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

James N. Ianelli, Taina Honkalehto, Steve Barbeaux,
Stan Kotwicki, Kerim Aydin and Neal Williamson

Alaska Fisheries Science Center
National Marine Fisheries Service

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, based on increased observer coverage in the shore-based catcher fleet in 2011, a dramatic catch increase inside the CVOA region is apparent (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 Eastern Bering Sea foraging area. In 2000, phased-in reductions in the proportions of seasonal TAC that could be caught within the BSAI Steller sea lion Conservation Area (SCA) were implemented. Since 2005, a limited pollock fishery has been prosecuted in the Aleutian Islands but with less than 2,000 t of annual catch.

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

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

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

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 more complex. The 2011 bottom temperatures (Fig. 1.13). However, the surface temperature was colder than 2010 and remains well below average. 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 conducted.

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 and is 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, σ=0.05)
- Log-normal indices of abundance (numbers of fish; bottom trawl surveys assume annual estimates of sampling error, as represented in Fig. 1.12; 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 most concentrated farther from Dutch Harbor, the principal offload port for shore-based catcher vessels. Consequently, we evaluated this specifically related to the F_{msy} estimation process. was undertaken this year which considers the size-specific spatial patterns of pollock. 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 15th, 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 this type of analysis applies regardless of fuel cost.

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.

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).

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

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 21st 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**	**Biomass in millions of t** (percent of total)						**Total Biomass**	**Estimation Error**
		(nmi)^2	**SCA**		**E170-SCA**		**W170**		**(millions t)**	**(millions t)**
1994	9 Jul-19 Aug	78,251	0.312	(11%)	0.399	(14%)	2.176	(75%)	2.886	0.136
1996	20 Jul-30 Aug	93,810	0.215	(9%)	0.269	(12%)	1.826	(79%)	2.311	0.090
1997	17 Jul-4 Sept	102,770	0.246	(10%)	0.527	(20%)	1.818	(70%)	2.591	0.096
1999	7 Jun-5 Aug	103,670	0.299	(9%)	0.579	(18%)	2.408	(73%)	3.290	0.181
2000	7 Jun-2 Aug	106,140	0.393	(13%)	0.498	(16%)	2.158	(71%)	3.049	0.098
2002	4 Jun -30 Jul	99,526	0.647	(18%)	0.797	(22%)	2.178	(60%)	3.622	0.112
2004	4 Jun -29 Jul	99,659	0.498	(15%)	0.516	(16%)	2.293	(69%)	3.307	0.122
2006	3 Jun -25 Jul	89,550	0.131	(8%)	0.254	(16%)	1.175	(75%)	1.560	0.061
2007	2 Jun -30 Jul	92,944	0.084	(5%)	0.168	(10%)	1.517	(86%)	1.769	0.080
2008	2 Jun -31 Jul	95,374	0.085	(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 2001-2011*.

	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	0.0	479.5
1966	8.8	95.2	62.6	219.9	130.1	21.7	9.3	14.1	5.6	0.0	567.1
1967	29.3	135.5	665.2	180.3	184.9	111.2	19.8	8.9	14.1	0.0	1,349.3
1968	29.8	303.8	374.7	687.5	110.2	107.2	64.8	11.4	5.1	0.0	1,694.4
1969	32.2	287.0	1,007.5	422.3	317.1	51.9	53.8	33.6	6.1	0.0	2,211.5
1970	30.3	616.9	1,247.4	816.0	251.6	193.7	38.5	40.2	25.3	0.0	3,259.9
1971	18.9	472.8	1,505.3	921.2	672.9	207.0	163.7	27.5	28.9	0.0	4,018.2
1972	23.1	399.3	1,356.7	1,133.0	592.4	380.5	121.8	97.0	16.9	0.0	4,120.7
1973	69.1	547.1	704.6	872.2	702.6	372.4	242.6	77.5	62.1	0.0	3,650.3
1974	52.3	1,974.4	900.4	397.9	398.0	319.5	171.0	113.6	36.7	0.0	4,363.8
1975	32.1	727.2	2,144.3	338.4	146.5	146.4	118.7	63.6	41.7	0.0	3,758.8
1976	19.8	526.7	1,381.7	836.7	140.1	62.8	63.7	52.0	27.9	0.0	3,111.2
1977	16.0	471.3	927.5	651.6	319.1	56.1	25.9	26.8	22.0	0.0	2,516.4
1978	29.2	426.6	754.8	627.9	346.2	156.9	29.1	13.8	14.4	0.0	2,398.9
1979	63.9	484.3	661.0	418.9	353.4	190.3	87.3	16.0	7.5	0.0	2,282.5
1980	15.9	486.5	822.4	444.6	263.6	177.3	94.6	44.4	7.8	0.0	2,357.1
1981	9.5	87.6	1,062.3	669.2	233.3	110.2	68.4	37.6	18.0	0.0	2,296.1
1982	2.8	46.3	183.5	1,124.7	397.4	88.8	42.1	27.6	15.4	0.0	1,928.6
1983	7.1	24.6	173.5	357.7	848.7	231.0	47.5	23.6	16.0	0.0	1,729.7
1984	1.5	66.2	90.6	375.4	440.0	620.8	136.2	29.4	15.3	0.0	1,775.4
1985	3.7	22.7	354.6	150.7	375.3	322.6	448.5	90.5	19.9	0.0	1,788.5
1986	1.2	64.8	80.3	629.9	182.0	352.0	181.9	243.6	53.5	0.0	1,789.1
1987	0.5	18.8	148.6	91.9	418.4	129.9	143.3	105.6	158.0	0.0	1,214.9
1988	0.4	15.6	245.4	415.2	200.4	526.6	140.9	147.3	70.5	0.0	1,762.3
1989	0.6	9.6	74.6	188.6	452.9	146.6	506.0	88.1	94.2	0.0	1,561.3
1990	3.9	28.6	52.4	215.6	315.9	581.2	147.4	376.0	66.2	0.0	1,787.3
1991	1.7	131.2	62.4	98.7	160.9	197.2	431.1	84.5	242.4	0.0	1,410.0
1992	1.7	81.9	719.0	163.8	91.9	134.1	167.5	291.8	73.7	0.0	1,725.1
1993	2.2	18.7	249.8	1,134.5	132.0	65.4	66.8	61.4	88.5	0.0	1,819.1
1994	0.5	34.3	70.4	344.9	1,048.4	144.1	41.2	29.9	26.7	0.0	1,740.5
1995	0.3	10.2	96.6	140.0	393.5	763.9	101.0	27.1	19.2	0.0	1,551.7
1996	0.7	17.6	49.9	118.0	190.7	402.4	516.5	74.3	20.2	0.0	1,390.2
1997	1.1	69.8	40.6	99.8	471.5	288.2	257.2	210.3	37.0	0.0	1,475.5
1998	0.5	51.2	97.3	74.4	150.5	678.2	195.6	128.6	112.3	0.0	1,488.6
1999	0.4	13.8	283.2	223.9	103.9	149.7	463.9	125.9	56.0	0.0	1,420.7
2000	0.7	13.8	81.8	422.6	341.7	108.2	160.2	348.4	83.9	0.0	1,561.5
2001	0.9	13.7	62.8	169.2	599.2	414.6	130.1	102.3	177.3	0.0	1,670.2
2002	0.7	44.6	120.3	218.0	290.5	617.8	274.6	87.1	65.3	0.0	1,718.9
2003	0.5	20.0	395.4	337.6	373.3	308.4	339.6	148.7	43.3	0.0	1,966.7
2004	0.2	7.7	100.6	846.1	500.7	249.0	161.5	148.9	63.4	0.0	2,078.0
2005	0.1	4.0	60.5	390.2	891.8	490.7	162.9	69.6	62.6	0.0	2,132.4
2006	0.3	4.5	73.3	277.5	603.9	619.4	290.7	104.8	45.9	0.0	2,020.4
2007	1.1	13.0	50.9	123.3	357.0	488.8	317.2	145.4	53.2	0.0	1,549.9
2008	0.3	26.3	63.2	81.4	151.7	302.1	236.8	161.3	81.9	0.0	1,105.0
2009	0.9	5.3	179.7	190.0	97.4	105.4	114.4	95.3	72.4	0.0	861.0
2010	0.5	25.3	35.0	573.7	227.9	56.9	45.1	53.8	45.2	0.0	1,063.4
2011	0.6	19.5	135.5	225.3	992.2	184.1	37.0	27.7	29.2	0.0	1,651.0
Median	1.7	37.9	148.6	338.4	317.1	190.3	130.1	69.6	36.7	0.0	1,751.4
Average	11.1	188.0	420.5	411.8	355.0	260.5	160.9	90.7	49.1	0.4	1,948.1

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

Tier (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

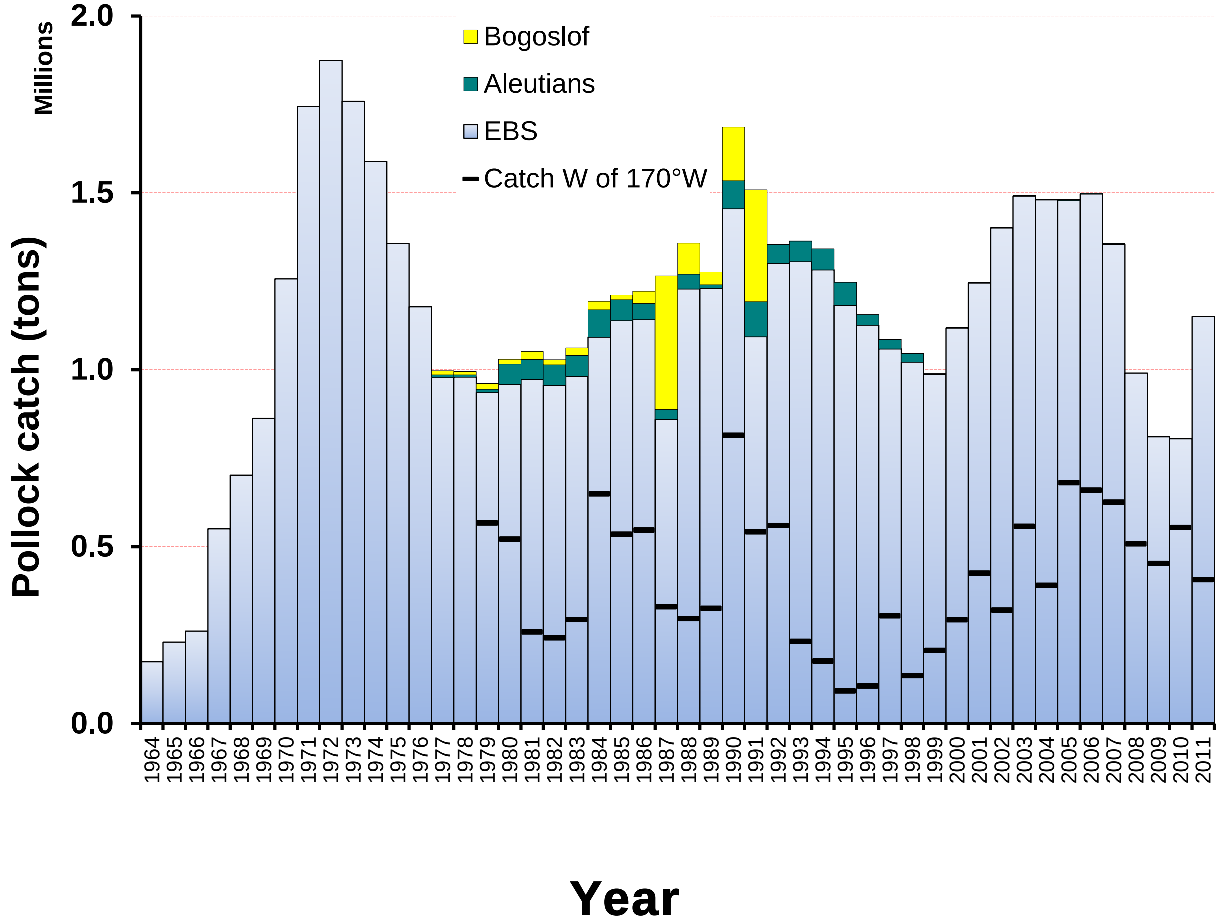

Figure 1.1. Alaska pollock catch estimates from the Eastern Bering Sea, Aleutian Islands, and Bogoslof Island regions, 1964-2011. The 2011 value is based on expected totals for the year.

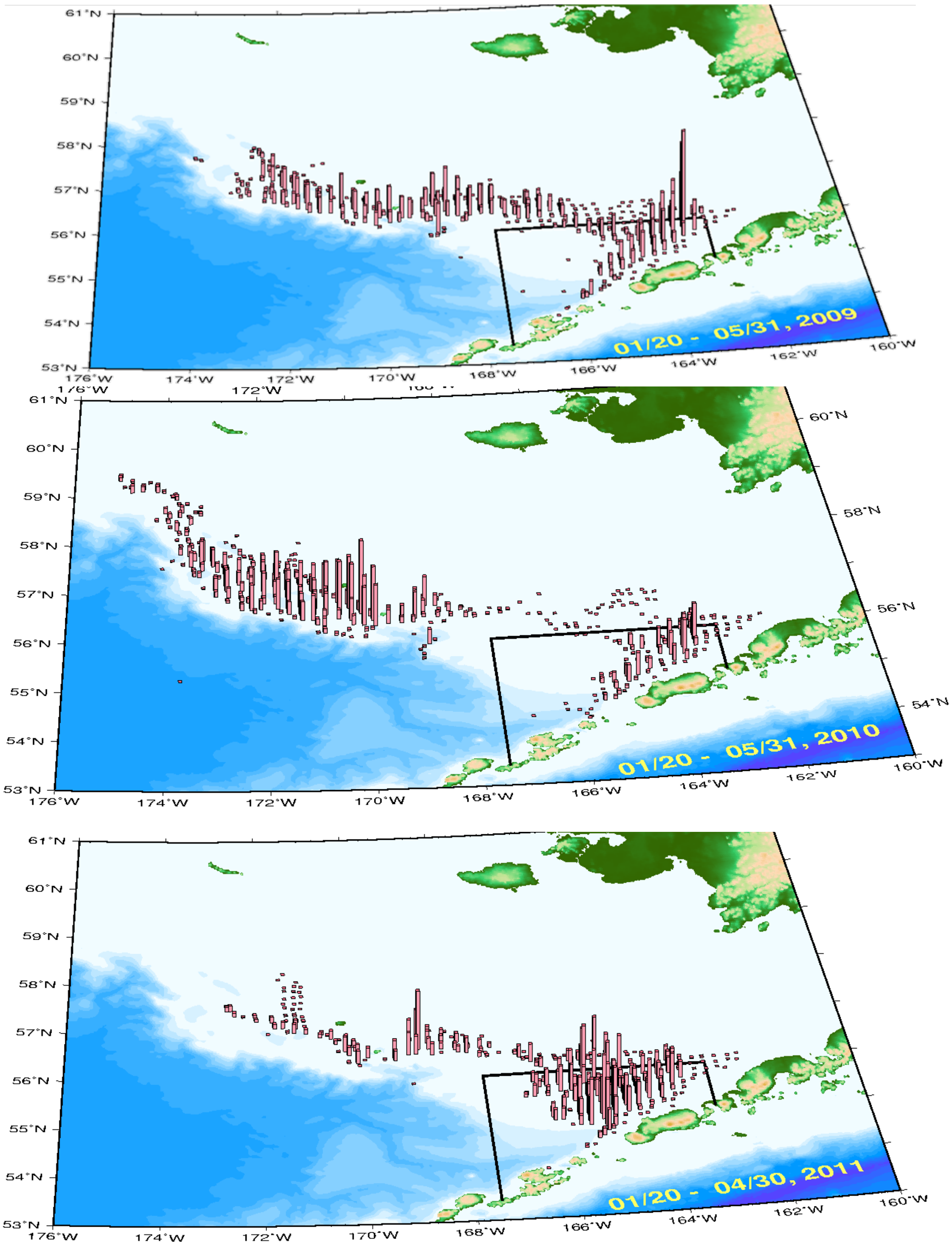

Figure 1.2. Pollock catch distribution 2009-2011, January – May on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

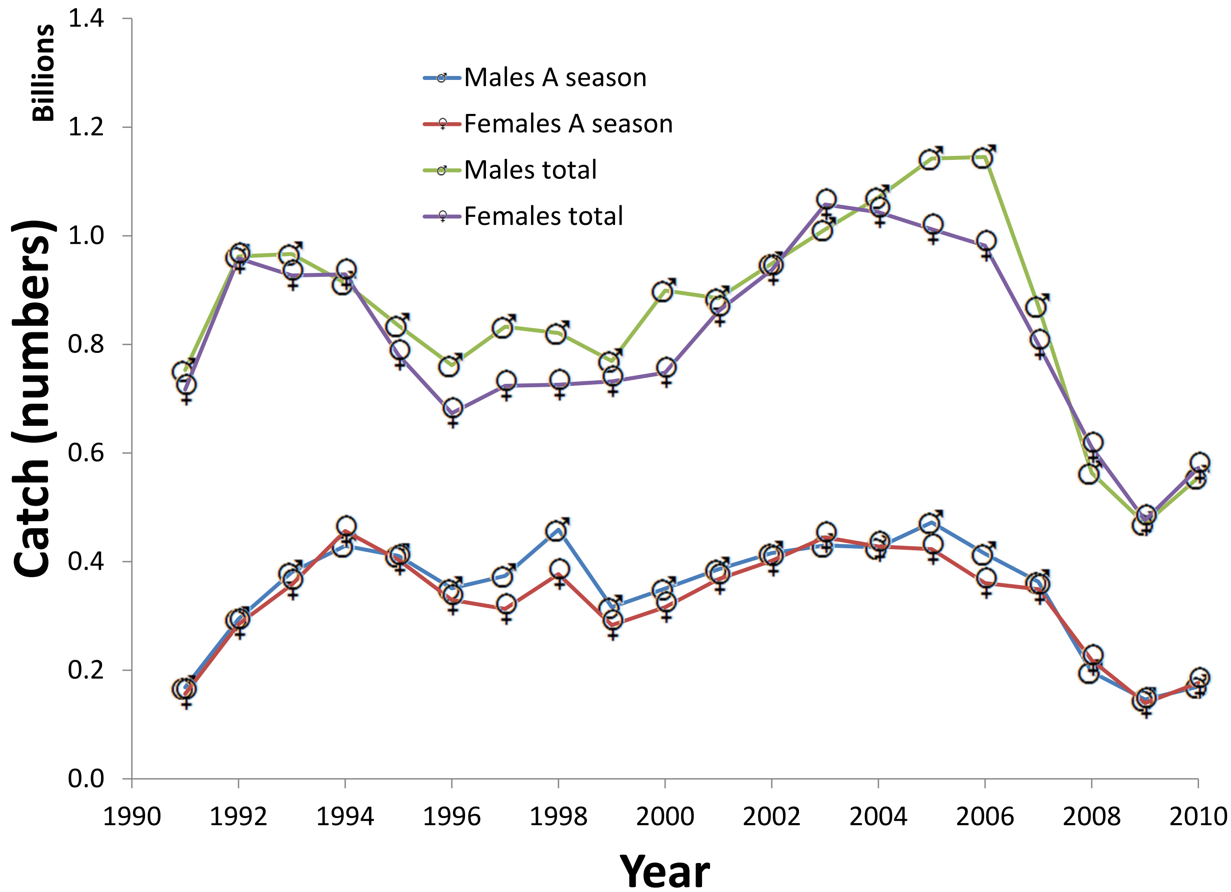

Figure 1.3. Estimate of EBS pollock catch numbers by sex for the “A season” (January-May) and for the entire annual fishery, 1991-2010.

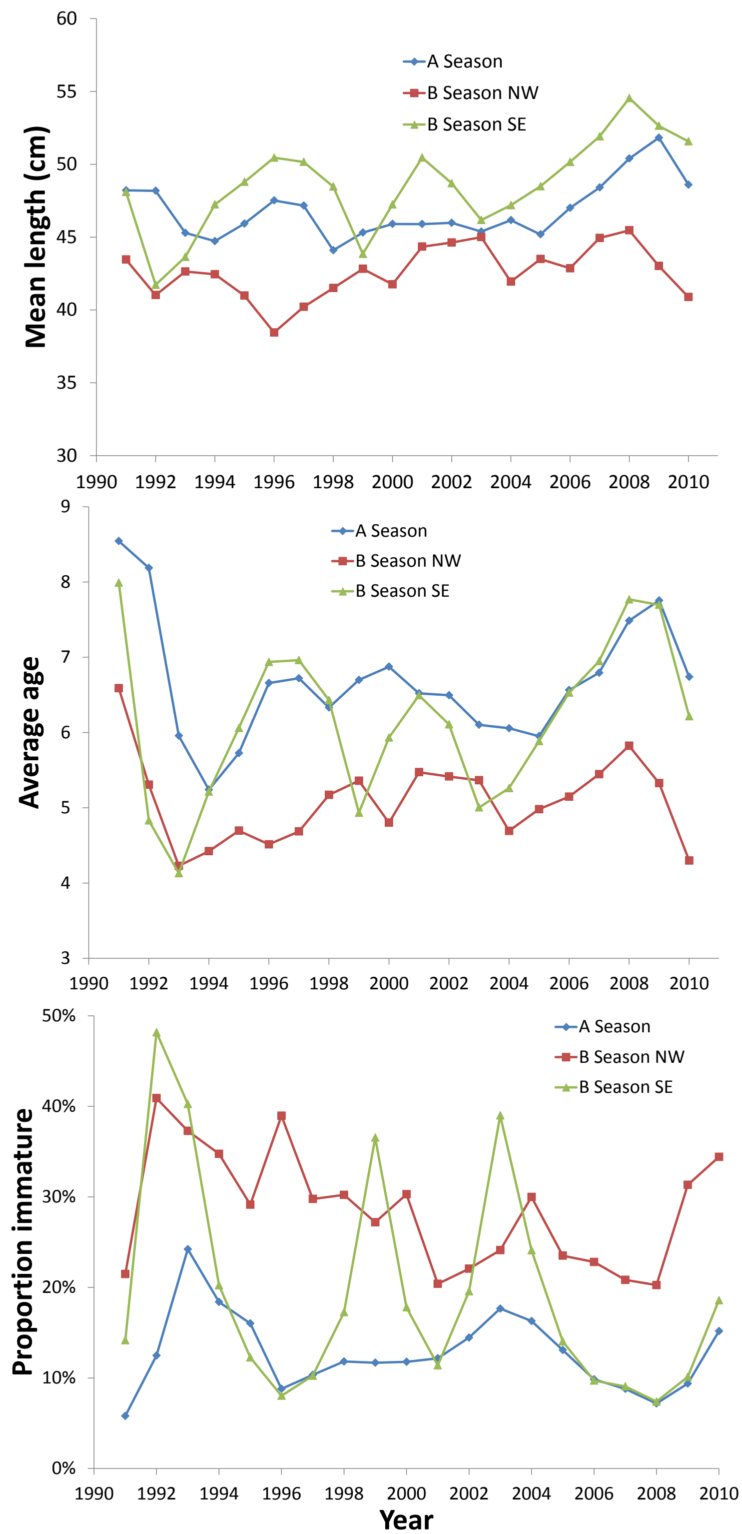

Figure 1.4. Estimated EBS pollock average length (top panel) and average age (middle panel) of the stratum-specific catch. The bottom panel shows the proportion of the catch estimated to be immature. Strata are all areas during the "A season" (January-April) and divided at 170°W for (SE and NW) for the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

