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

James N. Ianelli, Taina Honkalehto,
Steve Barbeaux, and Stan Kotwicki

Alaska Fisheries Science Center
National Marine Fisheries Service

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 2014 NMFS summer bottom-trawl survey (BTS) abundance at age estimates are included.
- The 2014 NMFS summer acoustic-trawl (AT) survey estimated abundance-at-age estimates were added.
- Observer data for catch-at-age and average weight-at-age from the 2013 fishery were finalized and included.
- Total catch as reported by NMFS Alaska Regional office was updated and included through 2014.

Changes in the assessment methods
The general modeling approach remained the same. As introduced in 2012, work on developing a density-dependence correction for the bottom-trawl survey data has progressed. This index is included as an alternative model run in which the age compositions and time series of the bottom trawl data are adjusted to account for gear efficiency for the entire time series. The time series of mean estimated population numbers is provided along with an externally estimated covariance matrix. These data are modeled following a multivariate lognormal distribution. The extent that selectivity should vary for the AT survey was re-evaluated. Given that selectivity estimates were exhibiting minor differences over time and, based on an Akaike's information criterion (AIC), the number of parameters was reduced.

Summary of results

EBS pollock results

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
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)	8,045,000 t	7,778,000 t	9,203,000 t	9,420,000 t
Projected female spawning biomass (t)	**2,606,000 t**	**2,467,000 t**	2,850**,000 t**	2,950**,000 t**
B_0	5,334,000 t	5,334,000 t	5,162,000 t	5,162,000 t
B_{MSY}	2,122,000 t	2,122,000 t	1,948,000 t	1,948,000 t
F_{OFL}	0.518	0.518	0.587	0.587
$maxF_{ABC}$	0.469	0.469	0.512	0.512
F_{ABC}	0.25	0.22	0.24	0.25
OFL (t)	2,795,000 t	2,693,000 t	3,330,000 t	3,490,000 t
maxABC (t)	2,528,000 t	2,436,000 t	2,900,000 t	3,040,000 t
ABC (t)	1,369,000 t	1,258,000 t	1,350,000 t	1,350,000 t
Status	As determined *last* year for: 2012	2013	As determined *this* year for: 2013	2014
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 2015 and 2016.

The survey and fishery data continue to confirm that the 2008 year class is well above average. These age 6 pollock in 2014 were estimated to represent 56% of the female spawning stock biomass (following years when that same class comprised 48% and 56% of the spawning biomass in 2012 and 2013 at ages 4 and 5, respectively. Projections indicate that catches in 2015 of 1.35 million t will result in a stable spawning biomass trend through 2016. The maximum permissible Tier 1a ABC remains high. After examining a other population indicators and some alternative model configurations, an ABC is recommended (1,350,000 t) which is well below the maximum permissible (Tier 1a) value of 2,900,000 t. The Tier 1a overfishing level (OFL) is estimated to be 3,330,000 t.

Response to SSC and Plan Team comments

General comments:

The SSC asks assessment authors to project the reference points for the future two years (e.g., 2015 and 2016) on the phase diagrams (December 2013 minutes).

This has been added to the diagram.

The Team also recommended that the authors consider the recommendations of the Recruitment Working Group, once the Teams and SSC have accepted final recommendations

A number of the provisional recommendations from the working group have been included in the approach used for projections and stock-recruit variability specifications. However, in this assessment the approach is the same as used for the 2013 assessment.

Comments specific to this assessment

The Team recommended that the authors explore the use of a matrix of cohort-specific weights at age for making projections.

Future expected body mass-at-age was developed, which account for two-year projections. Adding uncertainty and future expectations of mean body mass at age is an area of planned future research.

The SSC requests that the authors include survey weight-at-age in the assessment to assure that the decreases in weight-at-age are not an artifact of changes in the distribution of the fishery.

Survey weights at age are included in Table 1.14 and results presented in Fig. 1.19 suggests that the 2008 year class is lighter than average. The weights-at-age used in the projections are adjusted accordingly.

The SSC also requests that the study of survey efficiency by Kotwicki be presented to the SSC next September.

This was been included in the September and December 2013 assessments and is included here again as an optional model configuration (identified as mod2.0).

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 (headed and gutted), and surimi (Fissel et al. 2013). An important component of the commercial production is the sale of roe from pre-spawning pollock. Pollock are considered to be a relatively fast growing and short-lived species. They play an important role in the Bering Sea ecosystem.

Stock structure

In the U.S. portion of the Bering Sea three stocks of pollock are identified for management purposes. These are: Eastern Bering Sea which consists of pollock occurring on the Eastern Bering Sea shelf from Unimak Pass to the U.S.-Russia Convention line; the Aleutian Islands Region, encompassing the Aleutian Islands shelf region from 170°W to the U.S.-Russia Convention line; and the Central Bering Sea—Bogoslof Island pollock. These three management stocks undoubtedly have some degree of exchange. The Bogoslof stock forms a distinct spawning aggregation that has some connection with the deep-water region of the Aleutian Basin (Hinckley 1987). In the Russian EEZ, pollock are considered to form two stocks, a western Bering Sea stock centered in the Gulf of Olyutorski, and a northern stock located along the Navarin shelf from 171°E to the U.S.- Russia Convention line (Kotenev and Glubokov 2007). There is some indication (based on NMFS surveys) that the fish in the northern region may be a mixture of eastern and western Bering Sea pollock with the former predominant. Bailey et al. (1999) present a thorough review of population structure of pollock throughout the north Pacific region. Genetic differentiation using microsatellite methods suggest that populations from across the North Pacific Ocean and Bering Sea were similar. However, weak differences were significant on large geographical scales and conform to an isolation-by-distance pattern (O'Reilly et al. 2004; Canino et al. 2005; Grant et al. 2010). Bacheler et al. (2010) analyzed 19 years of egg and larval distribution data for the eastern Bering Sea. Their results suggested that pollock spawn in two pulses spanning 4-6 weeks: first in late February, then again in mid-late April. Their data also suggest three unique areas of egg concentrations, with the region north of Unimak Island and the Alaska Peninsula being the most concentrated. Such syntheses of egg and larval distribution data provide a useful baseline for comparing trends in the distribution of pre-spawning pollock. Recent studies on movement of pollock within the region data are presented in Hulson et al. (2011). This work was extended to evaluate environmental effects on spatial stock structure and the potential impact on management advice (Hulson et al. 2013).

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 either 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.

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. Between 1998 and 2004 a directed fishery for pollock was prohibited. Consequently, 210,350 km^2 (54%) of critical habitat was closed to the pollock fishery. The portion of critical habitat that remained open to the pollock fishery consisted primarily of the area between 10- and 20-nm from rookeries and haulouts in the GOA and parts of the southeastern Bering Sea foraging area. 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. Since 2005, a limited pollock fishery has been prosecuted in the Aleutian Islands but with less than 2,000 t of annual catch.

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% (since 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 1.2). In 2014 it increased to 38% during the A season and 37% 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, salmon bycatch management measures went into effect in 2011 (Amendment 91 to the Groundfish FMP resulting from the NPFMC's 2009 action). The 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 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 perhaps salmon abundance.

Measures to reduce salmon bycatch in the pollock fishery continue to be considered. This follows from a draft Environmental Assessment presented to the Council in 2012 that examined the impact of the chum salmon bycatch on western Alaska systems. The analysis indicated that the impact rates to some runs returning to Alaskan rivers (specifically western Alaska) appeared to be below 2% in the worst year (with caveats that genetic data failed to discern small regions which could potentially have been more heavily impacted than adjacent larger systems). Chum salmon bycatch remains a concern and the NPFMC is presently evaluating trade-offs of management measures. Due to differences in seasonal and spatial bycatch patterns between chum and Chinook salmon, measures that may reduce the bycatch of one species may increase the bycatch of the other. Consequently, a suite of management options is being evaluated and will be presented at the December 2014 meetings for initial review. Salmon bycatch statistics and further discussion are presented along with other bycatch estimates in the Ecosystem Considerations section below. A summary of some key management measures is provided in Table 1.3.

Fishery characteristics

Pre-spawning aggregations of pollock are the focus of the first so-called A-season that opens on January 20th and extends into early-mid April. During this season, the fishery is characterized as producing highly valued roe that 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. Since the closure of the Bogoslof management district (INPFC area 518) to directed pollock fishing in 1992, the A-season pollock fishery on the EBS shelf has been concentrated primarily north and west of Unimak Island (e.g., Ianelli *et al.* 2013). 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 but 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 2014 spatial pattern had relatively high concentrations of fishing on the shelf north of Unimak Island, especially compared to the pattern observed in 2012 and 2013 when most fishing activity occurred farther 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).

Fishing conditions during the A-season have in recent years appear to be characterized by lower production of roe relative to total pollock caught in that season but some improvement in 2014 (Fig. 1.4). This might be due in part to colder conditions, slower maturing pollock given their age/size (which may also be related to colder condtions), and changes in the fishery distribution (e.g., in areas outside of the industry’s Chinook salmon hot-spot closure areas; farther to the north than has been typical).

The 2014 summer and fall (B-season) fishing was also characterized as having catches distributed closer to Unimak Island than in recent years (Fig. 1.5). Fishing conditions, as measured by computing nominal catch per hour from NMFS observer data, were similar to the 2013 pattern with reasonably good rates compared with the previous two years (Fig. 1.6). For each tow in the pollock fishery, a NMFS observer records the estimated number of fish and the total weight. These data can be used to compute the average weight of pollock in each tow and when binned by 50-gram categories, fine-scale weekly size frequency patterns can be evaluated by sector (e.g., Fig. 1.7). Presently these data have only been used for visualization. Their value as a fishery indicator for the asssessment model (relative to the normal length frequency data collected by observers) is an area of research that might be worth pursuing.

From 1977-2014 the catch of EBS pollock has averaged 1.174 million t (Table 1.4). Since 2001, the average has been above 1.268 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 1.24 million t.

Pollock catch in the Eastern Bering Sea and Aleutian Islands by area from observer estimates of retained and discarded catch for 1991-2014 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	1964-2014
Fishery	Catch age composition	1964-2013
Fishery	Japanese trawl CPUE	1965-1976
EBS bottom trawl	Area-swept abundance (numbers) index	1982-2014
EBS bottom trawl	Proportions at age	1982-2014
Acoustic trawl survey	Population abundance (numbers) index	1979, 1982, 1985, 1988, 1991, 1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006-2010, 2012, 2014
Acoustic trawl survey	Proportions at 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	2006-2013 (same as in 2013)

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 1991-2013 (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. 1.8; Table 1.6).

Since 1999 the observer program adopted a new sampling strategy for lengths and age-determination studies (Barbeaux et al. 2005). Under this scheme, more observers collect otoliths from a greater number of hauls (but far fewer specimens per haul). This has improved the geographic coverage but lowered the total number of otoliths collected. Previously, large numbers were collected but most were not aged. The sampling effort for lengths has decreased since 1999 but the number of otoliths processed for age-determinations increased (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). For 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 - 2014) 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 2014 the BTS biomass estimates ranged from 2.28 to 8.39 million t (Table 1.10; Fig. 1.9). In the mid-1980s and early 1990s several years resulted in above-average biomass estimates. The stock appeared to be at lower levels during 1996-1999 then increased moderately until about 2003 and since then has averaged about 3.7 million t—excluding the jump in biomass observed in 2014 (which brings the 2004-2014 average to just over 4 million t). These surveys are multi-purpose and serve as a consistent measure of environmental conditions such as temperature characterizations that reflect the cold conditions experienced during 2006-2013. Large-scale zoogeographic shifts in the EBS shelf due to temperature changes have been documented during a warming trend (e.g., Mueter and Litzow 2008). However, after a period of relatively warm conditions ending in 2005, seven years were below average, indicating that the zoogeographic responses may be less temperature dependent than 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 and in 2014 increased dramatically along with surface temperatures (Fig. 1.10).

Beginning in 1987 NMFS expanded the standard survey area farther to the northwest. The pollock biomass levels found in these “non-standard” strata were highly variable, ranging from 1% to 22% of the total biomass; the 2014 estimate is 12% compared to the overall average of 6% overall (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 (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 2014 biomass estimate was 7.43 million t, about 55% more than the average for this survey (4.8 million t). This survey estimate ranks 2nd out of the 27 estimates since 1987 and is the largest estimate since 2003. The distribution of pollock was spread throughout the shelf region, with the biggest concentrations in the middle and outer domain of the shelf and relatively unconstrained by the warmer bottom temperatures (Fig. 1.11). Comparing the past several years shows that pollock appear to occur at higher densities in most stations in 2014 (Fig. 1.12).

In general, much of the interannual 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. 1.13). The BTS operations generally catch pollock above 40 cm in length, and in some years include many 1-year olds (with modal lengths around 10-19 cm) but rarely age 2 pollock (lengths around 20-29 cm). 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 dropped from 43 billion 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. Model 2.0 in this assessment accounts for this variability.

The 2014 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 the standard strata (1-6) and for the northern strata included are presented in Table 1.13 and the corresponding mean body mass at ages are given in Table 1.14.

As in previous assessments, a descriptive evaluation the BTS data alone was conducted to evaluate mortality patterns. Cotter et al. (2004) promoted this type of analysis as having a simple and intuitive appeal which is independent of population scale. In this approach, log-abundance of age 6 and older pollock is regressed against age by cohort. The negative values estimated for the slope are estimates of total annual mortality. Age-6 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. 1.14). Total mortality estimates by cohort represent lifetime averages since harvest rates (and actual natural mortality) vary from year to year. The low values estimated for some year classes (e.g., the 1992 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 types of values obtained from within the assessment models. The low values for the most recent cohorts are due to the increased abundances observed in 2013 and 2014. This can be observed in an output diagnostic using the software "YCC" (Cotter et al. 2007) which fit both age and year coefficients to examine trends in cohorts (Fig. 1.15).

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 index (normalized to have the same mean) shows a slight departure from the current BTS values and the estimated uncertainty is greater (Fig. 1.16). The input covariance matrix ($\boldsymbol{\Sigma}$) 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; Table 1.10). The number of trawl hauls, lengths, and ages sampled from the AT survey are presented in Table 1.15. 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). This method accounts for observed spatial structure for sampling along transects. As done 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 2014 summer AT survey was characterized by the predominance of 2-year old pollock—in fact the highest level observed since 1982 (Fig. 1.17; Table 1.16). The survey results also indicated relatively high numbers of 1-year-old pollock, and a relatively abundant 6-year old age group. The latter is consistent with the 2012 observations of 4-year olds (and consistent with other survey and fishery data on the 2008 year class).

Spatially, the 2014 mid-water pollock distribution differed from recent years. The biomass estimated east of 170º W was 41% compared to an average of 26% (since 1994; Table 1.17). Also, the distribution of pollock within the SCA rose to 12% compared to the 2007-2012 average of 7l% (and 1994-2014 average of 16%). Overall, the mid-water pollock densities from the AT survey were consistent with the findings from the bottom trawl survey in that pollock were wide-spread throughout the shelf but with lower concentrations in the mid-water zone compared to the bottom zone (Fig. 1.18).

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

In 2014 acoustic data were collected from commercial fishing vessels used 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). These data link integrated 38 kHz backscatter from an index area since 2006 and became formally included in the assessment in 2013 (Ianelli et al. 2013). The index remains the same as last year, with the time series covering the period 2006-2013 (Table 1.18). In 2015 we anticipate updating the index with the 2014 and 2015 estimates. This will provide some information on mid-water pollock abundance because the next AT survey in the region is planned for 2016.

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 1964-2014. 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 2014 EBS bottom trawl survey estimate of population numbers-at-age was added
- The 2014 EBS AT survey estimate of population numbers-at-age was added (the age-length key was adopted from the BTS with supplemental juvenile pollock otolith samples from the AT survey)

- The 2013 final fishery age composition data was updated.

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. In the 2009 assessment, based on a workshop on natural mortality hosted by the AFSC, alternative age-specific patterns of natural mortality were investigated. This approach combined Lorenzen's (2000) observation that natural mortality is inversely proportional to length for young fish with Lehodey et al.'s (2008) logistic model for older fish scaled to maturation. Applying this relationship with pollock life history characteristics indicated a vector of age-specific natural mortality for the youngest and oldest ages similar to that used here.

Estimates of natural mortality are also higher when predation is explicitly considered (Livingston and Methot 1998; Hollowed et al. 2000). However, Model 1 values were selected because Clark (1999) found that specifying a conservative (lower) natural mortality rate is advised when natural mortality rates are uncertain. For sensitivity, alternative estimates are included based on the Lorenzen approach and that of Gislason et al (2010) were compiled (see appendix on Model Details). Pollock natural mortality-at-age (by model) and maturity-at-age (for all models; Smith 1981) values used 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
Model 1.1 M	2.791	1.047	0.621	0.444	0.351	0.294	0.258	0.232	0.214	0.200	0.190	0.182	0.176	0.171	0.166
Model 1.2 M	0.990	0.754	0.601	0.554	0.521	0.490	0.468	0.451	0.439	0.424	0.416	0.402	0.396	0.349	0.990
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., 2013 for the assessment conducted in 2014). 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. For estimation errors due to sampling, bootstrap distributions of the variability (within-year) indicate that this source is relatively small compared to the between-year variability in mean weights-at-age implying that processes determining mean weights in the fishery cause more variability than sampling (Table 1.19). 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%.

Alternative estimators for mean weight at age were developed in Ianelli et al. (2009). This year, due to the apparently below-average mean weight of the 2008 year-class (as apparent in the fishery and modestly so in the survey; Fig. 1.19), an approach to account for this was developed as follows. For a given age *a* greater than age 2, three values were computed:

- w_1 The mean body mass at age *a* from 1991-2013,
- w_2 The percentile body mass of age *a* pollock 1991-2013 observations based on the rank of the age *a-1* body mass in 2013 (so if the age *a-1* pollock was about average in mass in 2013, then w_2 would be assigned a median value),
- w_3 The percentile body mass of age *a* pollock from the 1991-2013 observations based on the rank of the age *a-2* body mass in 2013,
- w_a^* the body mass assumed for 2014 and in future years set to the minimum of w_1,w_2, and w_3.

This method accounts for the cohort effect observed but will be biased low for the two-year projections. For example, the revised 2013 mean weights-at-age are slightly heavier than assumed in Ianelli et al. (2013) for the older pollock but nearly identical to that used for pollock younger than age 6 (Fig. 1.20).

Parameters estimated inside the assessment model

For the selected model, 758 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment, and stock-recruitment parameters account for 74 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 1964-2014 and projected recruitment variability (using the variance of past recruitments) for five years (2015-2019). 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 10x50 matrix of 500 parameters bringing the total fishing mortality parameters to 552.

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. Four catchability coefficients were estimated: one each for the early fishery catch-per-unit effort (CPUE) data (from Low and Ikeda, 1980), the early bottom trawl survey data (where only 6 strata were surveyed), the main bottom trawl survey data, and the AT survey data. The selectivity parameters for the 2 main indices total 116 and there are 5 scale parameters (q): 2 for the BTS index, and one each for the AT, CPUE, and AVO indices.

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. 1.9; 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 1.20).
- 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.

Results

Model evaluation

A preliminary sequence of models was developed that evaluated sensitivities to new data which included updating the catch biomass for 2013 and estimated levels for 2014 along with the 2013 fishery mean weights-at-age. As in past years, a set of models showing the impact of new data was constructed along with a few sensitivity analyses:

Name	Updated catch to 2014	2013 Catch age	2014 Bottom trawl data	2014 Acoustic Trawl data
Data considerations				
Model 0.0	X			
Model 0.1	X	X		
Model 0.2	X	X	X	
Model 0.3	X	X	X	X
Evaluate alternative natural mortality estimates				
Model 1.0	Status quo (Mod0.3)			
Model 1.1	Set to Lorenzen vector			
Model 1.2	Set to estimate based on Gislason approach			
Kotwicki index: efficiency correction for bottom trawl survey data				
Model 2.0	Uses multivariate lognormal (over time) instead of univariate			

The sequential addition of new data to the model indicated that the BTS survey had a large impact on the fit to the data, especially when the 2014 bottom trawl survey information was added (Mod0.2; Fig. 1.21). Adding in the 2014 AT survey data had a relatively minor impact (but indicated an above average 2012 year class Fig. 1.21).

In Ianelli et al. (2013) an iterative approach to estimating the stock recruitment variability (σ_R) parameter was conducted following methods proposed under the Plan Teams' recruitment working group report. The result for this indicated a value of about 0.674. This approach was tested again this year in place of the previously assumed value, 0.9. As before, the results of past biomass and recruitments were nearly identical but the fitted Ricker stock recruitment relationship changes significantly. The value for steepness (or slope at the origin) again increased due to two relative high year-classes that occurred at relatively low stock sizes (the 1978 and the more recent 2008 values) given the lower value assumed for variability about the stock recruitment curve. Based on this, and given the critical role that the bio-physical environmental conditions, more detailed study on the stock-recruit estimation relative to random effects should be undertaken before estimates of σ_R are adopted. Conseuquently, for consistency with past analyses, the fixed value of 0.9 was retained.

Model 2.0 was the same as Model 1.0 except that it used an alternative index and age composition for the BTS data. This index also included a covariance matrix that was used in model fitting. 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 2014 spawning biomass estimate (Fig. 1.22). For contrast, this figure also includes a sensitivity in which the BTS data are down-weighted and shows that the current stock size estimates are affected by the survey index.

Sensitivity runs for different natural mortality-at-age vectors suggested that the Lorenzen approach (Model 1.1) came close to fitting the data and model assumptions as well as the status quo model (Model 1.0), whereas Model 1.2 (the Gislason et al. derived natural mortality-at-age) performed poorly and resulted in unrealistically high biomass estimates (Table 1.21). Model 2.0 was included for reference (but note that the likelihood function differs for the BTS).

For the purposes of management, Model 1.0 performed similarly or out-performed the others evaluated and was carried forward for the remaining figures and considerations. The estimated parameters and standard errors are provided in Table 1.22.

The estimated selectivity pattern changes over time and reflects to some degree the extent to which the fishery is focused on particularly prominent year-classes (Fig. 1.23). The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 1.24). The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) is consistent with the population trends for this period (Fig. 1.25). The fit to the fishery-independent index from the 2006-2013 AVO data was reasonable, especially for 2011-2013 (Fig. 1.26).

Bottom-trawl survey selectivity and fits to the numbers of age 2 and older pollock indicate that the model predicts fewer pollock than observed in the 2014 survey but slightly more than observed in the 2012 and 2013 surveys (Fig. 1.27). The pattern of bottom trawl survey age composition data in recent years shows a decline in the abundance of older pollock since 2011. The 2006 year class observations are below model expectations in 2012 and 2013, partly due to the fact that in 2010 the survey estimates are greater than the model predictions (Fig. 1.28).

The AT survey selectivity estimates were allowed to differ in the 1979 survey; (Fig. 1.29; top panel). The fit to the numbers of age 2 and older pollock in the AT survey generally falls within the confidence bounds of the survey sampling distributions (here assumed to have an average CV of 20%) with a fairly reasonable pattern of residuals (Fig. 1.29, bottom panel). The AT age compositions consistently track large year classes through the population and the model fits these patterns reasonably well (Fig. 1.30).

The AT age-1 index is generally fit poorly but with residuals that appear to be reasonably random (Fig. 1.30, bottom panel).

Time series results

The estimate of B_{MSY} is 1,948,000 t (with a CV of 20%) which is less than the projected 2015 spawning biomass of 2,850,000 t; Table 1.23). For 2014, the Tier 1 levels of yield are 2,900,000 t from a fishable biomass estimated at around 5,669,000 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 1.0 results indicate that spawning biomass will be above $B_{40\%}$ (2,491,000 t) in 2015 and about 146% 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 2014 and 2015 (Fig. 1.31).

Another diagnostic (see Eq. 14 in appendix) on the impact of fishing shows that the 2014 spawning stock size is about 61% of the predicted value had no fishing occurred since 1978 (Table 1.23). This compares with the 47% of $B_{100\%}$ (based on the SPR expansion using mean recruitment from 1978-2012) and 57% of B_0 (based on the estimated stock-recruitment curve). The latter two values are based on expected recruitment either 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) derived from Model 1.0 suggest that the abundance of Eastern Bering Sea pollock remained at a fairly 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 above 8 million t in 2013 and 2014, following a low in 2008 at 4.7 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. 1.32). 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 is below 20% due to the reductions in TACs relative to the maximum permissible ABC values and increases 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 in 2014 (Fig. 1.33). The estimates of age 3+ pollock biomass are mostly higher than the estimates from previous years, especially the past 4 assessments (Fig. 1.34, 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. 1.35).

Recruitment

Model estimates indicate that the 2006 year class is only 12% above the average level (Fig. 1.36, top panel). This compares with the 2008 year class that appears to be about twice the mean value. The stock-recruitment curve as fit within the integrated model shows a fair amount of variability both in the estimated recruitments and in the uncertainty of the curve (Fig. 1.36; bottom panel). Note that the 2012 and 2013 year classes (as age 1 recruits in 2013 and 2014) 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) evaluate the consequences of current harvest policies in the face of warmer conditions and potentially lower pollock recruitment and noted that the current management system is likely to face higher chances of ABCs below the average.

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 1.0 runs indicate that the impact of new data in 2014 increases the overall historical biomass trajectory (Fig. 1.37). 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 increase based on new data this year has made the retrospective pattern (for the 10-year period) appear as mainly underestimates with Mohn’s rho equal to -0.11. However, the retrospective estimates still fall well within the bounds of uncertainty (Figs. 1.37).

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} = 1,948 thousand t female spawning biomass

B_0 = 5,162 thousand t female spawning biomass

$B_{100\%}$ = 6,227 thousand t female spawning biomass

$B_{40\%}$ = 2,491 thousand t female spawning biomass

$B_{35\%}$ = 2,179 thousand t female spawning biomass

Specification of OFL and Maximum Permissible ABC

The 2015 spawning biomass is estimated to be 2,850,000 t (at the time of spawning, assuming the stock is fished at recommended ABC level). This is above the B_{MSY} value of 1,948,000 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 2015 female spawning biomass is estimated to be above the B_{MSY} level (1,948,000 t) and the $B_{40\%}$ value (2,491,000 t) in 2015 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	2015	2,900,000 t	3,330,000 t
1a	2016	3,040,000 t	3,040,000 t

Tier	Year	MaxABC	OFL
3a	2015	1,637,000 t	2,022,000 t
3a	2016	1,642,000 t	2,026,000 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 2014 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2014. 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 2015 and 2016, 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 2015 and 2016 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 2010-2014 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 2014 or 2) above ½ of its MSY level in 2015 and above its MSY level in 2026 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, *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 expected to be above its MSY level in 2026 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 2014 (Table 1.29). Under the maximum permissible catch level in Tier 3, the expected spawning biomass will decline (and be below the target by 2015) through 2016 and eventually begin to increase and stabilize around $B_{40\%}$ (in expectation) by about 2020 years (Fig. 1.38).

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 2014:

If spawning biomass for 2014 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.

If spawning biomass for 2014 is estimated to be above $B_{35\%}$, the stock is above its MSST.

If spawning biomass for 2014 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 2024 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 2016 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

If the mean spawning biomass for 2016 is above $B_{35\%}$, the stock is not approaching an overfished condition.

If the mean spawning biomass for 2016 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2026. If the mean spawning biomass for 2026 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 2014, nor is it expected to be approaching an overfished condition based on Scenario 7 (the mean spawning biomass in 2014 is above the $B_{35\%}$ level; Table 1.29). Tier 1 calculations for ABC and OFL values in 2015 and 2016 (assuming catch is 1,350,000 t in 2015 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 2014 spawning biomass (2,945 kt) that is about 146% of B_{MSY} (1,948 kt). The spawning stock appears to have recovered well above the low point estimated in 2008. The replacement yield—defined as the catch next year that is expected to achieve a 2016 spawning biomass estimate equal to that from 2014—is estimated to be about 1,350,000 t.

Even though the EBS pollock stock has appeared to recover from its 2008 low, there are some reasons to remain conservative in specifying ABCs to be less than the maximum permissible Tier 1 values:

- The 2008 year class has represented the majority of the spawning biomass since 2012 when it was 48%. In 2013 and 2014 it was estimated to be 56% of the female spawning stock biomass in both years. This represents the 3rd highest proportion of spawning biomass consisting of a single cohort (over the period 1964-2014). Reliance on a single year class comprising such a large portion of the reproductive output may affect the robustness of the spawning stock.
- The fleet was able to operate with reasonably good catch rates and maintain salmon bycatch at relatively low levels. Relative to 2014, a catch of 1,350,000 t would require about 13% more effort (based on the ratio of fishing mortality rates).
- Roe recovery rates are still below average. This may be indicative of reduced reproductive potential.

Given these factors, a 2015 ABC of 1,350,000 t is recommended to provide an even chance that the current spawning stock will be achieved in 2016. The alternative maximum permissible Tier 1a ABC seems risky since the change in the stock size would be dramatic (i.e., large reductions in ABC would be needed due to normal recruitment variability). Adopting a Tier 3 approach for specifying ABC would also provide greater near-term yield but with less spawning stock and future catch variability than expected under Tier 1.

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. In 2010 and this year the index was updated and 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 this year with catches exceeding 13 thousand t. 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 (about 13% above the 2003-2013 average) after the low level observed in 2012 (Table 1.35). Chinook salmon bycatch in 2014 was low (36% of the 2003-2014 mean value) and consistent with the magnitude of bycatch since the implementation of Amendment 91 in 2011 (2014 was 92% of the 2011-2014 mean). 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 bottom trawl survey in 2014 found abundance levels for the 2008 year class to be at record levels—and this after record levels of age 5 pollock from the 2013 estimates. Research on developing and testing plausible hypotheses about the underlying processes that cause such observations is needed. 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.

Acknowledgements

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

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., 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, L. Pfeiffer, J. Sepez, C. Seung. 2012. 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, 2011.

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.

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. 2011 (In Review). Use of juvenile salmon growth and temperature change indices to predict groundfish post age-0 year class strengths in the Gulf of Alaska and eastern Bering Sea. Fisheries Oceanography (in review).

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.

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, 1979-2014 (2014 values through October 25th 2014). 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		
2006	827,207	660,823	1,488,031	1,745		
2007	728,249	626,253	1,354,502	2,519		
2008	482,748	507,880	990,629	1,278		9
2009	358,252	452,532	810,784	1,662		73
2010	255,023	555,192	810,215	1,285		176
2011	747,594	451,475	1,199,069	1,208		173
2012	618,854	586,343	1,205,197	975		79
2013	695,648	575,097	1,270,745	2,964		57
2014	852,399	438,175	1,290,574	2,348		428
Average since 1991	826,355	411,433	1,237,788			
1979	368,848	566,866	935,714	9,446		

1979-1989 data are from Pacfin.
1990-2014 data are from NMFS Alaska Regional Office, and include discards.
The 2014 EBS catch estimates are preliminary

Table 1.2. Total 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), 1998-2014. Note that the 2014 data are preliminary and observer coverage for shore-based catcher vessels increased in 2011.

