# 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 2011 NMFS summer bottom-trawl survey (BTS) abundance at age estimates were computed and included for this assessment.
- The 2010 age composition estimates were updated using AT age data (last year the age-length key used was derived from the 2010 BTS age data).
- Observer data for age and average weight-at-age from the 2010 fishery was finalized and formally included.
- Total catch as reported by NMFS Alaska Regional office was updated and included through 2011.
- The acoustic index from the bottom trawl survey vessels presented in 2010 was updated from 2006-2011. This index is derived from opportunistic acoustic recordings from the fishing vessels (so called acoustic vessels of opportunity or AVO index) chartered to conduct the bottom trawl survey and has been shown to be consistent with the AT survey data.

Changes in the assessment model
The general modeling approach remained unchanged this year. An economic vector to weight relative costs and value by age classes was developed as part of the model $F_{MSY}$ calculations for sensitivity.

Changes in the assessment results
The estimated increase in female spawning stock biomass is moderated somewhat from the 2010 assessment though continues to be projected as above $B_{msy}$ level in 2012 and is expected to continue increasing. Similar to the 2010 assessment, the maximum permissible Tier 1a ABC remains high since positive signs for incoming year classes continue (albeit moderated somewhat). The available data indicate that the spawning biomass for 2012 is projected to be slightly below the level expected from last year's assessment. Since in 2011 the stock remains composed of many immature (three year old) pollock and is recovering from recent low levels, the recommended ABC (1,088,000 t) is below the maximum permissible (Tier 1a) level. Other rationales for extra precaution are given in the section on ABC recommendation. The Tier 1a overfishing level (OFL) is estimated to be 2,474,000 t.

Summary results for EBS pollock.

| **Quantity** | As estimated or *specified last* year for: 2011 | 2012 | As estimated or *recommended this* year for: 2012 | 2013 |
|---|---|---|---|---|
| *M* (natural mortality rate, ages 3+) | 0.3 | 0.3 | 0.3 | 0.3 |
| Tier | 1a | 1a | 1a | 1a |
| Projected total (age 3+) biomass (t) | 9,620,000 t | 11,318,000 t | 8,341,000 t | 8,690,000 t |
| Female spawning biomass (t) | | | | |
| Projected | 2,444,500 t | 3,019,500 t | 2,379,000 t | 2,534,000 t |
| $B_0$ | 5,140,000 t | 5,140,000 t | 5,329,000 t | 5,329,000 t |
| $B_{MSY}$ | 1,948,000 t | 1,948,000 t | 2,034,000 t | 2,034,000 t |
| $F_{OFL}$ | 0.640 | 0.640 | 0.6 | 0.6 |
| $maxF_{ABC}$ | 0.564 | 0.564 | 0.533 | 0.533 |
| $F_{ABC}$ | 0.332 | 0.332 | 0.296 | 0.296 |
| OFL (t) | 2,447,000 t | 3,170,000 t | 2,474,000 t | 2,842,000 t |
| maxABC (t) | 2,154,000 t | 2,255,000 t | 2,198,000 t | 2,526,000 t |
| ABC (t) | 1,267,000 t | 1,595,000 t | 1,088,000 t | 1,142,000 t |
| **Status** | As determined *last* year for: 2009 | 2010 | As determined *this* year for: 2010 | 2011 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

## Response to SSC and Plan Team comments

*In October 2010 the SSC reiterated a previous recommendation that the assessment authors evaluate whether a plausible stock recruitment relationship, consistent with a Tier 1 designation, is still an appropriate basis for computing reference points in light of the apparent strong variation in recruitment related to the recent stanzas of warm and cold years. In the November 2010 the Plan Team recommended 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 and also develop guidance regarding which year classes to include in estimation of the stock-recruitment relationship (for Tier 1 stocks) and which year classes to include in estimation of average recruitment (for Tier 3 stocks). In December 2010 the SSC concurred with this recommendation.*

Unfortunately, a specific workshop on stock recruitment issues surrounding Alaska groundfish failed to occur in 2011. However, the lead author did present results of a meta-analysis on groundfish stock recruitment at an invited international workshop. A key topic of the workshop dealt with evaluating whether life-history correlates (e.g., longevity) appears to be related to stock recruitment productivity.

Additionally, results from the BSIERP project and the BASIS surveys provide carefully developed hypotheses on factors affecting pollock survival from age 0 to age 1. Results from this workshop and the new indices using environmental hypothesis are presented in the section titled "Recruitment."

*Continue work on incorporating an ageing error matrix into the model. This would make the model more consistent with the Aleutian Islands and GOA assessments.*

Age determination errors were again evaluated and results are presented under the section titled "Model Evaluations."

*Conduct a retrospective analysis on average fishing mortality to understand how actual harvest rates correspond to the harvest control rule. Current average fishing mortality is relatively high compared to previous time periods. This will also help in future decisions to reduce ABC from the maximum permissible value.*

Retrospective analyses were carried out again this year (back to 1992) and additional information was compiled to evaluate harvest strategies and issues related to the way the stock recruitment curve is used as part of the control rule.

*Determine if it is possible to determine at what age year class strength is set. Sometimes year classes appear strong but then fail to materialize at older ages. A retrospective analysis of patterns in the apparent availability of age-2 and age-3 pollock to the bottom trawl and acoustic surveys may help inform the model about the strength of incoming year classes.*

This was evaluated as part of the retrospective analysis mentioned above. Results indicate that *on average*, the model tends to underestimate year-classes until about the 6$^{th}$ year they are observed. However, this weighted average is affected by recruitment magnitudes (which is heavily influenced by the 1992 year class). The past several above-average year classes (1996, 2000, 2006) were overestimated in the early years when few observations were available. Additionally, an evaluation of when recruitments were "set" was conducted from this. Results indicate that errors based on retrospective analyses were highest for ages 1 and 2 which provide some justification for omitting their effects in stock recruitment curve fitting. Further details are provided in the section titled "Recruitment".

*Continue evaluation of the AVO index.*

This year the time series from this index increased by two years and now extends from 2006-2011. These data were consistent with the bottom-trawl survey and provide valuable new information for the pollock assessment.

*Under general SAFE report comments they requested that if alternative models are available, they be arrayed so that ABC and OFL and status determinations can be selected. They also requested that authors incorporate their best estimate of total landings that will occur for the entire year.*

Alternatives for ABC recommendations are provided in entirety for different Tier levels. Should unanticipated alternative models be requested by the SSC or Plan Teams, results from those alternatives can be done and provided by contacting the lead author.

Catch for 2011 was based on the expected total-year estimate.

## 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. Such syntheses of egg and larval distribution data provide a useful baseline for comparing trends in the distribution of pre-spawning pollock.

## Fishery

From 1954 to 1963, EBS pollock catches were low until directed foreign fisheries began in 1964. Catches increased rapidly during the late 1960s and reached a peak in 1970-75 when they ranged from 1.3 to 1.9 million t annually (Fig. 1.1). Following the peak catch in 1972, bilateral agreements with Japan and the USSR resulted in reductions.

Since 1977 (when the U.S. EEZ was declared) the annual average EBS pollock catch has been about 1.2 million t ranging from 0.815 million t in 2009 to nearly 1.5 million t during 2003-2006 (Fig. 1.1). United States vessels began fishing for pollock in 1980 and by 1987 they were able to take 99% of the quota. Prior to the domestication of the pollock fishery, the catch was monitored by placing observers on foreign vessels. Since 1988, only U.S. vessels have been operating in this fishery. By 1991, the current NMFS observer program for north Pacific groundfish fisheries was in place.

The international zone of the Bering Sea, commonly referred to as the "Donut Hole" is entirely contained in the deep water of the Aleutian Basin and is distinct from the customary areas of pollock fisheries, namely the continental shelves and slopes. Japanese scientists began reporting the presence of large quantities of pollock in the Aleutian Basin in the mid-to-late 1970's. By the mid-late 1980s foreign vessels were intensively fishing in the Donut Hole. In 1984, the Donut Hole catch was 181 thousand t (Table 1.1). The catch grew rapidly and by 1987 the high seas pollock catch exceeded that within the U.S. Bering Sea EEZ. The extra-EEZ catch peaked in 1989 at 1.45 million t and has declined sharply

since then. By 1991 the Donut Hole catch was 80% less than the peak catch, and catch 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 but there was a slight overall increase in 2010 (Fig. 1.3). This increase (even though the total tonnage was about the same) is due to the relatively younger pollock in the population and catches (e.g., a drop in mean length and mean age of the 2010 catch; Fig. 1.4 top and middle panels). As expected, the trend in proportion of the catch that is immature has also increased since 2008 but is about average (Fig. 1.4, bottom panel).

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.

Summer and fall fishing (B-season) in 2009 and 2010 was concentrated more in the NW region whereas for 2011 catches were more centrally located. Also, due to increased observer coverage for the 2011 shore-based catcher fleet comparability between other years (e.g., the apparent catch increase inside the CVOA region) is limited (Fig. 1.5).

The 2011 bottom temperatures were considerably warmer than in the past 5 years and this may have affected the distribution of pollock (see discussion of bottom trawl survey results below). Of particular concern is the apparent drop in nominal catch rate experienced by all fleets since the beginning of August 2011. Catch per hour towed based on observer data was about equal to the value observed in 2008 (which was estimated to be a low point in biomass in previous assessments) and considerably lower than typical for that time of year (Fig. 1.6).

To investigate fishery catch rates in more detail, a qualitative examination was undertaken with a special focus on B-season rates experienced by shore-based catcher vessels. The first step for this analysis was to extract all available observer data since 1990 and compare total observed pollock catch by vessel. When ranked by observed catch and plotted, these vessels sorted into two categories: the first 25 boats "group-1" had similar levels of catch followed by the next 28 boats which had catches similar to eachother ("group-2"; Fig. 1.7). Vessels falling in these two categories were selected for subsequent catch rate evaluations. Their average nominal catch rates (in kg per hr) followed similar trends between the two groups with both groups indicating a drop in B-season rates for 2011 (Fig. 1.8). A simple factor affecting catch rates can be the geographical locales. For example, the higher catch rates from 2010 coincided with more tows located in the northwest region (Fig. 1.9). Another way to evaluate the experiences of the

fishery is to examine catch rates by individual vessel. This was done by **ranking** each vessel's catch-rate records (for B-season only) relative to that vessel's performance in other years. This was intended to answer the question (on an individual vessel basis) "How many past years were worse than (say) 2011 conditions?" This analysis was restricted to the "group-1" catcher boats for presentation purposes and standardized so that the rankings would have a common number of reference years (to avoid the confusion of comparing boats that had a 16 year history with others that had shorter or longer histories). Consistent with a drop in average fishing rates shown above, most vessels ranked 2011 as one of their worse years (though for some boats 2011 was better than average; Fig. 1.10, lower right panel). This indicates that there is a fair amount of variability within the fleet but that 2007 and 2008 were uniformly worse compared to 2011.

New in this year's evaluation is an analysis relating spatial characteristics of pollock body size to distance from port was conducted. Generally speaking, smaller pollock (in B-season) are found farthest from port (Dutch Harbor, AK). The purpose of this study (presented in "Model Evaluation" section below) was to examine the potential for considering the costs associated with capturing different size pollock.

### 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 be seasonally and spatially explicit to be consistent with area-wide and annual exploitation rates for pollock. Three types of measures were implemented in the pollock fisheries: 1) pollock fishery exclusion zones around sea lion rookery or haulout sites; 2) phased-in reductions in the seasonal proportions of TAC that can be taken from critical habitat; and 3) additional seasonal TAC releases to disperse the fishery in time.

Prior to the management measures, the pollock fishery occurred in each of the three major fishery management regions of the North Pacific Ocean managed by the NPFMC: the Aleutian Islands (1,001,780 km$^2$ inside the EEZ), the Eastern Bering Sea (968,600 km$^2$), and the Gulf of Alaska (1,156,100 km$^2$). The marine portion of Steller sea lion critical habitat in Alaska west of 150°W encompasses 386,770 km$^2$ of ocean surface, or 12% of the fishery management regions.

Prior to 1999 84,100 km$^2$, or 22% of critical habitat, was closed to the pollock fishery. Most of this closure consisted of the 10- and 20-nm radius all-trawl fishery exclusion zones around sea lion rookeries (48,920 km$^2$ or 13% of critical habitat). The remainder was largely management area 518 (35,180 km$^2$, or 9% of critical habitat) which was closed pursuant to an international agreement to protect spawning stocks of central Bering Sea pollock.

In 1999, an additional 83,080 km$^2$ (21%) of critical habitat in the Aleutian Islands was closed to pollock fishing along with 43,170 km$^2$ (11%) around sea lion haulouts in the GOA and Eastern Bering Sea. In 1998, over 22,000 t of pollock were caught in the Aleutian Island regions, with over 17,000 t caught in Aleutian Islands critical habitat region. Between 1998 and 2004 a directed fishery for pollock was prohibited. Consequently, 210,350 km$^2$ (54%) of critical habitat was closed to the pollock fishery. The portion of critical habitat that remained open to the pollock fishery consisted primarily of the area between 10- and 20-nm from rookeries and haulouts in the GOA and parts of the southeastern Bering Sea foraging area. In 2000, phased-in reductions in the proportions of seasonal TAC that could be caught

within the BSAI Steller sea lion Conservation Area (SCA) were implemented. Since 2005, a limited pollock fishery has been prosecuted in the Aleutian Islands but with less than 2,000 t of annual catch.

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

On the EBS shelf, an estimate (based on observer at-sea data) of the proportion of pollock caught in the SCA has averaged about 38% annually. During the "A-season," the average is about 49% (since pollock are more concentrated in this area during this period). The proportion of pollock caught within the SCA varies considerably, presumably due to temperature regimes and population age structure. Since 2005 the annual proportion of catch within the SCA has dropped considerably with about 30% of the catch taken in this area. However, the proportion taken in the A-season reached 57% in 2007, the highest level since 1999 (Table 1.2).

An additional goal to minimize potential adverse effects on sea lion populations is to disperse the fishery throughout more of the pollock range on the Eastern Bering Sea shelf. While the distribution of fishing during the A season is limited due to ice and weather conditions, there appears to be some dispersion to the northwest area (Fig. 1.2).

During 2008 - 2011, bycatch levels for Chinook salmon have been well below average following record high levels in 2007. This is likely due to industry-based restrictions on areas where pollock fishing may occur, environmental conditions, and perhaps salmon abundance.

A major salmon bycatch management measure went into effect in 2011 (Amendment 91 to the Groundfish FMP in response to the NPFMC's 2009 action). The program imposes a dual cap system which is divided by sector and season. Annual bycatch is intended to remain below the lower cap to avoid penalty. In order to fish under the dual cap system (as opposed to solely the lower cap) sectors must participate in incentive program agreements (IPAs) that are approved by NMFS and are designed for further bycatch reduction and individual vessel accountability. The fishery has been operating under rules to implement this program since January 2011. Bycatch in recent years is much lower than the recent 10-year average, ranging from 9,000-12,000 fish since 2008) and substantially reduced from the historical high in 2007 of 121,000 fish. Chinook salmon caught as bycatch in the pollock fishery tend to be a higher proportion of western Alaskan origin. An Environmental Impact Statement (EIS) was completed in 2009 in conjunction with the Council's recommended management approach. This EIS evaluated the relative impacts of different bycatch management approaches as well as estimated the impact of bycatch levels on adult equivalent salmon (AEQ) returning to river systems (NMFS/NPFMC 2009).

Additional measures to reduce chum salmon bycatch in the pollock fishery are currently under development. Previously bycatch of chum salmon was managed using a broad scale time and area closure (the Chum Salmon Savings Area). Bycatch levels for chum salmon in 2005 were the highest on record (more than 700,000 fish) but levels have been much lower, ranging from 13,000 – 46,000 since 2008 until this year with bycatch exceeding 180,000 chum salmon. These elevated levels may be related to good runs returning to western Alaska river systems and to the continued large levels of hatchery releases from Asia. In June 2011 a draft Environmental Assessment was presented to the Council specifically on the impact of the chum salmon bycatch on western Alaska systems. The analysis

indicated that the impact rates to Alaska rivers (specifically western Alaska) appeared to be below 2% in the worse year (with caveats that genetic data failed to discern small regions which could potentially have been more heavily impacted than adjacent larger systems). Further Council action will occur in 2012 to recommend different management measures for chum salmon bycatch.

Salmon bycatch statistics are presented along with other bycatch estimates in the Ecosystem Considerations section below.

### Catch data

From 1977-2011 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). In 2011, the TAC was increased due to favorable signs of the 2006 and 2008 year classes and the catch is projected to be 1,150,000 t.

Pollock catch in the Eastern Bering Sea and Aleutian Islands by area from observer estimates of retained and discarded catch for 1991-2011 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 1991-2010 (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. In 2010 the fishery catch consisted primarily of age 4 pollock (the 2006 year class)

compared to past years when the age ranges varied between age 4 and 7 being the predominate age group (Fig. 1.11). 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 2011 the BTS biomass estimates ranged from 2.28 to 8.46 million t (Table 1.9; Fig. 1.12). 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 during 2006-2010. Large-scale zoogeographic shifts in the EBS shelf due to temperature changes have been documented during a warming trend (e.g., Mueter and Litzow 2008). However, after a period of relatively warm conditions ending in 2005, five years were below average and the zoogeographic response may be less predictable than they showed. In 2011 bottom temperatures increased to about average relative to 2010 whereas the surface temperature was colder than 2010 and remains well below average (Fig. 1.13). This is unusual since surface temperatures generally track bottom temperature trends in other years.

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 2011 biomass estimate was 3.11 million t, a drop of 17% from the 2010 value (3.75 million t) and 35% below the mean value for this survey (4.77 million t). This survey estimate ranks 21st out of the 25 estimates since 1987. In 2011, the distribution of pollock was densest closest to the convention line (border with Russian waters) and generally more broadly distributed across the shelf due to slightly warmer conditions (Fig. 1.14).

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. 1.15). The BTS survey operations generally catch pollock above 40 cm in length, and in some years include many 1-year olds (with modal lengths around 10-19 cm) and rarely age 2 pollock (lengths around 20-29 cm) during the summer. Other sources of variability may be due to unaccounted-for variability in natural mortality and migration. For example, some strong year classes appear in the surveys over several ages (e.g., the 1989 year class) while others appear at older ages (e.g., the 1992 year class). Also, from assessment model estimates the estimated strength of the 1996 year class has apparently waned compared to estimates from earlier years. Ianelli et al. (2007) reported a point estimate for the 1996 year class at around 32 billion one-year olds whereas in 2003, the estimate had been 43 billion. This could be due in part to emigration (and subsequent return) of this year-class outside of our main fishery and survey zones. Alternatively, this may reflect the effect of variable natural mortality rates. Retrospective analyses (e.g., Parma 1993) have also highlighted these patterns as presented in Ianelli et al. (2006) and redone in this assessment (see below).

The 2011 survey age compositions were developed from age-structures collected and processed at the AFSC labs within a few weeks after the survey was completed. The level of sampling for lengths and ages in the BTS is shown in Table 1.11. The estimated numbers-at-age from the BTS for the standard strata (1-6) and for the northern strata included are presented in Table 1.12.

As in previous assessments, an analysis using survey data alone was conducted to evaluate mortality patterns. Cotter et al. (2004) promoted this type of analysis as having a simple and intuitive appeal which is independent of population scale. In this approach, log-abundance of age 6 and older pollock is regressed against age by cohort. The negative values estimated for the slope are estimates of total annual mortality. Age-6 was selected because younger pollock are still recruiting to the bottom trawl survey gear. A key assumption of this analysis is that all ages are equally available to the gear. Total mortality by cohort seems to be variable (unlike the example in Cotter et al., 2004) with lower mortality overall for cohorts during the early 1990s followed by increases and a subsequent decline for the most recent cohort (Fig. 1.16). It appears that the total mortality has decreased somewhat on recent cohorts. Total mortality estimates by cohort represent lifetime averages since harvest rates (and actual natural mortality) vary from year to year. The low values estimated from some year classes (e.g., the 1990-1992 cohorts) could be because these age groups had only become available to the survey at a later age (i.e., that the availability/selectivity to the survey gear changed for these cohorts). Alternatively, it may suggest some net immigration into the survey area or a period of lower natural mortality. In general, these values are consistent with the types of values obtained from within the assessment models for total mortality. The higher recent values are somewhat expected given recent population trends. Please note that slope estimates for recent cohorts are relatively poorly determined since only a few abundance-at-ages are available (e.g., 5 years/data points for 2002 year class).

### Acoustic trawl (AT) surveys

The AT surveys are conducted biennially and are designed to estimate the off-bottom component of the pollock stock (compared to the BTS which are conducted annually and provide an abundance index of the near-bottom pollock). In 2011 the survey vessel operated in the Gulf of Alaska so the most recent estimate is from 2010 with a biomass estimate of 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 2010 survey and their estimated abundances were above the expectations projected from Ianelli et al.

(2009). The high abundance of 2-year olds was consistent with the above-average 1-year old abundance observed in 2009 and appeared consistent based on examination of the recent years abundance at length data where the modes corresponding to ages are clear (Fig. 1.17).

NMFS scientists extended the acoustic trawl survey into the Russian zone five times since 2004—most recently in 2010. 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. The number of trawl hauls and lengths and ages sampled from the AT survey are presented in Table 1.13.

In the 2010 stock assessment, the 2010 AT survey population numbers at age estimates were computed based on age-length keys compiled from the 2010 bottom-trawl survey. These were updated using geographically split age-length keys (E and W of 170°W) from the AT survey age data (rather than the BTS age data Table 1.14; Fig. 1.18).

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 25% for application within the assessment model.

Comparing the geographical differences between the BTS and the AT survey suggests that in some areas the major concentrations of pollock are either nearer the bottom or in mid-water and in other areas concentrations overlap (Fig. 1.19).

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

Acoustic data collected from commercial fishing vessels used for the eastern Bering Sea bottom trawl (BT) survey have been analyzed for several years now (e.g.,Von Szalay et al., 2007, Kotwicki et al., 2009, Honkalehto et al. 2011). Since this survey overlaps in space and time with the normal AT survey, a comparison of acoustic backscatter data between the two surveys was completed to determine feasibility of using the BT survey data to provide a new midwater pollock index (Honkalehto et al. 2011). Analysis of four years of AT survey data (1999, 2000, 2002, and 2004) identified a suitable index area to track midwater pollock abundance. Details for the AVO index methods are provided in Honkalehto et al. (2011). A key to this work included defining an area of the shelf where pollock were consistently found and easily indexed using acoustic backscatter at a single frequency, 38 kHz. Pollock backscatter from this index area was classified through a combination of visual examination by trained analysts and semi-automated processing in which all backscatter in a specified depth range was assumed to be pollock. Integrated 38 kHz backscatter in the index area classified using this approach was well correlated with AT survey biomass in the U.S. EEZ. Since 2006, commercial fishing vessels chartered for the BT survey have collected 38 kHz backscatter in this area, and AVO indices calculated from these data have also compared well with AT survey biomass estimates (2006-2009), providing information on both the biomass and spatial distribution of midwater pollock. The addition of 2010 data continued to be consistent between surveys ($r^2$ = 0.91; Fig. 1.20). Spatially, these areas appear consistent with both the bottom trawl survey in 2011 (Fig. 1.21). The precision of this index of pollock biomass for 2006-2011 was assumed to have an average CV of 33% (Table 1.16). This compares to the average CV assumed for the AT survey of 25%.

### Russian surveys in the Navarin/Anadyr region and western Bering Sea

Additional survey information from the Russian zone was obtained this year which included a time series of survey results covering the period 1990-2011 (Kuznetzov pers. comm.; Table 1.17). Biomass estimates from this region have been made available along with size composition estimates (sometimes with multiple surveys per year; Fig. 1. 22). Even though survey methodologies and sureveyed areas are not consistent through this time series, examination of this figure shows patterns that are consistent with strong year classes in the US zone of the EBS. For example, the number of one year olds (at about 15cm length) in 2007 is indicative of a strong 2006 year class and modes shown in 2002 and 2003 are consistent with strong 2000 year class. In some surveys there appears to be inconsistencies (e.g., poor showing of one year olds in 2001 and also in 2009). This may be partly explained by temperature conditions which indicate that during warmer years the abundance in Russian surveys tends to be greater (Fig. 1. 23). This is consistent with the temperature and distribution shifts of pollock found by Kotwicki et al. (2005). This may affect fishing conditions if pollock are more dispersed across a broader area. Also in 2002 and 2003 (warm years) it seems that more fish become apparent later in the summer possibly indicating an inflow of fish into Navarin/Anadyr area from the south (either from the EBS or western BS). This was not the case in 2007, a cold year.

### BASIS survey

Since 2006, BASIS survey scientists have collected acoustic backscatter both in and outside of standard survey areas usually from August through early October (after the AFSC standard BT and AT surveys have concluded). Surface and mid-water trawls have been conducted in recent years to provide information on ecosystem wide changes with particular reference to pelagic ecosystems. The research has focused on young-of-year pollock and juvenile salmon in particular. In 2011, several patches of age-2+ pollock were observed north of St. Matthew Island. Samples from these patches indicated a size distribution consistent with the 2008 year class. Based on qualitative examination of previous years' surveys in this region, the abundance of age 2 and older pollock for 2009, and 2010 appeared to be low (pers. comm. Sandra Parker-Stetter). Observations of three year-olds in 2011 (based on qualitative examinations), indicate that environmental conditions *may* have shifted the distribution of pollock outside of the standard survey areas. This is consistent with changes in the extent of the cold pool in 2011, temperature-related movement patterns hypothesized by Kotwicki et al. (2005), the density of pollock observed in bottom trawls relative to bottom temperatures, and the abundance of the 2008 year class.

## 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 1964-2011. 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 2011 EBS bottom trawl survey estimate of population numbers-at-age was added.
- The 2010 EBS AT survey estimate of population numbers-at-age were revised from last year using age data from the AT survey (in the 2010 assessment the values were based on an age-length key from the 2010 BTS survey data).
- The 2010 fishery age composition data were added.

- A revised index of abundance using acoustic backscatter data recorded aboard vessels conducting the bottom trawl survey from 2006-2011 was included. This index is based on methods detailed in Honkalehto et al. (2011).
- An evaluation of when recruitment estimates might be reliably included for stock-recruitment relationship estimation was conducted.
- Some economic factors accounting for the relationship between travel times, tow duration, and ex-vessel value to sizes of pollock were examined.

## 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 2010 CIE review requested that age-determination errors be re-examined. Ageing errors were consequently re-evaluated (Ianelli et al. 2010). They found that reader experience had similar

outcomes and percent agreements in reader-tester subsamples suggesting that the otoliths themselves were the cause of the variability as opposed to reader experience. The age-determination error methods and deviations at age was found by minimizing the differences between the observed and predicted percent agreements using a special case of Punt et al. (2008).

Regular age-determination methods coupled with extensive length and weight data collections show that growth may differ by sex, area, and year class. Pollock in the northwest area typically are smaller at age than pollock in the southeast area. The differences in average weight-at-age are taken into account by stratifying estimates of catch-at-age by year, area, season and weighting estimates proportional to catch.

Stock assessment models for groundfish in Alaska typically track numbers of individuals in the population. Management recommendations are based on allowable catch levels expressed as tons of fish. While estimates of pollock catch-at-age are based on large data sets, these are typically only available up until the most recent completed calendar year of fishing (i.e., 2010 for the assessment conducted in 2011). Consequently, estimates of weight-at-age in the current year are required to map total catch biomass (typically equal to the quota) to numbers of fish caught.

The mean weight at age in the fishery can vary due to environmental conditions in addition to spatial and temporal patterns of the fishery. For estimation errors due to sampling, bootstrap distributions of the variability (within-year) indicate that this source is relatively small compared to the between-year variability in mean weights-at-age implying that processes causing mean weights in the fishery cause more variability than sampling (Table 1.18). The coefficients of variation between years are on the order of 6% to 9% (for the ages that are targeted) whereas the sampling variability is generally around 1% or 2%.

Alternative estimators for mean weight at age were developed in Ianelli et al. (2009) and the same approach was selected for 2011 (and future year) mean weights at age (the most recent 10-year mean). The 2010 revised mean weights-at-age are larger than assumed for last year but mainly for age classes that are relatively low in abundance (i.e., ages 6 and older; Fig. 1.24).

### Parameters estimated conditionally

For the selected model, 803 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 49 parameters and the age-time forms a 10x49 matrix of 490 parameters bringing the total fishing mortality parameters to 538.

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 fishery catch-per-unit effort (CPUE) data (from Low and Ikeda, 1980), the early bottom trawl survey data (where only 6 strata were surveyed), the main bottom trawl survey data, and the AT survey data.

Based on the work of Von Szalay et al. (2007) prior distributions on the sum of the AT and BTS catchability coefficients were introduced in Ianelli et al. (2007). This simply allows an evaluation of the extent that BTS survey covers the bottom-dwelling pollock (up to ~3 m above the bottom) and the AT survey covers the remainder of the water column. 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, $\sigma$=0.05)
- Log-normal indices of abundance (numbers of fish; bottom trawl surveys assume annual estimates of sampling error, as represented in Fig. 1.12; for the AT index the annual errors were specified to have a mean of 0.25 whilst for the AVO data, a relative value was assumed which gave a mean of about 0.33).
- Fishery and survey proportions-at-age estimates (robust quasi-multinomial with effective sample sizes presented in Table 1.19).
- 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 revisions to values compared to the 2010 assessment)
b) Updating the 2010 fishery mean weights-at-age
c) Update the 2010 AT age data (using age determinations as collected from this survey rather than borrowing from the BTS).

These refinements were considered straightforward improvements and were included in all subsequent analyses. As in past assessments, the inclusion of age determination errors was also evaluated.

As requested by the Plan Team and SSC, we conducted an analysis that evaluated whether given the data, a characteristically strong year class can be "reliably" included. This implies that the statistical assumptions are specified correctly and that other the model specifications (e.g., for process errors) are correct. One approach to evaluate model performance is through retrospective analyses (e.g., Ianelli et al. 2006). The statistics to evaluate the retrospective analysis were focused on the tendencies for errors in recruitment and used the ratio of estimates from a particular retrospective "year" relative to estimates in 2011. For example, if the retrospective "year" was 2005, then data after 2005 would be omitted and all recruitment estimates up to 2005 would be evaluated relative to those recruitments as estimated in 2011. The evaluation criteria for the appropriate number of years to include in estimating the stock recruitment relationship thus included the potential for bias and variability.

Following selection of a model based on the retrospective analysis, the influence of the new data in 2011 was evaluated. This showed sensitivities to the new data as follows (note that the most recent Acoustic Trawl data were from 2010 so they are excluded from these sensitivities):

| Shorthand | Description |
|---|---|
| **C** | 2010 total catch only included |
| **CA** | Catch and 2010 fishery age data included |
| **CAB** | Catch, age, and bottom-trawl survey |
| **CAS** | Catch, age, and the new AVO (Sa) index |
| **CABS** | Catch, age bottom-trawl survey, and the new AVO (Sa) index |

*Additional consideration of size-specific fishery characteristics*

Fishing conditions are affected by the population age structure in a number of ways. For EBS pollock, with reasonably high inter-annual variability in year-class strengths, the population experiences fluctuations between being relatively "young" due to strong year classes entering the fishable ages (e.g., 2011 conditions) and relatively "old" where there was a 4-5 year gap in strong year classes from 2001-2006 (e.g., conditions during 2008). Since young and older pollock differ in where they tend to concentrate, these population fluctuations affect the relative spatial abundance *even at the same population biomass*. Namely, younger pollock tend to be more concentrated northwest of the Pribilof Islands—farther from Dutch Harbor, the principal offload port for shore-based catcher vessels. The working hypothesis is that as pollock grow, they move more to the east of the Pribilof Islands and consequently, would require less travel time for fishing trips. This suggests that pollock age and travel time (costs) from Dutch Harbor are related. This relationship is explored by embedding age-specific estimates of the costs into the yield estimation process. Additionally, there are trade-offs between the average tow duration and the distance from port that are related to the average size of the pollock in the catch. Specifically, age schedules are developed which can serve as a proxy for relative costs of fishing and, combined with a range of plausible relative ex-vessel values, can provide alternative yield curves.

Observer data were compiled for the period 2003-2011 (through Sept 15$^{th}$, 2011). These data contain measurements of the mean body mass of pollock in the catch. During this period more than 23,600 directed pollock fishing operations (for shore-based catcher vessels) were available for analysis. Statistics were compiled based on the mean body mass of pollock in the catch and subsequently categorized within 50 g intervals. For example, if a tow had a mean weight of 480 g then that tow (distance from port, tow duration) was pooled into the "500 g" category (the intervals were centered on 50 g increments). The number of tows (B season, shore based vessels) by size category is shown in Table 1.20 and the relative frequency is shown in Fig. 1.25.

Since tows are categorized by pollock mean body mass and the "costs" of fishing being considered here are the distance from port (Fig. 1.26) and the mean duration of tows (Fig. 1.27), it is important to combine these metrics on a common relative scale. This was done by converting tow duration to a kilometer scale by assuming initially that each hour towing consumed the same amount of fuel as transiting the grounds at 10 knots. This is likely to overestimate the fuel consumption during fishing because clearly vessels tow at slower speeds. However, the higher value was used to account for the extra power expended for towing and winch operations etc. Sigmoidal functions were fit to these distance measures and then converted to relative values by age (matching mean body mass with the nearest age; Table 1.21; Fig. 1.28).

Eliciting estimates on the fishery-wide relative value of pollock is a highly complicated and dynamic issue. A partial list of complicating factors affecting the value of pollock based on body size includes:

- The variability of sizes in the catch
- The product mix (e.g., surimi versus meal versus fillets)
- Recovery rates
- "age" of the delivery (how long fish were in hold prior to offload)
- Global market demand
- Exchange rates

With these caveats, a simple weight-specific pattern was developed which was governed by one parameter: the slope of relative value change for a 650 g (~age 5) pollock. The age-(~mean weight) specific relationships can be compared with observations on prices and sizes paid from shore-based plants should those data become available. This slope extended to age 3 (~370g) and out to age 7 (~870g). Fish older than age 7 were set equal to the age 7 value and age 2 fish were set to be 10% of the value of age 5 pollock.

A policy for the North Pacific Fisheries Management Council calls for an allocation of the TAC between the shore-based fishing sector and the at-sea processors. Since the calculations involved here only consider the shore-based fleet, and it could be argued that the at-sea fleet is neutral on costs of fishing relative to tow duration and distance from port. As such, the inverse age-specific cost was taken to be the weighted (60-40) average between the combined distance from port/tow duration estimate and the neutral (no added costs by age). This range was primarily to evaluate the sensitivity of the inputs. The effect of this weighting along with an example relative value by age with the relative value slope parameter fixed at 0.1 is shown in Fig. 1.29. Such age-specific schedules can be applied to evaluate whether the optimum yield is attained at stock sizes different than $B_{msy}$ (given the assumptions of the model). It should be noted that this focuses on B-season only (60% of the TAC allocation). This is reasonable since distances are generally less of an issue during A-season (the fleet is typically constrained by ice) and also, since they target pre-spawning mature pollock, the issue of age-selection is less important.

## Model evaluation results

*Results from retrospective analyses*

The retrospective analysis shows that recruitment generally tends to be underestimated when few years of data are available compared to the most current estimate (when the most data are available), especially for strong year classes (Fig. 1.30). The variability in estimates was particularly high for years when recruits were included in the model for a few years (Fig. 1.31; top panel). Recent strong year classes (1996, 2000, and 2006) tended to be overestimated compared to others (in particular 1992; Fig. 1.31; bottom panel). Also, the retrospective pattern varied for some of these year classes as well (switching from over- to underestimates). Overall, the variability of the ratio was highest for recruits that were only included in the model for less than three years (Fig. 1.32). Consequently, although the statistical components based on included data are an integral part of the estimation procedure, the additional variability when few years of data are available provides some justification for excluding them from productivity estimates (i.e., factoring into the stock recruitment curve estimation). This is also consistent with the notion that the assessment is generally two-stages: first to estimate the status and size of the population and secondarily, to evaluate the productivity of the resource. We argue here that resource productivity estimates should be based on results that are robust to model mis-specification issues as has been identified here via retrospective analyses. For the remaining analyses, the recruitment estimates from the most recent two years are omitted from the stock recruitment estimation. Note that this year's productivity estimate will include the information pertaining to the strength of the 2008 year class—the 2009 and 2010 year-classes (as age-1 recruits in 2010 and 2011) are omitted.

*Results from alternative model configurations*

Adding in the effect of age-determination errors degraded the negative log-likelihood by 26 units, 17 of which came from the fishery age composition data. The recruitment variability increased from 0.62 to

0.75 and the estimate of $B_{msy}$ also declines by about 9%. Other measures of stock condition were fairly similar (2011 spawning biomass differed by 4%). For consistency with past assessments and given the better fit to the data, we omitted age-determination error conversion matrix from subsequent model evaluations.

The sequential addition of new data to the model indicated that the BTS survey decreased the estimate of the 2008 year class slightly but increased the "fishable biomass" whereas the $F_{msy}$ rate was relatively insensitive to new data (Fig. 1.33). Closer examination of the age data that affect results show how incremental additions reflect the influence of the other sources of information. For example, the fits for model "CA" (only new data include 2010 fishery catch and age compositions) to the observed 2011 bottom-trawl survey age compositions (Fig. 1.34) were particularly poor for the age 4 group of fish in the BTS and the age 2 fish in the AT survey. The addition of the 2010 and 2011 AVO data had only imperceptible effect on fitting the age data (Fig. 1.34; bottom two panels). However, the overall effect of adding the AVO index into the model resulted in slightly lower biomass but was relatively consistent with other data (Fig. 1.35).

The sensitivity of $F_{msy}$ rates to the demographic spatial patterns was apparent when profiling over alternative F's (Fig. 1.36). Preliminary results on including the spatial demography indicates that a lower fishing mortality (on average) would result in better use of the resource depending on the relative weights and the additional value (or not) of large versus small pollock (Table 1.22). With a 60-40 weighting and assuming all sizes of pollock are equally valuable (during B-season), results indicate that the optimal harvest rate would be about 86% of the rate assumed without consideration of the distance required to catch smaller pollock. For that scenario, the optimal spawning stock biomass is about 11% larger than $B_{msy}$. Note that since the functional form is between relatively costs and pollock age, results are independent of actual (non-zero) fuel costs (since for this scenario, pollock of all ages are considered equally valuable).

## Time series results

The estimated selectivity pattern changes over time and reflects to some degree the extent that the fishery is focused on particularly prominent year-classes (Fig. 1.37). The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 1.38). The fit to the early Japanese fishery CPUE data (Low and Ikeda 1980) is consistent with the population trends for this period (Fig. 1.39).

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 and 2011 surveys (Fig. 1.40). The pattern of bottom trawl survey age composition data in recent years shows a reduction in relative importance of the 2000 year class and that in 2011 the large proportion of the ages belonging to the 2006 year class as five-year olds with the model predicting more than observed in the survey (Fig. 1.41, bottom-right panel).

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. 1.42; 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 25%) with a fairly reasonable pattern of residuals (Fig. 1.42; 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. 1.43). 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. 1.43; bottom panel).

The estimate of $B_{msy}$ is 2,034,000 t (with a CV of 20%) which is less than the projected 2012 spawning biomass of 2,379,000 t; Table 1.23). For 2011, the Tier 1 levels of yield are 2,198 thousand t from a

fishable biomass estimated at around 4,126,000 t (Table 1.24). Estimated numbers-at-age are presented in Table 1.25 and estimated catch-at-age presented in Table 1.26. Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment is given in Table 1.27.

The results indicate that spawning biomass will be below the $B_{40\%}$ (2,572,000 t ) in 2012 but 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 2011 and decreases for 2012 (Fig. 1.44).

Another metric on the impact of fishing suggests that the 2011 spawning stock size is about 53% of the predicted value had no fishing occurred since 1978 (Table 1.23). This compares with the 33% of $B_{100\%}$ (based on the SPR expansion from mean recruitment from 1978-2011) and 39% 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 1981-88, with estimates ranging from 8 to 12 million t (Table 1.28). Historically, biomass levels have increased from 1979 to the mid-1980's due to the strong 1978 and relatively strong 1982 and 1984 year classes recruiting to the fishable population. The stock is characterized by peaks in the mid 1980s and mid 1990s with a substantial decline to about 5.9 million t by 1991 and another low point occurring in 2008 at 4.4 million t[*]. Relative to last year's assessment which projected an age 3+ biomass of 11.3 million t for 2012 (which has now been revised to **8.3** million t) the largest contribution to this change is due to the change in estimates of the 2009 and 2008 year classes (Fig. 1.45).

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. 1.46). The estimate for 2009 through 2011 is below 20% due to the reductions in TACs arising from the ABC control rules. Age specific fishing mortality rates were fairly steady and were similar to the SER time series (Fig. 1.47)

Spawning biomass is projected to increase under a wide variety of catch scenarios (Fig. 1.48). 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. 1.49, Table 1.28). This is due primarily to the revised estimate of the 2006 year class (currently estimated at 30.6 billion compared to the 2009 estimate of 24.5 billion and the 2010 estimate of 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. 1.50).

### Recruitment

In the 2011 BTS survey, the number of 1-year olds (the 2010 year class) was close to the average observed in that survey (Fig. 1.51). Last year, the 2009 year class showed mixed signals from the appearance of one-year olds in the 2010 BTS and AT surveys. The number of 1-year olds in the 2010 surveys (the 2009 year class) was above average in the AT survey and below average in the BTS.

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

Data from the 2010 and 2011 bottom trawl survey continue to indicate a relatively strong 2006 year class that is about 40% above the average (Fig. 1.52, top panel). This compares with the 2008 year class that appears to be about 50% above the mean value (but with considerable uncertainty).

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. 1.52; bottom panel). Note that the 2009 and 2010 year classes (as age 1 recruits in 2010 and 2011) are excluded from estimating the stock-recruitment curve.

*Environmental factors affecting recruitment*

Previous studies linked strong Bering Sea pollock recruitment to years with warm sea temperatures and northward transport of pollock eggs and larvae (Wespestad et al. 2000; Mueter et al. 2006). As part of the "Bering-Aleutian Salmon International Survey" (BASIS) project research has also been directed on the relative density and quality (in terms of condition for survival) of young-of-year pollock. For example, Moss et al. (2009) found age-0 pollock were very abundant and widely distributed to the north and east on the Bering Sea shelf during 2004 and 2005 (warm sea temperature; high water column stratification) indicating high northern transport of pollock eggs and larvae during those years. More recently, Mueter et al. (2011) found that warmer conditions tended to result in lower pollock recruitment in the EBS. This is consistent with the hypothesis that when sea temperatures on the eastern Bering Sea shelf are warm and the water column is highly stratified during summer, age-0 pollock appear to allocate more energy to growth than to lipid storage, leading to low energy density prior to winter. This then may result in increased over-winter mortality (Swartzman et al. 2005, Winter et al. 2005). Ianelli et al. (2011) evaluate the consequences of current harvest policies in the face of warmer conditions and potentially lower pollock recruitment.

