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

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Executive Summary

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

Summary of major changes

Changes in the input data
The primary changes include:

- The 2012 NMFS summer bottom-trawl survey (BTS) abundance at age estimates are included.
- The 2012 NMFS summer acoustic-trawl (AT) survey estimated abundance-at-age are included (using age samples primarily from the bottom-trawl survey).
- Observer data for catch-at-age and average weight-at-age from the 2011 fishery was finalized and included.
- Preliminary 2012 fishery catch-at-age data was estimated using BTS survey age-length keys
- Total catch as reported by NMFS Alaska Regional office was updated and included through 2012.

Changes in the assessment model
The general modeling approach remained the same.

Changes in the assessment results
The estimated increase in female spawning stock biomass is moderated somewhat from the 2011 assessment though female spawning biomass is projected to have been above B_{msy} level in 2012 and is expected to continue increasing. Similar to the 2011 assessment, the maximum permissible Tier 1a ABC remains high since positive signs for incoming year classes continue (albeit moderated somewhat). The available data indicate that the spawning biomass for 2012 is projected to be slightly below the level expected from last year's assessment. In response to Plan Team requests, a wider range of indicators relative to the harvest policy was evaluated. Based on these, and other qualitative uncertainties, an ABC equal to last year's is recommended (1,200,000 t) which is well below the maximum permissible (Tier 1a) value 2.3 million t. The Tier 1a overfishing level (OFL) is estimated to be 2,549,000 t.

Summary results for EBS pollock.

Quantity	As estimated or *specified last* year for: 2012	2013	As estimated or *recommended this* year for: 2013	2014
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)	8,341,000 t	8,690,000 t	8,138,000 t	8,082,000 t
Female spawning biomass (t)				
Projected	2,379,000 t	2,534,000 t	2,580,000 t	2,522,000 t
B_0	5,329,000 t	5,329,000 t	5,377,000 t	5,377,000 t
B_{MSY}	2,034,000 t	2,034,000 t	2,114,000 t	2,114,000 t
F_{OFL}	0.6	0.6	0.543	0.543
$maxF_{ABC}$	0.533	0.533	0.491	0.491
F_{ABC}	0.296	0.296	0.26	0.32
OFL (t)	2,474,000 t	2,842,000 t	2,549,000 t	2,726,000 t
maxABC (t)	2,198,000 t	2,526,000 t	2,306,000 t	2,466,000 t
ABC (t)	1,220,000 t	1,360,000 t	1,200,000 t	1,547,000 t
Status	As determined *last* year for: 2010	2011	As determined *this* year for: 2011	2012
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

Response to SSC and Plan Team comments

General comments:

"We recommend that all assessment authors (Tier 3 and higher) bring ***retrospective analyses*** *forward in next year's assessments"*

Retrospective analyses were carried out again this year (back to 2002) and additional information was compiled to evaluate harvest strategies and issues related to the way the stock recruitment curve is used as part of the control rule.

From the September 2012 Plan Team minutes: The Teams recommend that authors continue to include ***other removals*** *in an appendix for 2012. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment much also be presented.*

We present a table of other removals but these were ignored in the estimation of 2013 and 2014 ABC and OFL.

Comments specific to this assessment

The Plan Team recommends that the authors or the AFSC analyze the consequences of adopting a target harvest rate lower than the MSY level which is now estimated to be 0.6, well above recent actual harvest rates of 0.3 -0.4. The alternative maximum targets could be, for example, 0.2, 0.3, 0.4, 0.5, and 0.6, with a B35 or B40 control rule. Possible performance measures could include the mean, variance, and example trajectories of:

1) *ABC*
2) *Spawning biomass,*
3) *Largest proportion of the catch contributed by a single cohort,*
4) *Largest proportion of the spawning biomass contributed by a single cohort,*
5) *Probability of falling below B20%,*
6) *Amount of salmon bycatch,*
7) *Total numbers of age 1-5 fish,*
8) *Probability of falling below the long-term average number of age 1-5 fish (about 40 billion), and*
9) *Other ecosystem metrics.*

The alternatives could be tested in simple simulations that assume the 2011 model parameter estimates are correct and impose an appropriate level of recruitment autocorrelation. The aim would be to show the main differences among cases in a straightforward way.

A decision table was developed to characterize near term trends and show approximate probability levels of conditions becoming "worse". The table uses a grid of different 2013 catch scenarios with outcomes on spawning biomass (which address items 2 and 5), whether the F would exceed F_{msy} (addressing item 1), salmon bycatch (based on historical rates—Chinook per t of pollock—and variability (addresses item 6), and characteristics of the age diversity and composition of the spawning stock (addressing items 4, 7 and 8). Alternative catch scenarios for 2013 were used (with subsequent years set at the F that satisfied that scenario) and projections were conducted only through to 2017.

Introduction

Walleye pollock (*Theragra chalcogramma;* 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. 2012). 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.

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 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.

Fishery

From 1954 to 1963, 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. Prior to the domestication of the pollock fishery, the catch was monitored by placing observers on foreign vessels. Since 1988, only U.S. vessels have been operating in this fishery. By 1991, the current NMFS observer program for north Pacific groundfish fisheries was in place.

The international zone of the Bering Sea, commonly referred to as the “Donut Hole” is entirely contained in the deep water of the Aleutian Basin and is distinct from the customary areas of pollock fisheries, namely the continental shelves and slopes. Japanese scientists began reporting the presence of large quantities of pollock in the Aleutian Basin in the mid-to-late 1970's. By the mid-late 1980s foreign vessels were intensively fishing in the Donut Hole. In 1984, the Donut Hole catch was 181 thousand t (Table 1.1). The catch grew rapidly and by 1987 the high seas pollock catch exceeded that within the U.S. Bering Sea EEZ. The extra-EEZ catch peaked in 1989 at 1.45 million t and has declined sharply since then. By 1991 the Donut Hole catch was 80% less than the peak catch, and catch in 1992 and 1993 was very low (Table 1.1). A fishing moratorium was enacted in 1993 and only trace amounts of pollock have been harvested from the Aleutian Basin by resource assessment fisheries.

Fishery characteristics

Pre-spawning aggregations of pollock are the focus of the first so-called “A-season” which opens on January 20th and extends into early-mid April. During this season the fishery produces highly valued roe which can comprise over 4% of the catch in weight. The second, or “B-season”, presently opens on June 10th and extends through late October. 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 (Ianelli *et al.* 2007). 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. The spatial pattern of fishing in 2012 winter was less dispersed than in the previous two years (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 but there was a slight overall increase in 2011 which is consistent with the increased catch (Fig. 1.3).

Summer and fall fishing (B-season) yielded catches that were widely and relatively evenly distributed in 2012 compared to that of 2011 and 2010 (Fig. 1.4). In terms of the pollock size composition from these areas, monthly data over the past three years shows that in summer of 2011 the mix of fish comprised a relatively large component of smaller fish (three-year olds; Fig. 1.5). The mode of these pollock can be seen to grow larger as 4-year-olds throughout 2012. The fishing conditions in terms of nominal catch rates were much better than those observed for 2011 (Fig. 1.6).

Fisheries Management

Due to concerns over possible impacts groundfish fisheries may have on rebuilding populations of Steller sea lions, NMFS and the NPFMC have changed management of Pacific cod, Atka mackerel (mackerel) and pollock fisheries in the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA). These changes were designed to reduce the possibility of competitive interactions between fisheries and Steller sea lions. For the pollock fisheries, comparisons of seasonal fishery catch and pollock biomass distributions (from surveys) by area in the EBS led to the conclusion that the pollock fishery may have had disproportionately high seasonal harvest rates within Steller sea lion critical habitat that *could* lead to reduced sea lion prey densities. Consequently, management measures redistributed the fishery both temporally and spatially according to pollock biomass distributions. The idea was that exploitation rates should be seasonally and spatially explicit to be consistent with area-wide and annual exploitation rates for pollock. Three types of measures were implemented in the pollock fisheries: 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 the management measures, the pollock fishery occurred in each of the three major fishery management regions of the North Pacific Ocean managed by the NPFMC: 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) which 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 regions, with over 17,000 t caught in Aleutian Islands 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.

The Bering Sea/Aleutian Islands pollock fishery was also subject to changes in total catch and catch distribution. Disentangling the specific changes in the temporal and spatial dispersion of the EBS pollock fishery resulting from the sea lion management measures from those resulting from implementation of the American Fisheries Act (AFA) is difficult. The AFA reduced the capacity of the catcher/processor fleet and permitted the formation of cooperatives in each industry sector by the year 2000. Both of these changes would be expected to reduce the rate at which the catcher/processor sector (allocated 36% of the EBS pollock TAC) caught pollock beginning in 1999, and the fleet as a whole in 2000 when a large component of the onshore fleet also joined cooperatives. Because of some of its provisions, the AFA gave the industry the ability to respond efficiently to changes mandated for sea lion conservation that otherwise could have been more disruptive.

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 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 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 1999 (Table 1.2).

An additional goal 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 in response to 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 - 2012, 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.

Additional measures to reduce chum salmon bycatch in the pollock fishery are currently under development. Previously bycatch of chum salmon was managed using a broad scale time and area closure (the Chum Salmon Savings Area). Bycatch levels for chum salmon in 2005 were the highest on record (more than 700,000 fish) but levels have been much lower, ranging from 13,000 – 46,000 since 2008 until this year with bycatch exceeding 180,000 chum salmon. In addition to possible environmental effects, these elevated levels may be related to good runs returning to western Alaska river systems and to the continued large levels of hatchery releases from Asia. In June 2011 a draft Environmental Assessment was presented to the Council specifically on the impact of the chum salmon bycatch on western Alaska systems. The analysis indicated that the impact rates to Alaska rivers (specifically western Alaska) appeared to be below 2% in the worse year (with caveats that genetic data failed to discern small regions which could potentially have been more heavily impacted than adjacent larger systems). Based on review of the analysis the Council has refined the alternatives to be examined and a revised draft EA will be presented in December 2012 for initial review. Salmon bycatch statistics are presented along with other bycatch estimates in the Ecosystem Considerations section below.

Catch data

From 1977-2012 the catch of EBS pollock has averaged 1.17 million t. Since 2001, the average has been above 1.28 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 (Table 1.3). In 2012, the TAC was set to be the same as for 2011 with the total catch at about 1.2 million t.

Pollock catch in the Eastern Bering Sea and Aleutian Islands by area from observer estimates of retained and discarded catch for 1991-2012 are shown in Table 1.4. 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. Historically, discard levels were likely affected by the age-structure and relative abundance of the available population, e.g., if the most abundant year class in the population is below marketable size. With the implementation of the AFA in 1999, 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.

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 1991-2010 (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 “fattest” 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 tend 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 the presence of age 3 pollock (the 2008 year class) in the catches began. The 2008 year class became prominent as 4-year olds in 2012 catches (Fig. 1.7; Table 1.5).

Since 1999 the observer program adopted a new sampling strategy for lengths and age-determination studies (Barbeaux et al. 2005a). 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 1.6 and 1.7). 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 catch biomass, a constant coefficient of variation was assumed to be 3% for this stock assessment application. This value is a slightly higher than the ~1% CVs estimated by Miller (2005) for pollock in the EBS.

Resource surveys

Scientific research catches are reported to fulfill requirements of the Magnuson-Stevens Fisheries Conservation and Management Act. The annual research catches (1963 - 2011) from NMFS surveys in the Bering Sea and Aleutian Islands Region is given in Table 1.8. 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 particularly critical since it complements the acoustic trawl (AT) surveys that sample mid-water abundance levels. Between 1991 and 2012 the BTS biomass estimates ranged from 2.28 to 8.46 million t (Table 1.9; Fig. 1.8). 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 3.6 million t. These surveys are multi-purpose and serve as a consistent measure of environmental conditions such as temperature characterizations which reflect the cold conditions during 2006-2012. 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, five years were below average and the zoogeographic response may be less predictable than they initially appeared. Bottom temperatures increased in 2011 to about average from the low value in 2010 but declined again in 2012 with one of the most extensive cold pools in recent decades (Fig. 1.9).

Beginning in 1987 NMFS expanded the standard survey area farther to the northwest. In earlier assessments, these extra strata (8 and 9) had been excluded from consideration within the model. The pollock biomass levels found in these non-standard regions were highly variable, ranging from 1% to 22% of the total biomass, and averaging about 6% (Table 1.10). Closer examination of the years where significant concentrations of pollock were found (1997 and 1998) revealed some stations with high catches of pollock. The variance estimates for these northwest strata were quite high in those years (CVs of 95% and 65% for 1997 and 1998 respectively). Nonetheless, since this region is contiguous with the Russian border, these strata are considered important and are included to improve coverage on 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 2012 biomass estimate was 3.49 million t, an increase of 12% from the 2011 value and 26% below the mean value for this survey (4.717 million t). This survey estimate ranks 20th out of the 26 estimates since 1987. In 2012, the distribution of pollock was unusual because concentrations appeared to extend into the cold pool, in particular in the region south of St. Mathew Island (Fig. 1.10).

In general, 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. 1.11). The BTS survey 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) and rarely age 2 pollock (lengths around 20-29 cm) during the summer. Other sources of variability may be due to unaccounted-for variability in natural mortality and migration. For example, some strong year classes appear in the surveys over several ages (e.g., the 1989 year class) while others appear at older ages (e.g., the 1992 year class). Also, from assessment model estimates the estimated strength of the 1996 year class has apparently waned compared to estimates from earlier years. Ianelli et al. (2007) reported a point estimate for the 1996 year class at around 32 billion one-year olds whereas in 2003, the estimate had been 43 billion. This could be due in part to emigration (and subsequent return) of this year-class outside of our main fishery and survey zones. Alternatively, this may reflect the effect of variable natural mortality rates. Retrospective analyses (e.g., Parma 1993) have also highlighted these patterns as presented in Ianelli et al. (2006, 2011).

The 2012 survey age compositions were developed from age-structures collected 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 1.11. The estimated numbers-at-age from the BTS for the standard strata (1-6) and for the northern strata included are presented in Table 1.12.

As in previous assessments, an analysis using survey 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) with lower mortality overall for cohorts during the early 1990s followed by increases and a subsequent decline for the most recent cohort (Fig. 1.12). It appears that the total mortality has decreased slightly on recent cohorts. Total mortality estimates by cohort represent lifetime averages since harvest rates (and actual natural mortality) vary from year to year. The low values estimated from some year classes (e.g., the 1990-1992 cohorts) could be because these age groups had 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 for total mortality. The higher recent values are somewhat expected given recent population trends. Please note that slope estimates for recent cohorts are relatively poorly determined since only a few abundance-at-ages are available (e.g., 5 years/data points for 2002 year class).

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). In 2012 the survey returned an estimated 1.843 million t compared to 2.323 million t for the US zone in 2010 and the 1982-2012 average of 2.723 million t (Table 1.9).

NMFS scientists have extended the acoustic trawl survey into the Russian zone six times since 2004 including 2012. The abundance in the Russian zone (to within 0.5 m of bottom) has varied substantially with 402 thousand t estimated in 2004 (Honkalehto et al. 2005) compared to 111, 34, 13, and 135 thousand t from 2007 to 2010, respectively. The 2012 estimate for the Russian Navarin zone was 657 thousand t, the most observed in this zone during the time series beginning in 1994 (when 651 thousand t were estimated). The pollock length composition within this Russian zone consisted of slightly smaller fish than that seen in the US zone west of 170°W. The number of trawl hauls, lengths, and ages sampled from the AT survey are presented in Table 1.13.

As in past assessments, length frequency based on age-length keys compiled from the 2012 bottom-trawl survey were used to convert the population-at-length estimates to ages. To supplement the process, 100 additional samples were collected by AT survey scientists to ensure adequate representation of ages in the smaller pollock size categories. The US EEZ population-at-length estimates indicate three closely spaced modes and a lower abundance than in 2010 (Fig. 1.13).

Four year old pollock (the 2008 year class) was the most abundant with 2 and 3 year olds slightly lower than the number of 4 year olds. There was a marked lack of one year olds in the survey and in general, a low overall level. (Fig. 1.14; Table 1.14). The 2012 estimate is about equal to the average since 2006 but well below the average since 1982 (Fig. 1.15).

Proportions of pollock biomass estimated east vs. west of 170º W, and inside vs. outside the SCA show some patterns based on summer AT surveys (Table 1.15). West of 170°W the proportions have averaged around 72% from 1994-2006. Since 2007 the western proportions have been 85% or higher (the 2012 value is 85%). For the SCA, the proportion was highest during 2000, 2002, and 2004 surveys (average 15%). For the period 2006-2012 the proportion has remained below 10%. The relative estimation errors for the total biomass were derived from a one-dimensional (1D) geostatistical method (Petitgas 1993, Walline 2007, Williamson and Traynor 1996). This method accounts for observed spatial structure for sampling along transects. 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.

Comparing the geographical differences between the BTS and the AT survey suggests that in some areas the major concentrations of pollock are either nearer the bottom or in mid-water and in other areas concentrations overlap (Fig. 1.16).

Biomass index from Acoustic-Vessels-of-Opportunity (AVO)
Acoustic data collected from commercial fishing vessels used for the eastern Bering Sea bottom trawl (BT) survey have been analyzed for several years now (e.g.,Von Szalay et al., 2007, Kotwicki et al., 2009, Honkalehto et al. 2011). Since this survey overlaps in space and time with the normal AT survey, a comparison of acoustic backscatter data between the two surveys was completed to determine feasibility of using the BT survey data to provide a new midwater pollock index (Honkalehto et al. 2011). Analysis of four years of AT survey data (1999, 2000, 2002, and 2004) identified a suitable index area to track midwater pollock abundance. Details for the AVO index methods are provided in Honkalehto et al. (2011). A key to this work included defining an area of the shelf where pollock were consistently found and easily indexed using acoustic backscatter at a single frequency, 38 kHz. Pollock backscatter from this index area was classified through a combination of visual examination by trained analysts and semi-automated processing in which all backscatter in a specified depth range was assumed to be pollock. Integrated 38 kHz backscatter in the index area classified using this approach was well correlated with AT survey biomass in the U.S. EEZ. Since 2006, commercial fishing vessels chartered for the BT survey have collected 38 kHz backscatter in this area, and AVO indices calculated from these data have also compared well with AT survey biomass estimates (2006-2009), providing information on both the biomass and spatial distribution of midwater pollock. The precision of this index of pollock biomass for 2006-2011 was assumed to have an average CV of 33% (Table 1.16). This compares to the average CV assumed for the AT survey of 20%. The analysis of summer 2012 AVO data is underway and we anticipate that two new AVO data points (2012 and 2013) will be available for the 2013 assessment model.

Analytic approach

The assessment model

A statistical age-structured assessment model conceptually outlined in Fournier and Archibald (1982) and similar to Methot's (1990) extensions was applied over the period 1964-2012. 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 the Academy of Sciences National Research Council (Ianelli and Fournier 1998). The model was implemented using automatic differentiation software developed as a set of libraries under the C++ language (AD Model Builder).

The main changes from last year's analyses include:

- The 2012 EBS bottom trawl survey estimate of population numbers-at-age was added.
- The 2012 EBS AT survey estimate of population numbers-at-age are included based on using an age-length key from the 2012 BTS survey data.
- The 2011 final fishery age composition data were added.
- Preliminary 2012 fishery age composition data were added (using the BTS age-length key).
- In response to the Plan Team's request to evaluate other risk factors, a decision table framework was constructed.

Parameters estimated outside of the assessment model

Natural mortality and maturity at age

For the reference model 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 that a similar vector of age-specific natural mortality for the youngest and oldest ages was obtained. Estimates of natural mortality are also higher when predation is explicitly considered (Livingston and Methot 1998; Hollowed et al. 2000). However, the reference model values were selected because Clark (1999) found that specifying a conservative (lower) natural mortality rate is typically more precautionary when natural mortality rates are uncertain.

Pollock maturity-at-age (Smith 1981) values (tabulated with reference model values for natural mortality-at-age) are:

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M	0.900	0.450	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
Prop. Mature	0.000	0.008	0.290	0.642	0.842	0.902	0.948	0.964	0.970	1.000	1.000	1.000	1.000	1.000	1.000

These maturity-at-age values were reevaluated based on the studies of Stahl (2004; subsequently Stahl and Kruse 2008a). The technicians collected 10,197 samples of maturity stage and gonad weight during late winter and early spring of 2002 and 2003 from 16 different vessels. In addition, 173 samples were collected for histological determination of maturity state (Stahl and Kruse, 2008b). In their study, maturity-at-length converted to maturity-at-age via a fishery-derived age-length key from the same seasons and areas suggests similar results to the maturity-at-age schedule used in this assessment but with some inter-annual variability.

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 the reference model) 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.

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). Age-determination errors were re-examined in Ianelli et al. (2011) and they found that reader experience had similar outcomes and percent agreements in reader-tester subsamples. This suggests that the otoliths themselves were the cause of the variability as opposed to reader experience. The age-determination error methods and deviations at age was found by minimizing the differences between the observed and predicted percent agreements using a special case of Punt et al. (2008).

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., 2011 for the assessment conducted in 2012). 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.

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 causing mean weights in the fishery cause more variability than sampling (Table 1.17). 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) and the same approach was selected for 2012 (and future year) mean weights at age (the most recent 10-year mean). The 2011 revised mean weights-at-age are somewhat smaller than assumed for the younger pollock last year but larger for older age classes (which are relatively low in abundance; Fig. 1.17).

Parameters estimated within the assessment model

For the selected model, 825 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment and stock-recruitment parameters account for 71 parameters. This includes vectors describing mean recruitment and variability for the first year (as ages 2-15 in 1964, projected forward from 1949) and the recruitment mean and deviations (at age 1) from 1964-2012 and projected recruitment variability (using the variance of past recruitments) for five years (2013-2017). 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 50 parameters and the age-time forms a 10x50 matrix of 500 parameters bringing the total fishing mortality parameters to 530.

Selectivity-at-age estimates for the bottom trawl survey are specified with age and year specific deviations in the average availability-at-age totaling 93 parameters. For the AT survey, which began in 1979, 112 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.

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 BTS survey 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 imply that there are spatial aspects of the pollock stock that are missed whereas values greater than one 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. 1.8; for the AT index the annual errors were specified to have a mean of 0.25 whilst for the AVO data, a relative value was assumed which gave a mean of about 0.33).
- Fishery and survey proportions-at-age estimates (robust quasi-multinomial with effective sample sizes presented in Table 1.18).
- Age 1 index from the AT survey (CV set equal to 30%)
- 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 2011 and estimated levels for 2012 along with the 2011 fishery mean weights-at-age.

As in past years, a set of models showing the impact of new data was constructed:

Shorthand	Description
C	2012 total catch only included (no new fishery age data)
CA	Catch and 2011 and preliminary 2012 fishery age data added
CAA	As in above but with acoustic-trawl (AT) survey data added
CAB	As in above but with bottom-trawl survey data added (no AT data)
CABA	With all new data added

As requested by the SSC and Plan Team, retrospective analyses were again conducted with results showing a slight tendency for over estimation of spawning biomass when it is declining and slightly underestimate during increases—however, all fall well within the bounds of uncertainty (Figs. 1.18 and 1.19).

The sequential addition of new data to the model indicated that the BTS survey decreased the estimate of the 2008 year class slightly but increased the “fishable biomass” whereas the F_{msy} rate was relatively insensitive to new data (Fig. 1.20). Closer examinations of the age data that affect results show how incremental additions reflect the influence of the other sources of information. For example, the fits for model “CA” (only new data include 2011 and preliminary 2012 fishery catch and age compositions) seems to begin to improve the fit to the other data and to some degree confirms that the observations between different types of observation are consistent within years for relative abundances of different ages (Fig. 1.21). As the data from the bottom trawl survey and then all data shows how the model balances observations between different years and data sources (Fig. 1.21).

Time series results

The estimated selectivity pattern changes over time and reflects to some degree the extent that the fishery is focused on particularly prominent year-classes (Fig. 1.22). The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 1.23). The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) is consistent with the population trends for this period (Fig. 1.24). The fit to the fishery-independent index from the AVO (which will be updated next year) is shown in Figure 1.25.

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 2011 survey but slightly more than observed in the 2012 survey (Fig. 1.26). The pattern of bottom trawl survey age composition data in recent years shows a decline in the abundance of pollock older than age 6 relative to 2011 and a somewhat lower than expected numbers at age 6 (the 2006 year-class; Fig. 1.27).

The AT survey selectivity estimates vary inter-annually but have generally stabilized since the early 1990s as the acoustic-trawl and bottom trawl methods have become more standardized (Fig. 1.28; top panel). These changes could also be due to changes in age-specific pollock distributions (and hence availability) over time. 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. 1.28, bottom panel). The model prediction for the 2009 numbers is higher than the survey estimate but provides a prediction that is lower than the 2010 survey estimate. The AT age compositions consistently track large year classes through the population and the model fits these patterns reasonably well (Fig. 1.29). The AT age-1 index indicates slightly larger than expected 2009 and 2010 year classes but much lower than expected age-1s in 2012 (Fig. 1.29, bottom panel).

The estimate of B_{msy} is 2,114,000 t (with a CV of 20%) which is less than the projected 2013 spawning biomass of 2,580,000 t; Table 1.19). For 2012, the Tier 1 levels of yield are 2,306 thousand t from a fishable biomass estimated at around 4,693,000 t (Table 1.20). Estimated numbers-at-age are presented in Table 1.21 and estimated catch-at-age presented in Table 1.22. Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment is given in Table 1.23.

The results indicate that spawning biomass will be above $B_{40\%}$ (2,570,000 t) in 2013 and about 122% 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 2012 and 2013 (Fig. 1.30).

Another metric on the impact of fishing suggests that the 2012 spawning stock size is about 54% of the predicted value had no fishing occurred since 1978 (Table 1.19). This compares with the 36% of $B_{100\%}$ (based on the SPR expansion from mean recruitment from 1978-2012) and 43% 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 whereas the value of 54% is based on the sequence of observed recruits relative to fishing intensities.

Abundance and exploitation trends

The current begin-year biomass estimates (ages 3 and older) derived from the statistical catch-age model 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 1.24). Historically, biomass levels have increased from 1979 to the mid-1980's 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 and mid-1990s with a substantial decline to about 5.9 million t by 1991 and another low point occurring in 2008 at 4.4 million t[*]. Relative to last year's assessment which projected an age 3+ biomass of 8.34 million t for 2012 the estimate is now down to 7.87 million t due to the downward change in estimates of the 2009 and 2006 year classes (Fig. 1.31). The change was offset somewhat by an increase in the estimate of the 2008 year class.

The level of fishing relative to biomass estimates show that the spawning exploitation rate (SER, defined as the percent removal of spawning-aged females in any given year) has been mostly below 20% since 1980 until 2006-2008 when the rate has averaged more than 20% while the average fishing mortality for ages 3-8 has been increasing during the period of stock decline (Fig. 1.32). The estimate for 2009 through 2012 is below 20% due to the reductions in TACs arising from the ABC control rules and increases in the spawning biomass. Age specific fishing mortality rates have been fairly steady but there is a marked increase estimated for the oldest ages in 2012(Fig. 1.33). This increase is presumably due to the lower levels of older age pollock observed in the bottom trawl survey and also to the relatively low abundance levels of those pollock in the population.

Spawning biomass is projected to increase under a wide variety of catch scenarios (Fig. 1.34). Compared with past year's assessments, the estimates of age 3+ pollock biomass are similar during the historical period but slightly lower compared to the 2011 assessment (Fig. 1.35, Table 1.24).

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 as 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. 1.36).

Recruitment

In the 2012 BTS survey, the number of 1-year olds (the 2011 year class) was slightly below average whereas the AT survey indicated very low numbers of age one pollock (Fig. 1.37). Model estimates combining all information indicate that the 2006 year class is only 17% above the average level (Fig. 1.38, 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 and also illustrates that the estimate of the 2011 spawning biomass was near the B_{msy} level (Fig. 1.38; bottom panel). Note that the 2010 and 2011 year classes (as age 1 recruits in 2011 and 2012) 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

[*] Please refer to Ianelli et al. (2001) for a discussion on the interpretation of age-3+ biomass estimates.

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.

Results from the BASIS research project suggest that age-0 pollock abundance was low during 2006 and 2007 (cool sea temperatures; lower water column stratification; Moss et al., 2009). However, age-1 pollock (from the 2008 cohort) were evident in the BASIS survey in 2009 which may indicate changes in spatial and vertical distribution due to environmental conditions and/or that the 2008 year class is abundant (which would be consistent with the recent AT surveys). The hypothesis is that the condition (or fitness) and the abundance of age 0 pollock during late summer are predictors for the overwintering survival to age-1 and thus year class strength. Based on direct observations of the 2010 year class from surveys the estimate is slightly below average (87% of the mean—i.e., 19,133 million compared to the mean age-1 recruitment of 21,899 million).

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} = 2,114 thousand t female spawning biomass

B_0 = 5,377 thousand t female spawning biomass

$B_{100\%}$ = 6,425 thousand t female spawning biomass

$B_{40\%}$ = 2,570 thousand t female spawning biomass

$B_{35\%}$ = 2,249 thousand t female spawning biomass

Specification of OFL and Maximum Permissible ABC

The 2013 spawning biomass is estimated to be 2,580,000 t (at the time of spawning, assuming the stock is fished at recommended ABC level). This is above the B_{msy} value of 2,114,000 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 (10-year average).

Since the 2013 female spawning biomass is estimated to be above the B_{msy} level (2,114 kt) but below the $B_{40\%}$ value (2,570 kt) in 2013. Assuming that the 2013 catch equals 1.2 million t, the OF and maximum permissible ABC values by Tier would be:

Tier	Year	MaxABC	OFL
1a	2013	2,306,000 t	2,549,000 t
1a	2014	2,551,000 t	2,820,000 t
3b	2013	1,452,000 t	1,753,000 t
3b	2014	1,547,000 t	1,858,000 t

If the 2013 catch is assumed to be 1.375 million t then the ABCs and OFLs would be

Tier	Year	MaxABC	OFL
1a	2013	2,306,000 t	2,549,000 t
1a	2014	2,466,000 t	2,726,000 t
3b	2013	1,452,000 t	1,753,000 t
3b	2014	1,462,000 t	1,759,000 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}. Projections based on Tier 3 are presented along with some considerations for a Tier 1 approach.

For each scenario, the projections begin with the vector of 2012 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2013 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2012. 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, fishing mortality rates, and catches.

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 2013 and 2014, are as follows (A "*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 2013 catch is equal to 1.2 million t and future years, *F* is set equal to the Tier 3 estimate (**Authors' recommendation**).

Scenario 3: In all future years, F is set equal to the 2008-2012 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 scenarios were designed based on the Mace et al. (1996) review of overfishing definitions and Restrepo et al. 1998 technical guidance. 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 2011 or 2) above ½ of its MSY level in 2013 and above its MSY level in 2025 under this scenario, then the stock is not overfished.)

Scenario 7: In 2013 and 2014, 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 2024 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 2012 (Table 1.25). Under Tier 3 Scenarios 1 and 2, the expected spawning biomass will increase and stabilize around $B_{40\%}$ (in expectation) in a few years (Fig. 1.39).

Any stock that is below its 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 2012:

If spawning biomass for 2012 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.

If spawning biomass for 2012 is estimated to be above $B_{35\%}$, the stock is above its MSST.

If spawning biomass for 2012 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 1.25). If the mean spawning biomass for 2021 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 2015 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

If the mean spawning biomass for 2015 is above $B_{35\%}$, the stock is not approaching an overfished condition.

