200,000	1,205,197
		2013	1,375,000	1,247,000	1,270,745
		2014	1,369,000	1,267,000	1,298,593
		2015	1,637,000	1,310,000	*1,318,000*
	1977-2015 average		1,383,641	1,198,494	1,178,008

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), 1998-2015. The 2015 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	512,000 t (56%)	689,000 t (42%)	1,201,000 t (48%)
2003	532,000 t (47%)	737,000 t (40%)	1,270,000 t (43%)
2004	533,000 t (45%)	711,000 t (34%)	1,243,000 t (38%)
2005	530,000 t (45%)	673,000 t (17%)	1,204,000 t (29%)
2006	533,000 t (51%)	764,000 t (14%)	1,298,000 t (29%)
2007	480,000 t (57%)	663,000 t (11%)	1,143,000 t (30%)
2008	342,000 t (46%)	499,000 t (12%)	841,000 t (26%)
2009	283,000 t (39%)	389,000 t (13%)	671,000 t (24%)
2010	270,000 t (15%)	403,000 t (9%)	673,000 t (11%)
2011	478,000 t (54%)	667,000 t (32%)	1,144,000 t (41%)
2012	457,000 t (52%)	687,000 t (17%)	1,145,000 t (31%)
2013	472,000 t (22%)	708,000 t (19%)	1,180,000 t (20%)
2014	483,000 t (38%)	741,000 t (37%)	1,224,000 t (37%)
2015	490,000 t (15%)	758,000 t (45%)	1,248,000 t (33%)

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

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 passed
1999	American Fisheries Act implemented
1999	Additional critical habitat areas around sea lion haulouts in the GOA and Eastern Bering Sea are closed.
2000	AFA implemented for all sectors
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 *(as of Sept 28th 2015 proposed rule being reviewed by NOAA General Council)*

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, 1991-2015. SE represents the EBS east of 170° W, NW is the EBS west of 170° W, source: NMFS Blend and catch-accounting system database. 2015 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 (11%)	53 (30%)	1,201 (tr)	2,510 (1%)	3,906 (tr)	1,285	176	555,189	255,024	811,675
2011	75 (6%)	23 (13%)	1,331 (tr)	3,444 (tr)	4,872 (tr)	1,208	173	451,150	747,893	1,200,424
2012	95 (10%)	(tr)	1,186 (tr)	4,183 (1%)	5,464 (tr)	975	71	586,343	618,863	1,206,251
2013	107 (4%)	(1%)	1,227 (tr)	4,145 (1%)	5,480 (tr)	2,964	57	575,099	695,667	1,273,787
2014	137 (6%)	54 (13%)	1,787 (tr)	12,568 (1%)	14,546 (1%)	2,375	427	439,180	858,239	1,300,220
2015	19 (2%)	138 (19%)	2,243 (tr)	6,546 (1%)	8,947 (1%)	897	733	623,419	692,308	1,317,356

Table 1.6. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2014. 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	227.0	102.9	51.7	29.6	16.1	9.3	7.5	4.6	1.5	1.0	2,175
1982	4.7	25.3	161.4	1172.2	422.3	103.7	36.0	36.0	21.5	9.1	5.4	3.2	1.9	1.0	2,004
1983	5.1	118.6	157.8	312.9	816.8	218.2	41.4	24.7	19.8	11.1	7.6	4.9	3.5	2.1	1,745
1984	2.1	45.8	88.6	430.4	491.4	653.6	133.7	35.5	25.1	15.6	7.1	2.5	2.9	3.7	1,938
1985	2.6	55.2	381.2	121.7	365.7	321.5	443.2	112.5	36.6	25.8	24.8	10.7	9.4	9.1	1,920
1986	3.1	86.0	92.3	748.6	214.1	378.1	221.9	214.3	59.7	15.2	3.3	2.6	0.3	1.2	2,041
1987	0.0	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	0.0	10.7	454.0	421.6	252.1	544.3	224.8	104.9	39.2	96.8	18.2	10.2	3.8	11.7	2,192
1989	0.0	4.8	55.1	149.0	451.1	166.7	572.2	96.3	103.8	32.4	129.0	10.9	4.0	8.5	1,784
1990	1.3	33.0	57.0	219.5	200.7	477.7	129.2	368.4	65.7	101.9	9.0	60.1	8.5	13.9	1,746
1991	0.7	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	11.7	1,757
Average	4.0	58.9	197.4	342.9	374.9	315.6	191.6	108.1	63.1	34.2	23.7	12.6	8.5	12.5	1,794

Table 1.7. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2014, 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

Table 1.7. (continued) Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2014, 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

Table 1.8. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2014, 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

Table 1.9. 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		
1981	466	1999	299		

Table 1.10. Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979-2015 (**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	na	10.869	68%
2015	6.390				
Average	4.843	2.763	84%	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 1.11. Survey biomass estimates (age 1+, t) of Eastern Bering Sea pollock based on area-swept expansion methods from NMFS bottom trawl surveys 1982-2015.

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	6,263,621			
1984	4,892,372			
1985	4,630,149	656,932	5,287,081	12%
1986	4,899,245			
1987	5,111,645	386,788	5,498,433	7%
1988	7,106,818	181,839	7,288,657	2%
1989	5,906,477	643,938	6,550,415	10%
1990	7,126,088	190,218	7,316,306	3%
1991	5,067,092	62,446	5,129,538	1%
1992	4,367,962	214,557	4,582,518	5%
1993	5,524,830	105,707	5,630,538	2%
1994	4,977,639	49,686	5,027,325	1%
1995	5,409,297	68,541	5,477,838	1%
1996	3,258,806	155,861	3,414,667	5%
1997	3,036,898	762,954	3,799,852	20%
1998	2,213,697	567,569	2,781,266	20%
1999	3,598,688	199,786	3,798,474	5%
2000	5,152,594	128,846	5,281,439	2%
2001	4,145,746	51,108	4,196,854	1%
2002	4,832,508	200,337	5,032,845	4%
2003	8,106,358	285,902	8,392,261	3%
2004	3,744,501	118,473	3,862,974	3%
2005	5,168,476	152,300	5,320,776	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%
Avg.	4,589,471	258,793	4,774,495	5%

Table 1.12. Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982-2015. 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*	1999	373	32,532	1,385
1983	*354*	*78,033*	*1,931*	2000	372	41,762	1,545
1984	*355*	*40,530*	*1,806*	2001	375	47,335	1,641
1985	434	48,642	1,913	2002	375	43,361	1,695
1986	*354*	*41,101*	*1,344*	2003	376	46,480	1,638
1987	356	40,144	1,607	2004	375	44,102	1,660
1988	373	40,408	1,173	2005	373	35,976	1,676
1989	373	38,926	1,227	2006	376	39,211	1,573
1990	371	34,814	1,257	2007	376	29,679	1,484
1991	371	43,406	1,083	2008	375	24,635	1,251
1992	356	34,024	1,263	2009	375	24,819	1,342
1993	375	43,278	1,385	2010	376	23,142	1,385
1994	375	38,901	1,141	2011	376	36,227	1,734
1995	376	25,673	1,156	2012	376	35,782	1,785
1996	375	40,789	1,387	2013	376	35,908	1,847
1997	376	35,536	1,193	2014	376	43,042	2,099
1998	375	37,673	1,261	2015	376	54,241	2,320

Table 1.13. Bottom-trawl survey estimated numbers (millions) at age used for the stock assessment model, 1982-2015 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	948	2,271	2,433	3,115	1,061	144	100	48	30	19	12	7	3	1	1	10,192	1,273	12%
1983	3,632	545	1,218	2,152	4,786	1,467	269	146	66	57	43	15	6	5	2	14,410	1,128	8%
1984	325	260	383	1,095	1,360	3,171	604	134	62	22	15	6	3	4	2	7,446	739	10%
1985	4,614	654	2,563	862	2,887	1,807	1,255	249	65	53	18	6	7	1	0	15,040	1,931	13%
1986	2,154	488	356	1,318	805	1,364	1,203	1,109	353	55	25	11	1	3	1	9,248	826	9%
1987	345	559	723	538	3,246	913	918	370	1,197	189	57	23	4	2	2	9,088	1,126	12%
1988	1,058	503	1,181	2,254	998	3,271	987	774	455	1,101	106	63	13	17	9	12,791	1,456	11%
1989	762	225	428	1,411	3,198	645	2,486	379	471	182	581	101	89	45	64	11,067	1,136	10%
1990	1,718	241	86	550	1,107	3,744	757	1,901	197	372	58	542	47	36	48	11,403	1,370	12%
1991	2,419	660	234	76	461	429	1,421	534	1,158	304	419	87	265	38	35	8,539	827	10%
1992	1,325	320	1,680	281	315	529	472	681	307	588	210	265	116	91	72	7,250	802	11%
1993	2,118	304	664	2,810	613	493	259	360	492	303	266	194	154	86	103	9,218	863	9%
1994	1,250	519	395	1,115	3,026	530	141	124	143	268	166	233	89	86	145	8,232	973	12%
1995	1,444	138	270	1,224	1,604	2,566	1,086	288	179	116	219	91	167	68	101	9,561	1,809	19%
1996	1,296	313	141	280	739	1,033	940	319	80	86	59	112	37	67	91	5,592	458	8%
1997	2,077	316	137	166	2,013	948	592	737	128	66	50	55	90	29	103	7,506	982	13%
1998	610	535	272	179	343	1,960	512	331	259	65	30	11	23	27	63	5,218	578	11%
1999	818	704	646	701	401	726	1,846	514	260	243	91	39	16	24	82	7,110	834	12%
2000	886	284	344	1,165	1,191	628	549	1,803	709	379	166	111	35	16	72	8,337	1,006	12%
2001	1,465	841	441	407	1,034	1,093	475	239	718	518	201	163	66	23	65	7,750	696	9%
2002	631	295	608	877	913	1,187	618	302	414	781	390	176	105	32	37	7,365	750	10%
2003	376	124	723	1,178	1,377	1,244	1,651	915	411	536	1,081	469	179	89	69	10,421	1,863	18%
2004	320	225	140	1,036	1,005	762	448	486	242	151	152	275	118	29	23	5,413	499	9%
2005	308	113	174	743	2,132	1,450	765	351	270	198	54	115	188	73	77	7,011	697	10%
2006	760	62	97	316	790	1,006	647	312	179	156	75	47	68	91	91	4,699	427	9%
2007	2,023	48	118	336	1,057	1,245	905	656	278	125	116	101	47	58	113	7,225	669	9%
2008	442	99	82	148	421	852	673	471	300	118	100	76	35	19	120	3,955	431	11%
2009	674	165	343	371	218	318	434	341	250	123	82	27	28	14	59	3,449	415	12%
2010	408	115	204	2,054	930	295	261	278	295	203	175	64	39	23	51	5,396	707	13%
2011	982	100	209	285	1,433	706	210	121	189	189	157	120	51	24	64	4,841	453	9%
2012	964	188	344	2,472	572	915	313	125	94	130	106	94	79	28	51	6,474	611	9%
2013	973	99	191	743	3,702	865	547	194	66	60	79	60	56	31	41	7,706	625	8%
2014	1,701	438	204	268	1,233	4,494	2,346	508	281	103	40	56	58	27	72	11,830	792	7%
2015	892	609	1,768	438	896	1,673	3,289	970	236	113	15	14	24	14	31	10,982	705	6%
Avg	1,256	393	582	970	1,408	1,308	882	502	319	234	159	113	68	36	58	8,287	896	11%

Table 1.14. Bottom-trawl efficiency **"corrected"** survey estimated numbers (millions) at age used for the stock assessment model, 1982-2015 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	1,287	3,059	3,356	4,377	1,505	206	143	68	43	27	17	10	4	1	1	14,106	2,463	17%
1983	5,235	782	1,756	3,171	7,134	2,185	399	215	97	84	62	22	9	7	3	21,162	2,834	13%
1984	496	395	564	1,633	2,073	4,890	935	208	97	34	23	9	5	6	3	11,374	1,789	16%
1985	6,146	1,033	3,976	1,260	4,145	2,508	1,709	336	85	71	24	8	9	1	0	21,312	3,409	16%
1986	2,820	694	515	1,907	1,154	1,920	1,680	1,523	477	73	34	15	1	4	1	12,818	1,908	15%
1987	440	794	1,082	817	4,956	1,371	1,313	519	1,640	253	74	29	5	3	2	13,298	2,528	19%
1988	1,655	855	1,977	3,752	1,633	5,298	1,571	1,191	687	1,627	154	91	19	25	13	20,548	3,687	18%
1989	1,051	347	672	2,218	4,981	989	3,761	571	687	267	837	145	128	64	90	16,808	2,785	17%
1990	2,376	403	145	928	1,853	6,213	1,247	3,068	311	551	85	792	69	51	69	18,161	3,425	19%
1991	3,184	913	326	106	643	600	1,986	747	1,606	420	568	117	353	50	45	11,664	1,719	15%
1992	1,637	461	2,399	404	451	756	664	952	424	809	284	354	152	120	95	9,962	1,623	16%
1993	2,912	433	969	4,095	886	710	369	509	693	428	375	273	214	118	142	13,126	1,802	14%
1994	1,690	750	573	1,631	4,413	774	202	175	196	369	225	314	119	114	190	11,732	2,061	18%
1995	2,236	221	427	1,995	2,654	4,323	1,835	483	296	185	349	140	258	102	147	15,651	4,038	26%
1996	1,779	424	194	389	1,071	1,513	1,386	472	118	127	86	161	53	95	126	7,993	1,000	13%
1997	2,751	424	221	285	3,408	1,490	883	1,066	181	92	69	76	123	40	138	11,248	2,180	19%
1998	758	664	348	249	486	2,775	705	446	345	86	39	13	30	33	77	7,054	1,127	16%
1999	1,137	1,044	968	1,050	599	1,069	2,691	725	350	326	119	50	20	29	98	10,275	1,855	18%
2000	1,187	441	549	1,861	1,862	962	817	2,674	1,043	547	232	157	48	21	92	12,493	2,339	19%
2001	1,832	1,057	571	546	1,381	1,444	621	308	918	659	252	201	80	29	77	9,976	1,289	13%
2002	836	426	877	1,261	1,308	1,695	880	426	576	1,082	539	239	140	42	46	10,373	1,627	16%
2003	558	171	1,045	1,752	2,078	1,908	2,555	1,445	660	861	1,752	758	286	148	108	16,085	4,480	28%
2004	406	287	182	1,372	1,338	1,018	598	648	321	200	200	361	154	37	29	7,150	985	14%
2005	448	168	266	1,174	3,328	2,245	1,176	535	407	300	81	170	277	108	110	10,794	1,633	15%
2006	878	81	125	408	1,023	1,299	831	400	228	197	95	59	85	114	113	5,934	817	14%
2007	2,359	67	169	483	1,511	1,768	1,275	920	388	174	161	140	64	80	155	9,716	1,327	14%
2008	528	130	108	198	565	1,135	889	618	392	154	128	98	44	24	153	5,165	766	15%
2009	800	221	463	498	290	421	569	445	323	157	104	34	34	18	72	4,448	722	16%
2010	511	144	278	2,985	1,337	417	359	380	399	272	234	85	51	29	63	7,544	1,433	19%
2011	1,160	125	272	372	1,859	910	267	151	237	236	197	151	64	30	80	6,111	826	14%
2012	1,187	242	455	3,256	761	1,228	421	168	127	176	144	127	106	38	67	8,504	1,146	13%
2013	1,234	133	256	1,008	5,012	1,162	725	254	86	78	102	77	71	39	52	10,289	1,328	13%
2014	2,261	612	281	369	1,705	6,257	3,255	693	381	139	53	75	76	36	94	16,288	1,999	12%
2015	1,205	828	2,332	586	1,222	2,276	4,434	1,293	306	147	19	18	31	18	39	14,753	1,811	12%
Avg	1,676	554	844	1,423	2,077	1,933	1,269	724	445	330	227	158	94	49	76	11,880	1,964	16%

Table 1.15. Mean EBS pollock body mass (kg) at age as observed in the summer NMFS bottom trawl survey, 1982- 2015.

	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

Table 1.16. 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	1739	849	2,588	72	845	1,735	2,580	72

Table 1.17. AT survey estimates of EBS pollock abundance-at-age (millions), 1979-2014. Age 2+ totals and age-1s are modeled as separate indices. CV's are 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
Avg.*	1,990	2,651	1,973	1,831	899	507	310	149	60	102	8,483	21%	10,473
Median*	508	1,776	1,156	1,483	717	339	220	105	45	53	7,551	20%	9,394

*Average and median values exclude 1979 values.

Table 1.18. Mid-water pollock abundance (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, 1994-2014 (as described in Honkalehto et al. 2015).

Date		Area (nmi)^2	Biomass in millions of t (percent of total) SCA		E170-SCA		W170		Total Biomass (millions t)
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	(10%)	0.527	(20%)	1.818	(70%)	2.591
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

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

Table 1.19. 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%

Table 1.20. Mean weight-at-age (kg) estimates from the fishery (1991-2014) showing the between-year variability (middle row) and sampling error (bottom panel) based on bootstrap resampling of observer data. Italicized values for 2015 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	*0.357*	*0.344*	*0.436*	*0.561*	***0.657***	*0.856*	*1.087*	*1.262*	*1.434*	*1.624*	*1.689*	*1.850*	*2.029*
Stdev	0.056	0.057	0.041	0.060	0.102	0.118	0.141	0.174	0.175	0.172	0.250	0.305	0.318
CV	16%	11%	6%	8%	11%	11%	12%	14%	13%	12%	16%	20%	19%
Mean	0.357	0.510	0.647	0.772	0.899	1.030	1.159	1.272	1.369	1.454	1.530	1.556	1.643

Sampling CV (from bootstrap)

	3	4	5	6	7	8	9	10	11	12	13	14	15
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%

Table 1.21. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964-2014.

Year	Fishery	Year	BTS	AT
1964-1977	10	1979	-	6
1978-1990	50			
1991	174			
1992	200	1982-2015	100	50
1993	273			
1994	108			
1995	138			
1996	149			
1997	256			
1998	270			
1999	456			
2000	452			
2001	269			
2002	367			
2003	347			
2004	301			
2005	348			
2006	334			
2007	369			
2008	315			
2009	182			
2010	391			
2011	460			
2012	473			
2013	390			
2014	352			

Table 1.22. Parameter estimates and their standard errors.

index	name	value	std.dev	index	name	value	std.dev	index	name	value	std.dev	index	name	value	std.dev	Index	Name	Value	std_dev
1	log_avgrec	10.03	0.10	81	log_F_devs	-0.21	0.21	161	sel_devs_fsh	0.13	0.58	241	sel_devs_fsh	-0.06	0.55	321	sel_devs_fsh	-0.45	0.56
2	log_avginit	4.86	0.70	82	log_F_devs	-0.23	0.20	162	sel_devs_fsh	-0.15	0.53	242	sel_devs_fsh	-0.10	0.43	322	sel_devs_fsh	0.09	0.51
3	log_avg_F	-1.54	0.08	83	log_F_devs	-0.25	0.21	163	sel_devs_fsh	0.08	0.50	243	sel_devs_fsh	0.09	0.36	323	sel_devs_fsh	0.03	0.43
4	log_q_bts	0.20	0.19	84	log_F_devs	0.21	0.22	164	sel_devs_fsh	-0.03	0.37	244	sel_devs_fsh	0.09	0.34	324	sel_devs_fsh	0.26	0.37
5	log_q_std_area	-0.64	0.21	85	log_F_devs	0.60	0.22	165	sel_devs_fsh	-0.05	0.34	245	sel_devs_fsh	0.08	0.35	325	sel_devs_fsh	0.07	0.35
6	log_q_eit	-1.09	0.11	86	log_F_devs	0.65	0.21	166	sel_devs_fsh	-0.06	0.32	246	sel_devs_fsh	0.07	0.38	326	sel_devs_fsh	0.08	0.35
7	log_Rzero	9.89	0.18	87	log_F_devs	0.77	0.21	167	sel_devs_fsh	-0.07	0.32	247	sel_devs_fsh	0.05	0.61	327	sel_devs_fsh	0.08	0.38
8	steepness	0.68	0.07	88	log_F_devs	0.75	0.21	168	sel_devs_fsh	-0.07	0.33	248	sel_devs_fsh	0.02	0.62	328	sel_devs_fsh	0.06	0.61
9	log_q_cpue	-0.04	0.19	89	log_F_devs	0.62	0.21	169	sel_devs_fsh	-0.08	0.35	249	sel_devs_fsh	-0.01	0.48	329	sel_devs_fsh	0.00	0.58
10	log_q_avo	-9.68	0.12	90	log_F_devs	0.48	0.20	170	sel_devs_fsh	0.33	0.63	250	sel_devs_fsh	-0.15	0.65	330	sel_devs_fsh	-0.22	0.68
11	log_initdevs	3.38	0.78	91	log_F_devs	0.27	0.28	171	sel_devs_fsh	0.04	0.58	251	sel_devs_fsh	0.26	0.55	331	sel_devs_fsh	0.23	0.57
12	log_initdevs	2.93	0.78	92	log_F_devs	0.28	0.25	172	sel_devs_fsh	0.29	0.54	252	sel_devs_fsh	-0.12	0.50	332	sel_devs_fsh	0.19	0.49
13	log_initdevs	1.33	0.90	93	log_F_devs	0.34	0.29	173	sel_devs_fsh	-0.13	0.37	253	sel_devs_fsh	-0.04	0.47	333	sel_devs_fsh	-0.26	0.46
14	log_initdevs	0.45	1.01	94	log_F_devs	0.34	0.32	174	sel_devs_fsh	-0.13	0.34	254	sel_devs_fsh	0.01	0.38	334	sel_devs_fsh	-0.34	0.39
15	log_initdevs	1.12	0.88	95	log_F_devs	0.07	0.35	175	sel_devs_fsh	-0.12	0.33	255	sel_devs_fsh	0.03	0.35	335	sel_devs_fsh	0.13	0.35
16	log_initdevs	0.33	1.03	96	log_F_devs	-0.23	0.37	176	sel_devs_fsh	-0.10	0.35	256	sel_devs_fsh	0.03	0.36	336	sel_devs_fsh	0.09	0.35
17	log_initdevs	-0.80	1.38	97	log_F_devs	-0.26	0.36	177	sel_devs_fsh	-0.08	0.38	257	sel_devs_fsh	0.02	0.39	337	sel_devs_fsh	0.11	0.43
18	log_initdevs	-1.25	1.54	98	log_F_devs	-0.33	0.33	178	sel_devs_fsh	-0.06	0.40	258	sel_devs_fsh	0.01	0.63	338	sel_devs_fsh	0.05	0.58
19	log_initdevs	-1.25	1.54	99	log_F_devs	-0.28	0.31	179	sel_devs_fsh	-0.05	0.39	259	sel_devs_fsh	-0.04	0.57	339	sel_devs_fsh	0.01	0.56
20	log_initdevs	-1.25	1.54	100	log_F_devs	-0.46	0.26	180	sel_devs_fsh	0.51	0.63	260	sel_devs_fsh	-0.27	0.64	340	sel_devs_fsh	-0.21	0.69
21	log_initdevs	-1.25	1.54	101	log_F_devs	-0.56	0.24	181	sel_devs_fsh	0.23	0.58	261	sel_devs_fsh	-0.12	0.52	341	sel_devs_fsh	-0.03	0.58
22	log_initdevs	-1.25	1.54	102	log_F_devs	-0.48	0.15	182	sel_devs_fsh	-0.07	0.49	262	sel_devs_fsh	0.10	0.48	342	sel_devs_fsh	0.00	0.49
23	log_initdevs	-1.25	1.54	103	log_F_devs	-0.41	0.13	183	sel_devs_fsh	-0.33	0.44	263	sel_devs_fsh	0.02	0.49	343	sel_devs_fsh	0.35	0.45
24	log_initdevs	-1.25	1.54	104	log_F_devs	-0.06	0.12	184	sel_devs_fsh	-0.22	0.41	264	sel_devs_fsh	0.04	0.37	344	sel_devs_fsh	0.00	0.45
25	log_rec_devs	-1.12	0.40	105	log_F_devs	0.18	0.12	185	sel_devs_fsh	-0.20	0.42	265	sel_devs_fsh	0.03	0.35	345	sel_devs_fsh	-0.01	0.40
26	log_rec_devs	-0.02	0.28	106	log_F_devs	0.48	0.12	186	sel_devs_fsh	-0.09	0.55	266	sel_devs_fsh	0.04	0.35	346	sel_devs_fsh	0.04	0.38
27	log_rec_devs	-0.32	0.34	107	log_F_devs	-0.02	0.14	187	sel_devs_fsh	-0.03	0.63	267	sel_devs_fsh	0.04	0.39	347	sel_devs_fsh	-0.06	0.42
28	log_rec_devs	0.18	0.28	108	log_F_devs	-0.21	0.18	188	sel_devs_fsh	-0.01	0.64	268	sel_devs_fsh	0.07	0.61	348	sel_devs_fsh	0.10	0.51
29	log_rec_devs	0.04	0.30	109	log_F_devs	-0.17	0.16	189	sel_devs_fsh	0.21	0.46	269	sel_devs_fsh	0.06	0.57	349	sel_devs_fsh	-0.18	0.55
30	log_rec_devs	0.16	0.28	110	log_F_devs	0.13	0.17	190	sel_devs_fsh	0.09	0.63	270	sel_devs_fsh	-0.18	0.61	350	sel_devs_fsh	-0.21	0.69
31	log_rec_devs	0.01	0.29	111	log_F_devs	0.10	0.18	191	sel_devs_fsh	-0.09	0.58	271	sel_devs_fsh	-0.45	0.45	351	sel_devs_fsh	-0.12	0.59
32	log_rec_devs	-0.46	0.33	112	log_F_devs	-0.05	0.16	192	sel_devs_fsh	-0.17	0.49	272	sel_devs_fsh	-0.16	0.43	352	sel_devs_fsh	0.01	0.50
33	log_rec_devs	-0.65	0.34	113	log_F_devs	-0.47	0.13	193	sel_devs_fsh	-0.02	0.49	273	sel_devs_fsh	-0.08	0.45	353	sel_devs_fsh	-0.25	0.46
34	log_rec_devs	0.16	0.22	114	log_F_devs	-0.33	0.12	194	sel_devs_fsh	0.08	0.42	274	sel_devs_fsh	0.10	0.36	354	sel_devs_fsh	-0.01	0.44
35	log_rec_devs	-0.06	0.21	115	log_F_devs	-0.15	0.12	195	sel_devs_fsh	0.05	0.42	275	sel_devs_fsh	0.13	0.33	355	sel_devs_fsh	-0.13	0.41
36	log_rec_devs	-0.17	0.20	116	log_F_devs	-0.01	0.11	196	sel_devs_fsh	-0.05	0.55	276	sel_devs_fsh	0.12	0.34	356	sel_devs_fsh	-0.14	0.39
37	log_rec_devs	-0.43	0.19	117	log_F_devs	0.00	0.11	197	sel_devs_fsh	-0.01	0.64	277	sel_devs_fsh	0.13	0.38	357	sel_devs_fsh	0.30	0.47
38	log_rec_devs	-0.38	0.17	118	log_F_devs	-0.10	0.13	198	sel_devs_fsh	0.00	0.64	278	sel_devs_fsh	0.18	0.61	358	sel_devs_fsh	0.22	0.51
39	log_rec_devs	0.22	0.14	119	log_F_devs	-0.19	0.12	199	sel_devs_fsh	0.12	0.45	279	sel_devs_fsh	0.21	0.56	359	sel_devs_fsh	0.33	0.53
40	log_rec_devs	1.09	0.12	120	log_F_devs	0.01	0.12	200	sel_devs_fsh	-0.47	0.63	280	sel_devs_fsh	-0.39	0.64	360	sel_devs_fsh	-0.21	0.69
41	log_rec_devs	0.19	0.13	121	log_F_devs	0.07	0.11	201	sel_devs_fsh	0.36	0.58	281	sel_devs_fsh	-0.63	0.44	361	sel_devs_fsh	-0.10	0.62
42	log_rec_devs	0.31	0.13	122	log_F_devs	0.15	0.11	202	sel_devs_fsh	0.16	0.52	282	sel_devs_fsh	-0.25	0.41	362	sel_devs_fsh	0.98	0.43
43	log_rec_devs	-0.33	0.14	123	log_F_devs	0.14	0.12	203	sel_devs_fsh	0.15	0.49	283	sel_devs_fsh	0.16	0.45	363	sel_devs_fsh	0.15	0.45
44	log_rec_devs	0.79	0.12	124	log_F_devs	-0.07	0.12	204	sel_devs_fsh	-0.03	0.38	284	sel_devs_fsh	0.13	0.44	364	sel_devs_fsh	0.21	0.44
45	log_rec_devs	-0.58	0.15	125	log_F_devs	0.24	0.13	205	sel_devs_fsh	-0.01	0.37	285	sel_devs_fsh	0.18	0.36	365	sel_devs_fsh	-0.09	0.40
46	log_rec_devs	0.36	0.12	126	log_F_devs	0.18	0.16	206	sel_devs_fsh	-0.01	0.40	286	sel_devs_fsh	0.18	0.35	366	sel_devs_fsh	0.19	0.40
47	log_rec_devs	-0.49	0.14	127	log_F_devs	0.22	0.23	207	sel_devs_fsh	-0.01	0.64	287	sel_devs_fsh	0.17	0.39	367	sel_devs_fsh	-0.24	0.47
48	log_rec_devs	-1.08	0.15	128	log_F_devs	0.08	0.24	208	sel_devs_fsh	0.00	0.64	288	sel_devs_fsh	0.13	0.63	368	sel_devs_fsh	-0.31	0.44
49	log_rec_devs	-1.43	0.16	129	log_F_devs	0.03	0.38	209	sel_devs_fsh	-0.13	0.44	289	sel_devs_fsh	0.31	0.59	369	sel_devs_fsh	-0.58	0.47
50	log_rec_devs	-0.69	0.13	130	sel_devs_fsh	-0.02	0.68	210	sel_devs_fsh	-0.49	0.64	290	sel_devs_fsh	-0.32	0.66	370	sel_devs_fsh	-0.21	0.69
51	log_rec_devs	0.78	0.11	131	sel_devs_fsh	0.05	0.63	211	sel_devs_fsh	0.11	0.58	291	sel_devs_fsh	-0.29	0.51	371	sel_devs_fsh	-0.03	0.62
52	log_rec_devs	0.14	0.12	132	sel_devs_fsh	0.30	0.60	212	sel_devs_fsh	-0.03	0.54	292	sel_devs_fsh	-0.24	0.40	372	sel_devs_fsh	-0.64	0.49
53	log_rec_devs	0.01	0.12	133	sel_devs_fsh	0.13	0.59	213	sel_devs_fsh	0.07	0.48	293	sel_devs_fsh	0.07	0.43	373	sel_devs_fsh	0.22	0.44
54	log_rec_devs	0.74	0.11	134	sel_devs_fsh	-0.01	0.38	214	sel_devs_fsh	0.09	0.37	294	sel_devs_fsh	0.16	0.44	374	sel_devs_fsh	-0.05	0.44
55	log_rec_devs	-0.39	0.12	135	sel_devs_fsh	-0.07	0.35	215	sel_devs_fsh	0.10	0.36	295	sel_devs_fsh	0.09	0.36	375	sel_devs_fsh	0.15	0.44
56	log_rec_devs	-0.75	0.13	136	sel_devs_fsh	-0.08	0.33	216	sel_devs_fsh	0.10	0.40	296	sel_devs_fsh	0.10	0.36	376	sel_devs_fsh	0.18	0.37
57	log_rec_devs	0.01	0.11	137	sel_devs_fsh	-0.09	0.33	217	sel_devs_fsh	0.08	0.64	297	sel_devs_fsh	0.11	0.39	377	sel_devs_fsh	0.16	0.37
58	log_rec_devs	0.32	0.11	138	sel_devs_fsh	-0.09	0.35	218	sel_devs_fsh	0.03	0.64	298	sel_devs_fsh	0.11	0.63	378	sel_devs_fsh	0.08	0.38
59	log_rec_devs	-0.36	0.12	139	sel_devs_fsh	-0.11	0.39	219	sel_devs_fsh	-0.05	0.45	299	sel_devs_fsh	0.21	0.59	379	sel_devs_fsh	0.12	0.38
60	log_rec_devs	-0.27	0.12	140	sel_devs_fsh	0.13	0.65	220	sel_devs_fsh	-0.29	0.64	300	sel_devs_fsh	-0.23	0.67	380	sel_devs_fsh	-0.20	0.69
61	log_rec_devs	0.17	0.11	141	sel_devs_fsh	0.22	0.61	221	sel_devs_fsh	0.27	0.56	301	sel_devs_fsh	-0.05	0.55	381	sel_devs_fsh	0.04	0.61
62	log_rec_devs	0.47	0.11	142	sel_devs_fsh	0.12	0.58	222	sel_devs_fsh	0.23	0.51	302	sel_devs_fsh	-0.42	0.45	382	sel_devs_fsh	-0.34	0.54
63	log_rec_devs	0.03	0.11	143	sel_devs_fsh	-0.08	0.37	223	sel_devs_fsh	0.00	0.47	303	sel_devs_fsh	-0.02	0.41	383	sel_devs_fsh	0.23	0.47
64	log_rec_devs	-0.47	0.11	144	sel_devs_fsh	-0.07	0.34	224	sel_devs_fsh	-0.02	0.39	304	sel_devs_fsh	0.10	0.36	384	sel_devs_fsh	0.35	0.39
65	log_rec_devs	-1.27	0.13	145	sel_devs_fsh	-0.07	0.33	225	sel_devs_fsh	-0.03	0.39	305	sel_devs_fsh	0.09	0.34	385	sel_devs_fsh	0.11	0.42
66	log_rec_devs	-1.64	0.14	146	sel_devs_fsh	-0.07	0.32	226	sel_devs_fsh	-0.02	0.54	306	sel_devs_fsh	0.09	0.35	386	sel_devs_fsh	-0.16	0.41
67	log_rec_devs	-0.69	0.12	147	sel_devs_fsh	-0.06	0.32	227	sel_devs_fsh	-0.02	0.64	307	sel_devs_fsh	0.09	0.38	387	sel_devs_fsh	0.02	0.34
68	log_rec_devs	0.18	0.12	148	sel_devs_fsh	-0.06	0.33	228	sel_devs_fsh	0.00	0.63	308	sel_devs_fsh	0.12	0.63	388	sel_devs_fsh	0.01	0.34
69	log_rec_devs	-0.40	0.14	149	sel_devs_fsh	-0.05	0.36	229	sel_devs_fsh	-0.14	0.45	309	sel_devs_fsh	0.22	0.60	389	sel_devs_fsh	-0.07	0.36
70	log_rec_devs	1.00	0.13	150	sel_devs_fsh	0.13	0.64	230	sel_devs_fsh	-0.26	0.65	310	sel_devs_fsh	-0.24	0.68	390	sel_devs_fsh	-0.19	0.69
71	log_rec_devs	0.04	0.16	151	sel_devs_fsh	0.15	0.59	231	sel_devs_fsh	-0.41	0.54	311	sel_devs_fsh	0.48	0.56	391	sel_devs_fsh	-0.02	0.57
72	log_rec_devs	-0.30	0.19	152	sel_devs_fsh	0.43	0.56	232	sel_devs_fsh	0.19	0.37	312	sel_devs_fsh	-0.10	0.49	392	sel_devs_fsh	-0.51	0.52
73	log_rec_devs	-0.77	0.26	153	sel_devs_fsh	-0.26	0.51	233	sel_devs_fsh	0.13	0.34	313	sel_devs_fsh	-0.22	0.42	393	sel_devs_fsh	-0.39	0.45
74	log_rec_devs	0.48	0.16	154	sel_devs_fsh	-0.16	0.36	234	sel_devs_fsh	0.09	0.34	314	sel_devs_fsh	-0.16	0.37	394	sel_devs_fsh	-0.15	0.38
75	log_rec_devs	0.13	0.18	155	sel_devs_fsh	-0.12	0.33	235	sel_devs_fsh	0.07	0.37	315	sel_devs_fsh	0.03	0.35	395	sel_devs_fsh	0.05	0.36
76	log_rec_devs	0.00	0.20	156	sel_devs_fsh	-0.09	0.32	236	sel_devs_fsh	0.06	0.54	316	sel_devs_fsh	0.02	0.35	396	sel_devs_fsh	0.31	0.40
77	repl_F	0.29	0.17	157	sel_devs_fsh	-0.05	0.32	237	sel_devs_fsh	0.00	0.63	317	sel_devs_fsh	0.02	0.39	397	sel_devs_fsh	0.05	0.34
78	log_F_devs	-0.51	0.32	158	sel_devs_fsh	-0.03	0.33	238	sel_devs_fsh	0.02	0.62	318	sel_devs_fsh	0.04	0.63	398	sel_devs_fsh	0.34	0.35
79	log_F_devs	-0.62	0.22	159	sel_devs_fsh	0.00	0.36	239	sel_devs_fsh	0.11	0.46	319	sel_devs_fsh	0.12	0.59	399	sel_devs_fsh	0.52	0.35
80	log_F_devs	-0.73	0.21	160	sel_devs_fsh	0.29	0.64	240	sel_devs_fsh	-0.21	0.65	320	sel_devs_fsh	-0.22	0.68	400	sel_devs_fsh	-0.17	0.69