Results from the BASIS research project suggest that age-0 pollock abundance was low during 2006 and 2007 (cool sea temperatures; lower water column stratification; Moss et al., 2009). However, age-1 pollock (from the 2008 cohort) were evident in the BASIS survey in 2009 which may indicate changes in spatial and vertical distribution due to environmental conditions and/or that the 2008 year class is abundant (which would be consistent with the recent AT surveys). The hypothesis is that the condition (or fitness) and the abundance of age 0 pollock during late summer are predictors for the overwintering survival to age-1 and thus year class strength. During the warm years from 2003 to 2005, the late summer energy density of age-0 pollock was at the spring threshold level suggesting that there could be high overwinter mortality on age-0 pollock during these years (Fig.1.53; Ron Heintz, NMFS/NOAA pers. comm.). During the cold years from 2006 to 2010, the late summer energy density was significantly higher than the following spring threshold level suggesting that these fish would have higher overwinter survival. Based on direct measurements of energy density from samples of age-0 pollock indicate that the 2010 year class should be above average (Ron Heintz, pers. comm.).

A separate survival index based on working hypotheses for conditions favorable for the overwintering survival of pollock in the Bering Sea was developed by scientists at the Auke Bay Lab. This index is based on temperature change and calculated as the difference between average monthly sea surface temperature in June and the previous August. Positive anomalies of this index represent a cool late summer during the age-0 phase (making fish more energy rich) followed by a warm spring (early ice retreat and more food at the right time for pelagic species) in the age-1 phase. These conditions are assumed favorable for the overwintering survival of pollock from age-0 to age-1 (Martinson et al. In Review). This relationship as applied to current conditions (June 2011 temperature and August 2010 temperatures) also suggests an above-average 2010 year class.

These two relatively independent methods for predicting pollock recruitment indicate that the 2010 year class is above average. The only direct observation on abundance arises from the BTS data which indicate that (relative to historical survey estimates of age-1 pollock) is estimated to be average (99.6% of

the mean). Note that this estimate may be affected by the apparent shift in distribution due to temperature changes observed in 2011. The model point estimate of the 2010 year class is 21,811 compared to the mean age-1 recruitment of 21,899 (in millions).

As environmental conditions are likely to affect recruitment, and given the results from the retrospective analysis presented in the above section "Model evaluation" it seems prudent to omit the recent two years of recruitment estimates from the stock recruitment fitting. The estimates remain integral to the current stock status condition (and associated uncertainty), but omitted from contributing to system productivity estimates (i.e., the stock recruitment relationship).

## 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:

$B_{msy}$ = 2,034 thousand t female spawning biomass

$B_0$ = 5,329 thousand t female spawning biomass

$B_{100\%}$ = 6,431 thousand t female spawning biomass*

$B_{40\%}$ = 2,572 thousand t female spawning biomass

$B_{35\%}$ = 2,251 thousand t female spawning biomass

### Specification of OFL and Maximum Permissible ABC

The 2012 spawning biomass is estimated to be 2,379,000 t (at the time of spawning, assuming the stock is fished at recommended ABC level). This is above the $B_{msy}$ value of 2,034,000 t. Under Amendment 56, this stock has qualified under Tier 1 and the harmonic mean value is considered a risk-averse policy since reliable estimates of $F_{msy}$ and its pdf are available (Thompson 1996). The exploitation-rate type value that corresponds to the $F_{msy}$ level was applied to the "fishable" biomass for computing ABC levels. For a future year, the fishable biomass is defined as the sum over ages of predicted begin-year numbers multiplied by age specific fishery selectivity (normalized to the value at age 6) and mean body mass (10-year average).

* Note that another theoretical "unfished spawning biomass level" (based on stock-recruitment relationship, $\tilde{B}_0$) is somewhat lower (5,329 kt).

Since the 2012 estimate of female spawning biomass is estimated to be above the $B_{msy}$ level (2,034 kt) but below the $B_{40\%}$ value (2,572 kt), the OFL's and maximum permissible ABC values by Tier are:

| Tier | Year | MaxABC | OFL |
|---|---|---|---|
| 1a | 2012 | 2,198,000 t | 2,474,000 t |
| 1a | 2013 | 2,526,000 t | 2,842,000 t |
| | | | |
| 3b | 2012 | 1,245,000 t | 1,507,000 t |
| 3a | 2013 | 1,466,000 t | 1,629 ,000 t |

## 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 2011 and refinements to the treatment of earlier data suggest that the stock is near $B_{msy}$ levels with near-term outlook apparently favorable. Under likely catch projections, the spawning stock biomass is expected be about 125% of $B_{msy}$ (2,034 kt) by 2012 with future status depending on specified catch levels (Fig. 1.54, 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 one year class in 2012 remains relatively high (~37% by weight)
- Two surveys indicated a drop in biomass from 2010
- Retrospective patterns indicate that recent strong recruitments tend to be over estimated
- A weak relationship between bottom temperature in the EBS (US zone) and biomass in the Russian Navarin area are positively correlated indicating a shift in spatial distribution
- A shift in spatial distribution (of 3-yr olds) in 2011 was apparent based on BASIS survey transects outside of standard survey areas in September
- Poor catch rates in the fishery starting in August 2011 affected the fishery considerably and the catch for 2011 is anticipated to fall short of the TAC by about 8%.
- In 2010, the proportion of a single age class contributing to the spawning biomass is estimated to have been the highest (including projections) for the period 1990-2015 (Fig. 1.55).
- The 2011 BTS pollock biomass estimate was 3.11 million t, a drop of 17% from the 2010 value (3.74 million t) and 35% below the mean value for this survey (4.76 million t).
- The 2011 BTS survey estimate ranks 21$^{st}$ out of the 25 estimates since 1987.
- The AVO index also indicated a decline similar to that of the BTS in 2011
- Catch "targeting" of 2008 year class (three year olds) may be higher than indicated by the assumed selectivity-at-age
- 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. This was demonstrated by a quantitative analysis accounting for the spatial distribution of pollock by size.
- Russian catches in the Navarin region may have more of an impact if the distribution of pollock has shifted considerably.
- Estimates of the 2008 (and 2009) year class are highly uncertain.

Given these factors, an added adjustment in harvest rates seems justified to ensure that fishing mortality increases at a more incremental pace. The current assessment model and data indicate that the 2008 year class is above average and that conditions appear favorable for 2010 (though the model estimates are presently slightly below average for that year class). These estimated conditions result in a maximum

permissible Tier 1a ABC that is very high even though the incoming year classes remain highly uncertain. As highlighted by the 2010 CIE review, some age specific fishing mortality rates had reached high levels even though spawning stock exploitation rates were moderate (e.g., Fig. 1.46). The fishing mortality (effort) that would be required to attain the maximum permissible would be considerably higher than recent levels. Facing these uncertain conditions, it would be prudent to proceed with stable or gradual increases in fishing mortality.

Selecting the approach used in 2010—that of stabilizing the fishing mortality rather than calling for increases—with the 2008 year class as estimated results in a catch of about 1.22 million t. However, given the uncertain status of incoming year classes and the conditions that seem to have dispersed pollock more than observed in recent years, we recommend that the 2012 ABC be set to the recent average fishing mortality *assuming that the 2008 year class is set to average*. This results in a 2012 ABC of 1,088,000 t. At this level of fishing the spawning biomass is projected to continue increasing and the 2013 ABC would be 1,142,000 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 2011 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2011. 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 were used as estimated except that the 2 and 3-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 2012 and 2013, 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 the average $F$ 2007-2011 (as Authors' recommendation). *NOTE this is identical to scenario 3.*

*Scenario 3*: In all future years, $F$ is set equal to the 2007-2011 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 2012 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

*Scenario 7*: In 2012 and 2013, $F$ 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 2011 (Table 1.29). Under Tier 3 Scenarios 1 and 2, the expected spawning biomass will increase and stabilize around $B_{40\%}$ (in expectation) in a few years (Fig. 1.54).

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 1.29). 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 1.29). The values that correspond with this projection scenario is provided in Table 1.30. As an alternative, projections were also conducted with the 2008 year class set to the mean value (Table 1.31).

For harvest recommendations a proxy for Tier 1 calculations were made that give ABC and OFL values for 2012 and 2013 (assuming catch is 1,200,000 t in 2012 (Table 1.32).

## 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 overlap of the pollock fishery and

northern fur seal foraging habitat (see Sterling and Ream 2004, Zeppelin and Ream 2006) will require careful monitoring and evaluation.

A brief summary of these two perspectives (ecosystem effects on pollock stock and pollock fishery effects on ecosystem) is given in Table 1.33. Unlike the food-web models discussed above, examining predators and prey in isolation may overly simplify relationships. This table serves to highlight the main connections and the status of our understanding or lack thereof.

### Ecosystem effects on the EBS pollock stock

Euphausiids, principally *Thysanoessa inermis* and *T. raschii*, are among the most important prey items for pollock in the Bering Sea (Livingston, 1991; Lang et al., 2000; Brodeur et al., 2002; Cianelli et al., 2004; Lang et al., 2005). In the 2009 SAFE report, an analysis of MACE AT survey backscatter as an index of euphausiid abundance on the Bering Sea shelf was presented. In 2010 the index was updated and spatial distributions and trends were evaluated using methods described in De Robertis et al., (2010) and Ressler et al. (accepted). New information on euphausiid abundance is anticipated from the planned 2012 surveys.

### EBS pollock fishery effects on the ecosystem.

Since the pollock fishery is primarily pelagic in nature, the bycatch of non-target species is small relative to the magnitude of the fishery (Table 1.34). Jellyfish represent the largest component of the bycatch of non-target species and have been stable at around 5-6 thousand tons per year with catches exceeding 8 thousand t in 2000, 2009, and 2011. Skate bycatch nearly doubled in 2008 compared to 2007 but declined to just over one thousand t in 2010 (Table 1.34). The data on non-target species shows a high degree of inter-annual variability which reflects the spatial variability of the fishery and high observation error. This variability may mask any significant trends in bycatch.

The catch of other target species in the pollock fishery represent less than 1% of the total pollock catch. Incidental catch of Pacific cod has increased since 1999 but remains below the 1997 levels (Table 1.35). The incidental catch of flatfish was variable over time and has increased, particularly for yellowfin sole in 2010. Proportionately, the incidental catch has decreased since the overall levels of pollock catch have increased. In fact, the bycatch of pollock in *other* target fisheries is more than double the bycatch of target species in the pollock fishery (Table 1.36).

The catch of prohibited species was also variable but showed noticeable trends, particularly increased "other salmon" (mainly comprising chum salmon) in 2011 (Table 1.37). Also, the level of crab bycatch drops considerably after 1998 when all BSAI pollock fishing was restricted to using only pelagic trawls but bairdi crab has averaged just under 10 thousand animals since 2008. Chinook salmon bycatch in the pollock fishery have averaged 17.7 thousand fish since 2008. Much of the salmon bycatch variability is likely attributed salmon run sizes (and in the case of chum salmon-hatchery releases) and also to environmental conditions. The bycatch rate per hour towed based on a subset of catcher vessels (Group-1 used above) shows a significant degree of inter-annual variability (Fig. 1.56).

## 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 1.38.

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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, 1979-2011 (2011 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 | 356,258 | 451,688 | 807,947 | | | |
| 2010 | 253,935 | 555,013 | 808,948 | | | |
| 2011 | 445,239 | 726,483 | 1,171,722 | | | |
| Average | 757,848 | 422,166 | 1,180,014 | | | |
| | 64% | 36% | | | | |

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

| | A season | B-season | Total |
|---|---|---|---|
| 1998 | 385,000 t (82%) | 403,000 t (38%) | 788,000 t (60%) |
| 1999 | 339,000 t (54%) | 468,000 t (23%) | 807,000 t (36%) |
| 2000 | 375,000 t (36%) | 572,000 t ( 4%) | 947,000 t (16%) |
| 2001 | 490,000 t (27%) | 674,000 t (46%) | 1,164,000 t (38%) |
| 2002 | 566,000 t (54%) | 690,000 t (49%) | 1,256,000 t (51%) |
| 2003 | 616,000 t (45%) | 680,000 t (42%) | 1,296,000 t (43%) |
| 2004 | 531,000 t (45%) | 711,000 t (34%) | 1,242,000 t (38%) |
| 2005 | 529,000 t (45%) | 673,000 t (17%) | 1,203,000 t (29%) |
| 2006 | 533,000 t (51%) | 764,000 t (14%) | 1,298,000 t (29%) |
| 2007 | 480,000 t (57%) | 663,000 t (11%) | 1,143,000 t (30%) |
| 2008 | 342,000 t (46%) | 490,000 t (12%) | 832,000 t (26%) |
| 2009 | 283,000 t (26%) | 389,000 t (13%) | 671,000 t (24%) |
| 2010 | 281,000 t (17%) | 412,000 t (9%) | 693,000 t (12%) |
| 2011 | 490,000 t (54%) | 531,000 t (28%) | 1,020,000 t (40%) |

Table 1.3. Time series of 1964-1976 catch (left) and ABC, TAC, and catch for EBS pollock, 1977-2011 in t. Source: compiled from NMFS Regional office web site and various NPFMC reports, ***catch for 2011 is based on an estimated projection***.

| Year | Catch | Year | ABC | TAC | Catch |
|---|---|---|---|---|---|
| 1964 | 174,792 | 1977 | 950,000 | 950,000 | 978,370 |
| 1965 | 230,551 | 1978 | 950,000 | 950,000 | 979,431 |
| 1966 | 261,678 | 1979 | 1,100,000 | 950,000 | 935,714 |
| 1967 | 550,362 | 1980 | 1,300,000 | 1,000,000 | 958,280 |
| 1968 | 702,181 | 1981 | 1,300,000 | 1,000,000 | 973,502 |
| 1969 | 862,789 | 1982 | 1,300,000 | 1,000,000 | 955,964 |
| 1970 | 1,256,565 | 1983 | 1,300,000 | 1,000,000 | 981,450 |
| 1971 | 1,743,763 | 1984 | 1,300,000 | 1,200,000 | 1,092,055 |
| 1972 | 1,874,534 | 1985 | 1,300,000 | 1,200,000 | 1,139,676 |
| 1973 | 1,758,919 | 1986 | 1,300,000 | 1,200,000 | 1,141,993 |
| 1974 | 1,588,390 | 1987 | 1,300,000 | 1,200,000 | 859,416 |
| 1975 | 1,356,736 | 1988 | 1,500,000 | 1,300,000 | 1,228,721 |
| 1976 | 1,177,822 | 1989 | 1,340,000 | 1,340,000 | 1,229,600 |
| | | 1990 | 1,450,000 | 1,280,000 | 1,455,193 |
| | | 1991 | 1,676,000 | 1,300,000 | 1,195,646 |
| | | 1992 | 1,490,000 | 1,300,000 | 1,390,331 |
| | | 1993 | 1,340,000 | 1,300,000 | 1,326,601 |
| | | 1994 | 1,330,000 | 1,330,000 | 1,329,350 |
| | | 1995 | 1,250,000 | 1,250,000 | 1,264,245 |
| | | 1996 | 1,190,000 | 1,190,000 | 1,192,778 |
| | | 1997 | 1,130,000 | 1,130,000 | 1,124,430 |
| | | 1998 | 1,110,000 | 1,110,000 | 1,101,165 |
| | | 1999 | 992,000 | 992,000 | 989,816 |
| | | 2000 | 1,139,000 | 1,139,000 | 1,132,707 |
| | | 2001 | 1,842,000 | 1,400,000 | 1,387,194 |
| | | 2002 | 2,110,000 | 1,485,000 | 1,480,195 |
| | | 2003 | 2,330,000 | 1,491,760 | 1,490,899 |
| | | 2004 | 2,560,000 | 1,492,000 | 1,480,543 |
| | | 2005 | 1,960,000 | 1,478,500 | 1,483,286 |
| | | 2006 | 1,930,000 | 1,485,000 | 1,486,435 |
| | | 2007 | 1,394,000 | 1,394,000 | 1,354,097 |
| | | 2008 | 1,000,000 | 1,000,000 | 990,566 |
| | | 2009 | 815,000 | 815,000 | 807,947 |
| | | 2010 | 813,000 | 813,000 | 808,948 |
| | | 2011 | 1,270,000 | 1,252,000 | *1,150,000* |
| | 1977-2011 average | | 1,381,657 | 1,192,350 | 1,168,097 |

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, 1991-2011. SE represents the EBS east of 170° W, NW is the EBS west of 170° W, source: NMFS Blend and catch-accounting system database. 2011 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 | 140 (11%) | 53 (30%) | 1,021 (0.2%) | 1,246 (0.5%) | 2,459 (0.3%) | 1,282 | 176 | 555,013 | 253,759 | 810,231 |
| 2011 | 74 (6%) | 19 (14%) | 1,216 (0.3%) | 1,318 (0.2%) | 2,628 (0.2%) | 1,159 | 137 | 445,239 | 726,483 | 1,173,017 |

Table 1.5. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2010. Units are in millions of fish.

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1979 | 101.4 | 543 | 719.8 | 420.1 | 392.5 | 215.5 | 56.3 | 25.7 | 35.9 | 27.5 | 17.6 | 7.9 | 3 | 1.1 | 2,567 |
| 1980 | 9.8 | 462.2 | 822.9 | 443.3 | 252.1 | 210.9 | 83.7 | 37.6 | 21.7 | 23.9 | 25.4 | 15.9 | 7.7 | 3.7 | 2,421 |
| 1981 | 0.6 | 72.2 | 1,012.70 | 637.9 | 227 | 102.9 | 51.7 | 29.6 | 16.1 | 9.3 | 7.5 | 4.6 | 1.5 | 1 | 2,175 |
| 1982 | 4.7 | 25.3 | 161.4 | 1,172.20 | 422.3 | 103.7 | 36 | 36 | 21.5 | 9.1 | 5.4 | 3.2 | 1.9 | 1 | 2,004 |
| 1983 | 5.1 | 118.6 | 157.8 | 312.9 | 816.8 | 218.2 | 41.4 | 24.7 | 19.8 | 11.1 | 7.6 | 4.9 | 3.5 | 2.1 | 1,745 |
| 1984 | 2.1 | 45.8 | 88.6 | 430.4 | 491.4 | 653.6 | 133.7 | 35.5 | 25.1 | 15.6 | 7.1 | 2.5 | 2.9 | 3.7 | 1,938 |
| 1985 | 2.6 | 55.2 | 381.2 | 121.7 | 365.7 | 321.5 | 443.2 | 112.5 | 36.6 | 25.8 | 24.8 | 10.7 | 9.4 | 9.1 | 1,920 |
| 1986 | 3.1 | 86 | 92.3 | 748.6 | 214.1 | 378.1 | 221.9 | 214.3 | 59.7 | 15.2 | 3.3 | 2.6 | 0.3 | 1.2 | 2,041 |
| 1987 | 0 | 19.8 | 111.5 | 77.6 | 413.4 | 138.8 | 122.4 | 90.6 | 247.2 | 54.1 | 38.7 | 21.4 | 28.9 | 14.1 | 1,379 |
| 1988 | 0 | 10.7 | 454 | 421.6 | 252.1 | 544.3 | 224.8 | 104.9 | 39.2 | 96.8 | 18.2 | 10.2 | 3.8 | 11.7 | 2,192 |
| 1989 | 0 | 4.8 | 55.1 | 149 | 451.1 | 166.7 | 572.2 | 96.3 | 103.8 | 32.4 | 129 | 10.9 | 4 | 8.5 | 1,784 |
| 1990 | 1.3 | 33 | 57 | 219.5 | 200.7 | 477.7 | 129.2 | 368.4 | 65.7 | 101.9 | 9 | 60.1 | 8.5 | 13.9 | 1,746 |
| 1991 | 0.7 | 111.8 | 39.9 | 86.5 | 139.2 | 152.8 | 386.2 | 51.9 | 218.4 | 21.8 | 115.0 | 13.8 | 72.6 | 59.0 | 1,469 |
| 1992 | 0.0 | 93.5 | 674.9 | 132.8 | 79.5 | 114.2 | 134.3 | 252.2 | 100.1 | 155.1 | 54.3 | 43.1 | 12.5 | 74.2 | 1,921 |
| 1993 | 0.2 | 8.1 | 262.7 | 1,146.2 | 102.1 | 65.8 | 63.7 | 53.3 | 91.2 | 20.5 | 32.3 | 11.7 | 12.5 | 23.2 | 1,893 |
| 1994 | 1.6 | 36.0 | 56.8 | 359.6 | 1,066.7 | 175.8 | 54.5 | 20.2 | 13.4 | 20.7 | 8.6 | 9.4 | 7.0 | 11.3 | 1,842 |
| 1995 | 0.0 | 0.5 | 81.3 | 151.7 | 397.5 | 761.2 | 130.6 | 32.2 | 11.1 | 8.5 | 18.2 | 5.5 | 6.3 | 10.6 | 1,615 |
| 1996 | 0.0 | 23.2 | 56.2 | 81.8 | 166.4 | 368.5 | 475.1 | 185.6 | 31.4 | 13.4 | 8.8 | 8.6 | 4.8 | 11.0 | 1,435 |
| 1997 | 2.4 | 83.6 | 37.8 | 111.7 | 478.6 | 288.3 | 251.3 | 196.7 | 61.6 | 13.6 | 6.4 | 5.0 | 3.5 | 15.9 | 1,556 |
| 1998 | 0.6 | 51.1 | 89.8 | 72.0 | 156.9 | 686.9 | 199.0 | 128.3 | 108.7 | 29.5 | 6.3 | 5.8 | 2.9 | 8.7 | 1,547 |
| 1999 | 0.4 | 11.6 | 295.0 | 227.7 | 105.3 | 155.7 | 473.7 | 132.7 | 57.5 | 32.9 | 3.5 | 2.2 | 0.7 | 2.3 | 1,501 |
| 2000 | 0.0 | 17.4 | 80.2 | 423.2 | 343.0 | 105.4 | 169.1 | 359.5 | 86.0 | 29.6 | 24.4 | 5.7 | 1.6 | 2.3 | 1,647 |
| 2001 | 0.0 | 3.7 | 56.8 | 162.0 | 574.8 | 405.8 | 136.1 | 129.2 | 158.3 | 57.5 | 35.1 | 16.0 | 5.9 | 5.1 | 1,746 |
| 2002 | 0.9 | 56.7 | 111.1 | 214.8 | 284.1 | 602.2 | 267.2 | 99.3 | 87.4 | 95.6 | 34.9 | 14.5 | 12.6 | 4.4 | 1,886 |
| 2003 | 0.0 | 17.3 | 402.2 | 320.8 | 366.8 | 305.2 | 332.1 | 157.3 | 53.0 | 40.2 | 36.5 | 23.7 | 7.0 | 7.0 | 2,069 |
| 2004 | 0.0 | 1.1 | 90.0 | 829.6 | 479.7 | 238.2 | 168.7 | 156.9 | 64.0 | 16.9 | 18.9 | 26.1 | 10.6 | 13.6 | 2,114 |
| 2005 | 0.0 | 3.1 | 53.7 | 391.2 | 861.8 | 489.1 | 156.4 | 67.5 | 67.1 | 33.7 | 11.2 | 10.2 | 3.4 | 5.5 | 2,154 |
| 2006 | 0.0 | 12.2 | 84.2 | 290.1 | 622.8 | 592.2 | 279.9 | 108.9 | 49.6 | 38.4 | 16.4 | 9.6 | 9.5 | 13.1 | 2,127 |
| 2007 | 1.8 | 19.5 | 57.2 | 124.2 | 374.0 | 514.7 | 306.3 | 139.0 | 50.2 | 28.0 | 23.3 | 9.4 | 6.5 | 16.3 | 1,671 |
| 2008 | 0.0 | 25.9 | 57.1 | 78.9 | 147.3 | 307.7 | 242.0 | 150.3 | 83.9 | 22.4 | 17.8 | 13.7 | 8.6 | 14.6 | 1,170 |
| 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 | 14.1 | 929 |
| 2010 | 0.7 | 28.7 | 31.2 | 561.4 | 221.2 | 54.8 | 43.2 | 54.6 | 49.8 | 33.4 | 14.4 | 9.2 | 5.1 | 12.5 | 1,120 |
| Average | 4.38 | 65.09 | 215.91 | 347.02 | 361.29 | 313.08 | 203.07 | 117.12 | 68.88 | 36.64 | 25.15 | 12.69 | 8.66 | 12.37 | 1,791 |
| Median | 0.51 | 25.61 | 89.91 | 258.94 | 354.37 | 263.24 | 162.56 | 102.11 | 58.61 | 27.77 | 17.98 | 9.52 | 6.09 | 9.85 | 1,813 |

Table 1.6. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2010, as sampled by the NMFS observer program.

| **Length** | A Season | | B Season SE | | B Season NW | | |
|---|---|---|---|---|---|---|---|
| **Frequency** | Males | Females | Males | Females | Males | Females | Total |
| 1977 | 26,411 | 25,923 | 4,301 | 4,511 | 29,075 | 31,219 | 121,440 |
| 1978 | 25,110 | 31,653 | 9,829 | 9,524 | 46,349 | 46,072 | 168,537 |
| 1979 | 59,782 | 62,512 | 3,461 | 3,113 | 62,298 | 61,402 | 252,568 |
| 1980 | 42,726 | 42,577 | 3,380 | 3,464 | 47,030 | 49,037 | 188,214 |
| 1981 | 64,718 | 57,936 | 2,401 | 2,147 | 53,161 | 53,570 | 233,933 |
| 1982 | 74,172 | 70,073 | 16,265 | 14,885 | 181,606 | 163,272 | 520,273 |
| 1983 | 94,118 | 90,778 | 16,604 | 16,826 | 193,031 | 174,589 | 585,946 |
| 1984 | 158,329 | 161,876 | 106,654 | 105,234 | 243,877 | 217,362 | 993,332 |
| 1985 | 119,384 | 109,230 | 96,684 | 97,841 | 284,850 | 256,091 | 964,080 |
| 1986 | 186,505 | 189,497 | 135,444 | 123,413 | 164,546 | 131,322 | 930,727 |
| 1987 | 373,163 | 399,072 | 14,170 | 21,162 | 24,038 | 22,117 | 853,722 |
| 1991 | 160,491 | 148,236 | 166,117 | 150,261 | 141,085 | 139,852 | 906,042 |
| 1992 | 158,405 | 153,866 | 163,045 | 164,227 | 101,036 | 102,667 | 843,244 |
| 1993 | 143,296 | 133,711 | 148,299 | 140,402 | 27,262 | 28,522 | 621,490 |
| 1994 | 139,332 | 147,204 | 159,341 | 153,526 | 28,015 | 27,953 | 655,370 |
| 1995 | 131,287 | 128,389 | 179,312 | 154,520 | 16,170 | 16,356 | 626,032 |
| 1996 | 149,111 | 140,981 | 200,482 | 156,804 | 18,165 | 18,348 | 683,890 |
| 1997 | 124,953 | 104,115 | 116,448 | 107,630 | 60,192 | 53,191 | 566,527 |
| 1998 | 136,605 | 110,620 | 208,659 | 178,012 | 32,819 | 40,307 | 707,019 |
| 1999 | 36,258 | 32,630 | 38,840 | 35,695 | 16,282 | 18,339 | 178,044 |
| 2000 | 64,575 | 58,162 | 63,832 | 41,120 | 40,868 | 39,134 | 307,689 |
| 2001 | 79,333 | 75,633 | 54,119 | 51,268 | 44,295 | 45,836 | 350,483 |
| 2002 | 71,776 | 69,743 | 65,432 | 64,373 | 37,701 | 39,322 | 348,347 |
| 2003 | 74,995 | 77,612 | 49,469 | 53,053 | 51,799 | 53,463 | 360,390 |
| 2004 | 75,426 | 76,018 | 63,204 | 62,005 | 47,289 | 44,246 | 368,188 |
| 2005 | 76,627 | 69,543 | 43,205 | 33,886 | 68,878 | 63,088 | 355,225 |
| 2006 | 72,353 | 63,108 | 28,799 | 22,363 | 75,180 | 65,209 | 327,010 |
| 2007 | 62,827 | 60,522 | 32,945 | 25,518 | 75,128 | 69,116 | 326,054 |
| 2008 | 46,125 | 51,027 | 20,493 | 23,503 | 61,149 | 64,598 | 266,894 |
| 2009 | 45,958 | 43,987 | 19,869 | 18,571 | 50,309 | 53,202 | 231,896 |
| 2010 | 39,495 | 41,054 | 40,449 | 41,323 | 19,194 | 20,591 | 202,106 |
| **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 |
| 2010 | 4,536 | 5,272 | 4,125 | 4,618 | 2,261 | 2,749 | 23,561 |

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 |
| 2010 | 624 | 545 | 465 | 414 | 504 | 419 | 2,971 |

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 1979-2011 (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% |
| 2011 | 3.112 | | | | |
| Average | 4.771 | 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 1982-2011.

| Year | Survey biomass estimates in strata 1-6 | Survey biomass estimates in strata 8 and 9 | All area Total | NW %Total |
|---|---|---|---|---|
| 1982 | 2,855,539 | | | |
| 1983 | 6,257,632 | | | |
| 1984 | 4,893,536 | | | |
| 1985 | 4,630,111 | 1,325,102 | 5,955,213 | 22% |
| 1986 | 4,896,780 | | | |
| 1987 | 5,111,645 | 386,788 | 5,498,433 | 7% |
| 1988 | 7,106,739 | 181,839 | 7,288,578 | 2% |
| 1989 | 5,905,641 | 643,938 | 6,549,579 | 10% |
| 1990 | 7,126,083 | 190,218 | 7,316,301 | 3% |
| 1991 | 5,064,313 | 62,446 | 5,126,759 | 1% |
| 1992 | 4,367,870 | 214,557 | 4,582,427 | 5% |
| 1993 | 5,521,208 | 105,707 | 5,626,916 | 2% |
| 1994 | 4,977,019 | 49,686 | 5,026,706 | 1% |
| 1995 | 5,408,653 | 68,541 | 5,477,195 | 1% |
| 1996 | 3,258,348 | 155,861 | 3,414,209 | 5% |
| 1997 | 3,036,898 | 762,954 | 3,799,852 | 20% |
| 1998 | 2,212,689 | 567,569 | 2,780,258 | 20% |
| 1999 | 3,598,286 | 199,786 | 3,798,072 | 5% |
| 2000 | 5,152,586 | 128,846 | 5,281,432 | 2% |
| 2001 | 4,145,746 | 51,108 | 4,196,854 | 1% |
| 2002 | 4,832,506 | 200,337 | 5,032,843 | 4% |
| 2003 | 8,106,139 | 285,902 | 8,392,041 | 3% |
| 2004 | 3,744,501 | 118,473 | 3,862,974 | 3% |
| 2005 | 5,168,295 | 152,300 | 5,320,595 | 3% |
| 2006 | 2,845,009 | 199,885 | 3,044,894 | 7% |
| 2007 | 4,156,687 | 179,986 | 4,336,672 | 4% |
| 2008 | 2,834,094 | 189,174 | 3,023,268 | 6% |
| 2009 | 2,231,225 | 51,184 | 2,282,409 | 2% |
| 2010 | 3,550,981 | 186,898 | 3,737,878 | 5% |
| 2011 | 2,945,640 | 166,672 | 3,112,312 | 5% |
| Avg. | 4,516,137 | 262,529 | 4,764,026 | 6% |

Table 1.11. Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982-2011. Years where only strata 1-6 were surveyed are shown in italics.

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

Table 1.12. Bottom-trawl survey estimated numbers (millions) at age used for the stock assessment model, 1982-2011 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 | 955 | 2,289 | 2,452 | 3,136 | 1,068 | 145 | 101 | 48 | 30 | 19 | 12 | 7 | 3 | 1 | 1 | 10,267 | 1,272 | 12% |
| 1983 | 3,909 | 582 | 1,278 | 2,266 | 5,051 | 1,552 | 286 | 157 | 71 | 61 | 46 | 16 | 7 | 5 | 2 | 15,290 | 1,192 | 8% |
| 1984 | 367 | 281 | 399 | 1,154 | 1,460 | 3,429 | 653 | 145 | 68 | 24 | 16 | 6 | 4 | 5 | 2 | 8,012 | 792 | 10% |
| 1985 | 4,789 | 677 | 2,565 | 833 | 2,878 | 1,836 | 1,273 | 252 | 65 | 53 | 18 | 6 | 7 | 1 | 0 | 15,253 | 1,949 | 13% |
| 1986 | 2,213 | 499 | 366 | 1,351 | 824 | 1,396 | 1,231 | 1,133 | 361 | 56 | 26 | 11 | 1 | 3 | 1 | 9,472 | 836 | 9% |
| 1987 | 345 | 560 | 723 | 539 | 3,246 | 913 | 918 | 370 | 1,197 | 189 | 57 | 23 | 4 | 2 | 2 | 9,090 | 1,126 | 12% |
| 1988 | 1,070 | 515 | 1,201 | 2,290 | 1,014 | 3,326 | 1,004 | 787 | 463 | 1,120 | 108 | 64 | 13 | 17 | 9 | 13,002 | 1,466 | 11% |
| 1989 | 761 | 225 | 428 | 1,411 | 3,198 | 645 | 2,486 | 379 | 471 | 182 | 581 | 101 | 89 | 45 | 63 | 11,067 | 1,136 | 10% |
| 1990 | 1,722 | 241 | 86 | 552 | 1,111 | 3,755 | 760 | 1,907 | 198 | 373 | 58 | 544 | 47 | 36 | 48 | 11,436 | 1,373 | 12% |
| 1991 | 2,427 | 662 | 234 | 76 | 463 | 431 | 1,425 | 536 | 1,161 | 304 | 420 | 88 | 266 | 38 | 35 | 8,567 | 827 | 10% |
| 1992 | 1,338 | 325 | 1,704 | 285 | 319 | 537 | 478 | 689 | 311 | 595 | 212 | 268 | 117 | 92 | 73 | 7,343 | 808 | 11% |
| 1993 | 2,354 | 335 | 711 | 2,989 | 651 | 524 | 277 | 386 | 529 | 327 | 287 | 209 | 165 | 92 | 110 | 9,945 | 919 | 9% |
| 1994 | 1,264 | 528 | 390 | 1,130 | 3,066 | 537 | 142 | 126 | 145 | 271 | 168 | 237 | 90 | 87 | 145 | 8,328 | 973 | 12% |
| 1995 | 1,441 | 142 | 270 | 1,227 | 1,607 | 2,571 | 1,088 | 288 | 179 | 116 | 220 | 91 | 168 | 68 | 101 | 9,577 | 1,800 | 19% |
| 1996 | 1,434 | 347 | 155 | 308 | 806 | 1,125 | 1,027 | 349 | 87 | 94 | 65 | 123 | 40 | 74 | 100 | 6,134 | 508 | 8% |
| 1997 | 2,244 | 339 | 147 | 180 | 2,171 | 1,011 | 627 | 784 | 137 | 70 | 53 | 59 | 96 | 32 | 111 | 8,060 | 1,081 | 13% |
| 1998 | 625 | 549 | 281 | 185 | 354 | 2,024 | 529 | 342 | 269 | 68 | 31 | 11 | 24 | 28 | 65 | 5,385 | 592 | 11% |
| 1999 | 818 | 704 | 646 | 701 | 401 | 726 | 1,846 | 514 | 260 | 243 | 91 | 39 | 16 | 24 | 82 | 7,111 | 834 | 12% |
| 2000 | 921 | 292 | 353 | 1,189 | 1,223 | 648 | 571 | 1,875 | 737 | 394 | 172 | 116 | 36 | 17 | 76 | 8,619 | 1,017 | 12% |
| 2001 | 1,467 | 842 | 441 | 407 | 1,035 | 1,094 | 475 | 240 | 719 | 519 | 202 | 163 | 66 | 23 | 65 | 7,756 | 695 | 9% |
| 2002 | 651 | 303 | 625 | 903 | 931 | 1,213 | 634 | 309 | 425 | 800 | 399 | 180 | 108 | 33 | 37 | 7,552 | 769 | 10% |
| 2003 | 376 | 124 | 723 | 1,179 | 1,377 | 1,244 | 1,652 | 915 | 411 | 536 | 1,081 | 469 | 179 | 89 | 69 | 10,425 | 1,863 | 18% |
| 2004 | 320 | 225 | 140 | 1,036 | 1,005 | 762 | 448 | 486 | 242 | 151 | 152 | 275 | 118 | 29 | 23 | 5,414 | 499 | 9% |
| 2005 | 345 | 124 | 185 | 799 | 2,319 | 1,579 | 838 | 387 | 297 | 230 | 60 | 127 | 207 | 81 | 84 | 7,662 | 743 | 10% |
| 2006 | 715 | 62 | 96 | 316 | 791 | 1,006 | 647 | 312 | 179 | 155 | 75 | 47 | 67 | 91 | 90 | 4,650 | 427 | 9% |
| 2007 | 2,023 | 48 | 117 | 336 | 1,057 | 1,245 | 905 | 656 | 278 | 125 | 116 | 101 | 46 | 58 | 113 | 7,224 | 669 | 9% |
| 2008 | 442 | 99 | 82 | 148 | 421 | 852 | 673 | 471 | 300 | 118 | 100 | 76 | 35 | 19 | 120 | 3,955 | 431 | 11% |
| 2009 | 677 | 166 | 344 | 372 | 220 | 319 | 435 | 343 | 251 | 122 | 82 | 28 | 28 | 14 | 59 | 3,458 | 415 | 12% |
| 2010 | 408 | 115 | 204 | 2,055 | 931 | 295 | 261 | 279 | 295 | 203 | 175 | 64 | 39 | 23 | 51 | 5,397 | 707 | 13% |
| 2011 | 983 | 101 | 200 | 280 | 1,434 | 710 | 213 | 122 | 191 | 190 | 159 | 121 | 51 | 24 | 63 | 4,844 | 453 | 9% |
| Avg | 1,313 | 410 | 585 | 988 | 1,414 | 1,248 | 797 | 520 | 344 | 257 | 175 | 122 | 71 | 38 | 60 | 8,343 | 939 | 11% |

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

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

Table 1.14. AT survey estimates of EBS pollock abundance-at-age (millions), 1979-2010. *NOTE: 2010 age specific values were preliminary and updated in 2011 with age samples from the AT survey sampling.* 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 (last year)* | *2,627* | *6,170* | *1,198* | *2,098* | *342* | *53* | *13* | *11* | *10* | *26* | *9,921* | *25%* | *12,548* |
| **2010 (as revised)** | **2,526** | **6,395** | **973** | **2,183** | **384** | **46** | **6** | **7** | **7** | **21** | **10,023** | **25%** | **12,548** |
| Avg. 1982-2010 | 1,958 | 2,321 | 2,058 | 1,838 | 943 | 495 | 325 | 163 | 66 | 112 | 8,321 | 20% | 10,279 |
| Median | 509 | 1,430 | 1,156 | 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** (nmi)$^2$ | **Biomass in millions of t** (percent of total) | | | | | | **Total Biomass (millions t)** | **Estimation Error (millions t)** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **SCA** | | **E170-SCA** | | **W170** | | | |
| **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 | 0.085 | (9%) | 0.029 | (3%) | 0.883 | (89%) | 0.997 | 0.076 |
| **2009** | 9 Jun -7 Aug | 91,414 | 0.070 | (8%) | 0.018 | (2%) | 0.835 | (90%) | 0.924 | 0.081 |
| **2010** | 5 Jun -7 Aug | 92,849 | 0.067 | (3%) | 0.113 | (5%) | 2.143 | (92%) | 2.323 | 0.139 |

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

Table 1.16. An abundance index derived from acoustic data collected opportunistically aboard bottom-trawl survey vessels (AVO index). Note $CV_{AT}^{t}$ and $CV_{AVO}^{t}$ are the coefficients of variation from using 1-D geostatistical estimates of sampling variability (Petitgas, 1993). The column titled $CV_{AT'}$ contain values of CV for the acoustic trawl survey used in the assessment (which has a mean of 25% over the whole time series) and the last column is $CV_{AVO'}^{t} = CV_{AT}^{t} \cdot r_A$ (shaded) for $t$=2006 through 2010 where $r_A = \sum_{t=2006}^{t=2010} CV_{AVO}^{t} \Big/ \sum_{t=2006}^{t=2010} CV_{AT}^{t}$ .

For 2011 the estimate is: $CV_{AVO'}^{2011} = CV_{AVO}^{2011} \cdot \sum_{t=2006}^{t=2010} CV_{AVO'}^{t} \Big/ \sum_{t=2006}^{t=2010} CV_{AVO}^{t}$ .

| | AT survey biomass (million t) | AT survey biomass* | $CV_{AT}$ | AVO Index | $CV_{AVO}$ | $CV_{AT'}$ | $CV_{AVO'}$ |
|---|---|---|---|---|---|---|---|
| 2006 | 1.560 | 0.471 | 0.039 | 0.555 | 0.051 | 0.160 | 0.211 |
| 2007 | 1.769 | 0.534 | 0.045 | 0.638 | 0.087 | 0.184 | 0.244 |
| 2008 | 0.997 | 0.301 | 0.076 | 0.316 | 0.064 | 0.313 | 0.414 |
| 2009 | 0.924 | 0.279 | 0.088 | 0.285 | 0.120 | 0.360 | 0.477 |
| 2010 | 2.323 | 0.701 | 0.060 | 0.679 | 0.086 | 0.246 | 0.325 |
| 2011 | Na | Na | Na | 0.543 | 0.057 | Na | 0.234 |
| 2006-2010 Mean | | 0.456 | 0.062 | 0.494 | 0.081 | 0.252 | 0.334 |

*Scaled to mean 1999-2004 mean

Table 1.17. Record of Russian research surveys occurring in the western Bering Sea area since 1990 (Stepanenko pers. comm.) and biomass estimates by year and survey that were made available (Kuznetzov pers. comm).