If the mean spawning biomass for 2015 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2025. If the mean spawning biomass for 2025 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 2011, nor is it expected to be approaching an overfished condition based on Scenario 7 (the mean spawning biomass in 2013 is above the $B_{35\%}$ level; Table 1.25). Tier 1 calculations for ABC and OFL values in 2013 and 2014 (assuming catch is 1,200,000 t in 2013 are given in Table 1.26.

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"). Information collected in 2012 and refinements to the treatment of earlier data suggest that the stock is near B_{msy} levels with near-term outlook apparently favorable. Under likely catch projections, the spawning stock biomass is expected be about 122% of B_{msy} (2,114 kt) by 2013 with future status depending on specified catch levels (Fig. 1.39).

A more formal consideration of alternative risk factors was requested by the Plan Team. In response, a set of risk measures were developed and applied directly within the model (Table 1.27). These catch levels for 2013 correspond to harvest rates that are 11%, 16%, 21%, 26%, 32%, and 43% of the "fishable" biomass. Results show that alternative 2013 catch levels are consistent with the data and stock status (Table 28). Namely that

- the catch is unlikely to exceed the OFL as defined by the F_{msy} nor is the stock likely be below the B_{msy} level (rows 1, 2 and 4);
- nearly all catch levels lead to a 2014 stock size that will likely be below average (Row 3);
- the expected proportion of fish between age 1-5 in the population will be higher than the long-term mean (row 8);
- the age groups comprising the spawning stock (by weight) are likely less diverse than that observed in 1994 (row 9);
- an increase in effort is unlikely except at higher catch levels (row 11); and
- at similar catch levels to 2011 and 2012, the probability of exceeding the average Chinook PSC is moderate (but note that the computation assumes independence of Chinook salmon run strengths).

For presentation purposes, a subset of key indicators which includes the impact of reduced catches may help in considering trade-offs (Table 1.29). Such a table may be used as ***an example approach*** to risk management (i.e., attempting to integrate over risk factors, Francis and Shotton, 1997). This would involve assigning relative weights to the risks and minimizing those risks. Explorations suggest that setting the catch at 1.2 million t will likely increase biomass and have a near even chance of returning fishing conditions to above average by 2017. In addition to the values presented in the decision table, rationales for setting the ABC below the maximum permissible include:

- Two surveys both remain below their average
- Retrospective patterns indicate that recent strong recruitments tend to be over estimated
- A significant biomass of pollock was observed in the Russian zone from the NMFS AT survey
- While B-season fishing conditions were better than observed for 2011, smaller pollock and the need for shore-based boats to travel far from port was noted
- Estimated fishing mortality for the oldest age groups has increased in 2012. While they don't represent a large component of the population in terms of biomass, pollock in these age groups

are generally most available to fishing operations that are closer to the southeast part of the Eastern Bering Sea.

- In 2012, the spawning stock diversity is at a low level (Fig. 1.40).
- The 2012 BTS survey estimate ranks 20th out of the 26 estimates since 1987.
- The AT survey found very few age 1 pollock (the third lowest out of 14 surveys conducted since 1991)
- Russian catches in the Navarin region may have more of an impact if the distribution of pollock has shifted considerably based on the relatively large biomass of young pollock observed in their zone in summer of 2012
- Estimates of the 2008 year class are better than in past years but remain uncertain and represent a significant component of the biomass (~52% of spawning biomass in 2013).

Given these factors, an added adjustment in harvest rates seems justified to ensure that fishing mortality increases at a more incremental pace. Estimated conditions result in a maximum permissible Tier 1a ABC that is very high even though the incoming year classes remain uncertain. Facing these uncertain conditions, it would be prudent to proceed with stable or gradual increases in fishing mortality. Consequently a 2013 ABC of 1,200,000 t is recommended. At this level of fishing the spawning biomass is projected to continue increasing and the 2014 ABC would be 1,547,000 t (based on a Tier 3 approach).

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 (via multi-species analyses of technical interactions);
- Controlling 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. 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 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 suggests 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 1.30. 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

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 the index was updated and spatial distributions and trends were evaluated using methods described in De Robertis et al., (2010) and Ressler et al. (In press). New information on euphausiid abundance is anticipated from the planned 2012 surveys.

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 1.31). Jellyfish represent the largest component of the bycatch of non-target species and have been stable at around 5-6 thousand tons per year with catches exceeding 8 thousand t in 2000, 2009, and 2011. Skate bycatch nearly doubled in 2008 compared to 2007 but declined to just over one thousand t in 2010 (Table 1.31). 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 mask any significant trends in bycatch.

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 1.32). The incidental catch of flatfish was variable over time and has increased, particularly for yellowfin sole in 2010. 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 1.33).

The catch of prohibited species was variable. A relatively high number of “other salmon” (mainly comprising chum salmon) was observed in 2011 but this returned to low levels again in 2012 (Table 1.34). Also, the level of crab bycatch drops considerably after 1998 when all BSAI pollock fishing was restricted to using only pelagic trawls but bairdi crab has averaged just under 10 thousand animals since 2008. Chinook salmon bycatch in the pollock fishery have averaged 15.9 thousand fish since 2008. Much of the salmon bycatch variability is likely attributed to salmon run sizes and also to environmental conditions.

Data gaps and research priorities

EBS pollock is likely the most data-rich species in the region. Nonetheless, research and studies that focus on the following would improve our understanding of stock dynamics useful for fisheries management: 1) age determination protocols, 2) spatial distribution of pollock by season including vertical dimension and how this impacts the availability of pollock to survey gear, 3) the relationship between climate and recruitment; 4) stock structure potential, and 5) trophic interactions of pollock within the ecosystem.

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. Grant Thompson provided the methodology used for the standard harvest scenarios and the associated text.

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Tables

Table 1.1 Catch from the Eastern Bering Sea by area, the Aleutian Islands, the Donut Hole, and the Bogoslof Island area, 1979-2012 (2012 values preliminary). 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	653,569	542,077	1,195,646	98,604	293,400	316,038
1992	830,560	559,771	1,390,331	52,352	10,000	241
1993	1,094,428	232,173	1,326,601	57,132	1,957	886
1994	1,152,573	176,777	1,329,350	58,659		556
1995	1,172,304	91,941	1,264,245	64,925		334
1996	1,086,840	105,938	1,192,778	29,062		499
1997	819,888	304,543	1,124,430	25,940		163
1998	965,767	135,399	1,101,165	23,822		136
1999	783,119	206,697	989,816	1,010		29
2000	839,175	293,532	1,132,707	1,244		29
2001	961,975	425,219	1,387,194	824		258
2002	1,159,730	320,465	1,480,195	1,156		1,042
2003	933,316	557,584	1,490,900	1,653		24
2004	1,089,999	390,544	1,480,543	1,150		0
2005	802,418	680,868	1,483,286	1,621		
2006	826,980	659,455	1,486,435	1,744		
2007	728,094	626,003	1,354,097	2,519		
2008	482,542	508,023	990,566	1,060		9
2009	356,258	451,688	807,947			73
2010	253,935	555,013	808,948			176
2011	445,239	726,483	1,171,722			173
2012	597,064	597,064	1,194,128			79
Average	753,119	427,310	1,180,429			
	64%	36%				

1979-1989 data are from Pacfin.
1990-2011 data are from NMFS Alaska Regional Office, and includes discards.
2012 EBS catch is 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), 1998-2012. *Note that the 2012 data are preliminary and the totals reflect only the catch recorded by observers.*

	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%)	674,000 t (16%)	1,131,000 t (31%)

Table 1.3. Time series of 1964-1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977-2012 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports, ***catch for 2012 is based on an estimated projection***.

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	1,195,646
		1992	1,490,000	1,300,000	1,390,331
		1993	1,340,000	1,300,000	1,326,601
		1994	1,330,000	1,330,000	1,329,350
		1995	1,250,000	1,250,000	1,264,245
		1996	1,190,000	1,190,000	1,192,778
		1997	1,130,000	1,130,000	1,124,430
		1998	1,110,000	1,110,000	1,101,165
		1999	992,000	992,000	989,816
		2000	1,139,000	1,139,000	1,132,707
		2001	1,842,000	1,400,000	1,387,194
		2002	2,110,000	1,485,000	1,480,195
		2003	2,330,000	1,491,760	1,490,899
		2004	2,560,000	1,492,000	1,480,543
		2005	1,960,000	1,478,500	1,483,286
		2006	1,930,000	1,485,000	1,486,435
		2007	1,394,000	1,394,000	1,354,097
		2008	1,000,000	1,000,000	990,566
		2009	815,000	815,000	807,947
		2010	813,000	813,000	810,215
		2011	1,270,000	1,252,000	1,199,073
		2012	1,220,000	1,200,000	*1,200,000*
	1977-2012 average		1,377,250	1,192,146	1,170,191

Table 1.4. Estimates of discarded pollock (t), percent of total (in parentheses) and total catch for the Aleutians, Bogoslof, Northwest and Southeastern Bering Sea, 1991-2012. SE represents the EBS east of 170° W, NW is the EBS west of 170° W, source: NMFS Blend and catch-accounting system database. 2012 data are preliminary.

	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%)	48,205 (9%)	66,789 (10%)	140,552 (9%)	98,604	316,038	542,056	653,552	1,610,250
1992	2,982 (6%)	240 (100%)	57,609 (10%)	71,195 (9%)	132,026 (9%)	52,352	241	559,771	830,560	1,442,924
1993	1,733 (3%)	308 (35%)	26,100 (11%)	83,989 (8%)	112,130 (8%)	57,132	886	232,173	1,094,431	1,384,622
1994	1,373 (2%)	11 (2%)	16,083 (9%)	88,098 (8%)	105,565 (8%)	58,659	556	176,777	1,152,573	1,388,565
1995	1,380 (2%)	267 (80%)	9,715 (11%)	87,491 (7%)	98,853 (7%)	64,925	334	91,941	1,172,304	1,329,504
1996	994 (3%)	7 (1%)	4,838 (5%)	71,367 (7%)	77,206 (6%)	29,062	499	105,938	1,086,840	1,222,339
1997	617 (2%)	13 (8%)	22,557 (7%)	71,031 (9%)	94,218 (8%)	25,940	163	304,543	819,888	1,150,534
1998	164 (1%)	3 (2%)	1,581 (1%)	15,135 (2%)	16,883 (2%)	23,822	136	135,399	965,767	1,125,124
1999	480 (48%)	11 (39%)	1,912 (0.9%)	26,912 (3.4%)	28,824 (2.9%)	1,010	29	206,698	782,982	990,719
2000	790 (63%)	20 (67%)	1,942 (0.7%)	19,678 (2.3%)	21,620 (1.9%)	1,244	29	293,532	839,177	1,133,984
2001	380 (46%)	28 (11%)	2,450 (0.6%)	14,874 (1.5%)	17,324 (1.2%)	825	258	425,220	961,891	1,388,194
2002	779 (66%)	12 (1%)	1,441 (0.4%)	19,430 (1.7%)	20,870 (1.4%)	1,177	1,042	320,442	1,160,334	1,482,995
2003	468 (28%)	-	2,959 (0.5%)	13,856 (1.5%)	16,815 (1.1%)	1,649	24	557,588	933,291	1,492,553
2004	287 (25%)	-	2,781 (0.7%)	20,380 (1.9%)	23,161 (1.6%)	1,158	0	390,544	1,089,999	1,481,701
2005	324 (20%)	-	2,586 (0.4%)	14,833 (1.8%)	17,419 (1.2%)	1,621	0	680,868	802,148	1,484,636
2006	311 (18%)	-	3,677 (0.6%)	11,877 (1.4%)	15,554 (1.0%)	1,745	0	660,444	827,207	1,489,396
2007	425 (17%)	-	3,769 (0.6%)	12,325 (1.7%)	16,094 (1.2%)	2,519	0	626,253	728,239	1,357,011
2008	81 (6%)	-	1,643 (0.3%)	5,960 (1.2%)	7,603 (0.8%)	1,278	9	507,880	482,690	991,857
2009	395 (22%)	6 (8%)	1,936 (0.4%)	4,014 (1.1%)	5,951 (0.7%)	1,779	73	452,416	358,252	812,520
2010	142 (11%)	53 (30%)	1,201 (0.2%)	2,510 (1.0%)	3,712 (0.5%)	1,285	176	555,180	255,010	811,651
2011	75 (6%)	23 (13%)	1,337 (0.3%)	3,442 (0.5%)	4,779 (0.4%)	1,208	173	451,478	747,592	1,200,451
2012	95 (10%)	5 (6%)	1,128 (0.2%)	3,859 (0.6%)	4,988 (0.4%)	971	79	585,901	611,030	1,197,981

Table 1.5. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2012. Units are in millions of fish (2012 data are preliminary).

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	1,012.70	637.9	227	102.9	51.7	29.6	16.1	9.3	7.5	4.6	1.5	1	2,175
1982	4.7	25.3	161.4	1,172.20	422.3	103.7	36	36	21.5	9.1	5.4	3.2	1.9	1	2,004
1983	5.1	118.6	157.8	312.9	816.8	218.2	41.4	24.7	19.8	11.1	7.6	4.9	3.5	2.1	1,745
1984	2.1	45.8	88.6	430.4	491.4	653.6	133.7	35.5	25.1	15.6	7.1	2.5	2.9	3.7	1,938
1985	2.6	55.2	381.2	121.7	365.7	321.5	443.2	112.5	36.6	25.8	24.8	10.7	9.4	9.1	1,920
1986	3.1	86	92.3	748.6	214.1	378.1	221.9	214.3	59.7	15.2	3.3	2.6	0.3	1.2	2,041
1987	0	19.8	111.5	77.6	413.4	138.8	122.4	90.6	247.2	54.1	38.7	21.4	28.9	14.1	1,379
1988	0	10.7	454	421.6	252.1	544.3	224.8	104.9	39.2	96.8	18.2	10.2	3.8	11.7	2,192
1989	0	4.8	55.1	149	451.1	166.7	572.2	96.3	103.8	32.4	129	10.9	4	8.5	1,784
1990	1.3	33	57	219.5	200.7	477.7	129.2	368.4	65.7	101.9	9	60.1	8.5	13.9	1,746
1991	0.7	111.8	39.9	86.5	139.2	152.8	386.2	51.9	218.4	21.8	115.0	13.8	72.6	17.1	1,428
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	41.8	1,888
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	6.7	1,877
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	3.7	1,834
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	1.5	1,606
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	5.3	1,429
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	4.8	1,545
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	3.2	1,541
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	0.4	1,499
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	0.8	1,646
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	2.9	1,744
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	2.8	1,884
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	3.0	2,065
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	6.6	2,107
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	2.0	2,151
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	5.1	2,119
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	3.4	1,658
2008	0.0	25.9	57.1	78.9	147.3	307.7	242.0	150.3	83.9	22.4	17.8	13.7	8.6	2.7	1,158
2009	0.0	1.3	176.8	183.5	94.6	102.2	112.4	96.0	69.2	38.0	24.8	8.1	8.0	2.9	918
2010	0.7	28.7	31.2	561.4	221.2	54.8	43.2	54.6	49.8	33.4	14.4	9.2	5.1	5.8	1,114
2011	0.4	11.5	193.2	115.1	807.5	284.8	64.5	37.2	39.0	40.6	25.3	13.4	1.9	4.0	1,639
2012	0.0	8.1	56.5	524.4	206.3	425.6	163.8	52.5	28.6	38.7	32.0	24.3	18.5	4.9	1,584
Average	4.1	61.8	210.6	345.4	369.9	315.6	197.8	112.9	66.8	36.8	25.4	13.1	8.7	6.0	1,775
Median	0.4	24.3	89.9	258.9	354.4	286.5	160.1	97.8	55.3	28.8	18.2	9.9	6.1	3.7	1,765

Table 1.6. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2012, as sampled by the NMFS observer program.

Length	A Season		B Season SE		B Season NW		
Frequency	Males	Females	Males	Females	Males	Females	Total
1977	26,411	25,923	4,301	4,511	29,075	31,219	121,440
1978	25,110	31,653	9,829	9,524	46,349	46,072	168,537
1979	59,782	62,512	3,461	3,113	62,298	61,402	252,568
1980	42,726	42,577	3,380	3,464	47,030	49,037	188,214
1981	64,718	57,936	2,401	2,147	53,161	53,570	233,933
1982	74,172	70,073	16,265	14,885	181,606	163,272	520,273
1983	94,118	90,778	16,604	16,826	193,031	174,589	585,946
1984	158,329	161,876	106,654	105,234	243,877	217,362	993,332
1985	119,384	109,230	96,684	97,841	284,850	256,091	964,080
1986	186,505	189,497	135,444	123,413	164,546	131,322	930,727
1987	373,163	399,072	14,170	21,162	24,038	22,117	853,722
1991	160,491	148,236	166,117	150,261	141,085	139,852	906,042
1992	158,405	153,866	163,045	164,227	101,036	102,667	843,244
1993	143,296	133,711	148,299	140,402	27,262	28,522	621,490
1994	139,332	147,204	159,341	153,526	28,015	27,953	655,370
1995	131,287	128,389	179,312	154,520	16,170	16,356	626,032
1996	149,111	140,981	200,482	156,804	18,165	18,348	683,890
1997	124,953	104,115	116,448	107,630	60,192	53,191	566,527
1998	136,605	110,620	208,659	178,012	32,819	40,307	707,019
1999	36,258	32,630	38,840	35,695	16,282	18,339	178,044
2000	64,575	58,162	63,832	41,120	40,868	39,134	307,689
2001	79,333	75,633	54,119	51,268	44,295	45,836	350,483
2002	71,776	69,743	65,432	64,373	37,701	39,322	348,347
2003	74,995	77,612	49,469	53,053	51,799	53,463	360,390
2004	75,426	76,018	63,204	62,005	47,289	44,246	368,188
2005	76,627	69,543	43,205	33,886	68,878	63,088	355,225
2006	72,353	63,108	28,799	22,363	75,180	65,209	327,010
2007	62,827	60,522	32,945	25,518	75,128	69,116	326,054
2008	46,125	51,027	20,493	23,503	61,149	64,598	266,894
2009	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	53,630	57,959	37,493	39,874	46,424	49,791	285,171

Table 1.6. (continued) Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2011, 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

Table 1.7. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2011, 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

Table 1.8. NMFS total pollock research catch by year in t, 1964-2011.

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

Table 1.9. Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979-2012 (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 (t)	AT Survey (t)	AT % age 3+	Total* (t)	Near bottom biomass
1979		7.458	22%	10.660	30%
1980					
1981					
1982	2.856	4.901	94%	7.756	37%
1983	6.258				
1984	4.894				
1985	6.056	4.799	97%	10.856	56%
1986	4.897				
1987	5.525				
1988	7.289	4.675	98%	11.969	61%
1989	6.519				
1990	7.322				
1991	5.168	1.454	55%	6.618	78%
1992	4.583				
1993	5.636				
1994	5.027	2.886	87%	7.917	63%
1995	5.482				
1996	3.371	2.311	97%	5.681	59%
1997	3.874	2.591	70%	6.464	60%
1998	2.852				
1999	3.801	3.285	95%	7.094	54%
2000	5.265	3.049	95%	8.315	63%
2001	4.200				
2002	5.038	3.622	85%	8.658	58%
2003	8.458				
2004	3.886	3.307	99%	7.196	54%
2005	5.294				
2006	3.045	1.560	98%	4.605	66%
2007	4.338	1.769	89%	6.108	71%
2008	3.031	0.997	76%	4.028	76%
2009	2.280	0.924	80%	3.204	71%
2010	3.748	2.323	64%	6.071	62%
2011	3.112				
2012	3.487	1.843	90%	5.330	65%
Average	4.729	2.986	85%	6.927	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 1.10. Survey biomass estimates (age 1+, t) of Eastern Bering Sea pollock based on area-swept expansion methods from NMFS bottom trawl surveys 1982-2012.

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	4,630,111	1,325,102	5,955,213	22%
1986	4,896,780			
1987	5,111,645	386,788	5,498,433	7%
1988	7,106,739	181,839	7,288,578	2%
1989	5,905,641	643,938	6,549,579	10%
1990	7,126,083	190,218	7,316,301	3%
1991	5,064,313	62,446	5,126,759	1%
1992	4,367,870	214,557	4,582,427	5%
1993	5,521,208	105,707	5,626,916	2%
1994	4,977,019	49,686	5,026,706	1%
1995	5,408,653	68,541	5,477,195	1%
1996	3,258,348	155,861	3,414,209	5%
1997	3,036,898	762,954	3,799,852	20%
1998	2,212,689	567,569	2,780,258	20%
1999	3,598,286	199,786	3,798,072	5%
2000	5,152,586	128,846	5,281,432	2%
2001	4,145,746	51,108	4,196,854	1%
2002	4,832,506	200,337	5,032,843	4%
2003	8,106,139	285,902	8,392,041	3%
2004	3,744,501	118,473	3,862,974	3%
2005	5,168,295	152,300	5,320,595	3%
2006	2,845,009	199,885	3,044,894	7%
2007	4,156,687	179,986	4,336,672	4%
2008	2,834,094	189,174	3,023,268	6%
2009	2,231,225	51,184	2,282,409	2%
2010	3,550,981	186,898	3,737,878	5%
2011	2,945,640	166,672	3,112,312	5%
2012	3,281,223	206,005	3,487,229	6%
Avg.	4,472,033	260,436	4,716,737	6%

Table 1.11. Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982-2012. 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*	1997	376	35,536	1,193
1983	*354*	*78,033*	*1,931*	1998	375	37,673	1,261
1984	*355*	*40,530*	*1,806*	1999	373	32,532	1,385
1985	434	48,642	1,913	2000	372	41,762	1,545
1986	*354*	*41,101*	*1,344*	2001	375	47,335	1,641
1987	356	40,144	1,607	2002	375	43,361	1,695
1988	373	40,408	1,173	2003	376	46,480	1,638
1989	373	38,926	1,227	2004	375	44,102	1,660
1990	371	34,814	1,257	2005	373	35,976	1,676
1991	371	43,406	1,083	2006	376	39,211	1,573
1992	356	34,024	1,263	2007	376	29,679	1,484
1993	375	43,278	1,385	2008	375	24,635	1,251
1994	375	38,901	1,141	2009	375	24,819	1,342
1995	376	25,673	1,156	2010	376	23,142	1,385
1996	375	40,789	1,387	2011	376	36,227	1,734
				2012	376	35,782	1,785

Table 1.12. Bottom-trawl survey estimated numbers (millions) at age used for the stock assessment model, 1982-2012 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	2,432	3,111	1,059	144	100	48	30	19	12	7	3	1	1	10,186	1,262	12%
1983	3,912	580	1,278	2,266	5,051	1,552	286	157	71	61	46	16	7	5	2	15,291	1,191	8%
1984	367	281	399	1,153	1,459	3,427	652	145	68	24	16	6	4	5	2	8,007	792	10%
1985	4,785	677	2,563	833	2,876	1,835	1,272	252	65	53	18	6	7	1	0	15,243	1,947	13%
1986	2,188	497	362	1,338	816	1,382	1,219	1,122	357	56	26	11	1	3	1	9,378	828	9%
1987	345	560	723	538	3,246	913	918	370	1,197	189	57	23	4	2	2	9,088	1,122	12%
1988	1,068	514	1,198	2,286	1,012	3,319	1,002	786	462	1,117	107	64	13	17	9	12,975	1,462	11%
1989	761	225	428	1,411	3,198	645	2,485	379	471	182	581	101	89	45	63	11,066	1,135	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	233	76	461	429	1,420	534	1,157	303	418	87	265	38	35	8,536	824	10%
1992	1,337	325	1,703	285	319	536	478	689	310	595	212	268	117	92	73	7,339	808	11%
1993	2,340	333	707	2,971	647	521	275	384	526	325	285	208	164	91	110	9,888	913	9%
1994	1,246	523	385	1,115	3,025	530	141	124	143	268	166	233	89	86	145	8,220	956	12%
1995	1,439	141	270	1,224	1,604	2,566	1,086	288	179	116	219	90	167	68	101	9,560	1,783	19%
1996	1,433	347	155	308	806	1,125	1,027	349	87	94	65	123	40	74	100	6,132	508	8%
1997	2,238	339	146	180	2,166	1,008	626	782	137	70	53	59	96	32	111	8,042	1,080	13%
1998	625	549	281	185	354	2,024	528	342	268	67	31	11	24	28	65	5,384	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	293	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	695	9%
2002	644	300	618	894	927	1,204	627	306	421	792	395	179	107	33	37	7,484	762	10%
2003	376	124	723	1,178	1,377	1,244	1,651	915	411	536	1,081	469	179	89	69	10,421	1,862	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	2,022	48	116	337	1,056	1,244	905	656	278	125	116	101	47	58	113	7,223	668	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	373	219	318	433	342	250	123	82	27	28	14	59	3,448	414	12%
2010	408	115	204	2,055	930	295	261	279	295	203	175	64	39	23	51	5,396	707	13%
2011	982	100	208	285	1,433	706	210	121	189	189	157	120	51	24	64	4,841	452	9%
2012	963	188	344	2,472	572	915	313	125	94	130	106	94	79	28	51	6,474	611	9%
Avg	1,299	402	576	1,033	1,384	1,236	780	506	335	252	172	121	71	38	60	8,265	926	11%

Table 1.13. Number of (age 1+) hauls and sample sizes for EBS pollock collected by the AT surveys.

Year	Stratum	No. Hauls	No. lengths	No. otoliths collected	No. aged
1979	**Total**	25	7,722	NA	2,610
1982	**Total**	48	8,687	3,164	2,741
	Midwater, east of St Paul	13	1,725	840	783
	Midwater, west of St Paul	31	6,689	2,324	1,958
	Bottom	4	273	0	0
1985	**Total** (Legs1 &2)	73	19,872	2,739	2,739
1988	**Total**	25	6,619	1,471	1,471
1991	**Total**	62	16,343	2,062	1,663
1994	**Total (US zone)**	76	25,564	4,966	1,770
	East of 170 W	25	4,553	1,560	612
	West of 170 W	51	21,011	3,694	932
	Navarin (Russia)	19	8,930	1,270	455
1996	**Total**	57	16,824	1,949	1,926
	East of 170 W	15	3,551	669	815
	West of 170 W	42	13,273	1,280	1,111
1997	**Total**	86	29,536	3,635	2,285
	East of 170 W	25	6,493	966	936
	West of 170 W	61	23,043	2,669	1,349
1999	**Total**	118	42,362	4,946	2,446
	East of 170 W	41	13,841	1,945	946
	West of 170 W	77	28,521	3,001	1,500
2000	**Total**	124	43,729	3,459	2,253
	East of 170 W	29	7,721	850	850
	West of 170 W	95	36,008	2,609	1,403
2002	**Total**	126	40,234	3,307	2,200
	East of 170 W	47	14,601	1,424	1,000
	West of 170 W	79	25,633	1,883	1,200
2004	**Total (US zone)**	90	27,158	3,169	2,351
	East of 170 W	33	8,896	1,167	798
	West of 170 W	57	18,262	2,002	1,192
	Navarin (Russia)	15	5,893	461	461
2006	**Total**	83	24,265	2,693	2,692
	East of 170 W	27	4,939	822	822
	West of 170 W	56	19,326	1,871	1,870
2007	**Total (US zone)**	69	20,355	2,832	2,560
	East of 170 W	23	5,492	871	823
	West of 170 W	46	14,863	1,961	1,737
	Navarin (Russia)	4	1,407	319	315
2008	**Total (US zone)**	62	17,748	2,039	1,719
	East of 170 W	9	2,394	341	338
	West of 170 W	53	15,354	1,698	1,381
	Navarin (Russia)	6	1,754	177	176
2009	**Total (US zone)**	46	10,833	1,518	1,511
	East of 170 W	13	1,576	308	306
	West of 170 W	33	9,257	1,210	1,205
	Navarin (Russia)	3	282	54	54
2010	**Total (US zone)**	59	22,695	2,521	2,250
	East of 170 W	11	2,432	653	652
	West of 170 W	48	20,263	1,868	1,598
	Navarin (Russia)	9	3,502	381	379
2012	**Total (US zone)**	77	28,351	2,695	Na
	East of 170 W	17	4,422	650	Na
	West of 170 W	60	23,929	2,045	Na
	Navarin (Russia)	14	5,620	418	Na

Table 1.14. AT survey estimates of EBS pollock abundance-at-age (millions), 1979-2012. *NOTE: 2012 age specific values are preliminary.* 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%	12,291
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%	6,525
1997	12,384	2,743	385	491	1,918	384	205	143	33	18	6,319	15%	18,703
1999	112	1,588	3,597	1,684	583	274	1,169	400	105	90	9,489	23%	9,601
2000	258	1,272	1,185	2,480	900	244	234	725	190	141	7,372	13%	7,630
2002	561	4,188	3,841	1,295	685	593	288	100	132	439	11,560	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	*76*	*1,875*	*1,745*	*2,343*	*254*	*246*	*63*	*19*	*9*	*37*	*6,592*	*25%*	*6,667*
Avg. 1982-2012	1,847	2,295	2,040	1,868	902	480	310	154	62	108	8,220	20%	10,067
Median	456	1,588	1,185	1,670	695	293	205	110	53	53	7,372	20%	9,207

Table 1.15. 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, 1994-2012 (as described in Honkalehto et al. 2010).

Date		**Area** (nmi)^2	**Biomass in millions of t** (percent of total) **SCA**		**E170-SCA**		**W170**		**Total Biomass (millions t)**	**Estimation Error (millions t)**
1994	9 Jul-19 Aug	78,251	0.312	(11%)	0.399	(14%)	2.176	(75%)	2.886	0.136
1996	20 Jul-30 Aug	93,810	0.215	(9%)	0.269	(12%)	1.826	(79%)	2.311	0.090
1997	17 Jul-4 Sept	102,770	0.246	(10%)	0.527	(20%)	1.818	(70%)	2.591	0.096
1999	7 Jun-5 Aug	103,670	0.299	(9%)	0.579	(18%)	2.408	(73%)	3.285	0.181
2000	7 Jun-2 Aug	106,140	0.393	(13%)	0.498	(16%)	2.158	(71%)	3.049	0.098
2002	4 Jun -30 Jul	99,526	0.647	(18%)	0.797	(22%)	2.178	(60%)	3.622	0.112
2004	4 Jun -29 Jul	99,659	0.498	(15%)	0.516	(16%)	2.293	(69%)	3.307	0.122
2006	3 Jun -25 Jul	89,550	0.131	(8%)	0.254	(16%)	1.175	(75%)	1.560	0.061
2007	2 Jun -30 Jul	92,944	0.084	(5%)	0.168	(10%)	1.517	(86%)	1.769	0.080
2008	2 Jun -31 Jul	95,374	0.085	(9%)	0.029	(3%)	0.883	(89%)	0.997	0.076
2009	9 Jun -7 Aug	91,414	0.070	(8%)	0.018	(2%)	0.835	(90%)	0.924	0.081
2010	5 Jun -7 Aug	92,849	0.067	(3%)	0.113	(5%)	2.143	(92%)	2.323	0.139
2012	7 Jun -10 Aug	96,852	0.142	(8%)	0.138	(7%)	1.563	(85%)	1.843	0.077

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

Table 1.16. An abundance index derived from acoustic data collected opportunistically aboard bottom-trawl survey vessels (AVO index). Note CV_{AT}^{t} and CV_{AVO}^{t} are the coefficients of variation from using 1-D geostatistical estimates of sampling variability (Petitgas, 1993). See Ianelli et al. (2011) for the derivation of these estimates.