Table 1.22. (continued) Parameter estimates and their standard errors.

Idx	name	Val	S_dev	Idx	name	Val	S_dev	Idx	name	Val	S_dev	Idx	name	Val	S_dev	Idx	name	Val	S_dev	Idx	name	Val	S_dev
401	sel_dv_fsh	0.00	0.42	481	sel_dv_fsh	-0.13	0.50	561	sel_dv_fsh	-0.27	0.49	641	sel_dv_eit	0.48	1.74	721	sel_a50_bts_dv	0.14	0.07	801	Ceff	-0.34	0.24
402	sel_dv_fsh	0.68	0.39	482	sel_dv_fsh	-0.67	0.32	562	sel_dv_fsh	-0.65	0.38	642	sel_dv_eit	1.24	1.52	722	sel_a50_bts_dv	0.23	0.06	802	Ceff	0.15	0.22
403	sel_dv_fsh	-0.46	0.40	483	sel_dv_fsh	0.26	0.29	563	sel_dv_fsh	0.01	0.34	643	sel_dv_eit	1.20	1.44	723	sel_a50_bts_dv	0.20	0.08	803	Ceff	0.07	0.22
404	sel_dv_fsh	-0.45	0.40	484	sel_dv_fsh	0.39	0.31	564	sel_dv_fsh	0.04	0.31	644	sel_dv_eit	1.11	1.39	724	sel_a50_bts_dv	0.23	0.07	804	Ceff	-0.01	0.22
405	sel_dv_fsh	-0.03	0.39	485	sel_dv_fsh	-0.04	0.31	565	sel_dv_fsh	0.12	0.28	645	sel_dv_eit	1.08	1.35	725	sel_a50_bts_dv	0.18	0.09	805	Ceff	-0.17	0.22
406	sel_dv_fsh	0.00	0.35	486	sel_dv_fsh	-0.02	0.30	566	sel_dv_fsh	0.17	0.28	646	sel_dv_eit	0.92	1.29	726	sel_a50_bts_dv	0.18	0.08	806	Ceff	-0.13	0.20
407	sel_dv_fsh	0.28	0.34	487	sel_dv_fsh	0.22	0.28	567	sel_dv_fsh	0.18	0.28	647	sel_dv_eit	0.63	1.22	727	sel_a50_bts_dv	0.17	0.08	807	Ceff	0.72	0.18
408	sel_dv_fsh	0.11	0.34	488	sel_dv_fsh	0.06	0.29	568	sel_dv_fsh	0.22	0.29	648	sel_dv_eit	0.62	1.30	728	sel_a50_bts_dv	0.16	0.08	808	Ceff	0.79	0.18
409	sel_dv_fsh	0.03	0.33	489	sel_dv_fsh	0.01	0.32	569	sel_dv_fsh	0.20	0.31	649	sel_dv_eit	0.55	1.29	729	sel_a50_bts_dv	0.22	0.08	809	Ceff	0.10	0.18
410	sel_dv_fsh	-0.14	0.69	490	sel_dv_fsh	-0.06	0.69	570	sel_dv_fsh	-0.01	0.70	650	sel_dv_eit	0.60	1.29	730	sel_a50_bts_dv	0.12	0.06	810	Ceff	-0.44	0.18
411	sel_dv_fsh	-0.81	0.48	491	sel_dv_fsh	-0.38	0.51	571	sel_dv_fsh	-0.51	0.49	651	sel_dv_eit	0.69	1.30	731	sel_a50_bts_dv	0.03	0.06	811	Ceff	0.25	0.18
412	sel_dv_fsh	0.06	0.32	492	sel_dv_fsh	-0.42	0.38	572	sel_dv_fsh	0.13	0.34	652	sel_dv_eit	0.74	1.32	732	sel_a50_bts_dv	0.10	0.06	812	Ceff	0.80	0.18
413	sel_dv_fsh	0.96	0.34	493	sel_dv_fsh	-0.32	0.31	573	sel_dv_fsh	0.04	0.33	653	sel_dv_eit	0.43	1.23	733	sel_a50_bts_dv	-0.05	0.07	813	Ceff	0.77	0.18
414	sel_dv_fsh	0.09	0.38	494	sel_dv_fsh	0.27	0.28	574	sel_dv_fsh	-0.21	0.33	654	sel_P_fsh	-4.33	1.10	734	sel_a50_bts_dv	-0.04	0.06	814	Ceff	0.94	0.18
415	sel_dv_fsh	0.00	0.41	495	sel_dv_fsh	0.67	0.29	575	sel_dv_fsh	-0.13	0.31	655	sel_P_fsh	-2.39	0.80	735	sel_a50_bts_dv	-0.07	0.06	815	Ceff	0.90	0.18
416	sel_dv_fsh	0.10	0.36	496	sel_dv_fsh	0.13	0.30	576	sel_dv_fsh	0.04	0.29	656	sel_P_fsh	-1.24	0.66	736	sel_a50_bts_dv	-0.17	0.05	816	Ceff	0.96	0.19
417	sel_dv_fsh	-0.03	0.33	497	sel_dv_fsh	-0.07	0.29	577	sel_dv_fsh	0.13	0.29	657	sel_P_fsh	0.28	0.60	737	sel_a50_bts_dv	0.03	0.05	817	Ceff	1.24	0.19
418	sel_dv_fsh	-0.08	0.32	498	sel_dv_fsh	0.06	0.29	578	sel_dv_fsh	0.21	0.32	658	sel_P_fsh	0.38	0.32	738	sel_a50_bts_dv	0.04	0.06	818	Ceff	1.72	0.19
419	sel_dv_fsh	-0.16	0.31	499	sel_dv_fsh	0.13	0.31	579	sel_dv_fsh	0.33	0.32	659	sel_P_fsh	0.38	0.29	739	sel_a50_bts_dv	0.01	0.05	819	Ceff	1.31	0.20
420	sel_dv_fsh	-0.10	0.69	500	sel_dv_fsh	-0.05	0.70	580	sel_dv_fsh	0.01	0.71	660	sel_P_fsh	0.35	0.28	740	sel_a50_bts_dv	0.07	0.07	820	Ceff	1.13	0.20
421	sel_dv_fsh	0.10	0.53	501	sel_dv_fsh	0.57	0.48	581	sel_dv_fsh	0.25	0.48	661	sel_P_fsh	0.31	0.28	741	sel_a50_bts_dv	-0.05	0.08	821	Ceff	1.20	0.21
422	sel_dv_fsh	-0.89	0.43	502	sel_dv_fsh	0.00	0.38	582	sel_dv_fsh	-0.64	0.36	662	sel_P_fsh	0.27	0.30	742	sel_one_bts_dv	-0.36	0.18	822	Ceff	0.86	0.23
423	sel_dv_fsh	-0.32	0.34	503	sel_dv_fsh	-0.07	0.32	583	sel_dv_fsh	0.46	0.29	663	sel_P_fsh	0.24	0.33	743	sel_one_bts_dv	-0.27	0.12	823	Ceff	0.45	0.23
424	sel_dv_fsh	0.91	0.33	504	sel_dv_fsh	-0.32	0.29	584	sel_dv_fsh	0.31	0.33	664	sel_P_eit	1.29	0.52	744	sel_one_bts_dv	-0.16	0.14	824	Ceff	0.14	0.23
425	sel_dv_fsh	0.27	0.39	505	sel_dv_fsh	0.00	0.28	585	sel_dv_fsh	-0.18	0.36	665	sel_P_eit	-0.05	1.20	745	sel_one_bts_dv	-0.50	0.12	825	Ceff	-0.60	0.25
426	sel_dv_fsh	0.01	0.35	506	sel_dv_fsh	0.02	0.28	586	sel_dv_fsh	-0.10	0.36	666	sel_P_eit	-0.72	1.03	746	sel_one_bts_dv	-0.57	0.14	826	Ceff	-1.51	0.25
427	sel_dv_fsh	0.00	0.33	507	sel_dv_fsh	0.01	0.29	587	sel_dv_fsh	0.02	0.31	667	sel_P_eit	-0.71	0.92	747	sel_one_bts_dv	-0.28	0.16	827	Ceff	-1.63	0.26
428	sel_dv_fsh	-0.01	0.32	508	sel_dv_fsh	-0.01	0.29	588	sel_dv_fsh	-0.04	0.32	668	sel_P_eit	-0.71	0.87	748	sel_one_bts_dv	-0.38	0.15	828	Ceff	-2.10	0.29
429	sel_dv_fsh	0.04	0.34	509	sel_dv_fsh	-0.14	0.30	589	sel_dv_fsh	-0.08	0.32	669	sel_P_eit	-0.70	0.86	749	sel_one_bts_dv	-0.11	0.13	829	Ceff	-2.17	0.42
430	sel_dv_fsh	-0.10	0.69	510	sel_dv_fsh	-0.04	0.70	590	sel_dv_fsh	-0.01	0.70	670	sel_P_eit	-0.69	0.86	750	sel_one_bts_dv	0.17	0.08	830	Ceff	0.00	1.00
431	sel_dv_fsh	0.17	0.56	511	sel_dv_fsh	-0.53	0.47	591	sel_dv_fsh	0.12	0.47	671	sel_slp_bts	1.06	0.05	751	sel_one_bts_dv	-0.08	0.09	831	Ceff	0.00	1.00
432	sel_dv_fsh	-0.32	0.46	512	sel_dv_fsh	0.83	0.31	592	sel_dv_fsh	0.06	0.37	672	sel_a50_bts	5.30	0.15	752	sel_one_bts_dv	0.07	0.09	832	Ceff	0.00	1.00
433	sel_dv_fsh	-0.70	0.39	513	sel_dv_fsh	-0.06	0.30	593	sel_dv_fsh	-1.18	0.32	673	sel_age_one	-2.85	0.09	753	sel_one_bts_dv	0.13	0.09	833	yeff	-0.03	0.31
434	sel_dv_fsh	-0.32	0.33	514	sel_dv_fsh	0.11	0.30	594	sel_dv_fsh	0.34	0.30	674	sel_slp_bts_dv	-0.19	0.30	754	sel_one_bts_dv	-0.04	0.11	834	yeff	0.14	0.29
435	sel_dv_fsh	0.50	0.33	515	sel_dv_fsh	-0.16	0.29	595	sel_dv_fsh	0.43	0.34	675	sel_slp_bts_dv	0.06	0.20	755	sel_one_bts_dv	-0.07	0.12	835	yeff	1.35	0.28
436	sel_dv_fsh	0.20	0.34	516	sel_dv_fsh	0.01	0.28	596	sel_dv_fsh	0.18	0.36	676	sel_slp_bts_dv	0.18	0.14	756	sel_one_bts_dv	0.00	0.10	836	yeff	0.92	0.27
437	sel_dv_fsh	0.20	0.32	517	sel_dv_fsh	0.00	0.29	597	sel_dv_fsh	0.04	0.32	677	sel_slp_bts_dv	-0.07	0.17	757	sel_one_bts_dv	-0.01	0.10	837	yeff	0.56	0.26
438	sel_dv_fsh	0.18	0.33	518	sel_dv_fsh	-0.05	0.30	598	sel_dv_fsh	0.01	0.31	678	sel_slp_bts_dv	-0.09	0.14	758	sel_one_bts_dv	0.06	0.10	838	yeff	0.19	0.25
439	sel_dv_fsh	0.19	0.35	519	sel_dv_fsh	-0.09	0.30	599	sel_dv_fsh	0.01	0.32	679	sel_slp_bts_dv	-0.14	0.15	759	sel_one_bts_dv	0.06	0.10	839	yeff	-0.10	0.24
440	sel_dv_fsh	-0.10	0.69	520	sel_dv_fsh	-0.03	0.70	600	sel_dv_fsh	0.00	0.71	680	sel_slp_bts_dv	-0.18	0.16	760	sel_one_bts_dv	0.21	0.10	840	yeff	-0.44	0.24
441	sel_dv_fsh	0.66	0.56	521	sel_dv_fsh	-0.27	0.56	601	sel_dv_fsh	0.42	0.51	681	sel_slp_bts_dv	-0.05	0.17	761	sel_one_bts_dv	0.14	0.08	841	yeff	-0.53	0.22
442	sel_dv_fsh	0.36	0.45	522	sel_dv_fsh	-0.76	0.34	602	sel_dv_fsh	0.40	0.35	682	sel_slp_bts_dv	0.08	0.14	762	sel_one_bts_dv	0.28	0.10	842	yeff	-0.73	0.22
443	sel_dv_fsh	-1.03	0.40	523	sel_dv_fsh	0.87	0.29	603	sel_dv_fsh	0.55	0.32	683	sel_slp_bts_dv	-0.03	0.12	763	sel_one_bts_dv	0.38	0.11	843	yeff	-0.23	0.22
444	sel_dv_fsh	-0.87	0.36	524	sel_dv_fsh	0.05	0.30	604	sel_dv_fsh	-1.20	0.32	684	sel_slp_bts_dv	-0.03	0.13	764	sel_one_bts_dv	0.10	0.12	844	yeff	-0.36	0.21
445	sel_dv_fsh	-0.34	0.32	525	sel_dv_fsh	-0.11	0.31	605	sel_dv_fsh	-0.14	0.31	685	sel_slp_bts_dv	0.03	0.13	765	sel_one_bts_dv	-0.02	0.14	845	yeff	-0.43	0.21
446	sel_dv_fsh	0.30	0.31	526	sel_dv_fsh	0.02	0.30	606	sel_dv_fsh	-0.01	0.31	686	sel_slp_bts_dv	0.06	0.12	766	sel_one_bts_dv	-0.09	0.10	846	yeff	-0.90	0.22
447	sel_dv_fsh	0.42	0.32	527	sel_dv_fsh	0.04	0.29	607	sel_dv_fsh	0.01	0.31	687	sel_slp_bts_dv	0.09	0.11	767	sel_one_bts_dv	-0.03	0.09	847	yeff	-1.60	0.22
448	sel_dv_fsh	0.34	0.33	528	sel_dv_fsh	0.07	0.30	608	sel_dv_fsh	-0.01	0.31	688	sel_slp_bts_dv	-0.07	0.12	768	sel_one_bts_dv	0.20	0.09	848	yeff	-1.87	0.22
449	sel_dv_fsh	0.27	0.35	529	sel_dv_fsh	0.13	0.32	609	sel_dv_fsh	-0.02	0.33	689	sel_slp_bts_dv	-0.23	0.13	769	sel_one_bts_dv	0.41	0.07	849	yeff	-1.00	0.23
450	sel_dv_fsh	-0.09	0.69	530	sel_dv_fsh	-0.03	0.70	610	sel_dv_fsh	0.00	0.71	690	sel_slp_bts_dv	-0.36	0.11	770	sel_one_bts_dv	0.34	0.10	850	yeff	-1.04	0.24
451	sel_dv_fsh	0.48	0.51	531	sel_dv_fsh	0.20	0.60	611	sel_dv_fsh	-0.24	0.54	691	sel_slp_bts_dv	-0.46	0.12	771	sel_one_bts_dv	0.08	0.10	851	yeff	0.32	0.25
452	sel_dv_fsh	0.04	0.46	532	sel_dv_fsh	0.02	0.39	612	sel_dv_fsh	-0.04	0.40	692	sel_slp_bts_dv	-0.35	0.13	772	sel_one_bts_dv	-0.07	0.12	852	yeff	0.24	0.26
453	sel_dv_fsh	0.89	0.39	533	sel_dv_fsh	-0.35	0.29	613	sel_dv_fsh	0.09	0.32	693	sel_slp_bts_dv	-0.38	0.12	773	sel_one_bts_dv	0.18	0.10	853	yeff	0.64	0.27
454	sel_dv_fsh	0.08	0.34	534	sel_dv_fsh	0.47	0.29	614	sel_dv_fsh	0.46	0.32	694	sel_slp_bts_dv	-0.20	0.12	774	sel_one_bts_dv	0.10	0.11	854	yeff	0.80	0.28
455	sel_dv_fsh	-0.47	0.32	535	sel_dv_fsh	0.28	0.31	615	sel_dv_fsh	-0.67	0.33	695	sel_slp_bts_dv	-0.05	0.12	775	sel_one_bts_dv	0.13	0.13	855	yeff	1.68	0.29
456	sel_dv_fsh	-0.42	0.32	536	sel_dv_fsh	-0.13	0.30	616	sel_dv_fsh	-0.28	0.36	696	sel_slp_bts_dv	-0.04	0.12	776	rec_dv_future	0.00	0.67	856	yeff	2.42	0.30
457	sel_dv_fsh	-0.40	0.34	537	sel_dv_fsh	-0.19	0.30	617	sel_dv_fsh	0.15	0.34	697	sel_slp_bts_dv	0.05	0.14	777	rec_dv_future	0.00	0.67	857	yeff	0.00	1.00
458	sel_dv_fsh	-0.08	0.34	538	sel_dv_fsh	-0.14	0.30	618	sel_dv_fsh	0.22	0.36	698	sel_slp_bts_dv	0.02	0.14	778	rec_dv_future	0.00	0.67	858	yeff	0.00	1.00
459	sel_dv_fsh	-0.03	0.35	539	sel_dv_fsh	-0.13	0.32	619	sel_dv_fsh	0.31	0.40	699	sel_slp_bts_dv	0.21	0.14	779	rec_dv_future	0.00	0.67	859	yeff	0.00	1.00
460	sel_dv_fsh	-0.10	0.69	540	sel_dv_fsh	-0.03	0.70	620	sel_dv_fsh	-0.01	0.70	700	sel_slp_bts_dv	0.38	0.12	780	rec_dv_future	0.00	0.67	801	Ceff	-0.34	0.24
461	sel_dv_fsh	-0.50	0.41	541	sel_dv_fsh	0.35	0.60	621	sel_dv_fsh	0.36	0.53	701	sel_slp_bts_dv	0.35	0.12	781	mnwt	0.36	0.01				
462	sel_dv_fsh	0.30	0.42	542	sel_dv_fsh	0.71	0.40	622	sel_dv_fsh	-0.21	0.47	702	sel_slp_bts_dv	0.60	0.12	782	mnwt	0.48	0.02				
463	sel_dv_fsh	0.22	0.38	543	sel_dv_fsh	-0.15	0.31	623	sel_dv_fsh	-0.27	0.36	703	sel_slp_bts_dv	0.48	0.11	783	mnwt	0.60	0.02				
464	sel_dv_fsh	0.20	0.32	544	sel_dv_fsh	-0.37	0.29	624	sel_dv_fsh	0.18	0.32	704	sel_slp_bts_dv	0.13	0.13	784	mnwt	0.72	0.02				
465	sel_dv_fsh	0.26	0.30	545	sel_dv_fsh	-0.14	0.28	625	sel_dv_fsh	0.20	0.33	705	sel_slp_bts_dv	0.14	0.14	785	mnwt	0.83	0.03				
466	sel_dv_fsh	-0.28	0.31	546	sel_dv_fsh	-0.09	0.29	626	sel_dv_fsh	0.16	0.34	706	sel_slp_bts_dv	0.12	0.12	786	mnwt	0.94	0.03				
467	sel_dv_fsh	-0.06	0.35	547	sel_dv_fsh	-0.07	0.30	627	sel_dv_fsh	-0.29	0.38	707	sel_slp_bts_dv	-0.05	0.15	787	mnwt	1.06	0.04				
468	sel_dv_fsh	-0.04	0.34	548	sel_dv_fsh	-0.12	0.31	628	sel_dv_fsh	-0.04	0.40	708	sel_a50_bts_dv	-0.55	0.22	788	mnwt	1.18	0.04				
469	sel_dv_fsh	0.01	0.35	549	sel_dv_fsh	-0.09	0.32	629	sel_dv_fsh	-0.09	0.43	709	sel_a50_bts_dv	-0.29	0.11	789	mnwt	1.26	0.04				
470	sel_dv_fsh	-0.09	0.69	550	sel_dv_fsh	-0.03	0.70	630	sel_dv_fsh	0.00	0.71	710	sel_a50_bts_dv	-0.14	0.07	790	mnwt	1.36	0.05				
471	sel_dv_fsh	-0.52	0.46	551	sel_dv_fsh	0.07	0.59	631	sel_dv_fsh	0.00	0.71	711	sel_a50_bts_dv	-0.19	0.09	791	mnwt	1.42	0.05				
472	sel_dv_fsh	0.90	0.33	552	sel_dv_fsh	-0.04	0.40	632	sel_dv_fsh	0.00	0.71	712	sel_a50_bts_dv	-0.02	0.08	792	mnwt	1.52	0.06				
473	sel_dv_fsh	0.50	0.35	553	sel_dv_fsh	-0.02	0.33	633	sel_dv_fsh	0.04	0.72	713	sel_a50_bts_dv	-0.09	0.08	793	mnwt	1.57	0.06				
474	sel_dv_fsh	0.13	0.34	554	sel_dv_fsh	-0.04	0.29	634	sel_dv_fsh	0.16	0.52	714	sel_a50_bts_dv	-0.21	0.10	794	coh_eff	-1.45	0.38				
475	sel_dv_fsh	-0.22	0.30	555	sel_dv_fsh	0.07	0.28	635	sel_dv_fsh	0.03	0.51	715	sel_a50_bts_dv	-0.25	0.09	795	coh_eff	-0.78	0.37				
476	sel_dv_fsh	0.27	0.29	556	sel_dv_fsh	0.02	0.28	636	sel_dv_fsh	-0.15	0.50	716	sel_a50_bts_dv	-0.13	0.07	796	coh_eff	-0.87	0.32				
477	sel_dv_fsh	-0.13	0.32	557	sel_dv_fsh	-0.03	0.29	637	sel_dv_fsh	-0.11	0.50	717	sel_a50_bts_dv	0.08	0.08	797	coh_eff	-0.96	0.33				
478	sel_dv_fsh	-0.39	0.31	558	sel_dv_fsh	-0.01	0.30	638	sel_dv_fsh	0.01	0.49	718	sel_a50_bts_dv	0.02	0.08	798	coh_eff	-0.73	0.27				
479	sel_dv_fsh	-0.45	0.33	559	sel_dv_fsh	0.01	0.32	639	sel_dv_fsh	0.01	0.48	719	sel_a50_bts_dv	-0.01	0.08	799	coh_eff	-0.33	0.28				
480	sel_dv_fsh	-0.08	0.69	560	sel_dv_fsh	-0.03	0.70	640	sel_dv_eit	-1.05	1.35	720	sel_a50_bts_dv	0.04	0.07	800	coh_eff	-0.26	0.24				

Table 1.23. 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
Biomass	
Year 2016 spawning biomass*	3,540,000 t
(CV)	(14%)
2015 spawning biomass	3,483,000 t
B_{MSY}	1,984,000 t
(CV)	(20%)
$SPR \mid F_{MSY}$	30%
$B_{40\%}$	2,813,000 t
$B_{35\%}$	2,461,000 t
B_0 (stock-recruitment curve)	5,676,000 t
2015 Percent of B_{MSY} spawning biomass	176%
2016 Percent of B_{MSY} spawning biomass	178%
Ratio of B_{2015} over B_{2015} under no fishing since 1978	0.59
Recruitment (millions of pollock at age 1)	
Steepness parameter (*h*)	0.671
Average recruitment (all yrs)	23,100
2000 year class	36,321
2006 year class	27,094
2008 year class	62,011
Natural Mortality (age 3 and older)	0.3

Table 1.24. Summary results of Tier 1 2016 yield projections for EBS pollock.