	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	566,000 t (54%)	690,000 t (49%)	1,256,000 t (51%)
2003	616,000 t (45%)	680,000 t (42%)	1,296,000 t (43%)
2004	531,000 t (45%)	711,000 t (34%)	1,242,000 t (38%)
2005	529,000 t (45%)	673,000 t (17%)	1,203,000 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%)	490,000 t (12%)	832,000 t (26%)
2009	283,000 t (26%)	389,000 t (13%)	671,000 t (24%)
2010	281,000 t (17%)	412,000 t (9%)	693,000 t (12%)
2011	490,000 t (54%)	531,000 t (28%)	1,020,000 t (40%)
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%)

Table 1.3. 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 2014 value is based on catch reported to October 25th 2014 plus an added estimated of 8.019 thousand t 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
	1977-2014 average		1,376,974	1,195,559	1,174,324

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 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
2005	Rolling hotspot program accepted
2011	Amendment 91 enacted, Chinook salmon regulations enhanced

Table 1.5. Estimates of discarded pollock (t), percent of total (in parentheses) and total catch for the Aleutians, Bogoslof, Northwest and Southeastern Bering Sea, 1991-2014. SE represents the EBS east of 170° W, NW is the EBS west of 170° W, source: NMFS Blend and catch-accounting system database. 2014 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%)	57,609 (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%)	16,083 (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 (2%)	16,037 (2%)	22,054	8	132,515	886,567	1,041,144
1999	480 (48%)	11 (39%)	1,912 (0.9%)	26,912 (3%)	29,315 (3%)	1,010	29	206,698	782,983	990,719
2000	790 (63%)	20 (67%)	1,942 (0.7%)	19,678 (2%)	22,429 (2%)	1,244	29	293,532	839,177	1,133,984
2001	380 (46%)	28 (11%)	2,450 (0.6%)	14,874 (2%)	17,732 (1%)	825	258	425,220	961,977	1,388,280
2002	779 (66%)	12 (1%)	1,441 (0.4%)	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 (0.5%)	13,795 (1%)	17,242 (1%)	1,649	24	557,588	933,191	1,492,453
2004	287 (25%)		2,781 (0.7%)	20,380 (2%)	23,448 (2%)	1,158	0	390,544	1,090,008	1,481,710
2005	324 (20%)		2,586 (0.4%)	14,838 (2%)	17,747 (1%)	1,621	0	680,868	802,154	1,484,643
2006	311 (18%)		3,677 (0.6%)	11,877 (1%)	15,865 (1%)	1,745	0	660,823	827,207	1,489,776
2007	425 (17%)		3,769 (0.6%)	12,334 (2%)	16,529 (1%)	2,519	0	626,253	728,249	1,357,021
2008	81 (6%)		1,643 (0.3%)	5,968 (1%)	7,692 (1%)	1,278	9	507,880	482,748	991,916
2009	395 (24%)	6 (8%)	1,936 (0.4%)	4,014 (1%)	6,351 (1%)	1,662	73	452,532	358,252	812,520
2010	142 (11%)	53 (30%)	1,201 (0.2%)	2,510 (1%)	3,907 (0%)	1,285	176	555,192	255,023	811,677
2011	75 (6%)	23 (13%)	1,335 (0.3%)	3,444 (0%)	4,876 (0%)	1,208	173	451,475	747,594	1,200,450
2012	95 (10%)	5.0 (6%)	1,187 (0.2%)	4,177 (1%)	5,464 (0%)	975	79	586,343	618,854	1,206,252
2013	107 (4%)	0.4 (1%)	1,227 (0.2%)	4,145 (1%)	5,480 (0%)	2,964	57	575,097	695,648	1,273,766
2014	110 (5%)	54 (13%)	1,681 (0.4%)	12,058 (1%)	13,902 (1%)	2,348	428	438,175	852,399	1,293,350

Table 1.6. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2013. 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
Average	4.2	61.0	207.7	357.4	384.8	312.0	196.3	111.6	65.6	35.6	24.6	12.9	8.5	12.5	1,795

Table 1.7. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2013, as sampled by the NMFS observer program.

Length Frequency	A Season Males	Females	B Season SE Males	Females	B Season NW 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	45,958	43,987	19,869	18,571	50,309	53,202	231,896
2010	39,495	41,054	40,449	41,323	19,194	20,591	202,106
2011	58,822	62,617	51,137	48,084	60,254	65,057	345,971
2012	53,641	57,966	50,167	53,224	45,044	46,940	306,982
2013	52,303	62,336	49,484	49,903	37,434	44,709	296,168

Table 1.7. (continued) Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2013, 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	3,890	4,461	1,839	2,370	4,179	5,318	22,057
2010	4,536	5,272	4,125	4,618	2,261	2,749	23,561
2011	6,772	6,388	5,809	4,634	6,906	6,455	36,964
2012	5,500	5,981	4,928	5,348	4,508	4,774	31,039
2013	6,525	5,690	4,920	4,849	4,313	3,613	29,910

Table 1.8. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2013, as sampled by the NMFS observer program.

	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	483	404	298	238	431	440	2,294
2010	624	545	465	414	504	419	2,971
2011	581	808	404	396	579	659	3,427
2012	517	571	485	579	480	533	3,165
2013	703	666	568	526	517	402	3,381

Table 1.9. NMFS total pollock research catch by year in t, 1964-2014.

Year	Aleutian Is.	Bering Sea	Year	Aleutian Is.	Bering Sea
1964	0	0	1989	0	393
1965	0	18	1990	0	369
1966	0	17	1991	51	465
1967	0	21	1992	0	156
1968	0	7	1993	0	221
1969	0	14	1994	48	267
1970	0	9	1995	0	249
1971	0	16	1996	0	206
1972	0	11	1997	36	262
1973	0	69	1998	0	121
1974	0	83	1999	0	299
1975	0	197	2000	40	313
1976	0	122	2001	0	241
1977	0	35	2002	79	440
1978	0	94	2003	0	285
1979	0	458	2004	51	363
1980	193	139	2005	0	87
1981	0	466	2006	21	251
1982	40	682	2007	0	333
1983	454	508	2008	0	168
1984	0	208	2009	0	156
1985	0	435	2010	62	226
1986	292	163	2011	0	124
1987	0	174	2012		
1988	0	467	2013	0	
			2014		

Table 1.10. Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979-2014 (**millions** of tons). Note that the bottom-trawl survey data only represent biomass from the standard 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%
Average	4.796	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 1982-2014.

Year	Survey biomass estimates in strata 1-6	Survey biomass estimates in strata 8 and 9	All area Total	NW %Total
1982	2,855,539			
1983	6,257,632			
1984	4,893,536			
1985	4,630,149	1,325,102	5,955,251	22%
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	5,168,300	152,300	5,320,600	3%
2006	2,845,129	199,885	3,045,015	7%
2007	4,158,176	179,986	4,338,162	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%
Avg.	4,548,395	282,286	4,805,851	6%

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

Table 1.13. Bottom-trawl survey estimated numbers (millions) at age used for the stock assessment model, 1982-2014 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	3,918	576	1,278	2,267	5,055	1,554	286	157	71	61	46	16	7	5	2	15,300	1,192	8%
1984	367	281	399	1,152	1,458	3,426	652	145	68	24	16	6	4	5	2	8,005	791	10%
1985	4,785	677	2,563	833	2,876	1,835	1,272	252	65	53	19	6	7	1	0	15,244	1,949	13%
1986	2,188	497	362	1,338	816	1,383	1,220	1,123	358	56	26	11	1	3	1	9,381	837	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	1,070	512	1,198	2,286	1,012	3,319	1,002	786	462	1,117	107	64	13	17	9	12,976	1,466	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	1,721	241	86	552	1,110	3,754	759	1,906	198	373	58	544	47	36	48	11,432	1,373	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	1,338	324	1,703	285	319	536	478	689	310	595	212	268	117	92	73	7,340	808	11%
1993	2,347	333	709	2,972	647	521	275	384	527	325	286	208	165	91	110	9,900	920	9%
1994	1,249	521	395	1,115	3,026	530	141	124	143	268	166	233	89	86	145	8,232	973	12%
1995	1,443	138	270	1,224	1,604	2,566	1,086	288	179	116	219	91	167	68	101	9,561	1,809	19%
1996	1,434	346	155	308	806	1,125	1,027	349	87	94	65	123	40	74	100	6,134	508	8%
1997	2,239	339	147	180	2,166	1,008	626	782	137	70	53	59	96	32	111	8,042	1,082	13%
1998	625	549	281	185	354	2,024	529	342	269	68	31	11	24	28	65	5,385	592	11%
1999	817	704	646	701	401	726	1,846	514	260	243	91	39	16	24	82	7,110	834	12%
2000	921	292	353	1,189	1,223	648	571	1,874	737	394	172	116	36	17	76	8,618	1,017	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	644	300	621	894	928	1,205	627	307	421	792	396	179	107	33	37	7,491	769	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	345	124	185	799	2,319	1,578	838	387	297	230	60	127	207	81	84	7,662	743	10%
2006	715	62	96	317	791	1,006	647	312	179	155	75	47	67	91	90	4,649	427	9%
2007	2,023	48	116	337	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	342	372	219	319	433	342	250	123	82	27	28	14	59	3,449	415	12%
2010	408	115	204	2,055	930	295	261	278	295	203	175	64	39	23	51	5,396	707	13%
2011	982	100	208	285	1,433	707	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	189	744	3,702	865	547	194	66	60	79	60	56	31	41	7,706	625	8%
2014	1,701	438	203	268	1,233	4,494	2,346	508	281	103	40	56	58	27	70	11,827	792	7%
Avg	1,302	393	553	1,001	1,450	1,323	820	497	326	242	165	117	70	37	60	8,358	915	11%

Table 1.14. Mean EBS pollock body mass (kg) at age as observed in the summer NMFS bottom trawl survey, 1982- 2014.

	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	2.140	2.673
1983	0.016	0.105	0.170	0.360	0.494	0.577	0.742	1.070	1.146	1.015	1.100	1.148	1.902	1.108	2.723
1984	0.017	0.064	0.193	0.361	0.487	0.616	0.752	1.013	1.220	1.368	1.678	1.655	1.404	1.470	2.506
1985	0.022	0.084	0.171	0.398	0.493	0.630	0.960	1.009	1.367	1.065	1.378	1.764	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	1.473	1.471	2.558	2.128	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	2.699
1988	0.021	0.080	0.210	0.356	0.460	0.521	0.602	0.760	0.851	0.992	1.201	1.209	1.532	1.051	2.441
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	2.163
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	2.295
1991	0.018	0.085	0.151	0.364	0.486	0.580	0.696	0.744	0.877	0.918	1.095	1.201	1.241	1.398	2.522
1992	0.029	0.093	0.205	0.373	0.522	0.623	0.777	0.844	0.898	0.988	1.123	1.241	1.391	1.360	2.484
1993	0.017	0.076	0.253	0.453	0.503	0.563	0.665	0.807	0.978	1.026	1.147	1.263	1.391	1.536	2.504
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	1.491	2.278
1995	0.019	0.064	0.114	0.377	0.485	0.629	0.655	0.840	0.966	1.181	1.163	1.330	1.398	1.479	2.234
1996	0.020	0.066	0.117	0.313	0.497	0.597	0.734	0.815	0.972	1.062	1.306	1.395	1.469	1.548	2.148
1997	0.017	0.068	0.209	0.322	0.499	0.597	0.789	0.935	0.966	1.035	1.169	1.295	1.275	1.495	2.080
1998	0.021	0.060	0.134	0.341	0.477	0.520	0.679	0.830	0.911	1.010	1.072	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	0.459	0.532	0.660	0.709	0.784	0.957	1.184	1.214	1.355	1.494	2.212
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	0.392	0.533	0.646	0.810	0.943	0.897	0.963	1.047	1.094	1.209	1.389	1.955
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	0.405	0.517	0.610	0.704	0.816	0.888	0.925	1.072	1.112	1.123	1.195	2.000
2006	0.023	0.073	0.177	0.363	0.517	0.607	0.721	0.807	0.908	1.046	1.273	1.206	1.272	1.246	2.095
2007	0.021	0.079	0.279	0.421	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	0.185	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	0.571	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	1.447	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	1.436	1.463	2.114
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

Table 1.15. Number of (age 1+) hauls and sample sizes for EBS pollock collected by the AT surveys. Sub-headings E and W represent collections east and west of 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	NA	NA	NA	NA

Table 1.16. 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	4,473	8,294	1,329	533	857	1,192	545	81	40	39	13,073	4,473	17,105
Avg.*	1,968	2,635	1,995	1,800	899	522	324	150	61	103	8,490	1,968	10,458
Median*	508	1,776	1,187	1,483	717	339	220	105	47	53	7,551	20%	9,394

*Average and median values exclude 1979 values.

Table 1.17. 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. 2010).

Date		Area	Biomass in millions of t (percent of total)						Total Biomass
		$(nmi)^2$	**SCA**		**E170-SCA**		**W170**		**(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 1.18. 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). *Note that data were collected in the 2014 bottom-trawl survey and will be developed and included for the 2015 assessment.*

	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 (6.3%)	28%
2013	*-no survey-*	0.696 (3.9%)	18%

Table 1.19. 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 2014 are preliminary (see text for how they were estimated). The bold values represent the 1992 year-class to show that it was below-average at most ages.

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	*0.290*	*0.447*	*0.600*	*0.698*	*0.726*	*1.030*	*1.160*	*1.273*	*1.370*	*1.454*	*1.531*	*1.559*	*1.648*
Stdev	0.057	0.058	0.041	0.061	0.104	0.121	0.144	0.178	0.179	0.176	0.256	0.312	0.325
CV	16%	11%	6%	8%	12%	12%	12%	14%	13%	12%	17%	20%	20%
Mean	0.357	0.510	0.647	0.773	0.899	1.030	1.160	1.273	1.370	1.454	1.531	1.559	1.648
						Sampling error (from bootstrap)							
1991	8%	4%	3%	2%	2%	4%	2%	6%	3%	6%	4%	6%	4%
1992	2%	4%	5%	3%	3%	2%	3%	3%	4%	4%	11%	6%	6%
1993	2%	1%	3%	4%	4%	4%	3%	4%	4%	6%	7%	10%	8%
1994	8%	2%	1%	3%	8%	12%	5%	5%	4%	5%	6%	11%	6%
1995	5%	3%	2%	1%	3%	4%	6%	6%	5%	10%	6%	48%	6%
1996	7%	10%	3%	2%	1%	2%	4%	6%	13%	7%	6%	7%	9%
1997	9%	2%	1%	2%	2%	2%	3%	6%	10%	9%	14%	6%	7%
1998	5%	5%	3%	1%	3%	3%	2%	4%	8%	9%	13%	16%	14%
1999	1%	1%	2%	2%	1%	2%	3%	4%	12%	19%	42%	102%	22%
2000	4%	1%	1%	2%	2%	1%	3%	6%	5%	10%	47%	63%	48%
2001	5%	3%	1%	2%	3%	3%	2%	4%	5%	6%	8%	10%	33%
2002	4%	2%	2%	1%	1%	2%	3%	3%	5%	5%	7%	25%	22%
2003	1%	2%	1%	2%	1%	2%	3%	5%	5%	6%	10%	28%	13%
2004	4%	1%	1%	2%	2%	2%	3%	7%	6%	5%	10%	14%	9%
2005	4%	1%	1%	1%	2%	3%	3%	4%	7%	6%	20%	35%	20%
2006	4%	1%	1%	1%	1%	3%	4%	4%	7%	11%	9%	14%	7%
2007	3%	2%	1%	1%	1%	2%	3%	4%	5%	9%	9%	7%	6%
2008	3%	2%	2%	1%	1%	2%	2%	5%	5%	5%	5%	14%	6%
2009	3%	2%	4%	2%	2%	3%	3%	4%	6%	7%	5%	14%	7%
2010	6%	1%	1%	4%	3%	3%	3%	3%	4%	5%	8%	6%	5%
2011	2%	3%	1%	1%	3%	4%	3%	4%	4%	5%	15%	10%	9%
2012	3%	1%	2%	1%	2%	4%	7%	7%	6%	6%	8%	10%	21%
2013	3%	1%	1%	2%	2%	3%	5%	5%	6%	7%	7%	9%	6%

Table 1.20. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964-2014. *Note that the sample size for 2014 is set to a lower value for the AT data because the age-length key is derived from the bottom-trawl survey.*

Year	Fishery	Year	BTS	AT
1964-1977	10	1979	-	6
1978-1990	50			
1991	174			
1992	200	1982-2013	100	50
1993	273	2014	100	20
1994	108			
1995	138			
1996	149			
1997	256			
1998	270			
1999	456			
2000	452			
2001	292			
2002	435			
2003	389			
2004	332			
2005	399			
2006	328			
2007	408			
2008	341			
2009	360			
2010	350			
2011	350			
2012	350			
2013	350			

Table 1.21 Negative-log likelihood (NLL) components for EBS pollock model alternatives along with the contribution by prior distributions assumed for the model. Note that the values for Model 2.0 are not strictly comparable because a different likelihood function was selected for the BTS abundance.

	Model 1.0	Model 1.1	Model 1.2	Model 2.0
Fishery Catch	0.9	1.2	0.3	0.9
CPUE NLL	1.1	1.1	0.7	1.1
BTS abundance NLL	9.6	10.6	11.8	17.3
AT abundance (age-2 and older) NLL	39.5	42.0	33.9	39.0
AT age-1 abundance NLL	29.1	29.3	28.9	29.4
AVO NLL	1.2	1.6	1.7	1.2
Fishery age composition NLL	-1,110.3	-1,112.5	-1,110.5	-1,111.0
BTS age composition NLL	-541.9	-555.1	-538.8	-553.2
AT age composition NLL	1,469.7	1,473.7	1,475.9	1,469.6
Priors	120.6	128.3	135.7	111.3
Data	-101.1	-108.1	-96.1	-99.3
Total	19.5	20.3	39.6	12.0
Number of parameters	758	758	758	758
AIC	1,555	1,557	1,595	1,540
2014 SSB	2,945	2,685	7,416	2,941
Age 5 M	0.30	0.35	0.55	0.30
Age 15 M	0.30	0.17	0.35	0.30

Table 1.22. Parameter estimates and their standard errors for Model 1.0.

index	name	value	std.dev	index	name	value	std.dev	index	name	value	std.dev
1	log_avgrec	9.9506	0.10124	76	repl_F	0.31037	0.17221	151	sel_devs_fsh	-0.21183	0.36585
2	log_avginit	4.5657	0.68142	77	log_F_devs	-0.40693	0.29725	152	sel_devs_fsh	-0.17266	0.33058
3	log_avg_F	-1.4835	0.083067	78	log_F_devs	-0.57276	0.21714	153	sel_devs_fsh	-0.13256	0.32006
4	log_q_bts	0.36751	0.077401	79	log_F_devs	-0.67495	0.20598	154	sel_devs_fsh	-0.086029	0.31908
5	log_q_std_area	-0.26477	0.16321	80	log_F_devs	-0.16183	0.20206	155	sel_devs_fsh	-0.048173	0.3198
6	log_q_eit	-1.081	0.11029	81	log_F_devs	-0.16529	0.19438	156	sel_devs_fsh	-0.02131	0.32795
7	log_Rzero	9.9104	0.15429	82	log_F_devs	-0.21144	0.21423	157	sel_devs_fsh	0.005489	0.35472
8	steepness	0.67425	0.068245	83	log_F_devs	0.22358	0.21563	158	sel_devs_fsh	0.07716	0.68206
9	log_q_cpue	0.03455	0.18969	84	log_F_devs	0.61362	0.21633	159	sel_devs_fsh	0.1124	0.57673
10	log_q_avo	-9.6805	0.13323	85	log_F_devs	0.67361	0.21472	160	sel_devs_fsh	-0.24342	0.5037
11	log_initdevs	3.6258	0.72802	86	log_F_devs	0.82005	0.21457	161	sel_devs_fsh	0.1007	0.36478
12	log_initdevs	3.1676	0.71995	87	log_F_devs	0.80444	0.21429	162	sel_devs_fsh	0.044156	0.33354
13	log_initdevs	1.5929	0.86039	88	log_F_devs	0.65878	0.20728	163	sel_devs_fsh	0.013824	0.32024
14	log_initdevs	0.79808	0.96937	89	log_F_devs	0.51301	0.19648	164	sel_devs_fsh	-0.0096289	0.31908
15	log_initdevs	1.2544	0.84361	90	log_F_devs	0.31071	0.23466	165	sel_devs_fsh	-0.023736	0.31981
16	log_initdevs	0.34742	1.1	91	log_F_devs	0.34085	0.25898	166	sel_devs_fsh	-0.029494	0.32665
17	log_initdevs	-0.65403	1.2784	92	log_F_devs	0.37618	0.25804	167	sel_devs_fsh	-0.041955	0.35219
18	log_initdevs	-1.4441	1.2288	93	log_F_devs	0.33072	0.22478	168	sel_devs_fsh	0.033706	0.68231
19	log_initdevs	-1.4187	1.2342	94	log_F_devs	0.10278	0.3161	169	sel_devs_fsh	0.065075	0.55762
20	log_initdevs	-1.4209	1.2346	95	log_F_devs	-0.17849	0.36258	170	sel_devs_fsh	0.38297	0.50054
21	log_initdevs	-1.4274	1.2361	96	log_F_devs	-0.18909	0.37507	171	sel_devs_fsh	-0.13128	0.3621
22	log_initdevs	-1.4473	1.2406	97	log_F_devs	-0.1653	0.36925	172	sel_devs_fsh	-0.11964	0.3305
23	log_initdevs	-1.4866	1.2509	98	log_F_devs	-0.13142	0.37741	173	sel_devs_fsh	-0.10676	0.32101
24	log_initdevs	-1.4872	1.251	99	log_F_devs	-0.27317	0.33285	174	sel_devs_fsh	-0.080806	0.32605
25	log_rec_devs	-1.3588	0.34236	100	log_F_devs	-0.58214	0.30094	175	sel_devs_fsh	-0.056941	0.34152
26	log_rec_devs	-0.016911	0.22889	101	log_F_devs	-0.51159	0.14743	176	sel_devs_fsh	-0.037639	0.37622
27	log_rec_devs	-0.36454	0.32415	102	log_F_devs	-0.45839	0.13491	177	sel_devs_fsh	0.05131	0.46112
28	log_rec_devs	0.31704	0.25609	103	log_F_devs	-0.13873	0.12239	178	sel_devs_fsh	0.0239	0.69131
29	log_rec_devs	0.24305	0.26587	104	log_F_devs	-0.0041678	0.11372	179	sel_devs_fsh	0.40237	0.56134
30	log_rec_devs	0.3316	0.25352	105	log_F_devs	0.32364	0.1181	180	sel_devs_fsh	0.02548	0.45111
31	log_rec_devs	-0.039685	0.2874	106	log_F_devs	-0.1908	0.13094	181	sel_devs_fsh	-0.25049	0.3702
32	log_rec_devs	-0.75705	0.34216	107	log_F_devs	-0.36102	0.14835	182	sel_devs_fsh	-0.22816	0.34555
33	log_rec_devs	-0.66337	0.31421	108	log_F_devs	-0.28304	0.1476	183	sel_devs_fsh	-0.20993	0.36244
34	log_rec_devs	0.31702	0.18913	109	log_F_devs	-0.041354	0.14972	184	sel_devs_fsh	-0.047292	0.38884
35	log_rec_devs	0.02138	0.1961	110	log_F_devs	-0.050507	0.18087	185	sel_devs_fsh	-0.041767	0.37829
36	log_rec_devs	-0.14226	0.18173	111	log_F_devs	-0.14079	0.16066	186	sel_devs_fsh	-0.038269	0.41007
37	log_rec_devs	-0.40402	0.18127	112	log_F_devs	-0.50303	0.12603	187	sel_devs_fsh	0.36416	0.46627
38	log_rec_devs	-0.40472	0.1625	113	log_F_devs	-0.35584	0.1186	188	sel_devs_fsh	-0.043721	0.68372
39	log_rec_devs	0.25839	0.13287	114	log_F_devs	-0.19475	0.11815	189	sel_devs_fsh	-0.1789	0.5649
40	log_rec_devs	1.1657	0.11881	115	log_F_devs	-0.05369	0.10817	190	sel_devs_fsh	-0.13546	0.45514
41	log_rec_devs	0.24815	0.12601	116	log_F_devs	-0.051961	0.11375	191	sel_devs_fsh	0.011679	0.45391
42	log_rec_devs	0.38361	0.12574	117	log_F_devs	-0.11694	0.12634	192	sel_devs_fsh	0.12974	0.37973
43	log_rec_devs	-0.2762	0.14658	118	log_F_devs	-0.22205	0.12141	193	sel_devs_fsh	0.1271	0.38096
44	log_rec_devs	0.94035	0.11339	119	log_F_devs	-0.0044829	0.11898	194	sel_devs_fsh	-0.035367	0.4538
45	log_rec_devs	-0.45405	0.14735	120	log_F_devs	0.05235	0.11324	195	sel_devs_fsh	-0.025636	0.55835
46	log_rec_devs	0.52313	0.11604	121	log_F_devs	0.12955	0.11071	196	sel_devs_fsh	-0.018603	0.59418
47	log_rec_devs	-0.36519	0.13145	122	log_F_devs	0.11872	0.12589	197	sel_devs_fsh	0.16917	0.42943
48	log_rec_devs	-0.9022	0.14858	123	log_F_devs	-0.073078	0.12548	198	sel_devs_fsh	-0.081469	0.68663
49	log_rec_devs	-1.3452	0.1641	124	log_F_devs	0.2788	0.13841	199	sel_devs_fsh	0.3864	0.59201
50	log_rec_devs	-0.705	0.1424	125	log_F_devs	0.28154	0.17304	200	sel_devs_fsh	0.1349	0.50119
51	log_rec_devs	0.87403	0.10664	126	log_F_devs	0.34692	0.26974	201	sel_devs_fsh	0.036245	0.46629
52	log_rec_devs	0.19887	0.11425	127	log_F_devs	0.16919	0.36348	202	sel_devs_fsh	-0.074586	0.37313
53	log_rec_devs	0.049038	0.11829	128	sel_devs_fsh	-0.069523	0.70628	203	sel_devs_fsh	-0.058674	0.35338
54	log_rec_devs	0.82024	0.10791	129	sel_devs_fsh	-0.00064539	0.61175	204	sel_devs_fsh	-0.051574	0.37635
55	log_rec_devs	-0.35973	0.12366	130	sel_devs_fsh	0.3165	0.57131	205	sel_devs_fsh	-0.063988	0.55971
56	log_rec_devs	-0.67305	0.12688	131	sel_devs_fsh	0.10657	0.5858	206	sel_devs_fsh	-0.011472	0.60261
57	log_rec_devs	0.099289	0.11107	132	sel_devs_fsh	0.0024275	0.38173	207	sel_devs_fsh	-0.21578	0.42894
58	log_rec_devs	0.40722	0.108	133	sel_devs_fsh	-0.05998	0.34705	208	sel_devs_fsh	-0.10761	0.69093
59	log_rec_devs	-0.28801	0.11588	134	sel_devs_fsh	-0.077108	0.3342	209	sel_devs_fsh	0.012384	0.59803
60	log_rec_devs	-0.1967	0.11431	135	sel_devs_fsh	-0.07546	0.33451	210	sel_devs_fsh	-0.077571	0.52304
61	log_rec_devs	0.23655	0.10913	136	sel_devs_fsh	-0.071755	0.34726	211	sel_devs_fsh	0.056583	0.36349
62	log_rec_devs	0.54022	0.10594	137	sel_devs_fsh	-0.071027	0.38193	212	sel_devs_fsh	0.067519	0.32974
63	log_rec_devs	0.10345	0.10884	138	sel_devs_fsh	0.016027	0.66644	213	sel_devs_fsh	0.076426	0.32589
64	log_rec_devs	-0.40563	0.11284	139	sel_devs_fsh	0.25988	0.5847	214	sel_devs_fsh	0.06857	0.34058
65	log_rec_devs	-1.2084	0.12702	140	sel_devs_fsh	0.14194	0.55022	215	sel_devs_fsh	0.068139	0.38031
66	log_rec_devs	-1.5946	0.13893	141	sel_devs_fsh	-0.077024	0.36014	216	sel_devs_fsh	0.0093996	0.59873
67	log_rec_devs	-0.65135	0.11867	142	sel_devs_fsh	-0.061146	0.33067	217	sel_devs_fsh	-0.17384	0.43747
68	log_rec_devs	0.19966	0.11421	143	sel_devs_fsh	-0.066137	0.32281	218	sel_devs_fsh	-0.066961	0.67282
69	log_rec_devs	-0.72387	0.15035	144	sel_devs_fsh	-0.061829	0.32002	219	sel_devs_fsh	0.24727	0.53103
70	log_rec_devs	0.98532	0.1314	145	sel_devs_fsh	-0.059735	0.32174	220	sel_devs_fsh	0.15394	0.47906
71	log_rec_devs	-0.020358	0.17908	146	sel_devs_fsh	-0.051322	0.33175	221	sel_devs_fsh	-0.015801	0.35417
72	log_rec_devs	0.14507	0.21178	147	sel_devs_fsh	-0.040654	0.36016	222	sel_devs_fsh	-0.024076	0.32863
73	log_rec_devs	-0.14627	0.17367	148	sel_devs_fsh	-0.021022	0.66637	223	sel_devs_fsh	-0.030178	0.332
74	log_rec_devs	0.39127	0.17671	149	sel_devs_fsh	0.16081	0.57829	224	sel_devs_fsh	-0.023924	0.36316
75	log_rec_devs	0.12385	0.18873	150	sel_devs_fsh	0.52728	0.5207	225	sel_devs_fsh	-0.010594	0.52866

Table 1.22. (continued) Parameter estimates and their standard errors for Model 1.0.