	AVO Index	$CV_{AVO'}$
2006	0.555	0.211
2007	0.638	0.244
2008	0.316	0.414
2009	0.285	0.477
2010	0.679	0.325
2011	0.543	0.234

Table 1.17. Mean weight-at-age (kg) estimates from the fishery (1991-2012) showing the between-year variability (middle row) and sampling error (bottom panel) based on bootstrap resampling of observer data.

	Mean weight-at-age (kg)												
	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	0.364	0.516	0.652	0.797	0.934	1.036	1.147	1.245	1.337	1.428	1.530	1.557	1.665
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	*0.290*	*0.448*	*0.651*	*0.799*	*0.935*	*1.059*	*1.174*	*1.282*	*1.362*	*1.445*	*1.583*	*1.584*	*1.725*
Stdev	0.055	0.055	0.039	0.053	0.080	0.092	0.123	0.122	0.127	0.132	0.223	0.255	0.281
CV	15%	11%	6%	7%	9%	9%	11%	10%	10%	9%	15%	17%	18%
Mean	0.360	0.516	0.649	0.763	0.876	0.998	1.126	1.218	1.315	1.398	1.475	1.472	1.564
	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%

Table 1.18. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964-2012. Note that 2012 fishery age-composition data are preliminary.

Year	Fishery	Year	BTS	AT
1964-1977	10	1979	-	6
1978-1990	50			
1991	174			
1992	200	1982-2012	100	51
1993	273			(average)
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			

Table 1.19. Summary model results showing the stock condition for EBS pollock. Values in parentheses are coefficients of variation (CV's) of values immediately above.

	2012 **Assessment**
Biomass	
Year 2013 spawning biomass*	2,580,000 t
(CV)	(14%)
2012 spawning biomass	2,306,000 t
B_{msy}	2,114,000 t
(CV)	(20%)
$SPR\|B_{msy}$	27.4%
$B_{40\%}$	2,570,000 t
$B_{35\%}$	2,249,000 t
B_0 (stock-recruitment curve)	5,377,000 t
2012 Percent of B_{msy} spawning biomass	109%
2013 Percent of B_{msy} spawning biomass	122%
Ratio of B_{2012} over B_{2012} under no fishing since 1978	0.536
Recruitment (millions of pollock at age 1)	
Steepness parameter (*h*)	0.671
Average recruitment (all yrs)	22,017
Average recruitment (since 1978)	23,252
2000 year class	35,891
2006 year class	25,683
2008 year class	43,607
Natural Mortality (age 3 and older)	0.3

*Assuming 2013 catch will be 1,200,00 t

Table 1.20. Summary results of Tier 1 2013 yield projections for EBS pollock.

Description	Value
Tier 1 maximum permissible ABC	
2013 “fishable” biomass (GM)	4,693,000 t
MSYR (HM)	0.491
Adjustment factor	1.0
Adjusted ABC rate	0.491
2013 MSYR yield (Tier 1 ABC)	2,306,000 t
OFL	
MSYR (AM)	0.543
2013 MSYR OFL	2,549,000 t
Recommended F_{ABC}	0.26
Recommended ABC	1,200,000 t
Fishable biomass at *MSY*	3,864,000 t

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

Table 1.21 Estimates of numbers at age for the EBS pollock stock as estimated in 2012 (millions).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	5,228	3,589	2,264	470	211	334	135	49	22	134	12,437
1965	20,407	2,123	2,259	1,609	284	127	200	82	30	98	27,218
1966	14,313	8,289	1,338	1,592	978	175	79	126	52	82	27,023
1967	28,708	5,814	5,210	938	991	613	111	50	81	87	42,605
1968	26,680	11,654	3,601	3,291	545	576	359	65	30	99	46,899
1969	29,281	10,829	7,190	2,349	1,853	311	334	210	38	77	52,473
1970	20,124	11,885	6,678	4,463	1,383	1,102	187	201	127	69	46,219
1971	9,676	8,163	7,091	3,881	2,609	812	652	107	115	106	33,212
1972	10,686	3,923	4,834	3,970	2,091	1,359	428	344	56	100	27,792
1973	28,947	4,331	2,194	2,431	1,972	1,045	684	215	174	66	42,059
1974	21,457	11,726	2,336	1,035	1,059	862	459	301	95	101	39,433
1975	18,171	8,692	5,920	972	433	447	367	196	128	82	35,406
1976	13,946	7,368	4,968	2,556	436	199	208	171	91	95	30,039
1977	13,901	5,658	4,283	2,504	1,179	206	95	101	83	90	28,100
1978	26,918	5,642	3,237	2,382	1,299	601	106	49	52	90	40,376
1979	65,651	10,926	3,261	1,756	1,230	667	312	54	25	72	83,955
1980	26,290	26,652	6,583	1,853	945	610	332	157	27	49	63,498
1981	29,778	10,679	16,609	4,174	994	477	301	166	79	38	63,295
1982	15,587	12,101	6,740	11,395	2,521	539	259	165	91	63	49,462
1983	52,550	6,336	7,679	4,837	7,481	1,530	323	156	98	89	81,079
1984	13,032	21,361	4,021	5,540	3,279	4,819	938	198	95	107	53,389
1985	35,369	5,297	13,568	2,902	3,782	2,058	3,041	579	122	115	66,832
1986	14,506	14,378	3,360	9,747	2,022	2,481	1,253	1,871	351	133	50,101
1987	8,493	5,897	9,117	2,421	6,680	1,344	1,538	775	1,179	286	37,731
1988	5,491	3,453	3,745	6,627	1,716	4,594	888	1,017	484	909	28,923
1989	10,357	2,232	2,189	2,565	4,554	1,104	2,955	540	627	859	27,981
1990	50,175	4,210	1,416	1,558	1,740	2,989	695	1,761	325	906	65,775
1991	25,582	20,397	2,662	1,003	973	1,023	1,724	392	982	708	55,445
1992	22,047	10,400	12,903	1,918	658	585	591	912	219	903	51,136
1993	47,813	8,963	6,567	8,946	1,282	409	320	297	429	515	75,541
1994	14,782	19,438	5,700	4,652	5,662	836	246	181	167	538	52,203
1995	10,798	6,010	12,367	4,163	3,154	3,305	496	146	108	427	40,973
1996	23,219	4,390	3,824	9,079	2,965	2,003	1,801	280	84	317	47,961
1997	31,494	9,440	2,785	2,790	6,625	2,035	1,144	896	143	217	57,569
1998	15,700	12,804	5,964	2,029	1,982	4,505	1,263	629	484	190	45,549
1999	17,239	6,383	8,124	4,335	1,439	1,339	2,760	770	357	365	43,112
2000	26,601	7,009	4,059	5,776	3,020	977	864	1,650	463	441	50,860
2001	35,891	10,815	4,458	2,937	3,918	1,946	631	504	926	537	62,563
2002	23,356	14,592	6,885	3,249	2,031	2,392	1,090	357	286	846	55,083
2003	14,087	9,495	9,269	4,997	2,221	1,257	1,249	574	190	634	43,972
2004	6,308	5,727	6,039	6,528	3,414	1,327	670	637	299	466	31,415
2005	4,471	2,565	3,645	4,387	4,115	2,103	771	360	345	434	23,197
2006	10,740	1,818	1,632	2,649	2,917	2,290	1,142	433	207	462	24,289
2007	25,683	4,366	1,155	1,147	1,726	1,648	1,172	598	231	374	38,100
2008	8,496	10,441	2,773	812	745	975	808	599	319	332	26,300
2009	43,607	3,454	6,638	1,999	532	423	468	398	307	345	58,171
2010	19,133	17,729	2,199	4,765	1,320	312	225	250	214	348	46,493
2011	18,621	7,779	11,284	1,600	3,043	787	182	127	139	315	43,876
2012	17,451	7,570	4,950	8,193	1,080	1,551	359	86	61	226	41,527
Median	18,877	7,674	4,646	2,719	1,733	1,000	482	265	133	217	44,761
Average	22,017	8,873	5,461	3,628	2,226	1,347	759	424	238	305	45,357

Table 1.22. Assessment model-estimated catch-at-age of EBS pollock (millions; 1964-2012).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	4.0	38.2	79.3	74.5	35.1	55.2	21.4	7.5	3.2	18.5	336.8
1965	12.8	20.0	95.2	251.0	42.2	17.7	26.4	10.2	3.6	11.2	490.2
1966	8.6	95.1	61.7	219.9	130.2	21.8	9.3	14.1	5.6	8.6	574.9
1967	29.1	134.3	665.7	176.6	186.2	111.9	20.0	9.0	14.2	15.1	1,362.0
1968	29.6	304.7	373.3	687.3	108.0	108.1	65.3	11.5	5.1	17.0	1,710.0
1969	32.0	287.1	1,011.4	418.8	317.0	51.0	54.3	34.0	6.2	13.1	2,224.8
1970	30.0	616.7	1,250.3	818.1	248.7	193.0	37.7	40.5	25.5	20.7	3,281.0
1971	18.3	470.4	1,506.8	921.8	675.4	204.5	162.9	26.8	29.1	45.1	4,061.3
1972	22.5	389.7	1,354.1	1,141.5	593.3	380.2	119.7	96.1	16.5	42.1	4,155.8
1973	68.9	540.1	696.6	876.2	707.7	372.7	242.1	76.1	61.5	28.9	3,670.9
1974	52.3	1,984.1	898.0	394.1	399.3	321.3	170.7	113.2	35.9	39.8	4,408.7
1975	32.1	727.5	2,162.4	334.6	143.9	145.6	118.3	62.9	41.1	29.6	3,798.0
1976	19.8	526.4	1,385.3	843.2	138.1	61.3	63.0	51.5	27.4	29.8	3,145.7
1977	16.0	469.3	928.8	654.7	320.4	55.1	25.2	26.4	21.7	23.3	2,541.0
1978	29.3	426.5	754.6	629.0	347.4	156.8	28.5	13.4	14.1	24.3	2,424.1
1979	63.9	484.9	661.1	418.7	354.4	190.5	87.1	15.6	7.2	20.7	2,304.1
1980	15.8	486.6	822.9	444.3	263.0	177.9	94.8	44.3	7.6	13.6	2,370.6
1981	9.5	87.0	1,062.5	669.2	232.4	110.1	68.7	37.7	17.9	9.4	2,304.4
1982	2.7	46.3	182.6	1,123.7	396.5	89.0	42.4	27.8	15.6	13.5	1,940.0
1983	7.0	24.1	174.0	355.8	846.6	229.2	48.1	23.9	16.4	20.5	1,745.6
1984	1.5	65.9	89.7	376.8	434.8	619.4	135.2	29.9	15.8	25.8	1,794.9
1985	3.6	22.3	355.6	149.6	375.0	318.1	446.8	91.5	20.8	28.9	1,812.2
1986	1.2	64.4	79.2	631.2	179.4	351.3	179.3	243.0	55.3	29.0	1,813.3
1987	0.4	18.7	148.0	90.7	415.2	126.5	143.3	105.4	159.7	47.0	1,254.9
1988	0.4	15.6	245.2	415.5	196.1	523.9	137.8	148.3	71.7	131.0	1,885.5
1989	0.6	9.8	74.5	187.4	450.0	143.2	502.6	87.8	96.5	131.6	1,684.0
1990	3.8	28.9	53.7	212.5	312.1	575.5	144.8	378.4	66.8	172.4	1,948.9
1991	1.7	130.4	62.4	99.0	159.2	195.3	428.6	83.9	243.3	167.9	1,571.7
1992	1.7	81.2	715.1	163.0	92.5	132.7	166.2	291.3	73.2	299.3	2,016.2
1993	2.1	18.6	248.4	1,130.0	132.4	66.1	66.5	61.5	89.1	101.0	1,915.6
1994	0.5	34.3	70.2	342.1	1,043.4	145.3	42.6	30.3	27.2	84.5	1,820.3
1995	0.3	10.2	96.3	138.8	390.6	761.5	102.1	28.1	19.5	74.0	1,621.5
1996	0.7	17.6	49.8	117.6	189.0	399.1	515.9	75.5	20.9	73.1	1,459.2
1997	1.1	69.6	40.6	99.6	470.6	286.5	256.0	211.3	37.4	53.6	1,526.2
1998	0.4	51.0	97.0	74.3	150.2	676.4	194.4	128.3	113.3	44.2	1,529.6
1999	0.4	13.8	283.0	223.6	104.0	149.6	463.0	125.3	56.1	54.0	1,472.9
2000	0.6	13.8	81.7	422.2	341.0	108.5	160.2	347.9	83.6	72.3	1,631.9
2001	0.8	13.7	62.7	168.7	597.5	413.0	130.3	102.7	177.9	100.9	1,768.4
2002	0.7	44.5	120.1	217.7	289.8	616.1	274.3	87.6	65.8	174.6	1,891.1
2003	0.4	20.0	394.8	337.0	372.9	307.5	338.6	149.0	43.7	124.9	2,088.9
2004	0.2	7.8	100.5	844.7	499.2	248.5	160.6	149.4	64.0	91.6	2,166.4
2005	0.1	4.2	60.4	389.7	890.6	489.3	162.5	70.0	63.4	71.8	2,201.9
2006	0.3	5.2	72.8	276.9	602.2	617.3	291.1	105.2	46.5	96.3	2,113.7
2007	0.8	14.4	51.3	122.7	356.2	487.1	316.6	146.0	53.4	82.8	1,631.3
2008	0.2	24.9	63.9	81.1	150.8	300.1	236.1	161.1	82.3	79.2	1,179.8
2009	0.9	4.7	178.2	189.0	96.3	104.3	113.5	95.0	72.3	87.0	941.2
2010	0.4	25.7	33.8	570.5	223.2	57.2	46.2	53.9	45.8	72.9	1,129.4
2011	0.5	12.0	194.0	122.8	827.5	264.6	58.4	39.0	40.8	89.3	1,648.8
2012	0.5	11.4	65.5	567.7	229.7	472.1	169.9	40.3	28.2	110.7	1,696.0
Median	1.6	36.3	161.0	339.5	314.5	194.1	132.8	66.5	36.6	46.1	1,816.8
Average	10.8	184.0	414.6	412.6	348.1	265.5	161.0	90.0	49.2	64.7	2,007.7

Table 1.23. Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2012. 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	1,608	444	5,228	1989	9,913	3,720	10,357
1965	2,059	566	20,407	1990	7,936	3,012	50,175
1966	2,157	675	14,313	1991	6,209	2,263	25,582
1967	3,353	853	28,708	1992	9,602	2,366	22,047
1968	3,809	1,053	26,680	1993	11,754	3,244	47,813
1969	5,154	1,332	29,281	1994	11,341	3,532	14,782
1970	6,188	1,669	20,124	1995	13,109	3,732	10,798
1971	6,894	1,883	9,676	1996	11,229	3,730	23,219
1972	6,308	1,810	10,686	1997	9,828	3,525	31,494
1973	4,700	1,441	28,947	1998	9,929	3,284	15,700
1974	3,298	988	21,457	1999	10,819	3,296	17,239
1975	3,523	822	18,171	2000	10,044	3,335	26,601
1976	3,587	850	13,946	2001	9,830	3,373	35,891
1977	3,624	923	13,901	2002	10,230	3,205	23,356
1978	3,537	973	26,918	2003	12,269	3,396	14,087
1979	3,403	955	65,651	2004	11,491	3,487	6,308
1980	4,333	1,071	26,290	2005	9,608	3,184	4,471
1981	8,364	1,761	29,778	2006	7,349	2,610	10,740
1982	9,549	2,682	15,587	2007	5,954	2,174	25,683
1983	10,621	3,308	52,550	2008	4,724	1,590	8,496
1984	10,300	3,522	13,032	2009	6,069	1,708	43,607
1985	12,478	3,777	35,369	2010	5,769	1,837	19,133
1986	11,685	4,002	14,506	2011	7,781	2,059	18,621
1987	12,308	4,122	8,493	2012	7,867	2,289	17,451
1988	11,642	4,120	5,491	2013	8,138		

Table 1.24. Estimates of begin-year age 3 and older biomass (thousands of tons) and coefficients of variation (CV) for the current assessment compared to estimates from the 2005-2011 assessments for EBS pollock. NOTE: see Ianelli et al. (2001) for a discussion on the interpretation of age-3+ biomass estimates.

	Current		2011		2010		2009		2008		2007		2006		2005	
	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV
1964	1,608	21%	1,602	21%	1,589	21%	1,564	22%	1,600	22%	1,717	23%	1,810	23%	1,779	23%
1965	2,059	20%	2,050	20%	2,008	19%	2,008	20%	2,050	20%	2,141	21%	2,231	21%	2,222	21%
1966	2,157	20%	2,159	20%	1,944	21%	1,947	22%	2,007	21%	2,037	22%	2,252	21%	2,288	21%
1967	3,353	16%	3,365	16%	3,140	17%	3,149	17%	3,245	17%	3,206	18%	3,518	17%	3,483	17%
1968	3,809	17%	3,838	17%	3,486	18%	3,510	19%	3,592	18%	3,558	19%	3,881	17%	3,881	17%
1969	5,154	16%	5,187	16%	4,879	17%	5,007	17%	5,020	17%	5,118	17%	5,058	16%	5,323	16%
1970	6,188	15%	6,221	15%	5,974	16%	6,159	15%	6,005	16%	6,368	15%	5,929	16%	6,447	15%
1971	6,894	14%	6,918	14%	6,785	13%	6,949	13%	6,727	14%	7,164	13%	6,617	13%	7,145	13%
1972	6,308	14%	6,329	14%	6,277	13%	6,444	13%	6,289	14%	6,666	13%	6,265	13%	6,692	13%
1973	4,700	16%	4,728	16%	4,547	16%	4,696	16%	4,556	17%	4,942	16%	4,751	16%	5,055	15%
1974	3,298	20%	3,329	20%	3,085	20%	3,196	20%	3,064	22%	3,475	20%	3,460	19%	3,635	19%
1975	3,523	14%	3,533	14%	3,366	13%	3,384	13%	3,276	14%	3,604	14%	3,585	13%	3,666	14%
1976	3,587	11%	3,580	11%	3,460	10%	3,431	11%	3,339	11%	3,584	11%	3,577	11%	3,614	11%
1977	3,624	10%	3,598	9%	3,500	9%	3,457	9%	3,340	10%	3,602	10%	3,582	10%	3,548	10%
1978	3,537	9%	3,497	9%	3,390	9%	3,340	9%	3,202	9%	3,476	9%	3,438	10%	3,361	10%
1979	3,403	9%	3,343	9%	3,267	9%	3,212	9%	3,090	9%	3,363	9%	3,323	9%	3,273	10%
1980	4,333	7%	4,230	7%	4,203	7%	4,124	8%	4,044	7%	4,384	8%	4,320	8%	4,373	8%
1981	8,364	6%	8,160	6%	8,190	6%	8,031	6%	7,704	6%	8,307	6%	8,364	7%	8,289	7%
1982	9,549	6%	9,313	6%	9,349	6%	9,165	6%	8,783	6%	9,439	6%	9,476	6%	9,446	7%
1983	10,621	5%	10,340	5%	10,376	5%	10,168	5%	9,804	5%	10,493	6%	10,443	6%	10,536	7%
1984	10,300	5%	10,031	5%	10,060	5%	9,857	5%	9,518	5%	10,200	6%	10,088	6%	10,244	7%
1985	12,478	4%	12,186	4%	12,246	4%	12,027	4%	11,802	4%	12,531	5%	12,285	5%	12,435	6%
1986	11,685	4%	11,426	4%	11,471	4%	11,269	4%	11,075	4%	11,773	5%	11,486	5%	11,609	6%
1987	12,308	4%	12,063	4%	12,111	4%	11,915	4%	11,732	4%	12,401	4%	12,077	5%	12,106	5%
1988	11,642	4%	11,424	4%	11,402	4%	11,227	4%	11,004	4%	11,617	4%	11,330	5%	11,153	5%
1989	9,913	4%	9,724	4%	9,671	4%	9,521	4%	9,320	4%	9,875	4%	9,584	5%	9,384	5%
1990	7,936	4%	7,764	4%	7,681	4%	7,558	4%	7,345	4%	7,847	5%	7,603	5%	7,392	6%
1991	6,209	5%	6,049	5%	5,911	5%	5,811	5%	5,590	5%	6,097	5%	5,929	6%	5,454	6%
1992	9,602	3%	9,411	3%	9,316	3%	9,211	4%	8,966	4%	9,557	4%	9,270	5%	8,905	5%
1993	11,754	3%	11,543	3%	11,493	3%	11,388	3%	11,175	3%	11,832	4%	11,795	4%	11,669	5%
1994	11,341	3%	11,146	3%	11,077	3%	10,990	4%	10,782	4%	11,485	4%	11,407	5%	11,000	5%
1995	13,109	3%	12,883	3%	12,779	3%	12,699	3%	12,704	3%	13,615	4%	13,658	4%	13,605	6%
1996	11,229	3%	11,019	3%	10,903	4%	10,843	4%	10,829	4%	11,537	4%	11,480	5%	11,826	6%
1997	9,828	4%	9,627	4%	9,485	4%	9,440	4%	9,403	4%	10,104	5%	10,056	5%	9,966	6%
1998	9,929	3%	9,722	4%	9,584	4%	9,538	4%	9,467	4%	10,178	5%	9,973	5%	9,915	7%
1999	10,819	3%	10,607	3%	10,509	3%	10,421	3%	10,379	4%	11,081	4%	10,872	5%	10,998	6%
2000	10,044	3%	9,841	3%	9,747	3%	9,632	3%	9,503	4%	10,201	4%	10,052	5%	9,947	7%
2001	9,830	3%	9,616	3%	9,506	3%	9,341	4%	9,175	4%	9,898	5%	9,800	6%	9,566	8%
2002	10,230	3%	9,988	3%	9,842	3%	9,595	4%	9,554	4%	10,224	5%	10,197	7%	9,824	9%
2003	12,269	3%	11,974	3%	11,805	3%	11,453	3%	11,182	4%	12,865	6%	13,320	10%	13,073	13%
2004	11,491	3%	11,178	3%	10,974	3%	10,606	4%	10,274	4%	11,784	7%	12,055	12%	10,972	15%
2005	9,608	3%	9,299	3%	9,079	4%	8,736	4%	8,423	5%	9,598	8%	9,759	14%	9,277	18%
2006	7,349	4%	7,060	4%	6,839	4%	6,543	5%	6,340	6%	7,178	10%	7,950	17%	8,232	21%
2007	5,954	4%	5,633	5%	5,386	5%	5,090	6%	5,015	8%	5,363	14%	6,361	21%		
2008	4,724	5%	4,393	6%	4,146	7%	3,809	8%	4,222	12%	4,357	20%				
2009	6,069	6%	6,172	8%	6,225	10%	4,762	11%	6,240	20%						
2010	5,769	7%	6,095	10%	6,582	12%	4,616	13%								
2011	7,781	9%	7,823	11%	9,620	15%										
2012	7,867	10%	8,341	12%												
2013	8,138	12%														

Table 1.25 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 6,425, 2,570 and 2,249 thousand t, respectively.

Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2012	1,200	1,200	1,200	1,200	1,200	1,200	1,200
2013	1,452	**1,200**	1,375	673	0	1,753	1,452
2014	1,426	1,547	1,430	802	0	1,554	1,426
2015	1,290	1,338	1,340	836	0	1,353	1,558
2016	1,245	1,263	1,291	854	0	1,318	1,388
2017	1,307	1,313	1,327	896	0	1,401	1,424
2018	1,383	1,385	1,386	948	0	1,477	1,485
2019	1,424	1,425	1,421	986	0	1,514	1,516
2020	1,432	1,432	1,431	1,007	0	1,513	1,513
2021	1,433	1,432	1,434	1,020	0	1,508	1,508
2022	1,445	1,445	1,443	1,031	0	1,525	1,525
2023	1,468	1,468	1,462	1,046	0	1,551	1,551
2024	1,490	1,490	1,482	1,061	0	1,574	1,574
2025	1,491	1,491	1,485	1,068	0	1,570	1,570
Fishing M.	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2012	0.412	0.412	0.412	0.412	0.412	0.412	0.412
2013	0.409	0.329	0.384	0.175	0.000	0.510	0.409
2014	0.389	0.405	0.384	0.175	0.000	0.462	0.389
2015	0.372	0.379	0.384	0.175	0.000	0.436	0.466
2016	0.366	0.368	0.384	0.175	0.000	0.433	0.443
2017	0.367	0.367	0.384	0.175	0.000	0.439	0.442
2018	0.370	0.370	0.384	0.175	0.000	0.443	0.444
2019	0.372	0.372	0.384	0.175	0.000	0.446	0.447
2020	0.372	0.372	0.384	0.175	0.000	0.446	0.446
2021	0.372	0.372	0.384	0.175	0.000	0.446	0.446
2022	0.374	0.374	0.384	0.175	0.000	0.449	0.449
2023	0.376	0.376	0.384	0.175	0.000	0.452	0.452
2024	0.377	0.377	0.384	0.175	0.000	0.454	0.454
2025	0.378	0.378	0.384	0.175	0.000	0.455	0.455
Spawning	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
2012	2,306	2,306	2,306	2,306	2,306	2,306	2,306
2013	2,546	2,580	2,557	2,648	2,728	2,503	2,546
2014	2,430	2,522	2,463	2,855	3,250	2,280	2,430
2015	2,345	2,385	2,366	2,988	3,712	2,161	2,305
2016	2,382	2,398	2,378	3,140	4,150	2,191	2,245
2017	2,490	2,497	2,470	3,324	4,578	2,288	2,308
2018	2,571	2,574	2,547	3,480	4,960	2,351	2,358
2019	2,603	2,605	2,583	3,579	5,254	2,368	2,370
2020	2,609	2,610	2,593	3,639	5,483	2,364	2,365
2021	2,617	2,618	2,605	3,688	5,684	2,368	2,368
2022	2,646	2,647	2,636	3,742	5,849	2,394	2,394
2023	2,678	2,679	2,672	3,799	6,008	2,423	2,423
2024	2,692	2,693	2,691	3,835	6,122	2,432	2,432
2025	2,682	2,682	2,685	3,845	6,200	2,418	2,418

Table 1.26 Maximum permissible Tier 1a EBS pollock ABC and OFL projections for 2013 and for 2014.

Year	Catch	ABC	OFL
2013	1,200,000 t	2,306,000 t	2,549,000 t
2014	1,400,000 t	2,466,000 t	2,726,000 t

Table 1.27. Details and explanation of the decision table factors selected in response to the Plan Team requests.

Term	Description	Rationale
$P\left[F_{2013} > F_{msy}\right]$	Probability that the fishing mortality in 2013 exceeds F_{msy}	OFL definition is based on F_{msy}
$P\left[B_{2014} < \bar{B}\right]$	Probability that the spawning biomass in 2014 is less than the 1978-2011 mean	To provide some perspective of what the stock condition might be relative to historical estimates after fishing in 2013.
$P\left[B_{2014} < B_{msy}\right]$	Probability that the spawning biomass in 2014 is less than B_{msy}	B_{msy} is a reference point target and biomass in 2014 provides an indication of the impact of 2013 fishing
$P\left[B_{2015} < B_{msy}\right]$	Probability that the spawning biomass in 2015 is less than B_{msy}	B_{msy} is a reference point target and biomass in 2015 provides an indication of the impact of fishing in 2013 and 2014
$P\left[B_{2015} < B_{20\%}\right]$	Probability that the spawning biomass in 2015 is less than $B_{20\%}$	$B_{20\%}$ has been selected as a Steller Sea Lion lower limit for allowing directed fishing
$P\left[B_{2017} < B_{2013}\right]$	Probability that the spawning biomass in 2017 is less than that estimated for 2013	To provide a medium term expectation of stock status relative to 2013 levels
$P\left[B_{2017} < \bar{B}\right]$	Probability that the spawning biomass in 2017 is less than the 1978-2011 mean	To provide some perspective of what the stock condition might be relative to historical estimates
$P\left[p_{1-5,2017} > \bar{p}_{1-5}\right]$	Probability that the proportion of age 1-5 pollock in the population exceeds the long-term mean proportion	To provide some relative indication of the age composition of the population relative to the long term mean.
$P\left[D_{2014} < D_{1994}\right]$	Probability that the diversity of ages represented in the spawning biomass (by weight) in 2014 is less than the value estimated for 1994	To provide a relative index on the abundance of different age classes in the 2014 population relative to 1994 (a year identified as having low age composition diversity)
$P\left[D_{2017} < D_{1994}\right]$	Probability that the diversity of ages represented in the spawning biomass (by weight) in 2017 is less than the value estimated for 1994	To provide a medium-term relative index on the abundance of different age classes in the population relative to 1994 (a year identified as having low age composition diversity)
$P\left[E_{2013} > E_{2012}\right]$	Probability that the theoretical fishing effort in 2013 will be greater than that estimated in 2012.	To provide the relative effort that is expected (and hence some idea of costs).
$P\left[S_{2013} > \bar{S}\right]$	Probability that the Chinook salmon PSC bycatch will exceed the 1991-2012 mean value (38,517 salmon)	Provide some index of risk based on historical rates (Chinook PSC / t of pollock) and variability of the rates over time. Computed given historical mean rates (Chinook / t of salmon) and variability from 1991-2012.

Table 1.28. Outcomes of decision (expressed as probabilities of "something bad happening") given different levels of 2013 catches (and constant F's based on the 2013 catches for subsequent years).

	2013 catch (kt)						
	0.01	**500**	**750**	**1000**	**1200**	**1500**	**2000**
$P\left[F_{2013} > F_{msy}\right]$	0%	0%	0%	0%	0%	3%	26%
$P\left[B_{2014} < B_{msy}\right]$	6%	10%	14%	18%	23%	30%	47%
$P\left[B_{2014} < \bar{B}\right]$	13%	39%	55%	70%	80%	91%	98%
$P\left[B_{2015} < B_{msy}\right]$	2%	7%	11%	17%	24%	36%	60%
$P\left[B_{2015} < B_{20\%}\right]$	0%	0%	0%	0%	0%	1%	3%
$P\left[B_{2017} < B_{2013}\right]$	1%	8%	15%	24%	33%	45%	63%
$P\left[B_{2017} < \bar{B}\right]$	2%	12%	23%	36%	46%	61%	80%
$P\left[p_{1-5,2017} > \bar{p}_{1-5}\right]$	4%	31%	49%	63%	71%	80%	88%
$P\left[D_{2014} < D_{1994}\right]$	84%	85%	85%	86%	87%	88%	90%
$P\left[D_{2017} < D_{1994}\right]$	0%	1%	4%	9%	15%	27%	51%
$P\left[E_{2013} > E_{2012}\right]$	0%	0%	0%	0%	7%	48%	91%
$P\left[S_{2013} > \bar{S}\right]$	0%	1%	14%	35%	48%	62%	74%

Table 1.29. A subset of decision indicators (expressed as probabilities of "something bad happening") given different levels of 2013 catches (and constant F's based on the 2013 catches for subsequent years). Landings values were simply scaled to be proportionate between the OY cap and a complete pollock fishery closure.