Description	Value
Tier 1 maximum permissible ABC	
2016 fishable biomass (GM)	7,610,000 t
MSYR (HM)	0.401
Adjustment factor	1.0
Adjusted ABC rate	0.401
2016 MSYR yield (Tier 1 ABC)	3,050,000 t
OFL	
MSYR (AM)	0.514
2016 MSYR OFL	3,910,000 t
Recommended F_{ABC}	0.27
Recommended ABC	2,090,000 t
Fishable biomass at *MSY*	3,661,000 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

*Assuming 2015 catch will be 1,350,00 t

Table 1.25 Estimates millions of EBS pollock at age from the 2015 model.

	1	2	3	4	5	6	7	8	9	10+	Total
1964	7,410	3,789	2,415	489	203	395	179	58	37	222	15,196
1965	22,290	3,008	2,390	1,729	310	126	246	112	37	164	30,412
1966	16,499	9,049	1,897	1,695	1,083	195	80	158	72	131	30,859
1967	27,209	6,697	5,697	1,341	1,083	695	126	52	103	134	43,137
1968	23,734	11,028	4,161	3,720	815	648	418	76	32	143	44,773
1969	26,781	9,608	6,819	2,753	2,208	487	390	253	46	107	49,451
1970	23,061	10,821	5,925	4,317	1,666	1,345	298	239	155	93	47,920
1971	14,389	9,230	6,474	3,516	2,565	972	785	170	134	135	38,370
1972	11,932	5,712	5,428	3,690	1,927	1,327	508	411	86	123	31,144
1973	26,783	4,772	3,202	2,860	1,856	971	670	257	200	93	41,663
1974	21,349	10,766	2,590	1,636	1,331	855	447	309	114	127	39,524
1975	19,146	8,604	5,518	1,182	749	611	393	205	137	105	36,651
1976	14,795	7,741	4,878	2,543	561	362	298	192	100	114	31,585
1977	15,612	5,992	4,494	2,513	1,243	280	183	151	98	107	30,673
1978	28,474	6,330	3,457	2,554	1,342	662	150	99	82	111	43,261
1979	67,784	11,554	3,705	1,935	1,372	713	355	81	53	103	87,654
1980	27,425	27,517	6,999	2,191	1,085	720	374	188	43	80	66,620
1981	30,874	11,141	17,162	4,499	1,248	586	382	200	101	62	66,254
1982	16,332	12,548	7,027	11,815	2,771	726	341	223	117	91	51,991
1983	50,333	6,639	7,949	5,049	7,803	1,732	455	215	140	125	80,438
1984	12,735	20,461	4,193	5,742	3,441	5,069	1,098	289	136	159	53,322
1985	32,660	5,177	12,975	3,030	3,938	2,186	3,229	701	185	178	64,258
1986	13,941	13,278	3,277	9,317	2,110	2,604	1,356	2,017	437	218	48,554
1987	7,729	5,667	8,412	2,359	6,367	1,408	1,640	853	1,286	404	36,127
1988	5,433	3,142	3,599	6,102	1,670	4,377	941	1,097	546	1,060	27,966
1989	11,458	2,209	1,993	2,450	4,173	1,077	2,810	579	682	1,004	28,435
1990	49,810	4,658	1,401	1,413	1,646	2,717	677	1,673	350	1,038	65,384
1991	26,087	20,250	2,947	992	877	937	1,550	384	924	800	55,749
1992	23,039	10,606	12,820	2,129	658	527	538	820	214	888	52,240
1993	47,646	9,367	6,699	8,902	1,439	409	282	257	370	489	75,859
1994	15,411	19,371	5,956	4,747	5,645	942	245	152	139	475	53,086
1995	10,725	6,266	12,323	4,350	3,224	3,303	564	142	89	362	41,347
1996	22,872	4,360	3,986	9,047	3,103	2,054	1,798	320	81	263	47,885
1997	31,391	9,299	2,766	2,910	6,602	2,142	1,193	895	153	178	57,530
1998	15,821	12,763	5,874	2,015	2,070	4,494	1,340	661	480	167	45,685
1999	17,291	6,432	8,098	4,268	1,429	1,403	2,754	822	377	346	43,221
2000	26,883	7,030	4,091	5,755	2,969	969	909	1,645	498	444	51,193
2001	36,321	10,930	4,472	2,961	3,898	1,905	624	535	925	565	63,134
2002	23,454	14,767	6,957	3,260	2,050	2,376	1,061	351	303	866	55,445
2003	14,150	9,535	9,380	5,052	2,231	1,271	1,232	554	185	661	44,251
2004	6,359	5,753	6,065	6,615	3,454	1,338	681	626	286	481	31,658
2005	4,422	2,585	3,663	4,408	4,180	2,130	779	367	340	442	23,316
2006	11,401	1,798	1,646	2,663	2,933	2,337	1,164	441	212	468	25,063
2007	27,094	4,635	1,142	1,157	1,736	1,661	1,201	614	238	388	39,867
2008	15,205	11,016	2,944	803	751	980	817	617	329	352	33,813
2009	62,012	6,182	7,004	2,126	526	428	472	404	320	366	79,840
2010	23,818	25,212	3,936	5,066	1,417	327	233	248	214	360	60,831
2011	16,973	9,684	16,052	2,885	3,263	860	195	132	138	324	50,505
2012	10,626	6,901	6,161	11,721	2,022	1,689	414	96	67	240	39,937
2013	36,897	4,320	4,385	4,465	7,871	1,341	854	204	48	160	60,546
2014	25,993	15,001	2,748	3,189	3,009	5,000	837	482	101	102	56,461
2015	22,783	10,568	9,536	2,008	2,211	1,883	3,053	462	271	105	52,880
Median	22,290	8,604	4,494	2,910	1,927	980	564	289	140	198	46,785
Average	23,089	9,265	5,686	3,768	2,426	1,472	839	444	246	322	47,557

Table 1.26. Assessment model-estimated catch-at-age of EBS pollock (millions; 1964-2015).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	7.6	33.0	70.7	61.4	28.0	54.5	24.0	7.5	4.6	27.0	318.3
1965	21.1	26.0	88.3	232.0	40.1	15.6	28.9	12.6	4.0	17.2	485.9
1966	16.9	92.8	75.5	201.4	125.2	21.5	8.5	16.0	7.1	12.5	577.3
1967	55.7	138.8	585.7	209.2	181.0	114.1	20.6	8.4	16.5	21.4	1,351.3
1968	67.4	269.4	385.2	641.8	136.7	105.3	66.6	11.9	4.9	21.9	1,711.1
1969	109.5	254.3	859.6	438.0	340.6	73.6	58.8	38.0	7.0	16.1	2,195.5
1970	236.4	538.7	1,024.4	742.6	306.9	247.7	59.9	50.6	33.4	24.5	3,265.0
1971	224.6	579.2	1,298.1	796.2	674.3	250.0	201.0	47.3	38.6	50.8	4,160.2
1972	129.1	557.8	1,366.1	1,033.6	537.5	368.4	140.8	123.4	26.8	45.7	4,329.1
1973	200.1	575.0	867.3	929.6	613.2	320.8	220.8	89.7	70.2	36.3	3,923.2
1974	123.5	1,713.7	869.4	545.5	442.6	283.7	148.8	109.2	41.0	45.5	4,322.8
1975	69.3	770.8	1,822.9	371.4	227.4	182.0	116.5	61.5	42.4	35.0	3,699.1
1976	36.9	560.8	1,296.2	755.0	160.0	100.6	81.6	52.5	27.6	32.8	3,103.9
1977	27.5	461.0	909.2	610.6	304.9	67.3	43.4	35.7	23.2	25.4	2,508.2
1978	36.7	420.4	736.0	612.1	330.2	158.5	35.5	23.3	19.8	26.8	2,399.3
1979	68.7	465.9	648.6	409.1	348.9	181.4	88.8	20.2	14.3	28.2	2,274.1
1980	15.2	484.5	802.6	440.6	256.3	177.7	91.0	45.2	10.6	23.5	2,347.1
1981	8.2	96.4	1,050.6	658.2	233.5	108.4	69.9	36.5	19.0	15.2	2,295.8
1982	2.2	65.7	183.5	1,110.9	375.5	96.9	44.9	29.4	16.4	18.3	1,943.7
1983	4.8	50.9	171.4	349.5	832.9	216.5	55.9	26.3	18.7	25.6	1,752.5
1984	0.9	90.4	89.2	369.1	425.2	615.1	132.5	34.6	17.3	29.7	1,804.0
1985	1.9	29.9	344.0	157.1	366.2	308.9	439.7	96.1	25.3	34.9	1,804.0
1986	0.6	68.6	80.3	625.2	181.1	338.6	176.8	243.2	60.7	33.6	1,808.6
1987	0.2	18.8	151.4	90.6	397.4	119.9	138.0	101.1	163.0	63.1	1,243.4
1988	0.2	14.1	252.4	405.7	187.6	506.0	138.4	152.3	76.1	141.2	1,874.2
1989	0.3	9.5	73.9	197.9	438.2	141.0	479.0	91.7	100.8	146.2	1,678.3
1990	1.4	29.8	53.1	199.2	331.1	543.7	138.1	370.4	72.2	196.1	1,935.0
1991	0.6	116.7	62.5	90.0	143.8	183.2	385.3	82.8	237.8	220.7	1,523.4
1992	0.6	79.9	695.3	162.1	91.8	127.7	167.3	280.6	75.4	311.6	1,992.2
1993	0.6	20.4	251.9	1,111.5	144.4	67.8	66.1	59.9	85.2	104.1	1,912.0
1994	0.1	36.2	72.4	342.7	1,031.5	157.5	46.6	28.4	25.3	83.3	1,824.1
1995	0.1	12.2	95.6	139.8	391.2	762.0	114.3	28.1	16.9	67.0	1,627.2
1996	0.2	18.4	49.3	116.9	182.7	385.6	515.3	99.2	22.8	67.3	1,457.5
1997	0.2	69.9	39.4	100.2	464.1	289.0	261.5	215.5	43.5	48.4	1,531.8
1998	0.1	50.0	97.2	74.4	152.9	674.1	199.9	132.7	115.9	40.5	1,537.6
1999	0.1	13.1	284.9	226.0	105.0	152.2	463.6	130.2	57.5	49.6	1,482.1
2000	0.1	13.8	81.5	427.0	344.5	110.2	162.9	344.7	86.7	69.7	1,641.2
2001	0.2	15.2	61.3	167.7	599.5	410.9	130.3	108.7	175.3	103.5	1,772.7
2002	0.1	45.7	119.1	215.5	289.7	621.4	273.6	87.7	69.5	171.6	1,894.0
2003	0.1	18.6	389.9	336.6	369.1	306.6	337.6	146.1	43.0	128.1	2,075.7
2004	0.0	7.1	99.5	843.7	502.9	248.2	162.1	145.5	59.6	88.5	2,157.0
2005	0.0	3.7	59.0	388.4	892.2	486.1	160.5	69.4	60.5	69.9	2,189.6
2006	0.1	5.1	72.9	277.3	601.2	623.3	292.6	103.6	45.4	90.9	2,112.3
2007	0.2	14.7	50.8	123.3	359.1	487.6	321.0	147.2	52.5	79.4	1,635.9
2008	0.1	24.7	64.4	80.5	150.6	299.3	236.3	162.0	82.6	80.1	1,180.5
2009	0.3	6.9	143.4	184.3	73.1	99.6	119.7	100.7	81.4	93.4	902.7
2010	0.1	30.2	36.1	573.3	222.7	55.8	46.7	53.9	45.5	73.5	1,137.9
2011	0.1	16.8	199.5	134.5	856.9	262.7	56.5	36.9	36.7	82.4	1,683.0
2012	0.1	18.6	115.8	948.5	183.1	467.5	121.2	27.4	18.0	61.5	1,961.6
2013	0.2	8.1	69.6	349.6	972.9	184.0	177.3	59.2	13.9	47.9	1,882.7
2014	0.1	37.1	32.5	177.4	405.6	762.8	184.8	101.5	26.3	26.4	1,754.4
2015	0.1	24.9	106.9	110.8	331.1	281.4	565.7	85.0	68.4	26.6	1,600.9
Median	0.6	36.2	119.1	342.7	331.1	216.5	138.0	69.4	38.6	48.1	1,816.3
Average	28.3	175.5	375.1	401.8	359.3	273.5	169.6	91.8	50.1	66.9	1,991.9

Table 1.27. Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2015. 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	1,869	545	7,410	1990	7,701	2,928	49,810
1965	2,324	664	22,290	1991	6,063	2,179	26,087
1966	2,563	794	16,499	1992	9,472	2,303	23,039
1967	3,888	1,015	27,209	1993	11,712	3,202	47,646
1968	4,495	1,268	23,734	1994	11,418	3,523	15,411
1969	5,690	1,559	26,781	1995	13,177	3,749	10,725
1970	6,424	1,832	23,061	1996	11,358	3,765	22,872
1971	6,858	1,943	14,389	1997	9,940	3,565	31,391
1972	6,431	1,836	11,932	1998	9,990	3,317	15,821
1973	5,161	1,539	26,783	1999	10,853	3,318	17,291
1974	3,846	1,159	21,349	2000	10,068	3,346	26,883
1975	3,868	981	19,146	2001	9,854	3,382	36,321
1976	3,872	977	14,795	2002	10,276	3,216	23,454
1977	3,939	1,039	15,612	2003	12,365	3,418	14,150
1978	3,888	1,095	28,474	2004	11,591	3,520	6,359
1979	3,859	1,101	67,784	2005	9,705	3,223	4,422
1980	4,887	1,251	27,425	2006	7,446	2,651	11,401
1981	9,054	1,986	30,874	2007	6,045	2,215	27,094
1982	10,289	2,946	16,332	2008	4,849	1,630	15,205
1983	11,383	3,594	50,333	2009	6,331	1,775	62,012
1984	11,040	3,812	12,735	2010	6,680	2,018	23,818
1985	12,951	4,030	32,660	2011	10,053	2,538	16,973
1986	12,019	4,183	13,941	2012	10,164	3,053	10,626
1987	12,334	4,216	7,729	2013	10,337	3,490	36,897
1988	11,536	4,130	5,433	2014	9,805	3,467	25,993
1989	9,700	3,668	11,458	2015	10,970	3,483	22,783

Table 1.28. Estimates of begin-year age 3 and older biomass (thousands of tons) and coefficients of variation (CV) for the current assessment compared to 2007-2013 assessments for EBS pollock.

	Current		2013		2012		2011		2010		2009		2008		2007	
	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV
1964	1,869	24%	1,622	21%	1,602	21%	1,608	21%	1,602	21%	1,589	21%	1,564	22%	1,600	22%
1965	2,324	22%	2,077	20%	2,051	20%	2,059	20%	2,050	20%	2,008	19%	2,008	20%	2,050	20%
1966	2,563	22%	2,186	20%	2,150	20%	2,157	20%	2,159	20%	1,944	21%	1,947	22%	2,007	21%
1967	3,888	19%	3,397	16%	3,344	16%	3,353	16%	3,365	16%	3,140	17%	3,149	17%	3,245	17%
1968	4,495	18%	3,871	17%	3,800	17%	3,809	17%	3,838	17%	3,486	18%	3,510	19%	3,592	18%
1969	5,690	16%	5,220	16%	5,145	16%	5,154	16%	5,187	16%	4,879	17%	5,007	17%	5,020	17%
1970	6,424	15%	6,253	15%	6,179	15%	6,188	15%	6,221	15%	5,974	16%	6,159	15%	6,005	16%
1971	6,858	14%	6,946	14%	6,884	14%	6,894	14%	6,918	14%	6,785	13%	6,949	13%	6,727	14%
1972	6,431	13%	6,353	14%	6,299	14%	6,308	14%	6,329	14%	6,277	13%	6,444	13%	6,289	14%
1973	5,161	14%	4,749	16%	4,692	16%	4,700	16%	4,728	16%	4,547	16%	4,696	16%	4,556	17%
1974	3,846	17%	3,348	20%	3,291	20%	3,298	20%	3,329	20%	3,085	20%	3,196	20%	3,064	22%
1975	3,868	13%	3,554	14%	3,516	14%	3,523	14%	3,533	14%	3,366	13%	3,384	13%	3,276	14%
1976	3,872	11%	3,609	11%	3,578	11%	3,587	11%	3,580	11%	3,460	10%	3,431	11%	3,339	11%
1977	3,939	10%	3,643	10%	3,613	9%	3,624	10%	3,598	9%	3,500	9%	3,457	9%	3,340	10%
1978	3,888	9%	3,557	9%	3,524	9%	3,537	9%	3,497	9%	3,390	9%	3,340	9%	3,202	9%
1979	3,859	9%	3,426	9%	3,387	9%	3,403	9%	3,343	9%	3,267	9%	3,212	9%	3,090	9%
1980	4,887	8%	4,372	7%	4,307	7%	4,333	7%	4,230	7%	4,203	7%	4,124	8%	4,044	7%
1981	9,054	6%	8,528	6%	8,321	6%	8,364	6%	8,160	6%	8,190	6%	8,031	6%	7,704	6%
1982	10,289	5%	9,767	5%	9,497	6%	9,549	6%	9,313	6%	9,349	6%	9,165	6%	8,783	6%
1983	11,383	5%	10,911	5%	10,560	5%	10,621	5%	10,340	5%	10,376	5%	10,168	5%	9,804	5%
1984	11,040	5%	10,601	5%	10,239	5%	10,300	5%	10,031	5%	10,060	5%	9,857	5%	9,518	5%
1985	12,951	4%	12,838	4%	12,409	4%	12,478	4%	12,186	4%	12,246	4%	12,027	4%	11,802	4%
1986	12,019	4%	12,036	4%	11,621	4%	11,685	4%	11,426	4%	11,471	4%	11,269	4%	11,075	4%
1987	12,334	4%	12,615	4%	12,243	4%	12,308	4%	12,063	4%	12,111	4%	11,915	4%	11,732	4%
1988	11,536	4%	11,906	3%	11,583	4%	11,642	4%	11,424	4%	11,402	4%	11,227	4%	11,004	4%
1989	9,700	4%	10,128	4%	9,861	4%	9,913	4%	9,724	4%	9,671	4%	9,521	4%	9,320	4%
1990	7,701	4%	8,102	4%	7,891	4%	7,936	4%	7,764	4%	7,681	4%	7,558	4%	7,345	4%
1991	6,063	5%	6,331	4%	6,171	5%	6,209	5%	6,049	5%	5,911	5%	5,811	5%	5,590	5%
1992	9,472	3%	9,705	3%	9,562	3%	9,602	3%	9,411	3%	9,316	3%	9,211	4%	8,966	4%
1993	11,712	3%	11,840	3%	11,712	3%	11,754	3%	11,543	3%	11,493	3%	11,388	3%	11,175	3%
1994	11,418	3%	11,402	3%	11,306	3%	11,341	3%	11,146	3%	11,077	3%	10,990	4%	10,782	4%
1995	13,177	3%	13,135	3%	13,074	3%	13,109	3%	12,883	3%	12,779	3%	12,699	3%	12,704	3%
1996	11,358	3%	11,235	3%	11,198	3%	11,229	3%	11,019	3%	10,903	4%	10,843	4%	10,829	4%
1997	9,940	3%	9,816	4%	9,801	4%	9,828	4%	9,627	4%	9,485	4%	9,440	4%	9,403	4%
1998	9,990	3%	9,907	3%	9,903	4%	9,929	3%	9,722	4%	9,584	4%	9,538	4%	9,467	4%
1999	10,853	3%	10,799	3%	10,791	3%	10,819	3%	10,607	3%	10,509	3%	10,421	3%	10,379	4%
2000	10,068	3%	10,031	3%	10,020	3%	10,044	3%	9,841	3%	9,747	3%	9,632	3%	9,503	4%
2001	9,854	3%	9,819	3%	9,803	3%	9,830	3%	9,616	3%	9,506	3%	9,341	4%	9,175	4%
2002	10,276	3%	10,221	3%	10,182	3%	10,230	3%	9,988	3%	9,842	3%	9,595	4%	9,554	4%
2003	12,365	3%	12,278	3%	12,211	3%	12,269	3%	11,974	3%	11,805	3%	11,453	3%	11,182	4%
2004	11,591	3%	11,493	3%	11,416	3%	11,491	3%	11,178	3%	10,974	3%	10,606	4%	10,274	4%
2005	9,705	3%	9,602	3%	9,522	3%	9,608	3%	9,299	3%	9,079	4%	8,736	4%	8,423	5%
2006	7,446	3%	7,343	3%	7,262	4%	7,349	4%	7,060	4%	6,839	4%	6,543	5%	6,340	6%
2007	6,045	4%	5,933	4%	5,840	4%	5,954	4%	5,633	5%	5,386	5%	5,090	6%	5,015	8%
2008	4,849	4%	4,722	5%	4,607	5%	4,724	5%	4,393	6%	4,146	7%	3,809	8%	4,222	12%
2009	6,331	5%	6,069	5%	5,880	5%	6,069	6%	6,172	8%	6,225	10%	4,762	11%	6,240	20%
2010	6,680	5%	5,937	5%	5,622	6%	5,769	7%	6,095	10%	6,582	12%	4,616	13%		
2011	10,053	7%	8,895	6%	7,928	8%	7,781	9%	7,823	11%	9,620	15%				
2012	10,164	8%	8,823	8%	7,853	10%	7,867	10%	8,341	12%						
2013	10,337	9%	9,541	8%	8,261	11%	8,138	12%								
2014	9,805	10%	8,960	9%	8,045	12%										
2015	10,970	11%	9,203	10%												
2016	11,292	12%														

Table 1.29 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 7,032, 2,813 and 2,461 thousand t, respectively.

Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2015	1,318	1,318	1,318	1,318	1,318	1,318	1,318
2016	2,087	1,350	1,011	922	0	2,580	2,087
2017	2,019	2,243	1,135	1,048	0	2,320	2,019
2018	1,918	2,053	1,203	1,121	0	2,082	2,376
2019	1,797	1,887	1,248	1,171	0	1,816	1,998
2020	1,672	1,715	1,252	1,182	0	1,715	1,779
2021	1,631	1,647	1,252	1,188	0	1,697	1,718
2022	1,623	1,627	1,250	1,188	0	1,702	1,708
2023	1,625	1,627	1,249	1,190	0	1,707	1,708
2024	1,620	1,619	1,247	1,188	0	1,700	1,700
2025	1,611	1,610	1,241	1,183	0	1,689	1,689
2026	1,601	1,602	1,236	1,179	0	1,676	1,676
2027	1,589	1,591	1,228	1,172	0	1,664	1,664
2028	1,588	1,589	1,224	1,168	0	1,665	1,665
Fishing M.	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2015	0.219	0.219	0.219	0.219	0.219	0.219	0.219
2016	0.375	0.227	0.165	0.149	0.000	0.486	0.375
2017	0.375	0.375	0.165	0.149	0.000	0.486	0.375
2018	0.375	0.375	0.165	0.149	0.000	0.480	0.486
2019	0.367	0.370	0.165	0.149	0.000	0.442	0.457
2020	0.352	0.354	0.165	0.149	0.000	0.425	0.430
2021	0.346	0.347	0.165	0.149	0.000	0.422	0.423
2022	0.344	0.344	0.165	0.149	0.000	0.422	0.422
2023	0.343	0.343	0.165	0.149	0.000	0.421	0.421
2024	0.342	0.342	0.165	0.149	0.000	0.418	0.418
2025	0.342	0.342	0.165	0.149	0.000	0.418	0.418
2026	0.341	0.341	0.165	0.149	0.000	0.416	0.416
2027	0.341	0.341	0.165	0.149	0.000	0.416	0.416
2028	0.341	0.341	0.165	0.149	0.000	0.415	0.415
SSB	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2015	3,381	3,381	3,381	3,381	3,381	3,381	3,381
2016	3,528	3,634	3,679	3,691	3,805	3,451	3,528
2017	3,409	3,693	3,996	4,045	4,577	3,152	3,409
2018	3,214	3,379	4,112	4,195	5,152	2,870	3,143
2019	3,062	3,150	4,155	4,264	5,616	2,704	2,833
2020	2,980	3,019	4,158	4,286	5,976	2,654	2,699
2021	2,951	2,968	4,146	4,286	6,246	2,645	2,659
2022	2,958	2,965	4,156	4,304	6,494	2,658	2,662
2023	2,961	2,965	4,154	4,306	6,669	2,663	2,663
2024	2,946	2,949	4,133	4,287	6,772	2,649	2,649
2025	2,931	2,934	4,112	4,268	6,850	2,634	2,634
2026	2,913	2,916	4,088	4,245	6,900	2,619	2,619
2027	2,906	2,908	4,072	4,229	6,937	2,614	2,614
2028	2,916	2,917	4,073	4,230	6,969	2,627	2,627

Table 1.30 Maximum permissible Tier 1a EBS pollock ABC and OFL projections for 2016 and 2017.

