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

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Executive Summary

The focus of this chapter is on the Eastern Bering Sea (EBS) region. The Aleutian Islands region (Chapter 1A) and the Bogoslof Island area (Chapter 1B) are presented as separate sections.

Summary of major changes

Changes in the input data
The primary changes include:

- The 2010 NMFS summer bottom-trawl survey (BTS) abundance at age estimates were computed and included for this assessment.
- The 2010 NMFS summer mid-water acoustic-trawl (AT) survey conducted aboard the NOAA Ship Oscar Dyson were included. This was the fourth consecutive complete AT survey conducted by this vessel in this region, and for the fourth straight year the survey extended into the Russian zone and covered part of the Navarin Basin.
- Age composition estimates for the AT survey derived from the population-at-length estimates using the 2010 BTS age-length key were included. To help cover younger ages that are less common in the BTS survey, about 100 samples from the AT survey were included with the bottom trawl survey ages to help construct a more complete age-length key.
- The 2009 age composition estimates were updated using AT age data (last year the age-length key used was derived from the 2009 BTS age data).
- Observer data for age and average weight-at-age from the 2009 fishery was finalized and formally included (a preliminary estimate was included in the 2009 assessment).
- Total catch as reported by NMFS Alaska Regional office was updated and included through 2010.
- A time series of relative errors (precision) for the AT survey abundance data were used from 1994-2010. This error was scaled to have the an average coefficient of variation equal to what was assumed as constant in previous assessments (i.e., 20% CV).
- A new acoustic index from 2006-2009 was experimentally added to the model. This index is derived from opportunistic acoustic recordings from the fishing vessels chartered to conduct the bottom trawl survey and has been shown to be consistent with the AT survey data. In 2011 it is hoped that this index will be complete for the period 2006-2011 and provide mid-water pollock abundance measures during off-years for the directed AT survey.

Changes in the assessment model
The general modeling approach remained unchanged this year. Refinements included adding an index based on acoustic data recorded from the bottom-trawl survey vessels and updating the aging error conversion matrix (based on recommendations from the CIE review). Also, the ability to omit recent year-classes from the estimation of the stock-recruitment relationship was added as an option.

Changes in the assessment results

The female spawning stock biomass is estimated to be above the B_{msy} level for 2011 and is increasing and presently projected to be well above B_{msy} by 2012. Several factors affected the change in the maximum permissible Tier 1a ABC levels and all had a uni-directional impact. These factors include:

- Increased average weight-at-age estimates for 2009 compared to what was assumed in the 2009 assessment
- Revised numbers at age estimates from the 2009 AT survey (due to age data becoming available) indicated slightly more age-3 pollock than from the preliminary data presented last year
- Greater-than-anticipated biomass estimates from the two 2010 surveys
- A lower statistical weight for the 2009 AT data due to the estimated relative precision (through sampling) of surveys in different years.
- Signs of a strong 2008 year class
- Spawning biomass is estimated to be above the B_{msy} level sooner than anticipated hence the adjustment to the target fishing mortality rate is removed and
- The fact that the 2006 and 2008 above-average year classes occurred at relatively low spawning biomass levels results in increased estimates of stock productivity/resiliency.

The available data indicate that the spawning biomass for 2011 is projected to be above the level expected from last year's assessment. Since the stock is estimated to comprise many immature (three year old) pollock in 2011 and that it is recovering from recent low levels, the recommended ABC (1,267,000 t) is below the maximum permissible (Tier 1a) level. The Tier 1a overfishing level (OFL) is estimated to be 2,447,000 t.

Summary results for EBS pollock.

	Last year		**This year**	
Quantity/Status	2010	2011	2011	2012
M (natural mortality, age 3+)	0.3	0.3	0.3	0.3
Specified/recommended Tier	1a	1a	1a	1a
Projected total biomass (ages 3+)	4,615,500 t	6,223,300 t	9,620,000 t	11,318,000 t
Female spawning biomass (t)				
Projected	1,316,000 t	1,588,000 t	2,444,500 t	3,019,500 t
B_0	4,934,000 t	4,934,000 t	5,140,000 t	5,140,000 t
B_{msy}	1,863,000 t	1,863,000 t	1,948,000 t	1,948,000 t
F_{OFL}	0.649	0.649	0.640	0.640
$maxF_{ABC}$	0.389	0.476	0.564	0.564
Specified/recommended F_{ABC}	0.389	0.476	0.332	0.332
Specified/recommended OFL (t)	918,000 t	1,220,000 t	2,447,000 t	3,170,000 t
Specified/recommended ABC (t)	813,000 t	1,109,000 t	1,267,000 t	1,595,000 t
Is the stock being subjected to overfishing?	No	n/a	No	n/a
Is the stock currently overfished?				
Is the stock approaching a condition of being overfished?	No		No	

Response to SSC and Plan Team comments

In their November 2009 minutes the BSAI Plan Team recommended (generally) that a workshop be held, or a working group be formed, to develop guidance regarding how to decide when a stock qualifies for management under Tier 1. In so doing, the Plan Team recognizes that the SSC has final responsibility for making tier determinations. Also, in September 2010 The BSAI Plan Team noted that the CIE review did not result in any progress being made on assessing the reliability of the stock-recruitment relationship, which had been identified as a key area of concern in last year's Plan Team review. In this year's assessment, some evaluation of the stock-recruitment relationship relative to new data was undertaken but a formal working group has yet to be established.

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. 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 suggests three unique areas of egg concentrations with the region north of Unimak Island and the Alaska Peninsula being the most concentrated. This new synthesis of egg and larval distribution data provides 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 in1992 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. This 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. This pattern is usually consistent between years but in 2010 catches appeared to be less concentrated and there were reports that pre-spawning pollock was less predictable than normal and extended farther north and later in the season (Fig. 1.2). The catch estimates by sex for the A-season compared to estimates for the entire season indicate that over time, the number of males and females has been fairly equal (Fig. 1.3).

In recent years the summer fishing has concentrated more in the NW region and this pattern continued in 2010 (Fig. 1.4). While the colder-than-usual bottom temperatures continue (see discussion of bottom trawl survey results below), it is unclear that these conditions are the major cause of this apparent shift in fish distribution. Ianelli et al. (2007) showed that from historical foreign-reported data that the pollock fishery often took more than half of their catch during the summer to the west of 170°W (the NW zone of the EBS). Only since 1991 had the summer pollock catches become more concentrated in the SE (east of 170°W).

Barbeaux et al. (2005b) presented some results on the development of small-scale spatial patterns of winter pollock aggregations. This involved a subset of some 32,000 km (~17,300 nm) of tracked acoustic backscatter collected opportunistically aboard commercial vessels. They found that during the daytime pollock tend to form patchy, dense aggregations while at night they disperse to a few uniform low-density aggregations. Changes in trawl tow duration and search patterns coincide with these changes in pollock distributions. Qualitative results suggest that rapid changes in distributions and local densities of Alaska pollock aggregations occur in areas of high fishing pressure. These analyses are expected to improve our understanding on the dynamics of the pollock stock in response to fishing activities.

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 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 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 Eastern 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 fishery continues to respond to issues related to salmon bycatch. In 2008 - 2010, bycatch levels for Chinook salmon have been well below average following record high levels in 2007 (Ianelli et al. 2009). This is likely due to industry-based restrictions on areas where pollock fishing may occur and also due to environmental conditions (and perhaps salmon abundance). Bycatch levels for chum ("other") salmon in 2005 were the highest on record but since have remained at low levels. Based on a final EIS released by NMFS in December 2009, revised salmon bycatch management measures have been developed and will become in effect by 2011. These measures were designed to have an overall Chinook salmon bycatch limit together with performance measures that will provide incentives for individual vessel operators to reduce bycatch. Salmon bycatch statistics are presented along with other bycatch estimates in the Ecosystem Considerations section below.

Catch data

From 1977-2010 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 has dropped to 0.81 million t due to stock declines and concomitant reductions in allowable harvest rates (Table 1.3).

Pollock catch in the Eastern Bering Sea and Aleutian Islands by area from observer estimates of retained and discarded catch for 1991-2010 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 Utilization and Improved Retention 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. Presentation of 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 1991-2004 (the period for which all the necessary information is readily available). Prior to 1991, we used the same catch - age composition estimates as presented in Wespestad *et al.* (1996).

The catch-age estimation method allows two-stage bootstrap re-sampling of the data. Observed tows were first selected with replacement, followed by re-sampling actual lengths and age-data 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. Estimates of 2009 fishery catch-at-age and 95% approximate confidence bands are presented in Fig. 1.5.

The recent fishery age ranges appear to focus primarily on pollock age 4-7 with the 2000 year class making up the majority of the catch until 2006 where the relative fraction of this year class drops considerably (Fig. 1.6). The 2006 and 2007 fishery data show higher levels (proportionally) of the 2001 and 2002 year class than in previous years. The corresponding values of catch-at-age used in the model are presented in 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). The sampling effort 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 - 2010) 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 contributing to the catches as modeled for assessment purposes.

Bottom trawl surveys

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 AT surveys that sample mid-water abundance levels. Between 1991 and 2010 the BTS biomass estimates ranged from 2.28 to 8.46 million t (Table 1.9; Fig. 1.7). In the mid-1980s 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 has followed a general decline since then. These surveys are multi-purpose and serve as a consistent measure of environmental conditions such as temperature characterizations which reflect the cold conditions of the past four years. 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, the past five years have been below average and the zoogeographic response may be more complex (Fig. 1.8).

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 2010 biomass estimate was 3.75 million t, up by 64% from the 2.28 million t observed in the 2009 survey. However, since 1987 this survey ranks 19th out of 24 surveys and is 78% of the average over this period. In 2010, the distribution of pollock was highest west of 170°W and typical for the recent cold bottom conditions compared to warmer years, (e.g., 2005) with concentrations somewhat closer to the shelf break (Fig. 1.9).

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. 1.10). 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 survey abundance levels in some other 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) and redone in this assessment (see below).

The 2010 survey age compositions were developed from age-structures collected and processed at the AFSC labs within a few weeks after the survey was completed. Since the bottom trawl survey overlaps in space and time with the AT survey, age data from the BTS survey were applied to the length compositions for the AT survey to provide two sources for abundances at age for 2010. However, since the AT survey generally has a higher relative occurrence of fish age 2-4 than the BTS survey, an additional sample of 100 pollock age structures (otoliths) was included from the AT survey and processed with the BTS data so that the smaller fish would be more adequately represented in constructing the age-length keys. The distributions of lengths-at-age between the surveys were similar (Fig. 1.11). This provides some assurance that mixing samples to better satisfy both requirements is reasonable.

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 recent increases (Fig. 1.12). 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 2001 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 2010 the AT survey biomass estimate was 2.323 million t compared to 0.924 million t for the US zone in 2009 (Table 1.9). Two and 4-year old pollock (the 2008 and 2006 year classes) were dominant in the survey and their estimated abundances were above the expectations projected from Ianelli et al. (2009). The high abundance of 2-year olds is consistent with the above-average 1-year old abundance observed in 2009 and appears consistent based on examination of the recent years abundance at length data where the modes corresponding to ages are clear (Fig. 1.13).

In 2010 NMFS scientists were able to extend the AT survey into the Russian zone—the fifth time they have been able to cover this region since 2004. The abundance in the Russian zone has varied substantially with 402 thousand t estimated in 2004 (Honkalehto et al. 2005) compared to 110, 32, and 5.4 thousand t during 2007 – 2009. The 2010 estimate for the Russian Navarin zone was 130.7 thousand t.

Using opportunistic acoustic data recording devices aboard the bottom-trawl survey data collection continues (e.g., as in Von Szalay et al. 2007 and Ressler et al. 2008). The analyses of these data to estimate a pollock biomass index are included for the first time in this assessment (Honkalehto et al. *In review*).

The number of trawl hauls and lengths and ages sampled from the AT survey are presented in Table 1.13. In 2009 the AT survey population numbers at age estimates were computed based on age-length keys compiled from the bottom-trawl survey. These were updated using geographically split age-length keys (E and W of 170°W) from the AT sampling (rather than the BTS age data; Fig. 1.14). The influence of this data refinement is provided in the section titled “model evaluations”.

For 2010 age compositions, the bottom-trawl survey collections (supplemented with 100 samples collected during the AT survey to cover size ranges of pollock less common in the bottom-trawl survey) and subsequent age-length keys were used and applied to the AT population-at-length estimates (Table 1.14; 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 70% from 1994-2006. Since 2007 the proportions have exceeded 85% (the 2010 value is 92%). For the SCA, the proportion was highest during 2000, 2002, and 2004 surveys (average 15%). For the period 2006-2010 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. Previously, for all survey years and for AT surveys between 1982 and 1991, a constant CV of 20% was assumed for these data (the 1979 data were assigned a negligible weight in fitting since protocols and methods for the survey were being developed). The influence of this data refinement is provided in the section titled “model evaluations”.

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).

Opportunistic acoustic data collection index

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. *In review*). 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. Analysis of four years of AT survey data (1999, 2000, 2002, and 2004) identified a suitable index area to track midwater pollock abundance. For the years 2006-2009 the BT survey acoustic data in that area tracked the AT survey abundance and captured its broad spatial patterns. The hope is that the new index can provide insight on mid-water pollock abundance during years when the dedicated AT research vessel is unavailable. The methods for developing this index and validating it with the dedicated AT survey operations are presented in Honkalehto et al. (in review). The new BT midwater pollock index presently for 2006-2009 (Table 1.16) was included in the stock assessment model patterned (using AT selectivity and mean weight-at-age estimates) to be scaled to the predicted AT biomass. The BT index will again be computed and compared with the AT survey in 2010. In 2011, the AT survey vessel will be working in the Gulf of Alaska. Thus 2011 will be the first year that the BT index will stand alone to provide EBS midwater pollock information (with data from 2010 and 2011 to be added to this time series by late 2011).

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 1964-2010. 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 2010 EBS bottom trawl survey estimate of population numbers-at-age was added.
- The 2010 EBS AT survey estimate of population numbers-at-age were included using an age-length key from the 2010 BTS survey data.
- The 2009 EBS AT survey estimate of population numbers-at-age were updated from last year’s values by using age-length keys from the 2009 AT survey data.
- A time series of relative errors (precision) for the AT survey abundance data were used from 1994-2010. This error was scaled to have the an average coefficient of variation equal to what was assumed as constant in previous assessments (i.e., 20% CV; Table 1.15, last column).
- The 2009 fishery age composition data were added.
- An index of abundance from 2006-2009 was added to the model. This index is based on Honkalehto et al (*In Review*) using acoustic backscatter data recorded aboard vessels conducting the bottom trawl survey
- The age-determination error was re-evaluated and use of an updated conversion matrix was explored.
- The ability to omit the most recent recruitment estimates from stock-recruitment relationship was added. While this should maintain the observation errors appropriately, they appear to have undue influence (relative to other year classes) on the stock-recruitment relationship and

consequently affect stock productivity/resiliency estimates (noting that recent data indicating strong 2006 and 2008 year classes appears to have come from relatively low spawning biomass levels).

Parameters estimated independently

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; Kastelle and Kimura 2006). However, the CIE review requested that age-determination errors be re-examined. Ageing errors were estimated in an earlier version of the assessment (Ianelli et al. 2003) and because including the age-error conversion matrix resulted in a poorer model fit, they were used in the assessment model as sensitivity analyses. This year, an alternative age-error conversion matrix was developed and an analysis begun. One item of interest is to evaluate how age readers vary with experience. Out of 16 individuals that have been ageing EBS pollock fishery samples since 1990 (representing over 56,900 pollock sampled) they could be divided into three approximately equal categories based on experience. The least

experienced had aged less than 3,000 structures whereas the most had aged over 9,000. These different groups of readers had very similar percent agreement in reader-tester subsamples (Fig. 1.17). This suggests that the structures themselves provide a substantial source of variability rather than experience. Using these same percent agreements and updating the age-error conversion matrix used in previous assessments (assuming all ageing is unbiased), the age-specific standard deviation of age-error is similar to what was used previously (Fig. 1.18). The method of converting percent agreements into standard deviations and estimating ageing error matrix was done by computing the expected agreement percentages conditioned on age specific standard deviations. The model for predicted percent agreement is thus:

P(reader 1 is correct) × P(reader 2 is correct) +

2P(reader 1 off by 1 year) × P(reader 2 off by 1 year) +

2P(reader 1 off by 2 years) × P(reader 2 off by 2 years)

The solution for standard deviations at age was found by minimizing the differences between the observed and predicted percent agreements.

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., 2009 for the assessment conducted in 2010). 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 (Table 1.17). The coefficients of variation between years is 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 2010 (and future year) mean weights at age (the most recent 10-year mean). The 2009 revised mean weights-at-age are larger than assumed for last year (Fig. 1.19). The influence of this data refinement is provided in the section titled "model evaluations".

Parameters estimated conditionally

For the selected model, 795 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment and stock-recruitment parameters account for 70 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 1964-2010 and projected recruitment variability (using the variance of past recruitments) for five years (2012-2015). 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 48 parameters and the age-time forms a 10x47 matrix of 470 parameters bringing the total fishing mortality parameters to 518.

Selectivity-at-age estimates for the bottom trawl survey are specified with age and year specific deviations in the average availability-at-age totaling 89 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 CPUE data, 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. Logically, the catchabilities from both surveys should sum to unity. 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. 1.7; for the AT and CPUE indices values of σ=0.2 were assumed)
- 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.

Model evaluation

A preliminary sequence of models was developed that evaluated sensitivities to data or model configuration refinements. These refinements included:

a) Update the catch biomass removed (minor change from the 2009 assessment)
b) Updating the 2009 fishery mean weights-at-age
c) Update the 2009 AT age data (using age determinations as collected from this survey rather than borrowing from the BTS).
d) Using the relative estimation errors for the AT survey time series (but with the same mean coefficient of variation of 20% for age 2+ numbers)
e) Add option to ignore recent recruitments role in estimating the stock-recruitment relationship

These refinements were considered straightforward improvements and were included in all subsequent analyses.

For illustrating the influence of the new data in 2010 on model results and to examine some additional sensitivities, the following models were considered (after options a) - e) above was examined:

Shorthand	Description
C	2010 total catch only included
CA	Catch and 2009 fishery age data included
CAB	Catch, age, and bottom-trawl survey
CAE	Catch, age, and AT survey
CBE	Catch, bottom-trawl survey, and AT survey
CABE	Catch, age, bottom-trawl survey, and AT survey
CABE_E	As with **CABE** but include age-determination error conversion matrix
CABEA	As with **CABE** but includes new AVO index

Model evaluation results

Results from model refinements
Updating the mean weights at age had little effect on the estimates of recruits (i.e., refinement b), nor did refinement c); update of the 2009 AT numbers at age estimates (Fig. 1.20). The largest impact from these refinements arose from d)—using the relative error estimates (even though the average contribution from these data were assumed to be the same). The reason for this impact is likely due to the fact that the relative error for 2009 data changed from 20% (assumed last year) to 36% (penultimate column of Table 1.14). That is, in last year's assessment, the assumed observation error was probably too low (at least relative to other years of data in this series) giving too much weight to the lower abundance levels observed in 2009.

Results from alternative model configurations
Unlike the recent two assessments, the influence of adding new data this year showed better consistency with prior years' data and with the main sources of information. For example, adding the AT survey increased the estimate of the 2008 year class and adding the bottom trawl survey data increased the estimate of the 2006 year class. Overall, adding data generally increased the "fishable biomass" and the F_{msy} rate (Fig. 1.21). This figure also indicates the sensitivity of including the most recent recruitment estimates on the F_{msy} rate estimates (which are closely related to stock-recruitment relationship estimates). The harvest rate with the recent recruitments included increases by about 11% compared to the CABE model.

Closer examination of the age data that affect results show how different "data omissions" reflect the influence of the other sources of information. For example, this year the fits for model CA (only new data include 2009 fishery catch and age compositions) to the observed 2010 survey age compositions (Fig. 1.22) were particularly poor for the age 4 group of fish in the BTS and the age 2 fish in the AT survey. Similarly, if the 2010 AT age composition data are omitted, (model CAB) the fit to the 2010 AT age data remains poor (Fig. 1.22).

Including the age-determination error conversion matrix resulted in a worse fit to the data: the negative log posterior density value was 82.91 when age-errors were included compared to a value 67.66 without ageing errors (the degradation in log-likelihood units for the fishery age composition data alone was

16.1). This suggest that the age-error conversion matrix is somehow inconsistent with the actual age data as compiled. Until this can be resolved, we recommend continuing to exclude the age error conversion matrix.

Adding the AVO index into the model resulted in slightly lower biomass estimated and it exhibited a relatively poor pattern of residuals (Fig. 1.23). As two more years of data should be available in 2011, it is hoped that this index will begin to provide some additional signal on stock trends. For the remainder of the discussion results from the CABE model are presented.

Time series results

Comparing this year's result with that from 2009 suggests that ages 1-4 were underestimated in the 2009 assessment (Fig. 1.24). As noted above, this is due to the addition of data in 2010 that are more consistent with historical data (i.e., that the 2006 year class is above average). When examined for the effect on biomass estimates, it is informative to compute the cumulative spawning biomass by age and compare the differences. Results show most of the difference (~51% in biomass) occurs due to the revised estimates of age 4 numbers at age (Fig. 1.25).

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. 1.26). The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 1.27). The fit to the early Japanese fishery CPUE data (Low and Ikeda, 1980) is consistent with the population trends for this period (Fig. 1.28).

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 2010 survey (Fig. 1.29). The pattern of bottom trawl survey age composition data in recent years shows the reduction in relative importance of the 2000 year class and that the 2002 and 2001 year-classes are more apparent (relatively) and in 2010 the large proportion of the ages belonging to the 2006 year class as four year olds (Fig. 1.30).

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. 1.31; 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. 1.31; 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. 1.32). The AT age-1 index indicates a larger than expected 2008 and 2009 year class but these data are generally imprecise as a pre-recruit index (Fig. 1.32; bottom panel).

The estimate of B_{msy} is 1,948,000 t (with a CV of 20%) which is less than the projected 2011 spawning biomass of 2,444,500 t; Table 1.19). For 2011, the Tier 1 levels of yield are 2,154 thousand t from a fishable biomass estimated at around 3,822,000 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 near the $B_{40\%}$ (2,523,000 t) in 2011 and about 125% 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 2010 and decreases for 2011 (Fig. 1.33).

Another metric on the impact of fishing suggests that the 2010 spawning stock size is about 50% of the predicted value had no fishing occurred since 1978 (Table 1.19). This compares with the 38% of $B_{100\%}$ (based on the SPR expansion from mean recruitment since 1978) and 48% of B_0 (based on the estimated stock-recruitment curve).

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 1982-88, 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 4.1 million t*.

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 4-9 has been increasing during the period of stock decline (Fig. 1.34). The estimate for 2009 and 2010 is below 20% due to the reductions in TACs arising from the ABC control rules.

The CIE review noted that the SER values may be misleading and requested that a table of age specific fishing mortality rates also be included. This shows that fishing mortality on some older age pollock was fairly steady with a similar peak shown in the SER time series (Fig. 1.35)

Spawning biomass is projected to increase under a wide variety of catch scenarios (Fig. 1.36). Compared with past year's assessments, the estimates of age 3+ pollock biomass are similar during the historical period but higher in recent years (Fig. 1.37, Table 1.24). This is due primarily to the revised estimate of the 2006 year class (last year the estimate was 24.5 billion, this year it is 34.0 billion age 1 pollock).

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. 1.38).

Recruitment

The 2008 year-class strength shows mixed signals from the appearance of one-year olds in the surveys in 2009. In the AT survey, the abundance of one-year olds was above average and the third highest since 1982 (behind 2007 and 1997) whereas in the bottom-trawl survey, one-year olds were below average (Fig. 1.39). The number of 1-year olds in the 2010 surveys (the 2009 year class) were above average in the AT survey and below average in the BTS.

Data from the 2010 bottom trawl survey strongly support that the 2006 year class is well above average. However, the AT survey observed fewer age three pollock in 2009 than expected and but the 2006 year class was present in the 2010 survey (Fig. 1.40, top panel). 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 2010 spawning biomass is approaching the B_{msy} level (Fig. 1.40; bottom panel). Note that the 2008 and 2009 age 1 recruits are excluded from estimating the stock-recruitment curve.

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 on the relative density and quality (in terms of condition for survival) of young-of-year pollock. For example,

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

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. However, recruitment success of these cohorts was low. This counter-intuitive result to the previous studies does not necessarily negate the current paradigm linking ocean conditions to successful pollock recruitment. Instead, BASIS results offer another possible explanation for the high variability in recruitment of Bering Sea pollock. When sea temperatures on the eastern Bering Sea shelf are very warm and the water column is highly stratified during summer, age-0 pollock appear to allocate more energy to growth than to lipid storage, leading to low energy density prior to winter, thus higher over-winter mortality (Swartzman et al. 2005, Winter et al. 2005).

Results from the BASIS research project also 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).

Projections and harvest alternatives

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Estimates of reference points related to maximum sustainable yield (MSY) are currently available. However, their reliability is questionable. We therefore present both reference points for pollock in the BSAI to retain the option for classification in either Tier 1 or Tier 3 of Amendment 56. These Tiers require reference point estimates for biomass level determinations. Consistent with other groundfish stocks, the following values are based on recruitment estimates from post-1976 spawning events:

B_{msy} = 1,948 thousand t female spawning biomass

B_0 = 5,140 thousand t female spawning biomass

$B_{100\%}$ = 6,308 thousand t female spawning biomass*

$B_{40\%}$ = 2,523 thousand t female spawning biomass

$B_{35\%}$ = 2,208 thousand t female spawning biomass

Specification of OFL and Maximum Permissible ABC

The 2011 spawning biomass is estimated to be 2,444,500 t (at the time of spawning, assuming the stock is fished at recommended ABC level). This is above the B_{msy} value of 1,948,000 t. Under Amendment 56, this stock has qualified under Tier 1 and the harmonic mean value is considered a risk-averse policy since reliable estimates of F_{msy} and its pdf are available (Thompson 1996). The exploitation-rate type value that corresponds to the F_{msy} level was applied to the "fishable" biomass for computing ABC levels. For a future year, the fishable biomass is defined as the sum over ages of predicted begin-year numbers multiplied by age specific fishery selectivity and mean body mass (10-year average).

* Note that another theoretical "unfished spawning biomass level" (based on stock-recruitment relationship, $\tilde{B}_0$) is somewhat lower (5,140 kt).

Since the 2011 estimate of female spawning biomass is estimated to be above the B_{msy} level (2,523 kt) but below the $B_{40\%}$ value (1,948 kt). The OFL's and maximum permissible ABC values by Tier are thus:

Tier	Year	MaxABC	OFL
1a	2011	2,154,000 t	2,447,000 t
1a	2012	2,255,000 t	2,501,000 t
3b	2011	1,292,000 t	1,351,000 t
3a	2012	1,681,000 t	1,505 ,000 t

As noted in the model evaluation section, there are a number of reasons why there is a substantial increase over the projected ABC for 2011 from last year's (2009) assessment. Some of these reasons include

1) In 2009, the projection to 2011 was that the spawning biomass was at 84% of B_{msy}, hence the maximum permissible rate was reduced by 16%. In the current assessment, the 2011 spawning biomass is projected to be above B_{msy} (no adjustment to F_{msy} required)
2) The weights-at-age recorded from the 2009 fishery were substantially larger than anticipated. Hence fewer numbers of fish were taken (lower fishing mortality) than expected and more fish survived
3) The 2009 fishery catch-at-age indicated greater selection of older fish than anticipated (Fig.1.41) again fewer fish per t of pollock)
4) Revision of the uncertainty estimates applied to the AT data (current model included year-specific estimates of uncertainty instead of a constant CV as had been done in the past. Since these data (on the relative uncertainty for each survey) indicated that the 2009 AT estimates had a relative high CV (~36%) then the estimates from 2009 received less statistical weight.

ABC Recommendation

ABC levels are affected by estimates of F_{msy} (which depends principally on the stock-recruitment relationship and demographic such as selectivity-at-age, maturity, growth), the B_{msy} level, and current stock size (both spawning and "fishable"). Information collected in 2010 and refinements to the treatment of earlier data all indicate that the stock is in better condition relative to B_{msy} levels and near-term outlook compared to the past few years. The stock is apparently recovering from period of 20% declines from 2003 – 2007 and data and model results indicate that the biomass is increasing. Under likely catch projections, the spawning stock biomass is expected be about 125% of B_{msy} (1,948 kt) by 2011 with future status depending on specified catch levels (Fig. 1.42, Scenario 2).

