1. Eastern Bering Sea Walleye Pollock

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Executive Summary

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

Changes in the input data

The 2007 NMFS summer bottom-trawl survey (BTS) abundance at age estimates were computed and included for this assessment. The NOAA ship R/V Oscar Dyson was diverted from planned survey research in the Gulf of Alaska this summer to add a mid-water echo-integration trawl (EIT) survey for the EBS. This was the first complete survey conducted by this vessel in this region. Age composition estimates were derived from the population-at-length estimates using the 2007 BTS age-length key. The 2006 age composition estimates were updated using EIT age data (last year the BTS age-length key was used). The EIT survey also extended into the Russian zone and covered part of the Navarin Basin.

The BTS biomass estimate was 4.3 million t, up by 42% from the 2006 estimate of 3.0 million t but still only 87% of the long-term mean of the bottom-trawl survey since 1982. The 2007 EIT survey biomass estimate was 1.88 million t, up slightly from last year's survey but only 55% of the long-term mean for this survey (since 1979). Both surveys indicate that the 2006 year class is strong and that the 2005 year-class is now apparently below average.

Observer data for age and size composition and average weight-at-age were evaluated for the 2006 fishery and were included in the analyses. The mean weights-at-age assumed in last year's assessment (for ABC and the 2006 fishery) were significantly higher than the new data indicate. The catch-at-age data were reanalyzed for uncertainty using a bootstrap two-stage sampling approach for 1991-2006. This includes an evaluation in fishery mean body weight-at-age. Results from these analyses are presented in Attachment A1. The total pollock catch for 2006 was estimated from the NMFS Alaska Region data and the value for 2007 catch was assumed to be 1,340,000 t.

Changes in the assessment model

The assessment model was modified to evaluate a broader range of options. The more significant of these changes are as follows: 1) an age-length transition matrix was estimated so that the current-year fishery length frequency data can be used; 2) the ability to split the age-1 values from the rest of the age compositions for the EIT survey was added so that the interaction between age-1 variability and other age groups was reduced; 3) total age 2 and older numbers-at-age from the surveys were used to tune the model (previously 1-year olds were included); and 4) The Tier 1 ABC estimation method now uses "fishable" biomass defined as the biomass of pollock available to the fishery as modified by the selectivity-at-age estimates; previously age 3+ biomass had been used.

Changes in the assessment results

As was projected in last year's assessment, the stock is estimated to be below the B_{msy} level beginning in 2007 and into 2008. Under FMP amendment 56, this invokes a proportional adjustment to the harvest rate. Since the available data indicate the spawning biomass for 2008 is projected to be lower than expected in last year's assessment, the adjustment to the harvest rate drops from about 84% to about 72%. Combined with other factors (e.g., a lower than expected mean weight-at-age observed in the 2006 fishery, a poorer showing of the 2005 year class in this year's surveys) this results in an ABC that is about 13% lower than projected from last year's assessment for 2008. The maximum permissible ABC based

on the Tier 1b harmonic mean F_{msy} is 1,170 thousand t for 2008. The corresponding overfishing level (OFL) is estimated 1,443 thousand t. The 2009 projection indicates that although the stock appears to show positive signs of recruitment, the impact of 4-5 successively below-average year-classes in the spawning component of the stock results in a 2009 Tier 1b ABC value to 976 thousand t. To return spawning biomass exploitation rates to pre 2006 levels and to reduce the projected variability, an ABC of 1.0 million t is recommended for 2008. Alternatively, a value of 1,020 thousand t is projected to be equal to the 1990 exploitation rate (the highest rate observed since 1978).

Response to SSC and Plan Team comments

The following SSC comments were provided in its December 2006 minutes along with responses relevant to this assessment.

From Juvenile weight-at-age: The SSC appreciates the effort to examine juvenile weight-at-age in the BASIS surveys and looks forward to seeing the results. In addition, the SSC would like to know if weight of age 1 fish in previous surveys could yield information of value to address ecosystem concerns.

The BASIS program continues to evaluate biological patterns in fish relative to environmental conditions. To date, there are limited data from this survey available. However, patterns in mean weights at age for juveniles in fishery and survey data are presented and discussed below. There appears to be some pattern in growth rates by years, and for survey data, part of the trend could be explained by the average date of survey operation.

Non-pollock backscatter: The SSC found this information intriguing and would like further evaluation of the composition of the backscatter. Could it be age – 0 pollock to any degree? Is there the possibility of using higher-frequency acoustics to measure zooplankton biomass?

Age 0 pollock probably form part of the 38-kHz non-pollock backscatter although their contribution relative to that of other scatterers (abiotic and biotic) is unknown. (see Fig. 1.46 and text below). The primary trawl sampling gear used to identify echosign during the EIT surveys is assumed to provide representative samples of larger fishes (e.g., age 1+-sized pollock). Without the use of other specialized sampling gear (and additional vessel time) the information needed to identify components of this non-pollock backscatter is unavailable. However, the species composition of this backscatter may be diverse and likely varies in time and space. Additionally, estimates of target strength for the species that comprise this backscatter may also be unknown. This lack of information means extra caution is needed to interpret the significance of the raw non-pollock unscaled acoustic backscatter data presented in Figure 1.46 relative to zooplankton biomass. MACE Program scientists are currently evaluating the use of multi-frequency acoustics and have had some success identifying euphausiid aggregations using the 38- and 120-kHz backscatter data.

Russian catches: The SSC appreciates the efforts to formally include Russian catches in the pollock model and to contact Russian scientists for information. The SSC encourages ongoing efforts to examine age composition, recognizing that standardization of ageing is still an issue.

The ability to explicitly evaluate Russian fishery impacts by modifying how survey catchabilities are treated was added this year. While this fails to address the issue of Russian fishery age compositions and removals directly, coupled with the EIT surveys that extended into the Russian zone this year, helps to more explicitly account for components of EBS pollock that move into the Russian zone.

Weight-length relationships: The SSC encourages the authors to see if weight-length relationships change from year to year in parallel with plankton abundance or other components of the ecosystem.

An evaluation of within-year changes in mean weights given length is presented, along with detailed patterns of fishery stratum-specific mean weights-at-age. Results suggest that the 2006 value of mean weight at age is substantially lower than the mean, consistent with other observations that the productivity of the environment was lower.

Arrowtooth flounder predation: The SSC encourages the authors to explore the sensitivity of the stock assessment model to this predation. This could be done in a variety of ways: (1) using time-varying M or (2) making M a function of arrowtooth flounder abundance or consumption of pollock by examining Jurado-Molina's multi-species VPA model.

Advances on developing the statistical multi-species model continue. In the past year a technical workshop was held where methods for parameterizations and treatment of stomach content data were presented and a number of improvements suggested. Additionally, a University of Washington post-doc was hired to assist in exploring patterns of EBS arrowtooth flounder bio-energetics and foraging patterns.

Introduction

Walleye pollock (*Theragra chalcogramma*) 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 (head and gutted), and surimi. An important component of the commercial production is the sale of roe from pre-spawning pollock. Pollock are considered a relatively fast growing and short-lived species and currently represents a major biological component of 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. 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. There is some indication (based on contiguous surveys) that the fishery 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 and Canino, 2004; Canino et al. 2005).

Fishery

From 1954 to 1963, pollock were harvested at low levels in the Eastern Bering Sea and 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 a peak catch of 1.9 million t in 1972, catches were reduced through bilateral agreements with Japan and the USSR.

Since the advent of the U.S. EEZ in 1977 the annual average Eastern Bering Sea pollock catch has been 1.2 million t and has ranged from 0.9 million t in 1987 to nearly 1.5 million t in recent years (Fig. 1.1). Stock biomass has apparently ranged from a low of 4-5 million t to highs of 10-12 million t. United States vessels began fishing for pollock in 1980 and by 1987 they were able to take 99% of the quota. Since 1988, only U.S. vessels have been operating in this fishery. By 1991, the current NMFS observer program for north Pacific groundfish-fisheries was in place.

Foreign vessels began fishing in the mid-1980s in the international zone of the Bering Sea (commonly referred to as the "Donut Hole"). 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, but large scale fisheries did not occur until the mid-1980s. In 1984, the Donut Hole catch was only 181 thousand t (Fig. 1.1, Table 1.1). The catch grew rapidly and by 1987 the high seas catch exceeded the pollock catch 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 data for 1992 and 1993 indicate very low catches (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. During 2002-2005 the EBS region pollock catch has averaged 1.463 million tons while for the period 1982-2000, the average was 1.15 million tons. The

effect of this level of fishing continues to be closely monitored by resource assessment surveys and an extensive fishery observer program.

Fishery characteristics

Pre-spawning aggregations of pollock are the focus of the 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 season presently opens on June 1st 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" (January – March) pollock fishery on the Eastern Bering Sea (EBS) shelf has been concentrated primarily north and west of Unimak Island (Ianelli *et al.* 1998). 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 has been fairly similar during the period 2006 - 2007 (Fig. 1.2), especially compared to the 2005 winter fishery which was distributed farther north. The catch estimates by sex for the A-season compared to estimates for the entire season indicate that over time, the number of males and females has been fairly equal (Fig. 1.3). The length frequency information from the fishery shows that the size of pollock caught are generally larger than 40 cm with some smaller fish caught during years when a strong year class appeared (Fig. 1.4).

In 2006 and 2007 the summer fishing has concentrated more in the NW region (Fig. 1.5). Coupled with higher fuel prices, this was a concern for shore-based vessels that had much longer distances to travel to the prime fishing grounds. While both these years exhibited colder-than-usual bottom temperatures (see discussion of bottom trawl survey results below), it is unclear that these conditions are the major cause of this apparent shift in fish distribution. For contrast, historical foreign-reported data were recovered and evaluated to see if the shift in distribution was a unique event. In fact, prior to 1986, in about half of the years the majority of the summer fish were taken to the west of 170°W (the NW zone of the EBS). Since 1991, the summer pollock catches have been much more concentrated in the SE (east of 170°W) zone (Fig. 1.6).

The length frequency information from the fishery reveals a marked progression of the large 1989 year class growing over time and the appearance of the 1992 year class in 1996-97, the 1996 year class in 1998-2001, and subsequently the 2000 year class (Fig. 1.7). The 2003 fishery data show an unusually high mode of fish at around 40cm that advanced to 45 cm by 2004 and reached about 48 cm in 2005.

Barbeaux et al. (2005b) presented some results on the development of small-scale spatial patterns of 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. Analyses of this type will continue to improve understanding on the dynamics of the pollock fishery and biological responses.

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 with Steller sea lions. For the pollock fisheries, comparisons of seasonal fishery catch and pollock biomass distributions (from surveys) by area in the Eastern Bering Sea led to the conclusion that the pollock fishery may have had disproportionately high seasonal harvest rates within 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 seasonal and spatially explicit exploitation rates should

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, a total of 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, a total of 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 to the industry.

On the Eastern Bering Sea 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 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:

Year	Months	Catch outside SCA	Catch Total	Percent catch inside SCA
1998	Jan-Jun	71	385	82%
	Jul-Dec	248	403	38%
	Jan-Dec	318	788	60%
1999	Jan-Jun	155	339	54%
	Jul-Dec	360	468	23%
	Jan-Dec	515	807	36%
2000	Jan-Jun	241	375	36%
	Jul-Dec	550	572	4%
	Jan-Dec	791	947	16%
2001	Jan-Jun	357	490	27%
	Jul-Dec	367	674	46%
	Jan-Dec	724	1,164	38%
2002	Jan-Jun	263	566	54%
	Jul-Dec	350	690	49%
	Jan-Dec	613	1,256	51%
2003	Jan-Jun	336	616	45%
	Jul-Dec	397	680	42%
	Jan-Dec	733	1,296	43%
2004	Jan-Jun	293	531	45%
	Jul-Dec	472	711	34%
	Jan-Dec	765	1,242	38%
2005	Jan-Jun	293	529	45%
	Jul-Dec	558	673	17%
	Jan-Dec	851	1,203	29%
2006	Jan-Jun	262	533	51%
	Jul-Dec	656	764	14%
	Jan-Dec	917	1,298	29%
2007	Jan-Jun	209	481	57%
	Jul-Dec	540	600	10%
	Jan-Dec	749	1,081	31%

Note: Pollock catches (thousands of tons) are as reported by at-sea observers only, 2007 data are preliminary.

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

The fishery in recent years has undertaken measures to reduce bycatch of salmon. Recent bycatch levels for Chinook and chum salmon have been very high due in part to large runs of salmon and in part to restrictions on areas where pollock fishing may occur. Bycatch levels for chum salmon in 2005 were the highest on record but declined substantially in 2006 and remain low in 2007 to date. Bycatch for Chinook salmon, however, remains at high levels with bycatch to date in 2007 the highest on record. Given information indicating that large scale regulatory closures were potentially exacerbating the bycatch of these species, the Council acted and developed an extensive analysis leading to amendment 84 of the FMP to a regulatory exemption for vessels participating in a voluntary rolling hot spot (VRHS) closure system. This system is thought to be more responsive and dynamic to changing conditions in the fishery compared to static area closures. Additional salmon bycatch management measures including new regulatory closures and caps on the pollock fishery are currently under consideration by the Council.

Catch data

Since 2001, the total allowable catch (TAC) for EBS pollock has been at record levels over 1.39 million t. This is roughly 22% above the average levels of catch from 1977-2004 (1.15 million t; Table 1.2).

Significant quantities of pollock are discarded and must be taken into account in estimation of population size and forecasts of yield. Observer length frequency observations indicated that discards include both large and small pollock. Since observers usually sample the catch prior to discarding, the size distribution of pollock sampled closely reflects that of the actual *total* catch. Discard data as compiled by the NMFS Alaska Regional Office have been included in estimates of total catch since 1990.

Pollock catch in the Eastern Bering Sea and Aleutian Islands by area from observer estimates of retained and discarded catch for 1991-2007 are shown in Table 1.3. 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 1%. These low values reflect the implementation of the Council's Improved Utilization and Improved Retention program. Discard levels are likely affected by the age-structure and relative abundance of the available population. For example, if the most abundant year class in the population is below marketable size, these smaller fish may be caught incidentally. With the implementation of the AFA in 1999, the fleets have more time to pursue the sizes of fish they desire since they are guaranteed a fraction of the quota. In addition, several vessels have made gear modifications to avoid retention of smaller pollock. In all cases, the magnitude of discards is accounted for within the population assessment and for management (to ensure the TAC is not exceeded). Presentation of bycatch of other non-target, target and prohibited species is presented in the section titled "Ecosystem Considerations" below.

The catch-at-age composition was estimated using the methods described by Kimura (1989) and modified by Dorn (1992). Briefly, length-stratified age data are used to construct age-length keys for each stratum and sex. These keys are then applied to randomly sampled catch length frequency data. The stratum-specific age composition estimates are then weighted by the catch within each stratum to arrive at an overall age composition for each year. Data were collected through shore-side sampling and at-sea observers. The three strata for the EBS were: *i*) January–June (all areas, but mainly east of 170°W); *ii*) INPFC area 51 (east of 170°W) from July–December; and *iii*) INPFC area 52 (west of 170°W) from July–December . This method was used to derive the age compositions from 1991-2004 (the period for which all the necessary information is readily available). Prior to 1991, we used the same catch - age composition estimates as presented in Wespestad *et al.* (1996).

Recently a comprehensive development of statistical estimators for catch (including length- and age-specific quantities for groundfish fisheries was completed (Miller 2005). Estimators presented in this study hold promise for use in stock assessment purposes since rigorously developed variance estimates are currently unavailable. For the analyses completed on EBS pollock, the estimated variance of the total catch is consistent with the assumption used in the assessment model. Also, the values on total pollock catch estimated by NMFS staff at the Regional Office appear to be unbiased (based on limited comparisons). The coefficient of variation of total catch is specified to be 3% for this stock assessment. This value is a bit higher than the ~1% CVs estimated by Miller (2005) for pollock in the EBS.

In 2006, all age-composition estimates were re-evaluated. This year, the catch-age estimation method was further modified to allow bootstrap re-sampling of the data. This involved a two stage process whereby observed tows were first selected with replacement, followed by re-sampling actual lengths and age-data specimens. The results and application of this approach is presented in attachment A1. Most significantly, this provides a method to more objectively specify the effective sample size for fitting fishery age composition data within the assessment model. An added benefit of this approach was to carefully evaluate general patterns in growth and growth variability. As part of this analysis, the seasonal aspect of pollock condition factor was evaluated from the fishery data from 1991-2006. This involved simply standardizing monthly mean weights given length. Results show 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 (Fig. 1.8). Relative to recent information, the mean body weight (mass, kg) from the 2006 fishery is considerably lower than the long term mean and the 3-year average (2003-2005) used in last year's assessment (Fig. 1.9 lower panel). A similar decline has been seen in the mean length at age observed in the fishery during 2004-2006 (Fig. 1.9, upper panel). These patterns are partially due to the fact that the fishery shifted more towards the northwest where pollock tend to be smaller at age. Interestingly, the bottom trawl survey mean weight-at-age data are relatively stable; this lends some support to the hypothesis that the pattern seen in the fishery data is a function of geographic distribution.

The recent fishery age ranges appear to be focused primarily on pollock age 4-7 with the 2000 year class making up the majority of the catch until 2006 where the relative fraction of this year class drops considerably (Fig. 1.10). The 2006 fishery data show higher levels (proportionately) of the 2001 year class than in previous years. The corresponding values of catch-at-age used in the model are presented in Table 1.4.

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. 5 and 1.6). The sampling effort for pollock catch, length, and age samples by area has been shown to be relatively proportional (e.g., Fig. 1.8 *in* Ianelli et al. 2004).

Resource surveys

Scientific research catches are reported to fulfill requirements of the Magnuson-Stevens Fisheries Conservation and Management Act. The annual research catches (1963 - 2007) from NMFS surveys in the Bering Sea and Aleutian Islands Region is given in Table 1.7. Since these values represent extremely small fractions of the total removals (~0.02%), they are not explicitly added to the total removals by the fishery.

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. Bottom trawl surveys are considered to assess pollock from the bottom to 3 m off bottom. Until 1975 the survey only covered a small portion of the pollock range. In 1975 and since 1979, the survey was expanded to encompass more of the EBS shelf occupied by pollock. The level of sampling for lengths and ages in the BTS is shown in Table 1.8.

Between 1983 and 1990 the BTS biomass estimates were relatively high and showed a slightly increasing trend (Table 1.9; Fig. 1.11). Between 1991 and 2005 the BTS biomass estimates ranged from 2.21 to 8.14 million t. The 2007 estimate is 4.33 million t, up from the 2.85 from 2006 survey but below the 2005 estimate of 5.13 million. This survey estimate is about 87% of the average of all BTS estimates since 1982 and reflects the apparent general decline in the stock since 2003. In 2007 the distribution of pollock from the BTS continued to show higher concentrations in the northwestern area of the surveys and closer to the shelf break compared to the 2005 pattern but also had some higher CPUE stations near Unimak Island in the south-east area of the survey (Fig. 1.12).

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. 1.13). The survey operations generally catch pollock above 40 cm in length, and in some years lots of 1-year olds (with modal lengths around 10-15 cm; Fig. 1.14). 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). More recently, the estimate of the strength of the 1996 year class has waned compared to previous assessments. In 2003 the point estimate for this year class was 43 billion one-year olds whereas for the past two assessments, the estimate from the model has been around 32 billion. This could be due in part to emigration of this year-class outside of our main fishery and survey zones. Alternatively, this may reflect the effect of variable natural mortality rates. In the retrospective analyses presented in a last year's report (Ianelli et al. 2006), the characteristics of how strong year-class estimates change over time were illustrated.

Beginning in 1987 NMFS expanded the standard survey area farther to the northwest. For consistency, these extra strata (8 and 9) had traditionally been excluded for 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, including these strata was considered important and better covered the range of the exploited stock of pollock. The use of the additional strata was evaluated in 2006 and accepted as appropriate by the Council's SSC. The estimated numbers-at-age from the BTS for the standard strata (1-6) and for the northern strata included are presented in Table 1.11.

In response to the SSC's request, an evaluation of body mass changes for juvenile pollock shows that there is a large degree of variability over time, particularly for 3-year old pollock (Fig. 1.15, top panel). As observed in the fishery, the mean weight is low in 2006 which may reflect feeding conditions. However, since the timing of surveys has varied (Ianelli et al. 2006), consideration on the mean date (allowing for growth) and temperature may be important (Fig. 1.15, bottom panel). Regarding conditions in 2007, it appears that the mean body weight at age is closer to or above recent averages and is unlike the 2006 observations (Fig. 1.16). This provides some justification to use a mean value for the 2007 fishery as opposed to using the 2006 estimates.

As in the past few assessments, an analysis using survey data alone was conducted to evaluate mortality patterns. Cotter et al. (2004) promote 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 1990s followed by recent increases (Fig. 1.17). 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 have only recently become available to the survey (i.e., that the availability/selectivity to the survey gear has 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 (although the model values tend to be somewhat higher, averaging about 0.5 for recent cohorts).

For the past several years the effect of bottom temperature on pollock habitat relative to the standard survey area has been evaluated. Modeling survey availability as a function of temperature helps account for the observation that environmental conditions affect the distribution of pollock. Previously, temperature was shown to affect the proportion of the stock that lies within or outside of the standard survey area (or extended area, as the case may be). This summer, the bottom trawl survey data revealed a cold pool similar to that observed last year and in 1999 (Fig. 1.18). As noted last year, the timing of the survey can affect the estimate of "cold" years since surveys that occur earlier in the summer (such as in

1999) tend to exhibit colder temperatures on average. Last year a refinement to using mean temperature relative to survey catchability was attempted. This involved computing the surface area between two isotherms within the shelf region thought to cover the desired habitat and using that measure to modify catchability/availability of the survey index. This measure, as well as others relating mean temperatures to survey catchability have been poorly correlated and were omitted in this assessment. Spatially, a relationship between temperature and pollock density appears to exist. However, it could be that the variability (e.g., patchiness) of the pollock increases during colder conditions which may mask relationships between temperature effects on the pollock habitat relative to the fixed survey area. Planned work on this is to use station-by-station data within the model so that individual survey trawl operations can be modeled within the stock assessment. This feature has been implemented in the assessment model but at the time of writing, requires more testing.

Echo-integration trawl (EIT) surveys

The EIT 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 summer 2004 NMFS conducted an EIT survey that extended into the Russian zone (Honkalehto et al. 2005). The biomass estimate from this survey was 3.31 million t (U.S. zone only), down from 3.62 million t estimated in 2002 but close to the average estimated by this survey since 1982 (3.36 million t; Table 1.9).

The 2007 echo-integration trawl (EIT) survey also extended into the Russian zone. The U.S. EEZ biomass estimate was low (1.88 million t) and represents only 55% of the long-term mean value from this survey (since 1979; Table 1.9). However, this is a modest improvement over the 2006 estimate of 1.56 million t. The geographic concentration and extent of pollock from the 2007 survey shows highest concentrations in the northwestern region (Fig. 1.19) with 5% of the total survey-wide biomass occurring in the Russian EEZ. Size composition in the Russian zone was similar to that observed in the U.S. EEZ west of 170° W. Also, these figures show that the EIT survey appears to detect pollock concentrations in areas where they were less abundant in the bottom-trawl survey.

The number of trawl hauls and sampling quantities for lengths and ages from the EIT survey are presented in Table 1.12. Last year, to estimate the 2006 EIT survey population numbers at age estimates geographically split age-length keys (E and W of 170°W) were used. These keys were developed from the 2006 BTS study since there was insufficient time to conduct the age-determinations from samples collected on this research cruise. These data have been revised using age data from EIT samples that have been processed in the last year. Comparing results using one or two age-length keys suggests that one age length key from the bottom-trawl survey more closely approximated the age composition from the EIT survey (Fig. 1.20). Hence, for the 2007 EIT survey, the age composition was generated using a single age-length key from the bottom-trawl survey (Table 1.13 and also Fig. 1.21).

Proportions of pollock biomass estimated east vs. west of 170º W, and inside vs. outside the SCA, are about the same for summer EIT surveys conducted from 1994 to 2007 (Table 1.14). Compared to 2004, the relative abundance of pollock in 2006 and 2007 was much lower overall with the biggest difference being the relative lack of pollock in the region east of 170°W.

Analytic approach

Model structure

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 1964-2007. A technical description is presented in the "Model Details" section. The analysis was first introduced in the 1996 SAFE report

(Ianelli 1996) 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:

New data:

- The 2007 EBS bottom trawl survey estimate of population numbers-at-age was added.
- The 2007 EBS EIT survey estimate of population numbers-at-age were included using age-length keys from the 2007 BTS survey data.
- The 2006 EBS EIT survey estimate of population numbers-at-age were updated from last year's values by using age-length keys from the 2006 EIT survey data.
- The 2006 fishery age composition data were added.
- Length frequency data from the 2007 fishery was incorporated (and growth estimates to use in tuning the model). This is the first time length frequency data have been applied directly within the EBS pollock model.

Changes to the model:

- Multi-year forecast projections to facilitate Tier 1 OFL and ABC determinations. For the purpose of these projections, catch in 2008 (for deriving the 2009 ABC and OFL) was assumed to be equal to the maximum permissible Tier 1b level (1,170 t).
- The growth transition matrix (based on 2006 fishery data) was used to estimate the dispersion of pollock lengths given age (Fig. 1.22)
- Age 1 data from the EIT survey were treated as a separate recruitment index. Previously, these were treated as part of the multinomial age-sampling process.
- The frequency of fishery selectivity change was modified to occur every two years instead of in 3-year blocks.
- Flexibility was added to allow more extensive evaluation of survey catchabilities (past models used surveys exclusively as relative indices).
- The facility to use alternative mean-weights-at-age for spawning biomass calculations were added (in the past, fishery values were used).
- The ability to apply uncertainty in future mean weights-at-age was developed.
- The Tier 1 ABC estimation method now uses "fishable" biomass defined as the biomass of pollock available to the fishery as modified by the selectivity-at-age estimates. Previously age 3+ biomass had been used. This was changed because based on evaluation, the knife-edge aspect of age 3+ biomass unnecessarily increased the variability of yield at F_{msyr}.

Also, alternative output values for diagnostic purposes added last year include a "replay" of the estimated time series of spawning biomass and age 3+ biomass given recruitments as estimated and omitting the fishing mortality component and the projection aspect of the model was modified to more easily accommodate Tier 1, 2-year and beyond forecasts for ABC and OFL levels.

Parameters estimated independently

Natural mortality and maturity at age

For the reference model fixed natural mortality-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. Estimates of natural mortality are higher when predation (e.g., when consumption by Steller sea lions and Pacific cod) are explicitly considered

(Livingston and Methot 1998; Hollowed et al. 2000). 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	
M	0.900	0.450	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	
Age	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
M	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
Prop. Mature	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). A total of 10,197 samples of maturity stage and gonad weight were collected 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 2004). In her study, maturity-at-length converted to maturity-at-age via a fishery-derived age-length key from the same seasons and areas suggest 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 get estimates of 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

Extensive length, weight, and age data have been collected and 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 (Table 1.15).

Parameters estimated conditionally

A total of 544 parameters were estimated conditioned on data and model assumptions. Initial age composition, subsequent recruitment values and stock-recruitment parameters account for 67 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 1964-2007 and projected recruitment variability (using the variance of past recruitments) for five years (2008-2012). 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 every two years (previously this was done at three-year intervals). The two most recent years (2006-2007) forming the last "group" of estimates. The mean value of the age component is constrained to equal one and the last 4 age groups (ages 12-15) are specified to be equal. The annual components of fishing mortality result in 45 parameters and the age-time forms an 11x22 matrix of 242 parameters bringing the total fishing mortality parameters to 287.

Selectivity-at-age estimates for the bottom trawl survey are specified with age and year specific deviations in the average availability-at-age and a catchability coefficient totaling 81 parameters. For the EIT survey, which began in 1979, 105 parameters are used to specify age-time specific availability. Unlike in previous versions of this model, the estimates in EIT selectivity occur only in years when the survey was conducted. Time-varying survey selectivity is estimated to account for the changes in availability of pollock to the survey gear. Four catchability coefficients were estimated; one each for the early CPUE data, the early bottom trawl survey data (where only 6 strata were surveyed), the main bottom trawl survey data, and the EIT survey data.

For all models presented this year, catchability coefficients for are estimated as independent indices of abundance. In the past, these values have been reported but without discussion on the implications. This year, based on the work of Von Szalay et al. (2007) we introduce prior distributions on the sum of the EIT and BTS catchability coefficients. If the BTS survey covers the bottom-dwelling pollock (up to ~3 m above the bottom) and the EIT survey covers the remainder of the water column, then 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 can thus be partitioned into the following groups:

- Total catch biomass (Log normal, σ=0.05)
- Log-normal indices of abundance (bottom trawl surveys assume annual estimates sampling error, as represented in Fig. 1.11; for the EIT and CPUE indices values of σ=0.2 were assumed)
- Fishery and survey proportions-at-age estimates (robust quasi-multinomial with effective sample sizes presented in Table 1.16).
- Age 1 index from the EIT survey
- 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

Last year's assessment with data and assumption revisions

The developments in data revisions and model configurations introduced from last year's model were evaluated in a stepwise fashion. This was done to reveal how revised historical data impact subsequent analysis. The revisions to the 2006 assessment and data were as follows: 1) revised EIT age data; 2) revised mean weights used in the 2006 fishery (and subsequently used for ABC projections; 3) fishery age-composition sample size revisions based on bootstrap analysis in presented in attachment 1A; 4) accounting for weight-at-age variability as an explicit part of the uncertainty for F_{msy} calculations (see section on Model Details for an explanation); and 5) a model run with all revisions indicated in 1) - 4). Note that 4) is equivalent to using the long-term mean weight-at-age (as opposed to the 3-year average).

Results from this exercise showed that the largest impact (using exactly the same model code from last year's assessment) was from the revised mean weights-at-age (Fig. 1.23). This is because these values were much lower than the mean value from 2003-2005 used for 2006 in last year's assessment.

To gain some appreciation for the impact of mean weight-at-age differences, equilibrium stock conditions using mean age-specific survival from 1997-2006 were calculated to obtain age 3+ biomass values using last year's mean weight-at-age estimates and then again with the revised estimates of mean weights-at-age observed in 2006. This resulted in a 12% reduction in age 3+ biomass due to changes in mean body weight alone. However, for last year's 2006 estimated numbers at age the reduction is only 7% due to the age distribution of the population.

This impacts the assessment in two important ways. First, the biomass levels will be lower for Tier 1 calculations. Secondly, the mean weights at age used for the quota are based on the most recent information (which the SSC has accepted as the most recent three-years of data).

Evaluation of the 2007 assessment model

Going forward with the addition of 2007 data, all historical data revisions from the previous section were included with one important exception: the assumed 2007 mean weights-at-age were set to the average observed during 2004-2006. This is significantly lower than what was assumed in last year's model for 2006, but isn't as low as the presently observed 2006 fishery mean weights at age. The survey data and evaluation of existing length-weight data for 2007 indicate that growth patterns and fish size have improved over the 2006 condition.

Following a similar approach to evaluating the influence of added data, models were constructed with combinations of including or excluding new data as follows:

	Shorthand	Description
Model_1	**C**	2007 total catch only included
Model_2	**CA**	Catch and 2006 fishery age data included
Model_3	**CB**	Catch, and 2007 bottom-trawl survey data included
Model_4	**CE**	Catch and 2007 EIT survey included
Model_5	**CAB**	Catch, age, and bottom-trawl survey
Model_6	**CAE**	Catch, age, and EIT survey
Model_7	**CBE**	Catch, bottom-trawl survey, and EIT survey
Model_8	**CABE**	Catch, age, bottom-trawl survey, and EIT survey

In last year's assessment an extensive retrospective analysis was conducted. This work concluded that in general, there was a tendency to under-estimate terminal year biomass levels even though the estimated uncertainty is quite high. Also, it appears that some strong year-class estimates evolve quite differently as additional data are added in each year suggesting unaccounted for process errors.

Results

Evaluating the influence of new data as they are introduced can reveal where consistencies with past predictions occur and where things may diverge. Adding the fishery catch-age data and other data affects the point estimates of the age 3+ biomass but reduces the uncertainty on the 2005 year class (Fig. 1.24). Closer examination of the age data that impact these results show how model CA (only new 2007 data include fishery catch and age compositions) results in particularly poor fits to the observed 2007 survey age compositions (Fig. 1.25). Similarly, if the 2006 fishery age composition data is omitted, (model C) the fit to the 2006 fishery age composition is also poor due to the lack of many age 6 pollock in the 2006 fishery (Fig. 1.26). This indicates that last year's model anticipated that the 2006 fishery would still have a strong showing of the 2000 year class. The new data contradict this prediction.