Year	Catch	ABC	OFL
2016	1,350,000 t	3,050,000 t	3,910,000 t
2017	1,350,000 t	2,760,000 t	3,540,000 t

Table 1.31. 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 1.32 Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 1997-2002 based on observer data, 2003-2014 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
Scypho jellies	5,644	6,590	5,196	2,716	2,398	4,183	8,115	2,661	8,893	3,878	6,117	13,886
Misc fish	101.3	89.8	157.9	154.1	202.9	120.2	135.1	173.0	325.8	163.0	151.0	50.1
Sea star	89.4	7.2	9.5	11.3	5.3	18.7	9.8	13.2	37.5	8.1	14.8	30.1
Eulachon	2.5	19.3	9.2	93.6	100.8	2.4	5.3	0.7	3.3	1.7	0.8	2.4
Eelpouts	7.0	0.7	1.3	21.0	118.7	8.9	4.3	2.1	1.3	1.3	1.8	8.1
osmerids	7.5	2.0	3.4	5.8	37.5	2.0	0.1	0.1	0.3	0.2	0.2	0.5
Sea pens	0.6	1.0	1.7	2.0	4.0	1.1	2.6	3.1	2.9	3.9	2.3	4.0
Sponge	0.1	0.0	0.0	0.0	1.4	0.2	0.5	4.9	3.9	0.5	6.6	2.5
Snails	1.3	1.0	6.9	0.2	0.5	1.9	1.5	1.4	1.4	1.5	1.1	1.7
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
Sea anemone	0.4	0.4	0.3	0.6	0.3	0.9	1.3	2.4	2.0	1.7	2.4	2.0
Brittle star	0.3	0.0	0.0	2.6	0.2	3.6	0.1	0.3	0.2	0.1	0.1	2.3
urochordata	0.0	0.0	0.5	0.0	0.0	0.8	0.7	3.1	0.9	0.1	1.9	1.1
Invertebrate	0.0	0.1	0.1	0.2	0.8	0.3	0.3	1.0	0.7	2.2	0.2	0.6
Misc crabs	0.7	0.0	0.3	0.1	1.3	0.6	0.2	0.1	0.3	0.2	0.6	0.4
All other	0.3	0.7	3.5	3.9	5.1	2.1	1.9	2.0	1.8	0.6	0.8	1.7

Table 1.33 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	9,998	4,846	8,463	1,095	1,599	660	894	1	29	74	2,342	178	65	315	590	31,150
2012	10,047	3,957	6,819	1,452	735	713	263	1	53	129	2,017	495	55	286	512	27,534
2013	2,054	1,016	2,306	822	180	0	0	0	1	20	449	0	1	26	34	6,907
2014	5,213	2,554	4,380	1,954	758	1,300	117	1	41	318	815	1,478	75	191	497	19,693
2015	8,284	2,253	1,705	845	398	2,474	195	0	41	97	824	2,206	109	184	342	19,957

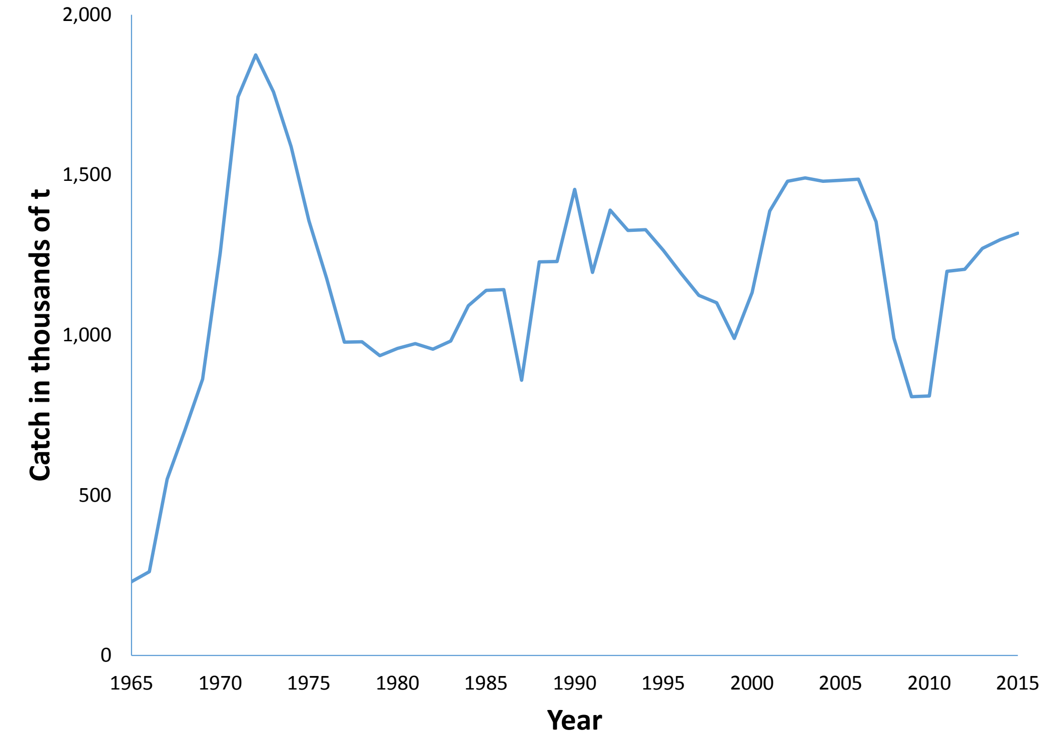
Table 1.34 Bycatch estimates (t) of **pollock** caught in the other non-pollock EBS directed fisheries, 2003-2015 based on then NMFS Alaska Regional Office reports from observers.

	Fishery						
	Pacific cod	Yellowfin sole	Rock sole	Flathead sole	Other flatfish	Others	**Total**
2003	15,922	11,570	4,925	2,989	691	265	36,362
2004	18,619	10,479	8,964	5,112	1,231	196	44,600
2005	14,105	10,312	7,240	3,664	1,394	202	36,917
2006	15,147	5,967	7,040	2,641	1,153	143	32,090
2007	20,306	4,042	3,220	3,448	932	268	32,215
2008	9,584	9,867	4,995	4,098	714	17	29,275
2009	7,879	6,998	6,150	3,166	347	14	24,553
2010	6,416	5,207	5,913	3,072	320	91	21,022
2011	8,965	8,695	7,090	1,491	832	301	27,373
2012	8,386	11,226	6,779	903	849	413	28,547
2013	9,096	20,246	7,372	2,021	2,037	252	40,881
2014	11,508	24,713	11,259	4,106	2,298	202	54,086
2015	6,648	18,335	9,379	2,632	2,360	79	39,433
Average	11,737	11,358	6,948	3,026	1,166	188	34,412

Table 1.35 Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997-2012 based on then AKFIN (NMFS Regional Office) reports from observers. **Herring and halibut units are in t,** all others represent numbers of individuals caught. Data for 2015 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	13,589	29	9,831	0	357	274	351	13,797	9,431		1,009
2011	10,319	20	25,499	0	509	382	377	193,555	6,332		577
2012	5,413	0	11,344	0	475	386	2,353	22,390	6,106		344
2013	8,015	34	11,261	103	308	251	958	123,087	7,617	316	8,015
2014	11,794	0	16,476	148	239	200	159	224,785	18,862	348	11,794
2015	8,675	0	20,678	0	151	129	1,490	241,971	7,606	0	8,675

Figures



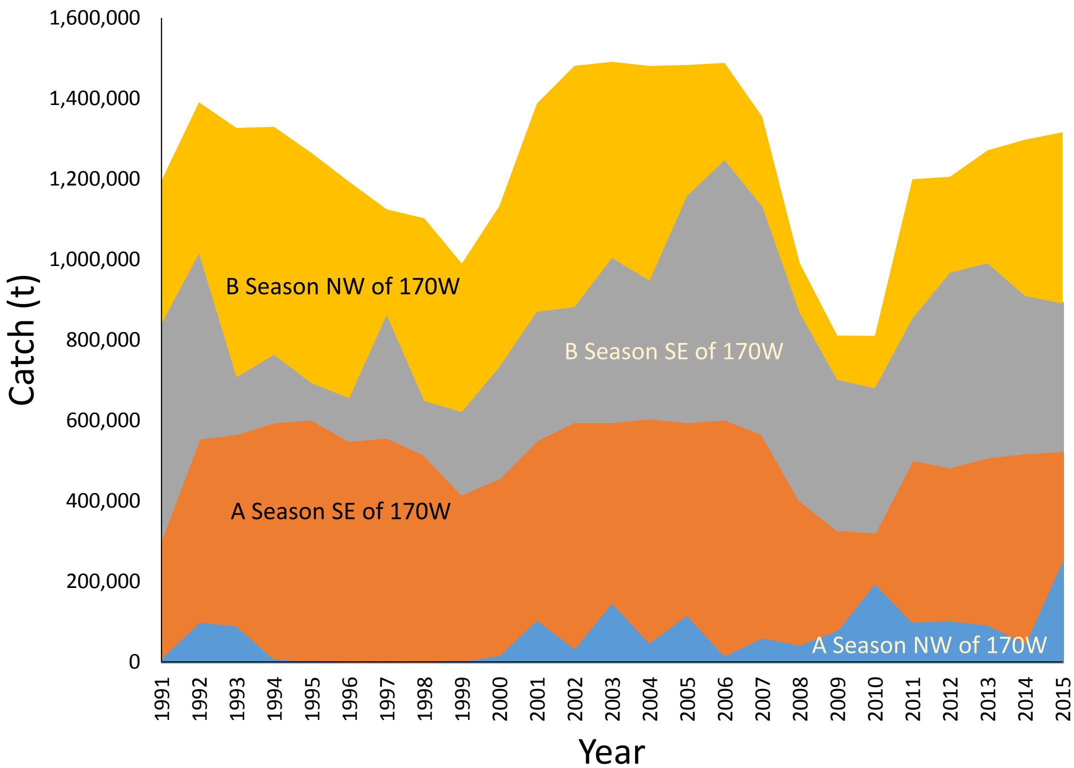


Figure 1.1. Pollock catch estimates from the Eastern Bering Sea overall (top) and by season and region (bottom) in metric t. The A-season is defined as from Jan-May and B-season from June-October.

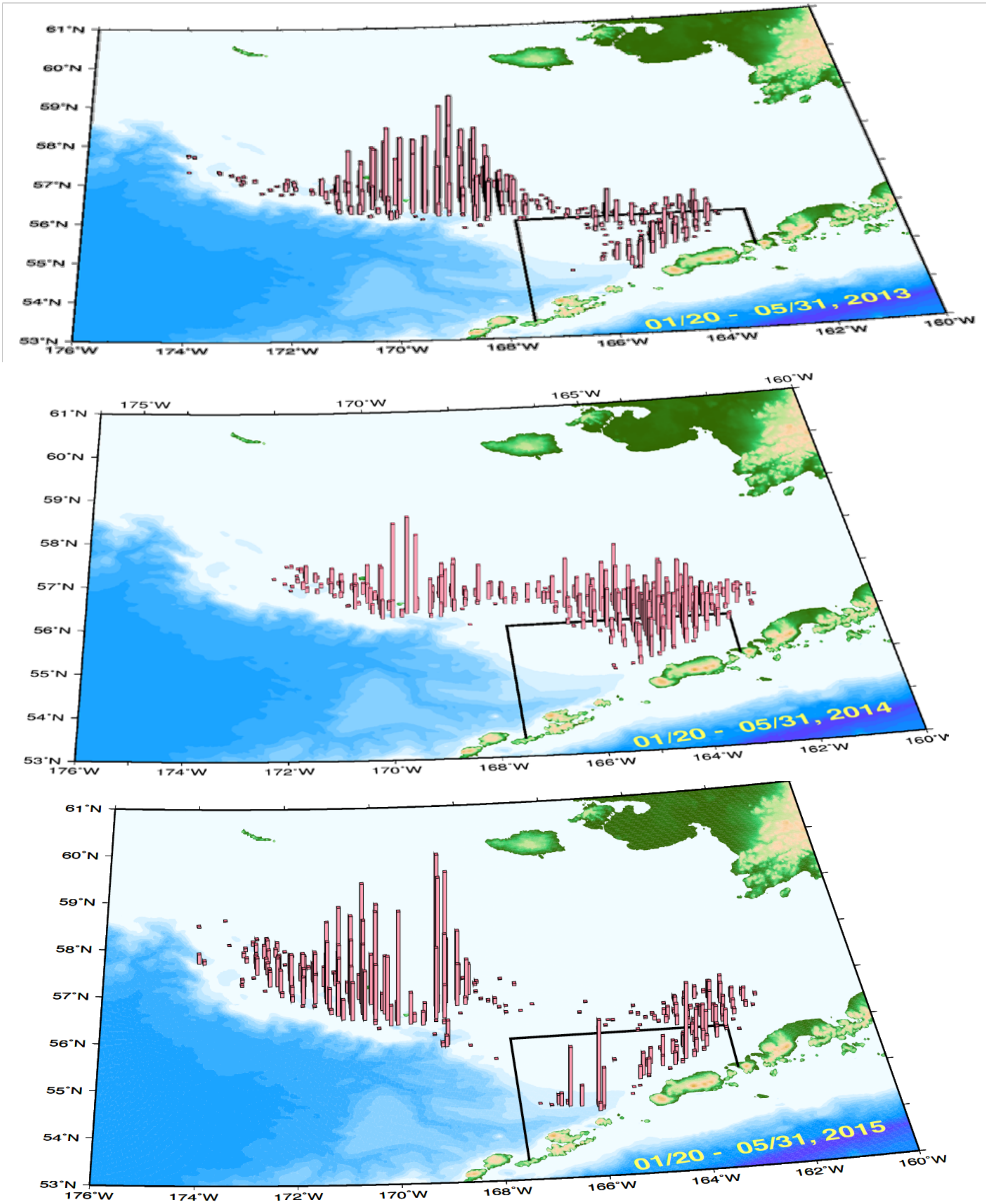


Figure 1.2. Pollock catch distribution 2013-2015, for the A-season on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

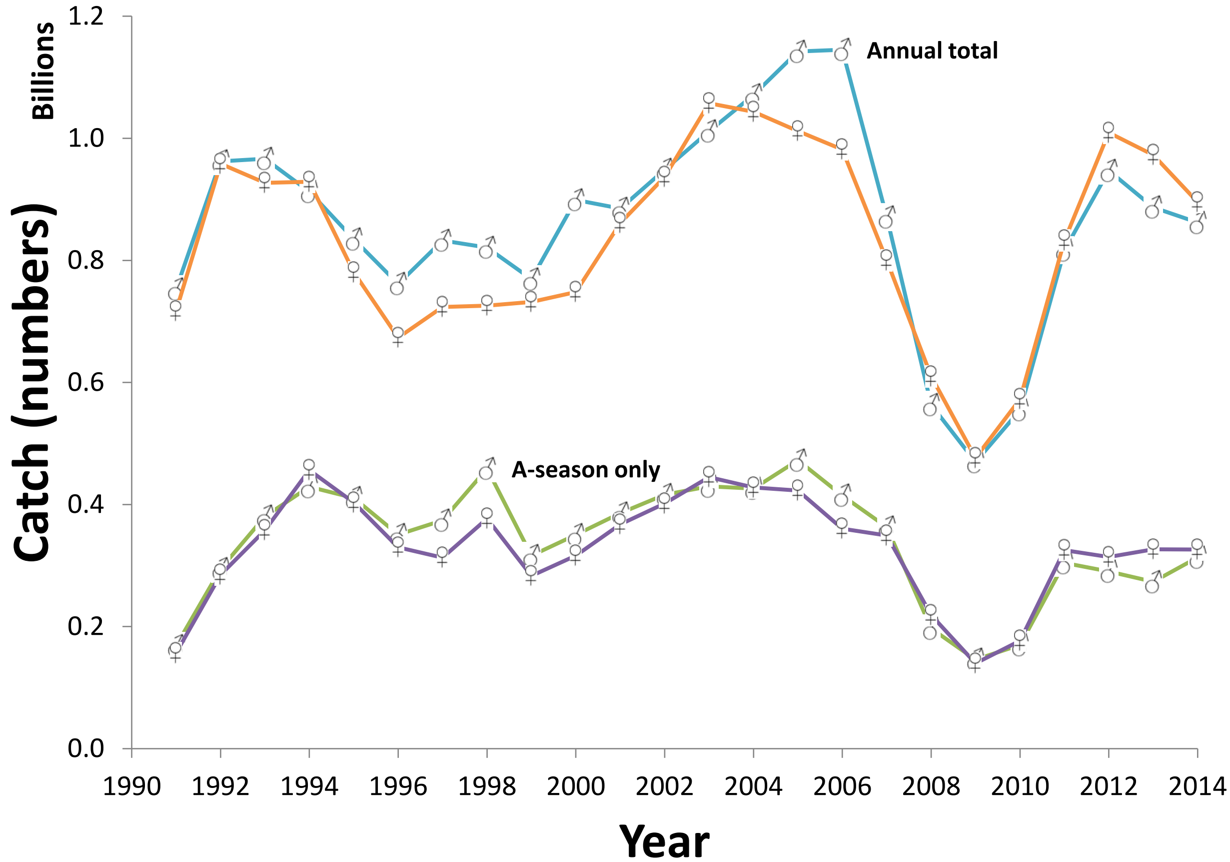


Figure 1.3. Estimate of EBS pollock catch numbers by sex for the A season (January-May) and for the entire annual fishery, 1991-2014.

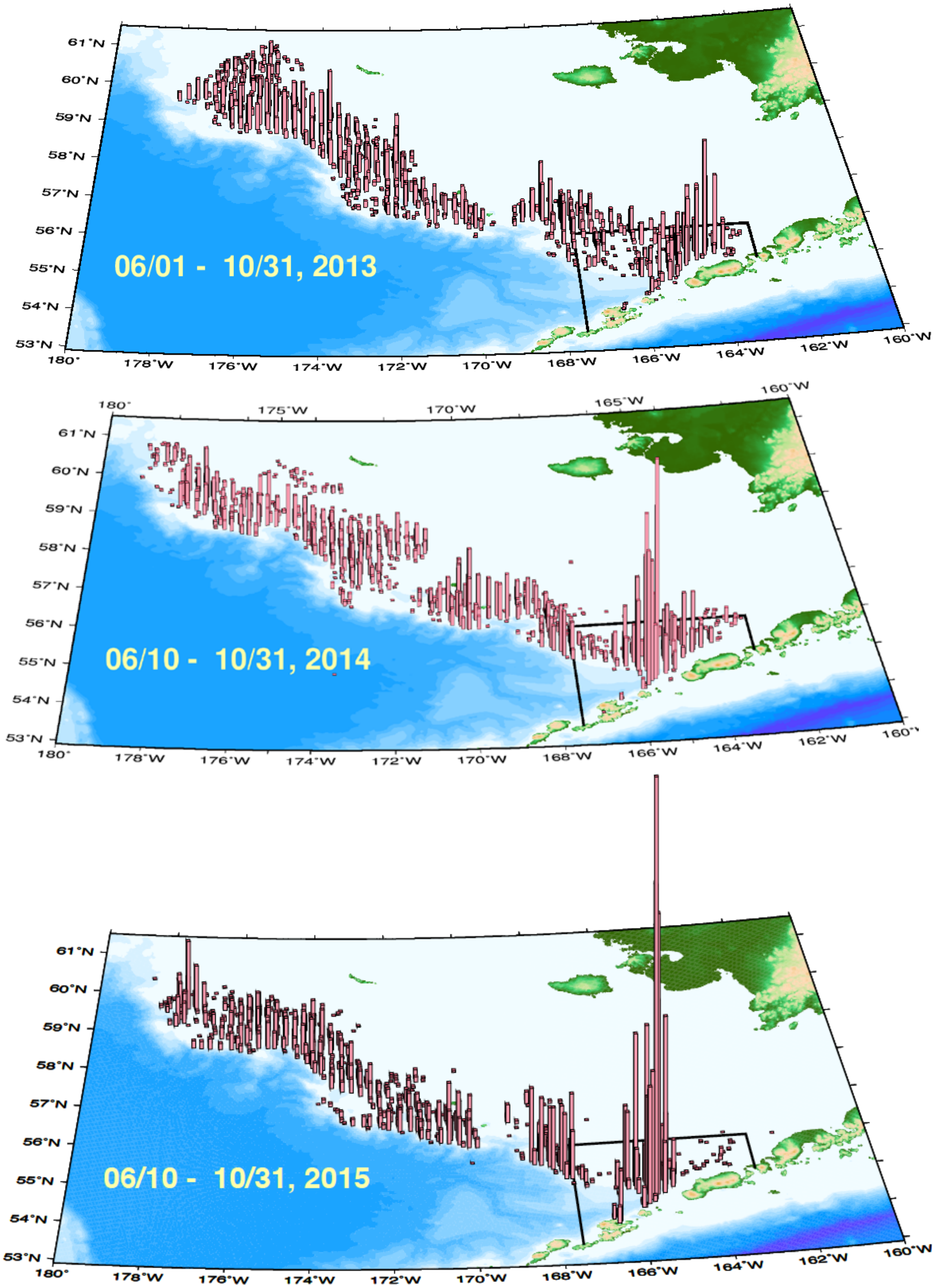


Figure 1.4. Pollock catch distribution during June – October, 2013-2015. The line delineates the catcher-vessel operational area (CVOA) and the height of the bars represents relative removal on the same scale between years.

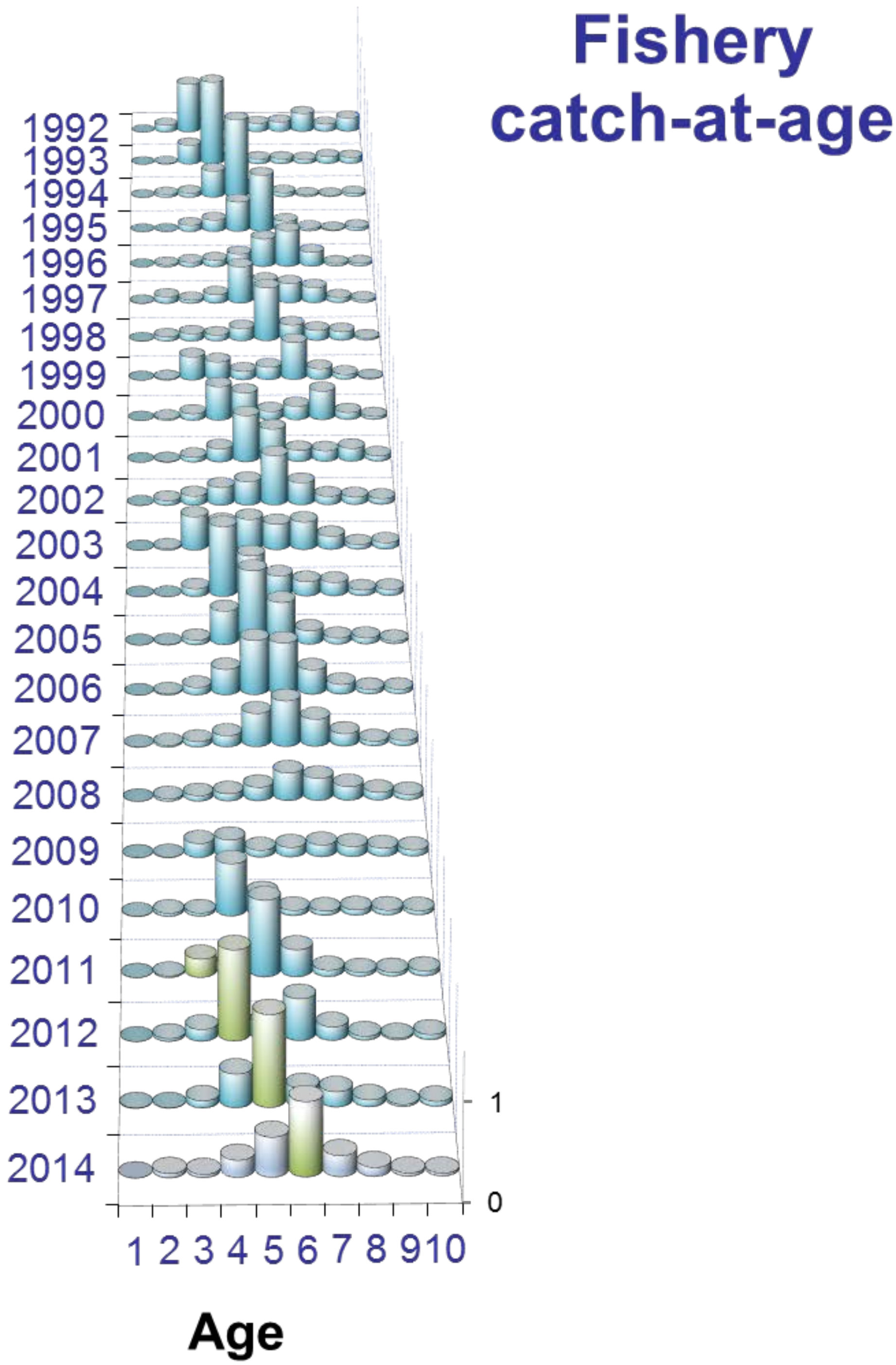


Figure 1.5. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2014. Age 10 represents pollock age 10 and older. The 2008 year-class is shaded in green.

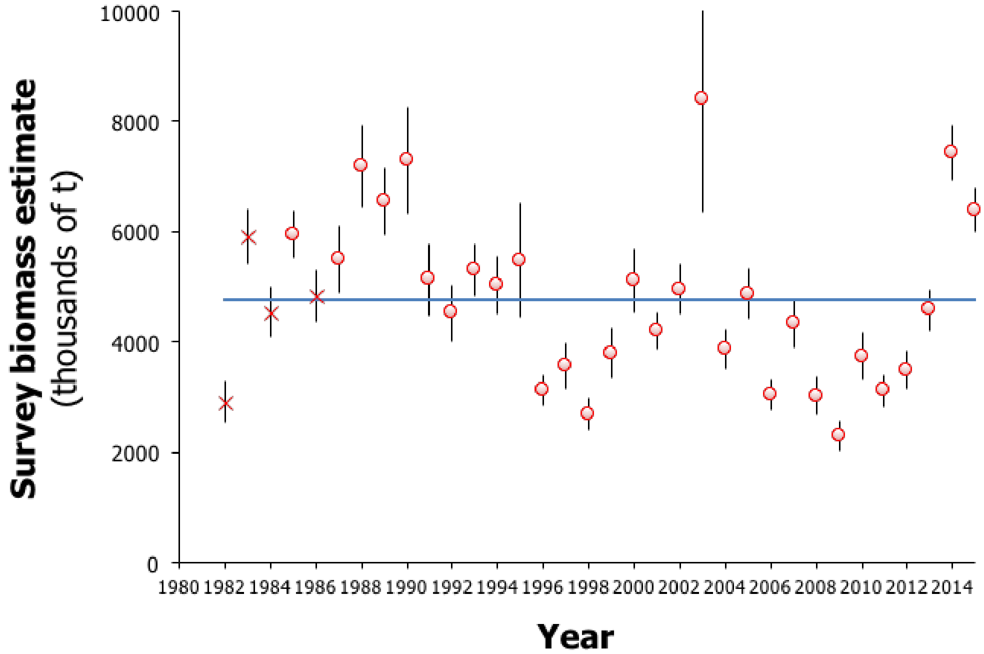


Figure 1.6. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS pollock, 1982-2015. These estimates **include** the northern strata except for 1982-84, and 1986. Horizontal line represents the long-term mean.