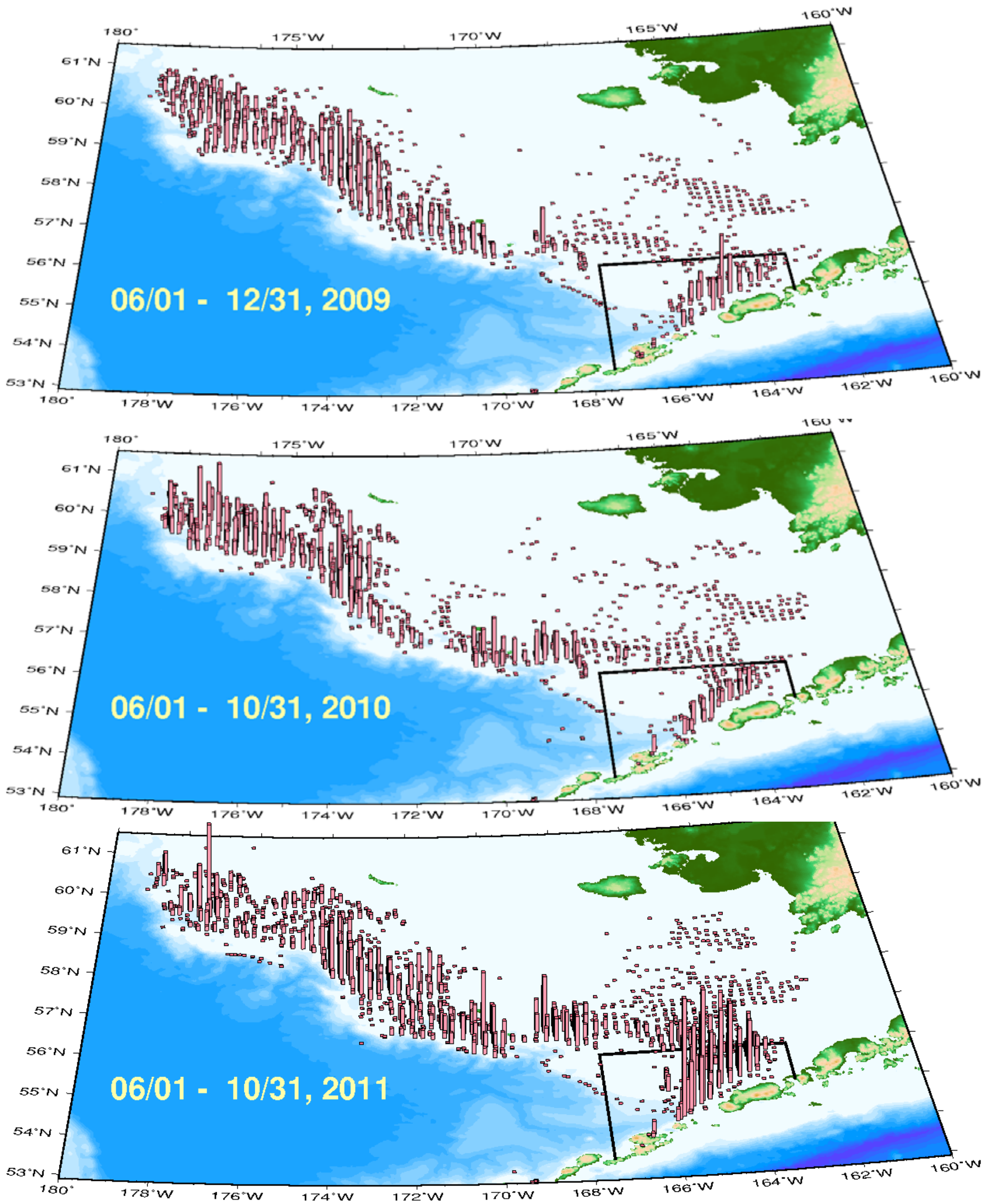

Figure 1.5. Pollock catch distribution during June – December, 2009-2011. The line delineates the catcher-vessel operational area (CVOA) and the height of the bars represents relative removal on the same scale between years. Note that in 2011 the observer coverage increased to 100% for all pollock vessels (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)

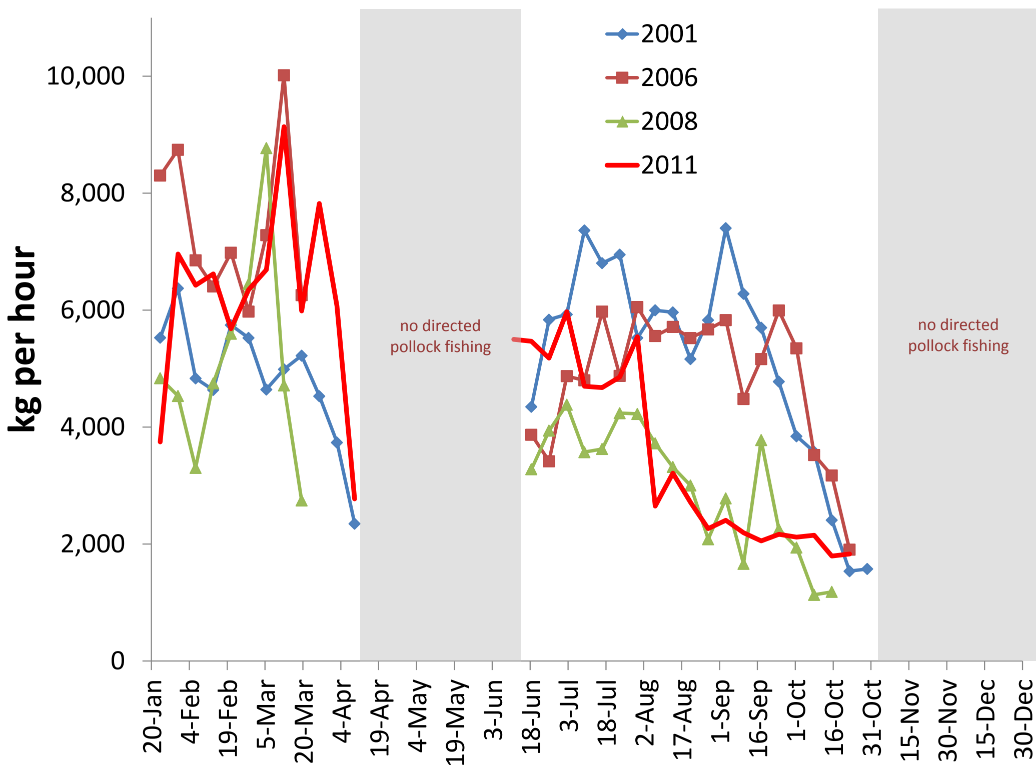

Figure 1.6. Weekly mean nominal pollock catch per hour towed for the EBS pollock fishery for selected years (2001, 2006, 2008, and 2011).

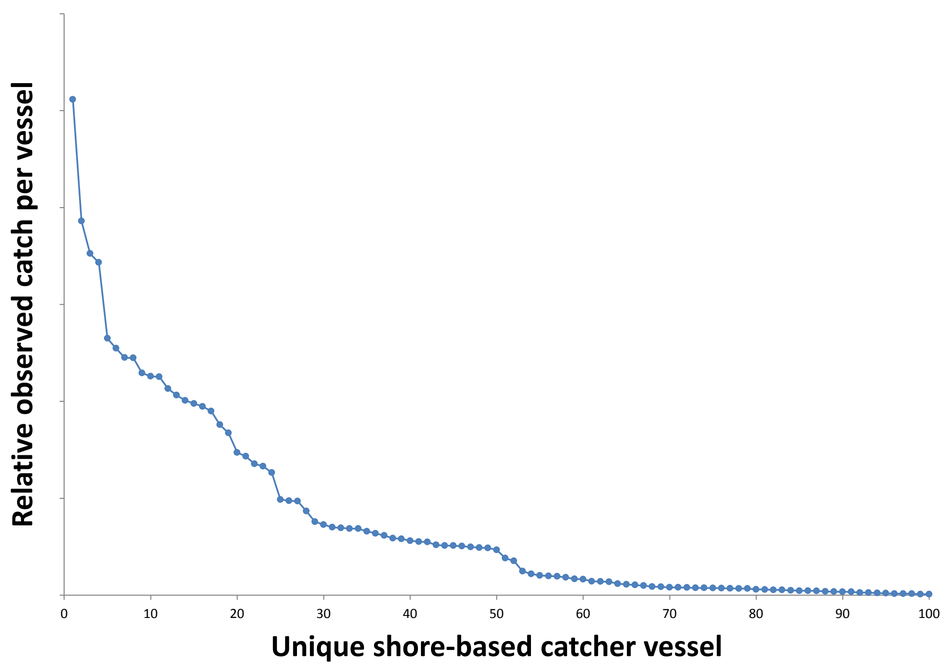

Figure 1.7. Relative observed catch by unique shore-based catcher vessel during the B-season of the EBS pollock fishery, 1990-2011. The vessels labeled 1-25 were selected as one group whereas vessels 26-53 were selected as a second group used in subsequent catch-rate evaluations.

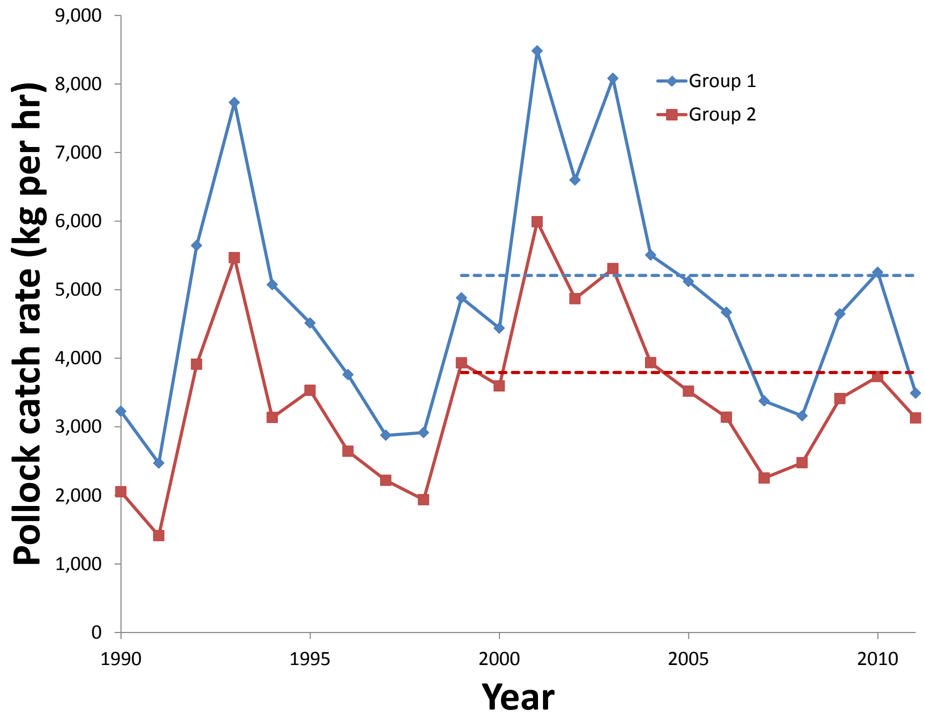

Figure 1.8. Mean observed catch rates in kg per hr for two groups of B-season shore-based catcher boats of the EBS pollock fishery, 1990-2011. Dashed lines show the mean values from 1999-2011.

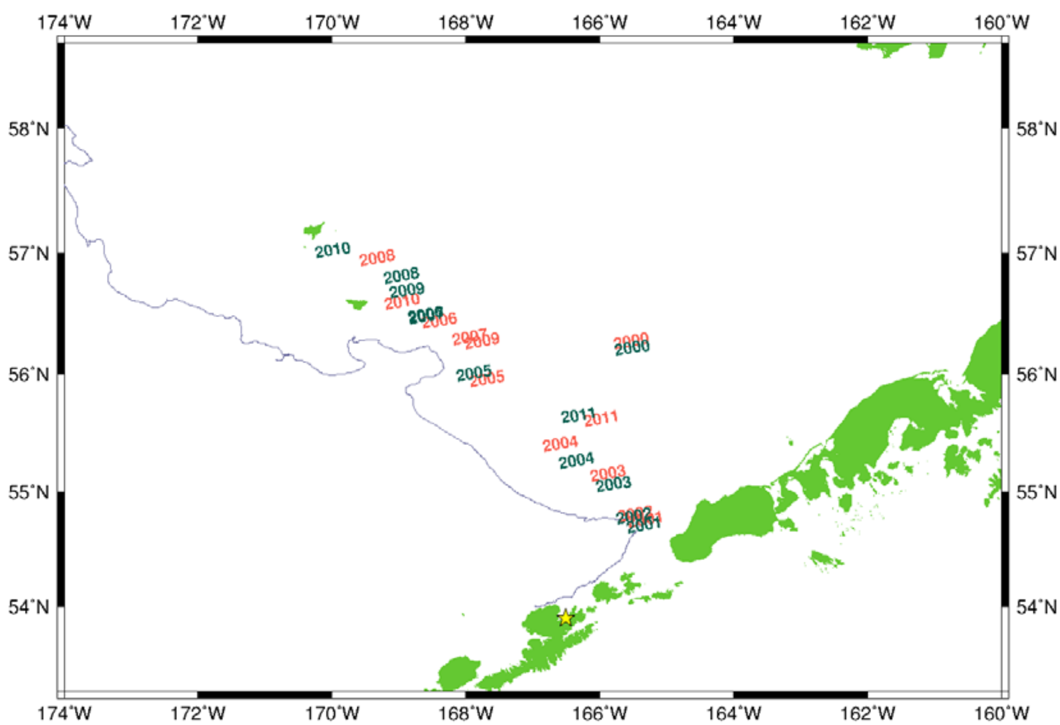

Figure 1.9. Mean observed catch locations by year for group 1 (black) and group 2 (red) shore-based catcher boats during B-season of the EBS pollock fishery, 2000-2011. Yellow star indicates the location of Dutch Harbor Alaska.

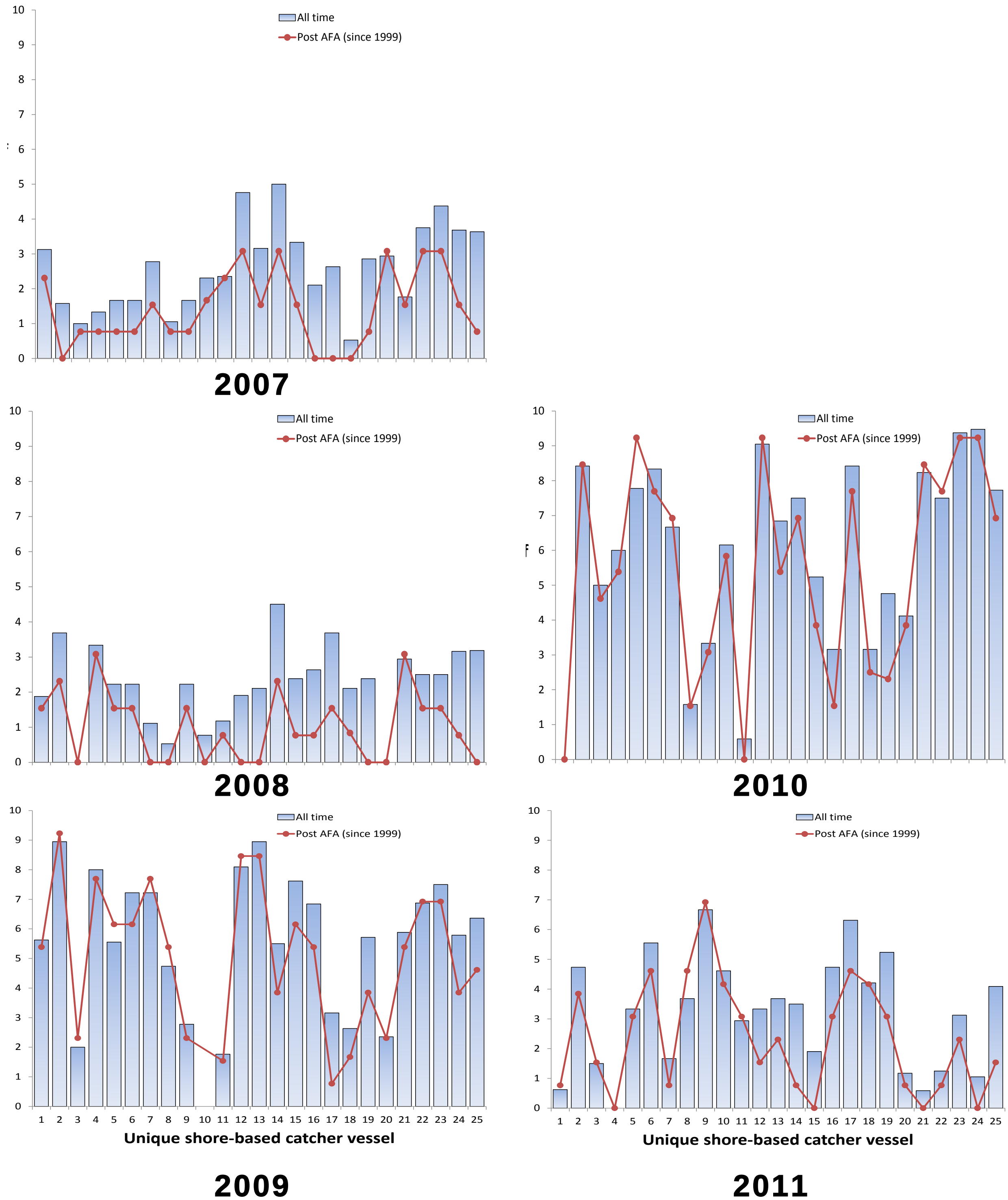

Figure 1.10. Number of years with worse conditions (out of standard 10 years) by the catcher vessels within group 1 as ranked for 2007 through 2011. Columns represent data from 1990-2011 whereas the lines are post-AFA (1999-2011). A score of "10" means that year ranked highest for that vessel, a score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

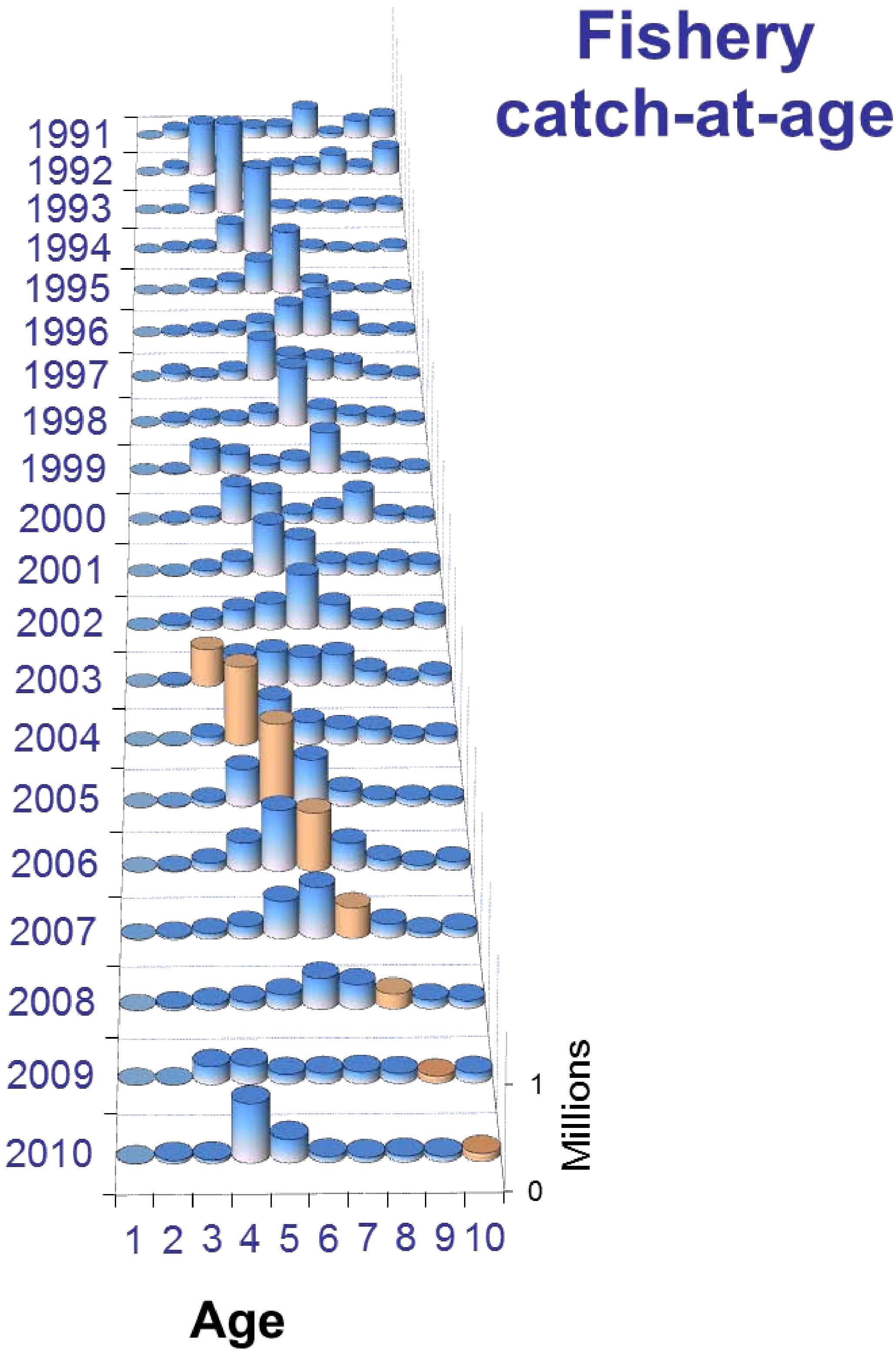

Figure 1.11. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2010. Age 10 represents pollock age 10 and older. The 2000 year-class is highlighted.