Nonetheless, there are a number of concerns that would justify precaution in setting the ABC below the maximum permissible. These include:

- The anticipated proportion of catch comprising just 5 year olds in 2011 is high (~49% numerically and 51% by weight)
- In 2010, the proportion of a single age class contributing to the spawning biomass is estimated to have been the highest since from 1990-2015 (Fig. 1.43)
- About 50% of the biomass change between last year's estimate for age-cumulative biomass is due to the revision of the 2006 year class estimate (e.g., Fig. 1.25) and hence places a high degree of reliance on the 2010 surveys

- The 2010 BTS pollock biomass estimate ranks 19th out of 24 surveys since 1987 and is below average
- The AT survey pollock biomass ranks 9th out of 17 surveys conducted since 1980 and is also below average
- The catch west of 170°W has averaged 580 kt from 2005-2010 whereas the long term average (1979-2010) is 413 kt. There may be some spatial catch disparity beyond what is anticipated due to the population age structure (with younger fish general further north and west)
- The spatial distribution of the 2010 A-season fishery was unusual and may indicate a shift in the contribution of spawning pollock from different areas and parts of the "normal" season
- The unintended catch of 2008 year class (three year olds) may be higher than indicated by the assumed selectivity-at-age (which
- The AT survey indicates the third lowest percentage of fish (in biomass) of pollock aged 3 and older based on 2010 data (this is partly due to the relatively high apparent abundance of 2 year olds)
- The fishery would presumably benefit by improved catch rates over broader regions, particularly for shore-based catcher vessels if the stock abundance is allowed to increase more
- The biomass observed in the Navarin region in the Russian zone remains relatively low
- The Biological opinion has identified that the increases in Steller sea lions are below standards in some areas
- Estimates of the 2008 (and 2009) year class are highly uncertain.

Given these, an added control rule adjustment in harvest rates seems justified to ensure that fishing mortality increases at a more incremental pace. In 2009, the assessment prognosis was to have an ABC of 1.11 million t for 2011. The current assessment has revised this value upward in the face of new information that affects the estimated population biomass and the allowable harvest rate. Combined, these estimated conditions result in a maximum permissible Tier 1a ABC that is unreasonably high. Note that this issue of rapid change due to the control rule is not unique to Tier 1. For example, the analogous calculations for Tier 3 would have resulted in an ABC for 2011 that was 2.8 times greater than the Tier 3 ABC for 2010 (the change using Tier 1 was a factor of 2.7).

As highlighted by the 2010 CIE review, age specific fishing mortality rates have recently been quite high and that presenting the spawning exploitation rate alone may be misleading (e.g., Fig. 1.34). Facing these kinds of uncertainties it seems prudent to increase fishing mortality more gradually. Consequently, we recommend that the 2011 ABC be set to the recent average fishing mortality. This results in a 2011 ABC of 1,267,000 t. At this level of fishing the spawning biomass is projected to continue increasing and the 2012 ABC would be 1,595,000 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 2010 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2011 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2010. 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. The begin year numbers at age in 2010 were used as estimated except that the 1 and 2-year olds were set to their mean values (the 2009 and 2008 year classes). This was to moderate the effect of large, highly uncertain, pre-recruit estimates from affecting near term ABC and OFL outlooks.

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 2010 and 2011, 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 all future years, *F* is set equal to a value that corresponds to some trial catch levels for 2011 and 2012 (1,100,000 t and 1,300,000 t). (Rationale: These catches are close to recent and historic mean levels and still would likely satisfy the constraint to be below the maximum permissible under Tier 1 levels).

Scenario 3: In all future years, *F* is set equal to the 2006-2010 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 2010 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2023 under this scenario, then the stock is not overfished.)

Scenario 7: In 2011 and 2012, *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 2023 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 2010 (Table 1.25). Under Tier 3 Scenarios 1 and 2, the expected spawning biomass will decrease to below the $B_{35\%}$ then begin increasing after 2010 but not reaching $B_{40\%}$ (in expectation) until after 2012 (Fig. 1.42).

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 2010:

If spawning biomass for 2010 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.

If spawning biomass for 2010 is estimated to be above $B_{35\%}$, the stock is above its MSST.

If spawning biomass for 2010 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 2020 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 2013 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

If the mean spawning biomass for 2013 is above $B_{35\%}$, the stock is not approaching an overfished condition.

If the mean spawning biomass for 2013 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2023. If the mean spawning biomass for 2023 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 2010, 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). For harvest recommendations, Tier 3 and a proxy for Tier 1 calculations were made that give ABC and OFL values for 2011 and 2013 (assuming catch is 1,200,000 t in 2011 Table 1.26).

Other considerations

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. (2004) 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 extent that the pollock fishery extends into 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 is given in Table 1.27. 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. We include an update this year to compare spatial distributions and the trend. The analysis relies on a comparison of acoustic backscatter at four frequencies (18, 38, 120, and 200 kHz) and net sampling with a Methot trawl (De Robertis et al., 2010; Ressler et al., in preparation). Typically, 12-24 tows are targeted at euphausiids during an AT survey.

The 2004-2010 time series of Bering Sea summer euphausiid abundance (Fig. 1.44) shows that euphausiid backscatter increased more than three-fold in 2009 (from the 2004 level) and preliminary data indicates a decline by about 30% in 2010. Interestingly, this decline coincides with a nearly doubling of the acoustic backscatter attributed to pollock by the AT survey and the increase estimated in this year's model estimated biomass. It is unknown if these opposing trends of euphausiid (prey) and pollock (predator) abundances are related or if they are independent responses to changes in environmental conditions. Predation by pollock may be a principal source of variability in euphausiid standing stock (Ressler et al., in preparation). However, other studies have suggested that euphausiids and large copepods could be more numerous in "cold" years such as 2006-2010 as opposed to "warm" years such as 2004 (Baier and Napp, 2003, Coyle et al., 2008), so other factors likely also play a role.

These euphausiid backscatter data are spatially explicit (Fig. 1.45), so distribution, as well as abundance, can be tracked over time. Further research on physical overlap using this index may help test hypotheses on linkages and hence help better understand temporal and spatial variability in pollock abundance.

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 1.28). Jellyfish represent the largest component of the bycatch of non-target species and has been stable at around 5-6 thousand tons per year (except for 2000 when over 9,000 t were caught). Skate bycatch has more than doubled in 2008 based on preliminary data (Table 1.28). 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. Nonetheless incidental catch of Pacific cod has increased since 1999 but is below the 1997 levels (Table 1.29). The incidental catch of flatfish was variable over time and has increased slightly. 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 1.30).

The catch of prohibited species was also variable but showed noticeable trends (Table 1.31). For example, the level of crab bycatch drops considerably after 1998 when all BSAI pollock fishing was restricted to using only pelagic trawls. Recent levels of salmon bycatch have increased dramatically and current restrictions are under revision to help minimize this problem.

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 as identified by the CIE review, 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.

Summary

Summary results are given in Table 1.32.

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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, 1979-2010 (2010 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		
2009	358,314	452,417	810,731			
2010	251,283	553,907	805,190			
Average	767,599	412,644	1,180,243			
	65%	35%				

1979-1989 data are from Pacfin.
1990-2010 data are from NMFS Alaska Regional Office, and includes discards.
2010 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), 1998-2010. *Note that the 2010 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 (16%)	412,000 t (9%)	693,000 t (12%)

Table 1.3. Time series of ABC, TAC, and catch levels for EBS pollock, 1977-2010 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports, catch for 2010 is an estimated projection.

Year	ABC	TAC	Catch
1977	950,000	950,000	978,370
1978	950,000	950,000	979,431
1979	1,100,000	950,000	935,714
1980	1,300,000	1,000,000	958,280
1981	1,300,000	1,000,000	973,502
1982	1,300,000	1,000,000	955,964
1983	1,300,000	1,000,000	981,450
1984	1,300,000	1,200,000	1,092,055
1985	1,300,000	1,200,000	1,139,676
1986	1,300,000	1,200,000	1,141,993
1987	1,300,000	1,200,000	859,416
1988	1,500,000	1,300,000	1,228,721
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	810,731
2010	813,000	813,000	813,000
1977-2010 average	1,385,029	1,190,155	1,168,547

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, 1991-2010. SE represents the EBS east of 170° W, NW is the EBS west of 170° W, source: NMFS Blend and catch-accounting system database. 2010 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	1,610,288
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	1,329,503
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	1,150,533
1998	164 (1%)	3 (2%)	1,581 (1%)	15,135 (2%)	16,883 (2%)	23,822	136	135,399	965,767	1,125,123
1999	480 (48%)	11 (38%)	1,912 (1%)	27,089 (3%)	29,492 (3%)	1,010	29	206,697	783,119	990,855
2000	790 (64%)	20 (69%)	1,941 (1%)	19,678 (2%)	22,429 (2%)	1,244	29	293,532	839,175	1,133,981
2001	380 (46%)	28 (11%)	2,450 (1%)	14,873 (2%)	17,731 (1%)	824	258	425,219	961,889	1,388,190
2002	758 (66%)	12 (1%)	1,439 (0%)	19,226 (2%)	21,435 (1%)	1,156	1,042	320,463	1,159,730	1,482,391
2003	468 (28%)	NA	2,980 (1%)	14,063 (2%)	17,512 (1%)	1,653	NA	557,552	933,459	1,492,664
2004	758 (66%)	NA	2,781 (0.2%)	20,380 (1.4%)	23,783 (2%)	1,158	NA	390,544	1,089,999	1,482,373
2005	324 (20%)		2,586 (0.2%)	14,838 (1.0%)	17,424 (1.2%)	1,621		680,868	802,418	1,484,907
2006	310 (18%)		3,672 (0.2%)	11,659 (0.8%)	15,331 (1.0%)	1,744		659,455	826,980	1,488,180
2007	425 (17%)		3,560 (0.3%)	12,313 (0.9%)	15,873 (1.2%)	2,519		626,003	728,094	1,356,616
2008	81 (6%)		1,644 (0.2%)	5,952 (0.6%)	7,597 (0.8%)	1,278		508,023	482,542	991,843
2009	345 (20%)		1,936 (0.2%)	4,009 (0.5%)	5,945 (0.7%)	1,729		452,417	358,314	809,467
2010	93 (8%)		1,033 (0.1%)	2,358 (0.3%)	3,391 (0.4%)	1,127		553,907	251,283	

Table 1.5. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2009. Units are in millions of fish.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Total
1979	101.4	543.0	719.8	420.1	392.5	215.5	56.3	25.7	35.9	27.5	17.6	7.9	3.0	1.1	2,567.3
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	2,420.8
1981	0.6	72.2	1,012.7	637.9	227.0	102.9	51.7	29.6	16.1	9.3	7.5	4.6	1.5	1.0	2,174.6
1982	4.7	25.3	161.4	1,172.2	422.3	103.7	36.0	36.0	21.5	9.1	5.4	3.2	1.9	1.0	2,003.8
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	1,744.5
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	1,938.0
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	1,920.0
1986	3.1	86.0	92.3	748.6	214.1	378.1	221.9	214.3	59.7	15.2	3.3	2.6	0.3	1.2	2,040.5
1987	0.0	19.8	111.5	77.6	413.4	138.8	122.4	90.6	247.2	54.1	38.7	21.4	28.9	14.1	1,378.6
1988	0.0	10.7	454.0	421.6	252.1	544.3	224.8	104.9	39.2	96.8	18.2	10.2	3.8	11.7	2,192.2
1989	0.0	4.8	55.1	149.0	451.1	166.7	572.2	96.3	103.8	32.4	129.0	10.9	4.0	8.5	1,783.8
1990	1.3	33.0	57.0	219.5	200.7	477.7	129.2	368.4	65.7	101.9	9.0	60.1	8.5	13.9	1,745.9
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	1,427.6
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	1,888.3
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	1,877.0
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	1,834.0
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	1,606.1
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	1,429.3
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	1,545.1
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	1,541.2
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	1,499.4
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	1,645.7
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	1,744.1
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	1,883.9
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	2,065.1
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	2,107.4
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	2,150.5
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	2,118.9
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	1,657.7
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	1,158.3
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	917.7
Average	4.5	66.3	221.9	340.1	365.8	321.4	208.2	119.1	69.5	36.7	25.5	12.8	8.8	6.1	1,806.7
Median	0.4	25.3	90.0	227.7	365.7	288.3	168.7	104.9	59.7	27.5	18.2	9.6	6.3	3.4	1,834.0

Table 1.6. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2009, 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
			Length – weight samples				
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

Table 1.7. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2009, 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

Table 1.8. NMFS total pollock research catch by year in t, 1964-2010.

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	145
1987	0	174			

Table 1.9. Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979-2010 (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		7.46	22%	10.660	30%
1980					
1981					
1982	2.856	4.9	94%	7.756	37%
1983	6.258				
1984	4.894				
1985	6.056	4.8	97%	10.856	56%
1986	4.897				
1987	5.525				
1988	7.289	4.68	98%	11.969	61%
1989	6.519				
1990	7.322				
1991	5.168	1.45	55%	6.618	78%
1992	4.583				
1993	5.636				
1994	5.027	2.89	87%	7.917	63%
1995	5.482				
1996	3.371	2.31	97%	5.681	59%
1997	3.874	2.59	70%	6.464	60%
1998	2.852				
1999	3.801	3.293	95%	7.094	54%
2000	5.265	3.05	95%	8.315	63%
2001	4.200				
2002	5.038	3.62	85%	8.658	58%
2003	8.458				
2004	3.886	3.31	99%	7.196	54%
2005	5.294				
2006	3.045	1.56	98%	4.605	66%
2007	4.338	1.77	89%	6.108	71%
2008	3.031	0.997	76%	4.028	76%
2009	2.280	0.924	78%	3.204	71%
2010	3.748	2.323	65%	6.071	62%
Average	4.622	2.779	86%	7.034	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 1982-2010.

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	1,298,185	5,928,295	22%
1986	4,896,780			
1987	5,108,035	406,587	5,514,622	7%
1988	7,106,739	181,909	7,288,648	2%
1989	5,906,636	673,313	6,579,949	10%
1990	7,126,083	195,894	7,321,977	3%
1991	5,088,046	62,505	5,150,551	1%
1992	4,367,870	214,676	4,582,546	5%
1993	5,521,208	114,757	5,635,966	2%
1994	4,977,019	49,706	5,026,726	1%
1995	5,408,653	68,983	5,477,637	1%
1996	3,258,348	167,090	3,425,438	5%
1997	3,036,898	842,276	3,879,175	22%
1998	2,212,689	639,715	2,852,404	22%
1999	3,598,286	203,314	3,801,600	5%
2000	5,152,586	129,932	5,282,518	2%
2001	4,145,746	54,162	4,199,909	1%
2002	4,832,506	205,231	5,037,737	4%
2003	8,106,139	314,637	8,420,776	4%
2004	3,744,501	130,227	3,874,729	3%
2005	5,168,295	160,109	5,328,404	3%
2006	2,845,009	199,932	3,044,940	7%
2007	4,156,687	180,856	4,337,542	4%
2008	2,834,094	197,106	3,031,200	7%
2009	2,231,225	51,193	2,282,418	2%
2010	3,550,981	197,038	3,748,019	5%
Avg.	4,586,823	277,573	4,842,149	6%

Table 1.11. Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982-2010. 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				

Table 1.12. Bottom-trawl survey estimated numbers (millions) at age used for the stock assessment model, 1982-2010 based on strata 1-8. 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	957	2,243	2,467	3,156	1,074	146	101	49	31	19	12	7	2	1	0	10,265	1,272	12%
1983	1,695	616	1,488	2,641	5,884	1,809	333	182	83	71	53	19	7	6	2	14,889	1,159	8%
1984	364	270	400	1,156	1,462	3,436	654	145	68	24	16	6	4	5	2	8,012	792	10%
1985	4,968	671	2,540	814	2,851	1,863	1,301	257	66	54	19	6	7	1	0	15,418	1,949	13%
1986	2,206	327	371	1,385	845	1,432	1,263	1,162	370	57	27	12	1	3	0	9,461	835	9%
1987	310	557	736	530	3,309	930	942	372	1,213	192	58	24	5	2	1	9,180	1,128	12%
1988	820	449	1,232	2,354	1,042	3,418	1,031	809	476	1,152	110	66	13	17	7	12,997	1,464	11%
1989	670	227	445	1,458	3,286	659	2,531	386	477	184	587	101	89	44	59	11,203	1,157	10%
1990	1,742	214	72	556	1,118	3,780	765	1,920	199	376	58	548	47	36	47	11,476	1,375	12%
1991	2,469	657	234	70	470	439	1,452	545	1,178	308	425	88	268	38	32	8,672	837	10%
1992	1,280	301	1,729	289	324	545	485	700	315	604	215	272	119	94	73	7,346	808	11%
1993	2,219	295	735	3,066	667	537	284	396	543	335	294	214	169	94	110	9,959	919	9%
1994	1,122	377	407	1,189	3,225	565	150	131	149	283	173	244	90	87	134	8,325	968	12%
1995	1,087	92	286	1,303	1,704	2,718	1,150	303	187	121	230	93	174	70	100	9,618	1,794	19%
1996	1,421	342	158	313	795	1,109	1,016	346	87	94	64	123	40	74	97	6,079	504	8%
1997	2,191	330	154	191	2,290	1,042	637	792	138	71	53	59	96	32	110	8,185	1,148	14%
1998	622	548	283	191	369	2,110	546	350	273	69	31	11	24	28	64	5,518	629	11%
1999	805	690	648	704	404	729	1,856	517	262	245	91	39	16	24	81	7,111	833	12%
2000	908	282	353	1,187	1,218	645	568	1,870	735	394	172	116	36	16	74	8,574	1,012	12%
2001	1,465	838	441	408	1,036	1,095	476	240	721	522	203	164	59	24	63	7,756	695	9%
2002	649	298	625	904	933	1,216	634	310	426	802	400	181	108	33	37	7,558	768	10%
2003	372	122	726	1,185	1,386	1,254	1,666	924	416	543	1,093	474	180	90	69	10,499	1,870	18%
2004	314	225	142	1,047	1,013	768	452	490	244	153	153	277	119	30	23	5,449	501	9%
2005	347	124	185	799	2,321	1,581	840	388	298	231	60	127	208	81	84	7,674	743	10%
2006	729	36	48	302	804	1,029	662	320	183	159	76	48	69	92	90	4,648	426	9%
2007	2,101	32	83	313	1,063	1,260	916	664	282	127	118	102	46	59	112	7,278	674	9%
2008	442	76	67	130	420	872	690	482	307	121	102	78	35	20	123	3,964	432	11%
2009	701	170	333	345	194	310	443	354	259	127	85	29	29	15	61	3,454	414	12%
2010	412	118	205	2,062	932	295	261	279	296	204	176	65	39	23	51	5,417	708	13%
Avg	1,220	397	607	1,036	1,464	1,296	831	541	355	263	178	124	72	39	59	8,482	959	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	NA
	East of 170 W	11	2,432	653	NA
	West of 170 W	48	20,263	1,868	NA
	Navarin (Russia)	9	3,502	381	NA

Table 1.14. AT survey estimates of EBS pollock abundance-at-age (millions), 1979-2010. *NOTE: 2010 age specific values are preliminary since they are mainly derived from the bottom-trawl age-length key.* 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	2,627	6,170	1,198	2,098	342	53	13	11	10	26	9,921	25%	12,548
Avg. 1982-2010	1,964	2,307	2,073	1,833	940	495	326	163	66	113	8,315	20%	10,279
Median	508	1,430	1,187	1,483	717	339	220	120	56	56	7,551	20%	9,395

Table 1.15. Mid-water pollock abundance (near surface down to 3 m from the bottom) by area as estimated from summer echo integration-trawl surveys on the U.S. EEZ portion of the of the Bering Sea shelf, 1994-2010 (as described in Honkalehto et al. 2010).

Date		**Area**	**Biomass in millions of t** (percent of total)						**Total**	**Estimation**
		(nmi)^2	**SCA**		**E170-SCA**		**W170**		**Biomass (millions t)**	**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%)	3.290	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	0.081	(9%)	0.027	(3%)	0.834	(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	(9%)	0.113	(5%)	2.143	(92%)	2.323	0.139

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).

Year	2006	2007	2008	2009
BT index (scaled to mean of corresponding AT index 1999-2004)	554.95	637.88	316.32	284.84
BT Index 1D EVA estimation error	50.99	86.54	64.33	120.35
Assumed coefficient of variation (mean 25%)	16%	27%	20%	37%

Table 1.17. Mean weight-at-age (kg) estimates from the fishery (1991-2010) showing the between-year variability (middle row) and sampling error (bottom panel) based on bootstrap resampling of observer data. *NOTE: 2010 weight-at-age is treated as the ten-year average of values from 2000-2009*.

	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	0.361	0.519	0.648	0.779	0.902	0.991	1.110	1.187	1.303	1.376	1.468	1.519	1.619
Mean	0.367	0.520	0.650	0.761	0.871	0.988	1.119	1.207	1.308	1.395	1.448	1.473	1.544
Stdev	0.053	0.055	0.040	0.054	0.080	0.079	0.118	0.106	0.113	0.119	0.177	0.251	0.234
CV	14%	11%	6%	7%	9%	8%	11%	9%	9%	9%	12%	17%	15%
	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%

Table 1.18. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964-2010. *Note: fishery data for 2010 are preliminary*.

Year	Fishery	Year	BTS	AT
1964-1977	10	1979	-	6
1978-1990	50			
1991	174			
1992	200	1982-2010	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			

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.

	Current 2010 Assessment
Biomass	
Year 2011 spawning biomass*	2,444,500 t
(CV)	(14%)
2010 spawning biomass	1,863,000 t
B_{msy}	1,948,000 t
(CV)	(20%)
$SPR \mid B_{msy}$	27.4%
$B_{40\%}$	2,523,000 t
$B_{35\%}$	2,271,000 t
B_0 (stock-recruitment curve)	5,140,000 t
2010 Percent of B_{msy} spawning biomass	96%
2011 Percent of B_{msy} spawning biomass	125%
Ratio of B_{2010} over B_{2010} under no fishing since 1978	50%
Recruitment (millions of pollock at age 1)	
Steepness parameter (*h*)	0.668
Average recruitment (all yrs)	22,368
(CV)	(61%)
Average recruitment (since 1978)	24,062
(CV since 1978)	(63%)
2000 year class	34,958
(CV 2000 year class)	(4%)
2006 year class	34,021
(CV 2006 year class)	(14%)
2008 year class	45,863
(CV 2008 year class)	(63%)
Natural Mortality (age 3 and older)	0.3

*Assuming 2011 catch will be 1,200,00 t

Table 1.20. Summary results of Tier 1 2011 yield projections for EBS pollock.

Description	Value
Tier 1 maximum permissible ABC	
2011 “fishable” biomass (GM)	3,822,000 t
MSYR (HM)	0.564
Adjustment factor	1.0
Adjusted ABC rate	0.564
2011 MSYR yield (Tier 1 ABC)	2,154,000 t
OFL	
MSYR (AM)	0.640
Adjusted OFL rate	0. 640
2011 MSYR OFL	2,447,000 t
Recommended F_{ABC}	0.332
Recommended ABC	1,267,000 t
Fishable biomass at *MSY*	3,374,000 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 2010 (millions).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	3,227	3,472	2,097	502	231	326	130	50	24	144	10,204
1965	20,575	1,310	2,182	1,471	307	140	199	80	31	107	26,403
1966	12,750	8,357	823	1,521	895	189	87	125	51	88	24,885
1967	29,209	5,179	5,244	568	940	557	119	55	80	90	42,040
1968	27,094	11,858	3,198	3,305	315	524	315	68	32	98	46,806
1969	30,131	10,999	7,302	2,028	1,832	177	300	181	39	76	53,066
1970	20,716	12,234	6,766	4,513	1,173	1,069	104	177	107	67	46,926
1971	7,712	8,409	7,376	3,940	2,590	671	615	58	99	92	31,562
1972	9,725	3,129	4,979	4,091	2,105	1,350	352	320	30	85	26,165
1973	29,283	3,944	1,792	2,519	2,015	1,040	671	172	156	46	41,639
1974	21,577	11,871	2,156	800	1,080	865	447	289	73	80	39,238
1975	18,024	8,745	6,167	836	311	423	342	177	113	57	35,194
1976	13,425	7,311	4,941	2,638	366	138	190	153	79	73	29,316
1977	13,793	5,448	4,225	2,449	1,202	170	65	89	72	70	27,585
1978	26,701	5,600	3,177	2,311	1,247	596	85	33	44	71	39,865
1979	64,918	10,840	3,280	1,725	1,177	613	296	41	15	55	82,960
1980	25,910	26,360	6,547	1,874	907	564	294	143	19	33	62,650
1981	29,125	10,525	16,387	4,126	1,004	446	273	144	70	25	62,125
1982	15,527	11,835	6,630	11,208	2,475	542	241	148	78	51	48,735
1983	52,413	6,311	7,502	4,735	7,328	1,499	325	145	89	76	80,424
1984	12,933	21,305	4,004	5,400	3,200	4,684	922	200	89	98	52,835
1985	35,197	5,257	13,525	2,883	3,679	2,006	2,932	564	122	109	66,273
1986	13,624	14,308	3,335	9,716	1,992	2,392	1,217	1,792	343	134	48,853
1987	8,023	5,538	9,076	2,401	6,671	1,316	1,477	744	1,114	283	36,645
1988	4,919	3,262	3,518	6,588	1,693	4,562	863	962	472	879	27,718
1989	9,243	2,000	2,069	2,496	4,527	1,095	2,903	519	585	819	26,256
1990	50,161	3,757	1,268	1,480	1,694	2,952	687	1,723	311	851	64,883
1991	25,616	20,391	2,377	900	947	1,006	1,697	376	944	653	54,907
1992	21,414	10,413	12,903	1,700	586	568	576	887	206	842	50,096
1993	46,740	8,705	6,584	8,945	1,105	352	303	280	412	479	73,904
1994	14,284	19,001	5,532	4,676	5,662	709	206	167	154	496	50,888
1995	10,254	5,807	12,082	4,027	3,174	3,310	415	117	96	382	39,664
1996	22,839	4,169	3,693	8,851	2,864	2,013	1,794	230	67	279	46,799
1997	31,282	9,285	2,647	2,694	6,428	1,941	1,134	891	122	190	56,615
1998	15,239	12,718	5,883	1,924	1,916	4,355	1,185	616	476	165	44,475
1999	16,678	6,195	8,072	4,267	1,360	1,290	2,651	707	345	348	41,914
2000	25,563	6,781	3,939	5,751	2,972	918	827	1,572	418	415	49,154
2001	34,958	10,393	4,312	2,846	3,903	1,910	583	477	871	488	60,740
2002	22,127	14,212	6,613	3,134	1,959	2,377	1,063	325	266	774	52,851
2003	13,130	8,995	9,034	4,788	2,134	1,200	1,229	553	170	572	41,807
2004	5,650	5,338	5,720	6,373	3,248	1,264	628	616	281	409	29,528
2005	3,676	2,297	3,397	4,141	4,007	1,974	717	332	328	386	21,255
2006	9,617	1,495	1,462	2,460	2,731	2,208	1,053	394	186	412	22,017
2007	34,021	3,910	951	1,035	1,584	1,508	1,098	536	204	324	45,172
2008	15,848	13,831	2,487	671	661	871	707	540	274	278	36,168
2009	45,863	6,443	8,802	1,786	427	360	391	325	260	275	64,932
2010	30,552	18,646	4,103	6,361	1,157	232	175	191	160	264	61,841
Median	21,718	8,501	5,235	3,385	2,141	1,299	739	406	222	279	44,873
Average	22,368	8,898	5,323	3,520	2,166	1,304	742	410	225	279	45,234