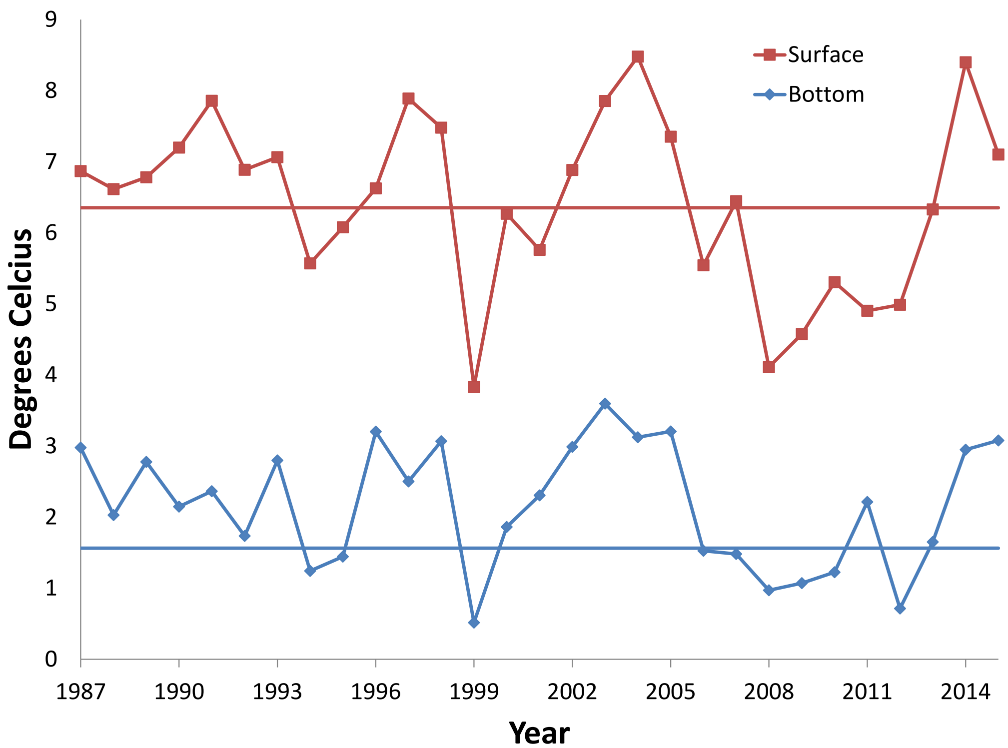


Figure 1.7. Area-weighted bottom (lower lines) and surface (upper lines) temperatures for the Bering Sea and mean values from the NMFS summer bottom-trawl surveys (1987-2015).

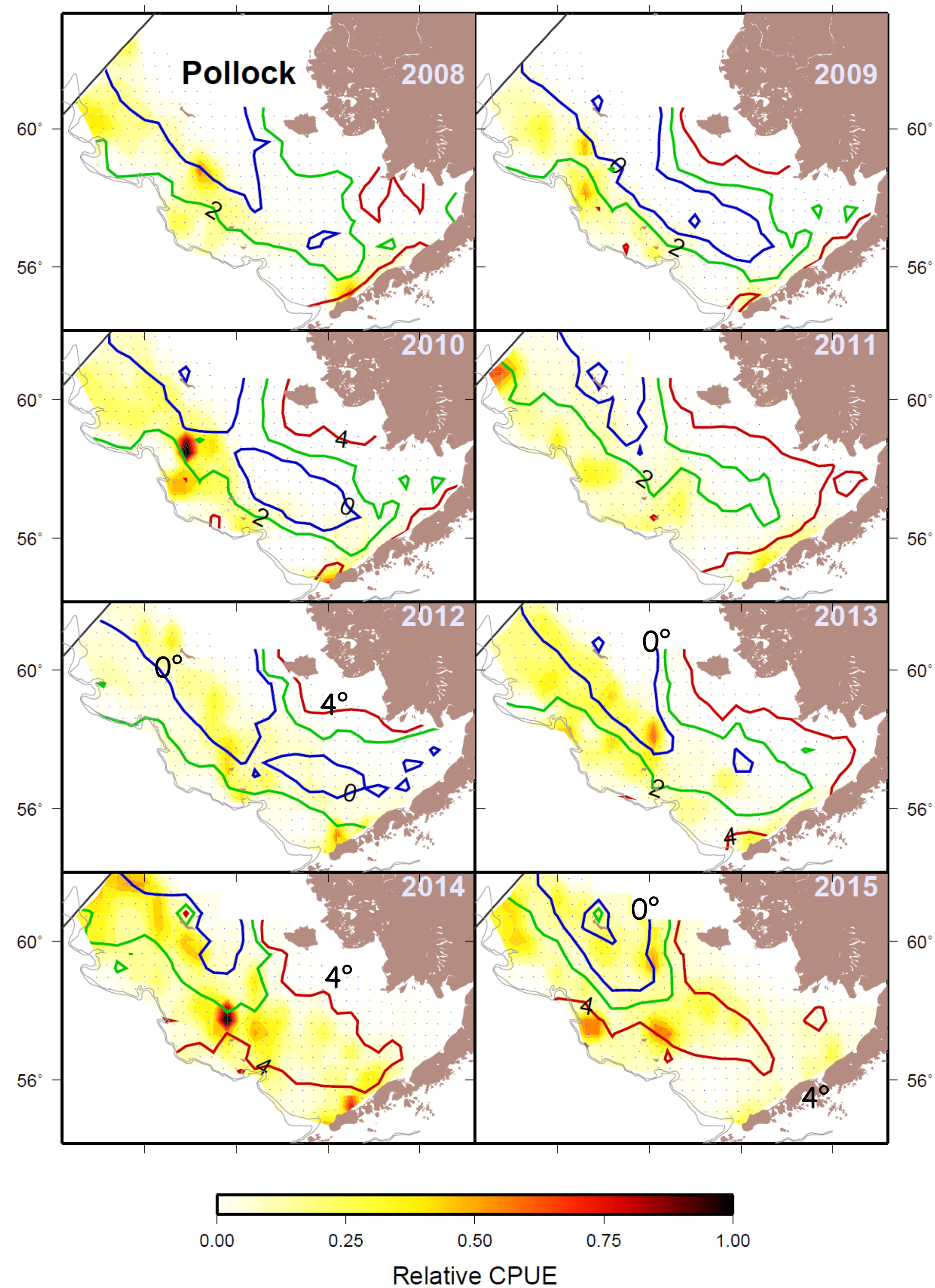


Figure 1.8. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 2007-2015.

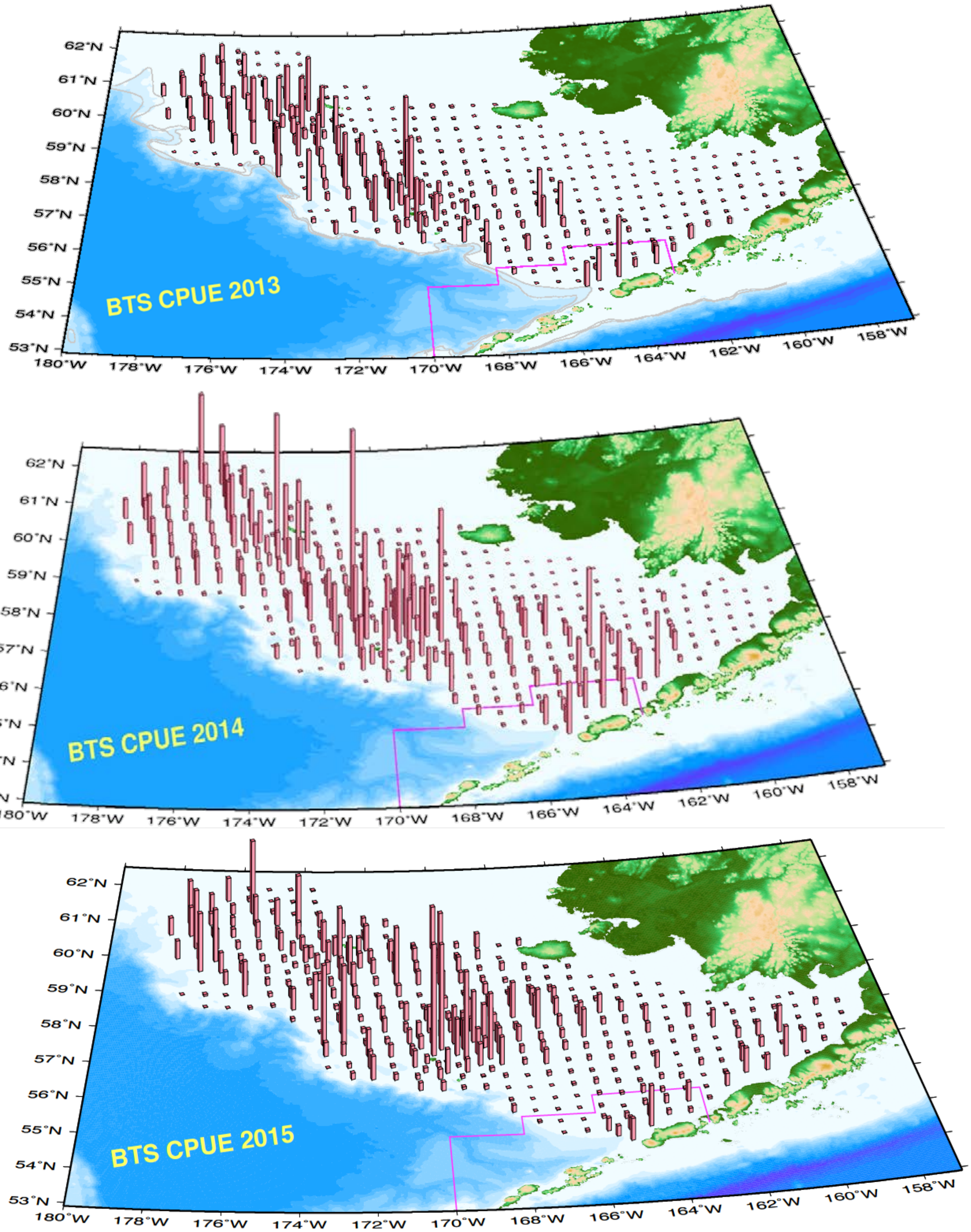


Figure 1.9. Bottom trawl survey pollock catch in kg per hectare for 2013 - 2015. Vertical lines represent station-specific pollock densities.

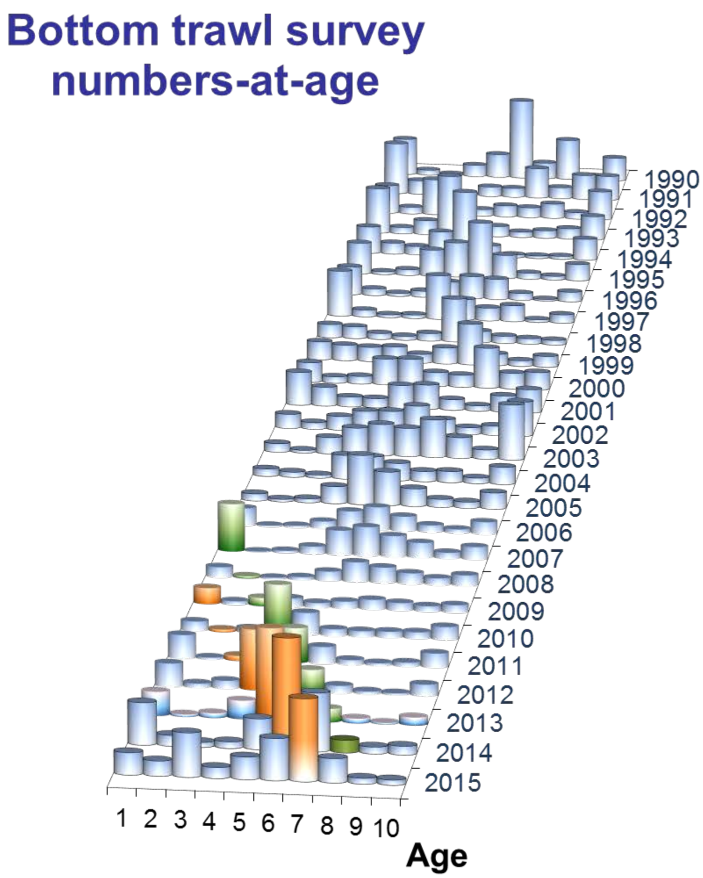


Figure 1.10. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1990-2015). The 2006 and 2008 year-classes are shaded differently.

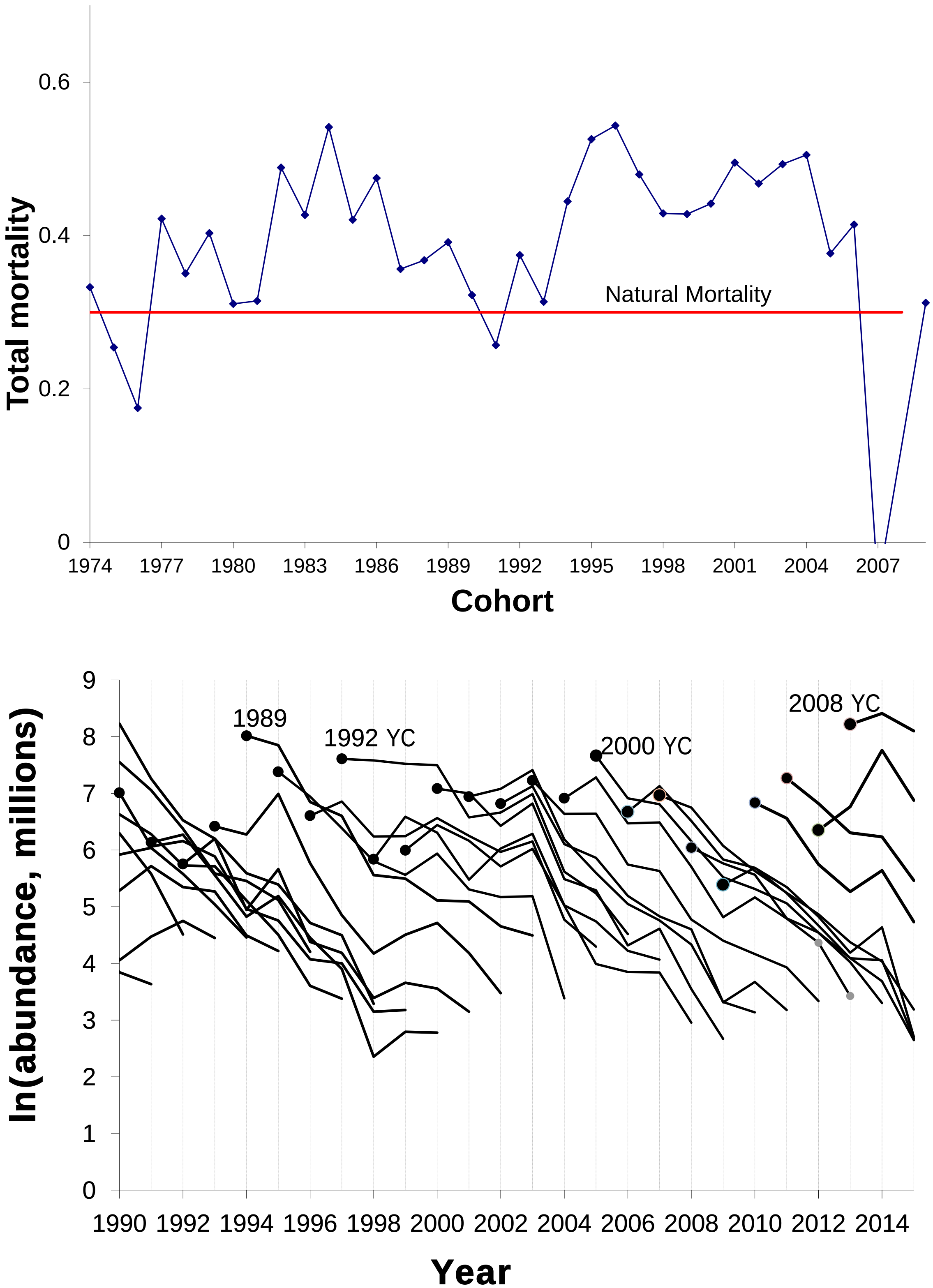


Figure 1.11. Evaluation of EBS pollock cohort abundances as observed for age 5 and older in the NMFS summer bottom trawl surveys, 1982-2015. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort (the 2007 year-class had anomalous increases in abundance from age 5-8).

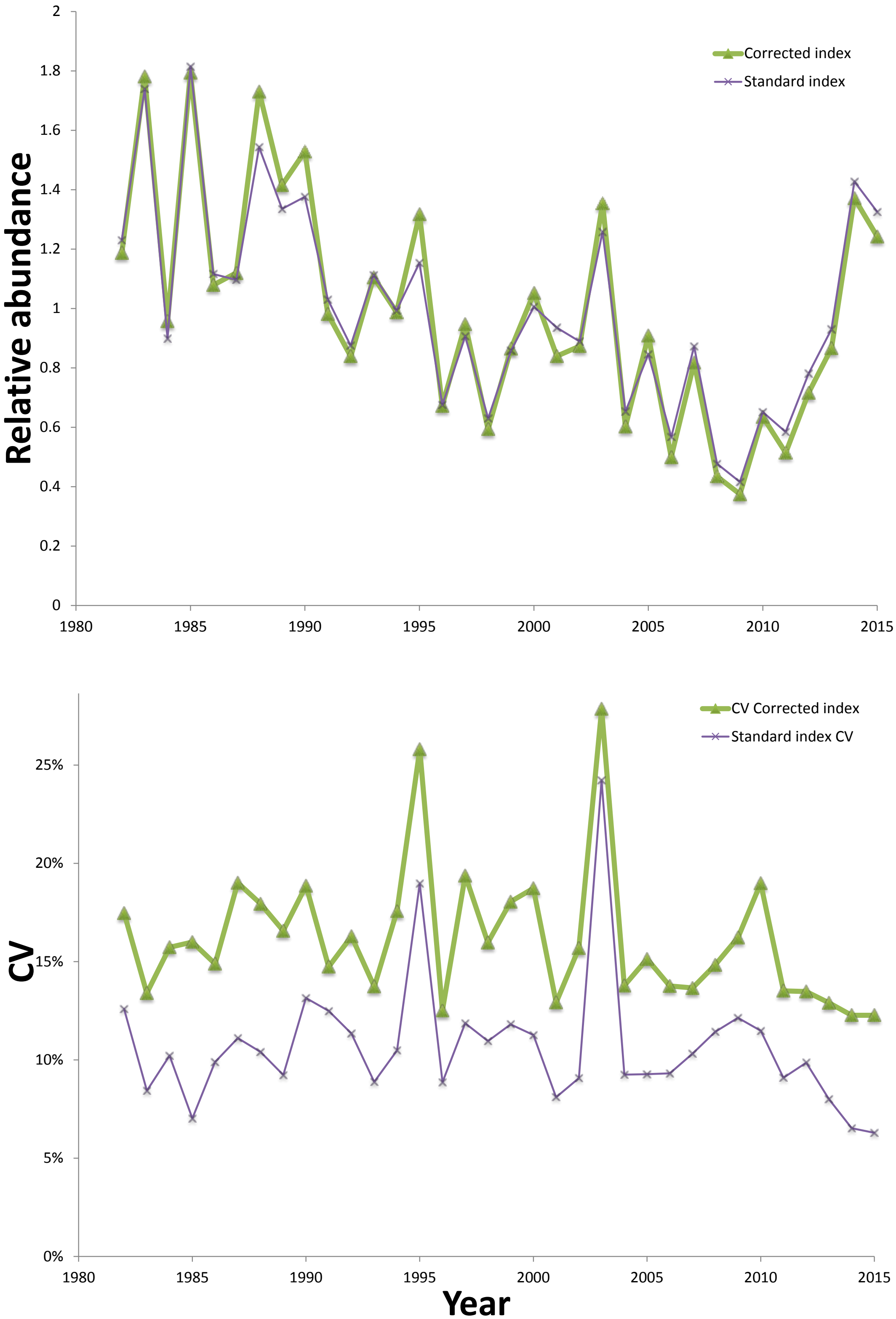


Figure 1.12. Relative abundance trends as estimated using the efficiency "corrected" index (based on Kotwicki et al. 2014) compared to the standard survey abundance estimate (top panel) and the estimated coefficients of variation (CVs; bottom) for EBS pollock.

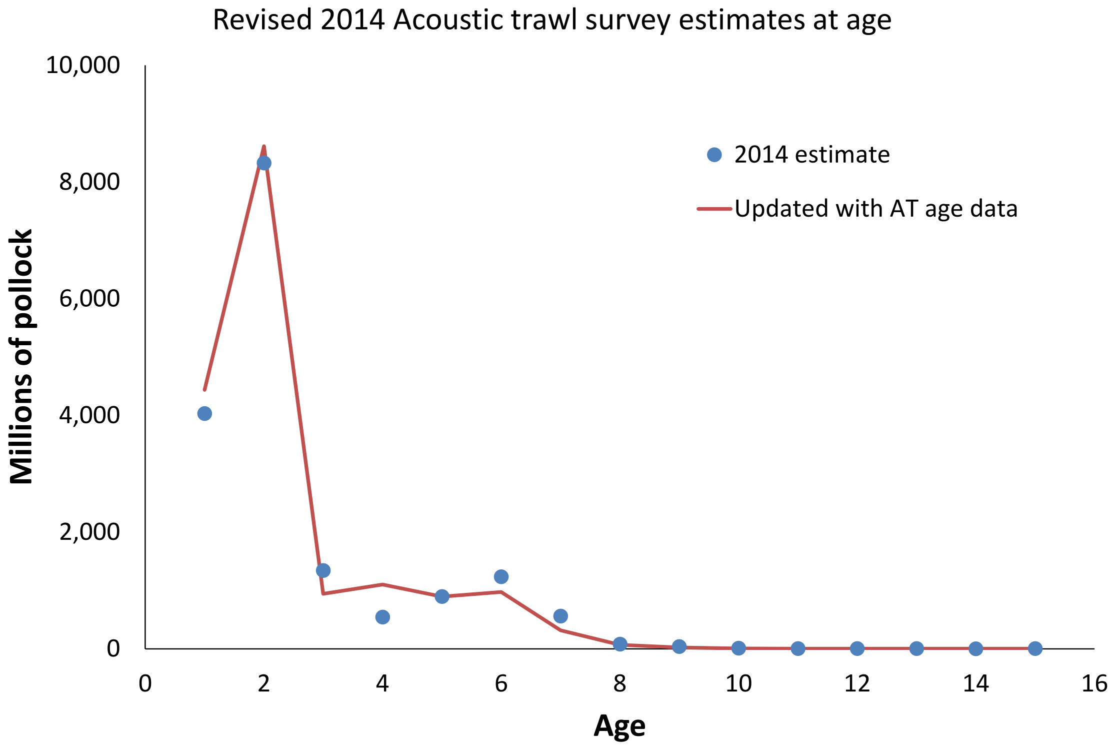


Figure 1.13. The 2014 EBS pollock abundance at age estimates from the AT survey comparing the updated values with those used in the 2014 assessment (based on the BTS survey age data).

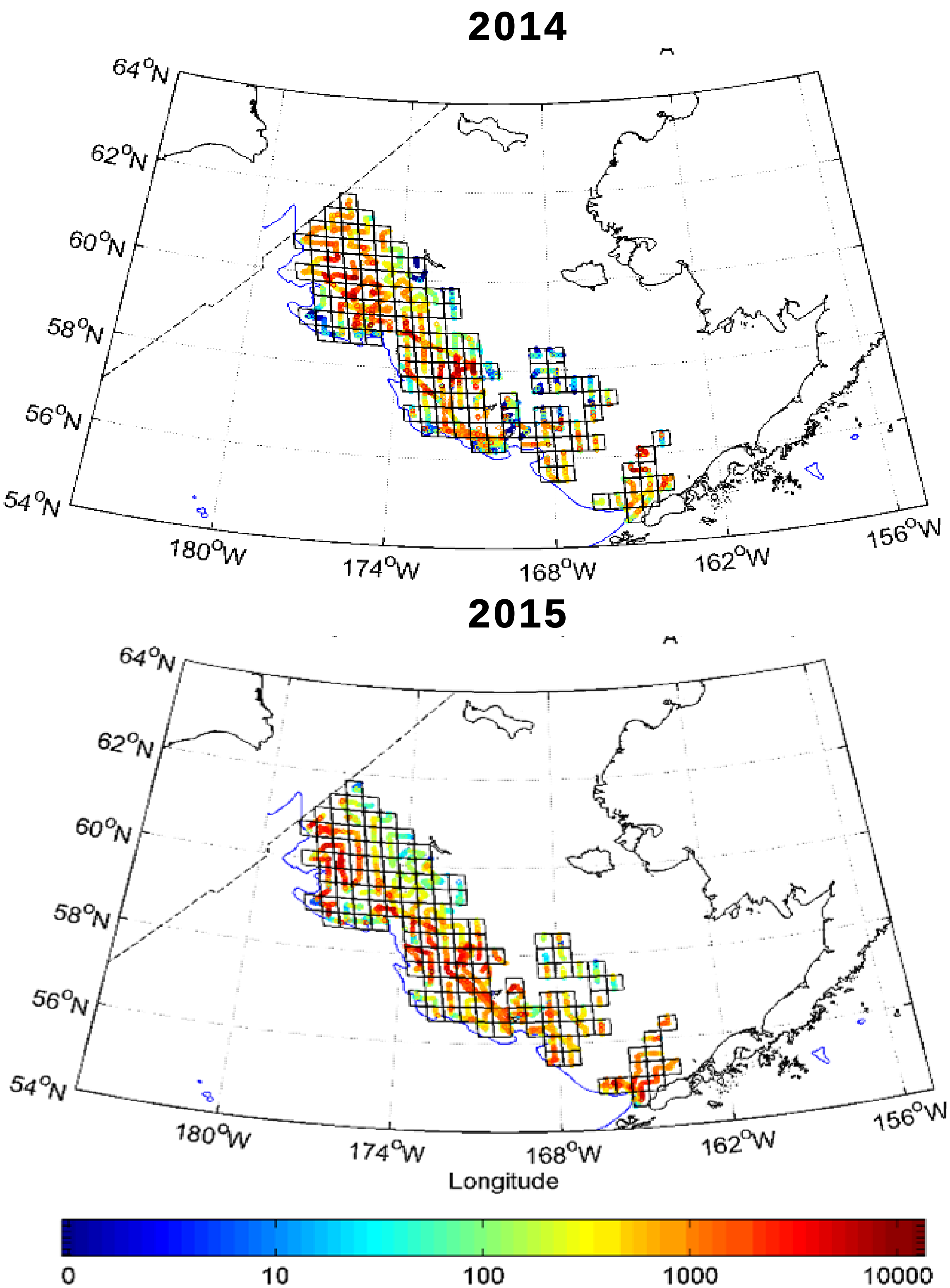


Figure 1.14. Results for the AVO acoustic backscatter index as estimated from 38 kHz acoustic data collected during the 2014 and 2015 bottom trawl surveys. Boxes represent the grids used for the index and the trackline shading indicates the relative density of pollock.

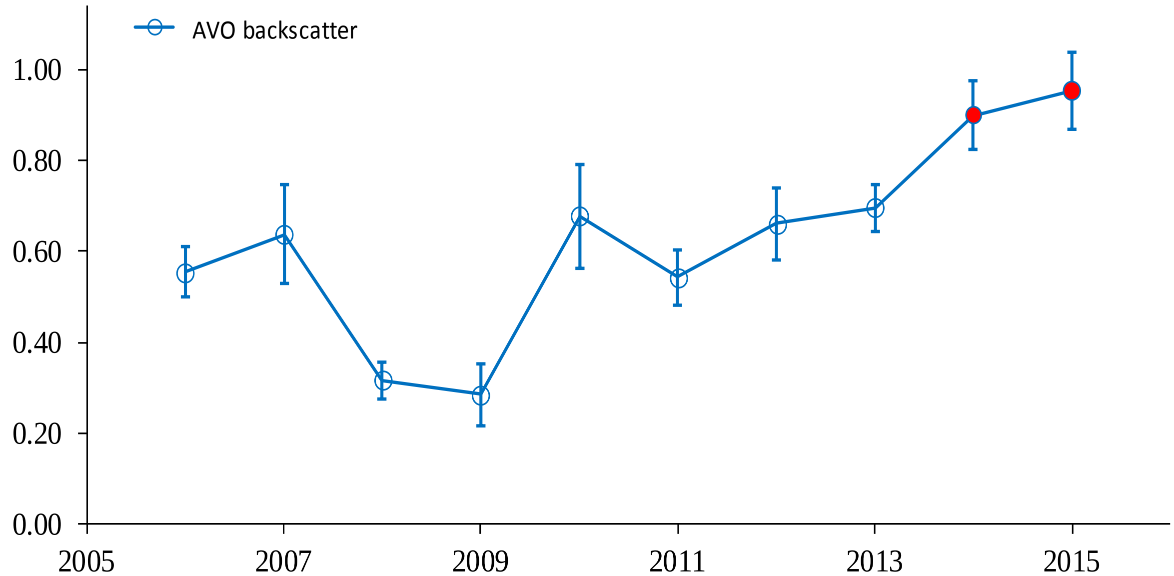


Figure 1.15. Results from the AVO midwater pollock backscatter index (2006-2015) showing the two new index values introduced this year (red dots).