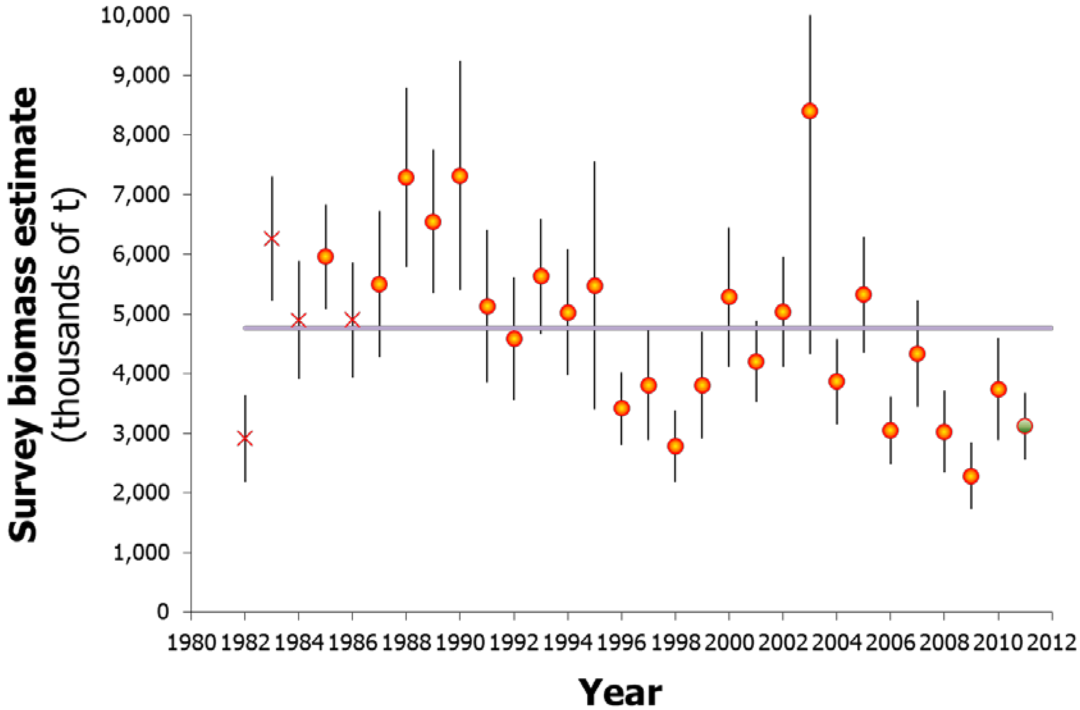

Figure 1.12. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS pollock, 1982-2011. These estimates **include** the northern strata except for 1982-84, and 1986 (years indicated with crosses).

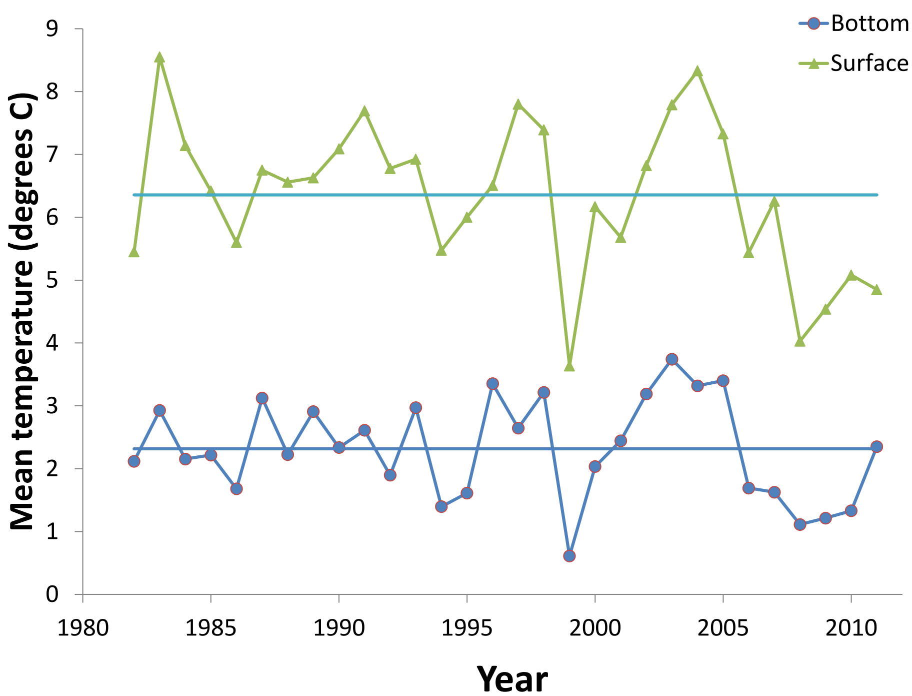

Figure 1.13. Area-weighted bottom (lower lines) and surface (upper lines) temperatures for the Bering Sea during the NMFS summer bottom-trawl surveys (1982-2011).

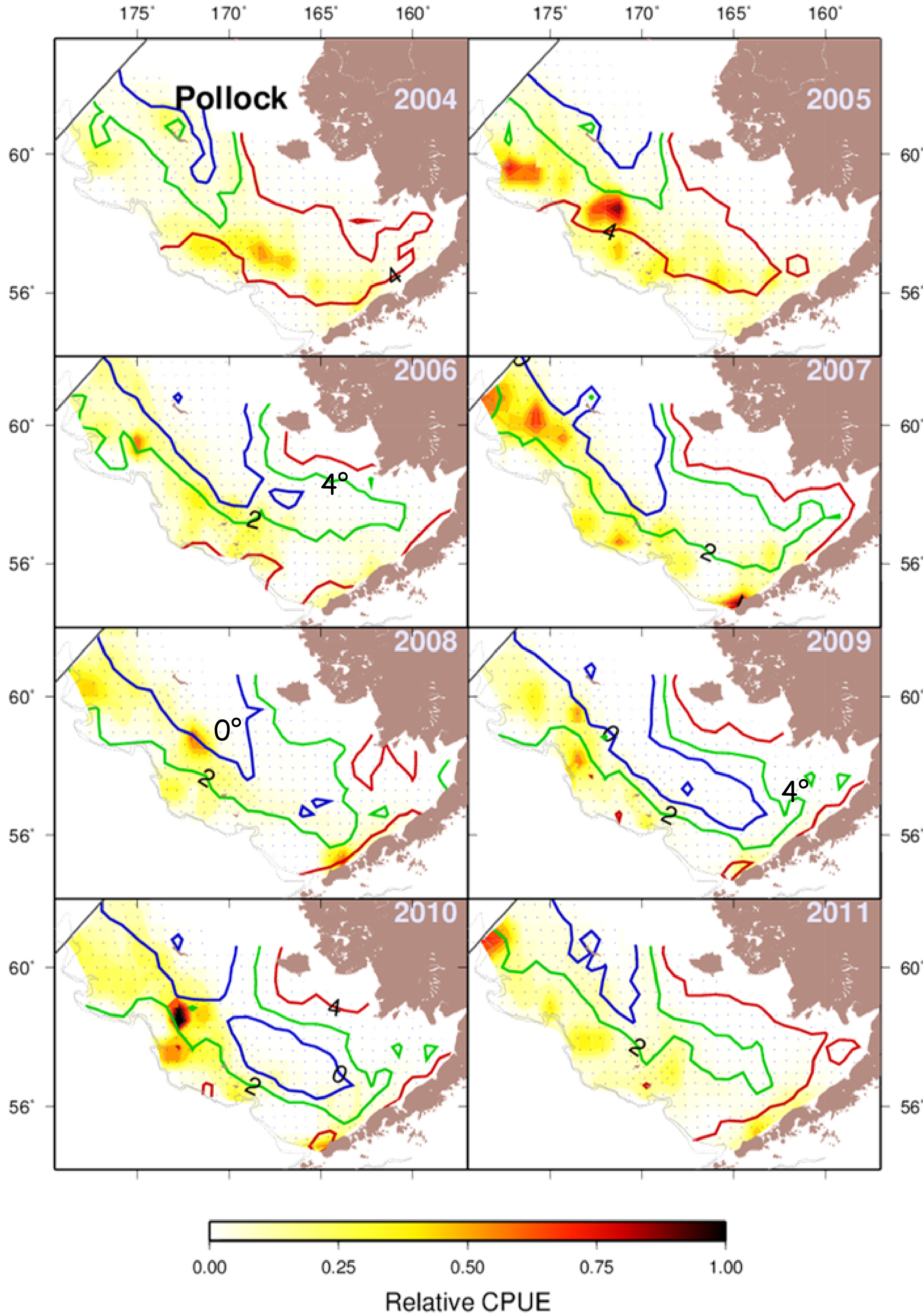

Figure 1.14. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 2004-2011.

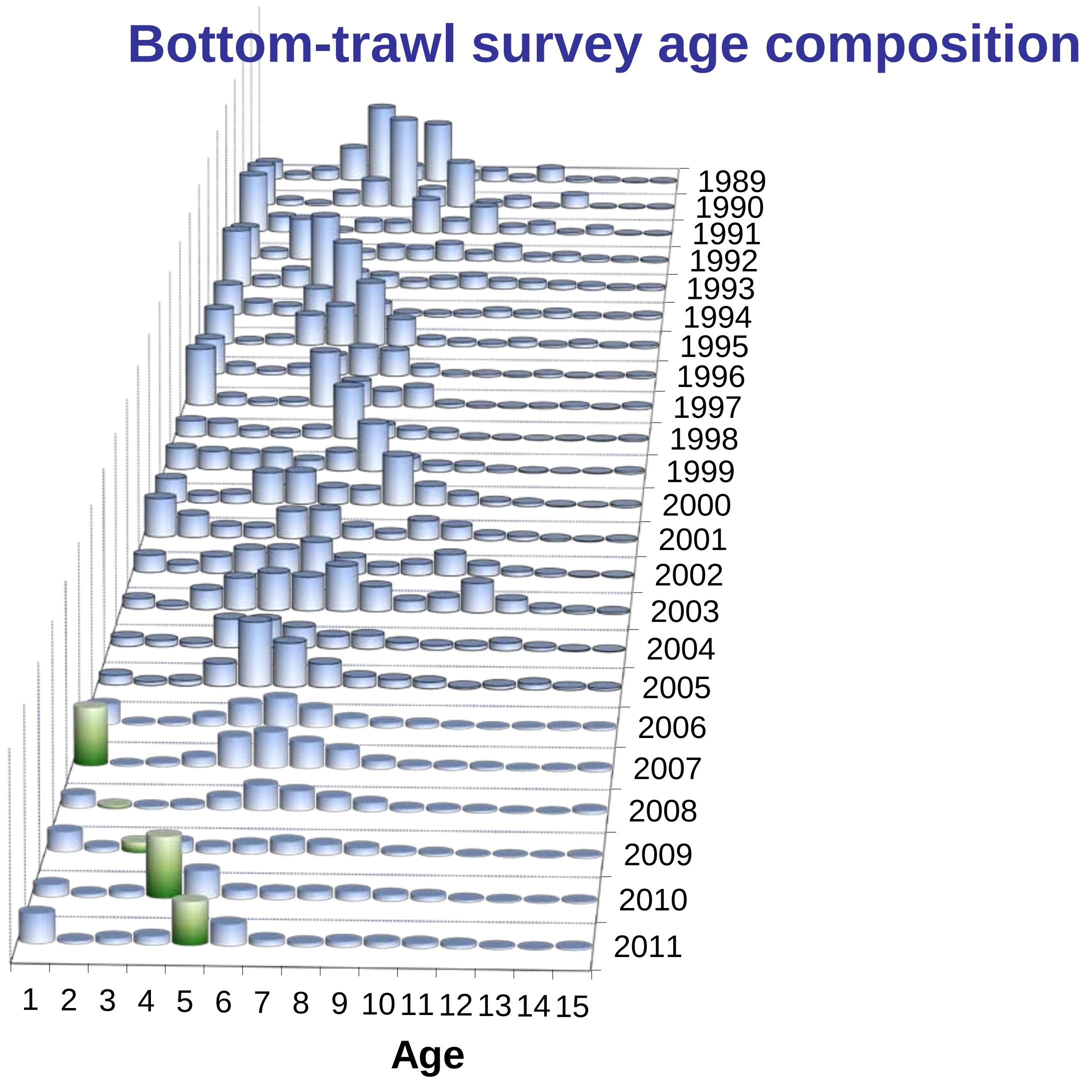

Figure 1.15. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1989-2011). The 2006 year-class is shaded differently.

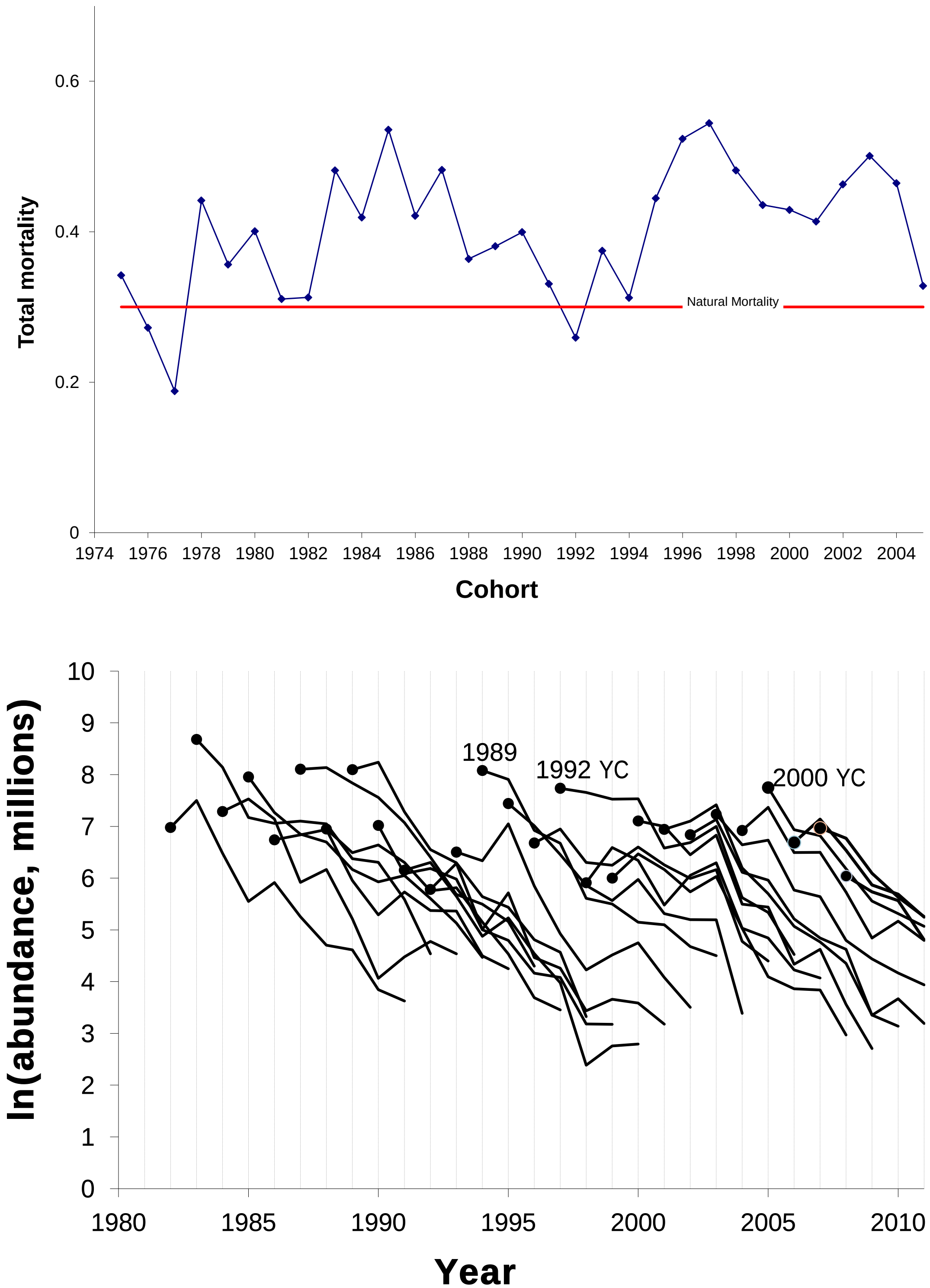

Figure 1.16. Evaluation of EBS pollock cohort abundances as observed for age 6 and older in the NMFS summer bottom trawl surveys. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort.

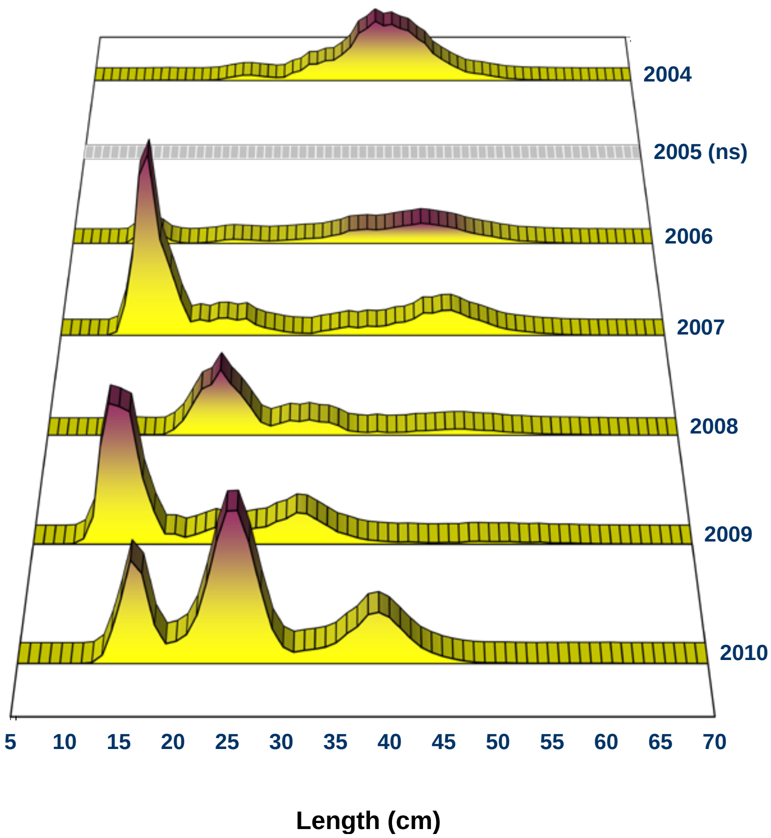

Figure 1.17. Acoustic-trawl survey relative abundances at length for EBS pollock, 2004-2010. Vertical scale is equal for all years and is relative to numbers of fish.

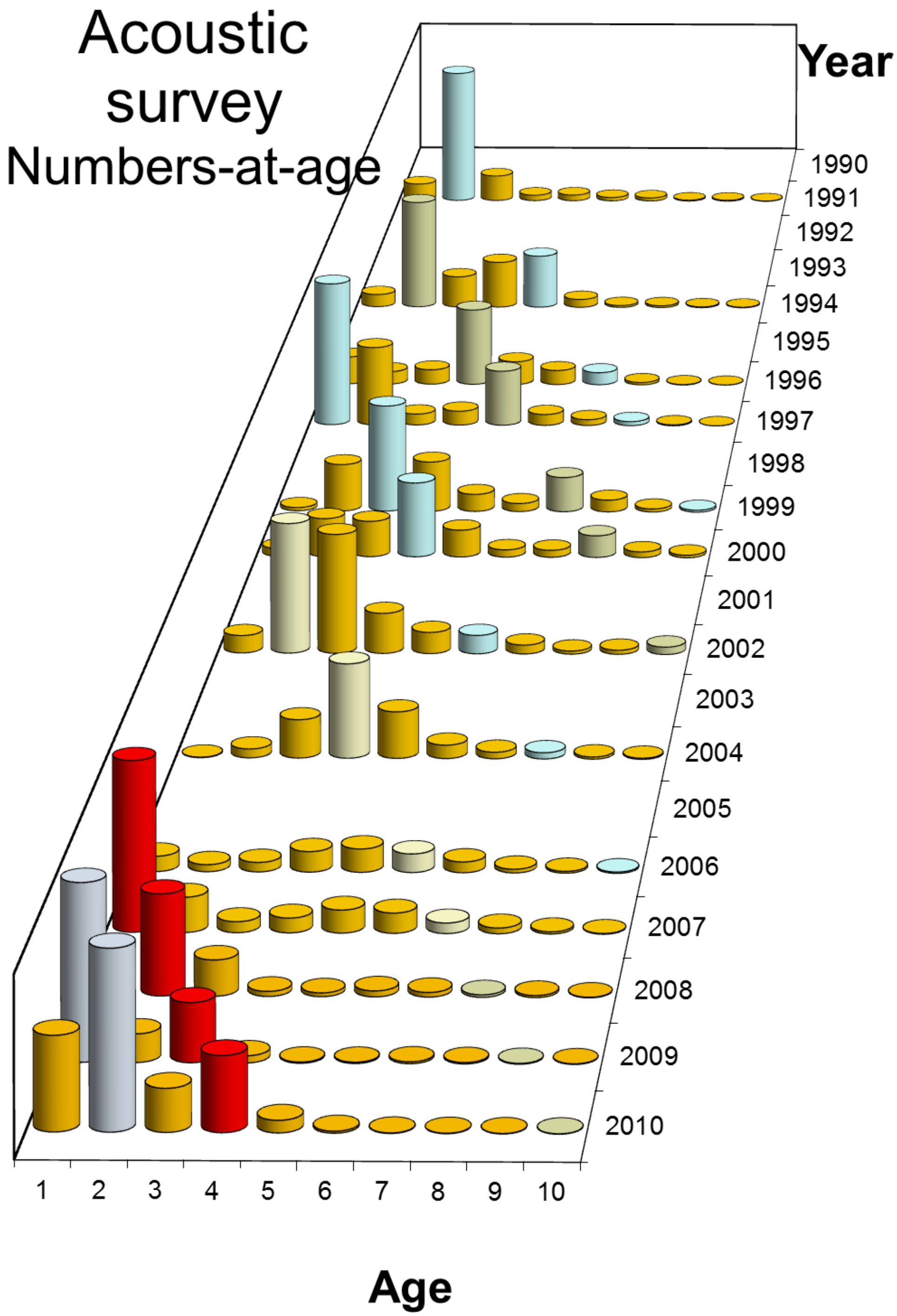

Figure 1.18. Time series of estimated abundances at age (numbers) for EBS pollock from the AT surveys, 1991-2010. The shaded columns represent selected cohorts through time.