**Midwater and upper layer trawl surveys**

| Resarch vessel | Period |
|---|---|
| R/V Professor Soldatov | October-November, 1990 |
| R/V Professor Kizevetter | November-December, 1991 |
| R/V Professor Levanidov | July-August, 1992 |
| R/V Professor Kizevetter | July-August, 1993 |
| R/V Professor Levanidov | July-August, 1995 |
| R/V Professor Kaganovskiy | September, 1997 |
| R/V Professor Kaganovskiy | September-October, 1998 |
| R/V TINRO | September-October, 1999 |
| R/V TINRO | August-October, 2000 |
| R/V Professor Kaganovskiy | November, 2001 |
| R/V TINRO | July-September, 2002 |
| R/V TINRO | August-October, 2003 |
| R/V TINRO | June-September, 2004 |
| R/V TINRO | June-July, 2005 |
| R/V TINRO | July-September, 2006 |
| R/V TINRO | June-September, 2007 |
| R/V TINRO | September, 2008 |
| R/V TINRO | June-September, 2009 |
| R/V Professor Kaganovskiy | September-November, 2009 |
| R/V TINRO | September-October, 2010 |
| R/V Professor Kaganovskiy | September-October, 2011 |

| Year | Month | thousands of t |
|---|---|---|
| 1997 | November | 583 |
| 1998 | October | 461 |
| 1999 | October | 320 |
| 2000 | September | 118 |
| 2001 | November | 62 |
| 2002 | July | 80 |
| 2002 | August | 434 |
| 2003 | August | 609 |
| 2003 | September | 932 |
| 2005 | July | 499 |
| 2007 | July | 104 |
| 2007 | September | 95 |
| 2008 | September | 246 |
| 2009 | September | 50 |
| 2010 | September | 144 |
| 2011 | September | 406* |

*Preliminary

Table 1.18. 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: 2011 weight-at-age is treated as the ten-year average of values from 2001-2010.*

| | Mean weight-at-age (kg) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1964-1990 | 0.303 | 0.447 | 0.589 | 0.722 | 0.840 | 0.942 | 1.029 | 1.102 | 1.163 | 1.212 | 1.253 | 1.286 | 1.312 |
| 1991 | 0.287 | 0.479 | 0.608 | 0.727 | 0.848 | 0.887 | 1.006 | 1.127 | 1.125 | 1.237 | 1.242 | 1.279 | 1.244 |
| 1992 | 0.398 | 0.468 | 0.645 | 0.712 | 0.814 | 0.983 | 1.028 | 1.224 | 1.234 | 1.270 | 1.175 | 1.353 | 1.441 |
| 1993 | 0.495 | 0.613 | 0.656 | 0.772 | 0.930 | 1.043 | 1.196 | 1.230 | 1.407 | 1.548 | 1.650 | 1.688 | 1.635 |
| 1994 | 0.394 | 0.649 | 0.730 | 0.746 | 0.706 | 1.010 | 1.392 | 1.320 | 1.339 | 1.417 | 1.374 | 1.310 | 1.386 |
| 1995 | 0.375 | 0.502 | 0.730 | 0.843 | 0.856 | 0.973 | 1.224 | 1.338 | 1.413 | 1.497 | 1.395 | 1.212 | 1.363 |
| 1996 | 0.322 | 0.428 | 0.680 | 0.790 | 0.946 | 0.949 | 1.021 | 1.090 | 1.403 | 1.497 | 1.539 | 1.750 | 1.536 |
| 1997 | 0.323 | 0.466 | 0.554 | 0.742 | 0.888 | 1.071 | 1.088 | 1.240 | 1.410 | 1.473 | 1.724 | 1.458 | 1.423 |
| 1998 | 0.372 | 0.588 | 0.627 | 0.623 | 0.779 | 1.034 | 1.177 | 1.243 | 1.294 | 1.417 | 1.559 | 1.556 | 1.720 |
| 1999 | 0.400 | 0.502 | 0.638 | 0.701 | 0.727 | 0.901 | 1.039 | 1.272 | 1.207 | 1.415 | 1.164 | 1.141 | 1.319 |
| 2000 | 0.351 | 0.524 | 0.630 | 0.732 | 0.782 | 0.805 | 0.972 | 1.018 | 1.268 | 1.317 | 1.320 | 1.665 | 1.738 |
| 2001 | 0.324 | 0.497 | 0.669 | 0.787 | 0.963 | 0.995 | 1.062 | 1.137 | 1.327 | 1.451 | 1.585 | 1.466 | 1.665 |
| 2002 | 0.380 | 0.508 | 0.669 | 0.795 | 0.908 | 1.024 | 1.117 | 1.096 | 1.300 | 1.430 | 1.611 | 1.319 | 1.636 |
| 2003 | 0.484 | 0.550 | 0.650 | 0.768 | 0.862 | 0.954 | 1.085 | 1.224 | 1.213 | 1.227 | 1.445 | 1.340 | 1.721 |
| 2004 | 0.404 | 0.580 | 0.640 | 0.770 | 0.890 | 0.928 | 1.026 | 1.207 | 1.159 | 1.179 | 1.351 | 1.292 | 1.232 |
| 2005 | 0.353 | 0.507 | 0.639 | 0.739 | 0.880 | 0.948 | 1.063 | 1.094 | 1.267 | 1.312 | 1.313 | 1.164 | 1.419 |
| 2006 | 0.305 | 0.448 | 0.604 | 0.754 | 0.855 | 0.958 | 1.055 | 1.126 | 1.219 | 1.283 | 1.306 | 1.399 | 1.453 |
| 2007 | 0.338 | 0.509 | 0.642 | 0.782 | 0.960 | 1.104 | 1.196 | 1.276 | 1.328 | 1.516 | 1.416 | 1.768 | 1.532 |
| 2008 | 0.329 | 0.521 | 0.652 | 0.772 | 0.899 | 1.042 | 1.114 | 1.204 | 1.309 | 1.404 | 1.513 | 1.599 | 1.506 |
| 2009 | 0.345 | 0.548 | 0.687 | 0.892 | 1.020 | 1.153 | 1.407 | 1.486 | 1.636 | 1.637 | 1.817 | 2.176 | 2.292 |
| 2010 | 0.364 | 0.516 | 0.652 | 0.797 | 0.934 | 1.036 | 1.147 | 1.245 | 1.337 | 1.428 | 1.530 | 1.557 | 1.665 |
| *2011* | *0.368* | *0.519* | *0.651* | *0.770* | *0.884* | *1.003* | *1.131* | *1.228* | *1.324* | *1.419* | *1.475* | *1.502* | *1.577* |
| Stdev | 0.052 | 0.054 | 0.039 | 0.063 | 0.094 | 0.097 | 0.125 | 0.133 | 0.128 | 0.152 | 0.204 | 0.275 | 0.270 |
| CV | 14% | 10% | 6% | 8% | 11% | 10% | 11% | 11% | 10% | 11% | 14% | 18% | 17% |
| Mean | 0.364 | 0.516 | 0.652 | 0.797 | 0.934 | 1.036 | 1.147 | 1.245 | 1.337 | 1.428 | 1.530 | 1.557 | 1.665 |
| | Sampling error (from bootstrap) | | | | | | | | | | | | |
| 1991 | 8% | 4% | 3% | 2% | 2% | 4% | 2% | 6% | 3% | 6% | 4% | 6% | 4% |
| 1992 | 2% | 4% | 5% | 3% | 3% | 2% | 3% | 3% | 4% | 4% | 11% | 6% | 6% |
| 1993 | 2% | 1% | 3% | 4% | 4% | 4% | 3% | 4% | 4% | 6% | 7% | 10% | 8% |
| 1994 | 8% | 2% | 1% | 3% | 8% | 12% | 5% | 5% | 4% | 5% | 6% | 11% | 6% |
| 1995 | 5% | 3% | 2% | 1% | 3% | 4% | 6% | 6% | 5% | 10% | 6% | 48% | 6% |
| 1996 | 7% | 10% | 3% | 2% | 1% | 2% | 4% | 6% | 13% | 7% | 6% | 7% | 9% |
| 1997 | 9% | 2% | 1% | 2% | 2% | 2% | 3% | 6% | 10% | 9% | 14% | 6% | 7% |
| 1998 | 5% | 5% | 3% | 1% | 3% | 3% | 2% | 4% | 8% | 9% | 13% | 16% | 14% |
| 1999 | 1% | 1% | 2% | 2% | 1% | 2% | 3% | 4% | 12% | 19% | 42% | 102% | 22% |
| 2000 | 4% | 1% | 1% | 2% | 2% | 1% | 3% | 6% | 5% | 10% | 47% | 63% | 48% |
| 2001 | 5% | 3% | 1% | 2% | 3% | 3% | 2% | 4% | 5% | 6% | 8% | 10% | 33% |
| 2002 | 4% | 2% | 2% | 1% | 1% | 2% | 3% | 3% | 5% | 5% | 7% | 25% | 22% |
| 2003 | 1% | 2% | 1% | 2% | 1% | 2% | 3% | 5% | 5% | 6% | 10% | 28% | 13% |
| 2004 | 4% | 1% | 1% | 2% | 2% | 2% | 3% | 7% | 6% | 5% | 10% | 14% | 9% |
| 2005 | 4% | 1% | 1% | 1% | 2% | 3% | 3% | 4% | 7% | 6% | 20% | 35% | 20% |
| 2006 | 4% | 1% | 1% | 1% | 1% | 3% | 4% | 4% | 7% | 11% | 9% | 14% | 7% |
| 2007 | 3% | 2% | 1% | 1% | 1% | 2% | 3% | 4% | 5% | 9% | 9% | 7% | 6% |
| 2008 | 3% | 2% | 2% | 1% | 1% | 2% | 2% | 5% | 5% | 5% | 5% | 14% | 6% |
| 2009 | 3% | 2% | 4% | 2% | 2% | 3% | 3% | 4% | 6% | 7% | 5% | 14% | 7% |
| 2010 | 6% | 1% | 1% | 4% | 3% | 3% | 3% | 3% | 4% | 5% | 8% | 6% | 5% |

Table 1.19. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and AT surveys, 1964-2011. Note that 2011 fishery age-composition data were unavailable for the assessment.

| Year | Fishery | Year | BTS | AT |
|---|---|---|---|---|
| 1964-1977 | 10 | 1979 | - | 6 |
| 1978-1990 | 50 | | | |
| 1991 | 174 | | | |
| 1992 | 200 | 1982-2011 | 100 | 51 |
| 1993 | 273 | | | (average) |
| 1994 | 108 | | | |
| 1995 | 138 | | | |
| 1996 | 149 | | | |
| 1997 | 256 | | | |
| 1998 | 270 | | | |
| 1999 | 456 | | | |
| 2000 | 452 | | | |
| 2001 | 292 | | | |
| 2002 | 435 | | | |
| 2003 | 389 | | | |
| 2004 | 332 | | | |
| 2005 | 399 | | | |
| 2006 | 328 | | | |
| 2007 | 408 | | | |
| 2008 | 341 | | | |
| 2009 | 360 | | | |
| 2010 | 350 | | | |

Table 1.20. Number of observed B season, shore-based vessel tows available for analysis by mean pollock body mass category. The 250 g row represents all tows where pollock had mean body masses less than 275g and 1500+ row represents all pollock tows averaging 1,475g and greater.

| Body mass Category (g) | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total |
|---|---|---|---|---|---|---|---|---|---|
| *250* | *0* | *4* | *3* | *35* | *44* | *44* | *10* | *19* | 159 |
| 300 | 1 | 2 | 9 | 26 | 33 | 25 | 37 | 19 | 152 |
| 350 | 3 | 10 | 18 | 48 | 28 | 25 | 126 | 42 | 300 |
| 400 | 9 | 25 | 29 | 91 | 33 | 26 | 111 | 42 | 366 |
| 450 | 21 | 21 | 58 | 154 | 55 | 28 | 114 | 130 | 581 |
| 500 | 192 | 37 | 91 | 153 | 66 | 47 | 76 | 164 | 826 |
| 550 | 337 | 26 | 73 | 138 | 86 | 43 | 66 | 134 | 903 |
| 600 | 353 | 11 | 55 | 132 | 101 | 79 | 53 | 124 | 908 |
| 650 | 242 | 34 | 58 | 50 | 93 | 135 | 57 | 219 | 888 |
| 700 | 221 | 232 | 161 | 34 | 96 | 154 | 72 | 170 | 1,140 |
| 750 | 178 | 665 | 210 | 83 | 120 | 200 | 77 | 95 | 1,628 |
| 800 | 192 | 760 | 484 | 267 | 166 | 168 | 38 | 67 | 2,142 |
| 850 | 186 | 396 | 470 | 377 | 202 | 170 | 44 | 40 | 1,885 |
| 900 | 168 | 194 | 300 | 411 | 180 | 171 | 50 | 25 | 1,499 |
| 950 | 108 | 174 | 396 | 297 | 200 | 160 | 55 | 36 | 1,426 |
| 1000 | 96 | 139 | 231 | 186 | 229 | 100 | 64 | 26 | 1,071 |
| 1050 | 76 | 121 | 159 | 165 | 233 | 117 | 84 | 31 | 986 |
| 1100 | 73 | 96 | 101 | 189 | 264 | 118 | 115 | 31 | 987 |
| 1150 | 73 | 83 | 96 | 195 | 228 | 123 | 122 | 39 | 959 |
| 1200 | 79 | 38 | 74 | 201 | 209 | 129 | 136 | 62 | 928 |
| 1250 | 62 | 34 | 53 | 151 | 224 | 164 | 145 | 53 | 886 |
| 1300 | 70 | 18 | 36 | 70 | 224 | 113 | 101 | 47 | 679 |
| 1350 | 52 | 17 | 23 | 44 | 180 | 97 | 95 | 48 | 556 |
| 1400 | 33 | 15 | 16 | 15 | 106 | 112 | 66 | 54 | 417 |
| 1450 | 24 | 6 | 13 | 11 | 60 | 103 | 53 | 59 | 329 |
| *1500+* | *36* | *5* | *64* | *72* | *123* | *385* | *114* | *259* | *1,058* |
| **Totals** | 2,885 | 3,163 | 3,281 | 3,595 | 3,583 | 3,036 | 2,081 | 2,035 | 23,659 |

Table 1.21. Mean body mass of pollock by age (based the time series from 1991-2010 presented in Ianelli et al. 2010) and estimated inverse distance to grounds, tow duration distance, and normalized steaming costs (i.e., sum of columns 3 and 4 divided by that sum at age 5). These results are based on B-season shore-based catcher vessel data only.

| Age | Pollock body mass (g) | Distance to Grounds$^{-1}$ | Tow Duration Distance$^{-1}$ | Normalized costs$^{-1}$ |
|---|---|---|---|---|
| 1 | 6.6 | NA | NA | NA |
| 2 | 207.5 | 13.4 | 123.1 | 0.220 |
| 3 | 367.1 | 182.1 | 116.1 | 0.480 |
| 4 | 520.3 | 360.5 | 108.0 | 0.755 |
| 5 | 649.8 | 521.1 | 99.6 | 1.000 |
| 6 | 761.3 | 646.0 | 91.7 | 1.188 |
| 7 | 870.8 | 732.4 | 84.9 | 1.317 |
| 8 | 987.6 | 787.5 | 79.5 | 1.397 |
| 9 | 1,118.9 | 820.9 | 75.4 | 1.444 |
| 10 | 1,206.9 | 840.4 | 72.6 | 1.471 |
| 11 | 1,308.0 | 851.7 | 70.6 | 1.486 |
| 12 | 1,395.2 | 858.1 | 69.3 | 1.494 |
| 13 | 1,448.3 | 861.7 | 68.4 | 1.499 |
| 14 | 1,472.7 | 863.7 | 67.9 | 1.501 |
| 15 | 1,544.1 | 864.8 | 67.5 | 1.502 |

Table 1.22. Preliminary results showing the sensitivity of different economic input scenarios to optimal harvest rates relative to $F_{msy}$. Also shown is the spawning biomass at that value.

| Scenario | Inverse cost | Age specific product value (slope) | $F_{msy}$ rate relative to Scenario 1 | SSB |
|---|---|---|---|---|
| 1 | Neutral | 0.0 | 100% | 100% |
| 2 | Unweighted | 0.0 | 77% | 119% |
| 3 | Unweighted | 0.1 | 69% | 126% |
| 4 | 60-40 weighting | 0.0 | 86% | 111% |
| 5 | 60-40 weighting | 0.1 | 76% | 120% |
| 6 | 60-40 weighting | 0.2 | 68% | 128% |

Table 1.23. Summary model results showing the stock condition for EBS pollock. Values in parentheses are coefficients of variation (CV's) of values immediately above.

| | 2011 **Assessment** |
|---|---|
| **Biomass** | |
| Year 2012 spawning biomass* | 2,379 t |
| (CV) | (14%) |
| 2011 spawning biomass | 2,097,000 t |
| $B_{msy}$ | 2,034,000 t |
| (CV) | (20%) |
| $SPR\|B_{msy}$ | 27.4% |
| $B_{40\%}$ | 2,572,000 t |
| $B_{35\%}$ | 2,251,000 t |
| $B_0$ (stock-recruitment curve) | 5,329,000 t |
| 2011 Percent of $B_{msy}$ spawning biomass | 103% |
| 2012 Percent of $B_{msy}$ spawning biomass | 125% |
| Ratio of $B_{2011}$ over B2011 under no fishing since 1978 | 0.530 |
| **Recruitment (millions of pollock at age 1)** | |
| Steepness parameter ($h$) | 0.670 |
| Average recruitment (all yrs) | 21,899 |
| Average recruitment (since 1978) | 23,233 |
| 2000 year class | 35,210 |
| 2006 year class | 30,631 |
| 2008 year class | 32,855 |
| Natural Mortality (age 3 and older) | 0.3 |

*Assuming 2012 catch will be 1,200,00 t

Table 1.24. Summary results of Tier 1 2012 yield projections for EBS pollock.

| Description | Value |
|---|---|
| **Tier 1 maximum permissible ABC** | |
| 2012 "fishable" biomass (GM) | 4,126,000 t |
| MSYR (HM) | 0.533 |
| Adjustment factor | 1.0 |
| Adjusted ABC rate | 0.533 |
| 2012 MSYR yield (Tier 1 ABC) | 2,198,000 t |
| **OFL** | |
| MSYR (AM) | 0.6 |
| 2012 MSYR OFL | 2,474,000 t |
| Recommended $F_{ABC}$ | 0.296 |
| Recommended ABC | 1,088,000 t |
| Fishable biomass at *MSY* | 3,661,000 t |

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

Table 1.25 Estimates of numbers at age for the EBS pollock stock as estimated in 2011(millions).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 5,353 | 3,576 | 2,257 | 467 | 210 | 333 | 134 | 49 | 22 | 133 | 12,535 |
| 1965 | 20,519 | 2,174 | 2,250 | 1,604 | 283 | 126 | 199 | 81 | 30 | 97 | 27,363 |
| 1966 | 14,524 | 8,334 | 1,370 | 1,586 | 974 | 173 | 78 | 125 | 51 | 81 | 27,297 |
| 1967 | 28,738 | 5,900 | 5,239 | 961 | 987 | 610 | 110 | 50 | 81 | 86 | 42,762 |
| 1968 | 26,710 | 11,666 | 3,655 | 3,313 | 559 | 574 | 357 | 65 | 29 | 99 | 47,025 |
| 1969 | 29,204 | 10,841 | 7,198 | 2,387 | 1,869 | 320 | 334 | 209 | 38 | 76 | 52,476 |
| 1970 | 20,152 | 11,854 | 6,685 | 4,473 | 1,408 | 1,114 | 193 | 201 | 127 | 68 | 46,275 |
| 1971 | 9,830 | 8,175 | 7,071 | 3,890 | 2,618 | 829 | 660 | 110 | 115 | 105 | 33,402 |
| 1972 | 10,788 | 3,985 | 4,839 | 3,956 | 2,098 | 1,367 | 438 | 350 | 58 | 100 | 27,980 |
| 1973 | 28,731 | 4,372 | 2,226 | 2,433 | 1,969 | 1,051 | 690 | 221 | 177 | 67 | 41,936 |
| 1974 | 21,291 | 11,638 | 2,357 | 1,052 | 1,064 | 864 | 463 | 306 | 98 | 103 | 39,236 |
| 1975 | 17,974 | 8,624 | 5,871 | 985 | 443 | 452 | 370 | 199 | 130 | 84 | 35,130 |
| 1976 | 13,783 | 7,288 | 4,925 | 2,535 | 443 | 204 | 210 | 173 | 93 | 97 | 29,753 |
| 1977 | 13,656 | 5,592 | 4,231 | 2,475 | 1,169 | 209 | 98 | 102 | 84 | 92 | 27,709 |
| 1978 | 26,356 | 5,542 | 3,194 | 2,345 | 1,280 | 595 | 107 | 50 | 53 | 91 | 39,614 |
| 1979 | 64,352 | 10,698 | 3,198 | 1,724 | 1,204 | 654 | 307 | 55 | 26 | 73 | 82,290 |
| 1980 | 25,905 | 26,124 | 6,438 | 1,806 | 921 | 592 | 323 | 154 | 27 | 49 | 62,338 |
| 1981 | 29,053 | 10,522 | 16,273 | 4,067 | 960 | 458 | 288 | 159 | 76 | 38 | 61,894 |
| 1982 | 15,505 | 11,806 | 6,640 | 11,146 | 2,442 | 512 | 246 | 155 | 86 | 61 | 48,600 |
| 1983 | 51,913 | 6,302 | 7,491 | 4,762 | 7,296 | 1,470 | 304 | 146 | 91 | 85 | 79,860 |
| 1984 | 13,063 | 21,102 | 3,999 | 5,401 | 3,222 | 4,680 | 892 | 185 | 88 | 100 | 52,731 |
| 1985 | 35,079 | 5,310 | 13,403 | 2,885 | 3,680 | 2,011 | 2,937 | 545 | 112 | 106 | 66,066 |
| 1986 | 14,407 | 14,260 | 3,368 | 9,625 | 2,008 | 2,405 | 1,214 | 1,793 | 326 | 121 | 49,528 |
| 1987 | 8,424 | 5,857 | 9,041 | 2,426 | 6,591 | 1,332 | 1,482 | 744 | 1,120 | 263 | 37,280 |
| 1988 | 5,296 | 3,425 | 3,719 | 6,571 | 1,719 | 4,525 | 876 | 975 | 461 | 852 | 28,419 |
| 1989 | 10,126 | 2,153 | 2,171 | 2,545 | 4,512 | 1,102 | 2,902 | 529 | 597 | 805 | 27,442 |
| 1990 | 49,702 | 4,116 | 1,365 | 1,545 | 1,724 | 2,956 | 691 | 1,719 | 316 | 850 | 64,984 |
| 1991 | 25,366 | 20,205 | 2,602 | 967 | 960 | 1,008 | 1,694 | 387 | 953 | 667 | 54,809 |
| 1992 | 21,833 | 10,312 | 12,779 | 1,874 | 632 | 574 | 579 | 889 | 214 | 856 | 50,543 |
| 1993 | 47,162 | 8,876 | 6,510 | 8,852 | 1,248 | 390 | 311 | 287 | 411 | 483 | 74,530 |
| 1994 | 14,527 | 19,174 | 5,645 | 4,609 | 5,589 | 812 | 233 | 174 | 160 | 503 | 51,425 |
| 1995 | 10,585 | 5,906 | 12,198 | 4,121 | 3,119 | 3,247 | 479 | 137 | 103 | 399 | 40,295 |
| 1996 | 22,905 | 4,303 | 3,758 | 8,954 | 2,933 | 1,975 | 1,755 | 269 | 79 | 295 | 47,225 |
| 1997 | 31,100 | 9,312 | 2,730 | 2,741 | 6,532 | 2,010 | 1,120 | 862 | 136 | 200 | 56,742 |
| 1998 | 15,459 | 12,644 | 5,882 | 1,988 | 1,945 | 4,436 | 1,243 | 611 | 460 | 173 | 44,839 |
| 1999 | 16,945 | 6,285 | 8,021 | 4,274 | 1,409 | 1,312 | 2,707 | 754 | 343 | 337 | 42,388 |
| 2000 | 26,038 | 6,889 | 3,996 | 5,700 | 2,975 | 955 | 844 | 1,610 | 451 | 412 | 49,870 |
| 2001 | 35,210 | 10,586 | 4,382 | 2,890 | 3,861 | 1,912 | 615 | 489 | 896 | 508 | 61,348 |
| 2002 | 22,707 | 14,315 | 6,739 | 3,192 | 1,997 | 2,349 | 1,063 | 345 | 275 | 805 | 53,786 |
| 2003 | 13,595 | 9,231 | 9,092 | 4,889 | 2,178 | 1,231 | 1,215 | 554 | 181 | 598 | 42,766 |
| 2004 | 6,005 | 5,527 | 5,870 | 6,397 | 3,333 | 1,295 | 650 | 612 | 284 | 436 | 30,410 |
| 2005 | 3,999 | 2,441 | 3,518 | 4,263 | 4,016 | 2,042 | 747 | 344 | 327 | 404 | 22,101 |
| 2006 | 10,083 | 1,626 | 1,554 | 2,554 | 2,824 | 2,216 | 1,095 | 415 | 196 | 428 | 22,991 |
| 2007 | 30,631 | 4,099 | 1,033 | 1,088 | 1,655 | 1,578 | 1,116 | 564 | 218 | 344 | 42,326 |
| 2008 | 10,161 | 12,453 | 2,603 | 722 | 701 | 922 | 754 | 557 | 294 | 303 | 29,471 |
| 2009 | 32,855 | 4,131 | 7,919 | 1,875 | 465 | 390 | 427 | 358 | 276 | 307 | 49,003 |
| 2010 | 21,764 | 13,357 | 2,630 | 5,713 | 1,226 | 262 | 199 | 219 | 184 | 298 | 45,852 |
| 2011 | 21,811 | 8,848 | 8,497 | 1,918 | 3,742 | 714 | 145 | 109 | 117 | 258 | 46,159 |
| Median | 20,519 | 8,175 | 4,382 | 2,554 | 1,724 | 955 | 479 | 269 | 130 | 186 | 45,346 |
| Average | 21,899 | 8,787 | 5,384 | 3,511 | 2,229 | 1,316 | 748 | 417 | 231 | 287 | 44,808 |

Table 1.26. Assessment model-estimated catch-at-age of EBS pollock (millions; 1964-2011).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | 4.1 | 37.9 | 79.2 | 74.4 | 35.1 | 55.4 | 21.4 | 7.5 | 3.2 | 18.4 | 336.6 |
| 1965 | 12.9 | 20.3 | 94.8 | 251.5 | 42.1 | 17.6 | 26.4 | 10.2 | 3.6 | 11.1 | 490.6 |
| 1966 | 8.8 | 95.2 | 62.6 | 219.9 | 130.1 | 21.7 | 9.3 | 14.1 | 5.6 | 8.5 | 575.7 |
| 1967 | 29.3 | 135.5 | 665.2 | 180.3 | 184.9 | 111.2 | 19.8 | 8.9 | 14.1 | 15.1 | 1,364.3 |
| 1968 | 29.8 | 303.8 | 374.7 | 687.5 | 110.2 | 107.2 | 64.8 | 11.4 | 5.1 | 16.8 | 1,711.2 |
| 1969 | 32.2 | 287.0 | 1,007.5 | 422.3 | 317.1 | 51.9 | 53.8 | 33.6 | 6.1 | 13.1 | 2,224.6 |
| 1970 | 30.3 | 616.9 | 1,247.4 | 816.0 | 251.6 | 193.7 | 38.5 | 40.2 | 25.3 | 20.6 | 3,280.5 |
| 1971 | 18.9 | 472.8 | 1,505.3 | 921.2 | 672.9 | 207.0 | 163.7 | 27.5 | 28.9 | 45.1 | 4,063.3 |
| 1972 | 23.1 | 399.3 | 1,356.7 | 1,133.0 | 592.4 | 380.5 | 121.8 | 97.0 | 16.9 | 42.3 | 4,162.9 |
| 1973 | 69.1 | 547.1 | 704.6 | 872.2 | 702.6 | 372.4 | 242.6 | 77.5 | 62.1 | 29.4 | 3,679.7 |
| 1974 | 52.3 | 1,974.4 | 900.4 | 397.9 | 398.0 | 319.5 | 171.0 | 113.6 | 36.7 | 40.8 | 4,404.6 |
| 1975 | 32.1 | 727.2 | 2,144.3 | 338.4 | 146.5 | 146.4 | 118.7 | 63.6 | 41.7 | 30.5 | 3,789.3 |
| 1976 | 19.8 | 526.7 | 1,381.7 | 836.7 | 140.1 | 62.8 | 63.7 | 52.0 | 27.9 | 30.5 | 3,141.8 |
| 1977 | 16.0 | 471.3 | 927.5 | 651.6 | 319.1 | 56.1 | 25.9 | 26.8 | 22.0 | 23.9 | 2,540.3 |
| 1978 | 29.2 | 426.6 | 754.8 | 627.9 | 346.2 | 156.9 | 29.1 | 13.8 | 14.4 | 24.8 | 2,423.7 |
| 1979 | 63.9 | 484.3 | 661.0 | 418.9 | 353.4 | 190.3 | 87.3 | 16.0 | 7.5 | 21.2 | 2,303.7 |
| 1980 | 15.9 | 486.5 | 822.4 | 444.6 | 263.6 | 177.3 | 94.6 | 44.4 | 7.8 | 14.0 | 2,371.1 |
| 1981 | 9.5 | 87.6 | 1,062.3 | 669.2 | 233.3 | 110.2 | 68.4 | 37.6 | 18.0 | 9.5 | 2,305.6 |
| 1982 | 2.8 | 46.3 | 183.5 | 1,124.7 | 397.4 | 88.8 | 42.1 | 27.6 | 15.4 | 13.1 | 1,941.7 |
| 1983 | 7.1 | 24.6 | 173.5 | 357.7 | 848.7 | 231.0 | 47.5 | 23.6 | 16.0 | 19.5 | 1,749.2 |
| 1984 | 1.5 | 66.2 | 90.6 | 375.4 | 440.0 | 620.8 | 136.2 | 29.4 | 15.3 | 24.3 | 1,799.7 |
| 1985 | 3.7 | 22.7 | 354.6 | 150.7 | 375.3 | 322.6 | 448.5 | 90.5 | 19.9 | 26.9 | 1,815.4 |
| 1986 | 1.2 | 64.8 | 80.3 | 629.9 | 182.0 | 352.0 | 181.9 | 243.6 | 53.5 | 27.0 | 1,816.2 |
| 1987 | 0.5 | 18.8 | 148.6 | 91.9 | 418.4 | 129.9 | 143.3 | 105.6 | 158.0 | 43.9 | 1,258.8 |
| 1988 | 0.4 | 15.6 | 245.4 | 415.2 | 200.4 | 526.6 | 140.9 | 147.3 | 70.5 | 126.6 | 1,888.9 |
| 1989 | 0.6 | 9.6 | 74.6 | 188.6 | 452.9 | 146.6 | 506.0 | 88.1 | 94.2 | 126.3 | 1,687.5 |
| 1990 | 3.9 | 28.6 | 52.4 | 215.6 | 315.9 | 581.2 | 147.4 | 376.0 | 66.2 | 165.0 | 1,952.3 |
| 1991 | 1.7 | 131.2 | 62.4 | 98.7 | 160.9 | 197.2 | 431.1 | 84.5 | 242.4 | 162.2 | 1,572.2 |
| 1992 | 1.7 | 81.9 | 719.0 | 163.8 | 91.9 | 134.1 | 167.5 | 291.8 | 73.7 | 292.3 | 2,017.4 |
| 1993 | 2.2 | 18.7 | 249.8 | 1,134.5 | 132.0 | 65.4 | 66.8 | 61.4 | 88.5 | 98.4 | 1,917.5 |
| 1994 | 0.5 | 34.3 | 70.4 | 344.9 | 1,048.4 | 144.1 | 41.2 | 29.9 | 26.7 | 81.4 | 1,821.9 |
| 1995 | 0.3 | 10.2 | 96.6 | 140.0 | 393.5 | 763.9 | 101.0 | 27.1 | 19.2 | 71.4 | 1,623.1 |
| 1996 | 0.7 | 17.6 | 49.9 | 118.0 | 190.7 | 402.4 | 516.5 | 74.3 | 20.2 | 70.6 | 1,460.8 |
| 1997 | 1.1 | 69.8 | 40.6 | 99.8 | 471.5 | 288.2 | 257.2 | 210.3 | 37.0 | 51.7 | 1,527.1 |
| 1998 | 0.5 | 51.2 | 97.3 | 74.4 | 150.5 | 678.2 | 195.6 | 128.6 | 112.3 | 42.2 | 1,530.7 |
| 1999 | 0.4 | 13.8 | 283.2 | 223.9 | 103.9 | 149.7 | 463.9 | 125.9 | 56.0 | 52.3 | 1,473.1 |
| 2000 | 0.7 | 13.8 | 81.8 | 422.6 | 341.7 | 108.2 | 160.2 | 348.4 | 83.9 | 70.2 | 1,631.7 |
| 2001 | 0.9 | 13.7 | 62.8 | 169.2 | 599.2 | 414.6 | 130.1 | 102.3 | 177.3 | 98.4 | 1,768.5 |
| 2002 | 0.7 | 44.6 | 120.3 | 218.0 | 290.5 | 617.8 | 274.6 | 87.1 | 65.3 | 172.0 | 1,890.9 |
| 2003 | 0.5 | 20.0 | 395.4 | 337.6 | 373.3 | 308.4 | 339.6 | 148.7 | 43.3 | 122.6 | 2,089.4 |
| 2004 | 0.2 | 7.7 | 100.6 | 846.1 | 500.7 | 249.0 | 161.5 | 148.9 | 63.4 | 89.2 | 2,167.2 |
| 2005 | 0.1 | 4.0 | 60.5 | 390.2 | 891.8 | 490.7 | 162.9 | 69.6 | 62.6 | 69.9 | 2,202.3 |
| 2006 | 0.3 | 4.5 | 73.3 | 277.5 | 603.9 | 619.4 | 290.7 | 104.8 | 45.9 | 93.3 | 2,113.7 |
| 2007 | 1.1 | 13.0 | 50.9 | 123.3 | 357.0 | 488.8 | 317.2 | 145.4 | 53.2 | 80.4 | 1,630.3 |
| 2008 | 0.3 | 26.3 | 63.2 | 81.4 | 151.7 | 302.1 | 236.8 | 161.3 | 81.9 | 77.3 | 1,182.4 |
| 2009 | 0.9 | 5.3 | 179.7 | 190.0 | 97.4 | 105.4 | 114.4 | 95.3 | 72.4 | 85.6 | 946.6 |
| 2010 | 0.5 | 25.3 | 35.0 | 573.7 | 227.9 | 56.9 | 45.1 | 53.8 | 45.2 | 71.4 | 1,134.8 |
| 2011 | 0.6 | 19.5 | 135.5 | 225.3 | 992.2 | 184.1 | 37.0 | 27.7 | 29.2 | 63.6 | 1,714.5 |
| Median | 1.7 | 37.9 | 148.6 | 338.4 | 317.1 | 190.3 | 130.1 | 69.6 | 36.7 | 44.5 | 1,819.0 |
| Average | 11.1 | 188.0 | 420.5 | 411.8 | 355.0 | 260.5 | 160.9 | 90.7 | 49.1 | 62.6 | 2,010.3 |

Table 1.27. Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2011. Biomass units are thousands of t, age-1 recruitment is in millions of pollock.

| Year | Age 3+ biomass | Spawning biomass | Age 1 Rec. | Year | Age 3+ biomass | Spawning biomass | Age 1 Rec. |
|---|---|---|---|---|---|---|---|
| 1964 | 1,602 | 442 | 5,353 | 1988 | 11,424 | 4,029 | 5,296 |
| 1965 | 2,050 | 563 | 20,519 | 1989 | 9,724 | 3,640 | 10,126 |
| 1966 | 2,159 | 673 | 14,524 | 1990 | 7,764 | 2,941 | 49,702 |
| 1967 | 3,365 | 854 | 28,738 | 1991 | 6,049 | 2,199 | 25,366 |
| 1968 | 3,838 | 1,059 | 26,710 | 1992 | 9,411 | 2,300 | 21,833 |
| 1969 | 5,187 | 1,342 | 29,204 | 1993 | 11,543 | 3,168 | 47,162 |
| 1970 | 6,221 | 1,682 | 20,152 | 1994 | 11,146 | 3,459 | 14,527 |
| 1971 | 6,918 | 1,894 | 9,830 | 1995 | 12,883 | 3,656 | 10,585 |
| 1972 | 6,329 | 1,819 | 10,788 | 1996 | 11,019 | 3,652 | 22,904 |
| 1973 | 4,728 | 1,451 | 28,730 | 1997 | 9,627 | 3,447 | 31,100 |
| 1974 | 3,329 | 998 | 21,290 | 1998 | 9,722 | 3,206 | 15,458 |
| 1975 | 3,533 | 830 | 17,974 | 1999 | 10,607 | 3,220 | 16,945 |
| 1976 | 3,580 | 852 | 13,783 | 2000 | 9,841 | 3,259 | 26,038 |
| 1977 | 3,598 | 919 | 13,656 | 2001 | 9,616 | 3,291 | 35,210 |
| 1978 | 3,497 | 962 | 26,356 | 2002 | 9,988 | 3,119 | 22,707 |
| 1979 | 3,343 | 937 | 64,352 | 2003 | 11,974 | 3,300 | 13,595 |
| 1980 | 4,230 | 1,042 | 25,905 | 2004 | 11,178 | 3,382 | 6,005 |
| 1981 | 8,160 | 1,710 | 29,053 | 2005 | 9,299 | 3,073 | 3,999 |
| 1982 | 9,313 | 2,606 | 15,505 | 2006 | 7,060 | 2,499 | 10,083 |
| 1983 | 10,340 | 3,212 | 51,913 | 2007 | 5,633 | 2,051 | 30,631 |
| 1984 | 10,031 | 3,417 | 13,063 | 2008 | 4,393 | 1,469 | 10,161 |
| 1985 | 12,186 | 3,668 | 35,079 | 2009 | 6,172 | 1,628 | 32,855 |
| 1986 | 11,426 | 3,895 | 14,407 | 2010 | 6,095 | 1,863 | 21,764 |
| 1987 | 12,063 | 4,023 | 8,424 | 2011 | 7,823 | 2,097 | 21,811 |
| | | | | 2012 | 8,341 | | |

Table 1.28. Estimates of begin-year age 3 and older biomass (thousands of tons) and coefficients of variation (CV) for the current assessment compared to estimates from the 2004-2010 assessments for EBS pollock. NOTE: see Ianelli et al. (2001) for a discussion on the interpretation of age-3+ biomass estimates.

| | Current | | 2010 | | 2009 | | 2008 | | 2007 | | 2006 | | 2005 | | 2004 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Assess. | CV | Assess. | CV | Assess. | CV | Assess. | CV | Assess. | CV | Assess. | CV | Assess. | CV | Assess. | CV |
| 1964 | 1,602 | 21% | 1,589 | 21% | 1,564 | 22% | 1,600 | 22% | 1,717 | 23% | 1,810 | 23% | 1,779 | 23% | 1,789 | 23% |
| 1965 | 2,050 | 20% | 2,008 | 19% | 2,008 | 20% | 2,050 | 20% | 2,141 | 21% | 2,231 | 21% | 2,222 | 21% | 2,272 | 20% |
| 1966 | 2,159 | 20% | 1,944 | 21% | 1,947 | 22% | 2,007 | 21% | 2,037 | 22% | 2,252 | 21% | 2,288 | 21% | 2,326 | 20% |
| 1967 | 3,365 | 16% | 3,140 | 17% | 3,149 | 17% | 3,245 | 17% | 3,206 | 18% | 3,518 | 17% | 3,483 | 17% | 3,514 | 17% |
| 1968 | 3,838 | 17% | 3,486 | 18% | 3,510 | 19% | 3,592 | 18% | 3,558 | 19% | 3,881 | 17% | 3,881 | 17% | 3,976 | 17% |
| 1969 | 5,187 | 16% | 4,879 | 17% | 5,007 | 17% | 5,020 | 17% | 5,118 | 17% | 5,058 | 16% | 5,323 | 16% | 5,258 | 16% |
| 1970 | 6,221 | 15% | 5,974 | 16% | 6,159 | 15% | 6,005 | 16% | 6,368 | 15% | 5,929 | 16% | 6,447 | 15% | 6,211 | 15% |
| 1971 | 6,918 | 14% | 6,785 | 13% | 6,949 | 13% | 6,727 | 14% | 7,164 | 13% | 6,617 | 13% | 7,145 | 13% | 6,714 | 14% |
| 1972 | 6,329 | 14% | 6,277 | 13% | 6,444 | 13% | 6,289 | 14% | 6,666 | 13% | 6,265 | 13% | 6,692 | 13% | 6,204 | 13% |
| 1973 | 4,728 | 16% | 4,547 | 16% | 4,696 | 16% | 4,556 | 17% | 4,942 | 16% | 4,751 | 16% | 5,055 | 15% | 4,632 | 16% |
| 1974 | 3,329 | 20% | 3,085 | 20% | 3,196 | 20% | 3,064 | 22% | 3,475 | 20% | 3,460 | 19% | 3,635 | 19% | 3,288 | 19% |
| 1975 | 3,533 | 14% | 3,366 | 13% | 3,384 | 13% | 3,276 | 14% | 3,604 | 14% | 3,585 | 13% | 3,666 | 14% | 3,440 | 14% |
| 1976 | 3,580 | 11% | 3,460 | 10% | 3,431 | 11% | 3,339 | 11% | 3,584 | 11% | 3,577 | 11% | 3,614 | 11% | 3,497 | 11% |
| 1977 | 3,598 | 9% | 3,500 | 9% | 3,457 | 9% | 3,340 | 10% | 3,602 | 10% | 3,582 | 10% | 3,548 | 10% | 3,504 | 10% |
| 1978 | 3,497 | 9% | 3,390 | 9% | 3,340 | 9% | 3,202 | 9% | 3,476 | 9% | 3,438 | 10% | 3,361 | 10% | 3,385 | 10% |
| 1979 | 3,343 | 9% | 3,267 | 9% | 3,212 | 9% | 3,090 | 9% | 3,363 | 9% | 3,323 | 9% | 3,273 | 10% | 3,341 | 10% |
| 1980 | 4,230 | 7% | 4,203 | 7% | 4,124 | 8% | 4,044 | 7% | 4,384 | 8% | 4,320 | 8% | 4,373 | 8% | 4,409 | 8% |
| 1981 | 8,160 | 6% | 8,190 | 6% | 8,031 | 6% | 7,704 | 6% | 8,307 | 6% | 8,364 | 7% | 8,289 | 7% | 8,301 | 7% |
| 1982 | 9,313 | 6% | 9,349 | 6% | 9,165 | 6% | 8,783 | 6% | 9,439 | 6% | 9,476 | 6% | 9,446 | 7% | 9,472 | 7% |
| 1983 | 10,340 | 5% | 10,376 | 5% | 10,168 | 5% | 9,804 | 5% | 10,493 | 6% | 10,443 | 6% | 10,536 | 7% | 10,552 | 7% |
| 1984 | 10,031 | 5% | 10,060 | 5% | 9,857 | 5% | 9,518 | 5% | 10,200 | 6% | 10,088 | 6% | 10,244 | 7% | 10,263 | 7% |
| 1985 | 12,186 | 4% | 12,246 | 4% | 12,027 | 4% | 11,802 | 4% | 12,531 | 5% | 12,285 | 5% | 12,435 | 6% | 12,492 | 6% |
| 1986 | 11,426 | 4% | 11,471 | 4% | 11,269 | 4% | 11,075 | 4% | 11,773 | 5% | 11,486 | 5% | 11,609 | 6% | 11,677 | 6% |
| 1987 | 12,063 | 4% | 12,111 | 4% | 11,915 | 4% | 11,732 | 4% | 12,401 | 4% | 12,077 | 5% | 12,106 | 5% | 12,226 | 5% |
| 1988 | 11,424 | 4% | 11,402 | 4% | 11,227 | 4% | 11,004 | 4% | 11,617 | 4% | 11,330 | 5% | 11,153 | 5% | 11,243 | 5% |
| 1989 | 9,724 | 4% | 9,671 | 4% | 9,521 | 4% | 9,320 | 4% | 9,875 | 4% | 9,584 | 5% | 9,384 | 5% | 9,466 | 5% |
| 1990 | 7,764 | 4% | 7,681 | 4% | 7,558 | 4% | 7,345 | 4% | 7,847 | 5% | 7,603 | 5% | 7,392 | 6% | 7,454 | 6% |
| 1991 | 6,049 | 5% | 5,911 | 5% | 5,811 | 5% | 5,590 | 5% | 6,097 | 5% | 5,929 | 6% | 5,454 | 6% | 5,637 | 7% |
| 1992 | 9,411 | 3% | 9,316 | 3% | 9,211 | 4% | 8,966 | 4% | 9,557 | 4% | 9,270 | 5% | 8,905 | 5% | 9,120 | 5% |
| 1993 | 11,543 | 3% | 11,493 | 3% | 11,388 | 3% | 11,175 | 3% | 11,832 | 4% | 11,795 | 4% | 11,669 | 5% | 11,721 | 6% |
| 1994 | 11,146 | 3% | 11,077 | 3% | 10,990 | 4% | 10,782 | 4% | 11,485 | 4% | 11,407 | 5% | 11,000 | 5% | 10,998 | 6% |
| 1995 | 12,883 | 3% | 12,779 | 3% | 12,699 | 3% | 12,704 | 3% | 13,615 | 4% | 13,658 | 4% | 13,605 | 6% | 13,554 | 6% |
| 1996 | 11,019 | 3% | 10,903 | 4% | 10,843 | 4% | 10,829 | 4% | 11,537 | 4% | 11,480 | 5% | 11,826 | 6% | 11,772 | 7% |
| 1997 | 9,627 | 4% | 9,485 | 4% | 9,440 | 4% | 9,403 | 4% | 10,104 | 5% | 10,056 | 5% | 9,966 | 6% | 9,949 | 8% |
| 1998 | 9,722 | 4% | 9,584 | 4% | 9,538 | 4% | 9,467 | 4% | 10,178 | 5% | 9,973 | 5% | 9,915 | 7% | 9,943 | 8% |
| 1999 | 10,607 | 3% | 10,509 | 3% | 10,421 | 3% | 10,379 | 4% | 11,081 | 4% | 10,872 | 5% | 10,998 | 6% | 11,093 | 10% |
| 2000 | 9,841 | 3% | 9,747 | 3% | 9,632 | 3% | 9,503 | 4% | 10,201 | 4% | 10,052 | 5% | 9,947 | 7% | 10,036 | 12% |
| 2001 | 9,616 | 3% | 9,506 | 3% | 9,341 | 4% | 9,175 | 4% | 9,898 | 5% | 9,800 | 6% | 9,566 | 8% | 9,675 | 14% |
| 2002 | 9,988 | 3% | 9,842 | 3% | 9,595 | 4% | 9,554 | 4% | 10,224 | 5% | 10,197 | 7% | 9,824 | 9% | 9,899 | 16% |
| 2003 | 11,974 | 3% | 11,805 | 3% | 11,453 | 3% | 11,182 | 4% | 12,865 | 6% | 13,320 | 10% | 13,073 | 13% | 12,239 | 19% |
| 2004 | 11,178 | 3% | 10,974 | 3% | 10,606 | 4% | 10,274 | 4% | 11,784 | 7% | 12,055 | 12% | 10,972 | 15% | 9,894 | 21% |
| 2005 | 9,299 | 3% | 9,079 | 4% | 8,736 | 4% | 8,423 | 5% | 9,598 | 8% | 9,759 | 14% | 9,277 | 18% | 8,573 | 22% |
| 2006 | 7,060 | 4% | 6,839 | 4% | 6,543 | 5% | 6,340 | 6% | 7,178 | 10% | 7,950 | 17% | 8,232 | 21% | | |
| 2007 | 5,633 | 5% | 5,386 | 5% | 5,090 | 6% | 5,015 | 8% | 5,363 | 14% | 6,361 | 21% | | | | |
| 2008 | 4,393 | 6% | 4,146 | 7% | 3,809 | 8% | 4,222 | 12% | 4,357 | 20% | | | | | | |
| 2009 | 6,172 | 8% | 6,225 | 10% | 4,762 | 11% | 6,240 | 20% | | | | | | | | |
| 2010 | 6,095 | 10% | 6,582 | 12% | 4,616 | 13% | | | | | | | | | | |
| 2011 | 7,823 | 11% | 9,620 | 15% | | | | | | | | | | | | |
| 2012 | 8,341 | 12% | | | | | | | | | | | | | | |