Observed Data

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.28	0.48	0.61	0.73	0.85	0.89	1.01	1.14	1.13	1.25	1.23	1.30	1.24
1992	0.40	0.47	0.65	0.71	0.81	0.98	1.03	1.20	1.24	1.28	1.21	1.37	1.45
1993	0.49	0.61	0.66	0.77	0.93	1.05	1.20	1.23	1.41	1.54	1.65	1.67	1.56
1994	0.40	0.65	0.73	0.75	0.73	1.05	1.38	1.32	1.32	1.39	1.39	1.30	1.35
1995	0.38	0.50	0.73	0.84	0.85	0.98	1.23	1.31	1.41	1.46	1.40	1.12	1.34
1996	0.33	0.44	0.68	0.79	0.95	0.95	1.02	1.10	1.40	1.49	1.51	1.73	1.52
1997	0.33	0.46	0.55	0.74	0.89	1.08	1.10	1.24	1.35	1.47	1.63	1.40	1.35
1998	0.36	0.58	0.63	0.62	0.78	1.03	1.17	1.25	1.32	1.42	1.44	1.54	1.55
1999	0.40	0.50	0.64	0.70	0.73	0.89	1.03	1.26	1.26	1.40	1.01	0.56	1.24
2000	0.35	0.53	0.63	0.73	0.78	0.81	0.97	1.01	1.25	1.29	1.11	1.21	1.46
2001	0.33	0.50	0.66	0.79	0.96	0.99	1.06	1.14	1.32	1.45	1.56	1.48	1.46
2002	0.38	0.51	0.67	0.80	0.91	1.03	1.11	1.10	1.28	1.45	1.59	1.33	1.63
2003	0.49	0.55	0.65	0.77	0.86	0.95	1.08	1.21	1.21	1.20	1.38	1.27	1.70
2004	0.40	0.58	0.64	0.76	0.89	0.93	1.03	1.18	1.13	1.17	1.33	1.28	1.22
2005	0.35	0.51	0.64	0.74	0.88	0.95	1.07	1.09	1.23	1.28	1.26	1.07	1.40
2006	0.31	0.45	0.60	0.75	0.86	0.96	1.06	1.12	1.22	1.24	1.30	1.39	1.42
2007	0.34	0.51	0.64	0.78	0.96	1.10	1.19	1.27	1.31	1.47	1.44	1.73	1.51
2008	0.33	0.52	0.65	0.77	0.90	1.04	1.11	1.22	1.30	1.41	1.49	1.50	1.50
2009	0.35	0.55	0.69	0.89	1.02	1.15	1.41	1.49	1.63	1.64	1.82	2.18	2.30
2010	0.38	0.49	0.67	0.92	1.11	1.26	1.34	1.60	1.61	1.85	1.94	2.06	2.21
2011	0.29	0.51	0.66	0.81	0.97	1.22	1.34	1.50	1.57	1.62	2.12	1.74	2.26
2012	0.27	0.41	0.64	0.82	0.97	1.18	1.31	1.53	1.61	1.65	1.73	2.03	2.12
2013	0.29	0.44	0.57	0.78	1.12	1.28	1.43	1.70	1.85	1.82	1.94	2.12	2.09
2014	0.32	0.46	0.62	0.75	0.89	1.15	1.32	1.38	1.68	1.80	1.75	1.68	2.21
2015	?	?	?	?	?	?	?	?	?	?	?	?	?
2016	?	?	?	?	?	?	?	?	?	?	?	?	?
2017	?	?	?	?	?	?	?	?	?	?	?	?	?

Model Estimates

	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	0.35	0.46	0.60	0.72	0.84	0.89	1.02	1.12	1.13	1.17	1.25	1.35	1.26
1992	0.40	0.48	0.59	0.73	0.85	0.97	1.03	1.15	1.22	1.23	1.25	1.35	1.41
1993	0.46	0.61	0.68	0.81	0.95	1.09	1.25	1.29	1.39	1.48	1.47	1.51	1.58
1994	0.40	0.59	0.73	0.78	0.88	1.03	1.18	1.33	1.32	1.43	1.49	1.50	1.49
1995	0.35	0.51	0.72	0.85	0.86	0.97	1.13	1.26	1.37	1.36	1.45	1.53	1.49
1996	0.38	0.46	0.62	0.82	0.94	0.94	1.06	1.20	1.30	1.41	1.38	1.49	1.52
1997	0.40	0.49	0.55	0.72	0.92	1.03	1.03	1.14	1.25	1.36	1.44	1.43	1.49
1998	0.38	0.51	0.59	0.64	0.80	1.01	1.13	1.11	1.17	1.29	1.37	1.48	1.42
1999	0.39	0.51	0.64	0.71	0.73	0.90	1.13	1.25	1.17	1.25	1.35	1.45	1.52
2000	0.38	0.51	0.62	0.75	0.79	0.81	1.00	1.23	1.30	1.23	1.29	1.41	1.47
2001	0.40	0.53	0.67	0.79	0.91	0.95	0.97	1.17	1.39	1.48	1.36	1.44	1.53
2002	0.42	0.53	0.66	0.80	0.89	1.02	1.06	1.06	1.23	1.47	1.53	1.44	1.47
2003	0.44	0.55	0.66	0.79	0.91	1.01	1.15	1.17	1.13	1.32	1.53	1.62	1.47
2004	0.40	0.56	0.66	0.76	0.86	0.98	1.09	1.21	1.19	1.16	1.32	1.56	1.59
2005	0.36	0.49	0.66	0.73	0.81	0.91	1.04	1.12	1.20	1.19	1.13	1.31	1.49
2006	0.35	0.47	0.60	0.77	0.82	0.89	1.00	1.12	1.16	1.26	1.22	1.17	1.31
2007	0.37	0.52	0.64	0.79	0.96	1.02	1.11	1.22	1.31	1.37	1.45	1.42	1.32
2008	0.34	0.49	0.64	0.77	0.90	1.09	1.15	1.22	1.30	1.40	1.44	1.54	1.46
2009	0.38	0.53	0.70	0.89	1.01	1.18	1.43	1.47	1.51	1.61	1.70	1.76	1.83
2010	0.33	0.50	0.66	0.84	1.01	1.14	1.33	1.57	1.56	1.61	1.67	1.79	1.80
2011	0.30	0.47	0.65	0.82	1.00	1.20	1.35	1.54	1.75	1.75	1.76	1.86	1.93
2012	0.30	0.41	0.59	0.80	0.96	1.16	1.39	1.52	1.67	1.91	1.87	1.91	1.95
2013	0.31	0.44	0.57	0.78	1.00	1.19	1.44	1.68	1.78	1.97	2.20	2.18	2.16
2014	0.33	0.45	0.60	0.74	0.97	1.23	1.47	1.73	1.94	2.07	2.23	2.53	2.43
2015	0.36	0.35	0.44	0.57	0.67	0.87	1.11	1.28	1.46	1.65	1.72	1.88	2.06
2016	0.36	0.49	0.44	0.53	0.66	0.76	0.99	1.23	1.37	1.57	1.73	1.83	1.94
2017	0.36	0.49	0.61	0.53	0.61	0.74	0.86	1.10	1.31	1.47	1.65	1.85	1.89

CVs of Observed Data

	3	4	5	6	7	8	9	10	11	12	13	14	15
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	?	?	?	?	?	?	?	?	?	?	?	?	?
2016	?	?	?	?	?	?	?	?	?	?	?	?	?
2017	?	?	?	?	?	?	?	?	?	?	?	?	?

Residuals & *CVs of projected estimates*

1.609	3	4	5	6	7	8	9	10	11	12	13	14	15
1991	-3.2	0.8	0.7	0.3	0.5	0.0	-0.7	0.2	0.0	1.1	-0.3	-0.7	-0.4
1992	-1.1	-0.1	1.7	-0.6	-1.4	0.5	0.1	1.5	0.5	0.9	-0.3	0.2	0.4
1993	3.4	0.0	-1.1	-1.0	-0.5	-1.0	-1.8	-1.3	0.3	0.6	1.6	1.0	-0.2
1994	0.0	4.7	-0.7	-1.4	-2.9	0.2	2.7	-0.1	0.1	-0.7	-1.3	-1.3	-1.7
1995	1.1	-0.8	1.1	-0.5	-0.3	0.2	1.5	0.6	0.6	0.7	-0.6	-0.8	-1.7
1996	-2.1	-0.4	2.6	-2.4	0.9	0.5	-0.8	-1.7	0.6	0.7	1.4	2.0	0.0
1997	-2.4	-2.2	-0.2	1.4	-1.8	2.1	1.7	1.4	0.8	0.8	0.8	-0.3	-1.5
1998	-0.9	2.4	1.7	-2.7	-1.1	0.9	1.5	2.6	1.3	1.0	0.4	0.2	0.6
1999	2.7	-0.7	-0.1	-0.5	-0.4	-0.4	-3.1	0.2	0.6	0.5	-0.8	-1.6	-1.0
2000	-2.1	2.8	1.0	-1.2	-1.0	-0.6	-1.1	-3.8	-0.9	0.4	-0.3	-0.3	0.0
2001	-5.2	-2.3	-1.2	0.0	2.0	1.6	4.4	-0.7	-1.0	-0.3	1.5	0.3	-0.1
2002	-2.3	-2.8	0.7	-0.2	1.4	0.3	1.4	1.3	0.8	-0.3	0.6	-0.3	0.4
2003	8.4	-0.2	-1.4	-1.6	-4.1	-2.6	-1.8	0.7	1.5	-1.7	-1.0	-1.0	1.0
2004	0.4	3.5	-2.3	0.5	1.7	-3.2	-1.7	-0.5	-1.0	0.2	0.1	-1.6	-3.3
2005	-0.4	2.5	-3.9	0.7	4.3	1.5	1.0	-0.8	0.3	1.2	0.5	-0.6	-0.3
2006	-3.5	-2.9	0.7	-1.4	2.9	2.5	1.5	-0.1	0.7	-0.1	0.7	1.2	1.1
2007	-2.5	-1.0	0.1	-1.2	-0.4	3.5	2.0	1.0	0.1	0.8	-0.1	2.6	2.0
2008	-1.2	2.9	0.8	1.1	-0.3	-2.8	-1.8	0.0	0.1	0.1	0.7	-0.2	0.4
2009	-3.2	1.5	-0.6	0.1	0.4	-0.9	-0.4	0.3	1.2	0.3	1.4	1.4	3.0
2010	1.9	-3.5	0.9	2.4	3.3	3.0	0.3	0.5	0.7	2.5	1.8	2.0	3.5
2011	-2.6	3.3	2.0	-1.5	-1.0	0.5	-0.2	-0.7	-2.7	-1.4	1.3	-0.8	1.6
2012	-4.0	-1.5	3.2	3.2	0.7	0.3	-0.9	0.0	-0.6	-2.6	-1.1	0.6	0.4
2013	-2.1	-0.5	-0.6	0.2	4.5	2.4	-0.2	0.1	0.6	-1.1	-1.9	-0.3	-0.4
2014	-0.8	1.0	2.1	3.0	-4.8	-2.7	-2.7	-2.5	-1.6	-1.4	-3.0	-3.9	-1.3
2015	*19%*	*12%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*
2016	*19%*	*19%*	*12%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*
2017	*19%*	*19%*	*19%*	*12%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*	*11%*

Figure 1.16. Schematic of EBS pollock data and model fits for the fishery mean body weights-at-age (kg). 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 that the model predictions for 2015-2017 (and their associated uncertainty shown in last three rows of lower-right table) are used for model projections and ABC/OFL estimates for models using these estimates.

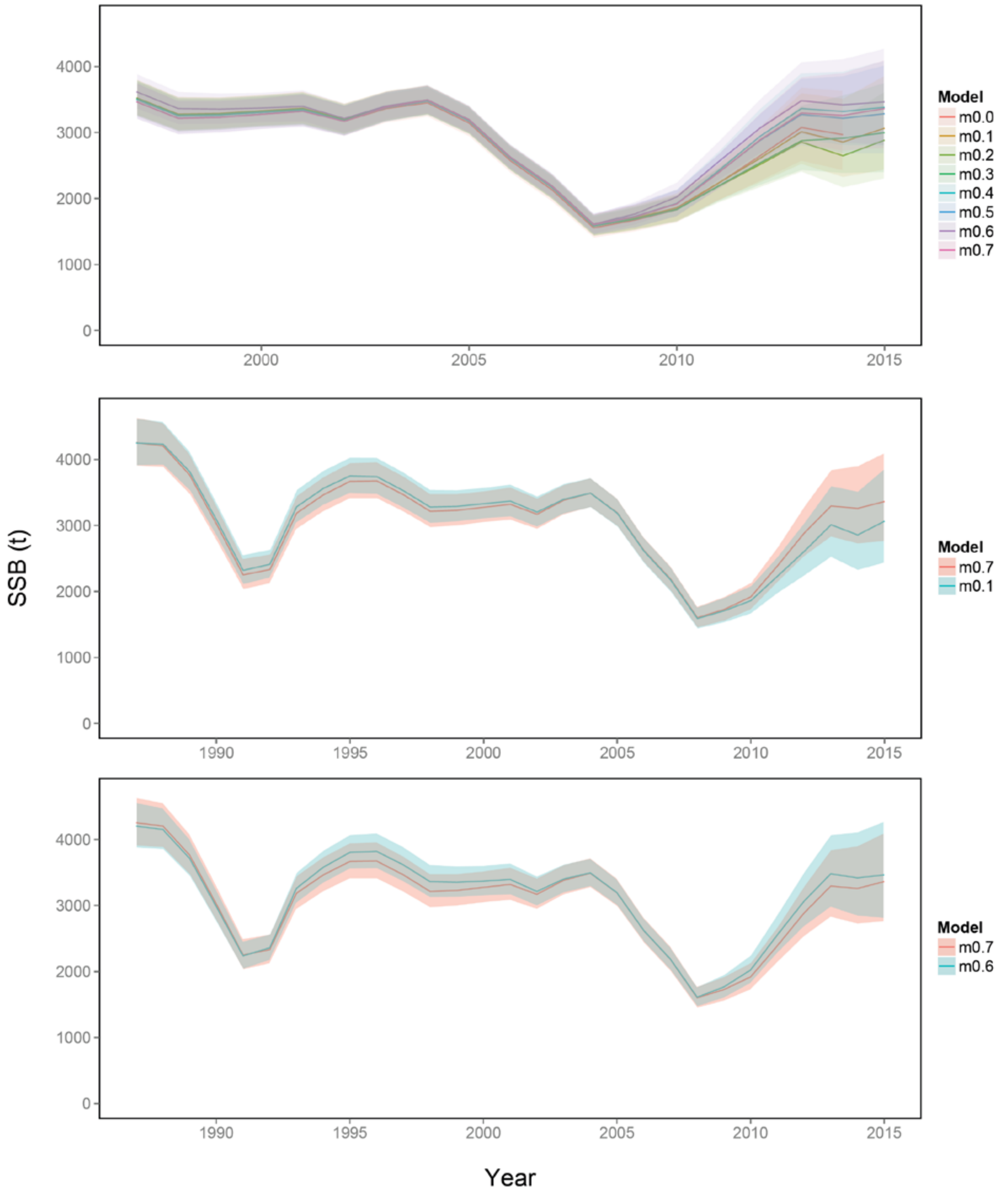


Figure 1.17. EBS pollock spawning stock biomass (SSB) for the 7 preliminary models that simply incrementally add data to the model accepted in 2014 (top) and comparing just two models (with “no new” data (m0.1) and all data added in the 2015 assessment relative to the 2014 assessment (middle panel). The bottom panel compares the model with all new data but using the standard BTS index (m0.6) and the index corrected for trawl efficiency (m0.7).

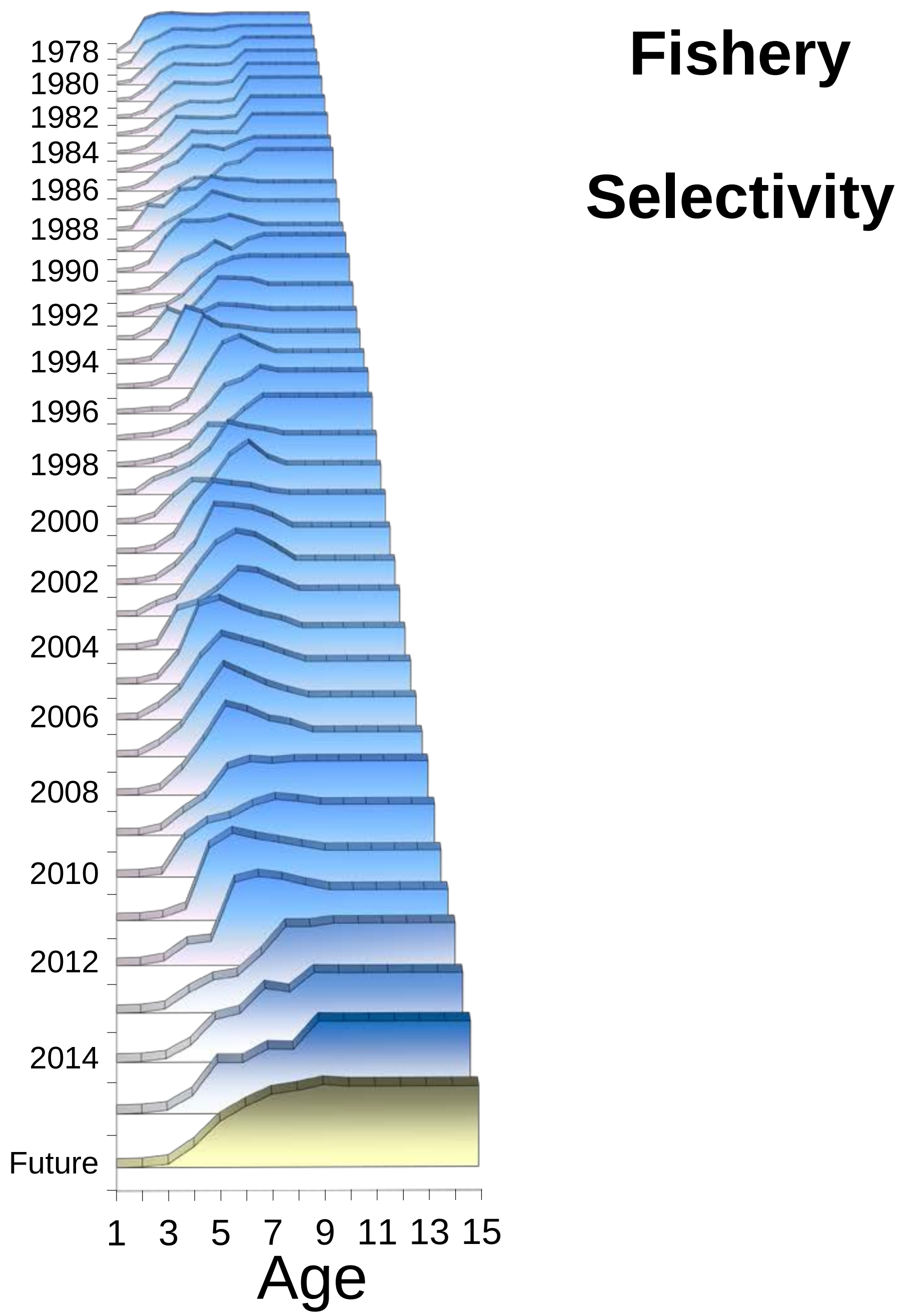


Figure 1.18. Selectivity at age estimates for the EBS pollock fishery, 1978-2015 including the estimates (front-most panel) used for the future yield considerations.

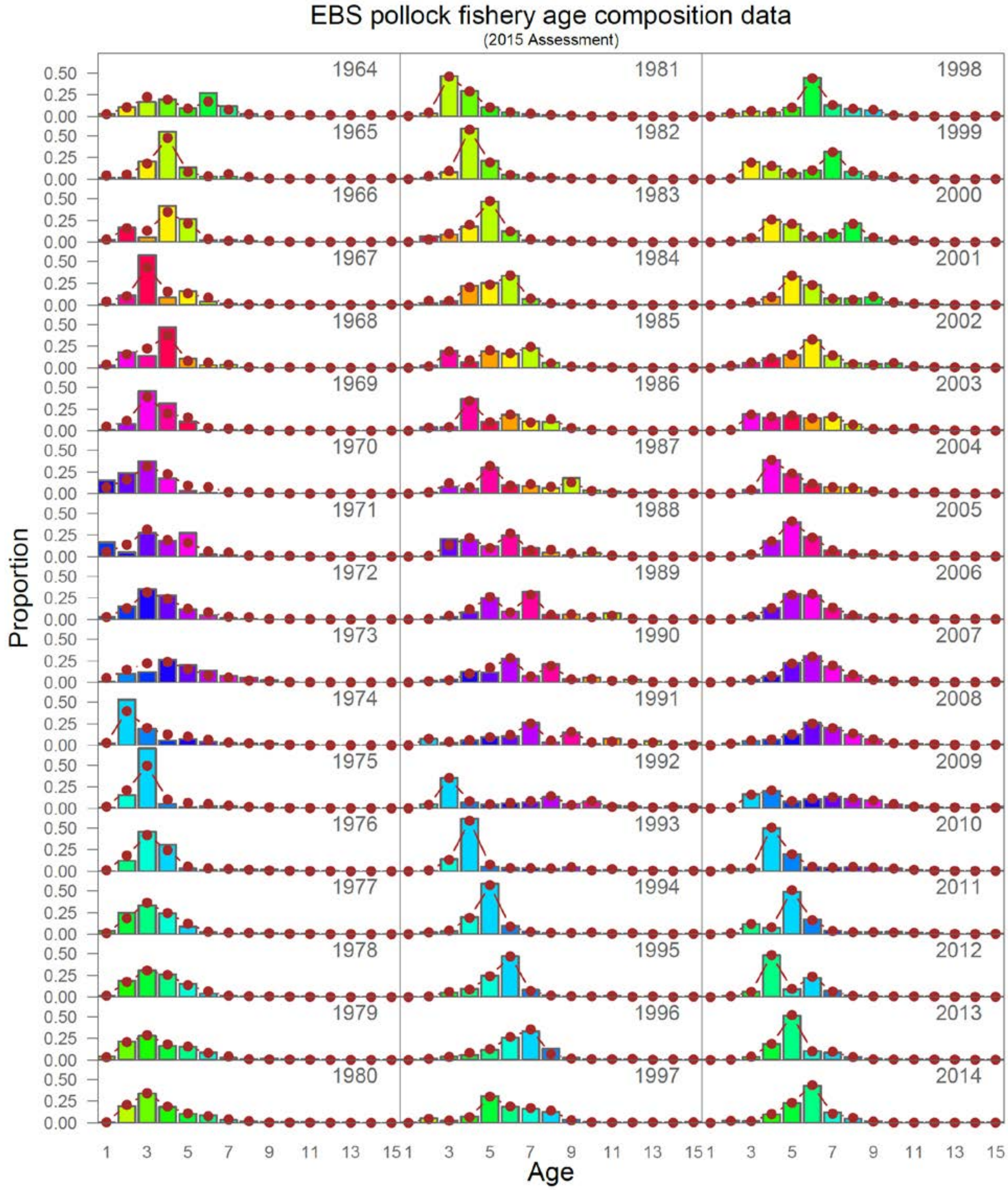


Figure 1.19. Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2014). The 2014 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

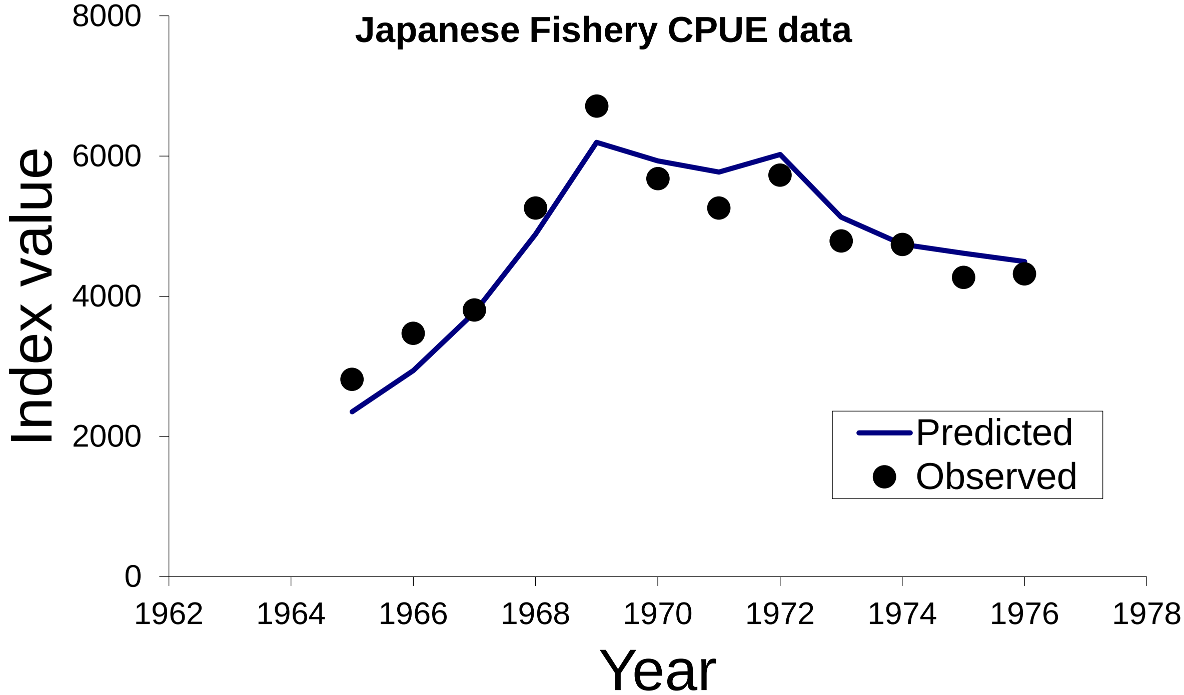


Figure 1.20. Japanese fishery CPUE (Low and Ikeda, 1980) model fits for EBS pollock, 1965-1976.

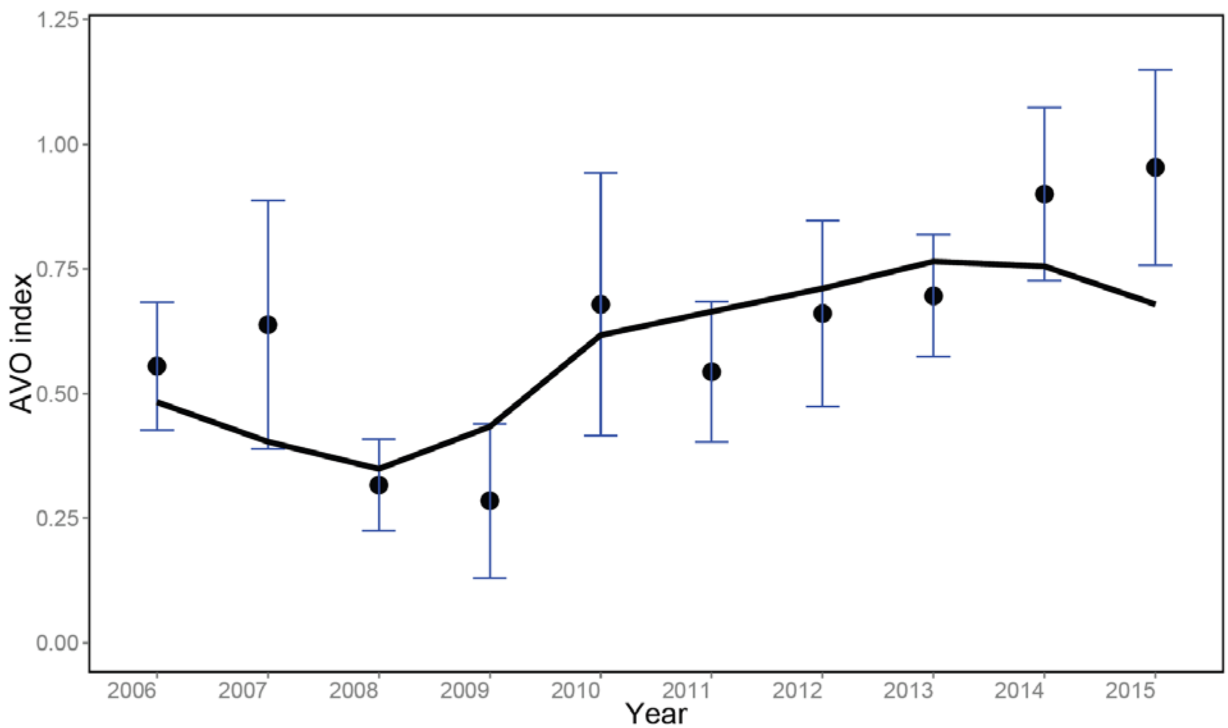


Figure 1.21. Model results of predicted EBS pollock biomass following the AVO index (under model 1.0). Error bars represent assumed 95% confidence bounds.