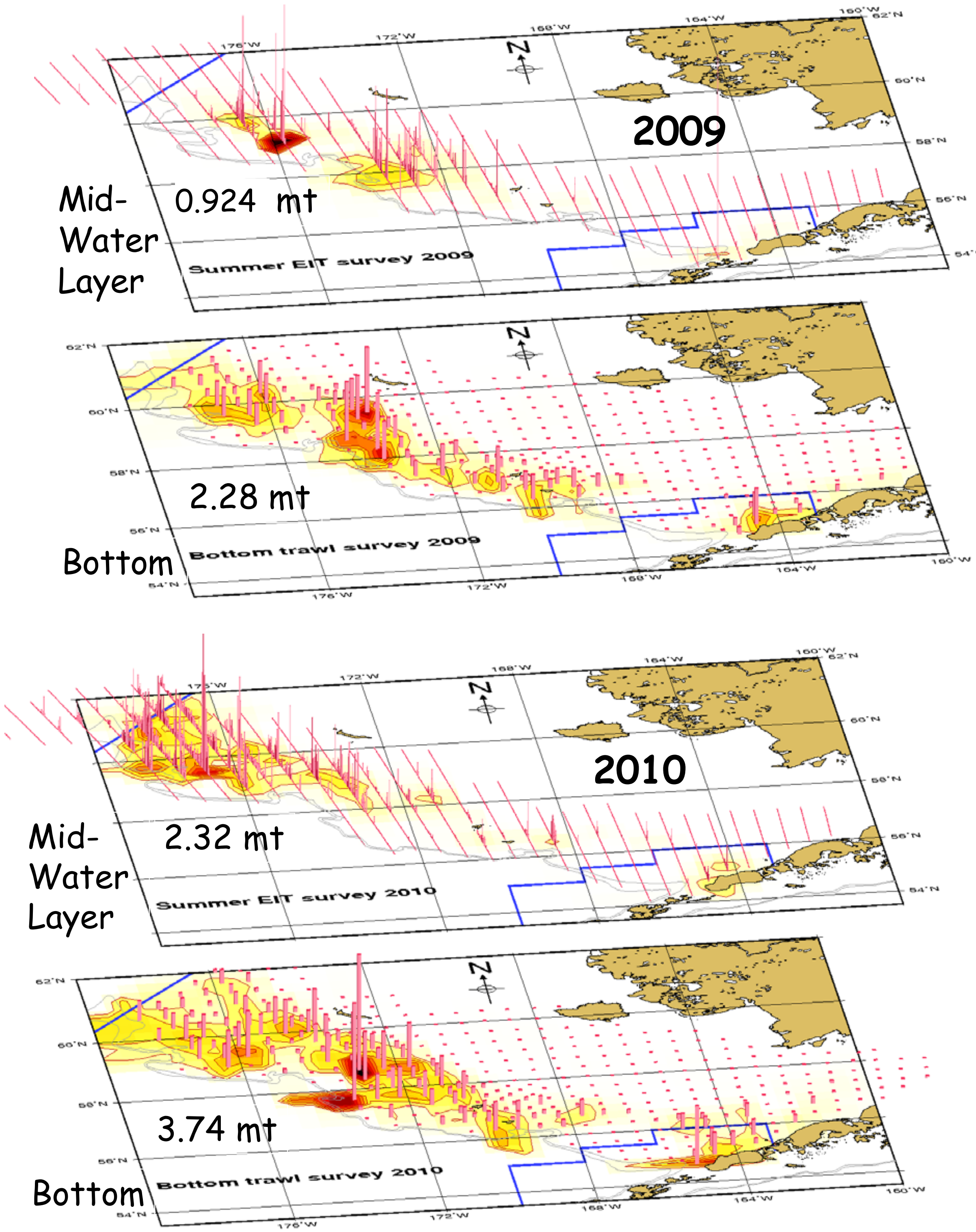

Figure 1.19. Acoustic-trawl survey results for 2009 and 2010. The lower figure is the result from the BTS data in the same years. Vertical lines represent biomass of pollock as observed in the different surveys (mt = millions of t).

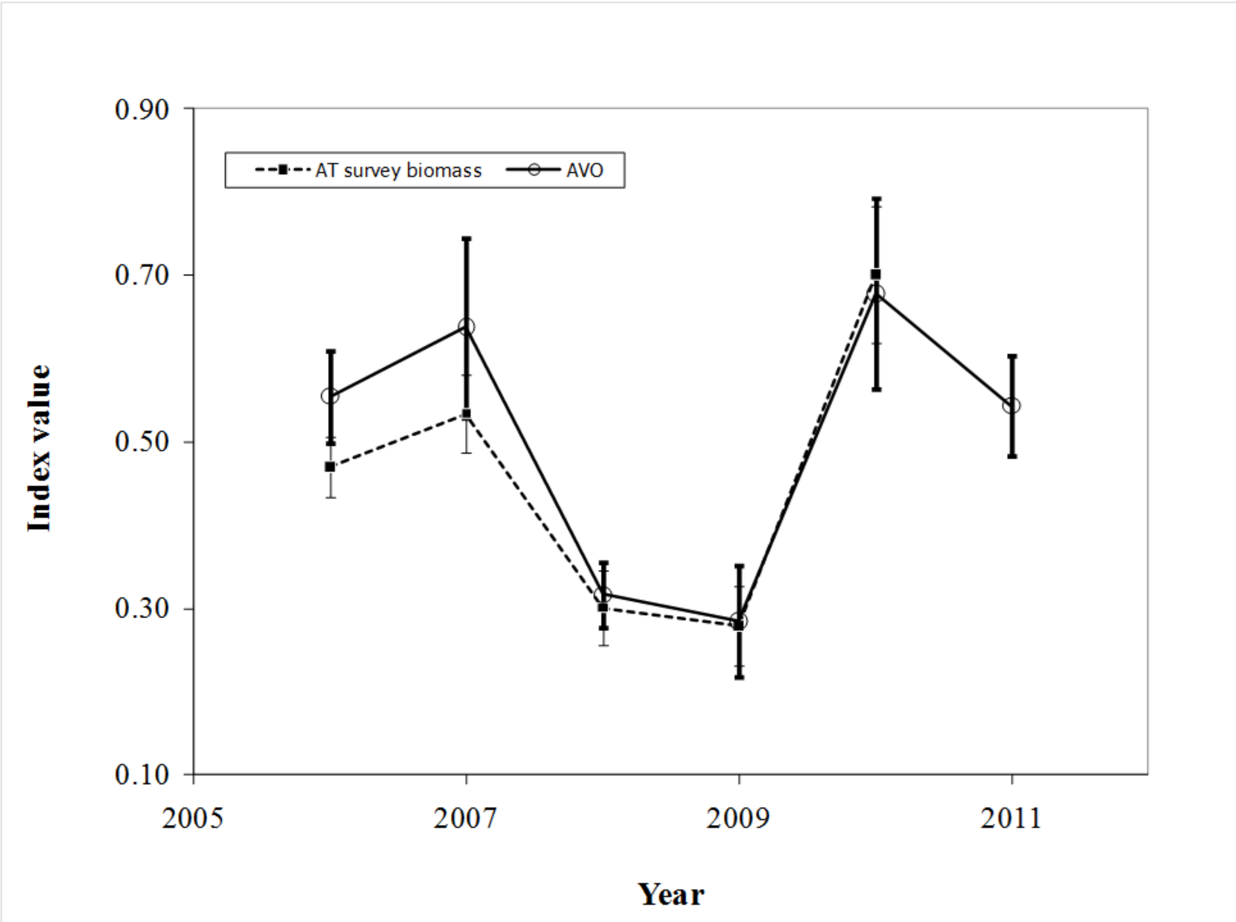

Figure 1.20. AT survey biomass in the U.S. EEZ and AVO index 2006-2011 with 95% confidence intervals based on estimates of 1-D geostatistical relative estimation error. Each time series has been scaled to its mean value for the period 1999-2004 (not shown).

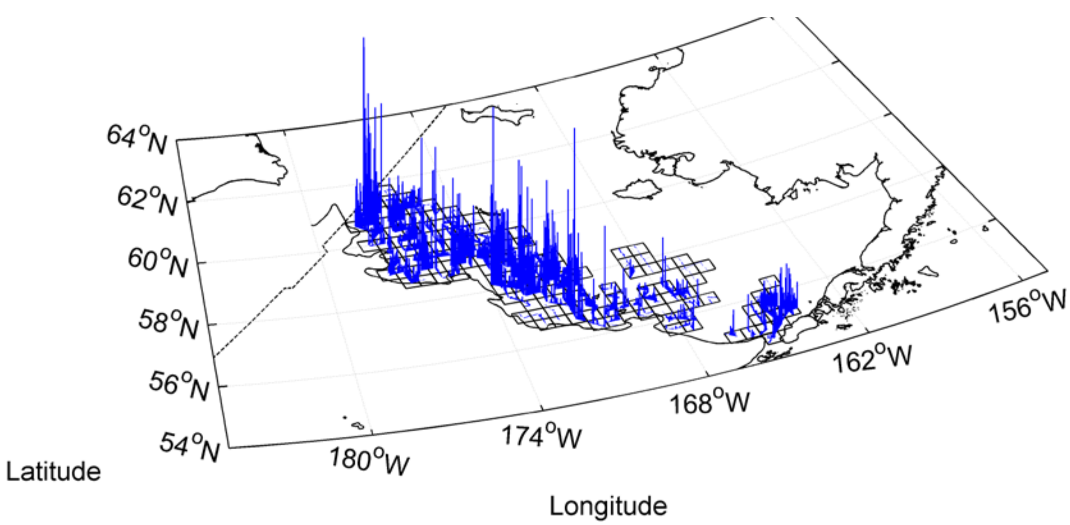

Figure 1.21. Acoustic backscatter assigned to pollock from acoustic vessels of opportunity (AVO) collected in the index areas from the 2011 bottom trawl survey.

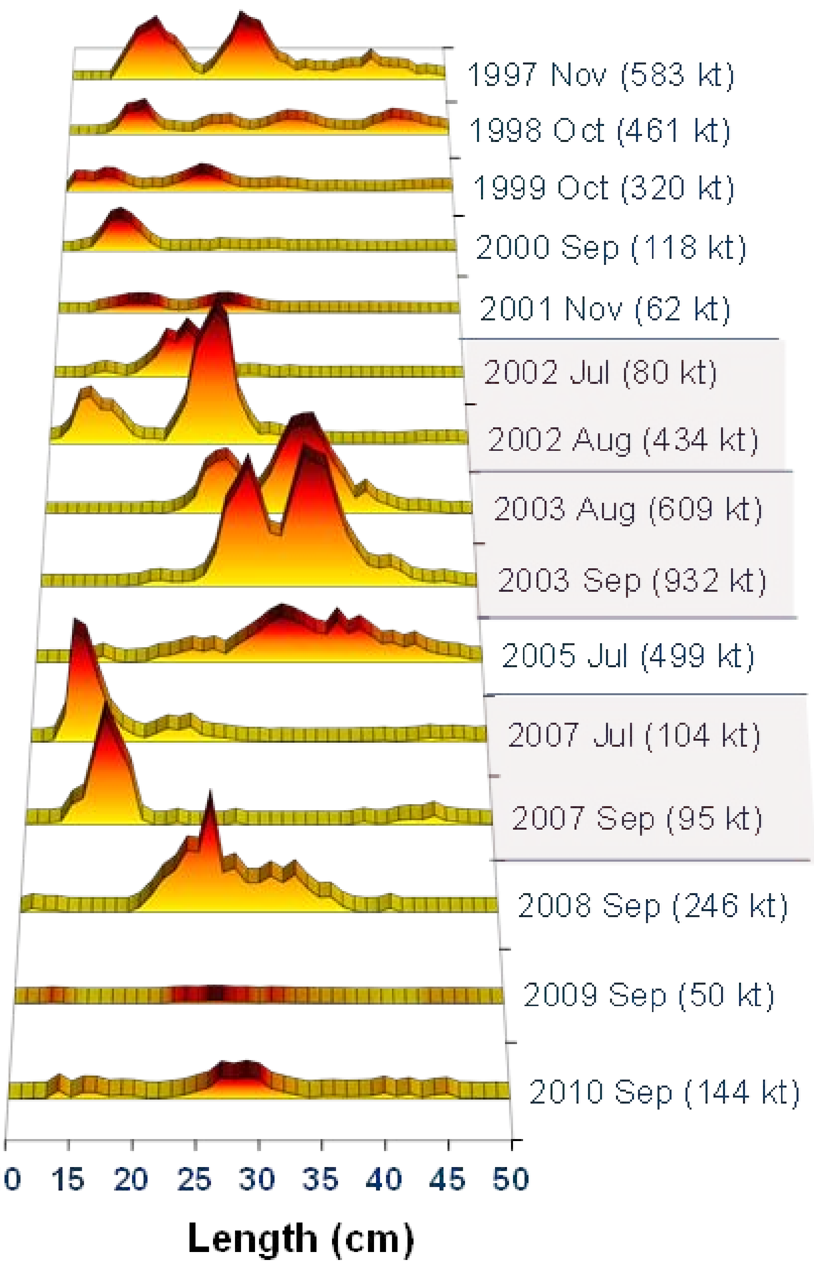

Figure 1.22. Russian Navarin/Anadyr region survey estimates of pollock numbers at length (vertical scale) by year and month survey conducted with biomass estimates shown in side labels (kt=thousands of t). Shaded labels indicate more than one survey within a year.

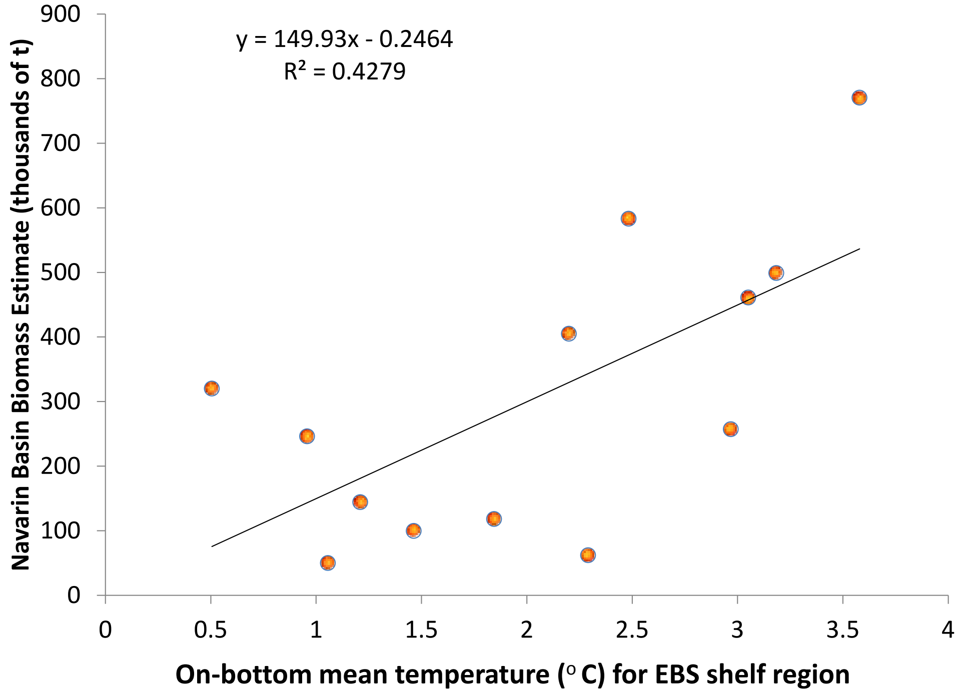

Figure 1.23. Russian Navarin/Anadyr region survey estimates of pollock compared to mean on-bottom temperatures from the EBS shelf survey 1997-2011. For years when multiple Russian surveys occurred (2002, 2003, and 2007) the mean biomass value was applied.

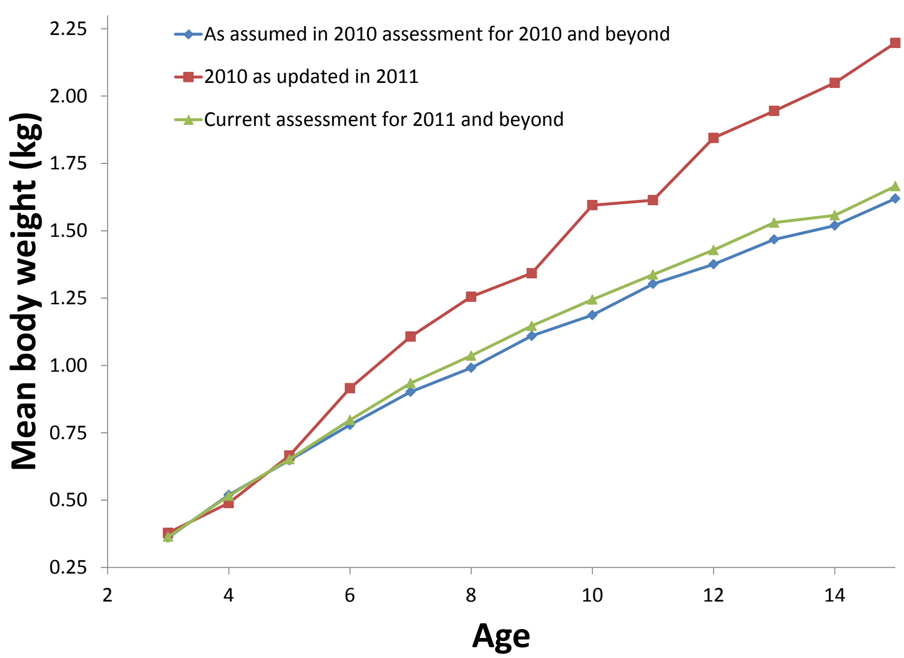

Figure 1.24. Mean fishery body weight (kg) for EBS pollock assumed for the 2010 assessment and as revised using observer data for the current assessment.

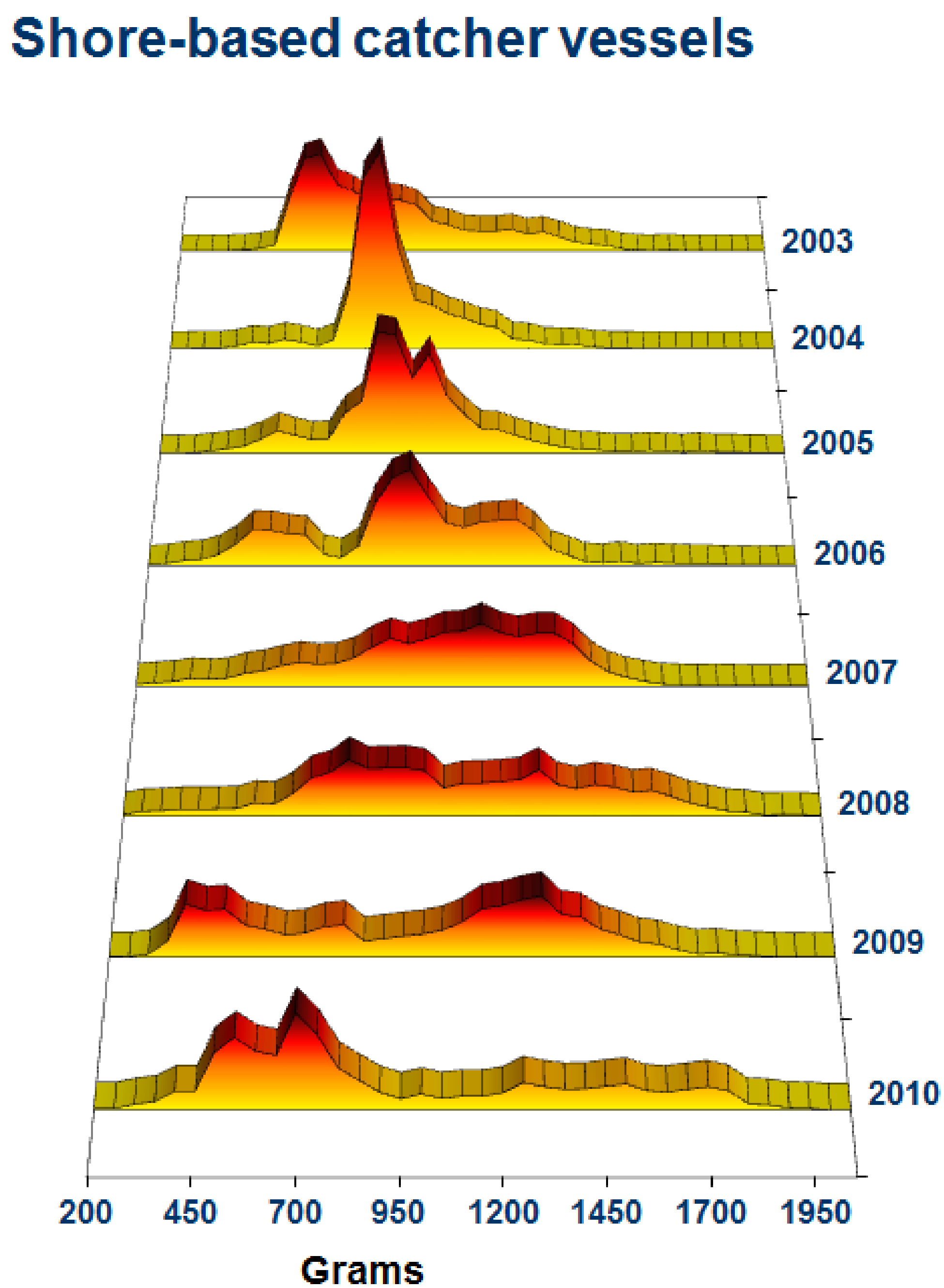

Figure 1.25. Frequency of pollock tows by 50g pollock body mass categories for the shore-based catcher vessels during June-October, 2003-2010.

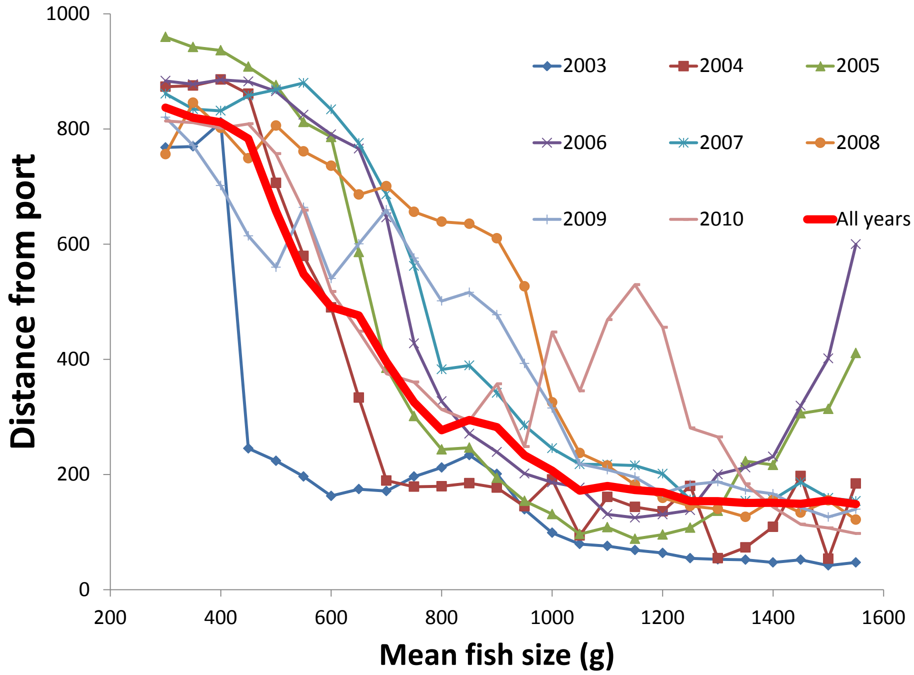

Figure 1.26. Average distance from port (km) by pollock body size category (at 50g intervals), 2003-2010 and all years combined. The "port" is defined as a point midway between Akutan and Dutch Harbor.