A variety of alternative model configurations have been explored in the past, and continued again this year. Alternative non-informative prior distributions on the aggregate "catchability" of the EIT and bottom trawl survey were examined. In particular, Von Szalay et al.'s (2007) results suggest that vertical herding of pollock (i.e., fish diving toward bottom and becoming vulnerable) was limited. This indicates that a rationale for having the combined catchability be closer to unity than the current estimated value of 1.54. However, alternatives lower than this number degraded the fit to the data substantially and represents a major departure from past assessments. Highlighting this fact does provide some added level of precaution since imposing an informative prior on the combined survey catchabilities to lower values would scale population to higher levels. A profile over this quantity indicates that the value is quite well determined and unlikely (given data and model structure assumptions) to be below a value of 1.3—which would increase the current stock-size estimated by 30% (Fig. 1.27). Thus for clarity and consistency, the model presented below represents that accepted in previous years with the modifications mentioned above. This model was used with all new data included (CABE) as a reasonable representation of stock status and associated uncertainty.

Comparing the current and projected age structure for this model relative to last year's assessment indicates that the abundance estimate of 2008 numbers at age is substantially lower, particularly for the 2005 and 2004 year classes (3 and 4 year olds; Fig. 1.28, top panel). When summed by age for biomass, the difference relative to last year's assessment is more dramatic indicating that the nominal age 3+ begin-year biomass is about 65% of last year's estimate for 2008 (Fig. 1.28; bottom panel). Part of this difference is due to the difference in mean weights-at-age used this year.

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. 1.29). As noted above, the 2005 fishery apparently caught a proportionately large amount of 5 year olds but these failed to show in substantial numbers in the 2006 fishery. Part of this may be due to the increased level of fishing in the northwest region during the summer/fall season. The model fits the fishery age-composition data quite well under this form of selectivity (Fig. 1.30). The length frequency data for 2007 also fit reasonably well. The model fit to the early Japanese fishery CPUE data (Low and Ikeda, 1980) is consistent with the population trends for this period and is essentially unchanged since introduced to the assessment several years ago.

Bottom-trawl survey selectivity and fits to the numbers of age 2 and older pollock are shown in Fig. 1.31. The bottom trawl survey age composition data continue to indicate that the 2006 year class is large but that the 2005 and 2000 year-classes are less abundant than in recent years. (Fig. 1.32).

The EIT survey selectivity shows some inter-annual variability but has generally stabilized since the early 1990s as the echo-sounder and trawl methods became more standardized (Fig. 1.33; top panel). Of course this could also be due in part to changes in age-specific pollock distributions over time. The fit to the numbers of age 2 and older pollock in the EIT survey generally falls within the confidence bounds of the survey sampling distributions (here assumed to have a CV of 20%) with a fairly reasonable pattern of residuals (Fig. 1.33; bottom panel). As with the fishery and bottom trawl survey age composition data, the EIT age compositions consistently track large year classes through the population and the model fits these patterns reasonably well (Fig. 1.34). The EIT age-1 index component which was split from the age composition data this year, demonstrates the difficulty in having a highly precise pre-recruit index (Fig. 1.34; bottom panel).

The estimate of 2008 spawning stock size and corresponding estimates of B_{msy} have coefficients of variation that exceed 20% (Table 1.17). For 2008, the Tier 1 levels of yield are 1,170 thousand t from a fishable biomass estimated at around 4.77 million t (Table 1.18). Estimated numbers-at-age are presented in Table 1.19 and estimated catch-at-age presented in Table 1.20. Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment is given in Table 1.21.

In addition to extensive model-specification evaluations, the selected model was used to examine the multidimensional parameter uncertainty by integrating approximations to the posterior distribution using

Monte-Carlo Markov Chain methods. This involved generating several million simulations drawn from the posterior distribution with the individual draws "weighted" by their density. This chain was then "thinned" to reduce potential serial correlation to 8,000 parameter vectors. Selected model parameters were then plotted pair-wise to provide some indication of the shape of the posterior distribution. In general, the model given the available data appears to be quite well behaved (no curved or skewed tear-drop shapes over critical parameters; Fig. 1.35). For a closer evaluation of how parameter uncertainty manifests in the posterior distribution, a subset of stock-recruitment "curves" from the posterior shows a broad range of values and shapes (Fig. 1.36).

The assessment results indicate that the spawning biomass will be well below $B_{40\%}$ in 2008 (53% of the value) and about 72% of the B_{msy} level but only 49% of the predicted value had no fishing occurred since 1978 (Table 1.17). This compares with the 21% of $B_{100\%}$ (based on the SPR expansion from mean recruitment since 1978) and 28% of B_0 (as from the estimated stock-recruitment curve). This range of alternative "reference point" systems serves to illustrate problems associated with developing robust guidelines for management.

Abundance and exploitation trends

The current mid-year biomass estimates (ages 3 and older) derived from the statistical catch-age model suggest that the abundance of Eastern Bering Sea pollock remained at a fairly high level from 1982-88, with estimates ranging from 8 to 10 million t (Table 1.22, Fig. 1.37). 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 4 million t by 1991 and another low point occurring at present with the stock projected to drop to the lowest levels since the late 1970s[*]. As predicted in last year's assessment, the stock has continued to decline substantially since 2003 due to apparently poor recruitment between 2000 and 2006.

Compared with past year's assessments, the estimates of age 3+ pollock biomass are significantly lower in the current assessment for recent years but are nearly identical before 2002 (Table 1.22). Overall, compared with the past several assessments, the pattern appears to be balanced between over and under estimates, especially since 1998 when the same statistical model has been used (Fig. 1.38).

The abundance and exploitation pattern estimates show that the spawning exploitation rate (SER, defined as the percent removal of spawning-aged females in any given year) has been below 20% since 1980 until 2006 and 2007 where the rate has averaged more than 25% (Fig. 1.39).

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 1981. Since that time, the levels of fishing mortality have averaged about 44% of $F_{40\%}$ (Fig. 1.40).

Recruitment

In this year's assessment, the 2000 year class abundance level dropped compared to last year though is still above average. The 2005 year-class, estimated as "about" average last year, also was estimated to be significantly below average. The 2006 year class appears to be well above average and based on survey data (Fig. 1.41, top panel). New data from the BASIS surveys suggests that the abundance of age-0 pollock (near the surface) was low in 2006 and 2007, with high levels observed in 2004 and 2005. This is

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

somewhat inconsistent with the relatively abundant 2006 year-class observed in the surveys this year. Further investigations on the water column temperature structure may shed light on the relative availability of pollock young-of-year to the BASIS sampling gear.

The high degree of uncertainty in the magnitude of these year classes can not be overemphasized, particularly as they extend to estimates of future stock size. Management will continue to rely on survey and fishery information to provide reasonable short-term forecasts on stock conditions. The stock-recruitment curve 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 2008 spawning biomass is below the B_{msy} level (Fig. 1.41, bottom panel).

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. For our analyses, the following values from are presented based on recruitment estimates from post-1976 spawning events:

$B_{100\%}$ = 6,569 thousand t female spawning biomass*

$B_{40\%}$ = **2,627** thousand t female spawning biomass

$B_{35\%}$ = 2,299 thousand t female spawning biomass

B_{msy} = **1,876** thousand t female spawning biomass

Specification of OFL and Maximum Permissible ABC

The year 2008 spawning biomass is estimated to be **1,380** thousand tons (at the time of spawning, assuming the stock is fished at Tier 1b level). This is below the B_{msy} value of **1,876**. 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. The exploitation-rate type value that corresponds to the F_{msy} level was applied to the "fishable" biomass for computing ABC levels. For a future year, the fishable biomass is defined as the sum over ages of predicted begin-year numbers multiplied by age specific fishery selectivity and body weights.

The 2008 estimate of female spawning biomass (at time of spawning assuming 2008 Tier 1b catch levels of 1.17 million t) is **1,380** thousand t. This is below the $B_{40\%}$ and B_{msy} values (**2,627** and **1,876** t, respectively). The OFL's and maximum permissible ABC values by Tier are thus:

Tier	Year	Max ABC	OFL
1b	2008	1,170 thousand t	1,443 thousand t
1b	2009	976 thousand t	1,204 thousand t
3b	2008	555 thousand t	677 thousand t
3b	2009	650 thousand t	794 thousand t

* Note that another theoretical "unfished spawning biomass level" (based on stock-recruitment relationship $\tilde{B}_0$) is somewhat lower (**5,013** t).

ABC Recommendation

This year's population estimates are significantly lower than last year's estimate which reflects a number of issues raised in the data sections above. The stock has dropped to below average levels after a number of years of above-average conditions. The biomass of Eastern Bering Sea pollock is projected to continue declining until the positive signs of incoming year classes recruit to the spawning biomass. The rate of decline since 2003 has been around 20% per year. The spawning exploitation rate has consequently increased by more than 15% from 2003-2007. Under likely catch projections, the spawning stock biomass is expected be about 72% of B_{msy} (**1,876** thousand t) by 2008 with future status depending on specified catch levels and recruitment (Fig. 1.42).

Given the rapidly declining stock and the recent increases in harvest rates, it could be argued that it would be prudent to consider harvest levels that would 1) provide stability to the fishery; 2) provide added conservation to an important prey species of the endangered stock of Steller sea lions; and 3) provide extra precaution due to uncertain stock removals in Russian waters. There are (as always) reasons to be concerned that specified harvest levels may cause "something bad to happen." Risk aversion is at the core of the NPFMC harvest guidelines. However, all forms of modeling have major weakness when it comes to predicting outcomes of highly variable and uncertain events. The following highlights some points to consider regarding whether the ABC should be set to the Tier 1b maximum permissible level:

1) The sum of the survey catchabilities for the accepted model is over 1.5, indicating that there is considerable overlap between the availability of pollock between the two surveys (or some other mechanism such as temporary immigration of pollock into the EBS region from elsewhere).
2) The stock-recruitment relationship continues to be constrained within the model which causes the harvest rate to be more conservative.
3) 2007 weights-at-age appear to be closer to mean values and are above the lower levels observed in the 2006 fishery.
4) In the two surveys conducted in 2007 signs of 1-year old abundance were above average.
5) The precautionary MSY harvest rate has been adjusted downward to nearly 72% to account for the stock being below the B_{msy} level.
6) In the 1998 assessment, the outlook for 1999 was fairly pessimistic (although the age 3+ biomass was about 1 million t higher than is presently estimated for 2008). In hindsight, the perception of relatively poor stock conditions at the time changed. For example, at the time, the 1992 year class was estimated to be about average whereas now it appears to be more than twice the average and represents the third highest year class.
7) The stock has been at low levels in the past (but this appears to be the lowest since before 1980).
8) The Tier 3 ABC levels are substantially lower than the Tier 1 values due to different assumptions about reference biomass levels (hence a larger adjustment).
9) Future selectivity patterns are unpredictable given fish distribution.
10) If the 2005 year class is in fact below average, then there will have been 5 year classes in sequence that have been below average, an apparently unique event for this stock.
11) Spatially equitable catch rates by the fishery may continue to be impacted (lower catch rates overall are to be expected, and this can manifest as spatial differences in pollock availability).
12) Absorbing some of the anticipated "adjustment" from the ABC control rule will likely reduce the inter-annual variability ABC recommendations.

Setting the ABC below the maximum permissible value may provide opportunities to reduce the projected declines. For example, under constant catch scenarios of 1.0 and 1.2 million t the stock is projected to rebound sooner (Fig. 1.43). These projections also suggest that the spawning stock exploitation rates will drop if 1.2 million t are caught in 2008. Alternatively, a value of 1.02 million t is projected to be equal to the 1990 exploitation rate (the highest rate observed since 1978). However, if the

stock was managed under the Tier 3b ($F_{40\%}$) harvest level, the decline in exploitation rate would be greater (Fig, 1.44).

The degree to which the ABC should be adjusted downwards is difficult to quantitatively justify. The maximum permissible ABC under Tier 1b seems too high given the continued decline and the lower abundances of older fish seen in the population in recent years. For stability in catches, it may be best to harvest at 1.0 million t in 2008. Since two more surveys will be conducted, next year's assessment should provide clearer guidance on the status of incoming recruits and adult abundance. Catch rates experienced by the fleet are also likely to drop as pollock stock densities reach lower levels.

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 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2007. 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. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2008 and 2009, are as follows (A "*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs).

Scenario 2: In all future years, F is set equal to a value that corresponds to a constant catch level of 1,200,000 t. (Rationale: This catch is close to the mean catch since 1981 and in most years, would satisfy the constraint to be below the maximum permissible under Tier 1 levels).

Scenario 3: In all future years, F is set equal to the 2003-2007 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 4: In all future years, F is set equal to $F_{60\%}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels. This was requested by public comment for the DSEIS developed in 2006)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2007 or 2) above ½ of its MSY level in 2008 and above its MSY level in 2020 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, 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 2020 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 2006 (Table 1.23). Under Scenarios 1 and 2, the expected spawning biomass will decrease to below the $B_{35\%}$ then begin increasing after 2008 but not reaching $B_{40\%}$ (in expectation) until after 2011 (Fig. 1.42).

Any stock that is below its MSST is defined to be overfished. Any stock that is expected to fall below its MSST in the next two years is defined to be approaching an overfished condition. Harvest scenarios 6 and 7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2008:

a) If spawning biomass for 2008 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.
b) If spawning biomass for 2008 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2008 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 1.23). If the mean spawning biomass for 2018 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:

a) If the mean spawning biomass for 2010 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2010 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c) If the mean spawning biomass for 2010 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2020. If the mean spawning biomass for 2020 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 2008, nor is it expected to be approaching an overfished condition based on Scenario 7 (the mean spawning biomass in 2010 is above the $B_{35\%}$ level; Table 1.23). For harvest recommendations, Tier 3 and a proxy for Tier 1 calculations were made that give ABC and OFL values for 2008 and 2009 (assuming catch is 1,170,000 t in 2008 Table 1.24). The Tier 1 projections were approximated by substituting the B_{msy} values for $B_{40\%}$ (for the harvest control rule) and setting the F_{ABC} and F_{OFL} values to their spawning biomass-per-recruit (SPR) equivalent fishing mortalities. These SPR rates correspond to $F_{32\%}$ and $F_{26\%}$, respectively. Additional projections using alternative future fixed catch levels (and alternative assumptions about the 2006 year class) are shown in Table 1.25.

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 (Fig. 1.45). 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).

Regarding specific small-scale ecosystems of the EBS, Ciannelli et al. (2004) presented an application of an ecosystem model scaled to data available around the Pribilof Islands region. They applied bioenergetics and foraging theory to characterize the spatial extent of this ecosystem. They compared energy balance, from a food web model relevant to the foraging range of northern fur seals and found that a range of 100 nautical mile radius encloses the area of highest energy balance representing about 50% of the observed foraging range for lactating fur seals. This suggests that fur seals depend on areas outside the energetic balance region. This study develops a method for evaluating the shape and extent of a key ecosystem in the EBS (i.e., the Pribilof Islands). Furthermore, the extent that the pollock fishery extends into northern fur seal foraging habitat (e.g., Robson et al. 2004) will require careful monitoring and evaluation.

Ecosystem effects on the EBS pollock stock

A brief summary of these two perspectives is given in Table 1.26. 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.

In 2006 the EIT survey found an unusually low level of “other” backscatter in the water column based on summaries of the data from acoustic-trawl surveys of the eastern Bering Sea shelf conducted in June-July of 1999, 2000, 2002, 2004, 2006 and 2007 (Fig. 1. 46). These plots represent 38-kHz acoustic backscatter

(s_A, m^2/nmi^2) attributed to an undifferentiated invertebrate-fish species mixture. For the 1999, 2000, 2002 and 2007 surveys, backscatter was measured between 14 m from the surface and 0.5 m off the bottom; in 2004 and 2006 it was measured between 12 m from the surface and 0.5 m off the bottom. These data should be interpreted with care because the exact biological composition of the non-pollock scatterers is unknown. Additionally, classification of non-pollock backscatter was not always performed as rigorously as classification of pollock, so non-pollock backscatter may contain some non-biological scatter. Trawl data suggest that biological components include jellyfish such as *Chrysaora* sp., other macrozooplankton, age 0 pollock, and other fishes. Some animals, such as fish with swimbladders and large medusae, are more easily detected at 38 kHz than small organisms such as copepods and euphausiids. Because these animals all reflect sound at different target strengths, comparison of backscatter both within and between years must be made with extreme caution. However, the data presented indicate that the contribution from non-pollock scatterers in 2006 was quite a bit lower than that in preceding years. In 2007, the contribution (or lack thereof) in the southeastern part of the shelf was similar to that in 2006 and quite different from preceding years. In 2007, most of the non-pollock backscatter was centered just to the north and west of the Pribilof Islands. These data suggest that the ecosystem, particularly in the southeastern region of the EBS, may have been different in the summers of 2006 and 2007, although the nature of the difference cannot be inferred from these data. The impact of this is unknown but should continue to be closely monitored. Work should be encouraged to better characterize the abiotic and biotic components of the non-pollock backscatter.

Furthermore, several other ecosystem indicators may give cause for concern. Zooplankton and non-pollock forage fish have been anomalously low in respective surveys (Figs. 3, 56, 64 in Ecosystem Considerations). While cannibalism still occurs within age-0 pollock (Fig. 61 in Ecosystem Considerations), cannibalism on age 1s by larger pollock has dropped since 1997 and may no longer be a main source of natural mortality for juvenile pollock (Fig. 4B in Ecosystem Considerations).

Moreover, the impact of non-cannibalistic predation may have shifted considerably in recent years. In particular, the increasing population of arrowtooth flounder in the Bering Sea is worth examining, especially considering the large predation caused by these flatfish in the Gulf of Alaska. Overall, the total non-cannibal groundfish predator biomass has gone down in the Bering Sea according to current stock assessments, with the drop of Pacific cod in the 1980s exceeding the rise of arrowtooth in terms of biomass (e.g., see Fig. 4 in Ecosystem Considerations chapter). This also represents a shift in the age of predation, with arrowtooth flounder consuming primarily age-2 pollock, while Pacific cod primarily consume larger pollock. However, the dynamics of this predation interaction may be quite different than in the Gulf of Alaska. A comparison of 1990-94 natural mortality by predator for arrowtooth flounder in the Bering Sea and the Gulf of Alaska shows that they are truly a top predator in the Gulf of Alaska. However, in the Bering Sea, pollock, skates, and sharks all prey on arrowtooth flounder, giving the species a relatively high predation mortality.

The predation on small arrowtooth flounder by large pollock gives rise to a specific concern for the Bering pollock stock. Walters and Kitchell (2001) describe a predator/prey system called "cultivation/depensation" whereby a species such as pollock "cultivates" its young by preying on species that would eat its young (for example, arrowtooth flounder). If these interactions are strong, the removal of the large pollock may lead to an accelerated decline, as the control it exerts on predators of its recruits is removed—this has been cited as a cause for a decline of cod in the Baltic Sea in the presence of herring feeding on cod young (Walters and Kitchell 2001). In situations like this, it is possible that predator culling (e.g., removing arrowtooth) may not have a strong effect towards controlling predation compared to applying additional caution to pollock harvest and thus preserving this natural control. At the moment, this concern for Bering Sea pollock is qualitative; work on extending a detailed, age-structured, multispecies statistical model (e.g., MSM; Jurado-Molina et al. 2005) to more completely model this complex interaction for pollock and arrowtooth flounder is continuing.

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 1.27). Jellyfish represent the largest component of the bycatch of non-target species and has been stable at around 5-6 thousand tons per year (except for 2000 when over 9,000 t were caught). The data on non-target species shows a high degree of inter-annual variability which reflects the spatial variability of the fishery and high observation error. This variability may mask any significant trends in bycatch.

The catch of other target species in the pollock fishery represent less than 1% of the total pollock catch. Nonetheless incidental catch of Pacific cod has increased since 1999 but is below the 1997 levels (Table 1.28). The incidental catch of flatfish was variable over time and has increased slightly. Proportionately, the incidental catch has decreased since the overall levels of pollock catch have increased. The catch of prohibited species was also variable but showed noticeable trends (Table 1.29). For example, the level of crab bycatch drops considerably after 1998 when all BSAI pollock fishing was restricted to using only pelagic trawls. Recent levels of salmon bycatch have increased dramatically and current restrictions are under revision to help minimize this problem.

Summary

Summary results are given in Table 1.30.

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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, 1979-2007 (2007 values estimated). 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	932,508	557,562	1,490,070	1,653		24
2004	1,089,970	390,708	1,480,678	1,150		0
2005	802,421	680,851	1,483,271	1,621		
2006	826,887	659,397	1,486,284	1,735		
2007			1,340,000			

1979-1989 data are from Pacfin.

1990-2006 data are from NMFS Alaska Regional Office, and includes discards.
2007 EBS catch is estimated

Table 1.2. Time series of ABC, TAC, and catch levels for EBS pollock, 1977-2007 in metric t. Source: compiled from NMFS Regional office web site and various NPFMC reports, catch for 2007 is an estimated projection.

Year	ABC	TAC	Catch
1977	950,000	950,000	978,370
1978	950,000	950,000	979,431
1979	1,100,000	950,000	935,714
1980	1,300,000	1,000,000	958,280
1981	1,300,000	1,000,000	973,502
1982	1,300,000	1,000,000	955,964
1983	1,300,000	1,000,000	981,450
1984	1,300,000	1,200,000	1,092,055
1985	1,300,000	1,200,000	1,139,676
1986	1,300,000	1,200,000	1,141,993
1987	1,300,000	1,200,000	859,416
1988	1,500,000	1,300,000	1,228,721
1989	1,340,000	1,340,000	1,229,600
1990	1,450,000	1,280,000	1,455,193
1991	1,676,000	1,300,000	1,195,646
1992	1,490,000	1,300,000	1,390,331
1993	1,340,000	1,300,000	1,326,601
1994	1,330,000	1,330,000	1,329,350
1995	1,250,000	1,250,000	1,264,245
1996	1,190,000	1,190,000	1,192,778
1997	1,130,000	1,130,000	1,124,430
1998	1,110,000	1,110,000	1,101,165
1999	992,000	992,000	989,816
2000	1,139,000	1,139,000	1,132,707
2001	1,842,000	1,400,000	1,387,194
2002	2,110,000	1,485,000	1,480,195
2003	2,330,000	1,491,760	1,490,070
2004	2,560,000	1,492,000	1,480,678
2005	1,960,000	1,478,500	1,483,271
2006	1,930,000	1,485,000	1,486,284
2007	1,394,000	1,394,000	1,340,000
1977-2007 average	1,434,290	1,220,557	1,197,244

Table 1.3. Estimates of discarded pollock (t), percent of total (in parentheses) and total catch for the Aleutians, Bogoslof, Northwest and Southeastern Bering Sea, 1991-2007. Units are in tons, SE represents the EBS east of 170° W, NW is the EBS west of 170° W, source: NMFS Blend and catch-accounting system database.

	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	2,723 (1%)	20,302 (2%)	23,783 (2%)	1,156	NA	390,414	1,089,880	1,482,373
2005	324 (20%)		2,581 (0%)	14,838 (2%)	17,742 (1%)	1,621		680,856	802,418	1,484,895
2006	310 (18%)		3,672 (1%)	11,588 (1%)	15,570 (1%)	1,735		659,397	826,887	1,488,019
2007	386 (16%)		4,136 (1%)	12,270 (2%)	16,792 (1%)	2,448		592,411	657,552	1,252,411

Table 1.4. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2006. Units are in millions of fish.

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14+**	**Total**
1979	101.4	543.0	719.8	420.1	392.5	215.5	56.3	25.7	35.9	27.5	17.6	7.9	3.0	1.1	2,567.3
1980	9.8	462.2	822.9	443.3	252.1	210.9	83.7	37.6	21.7	23.9	25.4	15.9	7.7	3.7	2,420.8
1981	0.6	72.2	1,012.7	637.9	227.0	102.9	51.7	29.6	16.1	9.3	7.5	4.6	1.5	1.0	2,174.6
1982	4.7	25.3	161.4	1,172.2	422.3	103.7	36.0	36.0	21.5	9.1	5.4	3.2	1.9	1.0	2,003.8
1983	5.1	118.6	157.8	312.9	816.8	218.2	41.4	24.7	19.8	11.1	7.6	4.9	3.5	2.1	1,744.5
1984	2.1	45.8	88.6	430.4	491.4	653.6	133.7	35.5	25.1	15.6	7.1	2.5	2.9	3.7	1,938.0
1985	2.6	55.2	381.2	121.7	365.7	321.5	443.2	112.5	36.6	25.8	24.8	10.7	9.4	9.1	1,920.0
1986	3.1	86.0	92.3	748.6	214.1	378.1	221.9	214.3	59.7	15.2	3.3	2.6	0.3	1.2	2,040.5
1987	0.0	19.8	111.5	77.6	413.4	138.8	122.4	90.6	247.2	54.1	38.7	21.4	28.9	14.1	1,378.6
1988	0.0	10.7	454.0	421.6	252.1	544.3	224.8	104.9	39.2	96.8	18.2	10.2	3.8	11.7	2,192.2
1989	0.0	4.8	55.1	149.0	451.1	166.7	572.2	96.3	103.8	32.4	129.0	10.9	4.0	8.5	1,783.8
1990	1.3	33.0	57.0	219.5	200.7	477.7	129.2	368.4	65.7	101.9	9.0	60.1	8.5	13.9	1,745.9
1991	1.0	109.1	41.0	86.8	140.0	156.0	389.1	52.5	219.4	22.2	114.8	13.9	72.0	59.3	1,477.0
1992	0.0	87.8	674.4	130.7	79.2	112.6	134.9	256.0	100.6	156.3	55.6	43.3	12.7	75.3	1,919.2
1993	0.1	7.5	260.9	1,153.8	102.4	64.8	62.4	52.6	91.0	21.2	33.4	12.1	12.4	23.8	1,898.3
1994	0.3	35.5	54.7	357.8	1,068.1	175.4	53.8	20.3	13.3	21.6	8.8	9.7	7.3	11.5	1,838.1
1995	0.0	0.4	80.6	152.2	398.9	765.2	131.2	31.6	9.6	8.2	18.3	5.4	6.0	10.5	1,618.2
1996	0.0	23.3	54.7	87.2	157.2	362.4	476.2	186.4	32.3	13.5	9.6	8.9	4.2	11.6	1,427.7
1997	0.0	79.7	34.2	108.5	467.3	288.1	252.9	199.0	62.7	13.8	6.9	5.1	3.5	16.1	1,537.6
1998	0.0	47.8	86.8	71.7	156.6	692.2	200.0	129.4	109.6	29.8	6.3	5.8	2.8	8.2	1,546.8
1999	0.4	11.5	294.2	226.1	105.3	156.1	473.3	133.3	57.8	33.1	3.5	2.3	0.5	2.3	1,499.6
2000	0.0	17.2	80.6	426.9	346.0	106.0	169.3	356.9	85.3	29.3	23.9	5.6	1.5	2.3	1,650.7
2001	0.0	3.6	56.3	161.9	575.3	408.2	135.3	130.1	157.8	57.5	35.0	15.9	5.9	5.0	1,747.8
2002	0.3	53.5	110.1	213.4	284.9	604.2	268.6	98.9	87.0	95.9	34.6	14.4	12.6	4.4	1,883.0
2003	0.0	17.5	414.4	320.3	365.9	304.8	330.4	156.3	53.0	39.8	36.2	23.6	7.0	7.0	2,076.3
2004	0.0	1.1	90.0	834.0	481.7	238.0	167.8	155.9	62.4	16.6	18.6	25.7	10.5	13.0	2,115.4
2005	0.0	3.3	54.6	391.0	859.2	490.4	156.6	67.8	67.0	33.1	10.8	10.2	3.4	5.4	2,152.7
2006	0.0	12.3	84.6	290.7	622.2	591.3	281.1	109.0	49.9	38.2	16.3	9.6	9.5	12.8	2,127.5
Average	4.7	71.0	235.2	363.1	382.5	323.1	207.1	118.3	69.7	37.6	25.9	13.1	8.8	12.1	1,872.4
Median	0.1	29.2	91.1	301.8	365.8	263.1	162.2	101.9	58.8	26.7	17.9	10.0	5.1	8.3	1,890.7

Table 1.5. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2007, 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	66,811	64,243	14,811	11,859	30,628	27,370	215,720
			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	6,664	6,618	1,750	1,300	3,095	2,634	22,061

Table 1.6. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2006, 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

Table 1.7. NMFS total pollock research catch by year in t, 1963-2007.

Year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Aleutian Is.	0	0	0	0	0	0	0	0	0	0	0
Bering Sea	4	0	18	17	21	7	14	9	16	11	69
Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Aleutian Is.	0	0	0	0	0	0	193	0	40	454	0
Bering Sea	83	197	122	35	94	458	139	466	682	508	208
Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Aleutian Is.	0	292	0	0	0	0	51	0	0	48	0
Bering Sea	435	163	174	467	393	369	465	156	221	267	249
Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2006	2007
Aleutian Is.	0	36	0	0	40	0	79	0	51	21	0
Bering Sea	206	262	121	299	313	241	440	285	363	251	333

Table 1.8. Sampling effort for pollock in the EBS from the NMFS bottom trawl survey 1982-2007. 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*	1995	376	25,673	1,156
1983	*354*	*78,033*	*1,931*	1996	375	40,789	1,387
1984	*355*	*40,530*	*1,806*	1997	376	35,536	1,193
1985	434	48,642	1,913	1998	375	37,673	1,261
1986	*354*	*41,101*	*1,344*	1999	373	32,532	1,385
1987	356	40,144	1,607	2000	372	41,762	1,545
1988	373	40,408	1,173	2001	375	47,335	1,641
1989	373	38,926	1,227	2002	375	43,361	1,695
1990	371	34,814	1,257	2003	376	46,480	1,638
1991	371	43,406	1,083	2004	375	44,102	1,660
1992	356	34,024	1,263	2005	373	35,976	1,676
1993	375	43,278	1,385	2006	376	39,211	1,573
1994	375	38,901	1,141	2007			1,484

Table 1.9. Biomass (age 1+) of Eastern Bering Sea pollock as estimated by surveys 1979-2006 (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)	EIT Survey (t)	EIT Percent age 3+	Total* (t)	Near bottom biomass
1979	*3.20*	7.46	(22%)	10.66	30%
1980	*1.00*				
1981	*2.30*				
1982	2.856	4.90	(95%)	7.76	46%
1983	6.258				
1984	4.894				
1985	5.928	4.80	(97%)	9.43	54%
1986	4.897				
1987	5.515				
1988	7.289	4.68	(97%)	11.79	63%
1989	6.519				
1990	7.322				
1991	5.168	1.45	(46%)	6.56	79%
1992	4.583				
1993	5.636				
1994	5.027	2.89	(85%)	7.87	64%
1995	5.482				
1996	3.371	2.31	(97%)	5.51	60%
1997	3.874	2.59	(70%)	5.62	54%
1998	2.852				
1999	3.801	3.29†	(95%)	6.86	52%
2000	5.265	3.05	(95%)	8.19	63%
2001	4.200				
2002	5.038	3.62	(82%)	8.39	57%
2003	8.458				
2004	3.886	3.31	(99%)	7.06	53%
2005	5.318				
2006	3.045	1.56		4.41	65%
2007	4.338	1.878		6.22	70%

* 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).

† This figure excludes the zone near the "horseshoe" area of the EBS (southeast) not usually surveyed, the value including this area was 3.35 million tons.

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 1982-2006.