index	name	value	std.dev	index	name	value	std.dev	index	name	value	std.dev
226	sel_devs_fsh	-0.0052364	0.54689	301	sel_devs_fsh	-0.055062	0.39169	376	sel_devs_fsh	0.082959	0.36242
227	sel_devs_fsh	-0.22444	0.45768	302	sel_devs_fsh	0.034414	0.40298	377	sel_devs_fsh	0.10838	0.37316
228	sel_devs_fsh	-0.094434	0.67287	303	sel_devs_fsh	0.099795	0.39794	378	sel_devs_fsh	-0.11567	0.6837
229	sel_devs_fsh	-0.53145	0.49814	304	sel_devs_fsh	0.10143	0.40167	379	sel_devs_fsh	0.076295	0.61033
230	sel_devs_fsh	0.16723	0.35869	305	sel_devs_fsh	0.14209	0.58335	380	sel_devs_fsh	-0.26049	0.54215
231	sel_devs_fsh	0.10127	0.32847	306	sel_devs_fsh	0.16161	0.61777	381	sel_devs_fsh	0.29137	0.45992
232	sel_devs_fsh	0.067506	0.32194	307	sel_devs_fsh	0.30661	0.59283	382	sel_devs_fsh	0.27646	0.39466
233	sel_devs_fsh	0.057397	0.33045	308	sel_devs_fsh	-0.12525	0.67054	383	sel_devs_fsh	0.070393	0.4351
234	sel_devs_fsh	0.048266	0.36135	309	sel_devs_fsh	0.13557	0.62072	384	sel_devs_fsh	-0.13833	0.41044
235	sel_devs_fsh	0.035233	0.52831	310	sel_devs_fsh	-0.044724	0.46974	385	sel_devs_fsh	-0.041661	0.33764
236	sel_devs_fsh	0.029607	0.54624	311	sel_devs_fsh	-0.16011	0.40171	386	sel_devs_fsh	-0.037335	0.33616
237	sel_devs_fsh	0.11938	0.47158	312	sel_devs_fsh	-0.22926	0.40791	387	sel_devs_fsh	-0.12103	0.35836
238	sel_devs_fsh	-0.089841	0.66958	313	sel_devs_fsh	0.032043	0.40629	388	sel_devs_fsh	-0.10306	0.68116
239	sel_devs_fsh	-0.032922	0.51887	314	sel_devs_fsh	0.036604	0.41559	389	sel_devs_fsh	-0.017713	0.58843
240	sel_devs_fsh	-0.19902	0.40417	315	sel_devs_fsh	0.03101	0.60087	390	sel_devs_fsh	-0.42876	0.53193
241	sel_devs_fsh	0.0797	0.34528	316	sel_devs_fsh	0.10331	0.62837	391	sel_devs_fsh	-0.28336	0.4509
242	sel_devs_fsh	0.073996	0.32572	317	sel_devs_fsh	0.22081	0.59529	392	sel_devs_fsh	-0.043708	0.39169
243	sel_devs_fsh	0.065877	0.32139	318	sel_devs_fsh	-0.11466	0.68078	393	sel_devs_fsh	0.044536	0.36033
244	sel_devs_fsh	0.057411	0.32624	319	sel_devs_fsh	-0.15619	0.62101	394	sel_devs_fsh	0.2566	0.40219
245	sel_devs_fsh	0.050331	0.34518	320	sel_devs_fsh	0.032434	0.49531	395	sel_devs_fsh	0.032444	0.34288
246	sel_devs_fsh	0.046234	0.3887	321	sel_devs_fsh	-0.039605	0.42101	396	sel_devs_fsh	0.25383	0.32564
247	sel_devs_fsh	-0.051769	0.47659	322	sel_devs_fsh	0.22274	0.37267	397	sel_devs_fsh	0.28919	0.3427
248	sel_devs_fsh	-0.037657	0.66222	323	sel_devs_fsh	-0.12861	0.38468	398	sel_devs_fsh	-0.097085	0.67981
249	sel_devs_fsh	0.32547	0.54459	324	sel_devs_fsh	0.014256	0.45737	399	sel_devs_fsh	-0.050434	0.43186
250	sel_devs_fsh	-0.12622	0.47362	325	sel_devs_fsh	0.027797	0.60239	400	sel_devs_fsh	0.62914	0.36328
251	sel_devs_fsh	-0.10995	0.45284	326	sel_devs_fsh	0.040872	0.63342	401	sel_devs_fsh	-0.40636	0.38968
252	sel_devs_fsh	-0.014288	0.35909	327	sel_devs_fsh	0.10096	0.58704	402	sel_devs_fsh	-0.41126	0.39344
253	sel_devs_fsh	-0.0033752	0.33454	328	sel_devs_fsh	-0.11601	0.68113	403	sel_devs_fsh	-0.050878	0.36846
254	sel_devs_fsh	0.0035683	0.33065	329	sel_devs_fsh	0.30206	0.61589	404	sel_devs_fsh	-0.10383	0.33445
255	sel_devs_fsh	0.0055679	0.343	330	sel_devs_fsh	0.1545	0.48216	405	sel_devs_fsh	0.23117	0.32758
256	sel_devs_fsh	0.0038965	0.37911	331	sel_devs_fsh	-0.29807	0.44149	406	sel_devs_fsh	0.10847	0.33136
257	sel_devs_fsh	-0.047009	0.5219	332	sel_devs_fsh	-0.3273	0.39217	407	sel_devs_fsh	0.15107	0.32024
258	sel_devs_fsh	-0.065504	0.66468	333	sel_devs_fsh	0.19079	0.36588	408	sel_devs_fsh	-0.078551	0.67915
259	sel_devs_fsh	-0.10695	0.52816	334	sel_devs_fsh	-0.0034513	0.44231	409	sel_devs_fsh	-0.86661	0.46832
260	sel_devs_fsh	0.075969	0.45577	335	sel_devs_fsh	0.03885	0.58338	410	sel_devs_fsh	0.068588	0.31026
261	sel_devs_fsh	0.0079622	0.47198	336	sel_devs_fsh	0.016034	0.63094	411	sel_devs_fsh	0.88425	0.32405
262	sel_devs_fsh	-0.02114	0.38405	337	sel_devs_fsh	0.042599	0.58794	412	sel_devs_fsh	0.13232	0.37484
263	sel_devs_fsh	-0.02878	0.37654	338	sel_devs_fsh	-0.11259	0.68386	413	sel_devs_fsh	0.084585	0.41212
264	sel_devs_fsh	0.017008	0.5217	339	sel_devs_fsh	0.1366	0.61338	414	sel_devs_fsh	0.10239	0.34915
265	sel_devs_fsh	0.038649	0.39123	340	sel_devs_fsh	-0.03154	0.49139	415	sel_devs_fsh	-0.058462	0.32141
266	sel_devs_fsh	0.041967	0.37507	341	sel_devs_fsh	0.31109	0.42492	416	sel_devs_fsh	-0.10347	0.32984
267	sel_devs_fsh	0.040822	0.40159	342	sel_devs_fsh	-0.044756	0.44405	417	sel_devs_fsh	-0.16503	0.31296
268	sel_devs_fsh	-0.067319	0.64016	343	sel_devs_fsh	-0.029352	0.3933	418	sel_devs_fsh	-0.029877	0.68737
269	sel_devs_fsh	-0.50449	0.43753	344	sel_devs_fsh	0.042935	0.3803	419	sel_devs_fsh	0.078781	0.51805
270	sel_devs_fsh	-0.11238	0.4102	345	sel_devs_fsh	-0.14959	0.50491	420	sel_devs_fsh	-0.89941	0.40706
271	sel_devs_fsh	-0.072173	0.43226	346	sel_devs_fsh	-0.021539	0.61826	421	sel_devs_fsh	-0.33894	0.32329
272	sel_devs_fsh	0.1399	0.3732	347	sel_devs_fsh	-0.10126	0.57326	422	sel_devs_fsh	0.86309	0.30542
273	sel_devs_fsh	0.15898	0.36811	348	sel_devs_fsh	-0.11576	0.68378	423	sel_devs_fsh	0.31328	0.38292
274	sel_devs_fsh	0.098158	0.52516	349	sel_devs_fsh	-0.001352	0.60845	424	sel_devs_fsh	0.035768	0.32622
275	sel_devs_fsh	0.11936	0.40701	350	sel_devs_fsh	-0.024493	0.49005	425	sel_devs_fsh	0.0054817	0.31068
276	sel_devs_fsh	0.11997	0.38168	351	sel_devs_fsh	-0.22016	0.43234	426	sel_devs_fsh	-0.031417	0.31163
277	sel_devs_fsh	0.12	0.40387	352	sel_devs_fsh	-0.023977	0.43238	427	sel_devs_fsh	0.003254	0.33195
278	sel_devs_fsh	-0.28566	0.63591	353	sel_devs_fsh	-0.093509	0.39769	428	sel_devs_fsh	-0.032181	0.68718
279	sel_devs_fsh	-0.71526	0.4199	354	sel_devs_fsh	-0.11885	0.38359	429	sel_devs_fsh	0.059467	0.5349
280	sel_devs_fsh	-0.33501	0.39649	355	sel_devs_fsh	0.39467	0.3892	430	sel_devs_fsh	-0.36101	0.43151
281	sel_devs_fsh	0.205	0.43436	356	sel_devs_fsh	0.18187	0.5185	431	sel_devs_fsh	-0.71536	0.3833
282	sel_devs_fsh	0.15794	0.43009	357	sel_devs_fsh	0.021556	0.56821	432	sel_devs_fsh	-0.33822	0.31129
283	sel_devs_fsh	0.22286	0.36542	358	sel_devs_fsh	-0.11594	0.68381	433	sel_devs_fsh	0.41807	0.29701
284	sel_devs_fsh	0.22475	0.36906	359	sel_devs_fsh	-0.047009	0.61528	434	sel_devs_fsh	0.29663	0.30793
285	sel_devs_fsh	0.17582	0.39305	360	sel_devs_fsh	1.009	0.40894	435	sel_devs_fsh	0.25095	0.31295
286	sel_devs_fsh	0.17287	0.37788	361	sel_devs_fsh	0.13024	0.42326	436	sel_devs_fsh	0.21548	0.31857
287	sel_devs_fsh	0.17669	0.40494	362	sel_devs_fsh	0.2399	0.37074	437	sel_devs_fsh	0.20619	0.33802
288	sel_devs_fsh	-0.23151	0.6437	363	sel_devs_fsh	-0.18728	0.3653	438	sel_devs_fsh	-0.03155	0.68733
289	sel_devs_fsh	-0.40889	0.49522	364	sel_devs_fsh	0.14997	0.38983	439	sel_devs_fsh	0.74969	0.55651
290	sel_devs_fsh	-0.31695	0.38147	365	sel_devs_fsh	-0.32644	0.38864	440	sel_devs_fsh	0.40791	0.38787
291	sel_devs_fsh	-0.054074	0.41389	366	sel_devs_fsh	-0.30609	0.39984	441	sel_devs_fsh	-1.0636	0.37375
292	sel_devs_fsh	0.19318	0.42546	367	sel_devs_fsh	-0.54633	0.52653	442	sel_devs_fsh	-0.80834	0.34131
293	sel_devs_fsh	0.1259	0.34941	368	sel_devs_fsh	-0.11633	0.68381	443	sel_devs_fsh	-0.27417	0.30407
294	sel_devs_fsh	0.13884	0.33006	369	sel_devs_fsh	0.01478	0.61673	444	sel_devs_fsh	0.27703	0.29656
295	sel_devs_fsh	0.148	0.34157	370	sel_devs_fsh	-0.63312	0.46343	445	sel_devs_fsh	0.27875	0.31825
296	sel_devs_fsh	0.15176	0.38068	371	sel_devs_fsh	0.19135	0.40792	446	sel_devs_fsh	0.2537	0.32283
297	sel_devs_fsh	0.25375	0.56615	372	sel_devs_fsh	-0.12012	0.37557	447	sel_devs_fsh	0.21057	0.3361
298	sel_devs_fsh	-0.11909	0.67016	373	sel_devs_fsh	0.16837	0.42997	448	sel_devs_fsh	-0.02909	0.688
299	sel_devs_fsh	-0.27929	0.53929	374	sel_devs_fsh	0.143	0.36539	449	sel_devs_fsh	0.48032	0.5458
300	sel_devs_fsh	-0.39251	0.43214	375	sel_devs_fsh	0.16074	0.35304	450	sel_devs_fsh	-0.01356	0.40694

Table 1.22. (continued) Parameter estimates and their standard errors for Model 1.0.

index	name	value	std.dev	index	name	value	std.dev	index	name	value	std.dev	index	name	value	std.dev
451	sel_devs_fsh	0.90312	0.36185	526	sel_devs_fsh	0.081277	0.30336	601	sel_devs_fsh	0.26598	0.32581	681	sel_slp_bts_dev	0.38544	0.12158
452	sel_devs_fsh	-0.012047	0.3251	527	sel_devs_fsh	0.16061	0.31478	602	sel_devs_fsh	-0.78178	0.32184	682	sel_slp_bts_dev	0.41198	0.12978
453	sel_devs_fsh	-0.51026	0.31542	528	sel_devs_fsh	-0.019692	0.68889	603	sel_devs_fsh	-0.13654	0.31477	683	sel_slp_bts_dev	0.64206	0.095692
454	sel_devs_fsh	-0.41442	0.30629	529	sel_devs_fsh	0.21346	0.60377	604	sel_devs_fsh	0.039662	0.31287	684	sel_slp_bts_dev	0.58967	0.097536
455	sel_devs_fsh	-0.27847	0.32344	530	sel_devs_fsh	0.02979	0.37995	605	sel_devs_fsh	0.062545	0.31255	685	sel_slp_bts_dev	0.31627	0.13634
456	sel_devs_fsh	-0.075958	0.35619	531	sel_devs_fsh	-0.36336	0.28685	606	sel_devs_fsh	0.051969	0.31516	686	sel_slp_bts_dev	0.38863	0.13183
457	sel_devs_fsh	-0.049631	0.34475	532	sel_devs_fsh	0.46179	0.28373	607	sel_devs_fsh	0.044081	0.33247	687	sel_slp_bts_dev	0.37243	0.17168
458	sel_devs_fsh	-0.045719	0.68793	533	sel_devs_fsh	0.28382	0.30128	608	sel_devs_fsh	0.024735	0.71315	688	sel_a50_bts_dev	-0.17571	0.13076
459	sel_devs_fsh	-0.49296	0.42968	534	sel_devs_fsh	-0.11121	0.29982	609	sel_devs_fsh	-0.46681	0.58333	689	sel_a50_bts_dev	-0.2005	0.084012
460	sel_devs_fsh	0.23461	0.40271	535	sel_devs_fsh	-0.18348	0.29523	610	sel_devs_fsh	-0.38633	0.42068	690	sel_a50_bts_dev	-0.045063	0.061397
461	sel_devs_fsh	0.15331	0.38472	536	sel_devs_fsh	-0.14557	0.30479	611	sel_devs_fsh	0.20519	0.3297	691	sel_a50_bts_dev	-0.072282	0.075985
462	sel_devs_fsh	0.19894	0.31807	537	sel_devs_fsh	-0.16554	0.32279	612	sel_devs_fsh	0.15449	0.33589	692	sel_a50_bts_dev	0.069866	0.070584
463	sel_devs_fsh	0.19872	0.29353	538	sel_devs_fsh	-0.019674	0.68888	613	sel_devs_fsh	-0.13037	0.32437	693	sel_a50_bts_dev	0.052023	0.059326
464	sel_devs_fsh	-0.29266	0.32083	539	sel_devs_fsh	0.24795	0.62131	614	sel_devs_fsh	-0.28052	0.35843	694	sel_a50_bts_dev	-0.061278	0.071895
465	sel_devs_fsh	-0.036694	0.33881	540	sel_devs_fsh	0.69708	0.41067	615	sel_devs_fsh	0.24994	0.36506	695	sel_a50_bts_dev	-0.13426	0.068366
466	sel_devs_fsh	0.013238	0.35742	541	sel_devs_fsh	-0.13688	0.30499	616	sel_devs_fsh	0.2891	0.38538	696	sel_a50_bts_dev	-0.1097	0.061862
467	sel_devs_fsh	0.06922	0.3575	542	sel_devs_fsh	-0.35791	0.28159	617	sel_devs_fsh	0.34058	0.45304	697	sel_a50_bts_dev	0.082089	0.067167
468	sel_devs_fsh	-0.046732	0.68795	543	sel_devs_fsh	-0.14762	0.28105	618	sel_devs_fsh	-0.000027996	0.7071	698	sel_a50_bts_dev	-0.014826	0.063555
469	sel_devs_fsh	-0.49947	0.45674	544	sel_devs_fsh	-0.085405	0.28641	619	sel_devs_fsh	-0.0014311	0.7066	699	sel_a50_bts_dev	-0.088196	0.051741
470	sel_devs_fsh	0.8822	0.32377	545	sel_devs_fsh	-0.053819	0.29718	620	sel_devs_fsh	0.018978	0.71372	700	sel_a50_bts_dev	-0.023806	0.047736
471	sel_devs_fsh	0.45864	0.34469	546	sel_devs_fsh	-0.086304	0.30688	621	sel_devs_fsh	0.047741	0.71325	701	sel_a50_bts_dev	0.058836	0.06854
472	sel_devs_fsh	0.063601	0.33641	547	sel_devs_fsh	-0.05742	0.32424	622	sel_devs_fsh	0.43554	0.4926	702	sel_a50_bts_dev	0.1896	0.045923
473	sel_devs_fsh	-0.20091	0.29586	548	sel_devs_fsh	-0.018135	0.68863	623	sel_devs_fsh	-0.13163	0.48374	703	sel_a50_bts_dev	0.19753	0.06256
474	sel_devs_fsh	0.21	0.29757	549	sel_devs_fsh	0.097247	0.62457	624	sel_devs_fsh	-0.093252	0.68103	704	sel_a50_bts_dev	0.25373	0.051407
475	sel_devs_fsh	-0.13857	0.32042	550	sel_devs_fsh	-0.031535	0.41969	625	sel_devs_fsh	-0.097228	0.44193	705	sel_a50_bts_dev	0.17557	0.060621
476	sel_devs_fsh	-0.33264	0.31035	551	sel_devs_fsh	-0.02873	0.32448	626	sel_devs_fsh	-0.086043	0.43661	706	sel_a50_bts_dev	0.11493	0.061351
477	sel_devs_fsh	-0.39612	0.33055	552	sel_devs_fsh	-0.050908	0.28703	627	sel_devs_fsh	-0.092656	0.50798	707	sel_a50_bts_dev	0.13053	0.054837
478	sel_devs_fsh	-0.045844	0.68779	553	sel_devs_fsh	0.066375	0.27831	628	sel_devs_eit	-1.2525	1.5589	708	sel_a50_bts_dev	0.055798	0.05761
479	sel_devs_fsh	-0.18104	0.51345	554	sel_devs_fsh	0.0053419	0.2804	629	sel_devs_eit	0.34102	1.9268	709	sel_a50_bts_dev	0.065664	0.065339
480	sel_devs_fsh	-0.64715	0.31692	555	sel_devs_fsh	-0.040635	0.2904	630	sel_devs_eit	1.2025	2.0296	710	sel_a50_bts_dev	0.079614	0.041117
481	sel_devs_fsh	0.26904	0.28263	556	sel_devs_fsh	-0.014557	0.30379	631	sel_devs_eit	1.1481	2.0361	711	sel_a50_bts_dev	-0.019642	0.041844
482	sel_devs_fsh	0.37657	0.30376	557	sel_devs_fsh	0.015536	0.31862	632	sel_devs_eit	1.1762	2.6242	712	sel_a50_bts_dev	0.12381	0.039915
483	sel_devs_fsh	-0.097962	0.31009	558	sel_devs_fsh	-0.031872	0.68824	633	sel_devs_eit	1.1245	1.6905	713	sel_a50_bts_dev	-0.063997	0.05823
484	sel_devs_fsh	0.02835	0.29821	559	sel_devs_fsh	-0.22628	0.53522	634	sel_devs_eit	0.97542	1.5784	714	sel_a50_bts_dev	-0.052431	0.05067
485	sel_devs_fsh	0.20328	0.27809	560	sel_devs_fsh	-0.64686	0.38683	635	sel_coffs_fsh	-4.8082	1.3119	715	sel_a50_bts_dev	-0.080322	0.047577
486	sel_devs_fsh	0.067179	0.29184	561	sel_devs_fsh	0.029151	0.34294	636	sel_coffs_fsh	-2.3707	0.75659	716	sel_a50_bts_dev	-0.20117	0.040656
487	sel_devs_fsh	0.02758	0.31088	562	sel_devs_fsh	0.036131	0.30304	637	sel_coffs_fsh	-1.2378	0.58912	717	sel_a50_bts_dev	-0.040788	0.038812
488	sel_devs_fsh	-0.032333	0.68753	563	sel_devs_fsh	0.11912	0.2763	638	sel_coffs_fsh	0.35011	0.58779	718	sel_a50_bts_dev	-0.071159	0.046226
489	sel_devs_fsh	-0.47051	0.50926	564	sel_devs_fsh	0.17418	0.27529	639	sel_coffs_fsh	0.39725	0.32218	719	sel_a50_bts_dev	-0.053041	0.03954
490	sel_devs_fsh	-0.38786	0.37346	565	sel_devs_fsh	0.16729	0.28048	640	sel_coffs_fsh	0.39236	0.2913	720	sel_a50_bts_dev	-0.1414	0.059429
491	sel_devs_fsh	-0.27985	0.30612	566	sel_devs_fsh	0.20804	0.294	641	sel_coffs_fsh	0.34728	0.28078	721	sel_one_bts_dev	-0.18148	0.14732
492	sel_devs_fsh	0.29439	0.2777	567	sel_devs_fsh	0.1711	0.31239	642	sel_coffs_fsh	0.28964	0.28507	722	sel_one_bts_dev	-0.13819	0.10289
493	sel_devs_fsh	0.6806	0.29084	568	sel_devs_fsh	-0.027268	0.68703	643	sel_coffs_fsh	0.23277	0.30264	723	sel_one_bts_dev	0.025307	0.11167
494	sel_devs_fsh	0.088341	0.30706	569	sel_devs_fsh	-0.38483	0.48143	644	sel_coffs_fsh	0.18876	0.33415	724	sel_one_bts_dev	-0.35137	0.1264
495	sel_devs_fsh	-0.065734	0.28592	570	sel_devs_fsh	0.12901	0.32696	645	sel_coffs_eit	1.3804	0.45957	725	sel_one_bts_dev	-0.46079	0.1229
496	sel_devs_fsh	0.043723	0.28834	571	sel_devs_fsh	0.022023	0.32524	646	sel_coffs_eit	-0.016874	1.2005	726	sel_one_bts_dev	-0.10963	0.11675
497	sel_devs_fsh	0.12924	0.31727	572	sel_devs_fsh	-0.19943	0.33198	647	sel_coffs_eit	-0.81875	1.3837	727	sel_one_bts_dev	-0.26384	0.16922
498	sel_devs_fsh	-0.020233	0.68838	573	sel_devs_fsh	-0.15215	0.30997	648	sel_coffs_eit	-0.81109	1.3923	728	sel_one_bts_dev	-0.10256	0.1287
499	sel_devs_fsh	0.64028	0.46453	574	sel_devs_fsh	0.019436	0.28397	649	sel_coffs_eit	-0.88835	2.1659	729	sel_one_bts_dev	0.14978	0.072159
500	sel_devs_fsh	-0.018872	0.36529	575	sel_devs_fsh	0.11947	0.2908	650	sel_coffs_eit	-0.89167	1.085	730	sel_one_bts_dev	-0.12744	0.087061
501	sel_devs_fsh	-0.075704	0.31706	576	sel_devs_fsh	0.17963	0.31625	651	sel_coffs_eit	-0.89011	0.93434	731	sel_one_bts_dev	-0.020798	0.086685
502	sel_devs_fsh	-0.31342	0.28569	577	sel_devs_fsh	0.29411	0.32267	652	sel_slp_bts	1.0864	0.049025	732	sel_one_bts_dev	0.049415	0.077229
503	sel_devs_fsh	-0.01531	0.27363	578	sel_devs_fsh	0.047371	0.71166	653	sel_a50_bts	5.2992	0.14597	733	sel_one_bts_dev	-0.12932	0.10366
504	sel_devs_fsh	-0.010693	0.28159	579	sel_devs_fsh	0.093769	0.4728	654	sel_age_one	-2.7416	0.084063	734	sel_one_bts_dev	-0.16809	0.11946
505	sel_devs_fsh	-0.023498	0.29279	580	sel_devs_fsh	-0.3993	0.36456	655	sel_slp_bts_dev	-0.54031	0.18224	735	sel_one_bts_dev	-0.0189	0.083804
506	sel_devs_fsh	-0.02998	0.29046	581	sel_devs_fsh	0.42917	0.28506	656	sel_slp_bts_dev	-0.13308	0.15478	736	sel_one_bts_dev	-0.042054	0.087888
507	sel_devs_fsh	-0.13257	0.30425	582	sel_devs_fsh	0.27436	0.32617	657	sel_slp_bts_dev	0.092908	0.10918	737	sel_one_bts_dev	0.078628	0.089571
508	sel_devs_fsh	-0.022938	0.68871	583	sel_devs_fsh	-0.17502	0.36137	658	sel_slp_bts_dev	-0.13166	0.16076	738	sel_one_bts_dev	0.070574	0.094991
509	sel_devs_fsh	-0.4452	0.48414	584	sel_devs_fsh	-0.12511	0.35957	659	sel_slp_bts_dev	-0.18287	0.14261	739	sel_one_bts_dev	0.18646	0.084832
510	sel_devs_fsh	0.8226	0.30686	585	sel_devs_fsh	-0.0013831	0.31189	660	sel_slp_bts_dev	-0.26303	0.14856	740	sel_one_bts_dev	0.10952	0.076603
511	sel_devs_fsh	-0.071614	0.29603	586	sel_devs_fsh	-0.048295	0.32476	661	sel_slp_bts_dev	-0.35073	0.15689	741	sel_one_bts_dev	0.22624	0.08764
512	sel_devs_fsh	0.10119	0.29161	587	sel_devs_fsh	-0.095564	0.32892	662	sel_slp_bts_dev	-0.23095	0.16469	742	sel_one_bts_dev	0.32296	0.094949
513	sel_devs_fsh	-0.14583	0.28494	588	sel_devs_fsh	0.021717	0.70507	663	sel_slp_bts_dev	-0.021598	0.13916	743	sel_one_bts_dev	0.063876	0.12363
514	sel_devs_fsh	0.0039444	0.27651	589	sel_devs_fsh	0.012152	0.49724	664	sel_slp_bts_dev	-0.093511	0.11258	744	sel_one_bts_dev	-0.057408	0.14255
515	sel_devs_fsh	-0.02036	0.28879	590	sel_devs_fsh	-0.2027	0.37356	665	sel_slp_bts_dev	-0.058958	0.12281	745	sel_one_bts_dev	-0.093885	0.095091
516	sel_devs_fsh	-0.085489	0.30041	591	sel_devs_fsh	-0.86252	0.31654	666	sel_slp_bts_dev	0.039214	0.12507	746	sel_one_bts_dev	-0.10133	0.081802
517	sel_devs_fsh	-0.1363	0.2953	592	sel_devs_fsh	0.30872	0.29578	667	sel_slp_bts_dev	0.064257	0.1068	747	sel_one_bts_dev	0.097745	0.096376
518	sel_devs_fsh	-0.019968	0.68889	593	sel_devs_fsh	0.41444	0.34378	668	sel_slp_bts_dev	-0.03139	0.1201	748	sel_one_bts_dev	0.40343	0.061223
519	sel_devs_fsh	-0.26136	0.53121	594	sel_devs_fsh	0.2011	0.3561	669	sel_slp_bts_dev	-0.14351	0.1345	749	sel_one_bts_dev	0.31715	0.091293
520	sel_devs_fsh	-0.77619	0.33057	595	sel_devs_fsh	0.052635	0.3179	670	sel_slp_bts_dev	-0.24576	0.12809	750	sel_one_bts_dev	0.14584	0.089138
521	sel_devs_fsh	0.85631	0.28312	596	sel_devs_fsh	0.031675	0.30834	671	sel_slp_bts_dev	-0.3747	0.1142	751	sel_one_bts_dev	0.032079	0.10106
522	sel_devs_fsh	0.023926	0.28992	597	sel_devs_fsh	0.022779	0.32041	672	sel_slp_bts_dev	-0.39178	0.12179	752	sel_one_bts_dev	0.15227	0.092875
523	sel_devs_fsh	-0.1301	0.30929	598	sel_devs_fsh	0.019492	0.70856	673	sel_slp_bts_dev	-0.28079	0.11832	753	sel_one_bts_dev	-0.06418	0.11955
524	sel_devs_fsh	0.019218	0.29548	599	sel_devs_fsh	0.017885	0.56779	674	sel_slp_bts_dev	-0.32248	0.12795	754	rec_dev_future	0	0.65971
525	sel_devs_fsh	0.046281	0.28962	600	sel_devs_fsh	0.41671	0.36053	675	sel_slp_bts_dev	-0.10104	0.10363	755	rec_dev_future	0	0.65971
								676	sel_slp_bts_dev	0.089221	0.10876	756	rec_dev_future	0	0.65971
								677	sel_slp_bts_dev	0.091142	0.11448	757	rec_dev_future	0	0.65971
								678	sel_slp_bts_dev	0.14573	0.12853	758	rec_dev_future	0	0.65971
								679	sel_slp_bts_dev	0.047259	0.14026	759	q_all	1.4592	0.09204
								680	sel_slp_bts_dev	0.22193	0.13373				

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.

	2014 **Assessment**
Biomass	
Year 2015 spawning biomass*	2,850,000 t
(CV)	(14%)
2014 spawning biomass	2,945,000 t
B_{MSY}	1,948,000 t
(CV)	(20%)
SPR| B_{MSY}	27.4%
$B_{40\%}$	2,491,000 t
$B_{35\%}$	2,179,000 t
B_0 (stock-recruitment curve)	5,162,000 t
2014 Percent of B_{MSY} spawning biomass	151%
2015 Percent of B_{MSY} spawning biomass	146%
Ratio of B_{2014} over B_{2014} under no fishing since 1978	0.61
Recruitment (millions of pollock at age 1)	
Steepness parameter (h)	0.671
Average recruitment (all yrs)	22,759
2000 year class	35,982
2006 year class	25,597
2008 year class	56,155
Natural Mortality (age 3 and older)	0.3

Table 1.24. Summary results of Tier 1 2015 yield projections for EBS pollock.

Description	Value
Tier 1 maximum permissible ABC	
2015 fishable biomass (GM)	5,669,000 t
MSYR (HM)	0.512
Adjustment factor	1.0
Adjusted ABC rate	0.512
2015 MSYR yield (Tier 1 ABC)	2,900,000 t
OFL	
MSYR (AM)	0.587
2015 MSYR OFL	3,330,000 t
Recommended F_{ABC}	0.24
Recommended ABC	1,350,000 t
Fishable biomass at *MSY*	3,495,000 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 2014 Model 1.0.

	1	2	3	4	5	6	7	8	9	10+	Total
1964	5,387	3,610	2,283	473	214	337	136	50	23	136	12,648
1965	20,612	2,188	2,272	1,623	287	128	203	83	31	99	27,524
1966	14,560	8,372	1,379	1,602	988	176	80	128	52	83	27,421
1967	28,785	5,914	5,263	968	999	621	112	51	82	88	42,884
1968	26,732	11,685	3,664	3,331	564	583	365	66	30	101	47,121
1969	29,207	10,850	7,210	2,394	1,884	324	340	215	39	79	52,542
1970	20,148	11,855	6,691	4,481	1,416	1,126	196	206	130	71	46,319
1971	9,833	8,173	7,072	3,897	2,626	834	668	112	118	109	33,441
1972	10,799	3,986	4,838	3,959	2,104	1,375	442	355	59	104	28,022
1973	28,784	4,376	2,227	2,434	1,974	1,056	695	224	180	70	42,020
1974	21,417	11,660	2,361	1,054	1,067	869	467	309	100	107	39,410
1975	18,184	8,675	5,888	989	445	454	373	201	132	87	35,429
1976	13,996	7,373	4,959	2,551	447	206	212	175	95	100	30,114
1977	13,986	5,678	4,286	2,501	1,182	212	99	103	86	94	28,227
1978	27,145	5,677	3,250	2,385	1,299	605	109	51	54	94	40,669
1979	67,256	11,018	3,283	1,766	1,234	669	315	56	26	76	85,699
1980	26,869	27,305	6,643	1,869	952	614	334	159	28	51	64,823
1981	30,766	10,914	17,025	4,219	1,006	482	304	167	80	40	65,003
1982	15,905	12,503	6,890	11,702	2,554	548	263	167	92	65	50,689
1983	53,686	6,465	7,935	4,948	7,706	1,554	330	159	100	92	82,974
1984	13,313	21,823	4,103	5,728	3,359	4,983	956	203	97	111	54,676
1985	35,373	5,412	13,863	2,963	3,918	2,117	3,159	593	125	118	67,641
1986	14,550	14,379	3,433	9,966	2,068	2,580	1,296	1,956	361	138	50,727
1987	8,505	5,915	9,119	2,475	6,842	1,379	1,609	806	1,239	298	38,185
1988	5,461	3,457	3,757	6,630	1,756	4,714	914	1,068	507	959	29,222
1989	10,359	2,220	2,192	2,576	4,561	1,133	3,041	559	662	909	28,212
1990	50,241	4,211	1,408	1,561	1,751	3,001	716	1,820	338	962	66,009
1991	25,577	20,424	2,662	998	978	1,034	1,739	406	1,018	752	55,588
1992	22,018	10,398	12,920	1,919	656	590	600	926	228	954	51,207
1993	47,610	8,951	6,566	8,962	1,283	408	324	303	439	552	75,398
1994	14,630	19,355	5,693	4,652	5,676	838	246	184	172	569	52,015
1995	10,695	5,948	12,314	4,157	3,155	3,317	497	146	110	451	40,791
1996	23,152	4,348	3,784	9,040	2,961	2,004	1,810	282	85	333	47,801
1997	31,501	9,413	2,759	2,761	6,597	2,032	1,146	904	145	228	57,485
1998	15,718	12,807	5,947	2,009	1,961	4,486	1,262	631	489	198	45,507
1999	17,221	6,390	8,126	4,323	1,425	1,325	2,749	770	359	374	43,060
2000	26,559	7,001	4,064	5,778	3,011	967	854	1,643	464	448	50,789
2001	35,982	10,798	4,453	2,941	3,920	1,940	624	497	923	542	62,621
2002	23,249	14,629	6,874	3,245	2,034	2,395	1,087	353	282	848	54,996
2003	13,974	9,452	9,292	4,990	2,219	1,261	1,252	573	188	634	43,833
2004	6,261	5,681	6,011	6,546	3,408	1,326	673	640	299	467	31,313
2005	4,255	2,546	3,616	4,367	4,129	2,099	772	363	348	436	22,930
2006	10,929	1,730	1,620	2,627	2,903	2,302	1,139	434	210	467	24,361
2007	25,597	4,443	1,099	1,138	1,710	1,639	1,182	597	233	381	38,019
2008	10,165	10,406	2,821	771	738	966	804	607	319	339	27,936
2009	56,155	4,132	6,615	2,035	503	420	463	396	313	350	71,383
2010	20,542	22,830	2,630	4,777	1,351	311	227	242	208	344	53,461
2011	24,237	8,351	14,532	1,920	3,056	813	183	129	133	307	53,660
2012	18,111	9,853	5,313	10,593	1,310	1,554	379	88	63	221	47,486
2013	31,003	7,363	6,268	3,839	7,039	815	765	177	41	139	57,449
2014	23,728	12,604	4,689	4,577	2,539	4,383	445	421	80	82	53,548
Median	20,577	8,262	4,764	2,851	1,820	1,001	482	262	131	198	47,121
Average	22,759	9,128	5,568	3,726	2,348	1,410	764	427	236	307	46,672