	2013 catch (kt)						
	0.01	500	750	1000	1200	1500	2000
Landings:	100%	96%	86%	65%	43%	16%	1%
Biomass:							
$P\left[B_{2015} < B_{msy}\right]$	2%	7%	11%	17%	24%	36%	60%
Fishing conditions:							
$P\left[B_{2014} < \bar{B}\right]$	13%	39%	55%	70%	80%	91%	98%
$P\left[B_{2017} < \bar{B}\right]$	2%	12%	23%	36%	46%	61%	80%
Age structure:							
$P\left[p_{1-5,2017} > \bar{p}_{1-5}\right]$	4%	31%	49%	63%	71%	80%	88%
Age diversity:							
$P\left[D_{2017} < D_{1994}\right]$	0%	1%	4%	9%	15%	27%	51%
Fishing effort:							
$P\left[E_{2013} > E_{2012}\right]$	0%	0%	0%	0%	7%	48%	91%
Salmon:							
$P\left[S_{2013} > \bar{S}\right]$	0%	1%	14%	35%	48%	62%	74%

Table 1.30. 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, ichthyoplankton surveys, changes mean wt-at-age	Data improving, indication of recent increases since 2004 (for euphasiids)	Nearly three-fold change in apparent abundance—indicates favorable conditions for 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 1.31 Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 1997-2002 based on observer data, 2003-2012 based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska). Note that in 2011 species groups left blank are because they have moved into "target" FMP categories.

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

Category	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Scypho jellies	5,644	6,590	5,196	2,714	2,376	4,183	8,100	2,659	8,898	3,801
Misc fish	101.3	89.8	157.9	148.5	201.7	120.2	134.9	172.0	326.0	157.0
Eulachon	2.5	19.3	9.2	93.9	101.9	2.4	5.4	0.7	3.3	0.8
Sea star	89.4	7.2	9.5	11.4	5.2	18.8	9.8	13.2	37.3	9.4
Eelpouts	7.0	0.7	1.3	21.1	118.9	8.9	4.4	2.1	1.3	1.2
Giant Grenadier	0.3	4.1	5.0	6.9	16.8	23.8	4.3	4.1	1.7	2.0
Grenadier	20.4	10.1	9.0	8.8	10.9	4.1	0.7	0.6	0.3	0.0
Osmerids	7.5	2.0	3.4	5.6	37.9	2.0	0.1	0.1	0.3	0.1
Sea pens	0.6	1.0	1.7	2.0	4.0	1.1	2.6	3.1	2.9	3.9
Lanternfish	0.3	0.1	0.6	9.6	5.9	1.5	0.4	0.0	0.0	0.1
Snails	1.3	1.0	6.9	0.2	0.5	1.9	1.5	1.4	1.4	1.4
Sponge unid.	0.1	0.0	0.0	0.0	1.4	0.2	0.5	4.9	3.9	1.8
Sea anemone	0.4	0.4	0.3	0.6	0.3	0.9	1.3	2.4	2.0	2.1
Brittle star unidentified	0.3	0.0	0.0	2.7	0.2	3.6	0.1	0.3	0.2	0.1
urochordata	0.0	0.0	0.5	0.0	0.0	0.8	0.7	3.1	0.9	0.1
Unid. Inverts	0.0	0.1	0.1	0.2	0.7	0.3	0.3	1.0	0.7	2.2
Pandalids	0.0	0.0	0.5	0.8	1.1	0.9	0.3	0.5	0.2	0.1
Capelin	0.0	0.3	0.3	2.5	0.9	0.0	0.2	0.0	0.1	0.1
All other	0.9	0.3	0.8	0.3	3.3	1.5	1.1	1.5	1.6	0.6

Table 1.32 Bycatch estimates (t) of other **target species** caught in the BSAI directed pollock fishery, 1997-2011 based on then NMFS Alaska Regional Office reports from observers (*2011 data are preliminary*). **Note that the increase in 2011 is partially due to earlier non-target species being moved into the FMP as "target" species (e.g., skates, squid, octopus etc).**

	Pacific Cod	Flathead Sole	Rock Sole	Yellowfin Sole	Arrowtooth Flounder	Pacific Ocean Perch	Atka Mackerel	Sablefish	Greenland Turbot	Alaska Plaice	Alaska skate	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	1,740	1,419	210	618	935	762	48	40	7		67	11,814
2004	6,437	2,009	2,554	755	557	394	1,053	17	18	8		120	14,100
2005	7,413	2,319	1,125	725	651	653	678	11	31	45		125	13,145
2006	7,291	2,837	1,361	1,304	1,089	737	789	9	65	11		152	14,612
2007	5,630	4,203	510	1,282	2,795	625	315	12	107	3		188	14,494
2008	6,969	4,288	2,125	2,708	1,712	336	20	5	85	49		39	15,205
2009	7,878	4,602	7,602	3,818	2,203	114	25	3	44	176		25	22,861
2010	6,987	4,309	2,330	646	1,502	231	57	2	26	126	1,234	1,579	19,111
2011	9,998	4,846	8,463	1,443	1,599	659	891	1	29	74	881	2,492	29,973
2012	9,998	3,904	6,809	1,468	615	700	263	1	52	125	515	641	25,091
Average	6,615	2,998	2,744	1,244	1,155	485	341	12	64	53	877	527	15,730

Group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Skates	462	841	732	1,308	1,287	2,758	3,856	1,886	2,348	1,985
Squid	952	977	1,150	1,399	1,169	1,452	209	277	178	479
Sharks	191	187	169	512	246	146	100	26	132	55
Sculpins	92	150	131	169	190	283	292	258	315	283
Octopus	9	3	1	2	4	4	5	4	9	3

Table 1.33 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 (*2012 data are preliminary*).

Target fishery	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Avg.
Pacific cod fishery	16,022	18,610	14,105	15,147	20,296	9,516	7,879	6,416	8,966	7,734	12,469
Yellowfin sole fishery	11,570	10,479	10,312	5,967	4,042	9,867	6,998	5,207	8,694	8,690	8,183
Rock sole fishery	4,925	8,964	7,240	7,040	3,220	4,995	6,150	5,913	7,091	6,769	6,231
Flathead sole fishery	2,989	5,112	3,664	2,641	3,448	4,098	3,166	3,072	1,491	886	3,057
Other flatfish	304	605	262	53	320	7	20	6	2	15	159
Other fisheries	653	826	1,353	1,244	880	725	340	407	1,130	903	846
Total from other fisheries	36,462	44,595	36,936	32,091	32,205	29,208	24,553	21,021	27,375	24,997	30,944

Table 1.34 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. Preliminary 2012 data are through October 31st, 2012.

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	1,398,107		39,054		2,156		3,159	28,709	4,380,023	33,346	17,777
1992	1,500,765		33,672		2,220		647	40,187	4,569,662	20,385	43,874
1993	1,649,103		36,619		1,326		527	241,980	738,259	1,926	58,140
1994	371,214		31,890		963	689	1,627	92,011	811,734	514	42,361
1995	153,993		13,403		492	397	905	17,755	206,651	941	4,644
1996	89,416		55,472		382	321	1,242	77,174	63,398	215	5,934
1997	17,046		44,320		257	200	1,135	65,415	216,152	393	137
1998	57,037		51,244		353	278	801	60,677	123,401	5,093	14,287
1999	2,397		10,381		154	125	800	44,610	15,830	7	91
2000	1,485		4,242		110	91	483	56,867	6,481	121	
2001	5,061		30,937		243	200	225	53,904	5,653	5,139	106
2002	2,113		32,402		199	168	109	77,178	2,698	194	17
2003	733	9	43,021	0	113	96	909	180,782	609		52
2004	1,189	4	51,700	2	109	93	1,104	440,477	743		27
2005	659	0	67,319	1	147	113	610	704,569	2,300		0
2006	1,666	0	82,596	3	156	122	436	309,642	2,947		203
2007	1,519	0	122,262	3	358	290	354	93,167	3,214		8
2008	8,888	8	21,358	33	425	333	128	15,420	9,573		576
2009	6,113	20	12,568	0	598	459	65	46,777	7,425		1,137
2010	13,531	29	9,796	0	355	272	351	13,806	9,439		1,009
2011	10,319	20	25,499	0	509	382	377	193,555	6,332		577
2012	3,650	0	10,157	0	456	369	2,357	21,945	16,508		292

Figures

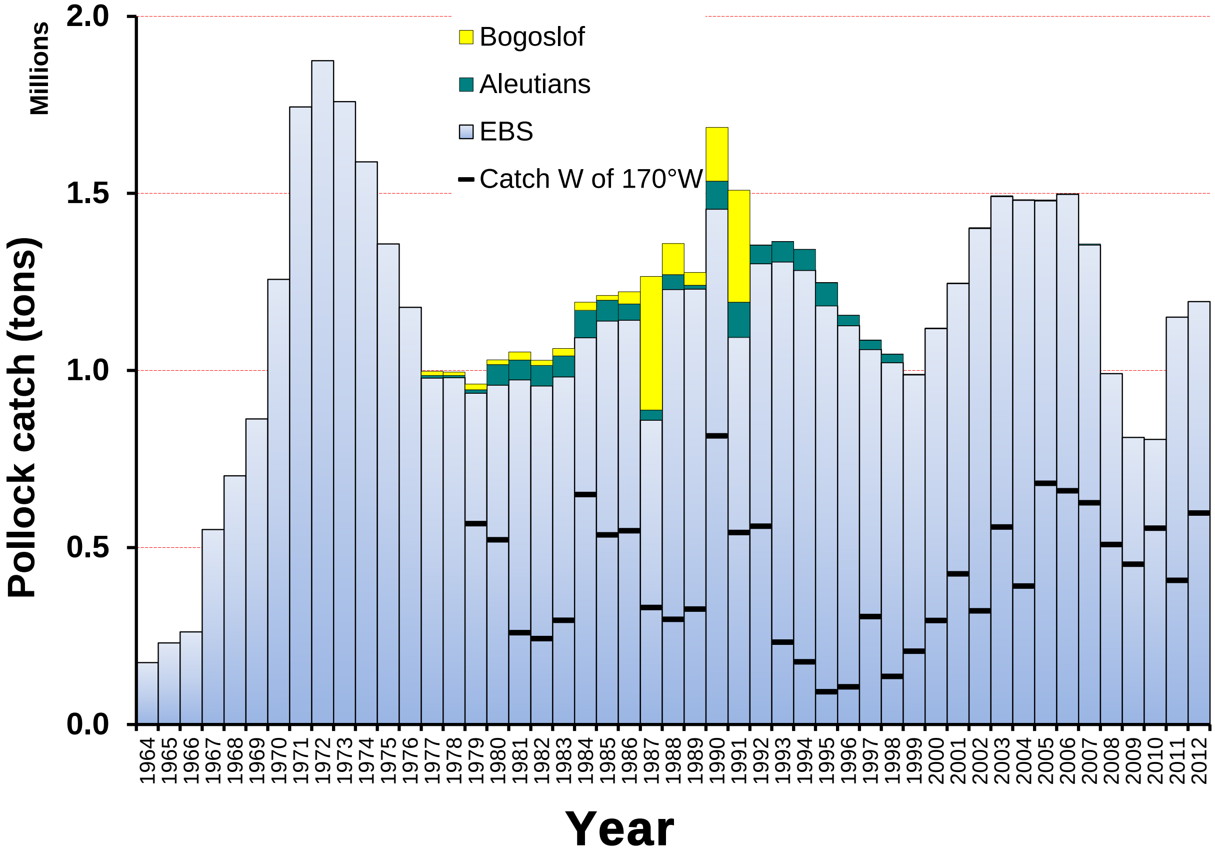

Figure 1.1. Alaska pollock catch estimates from the Eastern Bering Sea, Aleutian Islands, and Bogoslof Island regions, 1964-2012. The 2012 value is based on expected totals for the year.

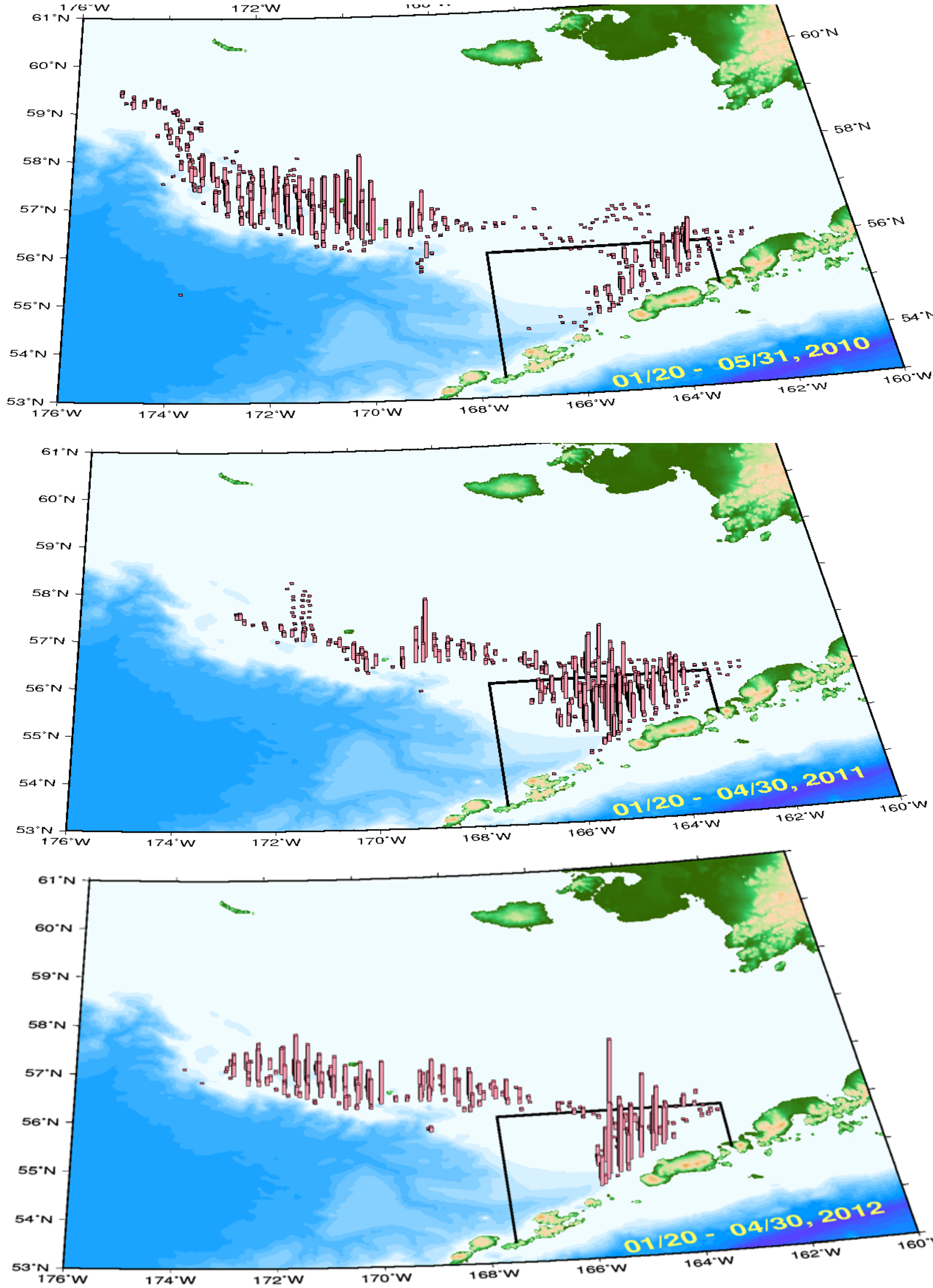

Figure 1.2. Pollock catch distribution 2010-2012, January – May on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

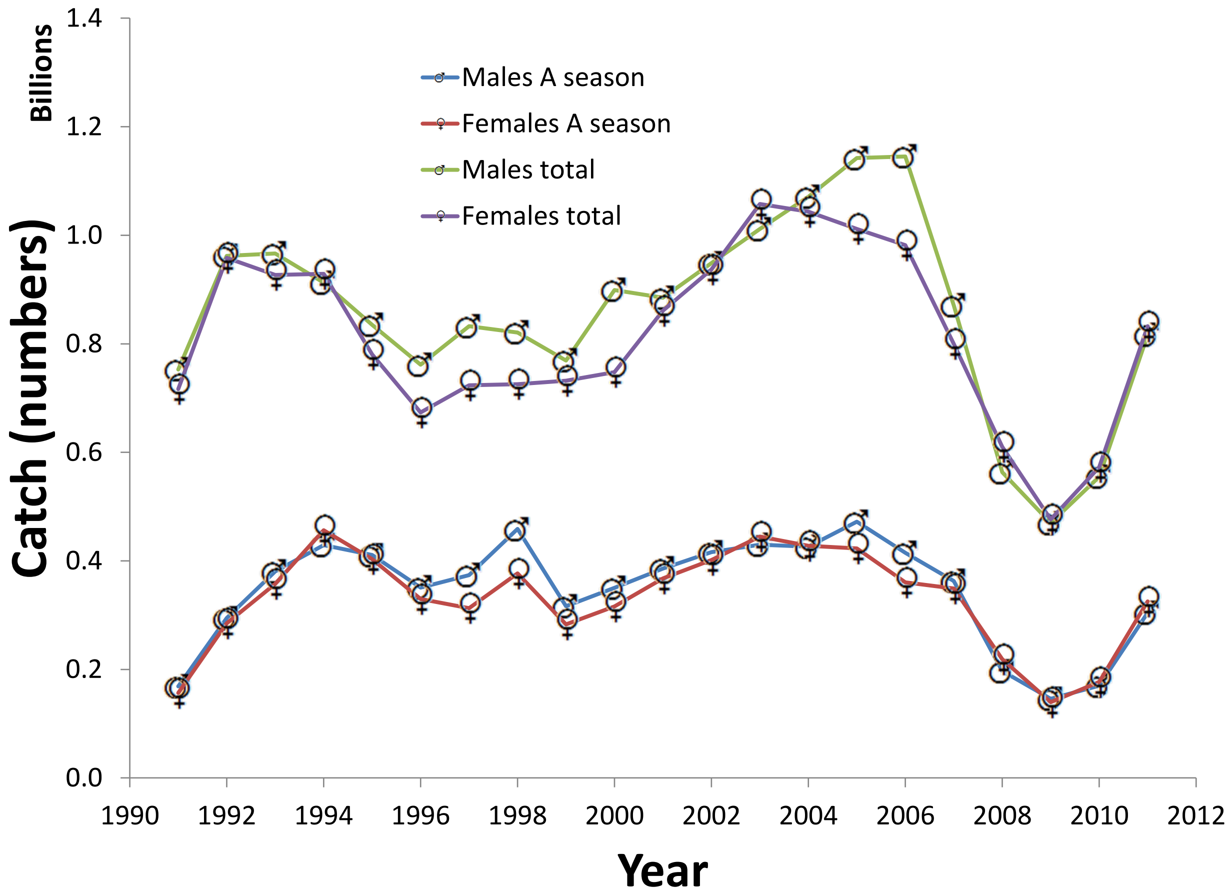

Figure 1.3. Estimate of EBS pollock catch numbers by sex for the “A season” (January-May) and for the entire annual fishery, 1991-2012.

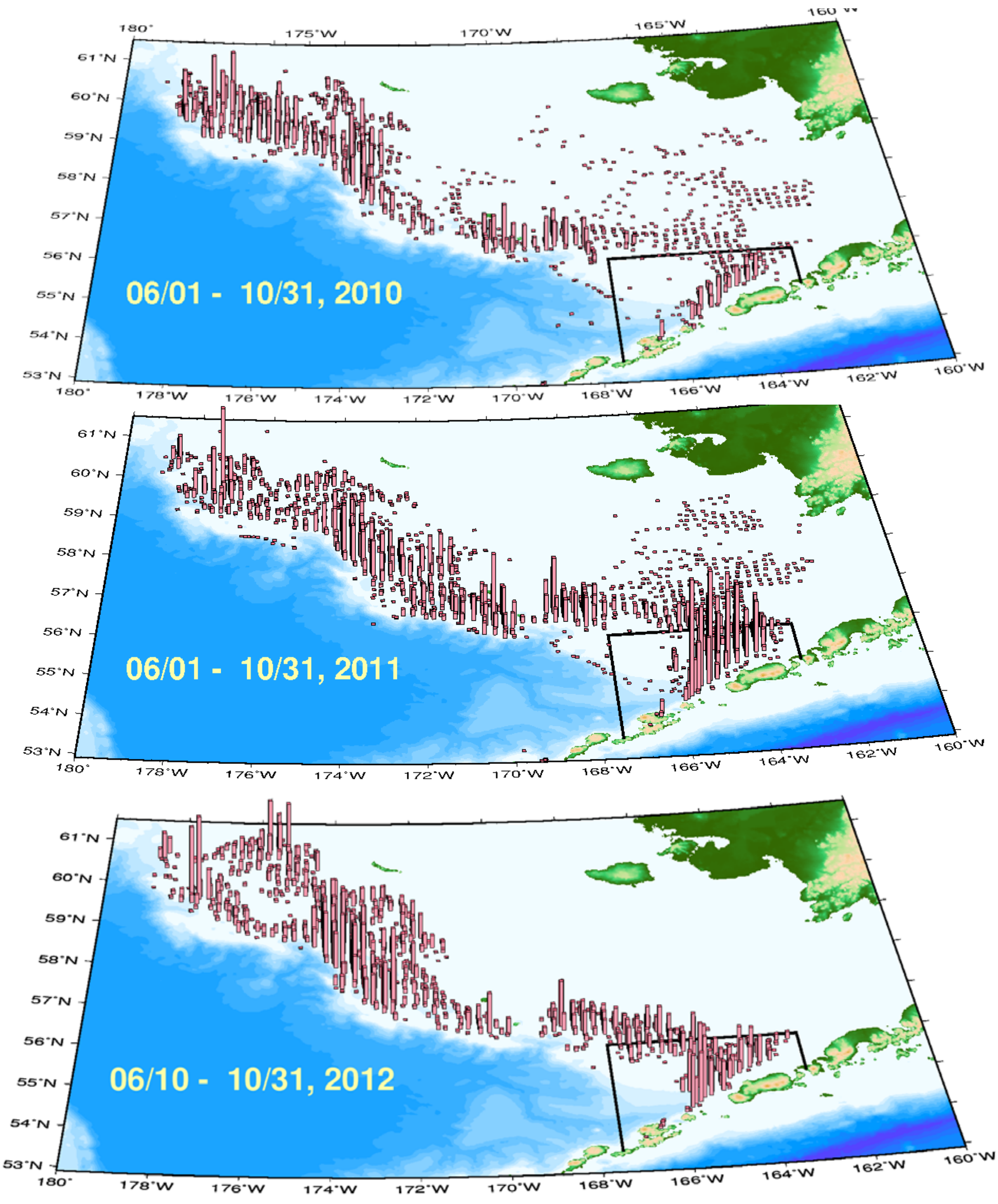

Figure 1.4. Pollock catch distribution during June – December, 2010-2012. The line delineates the catcher-vessel operational area (CVOA) and the height of the bars represents relative removal on the same scale between years. Note that since 2011 the observer coverage increased to 100% for all pollock vessels (for salmon bycatch monitoring) consequently the relative magnitude of the catch increase in the CVOA is affected (catcher-vessels previously had about 50% of their catch occur with observers on board).

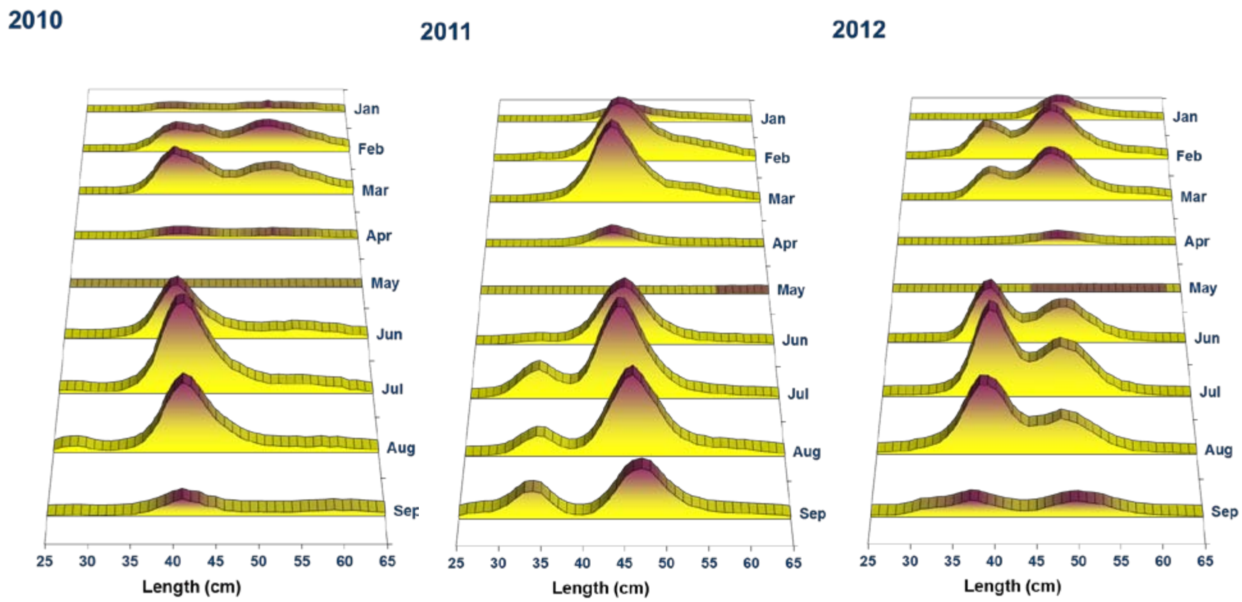

Figure 1.5. Monthly NMFS observer data on the length frequency of EBS pollock, 2010-2012.

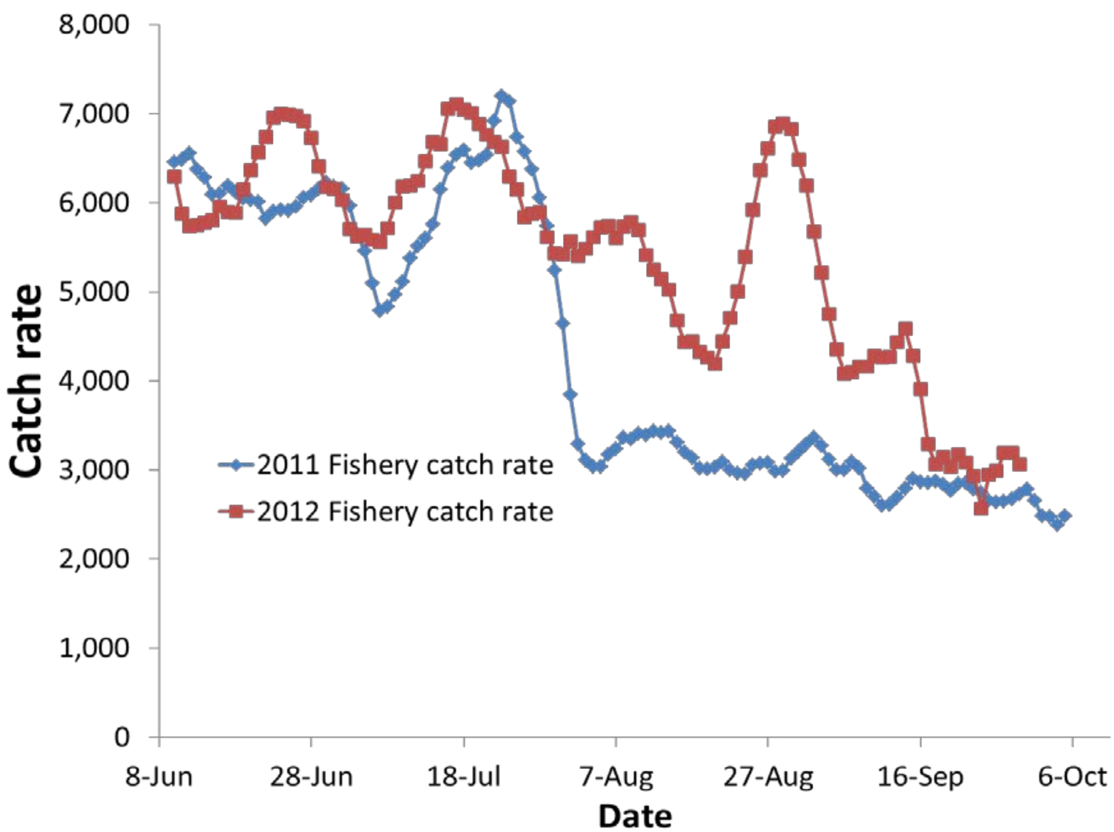

Figure 1.6. Weekly mean nominal pollock catch (kg) per hour towed for the EBS pollock fishery comparing 2011 with 2012. Note that by mid-September most of the larger boats had finished and that this is reflected in the drop in catch rates then.

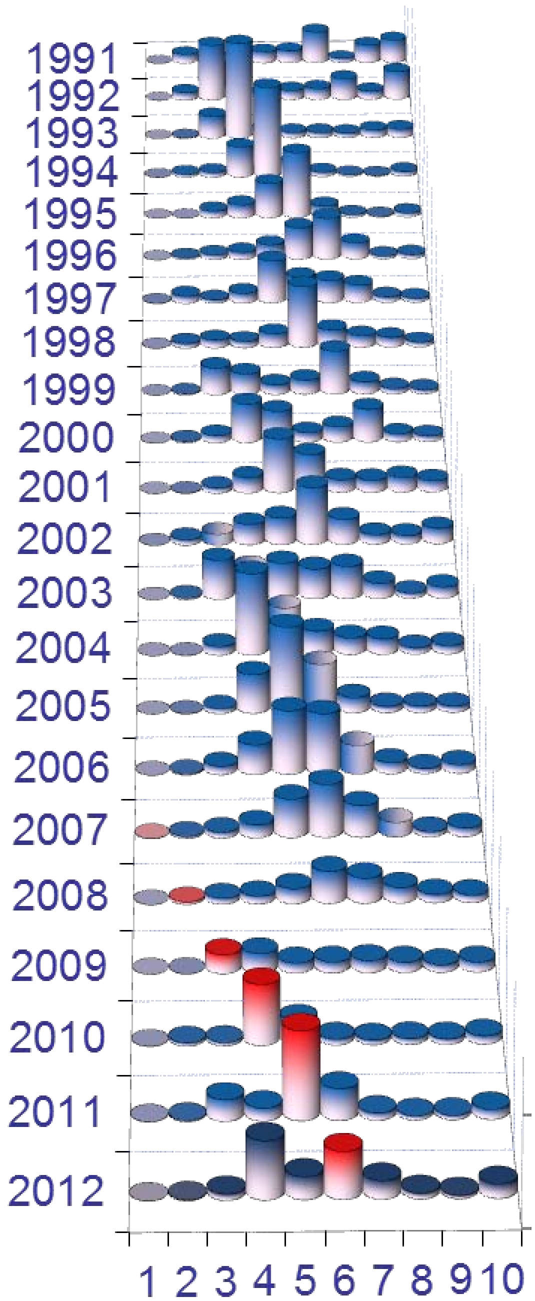

Figure 1.7. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2012 (2012 data are preliminary). Age 10 represents pollock age 10 and older. The 2006 year-class is highlighted with red shading.