Year	Survey biomass estimates in strata 1-6	Survey biomass estimates in strata 8 and 9 (NW)	All area Total	NW %Total
1982	2,855,539			
1983	6,257,632			
1984	4,893,536			
1985	4,630,111	1,425,625	6,055,736	24%
1986	4,896,780			
1987	5,108,035	416,558	5,524,593	8%
1988	7,107,258	181,909	7,289,168	2%
1989	5,927,187	591,622	6,518,809	9%
1990	7,126,083	195,894	7,321,977	3%
1991	5,105,224	62,523	5,167,748	1%
1992	4,367,870	214,676	4,582,546	5%
1993	5,520,892	114,757	5,635,649	2%
1994	4,977,019	49,721	5,026,740	1%
1995	5,413,270	68,983	5,482,253	1%
1996	3,204,106	167,090	3,371,196	5%
1997	3,031,557	842,276	3,873,833	22%
1998	2,212,689	639,715	2,852,404	22%
1999	3,597,403	203,314	3,800,717	5%
2000	5,134,616	129,932	5,264,548	2%
2001	4,145,746	54,162	4,199,909	1%
2002	4,832,506	205,231	5,037,737	4%
2003	8,140,573	317,089	8,457,662	4%
2004	3,756,228	130,227	3,886,455	3%
2005	5,133,606	160,109	5,293,715	3%
2006	2,845,507	199,932	3,045,438	7%
2007	4,156,687	180,856	4,337,542	4%
Avg.	4,783,756	297,827	5,092,108	6%

Table 1.11. Bottom-trawl survey estimated numbers (millions) at age used for the stock assessment model, 1982-2007 based on strata 1-8. Shaded cells represent years where only strata 1-6 were surveyed.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	StdErr	CV
1982	821	2,029	2,407	3,276	1,075	150	103	50	33	18	9	7	2	1	0	9,980	1,269	13%
1983	483	670	1,638	3,060	6,663	1,979	369	199	78	72	56	19	9	8	3	15,306	1,198	8%
1984	280	261	348	1,196	1,400	3,551	694	157	68	25	16	6	4	5	2	8,012	795	10%
1985	3,053	581	2,591	1,111	3,839	2,169	1,580	319	81	64	18	6	7	1	0	15,420	1,967	13%
1986	1,931	278	312	1,549	859	1,597	1,317	1,133	389	64	27	12	0	3	0	9,473	838	9%
1987	254	474	644	413	3,691	815	991	376	1,242	181	69	24	4	1	1	9,181	1,129	12%
1988	537	449	969	2,463	1,002	3,590	1,158	909	522	1,180	120	66	12	22	9	13,009	1,477	11%
1989	580	223	427	1,385	3,096	703	2,697	400	526	199	517	97	76	43	49	11,019	1,083	10%
1990	1,333	219	65	590	1,038	3,810	846	2,171	239	406	72	557	42	50	39	11,476	1,375	12%
1991	2,457	767	98	58	479	445	1,445	544	1,255	308	429	90	239	34	26	8,673	835	10%
1992	1,205	320	1,623	363	379	600	475	610	290	657	241	292	127	89	77	7,348	812	11%
1993	1,580	290	984	3,417	624	475	280	434	580	361	329	235	155	102	122	9,968	927	9%
1994	914	448	431	1,280	3,196	625	155	163	155	286	166	249	87	76	130	8,362	973	12%
1995	1,035	65	304	1,292	1,785	2,931	1,056	236	183	157	216	101	158	58	80	9,658	1,803	19%
1996	1,385	331	126	353	829	1,087	1,075	337	88	82	68	129	35	74	80	6,079	498	8%
1997	2,254	268	149	172	2,317	1,026	679	817	130	46	55	68	77	28	101	8,186	1,111	14%
1998	582	557	221	170	374	2,124	597	392	293	75	25	10	24	22	52	5,518	634	11%
1999	779	649	579	688	402	669	1,967	547	312	261	109	37	17	23	71	7,111	834	12%
2000	889	270	258	1,160	1,168	726	553	2,035	741	407	158	124	24	13	71	8,596	1,052	12%
2001	1,421	777	405	414	1,010	1,158	447	244	777	574	207	172	60	25	64	7,756	695	9%
2002	614	311	541	788	949	1,229	681	349	431	872	420	192	114	34	35	7,559	763	10%
2003	298	122	431	1,464	1,473	1,348	1,604	897	375	547	1,158	485	184	66	47	10,501	1,887	18%
2004	293	212	121	946	1,103	798	465	512	241	153	151	283	120	28	22	5,449	501	9%
2005	336	119	155	837	2,227	1,643	876	385	296	236	60	121	214	79	79	7,663	754	10%
2006	780	35	36	298	797	1,026	681	318	186	162	81	46	71	93	92	4,702	427	9%
2007	2,113	30	72	321	1,052	1,252	927	664	287	122	117	105	46	61	109	7,279	643	9%
Avg	1,087	417	615	1,120	1,648	1,443	912	585	377	289	188	136	73	40	52	8,984	1,025	11%

Table 1.12. Number of (non-YOY) hauls and sample sizes for EBS pollock collected by the EIT 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	21,506	4,966	1,770
	East of 170 W	25		1,550	612
	West of 170 W	51		3,416	1,158
	Navarin (Russia)	19		1,017	
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	-
	East of 170 W	23	5,492	871	-
	West of 170 W	46	14,863	1,961	-
	Navarin (Russia)	4	1,407	398	-

Table 1.13. EIT survey estimates of EBS pollock abundance-at-age (millions), 1979-2007. *NOTE: 2007 age specific values are preliminary since they are derived from the bottom-trawl age-length key.*

	Age										
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**Total**
1979	69,110	41,132	3,884	413	534	128	30	4	28	161	115,424
1982	108	3,401	4,108	7,637	1,790	283	141	178	90	177	17,913
1985	2,076	929	8,149	898	2,186	1,510	1,127	130	21	15	17,041
1988	11	1,112	3,586	3,864	739	1,882	403	151	130	414	12,291
1991	639	5,942	967	215	224	133	120	39	37	53	8,369
1994	453	3,906	1,127	1,670	1,908	293	69	67	30	59	9,582
1996	972	446	520	2,686	821	509	434	85	17	34	6,525
1997	12,384	2,743	385	491	1,918	384	205	143	33	18	18,703
1999	112	1,588	3,597	1,684	583	274	1,169	400	105	90	9,601
2000	258	1,272	1,185	2,480	900	244	234	725	190	141	7,630
2002	561	4,188	3,841	1,295	685	593	288	100	132	439	12,122
2004	16	275	1,189	2,929	1,444	417	202	193	68	101	6,834
2006	456	209	282	610	695	552	320	110	53	110	3,396
2007	*5,699*	*880*	*457*	*337*	*771*	*590*	*331*	*178*	*67*	*74*	*9,385*

Table 1.14. Pollock biomass estimates by area from summer echo integration-trawl surveys on the U.S. EEZ portion of the Bering Sea shelf from near-surface to 3 m off bottom, 1994-2007. Survey-derived relative sampling errors for the biomass estimates are provided in the last column.

			Biomass in millions of t (percent of total)				**Relative**
Year	**Survey Dates**	**Area** (nmi)^2	**SCA**	**E170-SCA**	**W170**	**Total Biomass (t)**	**estimation error**
1994	9 Jul-19 Aug	78,251	0.312 (10.8%)	0.399 (13.8%)	2.176 (75.4%)	2.886	0.047
1996	20 Jul-30 Aug	93,810	0.215 (9.3%)	0.269 (11.7%)	1.826 (79.0%)	2.311	0.039
1997	17 Jul-4 Sept	102,770	0.246 (9.5%)	0.527 (20.3%)	1.818 (70.2%)	2.591	0.037
1999	7 Jun-5 Aug	103,670	0.299 (9.1%)	0.579 (17.6%)	2.408 (73.2%)	3.290	0.055
2000	7 Jun-2 Aug	106,140	0.393 (12.9%)	0.498 (16.3%)	2.158 (70.8%)	3.049	0.032
2002	4 Jun -30 Jul	99,526	0.647 (17.9%)	0.797 (22.0%)	2.178 (60.1%)	3.622	0.031
2004	4 Jun -29 Jul	99,659	0.498 (15.1%)	0.516 (15.6%)	2.293 (69.3%)	3.307	0.037
2006	3 Jun -25 Jul	89,550	0.131 (8.4%)	0.254 (16.3%)	1.175 (75.3%)	1.560	0.039
2007	2 Jun -30 Jul	92,944	0.084 (4.5%)	0.168 (8.9%)	1.627 (86.6%)	1.878	

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

Table 1.15. Fishery annual average weights-at-age (kg) as estimated from NMFS observer data. These values are used in the model for computing the predicted fishery catch (in weight) and for computing biomass levels for EBS pollock. *NOTE: 2007 weight-at-age is treated as the three-year average of values from 2004-2006.*

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1964-1990	0.007	0.170	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	0.007	0.170	0.288	0.476	0.604	0.723	0.844	0.883	1.001	1.126	1.121	1.240	1.229	1.272	1.227
1992	0.007	0.170	0.396	0.464	0.646	0.712	0.814	0.982	1.020	1.221	1.231	1.265	1.170	1.342	1.428
1993	0.007	0.170	0.495	0.610	0.652	0.769	0.932	1.051	1.201	1.237	1.408	1.536	1.606	1.671	1.614
1994	0.007	0.170	0.393	0.647	0.729	0.746	0.705	1.012	1.382	1.334	1.341	1.434	1.383	1.314	1.401
1995	0.007	0.170	0.375	0.500	0.729	0.842	0.855	0.970	1.215	1.329	1.422	1.495	1.390	1.243	1.365
1996	0.007	0.170	0.318	0.413	0.691	0.794	0.951	0.951	1.022	1.092	1.408	1.503	1.519	1.745	1.551
1997	0.007	0.170	0.311	0.466	0.554	0.747	0.892	1.075	1.089	1.240	1.424	1.471	1.713	1.458	1.416
1998	0.007	0.170	0.371	0.588	0.624	0.622	0.775	1.033	1.177	1.241	1.295	1.413	1.546	1.546	1.620
1999	0.007	0.170	0.397	0.501	0.638	0.703	0.728	0.905	1.045	1.275	1.211	1.418	1.277	1.152	1.314
2000	0.007	0.170	0.352	0.524	0.629	0.731	0.782	0.803	0.971	1.018	1.274	1.317	1.316	1.725	1.825
2001	0.007	0.170	0.322	0.497	0.669	0.786	0.964	0.994	1.059	1.134	1.327	1.451	1.581	1.463	1.660
2002	0.007	0.170	0.379	0.507	0.669	0.795	0.908	1.025	1.115	1.097	1.297	1.434	1.611	1.323	1.631
2003	0.007	0.170	0.485	0.548	0.649	0.767	0.862	0.953	1.085	1.221	1.213	1.223	1.444	1.342	1.759
2004	0.007	0.170	0.404	0.581	0.640	0.770	0.891	0.929	1.027	1.208	1.167	1.188	1.373	1.303	1.254
2005	0.007	0.170	0.351	0.507	0.640	0.740	0.878	0.947	1.062	1.104	1.273	1.313	1.316	1.163	1.423
2006	0.007	0.170	0.304	0.448	0.603	0.754	0.855	0.958	1.056	1.128	1.219	1.315	1.315	1.381	1.459
2007	*0.007*	*0.170*	*0.353*	*0.512*	*0.627*	*0.754*	*0.875*	*0.945*	*1.048*	*1.147*	*1.220*	*1.272*	*1.334*	*1.282*	*1.379*

Table 1.16. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and EIT surveys, 1964-2007. The 2007 EIT sample size was down-weighted of the value since the BTS age-length key was used.

Year	Fishery	Year	BTS	EIT
1964-1977	10	1979 and 1982	-	6
1978-1990	50			
1991	179			
1992	207	1982-2007	100	55
1993	281			(average)
1994	111			
1995	142			
1996	154			
1997	265			
1998	278			
1999	470			
2000	467			
2001	301			
2002	449			
2003	402			
2004	343			
2005	412			
2006	339			

Table 1.17. Summary model results showing the stock condition for EBS pollock. Values in parentheses are coefficients of variation (CV's) of values immediately above.

Biomass (thousands of t)	
Year 2008 spawning biomass*	**1,380**
(CV)	**(20%)**
2007 spawning biomass	**1,946**
B_{msy}	**1,876**
(CV)	**(22%)**
$B_{40\%}$	**2,627**
(CV)	**(5%)**
$B_{35\%}$	2,299
B_0 (stock-recruitment curve)	**5,013**
2008 Percent of B_{msy} spawning biomass	**72%**
2008 Percent of $B_{40\%}$ spawning biomass	**57%**
Ratio of B_{2007} over B_{2007} under no fishing since 1978	**48%**
2009 Fishable biomass	**3,730**
Ratio B2009/B2008 (fishable biomass)	**78%**
Recruitment (millions of pollock at age 1)	
Steepness parameter (*h*)	0.68
Average recruitment (all yrs)	22,032
(CV)	64%
Average recruitment (since 1978)	23,690
(CV since 1978)	68%
2000 year class	41,060
(CV 2000 year class)	(8%)
Natural Mortality (age 3 and older)	**0.3**

Table 1.18. Summary results of Tier 1 yield projections for EBS pollock.

Yield projections	
B_{msy} (fishable biomass)	5,467
2008 "fishable" biomass (GM)	4,767
MSYR (HM)	0.341
2008 MSYR yield (Tier 1 ABC)	1,170
MSYR (AM)	0.422
2008 MSYR OFL	1,443

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

*Assuming 2008 catch will be 1,170,00 t

Table 1.19 Estimates of numbers at age for the EBS pollock stock as estimated in 2007 (millions).

	1	2	3	4	5	6	7	8	9	10+	Total
1964	2,991	3,665	2,065	508	233	357	145	61	34	174	10,232
1965	20,529	1,214	2,306	1,436	307	142	222	93	40	142	26,431
1966	13,053	8,335	764	1,605	870	187	88	143	61	111	25,218
1967	31,519	5,301	5,226	518	990	545	121	58	94	93	44,464
1968	28,971	12,790	3,280	3,299	276	543	314	71	35	84	49,662
1969	29,855	11,757	7,891	2,081	1,803	157	320	188	43	87	54,183
1970	21,139	12,117	7,263	5,034	1,149	1,038	94	193	115	67	48,208
1971	8,239	8,576	7,326	4,362	2,935	647	598	53	110	49	32,895
1972	10,242	3,341	5,111	4,154	2,381	1,531	348	317	28	57	27,509
1973	27,727	4,153	1,923	2,663	2,074	1,200	785	178	163	58	40,925
1974	20,578	11,235	2,317	900	1,178	929	549	360	82	32	38,160
1975	18,121	8,338	6,025	904	367	492	398	236	153	44	35,077
1976	13,429	7,348	4,632	2,676	416	172	236	191	112	36	29,247
1977	13,980	5,449	4,249	2,377	1,216	194	83	115	93	52	27,808
1978	28,035	5,675	3,211	2,340	1,186	620	101	44	61	56	41,328
1979	64,073	11,381	3,382	1,768	1,202	574	309	51	22	52	82,813
1980	25,898	26,014	6,816	1,901	932	599	294	160	26	42	62,682
1981	29,690	10,521	16,220	4,392	1,015	451	288	145	79	26	62,827
1982	15,979	12,065	6,615	11,015	2,652	576	255	165	83	22	49,427
1983	54,323	6,495	7,647	4,731	7,218	1,628	341	153	99	40	82,673
1984	13,136	22,081	4,122	5,511	3,183	4,612	1,011	214	96	55	54,020
1985	35,237	5,340	14,020	2,964	3,791	2,039	2,843	620	131	69	67,054
1986	13,056	14,324	3,391	10,088	2,042	2,435	1,261	1,750	380	75	48,801
1987	8,338	5,307	9,089	2,447	6,944	1,357	1,517	773	1,091	90	36,954
1988	4,783	3,390	3,373	6,609	1,720	4,760	888	981	506	200	27,210
1989	10,161	1,945	2,151	2,411	4,523	1,122	3,042	529	606	551	27,041
1990	50,836	4,131	1,234	1,538	1,649	2,947	716	1,809	326	526	65,713
1991	26,352	20,666	2,617	887	983	991	1,706	382	1,024	511	56,118
1992	22,593	10,712	13,086	1,878	562	584	566	893	213	383	51,469
1993	51,772	9,184	6,798	9,096	1,099	342	313	282	430	475	79,791
1994	14,648	21,047	5,837	4,828	5,763	715	205	178	157	336	53,713
1995	9,990	5,955	13,383	4,269	3,329	3,411	364	112	102	350	41,265
1996	24,079	4,061	3,789	9,815	2,991	2,071	1,889	213	68	281	49,258
1997	32,160	9,789	2,574	2,752	6,941	2,033	1,239	991	116	204	58,801
1998	14,840	13,074	6,207	1,873	1,953	4,749	1,237	668	553	146	45,300
1999	16,669	6,033	8,310	4,412	1,306	1,311	2,949	740	392	132	42,254
2000	26,483	6,777	3,836	5,926	3,092	884	826	1,796	443	289	50,351
2001	41,061	10,767	4,314	2,786	4,055	1,974	537	479	1,028	330	67,330
2002	21,082	16,693	6,852	3,119	1,872	2,504	1,148	295	259	362	54,187
2003	11,623	8,571	10,613	4,872	2,135	1,137	1,321	609	156	574	41,611
2004	4,215	4,725	5,448	7,523	3,315	1,277	585	683	314	431	28,515
2005	4,446	1,714	3,007	3,949	4,888	1,988	707	319	376	321	21,715
2006	11,468	1,808	1,091	2,178	2,556	2,912	1,091	383	174	308	23,969
2007	42,147	4,662	1,150	780	1,390	1,403	1,630	542	192	298	54,194
Median	20,553	7,841	4,473	2,769	1,838	1,080	558	259	123	122	46,754
Average	22,490	8,830	5,467	3,663	2,329	1,412	806	437	242	196	45,873

Table 1.20. Estimated catch-at-age of EBS pollock (millions).

Year	1	2	3	4	5	6	7	8	9	10+	Total
1964	2.6	38.9	109.3	81.4	36.1	49.2	17.1	6.2	3.0	15.7	359.6
1965	17.8	12.7	120.7	227.5	47.1	19.3	25.9	9.3	3.5	12.1	496.2
1966	9.4	112.2	56.5	233.7	116.4	21.3	9.1	13.2	5.1	10.5	587.4
1967	40.9	127.1	670.0	126.5	223.4	105.7	21.2	9.2	13.8	17.8	1,355.7
1968	35.2	333.3	408.4	753.7	55.2	96.2	52.2	11.2	5.3	21.0	1,771.8
1969	35.0	295.7	950.4	460.8	349.5	27.0	51.6	28.7	6.3	15.5	2,220.4
1970	29.4	505.9	1,193.9	932.4	240.5	200.6	18.9	38.8	22.8	23.9	3,207.0
1971	14.6	453.3	1,494.9	999.3	756.5	154.4	148.6	13.2	27.0	32.6	4,094.4
1972	17.5	262.4	1,320.7	1,182.1	663.9	411.4	93.2	83.9	7.6	32.6	4,075.2
1973	61.9	420.2	619.1	939.2	717.2	400.9	261.4	58.8	54.8	25.9	3,559.4
1974	46.0	1,446.9	963.3	355.0	450.0	343.1	201.7	134.8	31.7	41.6	4,014.1
1975	32.3	869.5	2,110.9	299.3	117.4	152.1	122.1	74.1	49.3	25.7	3,852.7
1976	17.8	553.1	1,240.7	905.0	134.7	52.5	70.1	56.8	33.8	32.0	3,096.4
1977	15.0	334.2	948.9	676.6	330.9	49.6	20.7	28.6	23.5	26.6	2,454.5
1978	27.6	299.1	717.8	625.1	359.4	176.5	28.5	12.9	17.9	30.5	2,295.4
1979	58.6	558.8	709.3	443.9	343.0	153.8	81.6	14.2	6.0	22.3	2,391.5
1980	14.6	463.7	768.5	462.6	282.5	183.7	86.7	46.2	7.4	15.4	2,331.1
1981	10.5	117.6	1,170.7	705.8	206.4	92.8	56.8	27.9	15.2	7.5	2,411.2
1982	3.1	57.9	197.6	1,102.3	394.9	100.2	42.4	27.6	14.1	12.0	1,952.1
1983	8.3	24.5	180.2	376.8	860.8	227.5	45.6	20.5	13.4	13.0	1,770.6
1984	1.7	74.5	104.2	340.8	373.0	671.1	151.2	32.7	15.5	20.9	1,785.5
1985	4.4	17.7	348.0	180.1	436.8	291.8	418.1	93.2	20.8	22.5	1,833.3
1986	1.3	55.0	75.4	618.6	181.9	336.0	189.2	240.7	64.1	27.6	1,789.9
1987	0.6	14.6	145.1	108.5	449.1	137.1	167.0	77.9	135.5	40.6	1,275.9
1988	0.4	12.5	101.8	436.6	178.2	567.5	151.1	141.2	72.2	129.3	1,790.8
1989	0.8	7.2	65.4	160.5	471.9	134.7	521.1	76.7	87.1	133.3	1,658.9
1990	4.4	21.9	31.4	183.2	269.9	560.5	174.8	371.0	72.3	184.1	1,873.5
1991	2.4	115.6	70.2	111.3	169.1	197.9	436.3	82.2	238.0	151.2	1,574.1
1992	2.1	41.4	698.2	342.8	87.3	140.4	161.7	272.5	64.8	259.9	2,071.0
1993	3.2	23.6	243.2	1,142.7	116.7	57.4	63.1	60.9	92.6	107.8	1,911.2
1994	0.7	46.8	64.7	288.7	1,006.4	194.4	46.4	34.7	27.3	90.2	1,800.2
1995	0.4	10.3	115.6	200.2	463.0	749.6	66.3	17.4	14.2	54.5	1,691.6
1996	1.0	19.7	63.4	386.0	213.6	345.7	479.8	49.0	14.6	60.2	1,633.1
1997	1.3	43.8	39.8	100.1	459.1	315.7	294.2	212.7	23.2	39.3	1,529.2
1998	0.5	33.9	217.9	94.7	159.2	666.2	206.7	120.4	95.8	29.7	1,625.1
1999	0.5	14.4	268.3	205.4	98.1	170.0	456.3	123.6	62.9	60.4	1,459.8
2000	0.8	8.7	65.1	392.2	371.2	137.6	155.9	354.4	69.4	69.8	1,625.2
2001	1.5	16.9	89.3	223.5	586.0	368.2	121.0	112.6	193.1	95.5	1,807.9
2002	0.9	38.5	238.3	205.4	293.3	627.5	284.4	73.7	58.3	159.9	1,980.1
2003	0.5	21.3	396.6	344.2	357.4	303.1	348.0	161.8	37.4	117.6	2,087.7
2004	0.1	7.3	101.3	801.8	548.6	280.2	134.0	152.4	60.7	70.6	2,157.1
2005	0.2	2.7	57.6	433.0	831.4	447.8	166.4	73.1	74.8	73.9	2,160.8
2006	0.5	3.7	32.5	261.5	576.4	618.8	313.5	107.3	44.1	105.3	2,063.6
2007	2.2	11.0	39.5	106.9	354.2	337.1	525.7	170.8	54.9	87.0	1,689.3
Median	2.9	42.6	207.7	349.6	346.2	196.2	141.3	67.0	29.5	32.6	1,853.4
Average	12.1	180.7	446.0	444.5	357.7	265.3	170.2	89.3	46.7	59.7	2,072.1

Table 1.21. Estimated EBS pollock age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2007. 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	1,717	510	2,991	1986	11,773	4,016	13,056
1965	2,141	609	20,529	1987	12,401	4,158	8,338
1966	2,037	680	13,053	1988	11,617	4,139	4,783
1967	3,206	815	31,519	1989	9,875	3,718	10,161
1968	3,558	985	28,971	1990	7,847	2,994	50,836
1969	5,118	1,272	29,855	1991	6,097	2,229	26,352
1970	6,368	1,664	21,139	1992	9,557	2,344	22,593
1971	7,164	1,945	8,239	1993	11,832	3,238	51,772
1972	6,666	1,918	10,242	1994	11,485	3,562	14,648
1973	4,942	1,550	27,727	1995	13,615	3,828	9,990
1974	3,475	1,059	20,578	1996	11,537	3,853	24,079
1975	3,604	856	18,121	1997	10,104	3,670	32,160
1976	3,584	871	13,429	1998	10,178	3,383	14,840
1977	3,602	922	13,980	1999	11,081	3,397	16,669
1978	3,476	950	28,035	2000	10,201	3,417	26,483
1979	3,363	933	64,073	2001	9,898	3,427	41,061
1980	4,384	1,067	25,898	2002	10,224	3,226	21,082
1981	8,307	1,763	29,690	2003	12,865	3,472	11,623
1982	9,439	2,666	15,979	2004	11,784	3,613	4,215
1983	10,493	3,268	54,323	2005	9,598	3,264	4,446
1984	10,200	3,476	13,136	2006	7,178	2,617	11,468
1985	12,531	3,757	35,237	2007	5,363	1,946	42,147
				2008	4,357	1,398	
				2009	6,658	1,533	

Table 1.22. 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 2000-2006 assessments for EBS pollock. NOTE: see Ianelli et al. (2001) for a discussion on the interpretation of age-3+ biomass estimates.

	Current		2006		2005		2004		2003		2002		2001		2000	
	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV
1964	1,717	23%	1,810	23%	1,779	23%	1,789	23%	1,822	23%	1,784	23%	1,726	23%	751	18%
1965	2,141	21%	2,231	21%	2,222	21%	2,272	20%	2,312	20%	2,266	20%	2,196	20%	976	18%
1966	2,037	22%	2,252	21%	2,288	21%	2,326	20%	2,372	20%	2,324	20%	2,251	21%	1,001	20%
1967	3,206	18%	3,518	17%	3,483	17%	3,514	17%	3,575	17%	3,511	17%	3,420	17%	1,957	17%
1968	3,558	19%	3,881	17%	3,881	17%	3,976	17%	4,049	17%	3,976	17%	3,876	17%	2,312	18%
1969	5,118	17%	5,058	16%	5,323	16%	5,258	16%	5,340	16%	5,252	16%	5,137	16%	3,379	15%
1970	6,368	15%	5,929	16%	6,447	15%	6,211	15%	6,296	15%	6,201	15%	6,079	15%	3,998	13%
1971	7,164	13%	6,617	13%	7,145	13%	6,714	14%	6,797	14%	6,702	14%	6,580	14%	4,372	11%
1972	6,666	13%	6,265	13%	6,692	13%	6,204	13%	6,282	13%	6,194	13%	6,078	14%	3,984	10%
1973	4,942	16%	4,751	16%	5,055	15%	4,632	16%	4,705	16%	4,626	16%	4,520	16%	2,873	13%
1974	3,475	20%	3,460	19%	3,635	19%	3,288	19%	3,356	19%	3,287	19%	3,193	20%	1,648	21%
1975	3,604	14%	3,585	13%	3,666	14%	3,440	14%	3,489	14%	3,436	14%	3,366	13%	2,536	12%
1976	3,584	11%	3,577	11%	3,614	11%	3,497	11%	3,538	11%	3,492	11%	3,434	11%	2,694	9%
1977	3,602	10%	3,582	10%	3,548	10%	3,504	10%	3,541	10%	3,496	10%	3,444	10%	2,701	7%
1978	3,476	9%	3,438	10%	3,361	10%	3,385	10%	3,422	10%	3,375	10%	3,327	10%	2,608	7%
1979	3,363	9%	3,323	9%	3,273	10%	3,341	10%	3,380	10%	3,329	10%	3,280	10%	2,640	8%
1980	4,384	8%	4,320	8%	4,373	8%	4,409	8%	4,462	8%	4,385	8%	4,322	8%	3,723	8%
1981	8,307	6%	8,364	7%	8,289	7%	8,301	7%	8,414	7%	8,239	7%	8,127	7%	7,834	6%
1982	9,439	6%	9,476	6%	9,446	7%	9,472	7%	9,614	7%	9,388	7%	9,261	7%	9,021	7%
1983	10,493	6%	10,443	6%	10,536	7%	10,552	7%	10,728	7%	10,441	7%	10,298	7%	9,958	6%
1984	10,200	6%	10,088	6%	10,244	7%	10,263	7%	10,456	7%	10,143	7%	10,000	7%	9,518	7%
1985	12,531	5%	12,285	5%	12,435	6%	12,492	6%	12,771	6%	12,344	6%	12,181	6%	11,182	5%
1986	11,773	5%	11,486	5%	11,609	6%	11,677	6%	11,973	6%	11,538	6%	11,381	6%	10,277	5%
1987	12,401	4%	12,077	5%	12,106	5%	12,226	5%	12,596	5%	12,116	5%	11,951	5%	10,636	5%
1988	11,617	4%	11,330	5%	11,153	5%	11,243	5%	11,633	5%	11,317	5%	11,159	5%	9,910	4%
1989	9,875	4%	9,584	5%	9,384	5%	9,466	5%	9,850	5%	9,540	5%	9,394	5%	8,251	5%
1990	7,847	5%	7,603	5%	7,392	6%	7,454	6%	7,811	6%	7,524	6%	7,393	6%	6,473	5%
1991	6,097	5%	5,929	6%	5,454	6%	5,637	7%	5,977	7%	5,708	7%	5,582	6%	4,859	6%
1992	9,557	4%	9,270	5%	8,905	5%	9,120	5%	9,614	5%	9,227	5%	8,898	5%	7,920	5%
1993	11,832	4%	11,795	4%	11,669	5%	11,721	6%	12,363	6%	12,110	5%	11,503	5%	10,233	5%
1994	11,485	4%	11,407	5%	11,000	5%	10,998	6%	11,696	6%	11,358	6%	10,590	6%	9,285	5%
1995	13,615	4%	13,658	4%	13,605	6%	13,554	6%	14,474	6%	13,848	6%	12,617	7%	10,267	6%
1996	11,537	4%	11,480	5%	11,826	6%	11,772	7%	12,630	7%	11,988	7%	10,752	7%	8,556	7%
1997	10,104	5%	10,056	5%	9,966	6%	9,949	8%	10,775	8%	10,142	8%	8,984	8%	7,057	9%
1998	10,178	5%	9,973	5%	9,915	7%	9,943	8%	11,110	8%	10,466	9%	9,335	10%	7,448	11%
1999	11,081	4%	10,872	5%	10,998	6%	11,093	10%	13,339	10%	12,712	11%	12,593	14%	10,772	15%
2000	10,201	4%	10,052	5%	9,947	7%	10,036	12%	12,498	12%	11,807	12%	11,680	17%	10,490	17%
2001	9,898	5%	9,800	6%	9,566	8%	9,675	14%	12,394	14%	11,511	14%	11,145	20%		
2002	10,224	5%	10,197	7%	9,824	9%	9,899	16%	12,930	16%	11,118	17%				
2003	12,865	6%	13,320	10%	13,073	13%	12,239	19%	12,688	19%						
2004	11,784	7%	12,055	12%	10,972	15%	9,894	21%	11,217	21%						
2005	9,598	8%	9,759	14%	9,277	18%	8,573									
2006	7,178	10%	7,950	17%	8,232	21%										
2007	5,363	14%	6,361	21%												
2008	4,357	20%														

Table 1.23 Projections of catch, fishing mortality, and spawning biomass (thousands of tons) for EBS pollock for the 7 scenarios. Note that the values for $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 6,569; **2,627**; and 2,299 thousand t, respectively.