Table 1.26. Assessment model-estimated catch-at-age of EBS pollock (millions; 1964-2014).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	4.1	38.1	79.2	74.5	35.1	55.2	21.4	7.5	3.2	18.5	336.9
1965	12.9	20.3	94.8	251.2	42.1	17.7	26.4	10.2	3.6	11.2	490.4
1966	8.7	95.2	62.6	219.2	130.2	21.7	9.3	14.2	5.6	8.6	575.3
1967	29.1	135.4	665.1	179.3	184.8	111.5	19.9	9.0	14.2	15.2	1,363.4
1968	29.7	304.0	374.8	684.7	110.2	107.6	65.3	11.5	5.2	17.0	1,710.0
1969	32.0	287.1	1,007.7	419.8	316.8	52.1	54.2	34.0	6.2	13.2	2,223.3
1970	30.2	617.2	1,243.9	813.8	251.5	194.5	38.8	40.7	25.7	20.9	3,277.1
1971	18.8	472.5	1,502.9	919.6	671.1	207.1	164.7	27.8	29.4	45.9	4,059.8
1972	23.0	399.0	1,354.8	1,129.3	591.7	380.8	122.2	97.9	17.2	43.0	4,159.1
1973	68.8	546.2	703.0	869.0	701.4	372.7	243.4	78.0	62.8	30.1	3,675.4
1974	52.2	1,970.9	898.0	396.9	397.5	319.8	171.5	114.2	37.0	41.3	4,399.3
1975	32.1	726.2	2,140.2	338.2	146.4	146.5	119.1	64.0	42.1	30.9	3,785.5
1976	19.8	526.4	1,381.0	835.4	140.1	62.8	63.8	52.2	28.1	30.9	3,140.3
1977	16.1	470.3	927.7	651.2	318.6	56.1	25.9	26.8	22.1	24.3	2,539.0
1978	29.3	426.5	754.4	627.9	345.5	156.8	29.1	13.8	14.4	25.1	2,422.9
1979	64.6	484.3	661.1	418.7	353.3	189.8	87.2	16.0	7.5	21.5	2,304.0
1980	15.9	487.3	822.6	444.5	263.0	177.3	94.4	44.4	7.8	14.2	2,371.4
1981	9.6	86.9	1,063.1	669.0	232.5	110.0	68.6	37.6	18.0	9.8	2,305.1
1982	2.7	46.5	183.0	1,126.3	396.4	89.1	42.3	27.7	15.5	13.7	1,943.2
1983	7.0	23.9	175.5	357.6	849.6	229.0	48.2	23.9	16.3	20.6	1,751.7
1984	1.5	65.8	89.2	379.9	435.0	622.8	135.3	29.9	15.8	26.0	1,801.2
1985	3.5	22.3	355.0	148.9	377.7	318.8	450.7	91.4	20.7	29.2	1,818.3
1986	1.2	63.3	79.5	632.2	178.6	354.5	180.3	246.3	55.1	29.3	1,820.3
1987	0.4	18.4	146.3	90.5	414.5	125.6	144.8	106.2	162.6	47.3	1,256.7
1988	0.4	15.4	241.6	408.9	197.0	527.9	138.3	151.5	73.0	134.1	1,888.1
1989	0.6	9.7	73.6	184.9	442.5	143.8	507.7	89.1	99.6	136.1	1,687.6
1990	3.9	28.7	52.6	208.7	308.0	567.6	146.8	387.7	68.6	180.1	1,952.6
1991	1.7	130.2	62.1	97.8	158.3	194.8	426.6	85.2	246.4	173.6	1,576.7
1992	1.7	80.7	712.1	161.9	91.5	132.1	166.2	291.1	74.1	307.1	2,018.5
1993	2.2	18.5	247.4	1,127.9	132.1	65.5	66.2	61.6	88.9	104.8	1,915.1
1994	0.5	34.3	70.0	340.8	1,041.3	144.6	42.1	30.5	27.5	87.8	1,819.5
1995	0.3	10.2	96.2	138.4	389.5	760.5	101.7	27.9	19.6	76.8	1,621.1
1996	0.8	17.5	49.5	117.3	188.5	398.2	515.1	75.0	20.7	75.4	1,458.0
1997	1.2	69.4	40.3	99.0	468.7	285.6	255.4	211.4	37.0	55.1	1,523.1
1998	0.5	50.9	96.6	73.9	149.1	672.7	193.5	128.0	113.3	45.5	1,524.0
1999	0.5	13.8	282.4	223.1	103.5	148.8	461.0	124.9	56.0	54.7	1,468.7
2000	0.7	13.8	81.5	421.2	340.2	107.7	159.1	345.8	83.3	72.9	1,626.2
2001	1.0	13.7	62.5	168.2	596.6	411.5	128.9	101.3	176.8	101.5	1,762.1
2002	0.8	44.5	119.9	217.0	288.8	614.7	272.9	86.5	64.8	174.2	1,884.1
2003	0.5	20.0	394.4	336.7	371.8	306.2	337.6	147.9	43.0	124.0	2,081.9
2004	0.2	7.8	100.3	844.1	499.4	247.6	159.6	148.5	63.2	90.4	2,161.2
2005	0.1	4.2	60.2	388.6	888.8	488.6	161.6	69.7	62.9	70.8	2,195.6
2006	0.4	5.0	72.9	275.9	600.4	616.2	290.0	104.4	46.2	95.1	2,106.6
2007	1.0	14.8	50.4	122.1	354.1	483.9	315.7	145.1	53.0	82.3	1,622.6
2008	0.4	25.9	64.2	79.8	148.7	297.3	234.5	160.5	82.0	80.2	1,173.5
2009	1.6	5.9	144.5	183.2	72.7	98.9	119.2	100.4	81.2	91.8	899.4
2010	0.5	31.2	33.7	564.9	220.7	55.5	46.6	54.3	45.9	73.9	1,127.4
2011	0.9	15.3	201.4	130.9	835.3	262.4	56.4	38.3	38.2	85.5	1,664.6
2012	0.7	18.7	113.1	945.6	182.4	455.4	122.4	27.8	19.1	64.6	1,949.7
2013	1.0	7.5	77.5	357.2	973.7	186.8	170.6	60.3	13.9	47.0	1,895.5
2014	0.7	11.4	52.9	400.9	471.0	811.6	82.9	121.2	23.1	23.5	1,999.1
Median	1.6	32.8	132.2	349.0	317.7	194.6	125.7	66.8	33.2	47.0	1,884.1
Average	10.6	177.5	400.4	417.6	360.8	273.8	158.9	90.2	48.2	64.6	2,002.6

Table 1.27. Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2014. 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	1,602	448	5,387	1990	7,891	3,085	50,241
1965	2,051	571	20,612	1991	6,171	2,318	25,577
1966	2,150	683	14,560	1992	9,562	2,410	22,018
1967	3,344	866	28,785	1993	11,712	3,281	47,610
1968	3,800	1,071	26,732	1994	11,306	3,560	14,630
1969	5,145	1,355	29,207	1995	13,074	3,750	10,695
1970	6,179	1,694	20,148	1996	11,198	3,740	23,152
1971	6,884	1,906	9,833	1997	9,801	3,526	31,501
1972	6,299	1,829	10,799	1998	9,903	3,279	15,718
1973	4,692	1,460	28,784	1999	10,791	3,289	17,221
1974	3,291	1,006	21,417	2000	10,020	3,330	26,559
1975	3,516	837	18,184	2001	9,803	3,369	35,982
1976	3,578	861	13,996	2002	10,182	3,203	23,249
1977	3,613	931	13,986	2003	12,211	3,397	13,974
1978	3,524	980	27,145	2004	11,416	3,490	6,261
1979	3,387	963	67,256	2005	9,522	3,187	4,255
1980	4,307	1,082	26,869	2006	7,262	2,612	10,929
1981	8,321	1,792	30,766	2007	5,840	2,173	25,597
1982	9,497	2,744	15,905	2008	4,607	1,589	10,165
1983	10,560	3,398	53,686	2009	5,880	1,708	56,155
1984	10,239	3,630	13,313	2010	5,622	1,862	20,542
1985	12,409	3,900	35,373	2011	7,928	2,239	24,237
1986	11,621	4,133	14,550	2012	7,853	2,623	18,111
1987	12,243	4,250	8,505	2013	8,261	3,043	31,003
1988	11,583	4,232	5,461	2014	8,045	2,945	23,728
1989	9,861	3,814	10,359	2015	7,778		

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	1,622	21%	1,602	21%	1,608	21%	1,602	21%	1,589	21%	1,564	22%	1,600	22%	1,717	23%
1965	2,077	20%	2,051	20%	2,059	20%	2,050	20%	2,008	19%	2,008	20%	2,050	20%	2,141	21%
1966	2,186	20%	2,150	20%	2,157	20%	2,159	20%	1,944	21%	1,947	22%	2,007	21%	2,037	22%
1967	3,397	16%	3,344	16%	3,353	16%	3,365	16%	3,140	17%	3,149	17%	3,245	17%	3,206	18%
1968	3,871	17%	3,800	17%	3,809	17%	3,838	17%	3,486	18%	3,510	19%	3,592	18%	3,558	19%
1969	5,220	16%	5,145	16%	5,154	16%	5,187	16%	4,879	17%	5,007	17%	5,020	17%	5,118	17%
1970	6,253	15%	6,179	15%	6,188	15%	6,221	15%	5,974	16%	6,159	15%	6,005	16%	6,368	15%
1971	6,946	14%	6,884	14%	6,894	14%	6,918	14%	6,785	13%	6,949	13%	6,727	14%	7,164	13%
1972	6,353	14%	6,299	14%	6,308	14%	6,329	14%	6,277	13%	6,444	13%	6,289	14%	6,666	13%
1973	4,749	16%	4,692	16%	4,700	16%	4,728	16%	4,547	16%	4,696	16%	4,556	17%	4,942	16%
1974	3,348	20%	3,291	20%	3,298	20%	3,329	20%	3,085	20%	3,196	20%	3,064	22%	3,475	20%
1975	3,554	14%	3,516	14%	3,523	14%	3,533	14%	3,366	13%	3,384	13%	3,276	14%	3,604	14%
1976	3,609	11%	3,578	11%	3,587	11%	3,580	11%	3,460	10%	3,431	11%	3,339	11%	3,584	11%
1977	3,643	10%	3,613	9%	3,624	10%	3,598	9%	3,500	9%	3,457	9%	3,340	10%	3,602	10%
1978	3,557	9%	3,524	9%	3,537	9%	3,497	9%	3,390	9%	3,340	9%	3,202	9%	3,476	9%
1979	3,426	9%	3,387	9%	3,403	9%	3,343	9%	3,267	9%	3,212	9%	3,090	9%	3,363	9%
1980	4,372	7%	4,307	7%	4,333	7%	4,230	7%	4,203	7%	4,124	8%	4,044	7%	4,384	8%
1981	8,528	6%	8,321	6%	8,364	6%	8,160	6%	8,190	6%	8,031	6%	7,704	6%	8,307	6%
1982	9,767	5%	9,497	6%	9,549	6%	9,313	6%	9,349	6%	9,165	6%	8,783	6%	9,439	6%
1983	10,911	5%	10,560	5%	10,621	5%	10,340	5%	10,376	5%	10,168	5%	9,804	5%	10,493	6%
1984	10,601	5%	10,239	5%	10,300	5%	10,031	5%	10,060	5%	9,857	5%	9,518	5%	10,200	6%
1985	12,838	4%	12,409	4%	12,478	4%	12,186	4%	12,246	4%	12,027	4%	11,802	4%	12,531	5%
1986	12,036	4%	11,621	4%	11,685	4%	11,426	4%	11,471	4%	11,269	4%	11,075	4%	11,773	5%
1987	12,615	4%	12,243	4%	12,308	4%	12,063	4%	12,111	4%	11,915	4%	11,732	4%	12,401	4%
1988	11,906	3%	11,583	4%	11,642	4%	11,424	4%	11,402	4%	11,227	4%	11,004	4%	11,617	4%
1989	10,128	4%	9,861	4%	9,913	4%	9,724	4%	9,671	4%	9,521	4%	9,320	4%	9,875	4%
1990	8,102	4%	7,891	4%	7,936	4%	7,764	4%	7,681	4%	7,558	4%	7,345	4%	7,847	5%
1991	6,331	4%	6,171	5%	6,209	5%	6,049	5%	5,911	5%	5,811	5%	5,590	5%	6,097	5%
1992	9,705	3%	9,562	3%	9,602	3%	9,411	3%	9,316	3%	9,211	4%	8,966	4%	9,557	4%
1993	11,840	3%	11,712	3%	11,754	3%	11,543	3%	11,493	3%	11,388	3%	11,175	3%	11,832	4%
1994	11,402	3%	11,306	3%	11,341	3%	11,146	3%	11,077	3%	10,990	4%	10,782	4%	11,485	4%
1995	13,135	3%	13,074	3%	13,109	3%	12,883	3%	12,779	3%	12,699	3%	12,704	3%	13,615	4%
1996	11,235	3%	11,198	3%	11,229	3%	11,019	3%	10,903	4%	10,843	4%	10,829	4%	11,537	4%
1997	9,816	4%	9,801	4%	9,828	4%	9,627	4%	9,485	4%	9,440	4%	9,403	4%	10,104	5%
1998	9,907	3%	9,903	4%	9,929	3%	9,722	4%	9,584	4%	9,538	4%	9,467	4%	10,178	5%
1999	10,799	3%	10,791	3%	10,819	3%	10,607	3%	10,509	3%	10,421	3%	10,379	4%	11,081	4%
2000	10,031	3%	10,020	3%	10,044	3%	9,841	3%	9,747	3%	9,632	3%	9,503	4%	10,201	4%
2001	9,819	3%	9,803	3%	9,830	3%	9,616	3%	9,506	3%	9,341	4%	9,175	4%	9,898	5%
2002	10,221	3%	10,182	3%	10,230	3%	9,988	3%	9,842	3%	9,595	4%	9,554	4%	10,224	5%
2003	12,278	3%	12,211	3%	12,269	3%	11,974	3%	11,805	3%	11,453	3%	11,182	4%	12,865	6%
2004	11,493	3%	11,416	3%	11,491	3%	11,178	3%	10,974	3%	10,606	4%	10,274	4%	11,784	7%
2005	9,602	3%	9,522	3%	9,608	3%	9,299	3%	9,079	4%	8,736	4%	8,423	5%	9,598	8%
2006	7,343	3%	7,262	4%	7,349	4%	7,060	4%	6,839	4%	6,543	5%	6,340	6%	7,178	10%
2007	5,933	4%	5,840	4%	5,954	4%	5,633	5%	5,386	5%	5,090	6%	5,015	8%	5,363	14%
2008	4,722	5%	4,607	5%	4,724	5%	4,393	6%	4,146	7%	3,809	8%	4,222	12%	4,357	20%
2009	6,069	5%	5,880	5%	6,069	6%	6,172	8%	6,225	10%	4,762	11%	6,240	20%		
2010	5,937	5%	5,622	6%	5,769	7%	6,095	10%	6,582	12%	4,616	13%				
2011	8,895	6%	7,928	8%	7,781	9%	7,823	11%	9,620	15%						
2012	8,823	8%	7,853	10%	7,867	10%	8,341	12%								
2013	9,541	8%	8,261	11%	8,138	12%										
2014	8,960	9%	8,045	12%												
2015	9,203	10%														

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 6,227, 2,491 and 2,179 thousand t, respectively.

Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2014	1,298	1,298	1,298	1,298	1,298	1,298	1,298
2015	1,637	1,350	1,409	732	0	2,023	1,637
2016	1,554	1,642	1,399	825	0	1,703	1,554
2017	1,394	1,466	1,321	849	0	1,450	1,707
2018	1,349	1,382	1,322	895	0	1,425	1,515
2019	1,345	1,358	1,325	926	0	1,433	1,464
2020	1,373	1,378	1,341	956	0	1,463	1,473
2021	1,395	1,397	1,353	979	0	1,484	1,486
2022	1,411	1,411	1,367	998	0	1,494	1,494
2023	1,410	1,410	1,369	1,009	0	1,487	1,487
2024	1,404	1,404	1,363	1,012	0	1,478	1,478
2025	1,395	1,395	1,356	1,012	0	1,466	1,466
2026	1,389	1,389	1,352	1,012	0	1,461	1,461
2027	1,387	1,387	1,349	1,010	0	1,459	1,459
Fishing M.	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2014	0.277	0.277	0.277	0.277	0.277	0.277	0.277
2015	0.392	0.313	0.329	0.160	0.000	0.507	0.392
2016	0.392	0.392	0.329	0.160	0.000	0.482	0.392
2017	0.381	0.387	0.329	0.160	0.000	0.453	0.485
2018	0.367	0.370	0.329	0.160	0.000	0.444	0.453
2019	0.359	0.360	0.329	0.160	0.000	0.437	0.440
2020	0.359	0.359	0.329	0.160	0.000	0.438	0.438
2021	0.360	0.360	0.329	0.160	0.000	0.440	0.440
2022	0.359	0.359	0.329	0.160	0.000	0.439	0.439
2023	0.359	0.358	0.329	0.160	0.000	0.436	0.436
2024	0.358	0.358	0.329	0.160	0.000	0.436	0.436
2025	0.358	0.358	0.329	0.160	0.000	0.435	0.435
2026	0.358	0.358	0.329	0.160	0.000	0.435	0.435
2027	0.357	0.357	0.329	0.160	0.000	0.433	0.433
Spawning Biomass	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2014	2,941	2,941	2,941	2,941	2,941	2,941	2,941
2015	2,714	2,755	2,747	2,839	2,929	2,654	2,714
2016	2,570	2,686	2,695	3,080	3,517	2,374	2,570
2017	2,478	2,543	2,644	3,224	3,982	2,255	2,431
2018	2,501	2,532	2,674	3,392	4,455	2,278	2,344
2019	2,532	2,546	2,692	3,497	4,816	2,304	2,327
2020	2,567	2,572	2,716	3,587	5,136	2,328	2,336
2021	2,597	2,599	2,741	3,661	5,407	2,349	2,351
2022	2,612	2,613	2,755	3,711	5,623	2,357	2,357
2023	2,605	2,605	2,749	3,732	5,787	2,346	2,346
2024	2,591	2,592	2,734	3,734	5,897	2,332	2,332
2025	2,579	2,579	2,721	3,730	5,978	2,320	2,320
2026	2,576	2,576	2,716	3,731	6,045	2,319	2,319
2027	2,582	2,582	2,720	3,735	6,094	2,327	2,327

Table 1.30 Maximum permissible Tier 1a EBS pollock ABC and OFL projections for 2015 and for 2016.

Year	Catch	ABC	OFL
2015	1,350,000 t	2,900,000 t	3,330,000 t
2016	1,350,000 t	3,040,000 t	3,490,000 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, 1997-2012 based on then NMFS Alaska Regional Office reports from observers (*2014 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	8,944	3,142	6,360	2,072	958	611	70	0	21	147	1,756	117	43	221	242	24,703
2014	5,193	2,537	4,380	1,927	756	1,295	117	1	41	322	811	1,478	75	189	495	19,617

Table 1.34 Bycatch estimates (t) of **pollock** caught in the other non-pollock EBS directed fisheries, 2003-2011 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	322	91	21,022
2011	8,965	8,695	7,090	1,491	831	301	27,373
2012	8,386	11,226	6,779	903	841	413	28,547
2013	9,044	20,246	7,372	2,021	2,026	252	40,961
2014	9,556	20,190	11,105	4,138	2,295	70	47,352
Average	11,994	10,400	6,733	3,062	1,065	186	33,439

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 2014 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		2,159,774		3,159,252	28,951	4,380,025	33,431	17,777
1992	1,501,801		35,950		2,221,417		647,013	40,274	4,570,741	20,387	43,874
1993	1,649,104		38,516		1,326,119		527,497	242,191	738,260	1,926	58,140
1994	371,238		33,136		963,417	689	1,626,561	92,672	811,758	514	42,361
1995	153,995		14,984		492,283	398	904,899	19,264	206,654	941	4,646
1996	89,416		55,623		382,071	321	1,241,853	77,236	63,398	215	5,934
1997	17,248		44,909		260,761	203	1,134,544	65,988	216,152	393	137
1998	57,042		51,322		353,210	278	800,753	64,042	123,405	5,093	14,287
1999	2,397		10,381		153,970	125	799,550	44,610	15,830	7	91
2000	1,485		4,242		110,456	91	482,751	56,867	6,481	121	0
2001	5,061		30,937		265,907	200	225,277	53,904	5,653	5,139	106
2002	2,113		32,402		199,299	168	108,584	77,178	2,698	194	17
2003	733	9	43,021		113,493	96	909,216	180,782	609		52
2004	1,189	4	51,700	2	108,623	93	1,104,136	440,475	743		27
2005	659	0	67,362	1	146,727	113	610,123	704,587	2,300		0
2006	1,657	0	82,750	3	156,510	122	435,558	306,047	2,909		203
2007	1,522	0	122,255	3	360,261	292	353,518	93,201	3,220		8
2008	8,839	8	21,398	33	424,351	334	127,805	15,555	9,428		576
2009	6,120	20	12,743	0	588,227	458	64,952	46,893	7,428		1,137
2010	13,589	29	9,831	0	356,652	274	351,378	13,797	9,431		1,009
2011	10,319	20	25,499	0	508,606	382	377,220	193,555	6,332		577
2012	5,413	0	11,344	0	474,800	386	2,352,551	22,390	6,106		344
2013	12,149	34	13,108	147	347,403	268	958,969	125,525	8,549		316
2014			15,020		191,011	160		219,092			

Figures

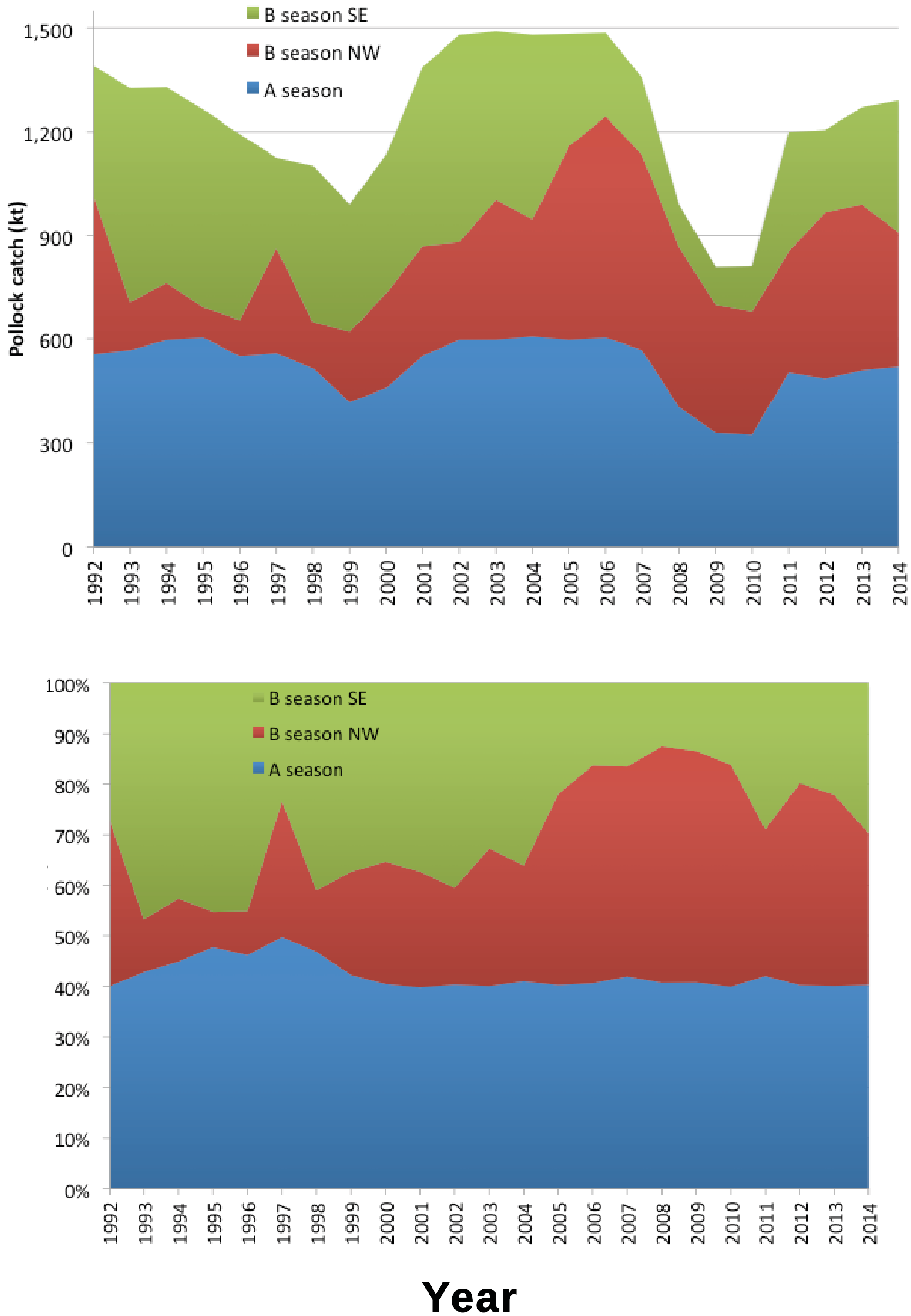

Figure 1.1. Pollock catch estimates from the Eastern Bering Sea by season and region in kt (top) and proportion (bottom). The A-season is defined as from Jan-May and B-season from June-October, 1992-2014.

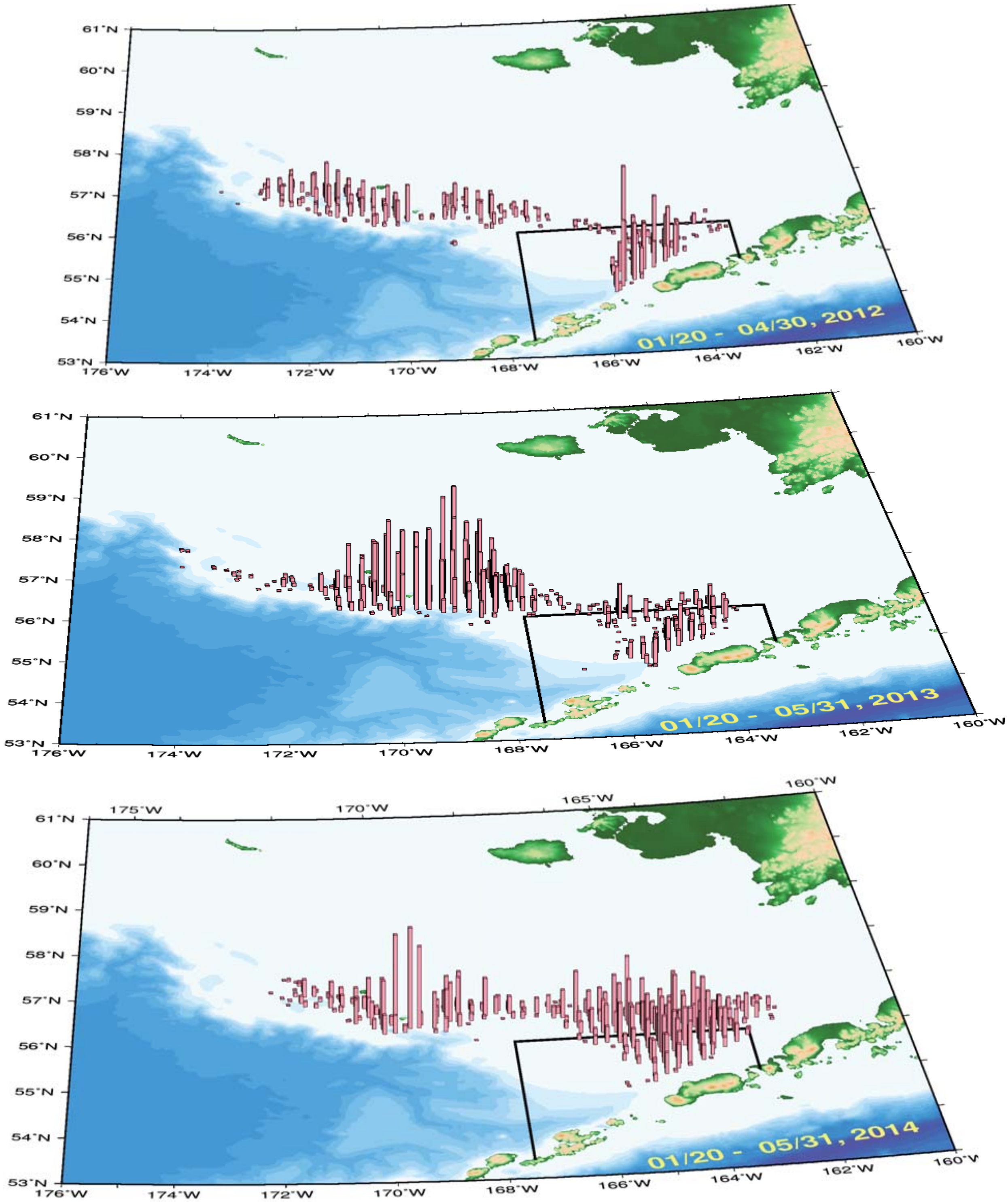

Figure 1.2. Pollock catch distribution 2012-2014, for the A-season on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

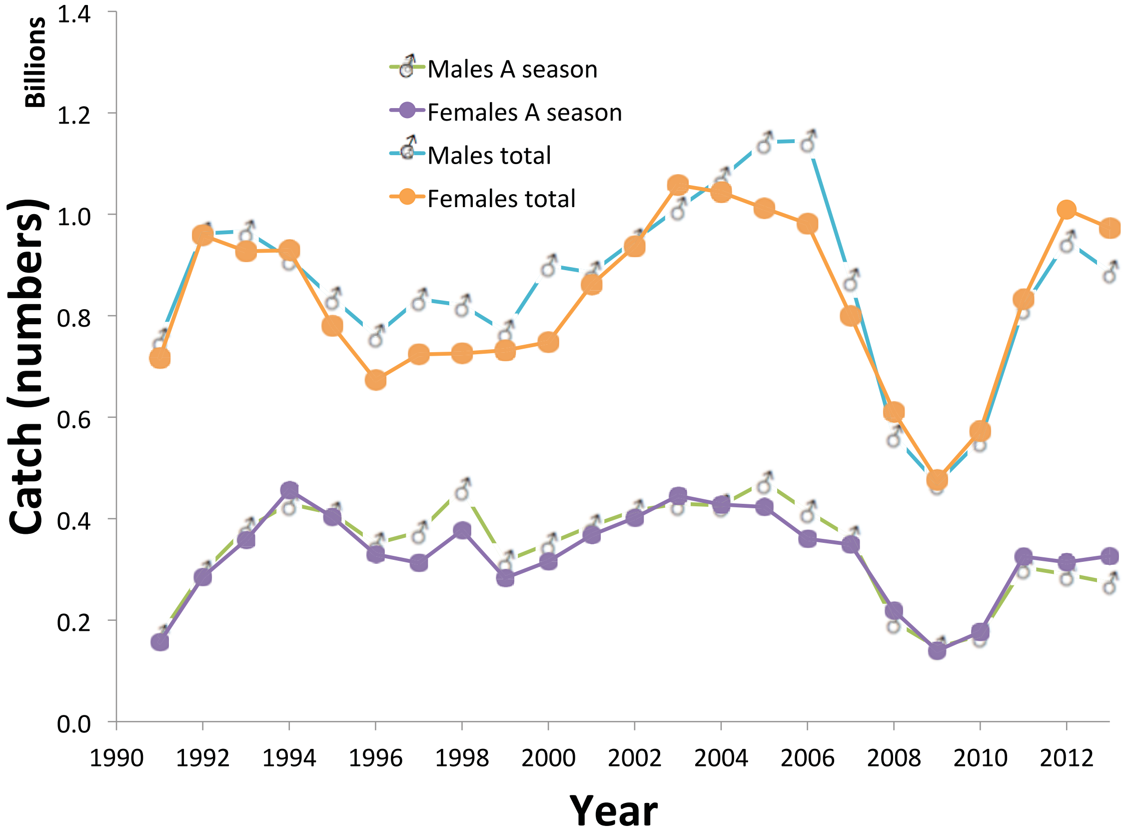

Figure 1.3. Estimate of EBS pollock catch numbers by sex for the A season (January-May) and for the entire annual fishery, 1991-2013.