Table 1.22. Assessment model-estimated catch-at-age of EBS pollock (millions; 1964-2010).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	2.2	40.2	96.3	76.1	35.8	49.9	19.0	6.9	3.2	18.3	348.1
1965	12.9	15.6	112.1	228.6	45.5	19.7	26.6	10.2	3.8	12.6	487.6
1966	7.5	107.2	49.1	218.8	124.2	24.6	10.8	14.8	5.8	9.8	572.5
1967	29.0	131.7	679.1	124.7	202.2	114.4	23.8	10.8	15.1	16.7	1,347.5
1968	26.1	326.9	399.8	724.1	65.3	103.8	60.8	12.8	5.9	18.2	1,743.8
1969	27.0	312.7	1050.2	386.4	338.2	31.7	53.3	32.1	6.9	14.7	2,253.4
1970	22.7	537.2	1258.0	884.6	232.5	207.0	22.2	37.9	23.4	20.2	3,245.7
1971	10.6	484.8	1613.7	957.5	668.9	170.2	159.5	15.7	27.4	38.7	4,147.1
1972	15.2	257.7	1376.2	1195.7	611.0	387.9	104.6	96.0	9.6	36.8	4,090.6
1973	56.0	456.6	623.2	929.5	742.3	382.2	246.3	64.0	60.7	21.1	3,581.8
1974	45.3	1784.6	902.0	332.9	446.5	354.4	183.2	119.9	31.6	35.7	4,236.2
1975	27.4	805.0	2282.5	298.6	109.1	146.3	117.5	61.3	40.4	21.6	3,909.9
1976	16.5	553.6	1426.5	888.0	119.3	44.3	60.2	48.7	25.7	24.4	3,207.3
1977	13.5	376.0	962.1	667.8	347.0	48.3	18.4	25.6	21.0	20.4	2,500.1
1978	25.5	368.2	738.9	630.0	366.8	171.5	25.7	10.2	13.9	22.0	2,372.8
1979	54.5	462.1	652.5	436.3	363.4	188.8	89.9	13.2	5.0	17.6	2,283.2
1980	15.3	532.5	847.5	451.5	266.1	170.1	87.2	42.3	5.7	10.0	2,428.3
1981	9.9	102.3	1088.8	682.5	237.4	104.6	63.4	33.2	16.1	6.4	2,344.8
1982	2.9	56.4	205.7	1140.5	391.5	89.8	39.5	24.3	12.9	10.2	1,973.7
1983	7.5	25.1	183.8	360.6	872.2	221.3	47.7	21.3	13.6	14.9	1,767.9
1984	1.7	75.9	97.6	376.1	427.0	630.1	139.4	30.2	14.3	20.6	1,812.9
1985	4.0	21.2	353.8	167.9	390.2	314.6	445.2	87.5	20.4	23.5	1,828.4
1986	1.3	58.9	81.5	616.1	186.4	345.4	184.4	249.4	55.8	26.5	1,805.7
1987	0.5	16.5	158.2	99.6	443.8	130.8	154.4	93.3	143.8	40.0	1,280.9
1988	0.4	13.9	128.3	413.3	186.2	558.0	141.8	149.4	75.4	137.5	1,804.2
1989	0.7	8.5	61.9	181.4	469.9	145.9	501.9	86.0	92.9	129.1	1,678.2
1990	4.9	23.5	46.5	174.3	292.0	575.2	156.0	389.8	68.5	175.3	1,905.9
1991	2.3	125.4	70.8	93.9	156.7	199.3	434.7	84.9	241.1	159.6	1,568.8
1992	2.3	70.9	717.1	181.3	96.9	139.0	173.0	289.1	69.1	282.2	2,020.7
1993	3.0	23.2	234.6	1128.7	128.2	64.5	67.6	62.3	91.8	101.3	1,905.3
1994	0.7	42.5	82.8	339.1	1038.0	129.7	40.9	32.2	28.7	88.3	1,822.8
1995	0.4	12.5	116.0	139.9	396.0	772.8	90.1	23.9	18.4	70.1	1,640.0
1996	0.9	14.2	49.2	150.2	210.5	419.4	516.1	57.7	15.5	61.7	1,495.4
1997	1.3	47.9	42.3	93.3	476.6	296.5	263.7	217.1	31.2	46.8	1,516.8
1998	0.6	46.9	106.2	76.2	150.5	674.3	200.1	131.2	110.7	37.4	1,534.1
1999	0.5	14.5	267.3	221.1	105.5	150.9	459.5	123.9	58.8	56.1	1,458.2
2000	0.9	14.0	84.2	417.9	341.7	112.7	159.6	344.3	79.8	72.2	1,627.3
2001	1.2	16.7	70.3	174.5	602.4	412.5	125.4	102.6	176.9	96.1	1,778.6
2002	0.9	35.1	129.8	219.3	294.8	625.5	276.3	83.1	63.9	169.2	1,897.7
2003	0.5	19.6	372.9	349.9	372.2	306.2	346.6	151.3	42.3	123.2	2,084.5
2004	0.2	8.3	113.0	837.3	505.8	256.9	157.6	151.1	63.0	84.3	2,177.4
2005	0.1	3.4	66.4	394.1	892.6	481.4	161.8	70.4	66.3	71.0	2,207.6
2006	0.4	2.8	56.5	278.3	604.7	633.6	287.0	102.8	45.4	94.1	2,105.5
2007	1.4	7.3	39.2	123.0	355.8	484.1	322.6	144.6	53.0	81.0	1,611.9
2008	0.6	21.4	65.8	81.6	153.0	300.6	234.5	164.2	80.8	76.9	1,179.5
2009	1.5	6.1	186.8	194.3	99.0	107.4	116.1	95.5	74.3	82.1	963.2
2010	0.9	15.8	78.2	654.8	256.1	61.4	46.2	49.9	41.4	68.3	1,272.9
Median	10	181	433	407	340	262	162	90	48	61	2,033.8
Average	9.8	180.9	434.6	421.1	345.1	263.0	163.0	90.8	48.3	61.0	2,017.6

Table 1.23. Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2010. 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	1,589	450	3,227	**1988**	11,402	4,034	4,919
1965	2,008	558	20,575	**1989**	9,671	3,629	9,243
1966	1,944	635	12,750	**1990**	7,681	2,917	50,161
1967	3,140	781	29,209	**1991**	5,911	2,163	25,616
1968	3,486	957	27,094	**1992**	9,316	2,257	21,414
1969	4,879	1,224	30,131	**1993**	11,493	3,131	46,740
1970	5,974	1,569	20,716	**1994**	11,077	3,435	14,284
1971	6,785	1,811	7,712	**1995**	12,779	3,627	10,254
1972	6,277	1,772	9,725	**1996**	10,903	3,615	22,839
1973	4,547	1,399	29,283	**1997**	9,485	3,399	31,282
1974	3,085	915	21,577	**1998**	9,584	3,153	15,239
1975	3,366	746	18,024	**1999**	10,509	3,173	16,678
1976	3,460	796	13,425	**2000**	9,747	3,220	25,563
1977	3,500	875	13,793	**2001**	9,506	3,251	34,958
1978	3,390	916	26,701	**2002**	9,842	3,073	22,127
1979	3,267	897	64,918	**2003**	11,805	3,242	13,130
1980	4,203	1,019	25,910	**2004**	10,974	3,315	5,650
1981	8,190	1,709	29,125	**2005**	9,079	2,999	3,676
1982	9,349	2,618	15,527	**2006**	6,839	2,417	9,617
1983	10,376	3,228	52,413	**2007**	5,386	1,956	34,021
1984	10,060	3,431	12,933	**2008**	4,146	1,377	15,848
1985	12,246	3,685	35,197	**2009**	6,225	1,564	45,863
1986	11,471	3,913	13,624	**2010**	6,582	1,863	30,552
1987	12,111	4,041	8,023	**2011**	9,620	2,426	

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 2003-2010 assessments for EBS pollock. NOTE: see Ianelli et al. (2001) for a discussion on the interpretation of age-3+ biomass estimates.

	Current		2009		2008		2007		2006		2005		2004		2003	
	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV
1964	1,589	21%	1,564	22%	1,600	22%	1,717	23%	1,810	23%	1,779	23%	1,789	23%	1,822	23%
1965	2,008	19%	2,008	20%	2,050	20%	2,141	21%	2,231	21%	2,222	21%	2,272	20%	2,312	20%
1966	1,944	21%	1,947	22%	2,007	21%	2,037	22%	2,252	21%	2,288	21%	2,326	20%	2,372	20%
1967	3,140	17%	3,149	17%	3,245	17%	3,206	18%	3,518	17%	3,483	17%	3,514	17%	3,575	17%
1968	3,486	18%	3,510	19%	3,592	18%	3,558	19%	3,881	17%	3,881	17%	3,976	17%	4,049	17%
1969	4,879	17%	5,007	17%	5,020	17%	5,118	17%	5,058	16%	5,323	16%	5,258	16%	5,340	16%
1970	5,974	16%	6,159	15%	6,005	16%	6,368	15%	5,929	16%	6,447	15%	6,211	15%	6,296	15%
1971	6,785	13%	6,949	13%	6,727	14%	7,164	13%	6,617	13%	7,145	13%	6,714	14%	6,797	14%
1972	6,277	13%	6,444	13%	6,289	14%	6,666	13%	6,265	13%	6,692	13%	6,204	13%	6,282	13%
1973	4,547	16%	4,696	16%	4,556	17%	4,942	16%	4,751	16%	5,055	15%	4,632	16%	4,705	16%
1974	3,085	20%	3,196	20%	3,064	22%	3,475	20%	3,460	19%	3,635	19%	3,288	19%	3,356	19%
1975	3,366	13%	3,384	13%	3,276	14%	3,604	14%	3,585	13%	3,666	14%	3,440	14%	3,489	14%
1976	3,460	10%	3,431	11%	3,339	11%	3,584	11%	3,577	11%	3,614	11%	3,497	11%	3,538	11%
1977	3,500	9%	3,457	9%	3,340	10%	3,602	10%	3,582	10%	3,548	10%	3,504	10%	3,541	10%
1978	3,390	9%	3,340	9%	3,202	9%	3,476	9%	3,438	10%	3,361	10%	3,385	10%	3,422	10%
1979	3,267	9%	3,212	9%	3,090	9%	3,363	9%	3,323	9%	3,273	10%	3,341	10%	3,380	10%
1980	4,203	7%	4,124	8%	4,044	7%	4,384	8%	4,320	8%	4,373	8%	4,409	8%	4,462	8%
1981	8,190	6%	8,031	6%	7,704	6%	8,307	6%	8,364	7%	8,289	7%	8,301	7%	8,414	7%
1982	9,349	6%	9,165	6%	8,783	6%	9,439	6%	9,476	6%	9,446	7%	9,472	7%	9,614	7%
1983	10,376	5%	10,168	5%	9,804	5%	10,493	6%	10,443	6%	10,536	7%	10,552	7%	10,728	7%
1984	10,060	5%	9,857	5%	9,518	5%	10,200	6%	10,088	6%	10,244	7%	10,263	7%	10,456	7%
1985	12,246	4%	12,027	4%	11,802	4%	12,531	5%	12,285	5%	12,435	6%	12,492	6%	12,771	6%
1986	11,471	4%	11,269	4%	11,075	4%	11,773	5%	11,486	5%	11,609	6%	11,677	6%	11,973	6%
1987	12,111	4%	11,915	4%	11,732	4%	12,401	4%	12,077	5%	12,106	5%	12,226	5%	12,596	5%
1988	11,402	4%	11,227	4%	11,004	4%	11,617	4%	11,330	5%	11,153	5%	11,243	5%	11,633	5%
1989	9,671	4%	9,521	4%	9,320	4%	9,875	4%	9,584	5%	9,384	5%	9,466	5%	9,850	5%
1990	7,681	4%	7,558	4%	7,345	4%	7,847	5%	7,603	5%	7,392	6%	7,454	6%	7,811	6%
1991	5,911	5%	5,811	5%	5,590	5%	6,097	5%	5,929	6%	5,454	6%	5,637	7%	5,977	7%
1992	9,316	3%	9,211	4%	8,966	4%	9,557	4%	9,270	5%	8,905	5%	9,120	5%	9,614	5%
1993	11,493	3%	11,388	3%	11,175	3%	11,832	4%	11,795	4%	11,669	5%	11,721	6%	12,363	6%
1994	11,077	3%	10,990	4%	10,782	4%	11,485	4%	11,407	5%	11,000	5%	10,998	6%	11,696	6%
1995	12,779	3%	12,699	3%	12,704	3%	13,615	4%	13,658	4%	13,605	6%	13,554	6%	14,474	6%
1996	10,903	4%	10,843	4%	10,829	4%	11,537	4%	11,480	5%	11,826	6%	11,772	7%	12,630	7%
1997	9,485	4%	9,440	4%	9,403	4%	10,104	5%	10,056	5%	9,966	6%	9,949	8%	10,775	8%
1998	9,584	4%	9,538	4%	9,467	4%	10,178	5%	9,973	5%	9,915	7%	9,943	8%	11,110	8%
1999	10,509	3%	10,421	3%	10,379	4%	11,081	4%	10,872	5%	10,998	6%	11,093	10%	13,339	10%
2000	9,747	3%	9,632	3%	9,503	4%	10,201	4%	10,052	5%	9,947	7%	10,036	12%	12,498	12%
2001	9,506	3%	9,341	4%	9,175	4%	9,898	5%	9,800	6%	9,566	8%	9,675	14%	12,394	14%
2002	9,842	3%	9,595	4%	9,554	4%	10,224	5%	10,197	7%	9,824	9%	9,899	16%	12,930	16%
2003	11,805	3%	11,453	3%	11,182	4%	12,865	6%	13,320	10%	13,073	13%	12,239	19%	12,688	19%
2004	10,974	3%	10,606	4%	10,274	4%	11,784	7%	12,055	12%	10,972	15%	9,894	21%	11,217	21%
2005	9,079	4%	8,736	4%	8,423	5%	9,598	8%	9,759	14%	9,277	18%	8,573			
2006	6,839	4%	6,543	5%	6,340	6%	7,178	10%	7,950	17%	8,232	21%				
2007	5,386	5%	5,090	6%	5,015	8%	5,363	14%	6,361	21%						
2008	4,146	7%	3,809	8%	4,222	12%	4,357	20%								
2009	6,225	10%	4,762	11%	6,240	20%										
2010	6,582	12%	4,616	13%												
2011	9,620	15%														

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 6,308; 2,523; and 2,208 thousand t, respectively.

Catch (kt)	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2010	813	813	813	813	813	813	813
2011	1,292	**1,267**	1,267	613	0	1,571	1,292
2012	1,681	**1,595**	1,595	861	0	1,972	1,681
2013	1,943	1,866	1,866	1,085	0	2,199	2,385
2014	1,955	1,904	1,904	1,201	0	2,069	2,200
2015	1,729	1,751	1,751	1,183	0	1,778	1,830
2016	1,587	1,629	1,629	1,139	0	1,640	1,659
2017	1,531	1,567	1,567	1,116	0	1,598	1,605
2018	1,505	1,532	1,532	1,097	0	1,581	1,583
2019	1,500	1,520	1,520	1,089	0	1,581	1,582
2020	1,503	1,517	1,517	1,086	0	1,588	1,588
2021	1,511	1,521	1,521	1,086	0	1,601	1,601
2022	1,521	1,528	1,528	1,089	0	1,613	1,613
2023	1,520	1,528	1,528	1,089	0	1,606	1,606
Fishing M.	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2010	0.250	0.250	0.250	0.250	0.250	0.250	0.250
2011	0.288	0.281	0.281	0.127	0.000	0.362	0.288
2012	0.300	0.281	0.281	0.127	0.000	0.384	0.300
2013	0.300	0.281	0.281	0.127	0.000	0.384	0.384
2014	0.299	0.281	0.281	0.127	0.000	0.367	0.374
2015	0.285	0.281	0.281	0.127	0.000	0.341	0.344
2016	0.275	0.281	0.281	0.127	0.000	0.328	0.330
2017	0.271	0.281	0.281	0.127	0.000	0.325	0.326
2018	0.270	0.281	0.281	0.127	0.000	0.325	0.325
2019	0.270	0.281	0.281	0.127	0.000	0.324	0.324
2020	0.270	0.281	0.281	0.127	0.000	0.325	0.325
2021	0.270	0.281	0.281	0.127	0.000	0.326	0.326
2022	0.270	0.281	0.281	0.127	0.000	0.326	0.326
2023	0.270	0.281	0.281	0.127	0.000	0.326	0.326
Spawning biomass (kt)	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2010	1,864	1,864	1,864	1,864	1,864	1,864	1,864
2011	2,423	2,426	2,426	2,506	2,574	2,386	2,423
2012	2,974	2,996	2,996	3,357	3,712	2,821	2,974
2013	3,165	3,221	3,221	3,878	4,606	2,903	3,103
2014	3,004	3,084	3,084	3,998	5,128	2,679	2,783
2015	2,816	2,898	2,898	3,986	5,498	2,491	2,534
2016	2,699	2,757	2,757	3,922	5,717	2,399	2,416
2017	2,640	2,672	2,672	3,867	5,876	2,359	2,366
2018	2,621	2,633	2,633	3,834	5,995	2,351	2,354
2019	2,616	2,615	2,615	3,813	6,086	2,353	2,354
2020	2,623	2,614	2,614	3,805	6,150	2,363	2,363
2021	2,637	2,624	2,624	3,810	6,213	2,378	2,378
2022	2,641	2,626	2,626	3,808	6,247	2,380	2,380
2023	2,636	2,620	2,620	3,802	6,271	2,374	2,374

Table 1.26 Maximum permissible Tier 1a EBS pollock ABC and OFL projections for 2011 and for 2012.

Year	Catch	ABC	OFL
2011	1,200,000 t	2,154,000 t	2,447,000 t
2012	1,400,000 t	2,255,000 t	2,501,000 t

Table 1.27. 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 1.28 Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 1997-2002 based on observer data, 2003-2010 based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska).

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

Group	2003	2004	2005	2006	2007	2008	2009	2010
Jellyfish	5,592	6,495	5,084	2,657	2,156	3,722	3,731	2,174
Skates	462	829	693	1,258	1,182	2,301	1,635	1,076
Squid	952	717	699	893	962	374	119	77
Sharks	191	186	163	506	214	114	92	24
Sculpins	92	141	140	171	161	254	153	157
Eulachon	2	19	9	87	101	2	2	1
Eelpouts	1	1	1	21	119	7	2	0
Sea stars	89	7	10	11	5	7	5	5
Grenadier	20	10	9	9	11	4	1	1
Other osmerids	7	2	3	5	37	2	0	0
Octopus	9	3	1	2	4	3	4	1
Lanternfish	0	0	0	10	6	1	0	0
Sea pens, whips	1	1	2	2	4	1	2	2
Birds	0	0	2	0	1	0	0	0
Capelin	0	0	0	2	1	0	0	0
Other fish	98	88	147	140	198	102	59	134
Other invertebrates	2	2	11	5	6	7	2	2

Table 1.29 Bycatch estimates (t) of other **target species** caught in the BSAI directed pollock fishery, 1997-2010 based on then NMFS Alaska Regional Office reports from observers (*2010 data are preliminary*).

	Pacific Cod	Flathead Sole	Rock Sole	Yellowfin Sole	Arrowtooth Flounder	Pacific Ocean Perch	Atka Mackerel	Sablefish	Greenland Turbot	Alaska Plaice	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	2,105	2,554	841	557	393	1,051	17	18	8	120	14,100
2005	7,413	2,352	1,125	63	651	652	677	11	31	45	125	13,145
2006	7,285	2,861	1,361	256	1,088	737	789	9	65	11	152	14,612
2007	5,627	4,228	510	86	2,794	624	315	12	107	3	188	14,494
2008	6,761	4,209	1,964	405	1,364	336	15	2	82	30	39	15,205
2009	7,876	4,652	7,534	269	2,143	114	25	2	44	176	25	22,861
2010	6,902	4,333	2,220	1,017	1,414	230	55	2	23	109	22	16,326
Average	6,110	2,813	2,021	621	1,126	457	306	13	67	44	268	13,845

Table 1.30 Bycatch estimates (t) of **pollock** caught in the other non-pollock EBS directed fisheries, 2003-2010 based on then NMFS Alaska Regional Office reports from observers (*2010 data are preliminary*).

Target fishery	2003	2004	2005	2006	2007	2008	2009	2010	Average
Pacific cod fishery	16,015	18,597	14,105	14,923	19,981	9,648	7,881	5,225	13,297
Yellowfin sole fishery	11,570	10,479	10,312	6,084	4,041	9,921	7,024	3,749	7,897
Rock sole fishery	4,928	8,964	7,240	6,923	3,212	5,324	6,124	5,777	6,061
Flathead sole fishery	2,989	5,100	3,664	2,641	3,613	4,234	3,166	2,904	3,539
Other flatfish fisheries	288	517	1,124	1,088	606	1,046	322	137	641
Other fisheries	667	939	492	209	594	75	38	50	383
Total from other fisheries	36,458	44,595	36,936	31,867	32,047	30,248	24,556	17,842	31,818

Table 1.31 Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997-2010 based on then NMFS Alaska Regional Office reports from observers. Herring and halibut units are in t, all others represent numbers of individuals caught. Preliminary 2010 data are through October 28th, 2010.

	Herring	Red king crab	Other king crab	Bairdi crab	Opilio crab	Chinook salmon	Other salmon	Halibut
1997	1,089	0	156	6,525	88,588	43,336	61,504	127
1998	821	5,098	1,832	35,594	45,623	49,373	62,276	144
1999	785	0	2	1,078	12,778	10,187	44,585	69
2000	482	0	104	173	1,807	3,966	56,707	80
2001	224	38	5,135	86	2,179	30,107	52,835	164
2002	105	6	81	651	1,667	32,222	76,998	127
2003	913	54	9	792	762	47,015	191,892	77
2004	1,134	27	6	1,215	748	54,058	438,199	84
2005	610	0	1	651	2,299	67,351	696,865	101
2006	435	203	3	1,666	2,934	82,591	308,414	112
2007	345	8	3	1,516	3,219	121,462	87,182	270
2008	130	35	10	852	4,364	19,656	14,644	268
2009	40	1,137	20	6,026	7,179	12,119	45,720	437
2010	422	978	8,612	11,800	8,612	9,087	12,721	249

Table 1.32 Bycatch rates (kg / t of catch) of target species categories caught in the BSAI directed pollock fishery by season and area for **2009** based on then NMFS Alaska Regional Office reports from observers.

kg/t of groundfish		Summer/fall (B-season)			
	Winter (A-season)	NW	SE	B Total	Annual rate
Pacific cod	11.03	4.48	3.56	4.29	6.28
Flathead Sole	6.67	2.02	1.03	1.81	3.24
"Other species"	5.96	1.45	1.66	1.49	2.81
Rock Sole	8.63	0.04	0.07	0.05	2.58
Arrowtooth/Kamchatka	2.21	0.69	2.47	1.07	1.40
Other flatfish	0.24	0.01	0.70	0.16	0.18
Squid	0.32	0.00	0.52	0.11	0.17
Yellowfin sole	0.46	0.00	0.03	0.01	0.14
Pacific ocean perch	0.10	0.01	0.43	0.10	0.10
Alaska plaice	0.24	0.01	0.00	0.01	0.08
All remaining species groups	0.06	0.10	0.01	0.08	0.06
Total	35.91	8.82	10.49	9.17	17.04

Table 1.33. Summary results for EBS pollock. Units are thousands of t.

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
Mature Fish.	0.000	0.004	0.145	0.321	0.421	0.451	0.474	0.482	0.485	0.500	0.500	0.500	0.500	0.500	0.500
Select	0.000	0.004	0.080	0.333	0.740	1.000	0.945	0.890	0.851	0.818	0.818	0.818	0.818	0.818	0.818

Tier (2011)	1a
Age 3+ 2011 begin-year biomass	**9,620** t
2011 Spawning biomass	**2,444,500** t
B_{msy}	1,948,000 t
$B_{40\%}$	2,523,000 t
$B_{35\%}$	2,208,000 t
$B_{100\%}$	6,308,000 t
B_0	5,140,000 t

Yield Considerations		2011	2012*
ABC:	Harmonic Mean F_{msy}	2,154,000 t	2,255,000 t
ABC:	Yield $F_{40\%}$ (Tier 3)	1,292,000 t	1,681,000 t
OFL:	Arithmetic Mean F_{msy} Yield	2,447,000 t	2,501,000 t
OFL:	Yield $F_{35\%}$ (Tier 3)	1,351,000 t	1,505 ,000 t

* Assuming 2011 catches equal 1,267000 t

Figures

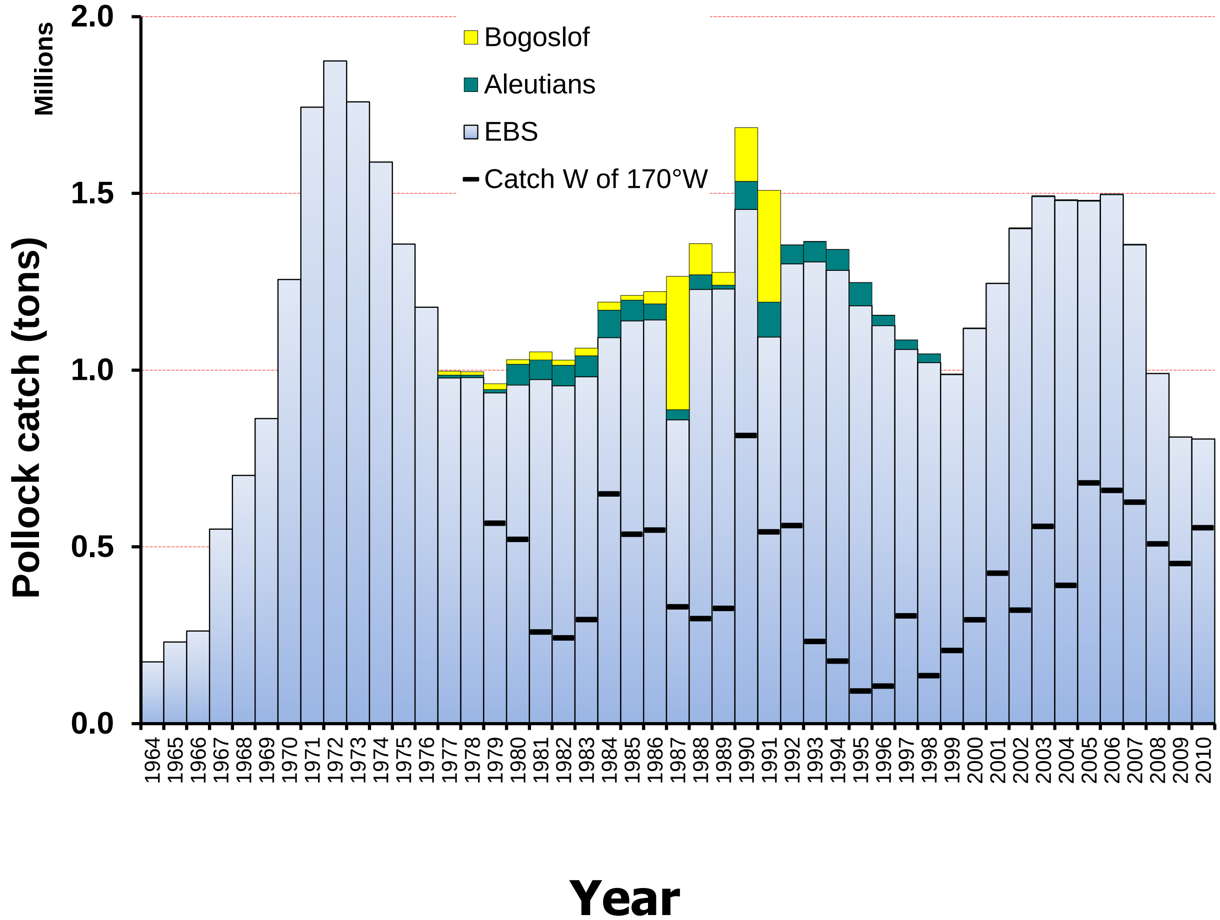

Figure 1.1. Alaska pollock catch estimates from the Eastern Bering Sea, Aleutian Islands, and Bogoslof Island regions, 1964-2010. The 2010 value is based on expected totals for the year.

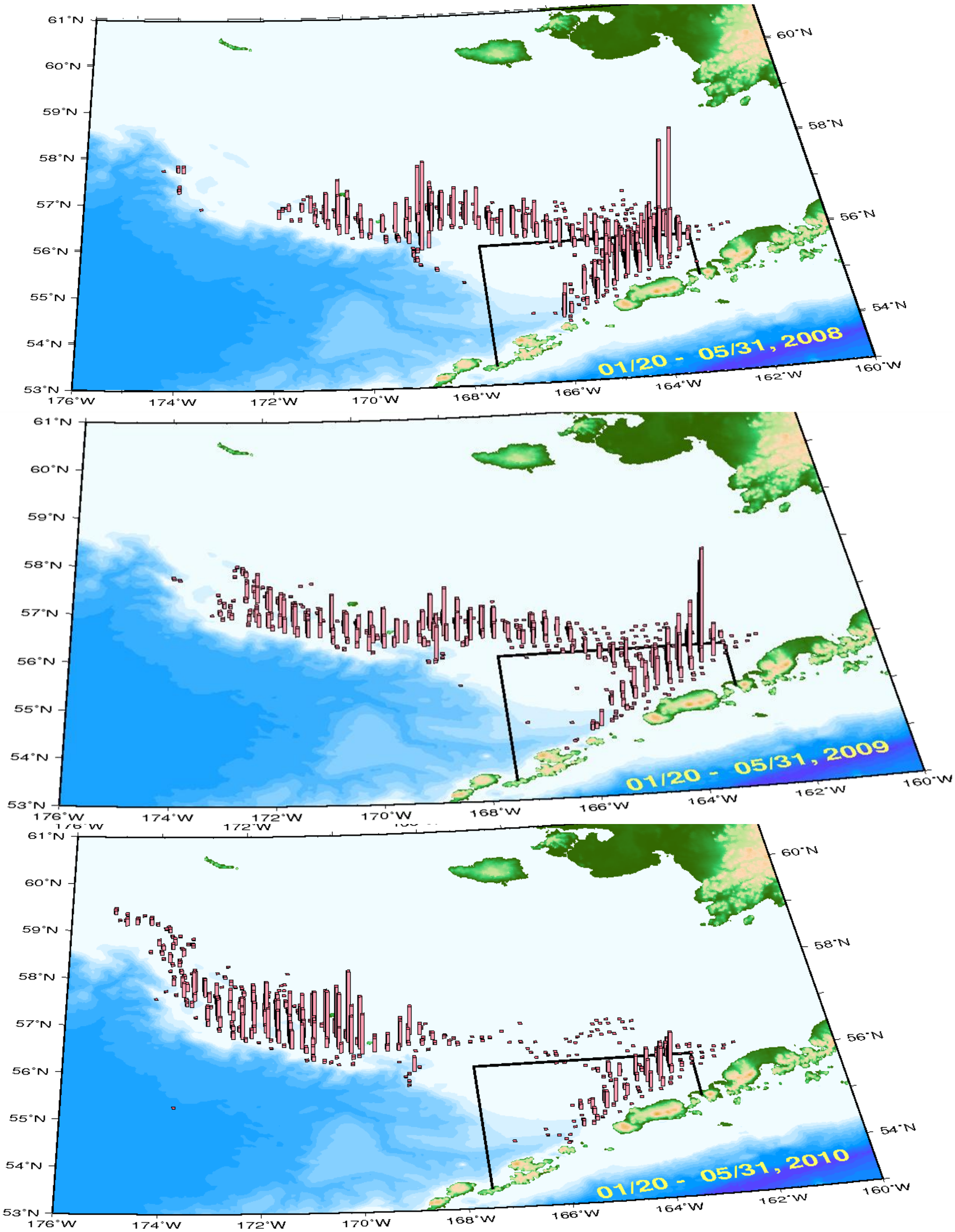

Figure 1.2. Pollock catch distribution in the fishery 2008-2010, January – May on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

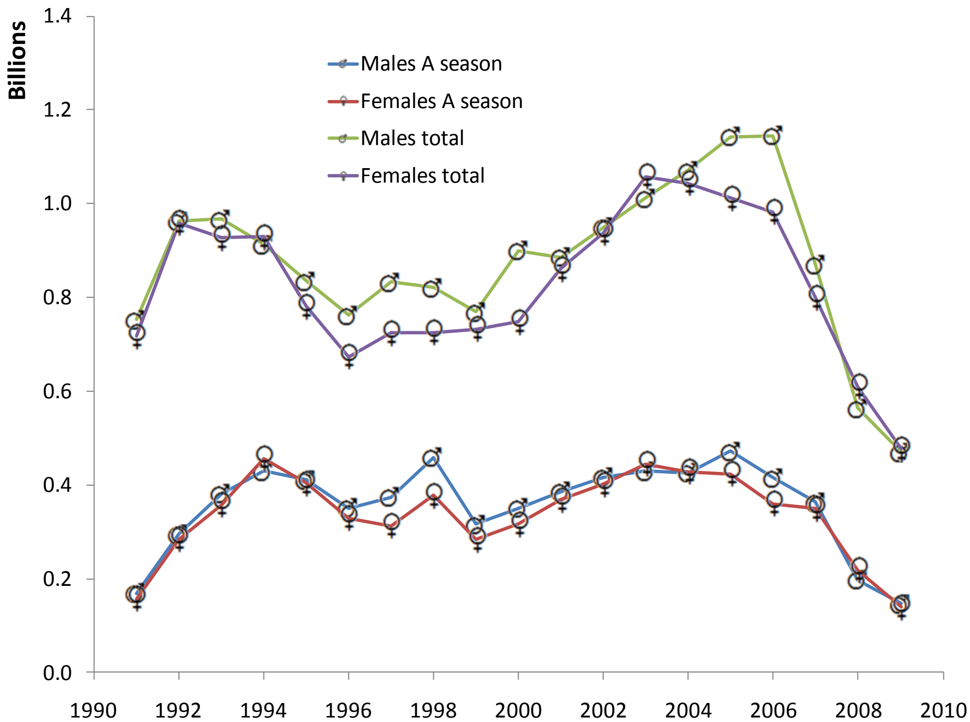

Figure 1.3. Estimate of EBS pollock catch numbers by sex for the “A season” (January-May) and for the entire annual fishery, 1991-2009.