Catch (1,000 t)	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2007	1,340	1,340	1,340	1,340	1,340	1,340	1,340
2008	555	1,000	454	457	0	677	555
2009	650	1,200	454	457	0	748	650
2010	1,186	1,200	637	641	0	1,353	1,445
2011	1,558	1,200	854	859	0	1,752	1,786
2012	1,634	1,200	976	981	0	1,785	1,797
2013	1,711	1,200	1,098	1,103	0	1,832	1,835
2014	1,687	1,200	1,137	1,142	0	1,788	1,789
2015	1,657	1,200	1,146	1,151	0	1,747	1,748
2016	1,637	1,200	1,146	1,151	0	1,723	1,723
2017	1,634	1,200	1,149	1,153	0	1,725	1,725
2018	1,642	1,200	1,155	1,160	0	1,738	1,738
2019	1,652	1,200	1,163	1,167	0	1,748	1,748
2020	1,648	1,200	1,165	1,169	0	1,743	1,743
Fishing M.	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2007	0.455	0.455	0.455	0.455	0.455	0.455	0.455
2008	0.258	0.510	0.207	0.209	0.000	0.323	0.258
2009	0.316	0.758	0.207	0.209	0.000	0.385	0.316
2010	0.431	0.547	0.207	0.209	0.000	0.523	0.539
2011	0.455	0.415	0.207	0.209	0.000	0.554	0.558
2012	0.451	0.381	0.207	0.209	0.000	0.545	0.547
2013	0.449	0.343	0.207	0.209	0.000	0.542	0.542
2014	0.445	0.328	0.207	0.209	0.000	0.535	0.535
2015	0.444	0.319	0.207	0.209	0.000	0.532	0.532
2016	0.444	0.313	0.207	0.209	0.000	0.530	0.531
2017	0.444	0.306	0.207	0.209	0.000	0.531	0.531
2018	0.444	0.294	0.207	0.209	0.000	0.532	0.532
2019	0.444	0.286	0.207	0.209	0.000	0.532	0.532
2020	0.444	0.283	0.207	0.209	0.000	0.532	0.532
Spawning Biomass (1,000 t)	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2007	1,945	1,945	1,945	1,945	1,945	1,945	1,945
2008	1,462	1,396	1,476	1,475	1,534	1,445	1,462
2009	1,758	1,502	1,824	1,823	2,066	1,695	1,758
2010	2,374	1,999	2,552	2,550	2,969	2,272	2,342
2011	2,692	2,400	3,105	3,102	3,766	2,528	2,557
2012	2,786	2,698	3,452	3,447	4,412	2,562	2,574
2013	2,818	2,953	3,685	3,679	4,955	2,561	2,565
2014	2,785	3,134	3,783	3,775	5,332	2,515	2,517
2015	2,752	3,267	3,836	3,827	5,636	2,478	2,479
2016	2,740	3,383	3,880	3,871	5,890	2,467	2,468
2017	2,746	3,485	3,918	3,908	6,082	2,475	2,476
2018	2,762	3,579	3,955	3,945	6,236	2,492	2,492
2019	2,769	3,652	3,980	3,970	6,354	2,497	2,497
2020	2,755	3,695	3,978	3,968	6,415	2,482	2,482

Table 1.24 Tier 1b EBS pollock ABC and OFL projections for 2008 and for 2009. **Units are thousands of tons.**

Year		ABC	OFL
2008		1,170	1,443
	Assumed 2008 catch	ABC	OFL
2009	1,170	976	1,204
2009	1,000	1,073	1,323

Table 1.25 Tier 1 (approximation) mean projections of female spawning biomass for EBS pollock under different assumptions of 2006 year class (as estimated or set to average) and catch scenarios (1.0, 1.2, million t in columns 2-5, and Tier 1 maximum permissible in last two columns with values in parentheses). **Units are thousands of tons.**

Year	As estimated Catch=1.0	Average Catch=1.0	As estimated Catch=1.2	Average Catch=1.2	As estimated (catch)	Average (catch)
2009	1,531	1,321	1,422	1,209	1,529 (976)	1,345 (792)
2010	2,118	1,628	1,948	1,456	2,044 (1,588)	1,671 (1,160)
2011	2,603	2,034	2,365	1,799	2,240 (1,889)	1,954 (1,513)
2012	2,919	2,386	2,619	2,091	2,254 (1,885)	2,116 (1,700)
2013	3,134	2,658	2,783	2,311	2,252 (1,913)	2,195 (1,826)
2014	3,269	2,871	2,884	2,483	2,217 (1,871)	2,200 (1,846)
2015	3,412	3,077	2,998	2,658	2,185 (1,840)	2,180 (1,833)
2016	3,578	3,297	3,141	2,852	2,174 (1,822)	2,172 (1,822)
2017	3,721	3,489	3,265	3,023	2,182 (1,826)	2,181 (1,825)
2018	3,826	3,638	3,357	3,155	2,197 (1,834)	2,197 (1,833)
2019	3,905	3,751	3,425	3,257	2,203 (1,844)	2,203 (1,843)
2020	3,979	3,857	3,493	3,355	2,189 (1,834)	2,189 (1,834)

Table 1.26. 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 limited, indication of recent declines (especially in summer 2006)	Growing concern Scarcity in inner and middle domain
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	No concern (dealt with in model)
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 1.27 Bycatch estimates (t) of non-target species caught in the BSAI directed pollock fishery, 1997-2002 based on observer data, 2003-2006 based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska).

	1997	1998	1999	2000	2001	2002		2003	2004	2005	2006
Jellyfish	6,632	6,129	6,176	9,361	3,095	1,530	Jellyfish	5,644	6,040	5,183	2,649
Squid	1,487	1,210	474	379	1,776	1,708	Squid	1,151	855	1,041	880
Skates	348	406	376	598	628	870	Skate	452	673	718	1,251
Misc Fish	207	134	156	236	156	134	Misc fish	101	77	154	141
Sculpins	109	188	67	185	199	199	Large Sculpins	42.6	116	137	148
Sleeper shark	105	74	77	104	206	149	Shark	81.8	107	84	194
Smelts	19.5	30.2	38.7	48.7	72.5	15.3	Sea star	89.4	6.77	9.22	11.05
Grenadiers	19.7	34.9	79.4	33.2	11.6	6.5	Other Sculpins	59.2	15.5	10.8	22.67
Salmon shark	6.6	15.2	24.7	19.5	22.5	27.5	Grenadier	20.4	9.40	8.99	15.73
Starfish	6.5	57.7	6.8	6.2	12.8	17.4	Eulachon	2.49	18.8	8.98	87.37
Shark	15.6	45.4	10.3	0.1	2.3	2.3	Other osmerids	7.51	1.97	3.38	4.99
Benthic inverts.	2.5	26.3	7.4	1.7	0.6	2.1	Snails	1.26	0.94	6.91	0.16
Sponges	0.8	21.0	2.4	0.2	2.1	0.3	Eelpouts	7.03	0.61	1.33	20.60
Octopus	1.0	4.7	0.4	0.8	4.8	8.1	Giant Grenad.	0.31	3.50	5.02	8.80
Crabs	1.0	8.2	0.8	0.5	1.8	1.5	Octopus	1.10	2.58	1.16	1.67
Anemone	2.6	1.8	0.3	5.8	0.1	0.6	Sea pens/whips	0.58	0.95	1.65	1.96
Tunicate	0.1	1.5	1.5	0.4	3.7	3.8	Birds	0.13	0.11	2.42	0.39
Unident. inverts	0.2	2.9	0.1	4.4	0.1	0.2	Anemone	0.40	0.41	0.29	0.60
Echinoderms	0.8	2.6	0.1	0.0	0.2	0.1	Misc crabs	0.75	0.03	0.26	0.08
Seapen/whip	0.1	0.2	0.5	0.9	1.5	2.1	Lanternfish	0.29	0.07	0.63	9.59
Birds	0.2	2.1	0.7	0.2	0.3	0.3	Capelin	0.01	0.32	0.35	1.51
Lanternfish	0.4	0.2	0.0	0.1	0.3	2.7	Urochordate	0.00	0.01	0.49	0.01
Coral	0.0	0.2	0.0	0.1	0.0	0.0	Pandal. shrimp	0.01	0.01	0.43	0.80
Dogfish	0.0	0.1	0.0	0.0	0.1	0.0	Corals Bryozo.	0.01	0.04	0.35	0.01
Sandfish	0.0	0.0	0.1	0.4	0.1	0.3	Brittle star	0.26	0.01	0.02	2.67
Sandlance	0.0	0.0	0.0	0.0	0.0	0.2	Invertebrate	0.04	0.12	0.09	0.14
Shrimp	0.1	0.3	0.3	0.0	0.1	0.2	Stichaeidae	0.08	0.07	0.04	0.01
Sticheidae	0.1	0.0	0.0	0.0	0.3	0.0	Sponge	0.10	0.05	0.03	0.01
							Other	0.09	0.08	0.07	0.22

Table 1.28 Bycatch estimates (t) of target species caught in the BSAI directed pollock fishery, 1997-2006 based on then NMFS Alaska Regional Office reports from observers.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Pacific Cod	8,478	6,560	3,220	3,432	3,879	5,928	5,773	6,192	6,420	6,867
Flathead Sole	2,353	2,118	1,885	2,510	2,199	1,844	1,629	2,019	2,095	2,637
Rock Sole	1,529	779	1,058	2,688	1,673	1,885	1,345	2,301	1,041	1,189
Yellowfin Sole	606	1,762	350	1,466	594	768	150	671	17	148
Arrowtooth Flounder	1,155	1,762	273	979	529	607	550	541	551	951
Pacific Ocean Perch	512	692	121	22	574	545	691	321	503	423
Atka Mackerel	229	91	165	2	41	221	379	369	211	154
Rex Sole	151	68	34	10	103	169	199	322	307	1
Greenland Turbot	125	178	30	52	68	70	38	18	30	64
Alaska Plaice	1	14	3	147	14	50	7	7	4	5
All other	93	41	31	77	118	103	144	130	137	133

Table 1.29 Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997-2006 based on then NMFS Alaska Regional Office reports from observers. Herring and halibut units are in t, all others represent thousands of individuals caught.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Herring	1,089	821	785	482	224	105	895	963	442	229
Red king crab	0.00	5.10	0.00	0.00	0.04	0.01	0.05	0.01	0.00	0.03
Other king crab	0.16	1.83	0.00	0.10	5.14	0.08	0.01	0.01	0.01	0.00
Bairdi crab	6.53	35.59	1.08	0.17	0.09	0.65	0.78	1.20	0.59	0.08
Opilio crab	88.59	45.62	12.78	1.81	2.18	1.67	0.76	0.74	1.93	0.00
Chinook salmon	43.34	49.37	10.19	3.97	30.11	32.22	46.04	53.34	65.34	84.4
Other salmon	61.50	62.28	44.59	56.71	52.84	77.00	190.15	436.18	690.32	295.5
Halibut	127	144	69	80	164	127	97	92	190	102

Table 1.30 Bycatch rates (kg / t of pollock) of target species caught in the BSAI directed pollock fishery by season and area for 2007 based on then NMFS Alaska Regional Office reports from observers.

kg/t of pollock	Winter (A-season)			Summer/fall (B-season)			Total
	NW	SE	A Total	NW	SE	B Total	
Alaska Plaice	0.002	0.001	0.001	0.001	0.004	0.002	0.002
Atka mackerel	0.001	0.178	0.159	0.009	0.105	0.030	0.088
Arrowtooth flounder	0.237	1.923	1.743	0.624	2.546	1.035	1.352
Flounder	0.018	0.242	0.218	0.094	0.628	0.208	0.213
Flathead sole	3.634	3.150	3.202	2.066	3.032	2.273	2.689
Greenland turbot	0.004	0.060	0.054	0.135	0.011	0.109	0.084
Northern rockfish	0.000	0.001	0.001	0.015	0.052	0.023	0.013
Other	1.056	1.103	1.098	1.055	1.858	1.227	1.169
Pacific cod	4.075	3.754	3.789	3.786	4.922	4.028	3.921
Pacific ocean perch	1.413	0.126	0.264	0.304	0.667	0.382	0.329
Rougheye rockfish	0.001	0.006	0.006	0.000	0.001	0.000	0.003
Rockfish	0.000	0.168	0.150	0.001	0.040	0.009	0.072
Rock sole	1.174	0.638	0.695	0.027	0.090	0.041	0.334
Sablefish	0.000	0.022	0.019	0.000	0.004	0.001	0.009
Squid	0.344	1.504	1.380	0.029	1.263	0.293	0.780
Shortraker	0.037	0.147	0.135	0.000	0.000	0.000	0.061
Yellowfin sole	0.036	0.011	0.013	0.000	0.097	0.021	0.017
Total	12.032	13.033	12.926	8.148	15.321	9.681	11.135

Table 1.31. Summary results for EBS pollock. Tonnage 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
Prop. F. Mature	0.000	0.004	0.145	0.321	0.421	0.451	0.474	0.482	0.485	0.500	0.500	0.500	0.500	0.500	0.500
Fish. Select	0.000	0.011	0.145	0.693	1.291	1.388	1.765	1.714	1.498	1.235	1.052	1.052	1.052	1.052	1.052

Tier (2008)	1b
Age 3+ 2008 begin-year biomass	4,357 t
2008 Spawning biomass	**1,380** t
B_{msy}	**1,876** t
$B_{40\%}$	**2,627** t
$B_{35\%}$	2,299 t
$B_{100\%}$	6,569 t
B_{0}	**5,013** t

Yield Considerations		2008	2009*
ABC:	Harmonic Mean F_{msy}	1,170 t	976 t
ABC:	Yield $F_{40\%}$ (Tier 3)	555 t	650 t
OFL:	Arithmetic Mean F_{msy} Yield	1,443 t	1,204 t
OFL:	Yield $F_{35\%}$ (Tier 3)	677 t	794 t
	Full Selection F's		
	F_{msy}	0.919	
	$F_{40\%}$	0.506	
	$F_{35\%}$	0.650	

* Assuming 2008 catches equal 1,170,000 t

Figures

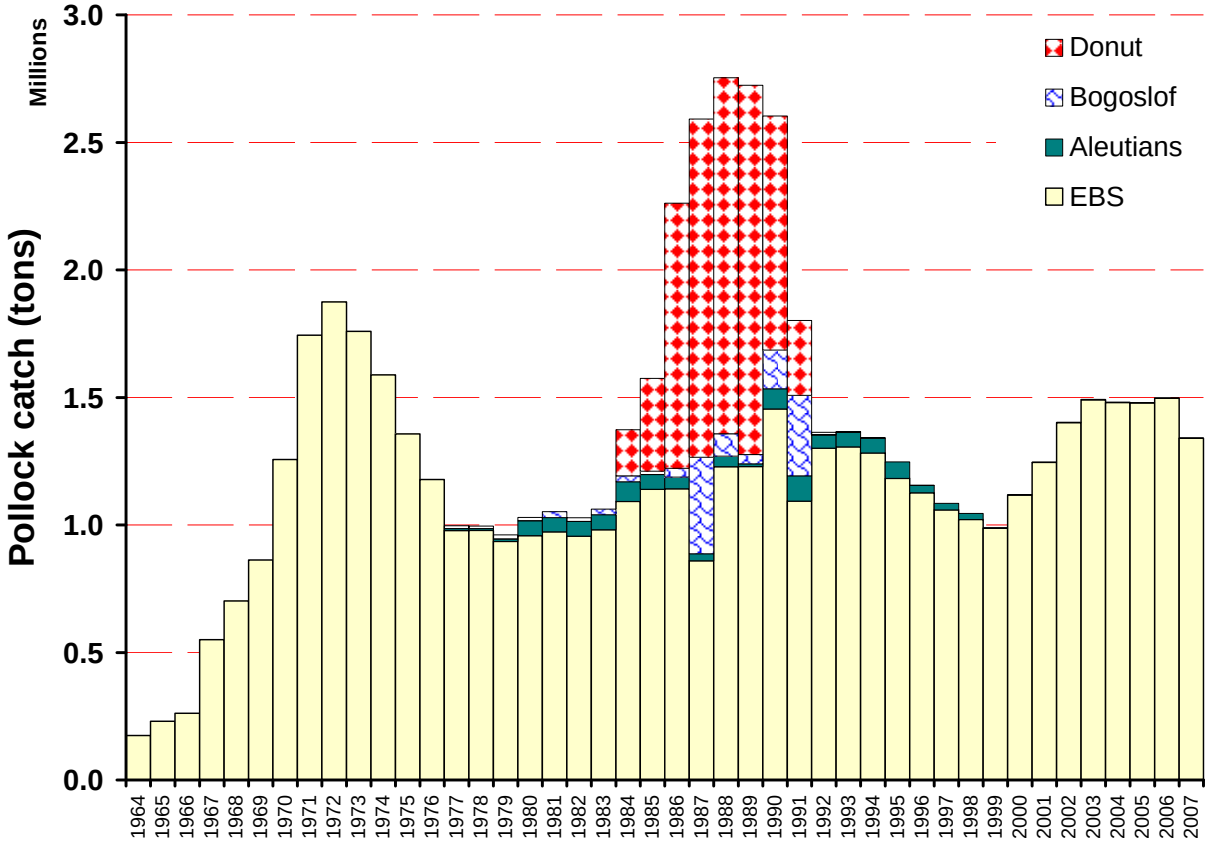


Figure 1.1. Alaska pollock catch estimates from the Eastern Bering Sea, Aleutian Islands, Bogoslof Island, and Donut Hole regions, 1964-2007. The 2007 value is based on expected totals for the year.

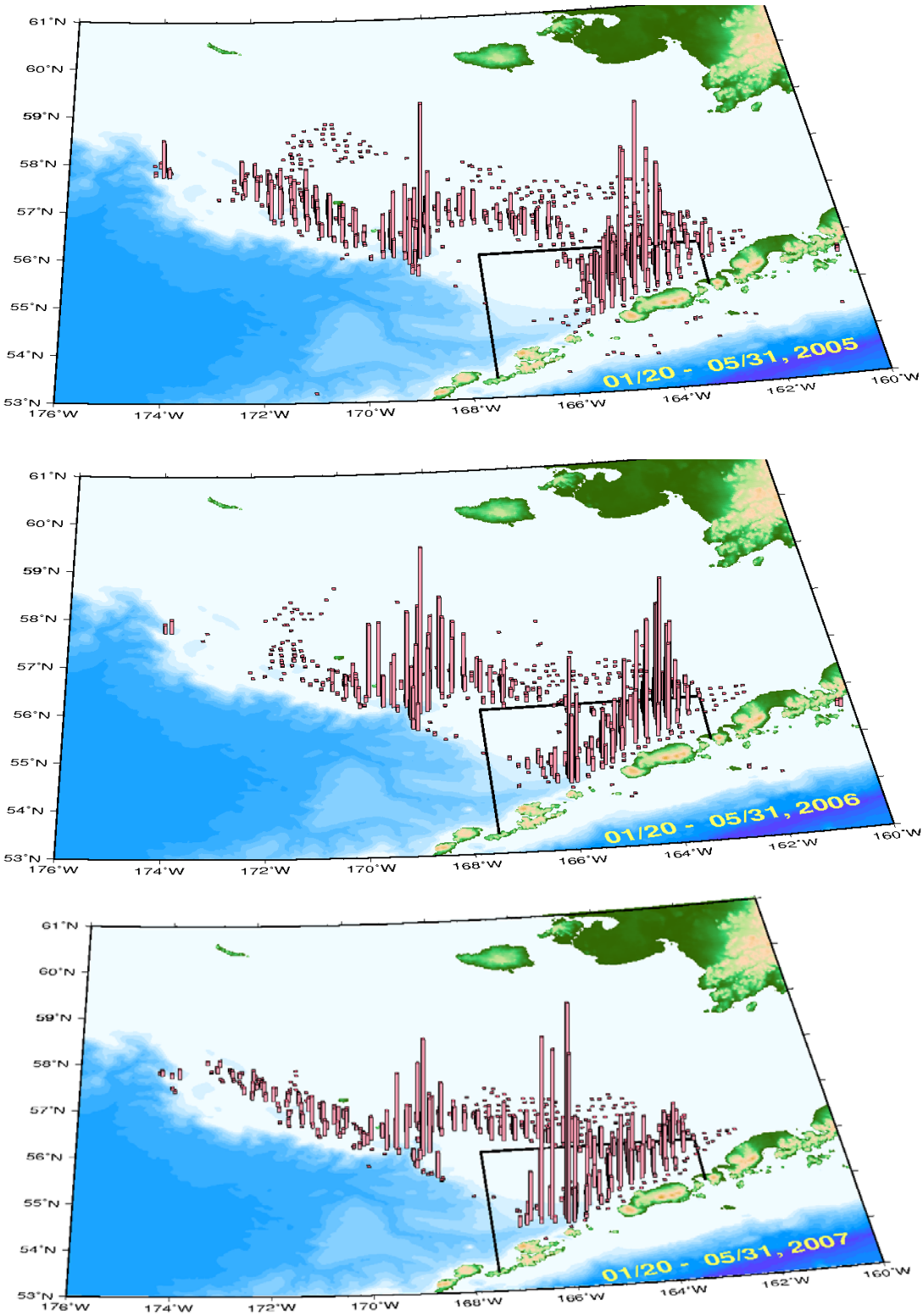


Figure 1.2. Pollock catch distribution in the fishery 2005-2007, January – May on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

Figure 1.3. Estimate of EBS pollock catch numbers by sex for the "A season" (January-June) and for the entire annual fishery, 1991-2006.

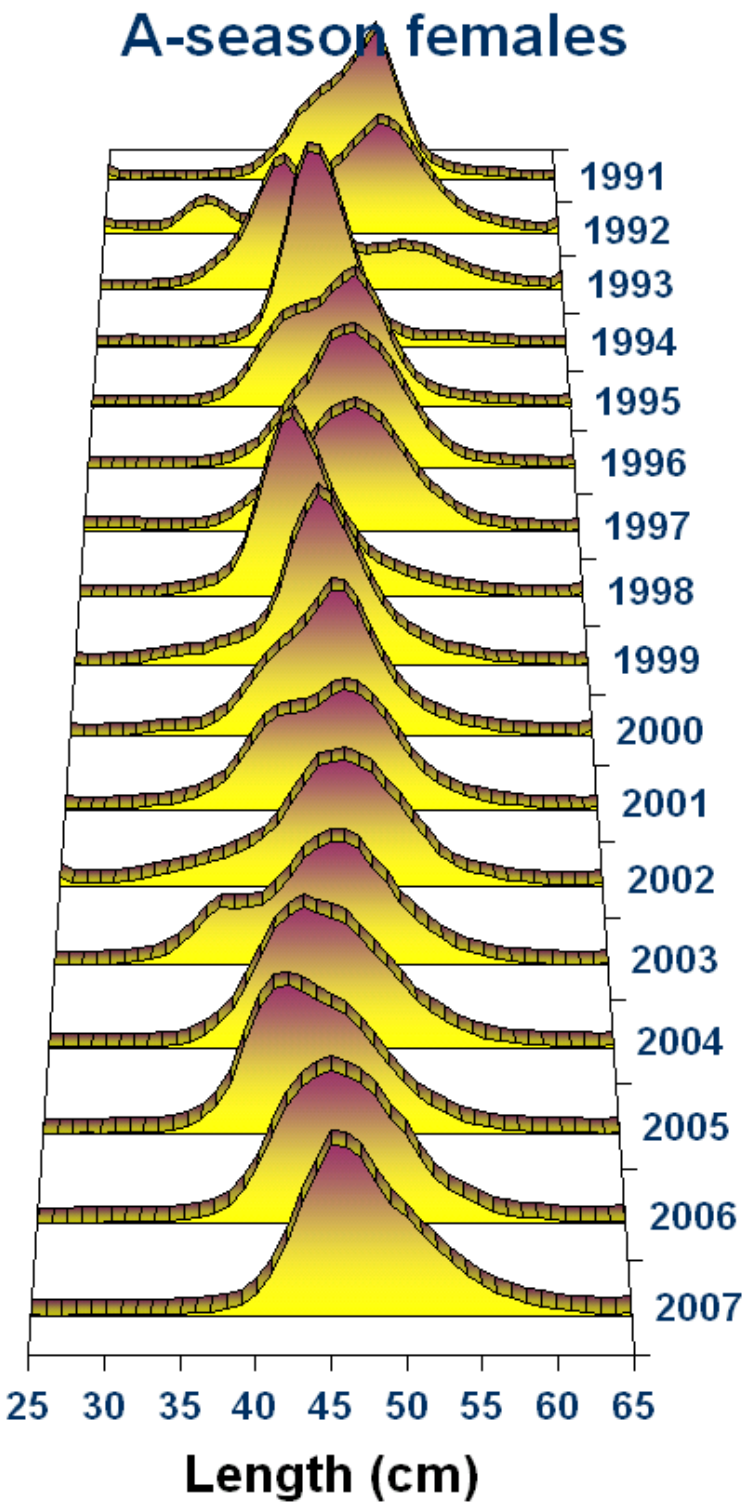


Figure 1.4. Fishery length frequency for the "A season" (January-May) female EBS pollock, 1991-2007. Data for 2007 are preliminary.

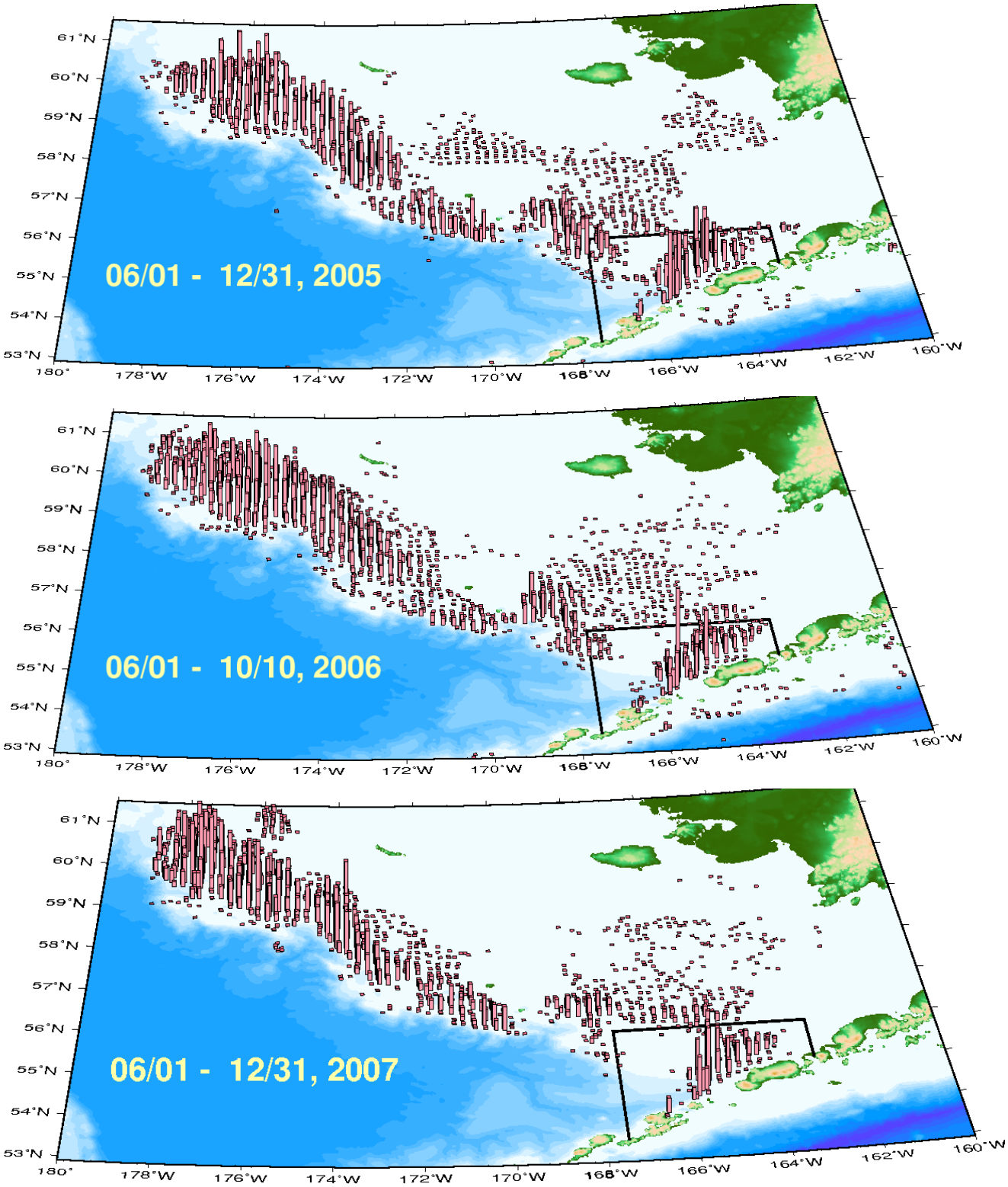


Figure 1.5. Pollock catch distribution during June – December, 2005-2007. Line delineates the catcher-vessel operational area (CVOA). The height of the bars represents relative removal on the same scale over all years.

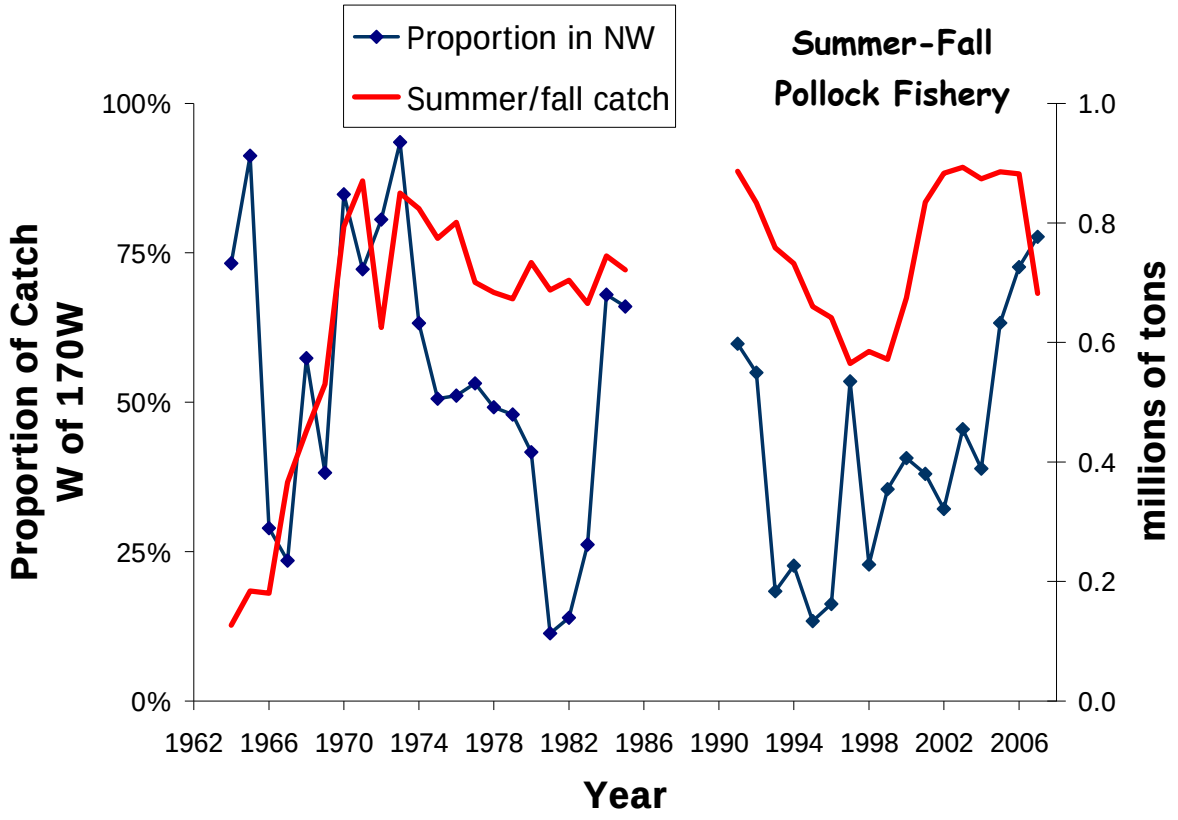


Figure 1.6. Comparison of foreign reported pollock catch (prior to 1986) with recent fishery data during the summer-fall fishery relative to the northwest zone (W of 170°W) of the EBS.