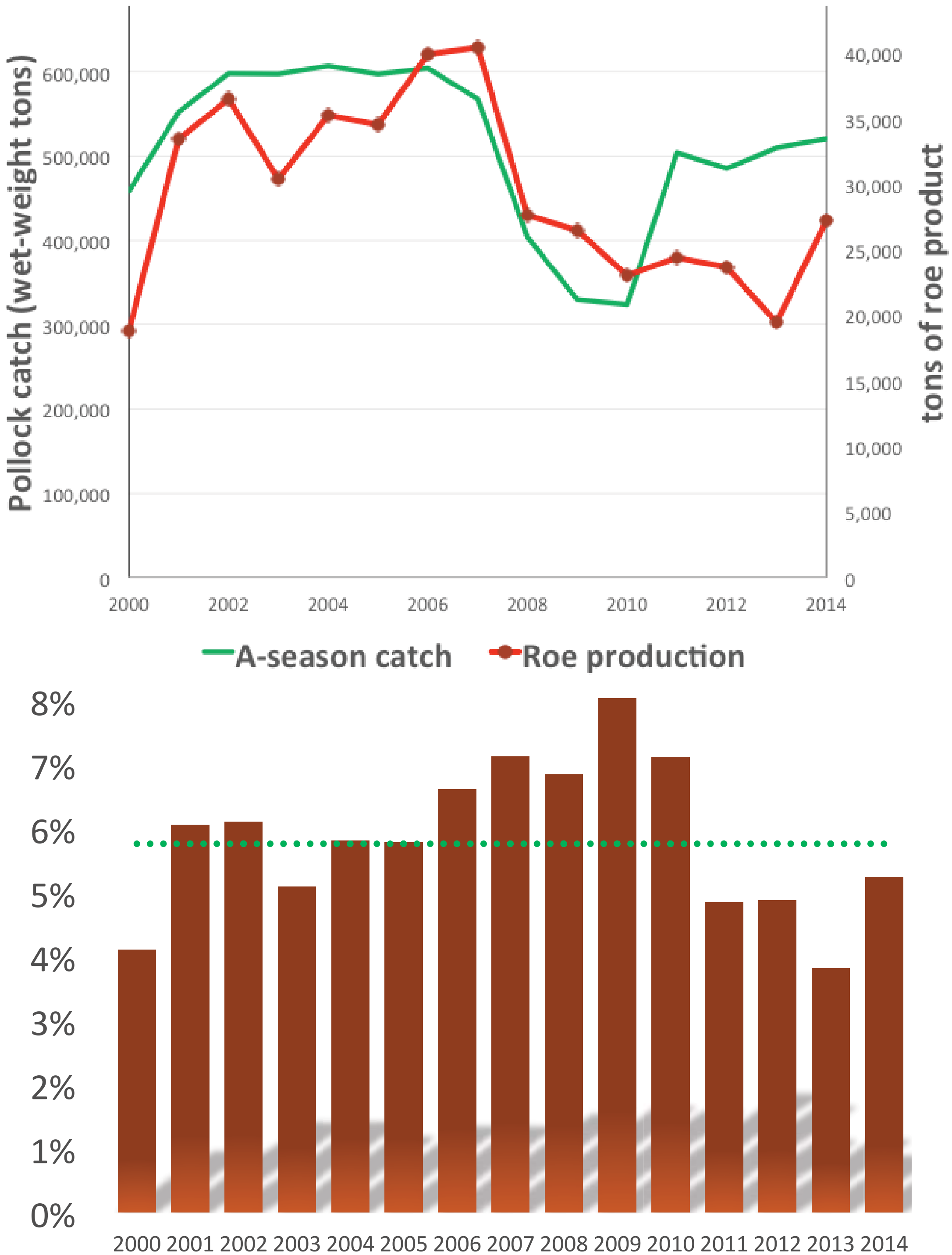

Figure 1.4. EBS pollock fishery catch in the A-season compared to tons of roe produced (top) and ratio of roe recovery relative to the mean value for 2000-2014 (bottom). Note that pollock catch for the A-season is from NMFS catch-accounting system and roe production data is derived from NMFS REFM-Division socio-economic database.

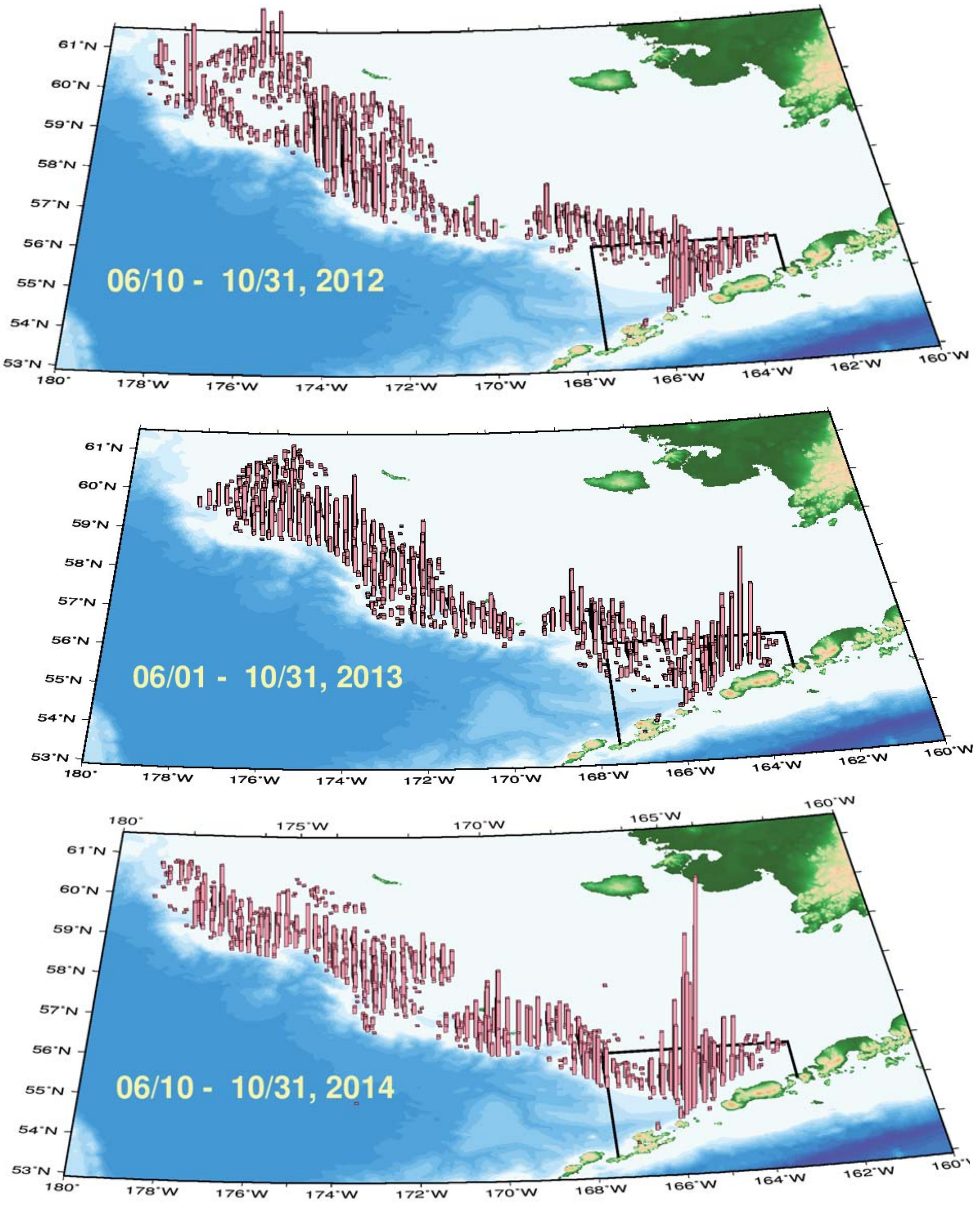

Figure 1.5. Pollock catch distribution during June – October, 2012-2014. The line delineates the catcher-vessel operational area (CVOA) and the height of the bars represents relative removal on the same scale between years.

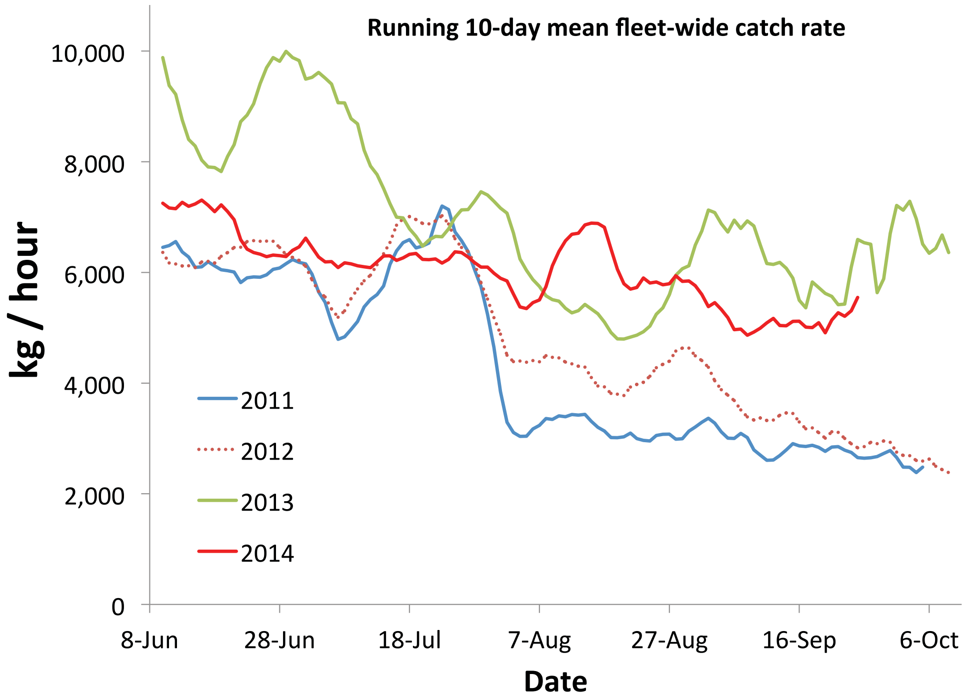

Figure 1.6. Moving average (10-day) pollock catch (kg) per hour towed for the EBS pollock fishery comparing 2011-2014.

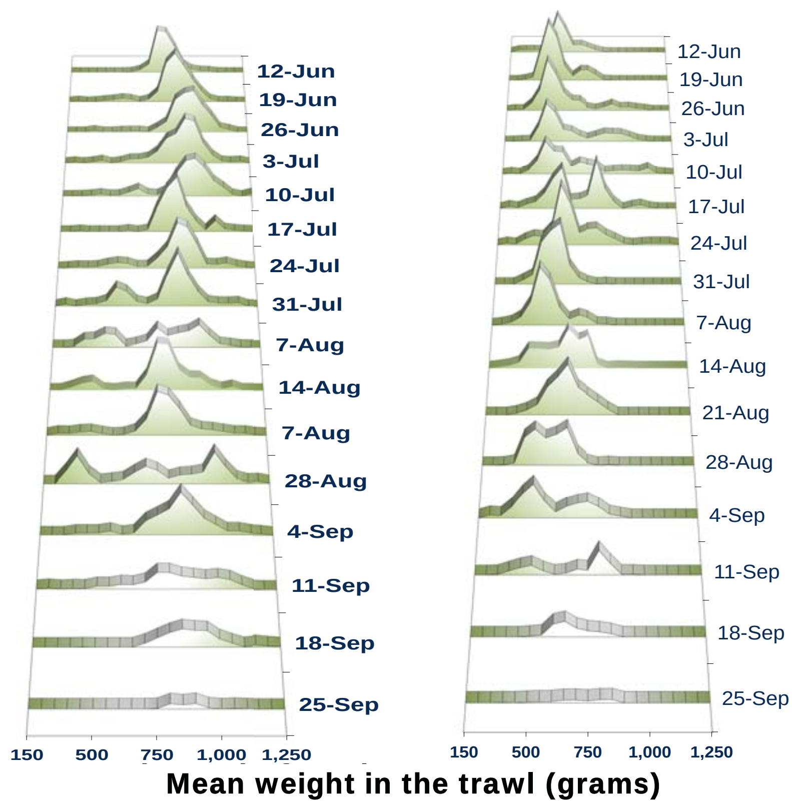

Figure 1.7. Weekly NMFS observer data on the frequency distribution of mean weight (by 50-gram categories) per tow for the summer 2014 EBS pollock fishery with shore-based fleet represented on the left and offshore fleet on the right.

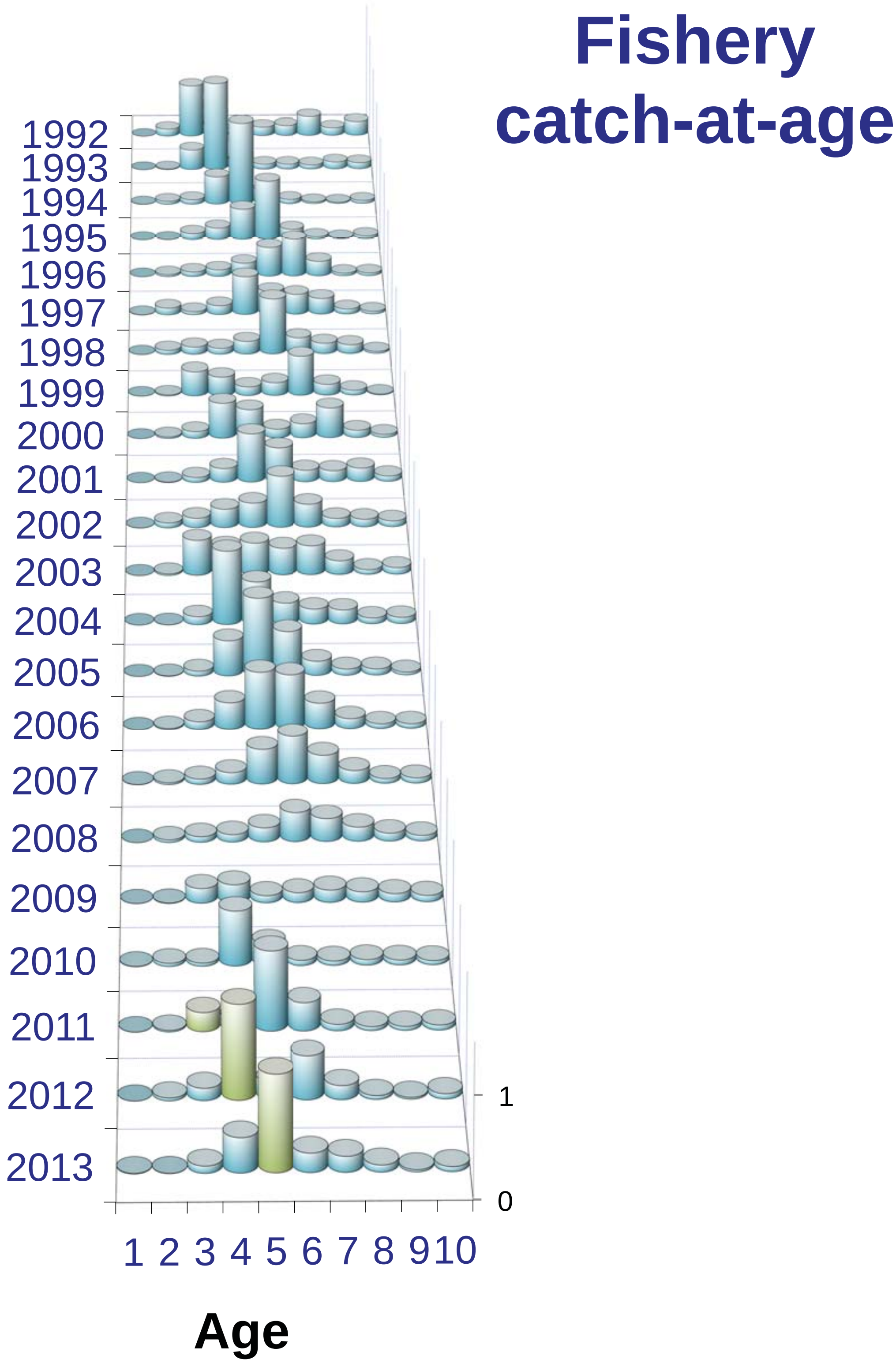

Figure 1.8. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2013. Age 10 represents pollock age 10 and older. The 2008 year-class is shaded in green.

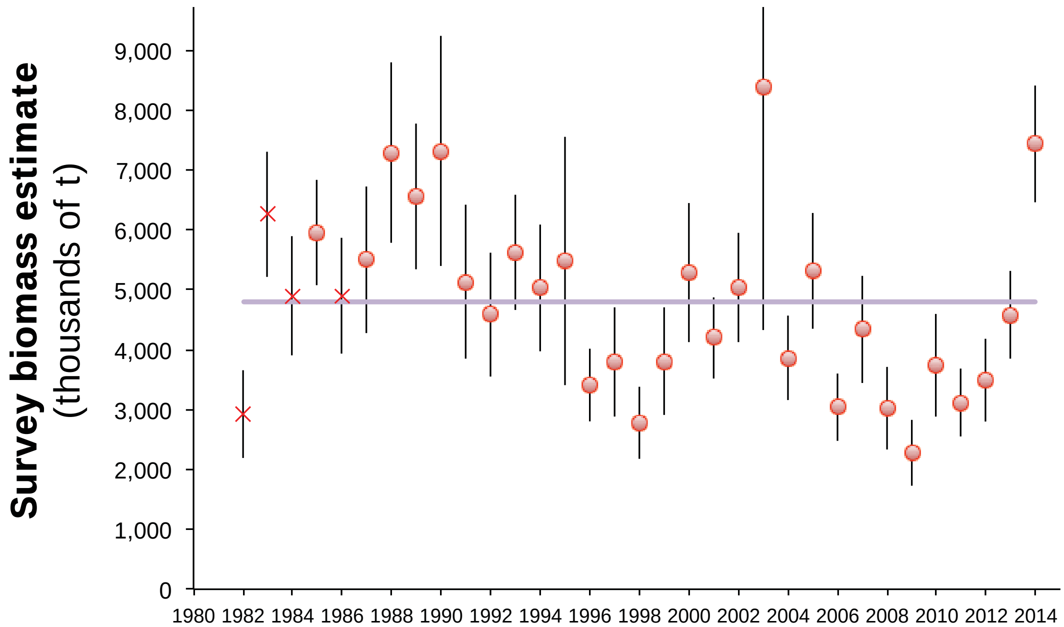

Figure 1.9. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS pollock, 1982-2014. These estimates **include** the northern strata except for 1982-84, and 1986. Horizontal line represents the long-term mean.

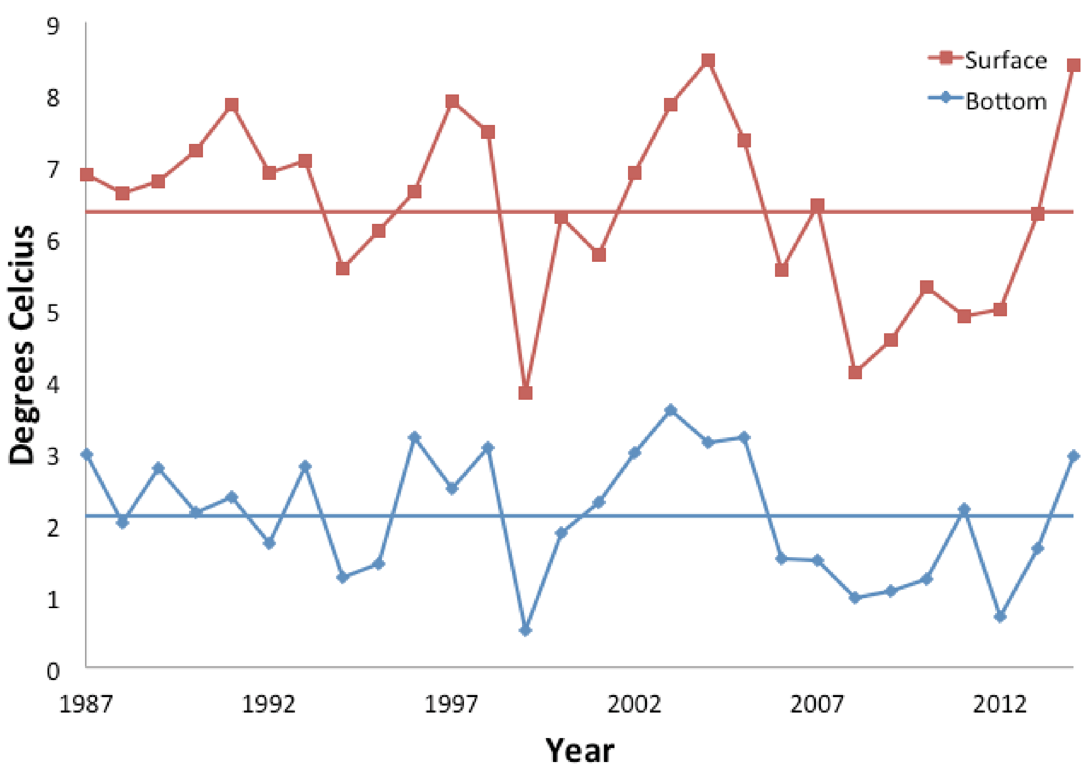

Figure 1.10. Area-weighted bottom (lower lines) and surface (upper lines) temperatures for the Bering Sea and mean values from the NMFS summer bottom-trawl surveys (1987-2014).

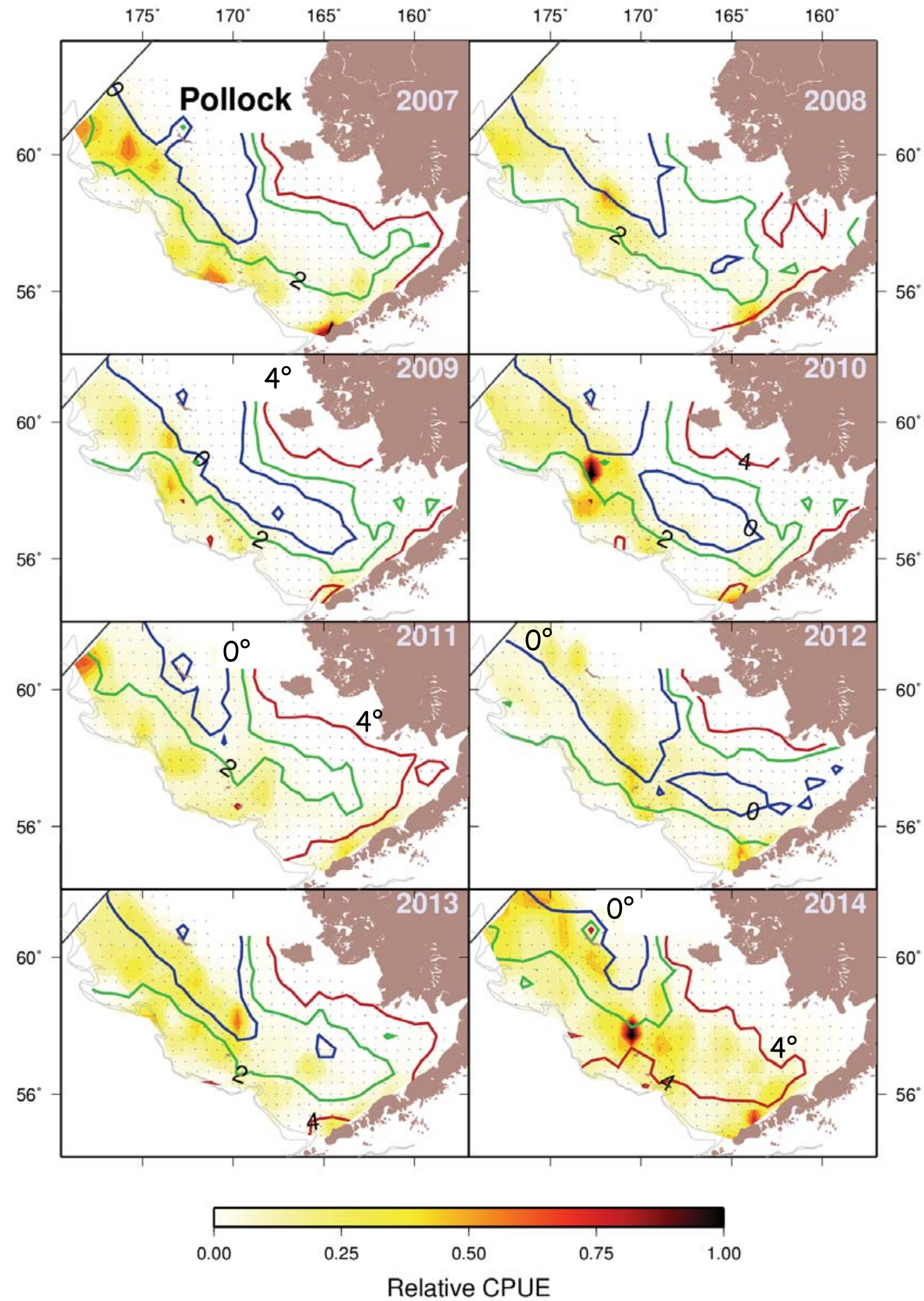

Figure 1.11. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 2007-2014.

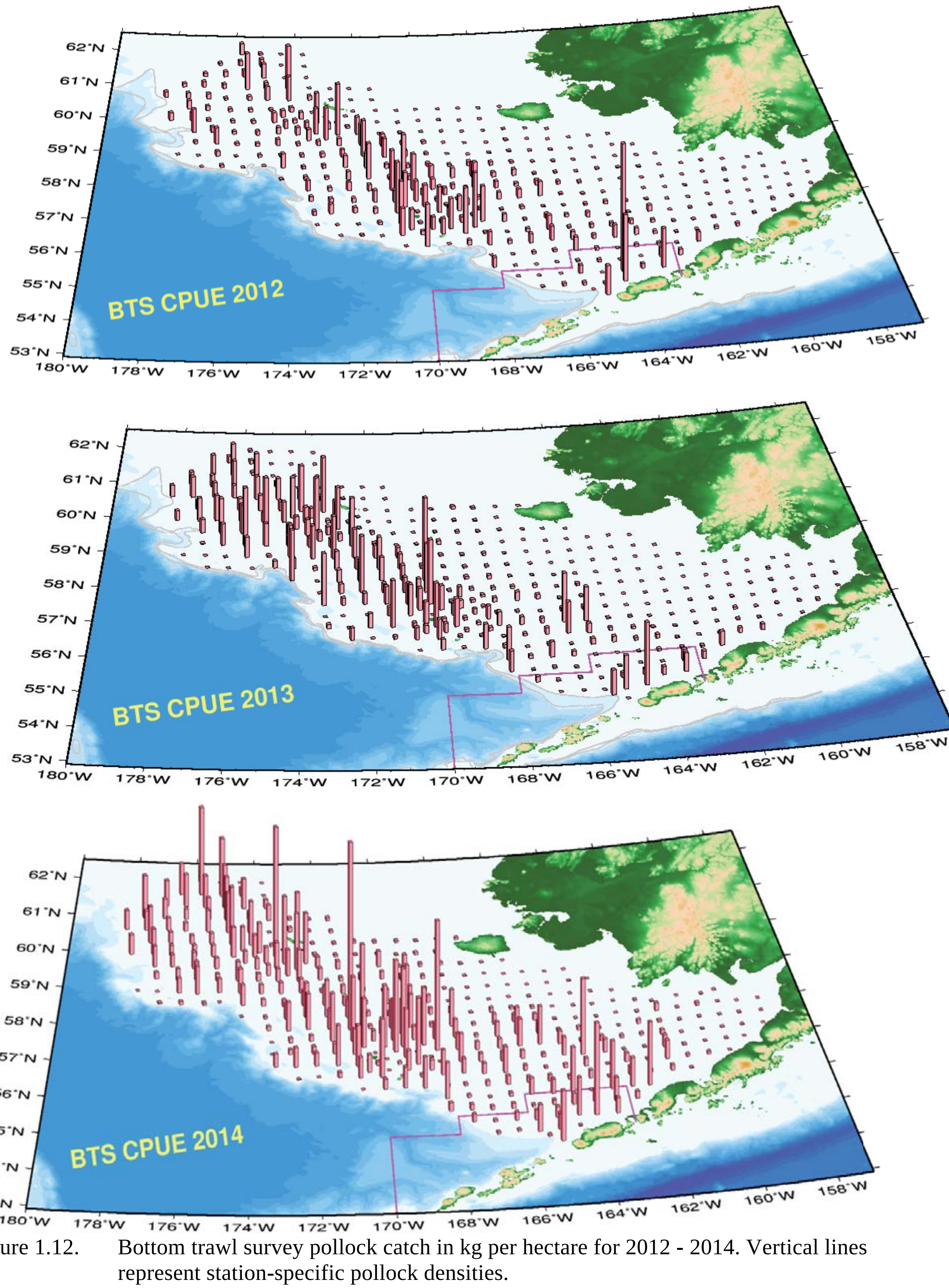

Figure 1.12. Bottom trawl survey pollock catch in kg per hectare for 2012 - 2014. Vertical lines represent station-specific pollock densities.

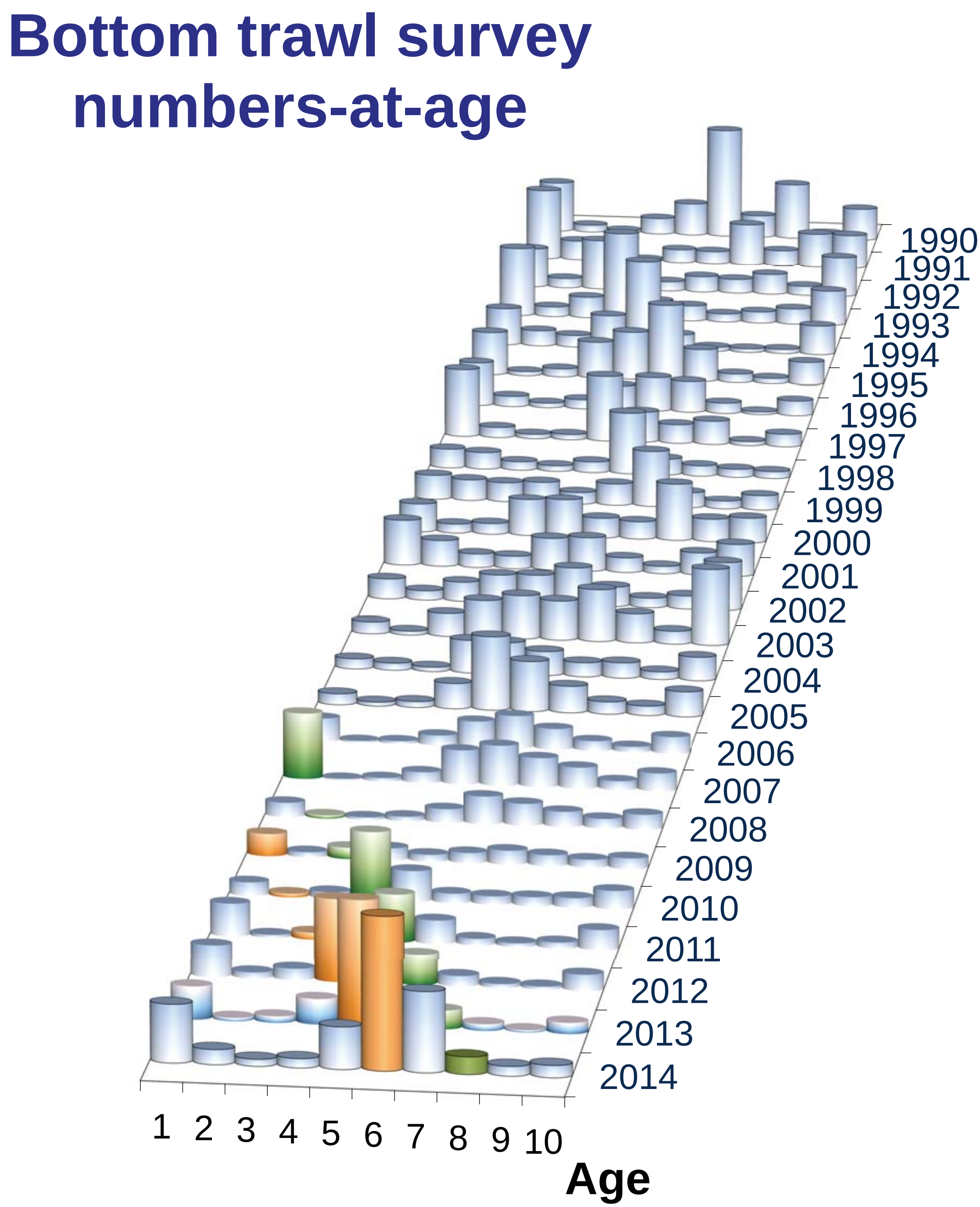

Figure 1.13. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1989-2014). The 2006 and 2008 year-classes are shaded differently.