Table 1.29 Tier 3 projections of catch, fishing mortality, and spawning biomass (thousands of tons) for EBS pollock for the 7 scenarios **assuming the 2008 year class is as estimated** (as 32,855 million age-1 pollock in 2009). Note that the values for $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 6,431, 2,572 and 2,251 thousand t, respectively.

| Catch | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 | Scenario 7 |
|---|---|---|---|---|---|---|---|
| 2011 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 |
| 2012 | 1,277 | 1,277 | 1,223 | 638 | 0 | 1,545 | 1,277 |
| 2013 | 1,484 | 1,484 | 1,356 | 784 | 0 | 1,647 | 1,484 |
| 2014 | 1,508 | 1,508 | 1,438 | 903 | 0 | 1,618 | 1,821 |
| 2015 | 1,442 | 1,442 | 1,428 | 948 | 0 | 1,537 | 1,606 |
| 2016 | 1,440 | 1,440 | 1,432 | 981 | 0 | 1,536 | 1,560 |
| 2017 | 1,461 | 1,460 | 1,447 | 1,011 | 0 | 1,554 | 1,562 |
| 2018 | 1,477 | 1,476 | 1,456 | 1,032 | 0 | 1,569 | 1,571 |
| 2019 | 1,486 | 1,485 | 1,460 | 1,046 | 0 | 1,575 | 1,576 |
| 2020 | 1,497 | 1,495 | 1,468 | 1,057 | 0 | 1,584 | 1,584 |
| 2021 | 1,507 | 1,506 | 1,477 | 1,068 | 0 | 1,593 | 1,593 |
| 2022 | 1,515 | 1,515 | 1,484 | 1,076 | 0 | 1,603 | 1,603 |
| 2023 | 1,524 | 1,525 | 1,493 | 1,083 | 0 | 1,613 | 1,613 |
| 2024 | 1,522 | 1,522 | 1,493 | 1,087 | 0 | 1,606 | 1,606 |
| Fishing M. | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 | Scenario 7 |
| 2011 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 | 0.429 |
| 2012 | 0.418 | 0.418 | 0.398 | 0.194 | 0.000 | 0.522 | 0.418 |
| 2013 | 0.446 | 0.446 | 0.398 | 0.194 | 0.000 | 0.534 | 0.446 |
| 2014 | 0.435 | 0.435 | 0.398 | 0.194 | 0.000 | 0.518 | 0.545 |
| 2015 | 0.418 | 0.418 | 0.398 | 0.194 | 0.000 | 0.498 | 0.508 |
| 2016 | 0.411 | 0.411 | 0.398 | 0.194 | 0.000 | 0.491 | 0.494 |
| 2017 | 0.408 | 0.408 | 0.398 | 0.194 | 0.000 | 0.488 | 0.489 |
| 2018 | 0.409 | 0.408 | 0.398 | 0.194 | 0.000 | 0.490 | 0.490 |
| 2019 | 0.410 | 0.410 | 0.398 | 0.194 | 0.000 | 0.491 | 0.492 |
| 2020 | 0.411 | 0.411 | 0.398 | 0.194 | 0.000 | 0.493 | 0.493 |
| 2021 | 0.412 | 0.411 | 0.398 | 0.194 | 0.000 | 0.493 | 0.493 |
| 2022 | 0.412 | 0.412 | 0.398 | 0.194 | 0.000 | 0.494 | 0.494 |
| 2023 | 0.413 | 0.413 | 0.398 | 0.194 | 0.000 | 0.495 | 0.495 |
| 2024 | 0.412 | 0.412 | 0.398 | 0.194 | 0.000 | 0.494 | 0.494 |
| Spawning biomass | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 | Scenario 7 |
| 2011 | 2,101 | 2,101 | 2,101 | 2,101 | 2,101 | 2,101 | 2,101 |
| 2012 | 2,379 | 2,379 | 2,386 | 2,459 | 2,531 | 2,343 | 2,379 |
| 2013 | 2,530 | 2,530 | 2,570 | 2,890 | 3,254 | 2,395 | 2,530 |
| 2014 | 2,529 | 2,529 | 2,613 | 3,148 | 3,835 | 2,344 | 2,485 |
| 2015 | 2,540 | 2,540 | 2,637 | 3,339 | 4,351 | 2,331 | 2,386 |
| 2016 | 2,578 | 2,578 | 2,668 | 3,482 | 4,777 | 2,355 | 2,376 |
| 2017 | 2,605 | 2,605 | 2,687 | 3,580 | 5,116 | 2,370 | 2,378 |
| 2018 | 2,621 | 2,622 | 2,699 | 3,652 | 5,399 | 2,376 | 2,380 |
| 2019 | 2,638 | 2,640 | 2,715 | 3,710 | 5,629 | 2,388 | 2,389 |
| 2020 | 2,650 | 2,651 | 2,728 | 3,750 | 5,807 | 2,395 | 2,396 |
| 2021 | 2,664 | 2,666 | 2,744 | 3,788 | 5,962 | 2,407 | 2,407 |
| 2022 | 2,680 | 2,682 | 2,762 | 3,821 | 6,084 | 2,421 | 2,421 |
| 2023 | 2,684 | 2,685 | 2,768 | 3,839 | 6,177 | 2,422 | 2,422 |
| 2024 | 2,675 | 2,677 | 2,761 | 3,842 | 6,237 | 2,412 | 2,412 |

Table 1.30 An alternative executive summary table for EBS pollock **assuming the 2008 year class is as estimated**.

| **Quantity** | As estimated or *specified last* year for: 2011 | 2012 | As estimated or *recommended this* year for: 2012 | 2013 |
|---|---|---|---|---|
| *M* (natural mortality rate, ages 3+) | 0.3 | 0.3 | 0.3 | 0.3 |
| Tier | 1a | 1a | 1a | 1a |
| Projected total (age 3+) biomass (t) | 9,620,000 | 11,318,000 t | 8,341,000 t | 8,568,000 t |
| Female spawning biomass (t) | | | | |
| Projected | 2,444,500 | 3,019,500 t | 2,386,000 t | 2,570,000 t |
| $B_0$ | 5,140,000 | 5,140,000 t | 5,329,000 t | 5,329,000 t |
| $B_{MSY}$ | 1,948,000 | 1,948,000 t | 2,034,000 t | 2,034,000 t |
| $F_{OFL}$ | 0.640 | 0.640 | 0.6 | 0.6 |
| $maxF_{ABC}$ | 0.564 | 0.564 | 0.533 | 0.533 |
| $F_{ABC}$ | 0.332 | 0.332 | 0.296 | 0.296 |
| OFL (t) | 2,447,000 | 3,170,000 t | 2,474,000 t | 2,842,000 t |
| maxABC (t) | 2,154,000 | 2,255,000 t | 2,198,000 t | 2,526,000 t |
| ABC (t) | 1,267,000 | 1,595,000 t | 1,223,000 t | 1,356,000 t |
| **Status** | As determined *last* year for: 2009 | 2010 | As determined *this* year for: 2010 | 2011 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

Table 1.31 Tier 3 projections of catch, fishing mortality, and spawning biomass (thousands of tons) for EBS pollock for the 7 scenarios **assuming the 2008 year class is average**. Note that the values for $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 6,431, 2,572 and 2,251 thousand t, respectively.

| Catch | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 | Scenario 7 |
|---|---|---|---|---|---|---|---|
| 2011 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 | 1,150 |
| 2012 | 988 | 988 | 1,088 | 570 | 0 | 1,200 | 988 |
| 2013 | 1,156 | 1,156 | 1,142 | 663 | 0 | 1,298 | 1,156 |
| 2014 | 1,310 | 1,310 | 1,246 | 775 | 0 | 1,423 | 1,585 |
| 2015 | 1,370 | 1,370 | 1,322 | 862 | 0 | 1,479 | 1,537 |
| 2016 | 1,415 | 1,415 | 1,375 | 926 | 0 | 1,522 | 1,541 |
| 2017 | 1,450 | 1,449 | 1,416 | 975 | 0 | 1,549 | 1,556 |
| 2018 | 1,472 | 1,471 | 1,439 | 1,008 | 0 | 1,567 | 1,569 |
| 2019 | 1,484 | 1,483 | 1,450 | 1,029 | 0 | 1,574 | 1,575 |
| 2020 | 1,496 | 1,494 | 1,462 | 1,046 | 0 | 1,584 | 1,584 |
| 2021 | 1,506 | 1,505 | 1,474 | 1,060 | 0 | 1,593 | 1,593 |
| 2022 | 1,514 | 1,515 | 1,483 | 1,071 | 0 | 1,603 | 1,603 |
| 2023 | 1,524 | 1,525 | 1,491 | 1,080 | 0 | 1,613 | 1,613 |
| 2024 | 1,522 | 1,522 | 1,493 | 1,085 | 0 | 1,606 | 1,606 |
| **Fishing M.** | **Scenario 1** | **Scenario 2** | **Scenario 3** | **Scenario 4** | **Scenario 5** | **Scenario 6** | **Scenario 7** |
| 2011 | 0.447 | 0.447 | 0.447 | 0.447 | 0.447 | 0.447 | 0.447 |
| 2012 | 0.356 | 0.356 | 0.398 | 0.194 | 0.000 | 0.445 | 0.356 |
| 2013 | 0.394 | 0.394 | 0.398 | 0.194 | 0.000 | 0.474 | 0.394 |
| 2014 | 0.413 | 0.413 | 0.398 | 0.194 | 0.000 | 0.492 | 0.517 |
| 2015 | 0.411 | 0.411 | 0.398 | 0.194 | 0.000 | 0.491 | 0.499 |
| 2016 | 0.408 | 0.408 | 0.398 | 0.194 | 0.000 | 0.489 | 0.491 |
| 2017 | 0.407 | 0.407 | 0.398 | 0.194 | 0.000 | 0.487 | 0.488 |
| 2018 | 0.408 | 0.408 | 0.398 | 0.194 | 0.000 | 0.489 | 0.490 |
| 2019 | 0.410 | 0.409 | 0.398 | 0.194 | 0.000 | 0.491 | 0.491 |
| 2020 | 0.411 | 0.411 | 0.398 | 0.194 | 0.000 | 0.493 | 0.493 |
| 2021 | 0.412 | 0.411 | 0.398 | 0.194 | 0.000 | 0.493 | 0.493 |
| 2022 | 0.412 | 0.412 | 0.398 | 0.194 | 0.000 | 0.494 | 0.494 |
| 2023 | 0.413 | 0.413 | 0.398 | 0.194 | 0.000 | 0.495 | 0.495 |
| 2024 | 0.412 | 0.412 | 0.398 | 0.194 | 0.000 | 0.494 | 0.494 |
| **Spawning biomass** | **Scenario 1** | **Scenario 2** | **Scenario 3** | **Scenario 4** | **Scenario 5** | **Scenario 6** | **Scenario 7** |
| 2011 | 1,941 | 1,941 | 1,941 | 1,941 | 1,941 | 1,941 | 1,941 |
| 2012 | 2,046 | 2,046 | 2,032 | 2,099 | 2,165 | 2,017 | 2,046 |
| 2013 | 2,248 | 2,248 | 2,208 | 2,488 | 2,809 | 2,140 | 2,248 |
| 2014 | 2,381 | 2,381 | 2,358 | 2,815 | 3,405 | 2,227 | 2,342 |
| 2015 | 2,474 | 2,474 | 2,480 | 3,088 | 3,960 | 2,290 | 2,336 |
| 2016 | 2,550 | 2,550 | 2,577 | 3,307 | 4,450 | 2,342 | 2,359 |
| 2017 | 2,592 | 2,592 | 2,633 | 3,458 | 4,847 | 2,365 | 2,372 |
| 2018 | 2,614 | 2,615 | 2,667 | 3,565 | 5,176 | 2,374 | 2,377 |
| 2019 | 2,635 | 2,636 | 2,697 | 3,650 | 5,451 | 2,387 | 2,388 |
| 2020 | 2,648 | 2,650 | 2,717 | 3,710 | 5,667 | 2,395 | 2,395 |
| 2021 | 2,663 | 2,665 | 2,737 | 3,760 | 5,851 | 2,407 | 2,407 |
| 2022 | 2,680 | 2,682 | 2,759 | 3,803 | 6,000 | 2,421 | 2,421 |
| 2023 | 2,683 | 2,685 | 2,766 | 3,827 | 6,111 | 2,422 | 2,422 |
| 2024 | 2,675 | 2,677 | 2,760 | 3,835 | 6,188 | 2,412 | 2,412 |

Table 1.32 Maximum permissible Tier 1a EBS pollock ABC and OFL projections for 2012 and for 2013.

| Year | Catch | ABC | OFL |
|---|---|---|---|
| 2012 | 1,200,000 t | 2,198,000 t | 2,474,000 t |
| 2013 | 1,400,000 t | 2,526,000 t | 2,842,000 t |

Table 1.33. 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 1.34 Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 1997-2002 based on observer data, 2003-2011 based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska). Note that in 2011 species groups left blank are because they have moved into "target" FMP categories.

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

| Group | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| Jellyfish | 5,592 | 6,495 | 5,198 | 2,716 | 2,381 | 4,179 | 8,092 | 2,648 | 8,205 |
| 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 | 94 | 102 | 2 | 4 | 1 | 3 |
| Eelpouts | 1 | 1 | 1 | 21 | 119 | 9 | 4 | 1 | 1 |
| Sea stars | 89 | 7 | 10 | 11 | 5 | 18 | 10 | 13 | 35 |
| Grenadier | 20 | 10 | 14 | 16 | 28 | 28 | 5 | 3 | 1 |
| Other osmerids | 7 | 2 | 3 | 6 | 38 | 2 | 0 | 0 | 0 |
| Octopus | 9 | 3 | 1 | 2 | 4 | 3 | 4 | 1 | |
| Lanternfish | 0 | 0 | 1 | 10 | 6 | 1 | 0 | 0 | 0 |
| Sea pens, whips | 1 | 1 | 2 | 2 | 4 | 1 | 3 | 3 | 3 |
| Birds | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| Capelin | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 |
| Other fish | 98 | 88 | 158 | 149 | 202 | 119 | 135 | 169 | 319 |
| Other invertebrates | 2 | 2 | 9 | 5 | 5 | 10 | 6 | 14 | 10 |

Table 1.35 Bycatch estimates (t) of other **target species** caught in the BSAI directed pollock fishery, 1997-2011 based on then NMFS Alaska Regional Office reports from observers (*2011 data are preliminary*). **Note that the increase in 2011 is partially due to earlier non-target species being moved into the FMP as "target" species (e.g., skates, squid, octopus etc).**

| | Pacific Cod | Flathead Sole | Rock Sole | Yellowfin Sole | Arrowtooth Flounder | Pacific Ocean Perch | Atka Mackerel | Sablefish | Greenland Turbot | Alaska Plaice | Alaska skate | All other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997 | 8,262 | 2,350 | 1,522 | 606 | 985 | 428 | 83 | 2 | 123 | 1 | | 879 | 15,241 |
| 1998 | 6,559 | 2,118 | 779 | 1,762 | 1,762 | 682 | 91 | 2 | 178 | 14 | | 805 | 14,751 |
| 1999 | 3,220 | 1,885 | 1,058 | 350 | 273 | 121 | 161 | 7 | 30 | 3 | | 249 | 7,357 |
| 2000 | 3,432 | 2,510 | 2,688 | 1,466 | 979 | 22 | 2 | 12 | 52 | 147 | | 306 | 11,615 |
| 2001 | 3,878 | 2,199 | 1,673 | 594 | 529 | 574 | 41 | 21 | 68 | 14 | | 505 | 10,098 |
| 2002 | 5,925 | 1,843 | 1,885 | 768 | 606 | 544 | 221 | 34 | 70 | 50 | | 267 | 12,214 |
| 2003 | 5,968 | 1,740 | 1,419 | 210 | 618 | 935 | 762 | 48 | 40 | 7 | | 67 | 11,814 |
| 2004 | 6,437 | 2,105 | 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 | 6,927 | 4,271 | 2,221 | 1,017 | 1,450 | 230 | 55 | 2 | 23 | 109 | 1,228 | 1,579 | 19,111 |
| 2011 | 9,479 | 4,598 | 8,448 | 1,089 | 1,369 | 631 | 884 | 1 | 28 | 73 | 881 | 2,492 | 29,973 |
| Average | 6,337 | 2,928 | 2,449 | 652 | 1,145 | 468 | 345 | 12 | 64 | 46 | | 520 | 15,106 |

Table 1.36 Bycatch estimates (t) of **pollock** caught in the other non-pollock EBS directed fisheries, 2003-2011 based on then NMFS Alaska Regional Office reports from observers (*2011 data are preliminary*).

| Target fishery | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|
| Pacific cod fishery | 16,015 | 18,597 | 14,105 | 14,923 | 19,981 | 9,648 | 7,881 | 6,415 | 7,925 | 12,832 |
| Yellowfin sole fishery | 11,570 | 10,479 | 10,312 | 6,084 | 4,041 | 9,921 | 7,024 | 5,225 | 6,644 | 7,922 |
| Rock sole fishery | 4,928 | 8,964 | 7,240 | 6,923 | 3,212 | 5,324 | 6,124 | 6,016 | 7,086 | 6,202 |
| Flathead sole fishery | 2,989 | 5,100 | 3,664 | 2,641 | 3,613 | 4,234 | 3,166 | 3,086 | 1,490 | 3,331 |
| Other flatfish | 288 | 517 | 1,124 | 1,088 | 606 | 1,046 | 322 | 321 | 797 | 679 |
| Other fisheries | 667 | 939 | 492 | 209 | 594 | 75 | 38 | 92 | 163 | 363 |
| **Total** from other fisheries | 36,457 | 44,596 | 36,937 | 31,868 | 32,047 | 30,248 | 24,555 | 21,155 | 24,104 | 31,330 |

Table 1.37 Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997-2011 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 2011 data are through November 4th, 2011.

| | 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 | 909 | 52 | 9 | 733 | 609 | 43,021 | 180,782 | 96 |
| 2004 | 1,104 | 27 | 6 | 1,189 | 743 | 51,700 | 440,477 | 93 |
| 2005 | 610 | 0 | 1 | 659 | 2,300 | 67,364 | 704,586 | 113 |
| 2006 | 436 | 204 | 3 | 1,753 | 3,282 | 84,436 | 310,858 | 122 |
| 2007 | 345 | 8 | 3 | 1,574 | 3,412 | 127,409 | 100,261 | 293 |
| 2008 | 128 | 588 | 41 | 9,071 | 10,133 | 22,123 | 15,845 | 331 |
| 2009 | 40 | 1,137 | 20 | 6,267 | 7,625 | 13,010 | 47,602 | 460 |
| 2010 | 351 | 1,038 | 29 | 13,552 | 10,020 | 10,129 | 14,194 | 264 |
| 2011 | 375 | 581 | 20 | 10,266 | 6,550 | 25,451 | 191,441 | 342 |

Table 1.38. 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 | 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 |
| Fish. 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 (2012) | 1a |
|---|---|
| Age 3+ 2012 begin-year biomass | 8,341,000 t |
| 2011 Spawning biomass | 2,097,000 t |
| $B_{msy}$ | 2,034,000 t |
| $B_{40\%}$ | 2,572,000 t |
| $B_{35\%}$ | 2,251,000 t |
| $B_{100\%}$ | 6,431,000 t |
| $B_0$ | 5,329,000 t |

| Yield Considerations | | 2012 | 2013* |
|---|---|---|---|
| ABC: | Harmonic Mean $F_{msy}$ | 2,198,000 t | 2,526,000 t |
| ABC: | Yield $F_{40\%}$ (Tier 3) | 1,245,000 t | 1,466,000 t |
| OFL: | Arithmetic Mean $F_{msy}$ Yield | 2,474,000 t | 2,842,000 t |
| OFL: | Yield $F_{35\%}$ (Tier 3) | 1,507,000 t | 1,629 ,000 t |

* Assuming 2011 catches equal 1,088000 t

## Figures

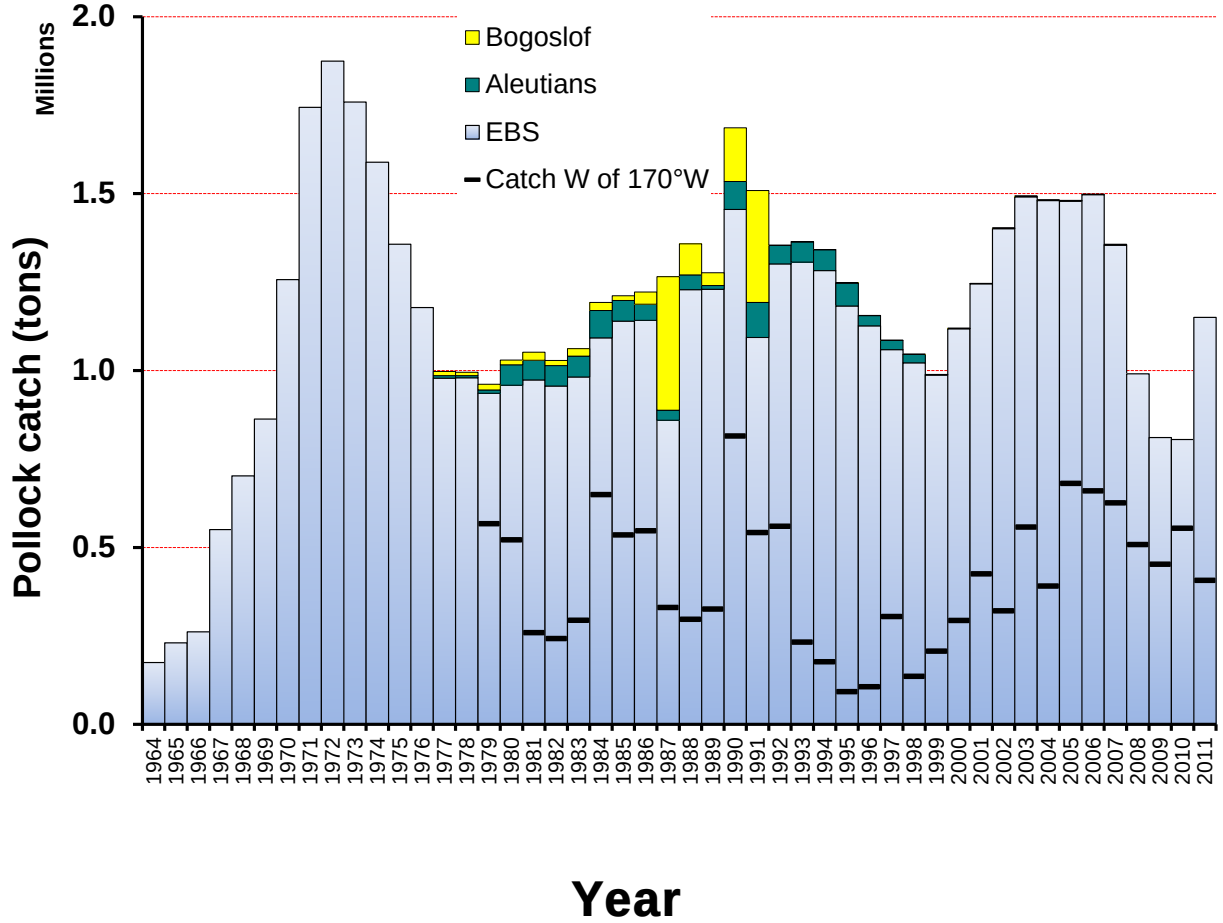


Figure 1.1. Alaska pollock catch estimates from the Eastern Bering Sea, Aleutian Islands, and Bogoslof Island regions, 1964-2011. The 2011 value is based on expected totals for the year.

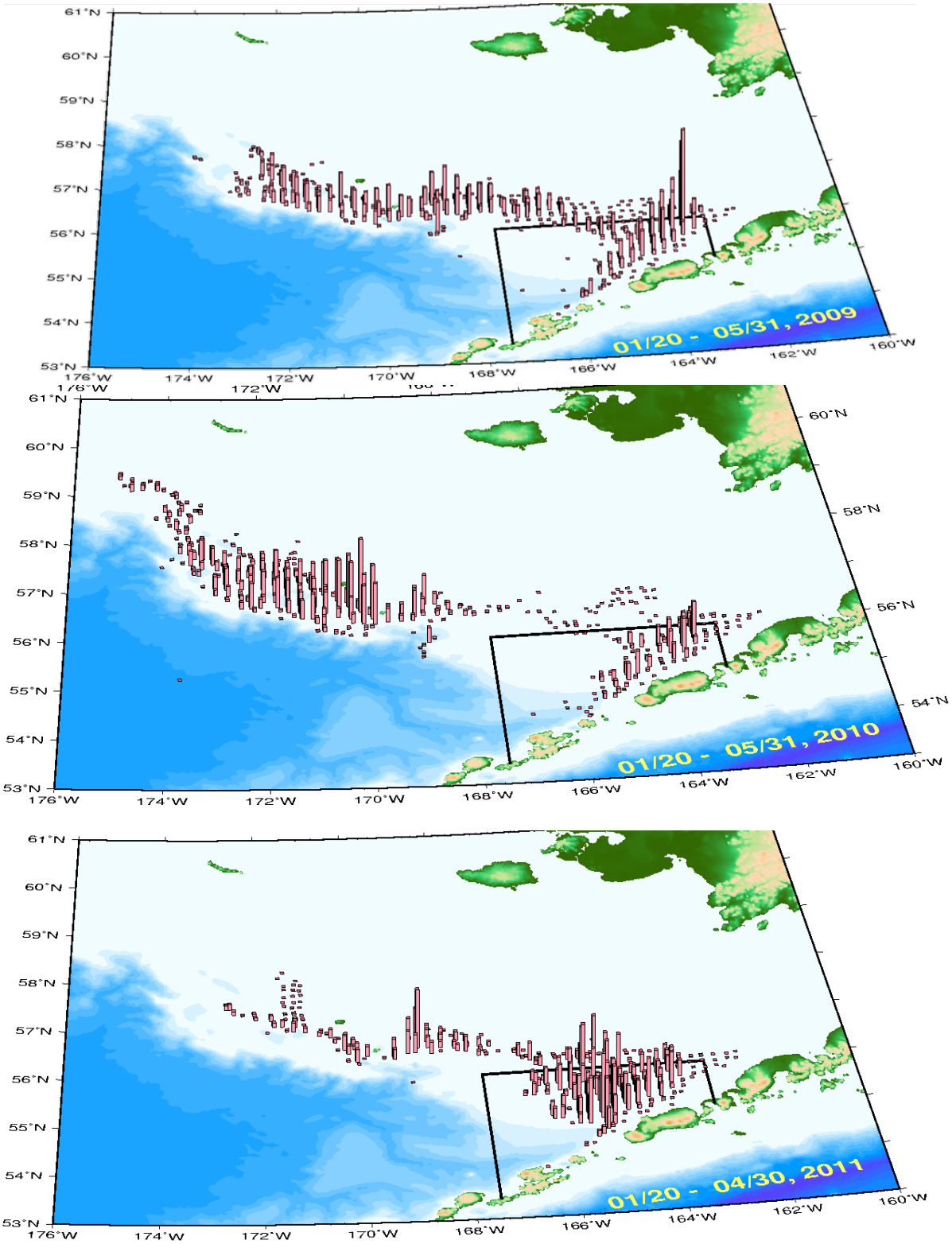


Figure 1.2. Pollock catch distribution 2009-2011, January – May on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

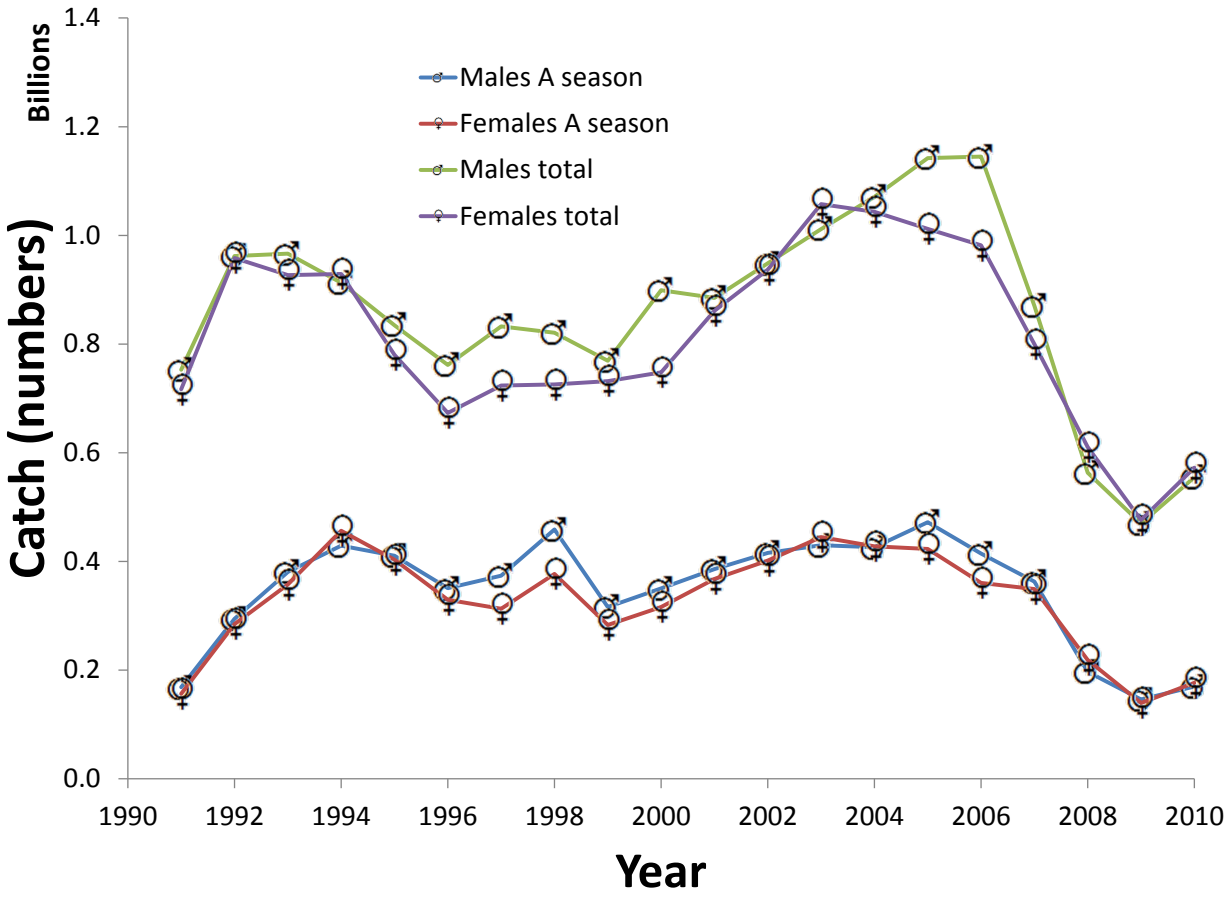


Figure 1.3. Estimate of EBS pollock catch numbers by sex for the "A season" (January-May) and for the entire annual fishery, 1991-2010.

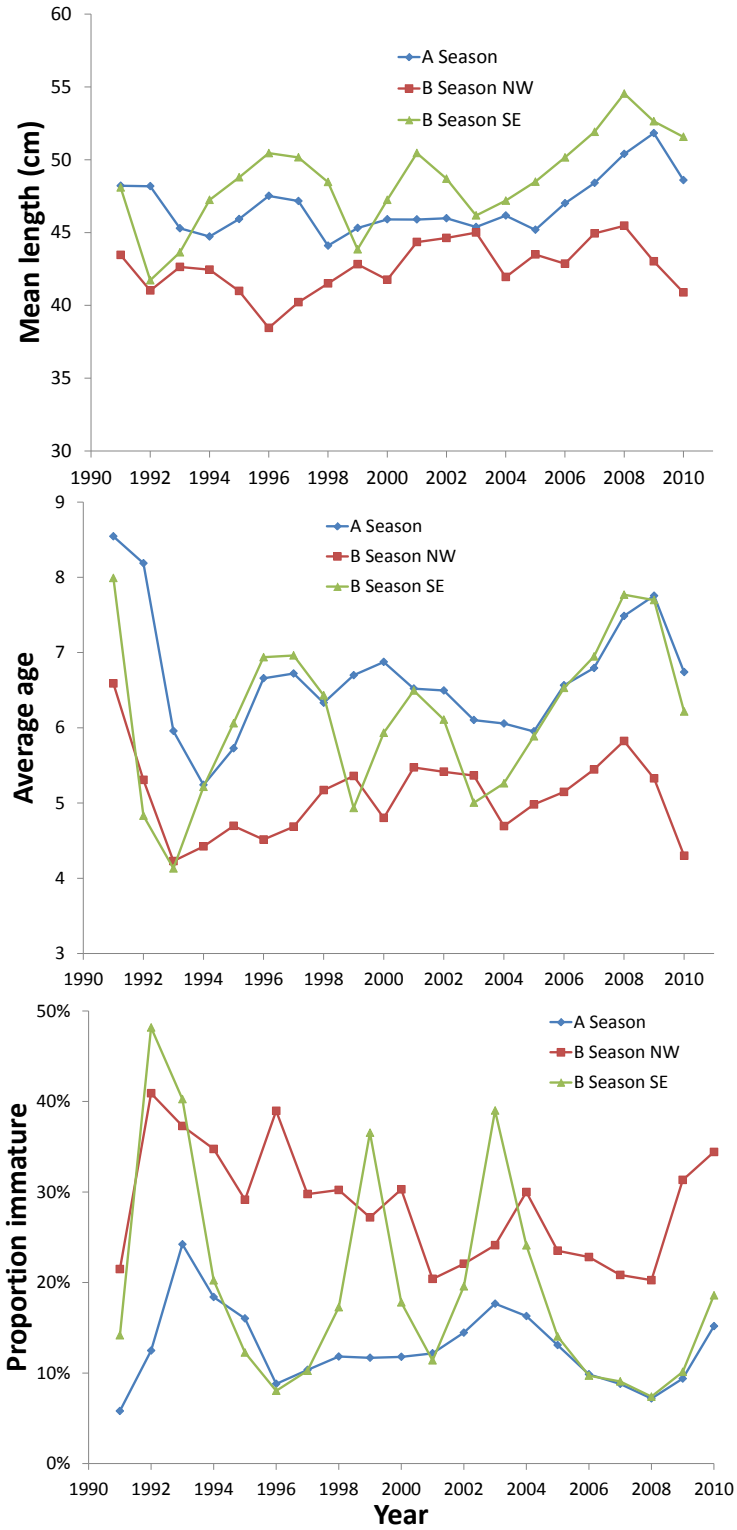


Figure 1.4. Estimated EBS pollock average length (top panel) and average age (middle panel) of the stratum-specific catch. The bottom panel shows the proportion of the catch estimated to be immature. Strata are all areas during the "A season" (January-April) and divided at 170°W for (SE and NW) for the B-season (June-October); 1991-2010.

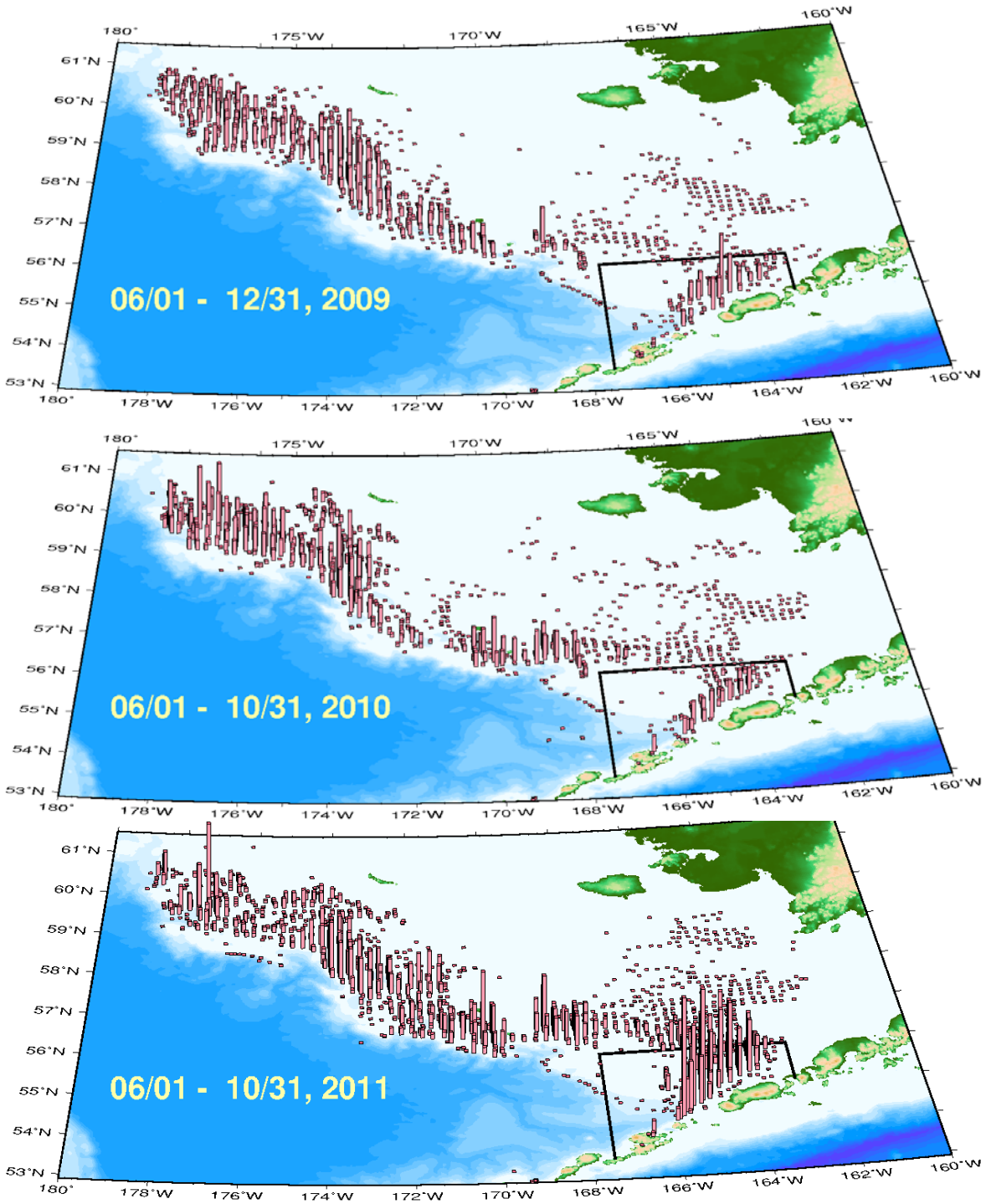


Figure 1.5. Pollock catch distribution during June – December, 2009-2011. The line delineates the catcher-vessel operational area (CVOA) and the height of the bars represents relative removal on the same scale between years. Note that in 2011 the observer coverage increased to 100% for all pollock vessels (for salmon bycatch monitoring) consequently the relative magnitude of the catch increase in the CVOA is affected (catcher-vessels previously had about 50% of their catch occur with observers on board)

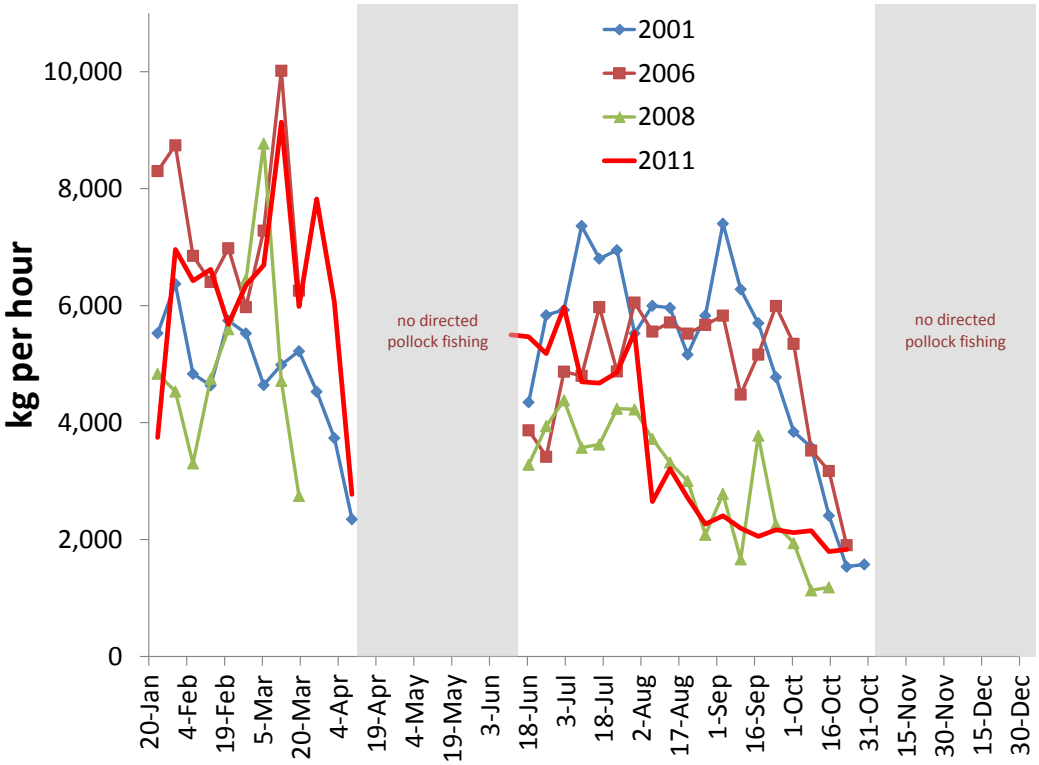


Figure 1.6. Weekly mean nominal pollock catch per hour towed for the EBS pollock fishery for selected years (2001, 2006, 2008, and 2011).