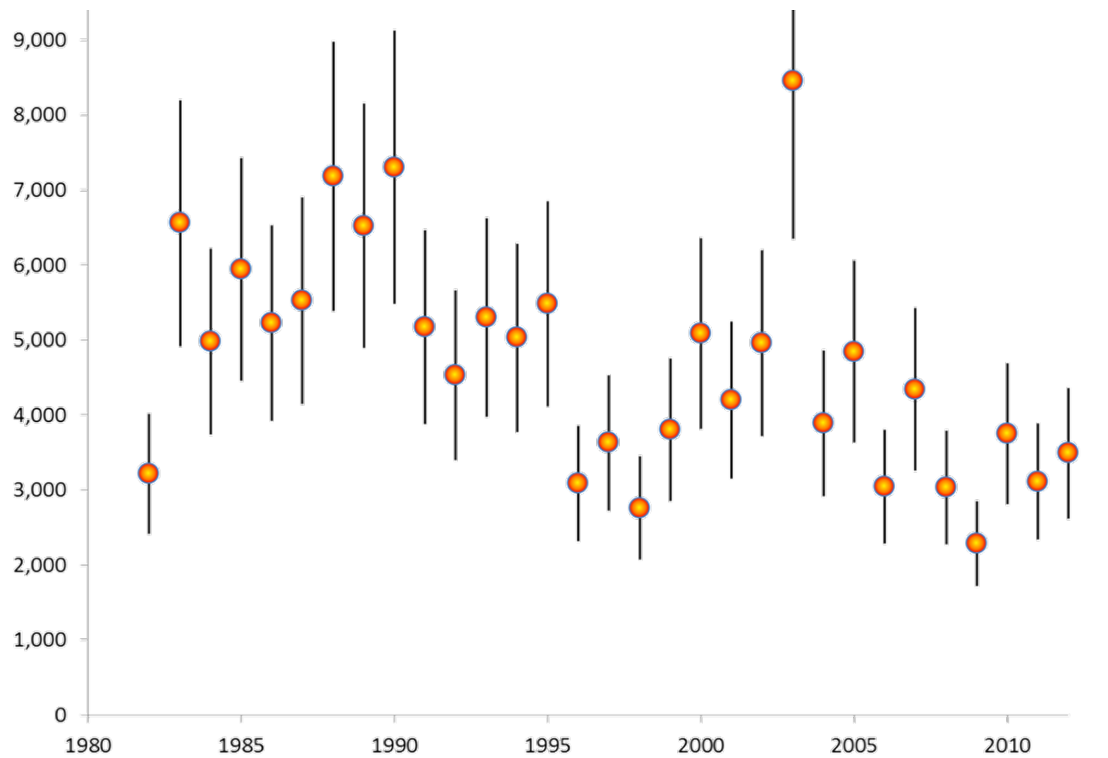

Figure 1.8. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS pollock, 1982-2012. These estimates **include** the northern strata except for 1982-84, and 1986.

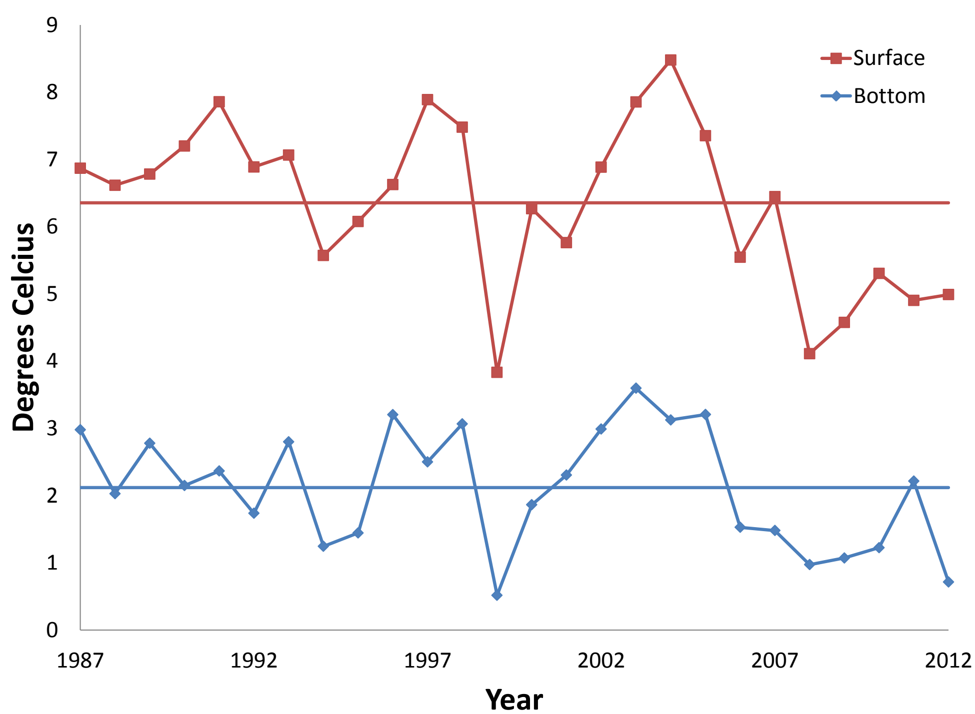

Figure 1.9. Area-weighted bottom (lower lines) and surface (upper lines) temperatures for the Bering Sea and mean values from the NMFS summer bottom-trawl surveys (1982-2012).

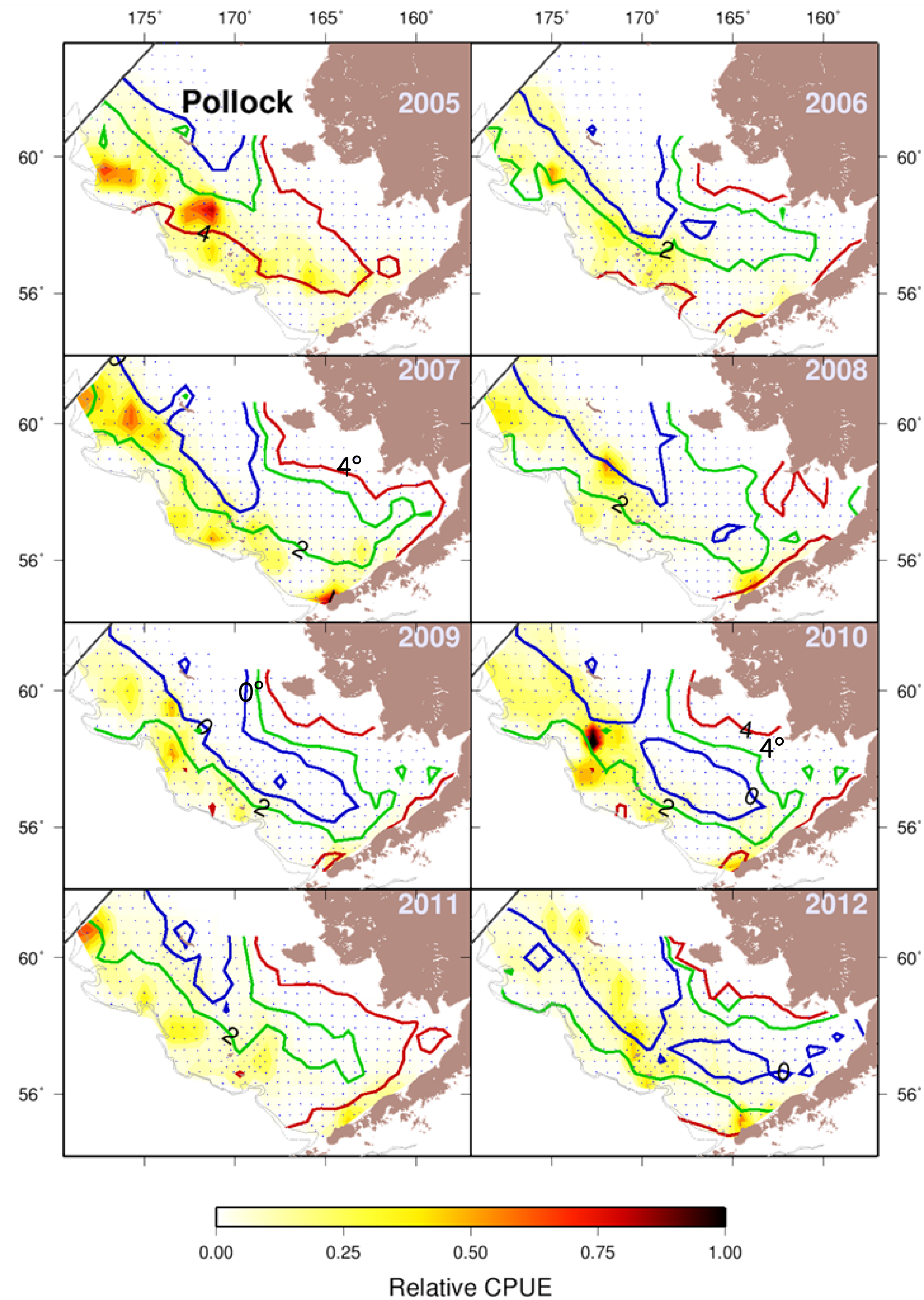

Figure 1.10. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 2005-2012.

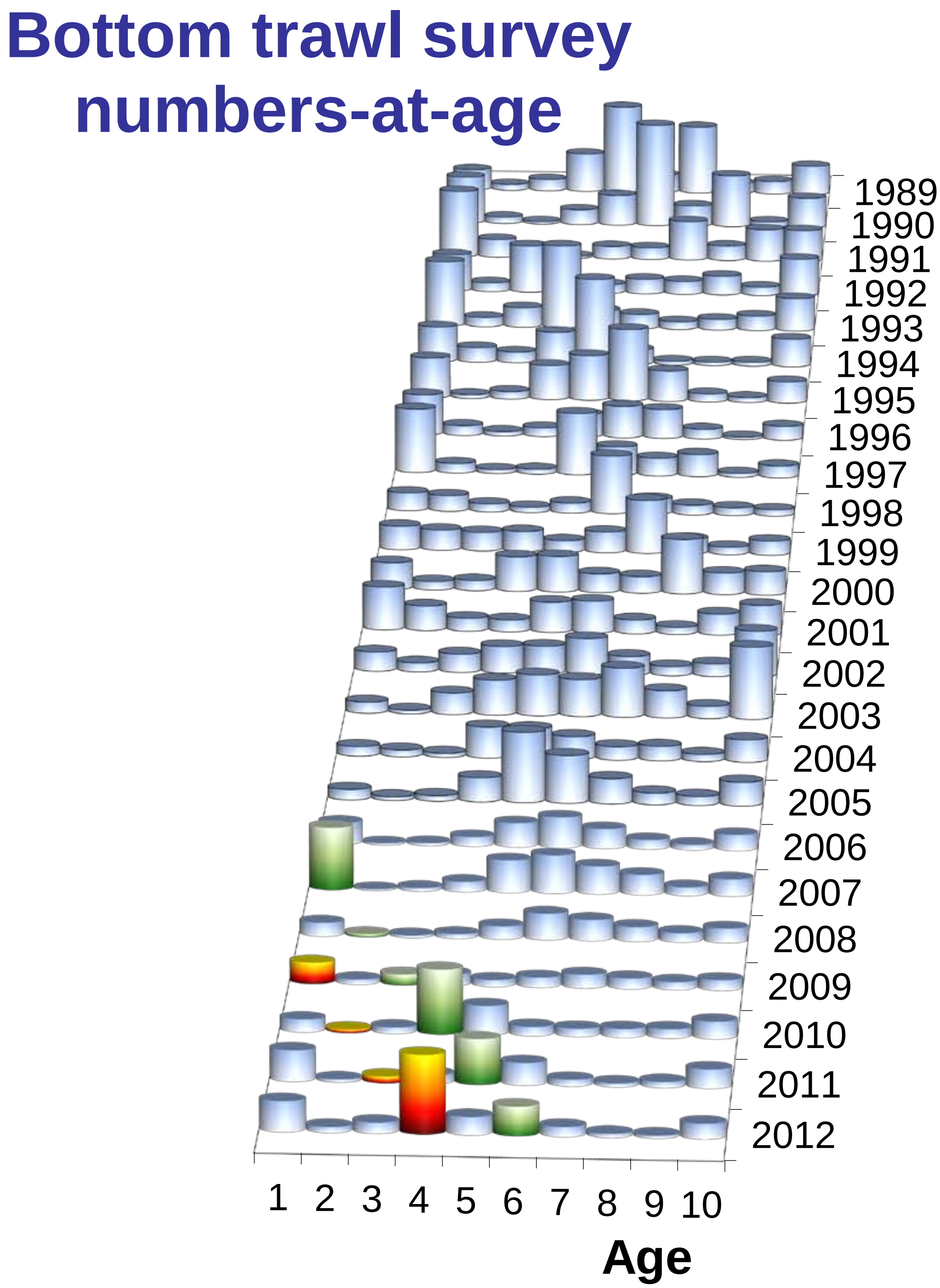

Figure 1.11. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1989-2012). The 2006 and 2008 year-classes are shaded differently.

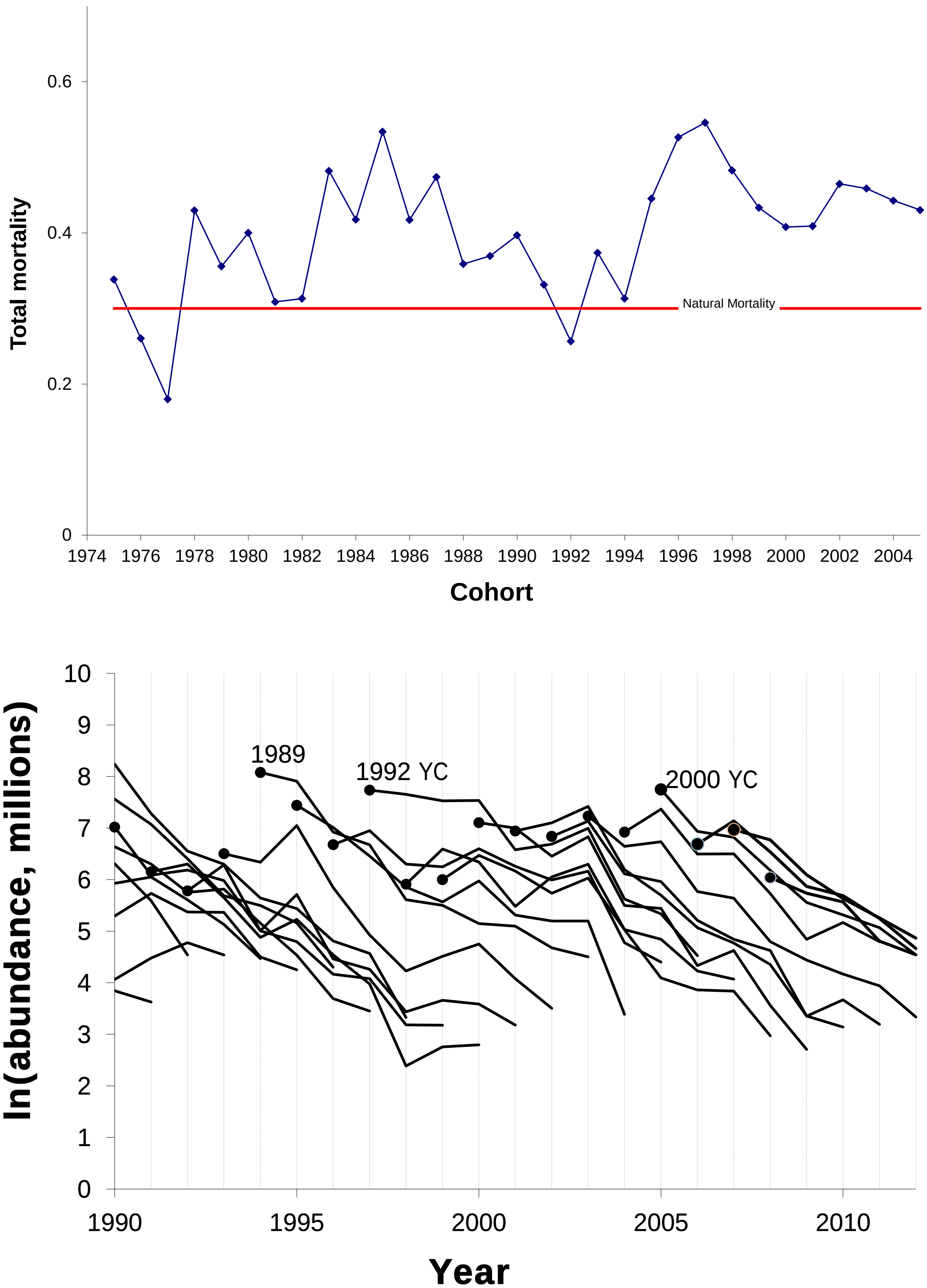

Figure 1.12. Evaluation of EBS pollock cohort abundances as observed for age 6 and older in the NMFS summer bottom trawl surveys. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort.

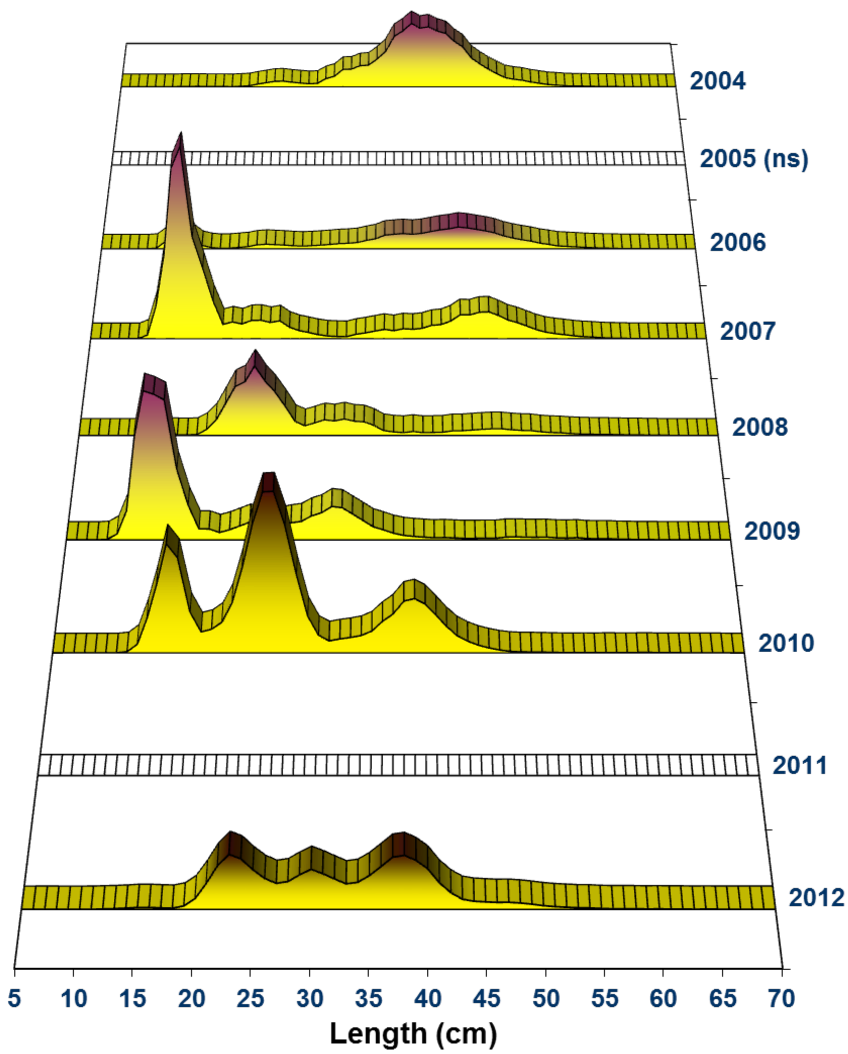

Figure 1.13. Acoustic-trawl survey relative abundances at length for EBS pollock, 2004-2012. Vertical scale is equal for all years and is relative to numbers of fish.

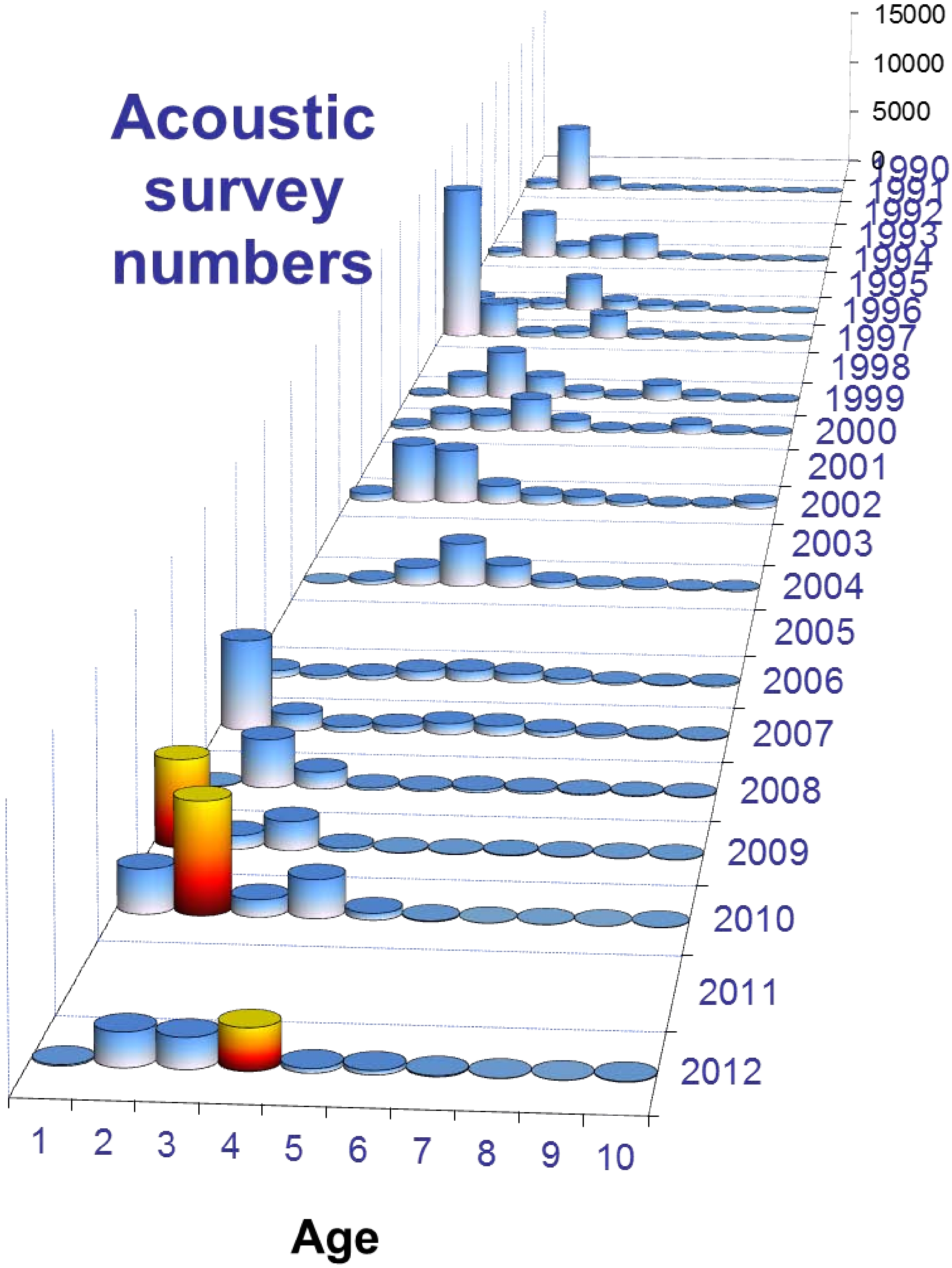

Figure 1.14. Time series of estimated numbers at age (millions) for EBS pollock from the AT surveys, 1991-2012. The differently shaded columns represent the 2008 cohort.

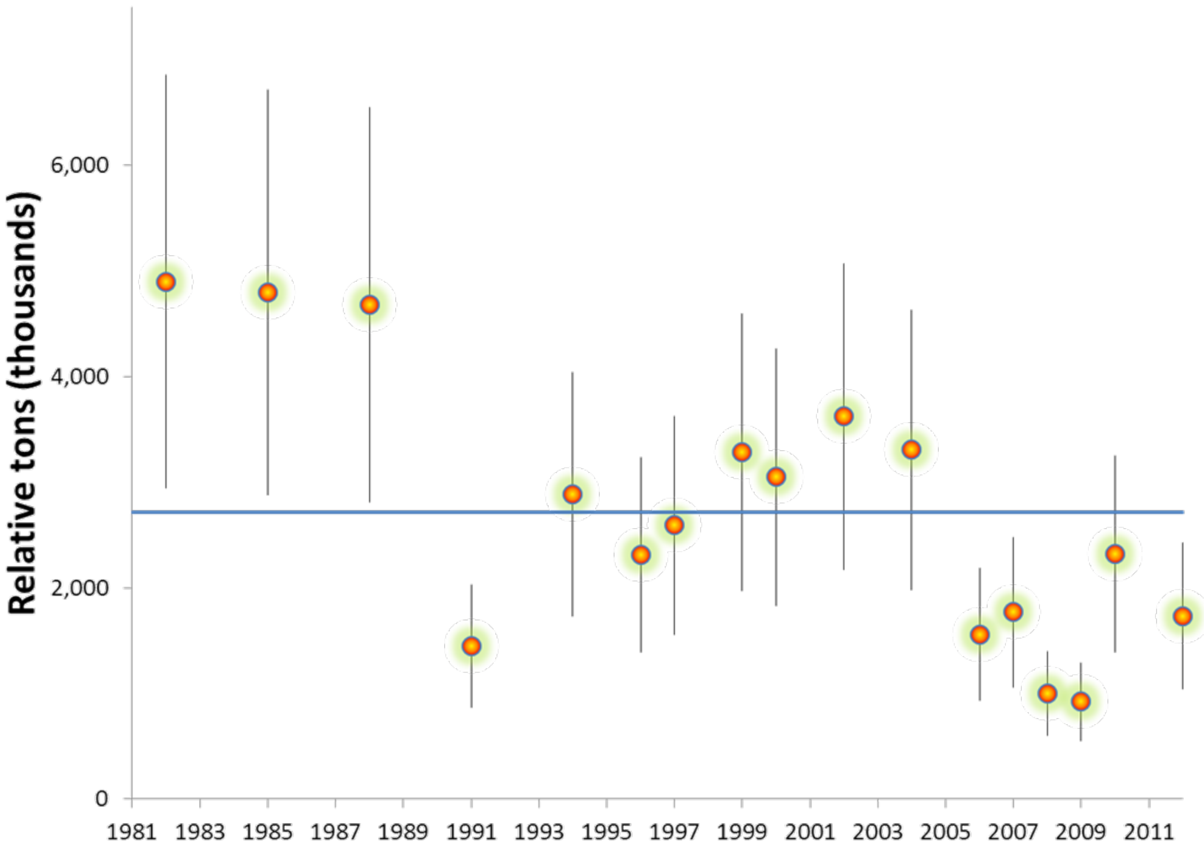

Figure 1.15. Time series of EBS pollock biomass estimates from the AT surveys, 1982-2012.

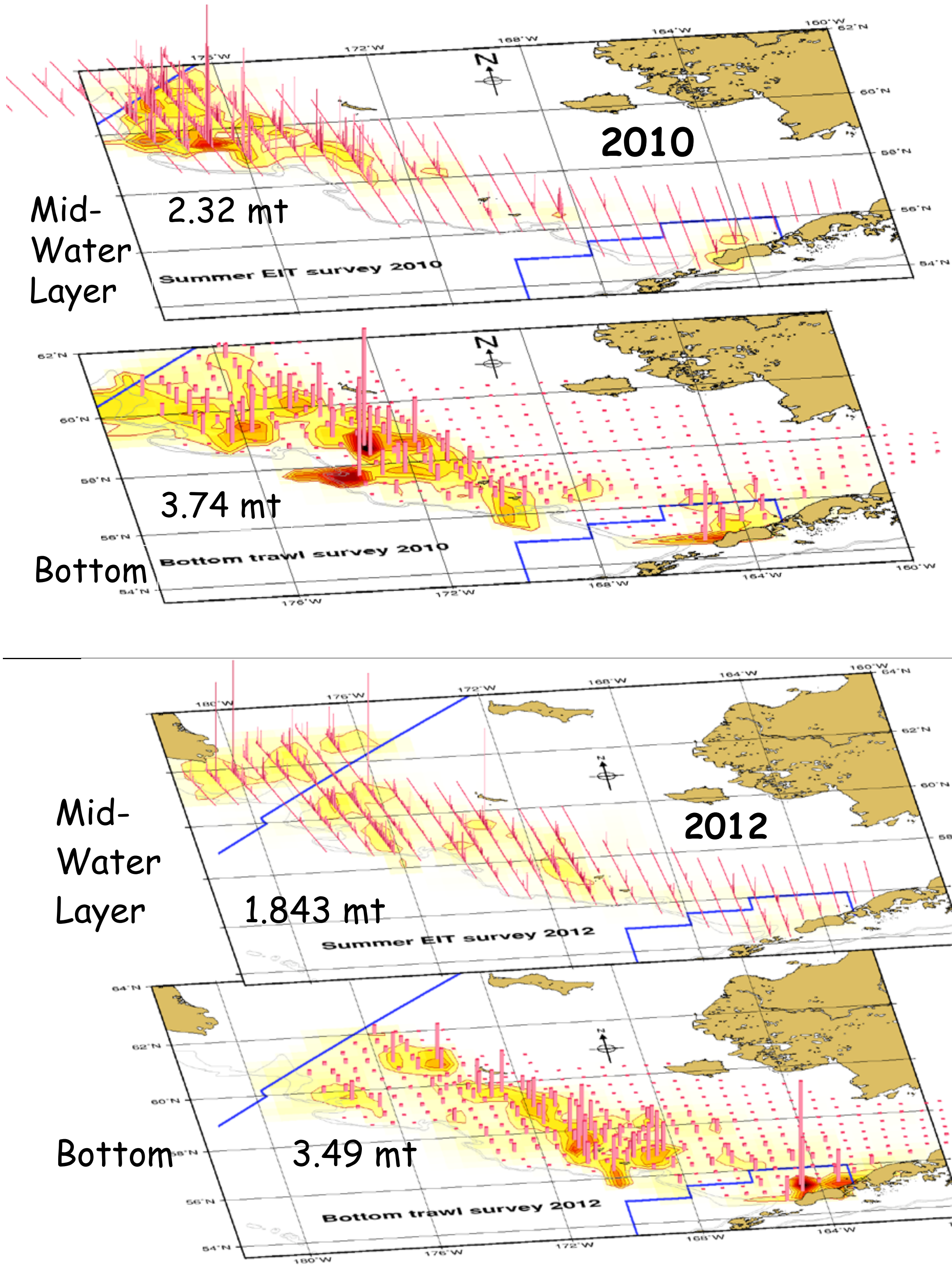

Figure 1.16. Acoustic-trawl and bottom trawl survey results for 2010 and 2012. Vertical lines represent biomass of pollock as observed in the different surveys (mt = millions of t).