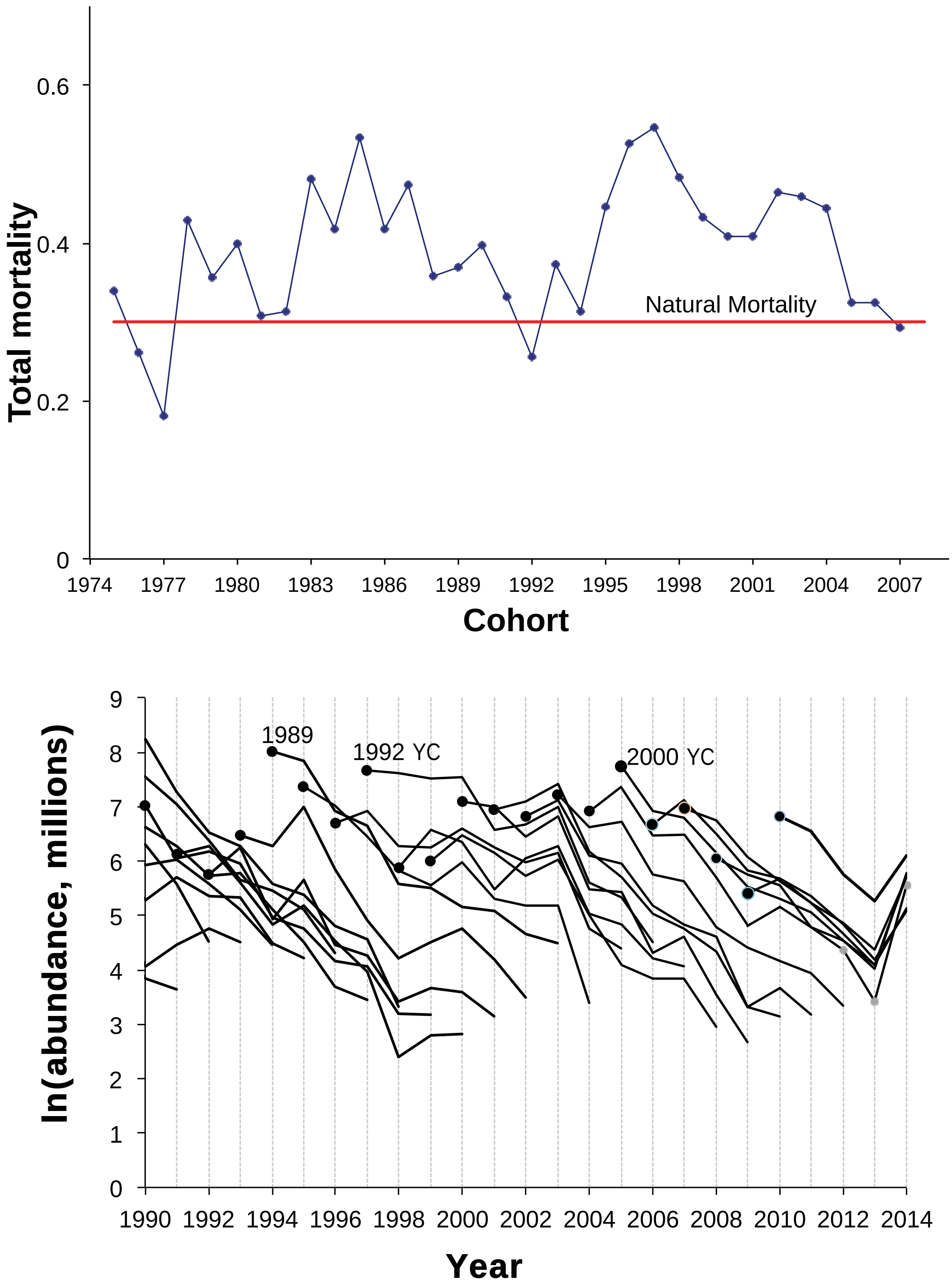

Figure 1.14. Evaluation of EBS pollock cohort abundances as observed for age 5 and older in the NMFS summer bottom trawl surveys, 1982-2014. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort.

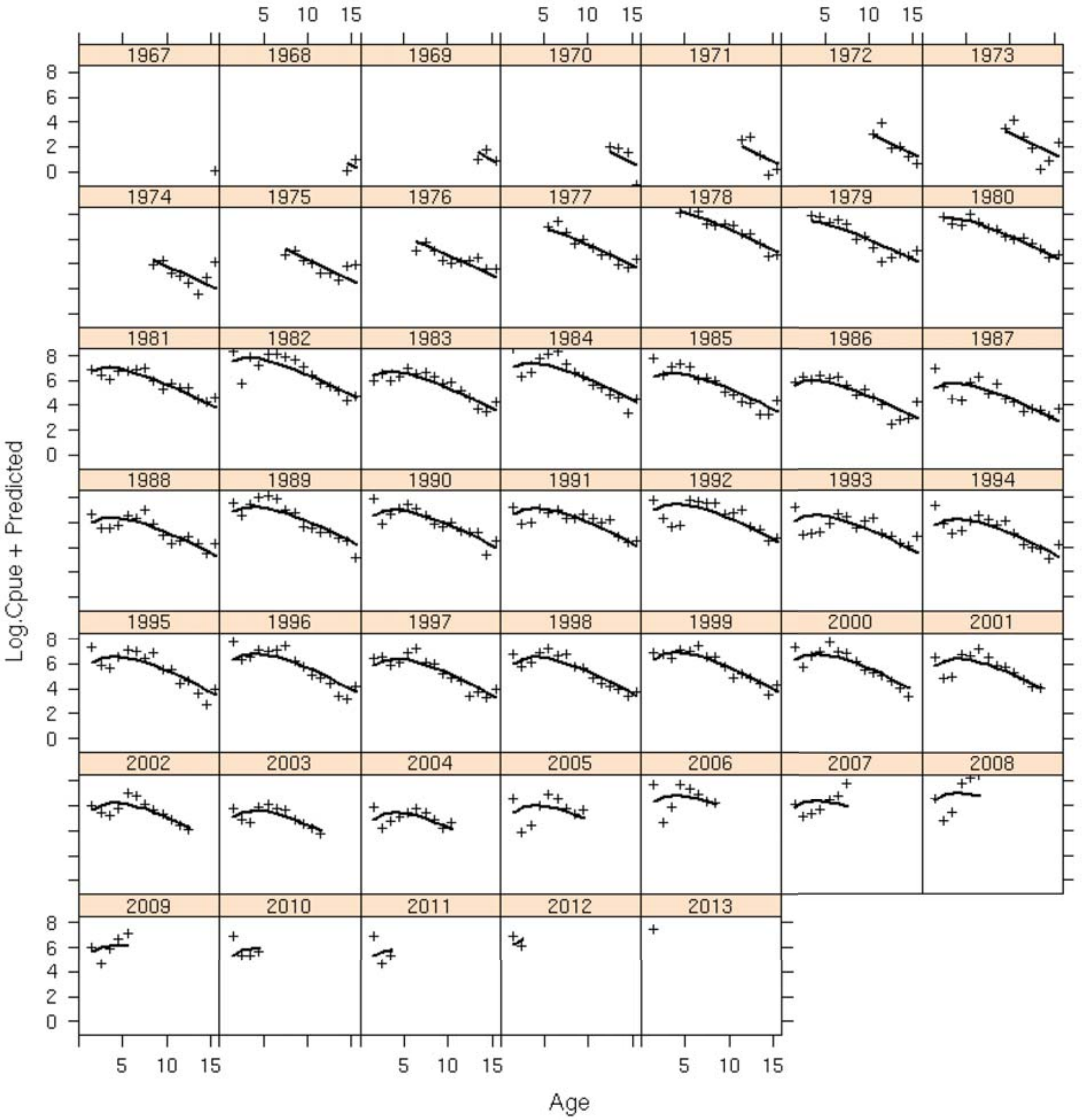

Figure 1.15. Representation of EBS pollock bottom-trawl survey log-cohort abundances modeled using the software of Cotter et al. (2007) YCC (meaning Year-Class Curves). Model configuration included cohort and age effects and each panel shows the data (+) and the model fit for each cohort.

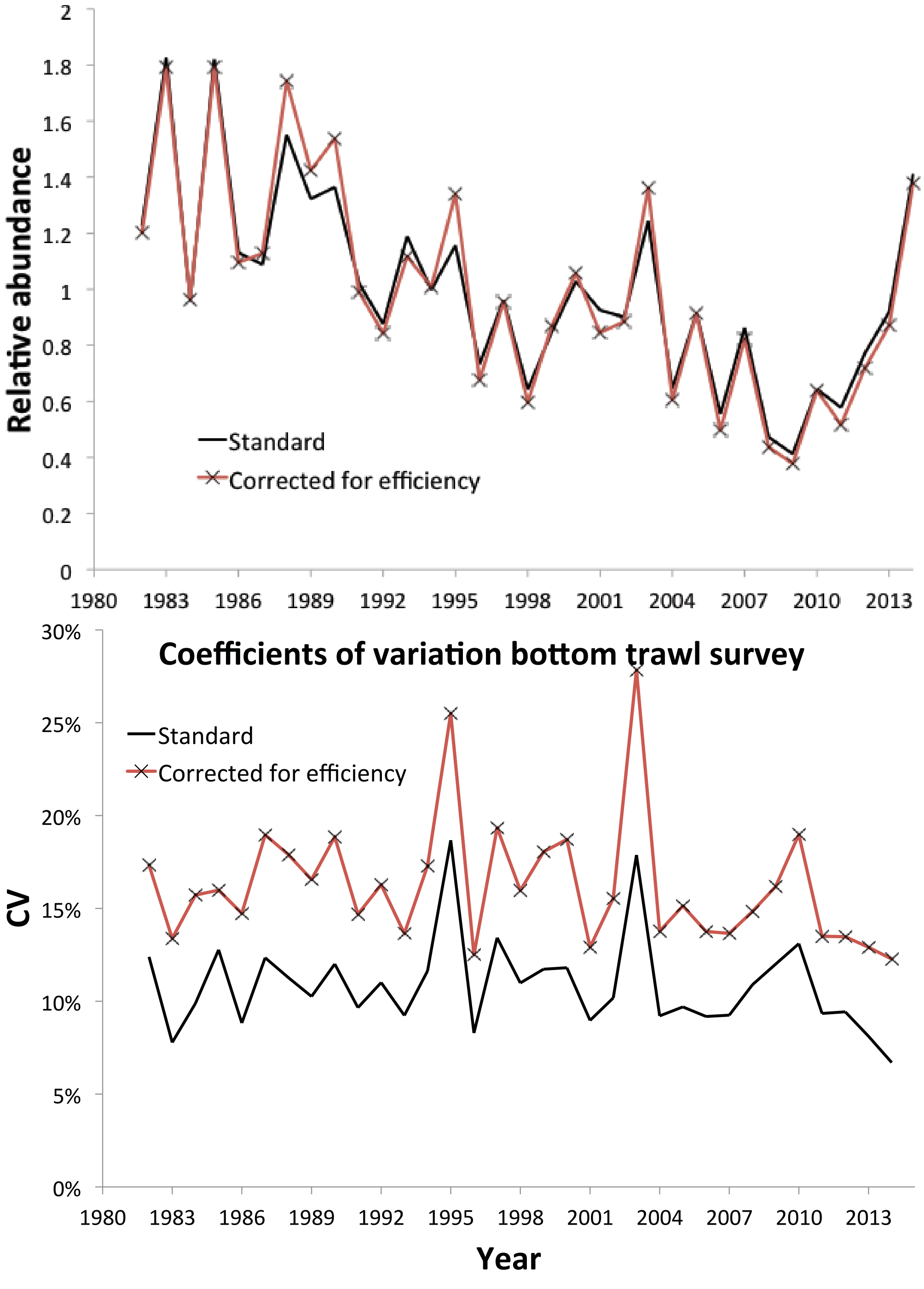

Figure 1.16. Relative abundance trends as estimated using the Kotwicki index compared to the standard survey abundance estimate (top panel) and the estimated coefficients of variation (CVs; bottom) for EBS pollock.

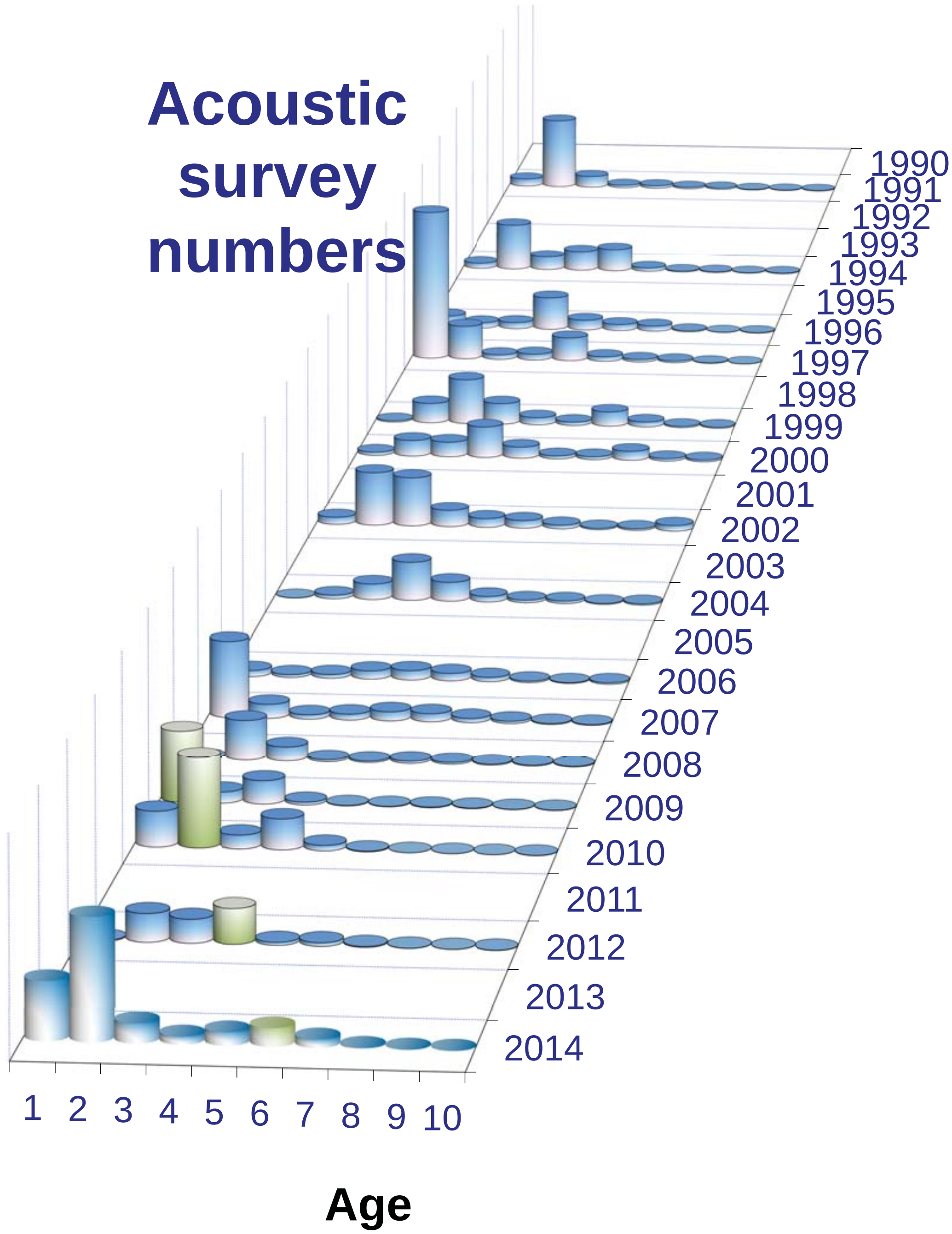

Figure 1.17. Time series of estimated numbers at age (millions) for EBS pollock from the AT surveys, 1991-2014. The differently shaded columns represent the 2008 cohort.

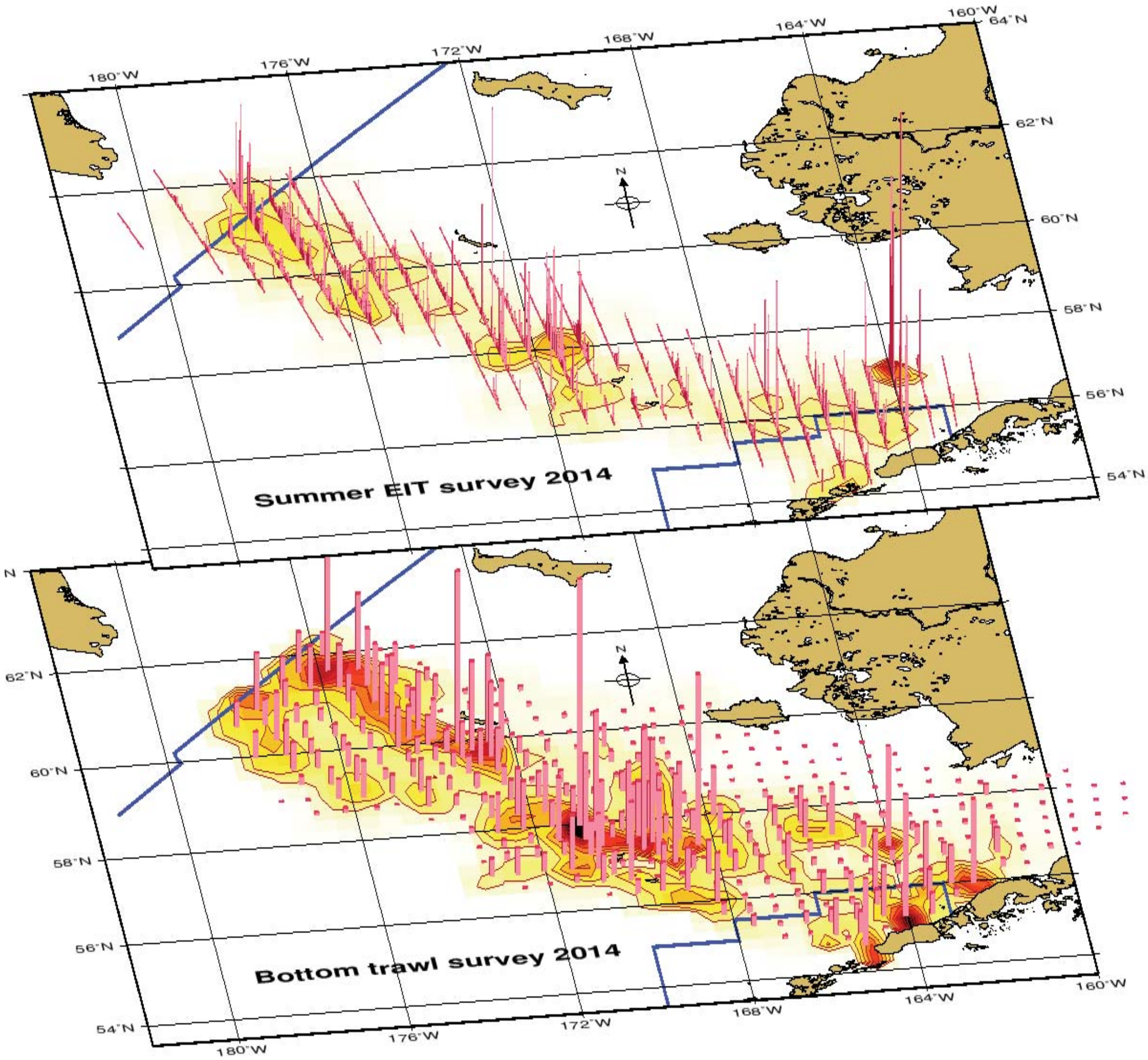

Figure 1.18. Comparison of the mid-water EBS pollock density from the AT survey (top layer) and that of the BTS (bottom layer). The blue line in the SE corner of the region delineates the Steller sea lion conservation area (SCA).

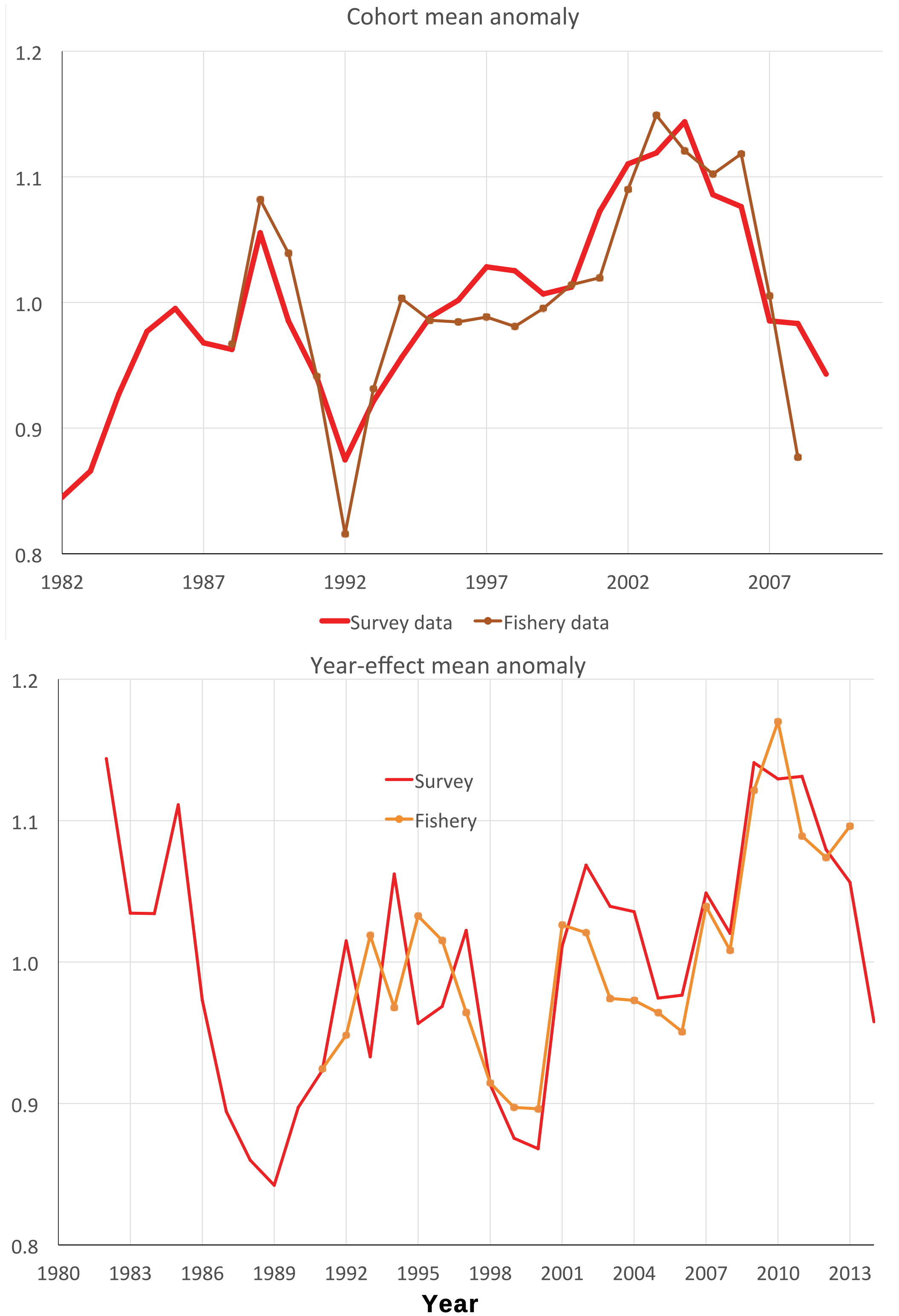

Figure 1.19. Mean fishery and bottom-trawl survey body weight anomaly (relative to their mean values) for EBS pollock by cohort (top) and by year (bottom).

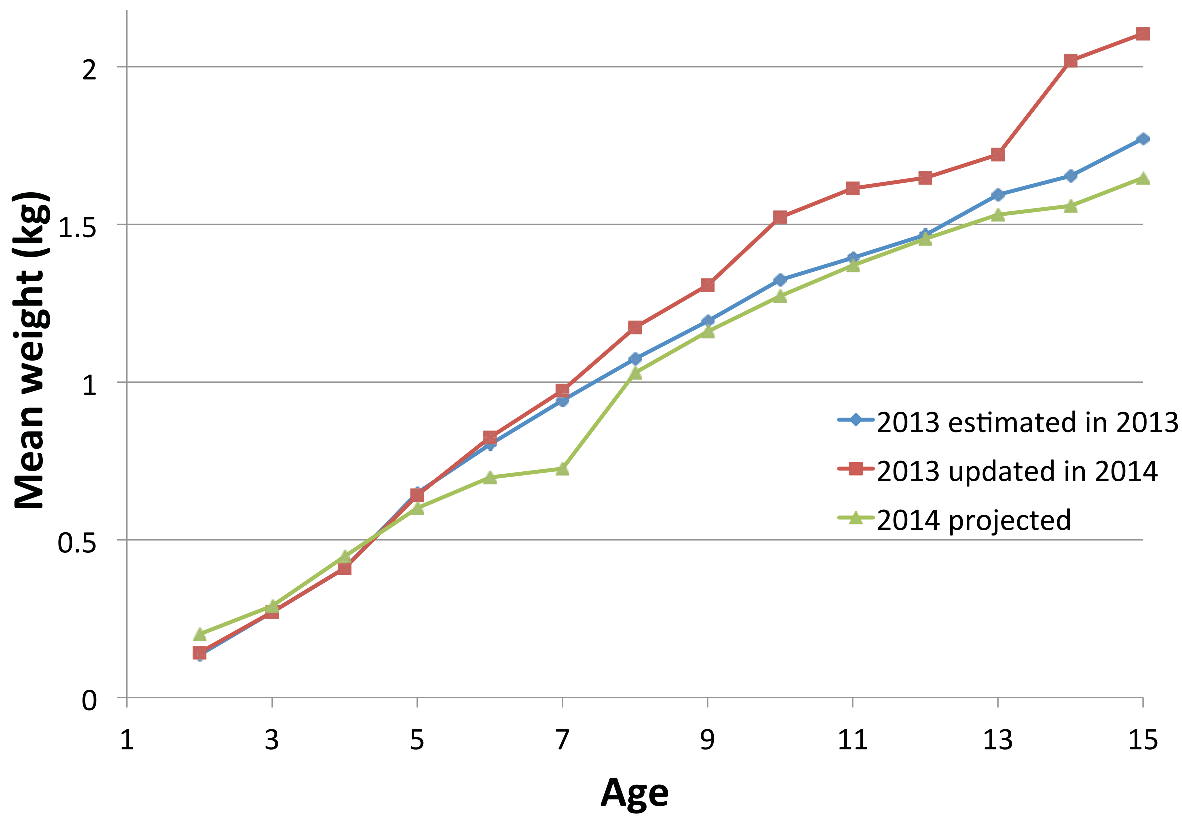

Figure 1.20. Mean fishery body mass (kg) for EBS pollock assumed for the 2013 assessment and as revised using observer data. The 2014 values are estimated as described in the text.

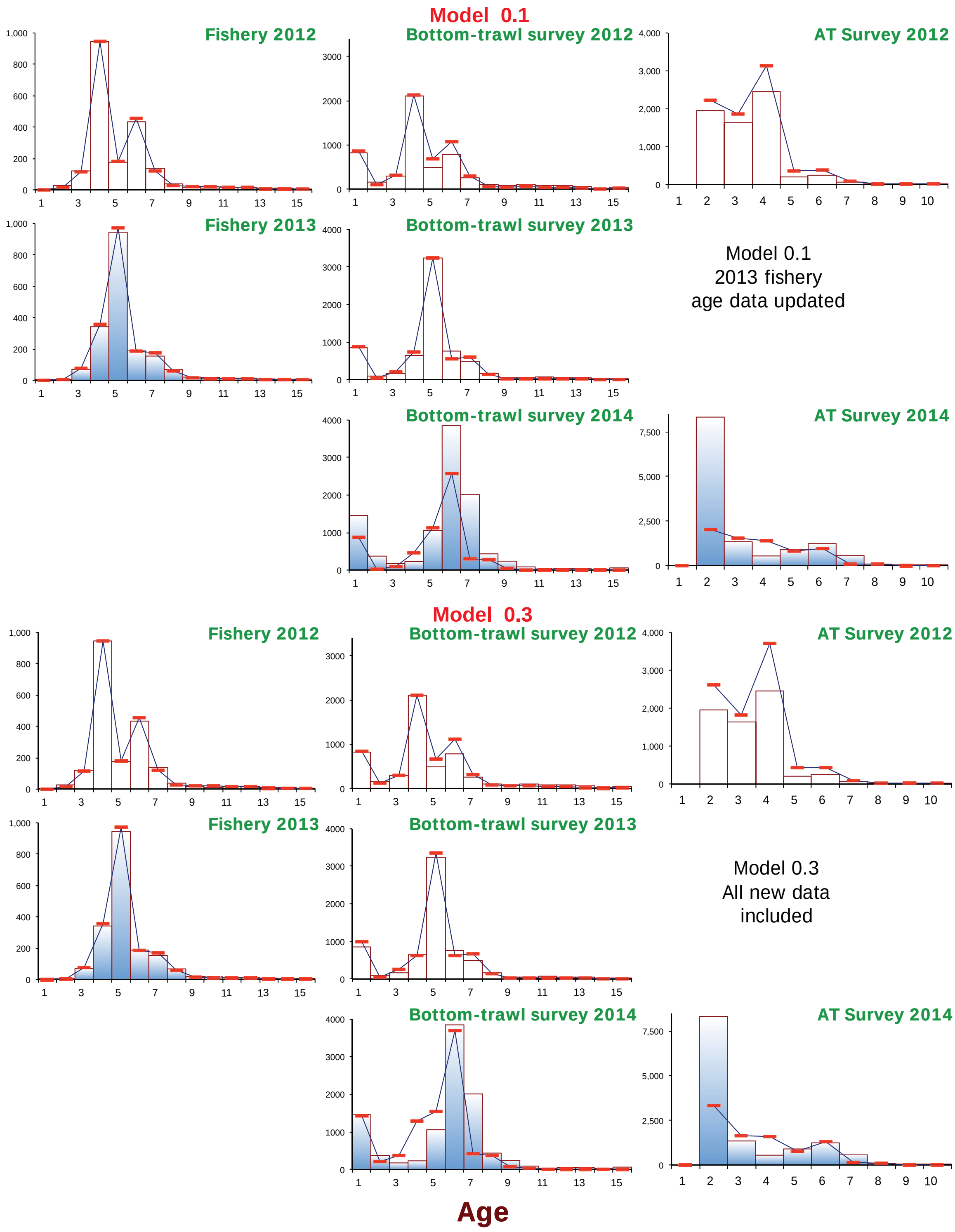

Figure 1.21. Three model configuration results of predicted EBS pollock numbers-at-age for catch and surveys as new data were added. Columns represent the data, horizontal red lines represent model predictions.

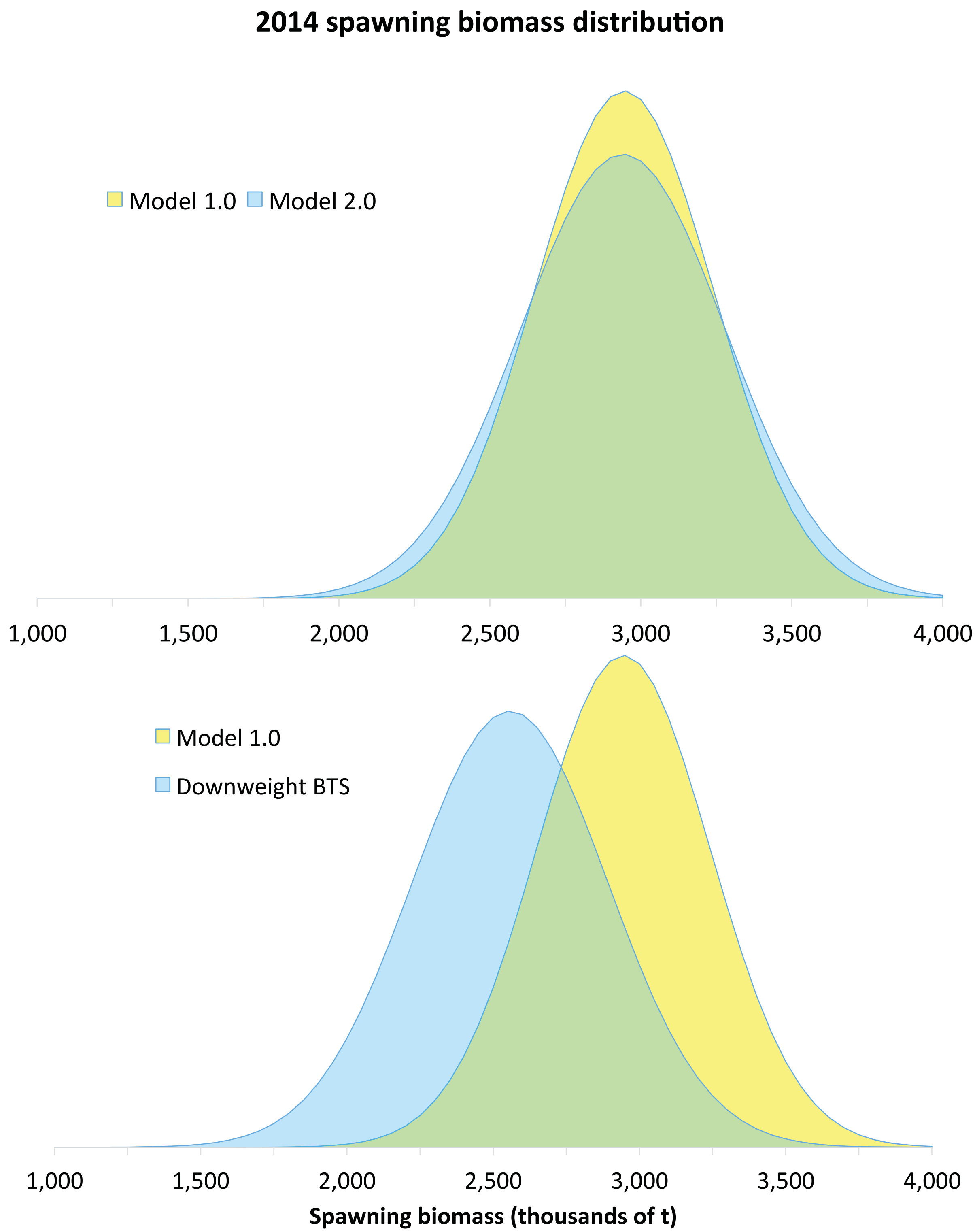

Figure 1.22. Approximate probability distributions for EBS 2014 pollock spawning biomass comparing model 1.0 (reference model) with 2.0 (model with efficiency adjusted data for the bottom trawl survey) and with a run where the BTS data area all downweighted (standard errors inflated by a factor of 100).