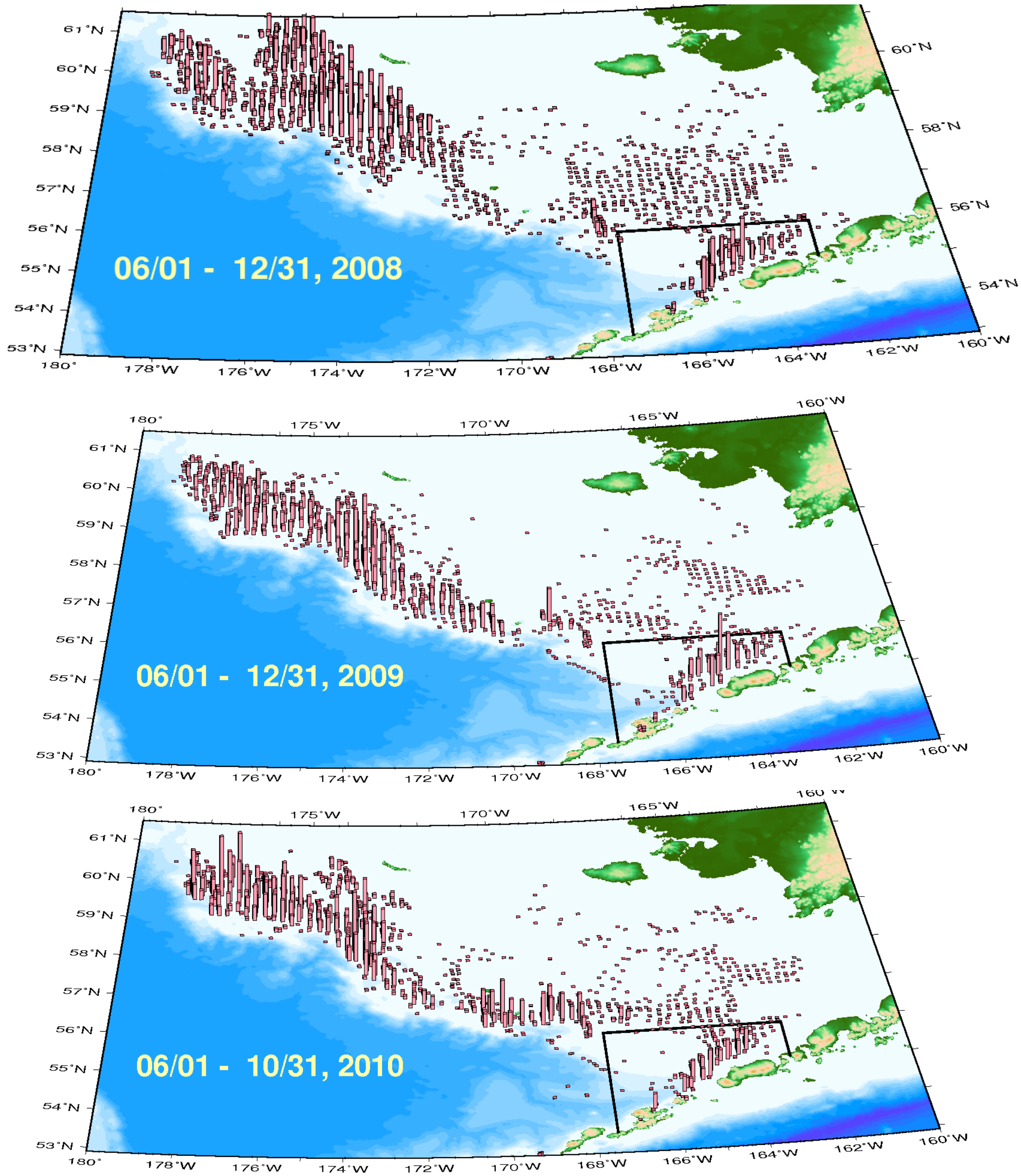

Figure 1.4. Pollock catch distribution during June – December, 2008-2010. The line delineates the catcher-vessel operational area (CVOA) and the height of the bars represents relative removal on the same scale over all years.

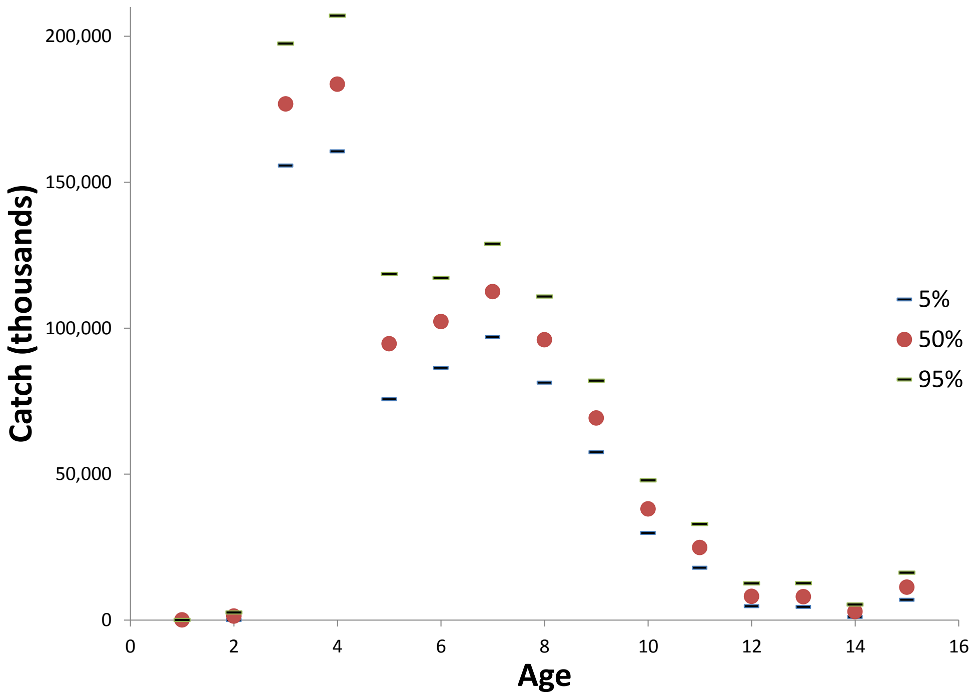

Figure 1.5. The 2009 fishery catch-at-age estimates and bootstrap estimates and 5th and 95th percentiles (based on 1000 bootstrap samples).

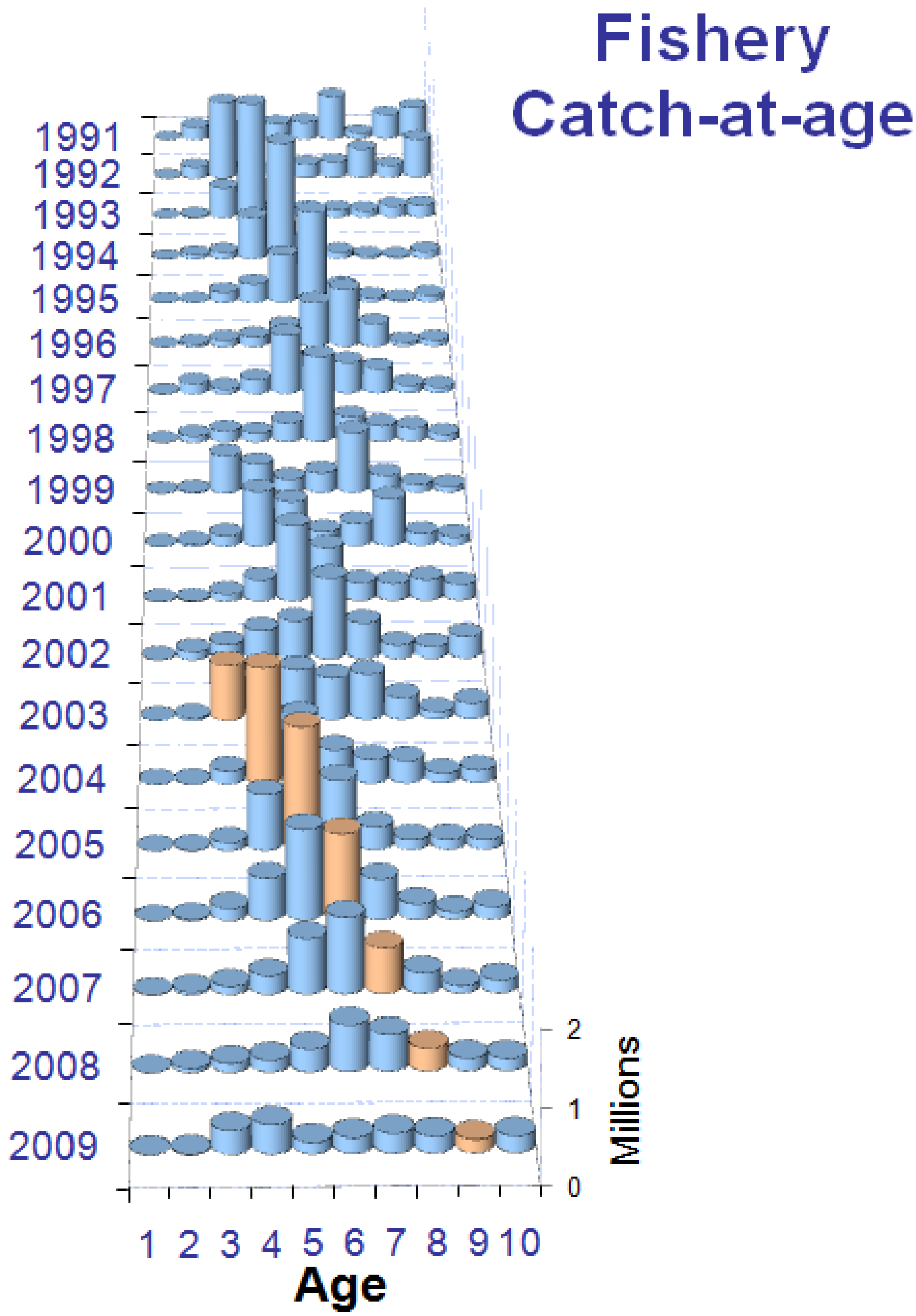

Figure 1.6. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2009. Age 10 represents pollock age 10 and older. The 2000 year-class is highlighted.

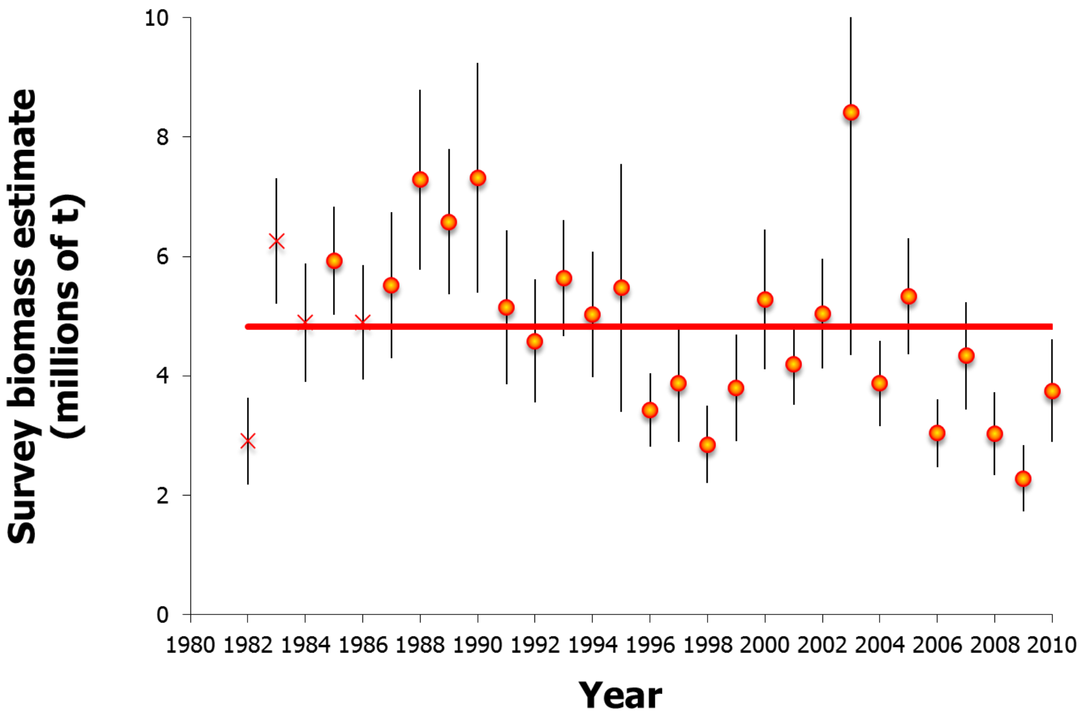

Figure 1.7. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS pollock, 1982-2010. These estimates **include** the northern strata except for 1982-84, and 1986 (years indicated with crosses).

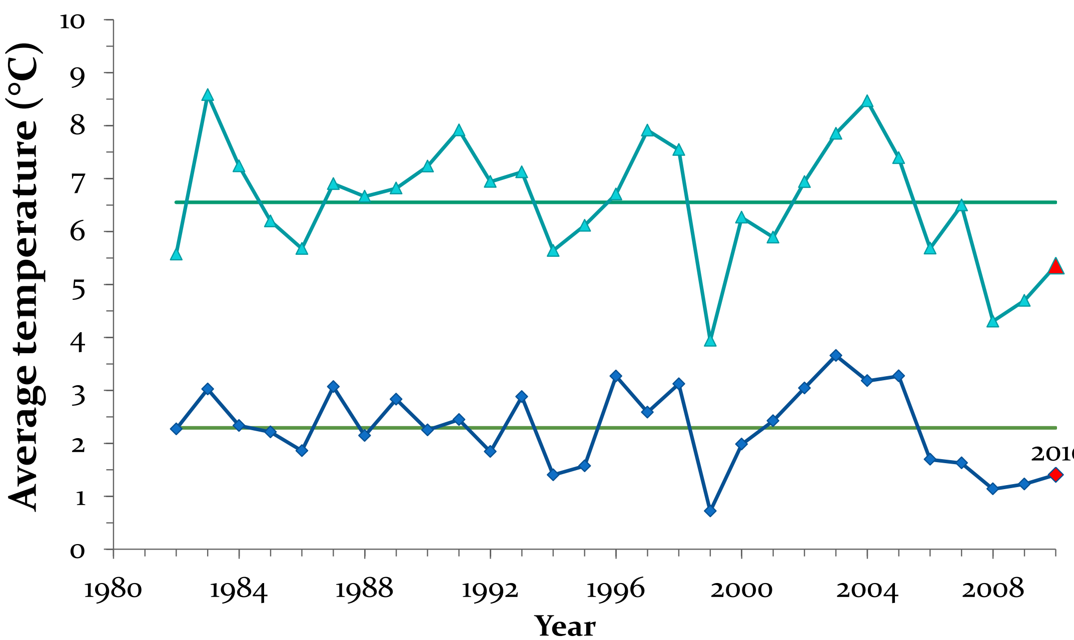

Figure 1.8. Area-weighted bottom (lower lines) and surface (upper lines) temperatures for the Bering Sea during the NMFS summer bottom-trawl surveys (1982-2010).

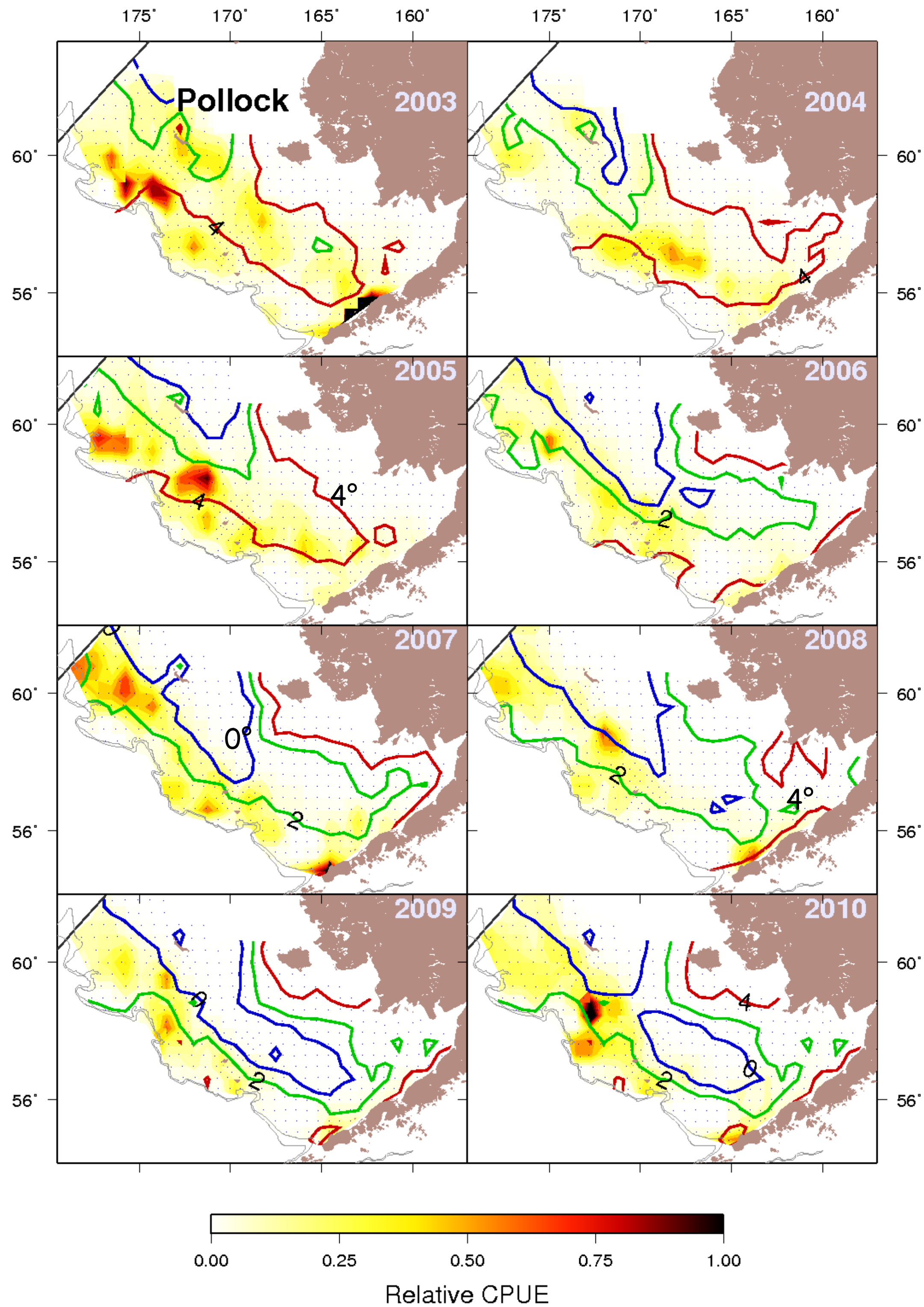

Figure 1.9. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 2003-2010.

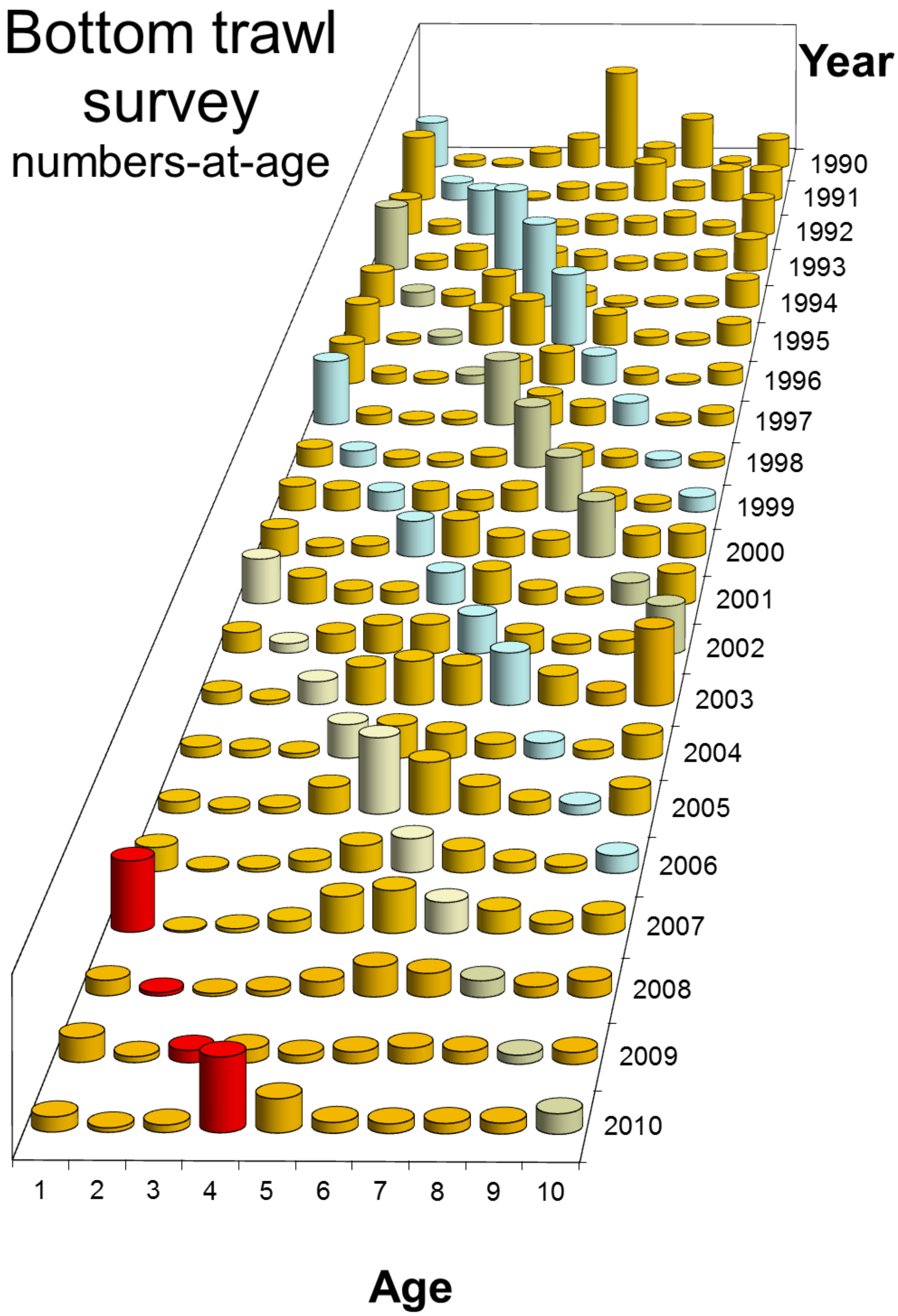

Figure 1.10. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1982-2010). Selected cohorts are shaded differently to follow them through time.

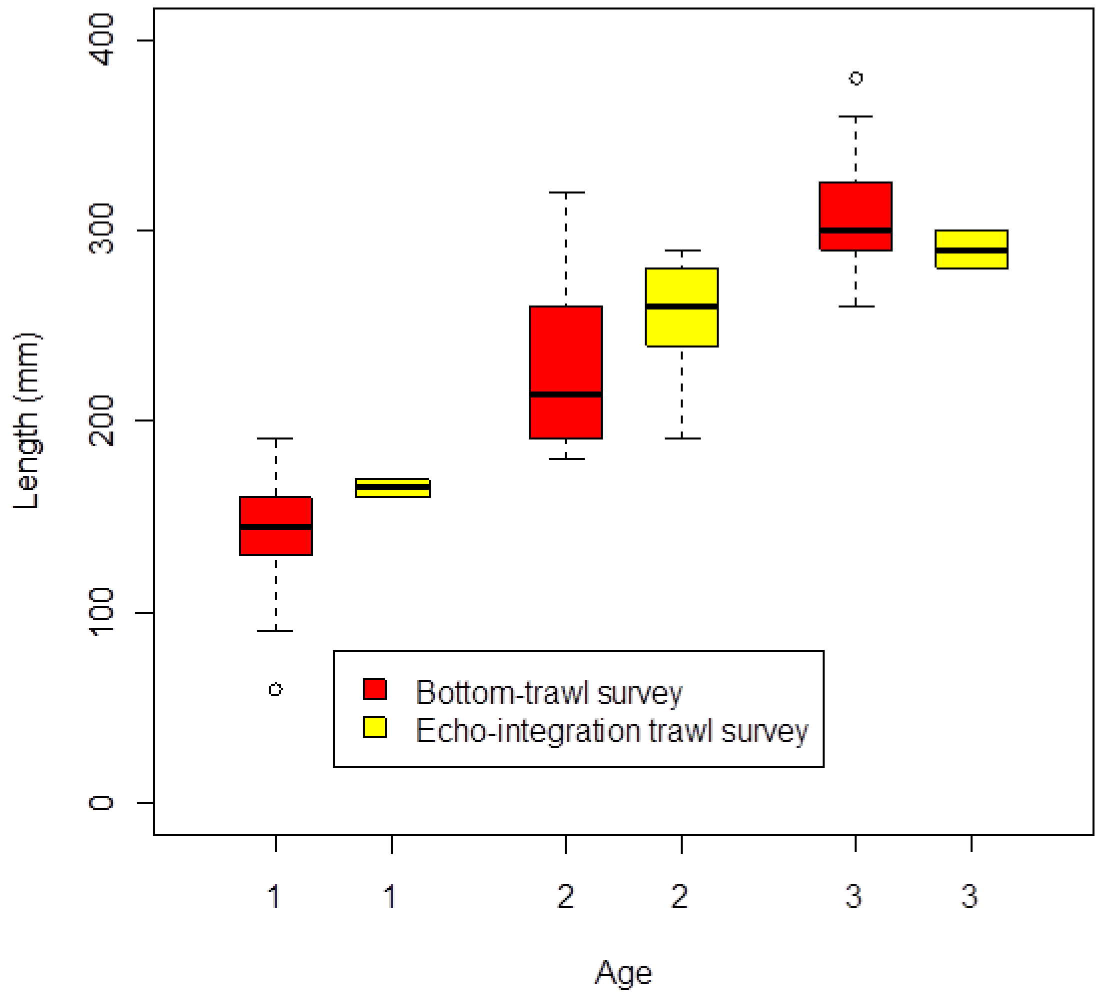

Figure 1.11. Comparisons of age samples collected from the bottom-trawl survey and Acoustic Trawl for 2010 EBS shelf pollock. The data shown from the AT survey are the additional 100 samples added to the bottom-trawl age data to improve the resolution of the age-length key for application to the AT population-at-length estimates (bottom trawl surveys tend to catch relatively few 2 and 3 year-old pollock).