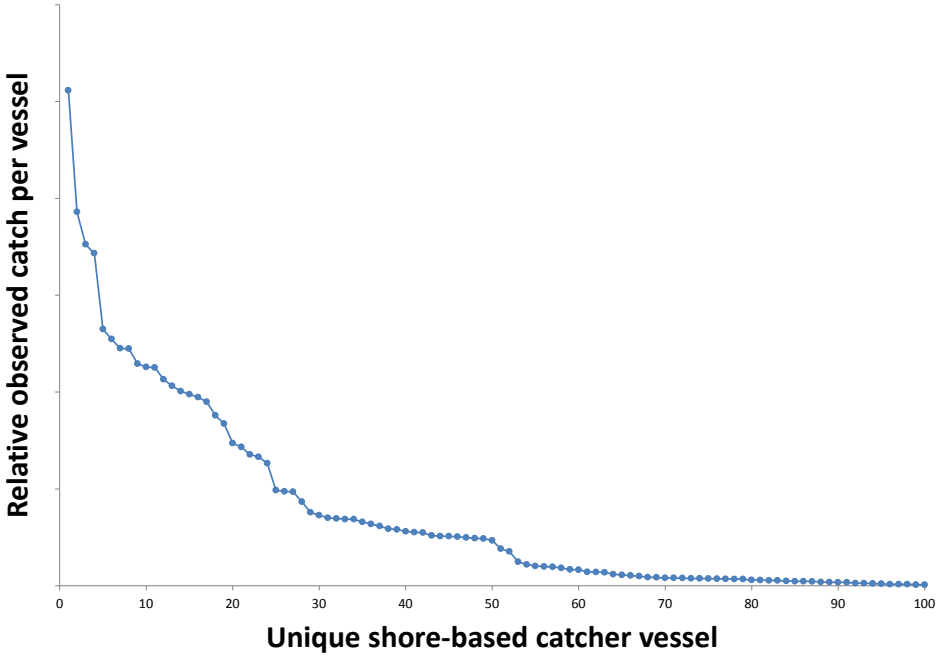


Figure 1.7. Relative observed catch by unique shore-based catcher vessel during the B-season of the EBS pollock fishery, 1990-2011. The vessels labeled 1-25 were selected as one group whereas vessels 26-53 were selected as a second group used in subsequent catch-rate evaluations.

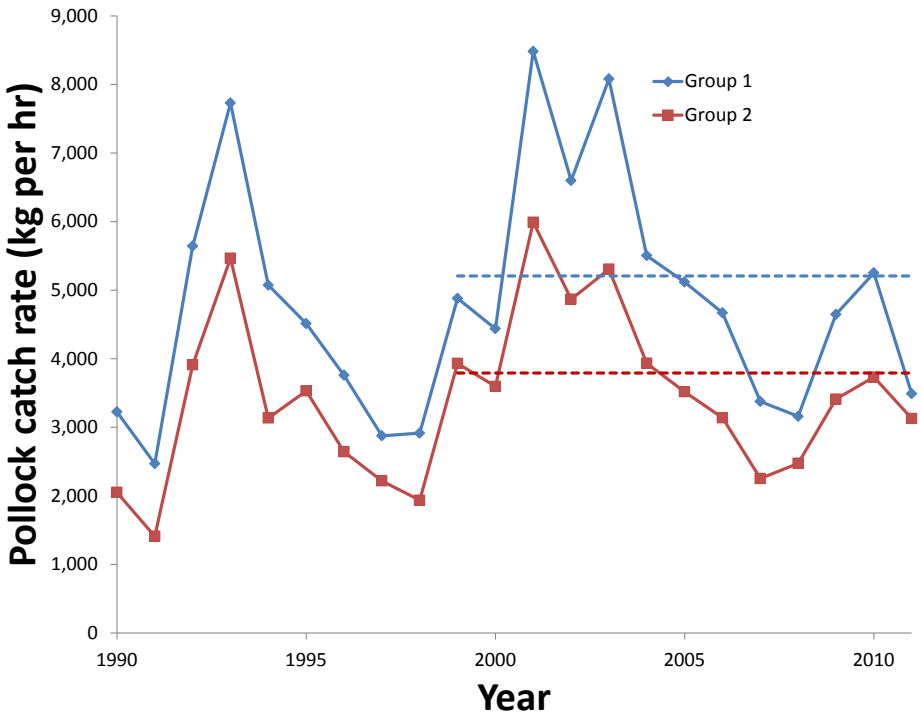


Figure 1.8. Mean observed catch rates in kg per hr for two groups of B-season shore-based catcher boats of the EBS pollock fishery, 1990-2011. Dashed lines show the mean values from 1999-2011.

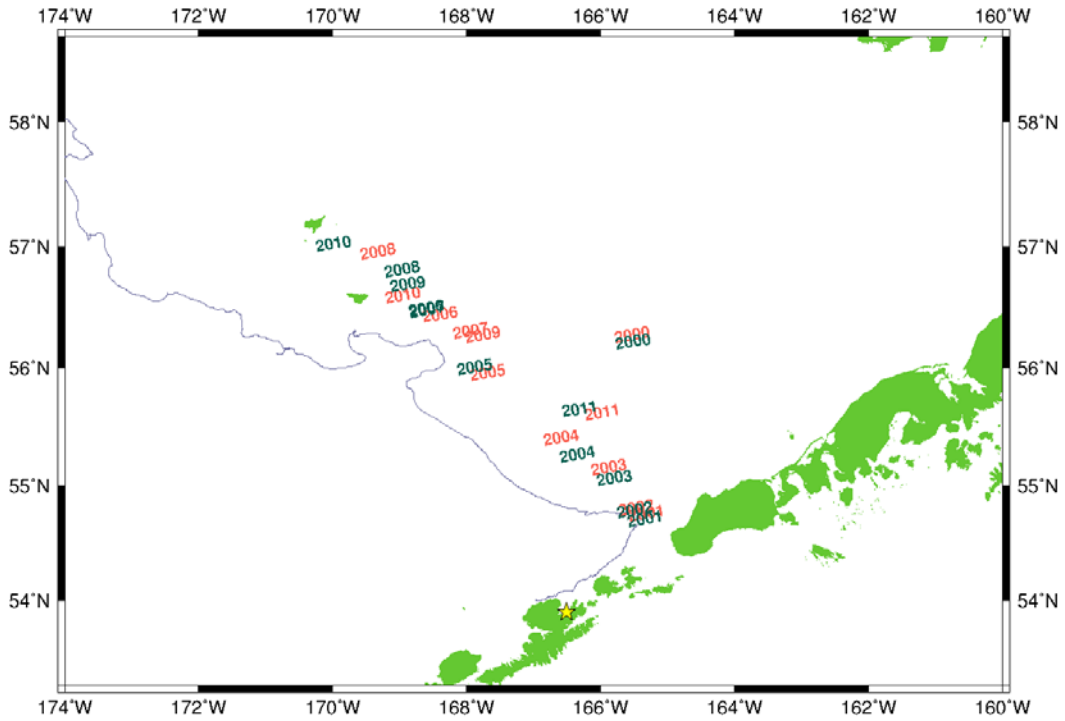


Figure 1.9. Mean observed catch locations by year for group 1 (black) and group 2 (red) shore-based catcher boats during B-season of the EBS pollock fishery, 2000-2011. Yellow star indicates the location of Dutch Harbor Alaska.

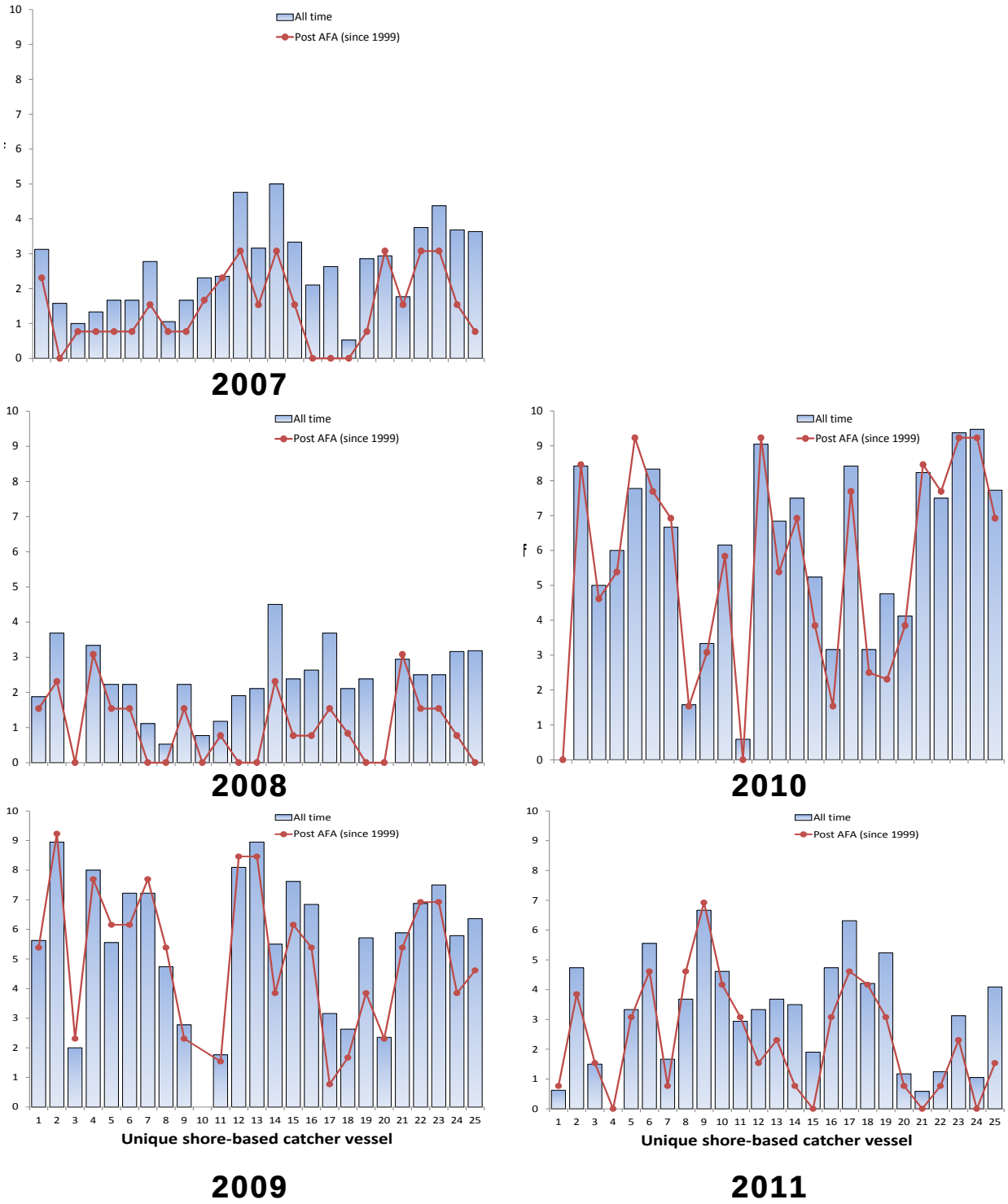


Figure 1.10. Number of years with worse conditions (out of standard 10 years) by the catcher vessels within group 1 as ranked for 2007 through 2011. Columns represent data from 1990-2011 whereas the lines are post-AFA (1999-2011). A score of "10" means that year ranked highest for that vessel, a score of "0" means it was the worst (in terms of kg of pollock caught per year during B-season).

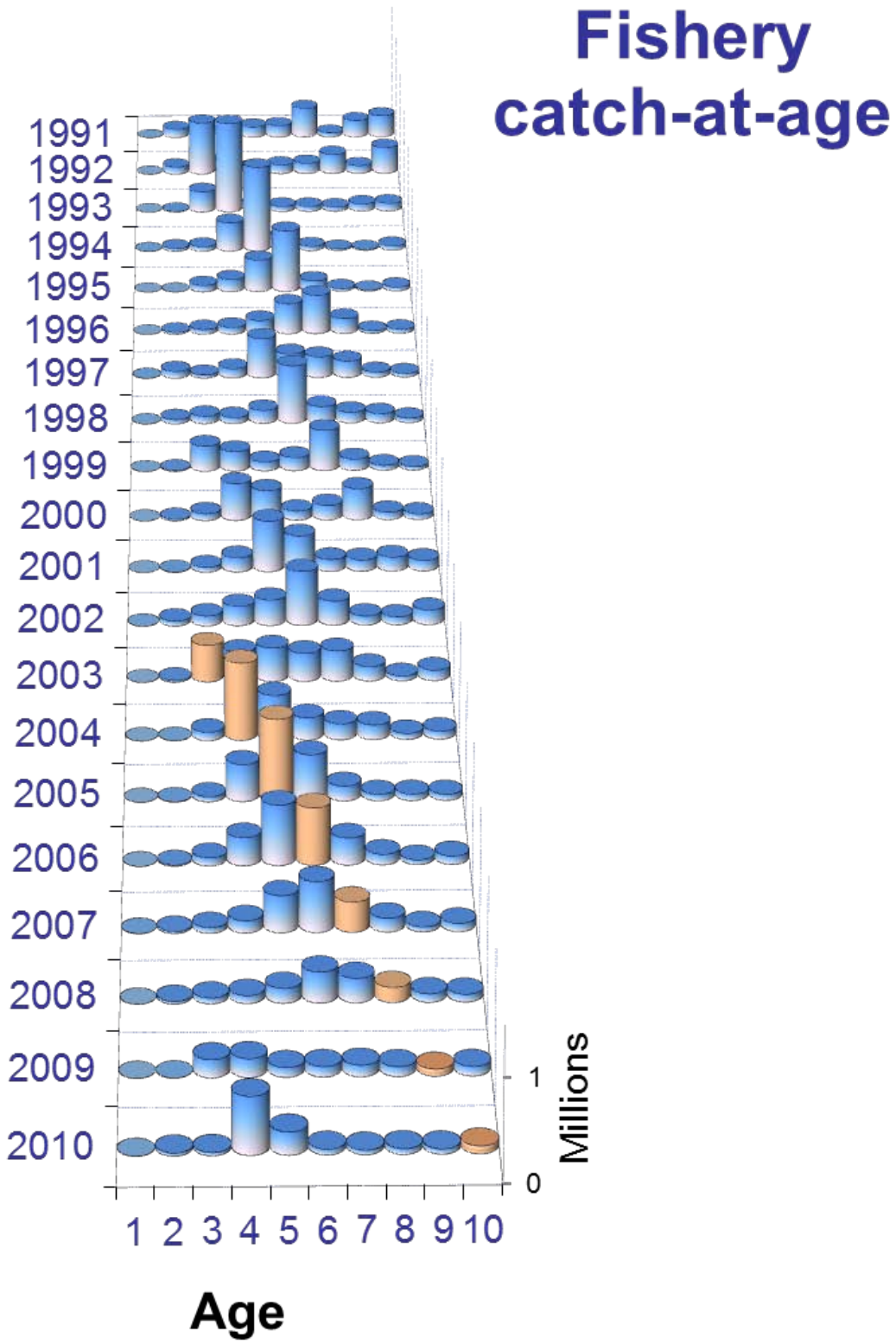


Figure 1.11. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2010. Age 10 represents pollock age 10 and older. The 2000 year-class is highlighted.

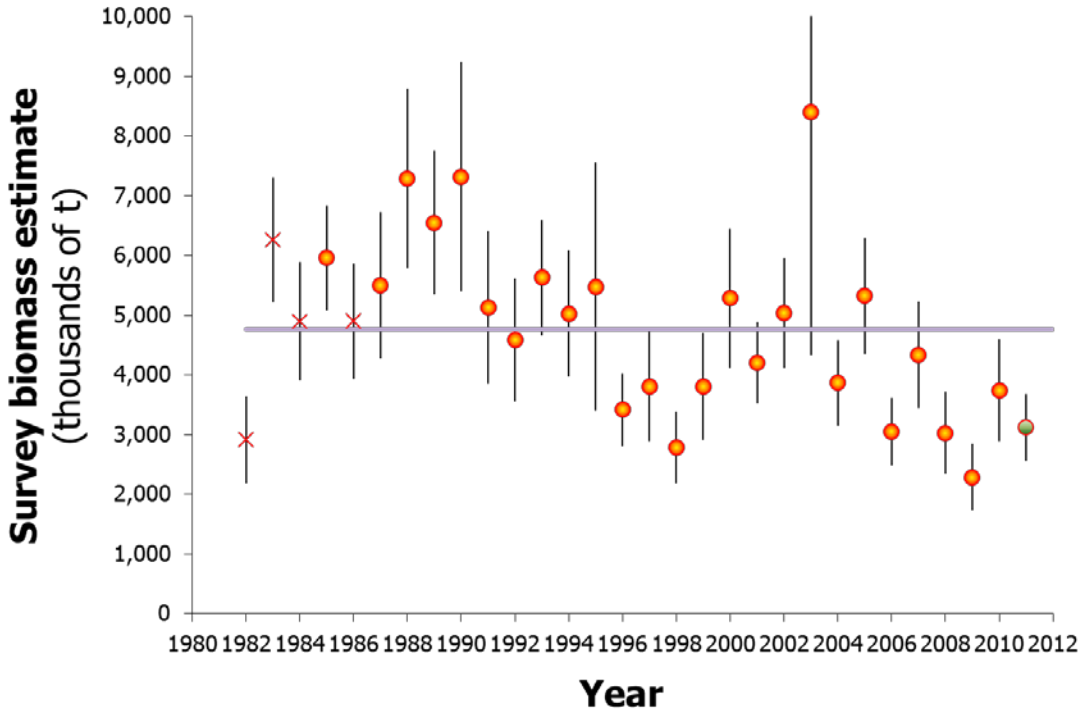


Figure 1.12. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS pollock, 1982-2011. These estimates **include** the northern strata except for 1982-84, and 1986 (years indicated with crosses).

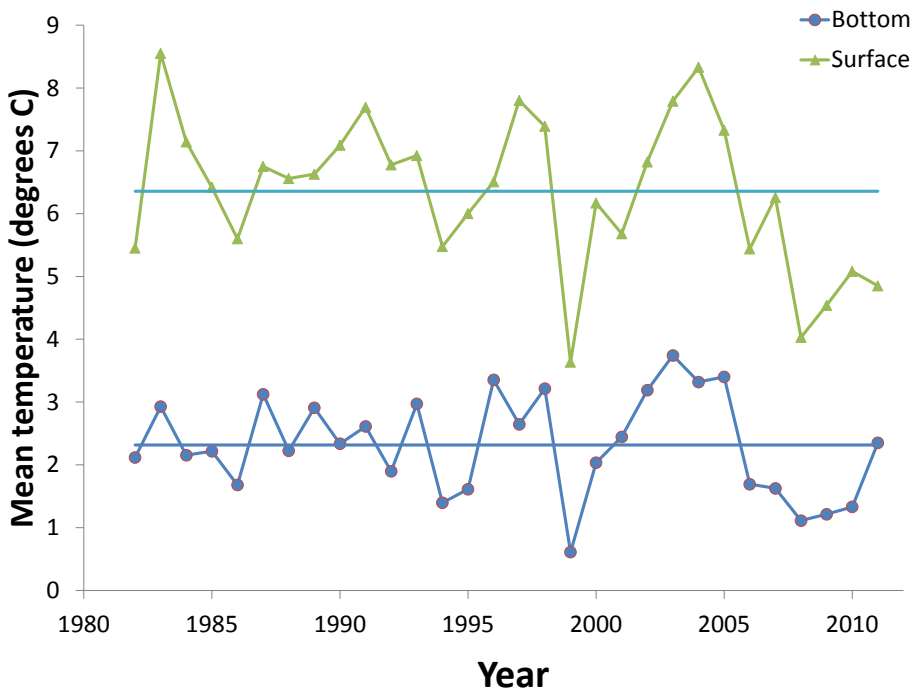


Figure 1.13. Area-weighted bottom (lower lines) and surface (upper lines) temperatures for the Bering Sea during the NMFS summer bottom-trawl surveys (1982-2011).

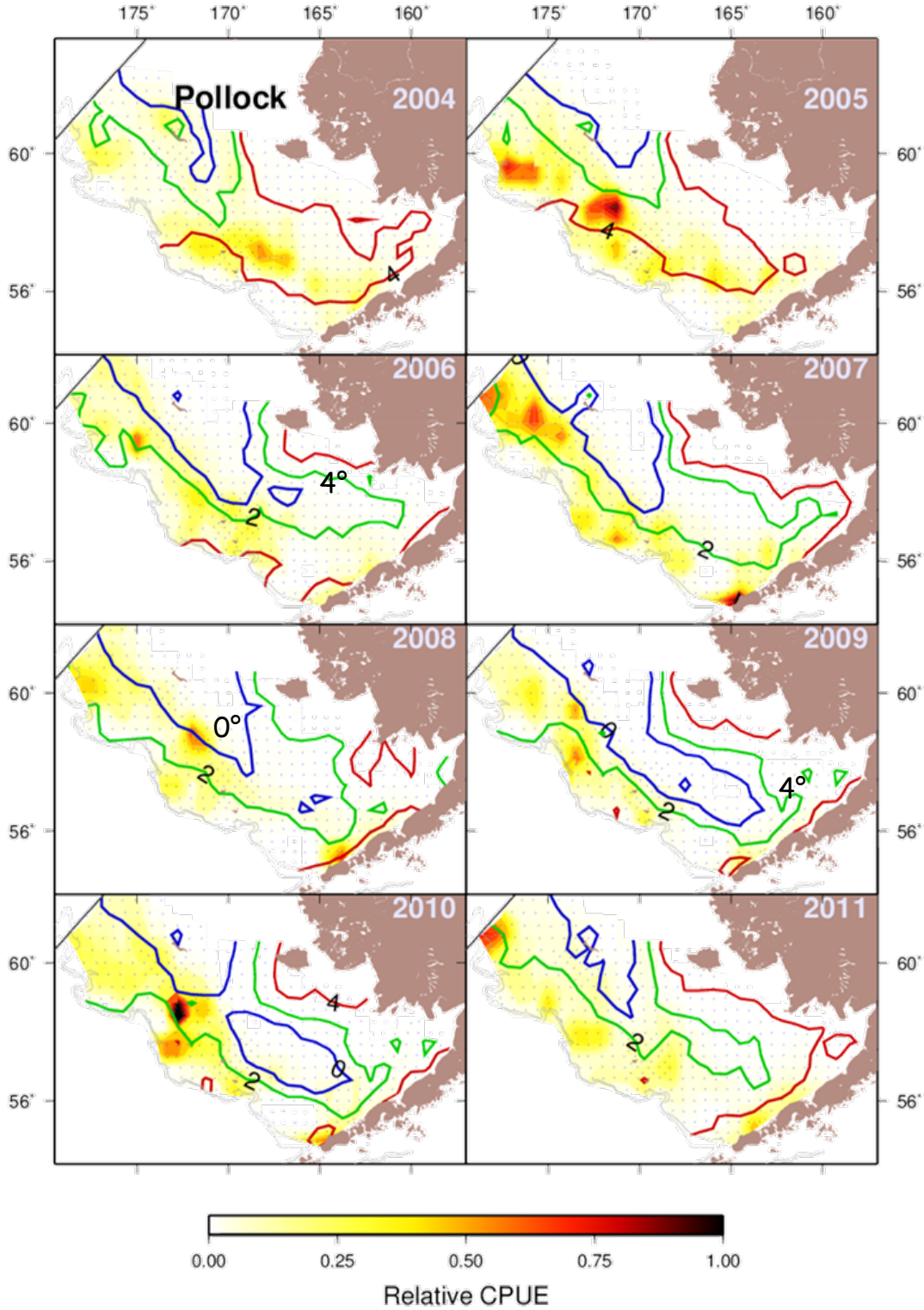


Figure 1.14. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 2004-2011.

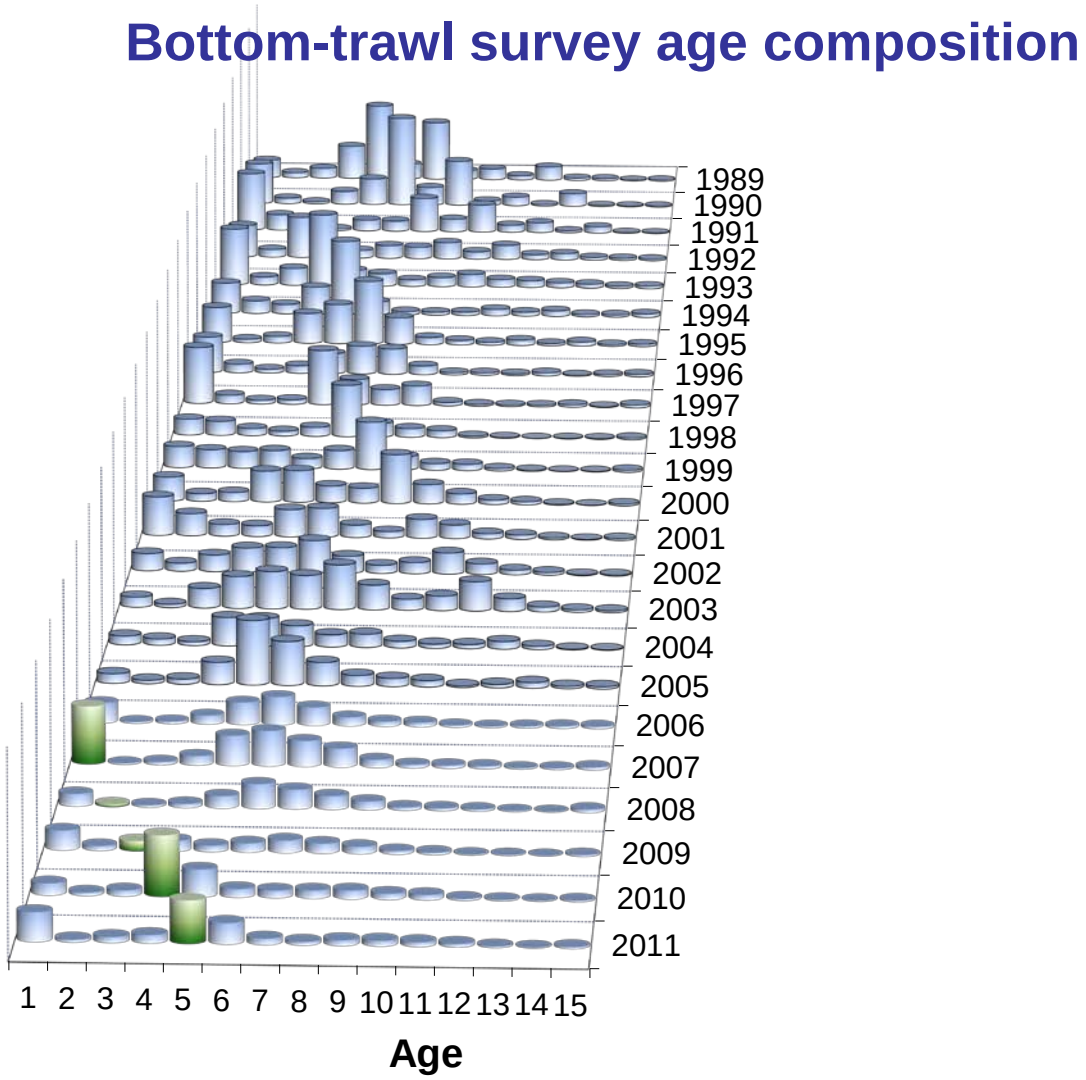


Figure 1.15. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1989-2011). The 2006 year-class is shaded differently.

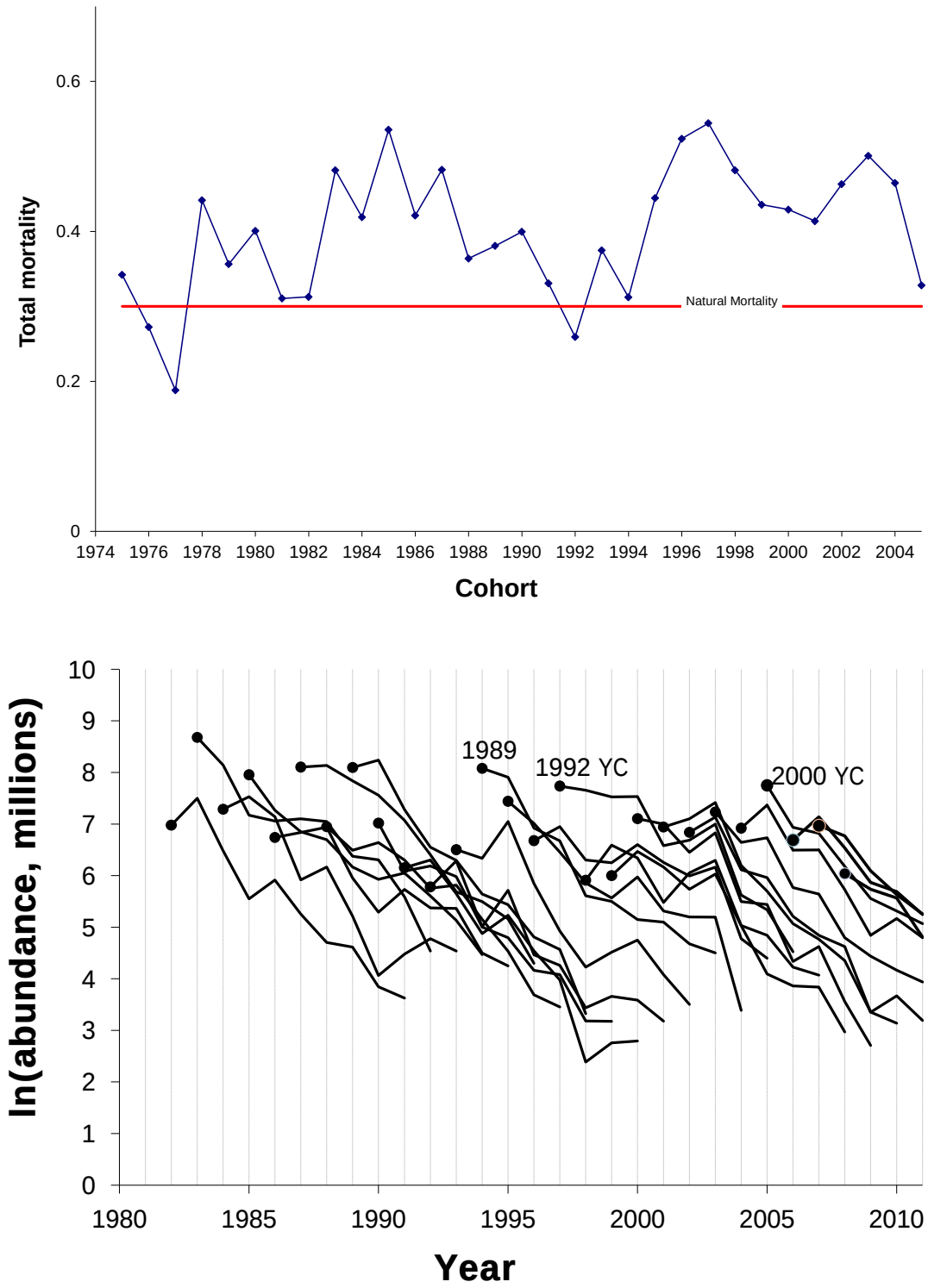


Figure 1.16. Evaluation of EBS pollock cohort abundances as observed for age 6 and older in the NMFS summer bottom trawl surveys. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort.

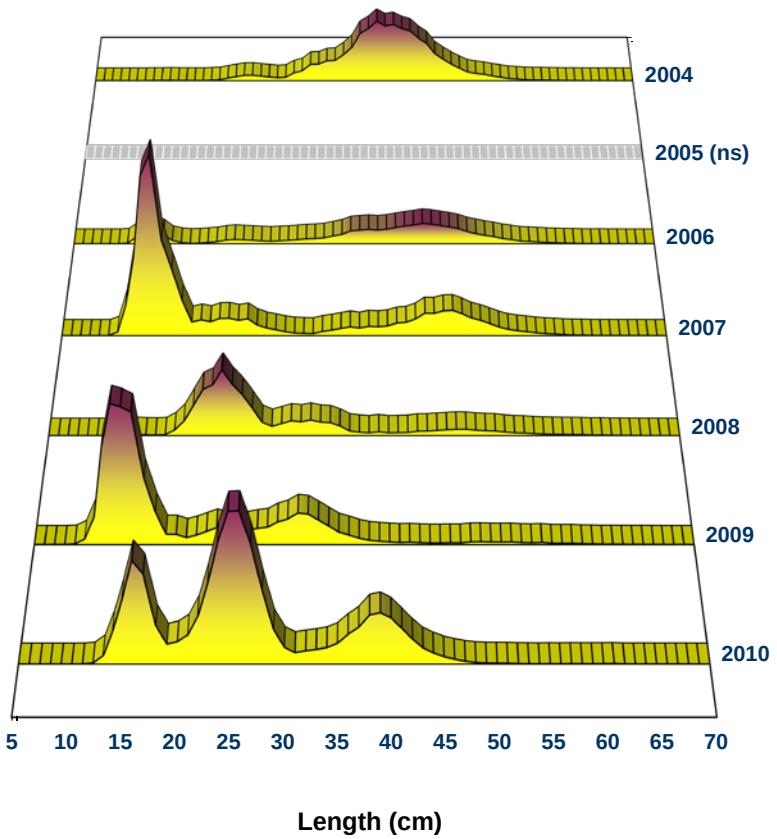


Figure 1.17. Acoustic-trawl survey relative abundances at length for EBS pollock, 2004-2010. Vertical scale is equal for all years and is relative to numbers of fish.

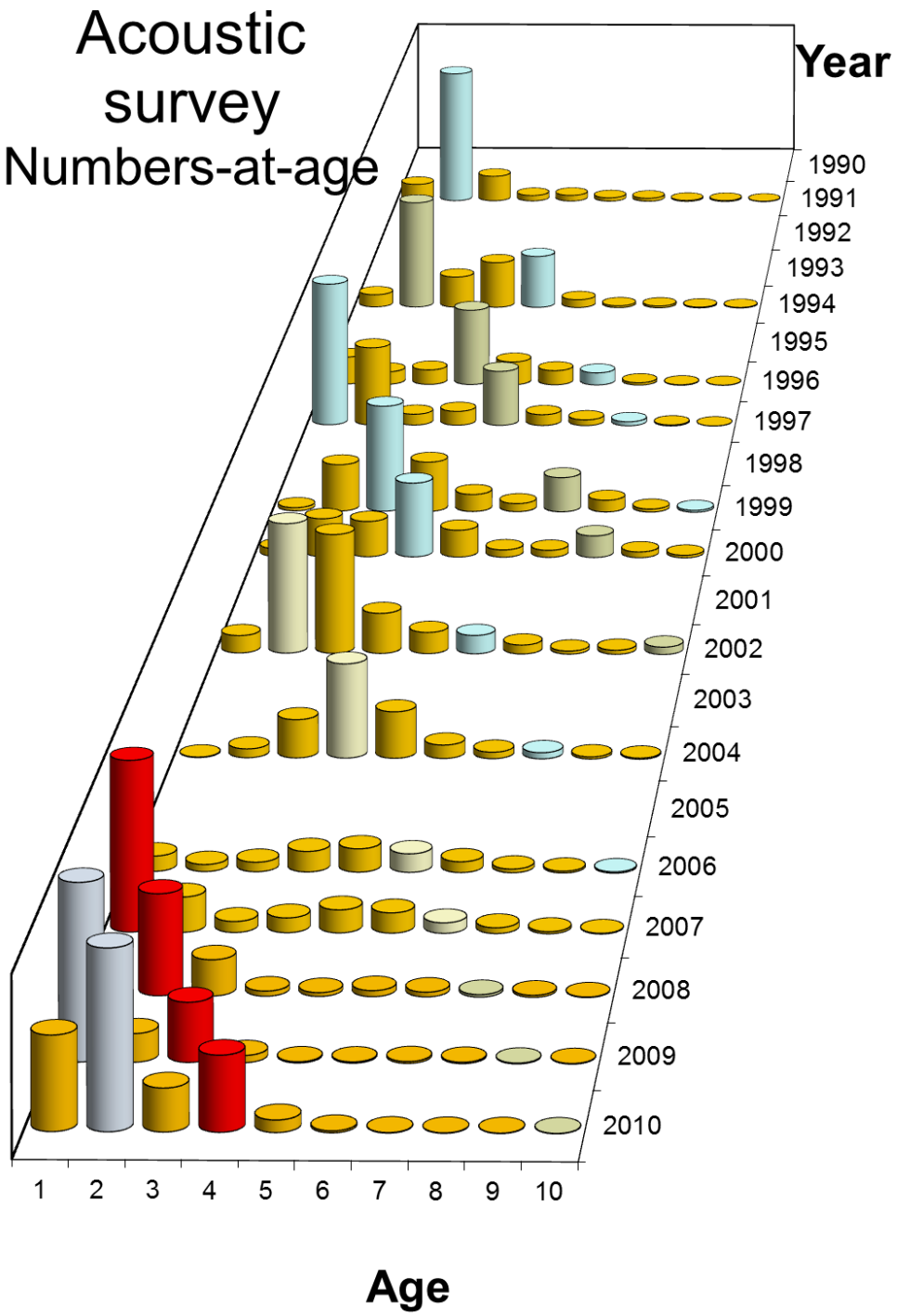


Figure 1.18. Time series of estimated abundances at age (numbers) for EBS pollock from the AT surveys, 1991-2010. The shaded columns represent selected cohorts through time.

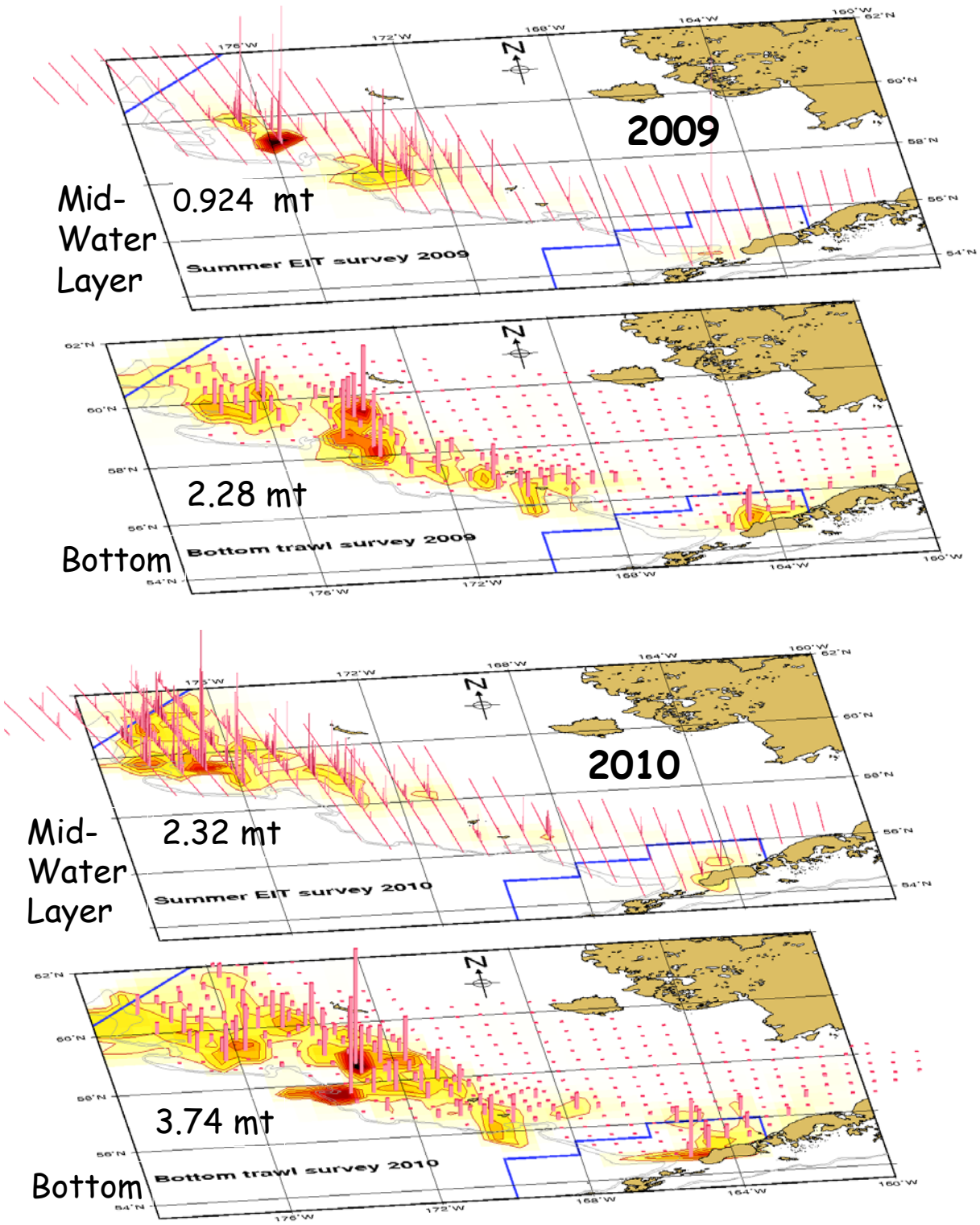


Figure 1.19. Acoustic-trawl survey results for 2009 and 2010. The lower figure is the result from the BTS data in the same years. Vertical lines represent biomass of pollock as observed in the different surveys (mt = millions of t).