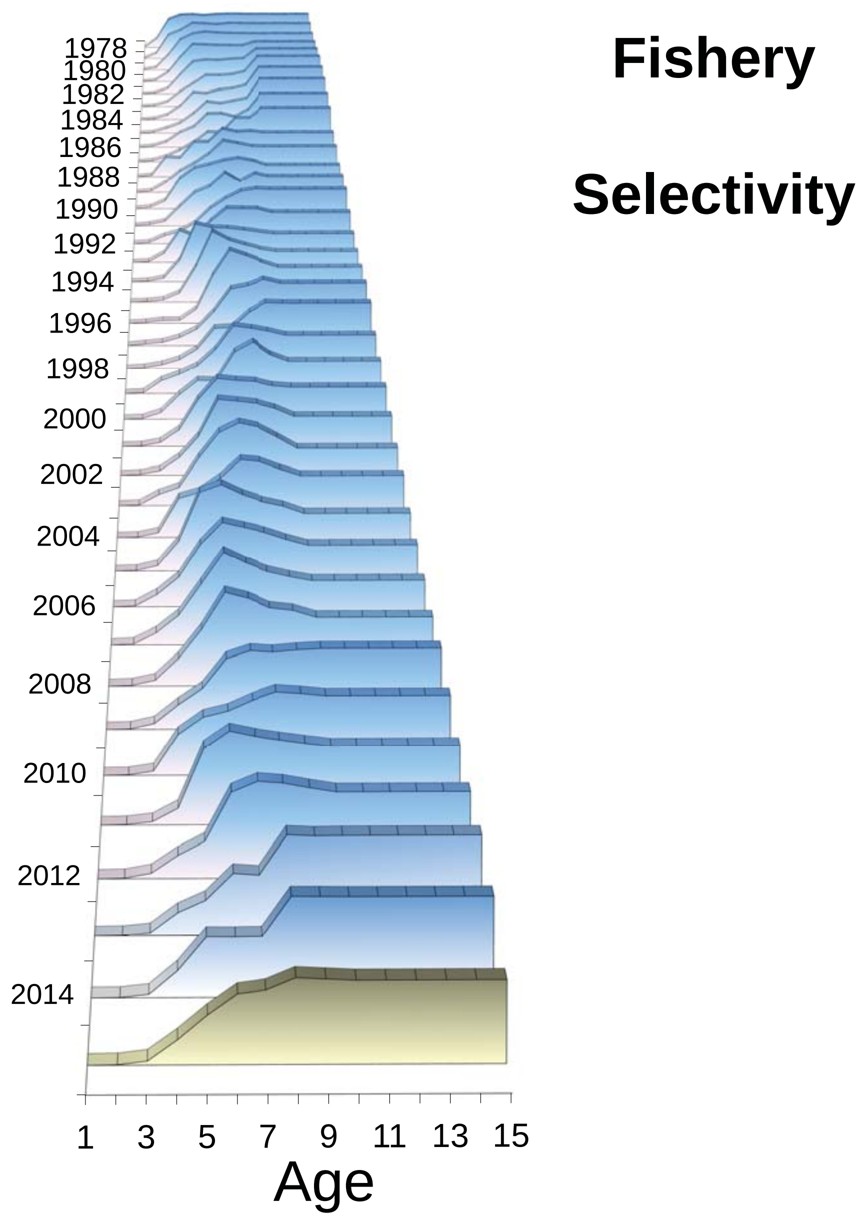

Figure 1.23. Selectivity at age estimates for the EBS pollock fishery, 1978-2014 including the estimates (front-most panel) used for the future yield considerations.

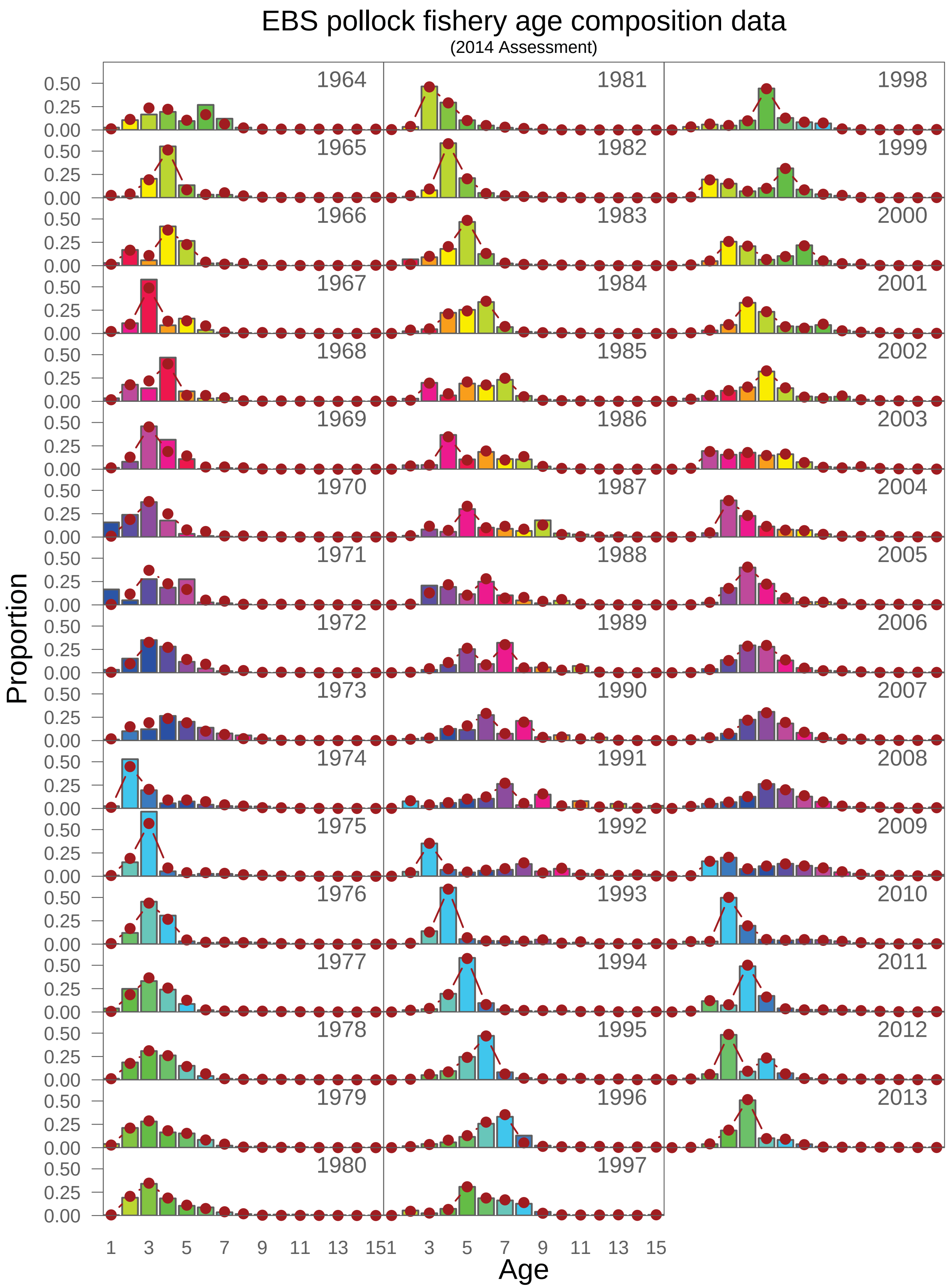

Figure 1.24. Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2013). The 2013 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

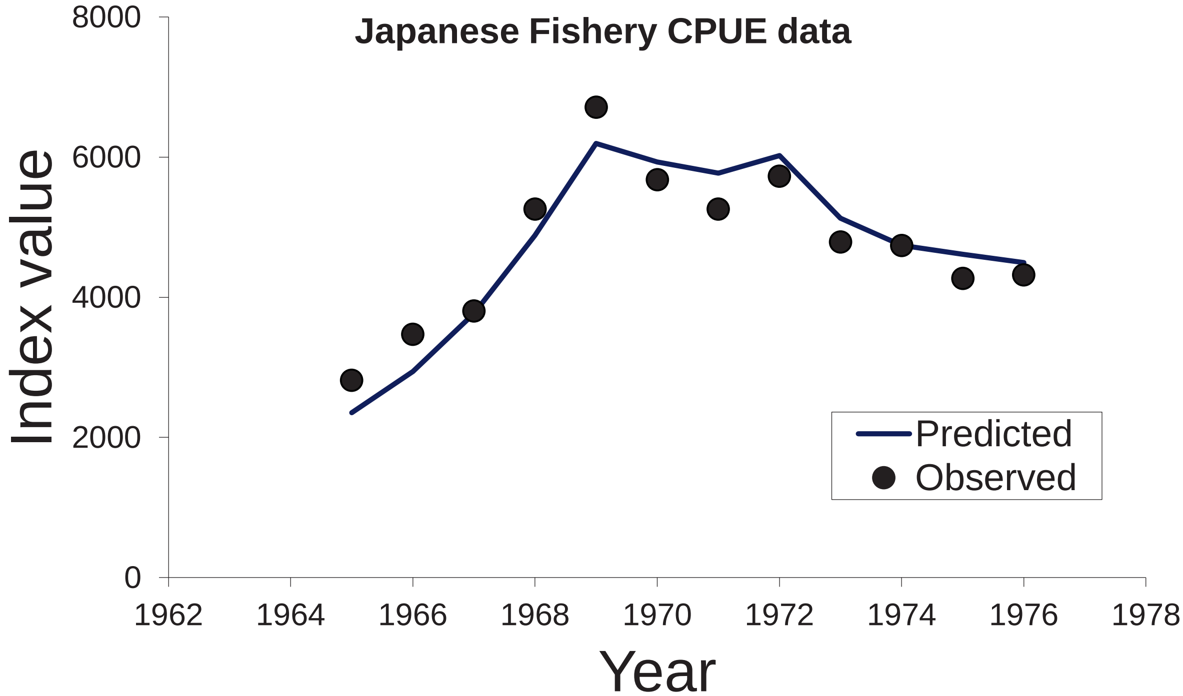

Figure 1.25. Japanese fishery CPUE (Low and Ikeda, 1980) model fits for EBS pollock, 1965-1976.

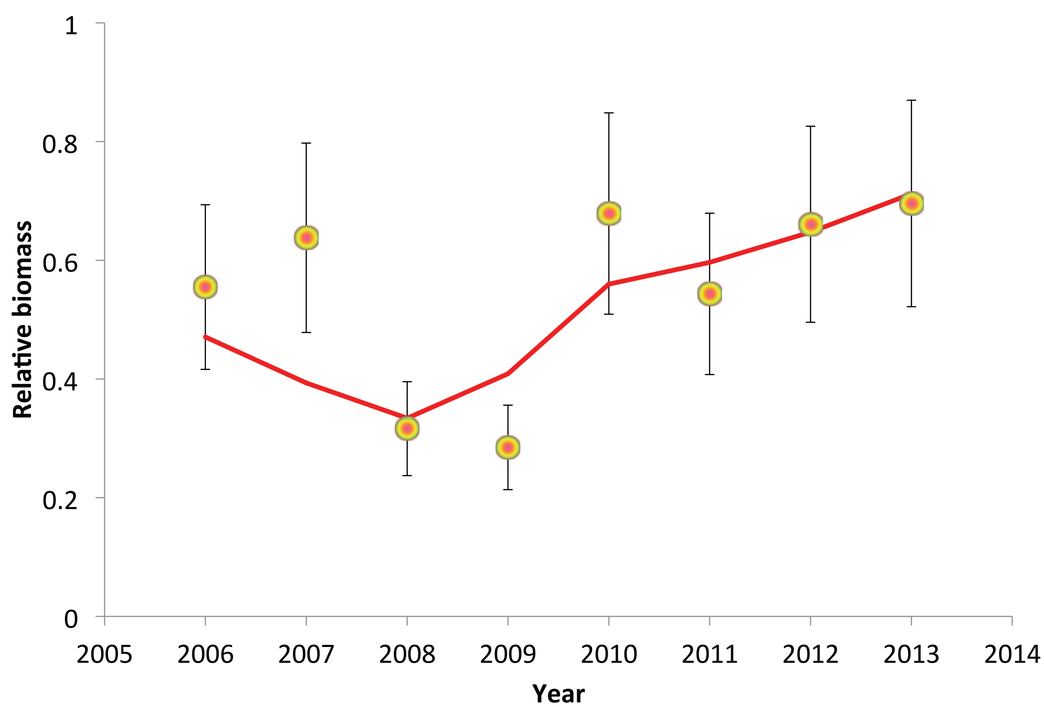

Figure 1.26. Model results of predicted EBS pollock biomass following the AVO index (under model 1.0). Error bars represent assumed 95% confidence bounds.

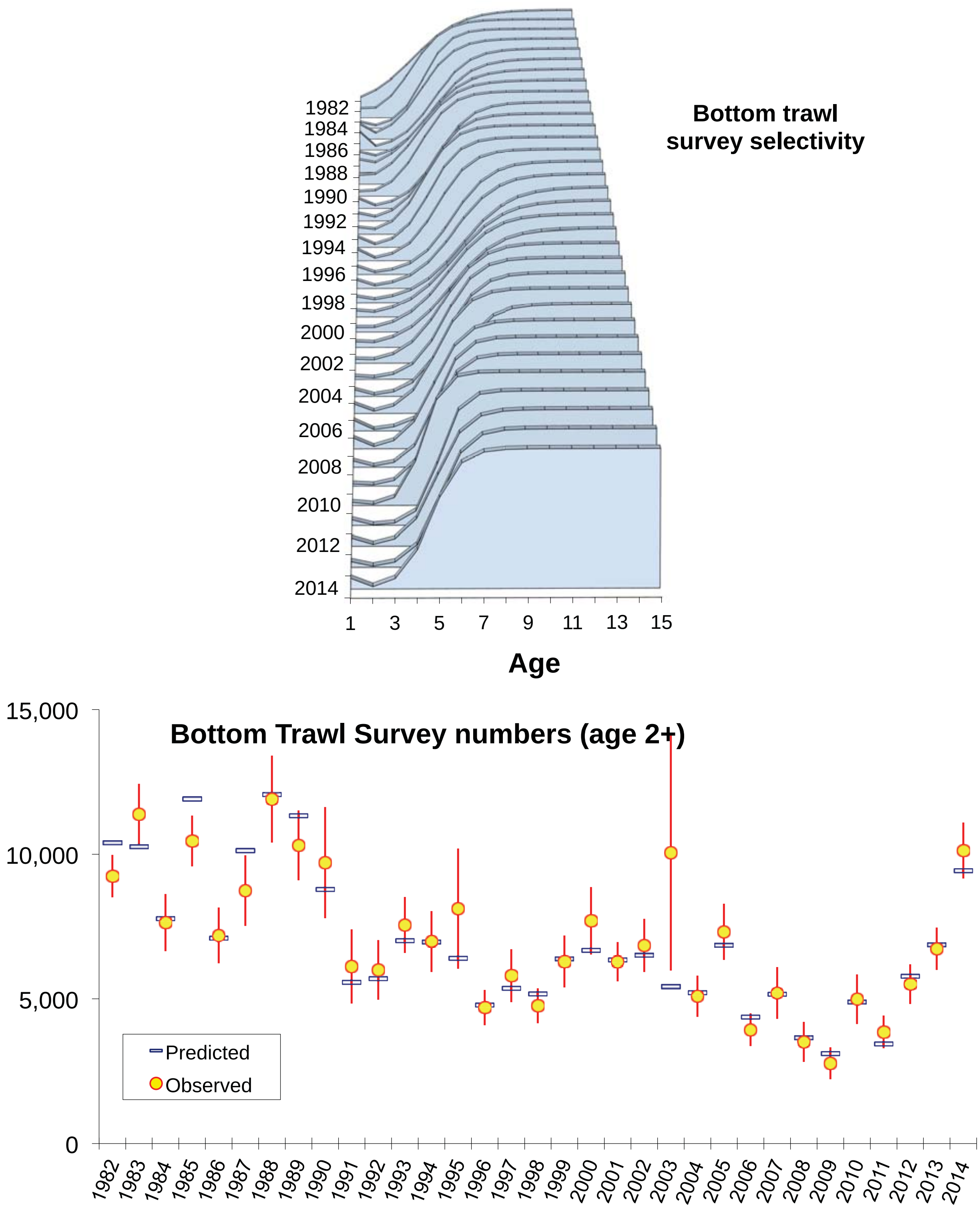

Figure 1.27. Estimates of bottom-trawl survey numbers (millions age 2 and older, lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2014.

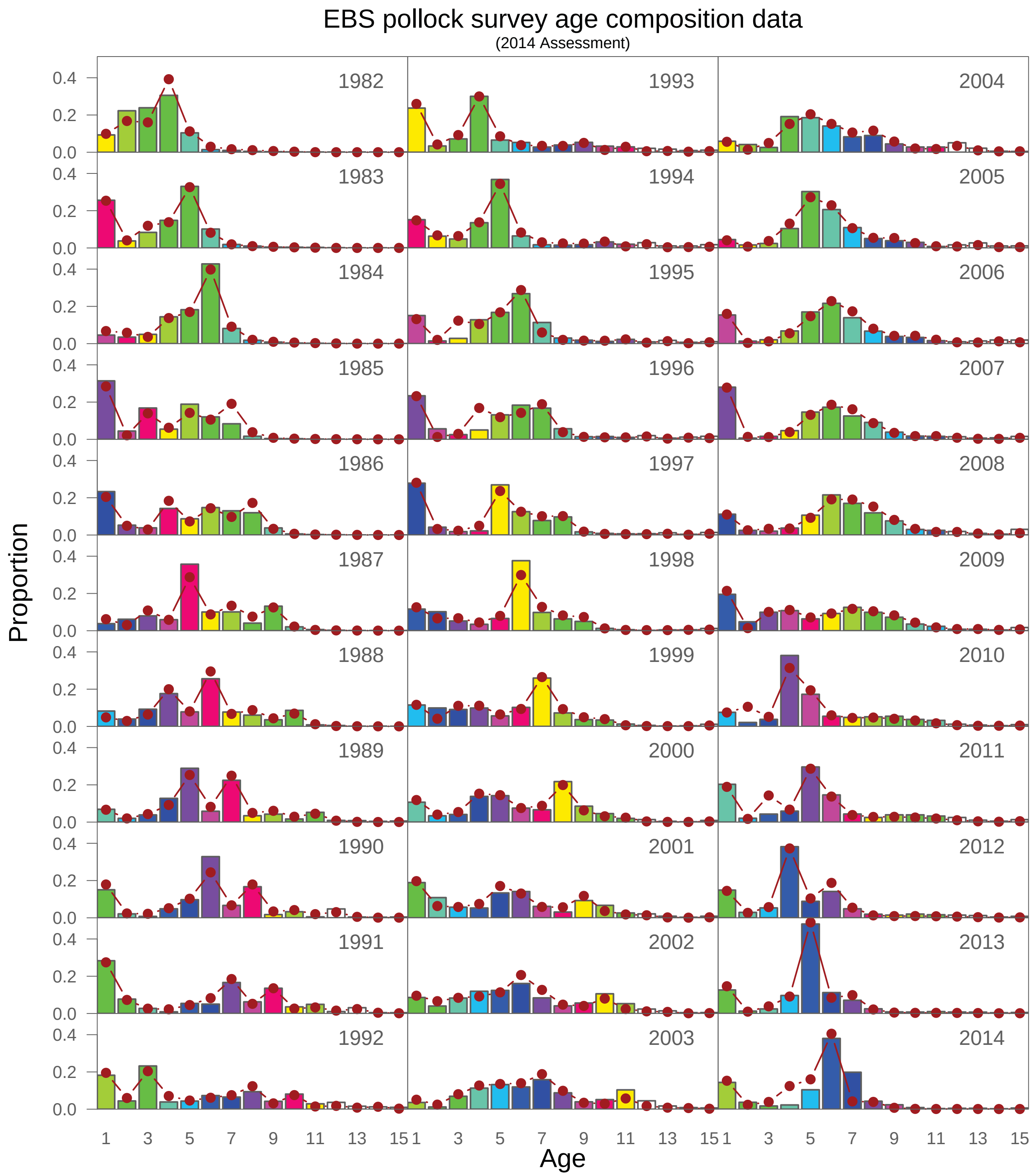

Figure 1.28. Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2014.

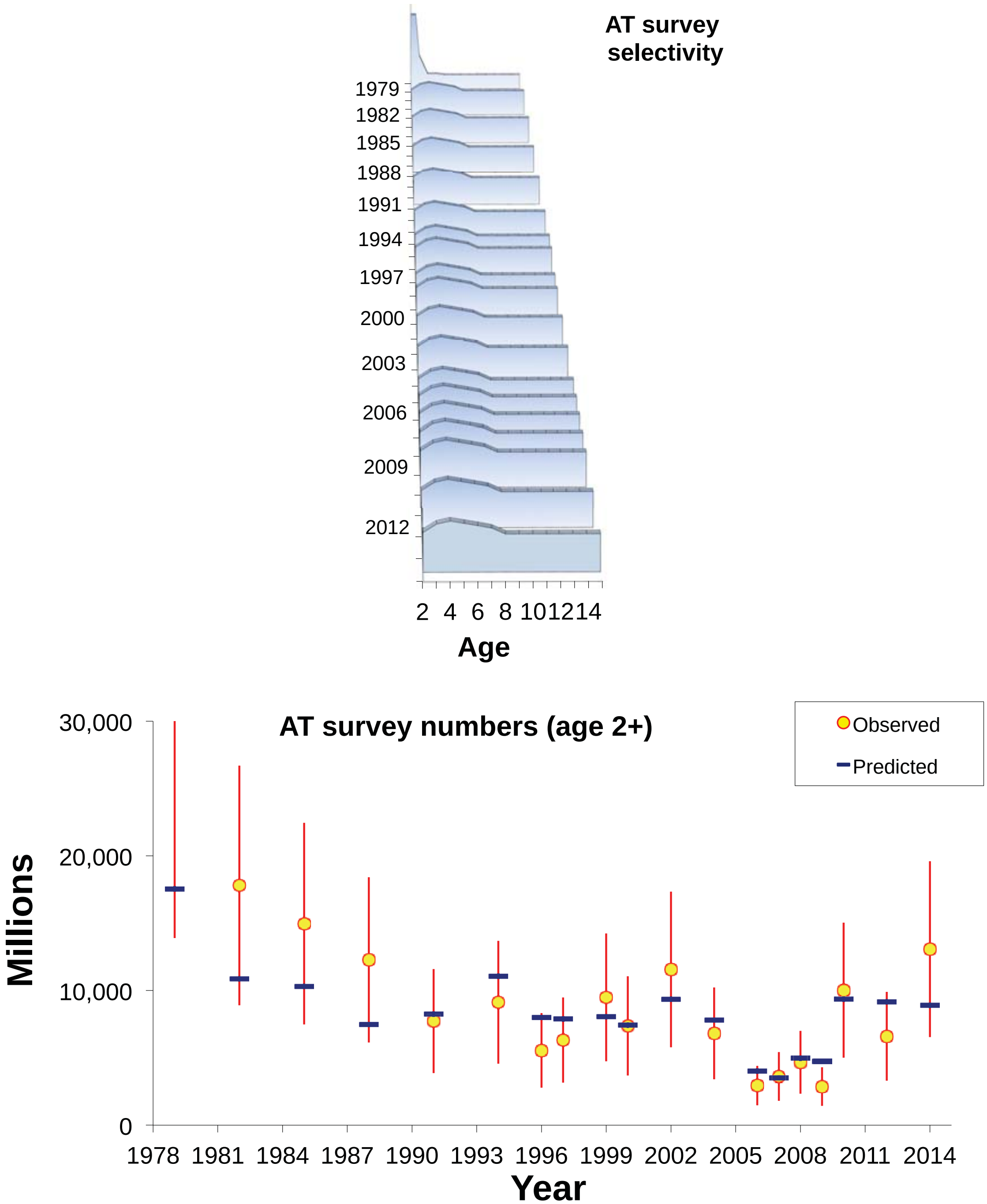

Figure 1.29. Estimates of AT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older, 1979-2014. Note that the 1979 observed value (=46,314) is off the scale of the figure.

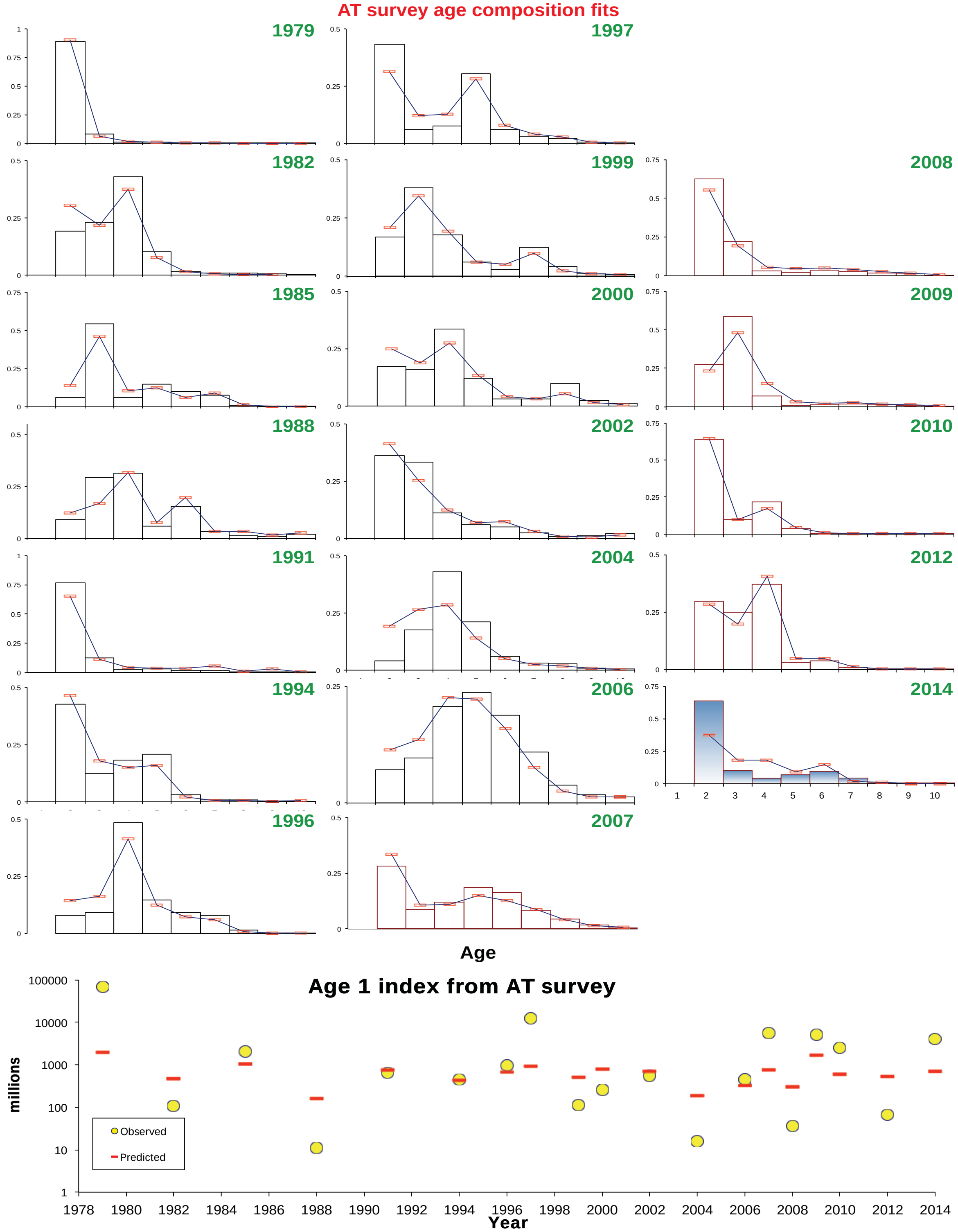

Figure 1.30. Fit to the AT survey EBS pollock age composition data (proportion of numbers) and age 1 index (bottom panel; log-scale). Lines represent model predictions while the vertical columns and dots represent data. The 2014 age composition data were based on using a bottom trawl survey age-length key, with some supplemental samples (juveniles) from the AT survey.

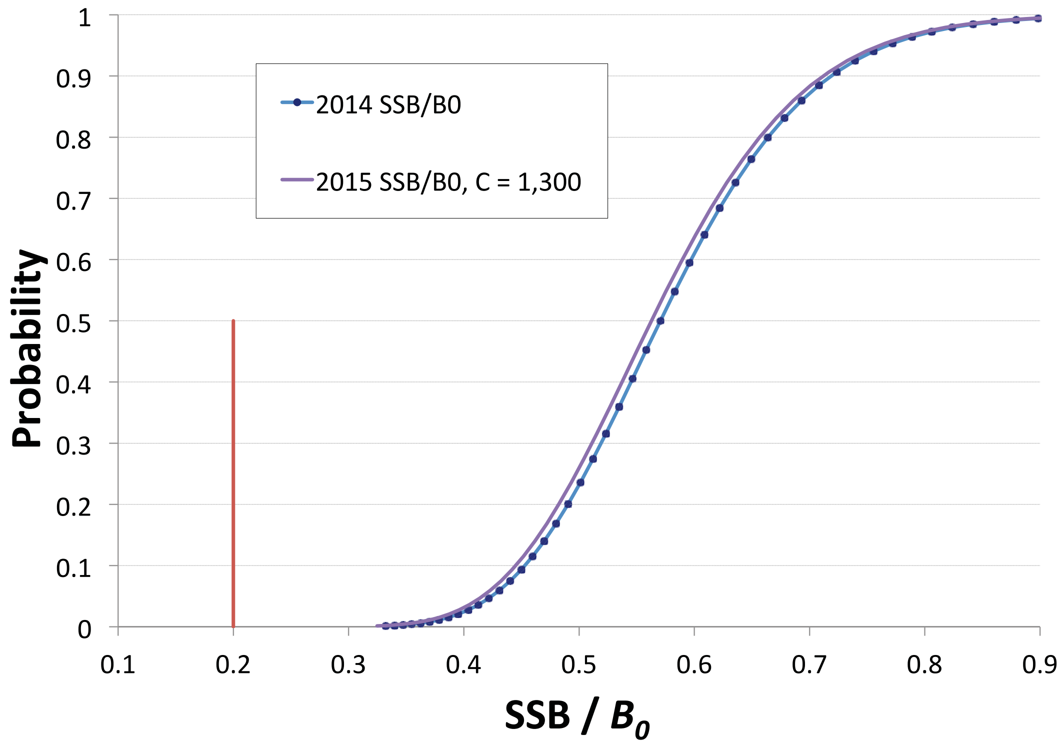

Figure 1.31. Estimated cumulative probability distribution of the 2014 and 2015 EBS pollock spawning biomass relative to B_0. C represents catch

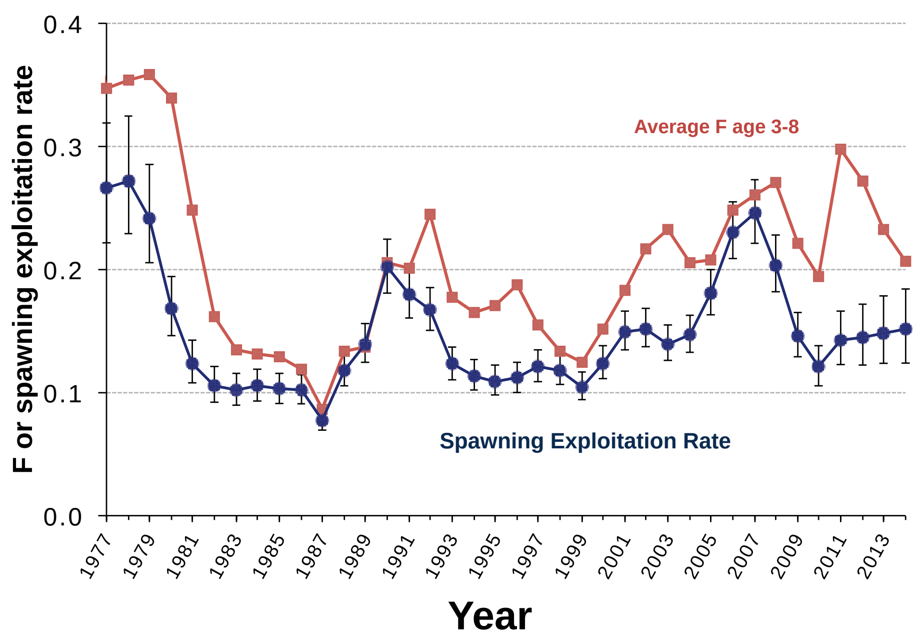

Figure 1.32. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) and average fishing mortality (ages 3-8) for EBS pollock, 1977-2014. Error bars represent two standard deviations from the estimates.