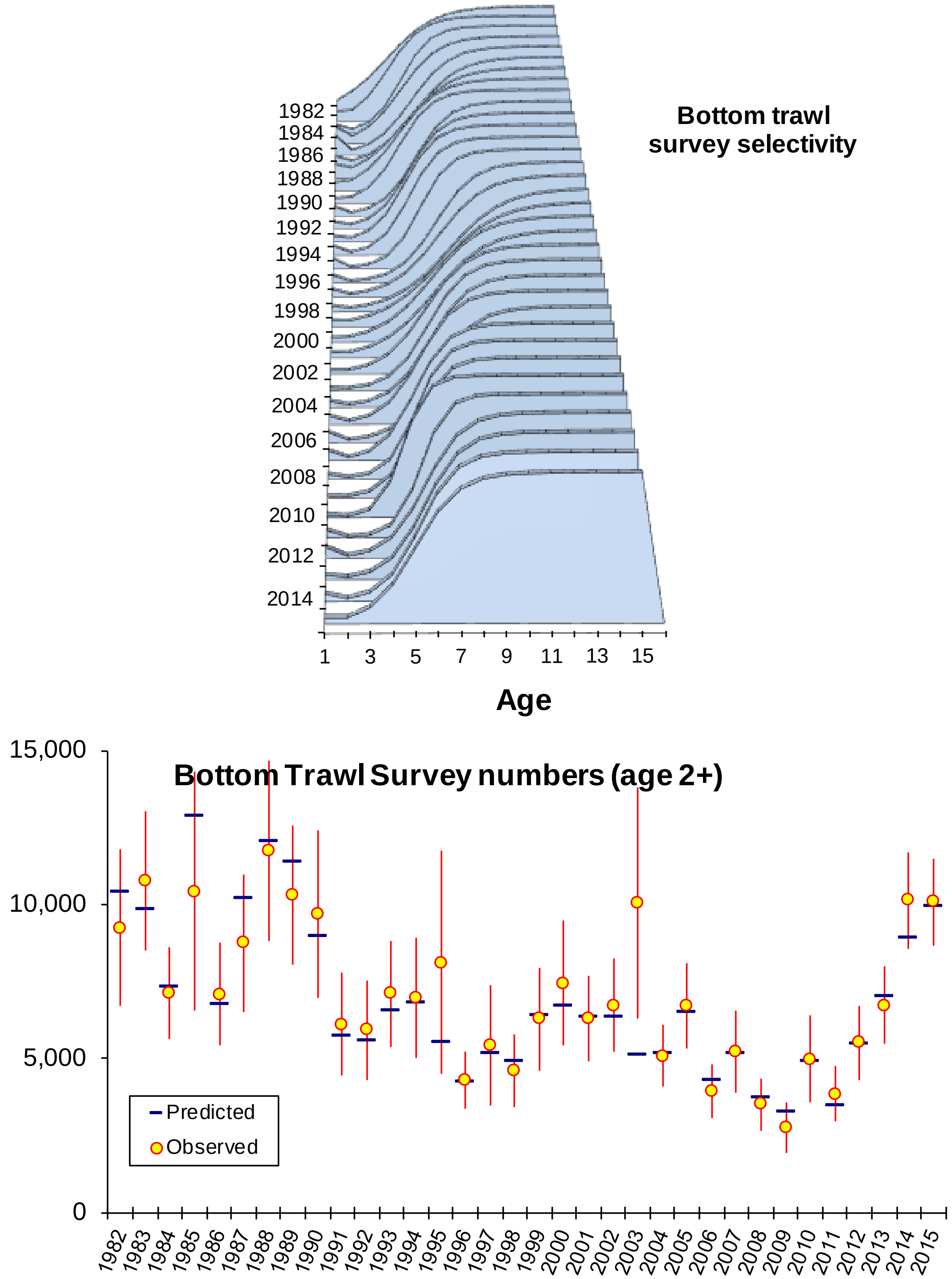


Figure 1.22. Estimates of bottom-trawl survey numbers (millions age 2 and older, lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2015.

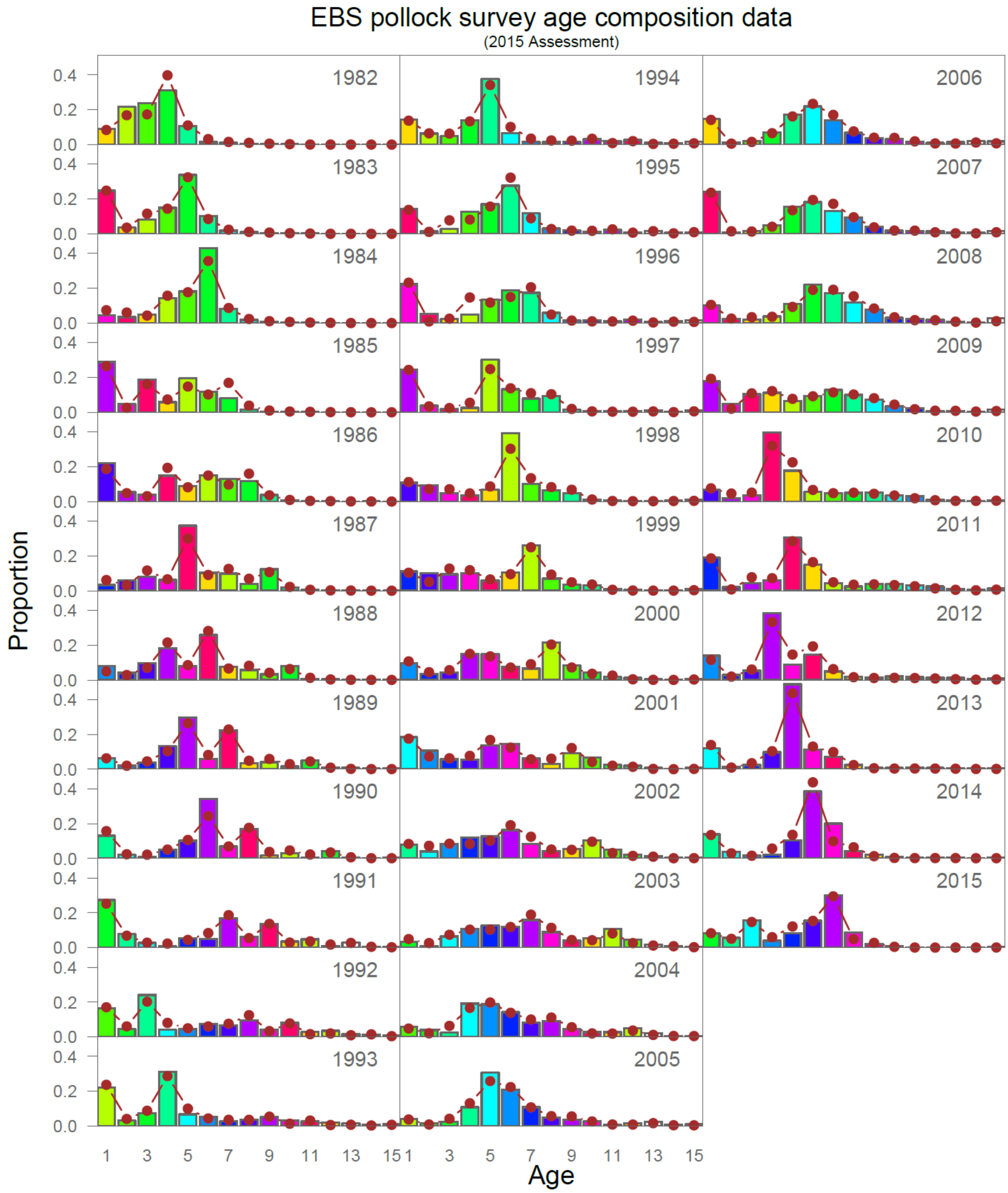


Figure 1.23. Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2015.

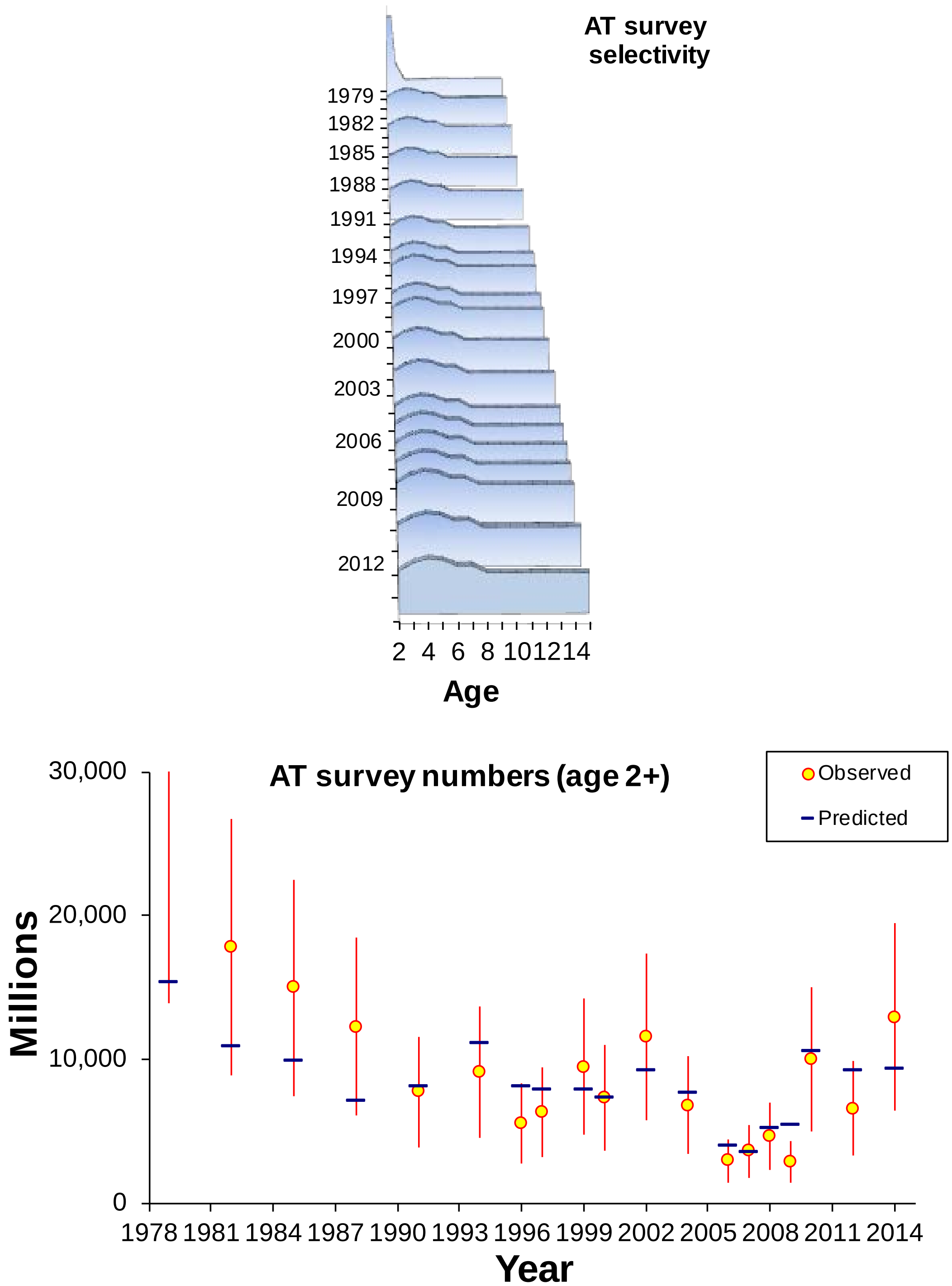


Figure 1.24. Estimates of AT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older, 1979-2014. Note that the 1979 observed value (=46,314) is off the scale of the figure.

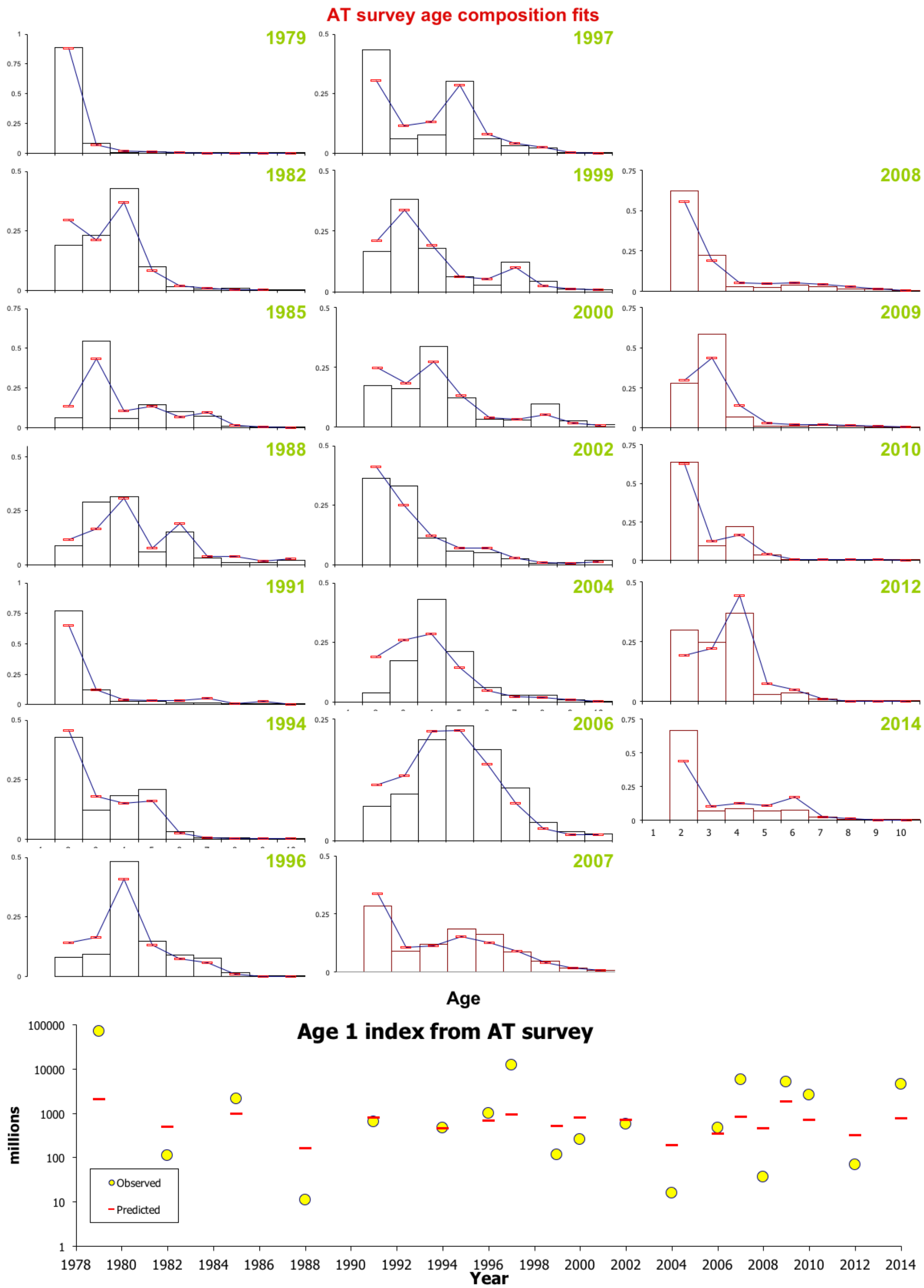


Figure 1.25. Fit to the AT survey EBS pollock age composition data (top panel; proportion of numbers) and age 1 index (bottom panel; log-scale). Lines represent model predictions while the vertical columns and dots represent data. The 2014 age composition data were updated using age data from the AT survey (in the 2014 assessment, age data from the BTS were used to estimate composition in this survey).

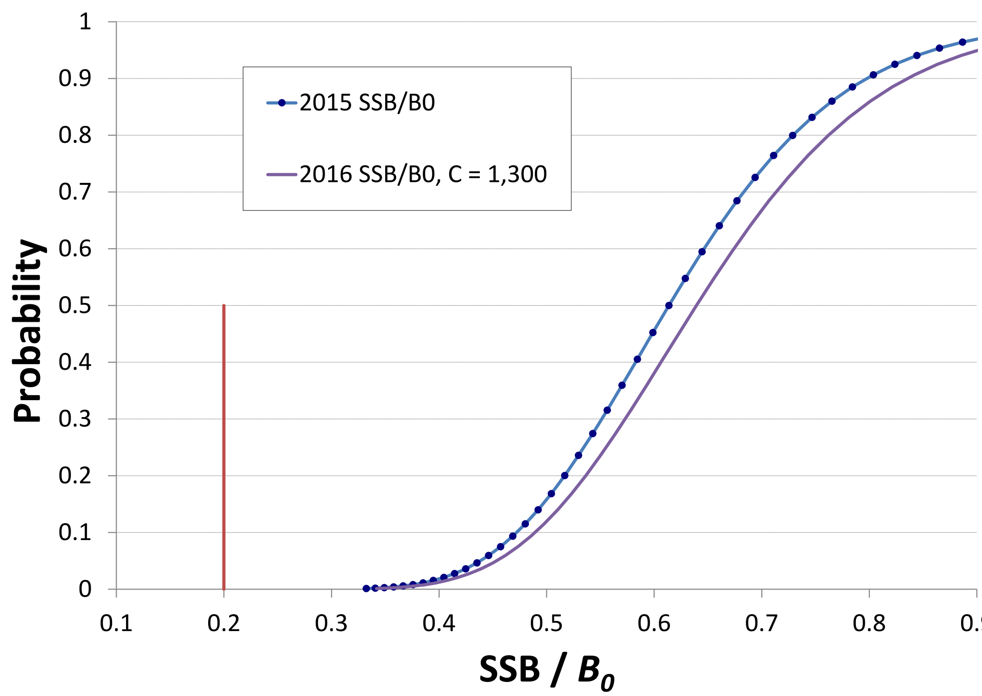


Figure 1.26. Estimated cumulative probability distribution of the 2015 and 2016 EBS pollock spawning biomass relative to B_0. C represents catch

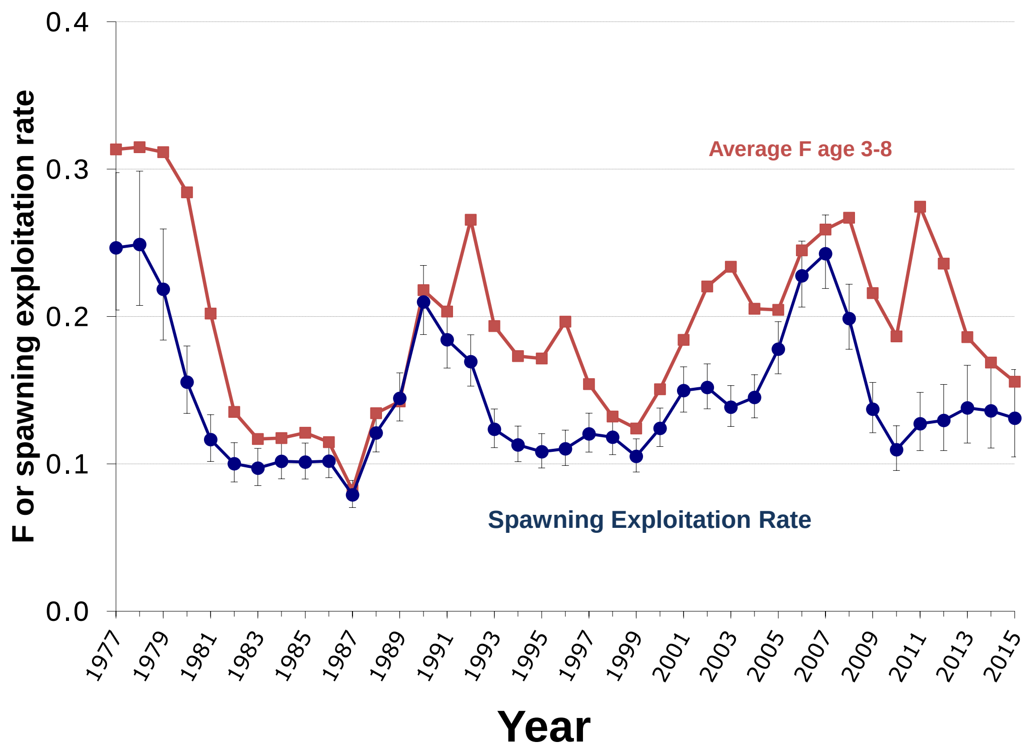


Figure 1.27. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) and average fishing mortality (ages 3-8) for EBS pollock, 1977-2015. Error bars represent two standard deviations from the estimates.

Age

Year	2	3	4	5	6	7	8	9	10
1964	0.01	0.03	0.16	0.17	0.17	0.17	0.16	0.16	0.15
1965	0.01	0.04	0.17	0.16	0.15	0.15	0.14	0.13	0.13
1966	0.01	0.05	0.15	0.14	0.14	0.13	0.12	0.12	0.12
1967	0.03	0.13	0.20	0.21	0.21	0.21	0.21	0.20	0.20
1968	0.03	0.11	0.22	0.21	0.21	0.20	0.20	0.20	0.19
1969	0.03	0.16	0.20	0.20	0.19	0.19	0.19	0.19	0.19
1970	0.06	0.22	0.22	0.24	0.24	0.26	0.28	0.29	0.36
1971	0.08	0.26	0.30	0.36	0.35	0.35	0.39	0.40	0.56
1972	0.13	0.34	0.39	0.39	0.38	0.38	0.42	0.44	0.55
1973	0.16	0.37	0.47	0.47	0.47	0.47	0.51	0.51	0.59
1974	0.22	0.48	0.48	0.48	0.48	0.48	0.52	0.53	0.53
1975	0.12	0.47	0.45	0.43	0.42	0.41	0.42	0.44	0.48
1976	0.09	0.36	0.42	0.40	0.38	0.38	0.38	0.38	0.40
1977	0.10	0.26	0.33	0.33	0.32	0.32	0.32	0.32	0.32
1978	0.09	0.28	0.32	0.33	0.32	0.32	0.32	0.33	0.33
1979	0.05	0.23	0.28	0.35	0.34	0.34	0.34	0.37	0.38
1980	0.02	0.14	0.26	0.32	0.33	0.33	0.32	0.34	0.41
1981	0.01	0.07	0.18	0.24	0.24	0.24	0.24	0.25	0.33
1982	0.01	0.03	0.11	0.17	0.17	0.16	0.16	0.18	0.26
1983	0.01	0.03	0.08	0.13	0.16	0.15	0.15	0.17	0.27
1984	0.01	0.02	0.08	0.15	0.15	0.15	0.15	0.16	0.24
1985	0.01	0.03	0.06	0.11	0.18	0.17	0.17	0.17	0.25
1986	0.01	0.03	0.08	0.10	0.16	0.16	0.15	0.17	0.20
1987	0.00	0.02	0.05	0.07	0.10	0.10	0.15	0.16	0.20
1988	0.01	0.08	0.08	0.14	0.14	0.19	0.17	0.18	0.17
1989	0.01	0.04	0.10	0.13	0.16	0.22	0.20	0.19	0.18
1990	0.01	0.04	0.18	0.26	0.26	0.27	0.29	0.27	0.24
1991	0.01	0.02	0.11	0.21	0.25	0.34	0.28	0.35	0.38
1992	0.01	0.06	0.09	0.18	0.33	0.44	0.50	0.52	0.51
1993	0.00	0.04	0.16	0.12	0.21	0.31	0.31	0.31	0.28
1994	0.00	0.01	0.09	0.24	0.21	0.25	0.24	0.23	0.23
1995	0.00	0.01	0.04	0.15	0.31	0.27	0.26	0.25	0.24
1996	0.01	0.01	0.02	0.07	0.24	0.40	0.44	0.39	0.35
1997	0.01	0.02	0.04	0.08	0.17	0.29	0.32	0.39	0.37
1998	0.00	0.02	0.04	0.09	0.19	0.19	0.26	0.32	0.32
1999	0.00	0.04	0.06	0.09	0.13	0.22	0.20	0.19	0.18
2000	0.00	0.02	0.09	0.14	0.14	0.23	0.28	0.22	0.20
2001	0.00	0.02	0.07	0.19	0.28	0.27	0.27	0.25	0.24
2002	0.00	0.02	0.08	0.18	0.36	0.35	0.34	0.31	0.26
2003	0.00	0.05	0.08	0.21	0.32	0.38	0.36	0.31	0.25
2004	0.00	0.02	0.16	0.18	0.24	0.32	0.31	0.27	0.24
2005	0.00	0.02	0.11	0.28	0.30	0.27	0.25	0.23	0.20
2006	0.00	0.05	0.13	0.27	0.37	0.34	0.31	0.28	0.25
2007	0.00	0.05	0.13	0.27	0.41	0.37	0.32	0.29	0.27
2008	0.00	0.03	0.12	0.26	0.43	0.40	0.36	0.34	0.30
2009	0.00	0.02	0.11	0.17	0.31	0.34	0.34	0.35	0.35
2010	0.00	0.01	0.14	0.20	0.22	0.26	0.29	0.28	0.27
2011	0.00	0.01	0.06	0.36	0.43	0.40	0.38	0.36	0.35
2012	0.00	0.02	0.10	0.11	0.38	0.41	0.39	0.37	0.35
2013	0.00	0.02	0.09	0.15	0.17	0.27	0.40	0.40	0.42
2014	0.00	0.01	0.07	0.17	0.19	0.29	0.28	0.35	0.35
2015	0.00	0.01	0.07	0.19	0.19	0.24	0.24	0.34	0.34
5-yr Aver	**0.00**	**0.02**	**0.08**	**0.20**	**0.27**	**0.32**	**0.34**	**0.37**	**0.36**
5-yr Max	**0.00**	**0.02**	**0.10**	**0.36**	**0.43**	**0.41**	**0.40**	**0.40**	**0.42**
5-yr Min	**0.00**	**0.01**	**0.06**	**0.11**	**0.17**	**0.24**	**0.24**	**0.34**	**0.34**

Figure 1.28. Estimated instantaneous age-specific fishing mortality rates for EBS pollock, 1964-2015. (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).