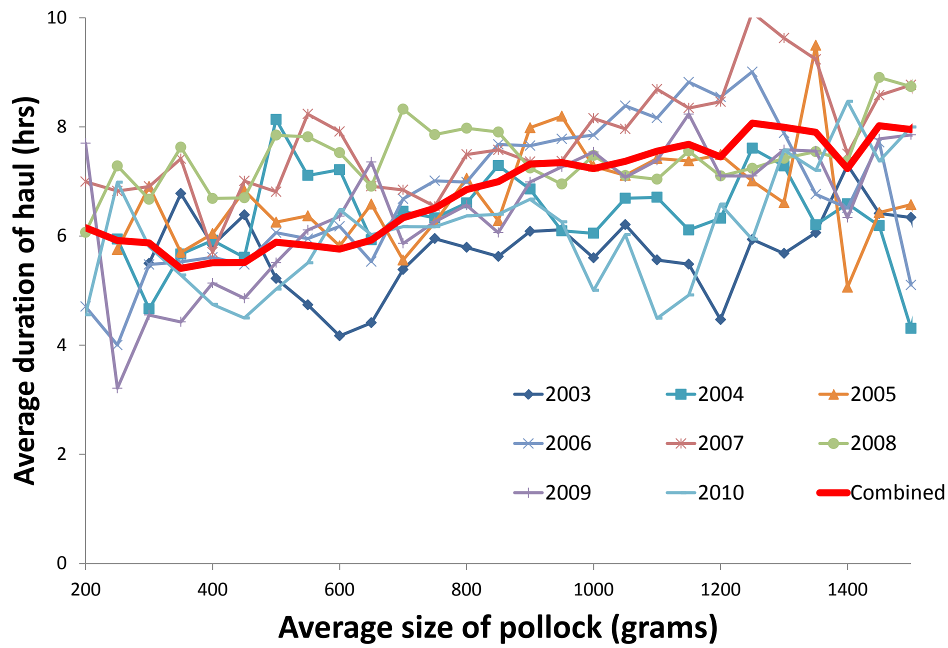

Figure 1.27. Average tow duration by pollock body size category (at 50g intervals), 2003-2010 and all years combined.

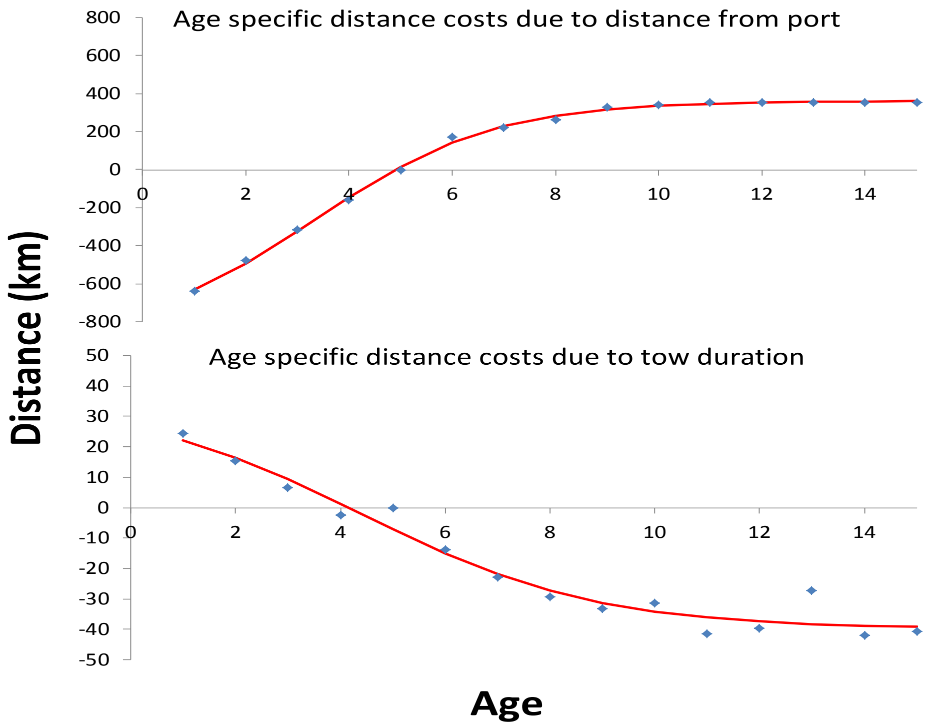

Figure 1.28. Estimated relationship between pollock ages (as mapped from mean body mass at age) and mean distance from port (top panel) and mean distance (in equivalent units) of tow duration. In both figures, the values fitted (points) represent relative distances to observations at age 5. Lines represent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

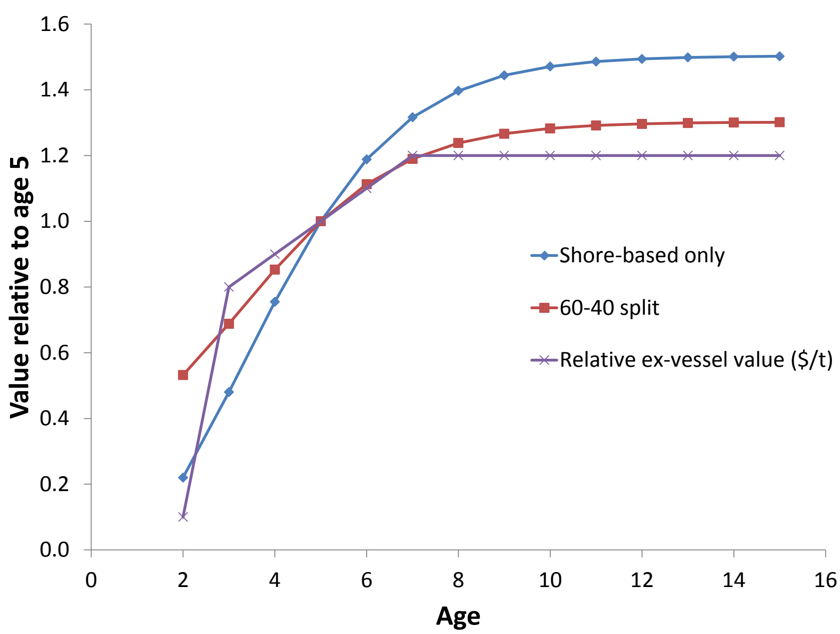

Figure 1.29. Population-level estimated relationship between pollock ages and relative effort (distance) required for capture with and without a 60-40 split and an example relative age-specific value for ex-vessel landings (slope parameter equal to 0.1).

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	0.36	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																				

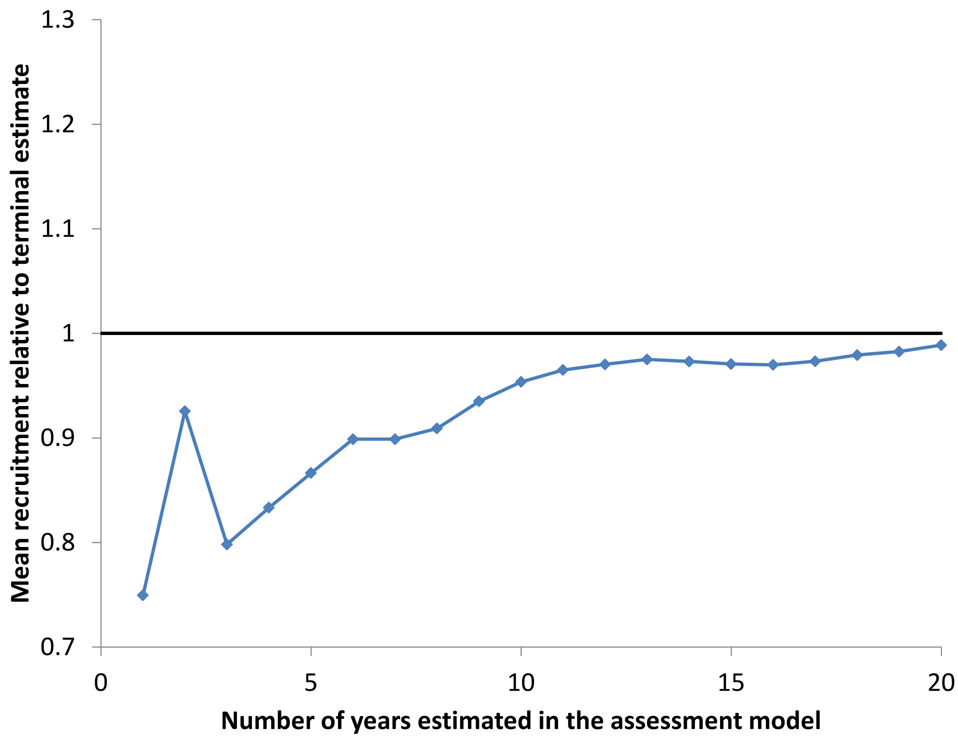

Figure 1.30. Retrospective ratios of estimated age 1 pollock recruitment in retrospective year divided by the terminal, 2011 estimate for each of the 1990-2010 retrospective runs (columns) by year class (rows; top panel). Shading denotes high and low values, bold values in rows are from above-average 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.

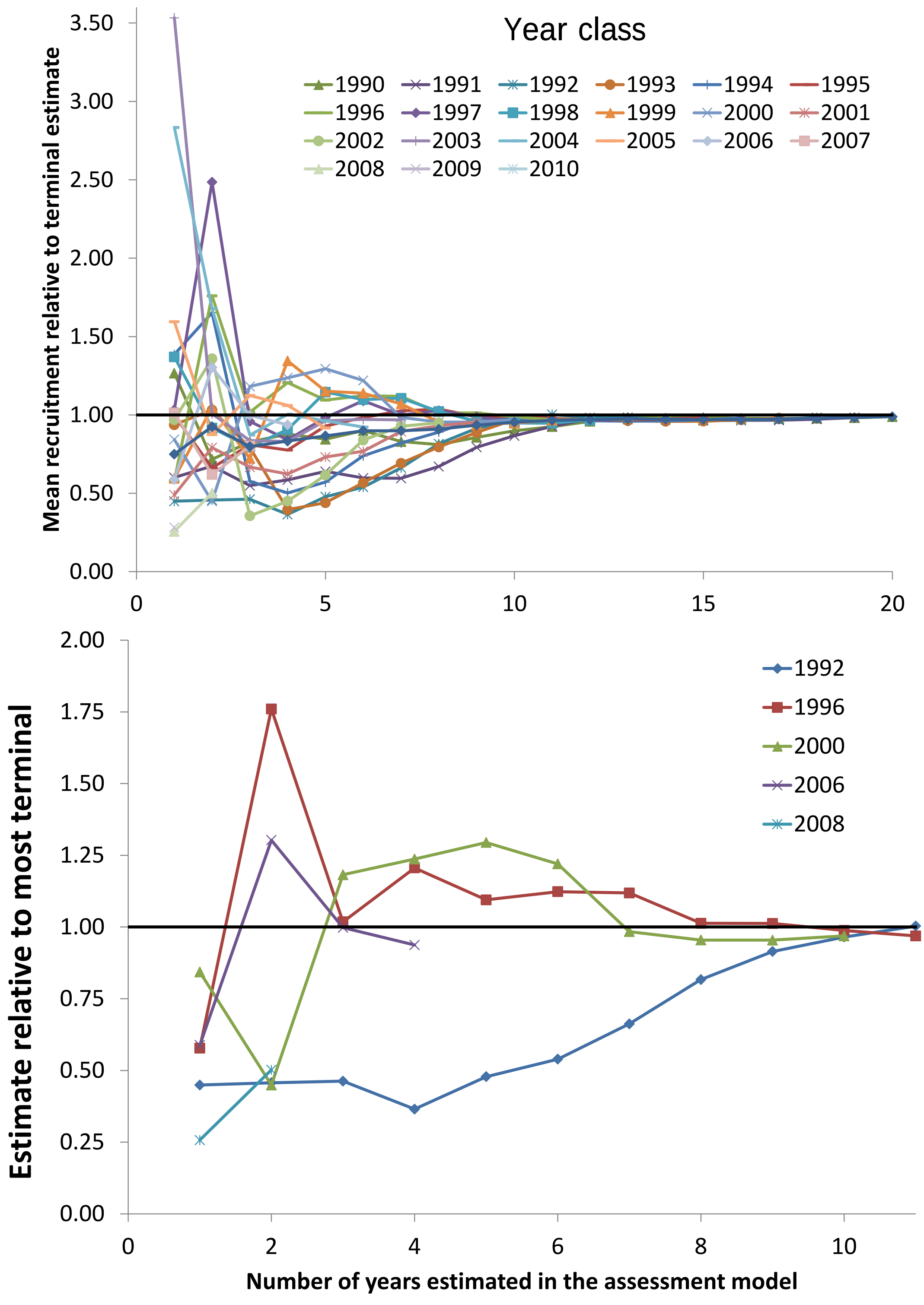

Figure 1.31. Evaluation of EBS pollock retrospective errors on recruitment estimates as a function of the number of the years in the model. The top panel shows all the cohorts (year classes) whereas the bottom panel shows some of the key above average year classes.

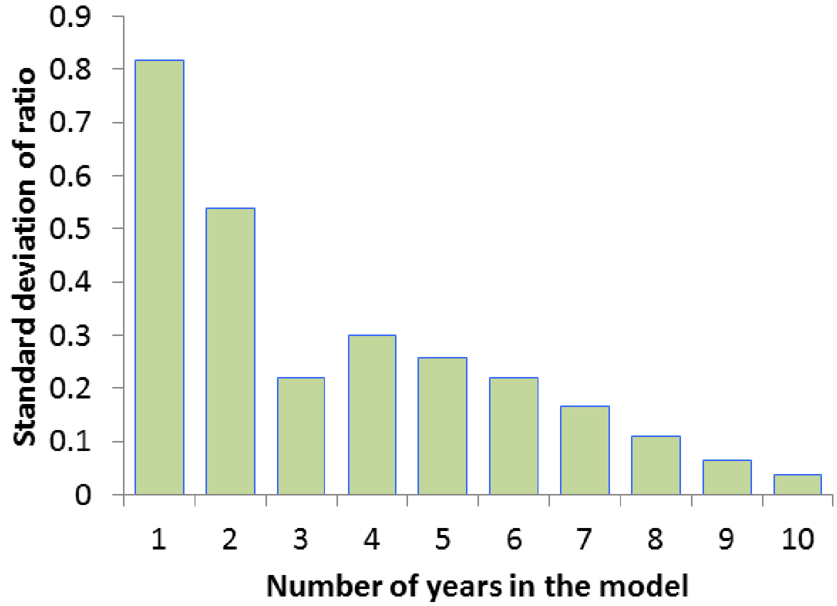

Figure 1.32. Retrospective evaluation of EBS pollock model testing the variability of errors on recruitment estimates as a function of the number of the years in the model.

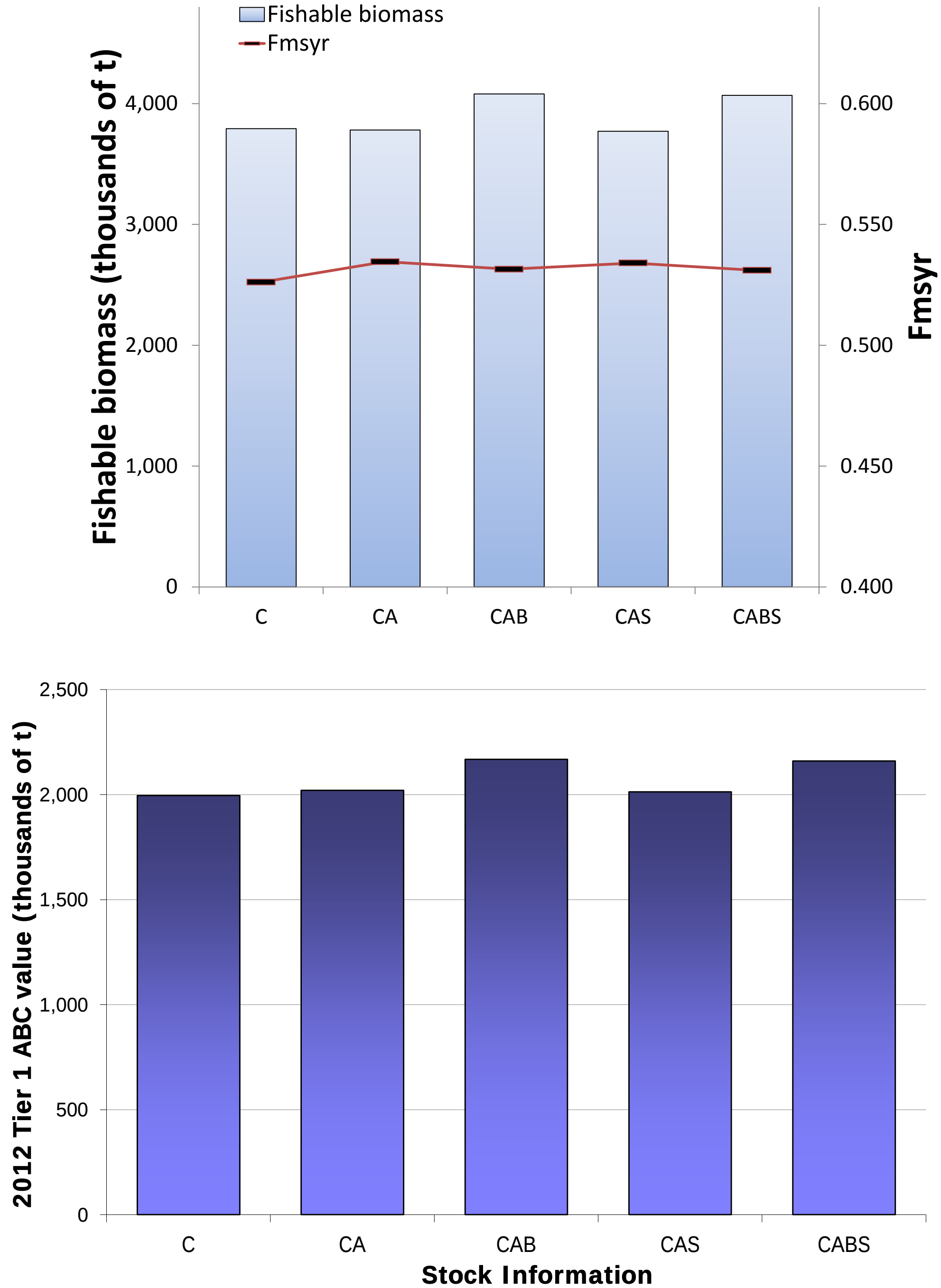

Figure 1.33. The impact of introducing new data to the assessment model on fishable biomass values, F_{msy} rates, and ABC (bottom panel) for 2011 (key: fishery **C**atch, fishery **A**ge, **B**ottom-trawl survey data, and **S** for **AVO** (**S**a) index.

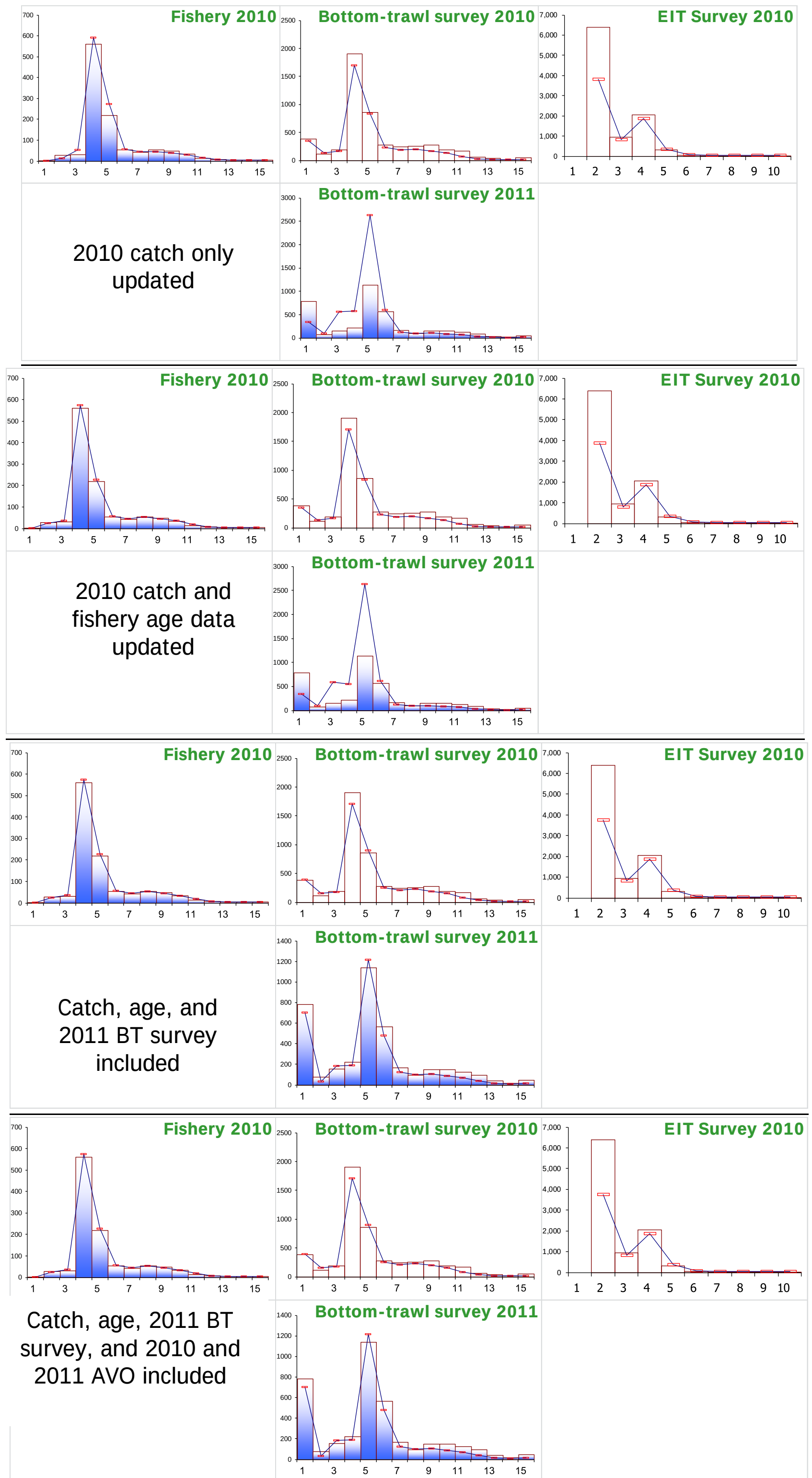

Figure 1.34. Model results of predicted EBS pollock numbers-at-age for catch and surveys as new data were added. Columns represent the data, lines represent model predictions. Shaded columns indicate data introduced in the current assessment.