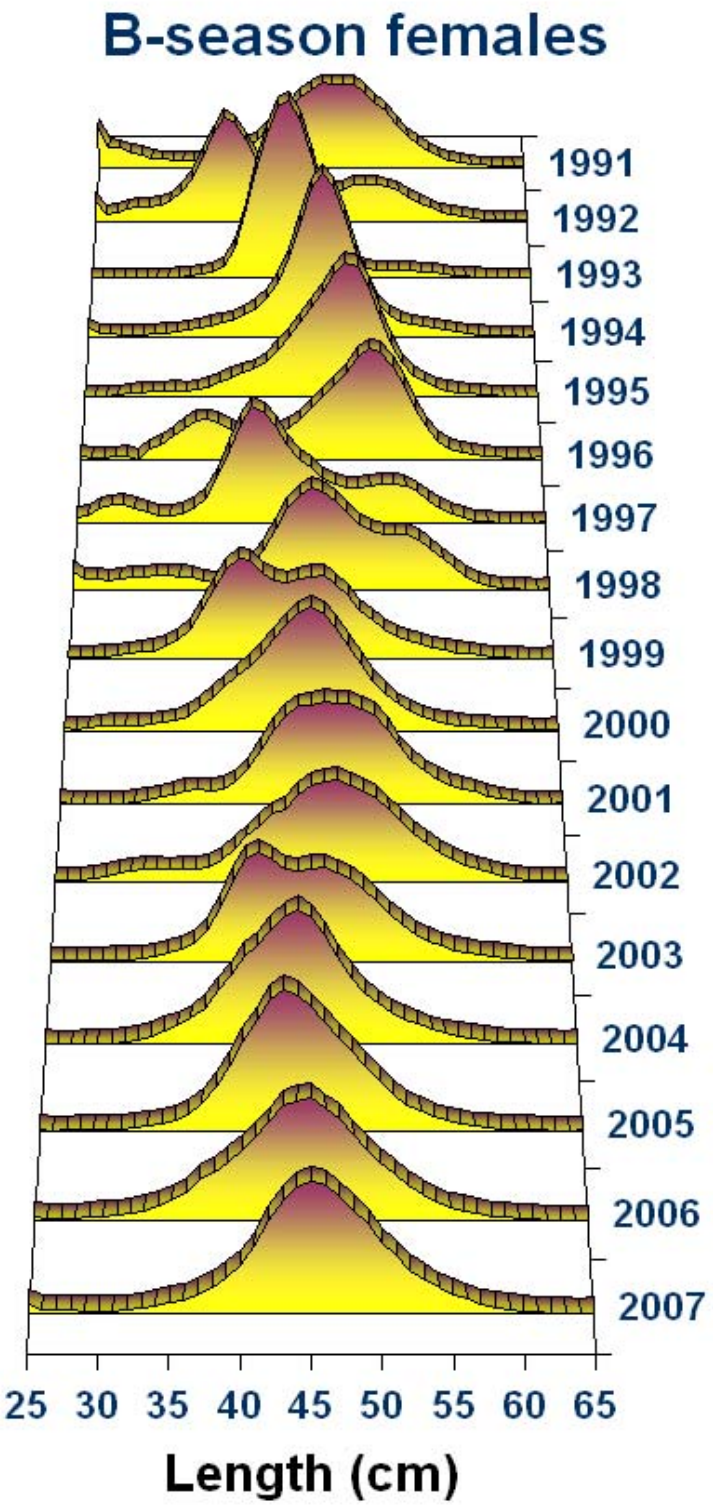


Figure 1.7. Length frequency of EBS pollock observed in period July-December for 1991-2007. Data for 2007 are preliminary.

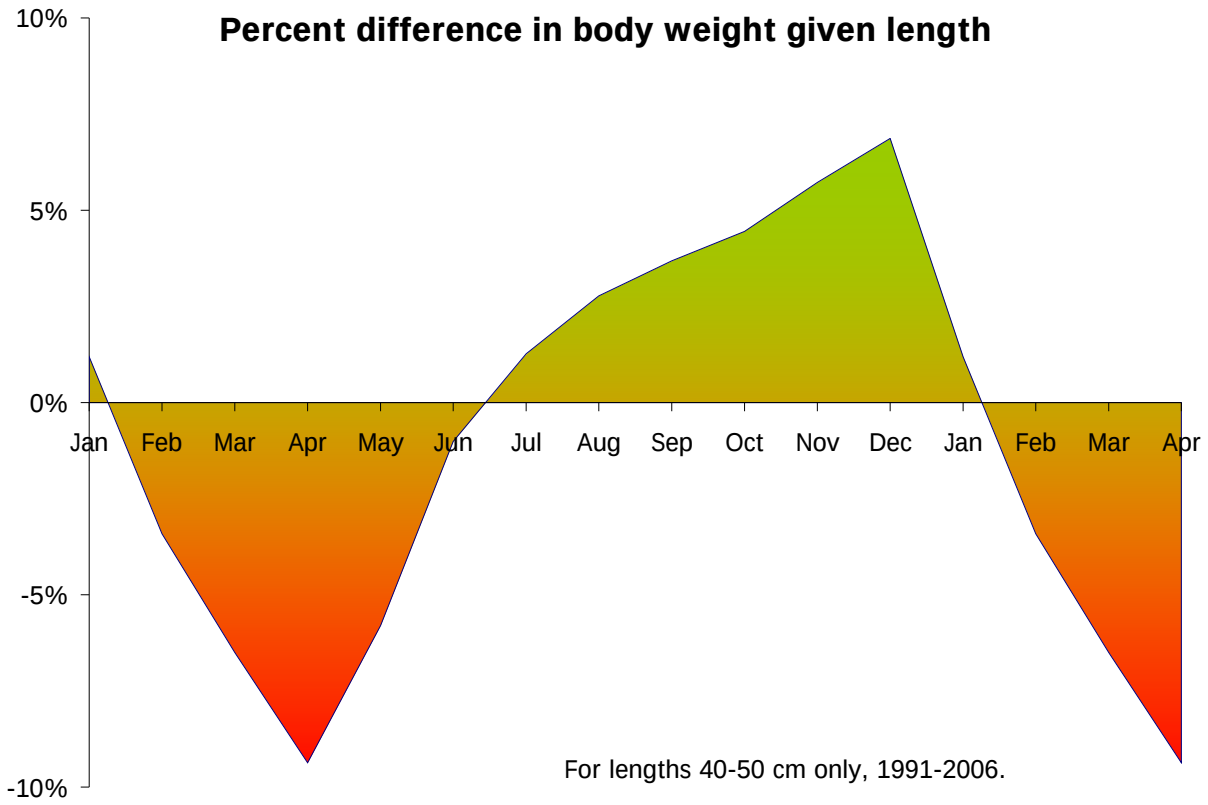


Figure 1.8. Relative monthly body mass deviation for EBS pollock standardized by the mean long-term weight at length (from 40 to 50cm), 1991-2006 combined data.

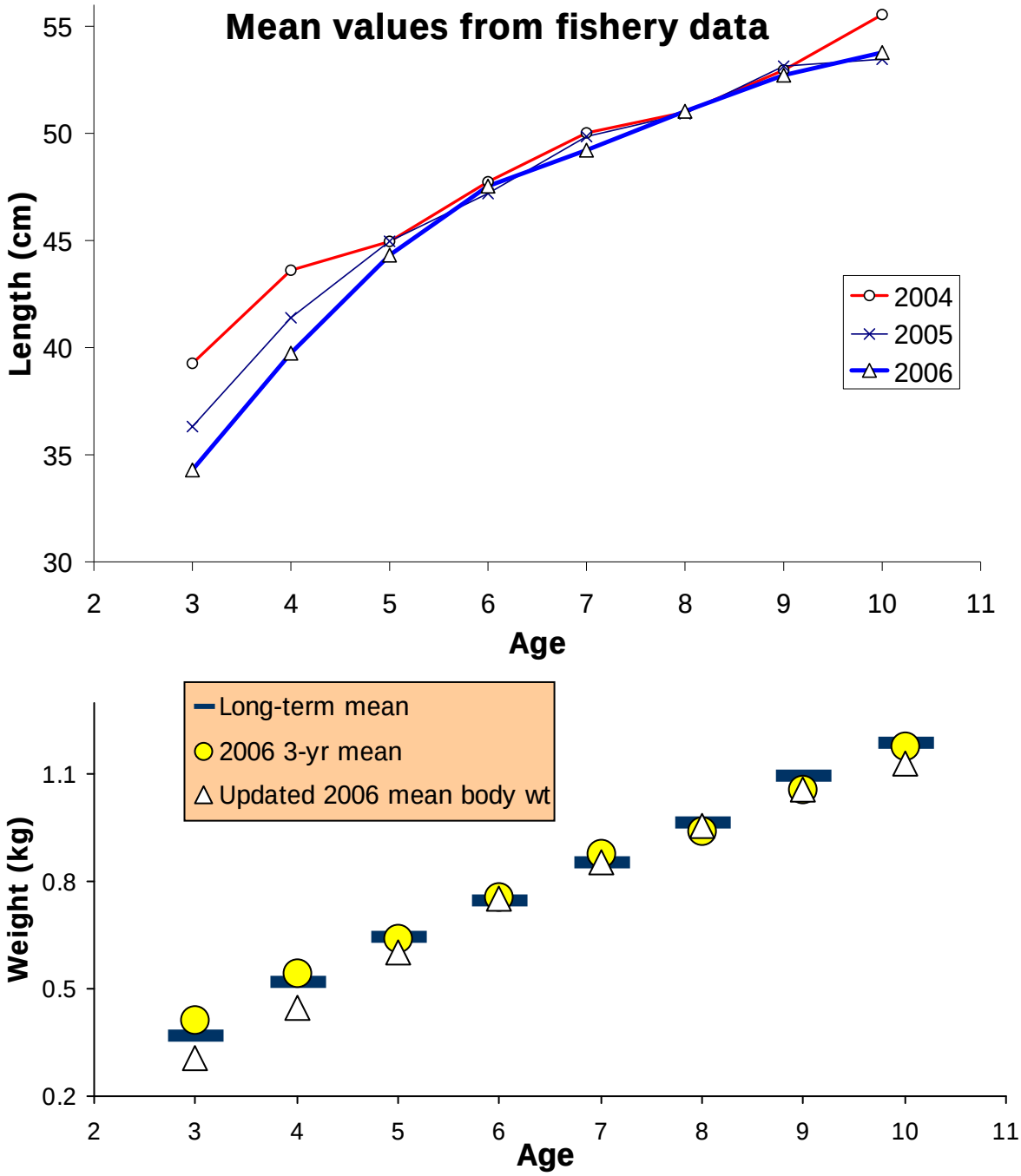


Figure 1.9. Relative monthly body mass deviation for EBS pollock standardized by the mean long-term weight at length (from 40 to 50cm), 1991-2006 combined data.

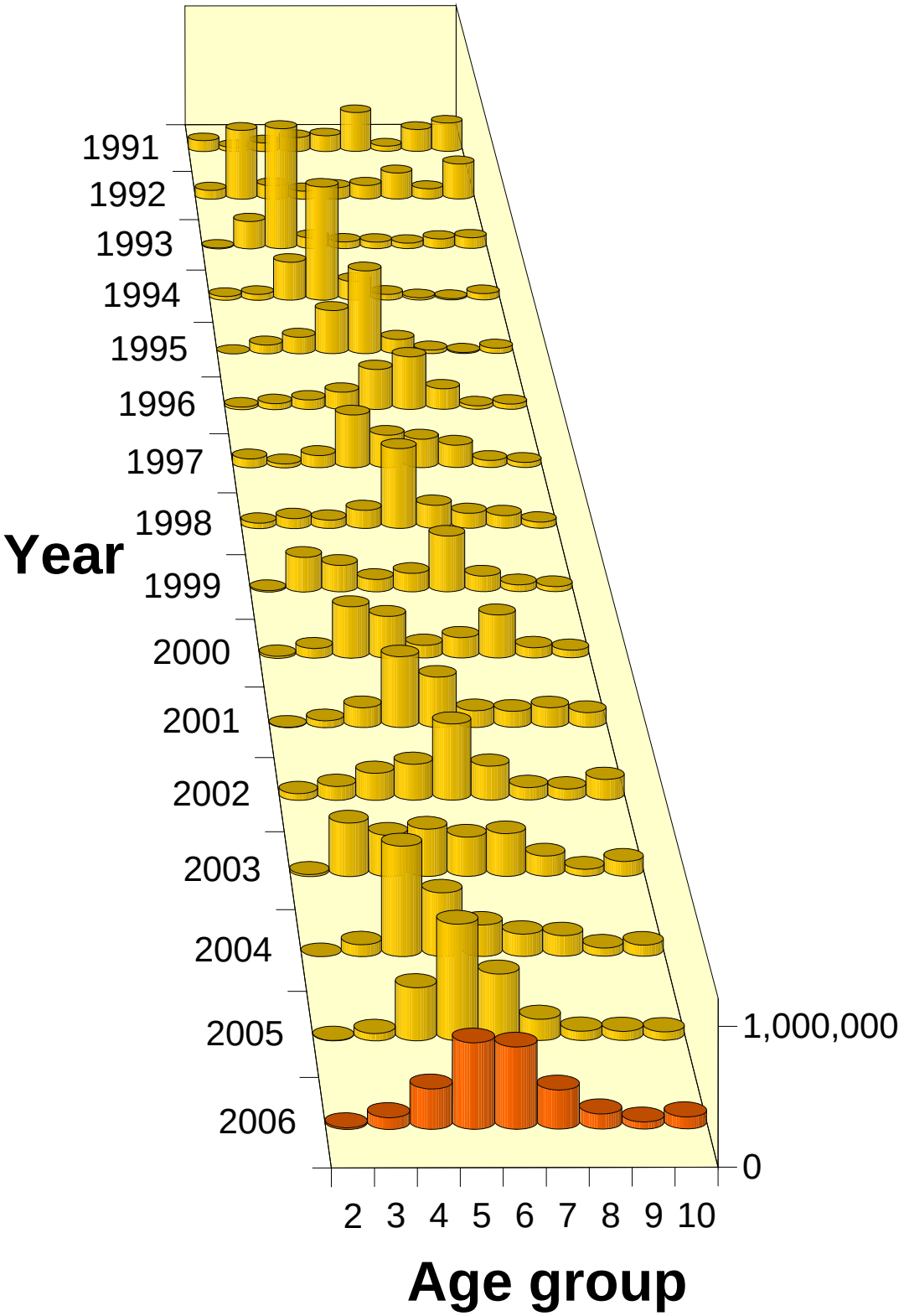


Figure 1.10. EBS pollock fishery estimated catch-at-age data (in number) for 1991-2006. Age 10 represents pollock age 10 and older.

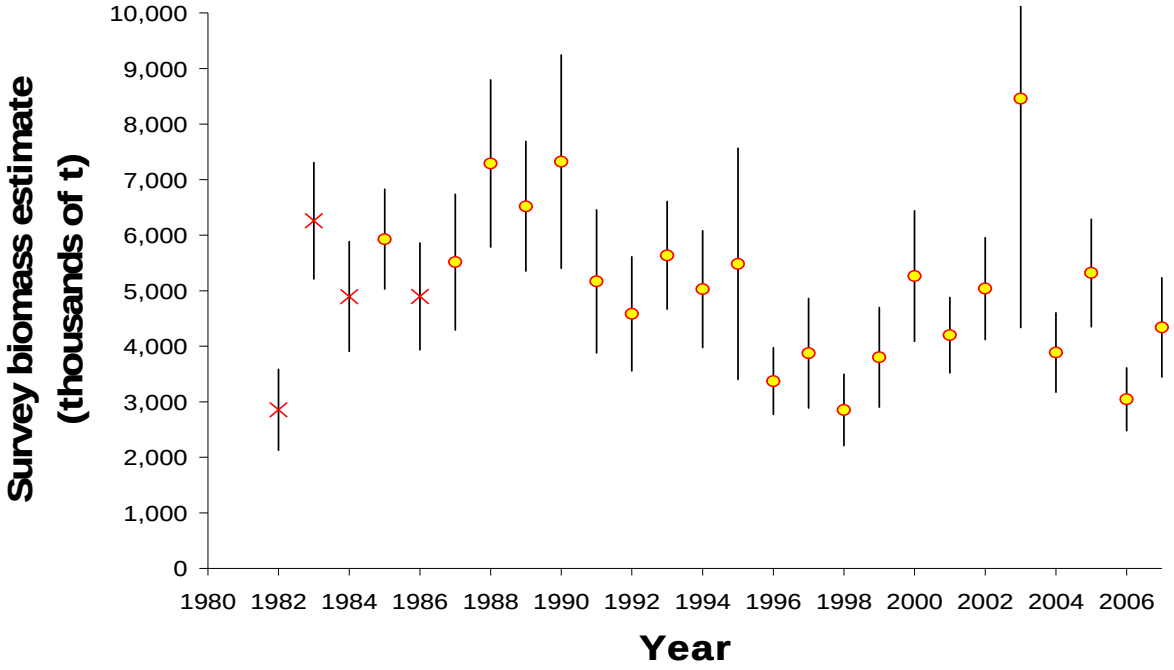


Figure 1.11. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS pollock, 1982-2007. These estimates **include** the northern strata except for 1982-84, and 1986 (indicated by cross symbols).

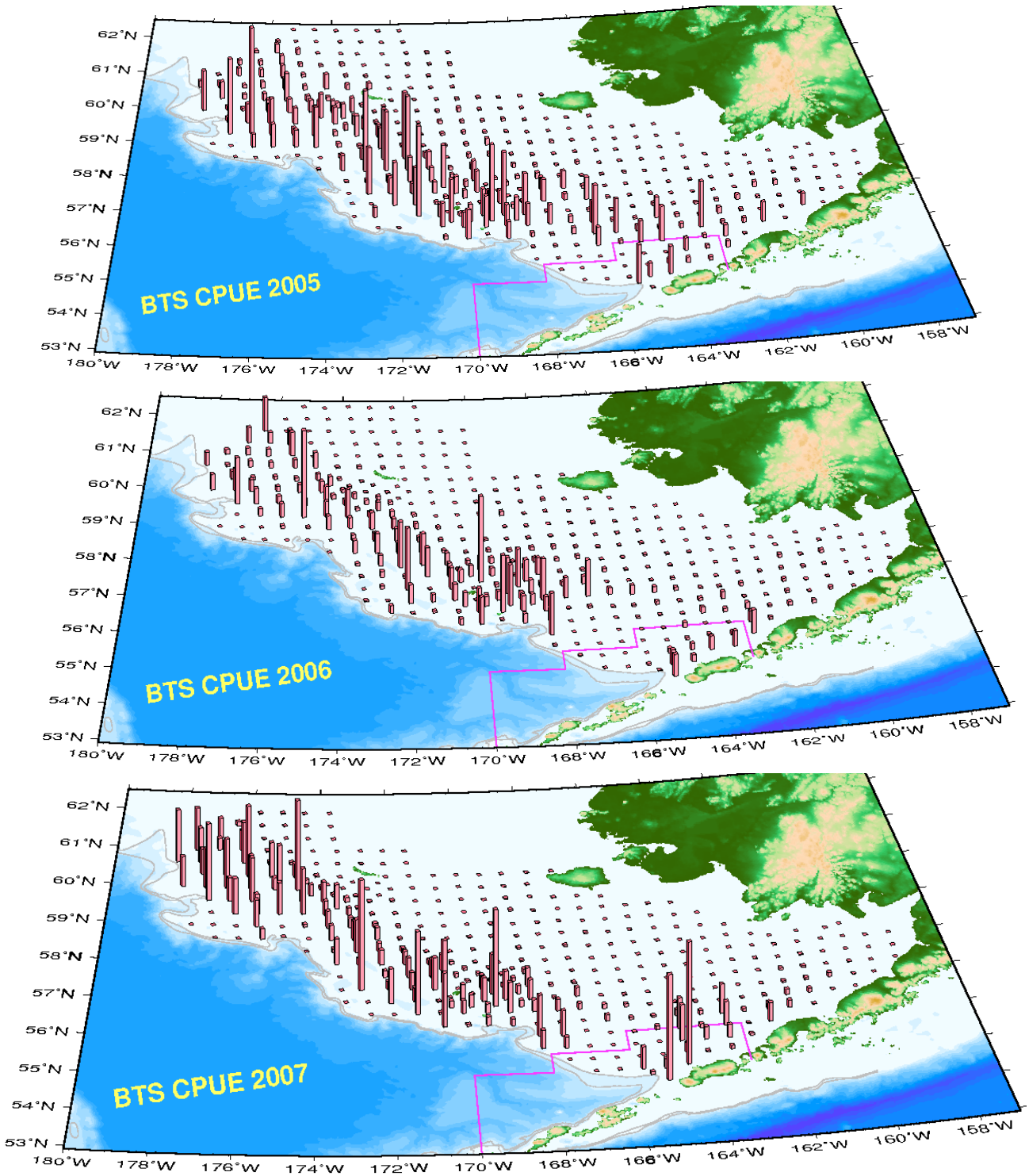


Figure 1.12. Maps showing the pollock catch-per-unit effort observed from the 2005 - 2007 NMFS EBS shelf bottom-trawl surveys.

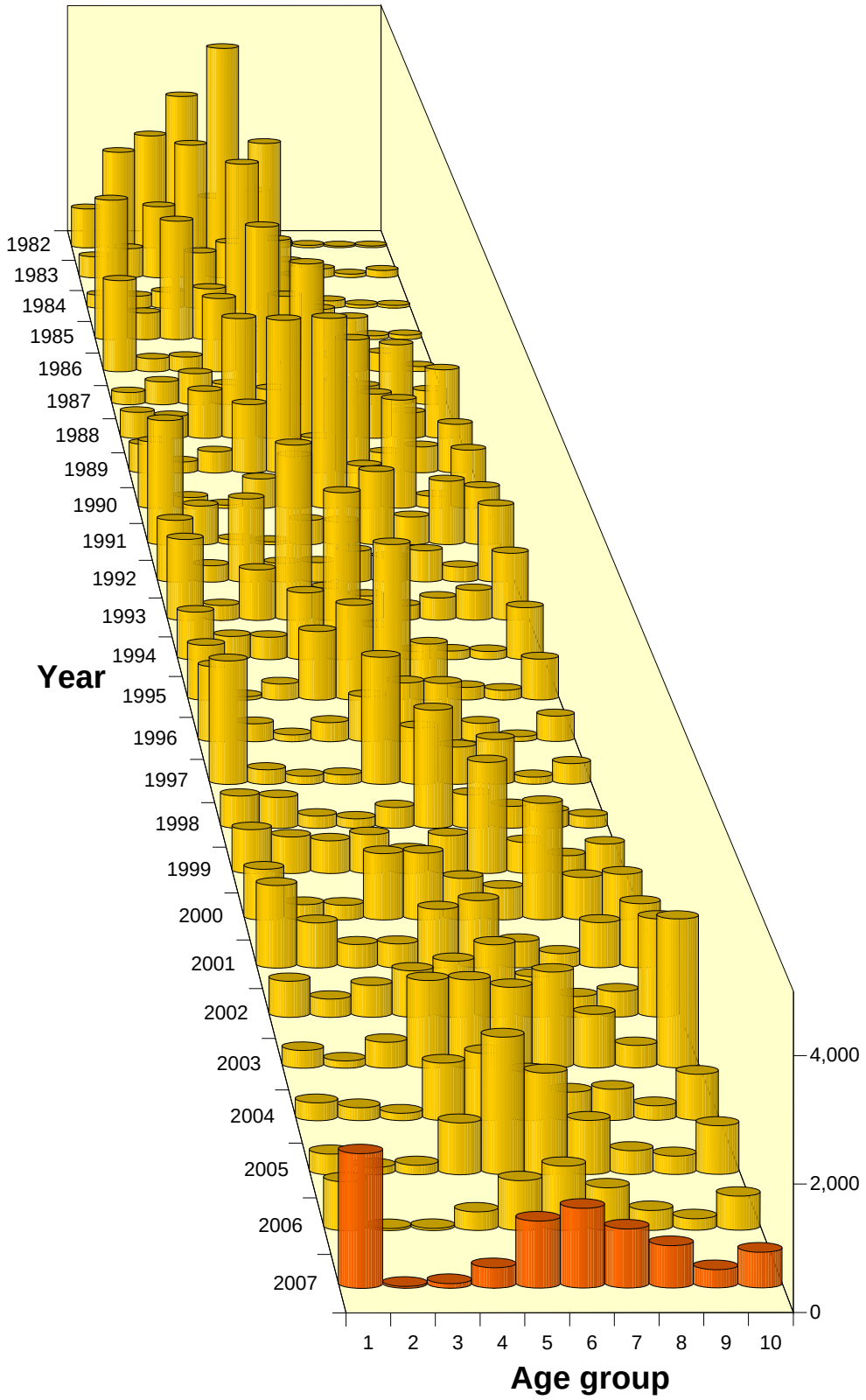


Figure 1.13. Pollock abundance levels by age and year as estimated directly from the NMFS bottom-trawl surveys (1982-2007).

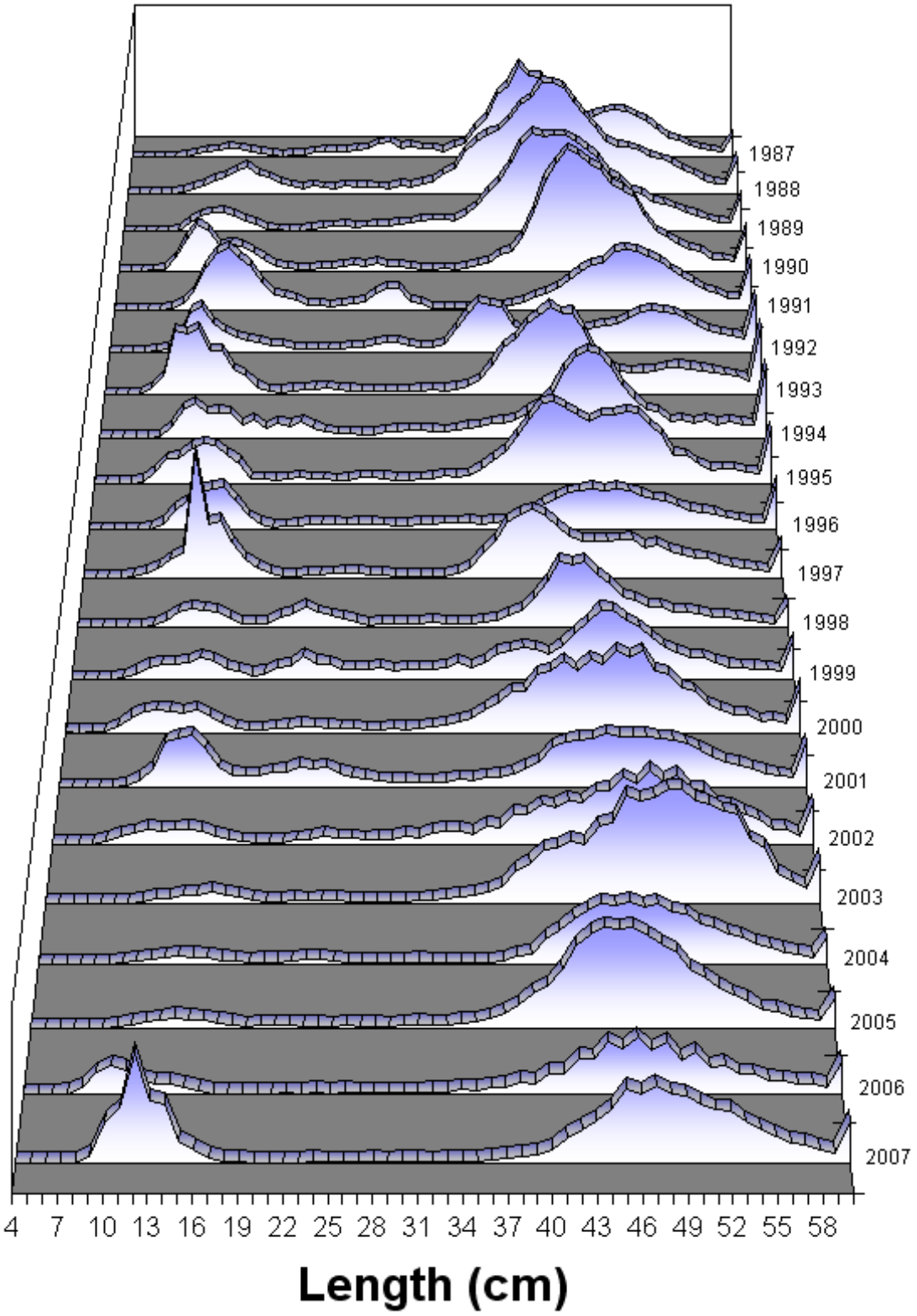


Figure 1.14. Pollock abundance levels by length plotted over time as estimated directly from the NMFS bottom-trawl surveys (1987-2007).

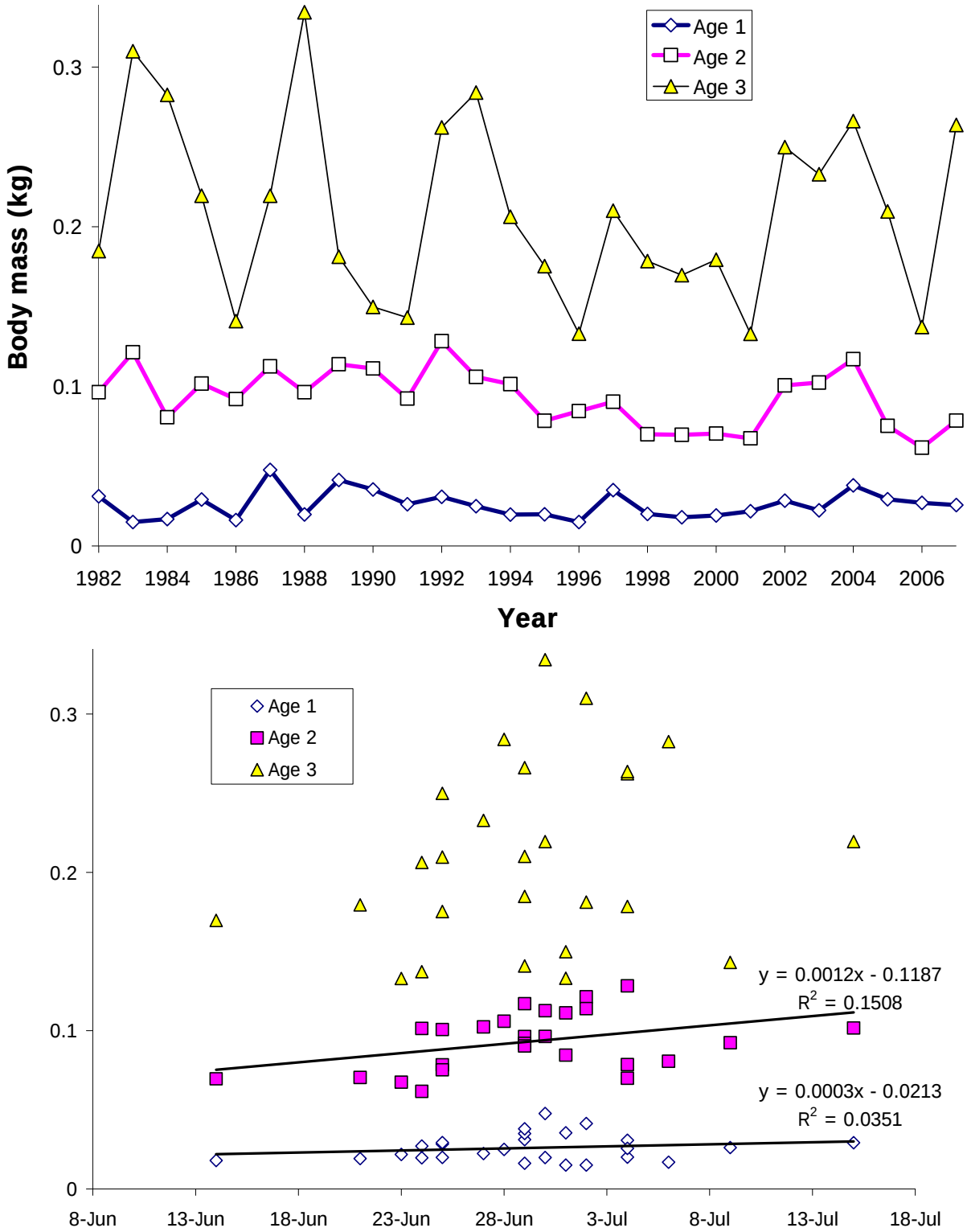


Figure 1.15. Mean EBS pollock body-mass-at-age as observed in the summer bottom trawl surveys, 1982-2007 (top panel) and relative to the mean date of the bottom trawl survey operations (bottom panel) for ages 1-3.