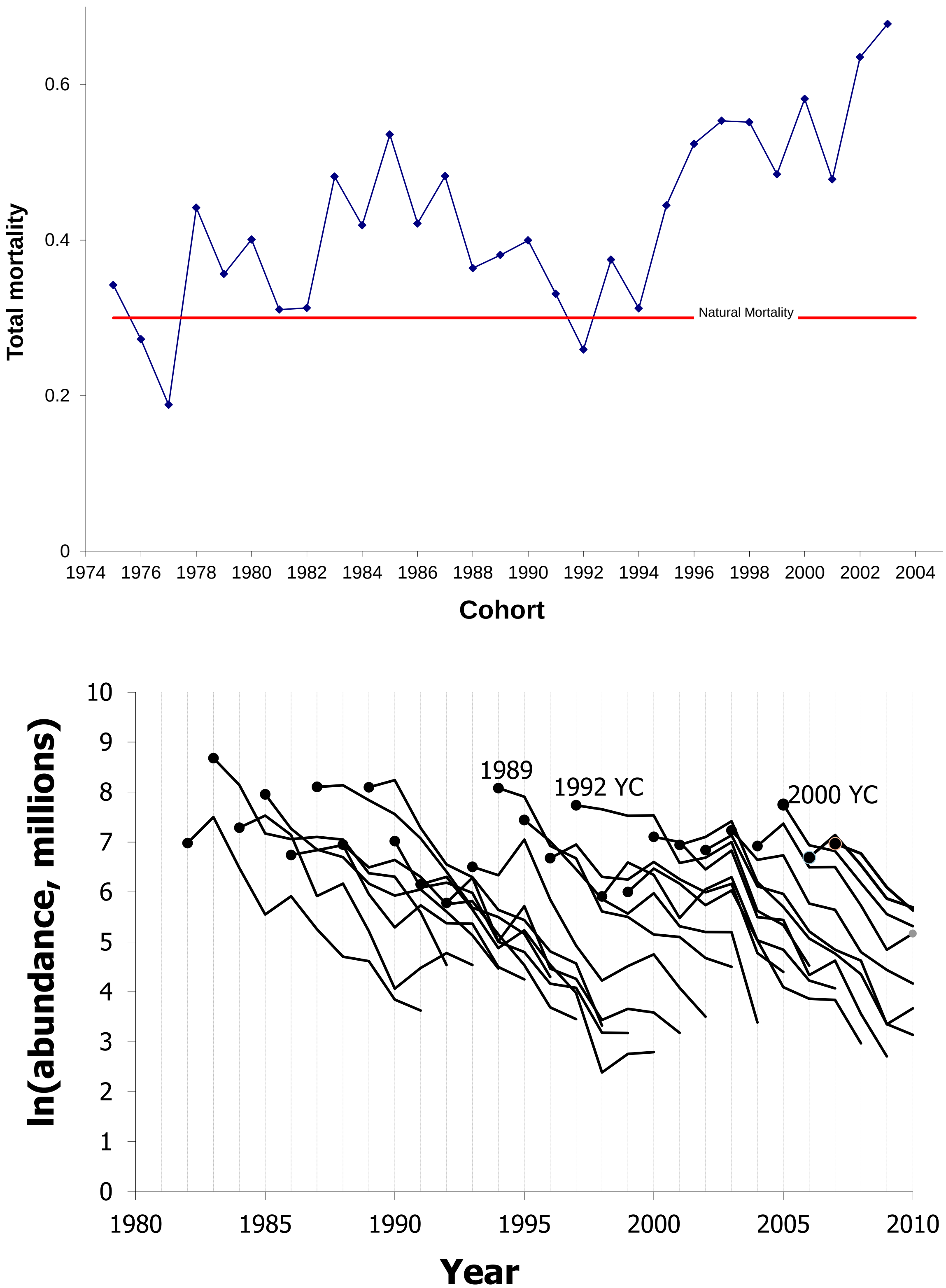

Figure 1.12. Evaluation of EBS pollock cohort abundances as observed for age 6 and older in the NMFS summer bottom trawl surveys. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort.

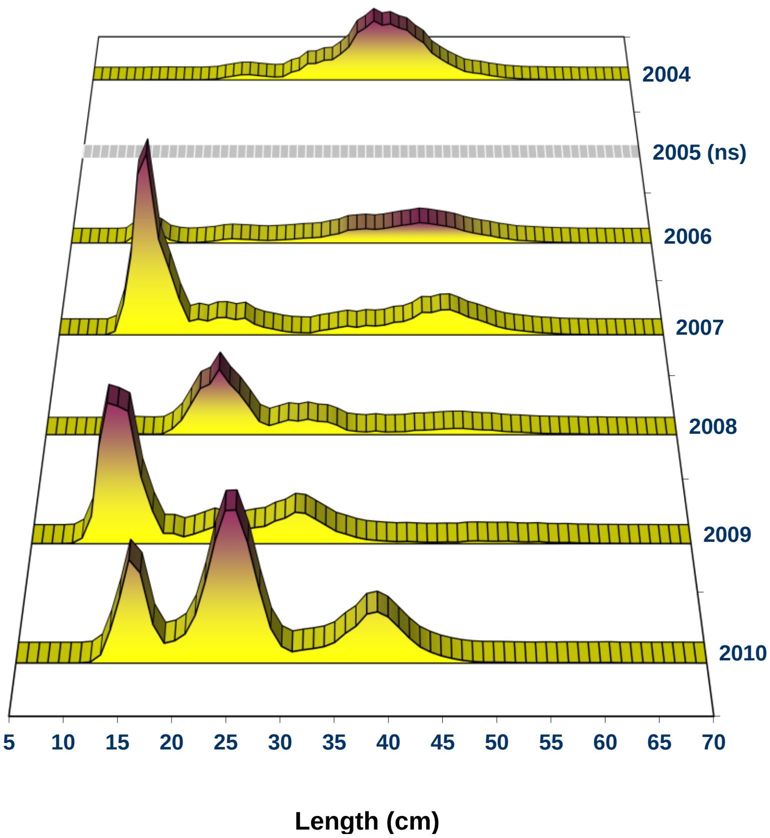

Figure 1.13. Acoustic-trawl survey relative abundances at length for EBS pollock, 2004-2010. Vertical scale is equal for all years and is relative to numbers of fish.

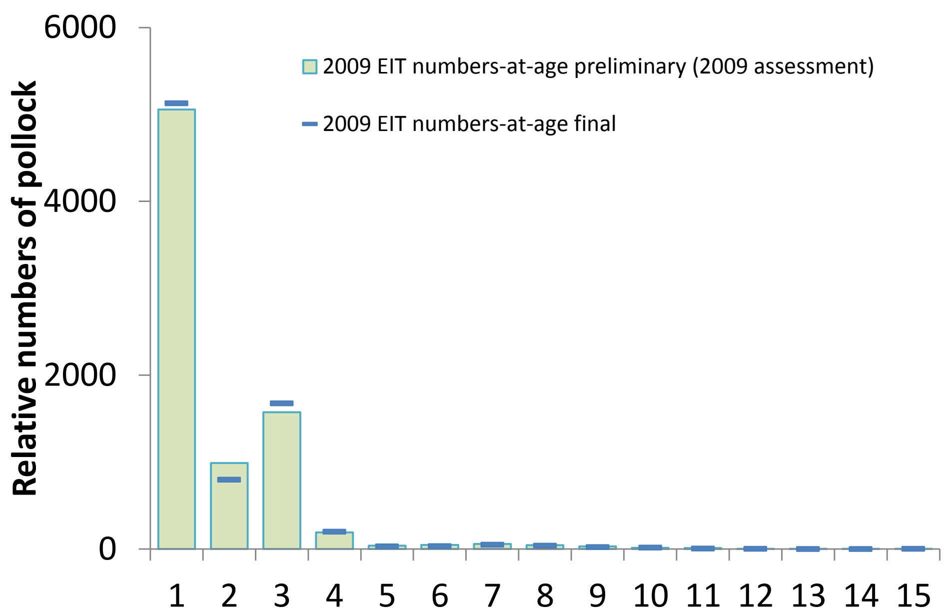

Figure 1.14. Acoustic-trawl survey 2009 age data used in the 2009 assessment (as preliminary numbers; columns) compared to revised values used in the present assessment (symbols). The revised estimates use age-samples collected only from the acoustic trawl survey whereas the preliminary data used in the 2009 assessment were derived from samples collected from the 2009 bottom-trawl survey.

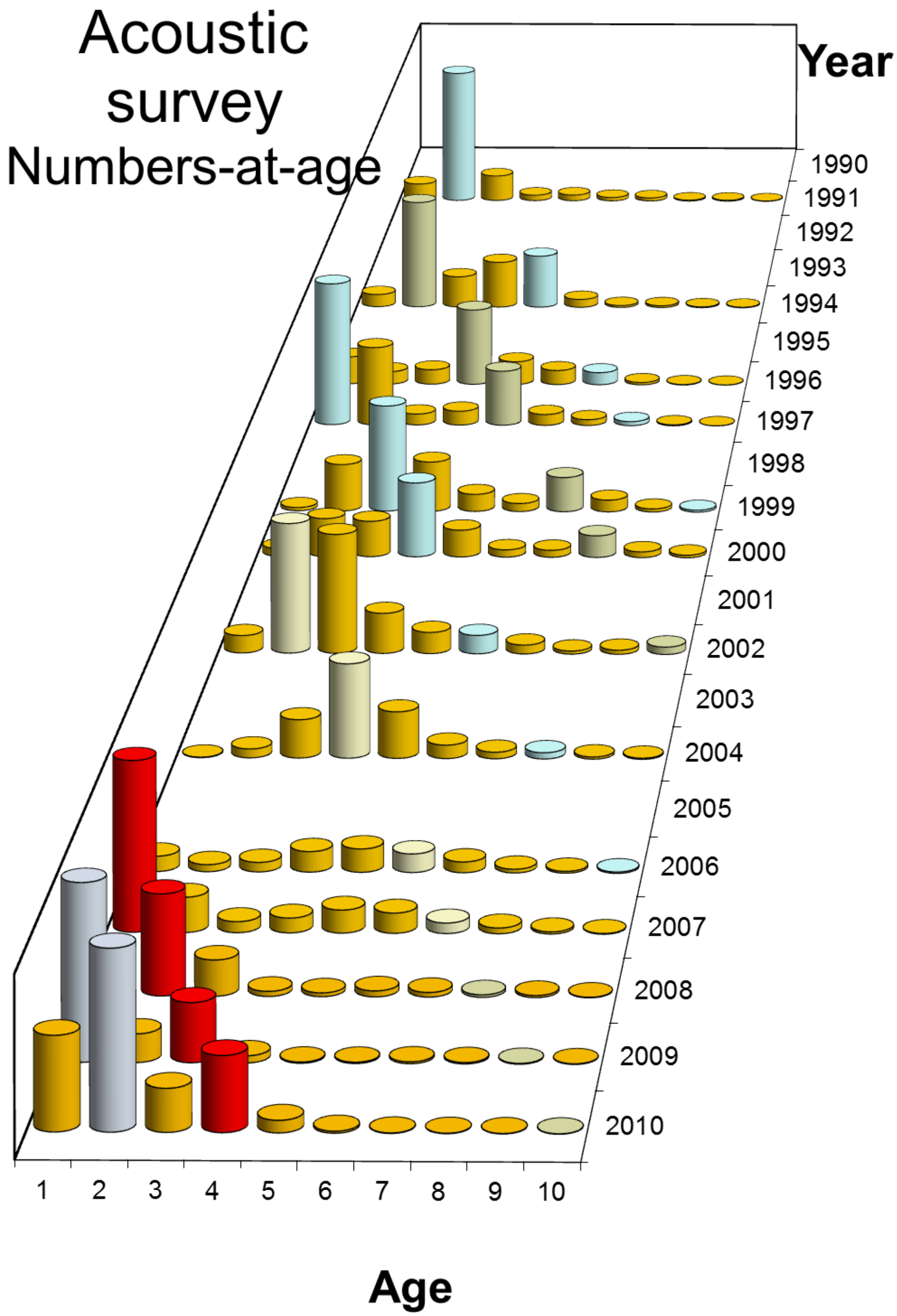

Figure 1.15. Time series of estimated abundances at age (numbers) for EBS pollock from the AT surveys, 1991-2010. The shaded columns represent selected cohorts through time. Note that the 2010 age compositions were computed using an age-length key derived from the 2010 BTS data and as such, are preliminary.

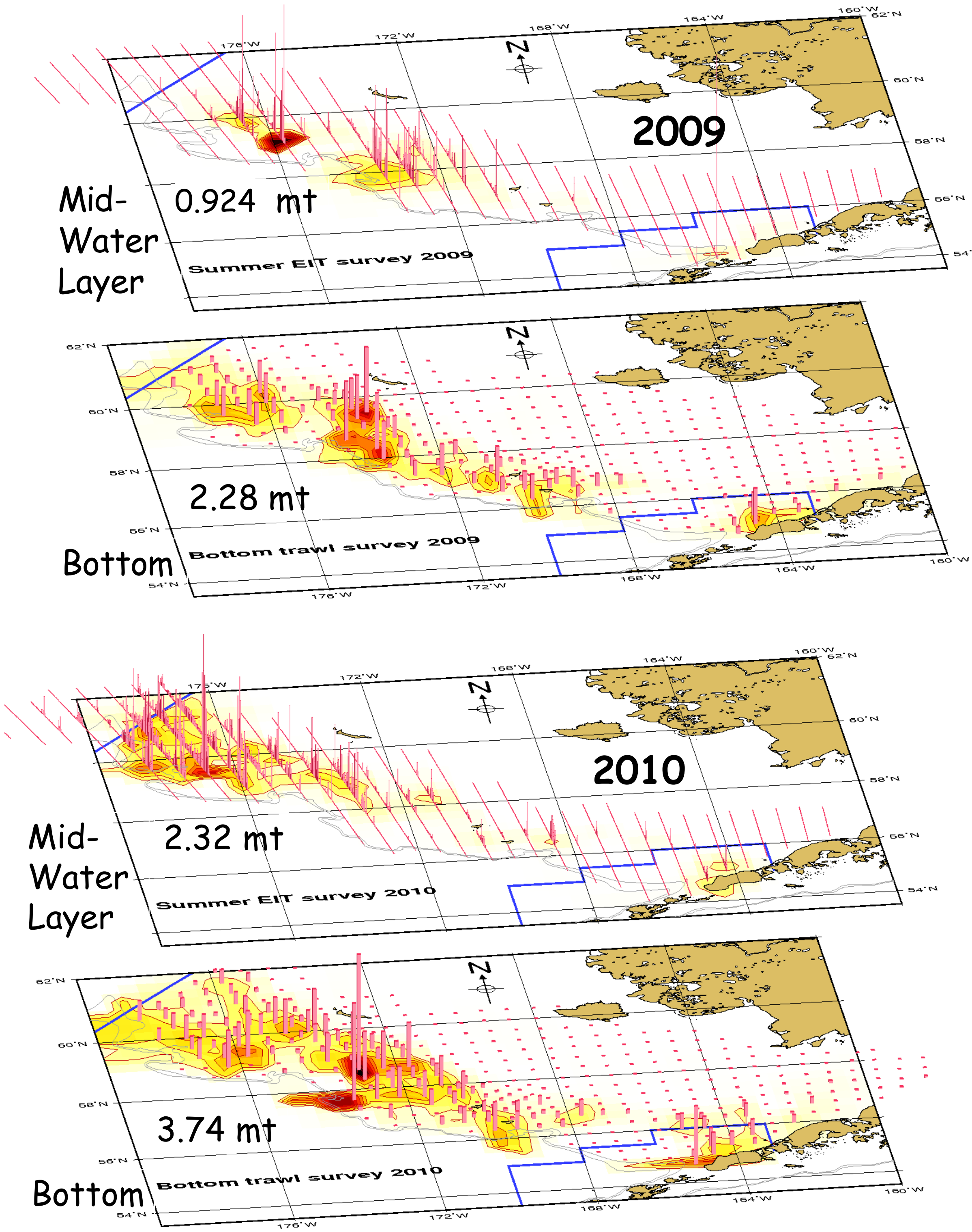

Figure 1.16. Acoustic-trawl survey results for 2009 and 2010. The lower figure is the result from the BTS data in the same years. Vertical lines represent biomass of pollock as observed in the different surveys (mt = millions of t).

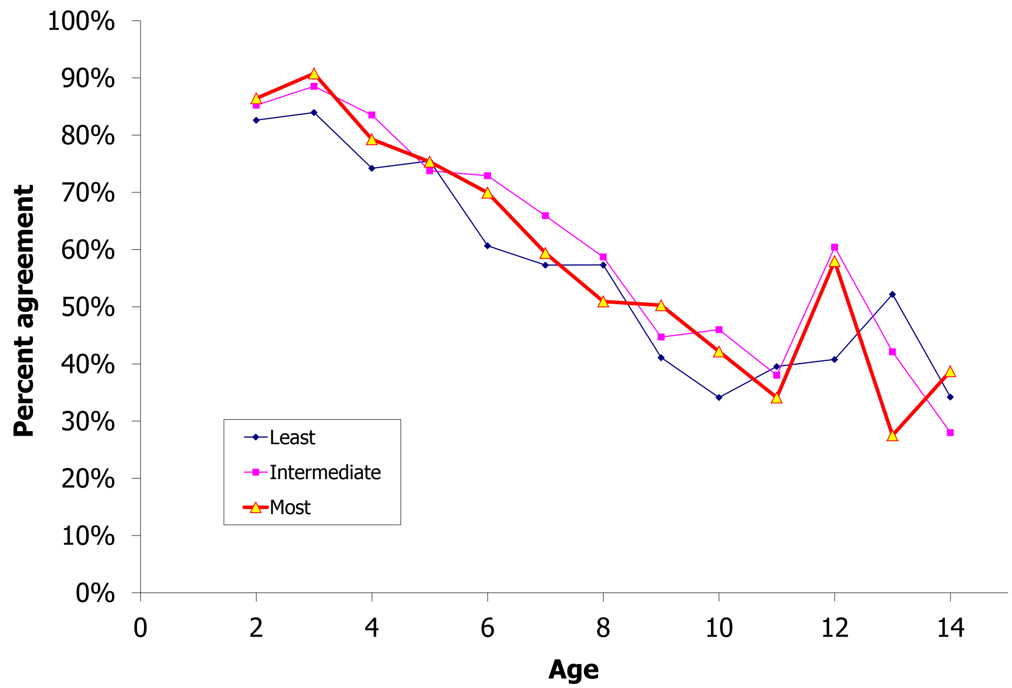

Figure 1.17. Percent agreement in reader-tester samples by reader experience category (least < 3000 ages read, 3000 < intermediate < 9000, and most > 9000) for EBS pollock from fishery data, 1990-2010. Increased variability at older ages is due to lower sample sizes.

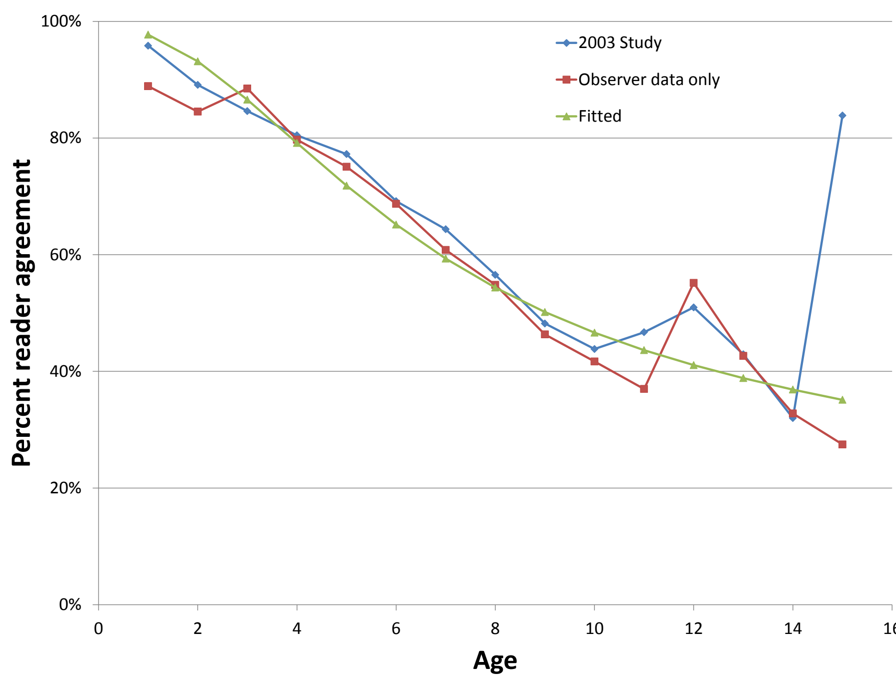

Figure 1.18. Percent agreement from observer data only (present study) compared to previous analysis (Ianelli et al 2003) and fitted relationship used to determine age-error conversion matrix.

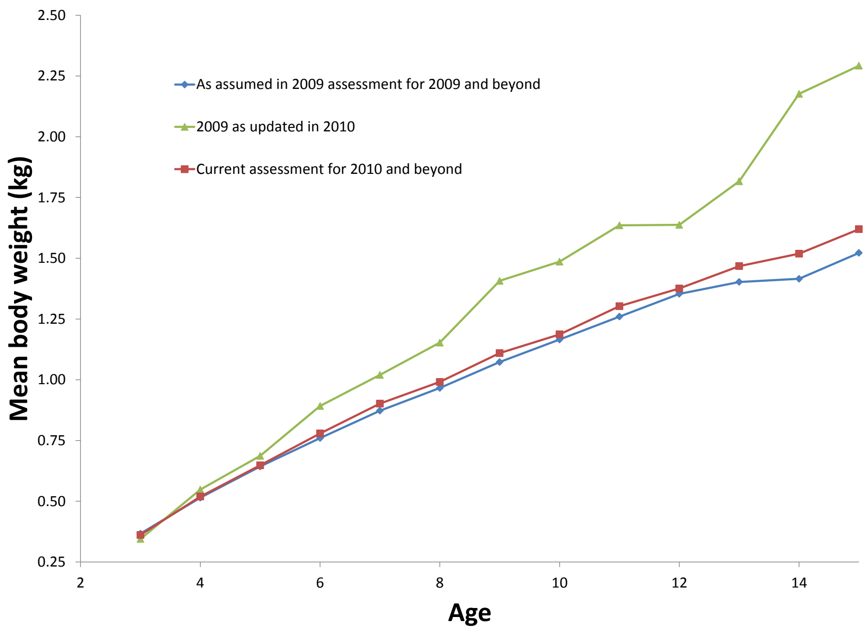

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Figure 1.19. Mean fishery body weight (kg) for EBS pollock assumed for the 2009 assessment and as revised using observer data for the current assessment.

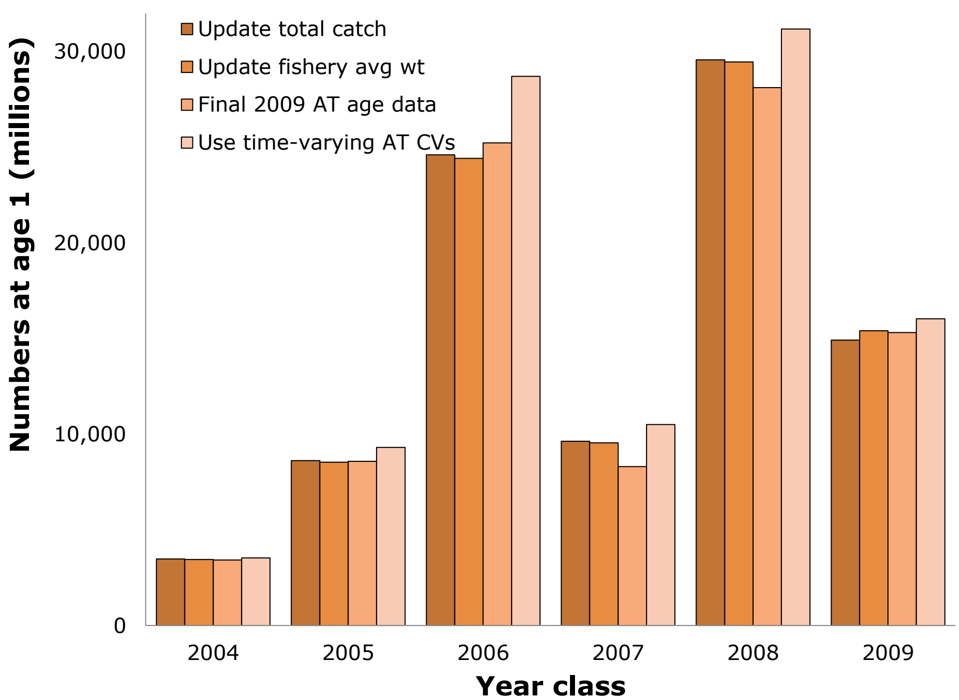


Figure 1.20. The impact of refinements to the data and assessment model on recent year-class estimates.

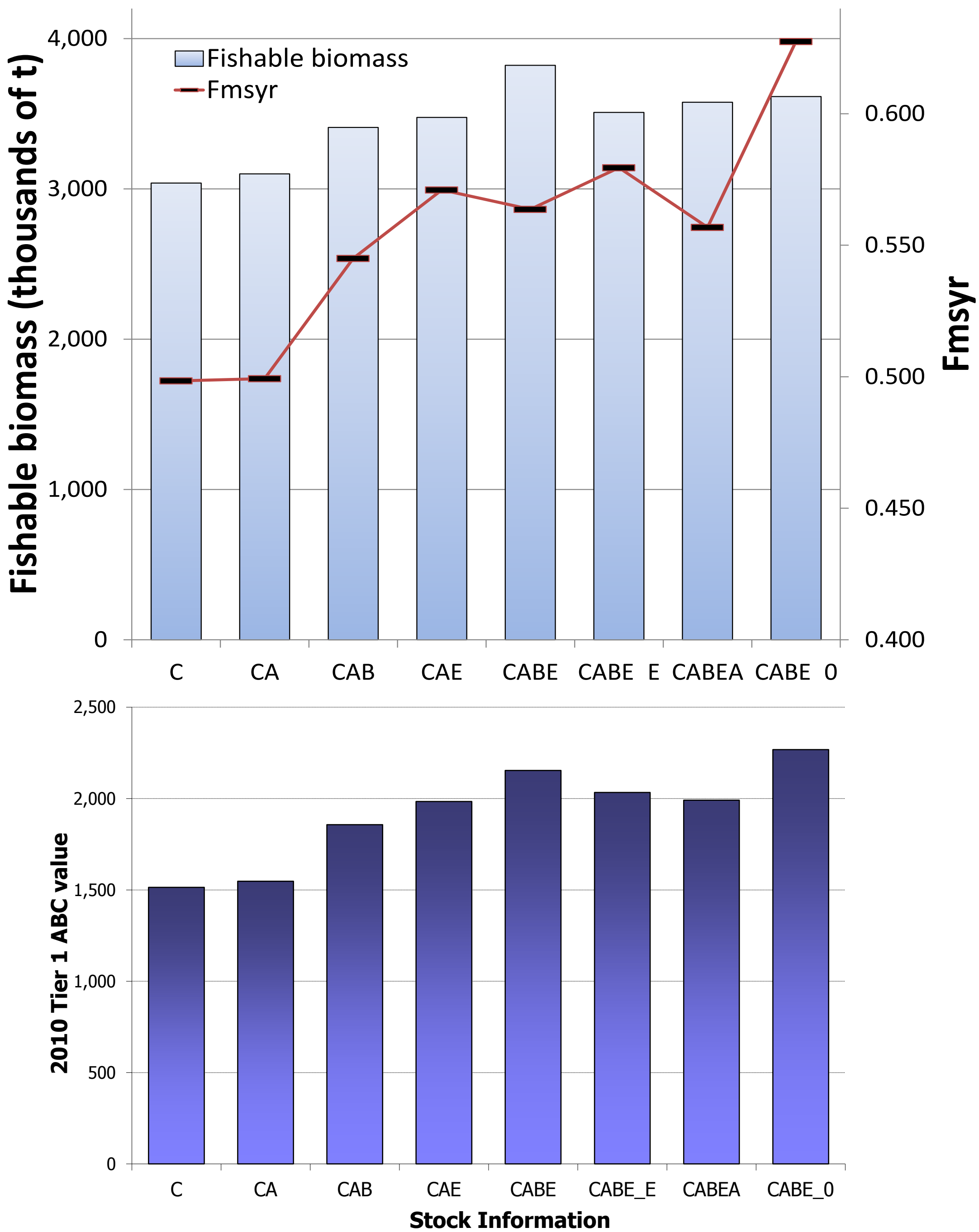


Figure 1.21. The impact of introducing new data to the assessment model on fishable biomass values, F_{msy} rates, and ABC (bottom panel) for 2010 (key: fishery **C**atch, fishery **A**ge, **B**ottom-trawl survey data, **Acoustic-**trawl data, . 2nd **A** for **AVO** index, **_E** indicates that age-error conversion matrix is included and **_O** means that all post 1977 recruits were included in estimating the stock-recruitment relationship.