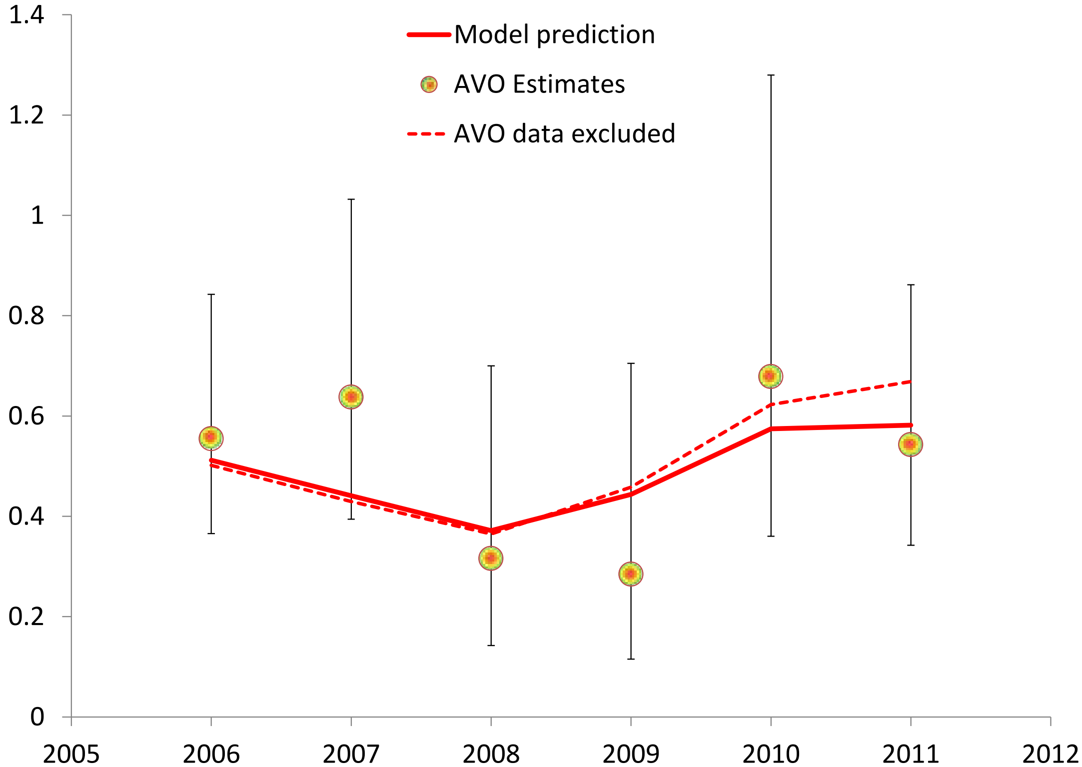

Figure 1.35. Model results of predicted EBS pollock biomass following the AVO index (with and without inclusion of the index. Error bars represent assumed 95% confidence bounds.

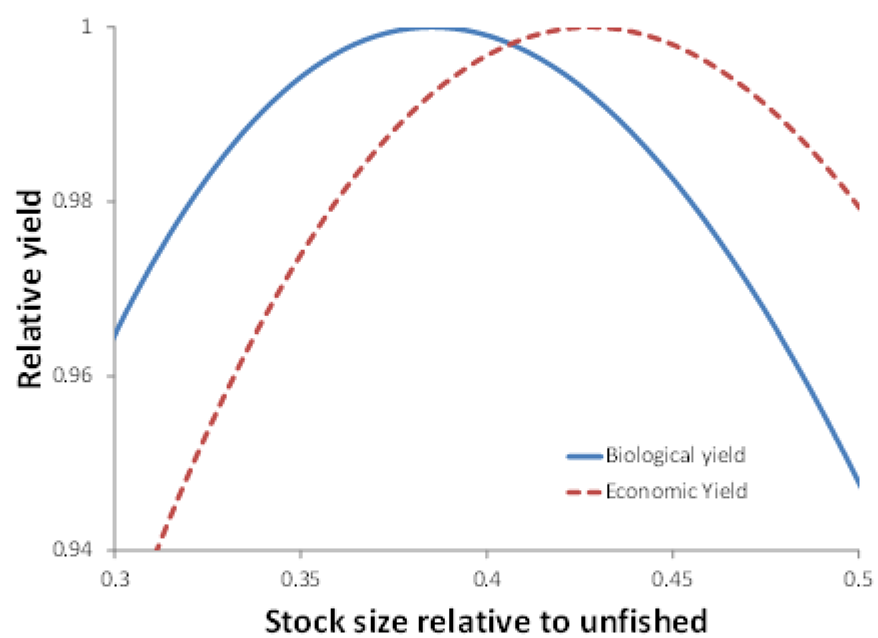

Figure 1.36. Population-level estimated yield curves normalized for biomass (solid line) and economic yield (dashed line). The economic curve uses age-specific with relationship between relative effort (distance) required for capture with a 60-40 weighting and an example age-specific value for ex-vessel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

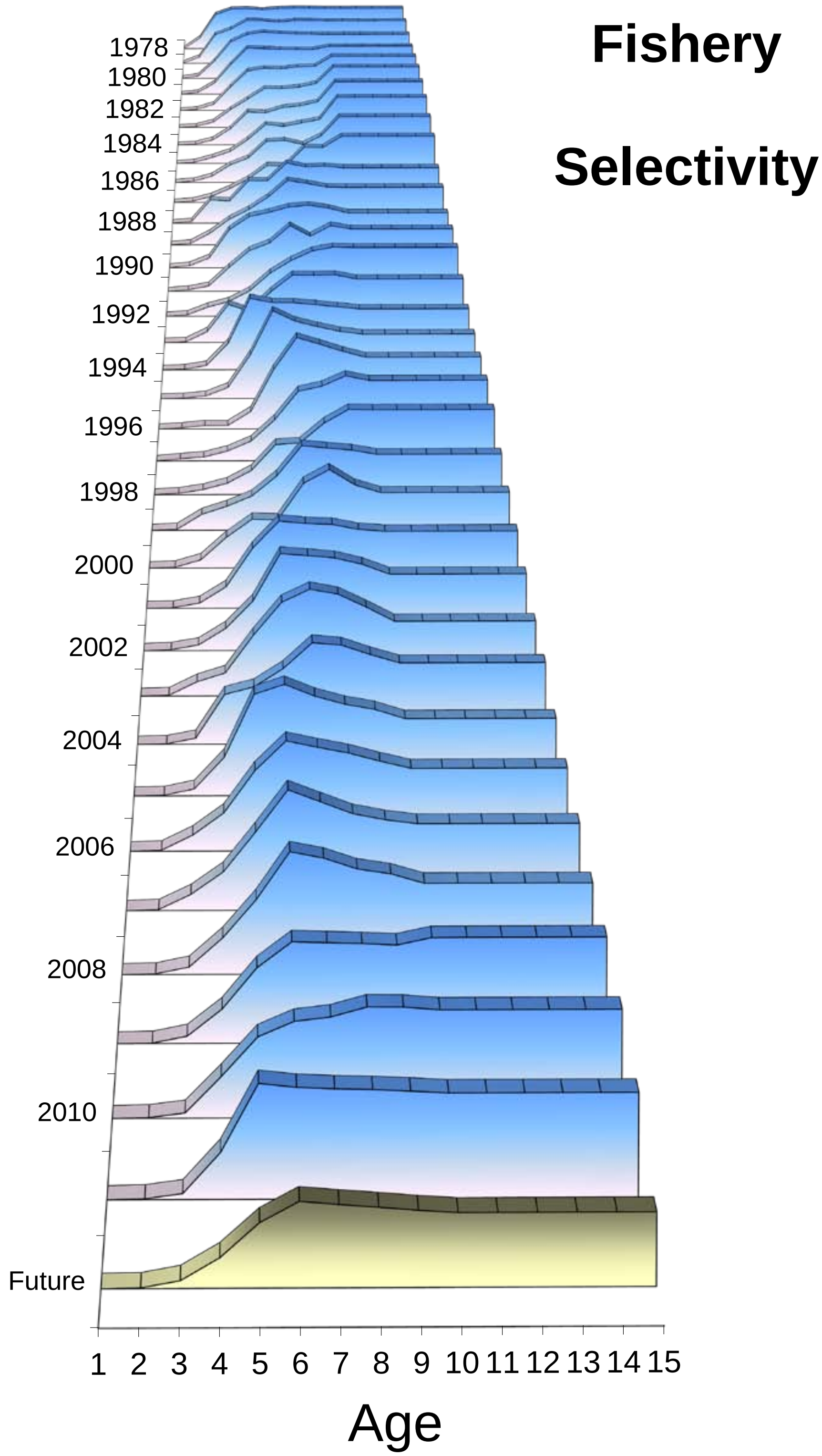

Figure 1. 37. Selectivity at age estimates for the EBS pollock fishery, 1978-2011 including the estimates (front-most panel) used for the future yield considerations.

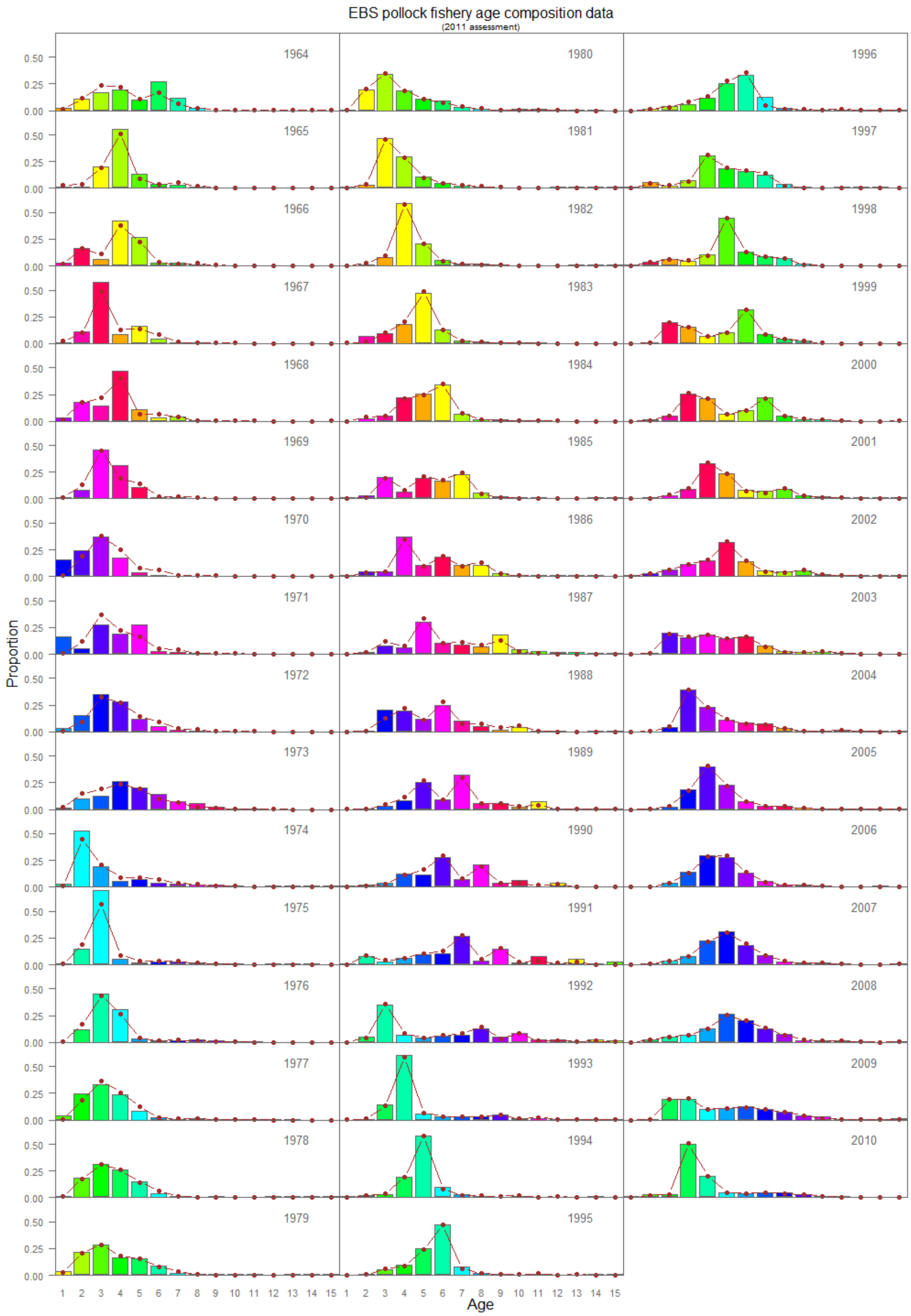

Figure 1.38. Model fit (dots) to the EBS pollock fishery proportion-at-age data (columns; 1964-2010). The 2010 data are new to this year's assessment. Colors coincide with cohorts progressing through time.

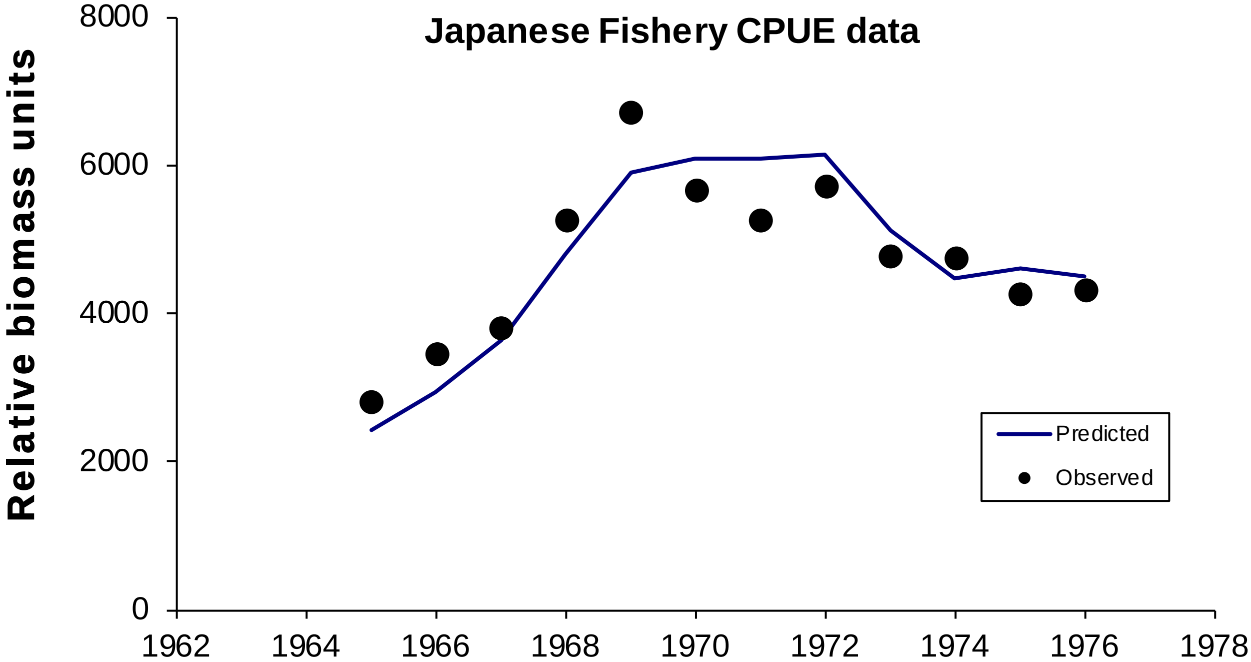

Figure 1.39. Japanese fishery CPUE (Low and Ikeda, 1980) model fits for EBS pollock, 1963-1976.

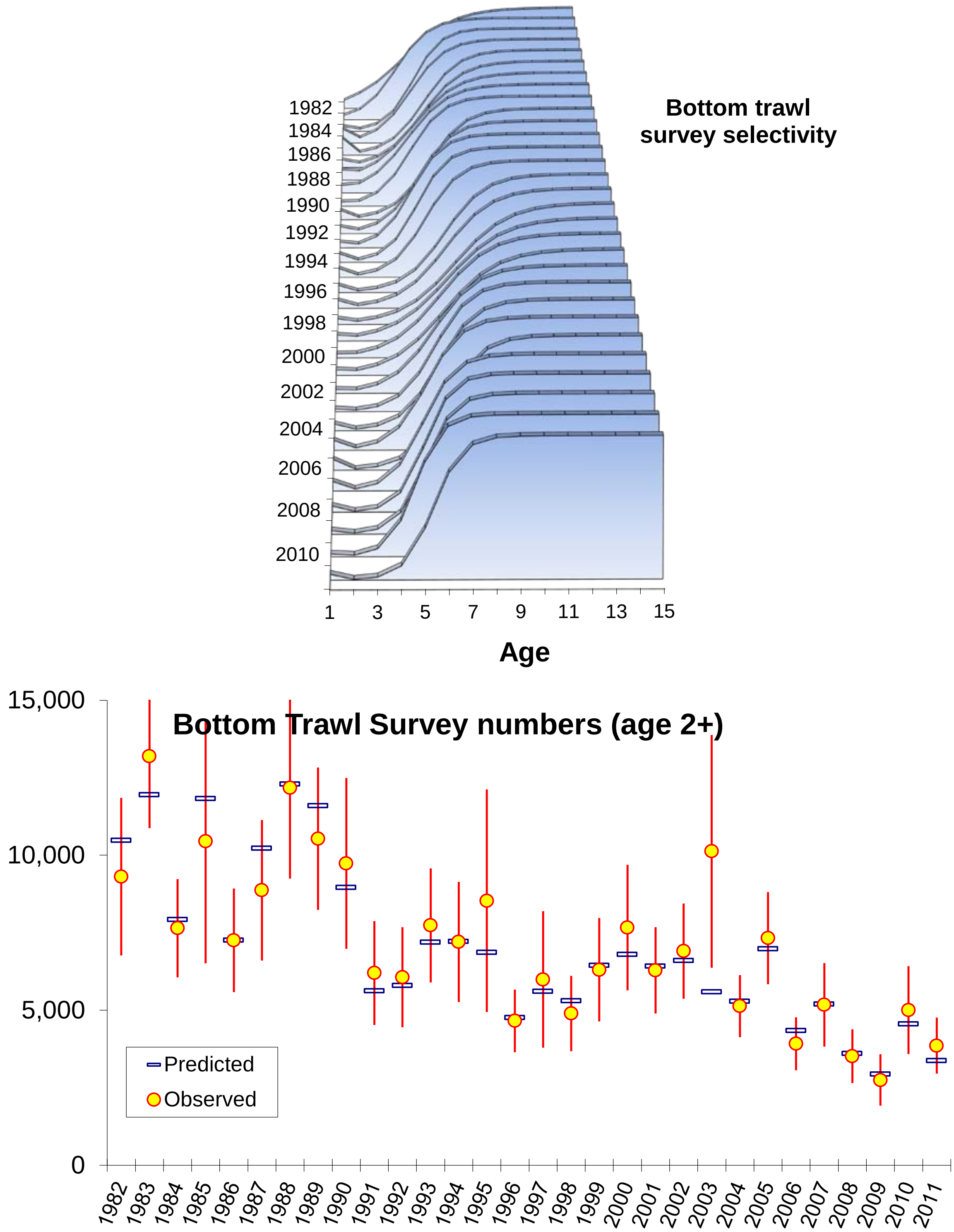

Figure 1.40. Estimates of bottom-trawl survey numbers (millions age 2 and older, lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2011.

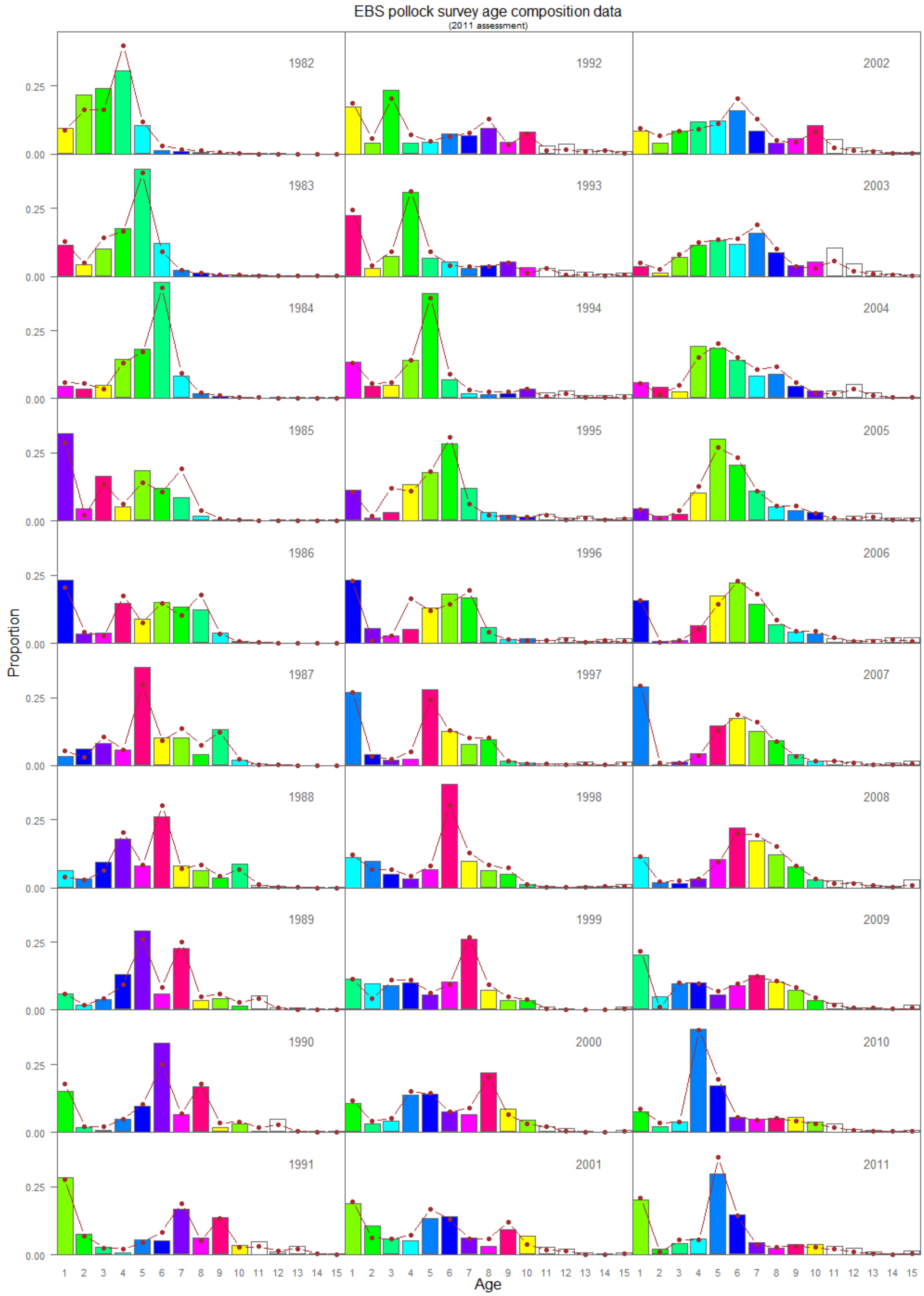

Figure 1.41. Model fit (dots) to the bottom trawl survey age composition data (columns) for EBS pollock. Colors correspond to cohorts over time. Data new to this assessment are from 2011.