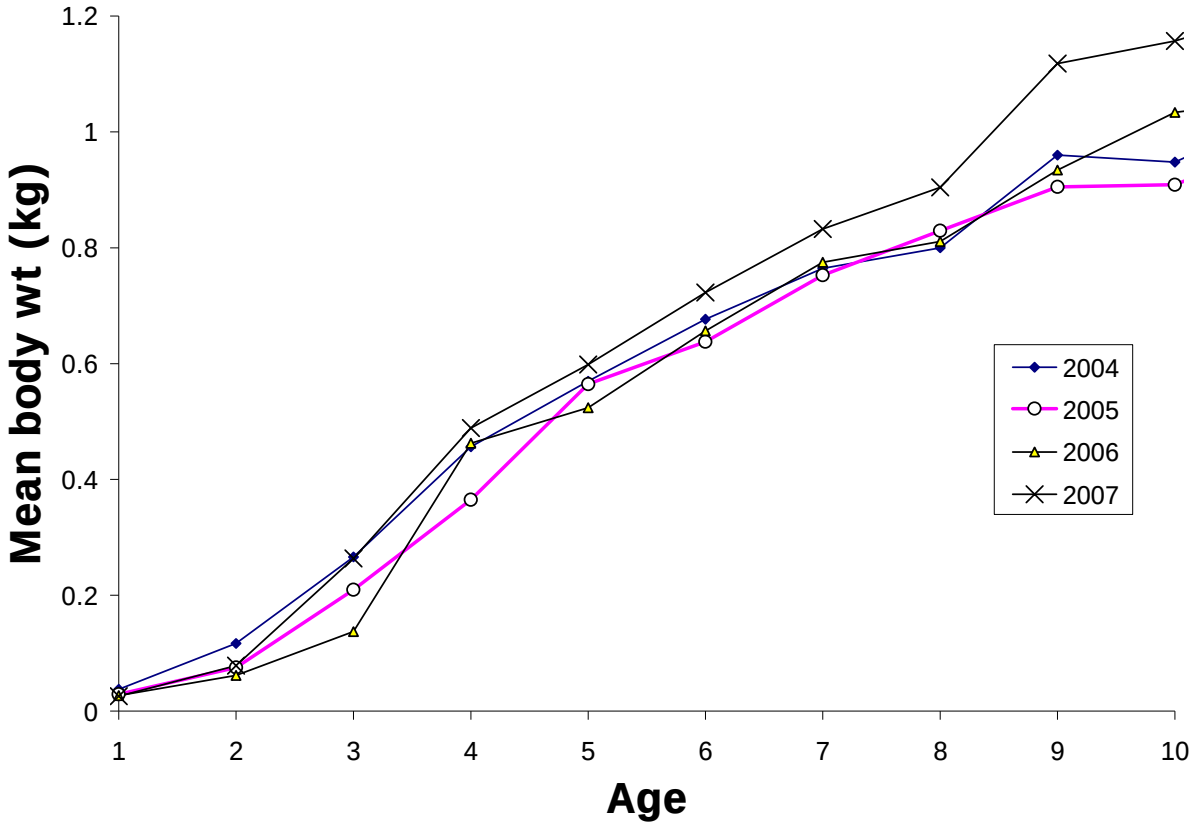


Figure 1.16. Mean EBS pollock body-mass-at-age as observed in the summer bottom trawl surveys, 2004-2007.

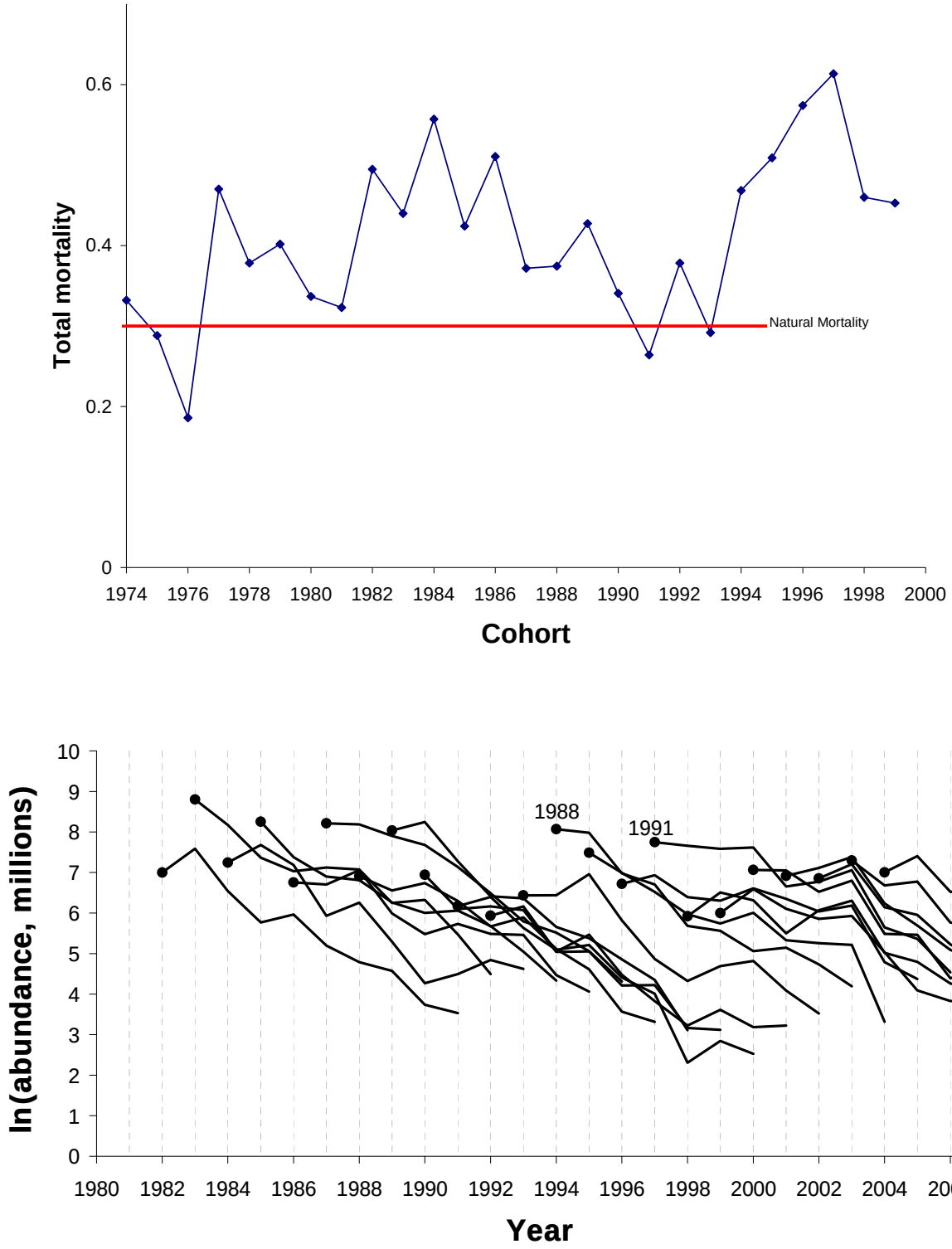


Figure 1.17. Evaluation of EBS pollock cohort abundances as observed for age 6 and older in the NMFS summer bottom trawl surveys. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort.

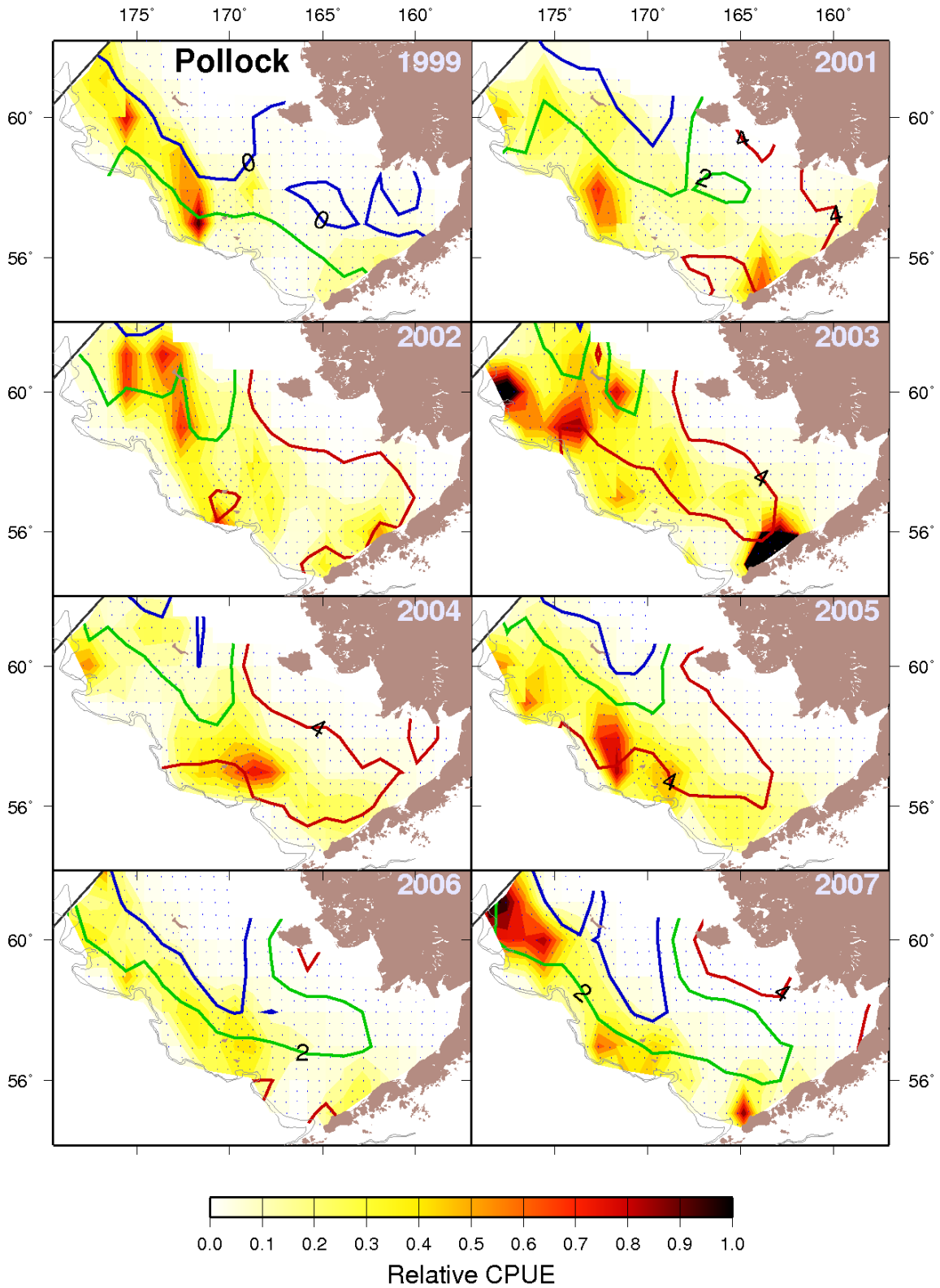


Figure 1.18. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 1999-2007 (2000 was omitted from the display).

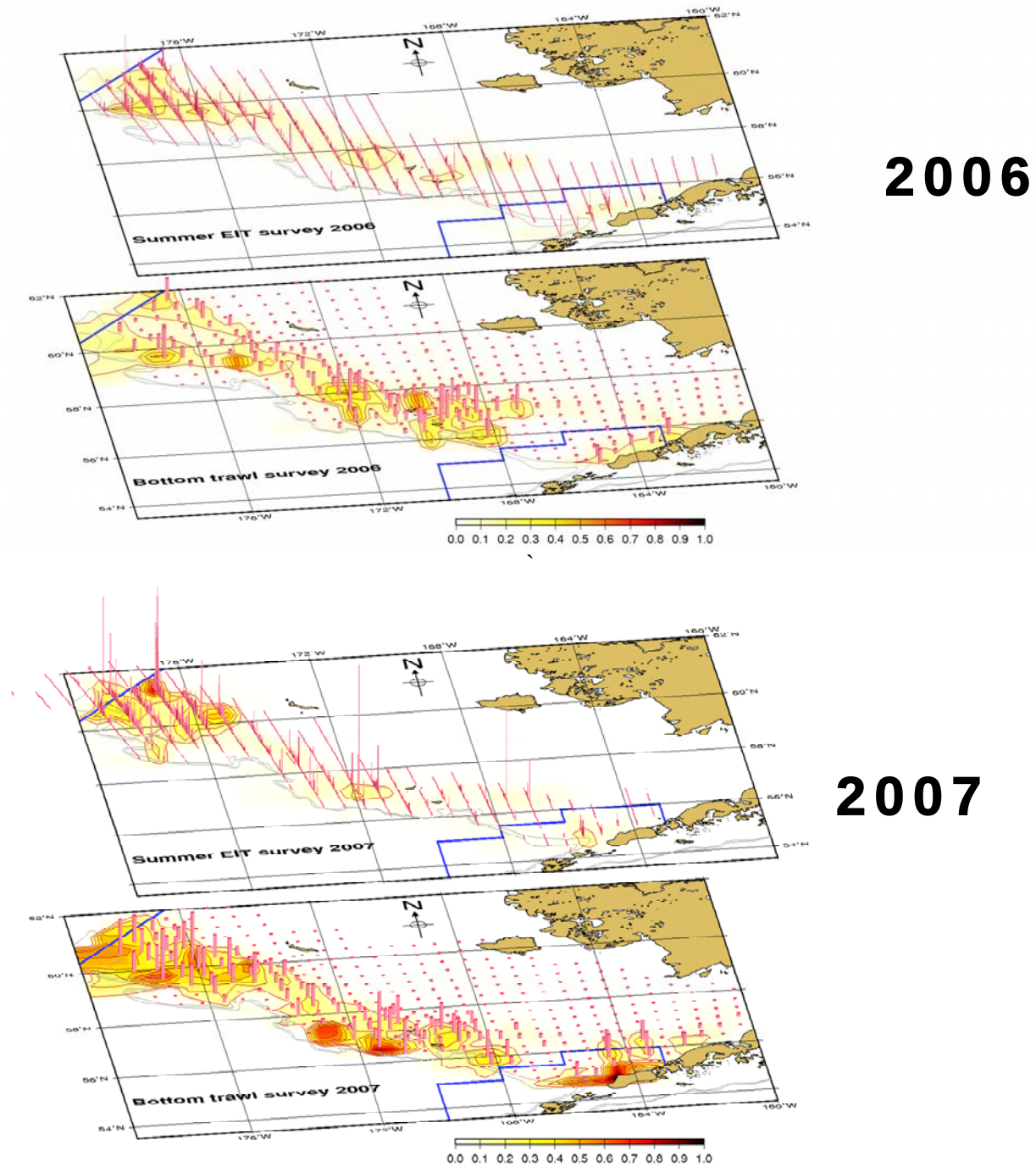


Figure 1.19. Echo-integration trawl survey results for 2006 and 2007. The lower figure is the result from the BTS data in the same years. Vertical lines represent biomass of pollock as observed in the different surveys.

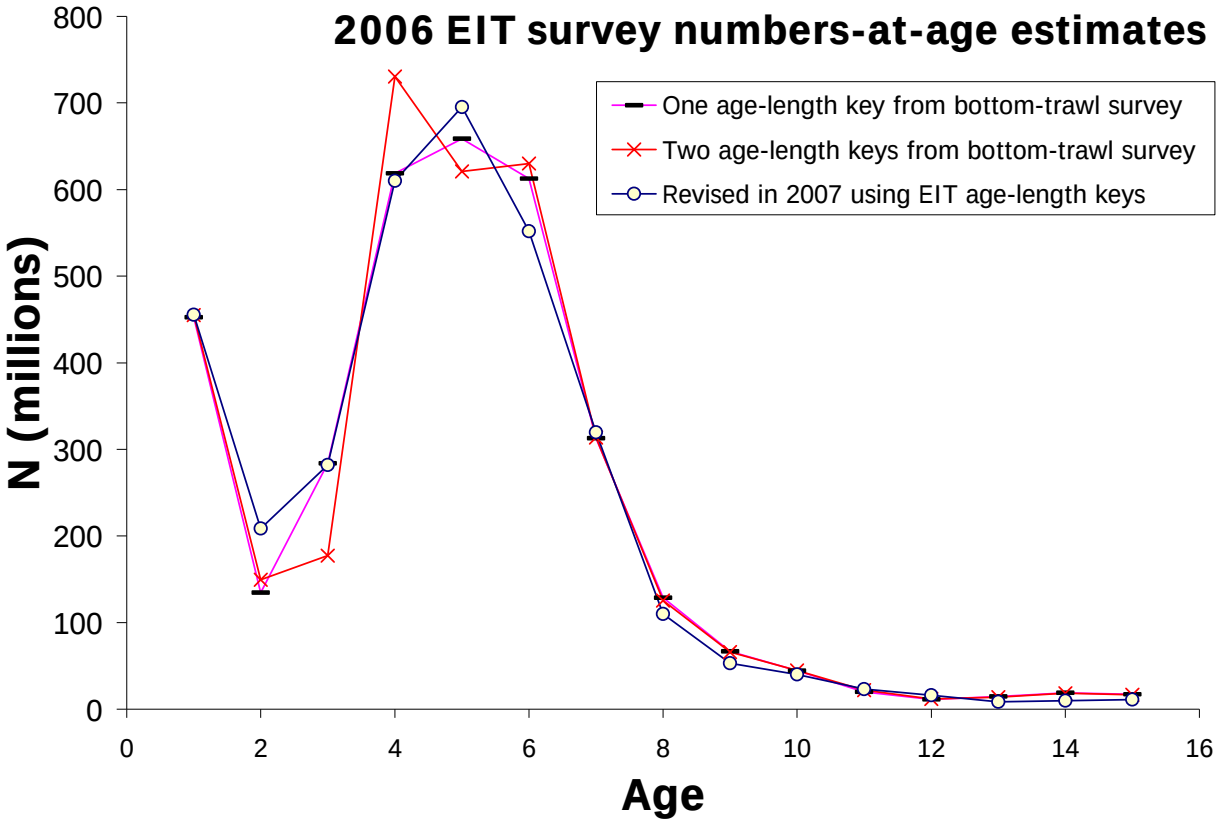


Figure 1.20. EBS pollock population at age estimates from the 2006 echo-integration trawl survey as estimated in 2006 based on one or two age-length keys from the bottom trawl surveys and as revised in 2007 using age-length keys derived from the EIT surveys.

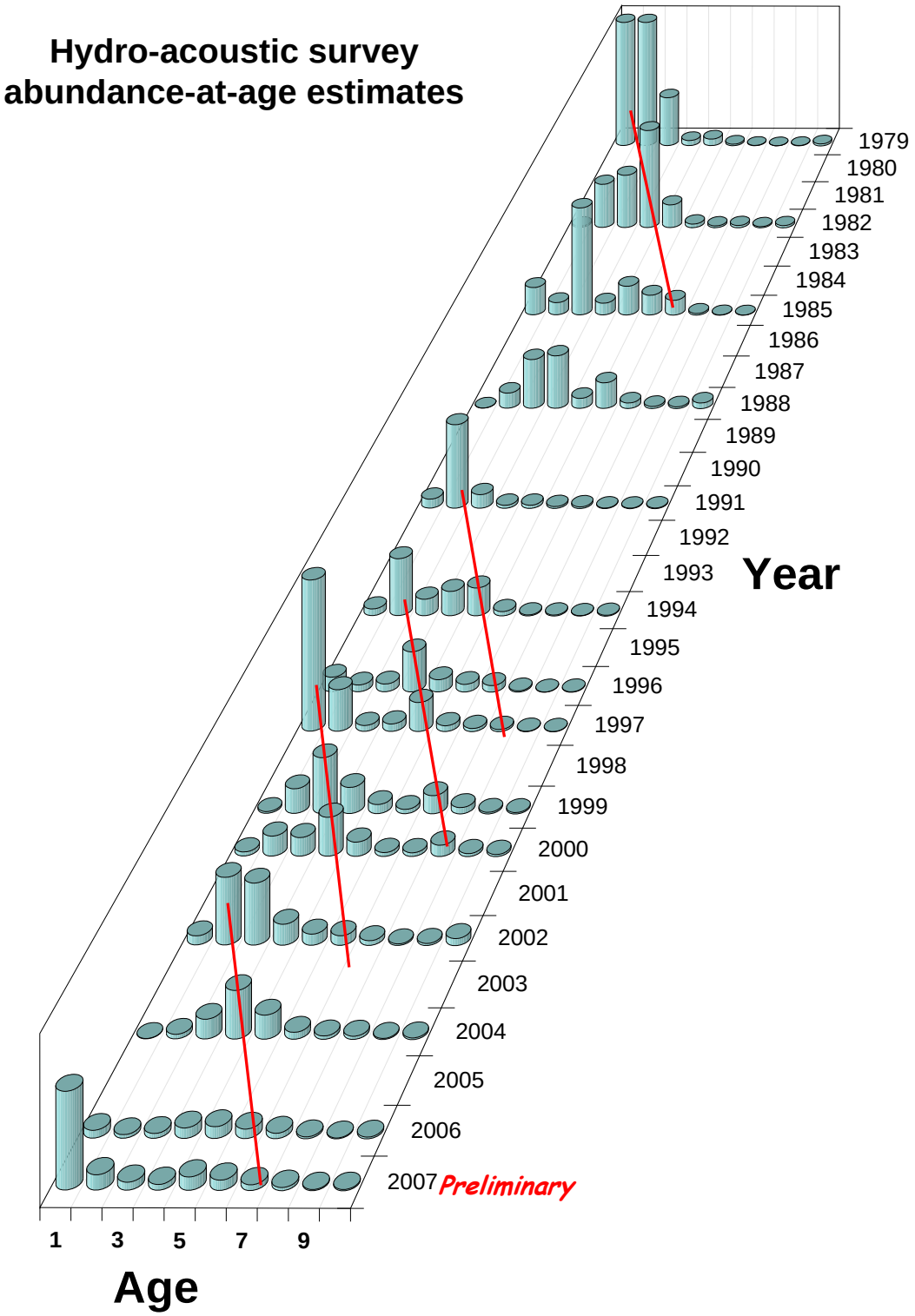


Figure 1.21. Time series of estimated abundances at age (numbers) for EBS pollock from the EIT surveys, 1979-2007. Note that the 2007 age compositions were computed using an age-length key derived from the 2007 BTS data and as such, are preliminary. The diagonal lines are placed to follow year classes over time.

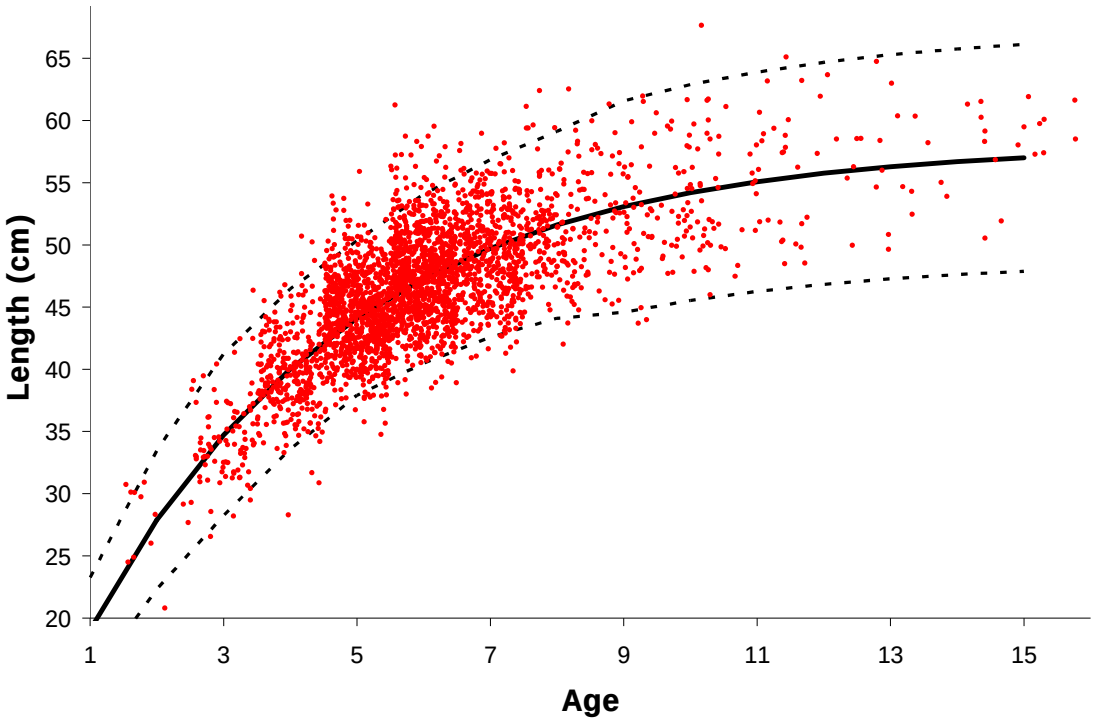


Figure 1.22. Length and age relationship for EBS pollock from the 2006 fishery data showing the fit and variability (dashed lines represent ± 2 standard deviations). This relationship was used to develop age-size conversion to fit the available 2007 fishery length frequency data. Points were randomized slightly for visibility purposes.

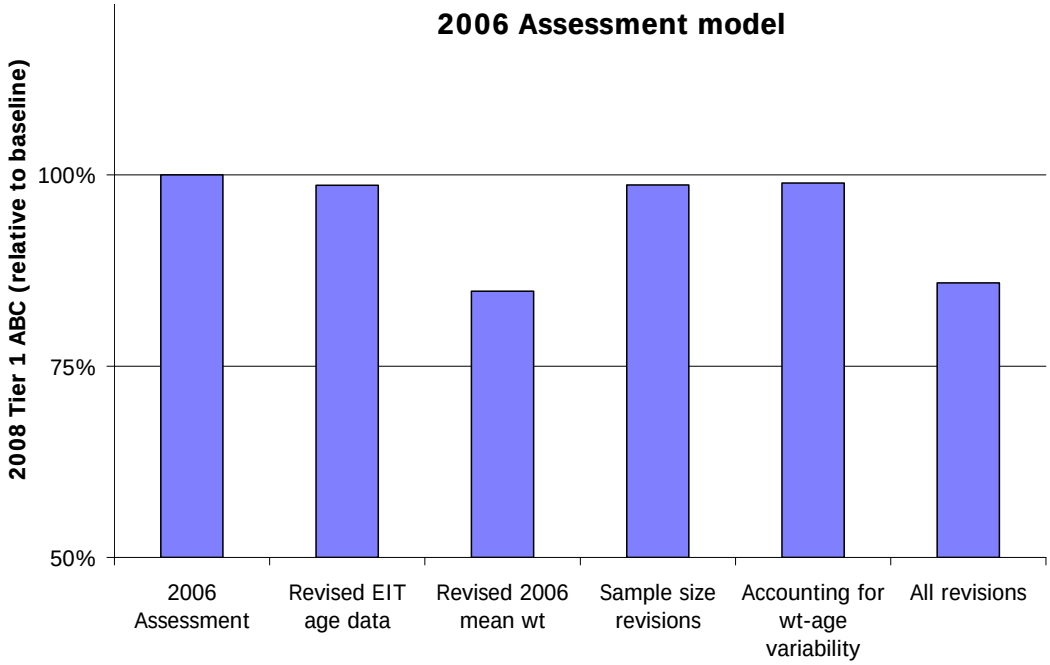


Figure 1.23. The impact of the 2006 assessment model with revisions given data and other revisions on Tier 1 ABC values for 2008. NOTE: this does not reflect the addition of any data collected in 2007 and is meant for illustration purposes.

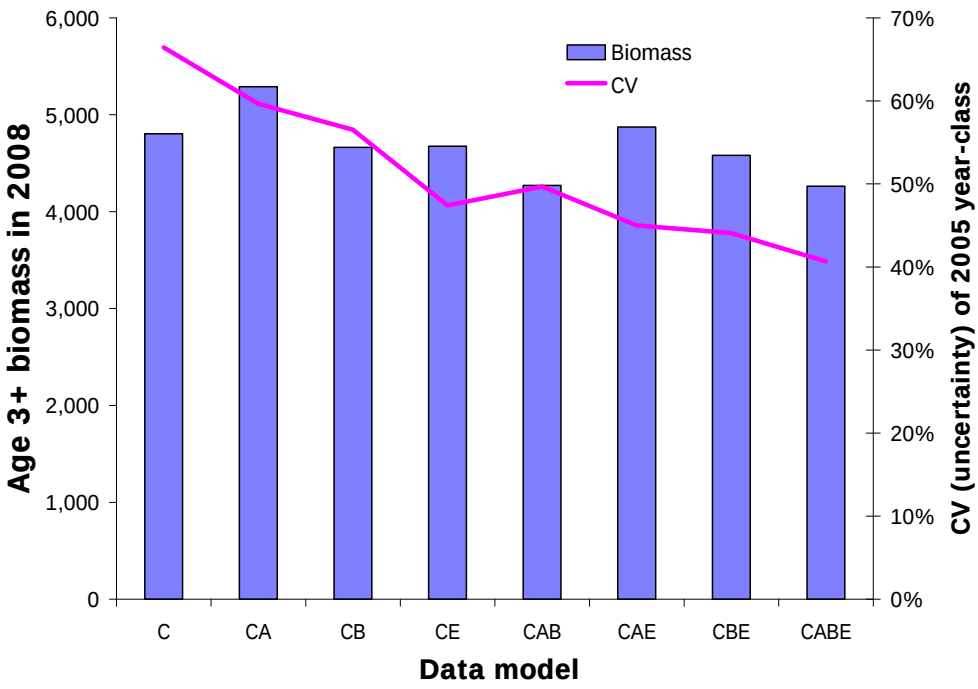


Figure 1.24. Evaluation of how new data affect the model for 2007. The CABE model (right-most) includes all of the new information (**C**atch, fishery **A**ge, **B**ottom-trawl survey data, and **E**cho-integration trawl data. Bars represent predicted EBS pollock begin-year age 3+ biomass and the line indicates the uncertainty in estimating the 2005 year class.

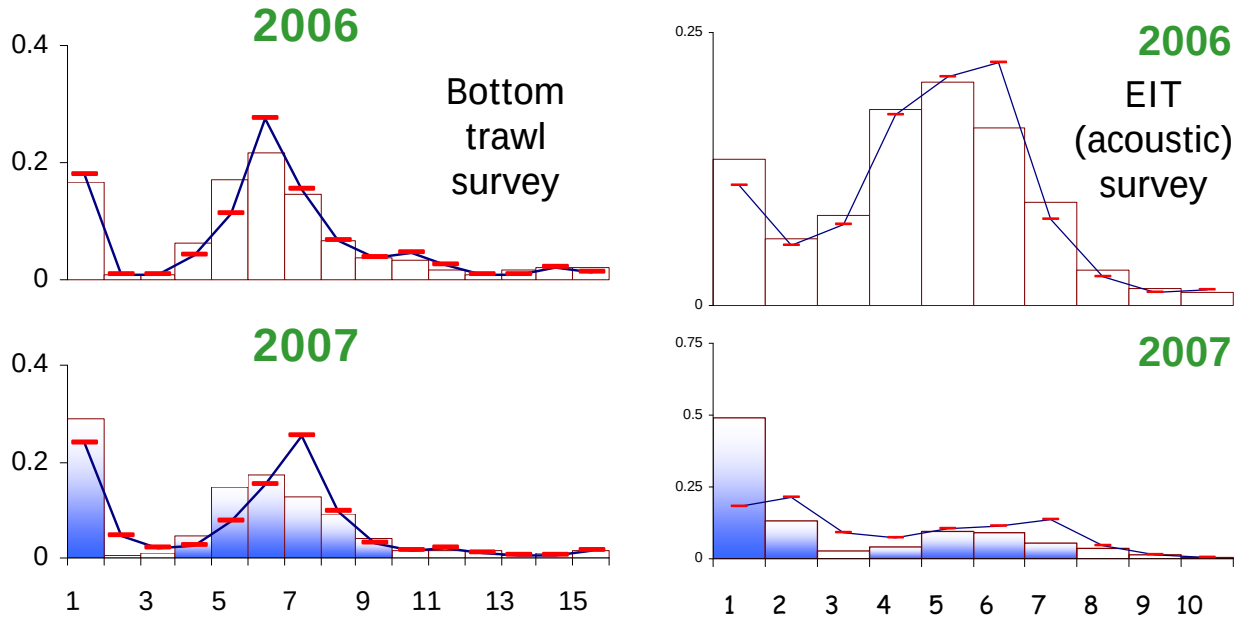


Figure 1.25. Model results of predicted EBS pollock survey proportions-at-age under Model **CA** where only 2006 fishery age and 2007 length composition data were added.

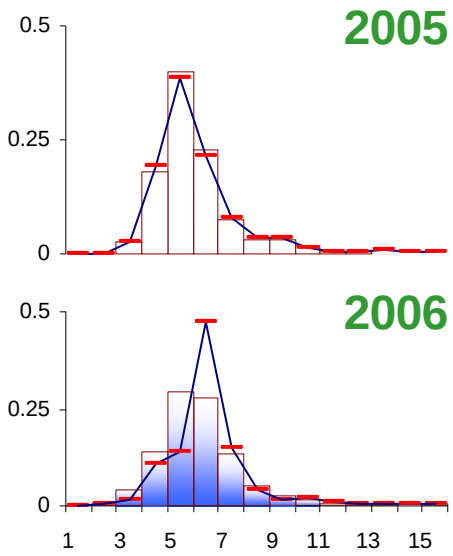


Figure 1.26. Model results for predicted EBS pollock fishery proportions at age under Model **C** without the 2006 fishery age and 2007 length data included.