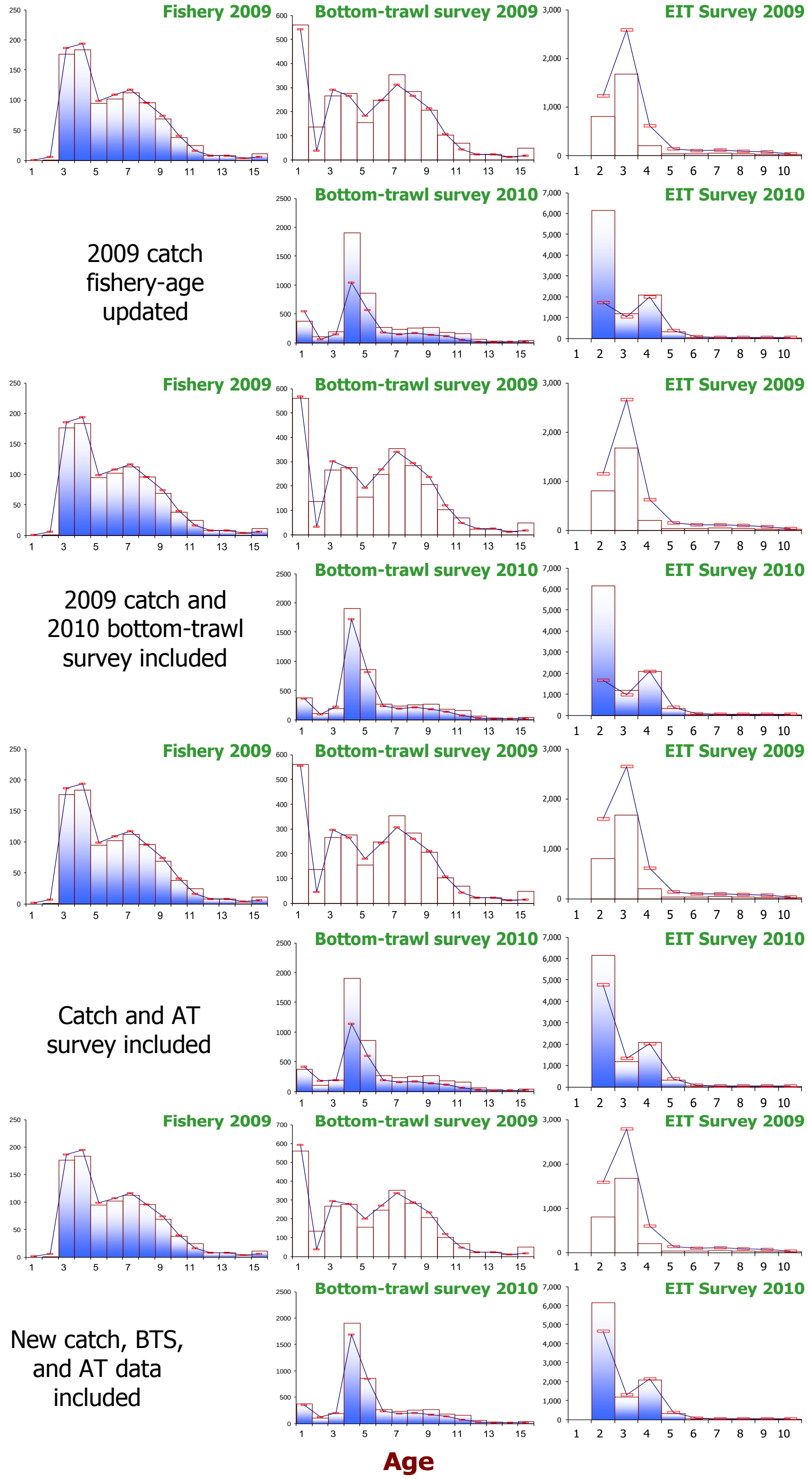


Figure 1.22. Model results of predicted EBS pollock numbers-at-age for catch and surveys as new data were added. Columns represent the data, lines represent model predictions. Shaded columns indicate data introduced in the current assessment.

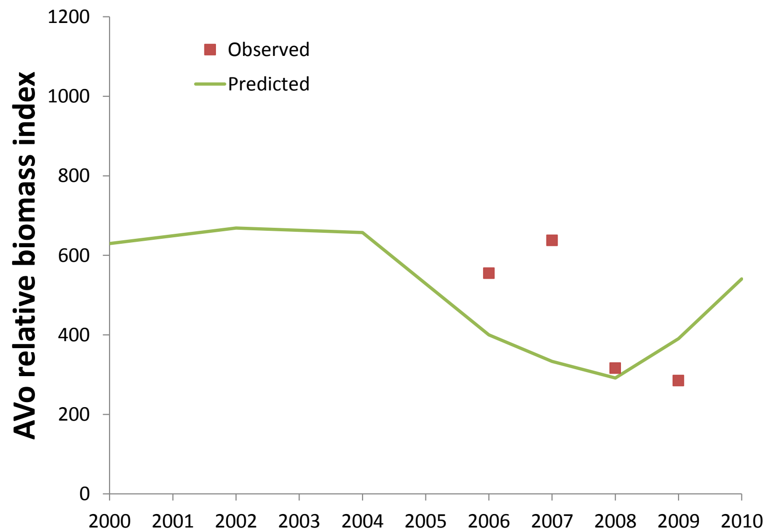


Figure 1.23. Model results of predicted EBS pollock biomass following the AVO index (model CABEA). Squares represent the data and the line represents the model predictions.

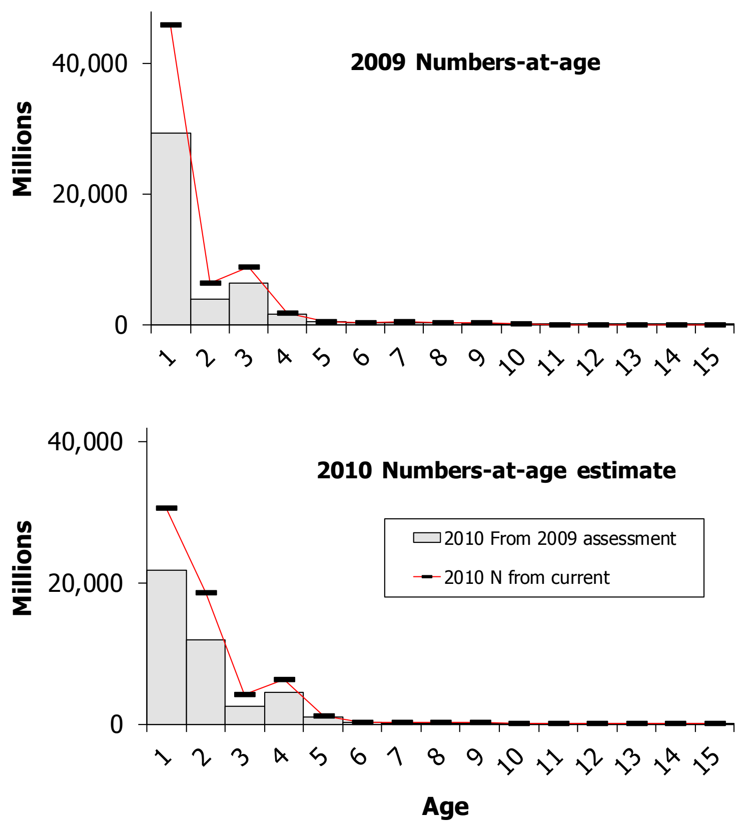


Figure 1.24. Comparison of changes in age composition estimates between last year's assessment model--columns for 2009 (top) and 2010 (bottom)—compared to current estimates (connected dashes).

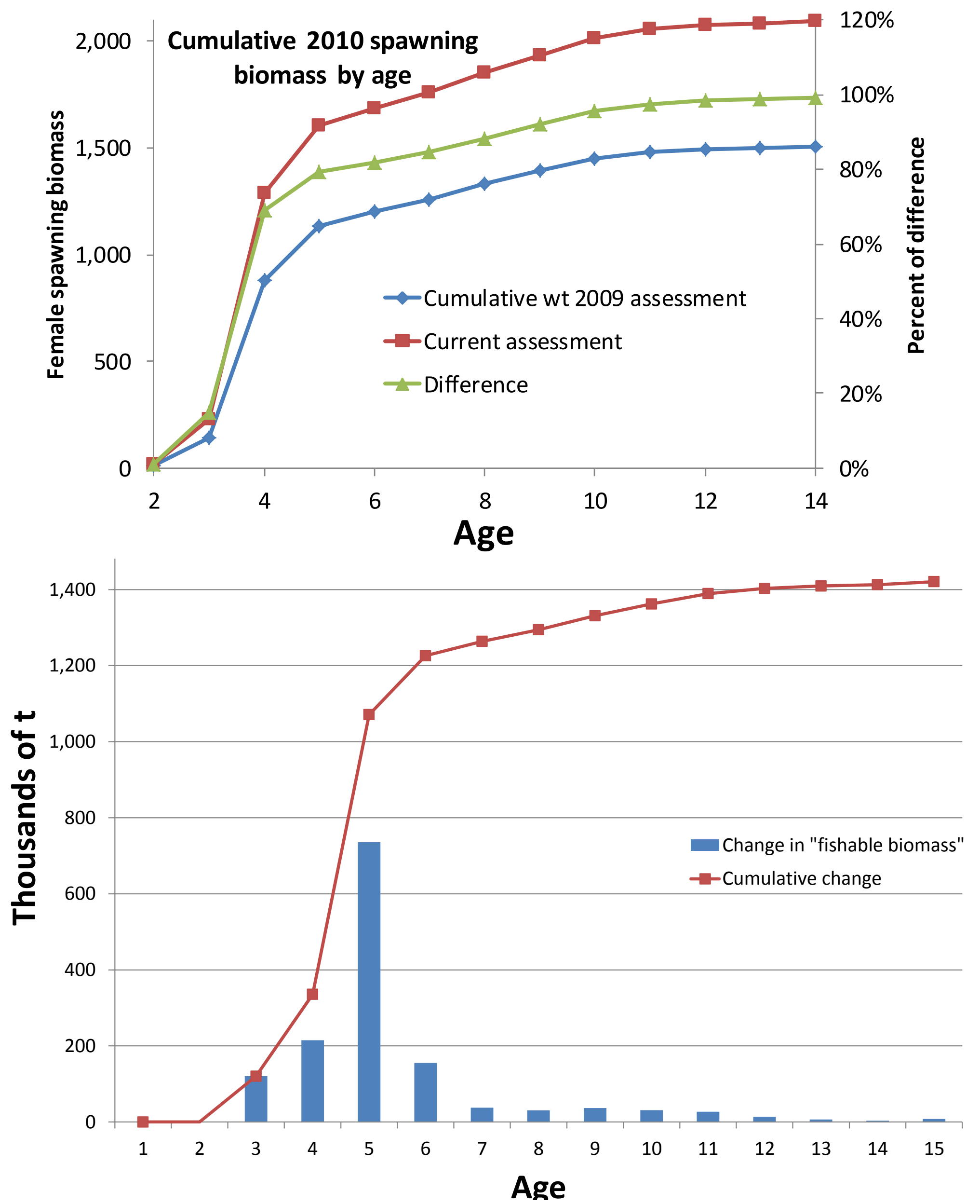


Figure 1.25. Comparison of cumulative EBS pollock female biomass-at-age (using begin-year numbers) as estimated from the 2009 assessment (for 2010) with estimates from the current assessment (top panel). The bottom panel shows the contribution of change in the estimated 2011 “fishable biomass” between last year’s assessment and the present analysis. Most of the difference occurs due to the revision of the 2006 year class.

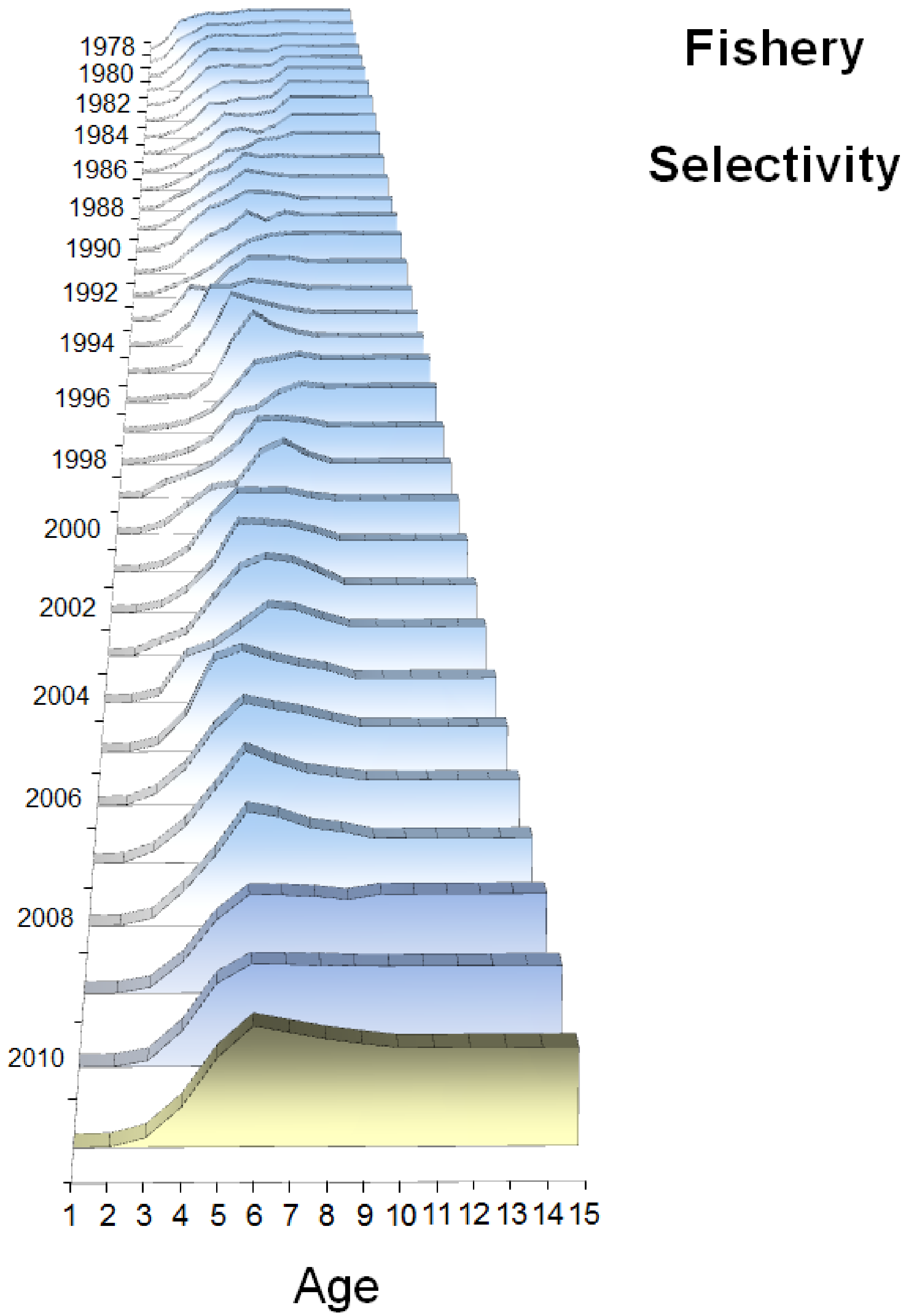


Figure 1. 26. Selectivity at age estimates for the EBS pollock fishery, 1978-2010 including the estimates (front-most panel) used for the future yield considerations.

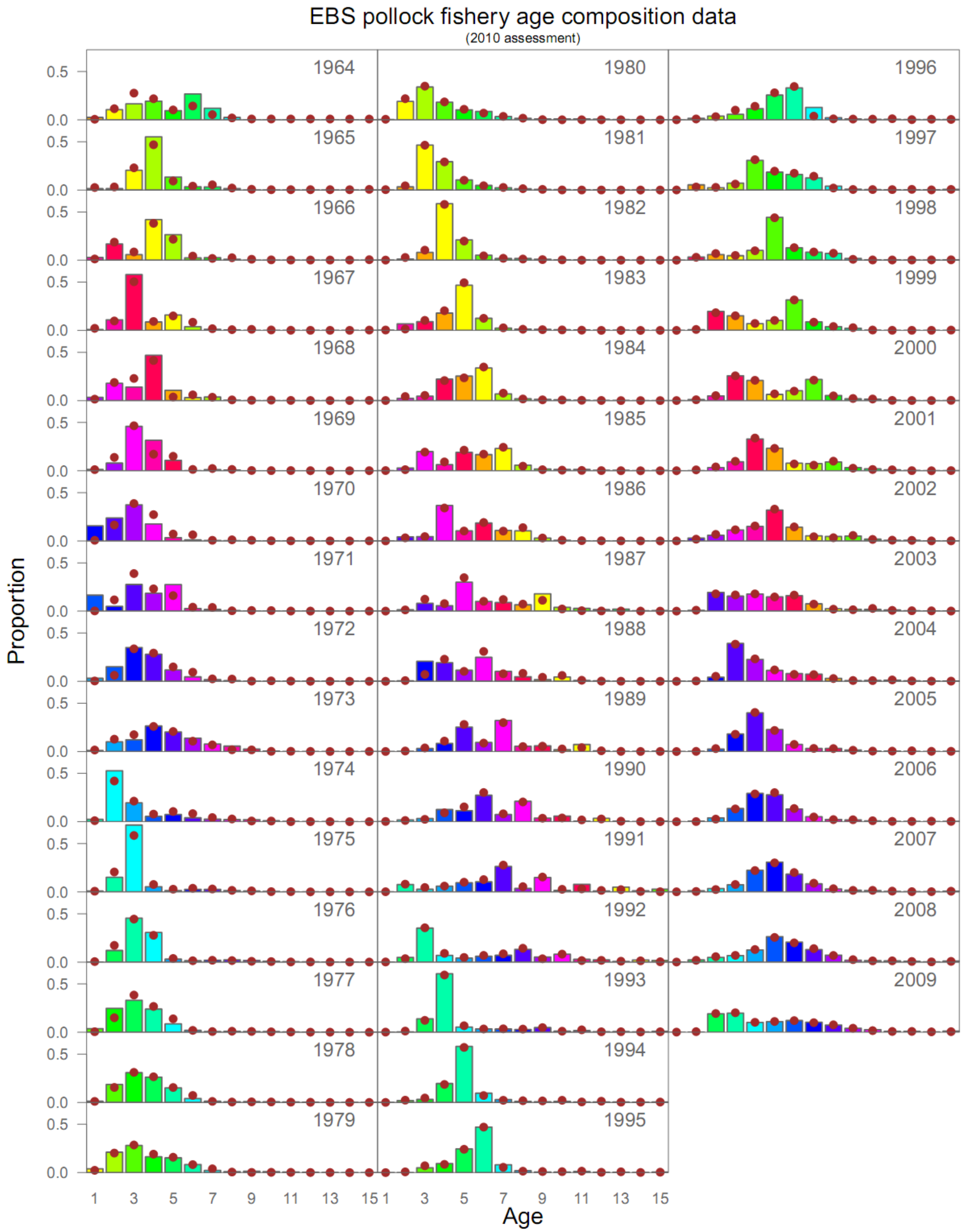


Figure 1.27. Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2009). The 2009 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

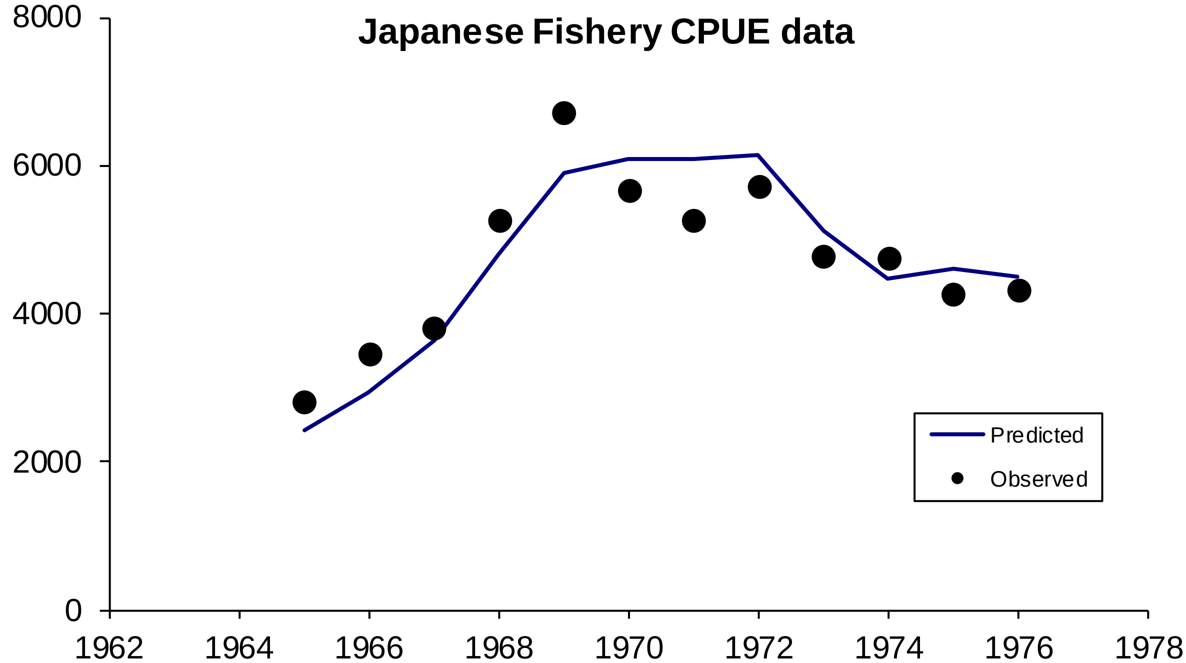


Figure 1.28. Japanese fishery CPUE (Low and Ikeda, 1980) model fits for EBS pollock, 1963-1976.

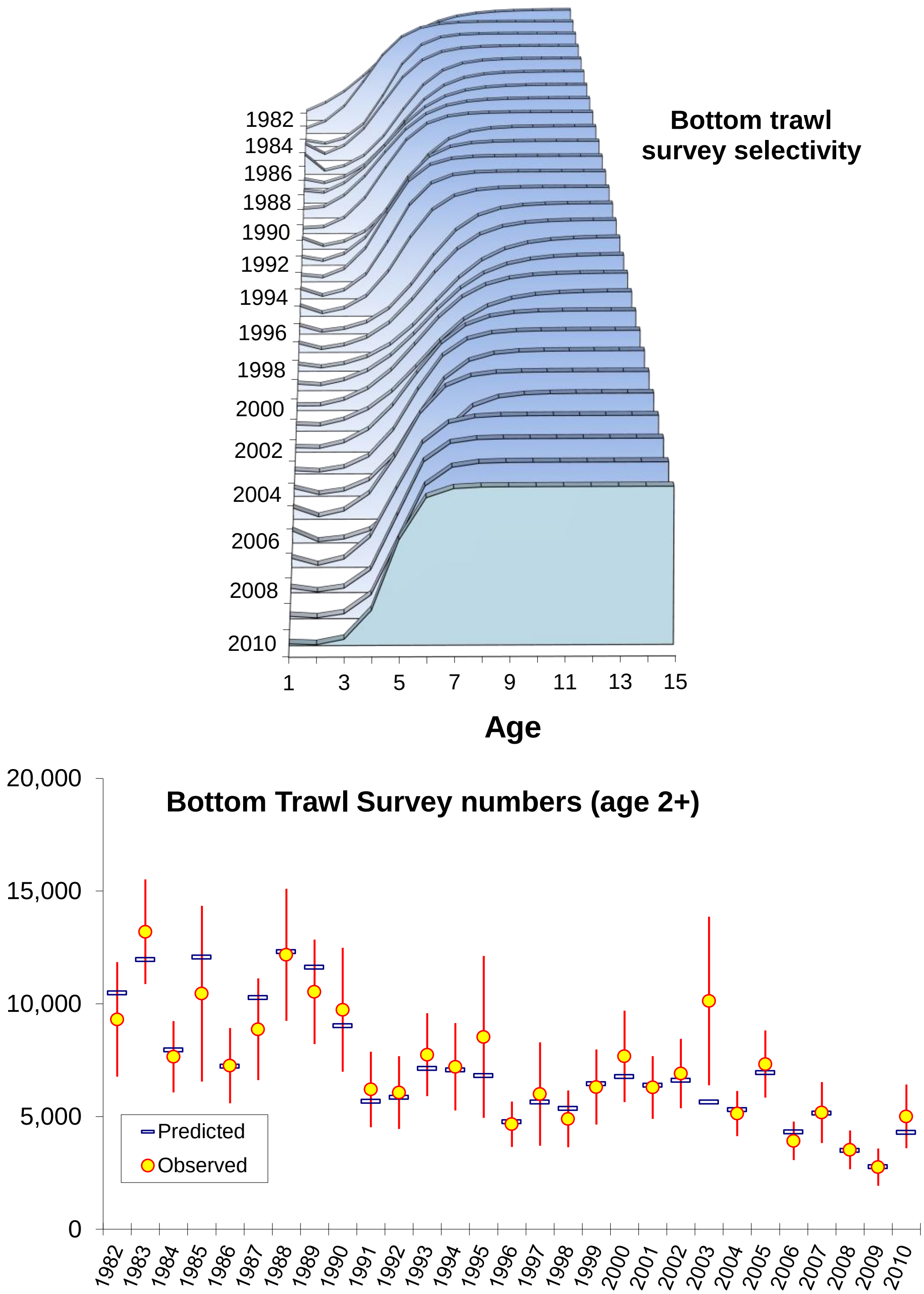


Figure 1.29. Estimates of bottom-trawl survey numbers (millions age 2 and older, lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2010.

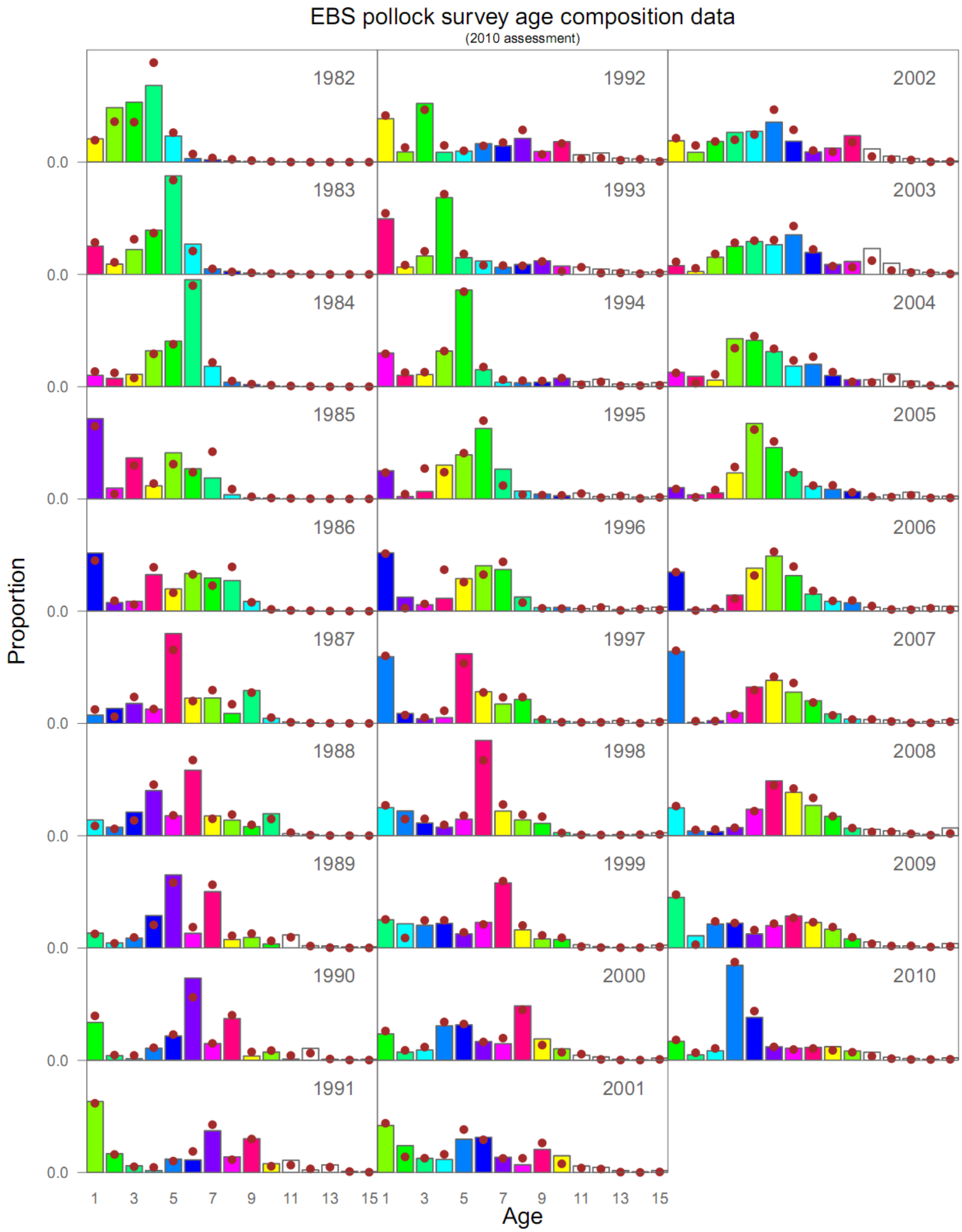


Figure 1.30. Model fit (dots) to the bottom trawl survey age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2010.