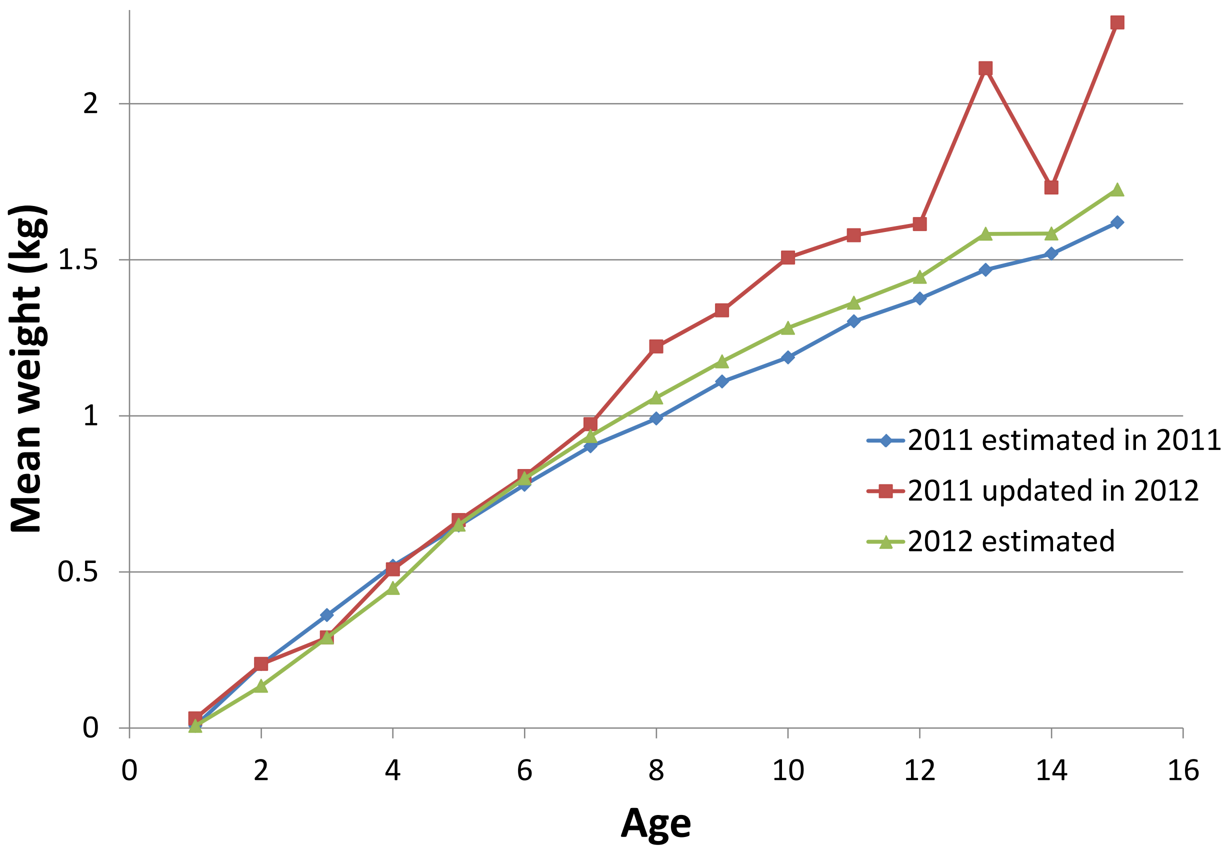

Figure 1.17. Mean fishery body weight (kg) for EBS pollock assumed for the 2011 assessment and as revised using observer data for the current assessment.

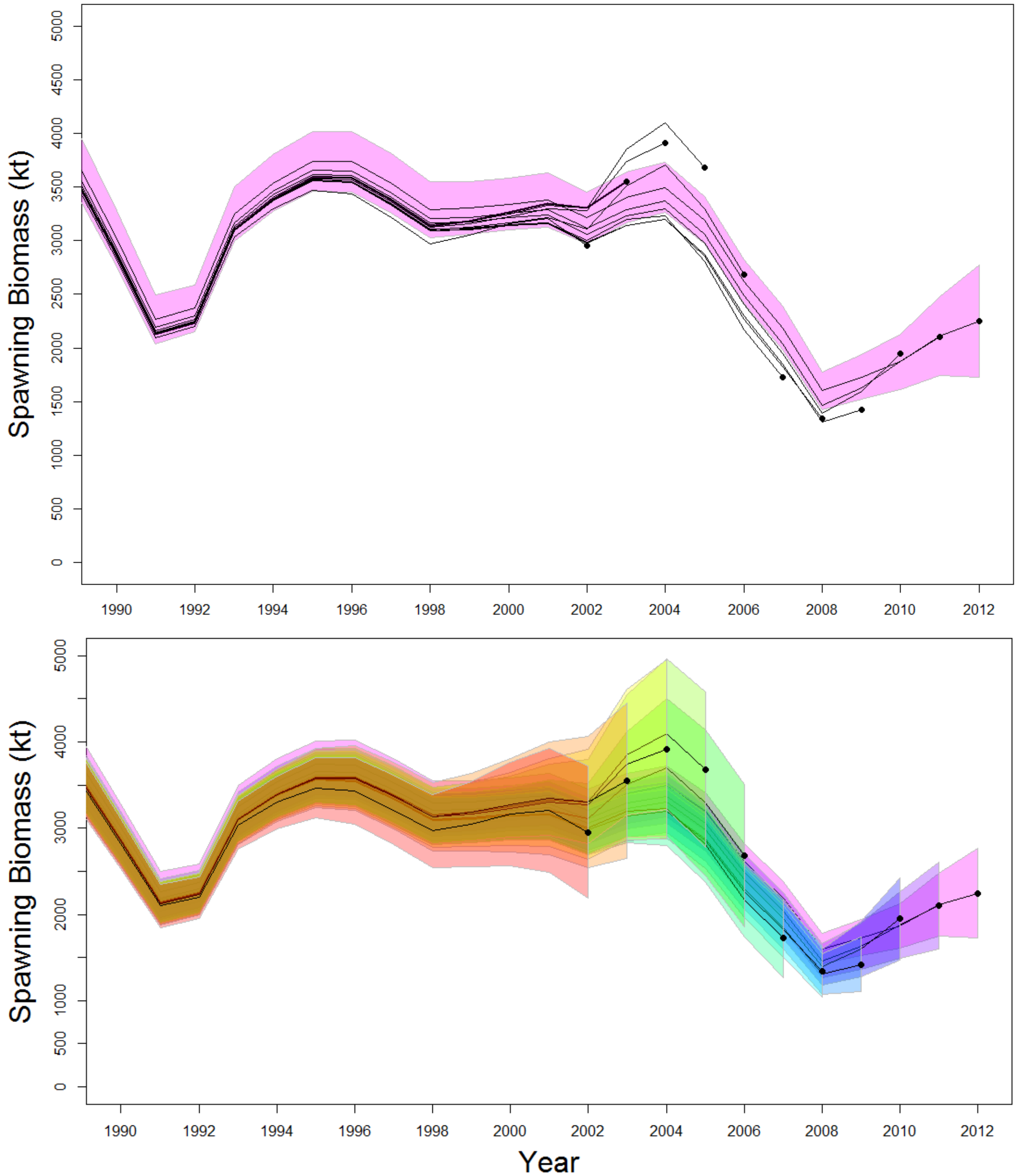

Figure 1.18. Retrospective patterns of EBS pollock spawning in retrospective year for 2002-2012 showing the point estimates relative to the terminal year (top panel) and with approximate confidence bounds (± 2 standard devations; bottom panel.

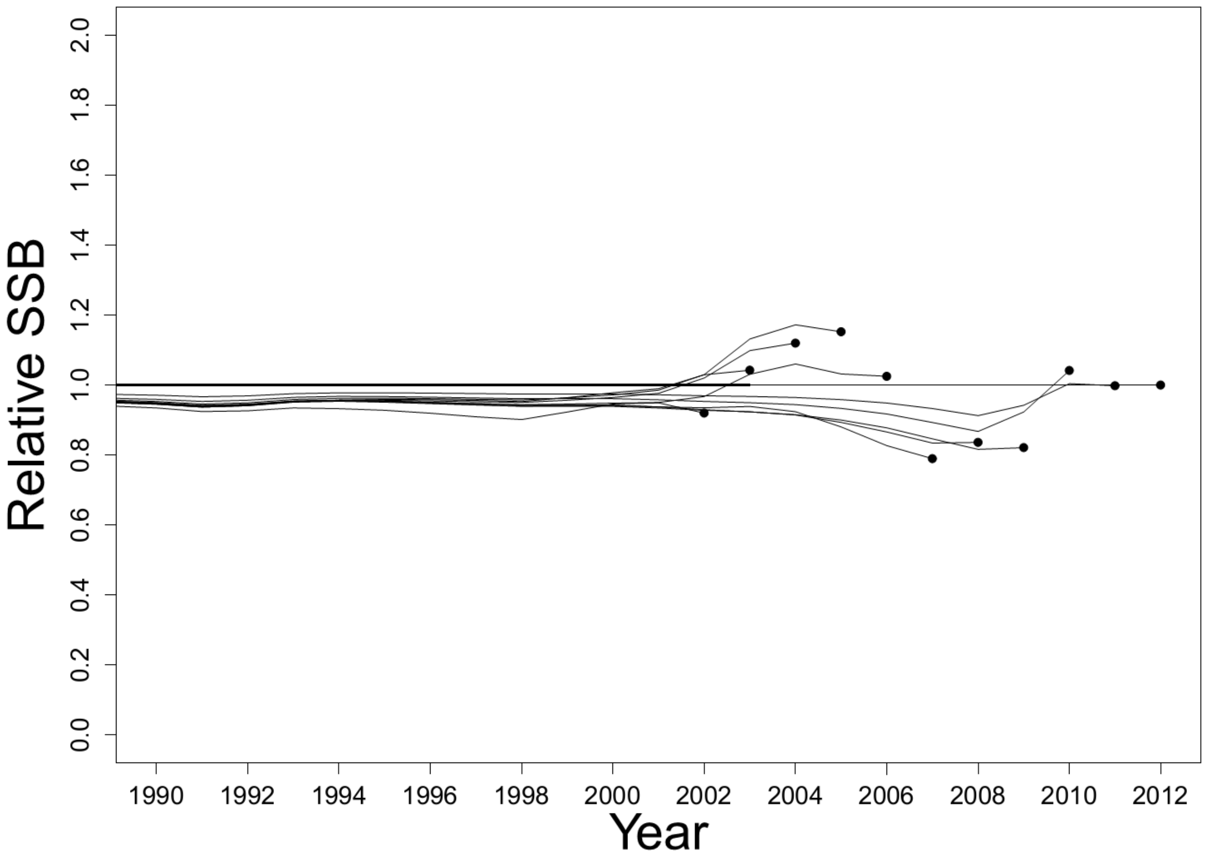

Figure 1.19. Retrospective ratios for point estimates of EBS pollock spawning biomass as a function of the number of the years in the model. The ratio represents the estimate from retrospective year divided by the terminal, 2012 estimate for each of the 2002-2012 model runs.

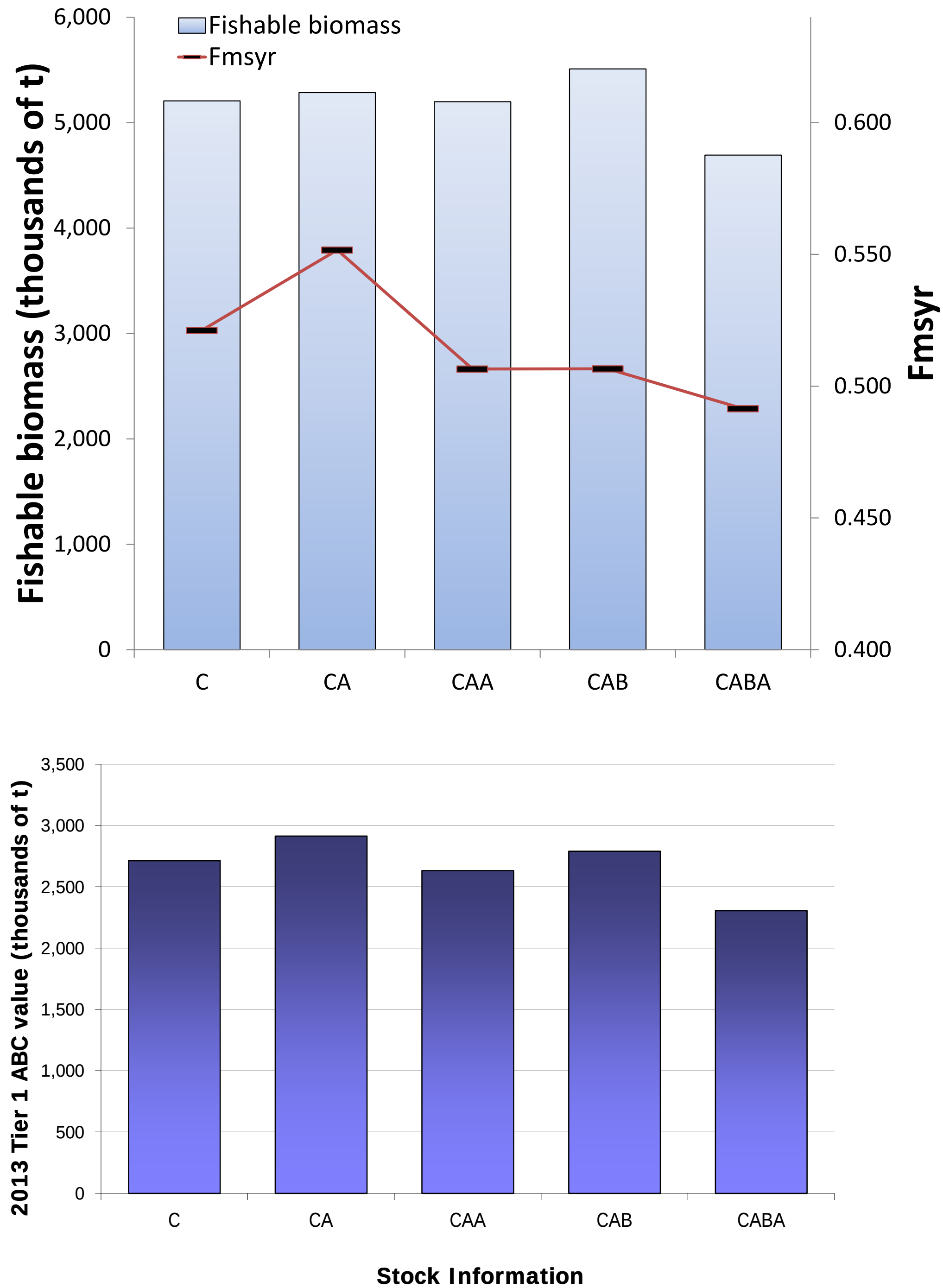

Figure 1.20. The impact of introducing new data to the assessment model on fishable biomass values, F_{msy} rates, and ABC (bottom panel) for 2013 (key: fishery **C**atch, fishery **A**ge, **B**ottom-trawl survey data, and **A** for **A**coustic trawl survey data.

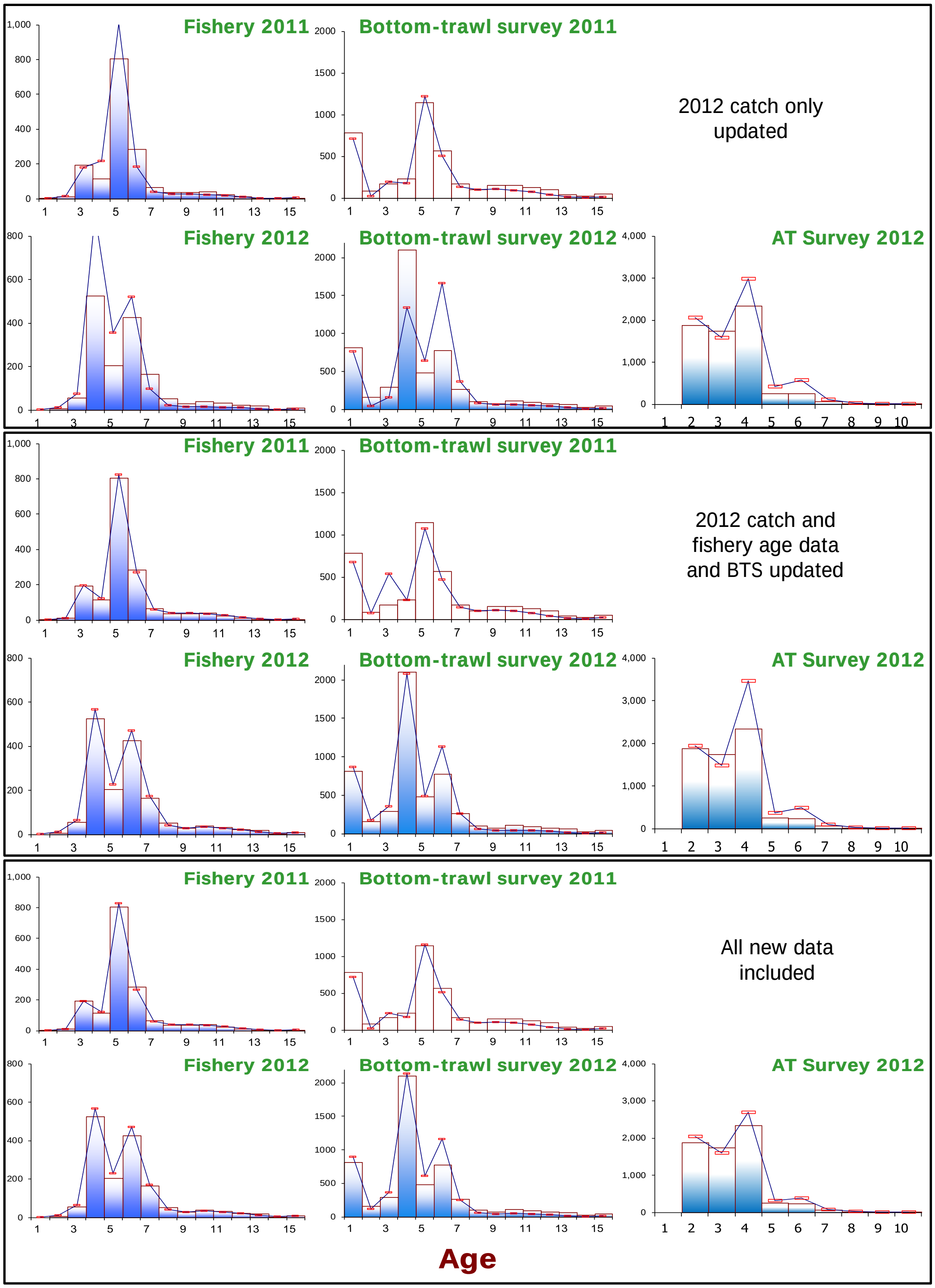

Figure 1. 21. Three model configuration results of predicted EBS pollock numbers-at-age for catch and surveys as new data were added. Columns represent the data, lines represent model predictions. Shaded columns indicate data introduced in the current assessment. The top box are results without fitting any of the new age data (catch updated only), the middle box is with the addition of the fishery and bottom trawl survey age data and the bottom box is with all new data included.

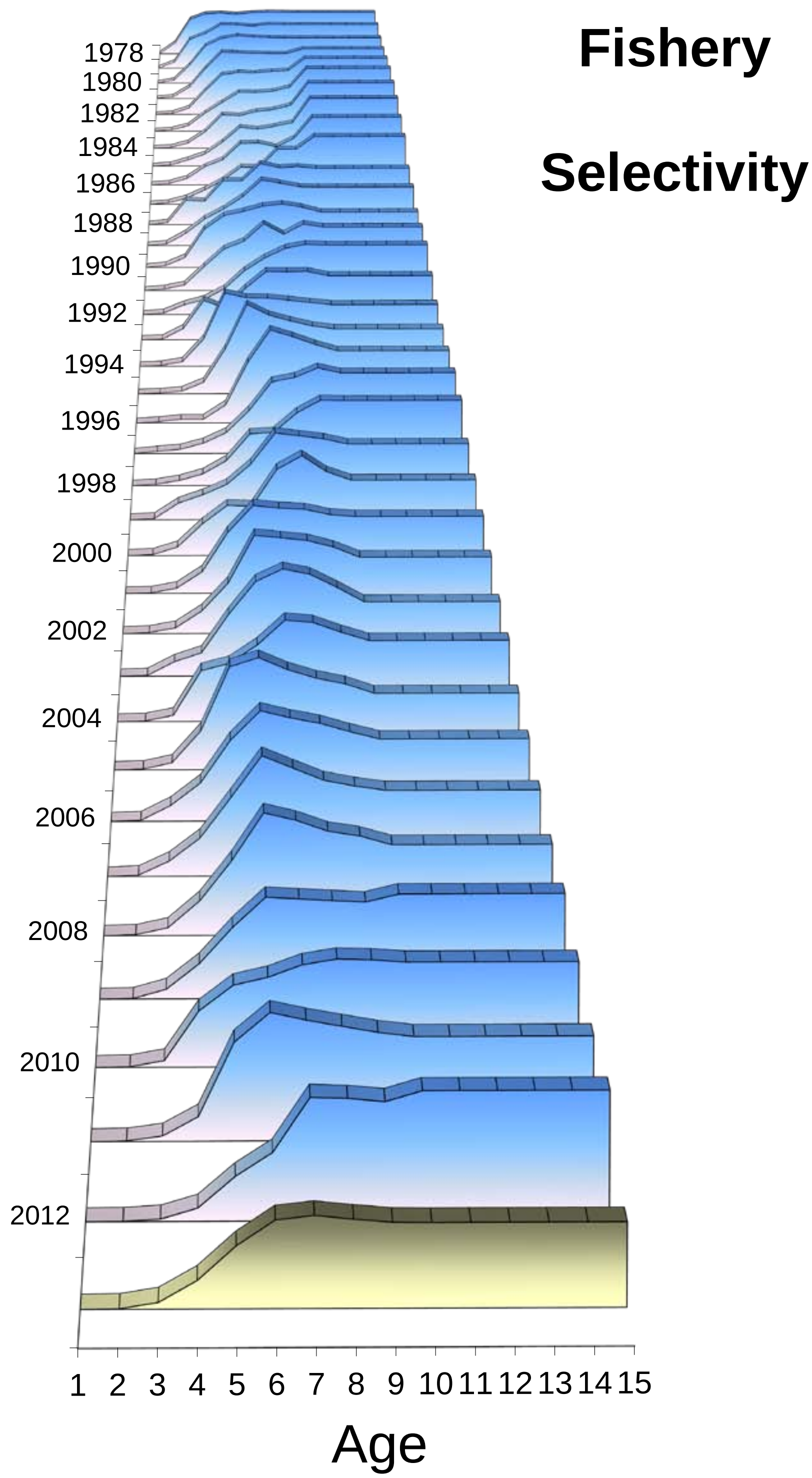

Figure 1. 22. Selectivity at age estimates for the EBS pollock fishery, 1978-2012 including the estimates (front-most panel) used for the future yield considerations.

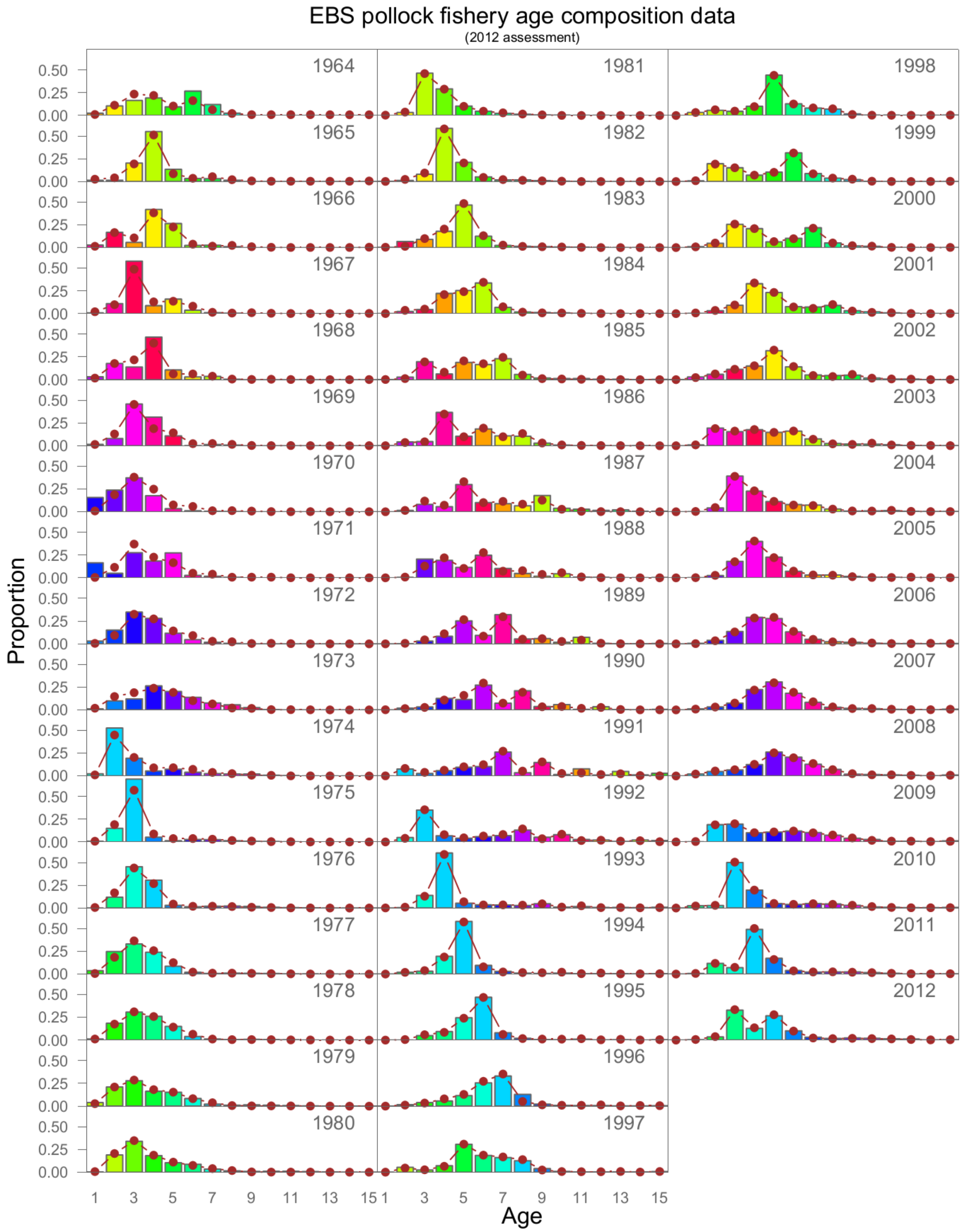

Figure 1.23. Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2012). The 2011 and 2012 (preliminary) data are new to this year's assessment. Colors coincide with cohorts progressing through time.

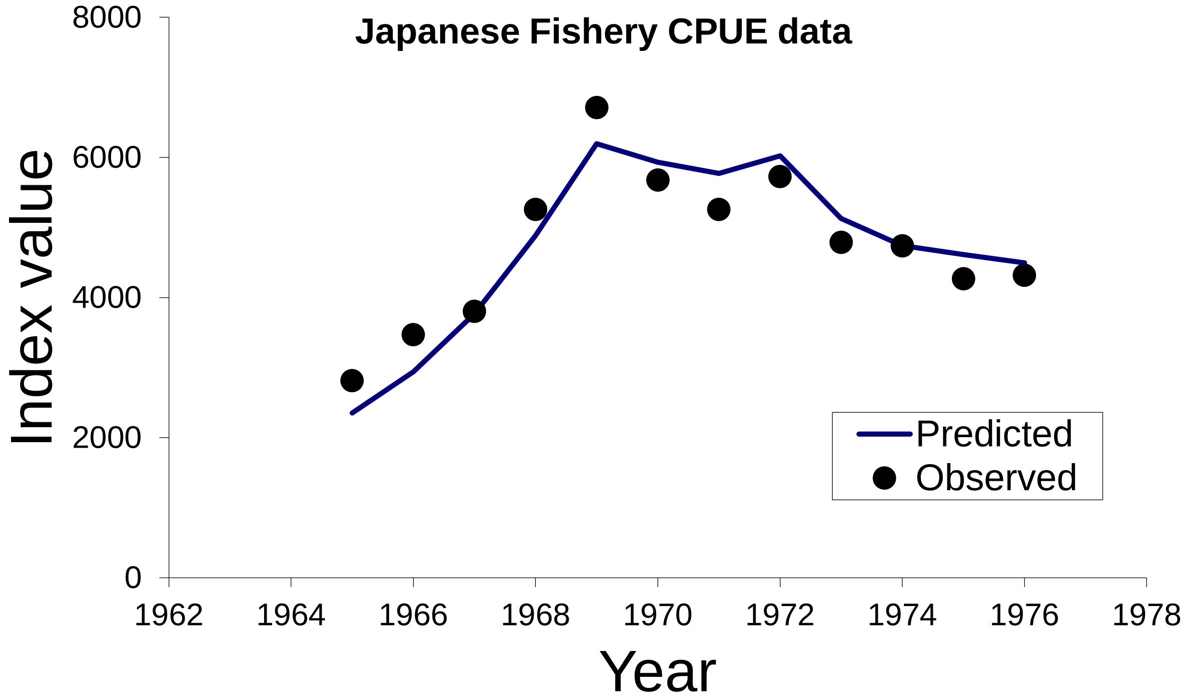

Figure 1.24. Japanese fishery CPUE (Low and Ikeda, 1980) model fits for EBS pollock, 1963-1976.

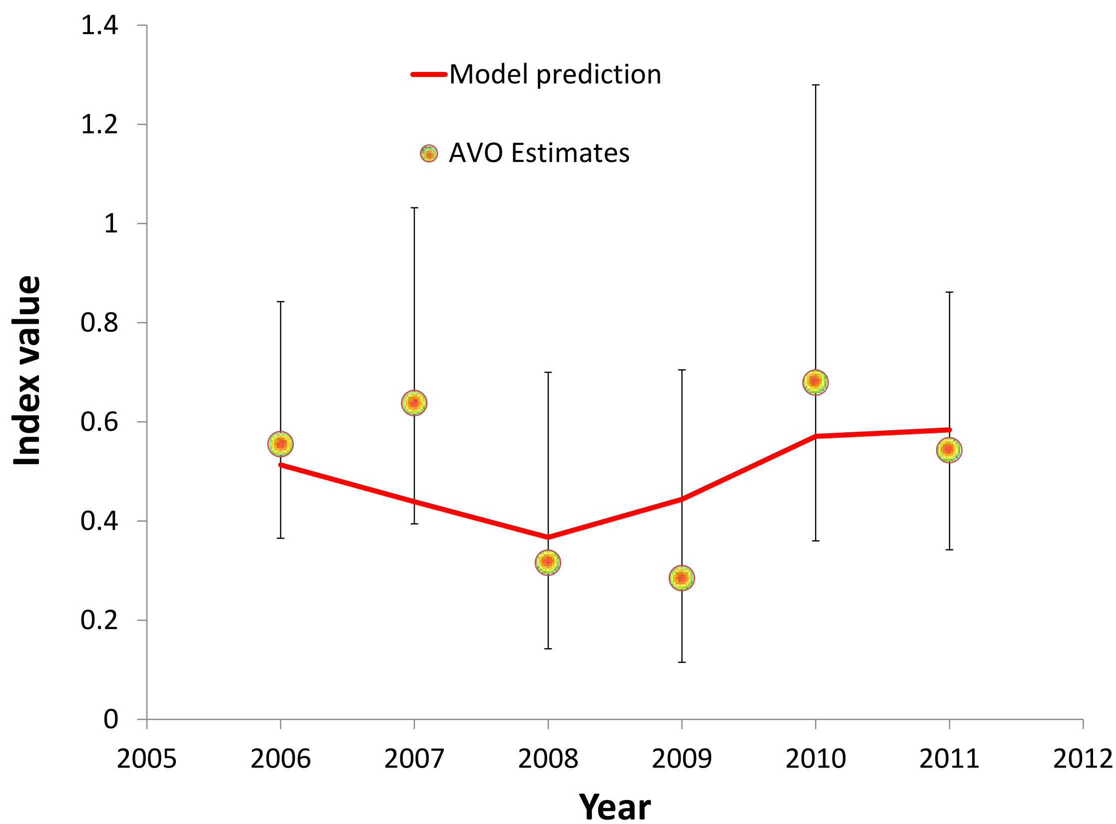

Figure 1.25. Model results of predicted EBS pollock biomass following the AVO index (with and without inclusion of the index. Error bars represent assumed 95% confidence bounds.