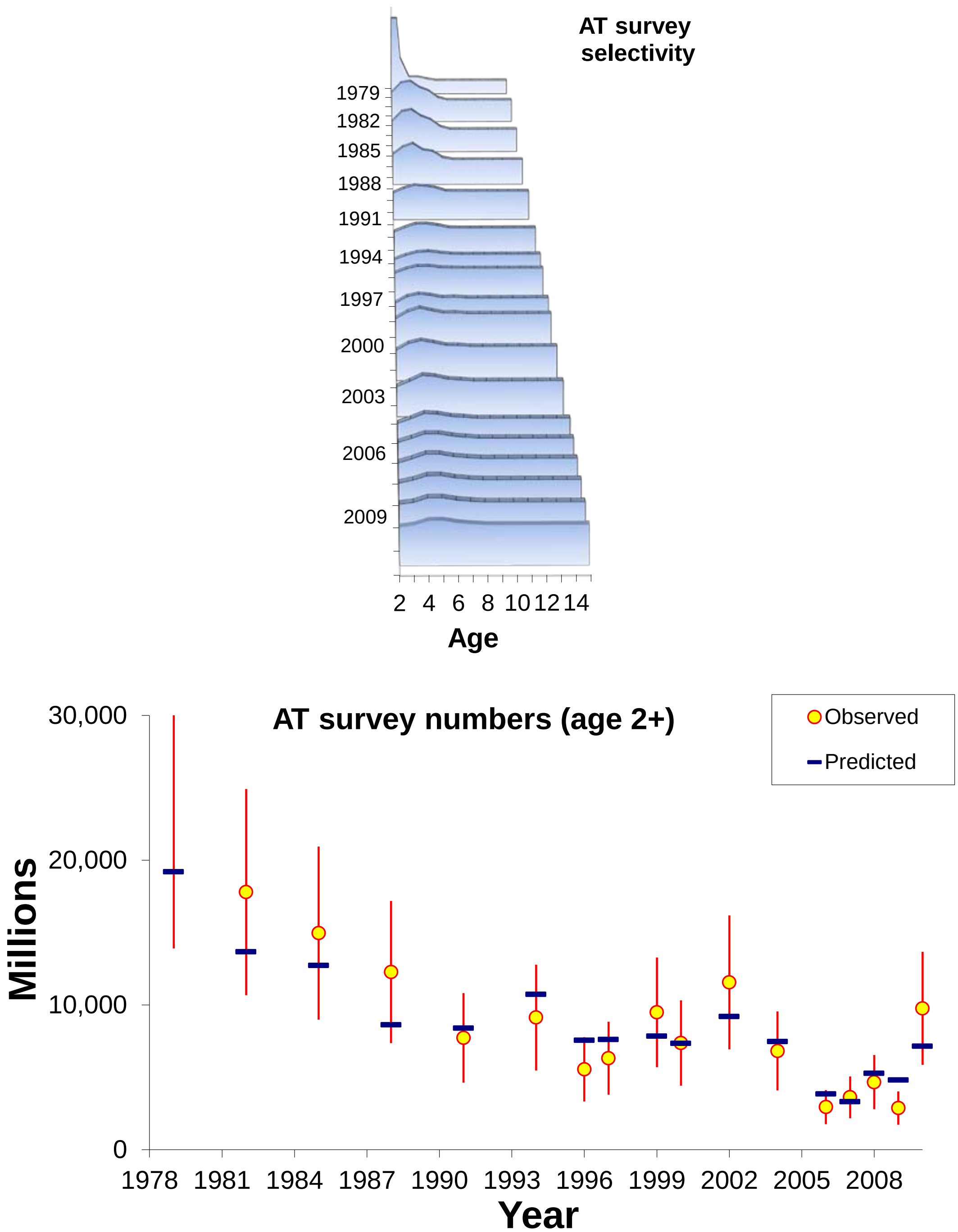

Figure 1.42. Estimates of AT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older, 1979-2010. Note that the 1979 observed value (=46,314) is off the scale of the figure.

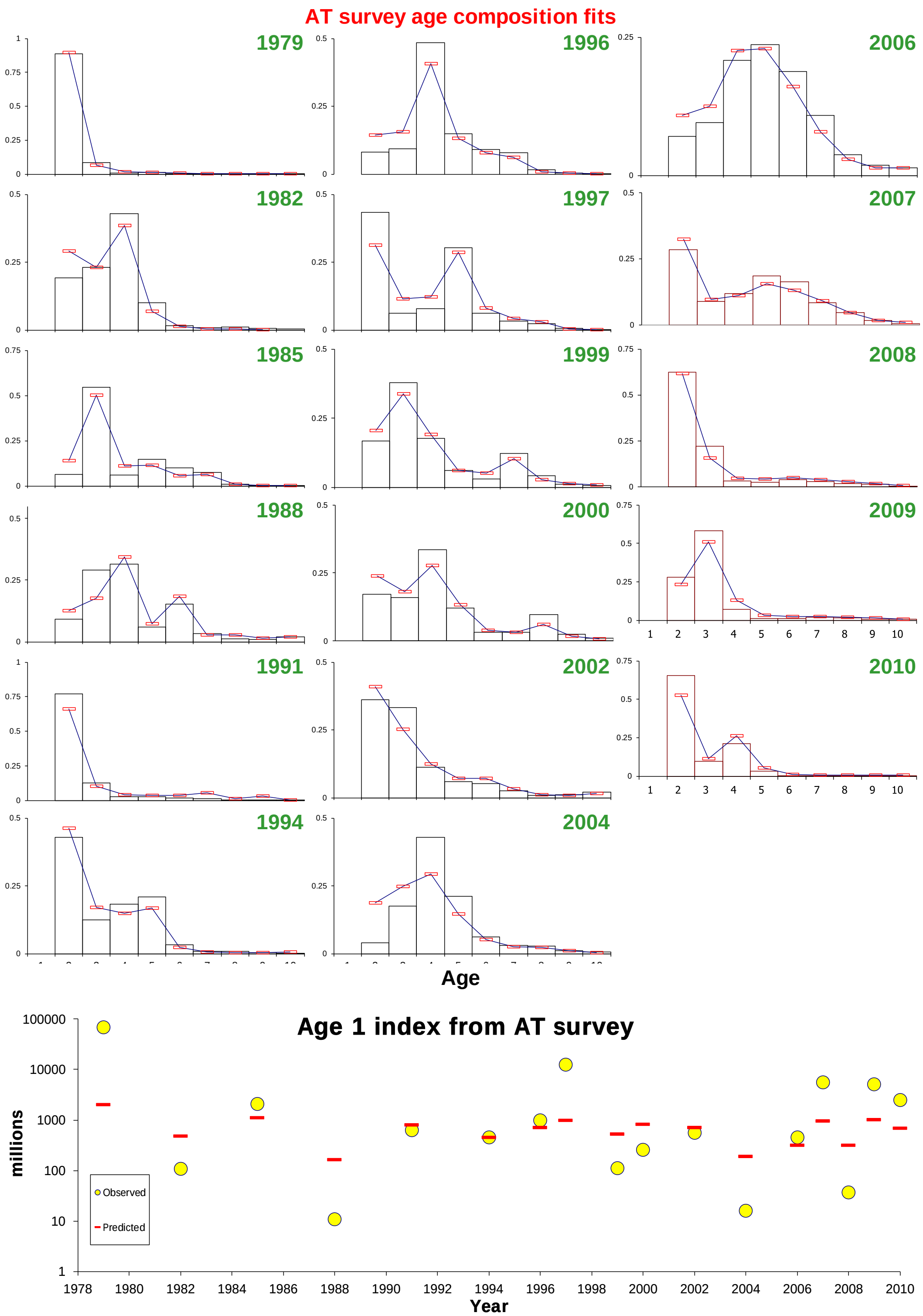

Figure 1.43. Fit to the AT survey EBS pollock age composition data (proportions) and age 1 index (bottom panel; log-scale). Lines represent model predictions while the vertical columns and dots represent data. The 2010 age composition data were based on revised values using AT age-length keys (previously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

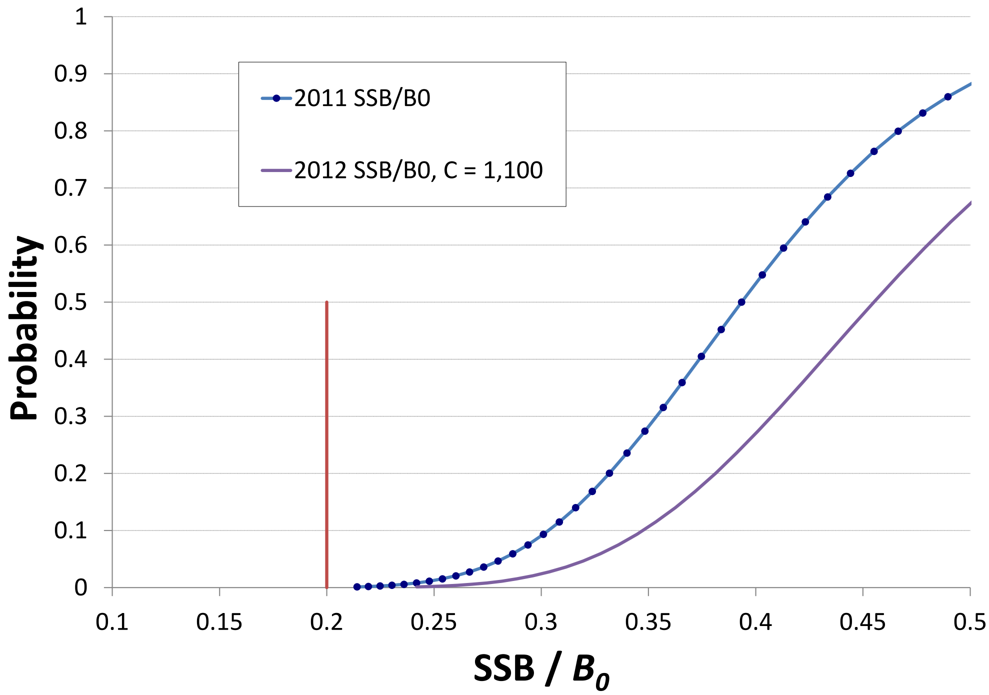

Figure 1.44. Cumulative probability estimates of 2011 and 2012 stock sizes relative to B_0 for EBS pollock assuming a catch of 1,100 kt. Note that these reflect the estimation uncertainty of stock status.

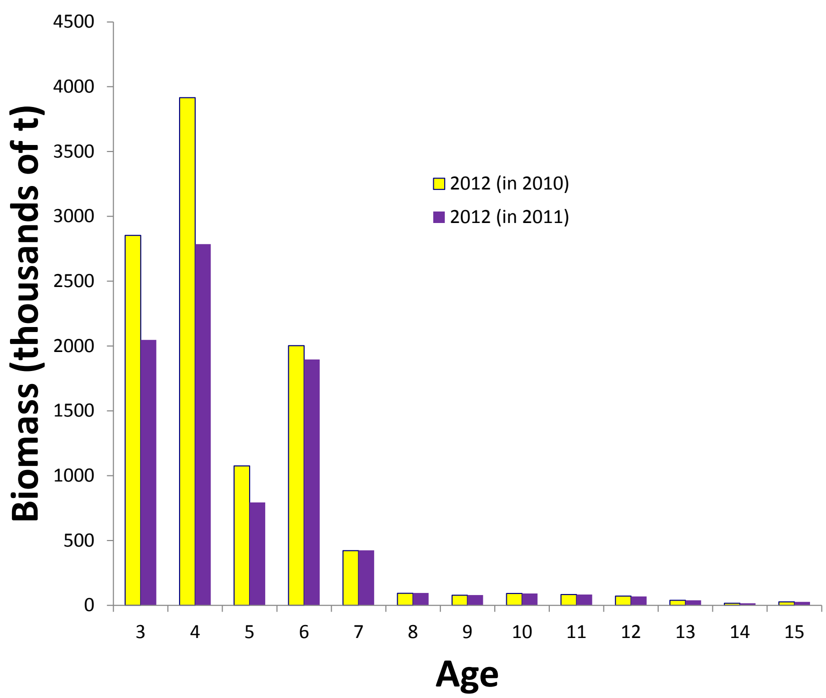

Figure 1.45. Projected begin-year EBS pollock model biomass at age as estimated for 2012 in the 2010 assessment and as estimated in the current model for ages 3-15.

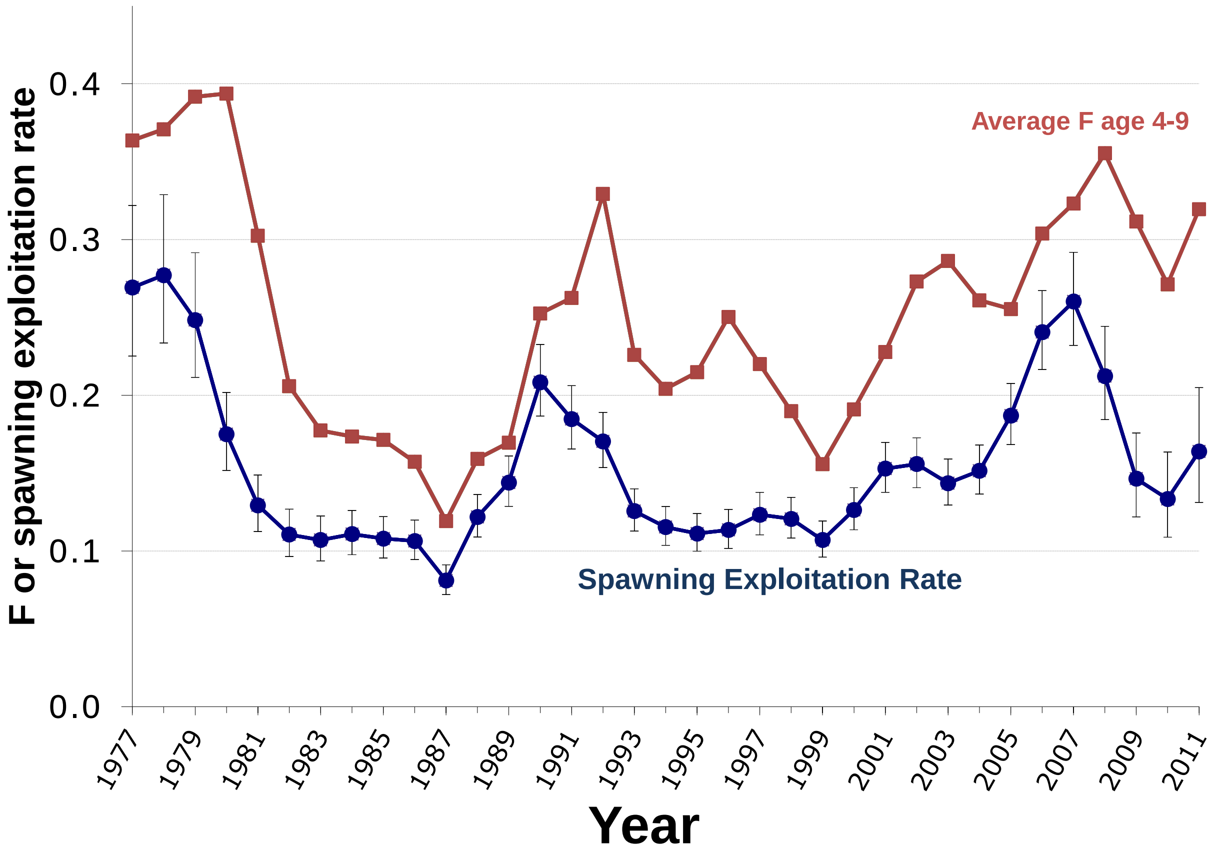

Figure 1.46. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) and average fishing mortality (ages 4-9) for EBS pollock, 1977-2011. Error bars represent two standard deviations from the estimates.

	Age													
Year	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).

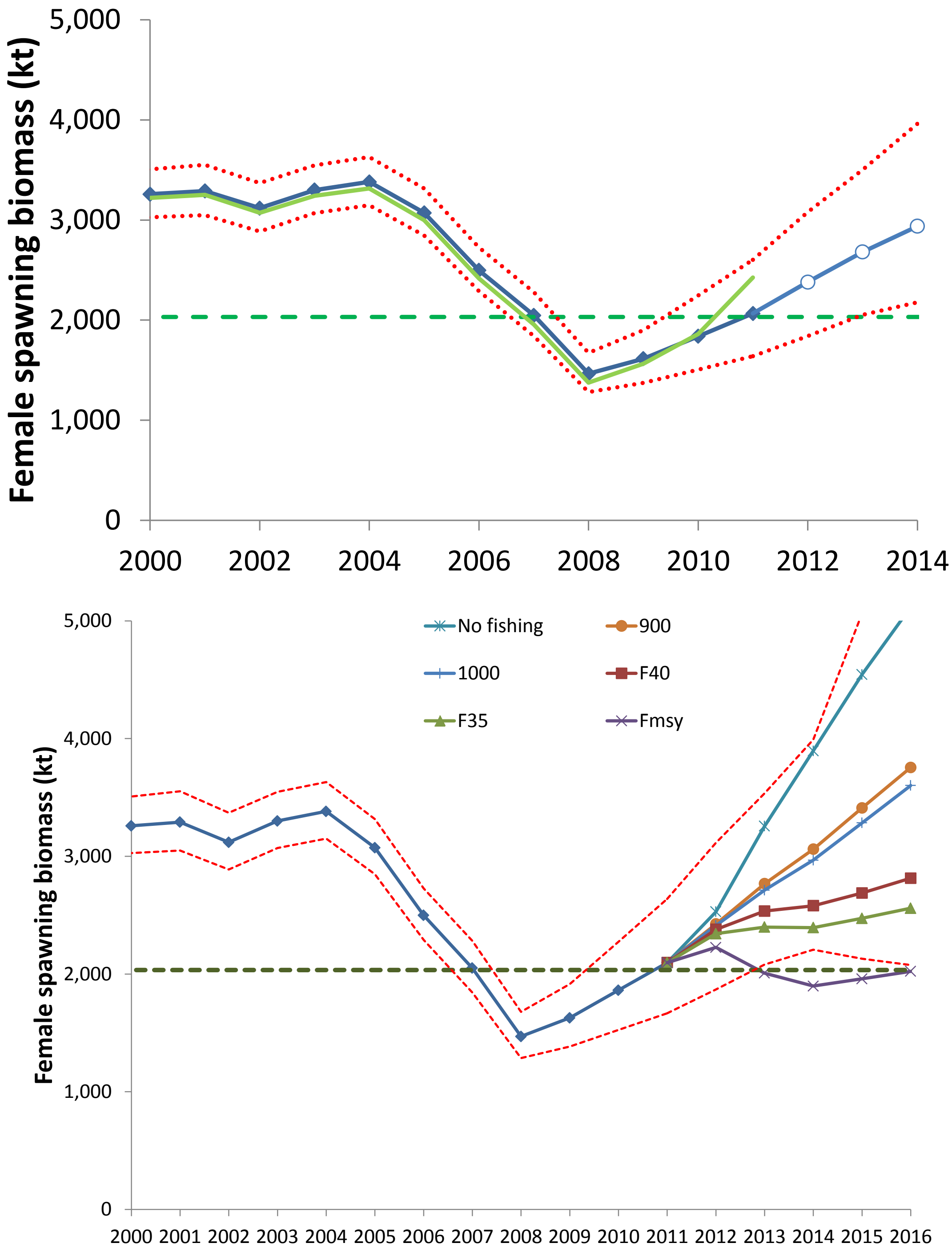

Figure 1.48. Estimated EBS pollock female spawning biomass and approximate 95% confidence intervals (filled area and dashed lines) comparing the current assessment with the past two (top) and examining near term projections under different variable and constant catch settings. Horizontal straight line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

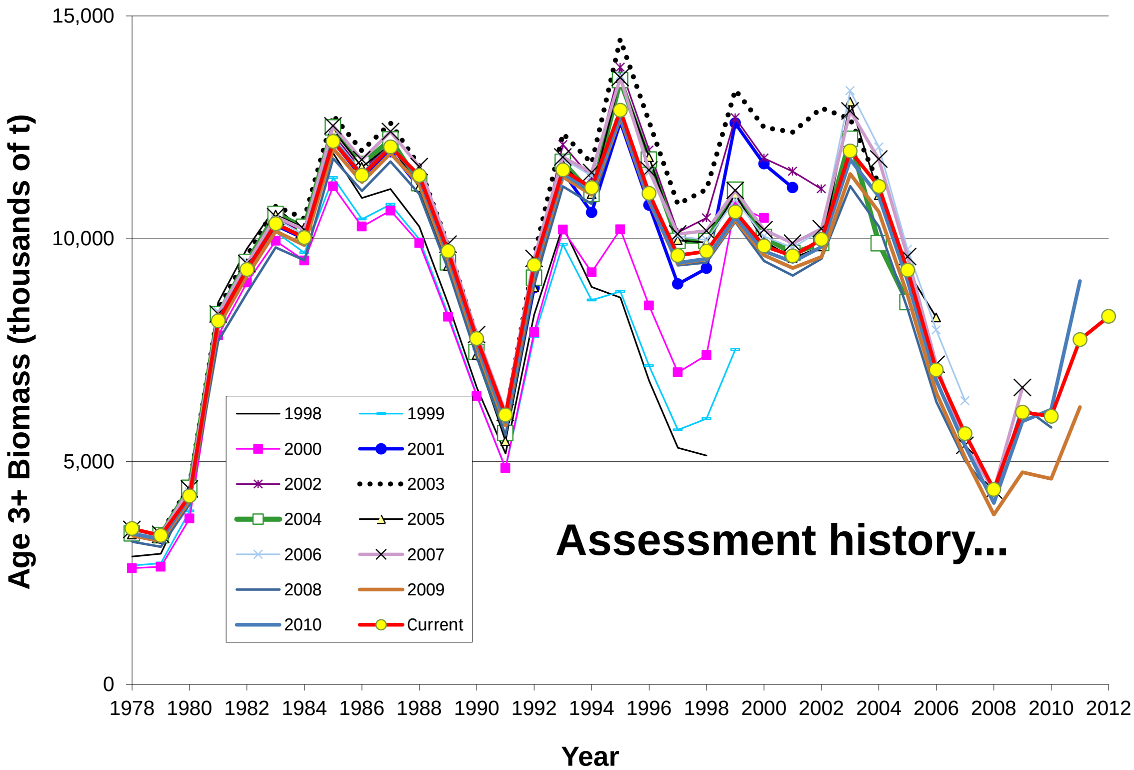

Figure 1.49. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2012.