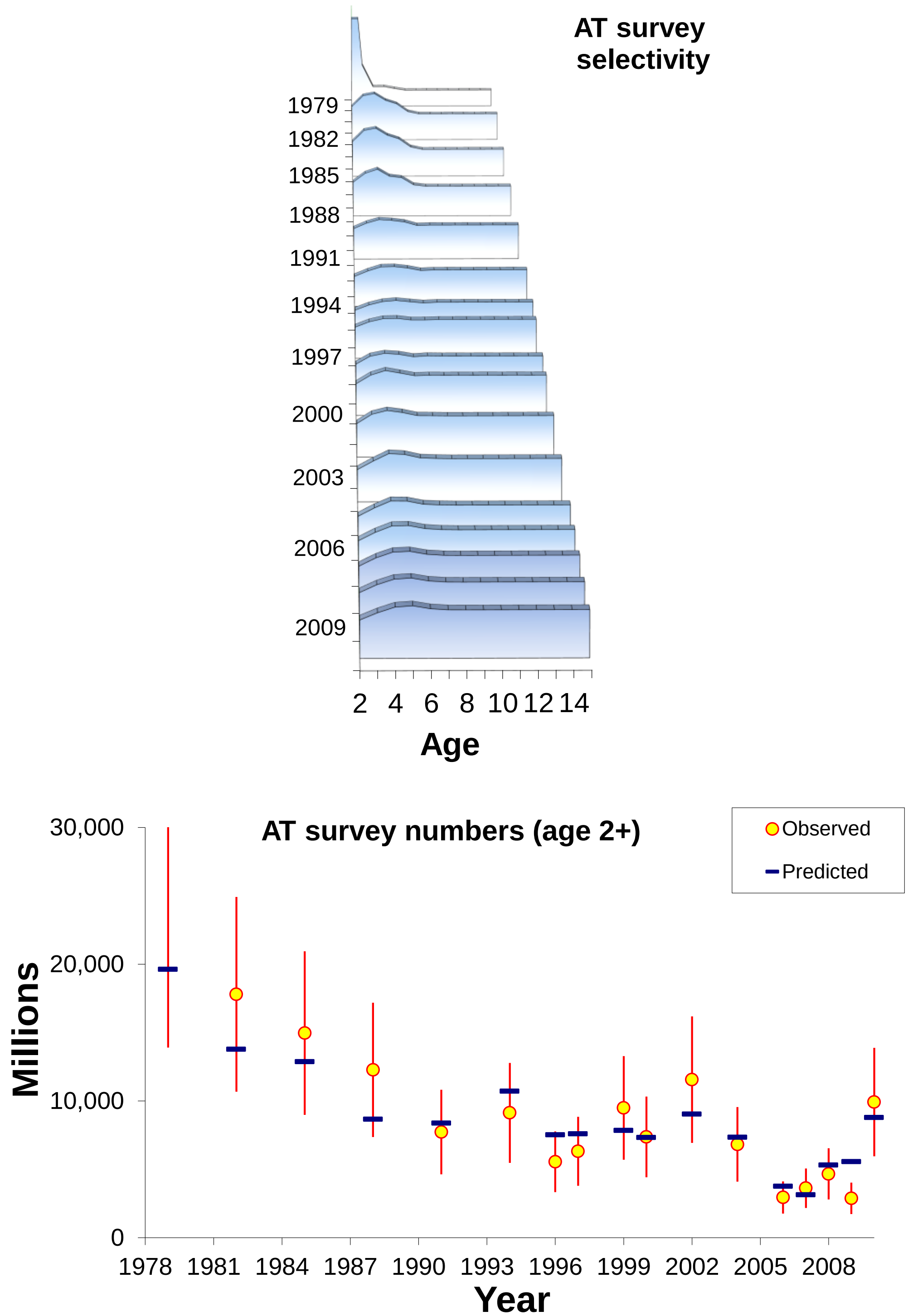


Figure 1.31. Estimates of AT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older, 1979-2010. Note that the 1979 observed value (=46,314) is off the scale of the figure.

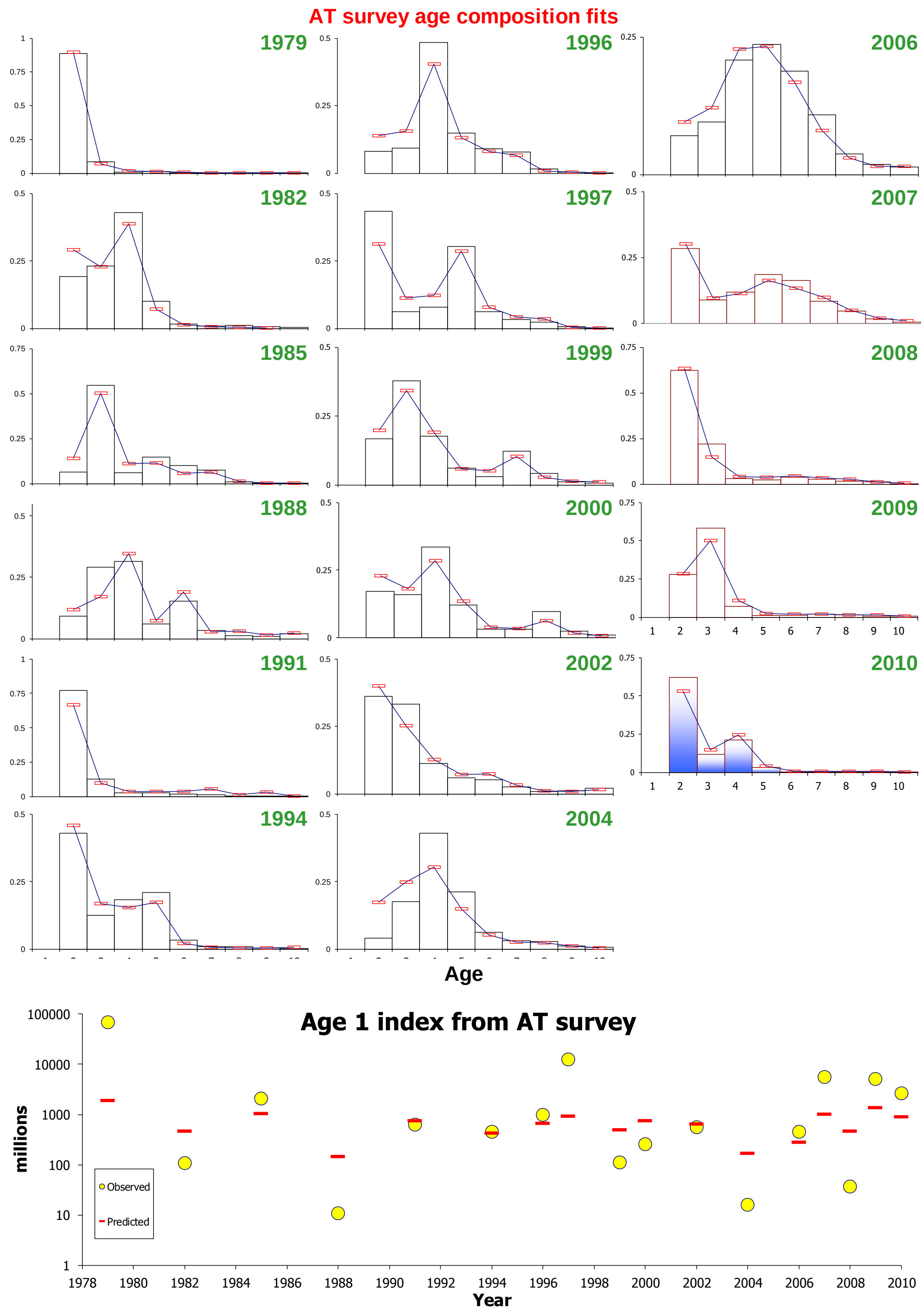


Figure 1.32. Fit to the AT survey EBS pollock age composition data (proportions) and age 1 index (bottom panel; log-scale). Lines represent model predictions while the vertical columns and dots represent data. The 2010 age composition data are new to the assessment are shaded and the 2009 data were based on revised values using AT age-length keys.

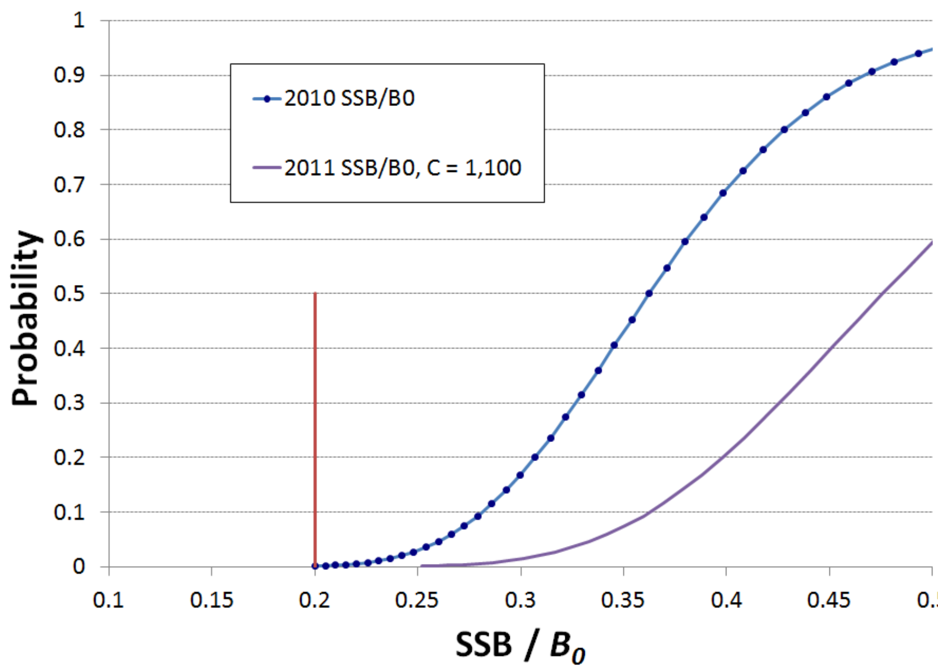


Figure 1.33. Cumulative probability estimates of 2010 and 2011 stock sizes relative to B_0 for EBS pollock assuming a catch of 1,100 kt. Note that these reflect the estimation uncertainty of stock status.

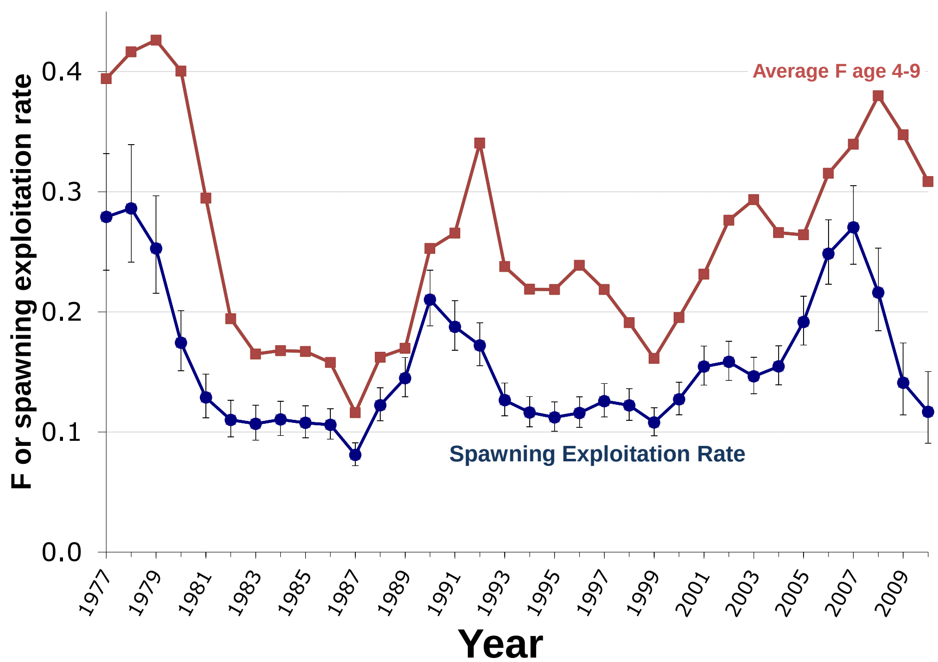
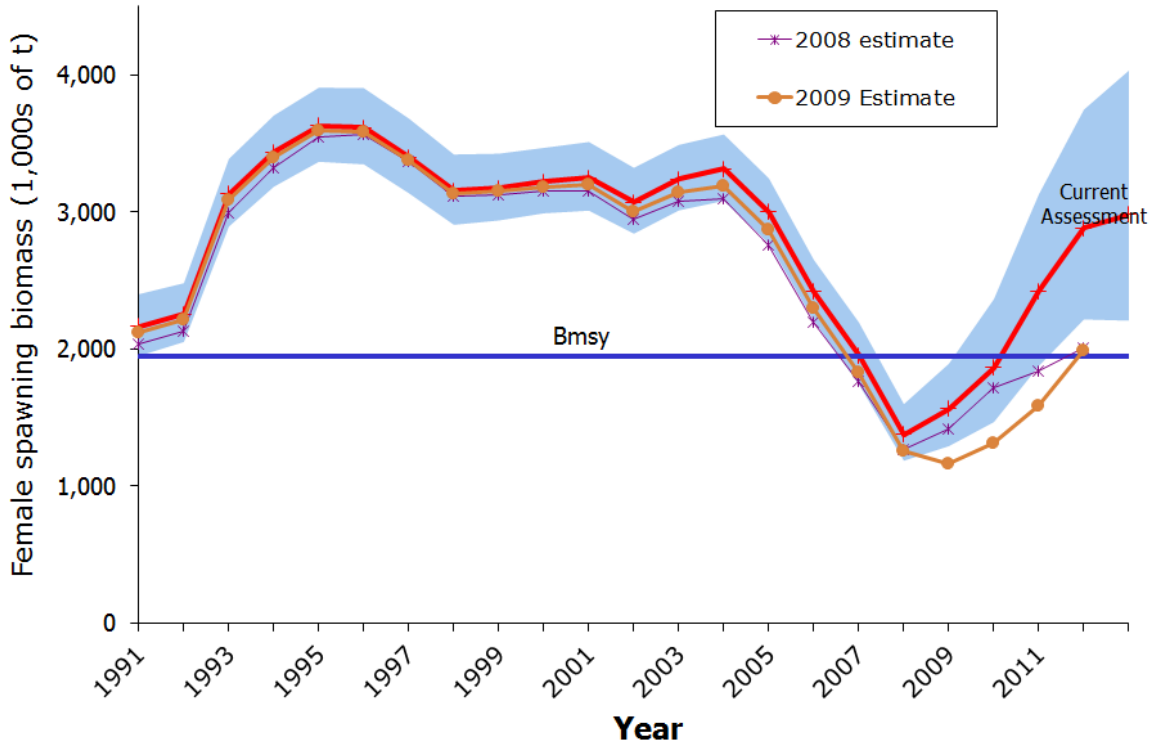


Figure 1.34. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) and average fishing mortality (ages 4-9) for EBS pollock, 1977-2010. Error bars represent two standard deviations from the estimates.

Age

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1964	0.01	0.05	0.19	0.20	0.19	0.18	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1965	0.01	0.06	0.20	0.19	0.18	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1966	0.02	0.07	0.18	0.17	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14
1967	0.03	0.16	0.29	0.28	0.27	0.26	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.24
1968	0.03	0.16	0.29	0.27	0.26	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.24
1969	0.04	0.18	0.25	0.24	0.23	0.23	0.23	0.23	0.25	0.25	0.25	0.25	0.25	0.25
1970	0.06	0.24	0.26	0.26	0.25	0.28	0.28	0.29	0.43	0.43	0.43	0.43	0.43	0.43
1971	0.07	0.29	0.33	0.35	0.34	0.35	0.37	0.38	0.66	0.66	0.66	0.66	0.66	0.66
1972	0.11	0.38	0.41	0.40	0.40	0.42	0.42	0.46	0.68	0.68	0.68	0.68	0.68	0.68
1973	0.15	0.51	0.55	0.55	0.54	0.54	0.55	0.59	0.73	0.73	0.73	0.73	0.73	0.73
1974	0.20	0.65	0.64	0.64	0.63	0.63	0.64	0.67	0.70	0.70	0.70	0.70	0.70	0.70
1975	0.12	0.55	0.52	0.51	0.50	0.50	0.50	0.53	0.56	0.56	0.56	0.56	0.56	0.56
1976	0.10	0.40	0.49	0.47	0.46	0.45	0.45	0.47	0.48	0.48	0.48	0.48	0.48	0.48
1977	0.09	0.30	0.37	0.40	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
1978	0.08	0.31	0.37	0.41	0.40	0.43	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
1979	0.05	0.26	0.34	0.44	0.44	0.43	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
1980	0.03	0.16	0.32	0.41	0.42	0.42	0.41	0.41	0.43	0.43	0.43	0.43	0.43	0.43
1981	0.01	0.08	0.21	0.32	0.31	0.31	0.31	0.31	0.34	0.34	0.34	0.34	0.34	0.34
1982	0.01	0.04	0.12	0.20	0.21	0.21	0.21	0.21	0.26	0.26	0.26	0.26	0.26	0.26
1983	0.00	0.03	0.09	0.15	0.19	0.19	0.19	0.19	0.25	0.25	0.25	0.25	0.25	0.25
1984	0.00	0.03	0.08	0.17	0.17	0.19	0.19	0.20	0.28	0.28	0.28	0.28	0.28	0.28
1985	0.01	0.03	0.07	0.13	0.20	0.19	0.20	0.21	0.28	0.28	0.28	0.28	0.28	0.28
1986	0.01	0.03	0.08	0.11	0.18	0.19	0.17	0.21	0.26	0.26	0.26	0.26	0.26	0.26
1987	0.00	0.02	0.05	0.08	0.12	0.13	0.16	0.16	0.18	0.18	0.18	0.18	0.18	0.18
1988	0.01	0.04	0.08	0.14	0.15	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1989	0.01	0.04	0.09	0.13	0.17	0.22	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1990	0.01	0.04	0.15	0.22	0.25	0.30	0.30	0.29	0.27	0.27	0.27	0.27	0.27	0.27
1991	0.01	0.04	0.13	0.21	0.26	0.35	0.30	0.35	0.33	0.33	0.33	0.33	0.33	0.33
1992	0.01	0.07	0.13	0.21	0.33	0.42	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48
1993	0.00	0.04	0.16	0.14	0.24	0.30	0.30	0.30	0.28	0.28	0.28	0.28	0.28	0.28
1994	0.00	0.02	0.09	0.24	0.24	0.26	0.25	0.24	0.23	0.23	0.23	0.23	0.23	0.23
1995	0.00	0.01	0.04	0.16	0.31	0.29	0.27	0.25	0.24	0.24	0.24	0.24	0.24	0.24
1996	0.00	0.02	0.02	0.09	0.27	0.40	0.34	0.31	0.29	0.29	0.29	0.29	0.29	0.29
1997	0.01	0.02	0.04	0.09	0.19	0.31	0.33	0.35	0.33	0.33	0.33	0.33	0.33	0.33
1998	0.00	0.02	0.05	0.10	0.20	0.22	0.28	0.31	0.30	0.30	0.30	0.30	0.30	0.30
1999	0.00	0.04	0.06	0.09	0.14	0.22	0.23	0.22	0.21	0.21	0.21	0.21	0.21	0.21
2000	0.00	0.03	0.09	0.14	0.15	0.25	0.29	0.25	0.22	0.22	0.22	0.22	0.22	0.22
2001	0.00	0.02	0.07	0.20	0.29	0.28	0.28	0.27	0.26	0.26	0.26	0.26	0.26	0.26
2002	0.00	0.02	0.08	0.19	0.36	0.35	0.35	0.32	0.29	0.29	0.29	0.29	0.29	0.29
2003	0.00	0.05	0.09	0.22	0.35	0.39	0.38	0.33	0.28	0.28	0.28	0.28	0.28	0.28
2004	0.00	0.02	0.16	0.20	0.27	0.34	0.33	0.30	0.27	0.27	0.27	0.27	0.27	0.27
2005	0.00	0.02	0.12	0.30	0.33	0.30	0.28	0.26	0.24	0.24	0.24	0.24	0.24	0.24
2006	0.00	0.05	0.14	0.29	0.40	0.37	0.36	0.33	0.30	0.30	0.30	0.30	0.30	0.30
2007	0.00	0.05	0.15	0.30	0.46	0.41	0.37	0.35	0.34	0.34	0.34	0.34	0.34	0.34
2008	0.00	0.03	0.15	0.31	0.50	0.48	0.43	0.41	0.38	0.38	0.38	0.38	0.38	0.38
2009	0.00	0.02	0.13	0.31	0.42	0.42	0.41	0.40	0.42	0.42	0.42	0.42	0.42	0.42
2010	0.00	0.02	0.13	0.29	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.35	0.35

Figure 1.35. Estimated instantaneous age-specific fishing mortality rates for EBS pollock, 1964-2010.



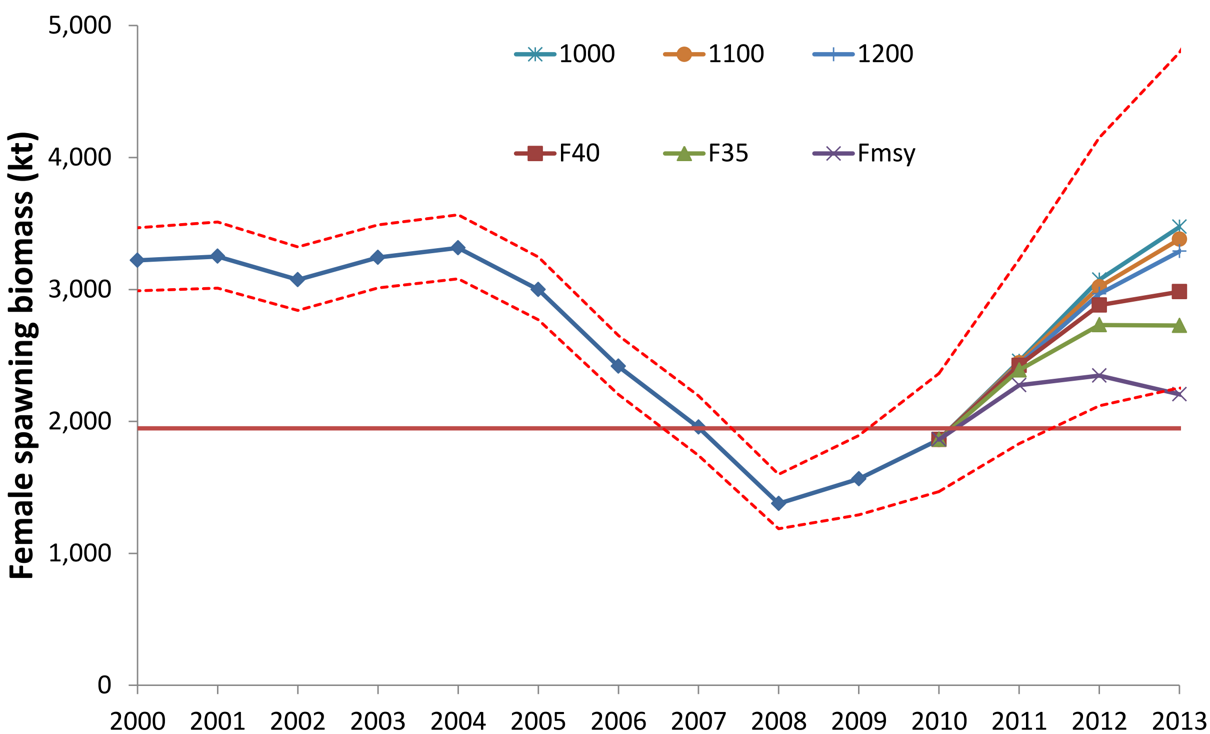


Figure 1.36. Estimated EBS pollock female spawning biomass and approximate 95% confidence intervals (filled area and dashed lines) comparing the current assessment with the past two (top) and examining near term projections under different variable and constant catch settings. Horizontal straight line represents B_{msy} estimate.

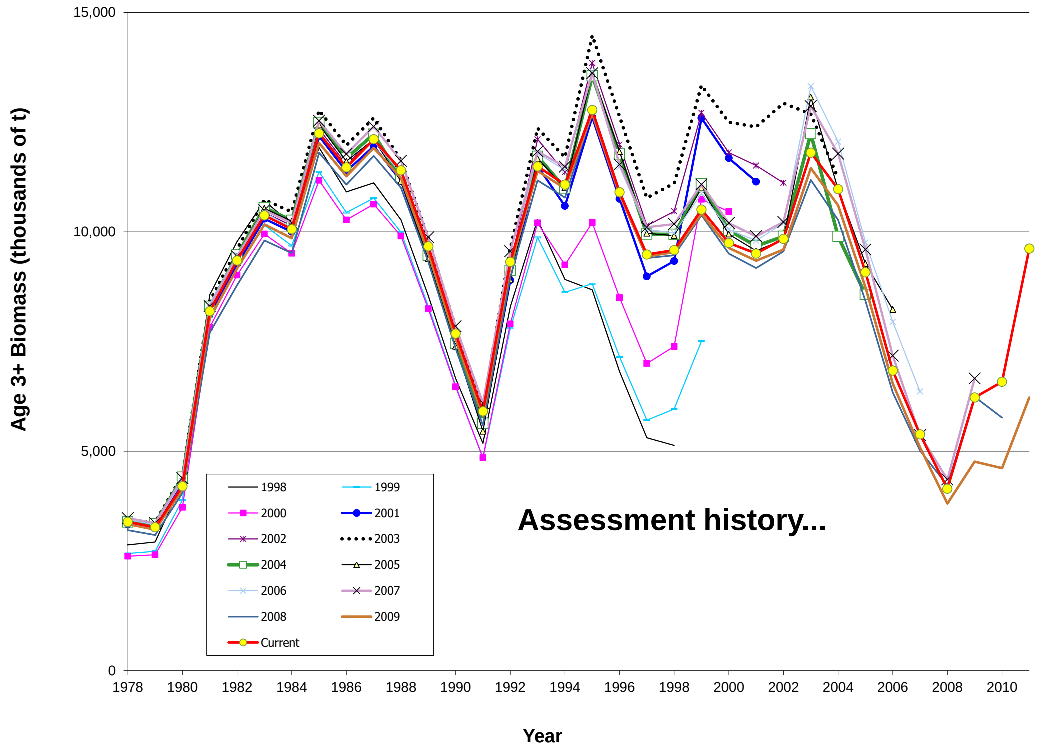


Figure 1.37. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2010.

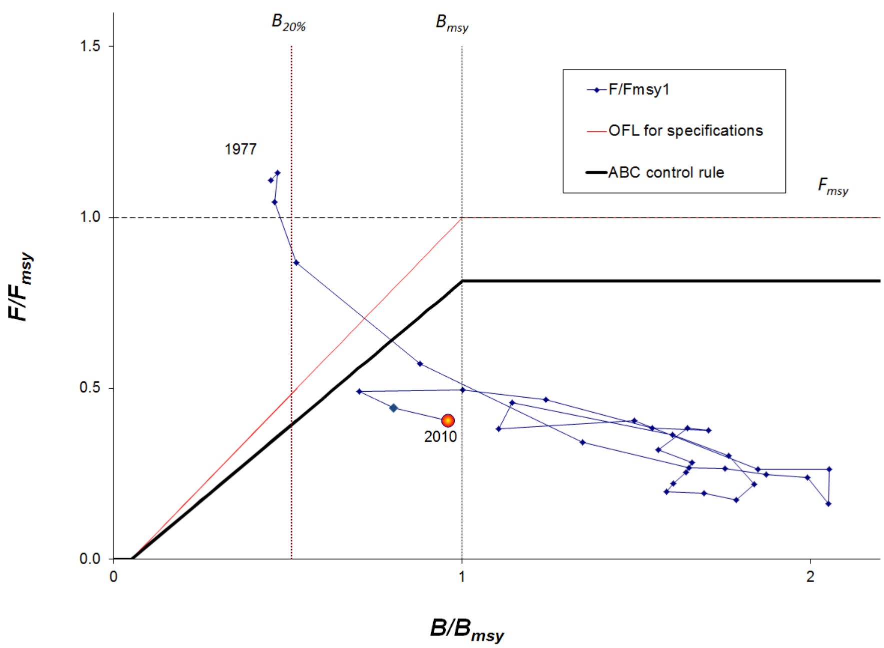


Figure 1.38. Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock, 1977-2010. *Note that the control rules for OFL and ABC are designed for setting specifications in future years.*

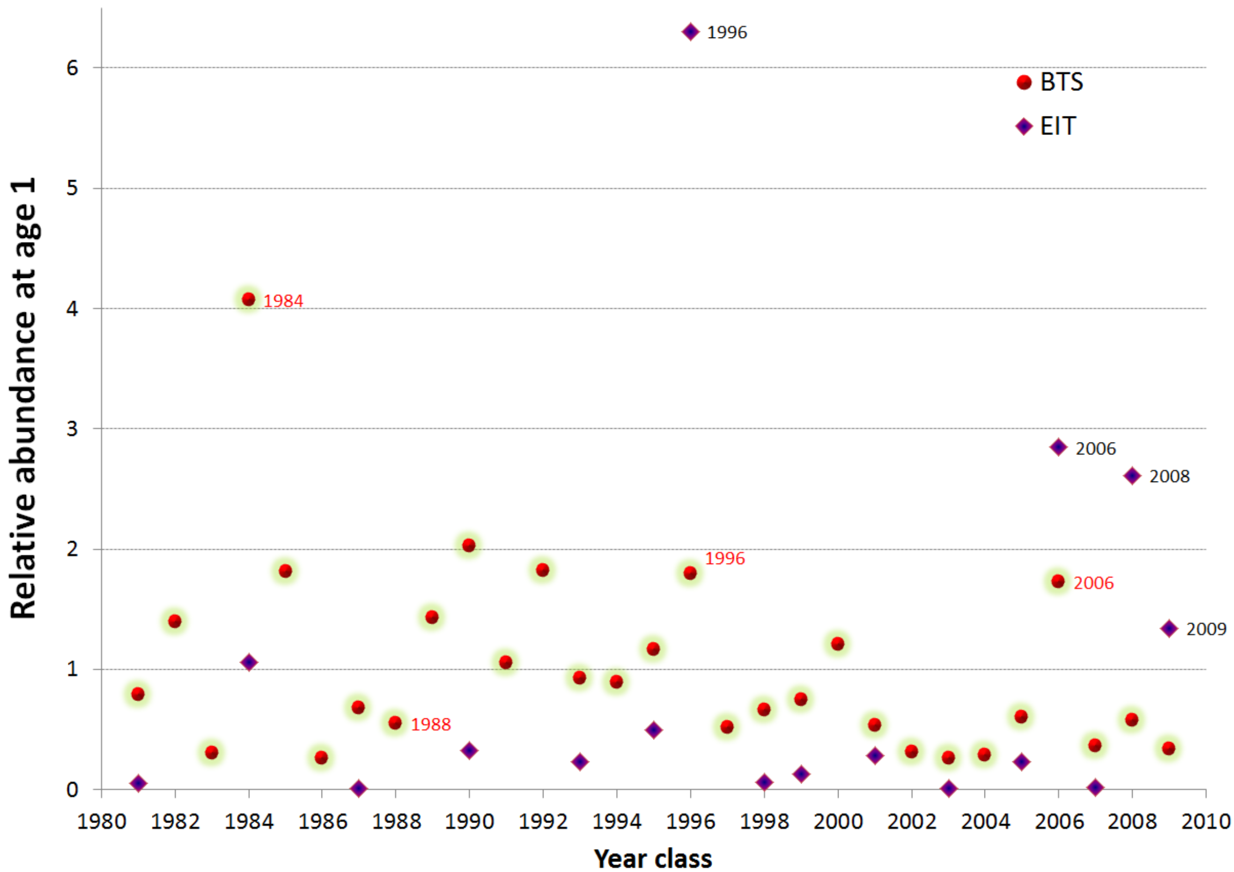


Figure 1.39. Time series of estimated age-1 abundance (relative numbers) for EBS pollock from the AT surveys, 1982-2010 (diamonds) and from the BTS surveys (bullets). Both survey indices have been rescaled to have a mean value of 1.0.