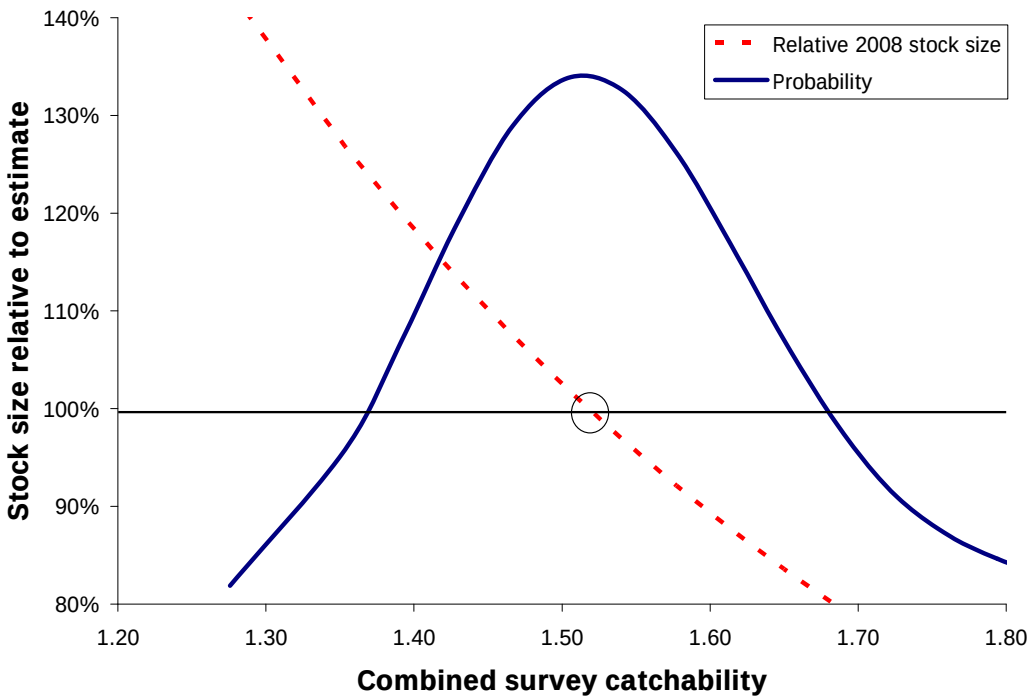


Figure 1.27. Profile likelihood over the combined EIT and bottom-trawl survey selectivity (ages 3-15) relative to the point estimate for EBS pollock. The dashed line traces the change in stock size under different values of catchability and the circle highlights the value estimated (and used) in the assessment.

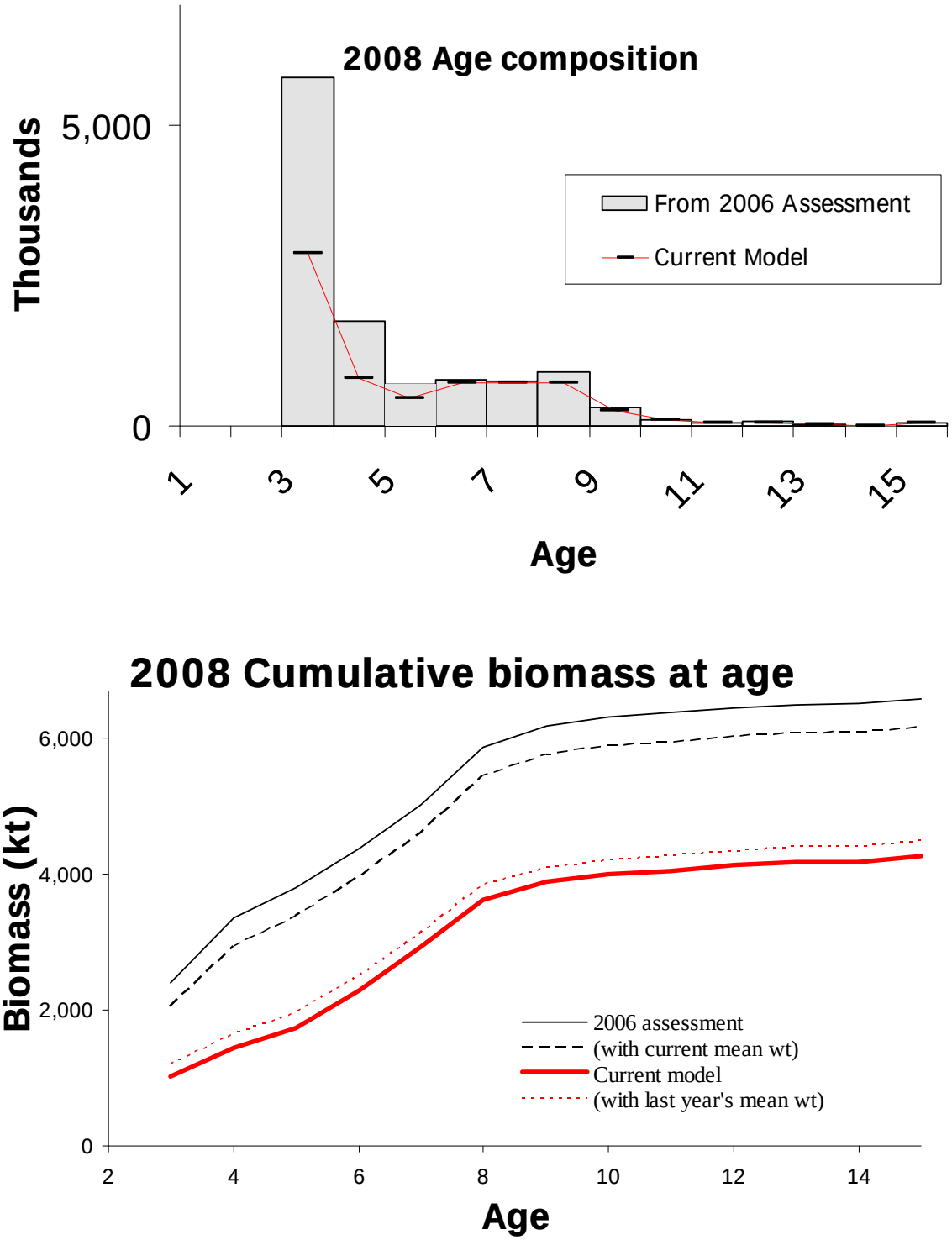


Figure 1.28. Estimates of 2008 EBS pollock population abundance as estimated in this assessment compared to last year's estimates (top panel) and a similar figure showing cumulative population biomass-at-age differences (bottom panel). Dashed lines in bottom panel show calculations using alternative mean weights-at-age values.

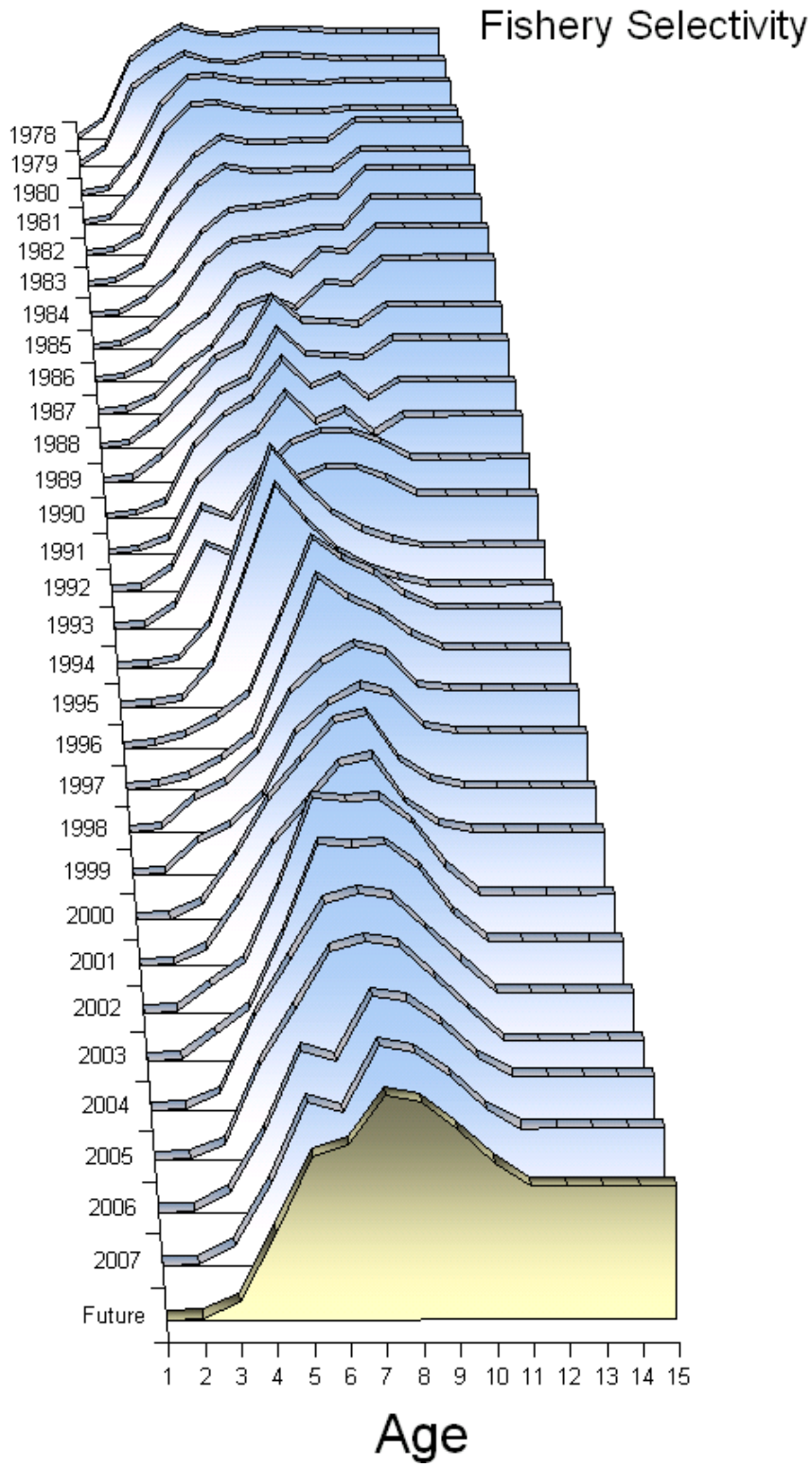


Figure 1.29. Selectivity at age estimates for the EBS pollock fishery, 1978-2007 including the estimates used for the future yield considerations.

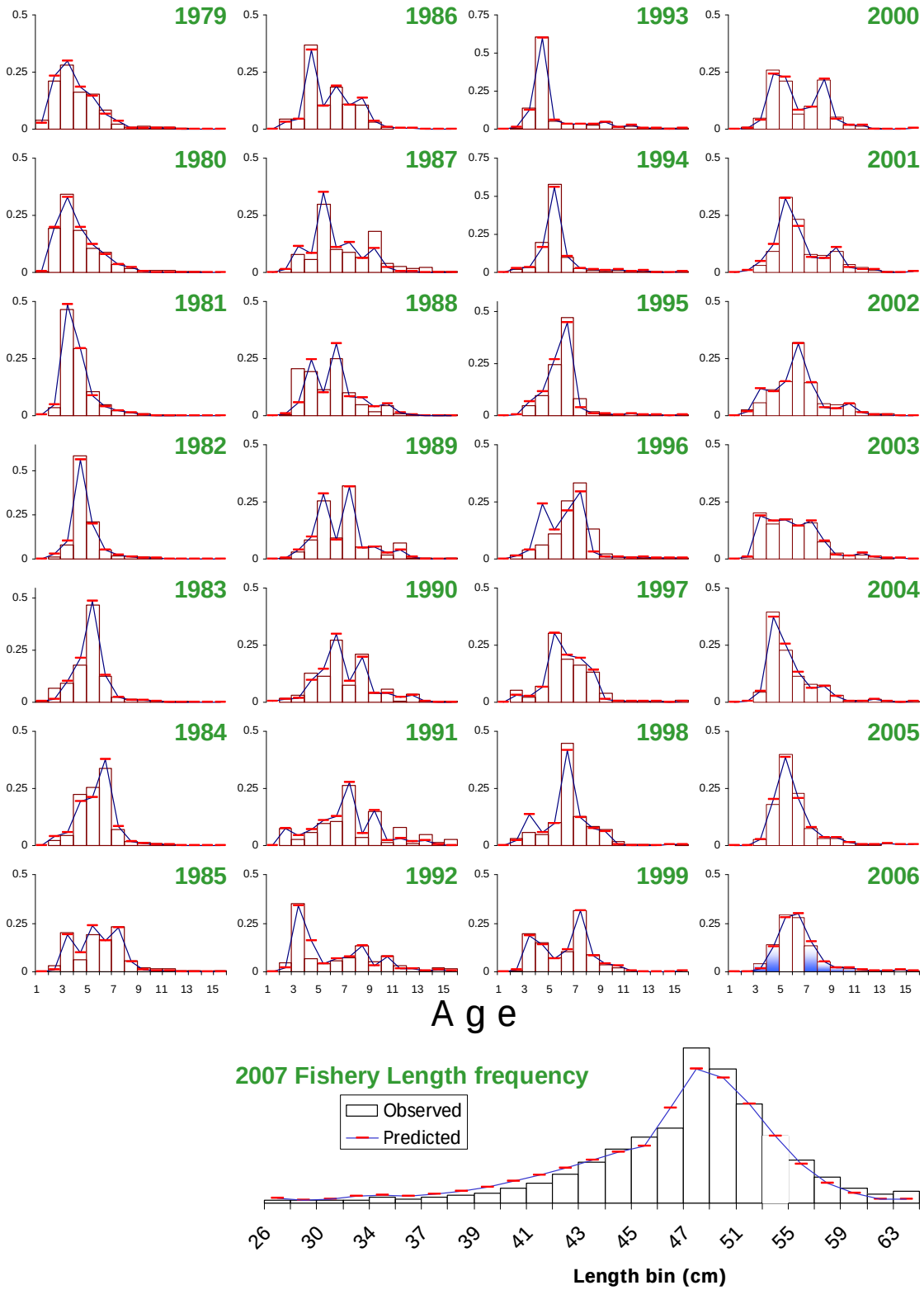
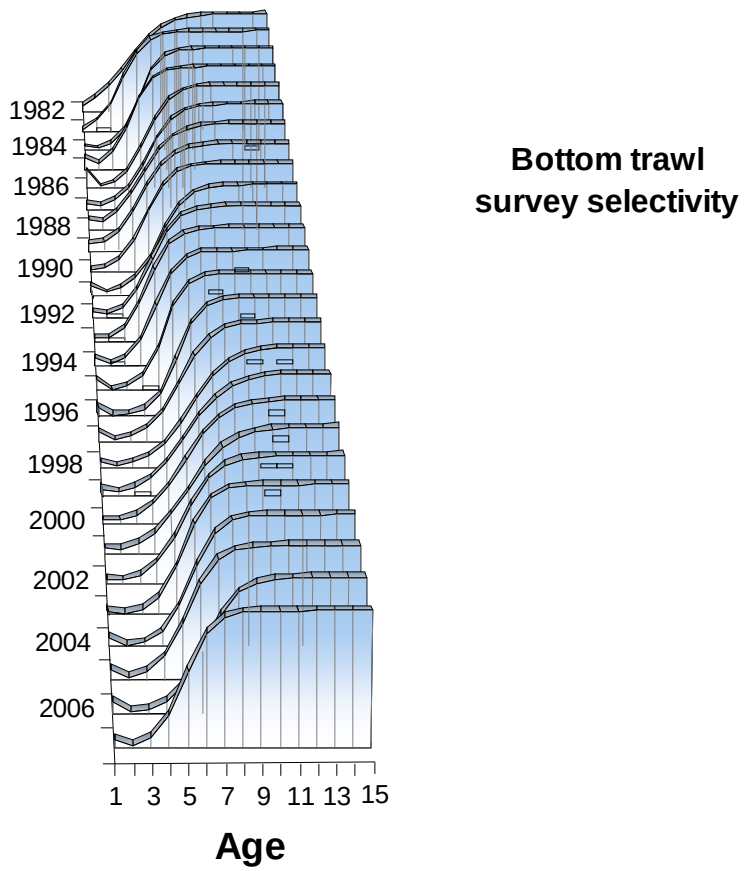


Figure 1.30. **F**it to the EBS pollock fishery age composition estimates (1979-2006) and to the current-year estimate of fishery length frequency data (bottom most panel). Lines represent model predictions while the vertical columns represent the data. Age data new to this year's assessment are shaded.



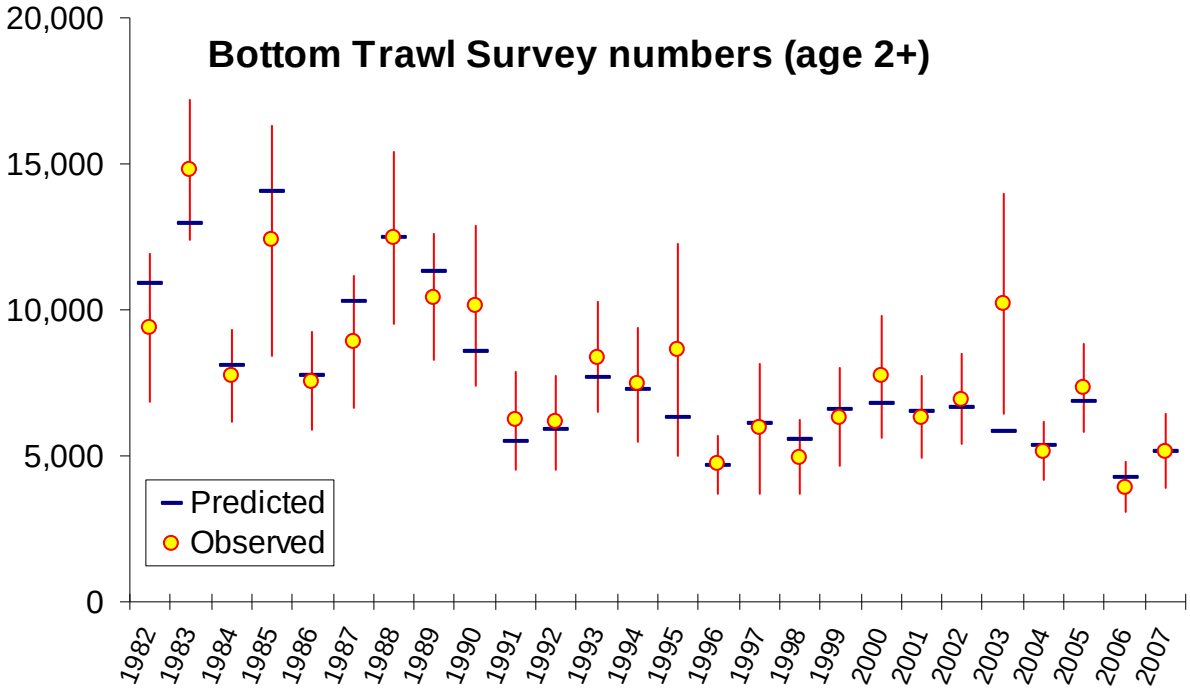


Figure 1.31. Estimates of bottom-trawl survey numbers (lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS pollock, 1982-2007.

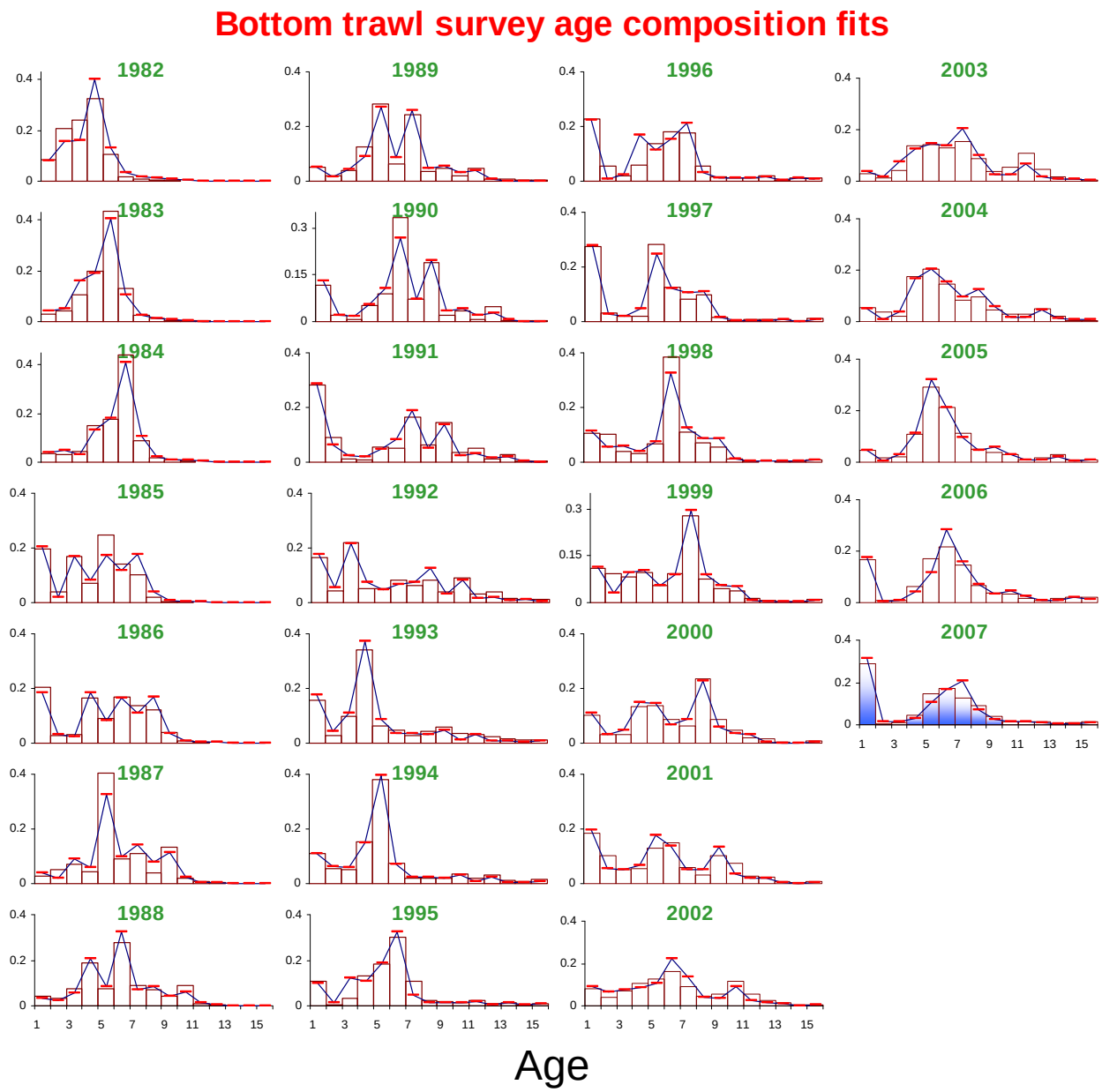


Figure 1.32. Fit to the bottom trawl survey age composition data (proportions) for EBS pollock. Lines represent model predictions while the vertical columns represent the data. Data new to this assessment are shaded (2007).

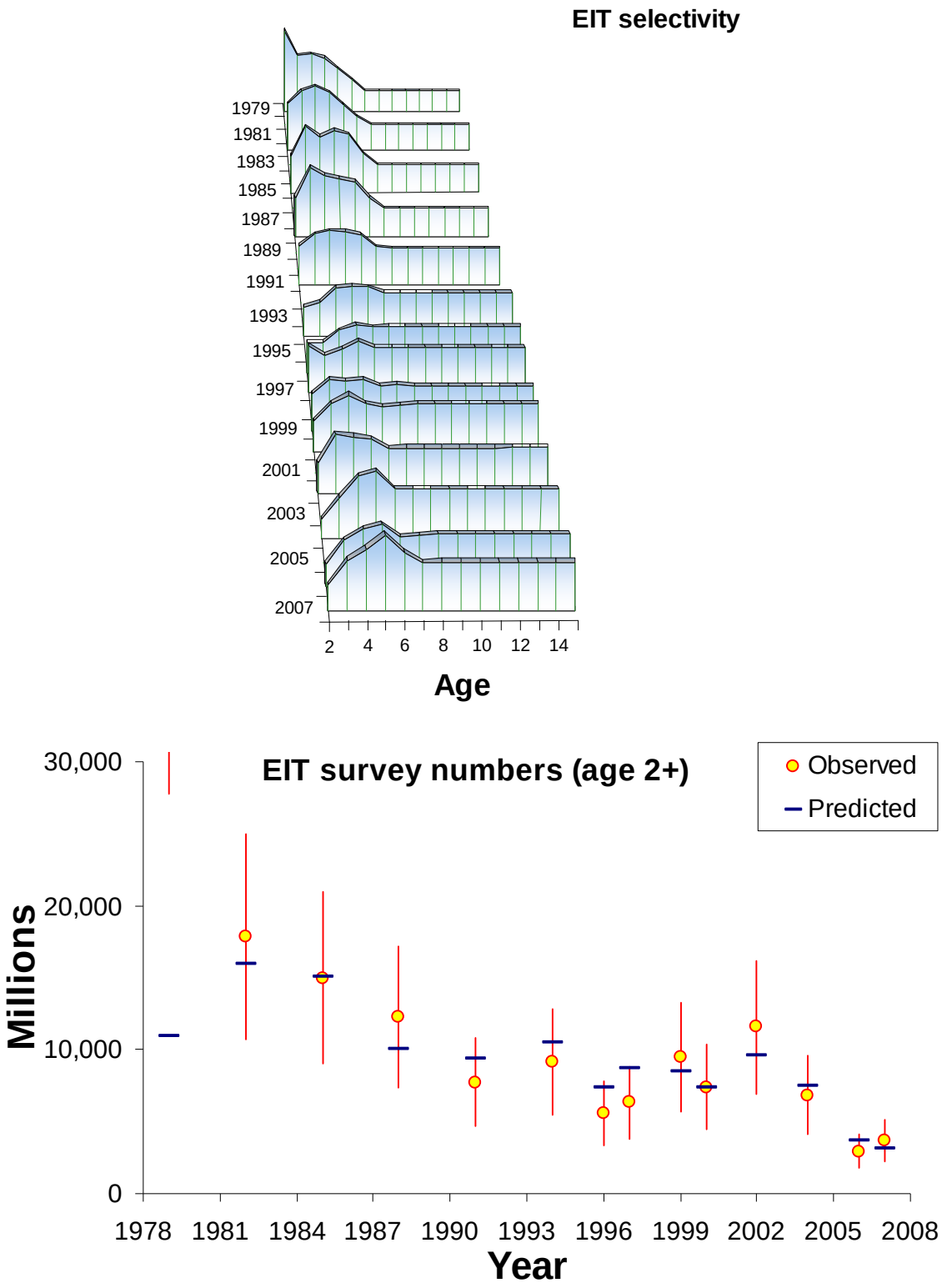


Figure 1.33. **E**stimates of EIT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS pollock age 2 and older. Note that the 1979 observed value (=46,314) is off the scale of the figure.

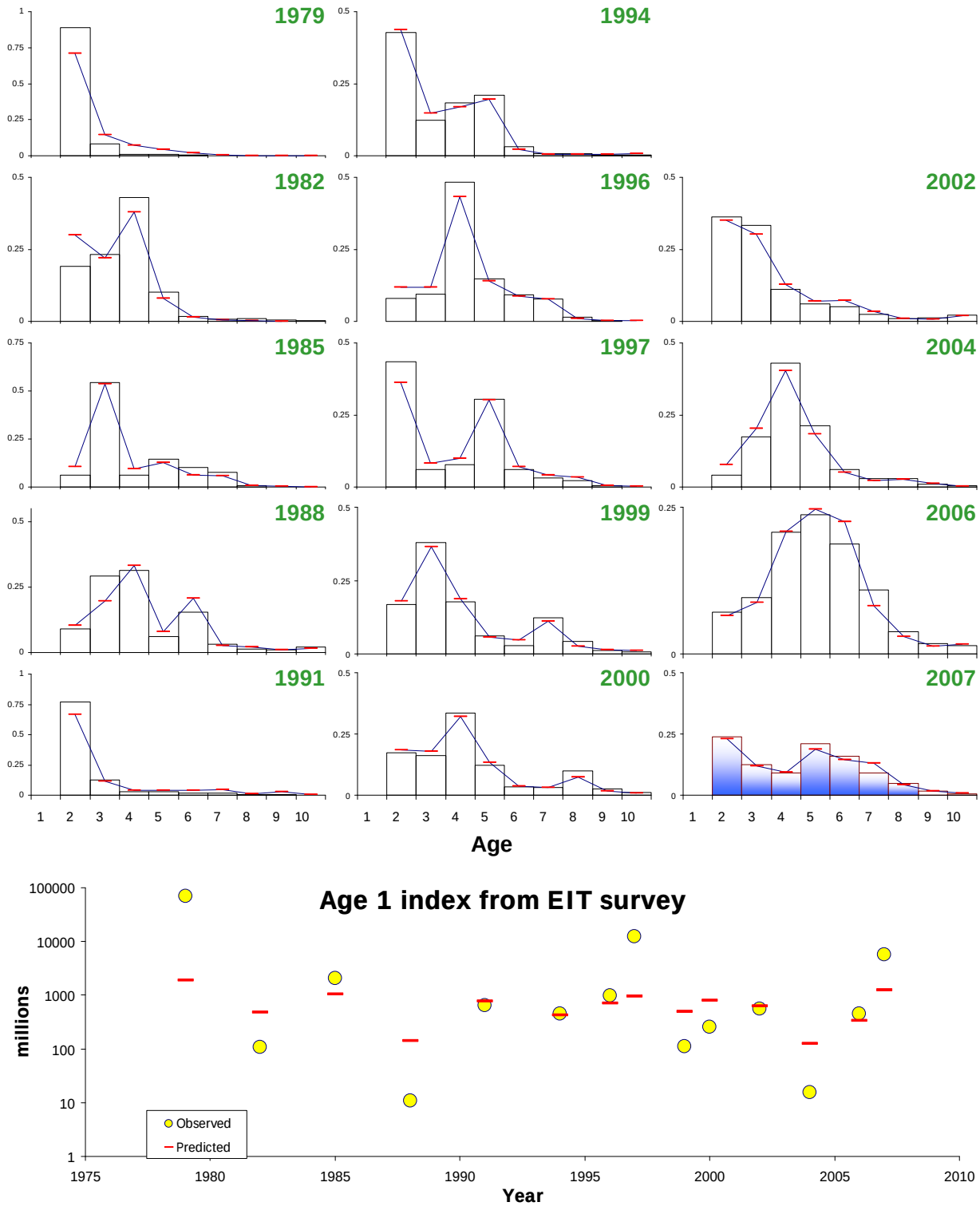


Figure 1.34. Fit to the EIT survey EBS pollock age composition data (proportions) and age 1 index (bottom panel; log-scale). Lines represent model predictions while the vertical columns and dots represent data. The 2007 age composition data are new to the assessment are shaded and the 2006 data were based on revised values using EIT age-length keys.