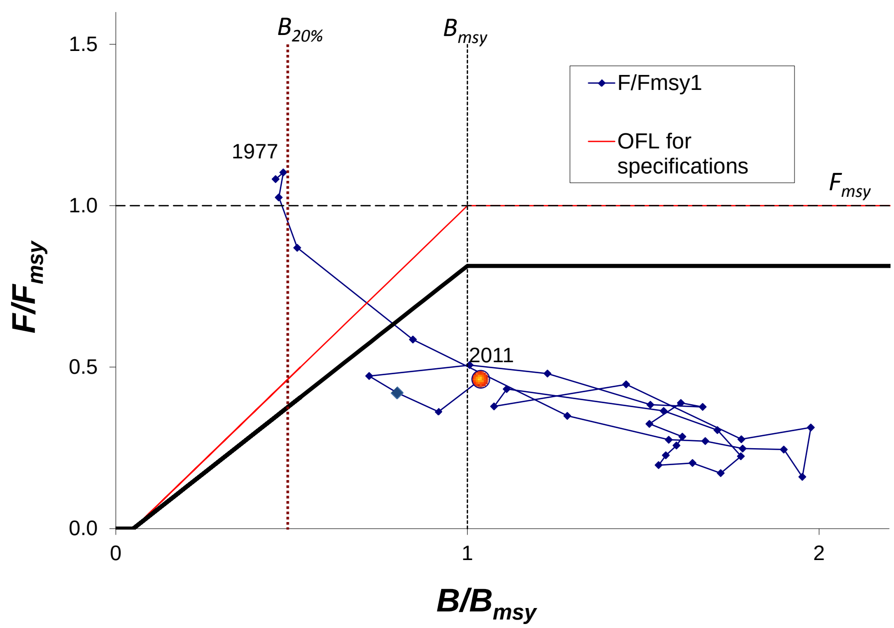

Figure 1.50. Estimated spawning biomass relative to annually estimated F_{MSY} values and fishing mortality rates for EBS pollock, 1977-2011. *Note that the control rules for OFL and ABC are designed for setting specifications in future years.*

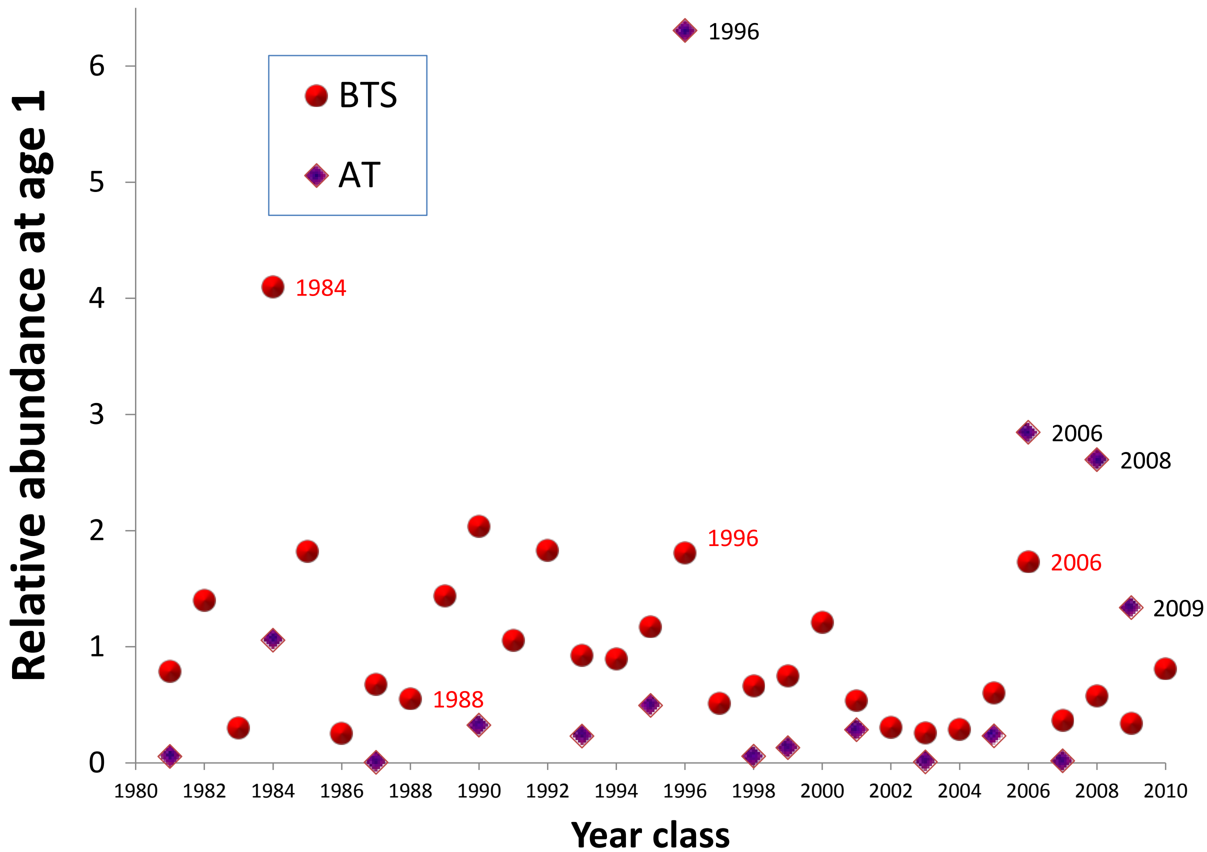

Figure 1.51. Time series of estimated age-1 abundance (relative numbers) for EBS pollock from the AT surveys, 1982-2011 (diamonds) and from the BTS surveys (bullets). Both survey indices have been rescaled to have a mean value of 1.0.

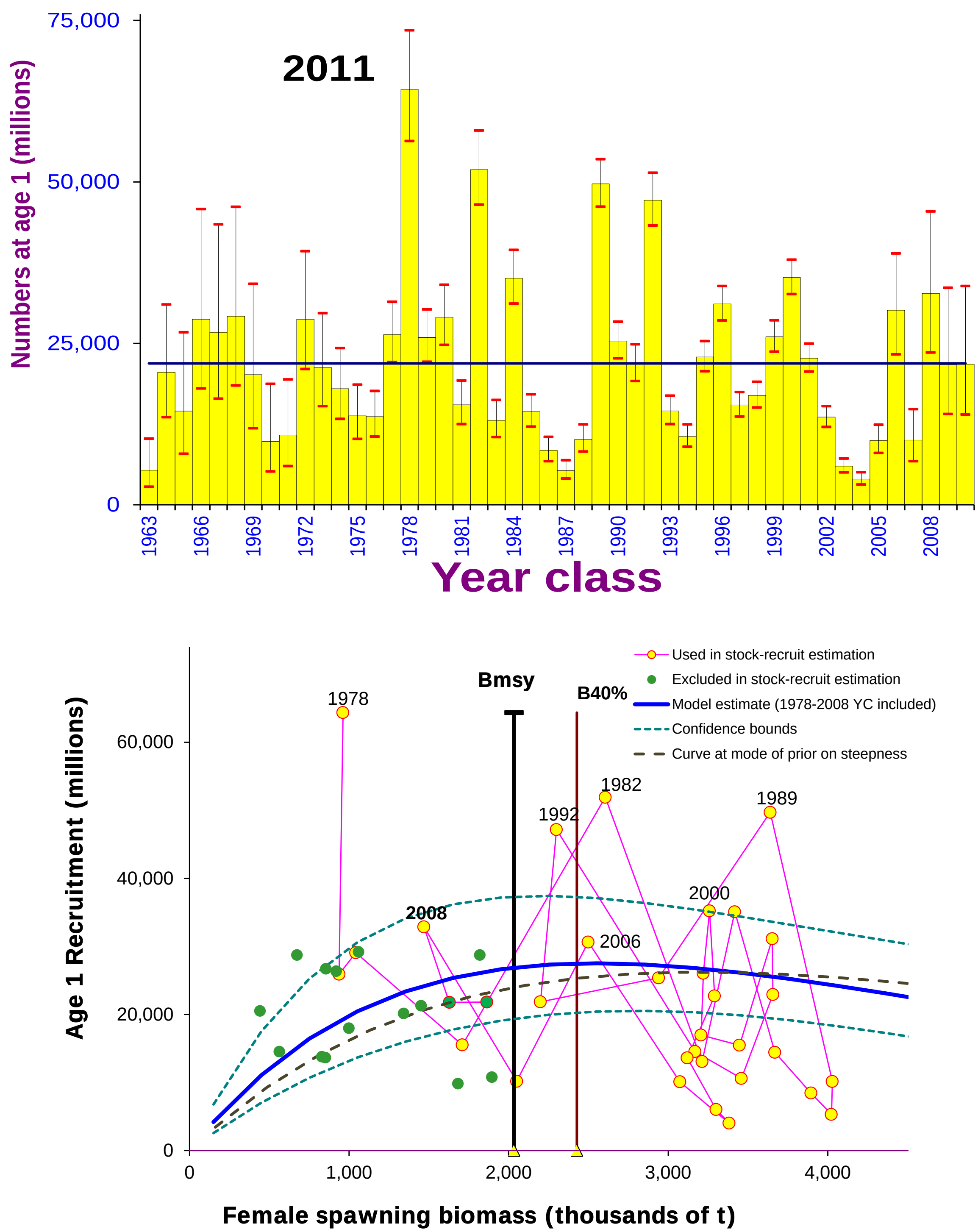

Figure 1.52. Year-class strengths by year (as age-1 recruits, upper panel) and relative to female spawning biomass (thousands of tons, lower panel) for EBS pollock. Labels on points correspond to year classes labels (measured as one-year olds). Solid line in upper panel represents the mean age-1 recruitment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

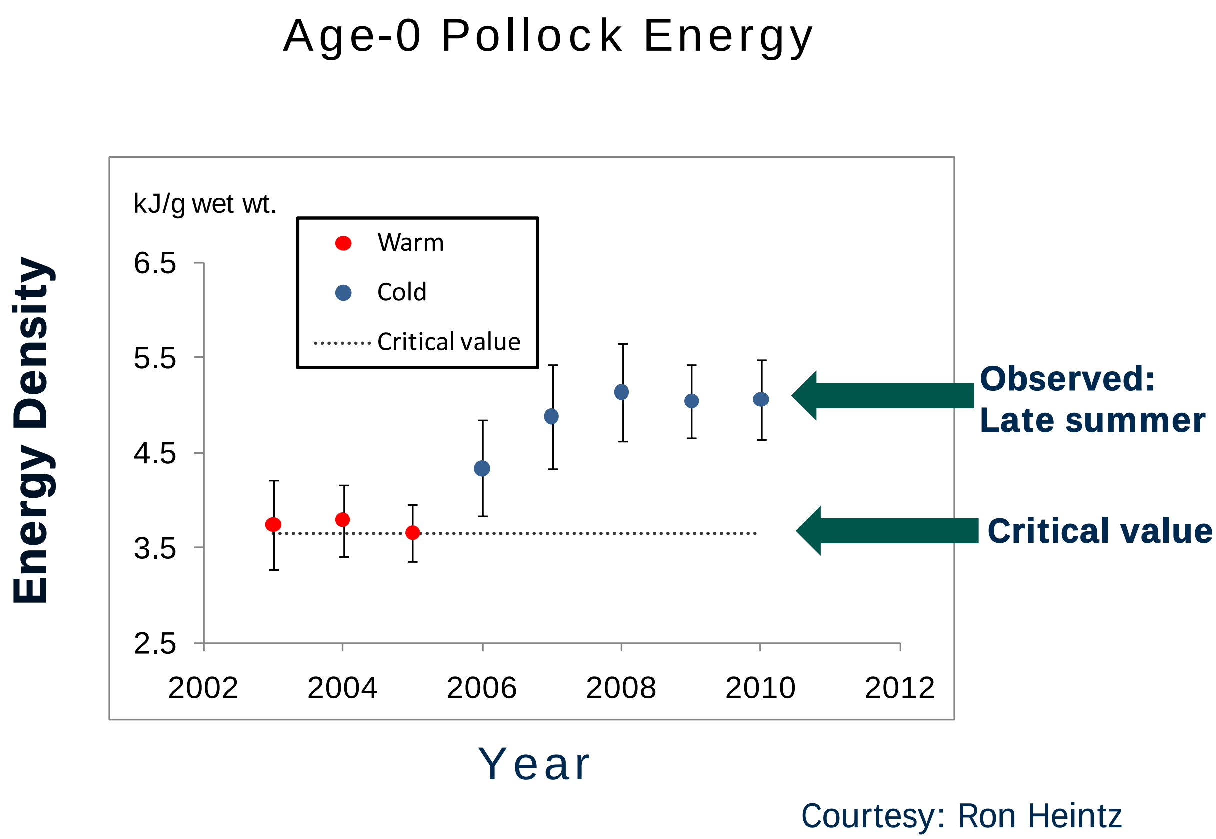

Figure 1.53. Mean and 95% confidence intervals of estimated age 0 pollock energy density (Kj/g wet weight) prior to their first winter (2003-2009). The dashed line is the expected amount of energy of the age 1 in the spring after they have lived through their first winter at sea.

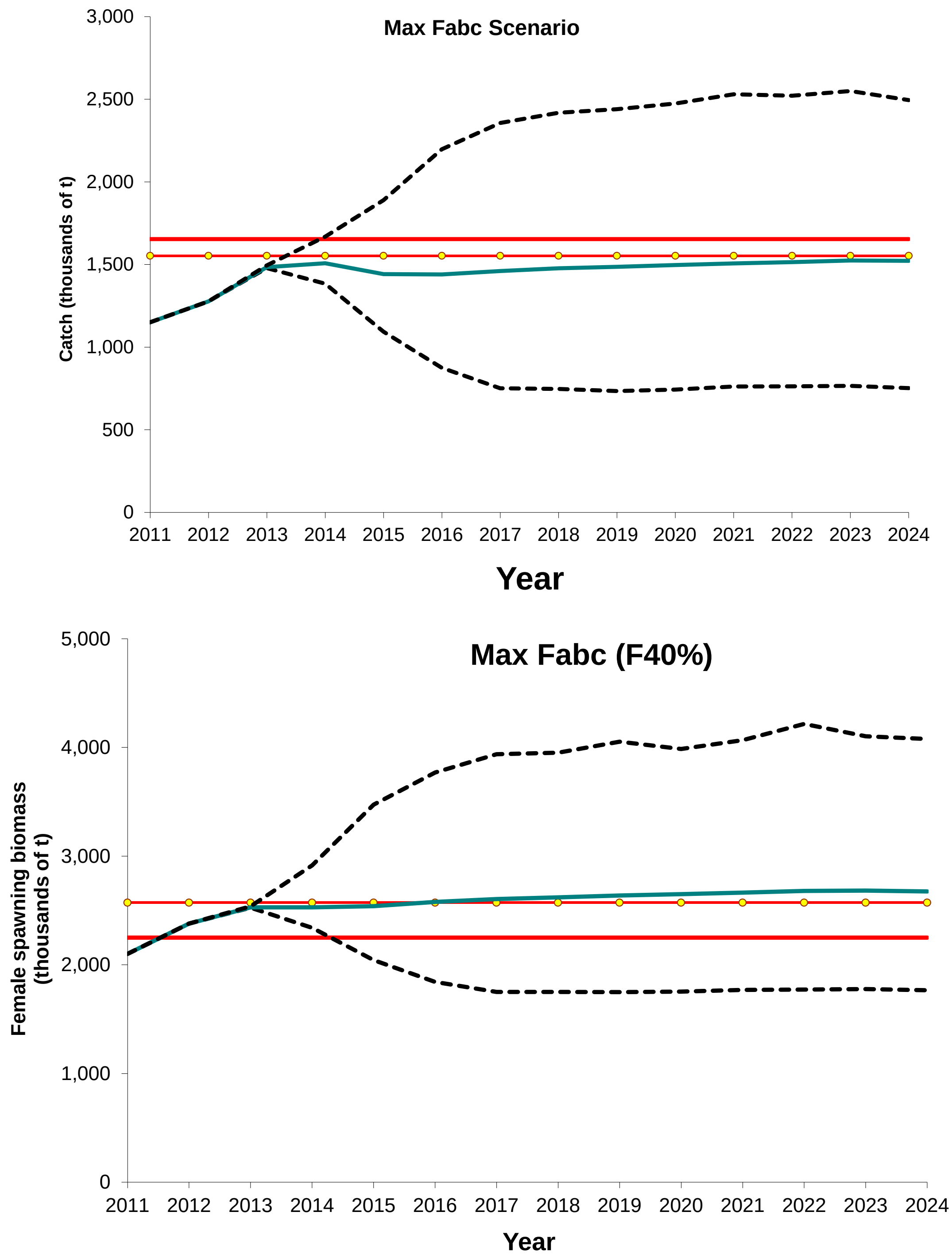

Figure 1.54. Projected EBS **Tier 3** pollock **yield** (top) and **female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2010. Future harvest rates follow the guidelines 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.*

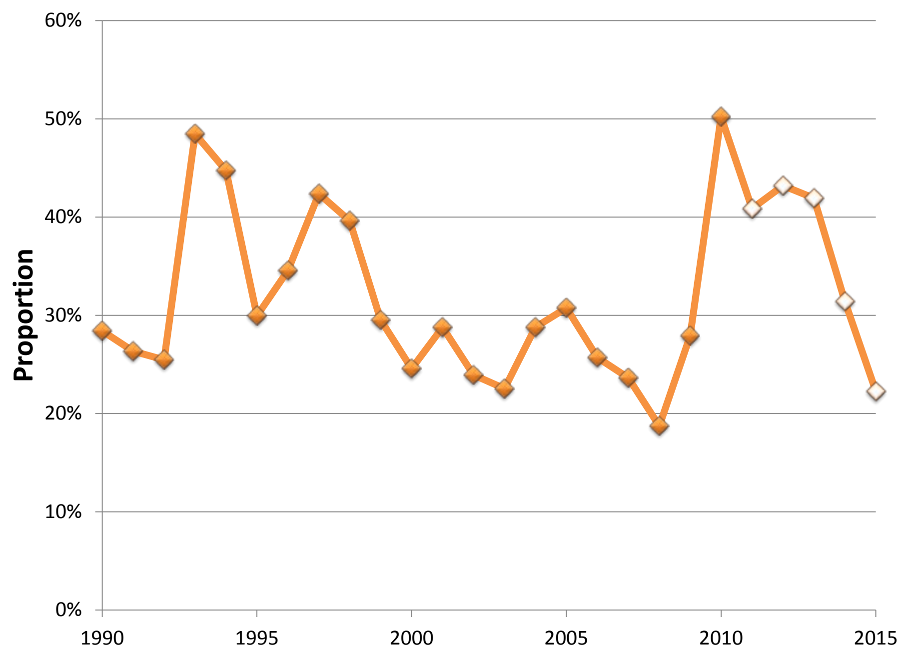

Figure 1.55. The proportion that a single year class contributes to the spawning biomass for EBS pollock, 1990-2015. Values for 2011-2015 are projected based on constant catch projections of 1.2 million t.

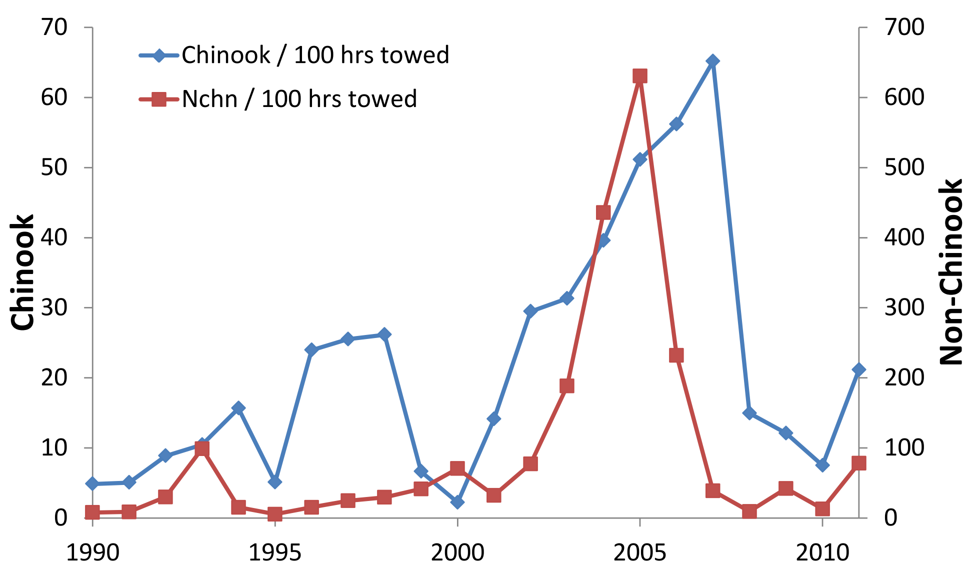

Figure 1.56. NMFS observer data on Chinook salmon (left axis) and non-Chinook (Nchn; right axis) per hundred hours of pollock trawl using 25 selected shore-based catcher vessels, 1990-2011.

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

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

where

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

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

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

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

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

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

Bottom-trawl survey selectivity was set to be asymptotic yet retain the properties desired for the characteristics of this gear. Namely, that the function should allow flexibility in selecting age 1 pollock over time. The functional form of this selectivity is:

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

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

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

where r_i^a is the residual of mean age and

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

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

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

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

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

where

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

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

ε_t is the “recruitment anomaly” for year *t,*

α, β are stock-recruitment function parameters.

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

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

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

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

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

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

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

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

Diagnostics

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

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

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

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

Parameter estimation

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

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

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

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

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

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

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

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

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

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} :

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

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

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

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

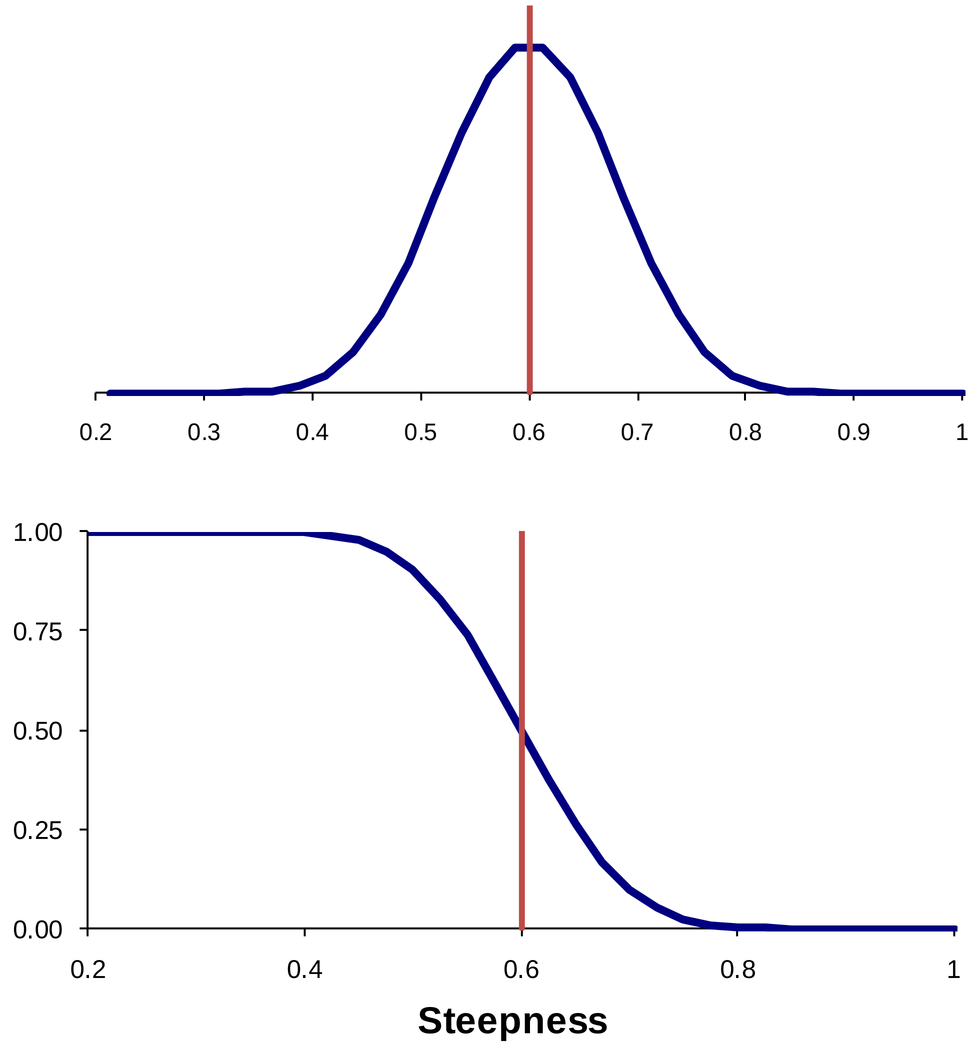

Figure 1.57. Cumulative prior probability distribution of steepness based on the beta distribution with α and β set to values which assume a mean and CV of 0.6 and 0.12, respectively. This prior distribution implies that there is about 8% chance that the value for steepness is greater than 0.7. See text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