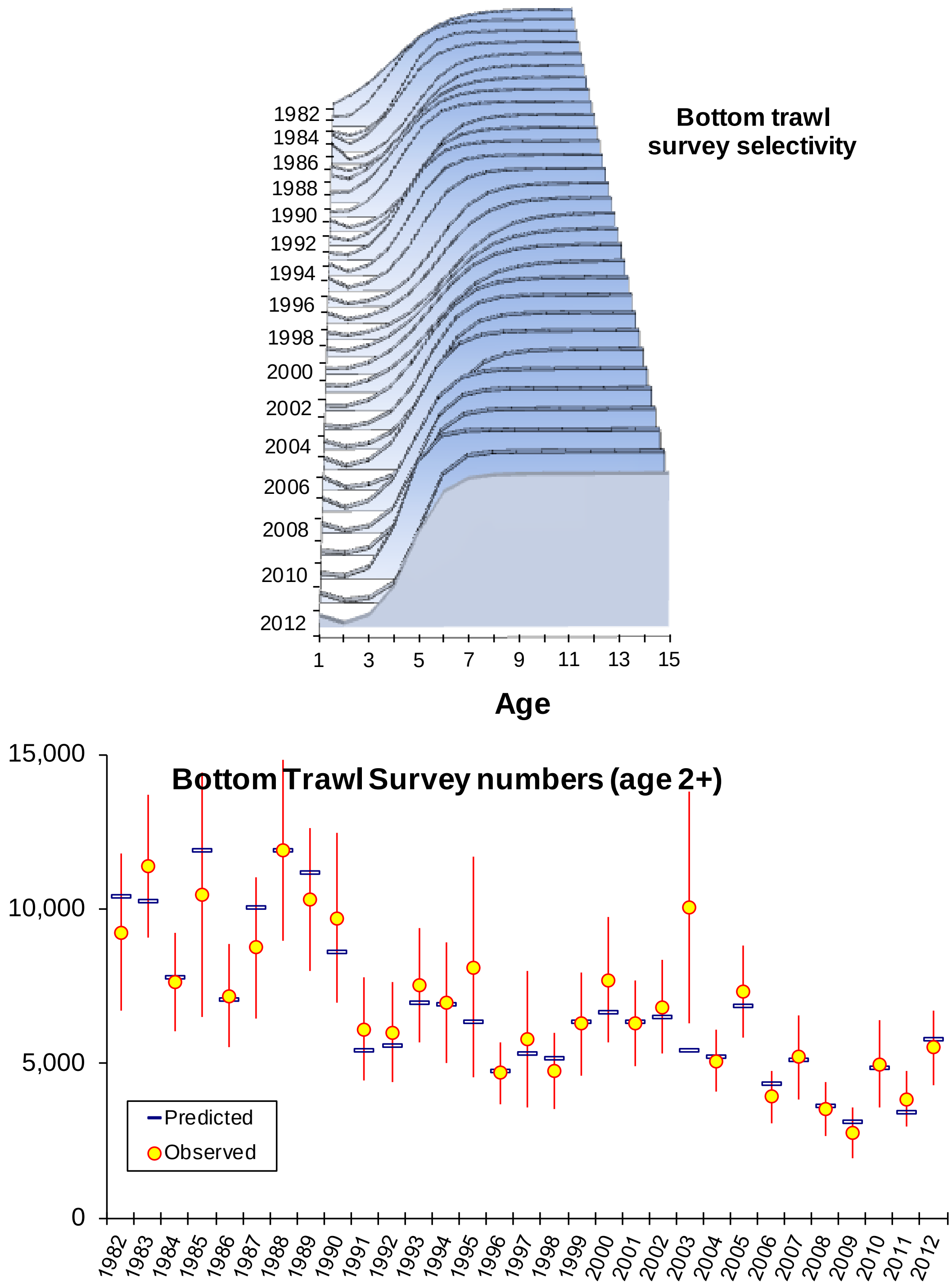

Figure 1.26. Estimates of bottom-trawl survey numbers (millions age 2 and older, lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2012.

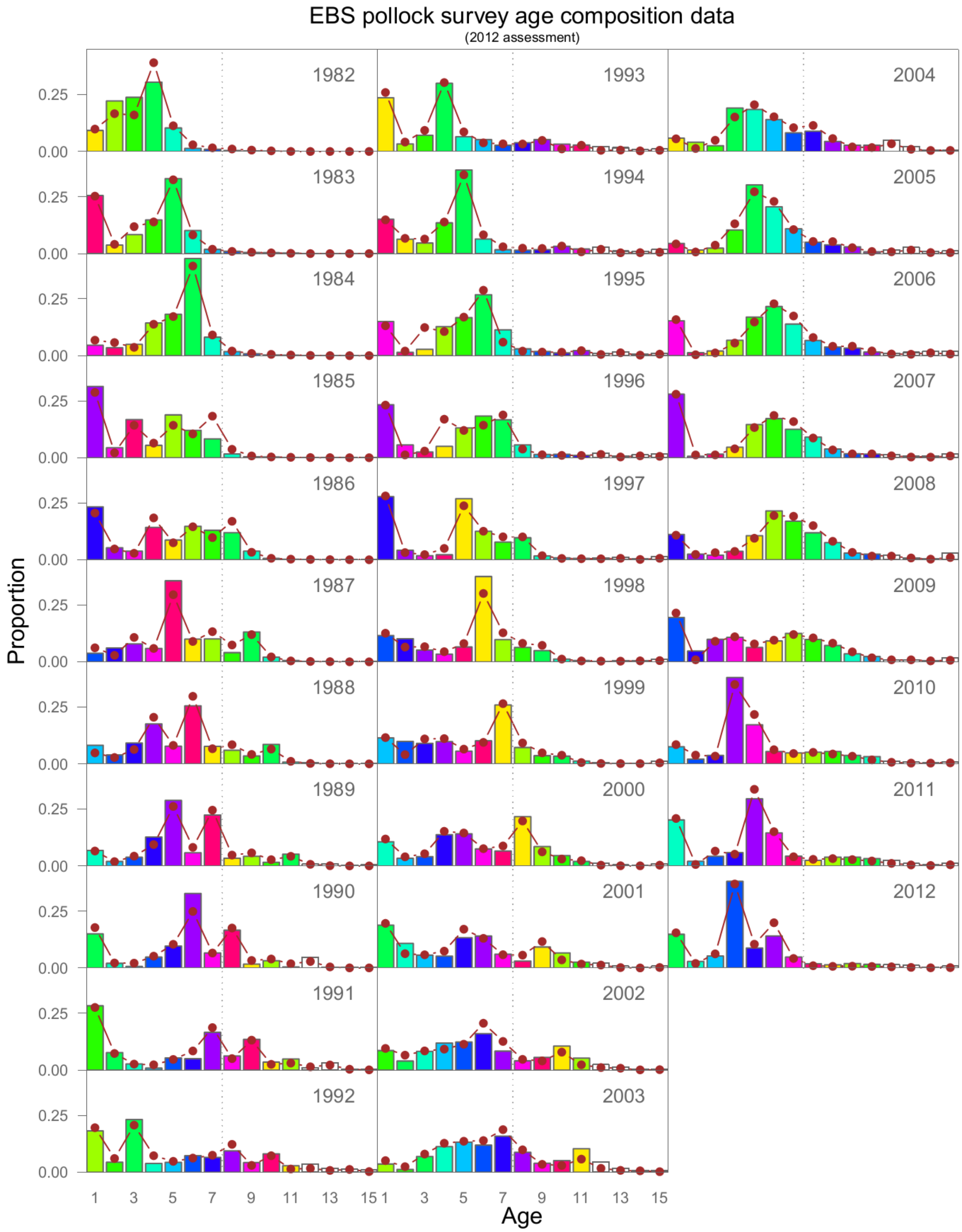

Figure 1.27. Model fit (dots) to the bottom trawl survey proportion-at-age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2012.

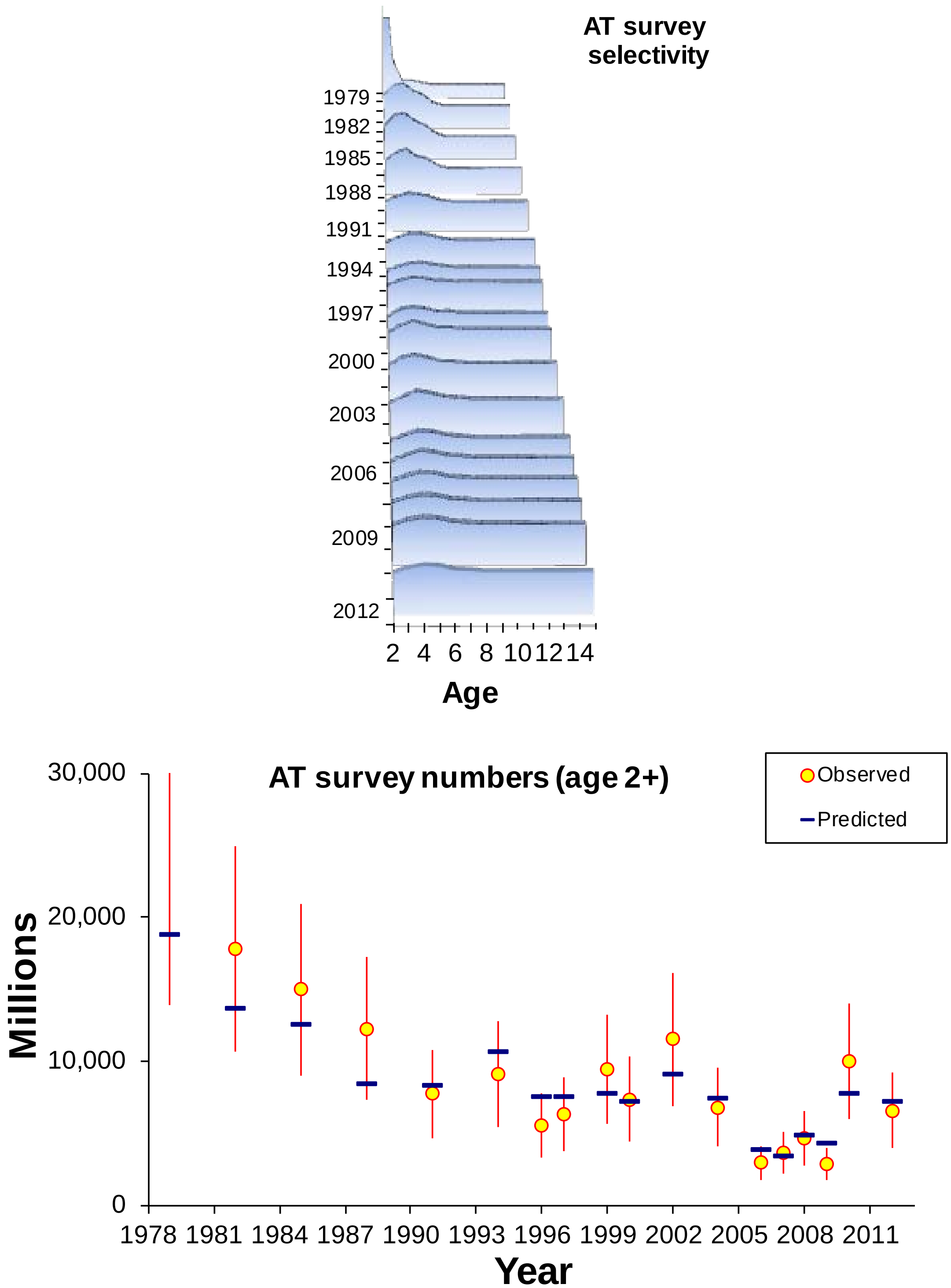

Figure 1.28. Estimates of AT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older, 1979-2012. Note that the 1979 observed value (=46,314) is off the scale of the figure.

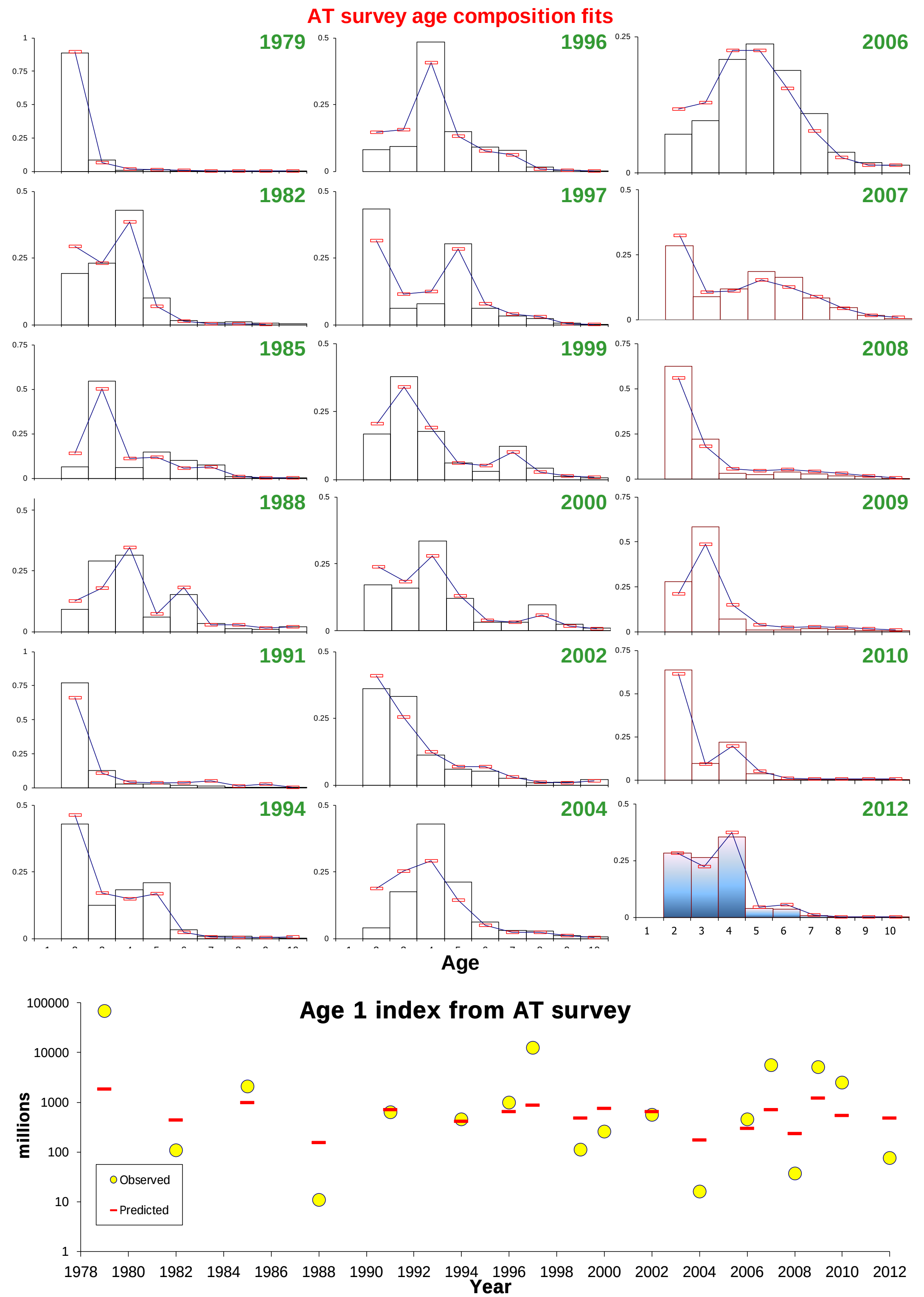

Figure 1.29. Fit to the AT survey EBS pollock age composition data (proportion of numbers) and age 1 index (bottom panel; log-scale). Lines represent model predictions while the vertical columns and dots represent data. The 2012 age composition data were based on using the bottom trawl age-length keys.

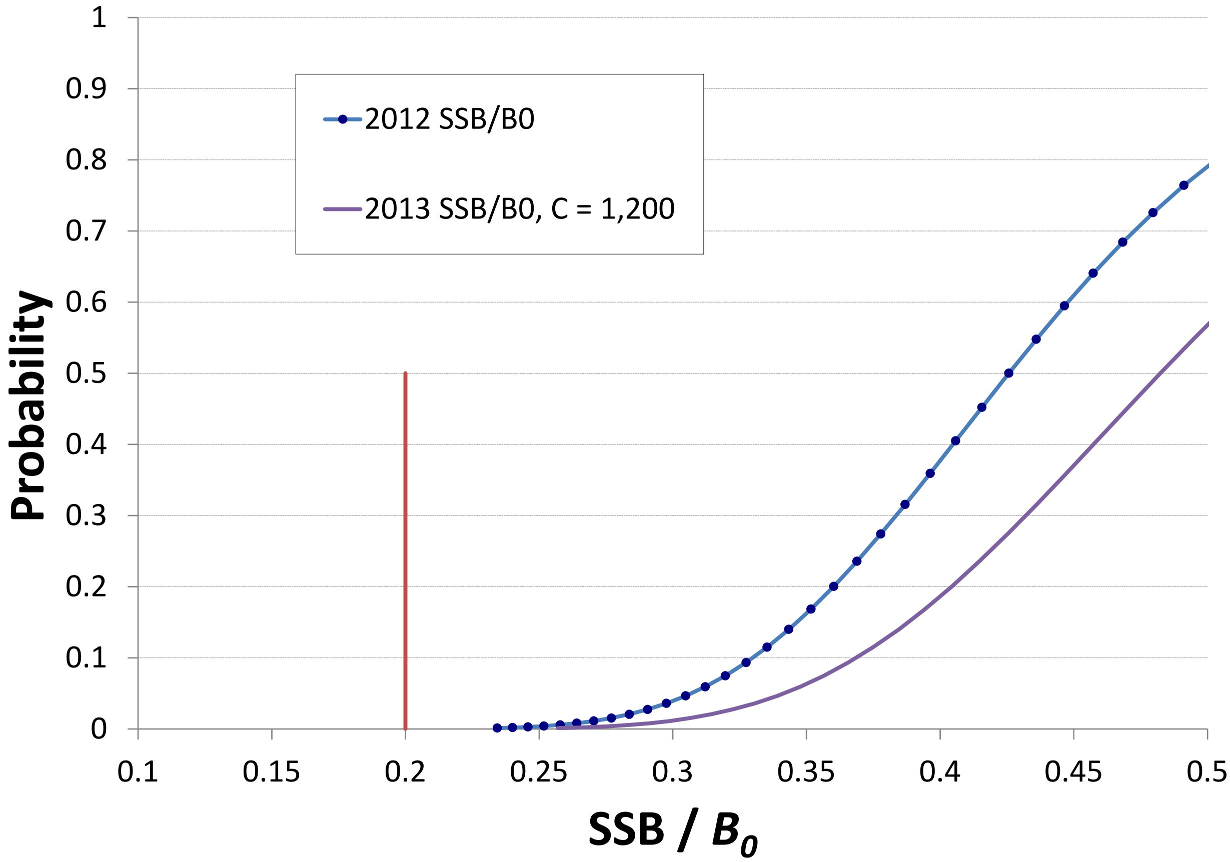

Figure 1.30. Cumulative probability estimates of 2012 and 2013 stock sizes relative to B_0 for EBS pollock assuming a catch of 1,200 kt. Note that these only reflect the estimation uncertainty of stock status (as opposed to the probability of finding the stock below 20% of B_0 from a future assessment model).

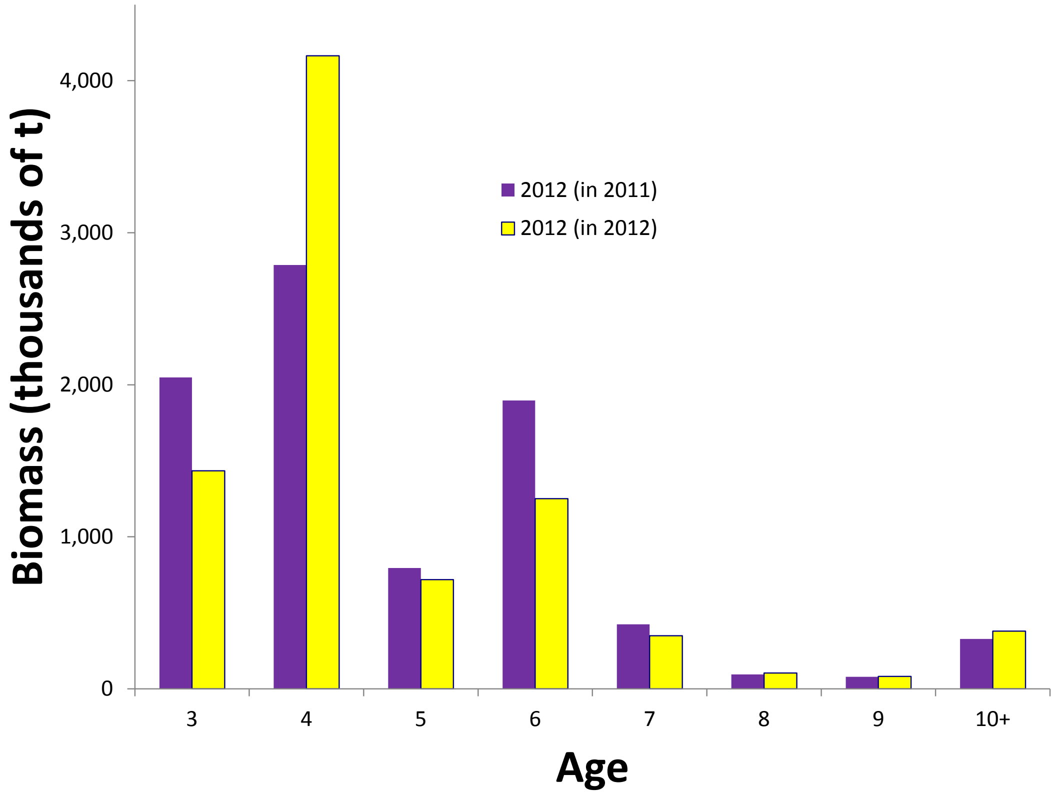

Figure 1.31. Projected begin-year EBS pollock model biomass-at-age as estimated for 2012 in the 2011 assessment and as estimated in the current model for ages 3-10+.

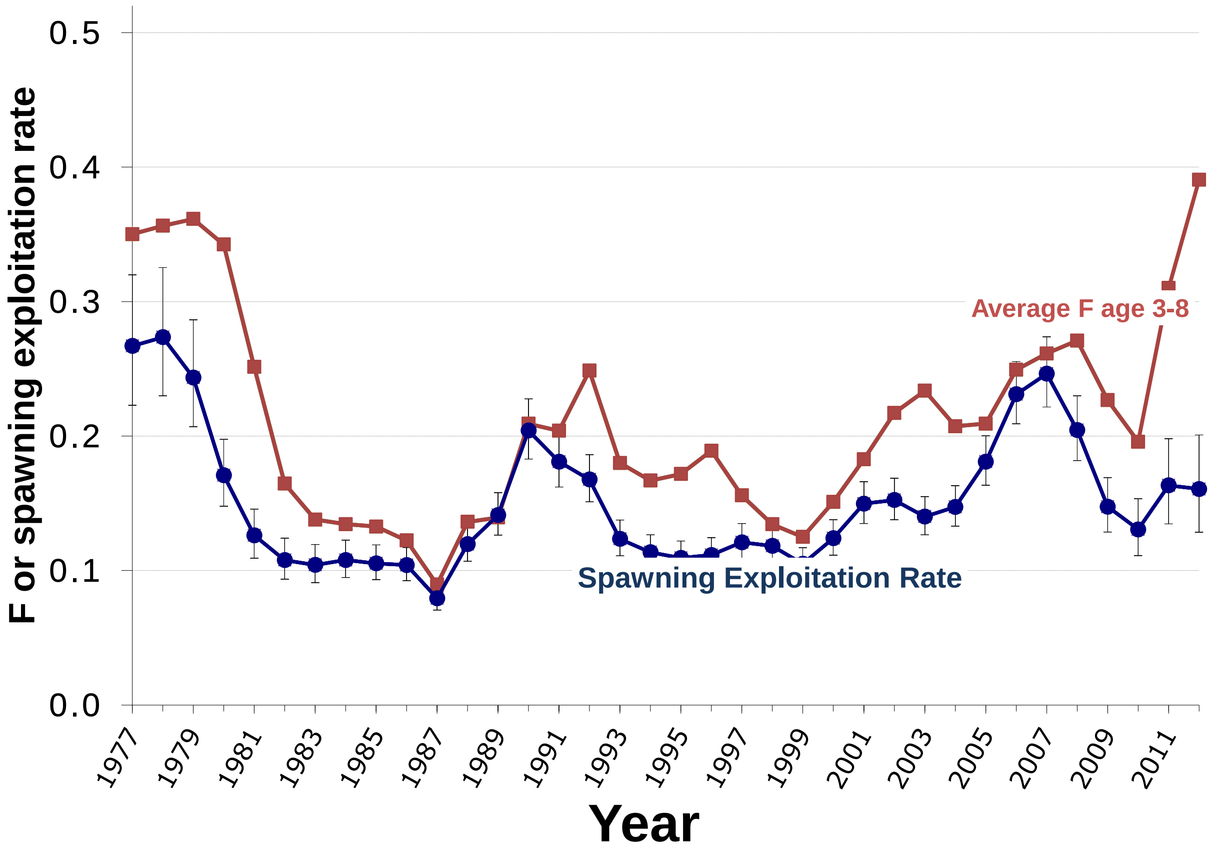

Figure 1.32. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) and average fishing mortality (ages 3-8) for EBS pollock, 1977-2012. Error bars represent two standard deviations from the estimates.

Year	Age 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	0.18	0.16	0.16	0.15	0.14
1966	0.01	0.05	0.17	0.17	0.16	0.15	0.14	0.13	0.13
1967	0.03	0.16	0.24	0.24	0.24	0.23	0.23	0.23	0.22
1968	0.03	0.13	0.27	0.26	0.24	0.23	0.23	0.22	0.22
1969	0.03	0.18	0.23	0.22	0.21	0.21	0.21	0.20	0.22
1970	0.07	0.24	0.24	0.23	0.23	0.26	0.26	0.26	0.42
1971	0.07	0.28	0.32	0.35	0.34	0.34	0.34	0.34	0.67
1972	0.13	0.39	0.40	0.39	0.39	0.39	0.39	0.41	0.65
1973	0.17	0.45	0.53	0.53	0.52	0.52	0.52	0.52	0.68
1974	0.23	0.58	0.57	0.56	0.55	0.55	0.56	0.56	0.59
1975	0.11	0.54	0.50	0.48	0.47	0.46	0.46	0.46	0.53
1976	0.09	0.39	0.47	0.45	0.44	0.43	0.42	0.42	0.44
1977	0.11	0.29	0.36	0.37	0.37	0.36	0.36	0.36	0.35
1978	0.10	0.31	0.36	0.37	0.36	0.37	0.37	0.37	0.37
1979	0.06	0.27	0.32	0.40	0.40	0.39	0.40	0.40	0.40
1980	0.02	0.16	0.32	0.38	0.41	0.40	0.39	0.39	0.39
1981	0.01	0.08	0.20	0.31	0.31	0.30	0.30	0.30	0.33
1982	0.00	0.03	0.12	0.20	0.21	0.21	0.22	0.22	0.28
1983	0.00	0.03	0.09	0.14	0.19	0.19	0.19	0.21	0.31
1984	0.00	0.03	0.08	0.17	0.16	0.18	0.19	0.21	0.32
1985	0.01	0.03	0.06	0.12	0.20	0.19	0.20	0.22	0.34
1986	0.01	0.03	0.08	0.11	0.18	0.18	0.16	0.20	0.29
1987	0.00	0.02	0.04	0.07	0.12	0.11	0.17	0.17	0.21
1988	0.01	0.08	0.08	0.14	0.14	0.20	0.18	0.19	0.18
1989	0.01	0.04	0.09	0.12	0.16	0.22	0.21	0.20	0.19
1990	0.01	0.04	0.17	0.23	0.25	0.27	0.28	0.27	0.25
1991	0.01	0.03	0.12	0.21	0.25	0.34	0.28	0.33	0.32
1992	0.01	0.07	0.10	0.18	0.30	0.39	0.45	0.48	0.48
1993	0.00	0.04	0.16	0.13	0.21	0.27	0.27	0.27	0.26
1994	0.00	0.01	0.09	0.24	0.22	0.22	0.21	0.21	0.20
1995	0.00	0.01	0.04	0.15	0.31	0.27	0.25	0.23	0.22
1996	0.00	0.02	0.02	0.08	0.26	0.40	0.37	0.34	0.31
1997	0.01	0.02	0.04	0.09	0.18	0.30	0.32	0.36	0.33
1998	0.00	0.02	0.04	0.09	0.19	0.20	0.27	0.31	0.31
1999	0.00	0.04	0.06	0.09	0.14	0.21	0.21	0.20	0.19
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	0.31	0.26
2004	0.00	0.02	0.16	0.18	0.24	0.32	0.31	0.28	0.26
2005	0.00	0.02	0.11	0.29	0.31	0.28	0.25	0.24	0.21
2006	0.00	0.05	0.13	0.27	0.37	0.35	0.33	0.30	0.27
2007	0.00	0.05	0.13	0.27	0.41	0.37	0.33	0.31	0.29
2008	0.00	0.03	0.12	0.27	0.43	0.41	0.37	0.35	0.32
2009	0.00	0.03	0.12	0.23	0.33	0.33	0.32	0.32	0.34
2010	0.00	0.02	0.15	0.22	0.24	0.27	0.28	0.28	0.28
2011	0.00	0.02	0.09	0.37	0.49	0.46	0.43	0.41	0.39
2012	0.00	0.02	0.08	0.28	0.43	0.77	0.76	0.74	0.81

Figure 1.33. Estimated instantaneous age-specific fishing mortality rates for EBS pollock, 1964-2012. (note that these are the continuous form of fishing mortality rate as specified in Eq. 1).