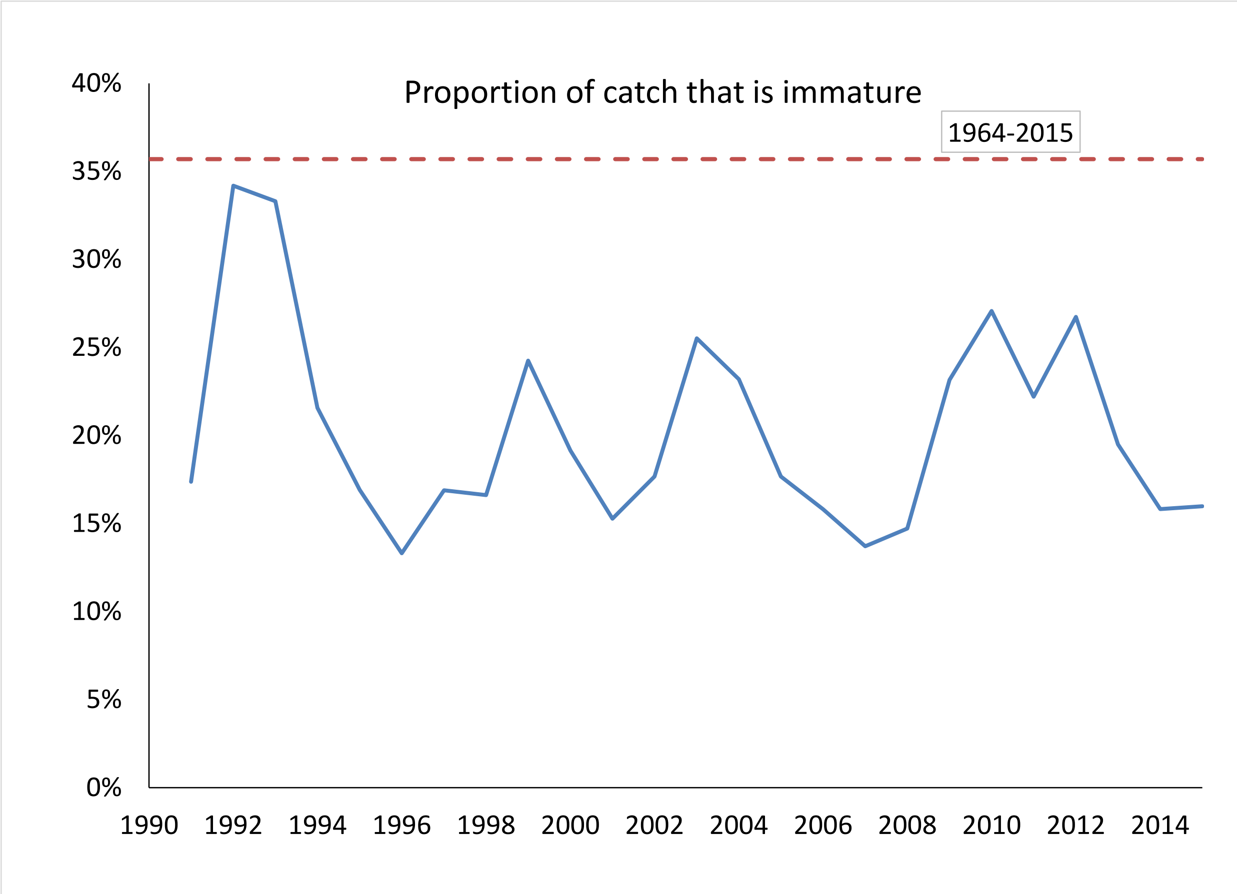


Figure 1.29. Estimated proportion of the EBS pollock fishery catch that is immature, 1991-2015 compared to ratio of all immature pollock caught over the entire 1964-2015 period (dashed line).

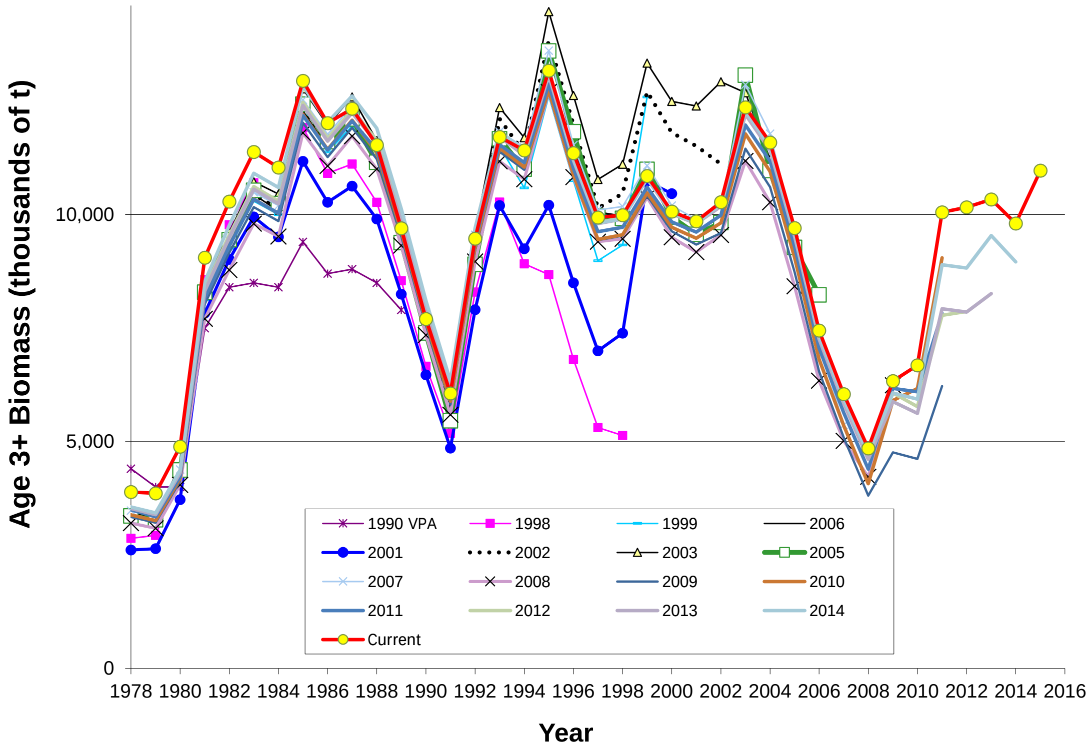


Figure 1.30. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2015.

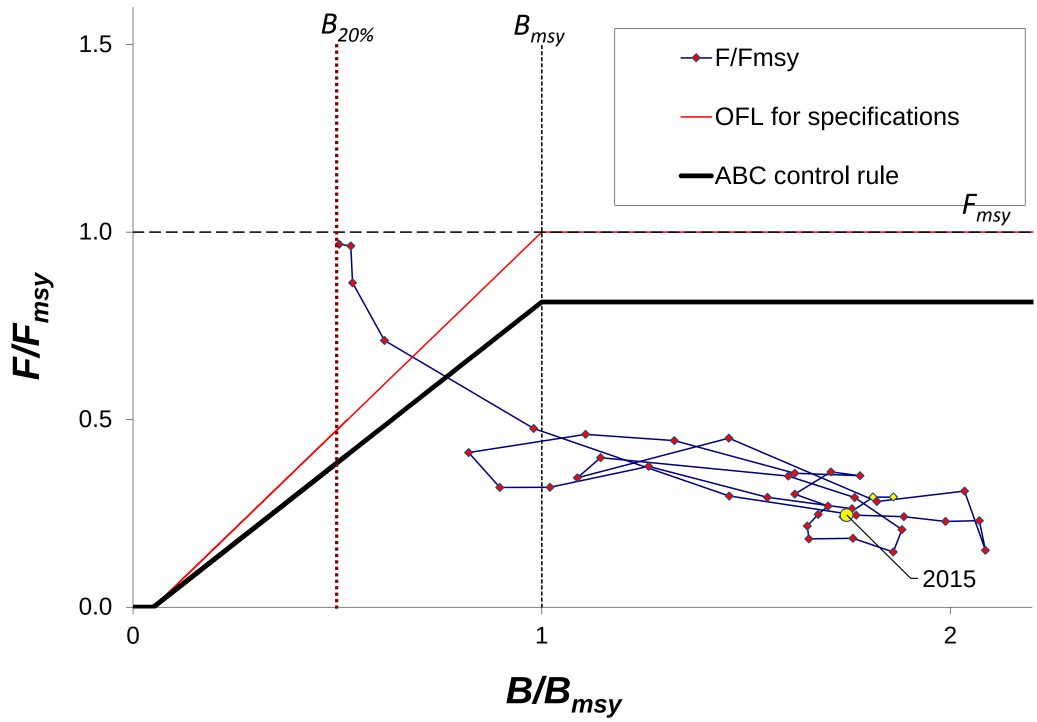


Figure 1.31. Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock, 1977-2015 (plus 2016 and 2017 in highlighted dots). *Note that the control rules for OFL and ABC are designed for setting specifications in future years.*

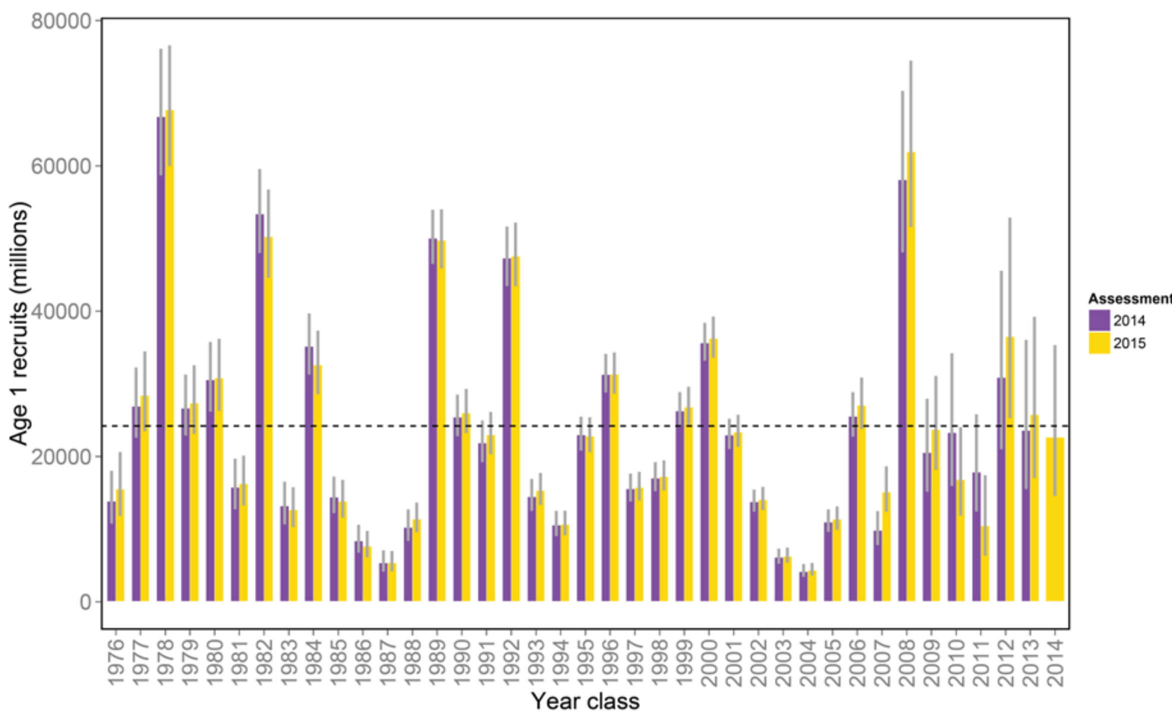


Figure 1.32. Year-class strengths by year (as age-1 recruits) for EBS pollock from the current model compared with the previous assessment. The horizontal line represents the mean age-1 recruitment for all years since 1964 (1963-2013 year classes). Error bars reflect 90% credible intervals based on model estimates of uncertainty.

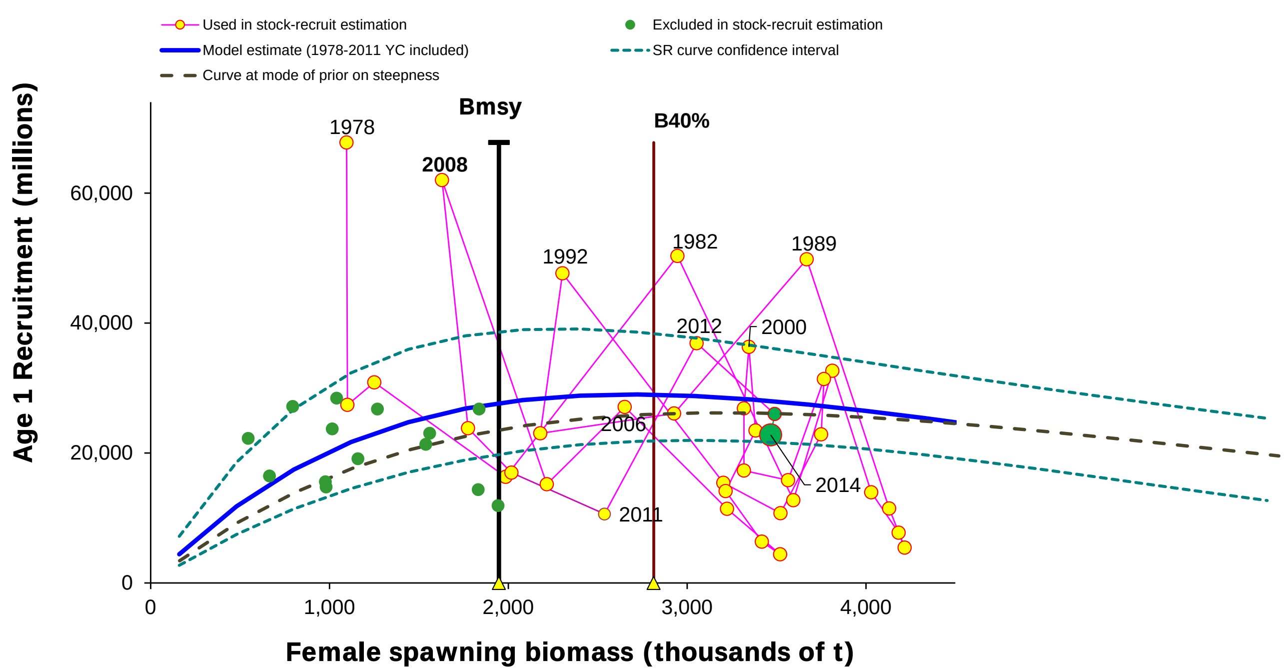


Figure 1.33. Year-class strengths by relative to female spawning biomass (thousands of t) for EBS pollock. Labels on points correspond to year classes labels (measured as one-year olds). Vertical lines indicate B_{MSY} and $B_{40\%}$ levels whereas the solid curve represents fitted stock-recruitment relationship (dashed lines represent estimated 90% credible intervals).

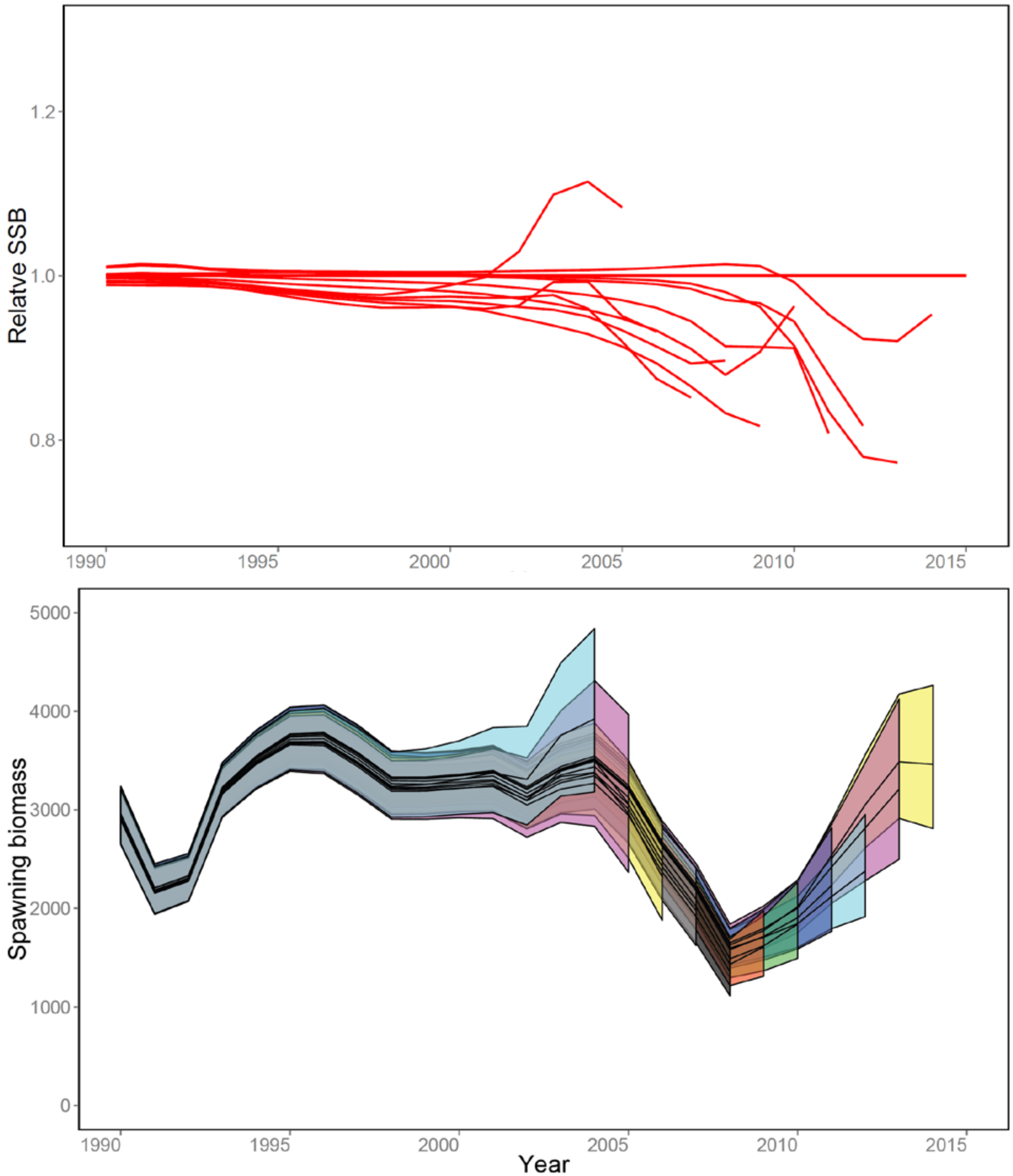


Figure 1.34. Retrospective patterns of model 1 for EBS pollock spawning in retrospective year for 2003-2015 showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations; bottom panel). Mohn's rho was estimated to be -0.14 for the 10 year period.

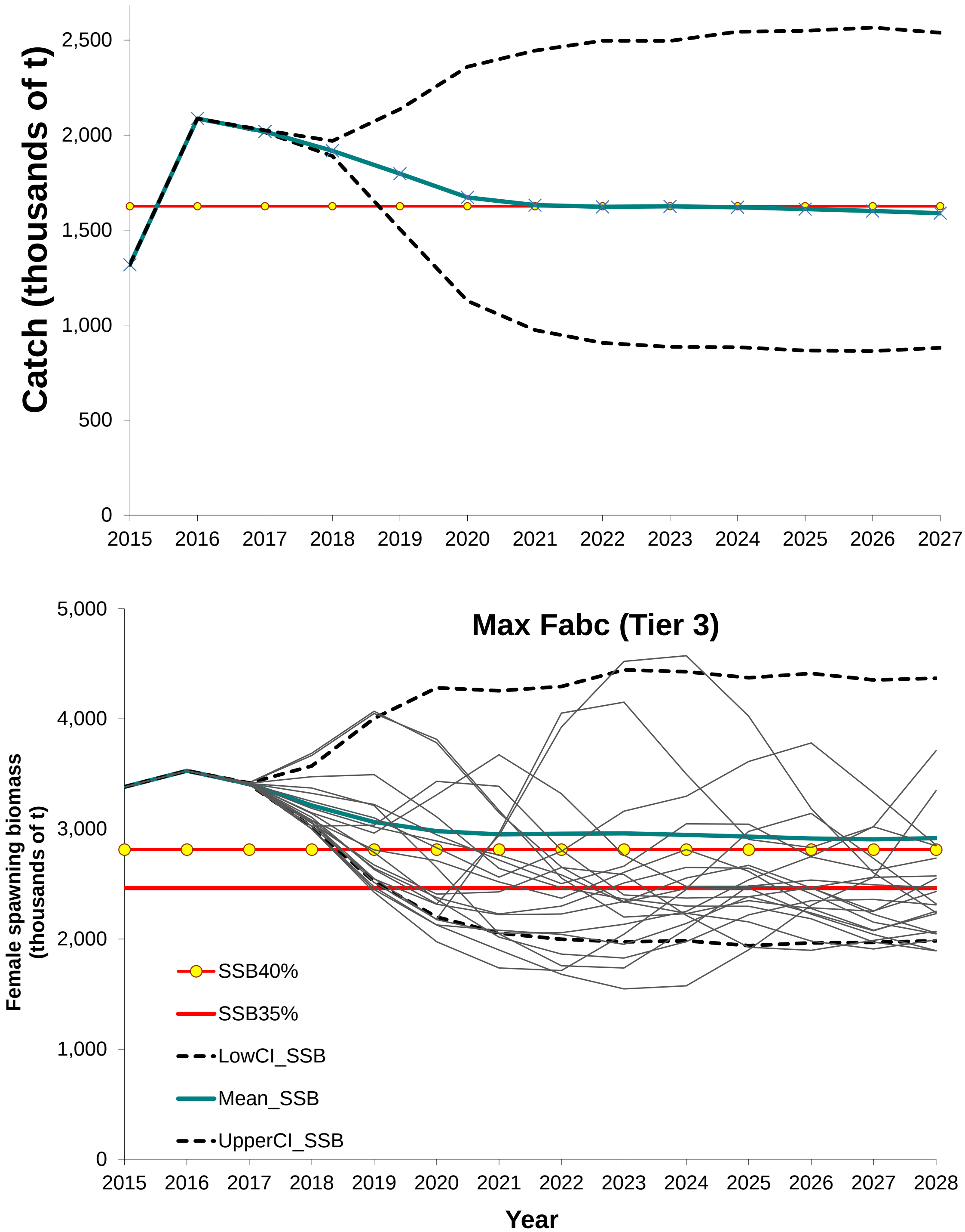


Figure 1.35. Projected EBS **Tier 3** pollock **yield** (top) and **female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2013. Future harvest rates follow the guidelines 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.

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

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

....(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

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

$$S_{t+1,a} = s_{t,a} e^{\gamma_t} \quad \gamma_t \sim N\left(0, \sigma_s^2\right)$$ ....(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 s_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., s_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:

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

....(Eq. 4)

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

$$\begin{aligned} \delta_t^\mu - \delta_{t+1}^\mu &\sim N\left(0, \sigma_{\delta^\mu}^2\right) \\ \delta_t^\alpha - \delta_{t+1}^\alpha &\sim N\left(0, \sigma_{\delta^\alpha}^2\right) \\ \delta_t^\beta - \delta_{t+1}^\beta &\sim N\left(0, \sigma_{\delta^\beta}^2\right) \end{aligned}$$

....(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,…2015. 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 ($\hat{\bar{a}}$):

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

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:

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

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:

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

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. 1.36. 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 s_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):

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

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 j_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):

$$f = n \cdot \sum_{a,t} p_{at} \ln \hat{p}_{at} \quad ,$$

$$p_{at} = \frac{O_{at}}{\sum_a O_{at}}, \qquad \hat{p}_{at} = \frac{\hat{C}_{at}}{\sum_a \hat{C}_{at}}$$

$$\hat{C} = C \cdot E_{ageing}$$

$$E_{ageing} = \begin{pmatrix} b_{1,1} & b_{1,2} & b_{1,3} & \cdots & b_{1,15} \\ b_{2,1} & b_{2,2} & & & \\ b_{3,1} & & \ddots & & \\ \vdots & & & \ddots & \\ b_{15,2} & & & & b_{15,15} \end{pmatrix} ; \quad \text{(Eq. 15)}$$

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 $t^{2}=1/n$

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

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

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:

$$\hat{N}_{t,a}^{s}=e^{-0.5Z_{t,a}}N_{t,a}q_{t}^{s}s_{t,a}^{s}$$ ....(Eq. 18)

where the superscript *s* indexes the type of survey (AT or BTS).

$$\hat{N}_{t,a}^{s}=e^{-0.5Z_{t,a}}w_{t,a}N_{t,a}q_{t}^{s}s_{t,a}^{s}$$ ....(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:

$$\sum_{t}\left(\frac{\ln\ A_{t}^{s}/\hat{N}_{t}^{s}\ ^{2}}{2\sigma_{s,t}^{2}}\right)$$ ....(Eq. 20)

where A_{t}^{s} is the total (numerical) abundance estimate with variance $s_{s,t}^{2}$ from survey *s* in year *t* or optionally, the normal distribution is used:

$$\sum_t \left(\frac{A_t^s - \hat{N}_t^s}{2\sigma_{s,t}^2} \right)^2.$$

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 S 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

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

where $s_{c,t}$ 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 $\lambda_\varepsilon \sum_t \varepsilon^2 + \lambda_\gamma \sum_{t,a} \gamma_{t,a}^2 + \lambda_\delta \sum_t \delta_t^2$ 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 1991-2014. The values of $\overline{w}_i, \sigma_{w_i}^2$ based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

$$w_i^{future} \sim N\left(\overline{w}_i, \sigma_{w_i}^2\right) \text{...} \text{(Eq. 22).}$$

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 2016 and 2017 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}:

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

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

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

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.

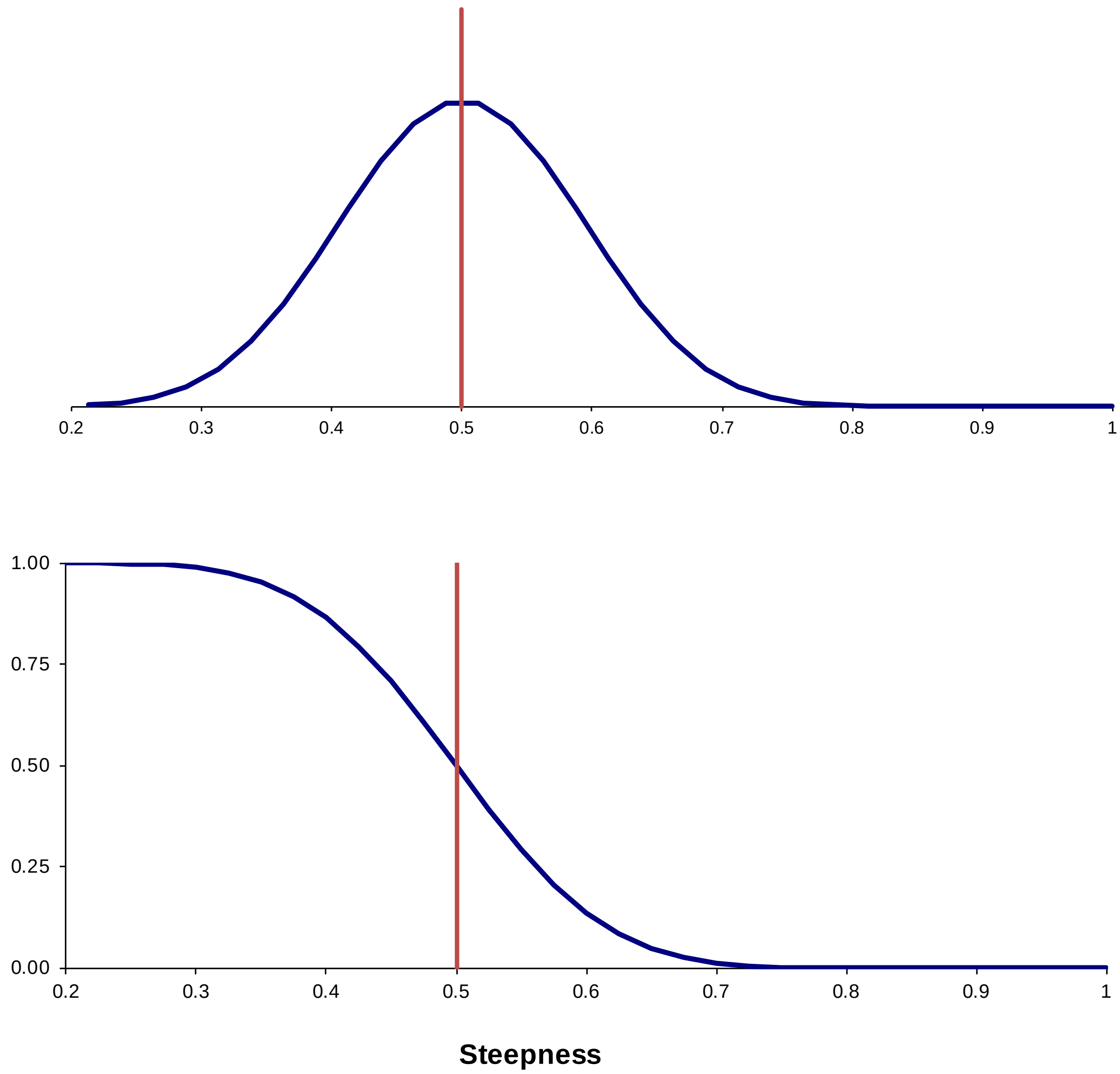


Figure 1.36. Cumulative prior probability distribution of steepness based on the beta distribution with α and β set to values which assume a mean and CV of 0.5 and 0.12, respectively. This prior distribution implies that there is about 14% chance that the value for steepness is greater than 0.6.

Appendix 1.1: Stock structure of EBS pollock presented in September 2015

Can be found here: http://www.afsc.noaa.gov/REFM/Docs/2015/EBSpollock_Stock_Structure.pdf

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