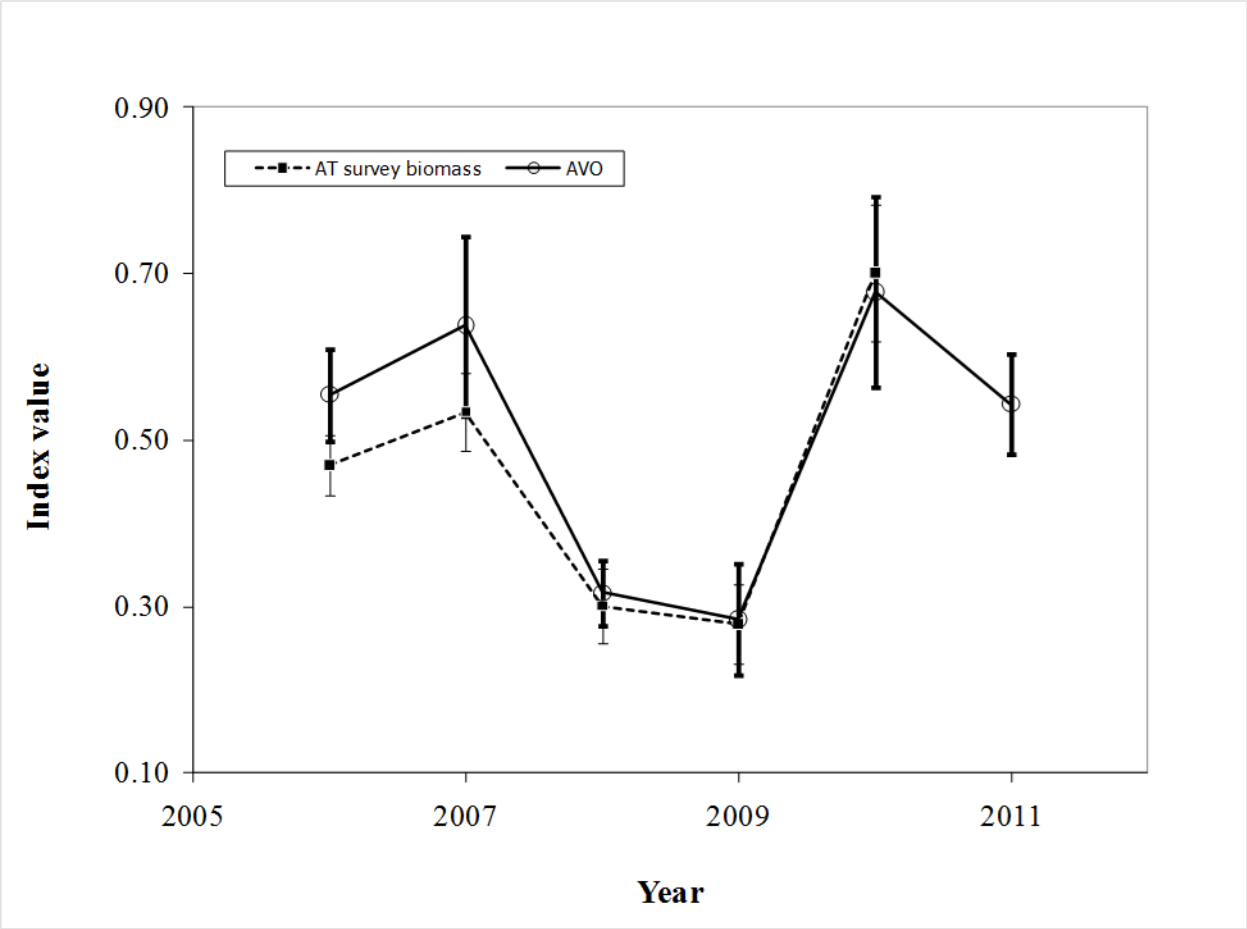


Figure 1.20. AT survey biomass in the U.S. EEZ and AVO index 2006-2011 with 95% confidence intervals based on estimates of 1-D geostatistical relative estimation error. Each time series has been scaled to its mean value for the period 1999-2004 (not shown).

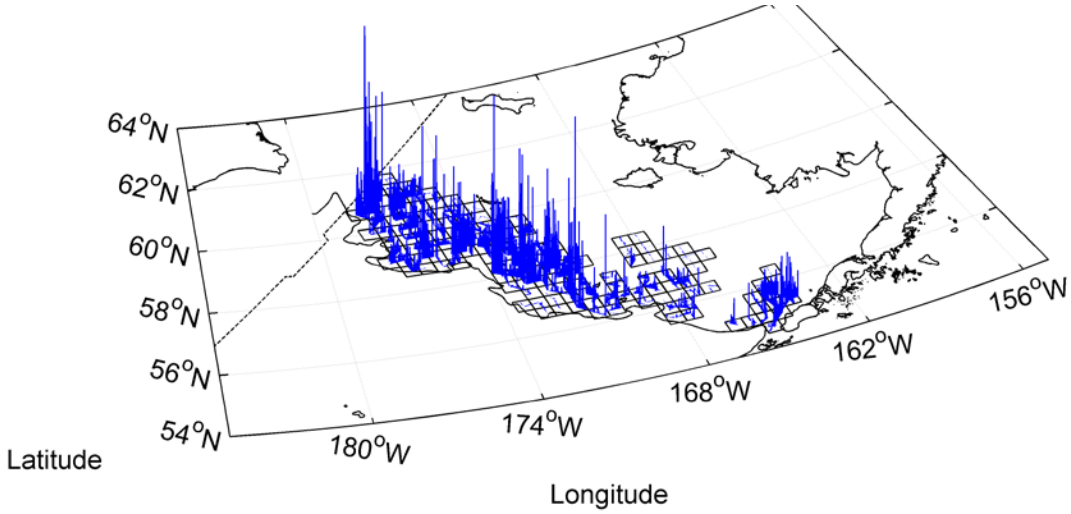


Figure 1.21. Acoustic backscatter assigned to pollock from acoustic vessels of opportunity (AVO) collected in the index areas from the 2011 bottom trawl survey.

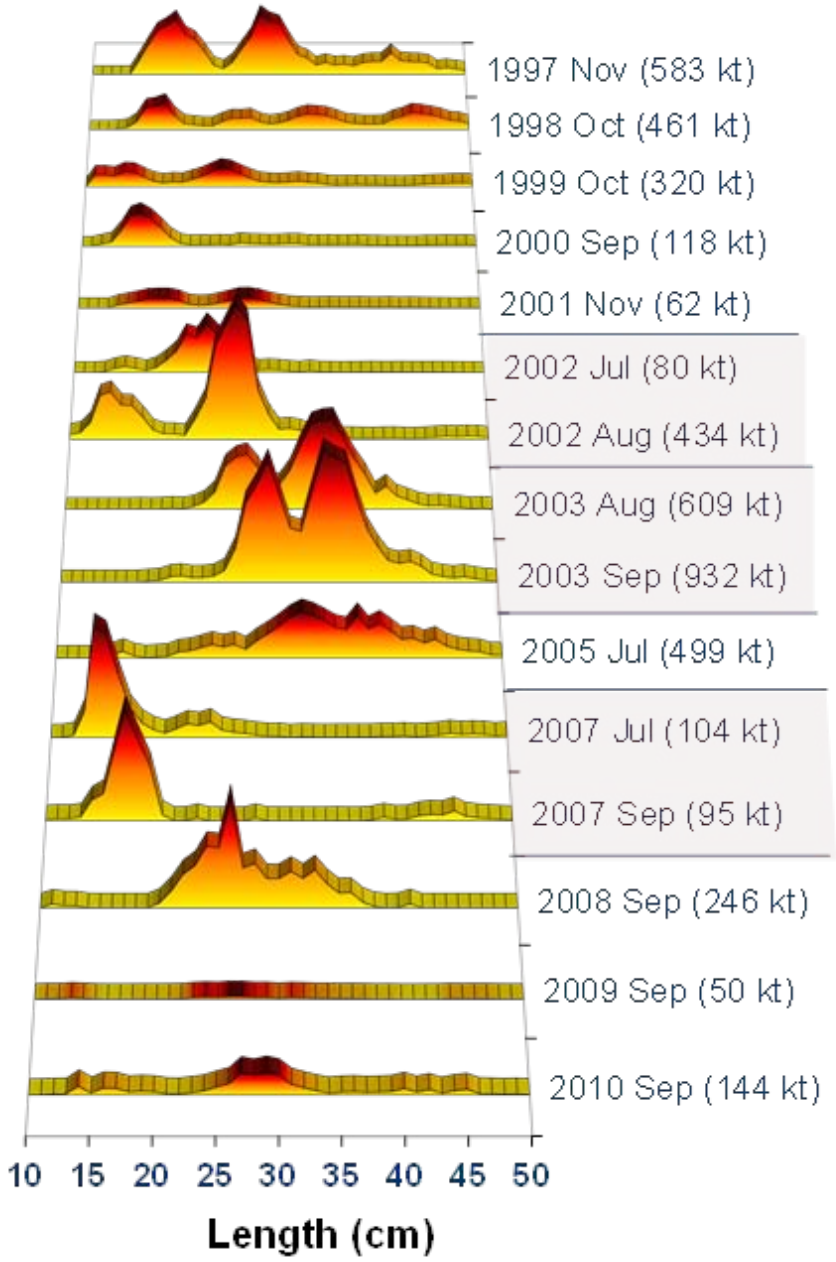


Figure 1.22. Russian Navarin/Anadyr region survey estimates of pollock numbers at length (vertical scale) by year and month survey conducted with biomass estimates shown in side labels (kt=thousands of t). Shaded labels indicate more than one survey within a year.

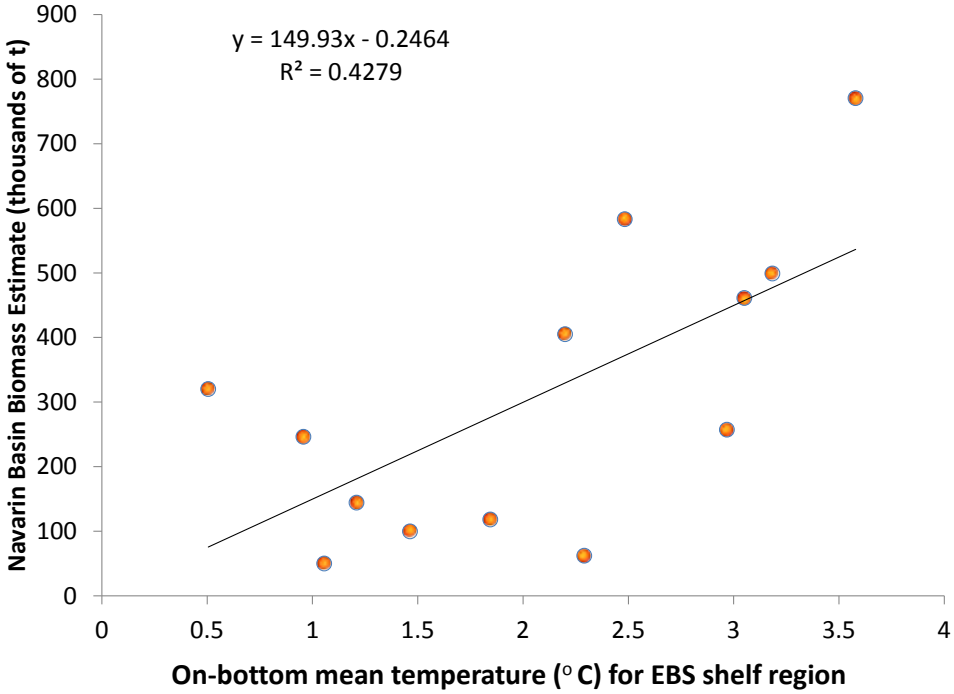


Figure 1.23. Russian Navarin/Anadyr region survey estimates of pollock compared to mean on-bottom temperatures from the EBS shelf survey 1997-2011. For years when multiple Russian surveys occurred (2002, 2003, and 2007) the mean biomass value was applied.

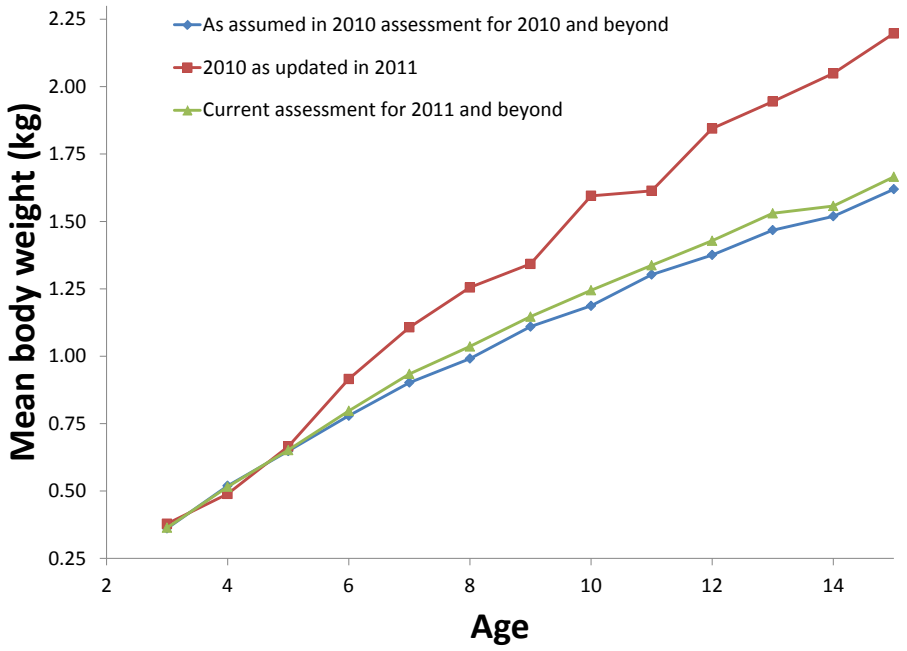


Figure 1.24. Mean fishery body weight (kg) for EBS pollock assumed for the 2010 assessment and as revised using observer data for the current assessment.

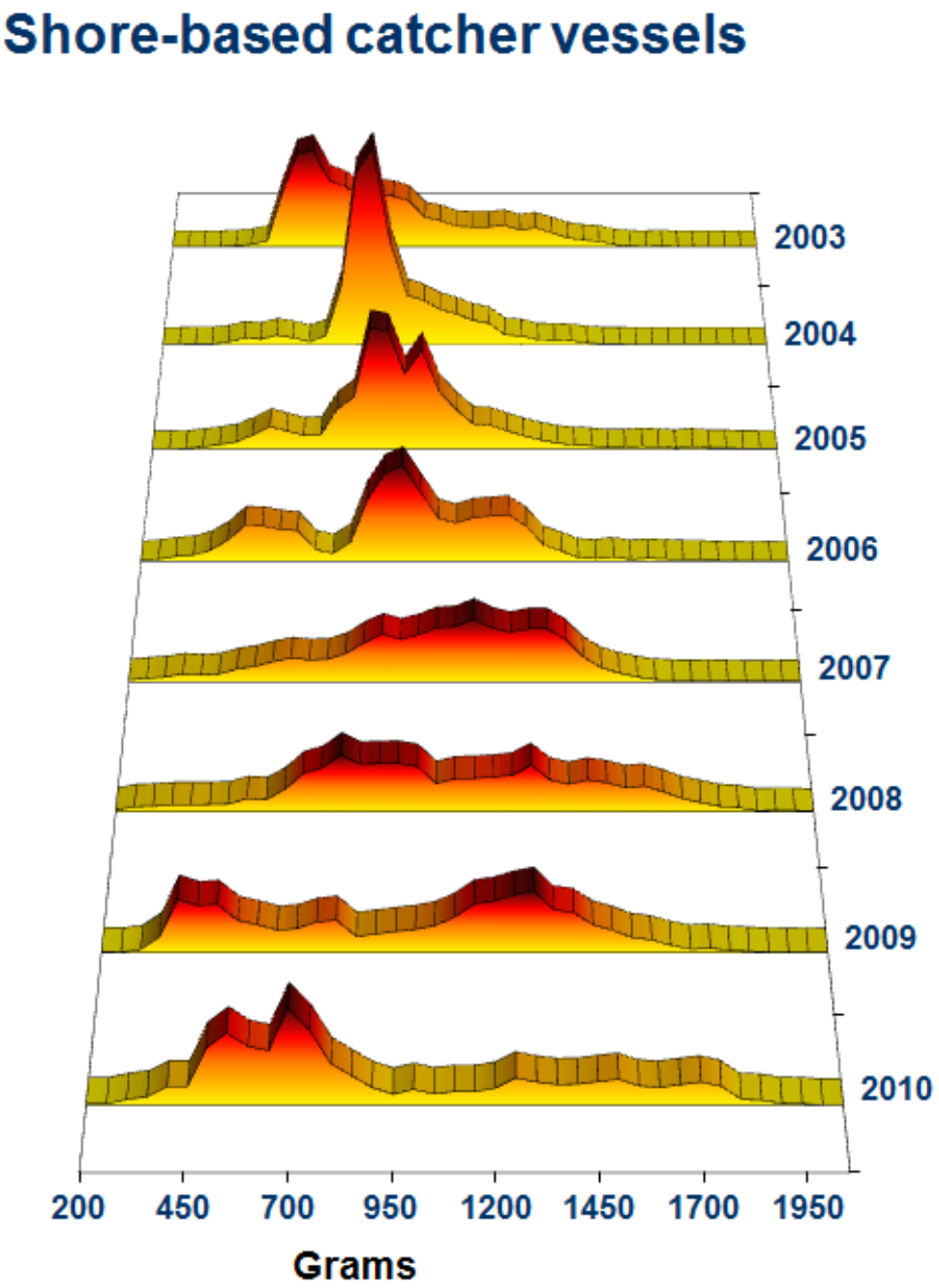


Figure 1.25. Frequency of pollock tows by 50g pollock body mass categories for the shore-based catcher vessels during June-October, 2003-2010.

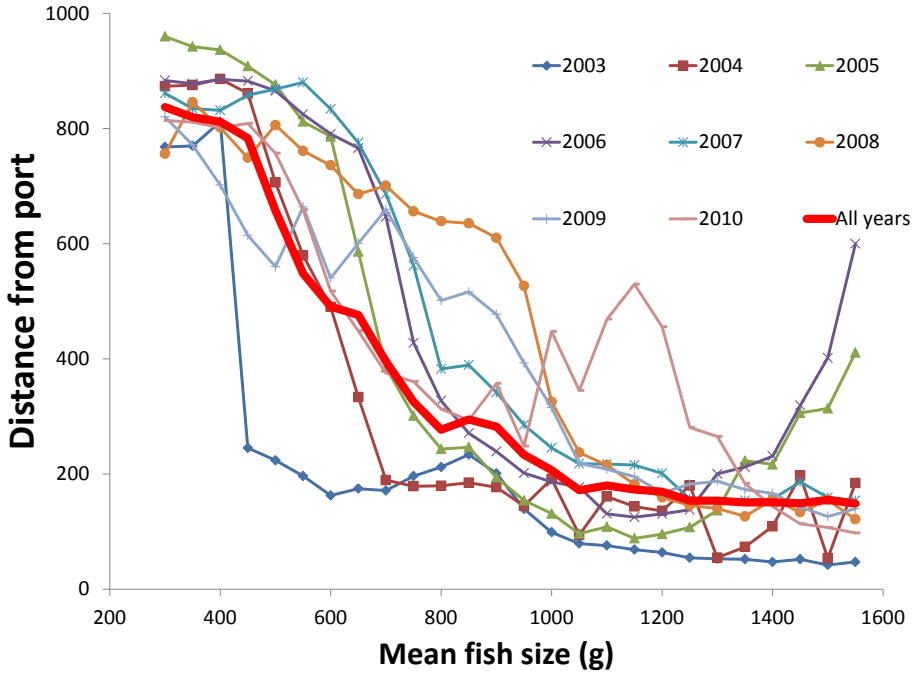


Figure 1.26. Average distance from port (km) by pollock body size category (at 50g intervals), 2003-2010 and all years combined. The "port" is defined as a point midway between Akutan and Dutch Harbor.

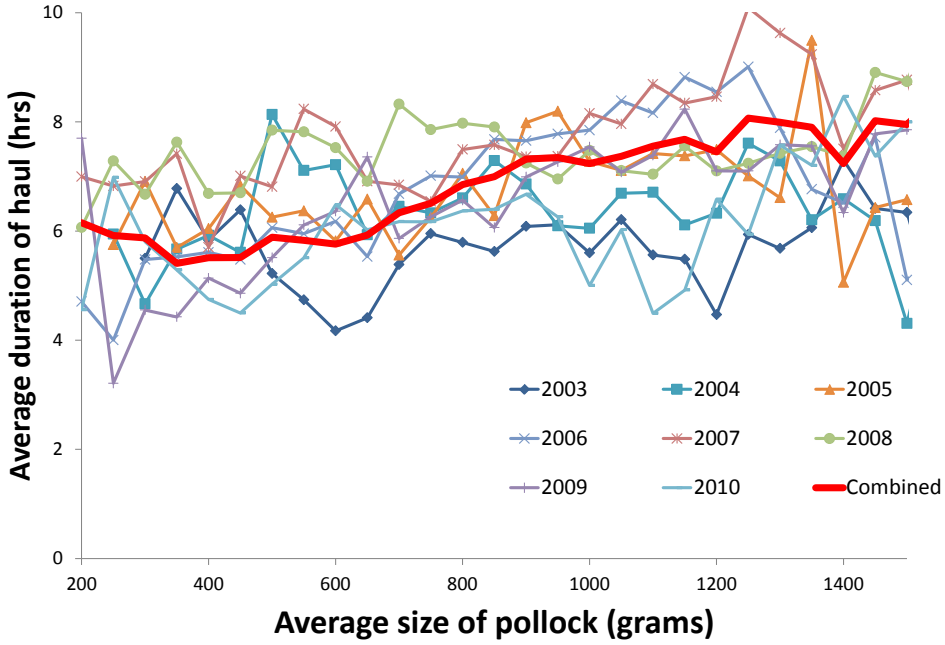


Figure 1.27. Average tow duration by pollock body size category (at 50g intervals), 2003-2010 and all years combined.

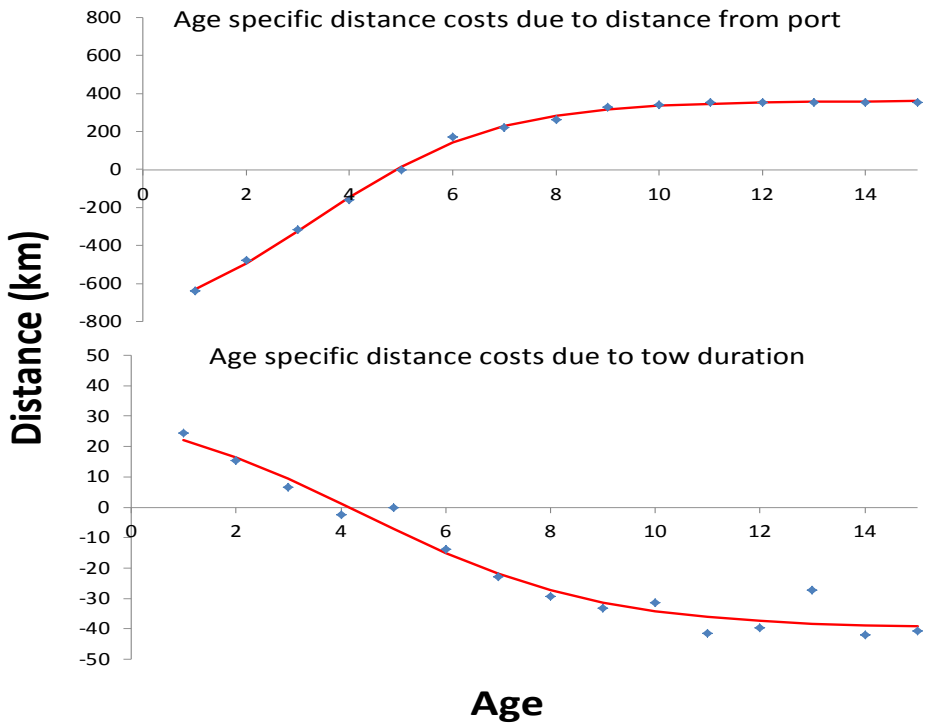


Figure 1.28. Estimated relationship between pollock ages (as mapped from mean body mass at age) and mean distance from port (top panel) and mean distance (in equivalent units) of tow duration. In both figures, the values fitted (points) represent relative distances to observations at age 5. Lines represent sigmoidal curve fits.

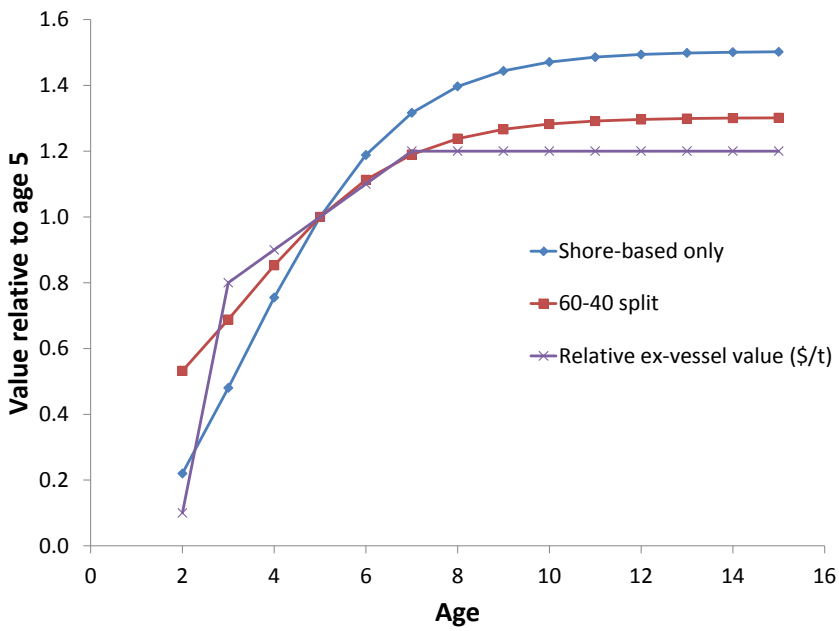


Figure 1.29. Population-level estimated relationship between pollock ages and relative effort (distance) required for capture with and without a 60-40 split and an example relative age-specific value for ex-vessel landings (slope parameter equal to 0.1).

**Years in model**

| Year class | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 1.27 | 0.72 | 0.83 | 0.88 | 0.84 | 0.90 | 0.83 | 0.81 | 0.86 | 0.90 | 0.93 | 0.96 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 | 0.99 |
| 1991 | 0.60 | 0.67 | 0.55 | 0.59 | 0.64 | 0.60 | 0.60 | 0.67 | 0.79 | 0.87 | 0.93 | 0.97 | 0.97 | 0.98 | 0.97 | 0.96 | 0.97 | 0.97 | 0.98 | |
| **1992** | **0.45** | **0.46** | **0.46** | **0.37** | **0.48** | **0.54** | **0.66** | **0.82** | **0.91** | **0.97** | **1.00** | **0.98** | **0.98** | **0.97** | **0.96** | **0.97** | **0.97** | **0.98** | | |
| 1993 | 0.94 | 1.03 | 0.79 | 0.40 | 0.44 | 0.57 | 0.69 | 0.80 | 0.89 | 0.97 | 0.96 | 0.97 | 0.96 | 0.96 | 0.96 | 0.97 | 0.98 | | | |
| 1994 | 1.39 | 1.65 | 0.58 | 0.50 | 0.57 | 0.74 | 0.82 | 0.89 | 0.98 | 0.97 | 0.97 | 0.96 | 0.96 | 0.96 | 0.97 | 0.98 | | | | |
| 1995 | 1.00 | 0.66 | 0.81 | 0.78 | 0.93 | 0.98 | 1.03 | 1.04 | 0.99 | 0.99 | 0.98 | 0.97 | 0.97 | 0.97 | 0.98 | | | | | |
| **1996** | **0.58** | **1.76** | **1.02** | **1.21** | **1.09** | **1.12** | **1.12** | **1.01** | **1.01** | **0.99** | **0.97** | **0.97** | **0.97** | **0.98** | | | | | | |
| 1997 | 1.03 | 2.49 | 0.96 | 0.84 | 0.98 | 1.09 | 1.00 | 1.03 | 0.99 | 0.96 | 0.96 | 0.96 | 0.98 | | | | | | | |
| 1998 | 1.37 | 0.92 | 0.80 | 0.91 | 1.15 | 1.10 | 1.11 | 1.02 | 0.96 | 0.95 | 0.95 | 0.97 | | | | | | | | |
| 1999 | 0.59 | 1.05 | 0.72 | 1.35 | 1.15 | 1.14 | 1.07 | 0.95 | 0.94 | 0.95 | 0.97 | | | | | | | | | |
| **2000** | **0.84** | **0.45** | **1.18** | **1.24** | **1.29** | **1.22** | **0.98** | **0.95** | **0.95** | **0.97** | | | | | | | | | | |
| 2001 | 0.49 | 0.79 | 0.67 | 0.62 | 0.73 | 0.77 | 0.89 | 0.93 | 0.96 | | | | | | | | | | | |
| 2002 | 0.97 | 1.36 | 0.55 | 0.45 | 0.62 | 0.84 | 0.93 | 0.95 | | | | | | | | | | | | |
| 2003 | 3.53 | 1.01 | 0.84 | 0.83 | 0.96 | 0.97 | 0.97 | | | | | | | | | | | | | |
| 2004 | 2.83 | 1.68 | 0.87 | 1.00 | 0.96 | 0.92 | | | | | | | | | | | | | | |
| 2005 | 1.59 | 0.88 | 1.12 | 1.06 | 0.92 | | | | | | | | | | | | | | | |
| **2006** | **0.59** | **1.30** | **1.00** | **0.94** | | | | | | | | | | | | | | | | |
| 2007 | 1.01 | 0.62 | 0.80 | | | | | | | | | | | | | | | | | |
| **2008** | **0.26** | **0.50** | | | | | | | | | | | | | | | | | | |
| 2009 | 0.28 | | | | | | | | | | | | | | | | | | | |
| 2010 | | | | | | | | | | | | | | | | | | | | |

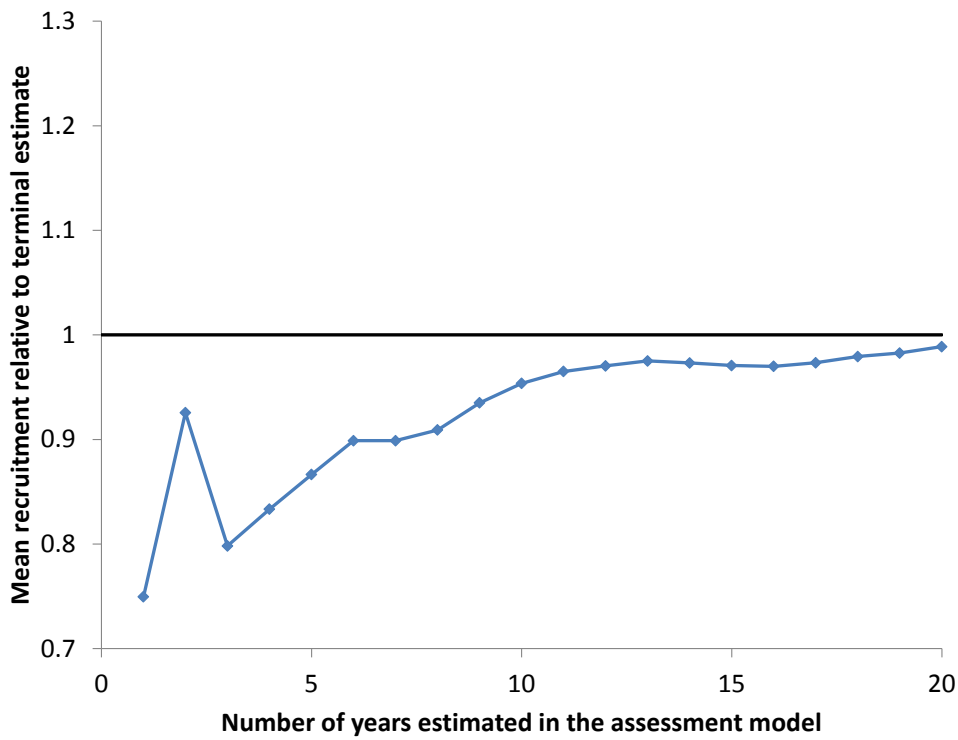


Figure 1.30. Retrospective ratios of estimated age 1 pollock recruitment in retrospective year divided by the terminal, 2011 estimate for each of the 1990-2010 retrospective runs (columns) by year class (rows; top panel). Shading denotes high and low values, bold values in rows are from above-average year classes. The bottom panel depicts the weighted mean retrospective errors on recruitment estimates as a function of the number of the years in the model.

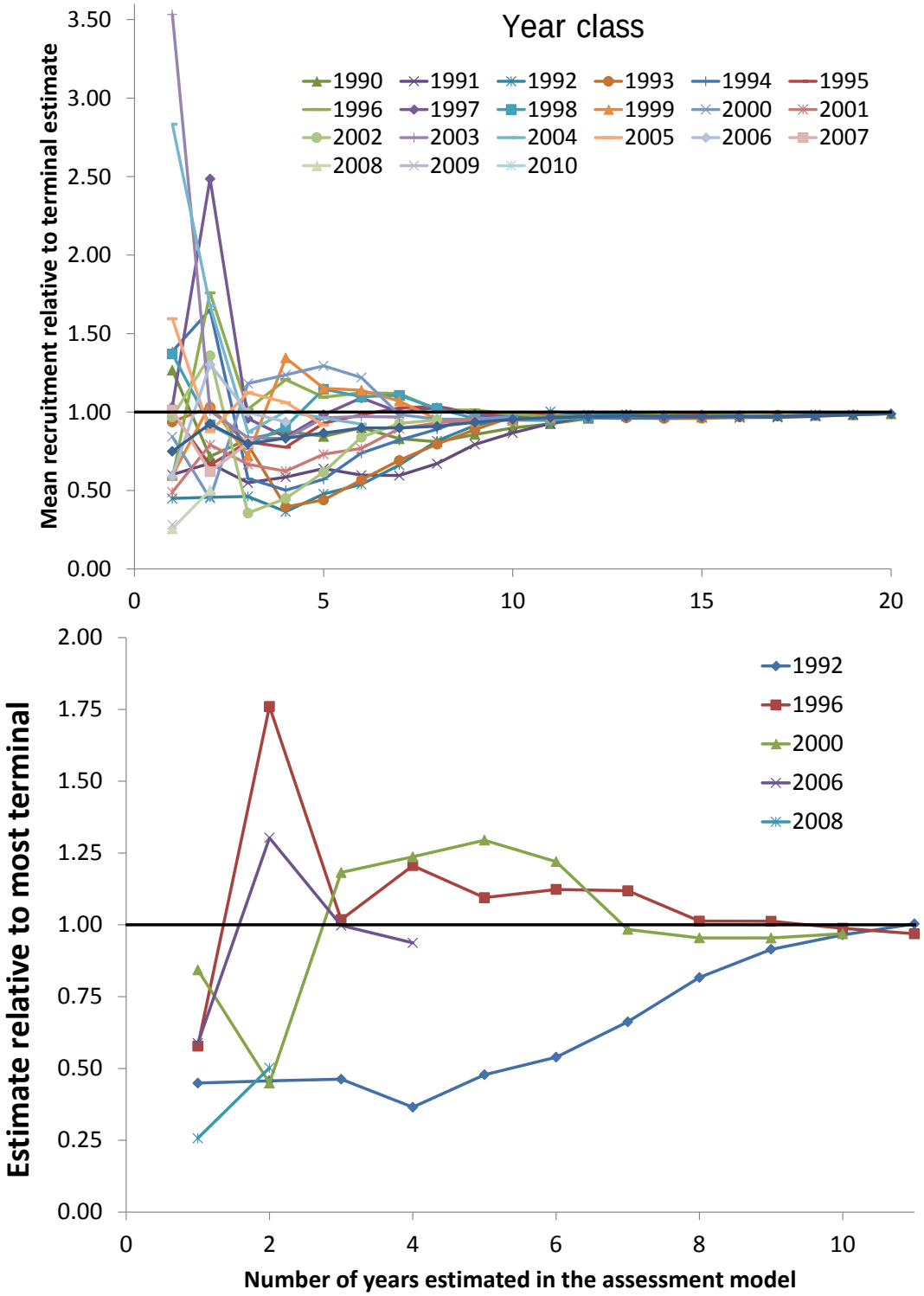


Figure 1.31. Evaluation of EBS pollock retrospective errors on recruitment estimates as a function of the number of the years in the model. The top panel shows all the cohorts (year classes) whereas the bottom panel shows some of the key above average year classes.

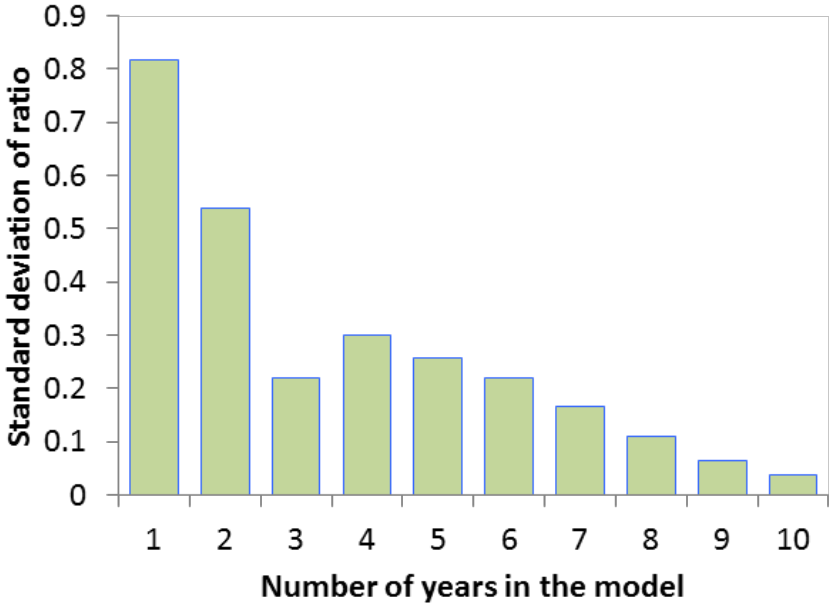


Figure 1.32. Retrospective evaluation of EBS pollock model testing the variability of errors on recruitment estimates as a function of the number of the years in the model.

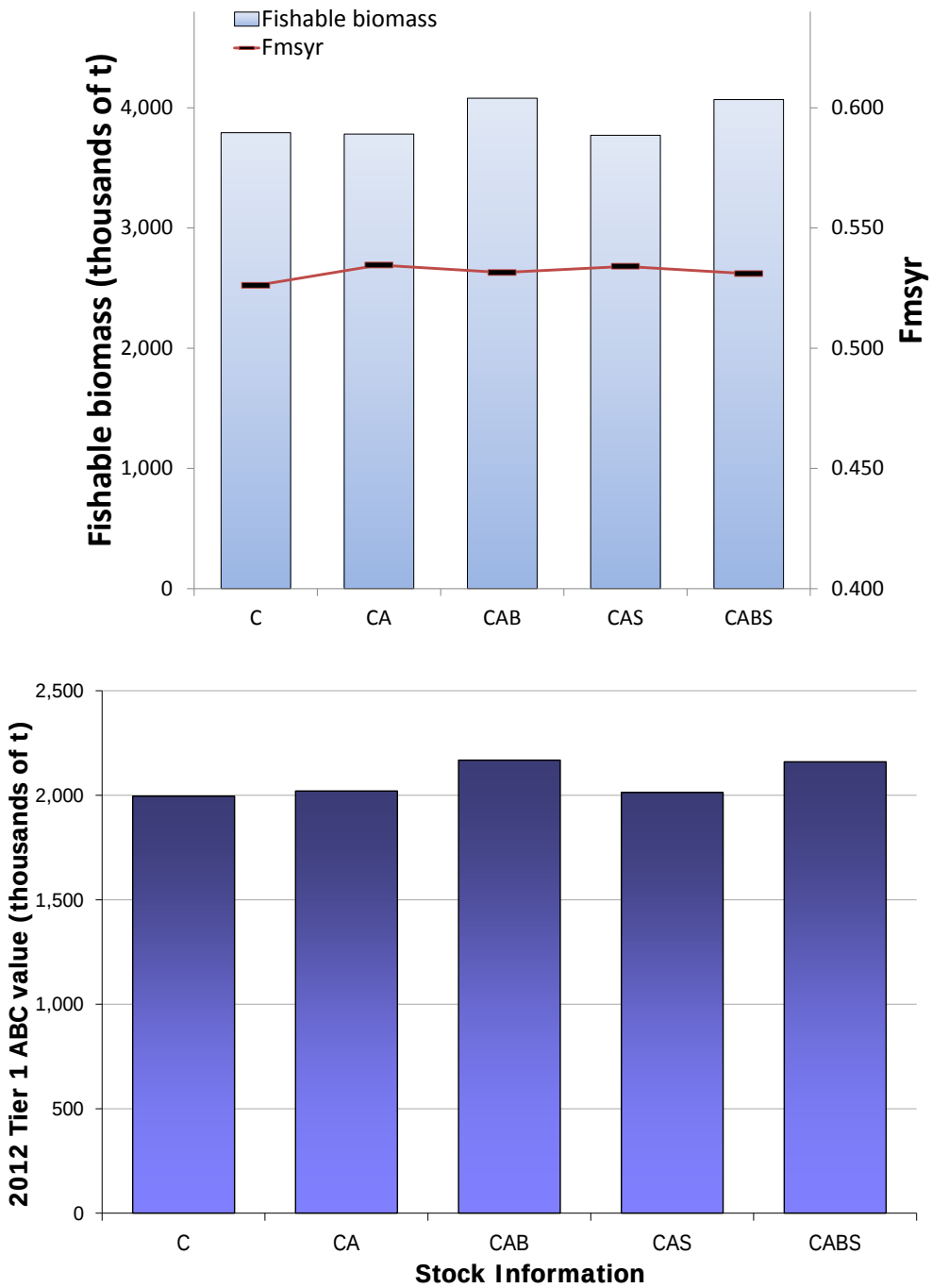


Figure 1.33. The impact of introducing new data to the assessment model on fishable biomass values, $F_{msy}$ rates, and ABC (bottom panel) for 2011 (key: fishery **C**atch, fishery **A**ge, **B**ottom-trawl survey data, and **S** for **AVO** (**S**a) index.