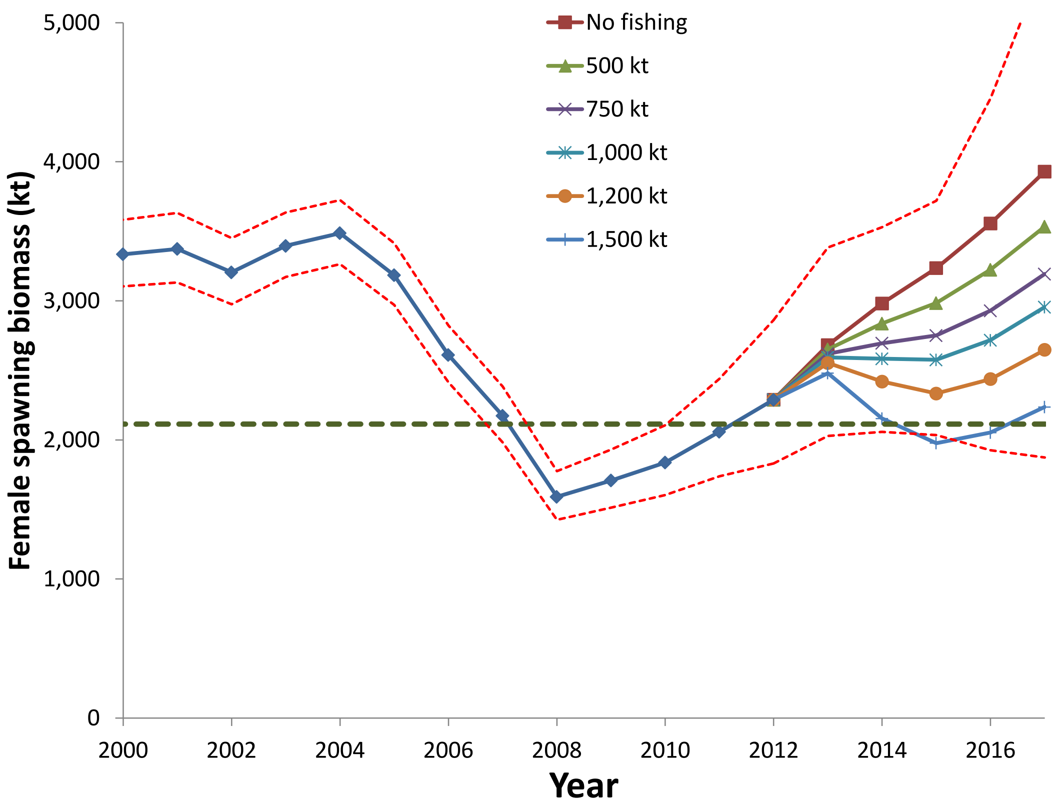

Figure 1.34. Estimated EBS pollock female spawning biomass and approximate 95% confidence intervals (filled area and dashed lines) under near term projections assuming 2013 catch specifications and constant F's (from that 2013 catch) for subsequent years. Horizontal straight line represents B_{msy} estimate.

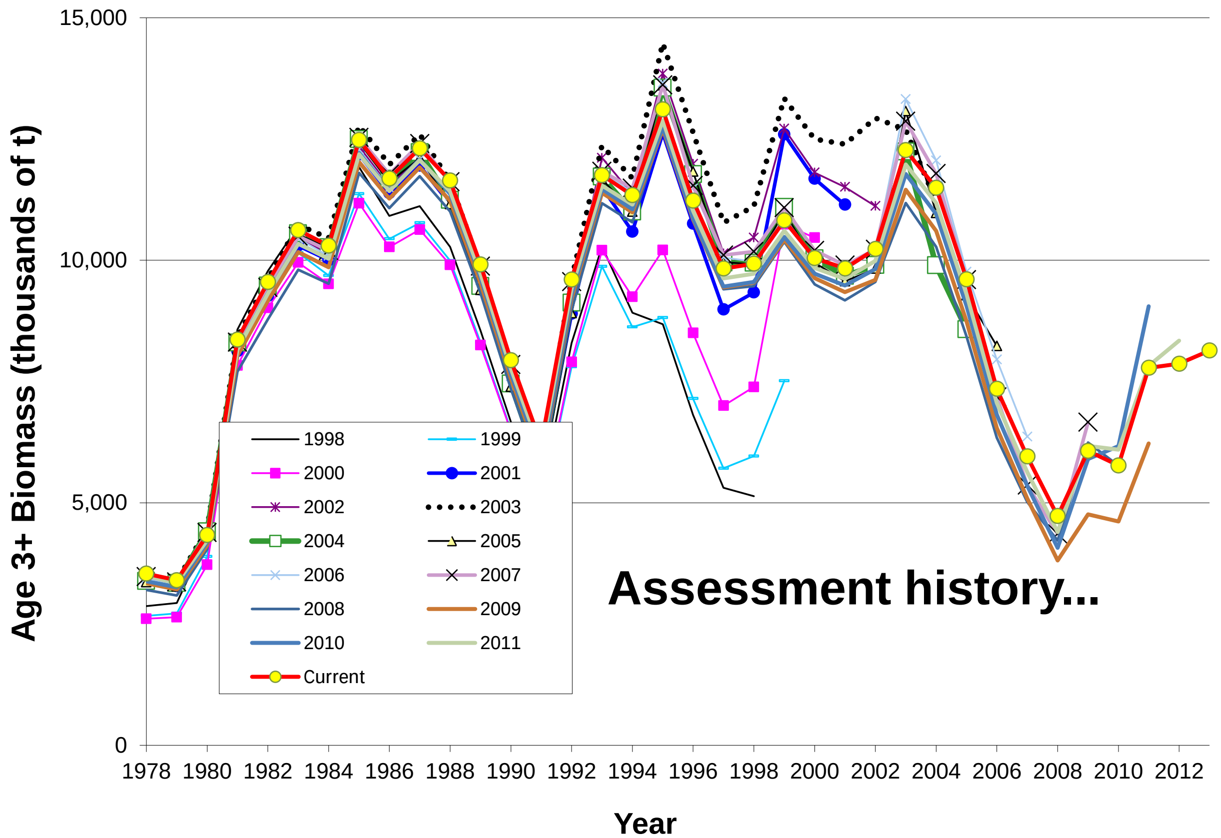

Figure 1.35. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2013.

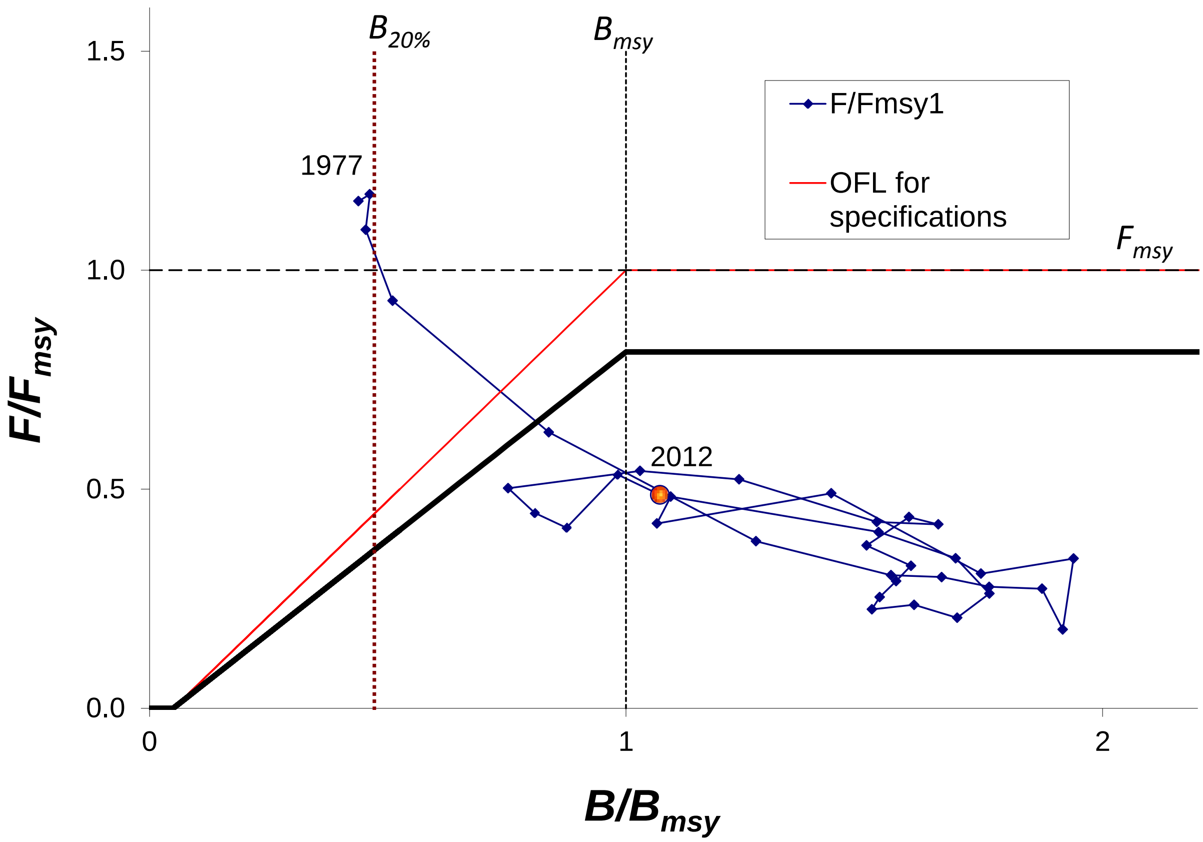

Figure 1.36. Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock, 1977-2012. *Note that the control rules for OFL and ABC are designed for setting specifications in future years.*

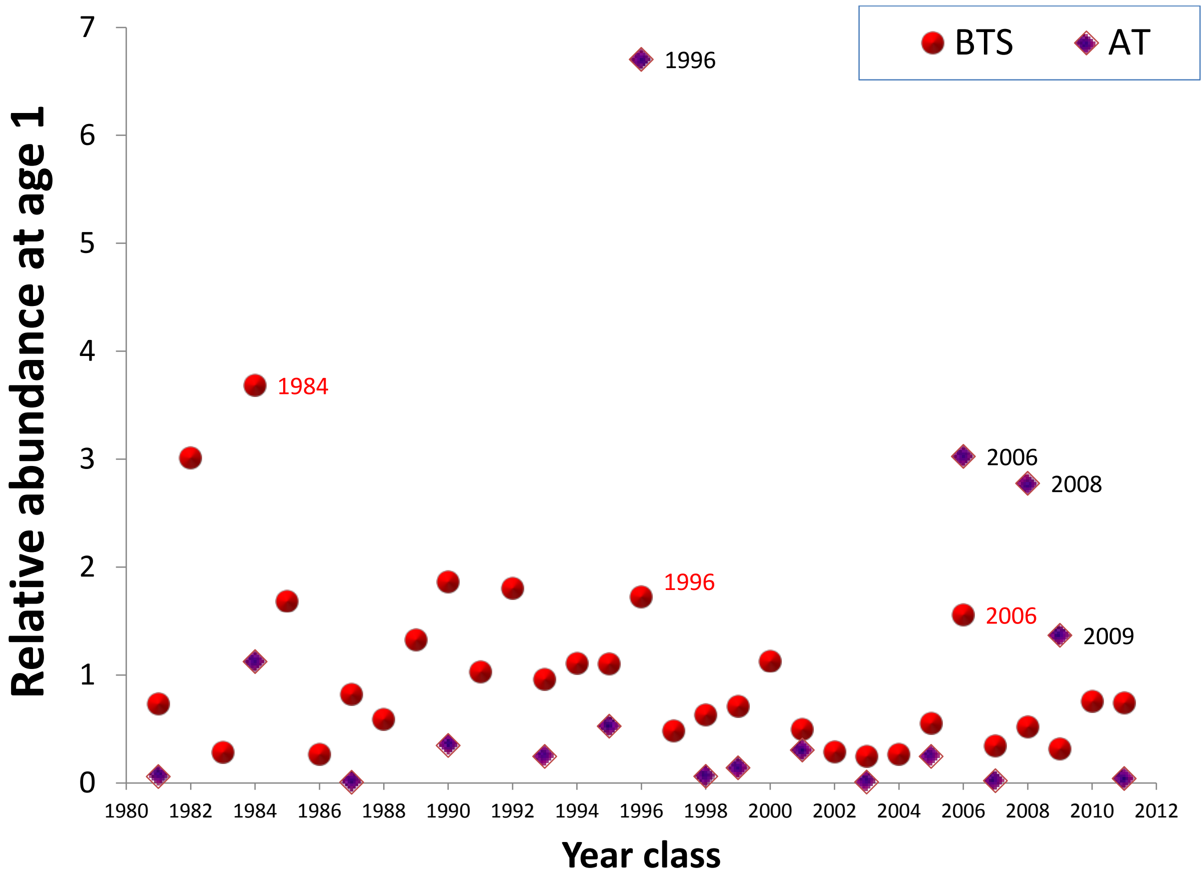

Figure 1.37. Time series of estimated age-1 abundance (relative numbers) for EBS pollock from the AT surveys (diamonds) and from the BTS surveys (bullets). Both survey indices have been rescaled to have a mean value of 1.0. Horizontal axis is by year class (hence 2011 index is age 1 pollock observed in 2012 surveys).

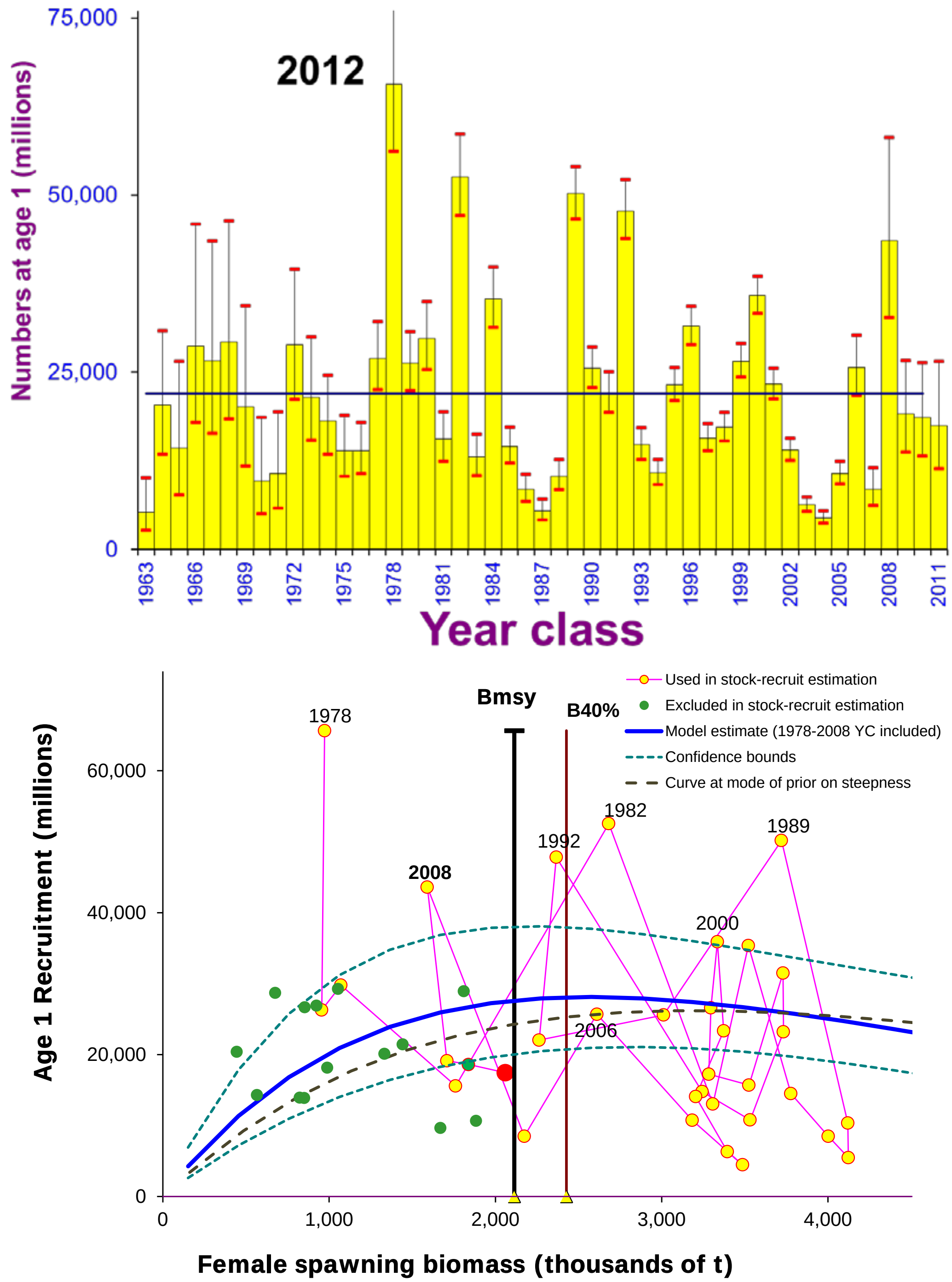

Figure 1.38. Year-class strengths by year (as age-1 recruits, upper panel) and relative to female spawning biomass (thousands of tons, lower panel) for EBS pollock. Labels on points correspond to year classes labels (measured as one-year olds). Solid line in upper panel represents the mean age-1 recruitment for all years since 1964 (1963-2011 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. The larger red dot is the 2011 (terminal) estimate.

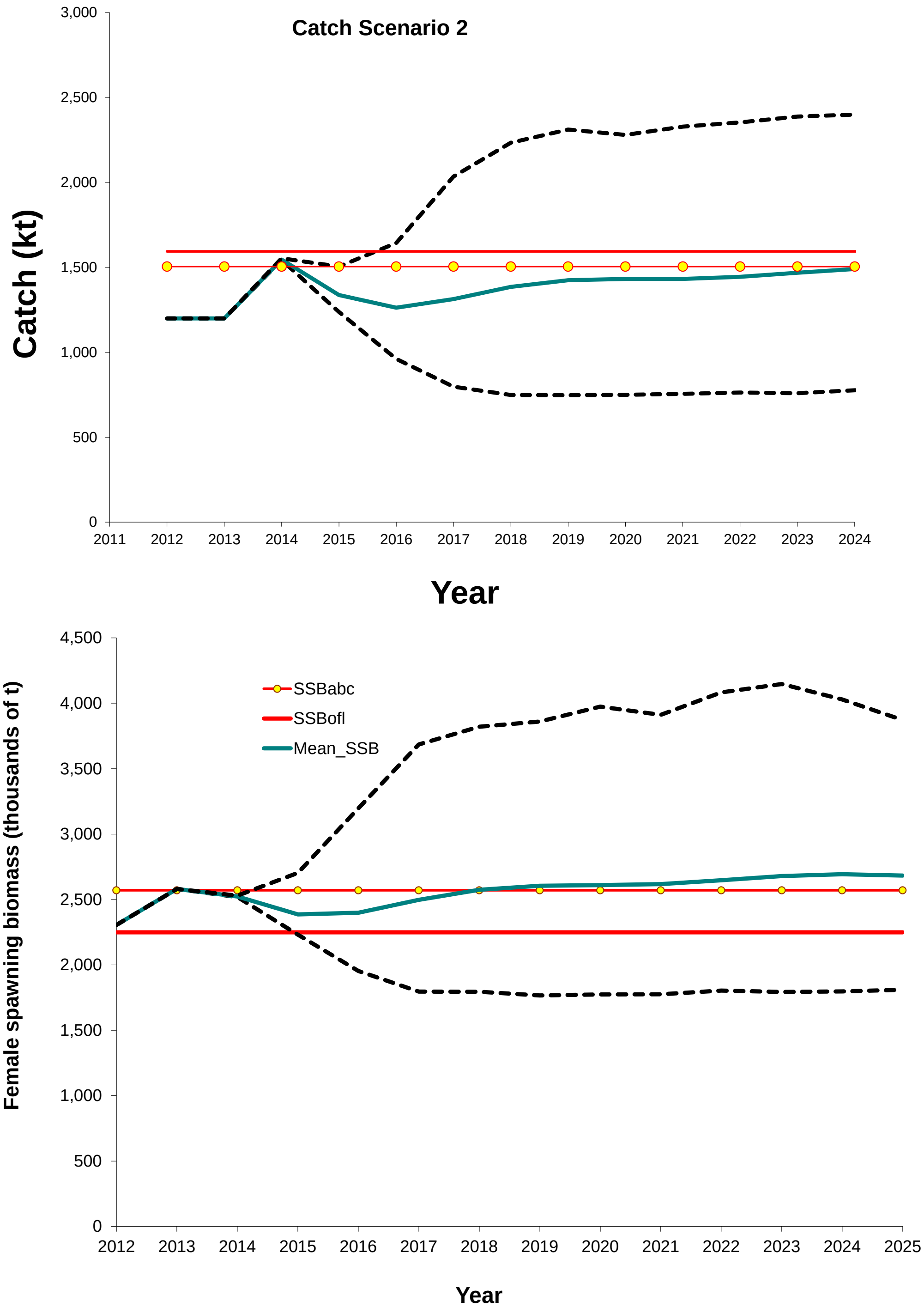

Figure 1.39. Projected EBS **Tier 3** pollock **yield** (top) and **female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2011. Future harvest rates follow the guidelines specified under Tier 3 Scenarios 1 and 2, $F_{ABC} = F_{40\%}$. *Note that this projection method is provided only for reference purposes, the SSC has determined that a Tier 1 approach is recommended for this stock.*

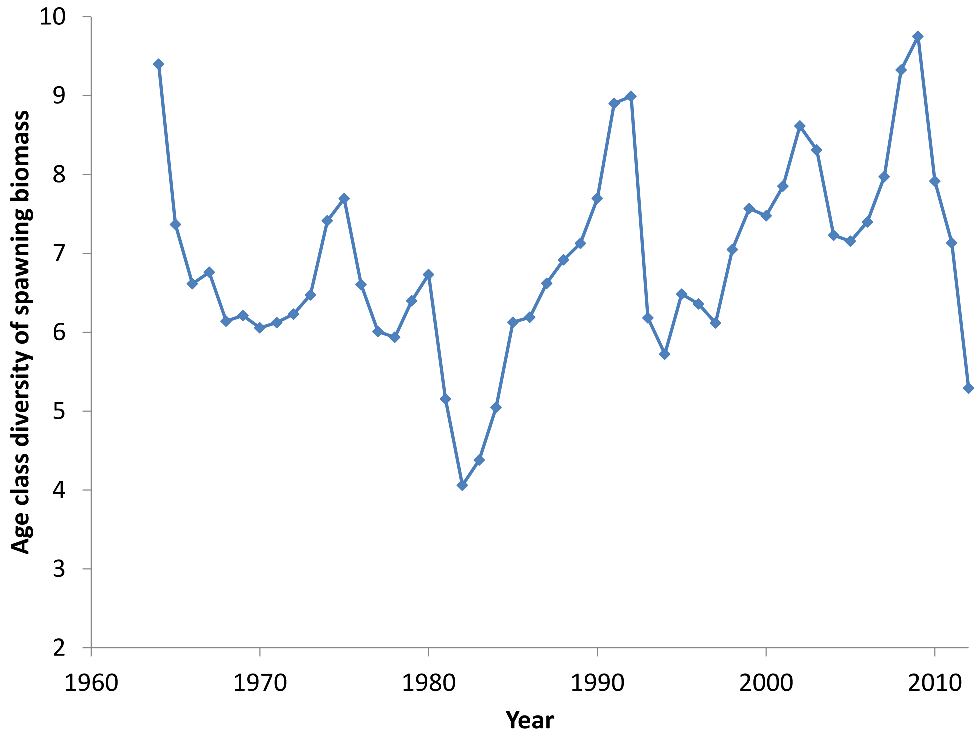

Figure 1.40. Weight-specific age-class diversity of the spawning biomass for EBS pollock, 1990-2012. This calculation is $D = \exp\left(-\sum p_i \ln p_i\right)$ where $p_i = w_i \phi_i N_i \left(\sum_{i=1}^{n} w_i \phi_i N_i\right)^{-1}$ for each year

Model details

Below is extracted from the assessment document with equation numbers added (and some updated equations due to software changes in Microsoft word over the years).

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

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

where

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

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

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

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

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

If the selectivities ($s_{t,a}$) are constant over time then fishing mortality rate decomposes into an age component and a year component. This assumption creates what is known as a separable model. If selectivity in fact changes over time, then the separable model can mask important changes in fish abundance. In our analyses, we constrain the variance term σ_s^2 to allow selectivity to change slowly over time–thus improving our ability to estimate $\gamma_{t,a}$. Also, to provide regularity in the age component, we placed a curvature penalty on the selectivity coefficients using the squared second-differences. We selected a simple random walk as our time-series effect on these quantities. Prior assumptions about the relative variance quantities were made. For example, we assume that the variance of transient effects (e.g., σ_E^2) is large to fit the catch biomass precisely. Perhaps the largest difference between the model presented here and those used for other groundfish stocks is in how we model "selectivity" of both the fishery and survey gear types. The approach taken here assumes that large differences between a selectivity coefficient in a given year for a given age should not vary too much from adjacent years and ages (unless the data suggest otherwise, e.g., Lauth et al. 2004). The magnitude of these changes is determined by the prior variances as presented above. For the application here selectivity is allowed to change in each year (previously selectivity was modeled in 2-year blocks were used). 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 2004-2009.

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 the $\bar{\alpha}, \bar{\beta}, \delta_t^\mu, \delta_t^\alpha, \text{and } \delta_t^\beta$ for t=1982, 1983,…2010. The variance terms for these process-error parameters were specified to be 0.04.

In 2008 the AT survey selectivity approach was modified. As an option, the age one pollock observed in this trawl can be treated as an index and are not considered part of the age composition (which then ranges from age 2-15). This was done to improve some interaction with the flexible selectivity smoother that is used for this gear and was compared. Additionally, the annual specification of input 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 ($\hat{\bar{a}}$):

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

where r_i^a is the residual of mean age and

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

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. 1.41).

Recruitment

In these analyses, recruitment (R_t) represents numbers of age-1 individuals modeled as a stochastic function of spawning stock biomass. A further modification made in Ianelli et al. (1998) was to have an environmental component to account for the differential survival attributed to larval drift (e.g., Wespestad et al. 2000). (κ_t):

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

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

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

and ϕ_a , the proportion of mature females at age is as shown in the sub-section titled "Natural mortality and maturity at age" under "Parameters estimated independently" above.

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

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

where

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

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

ε_t is the "recruitment anomaly" for year *t*,

α, β are stock-recruitment function parameters.

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

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

where

$\tilde{B}_0$ is the total egg production (or proxy, e.g., female spawning biomass) in the absence of exploitation (and recruitment variability) expressed as a fraction of R_0.

Some interpretation and further explanation follows. For steepness equal 0.2, then recruits are a linear function of spawning biomass (implying no surplus production). For steepness equal to 1.0, then recruitment is constant for all levels of spawning stock size. A value of h = 0.9 implies that at 20% of the unfished spawning stock size will result in an expected value of 90% unfished recruitment level. Steepness of 0.7 is a commonly assumed default value for the Beverton-Holt form (e.g., Kimura 1988). The prior distribution for steepness used a beta distribution as in Ianelli et al. (2001) is shown in Fig. 1.42. The prior on steepness was specified to be a symmetric form of the Beta distribution with alpha=beta=13.06 implying a prior mean of 0.6 and CV of 12.8% (implying that there is about 10% 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.

The value of σ_R was fixed at 0.9. This choice was selected to be larger than the output stock-recruitment variability (~0.67) since proper estimation of this quantity would require integration over the random-effects (inter-annual recruitment variability). In addition, retaining the uncertainty at a somewhat higher level increases the uncertainty on the stock-recruitment curve estimation that in turn propagates through to the pdf of F_{msy} and hence provides a greater buffer between yield at F_{msy} (the OFL) and maximum permissible ABC. Investigations on the choice of σ_R and the interaction with priors and stock-recruitment assumptions/estimation approaches are planned with a view towards how judge "reliability" of F_{msy} and the PDF of that quantity (needed for Tier 1 management).

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 14 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):

$$f = n \cdot \sum_{a,t} p_{at} \ln\left(\hat{p}_{at}\right),$$

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

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

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

where *A*, and *T*, represent the number of age classes and years, respectively, *n* is the sample size, and

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

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

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

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

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

where $\eta_{t,a} = p_{t,a}\left(1-p_{t,a}\right)$

and $\tau^2 = 1/n$

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

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

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

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

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

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

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

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 $\sigma_{s,t}^2$ 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 in fitting.

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 $\sigma_{c,t}$ is pre-specified (set to 0.05) affecting the accuracy of the overall observed catch in biomass. Similarly, the contribution of prior distributions (in negative log-density) to the log-likelihood function include $\lambda_\varepsilon \sum_t \varepsilon_t^2 + \lambda_\gamma \sum_{t,a} \gamma_{t,a}^2 + \lambda_\delta \sum_t \delta_t^2$ 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 1991-2010. The model simply computes the values of $\overline{w}_i, \sigma_{w_i}^2$ based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

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

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 2013 and 2014 ABC and OFL levels, the harmonic mean F_{msy} value was computed and the analogous harvest rate ($\hat{u}_{HM}$) applied to the estimated geometric mean "fishable" biomass at B_{msy} :

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

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

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

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. Refinements to this approach are underway and are planned for the future assessments.

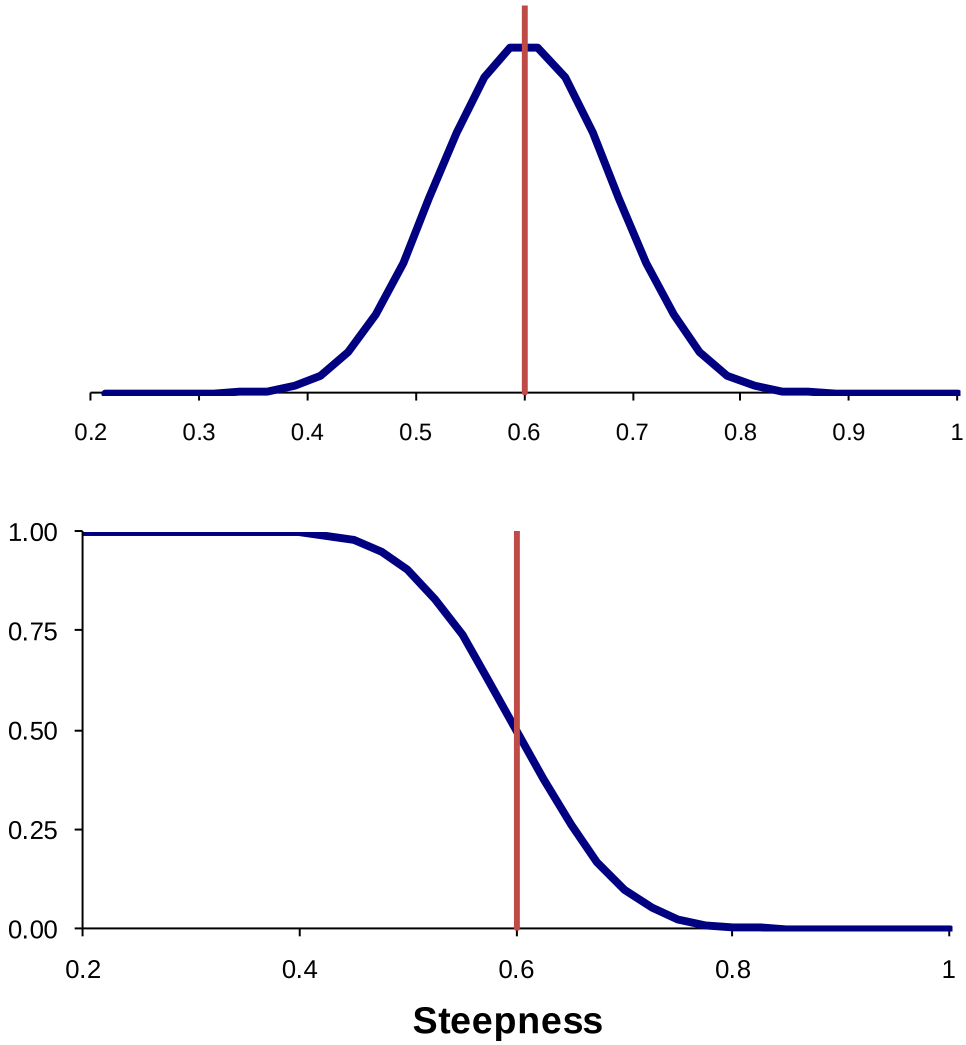

Figure 1.41. Cumulative prior probability distribution of steepness based on the beta distribution with α and β set to values which assume a mean and CV of 0.6 and 0.12, respectively. This prior distribution implies that there is about 8% chance that the value for steepness is greater than 0.7. See text for discussion.

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