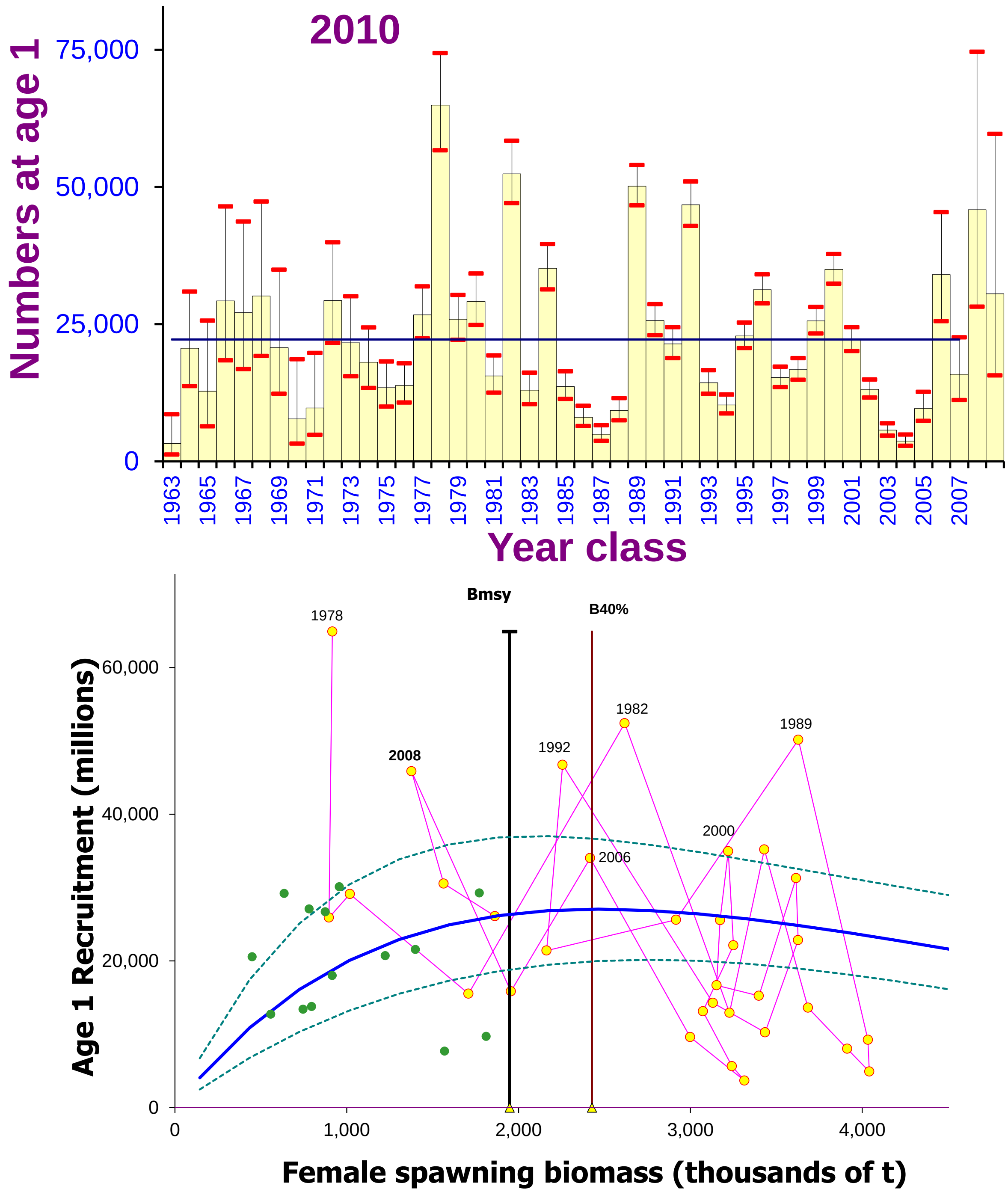


Figure 1.40. Year-class strengths by year (as age-1 recruits, upper panel) and relative to female spawning biomass (thousands of tons, lower panel) for EBS pollock. Labels on points correspond to year classes labels (measured as one-year olds). Solid line in upper panel represents the mean age-1 recruitment for all years since 1964 (1963-2009 year classes). Vertical lines in lower panel indicate B_{msy} and $B_{40\%}$ level, curve represents fitted stock-recruitment relationship with dashed lines representing approximate lower and upper 95% confidence limits about the estimated curve.

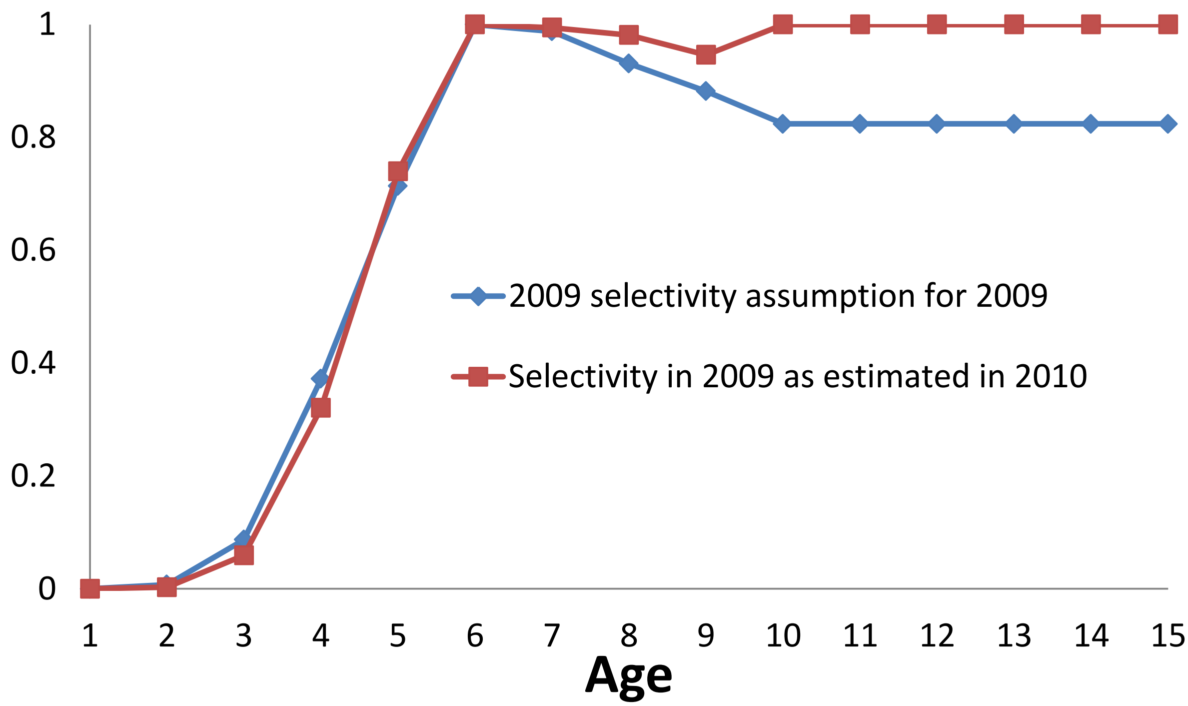
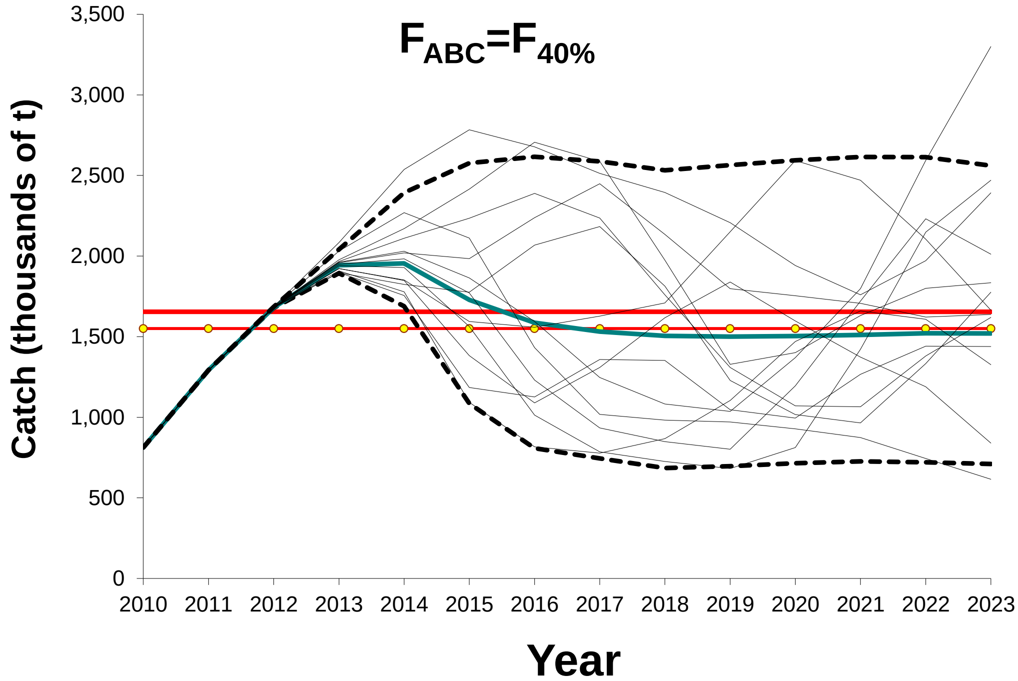


Figure 1.41. EBS pollock selectivity-at-age estimates for 2009 from last year's assessment (line with diamonds) and as estimated (with catch-age data) in this year's assessment (line with squares).



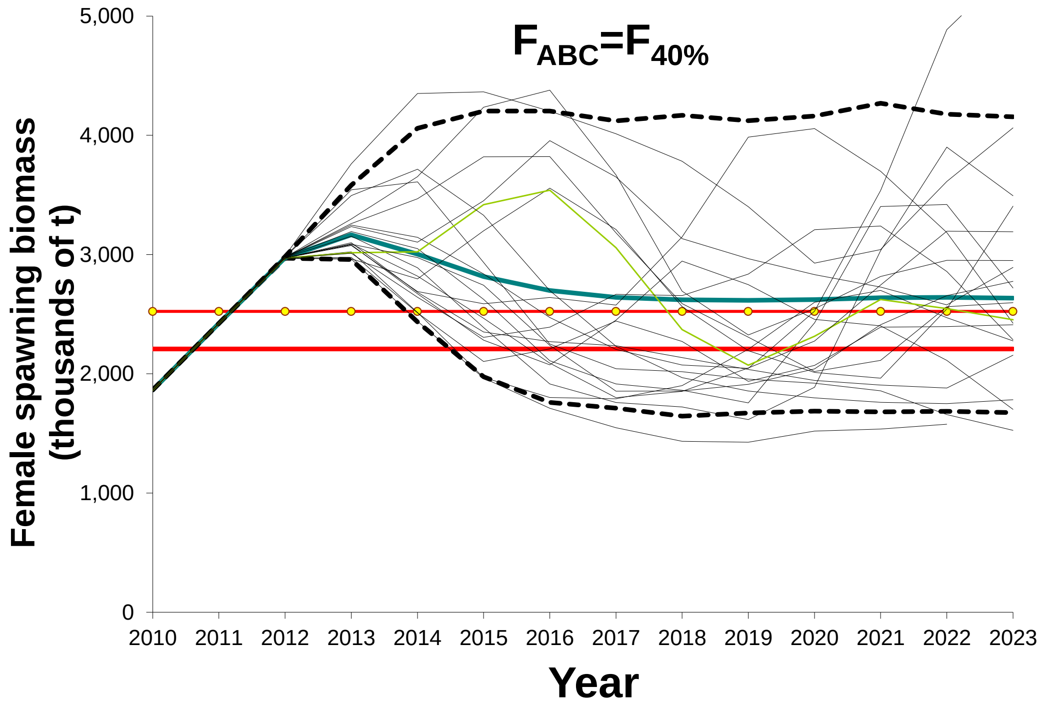


Figure 1.42. Projected EBS **Tier 3** pollock **yield** (top) and **Female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2007. Future harvest rates follow the guidelines specified under Tier 3 Scenario 1, $F_{ABC} = F_{40\%}$. *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.*

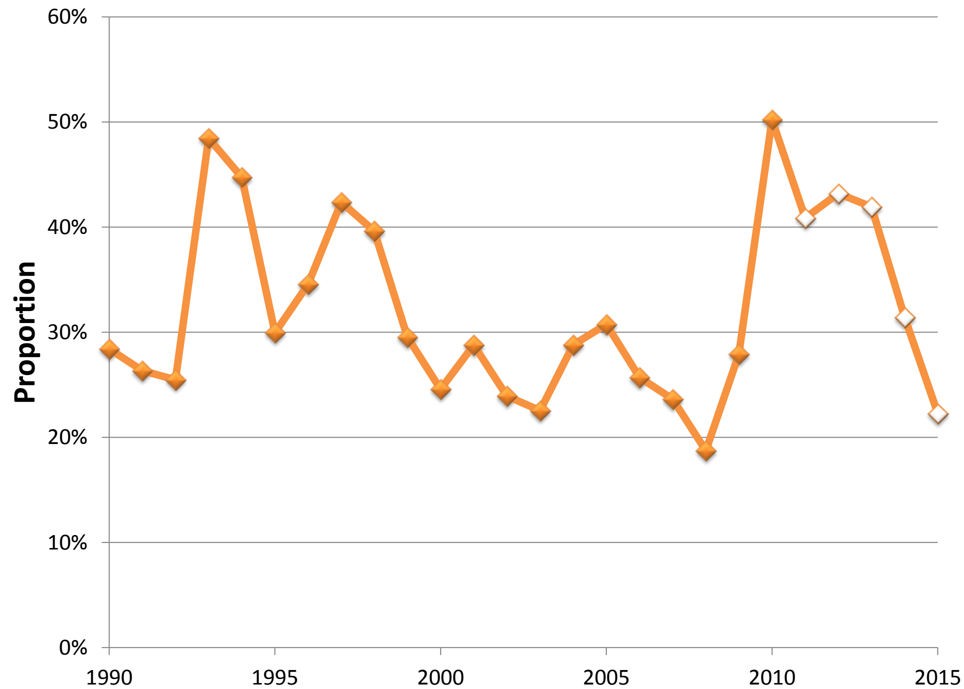


Figure 1.43. The proportion that a single year class contributes to the spawning biomass for EBS pollock, 1990-2015. Values for 2011-2015 are projected based on constant catch projections of 1.2 million t.

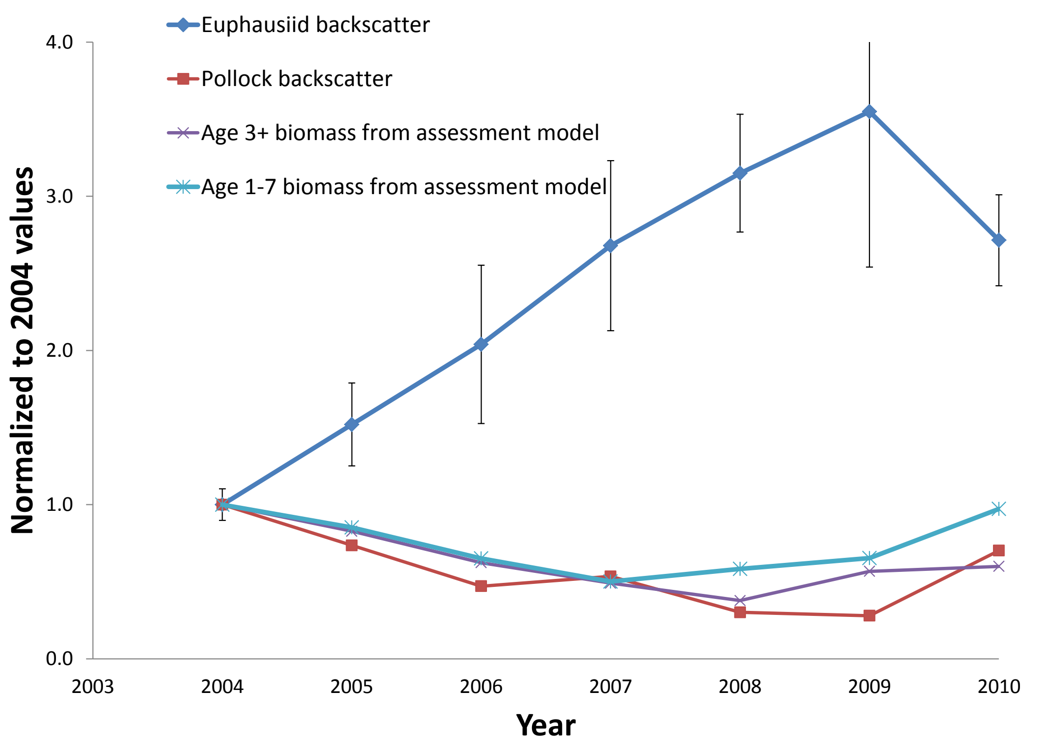


Figure 1.44. Time series of Bering Sea summer euphausiid and pollock backscatter (normalized to their 2004 values), 2004 – 2010, and walleye pollock biomass estimated by the stock assessment model. Error bars are approximate 95% confidence bands.

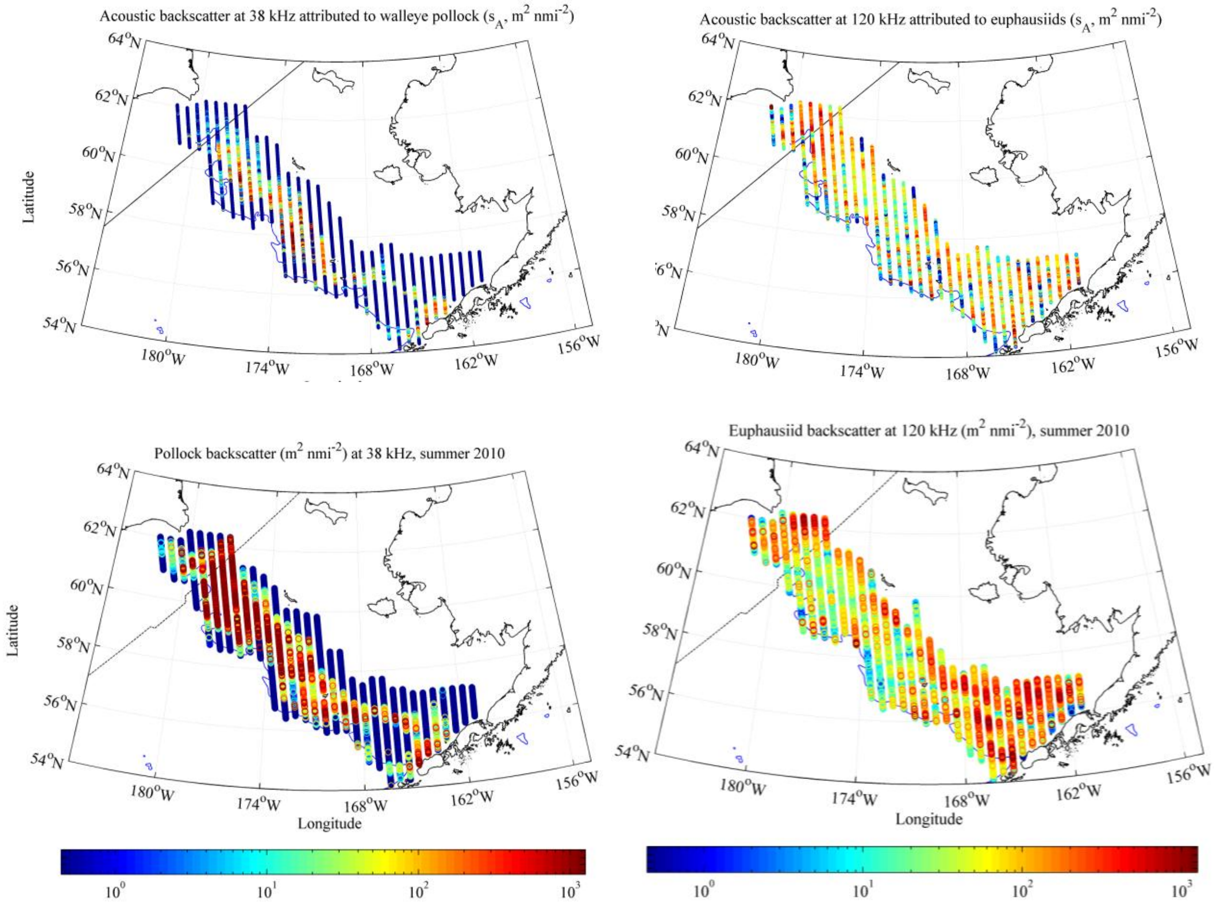


Figure 1.45. Pollock backscatter at 38 kHz (left panels) and euphausiid backscatter at 120 kHz (right panels) along tracklines from the summer 2009 (top) and 2010 (bottom) AT survey of Bering Sea pollock.

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

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

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

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

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

where $s_{t,a}$ is the selectivity for age class a in year t, and μ 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:

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

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

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

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

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

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

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

where r_i^a is the residual of mean age and

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

For this assessment, we use the above relationship as a diagnostic for evaluating input sample sizes by comparing model predicted mean ages with "observed" mean ages and the implied 95% confidence bands. This method provided support for modifying the frequency of allowing selectivity changes (e.g., Fig. 1.46).

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):

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

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

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

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

A reparameterized form for the stock-recruitment relationship following Francis (1992) was used. For the optional Beverton-Holt form we have:

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

where

- R_t is recruitment at age 1 in year *t*,
- B_t is the biomass of mature spawning females in year *t*,
- ε_t is the "recruitment anomaly" for year *t*,

α, β are stock-recruitment function parameters.

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

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

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. 1.47. For this assessment and the prior on steepness used 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 unreasonably 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.

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.

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

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

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

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

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:

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

where $\hat{R}_t$ is the original recruitment estimate in year *t* with $f\left(S_t^{'}\right)$ and $f\left(\widehat{S}_t\right)$ 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 product of the negative log-likelihood function and prior distributions. To fit large numbers of parameters in nonlinear models it is useful to be able to estimate certain parameters in different stages. The ability to estimate stages is also important in using robust likelihood functions since it is often undesirable to use robust objective functions when models are far from a solution. Consequently, in the early stages of estimation we use the following log-likelihood function for the survey and fishery catch at age data (in numbers):

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

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

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

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

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

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:

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

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

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

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:

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

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

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

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 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:

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

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 1991-2007. The model simply computes the values of $\bar{w}_i, \sigma_{w_i}^2$ based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

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

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 2011 and 2012 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} :

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

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

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

with N_j, s_j and w_j the estimated population numbers (begin year), selectivity and weights-at-age j, respectively. B_{msy} and B_t are the point estimates spawning biomass levels at equilibrium F_{msy} and in year t (at time of spawning). For these projections, catch must be specified (or solved for if in the current year when $B_t < B_{msy}$). For longer term projections a form of operating model (as has been presented for the evaluation of $B_{20\%}$) with feedback (via future catch specifications) using the control rule and assessment model would be required. Refinements to this approach are underway and are planned for the future assessments.

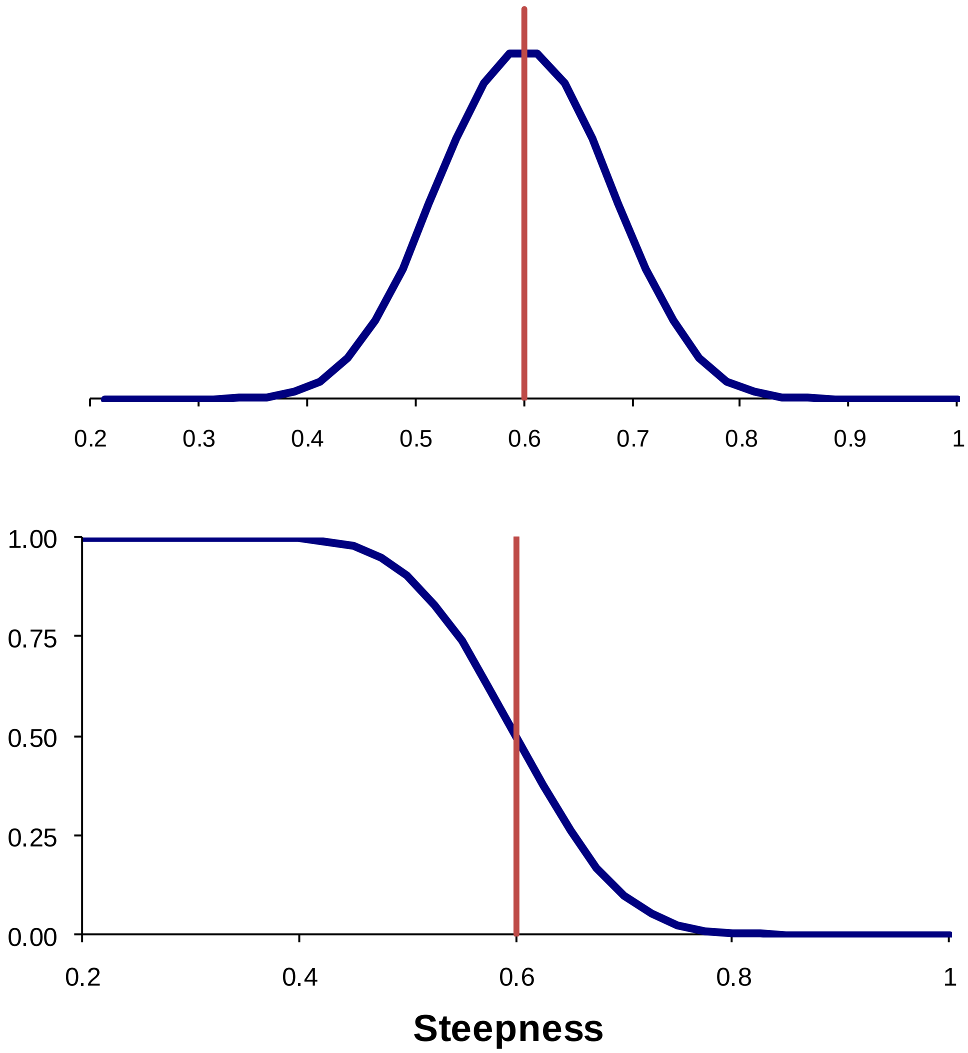


Figure 1.46. Cumulative prior probability distribution of steepness based on the beta distribution with α and β set to values which assume a mean and CV of 0.6 and 0.12, respectively. This prior distribution implies that there is about 8% chance that the value for steepness is greater than 0.7. See text for discussion.

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