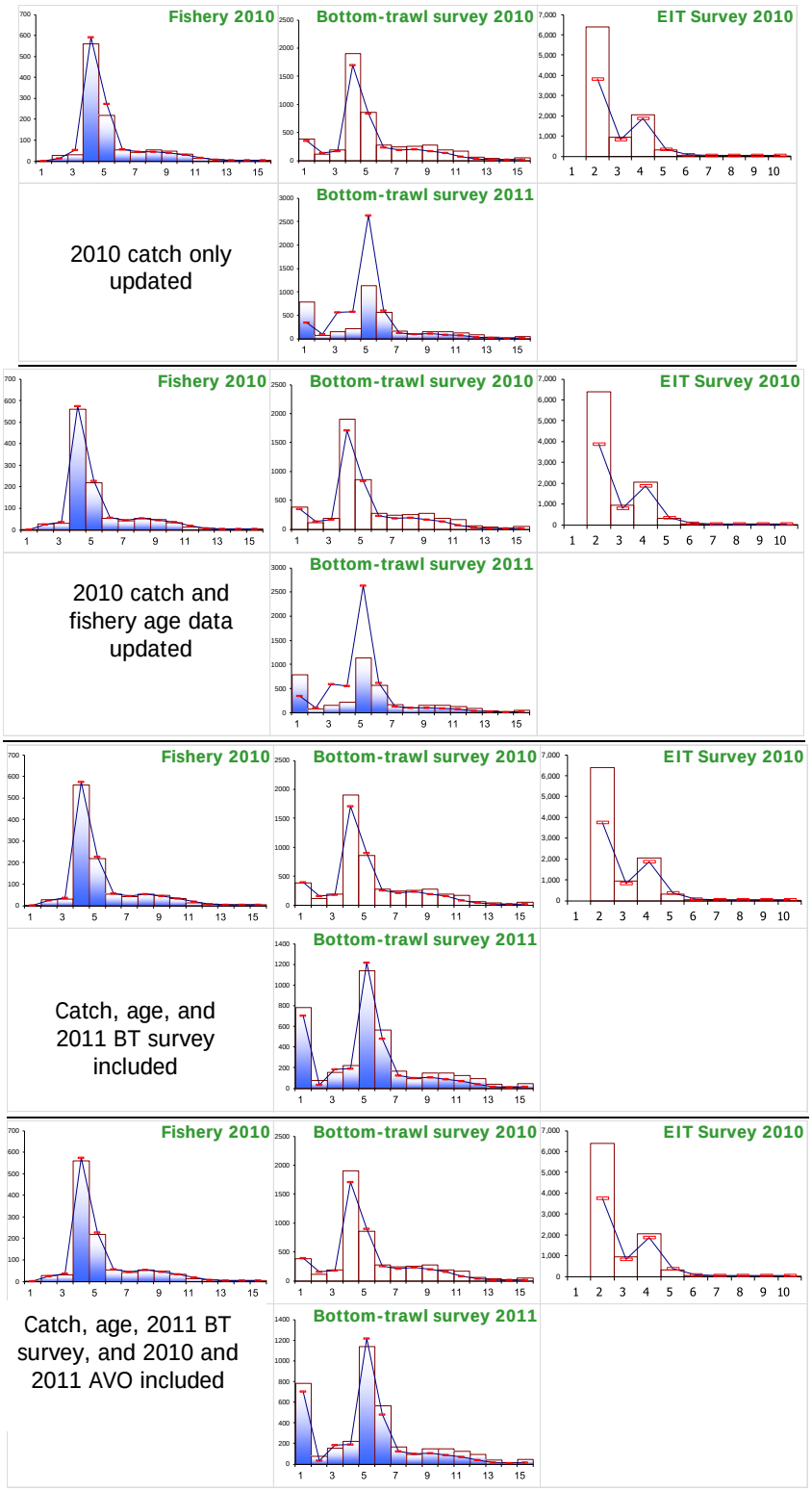


Figure 1.34. Model results of predicted EBS pollock numbers-at-age for catch and surveys as new data were added. Columns represent the data, lines represent model predictions. Shaded columns indicate data introduced in the current assessment.

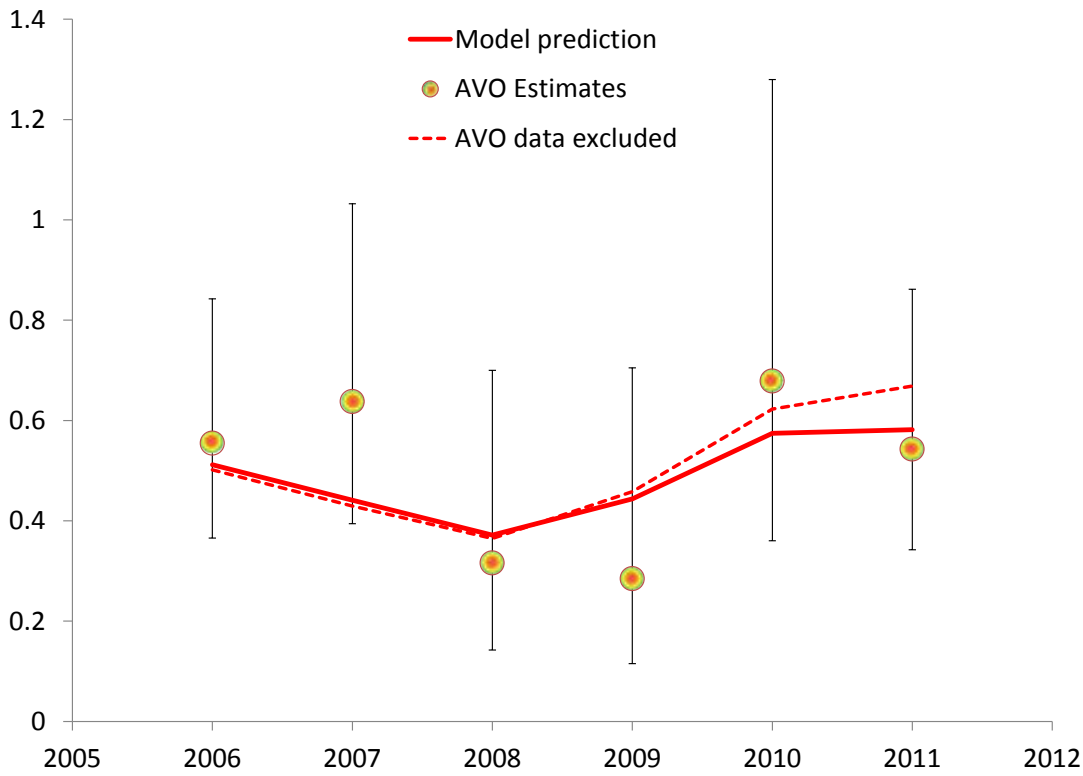


Figure 1.35. Model results of predicted EBS pollock biomass following the AVO index (with and without inclusion of the index. Error bars represent assumed 95% confidence bounds.

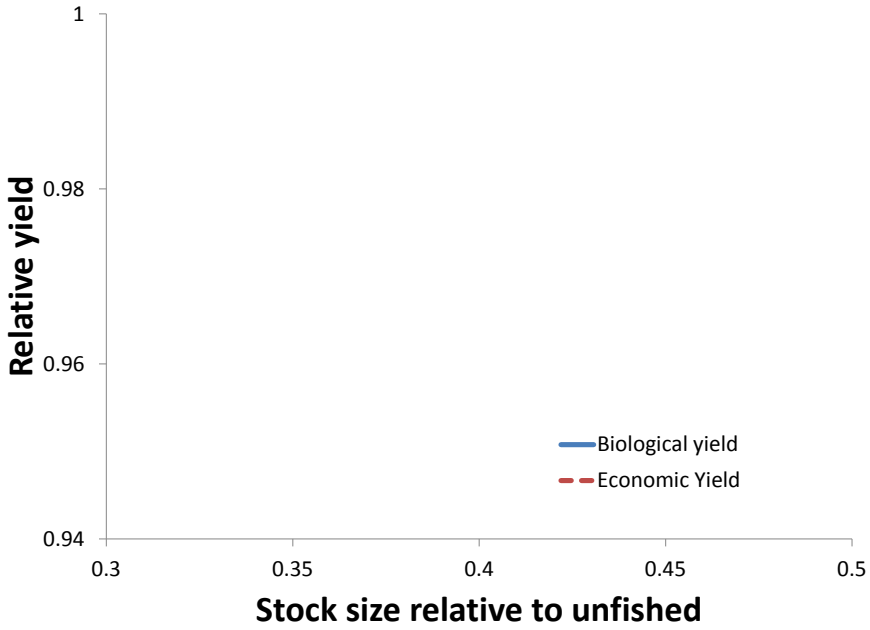


Figure 1.36. Population-level estimated yield curves normalized for biomass (solid line) and economic yield (dashed line). The economic curve uses age-specific with relationship between relative effort (distance) required for capture with a 60-40 weighting and an example age-specific value for ex-vessel landings (slope parameter equal to 0.1).

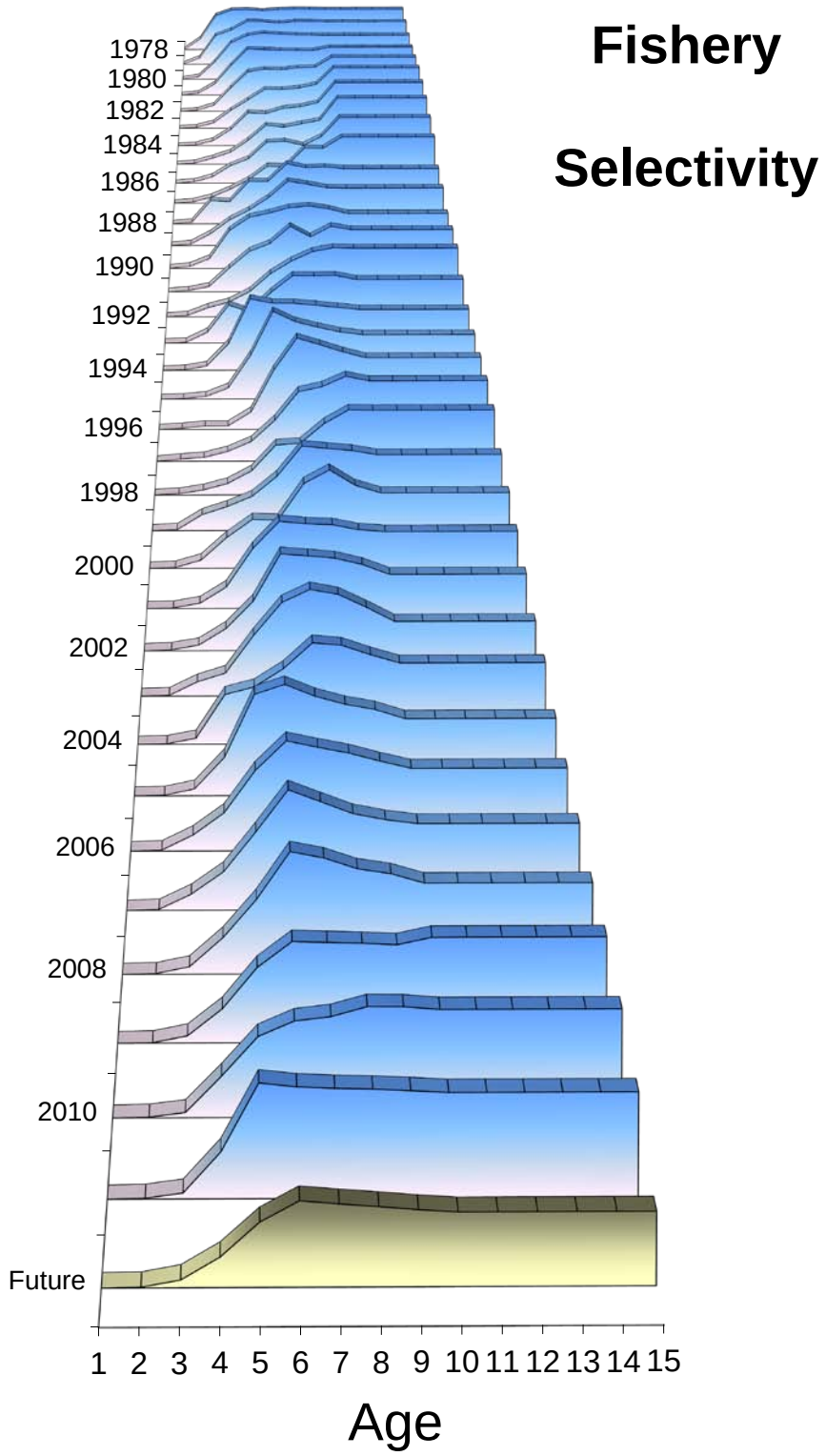


Figure 1. 37. Selectivity at age estimates for the EBS pollock fishery, 1978-2011 including the estimates (front-most panel) used for the future yield considerations.

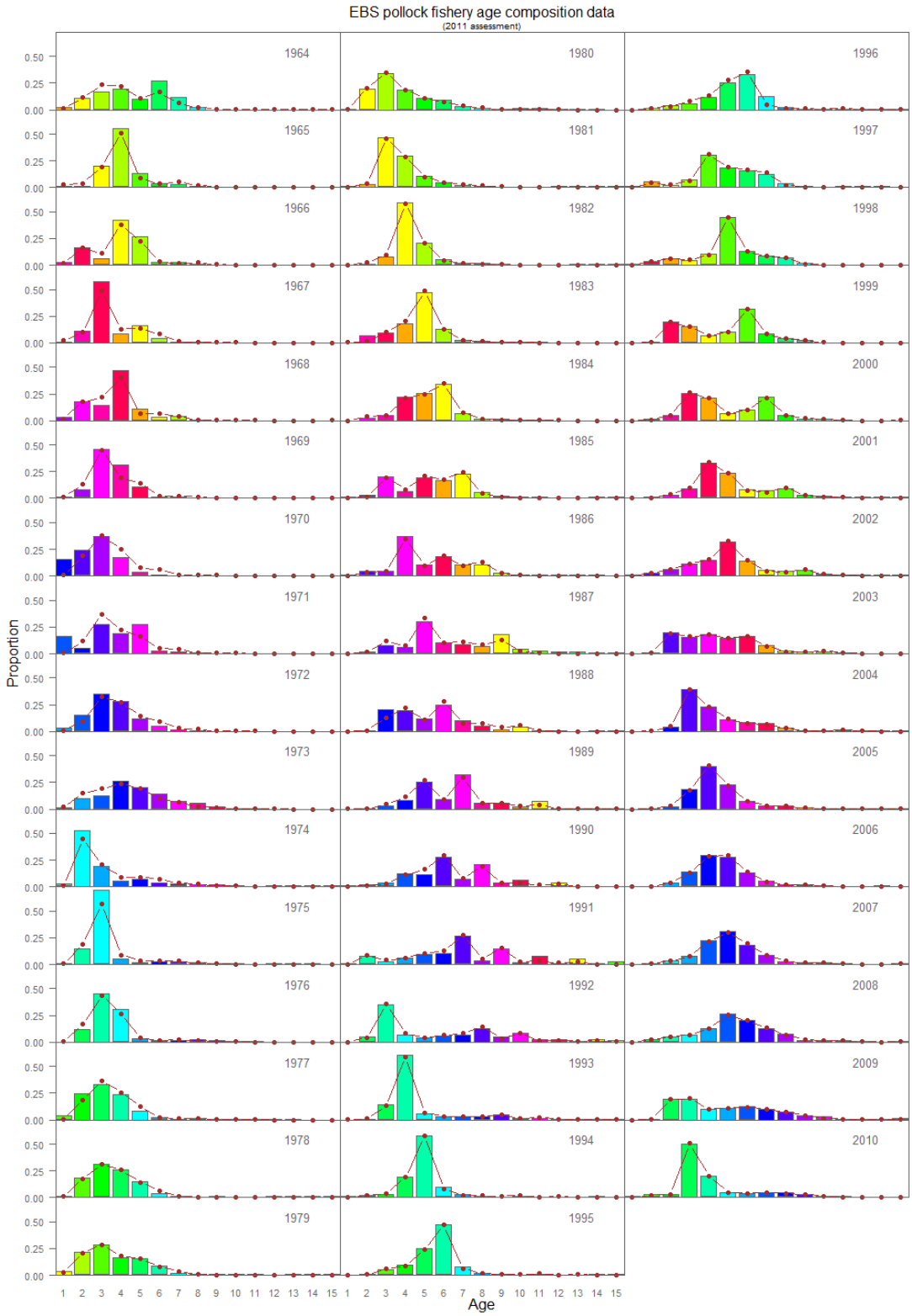


Figure 1.38. Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2010). The 2010 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

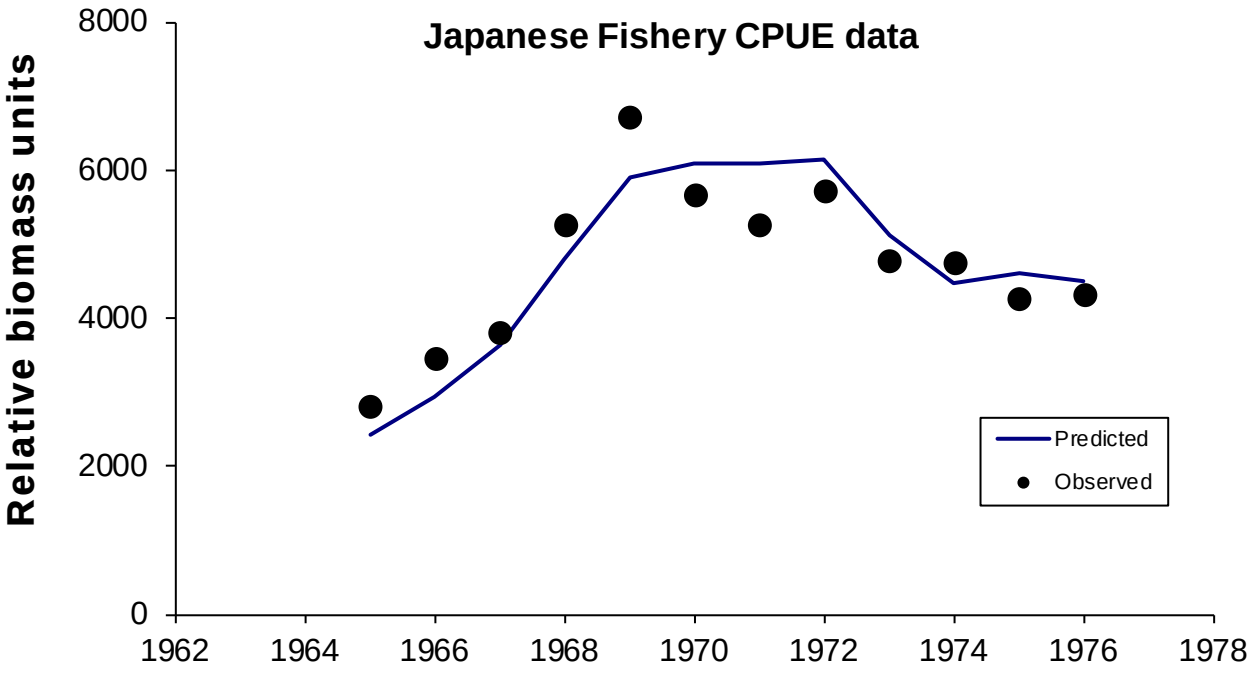


Figure 1.39. Japanese fishery CPUE (Low and Ikeda, 1980) model fits for EBS pollock, 1963-1976.

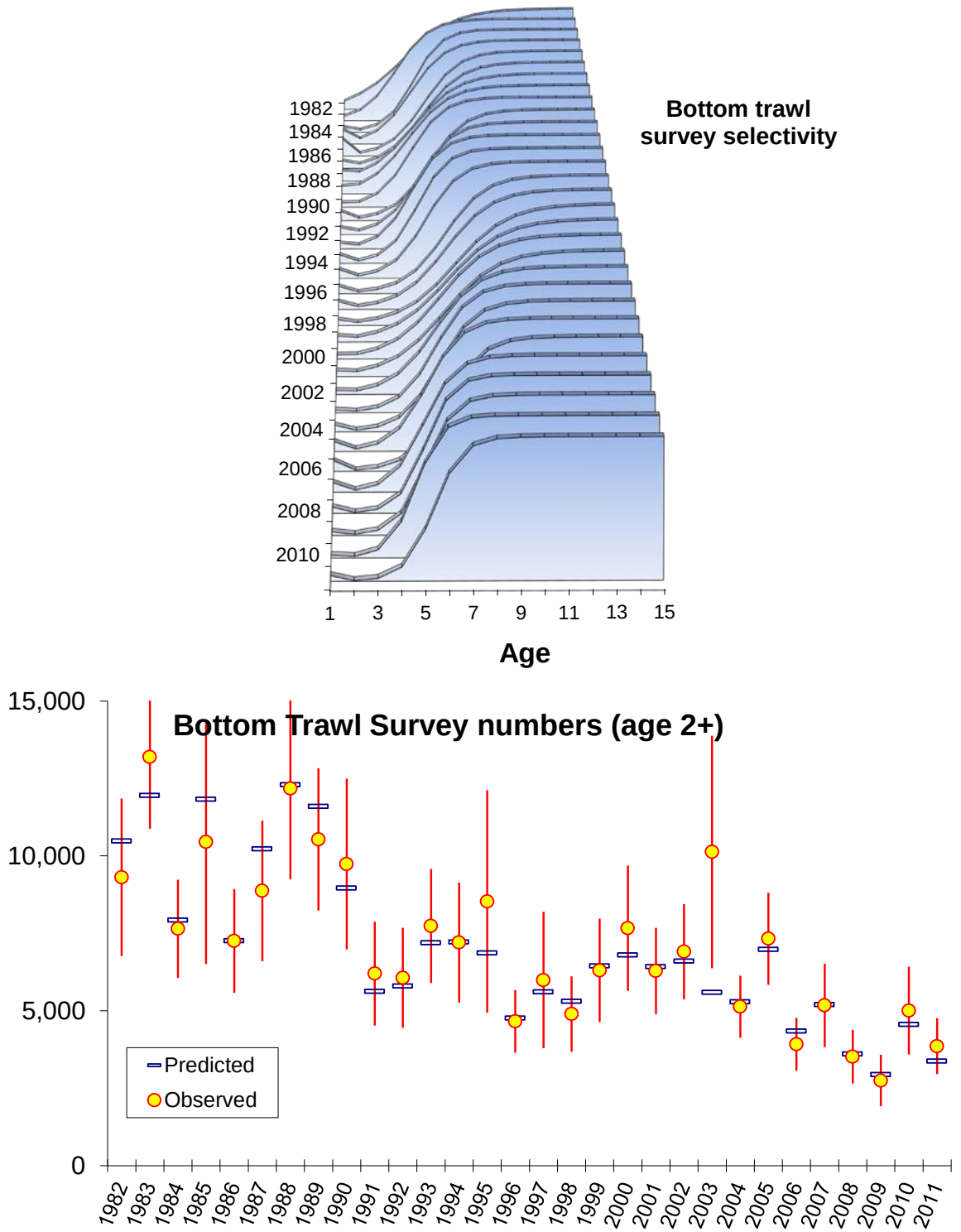


Figure 1.40. Estimates of bottom-trawl survey numbers (millions age 2 and older, lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2011.

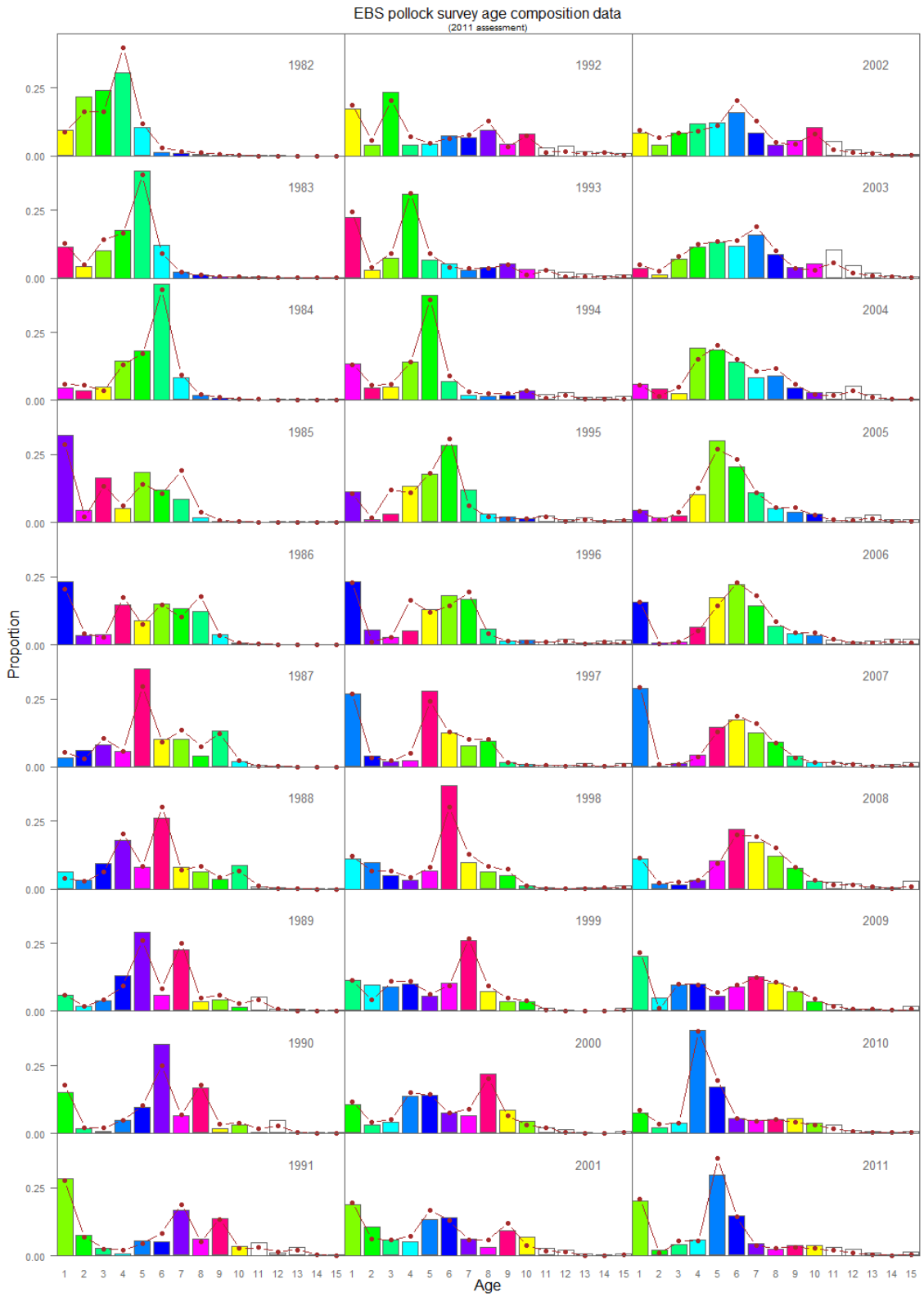


Figure 1.41. Model fit (dots) to the bottom trawl survey age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2011.

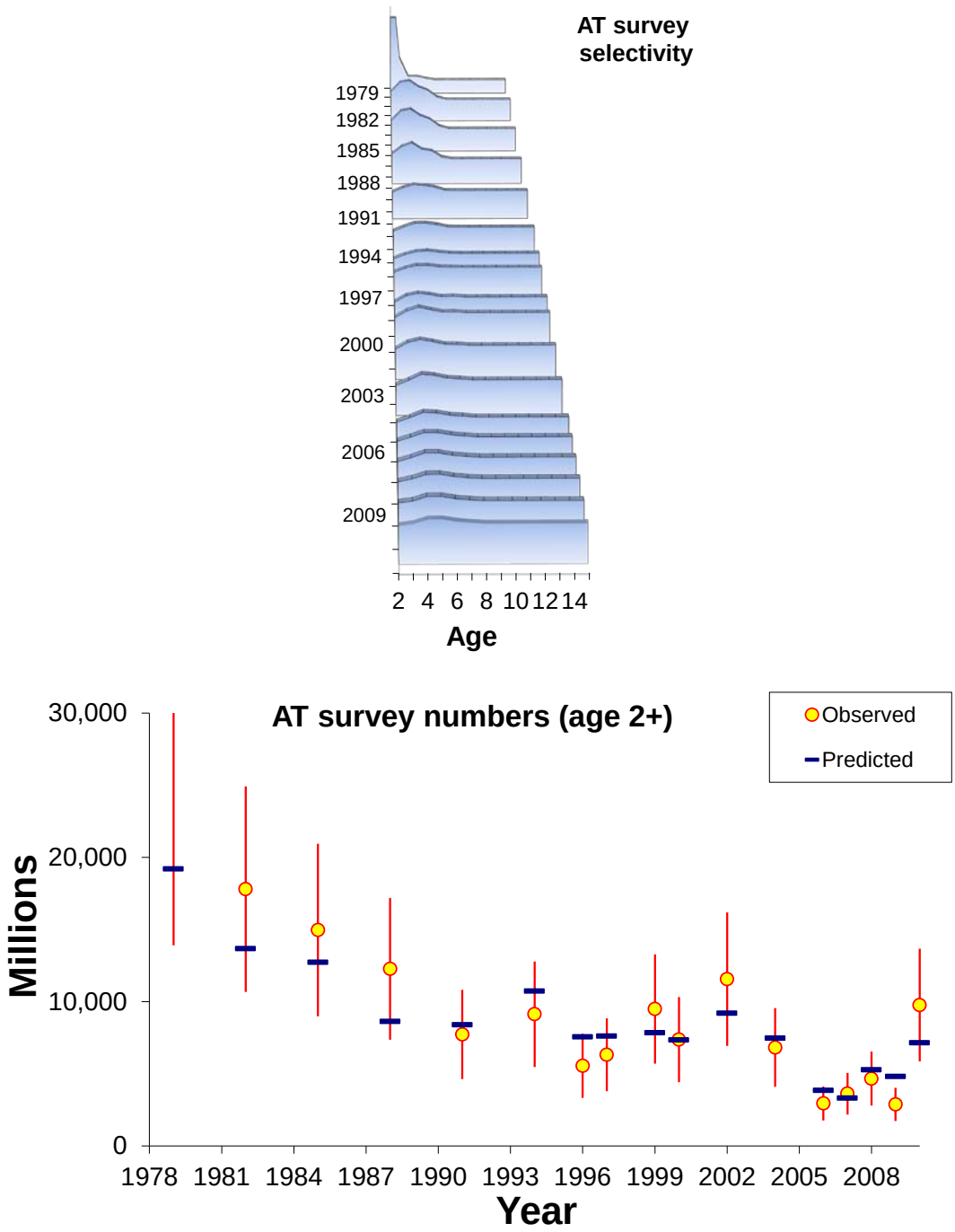


Figure 1.42. Estimates of AT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older, 1979-2010. Note that the 1979 observed value (=46,314) is off the scale of the figure.

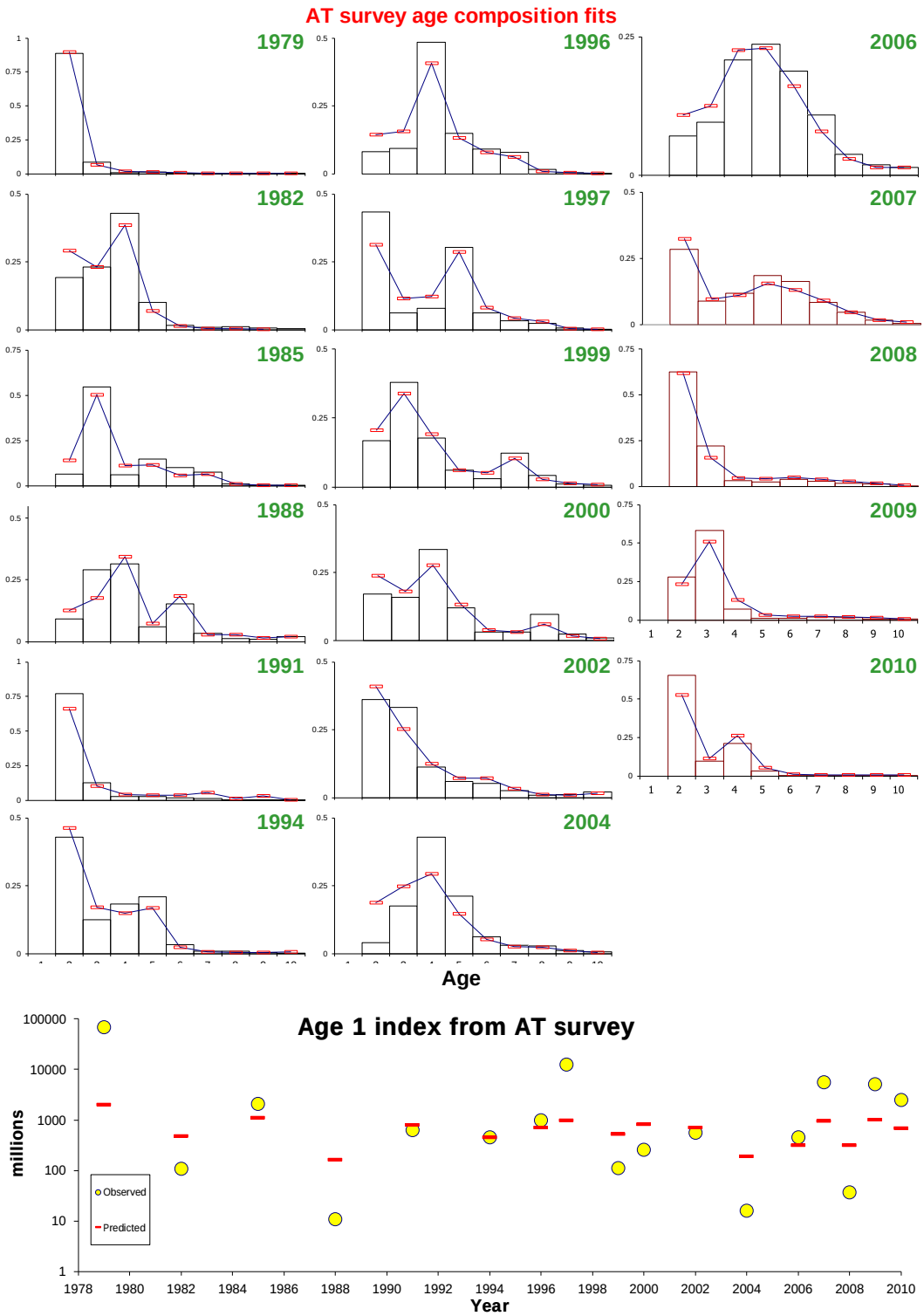


Figure 1.43. Fit to the AT survey EBS pollock age composition data (proportions) and age 1 index (bottom panel; log-scale). Lines represent model predictions while the vertical columns and dots represent data. The 2010 age composition data were based on revised values using AT age-length keys (previously they were estimated using the bottom trawl age-length keys).

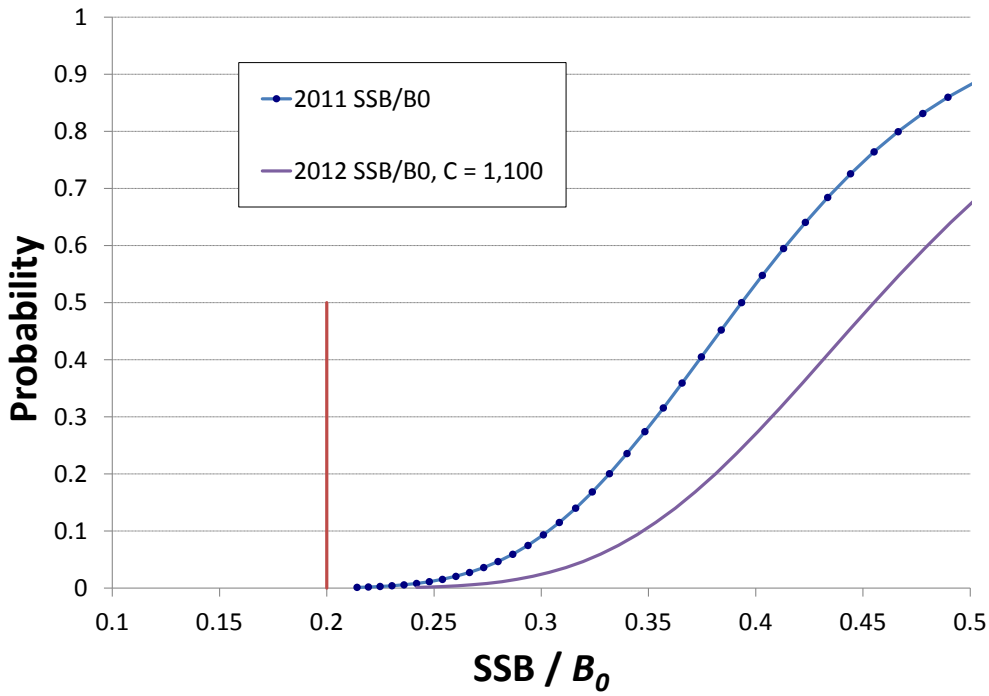


Figure 1.44. Cumulative probability estimates of 2011 and 2012 stock sizes relative to $B_0$ for EBS pollock assuming a catch of 1,100 kt. Note that these reflect the estimation uncertainty of stock status.

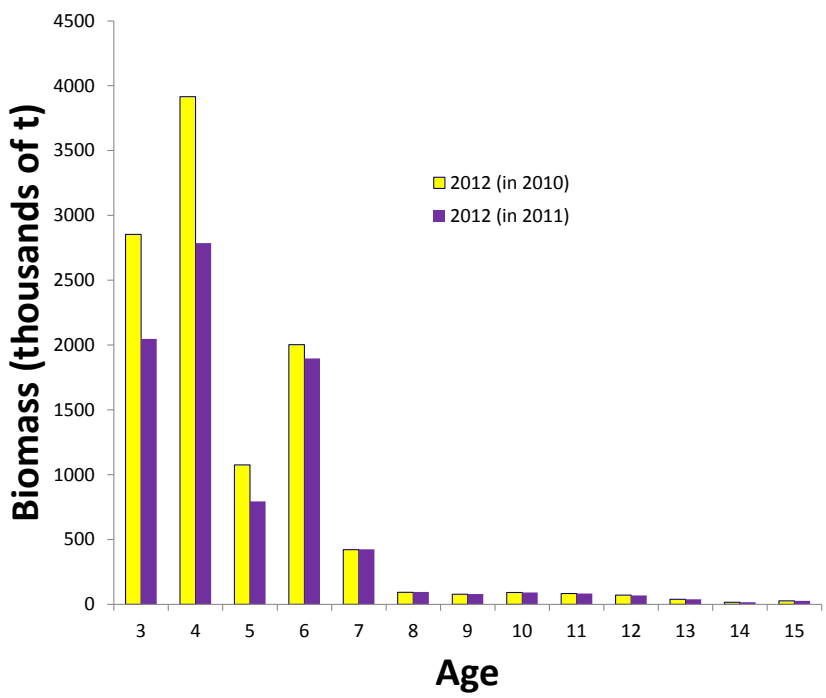


Figure 1.45. Projected begin-year EBS pollock model biomass at age as estimated for 2012 in the 2010 assessment and as estimated in the current model for ages 3-15.