Year	2	3	4	5	6	7	8	9	10
1964	0.01	0.04	0.20	0.21	0.21	0.20	0.19	0.18	0.17
1965	0.01	0.05	0.20	0.19	0.17	0.16	0.15	0.15	0.14
1966	0.01	0.05	0.17	0.16	0.15	0.14	0.14	0.13	0.13
1967	0.03	0.16	0.24	0.24	0.23	0.23	0.23	0.22	0.22
1968	0.03	0.13	0.27	0.25	0.24	0.23	0.22	0.22	0.21
1969	0.03	0.18	0.23	0.22	0.20	0.20	0.20	0.20	0.22
1970	0.07	0.24	0.23	0.23	0.22	0.26	0.26	0.26	0.41
1971	0.07	0.28	0.32	0.35	0.34	0.33	0.34	0.34	0.65
1972	0.13	0.39	0.40	0.39	0.38	0.38	0.38	0.40	0.64
1973	0.17	0.45	0.52	0.52	0.52	0.51	0.51	0.51	0.67
1974	0.23	0.57	0.56	0.55	0.55	0.54	0.55	0.55	0.58
1975	0.11	0.54	0.50	0.47	0.46	0.45	0.45	0.45	0.52
1976	0.09	0.38	0.47	0.44	0.43	0.42	0.42	0.41	0.43
1977	0.11	0.29	0.35	0.37	0.36	0.36	0.35	0.35	0.35
1978	0.10	0.31	0.36	0.36	0.35	0.36	0.37	0.37	0.37
1979	0.06	0.26	0.32	0.40	0.39	0.38	0.40	0.39	0.39
1980	0.02	0.15	0.32	0.38	0.40	0.39	0.39	0.38	0.38
1981	0.01	0.07	0.20	0.31	0.30	0.30	0.30	0.30	0.33
1982	0.00	0.03	0.12	0.20	0.21	0.20	0.21	0.22	0.28
1983	0.00	0.03	0.09	0.14	0.19	0.18	0.19	0.21	0.30
1984	0.00	0.03	0.08	0.16	0.16	0.18	0.19	0.21	0.31
1985	0.01	0.03	0.06	0.12	0.19	0.18	0.20	0.21	0.33
1986	0.01	0.03	0.08	0.11	0.17	0.17	0.16	0.19	0.28
1987	0.00	0.02	0.04	0.07	0.11	0.11	0.16	0.16	0.20
1988	0.01	0.08	0.07	0.14	0.14	0.19	0.18	0.18	0.18
1989	0.01	0.04	0.09	0.12	0.16	0.21	0.20	0.19	0.19
1990	0.01	0.04	0.17	0.23	0.25	0.27	0.28	0.27	0.24
1991	0.01	0.03	0.12	0.21	0.24	0.33	0.28	0.33	0.31
1992	0.01	0.07	0.10	0.18	0.30	0.38	0.45	0.47	0.46
1993	0.00	0.04	0.16	0.13	0.20	0.27	0.27	0.27	0.25
1994	0.00	0.01	0.09	0.24	0.22	0.22	0.21	0.20	0.20
1995	0.00	0.01	0.04	0.15	0.31	0.27	0.25	0.23	0.22
1996	0.01	0.02	0.02	0.08	0.26	0.39	0.36	0.33	0.30
1997	0.01	0.02	0.04	0.09	0.18	0.30	0.31	0.35	0.32
1998	0.00	0.02	0.04	0.09	0.19	0.19	0.27	0.31	0.31
1999	0.00	0.04	0.06	0.09	0.14	0.21	0.21	0.20	0.18
2000	0.00	0.02	0.09	0.14	0.14	0.24	0.28	0.23	0.21
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	0.35	0.34	0.33	0.31	0.27
2003	0.00	0.05	0.08	0.21	0.33	0.37	0.35	0.30	0.25
2004	0.00	0.02	0.16	0.18	0.24	0.32	0.31	0.28	0.25
2005	0.00	0.02	0.11	0.28	0.31	0.28	0.25	0.23	0.21
2006	0.00	0.05	0.13	0.27	0.37	0.35	0.32	0.29	0.27
2007	0.00	0.05	0.13	0.27	0.41	0.37	0.33	0.30	0.29
2008	0.00	0.03	0.13	0.26	0.43	0.41	0.36	0.35	0.32
2009	0.00	0.03	0.11	0.18	0.31	0.35	0.34	0.35	0.36
2010	0.00	0.01	0.15	0.21	0.23	0.27	0.30	0.29	0.28
2011	0.00	0.02	0.08	0.38	0.46	0.44	0.42	0.40	0.38
2012	0.00	0.02	0.11	0.17	0.41	0.46	0.45	0.43	0.41
2013	0.00	0.01	0.11	0.17	0.31	0.30	0.49	0.49	0.49
2014	0.00	0.01	0.11	0.24	0.24	0.24	0.40	0.40	0.40
5-yr Avera	**0.00**	**0.02**	**0.11**	**0.23**	**0.33**	**0.34**	**0.41**	**0.40**	**0.39**
5-yr Max	**0.00**	**0.02**	**0.15**	**0.38**	**0.46**	**0.46**	**0.49**	**0.49**	**0.49**
5-yr Min	**0.00**	**0.01**	**0.08**	**0.17**	**0.23**	**0.24**	**0.30**	**0.29**	**0.28**

Figure 1.33. Estimated instantaneous age-specific fishing mortality rates for EBS pollock, 1964-2014. (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).

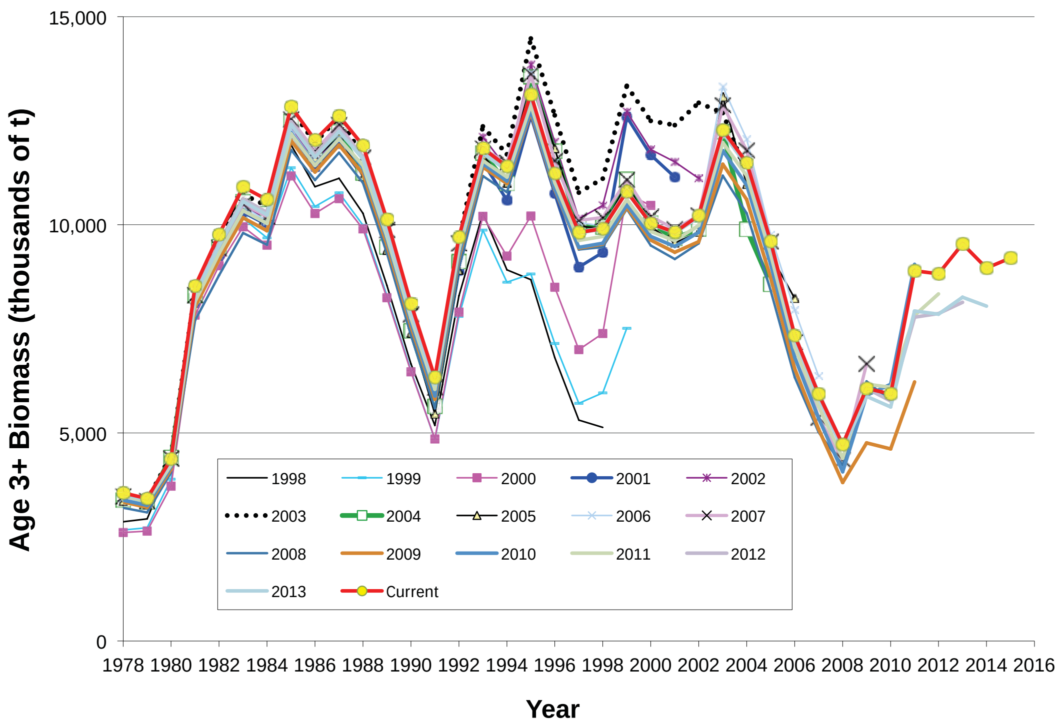

Figure 1.34. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2015.

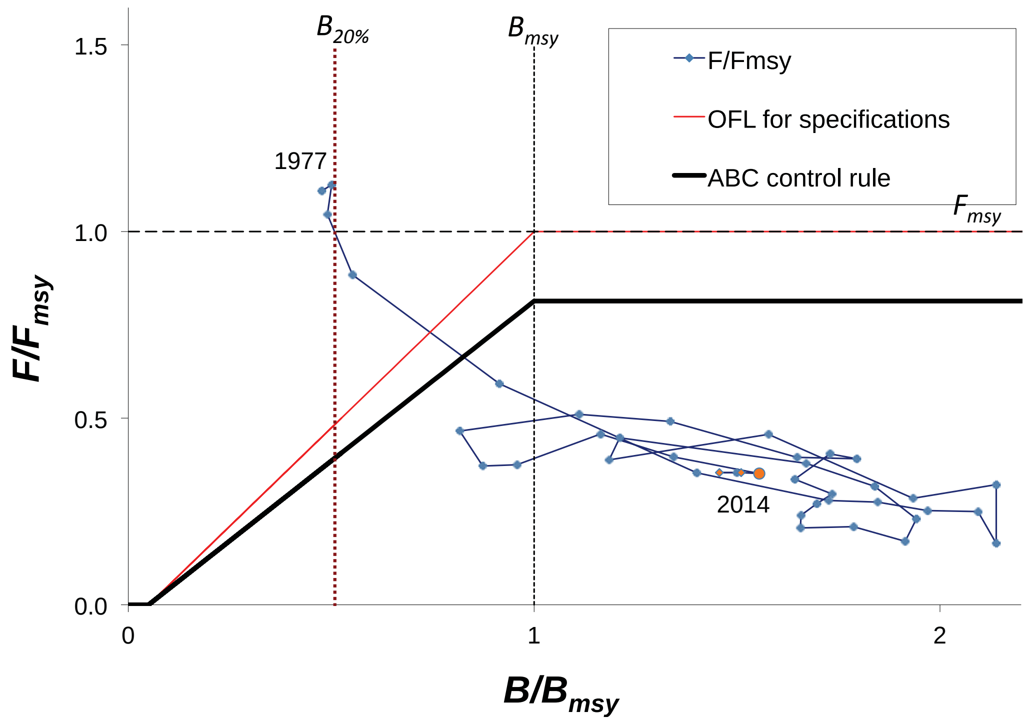

Figure 1.35. Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock, 1977-2014 (plus 2015 and 2016 in highlighted dots). *Note that the control rules for OFL and ABC are designed for setting specifications in future years.*

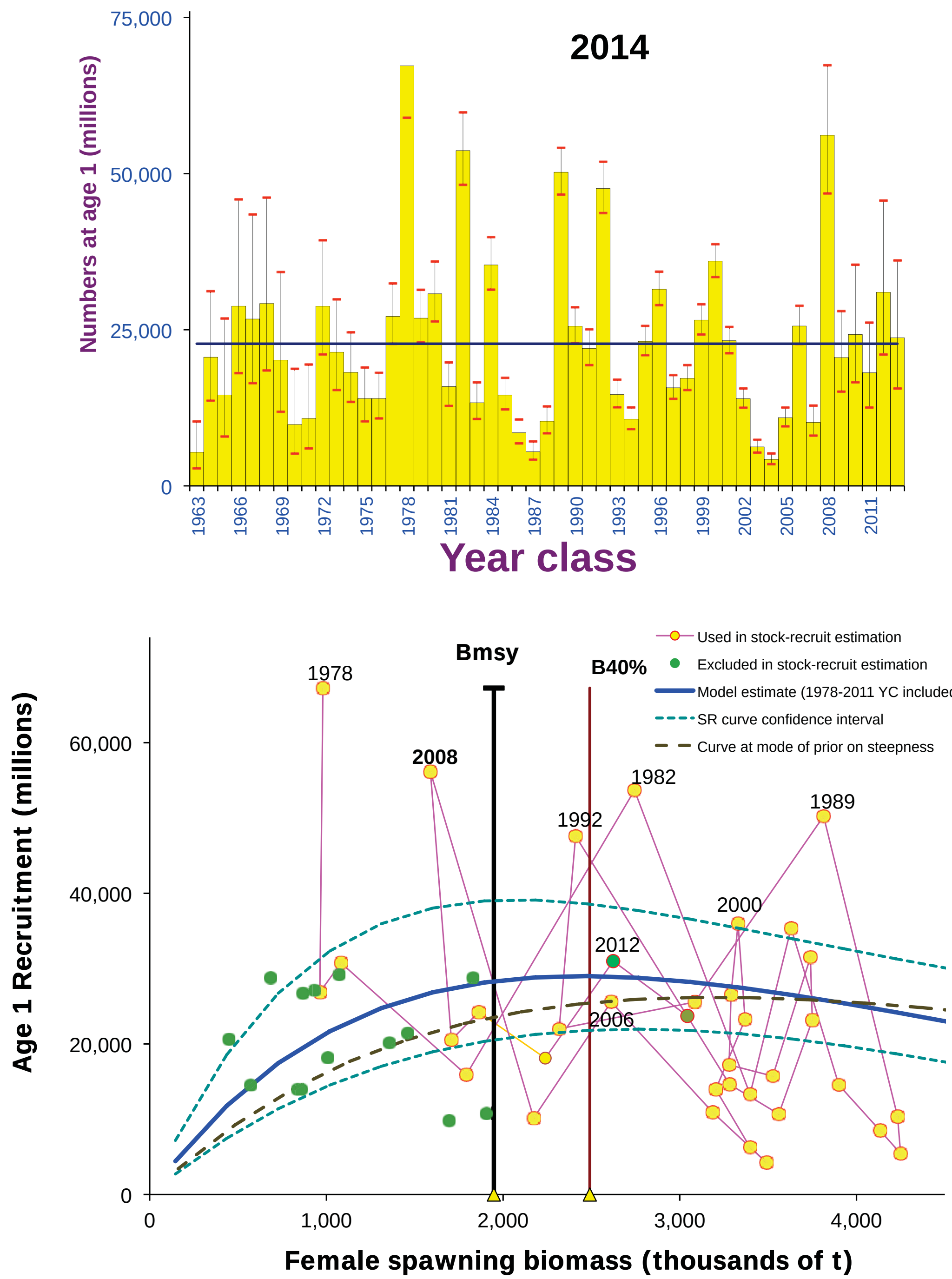

Figure 1.36. Year-class strengths by year (as age-1 recruits, upper panel) and relative to female spawning biomass (thousands of tons, lower panel) for EBS pollock. Labels on points correspond to year classes labels (measured as one-year olds). Solid line in upper panel represents the mean age-1 recruitment for all years since 1964 (1963-2013 year classes). Vertical lines in lower panel indicate B_{MSY} and $B_{40\%}$ level, curve represents fitted stock-recruitment relationship with dashed lines representing approximate lower and upper 95% confidence limits about the estimated curve.

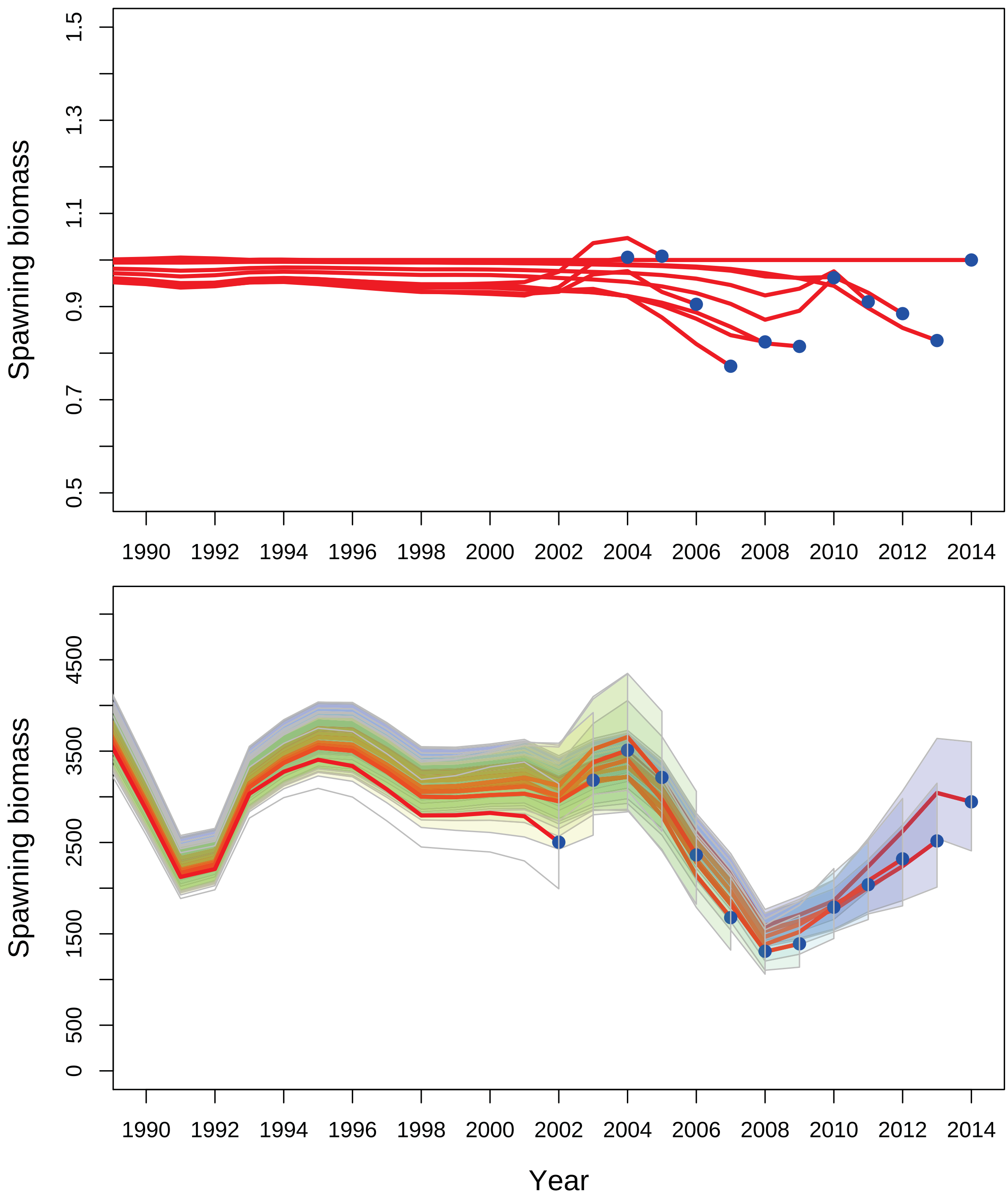

Figure 1.37. Retrospective patterns of model 1 for EBS pollock spawning in retrospective year for 2002-2014 showing the point estimates relative to the terminal year (top panel) and approximate confidence bounds on absolute scale (+2 standard deviations; bottom panel). Mohn's rho was estimated at -0.11 for the 10-year period.

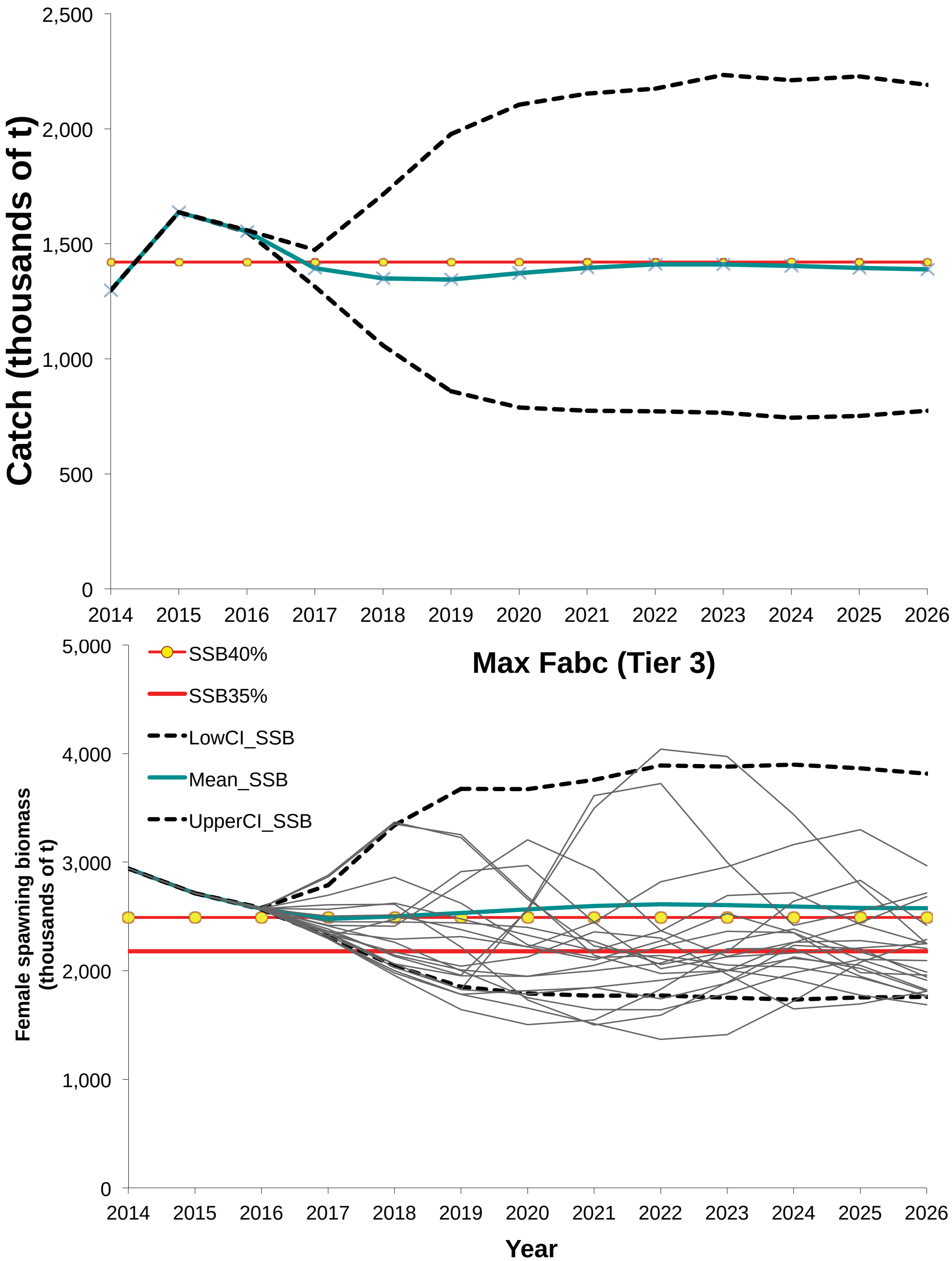

Figure 1.38. Projected EBS **Tier 3** pollock **yield** (top) and **female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2012. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1. The grey lines represent a sub-sample of simulated trajectories. Note that the numbers at age 2 in 2014 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

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

.... (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	is the total catch in year t,
w_a	is the mean body weight (kg) of fish in age class a,
Y_t	is the total yield biomass in year t,
$F_{t,a}$	is the instantaneous fishing mortality for age class a, in year t,
M_{ta}	is the instantaneous natural mortality in year t for age class a, and
Z_{ta}	is the instantaneous total mortality for age class a, in year t.

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

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

$$S_{t+1,a} = s_{t,a} e^{\gamma_t} \quad \gamma_t \sim N\; 0, \sigma_s^2$$

.... (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:

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

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

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

The parameters to be estimated in this part of the model are thus $\bar{\alpha}, \bar{\beta}, \delta_t^{\mu}, \delta_t^{\alpha}$, and δ_t^{β} for t=1982, 1983,…2014. The variance terms for these process-error parameters were specified to be 0.04.

For the natural mortality-at-age options, we followed the Lorenzen (1996) equation:

$$M_a = 3.69 \bar{W}_a^{-0.305}$$

and for the Gislason et al. (2010) :

$$\ln M_a = 0.55 - 1.61 \ln L_a + 1.44 \ln L_\infty + \ln K$$

with L_∞, K equal to 706 mm and K equal to 0.1757.

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 sigmas was allowed for the AT data. This allowed better flexibility for this survey that occurs at irregular intervals and reduces the number of parameters estimated (previously, the random walk penalty occurred for every year regardless of whether a survey occurred).

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 ($\hat{\bar{a}}$):

$$f = \text{var}\left(r_i^a \sqrt{\frac{N_i}{s_i}} \right)^{-1}$$

$$r_i^a = \bar{a}_i - \hat{\bar{a}}_i$$

$$s_i = \left[\sum_j^A \bar{a}_i^2 p_{ij} - \hat{\bar{a}}_i^2 \right]^{0.5} \quad \text{(Eq. 6)}$$

where r_i^a is the residual of mean age and

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

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 (e.g., Fig. 1.39).

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). (k_t):

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

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

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

and f_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:

$$R_t = f(B_{t-1}) = \frac{B_{t-1}e^{e_t}}{a + bB_{t-1}} \quad \text{(Eq. 10)}$$

where

R_t is recruitment at age 1 in year *t*,

B_t is the biomass of mature spawning females in year *t*,

e_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. 1.40. 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 0.6 and CV of 12% (implying that there is about an 8% chance that the steepness is greater than 0.7). 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.

In past years the value of s_R was fixed at 0.9. In 2013 an iterative approach to estimating the value was adopted which involved the following steps:

1) Estimate the recruitment variability about the stock recruitment with negligible constraint, and compute the resulting standard deviation of the residuals, σ_{R_u} (which results in a value of 0.731)
2) Estimate the value of stock recruitment variability within the model (σ_{R_E} = 0.598)
3) Compute the approximate value of specified variability as $\sigma_R = \sqrt{\sigma_{R_u}^2 - \sigma_{R_E}\left(\sigma_{R_u} - \sigma_{R_E}\right)}$ which results in a value of 0.674; preliminary results with this value results in unreasonably high estimated productivity from the stock-recruit curve. Further analysis are required to ascertain whether the impact on stock productivity would lead to robust management measures.

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

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

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

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

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

Diagnostics

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

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

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

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

Parameter estimation

The objective function was simply the sum of the negative log-likelihood function and logs of the prior distributions. To fit large numbers of parameters in nonlinear models it is useful to be able to estimate certain parameters in different stages. The ability to estimate stages is also important in using robust likelihood functions since it is often undesirable to use robust objective functions when models are far from a solution. Consequently, in the early stages of estimation we use the following log-likelihood function for the survey and fishery catch at age data (in numbers):

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

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

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

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

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:

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

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

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

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

and $t^2 = 1/n$

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

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

Completing the estimation in this fashion reduces the model sensitivity to data that would otherwise be considered outliers.

Within the model, predicted survey abundance accounted for within-year mortality since surveys occur during the middle of the year. As in previous years, we assumed that removals by the survey were insignificant (i.e., the mortality of pollock caused by the survey was considered insignificant). Consequently, a set of analogous catchability and selectivity terms were estimated for fitting the survey observations as:

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

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

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

For the AVO index, the values for selectivity were assumed to be the same as for the AT survey and the mean weights at age over time was also assumed to be equal to the values estimated for the AT survey.

For these analyses we chose to keep survey catchabilities constant over time (though they are estimated separately for the AVO index and for the AT and bottom trawl surveys). The contribution to the negative log-likelihood function (ignoring constants) from the surveys is given by either the lognormal distribution:

$$\sum_t \left(\frac{\ln\left(A_t^s / \hat{N}_t^s\right)^2}{2\sigma_{s,t}^2} \right) \text{ .... (Eq. 20)}$$

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:

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

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

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

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

where $\mathbf{X}$ is a vector of observed minus model predicted values for this index and Σ is the estimated covariance matrix provided from the method provided in Kotwicki et al. 2013.

The contribution to the negative log-likelihood function for the observed total catches (O_t) by the fishery is given by

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

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 future mean weights for each age i, i= (1, 2,…,15), given actual observed mean and variances in weight-at-age over the period 1991-2013. The values of $\bar{w}_i, \sigma^2_{w_i}$ based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

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

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 2015 and 2016 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}:

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

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.

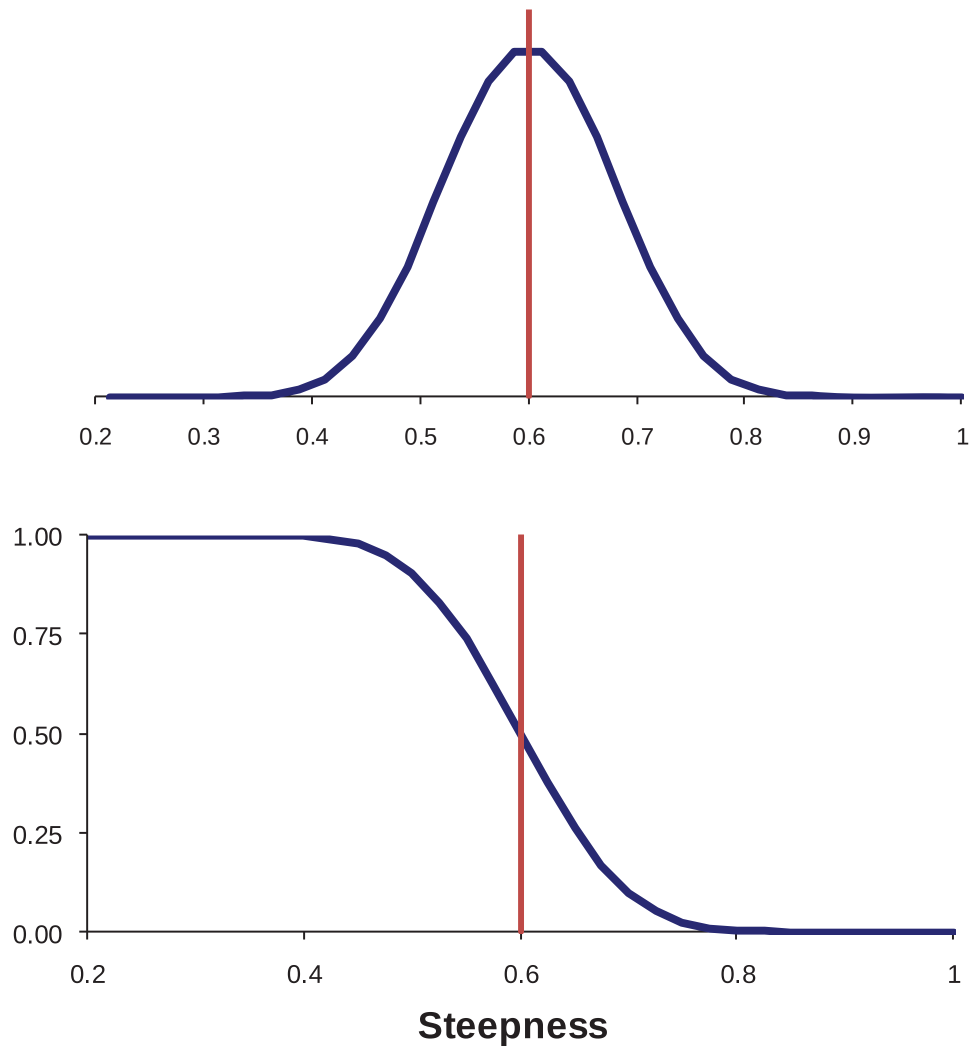

Figure 1.39. Cumulative prior probability distribution of steepness based on the beta distribution with α and β set to values which assume a mean and CV of 0.6 and 0.12, respectively. This prior distribution implies that there is about 8% chance that the value for steepness is greater than 0.7. See text for discussion.