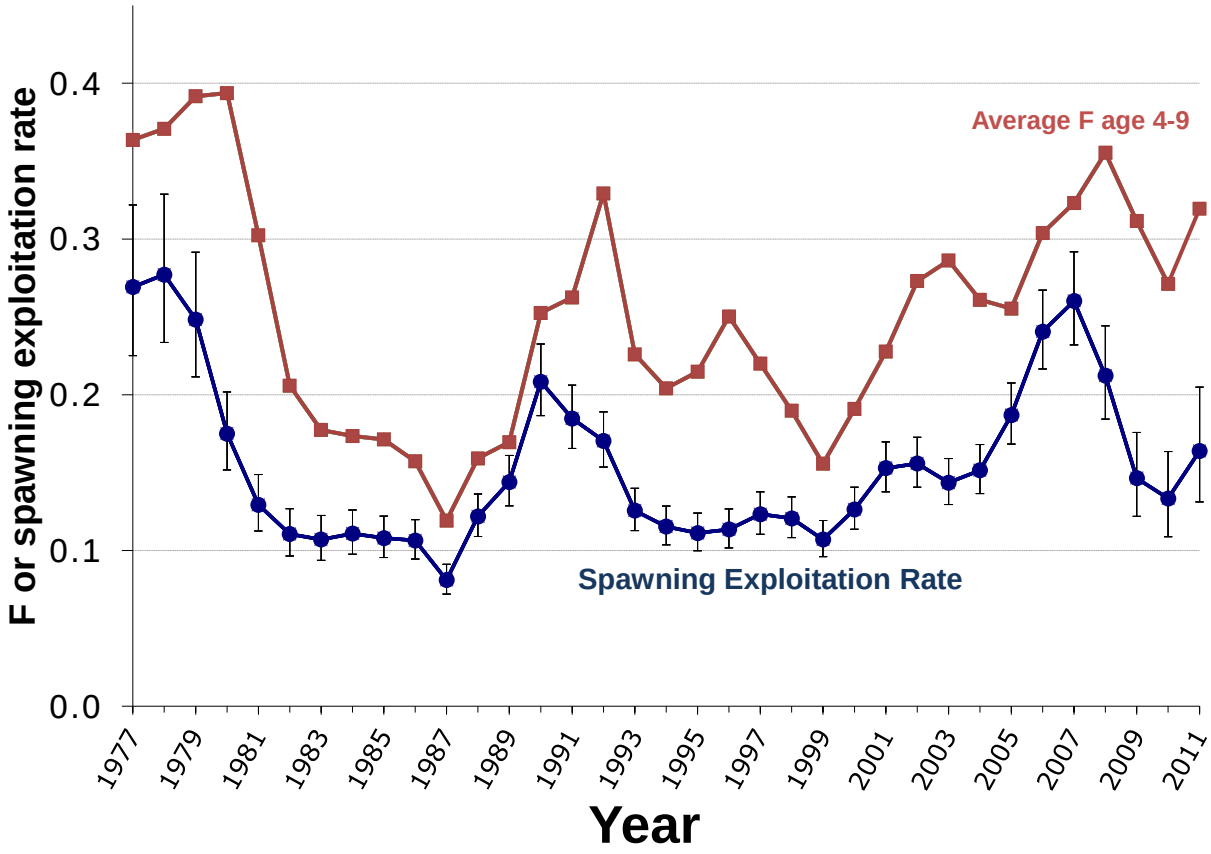


Figure 1.46. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) and average fishing mortality (ages 4-9) for EBS pollock, 1977-2011. Error bars represent two standard deviations from the estimates.

| Year | Age 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1964** | 0.01 | 0.04 | 0.20 | 0.21 | 0.21 | 0.20 | 0.19 | 0.18 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| **1965** | 0.01 | 0.05 | 0.20 | 0.19 | 0.18 | 0.17 | 0.16 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| **1966** | 0.01 | 0.05 | 0.17 | 0.17 | 0.16 | 0.15 | 0.14 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| **1967** | 0.03 | 0.16 | 0.24 | 0.24 | 0.24 | 0.23 | 0.23 | 0.23 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| **1968** | 0.03 | 0.13 | 0.27 | 0.26 | 0.24 | 0.23 | 0.23 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| **1969** | 0.03 | 0.18 | 0.23 | 0.22 | 0.21 | 0.21 | 0.20 | 0.20 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| **1970** | 0.07 | 0.24 | 0.24 | 0.23 | 0.22 | 0.26 | 0.26 | 0.26 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 |
| **1971** | 0.07 | 0.28 | 0.32 | 0.35 | 0.34 | 0.34 | 0.34 | 0.34 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| **1972** | 0.13 | 0.39 | 0.40 | 0.39 | 0.38 | 0.38 | 0.38 | 0.41 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| **1973** | 0.17 | 0.45 | 0.53 | 0.52 | 0.52 | 0.51 | 0.51 | 0.51 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 | 0.69 |
| **1974** | 0.23 | 0.57 | 0.57 | 0.56 | 0.55 | 0.55 | 0.55 | 0.56 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| **1975** | 0.11 | 0.54 | 0.50 | 0.48 | 0.46 | 0.46 | 0.46 | 0.46 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 | 0.54 |
| **1976** | 0.09 | 0.39 | 0.47 | 0.45 | 0.43 | 0.43 | 0.42 | 0.42 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| **1977** | 0.11 | 0.29 | 0.36 | 0.38 | 0.37 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 | 0.36 |
| **1978** | 0.10 | 0.32 | 0.37 | 0.37 | 0.36 | 0.37 | 0.38 | 0.38 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 |
| **1979** | 0.06 | 0.27 | 0.33 | 0.41 | 0.41 | 0.39 | 0.41 | 0.41 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| **1980** | 0.02 | 0.16 | 0.33 | 0.40 | 0.42 | 0.41 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| **1981** | 0.01 | 0.08 | 0.21 | 0.33 | 0.32 | 0.32 | 0.32 | 0.32 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| **1982** | 0.00 | 0.03 | 0.12 | 0.21 | 0.22 | 0.22 | 0.23 | 0.23 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| **1983** | 0.00 | 0.03 | 0.09 | 0.14 | 0.20 | 0.20 | 0.21 | 0.22 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 |
| **1984** | 0.00 | 0.03 | 0.08 | 0.17 | 0.17 | 0.19 | 0.20 | 0.22 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| **1985** | 0.01 | 0.03 | 0.06 | 0.13 | 0.20 | 0.19 | 0.21 | 0.23 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| **1986** | 0.01 | 0.03 | 0.08 | 0.11 | 0.18 | 0.19 | 0.17 | 0.21 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| **1987** | 0.00 | 0.02 | 0.04 | 0.08 | 0.12 | 0.12 | 0.18 | 0.18 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| **1988** | 0.01 | 0.08 | 0.08 | 0.14 | 0.14 | 0.21 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 |
| **1989** | 0.01 | 0.04 | 0.09 | 0.12 | 0.17 | 0.22 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| **1990** | 0.01 | 0.05 | 0.18 | 0.24 | 0.26 | 0.28 | 0.29 | 0.28 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **1991** | 0.01 | 0.03 | 0.13 | 0.21 | 0.25 | 0.35 | 0.29 | 0.35 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| **1992** | 0.01 | 0.07 | 0.11 | 0.18 | 0.31 | 0.40 | 0.47 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| **1993** | 0.00 | 0.05 | 0.16 | 0.13 | 0.22 | 0.28 | 0.28 | 0.28 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |
| **1994** | 0.00 | 0.01 | 0.09 | 0.24 | 0.23 | 0.23 | 0.22 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 | 0.21 |
| **1995** | 0.00 | 0.01 | 0.04 | 0.16 | 0.32 | 0.28 | 0.26 | 0.24 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| **1996** | 0.01 | 0.02 | 0.02 | 0.08 | 0.27 | 0.41 | 0.38 | 0.35 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| **1997** | 0.01 | 0.02 | 0.04 | 0.09 | 0.18 | 0.31 | 0.33 | 0.37 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| **1998** | 0.01 | 0.02 | 0.04 | 0.09 | 0.19 | 0.20 | 0.28 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| **1999** | 0.00 | 0.04 | 0.06 | 0.09 | 0.14 | 0.22 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| **2000** | 0.00 | 0.02 | 0.09 | 0.14 | 0.14 | 0.25 | 0.29 | 0.24 | 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 | 0.26 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| **2002** | 0.00 | 0.02 | 0.08 | 0.18 | 0.36 | 0.35 | 0.34 | 0.32 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 | 0.28 |
| **2003** | 0.00 | 0.05 | 0.08 | 0.22 | 0.34 | 0.39 | 0.37 | 0.32 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |
| **2004** | 0.00 | 0.02 | 0.17 | 0.19 | 0.25 | 0.34 | 0.33 | 0.30 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 |
| **2005** | 0.00 | 0.02 | 0.11 | 0.29 | 0.32 | 0.29 | 0.26 | 0.25 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 | 0.22 |
| **2006** | 0.00 | 0.06 | 0.13 | 0.28 | 0.39 | 0.36 | 0.34 | 0.31 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| **2007** | 0.00 | 0.06 | 0.14 | 0.29 | 0.44 | 0.39 | 0.35 | 0.33 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 |
| **2008** | 0.00 | 0.03 | 0.14 | 0.29 | 0.47 | 0.45 | 0.40 | 0.38 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 | 0.35 |
| **2009** | 0.00 | 0.03 | 0.13 | 0.28 | 0.37 | 0.37 | 0.37 | 0.36 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 |
| **2010** | 0.00 | 0.02 | 0.13 | 0.24 | 0.29 | 0.30 | 0.33 | 0.33 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| **2011** | 0.00 | 0.02 | 0.15 | 0.37 | 0.36 | 0.35 | 0.35 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |

Figure 1.47. Estimated instantaneous age-specific fishing mortality rates for EBS pollock, 1964-2011. (note that these are the continuous form of fishing mortality rate as specified in Eq. 1).

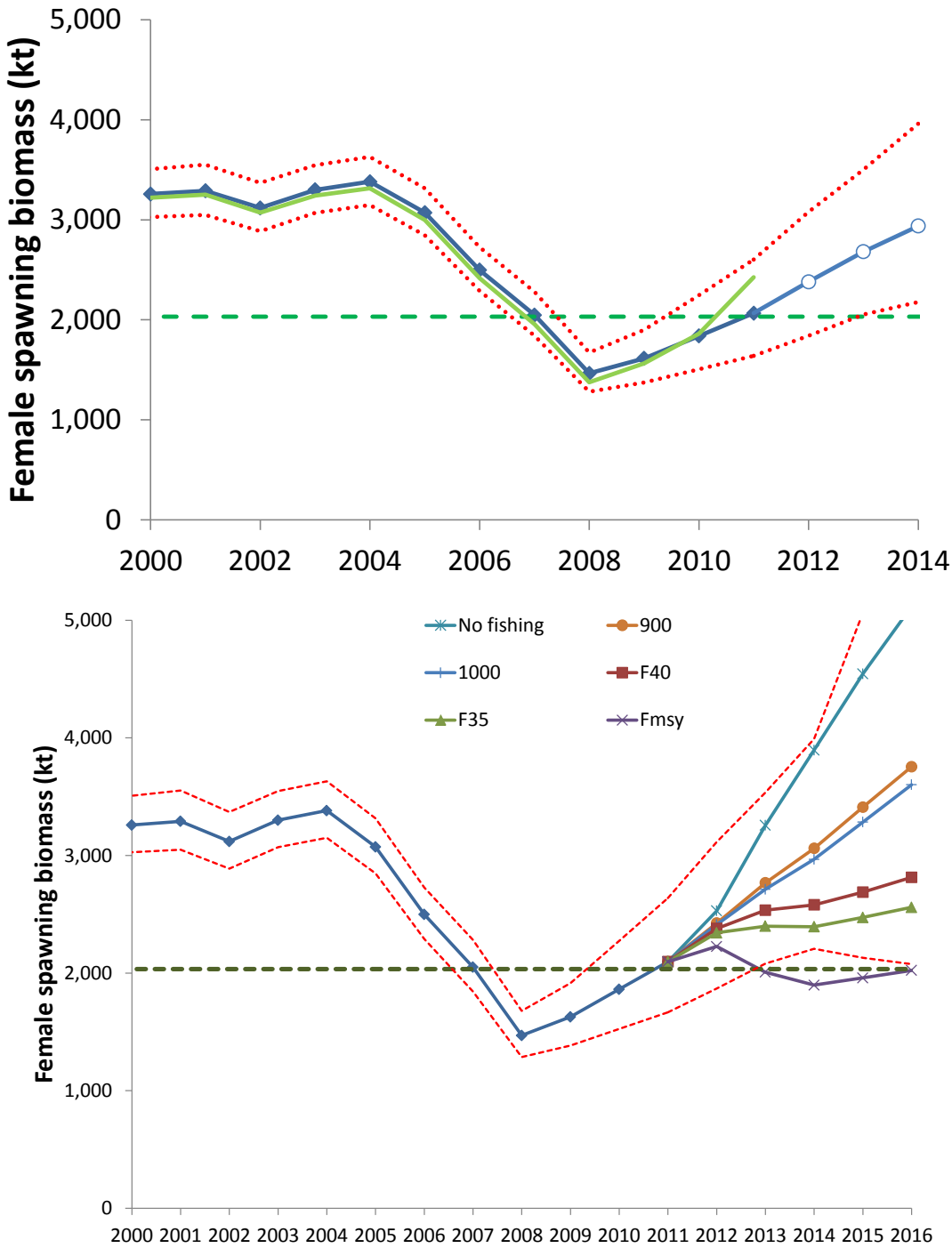


Figure 1.48. Estimated EBS pollock female spawning biomass and approximate 95% confidence intervals (filled area and dashed lines) comparing the current assessment with the past two (top) and examining near term projections under different variable and constant catch settings. Horizontal straight line represents $B_{msy}$ estimate.

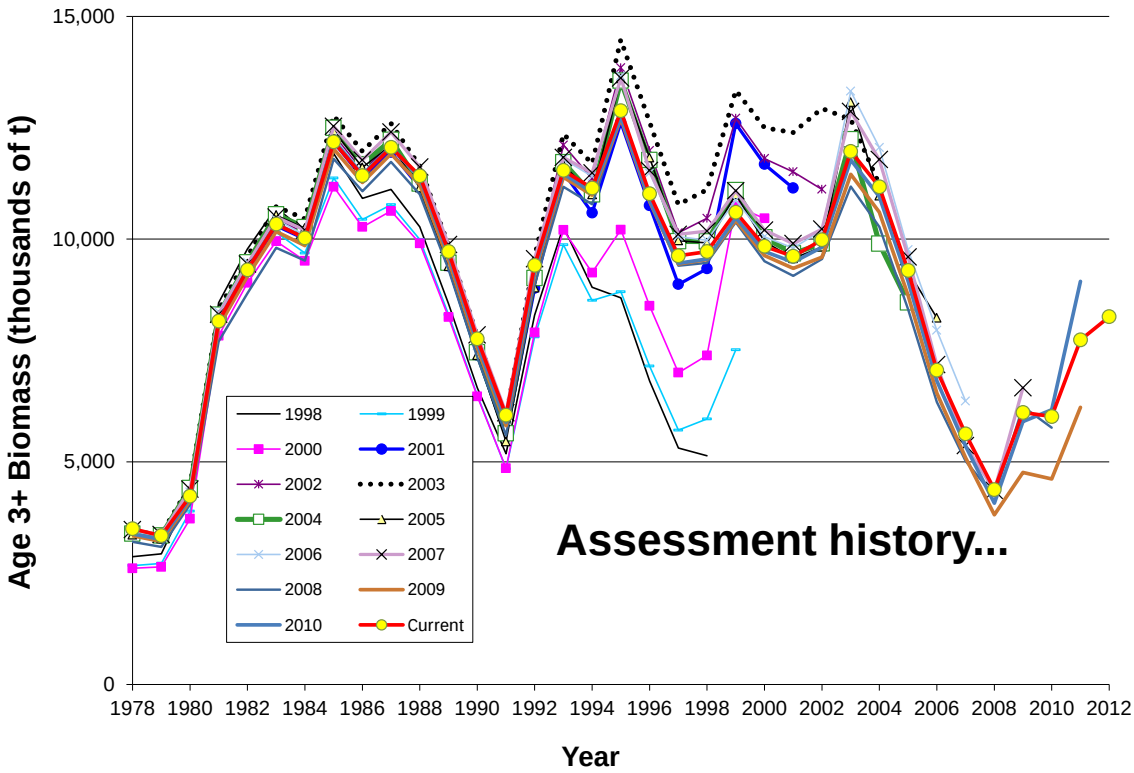


Figure 1.49. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2012.

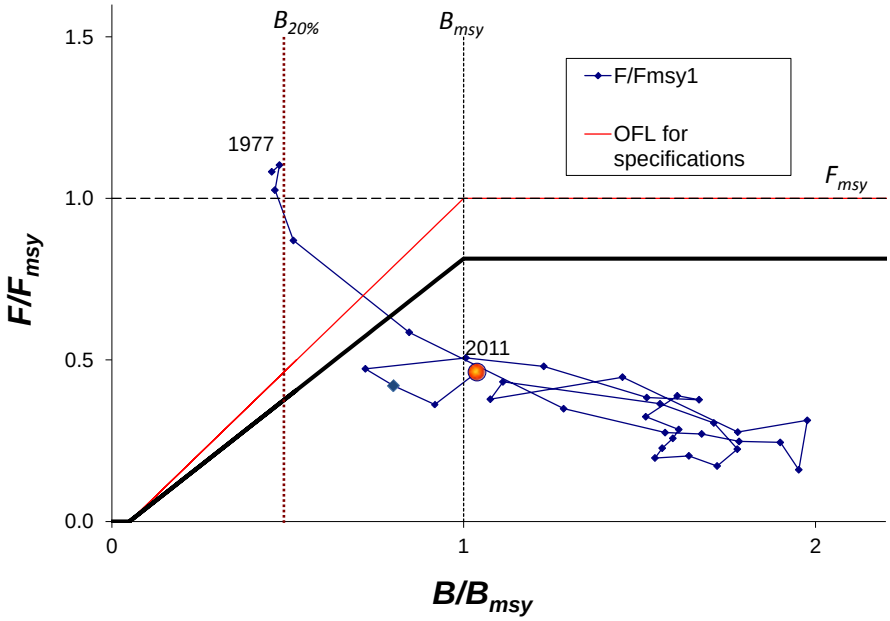


Figure 1.50. Estimated spawning biomass relative to annually estimated $F_{MSY}$ values and fishing mortality rates for EBS pollock, 1977-2011. *Note that the control rules for OFL and ABC are designed for setting specifications in future years.*

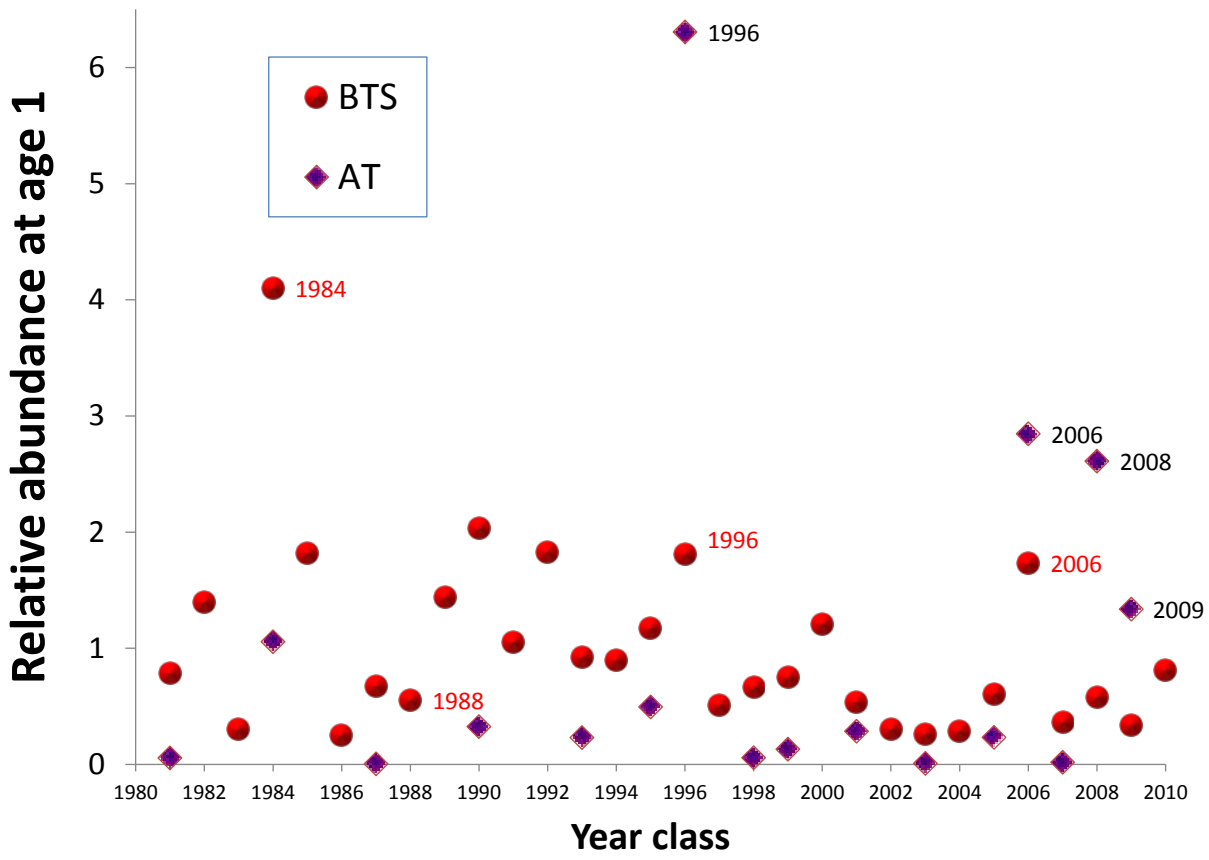


Figure 1.51. Time series of estimated age-1 abundance (relative numbers) for EBS pollock from the AT surveys, 1982-2011 (diamonds) and from the BTS surveys (bullets). Both survey indices have been rescaled to have a mean value of 1.0.

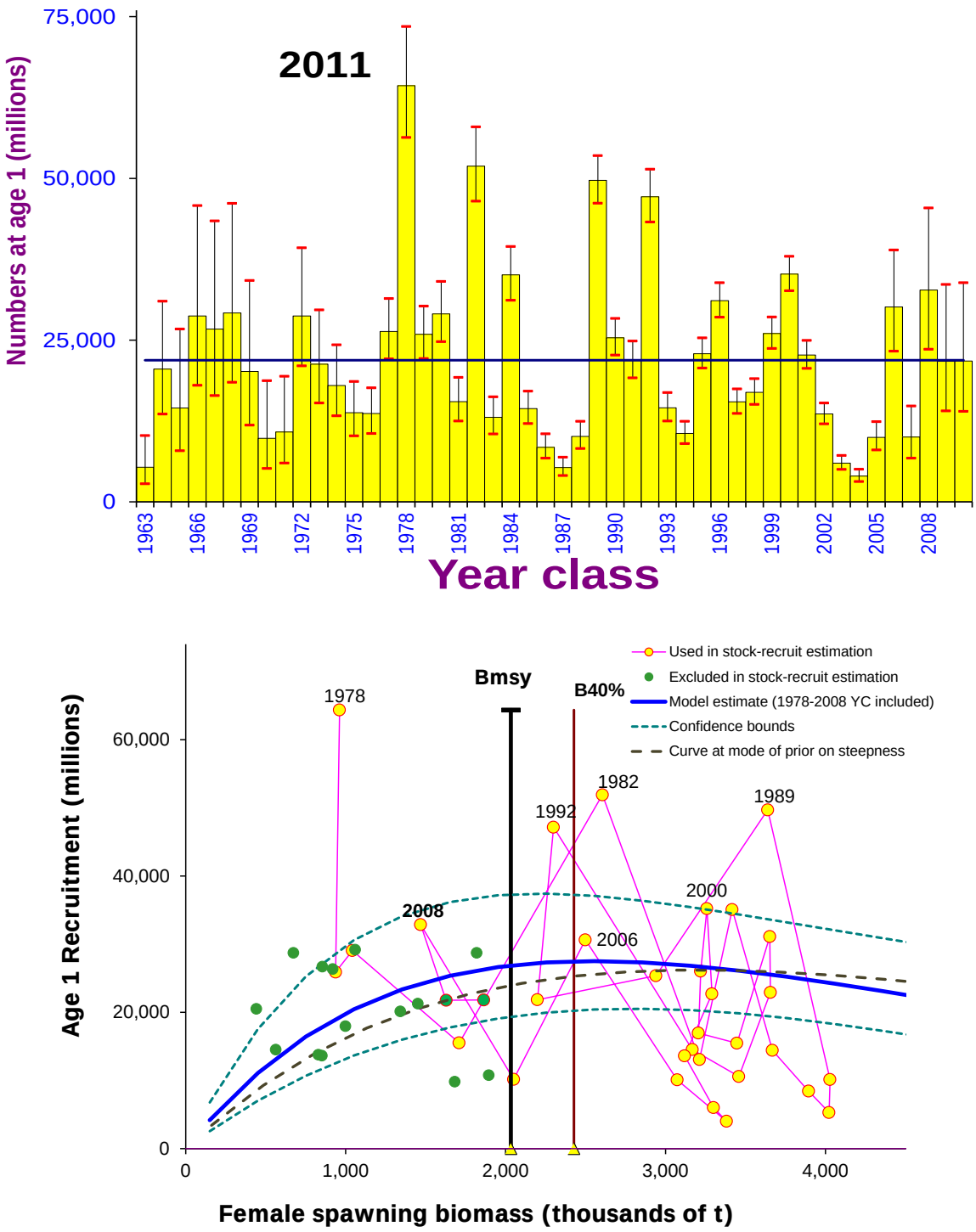


Figure 1.52. Year-class strengths by year (as age-1 recruits, upper panel) and relative to female spawning biomass (thousands of tons, lower panel) for EBS pollock. Labels on points correspond to year classes labels (measured as one-year olds). Solid line in upper panel represents the mean age-1 recruitment for all years since 1964 (1963-2010 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.

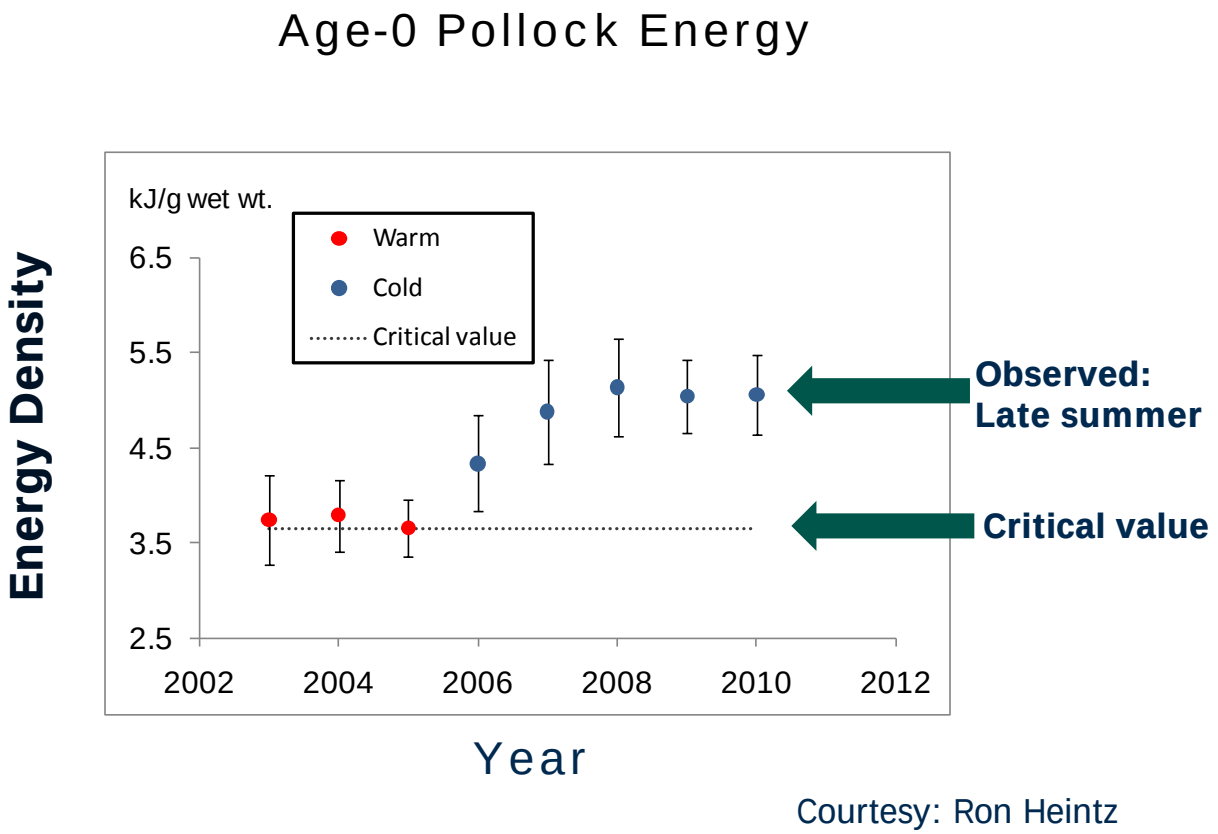


Figure 1.53. Mean and 95% confidence intervals of estimated age 0 pollock energy density (Kj/g wet weight) prior to their first winter (2003-2009). The dashed line is the expected amount of energy of the age 1 in the spring after they have lived through their first winter at sea.

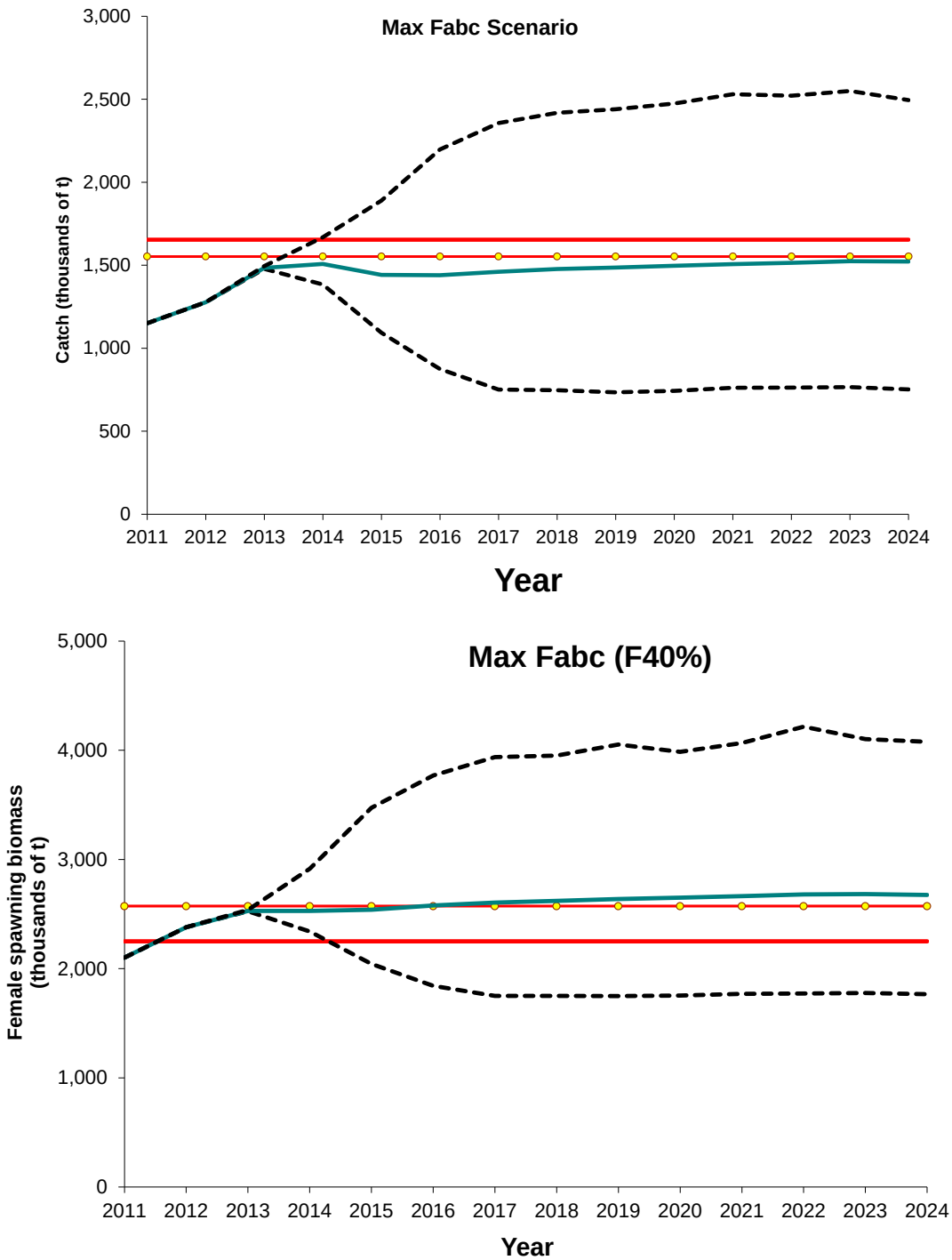


Figure 1.54. Projected EBS **Tier 3** pollock **yield** (top) and **female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2010. Future harvest rates follow the guidelines specified under Tier 3 Scenarios 1 and 2, $F_{ABC} = F_{40\%}$. *Note that this projection method is provided only for reference purposes, the SSC has determined that a Tier 1 approach is recommended for this stock.*

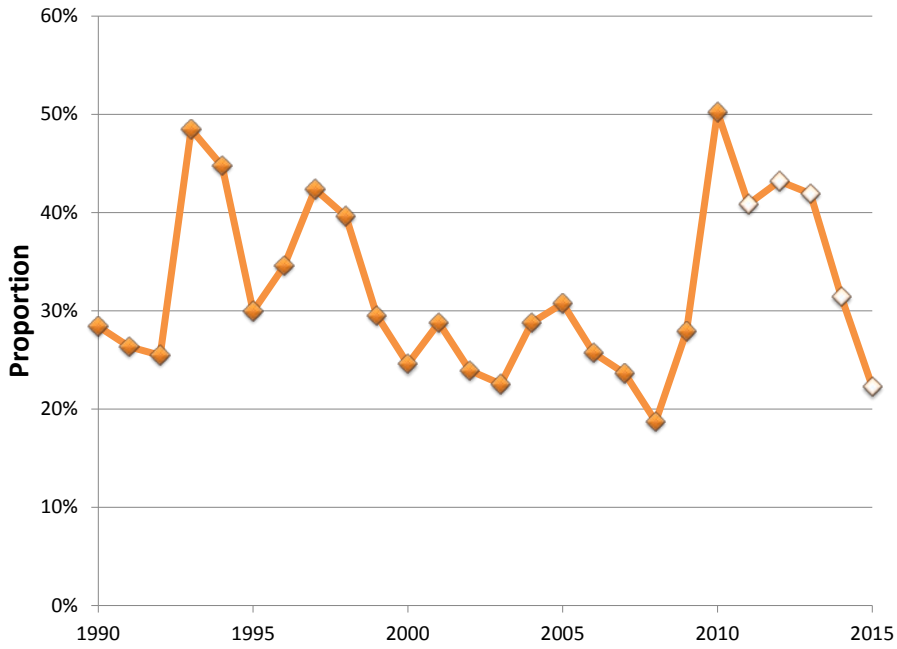


Figure 1.55. The proportion that a single year class contributes to the spawning biomass for EBS pollock, 1990-2015. Values for 2011-2015 are projected based on constant catch projections of 1.2 million t.

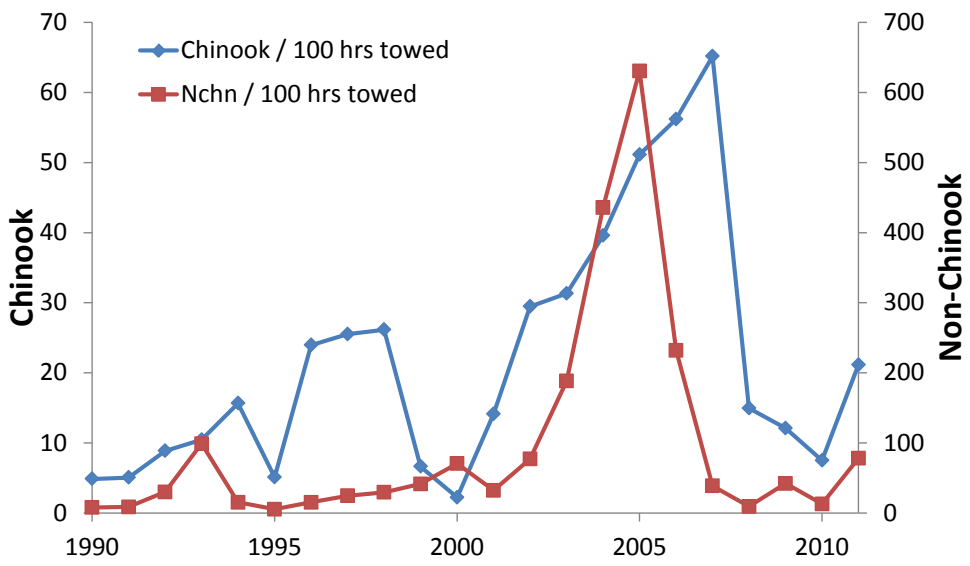


Figure 1.56. NMFS observer data on Chinook salmon (left axis) and non-Chinook (Nchn; right axis) per hundred hours of pollock trawl using 25 selected shore-based catcher vessels, 1990-2011.

## Model details

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

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

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

where

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

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

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

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

where $s_{t,a}$ is the selectivity for age class $a$ in year $t$, and $\mu$ 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 $\sigma_s^2$ 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., $\sigma_E^2$) 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):

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

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

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

For this assessment, we use the above relationship as a diagnostic for evaluating input sample sizes by comparing model predicted mean ages with "observed" mean ages and the implied 95% confidence bands. This method provided support for modifying the frequency of allowing selectivity changes (e.g., Fig. 1.57).

*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). ( $\kappa_t$ ):

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

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

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

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

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

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

where

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

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

$\varepsilon_t$ is the "recruitment anomaly" for year *t*,

α, β are stock-recruitment function parameters.

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

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

where

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

Some interpretation and further explanation follows. For steepness equal 0.2, then recruits are a linear function of spawning biomass (implying no surplus production). For steepness equal to 1.0, then recruitment is constant for all levels of spawning stock size. A value of *h* = 0.9 implies that at 20% of the unfished spawning stock size will result in an expected value of 90% unfished recruitment level. Steepness of 0.7 is a commonly assumed default value for the Beverton-Holt form (e.g., Kimura 1988). The prior distribution for steepness used a beta distribution as in Ianelli et al. (2001) is shown in Fig. 1.58. The prior on steepness was specified to be a symmetric form of the Beta distribution with alpha=beta=13.06 implying a prior mean of 0.6 and CV of 12.8% (implying that there is about 10% chance that the steepness is greater than 0.7). This conservative prior is consistent with previous years' application and serves to constrain the stock-recruitment curve from favoring steep slopes (uninformative priors result in $F_{msy}$ values near an $F_{SPR}$ of about $F_{18\%}$, a value considerably higher than the default proxy of $F_{35\%}$). The residual pattern for the post-1977 recruits used in fitting the curve with a more diffuse prior resulted in all estimated recruits being below the curve for stock sizes less than $B_{msy}$ (except for the 1978 year class). We believe this to be driven primarily by the apparent negative-slope for recruits relative to stock sizes above $B_{msy}$ and as such, provides a potentially unrealistic estimate of productivity at low stock sizes. This prior was elicited from the rationale that residuals should be reasonably balanced throughout the range of spawning stock sizes. Whereas this is somewhat circular (i.e., using "data" for prior elicitation), the point here is that residual patterns (typically ignored in these types of models) are being qualitatively considered.

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

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

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

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

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

so that the prior used on *h* can be implemented in both the Ricker and Beverton-Holt stock-recruitment forms. Here the term $\varphi_0$ represents the equilibrium unfished spawning biomass per-recruit.

*Diagnostics*

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

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

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

The assessment model code allows retrospective analyses (e.g., Parma 1993, and Ianelli and Fournier 1998). This was designed to assist in specifying how spawning biomass patterns (and uncertainty) have changed due to new data. The retrospective approach simply uses the current model to evaluate how it may change over time with the addition of new data based on the evolution of data collected over the past 14 years.

*Parameter estimation*

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

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

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

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

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

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

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

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

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

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:

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

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

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

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

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

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

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

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

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

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

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

where $\sigma_{c,t}$ is pre-specified (set to 0.05) affecting the accuracy of the overall observed catch in biomass. Similarly, the contribution of prior distributions (in negative log-density) to the log-likelihood function include $\lambda_\varepsilon \sum_t \varepsilon_t^2 + \lambda_\gamma \sum_{t,a} \gamma_{t,a}^2 + \lambda_\delta \sum_t \delta_t^2$ where the size of the *λ's* represent prior assumptions about the variances of these random variables. Most of these parameters are associated with year-to-year and age specific deviations in selectivity coefficients. For a presentation of this type of Bayesian approach to modeling errors-in-variables, the reader is referred to Schnute (1994). To facilitate estimating such a large number of parameters, automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries was used. This software provided the derivative calculations needed for finding the posterior mode via a quasi-Newton function minimization routine (e.g., Press et al. 1992). The model implementation language (ADModel Builder) gave simple and rapid access to these routines and provided the ability estimate the variance-covariance matrix for all dependent and independent parameters of interest.

The approach we use to solve for $F_{msy}$ and related quantities (e.g., $B_{msy}$, MSY) within a general integrated model context was shown in Ianelli et al. (2001). In 2007 this was modified to include uncertainty in weight-at-age as an explicit part of the uncertainty for $F_{msy}$ calculations. This involved estimating a vector of parameters ($w_i^{future}$) on "future" mean weights for each age *i*, *i*= (1, 2,…,15), given actual observed mean and variances in weight-at-age over the period 1991-2010. The model simply computes the values of $\overline{w}_i, \sigma_{w_i}^2$ based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

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

Note that this converges to the mean values over the time series of data (no other likelihood component within the model is affected by "future" mean weights-at-age) while retaining the natural uncertainty that

can propagate through estimates of $F_{msy}$ uncertainty. This latter point is essentially a requirement of the Tier 1 categorization.

*Tier 1 projections*

Tier 1 projections were calculated two ways. First, for 2012 and 2013 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 $B_{msy}$ :

$$ABC = B'_{GM}\hat{u}_{HM}\zeta$$

$$B'_{GM} = e^{\ln\left(\hat{B}'\right)-0.5\sigma_B^2}$$

$$\hat{u}_{HM} = e^{\ln u_{msy}-0.5\sigma_{u_{msy}}^2} \qquad \text{(Eq. 23)}$$

$$\zeta = \frac{B_t / B_{msy} - 0.05}{1-0.05} \qquad B_t < B_{msy}$$

$$\zeta = 1 \qquad B_t \geq B_{msy}$$

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.

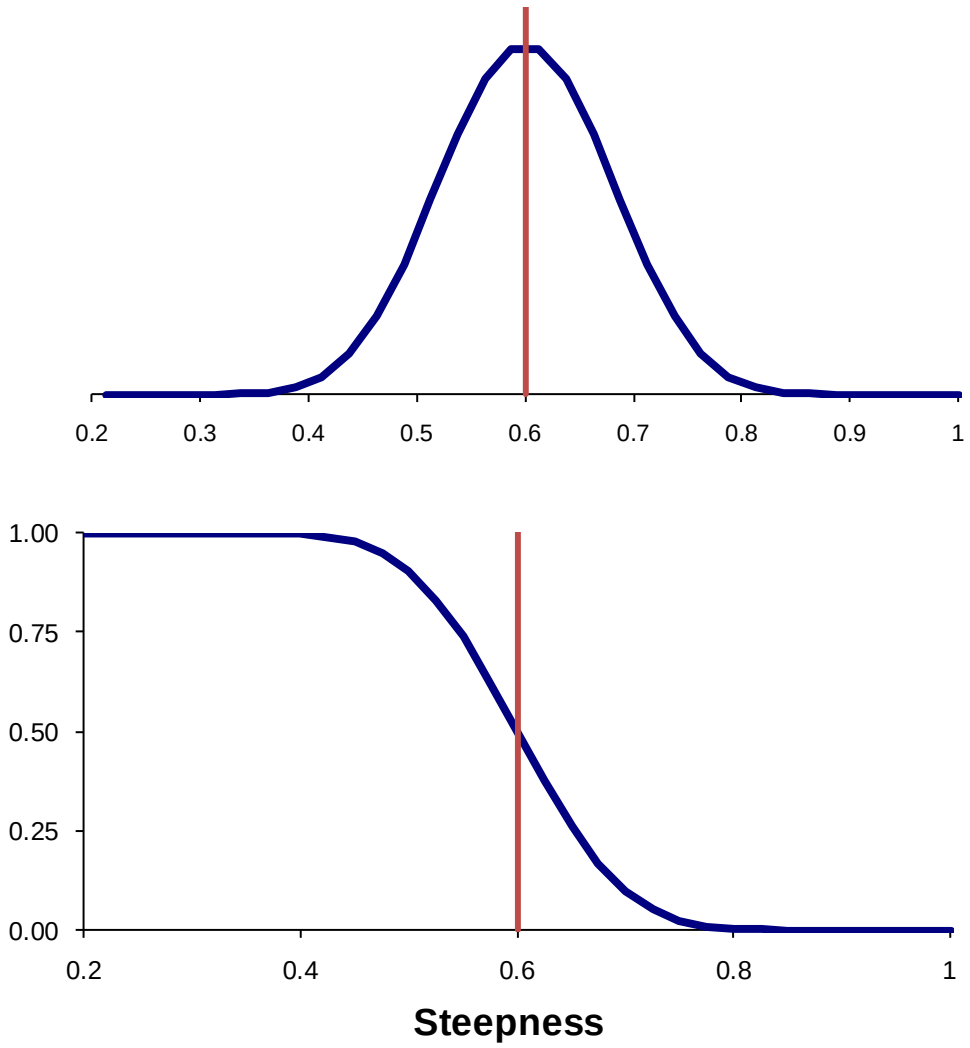


Figure 1.57. Cumulative prior probability distribution of steepness based on the beta distribution with $\alpha$ and $\beta$ set to values which assume a mean and CV of 0.6 and 0.12, respectively. This prior distribution implies that there is about 8% chance that the value for steepness is greater than 0.7. See text for discussion.