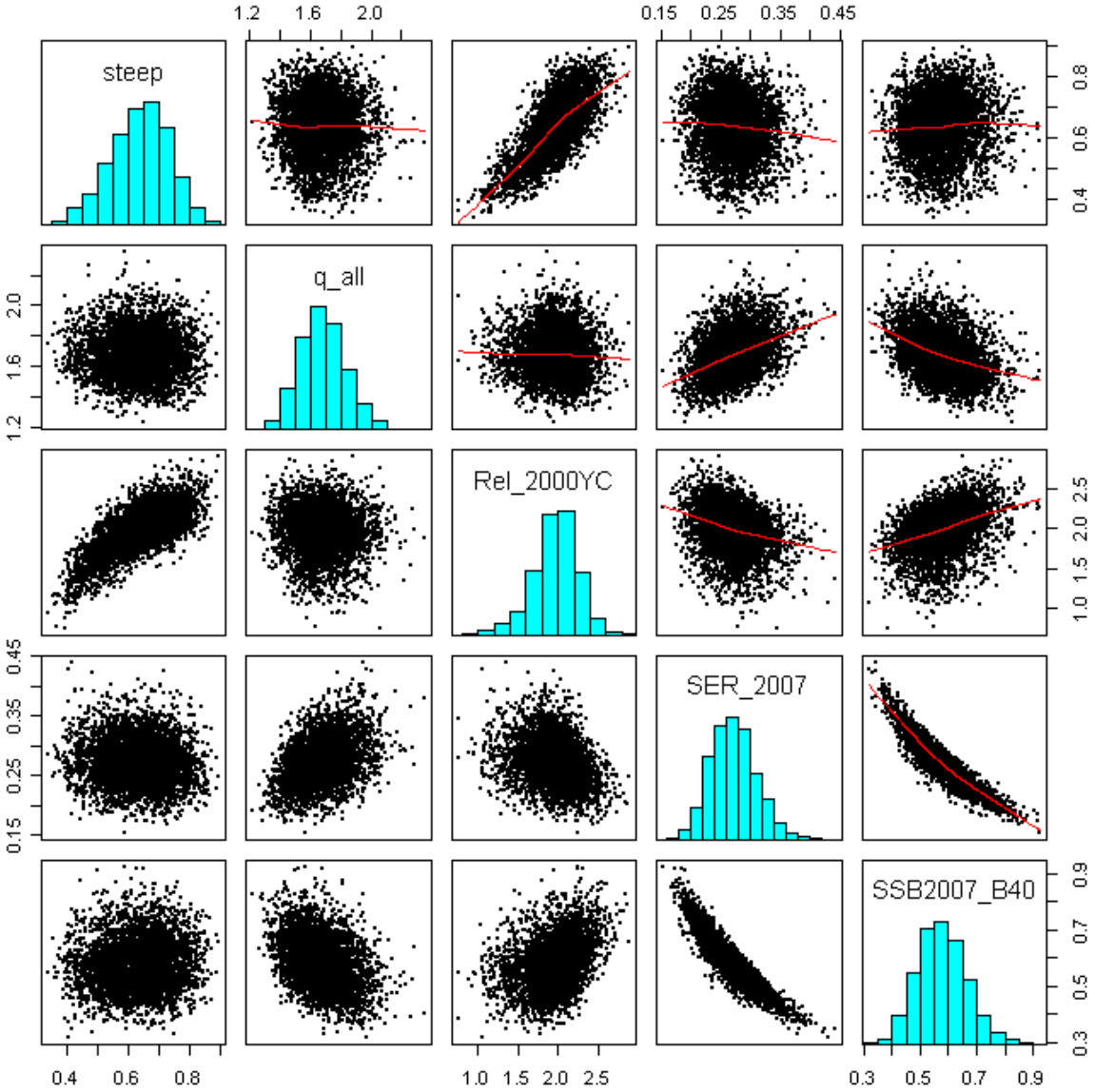


Figure 1.35. Bivariate and marginal distributions of key parameters integrated over an MCMC chain (length 4 million with every 500th sample selected and a burn-in of 4,000).

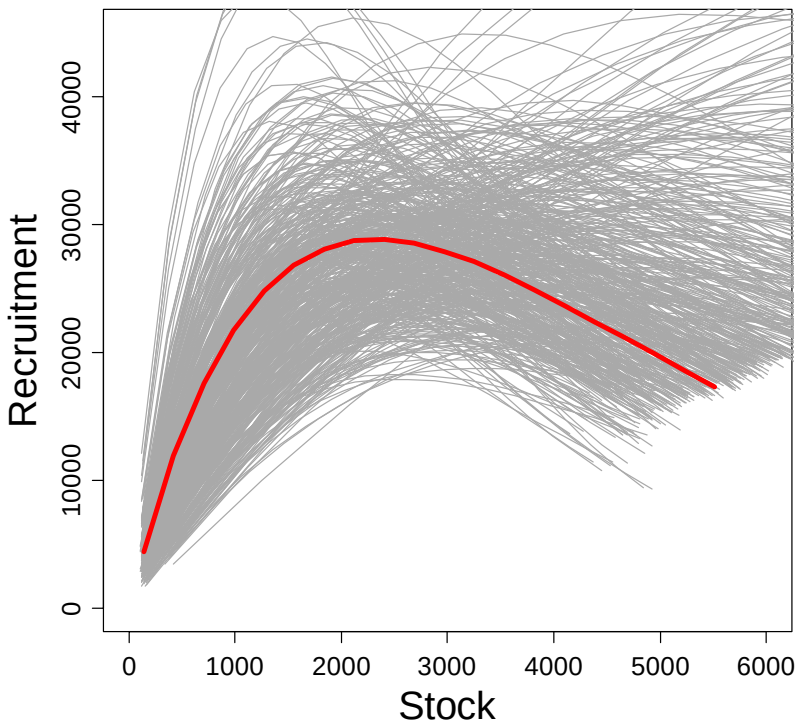


Figure 1.36. Distribution of stock-recruitment relationships drawn from posterior distribution for EBS pollock.

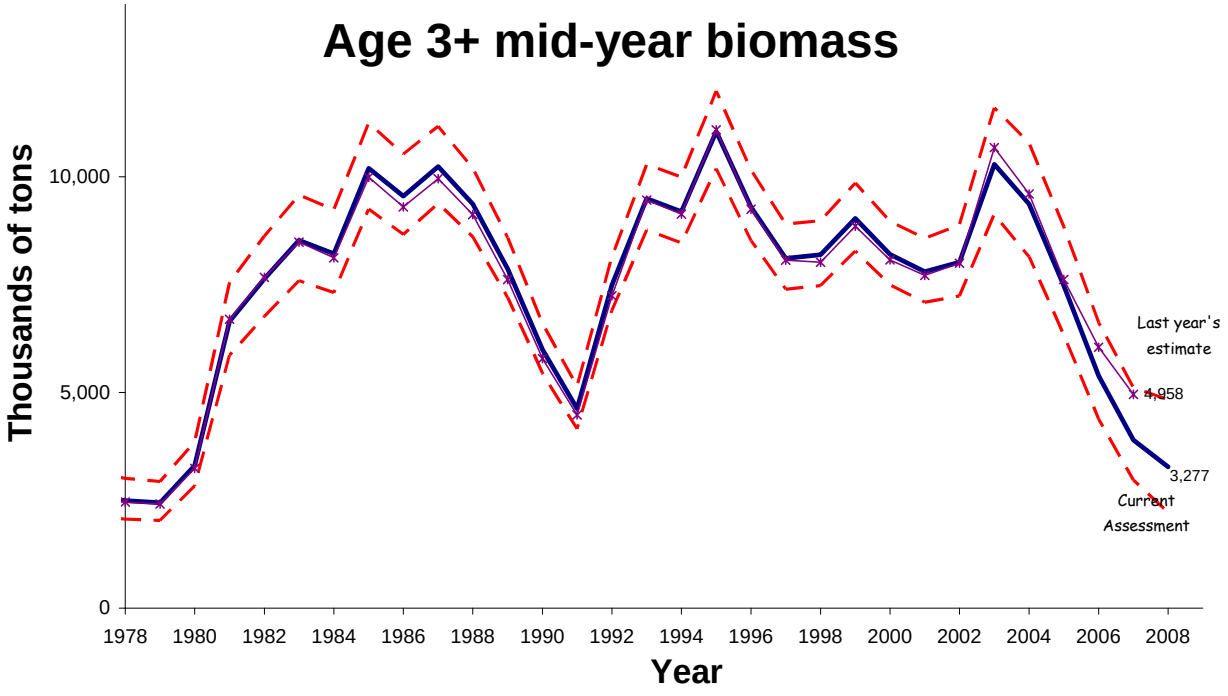


Figure 1.37. Estimated age 3+ EBS mid-year pollock biomass, 1978-2008. Approximate upper and lower 95% confidence limits are shown by dashed lines. Superimposed is the estimate of mid-year age 3+ biomass from last year's assessment

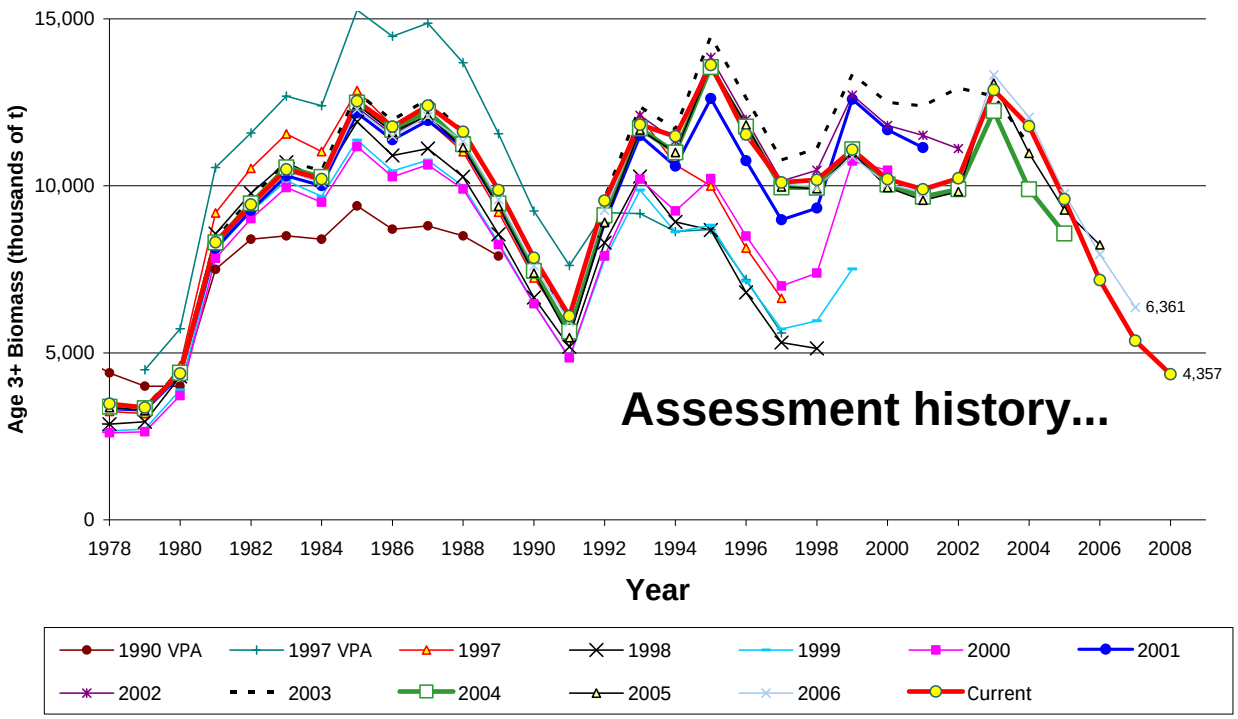


Figure 1.38. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2006.

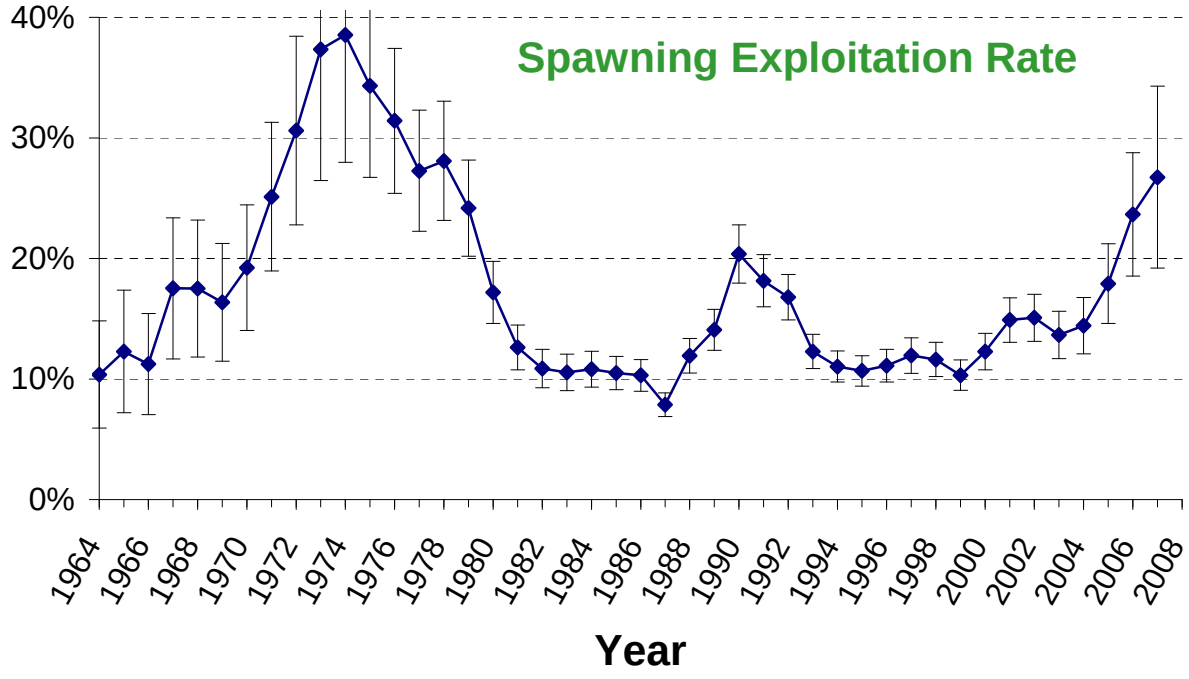


Figure 1.39. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) for EBS pollock. Error bars represent two standard deviations from the estimates.

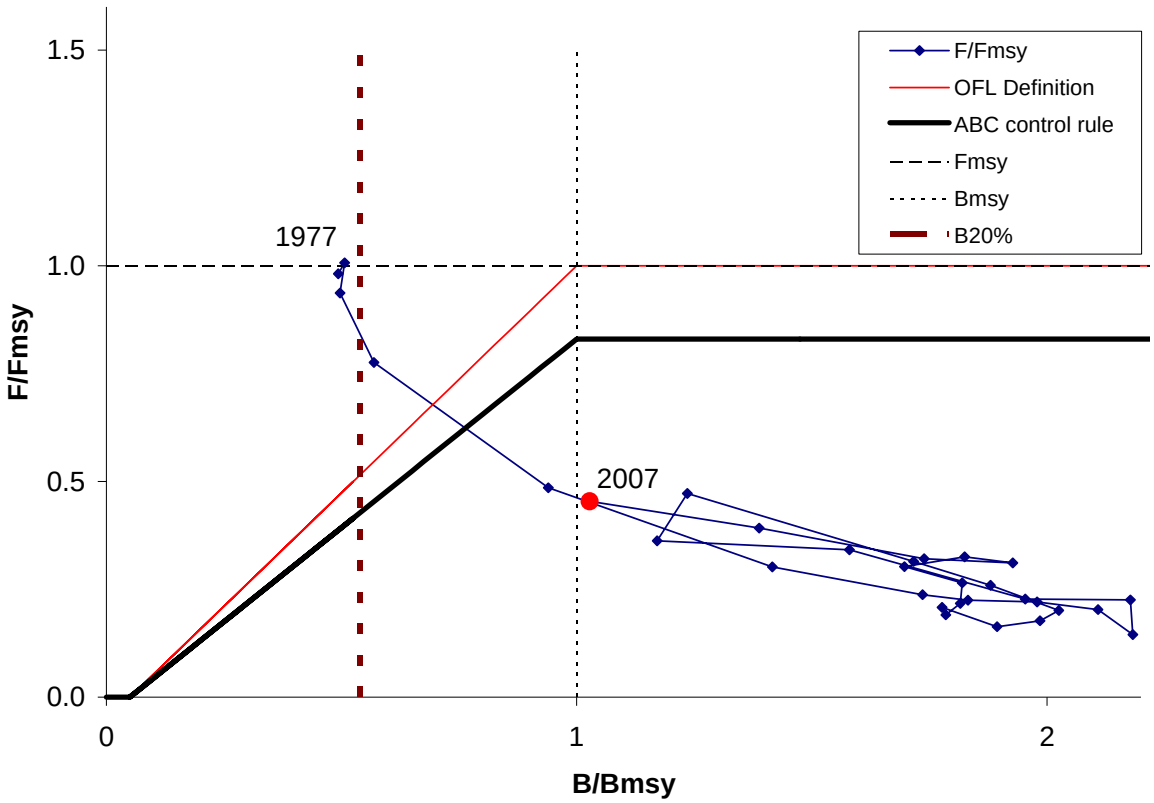
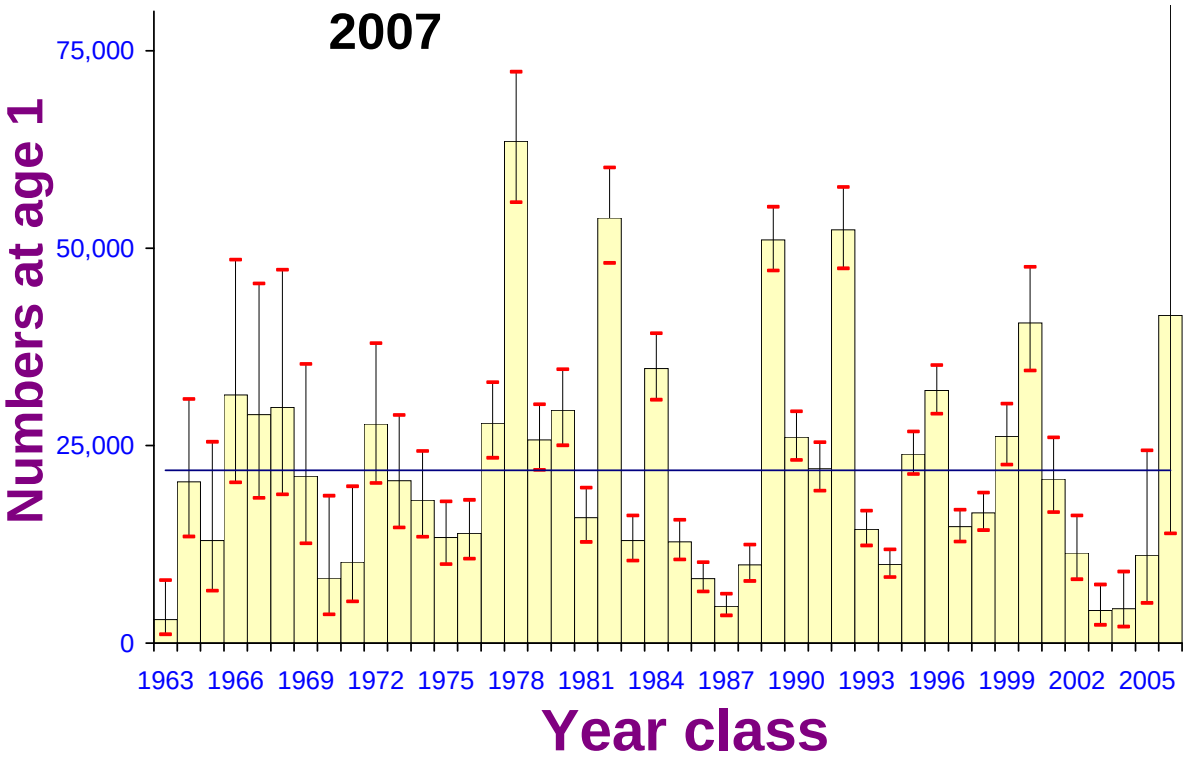


Figure 1.40. Spawning biomass relative to annually computed F_{MSY} values and fishing mortality rates for EBS pollock, 1977-2007. Note that as the stock drops below the $B_{20\%}$ level that the directed pollock fishery would be closed.



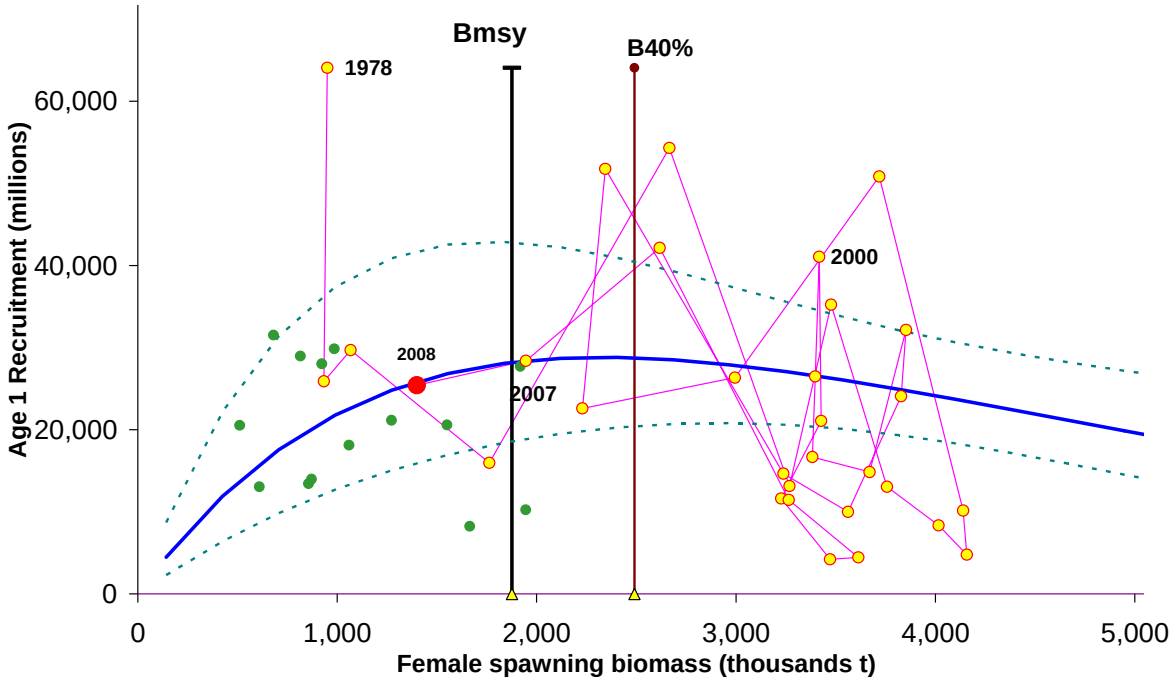
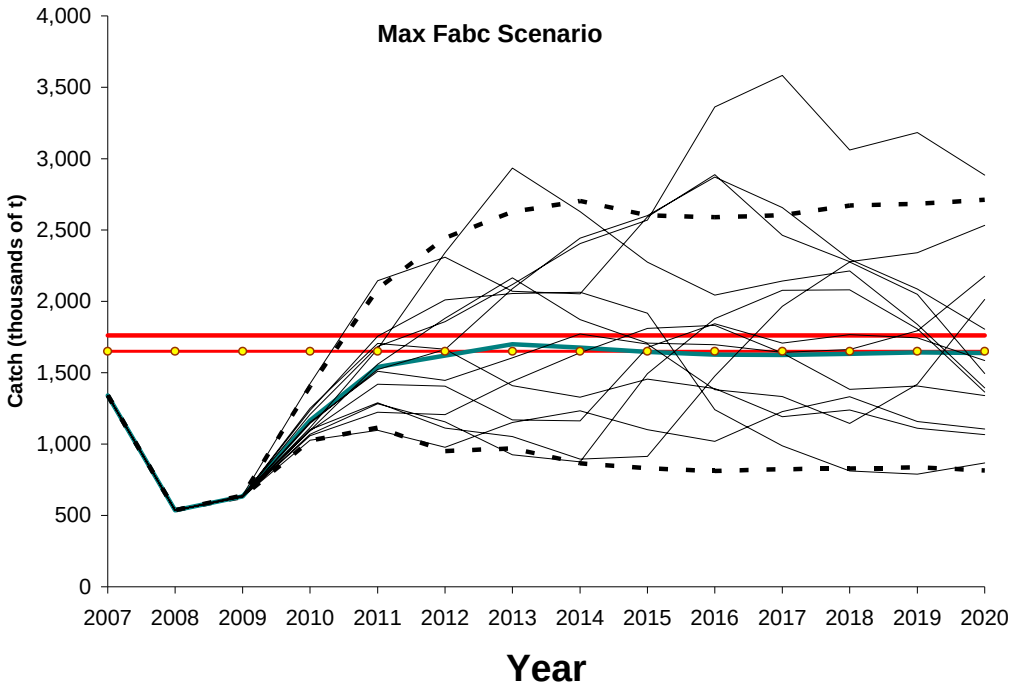


Figure 1.41. Year-class strengths by year (as age-1 recruits, upper panel) and relative to female spawning biomass (thousands of tons, lower panel) for EBS pollock. Labels on points correspond to year classes. Solid line in upper panel represents the mean age-1 recruitment for all years since 1964 (1963-2006 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 curve.



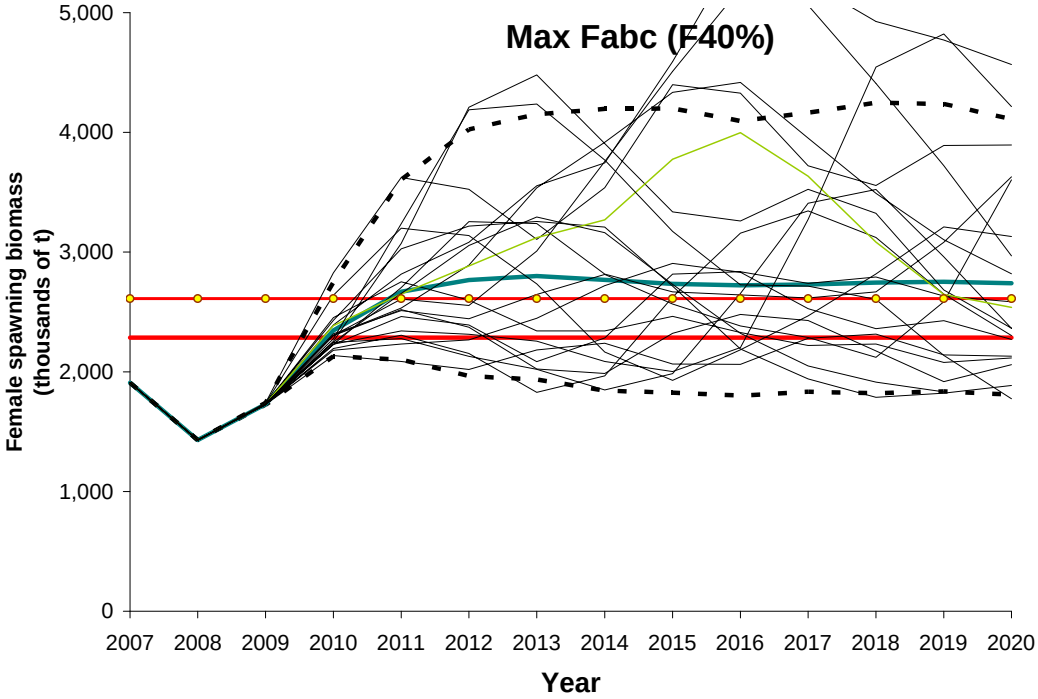


Figure 1.42. Projected EBS pollock **yield** (top) and **Female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines). $B_{40\%}$ is computed from average recruitment from 1978-2006. Future harvest rates follow the guidelines specified under Scenario 1, max F_{ABC} assuming $F_{ABC} = F_{40\%}$. Note that this projection method is provided only for reference purposes, the SSC has determined that a Tier 1 approach is recommended for this stock.

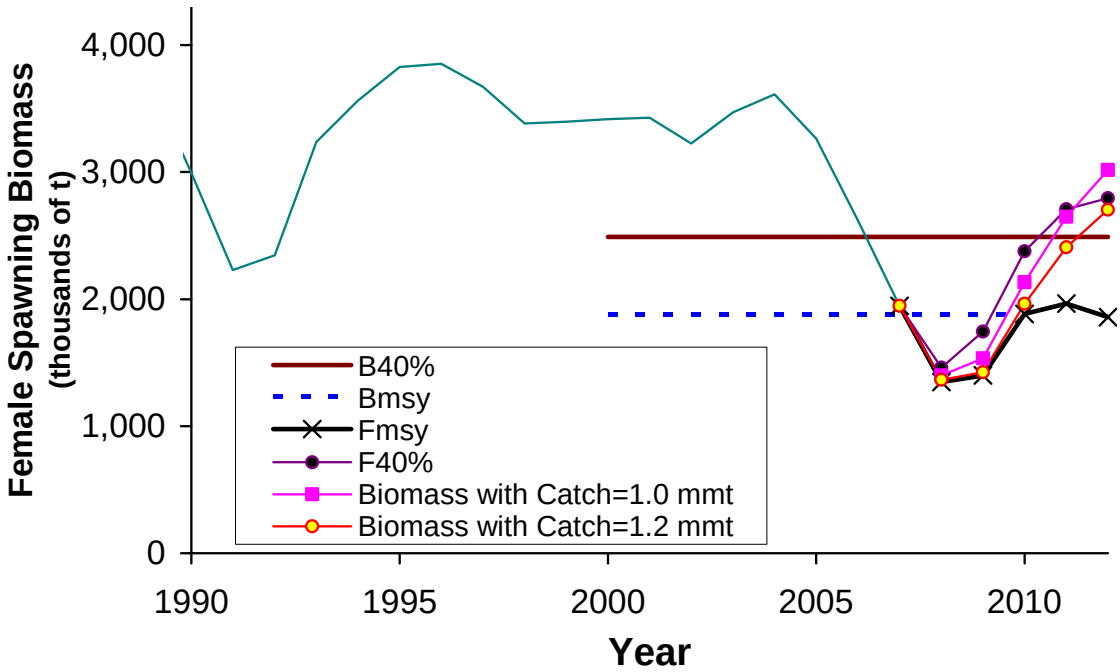


Figure 1.43. Estimated EBS pollock female spawning biomass trends, 1990-2012, under different 2008-2012 harvest levels. Note that the F_{msy} catch levels represent unadjusted arithmetic mean fishing mortality rates. Horizontal solid and dashed lines represent the B_{msy}, and $B_{40\%}$ levels, respectively.

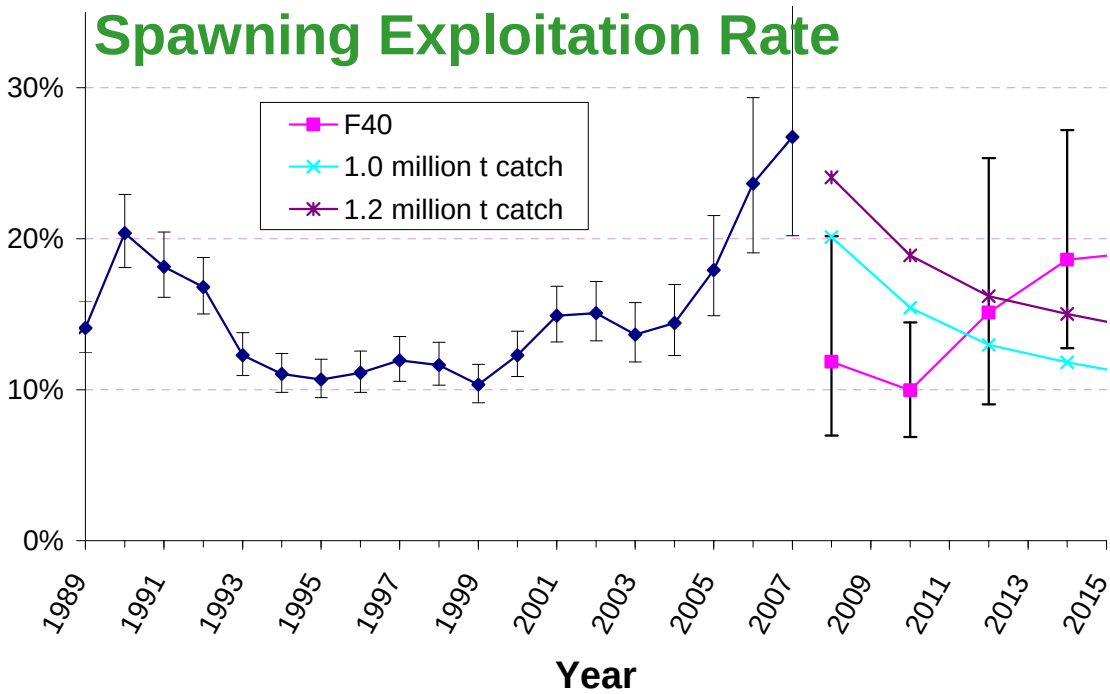


Figure 1.44. Estimated EBS pollock spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery). Error bars represent two standard deviations from the estimate and projections for 2008 show the implications of different harvest levels. Note that the $F_{40\%}$ level represents the adjusted Tier 3b value.

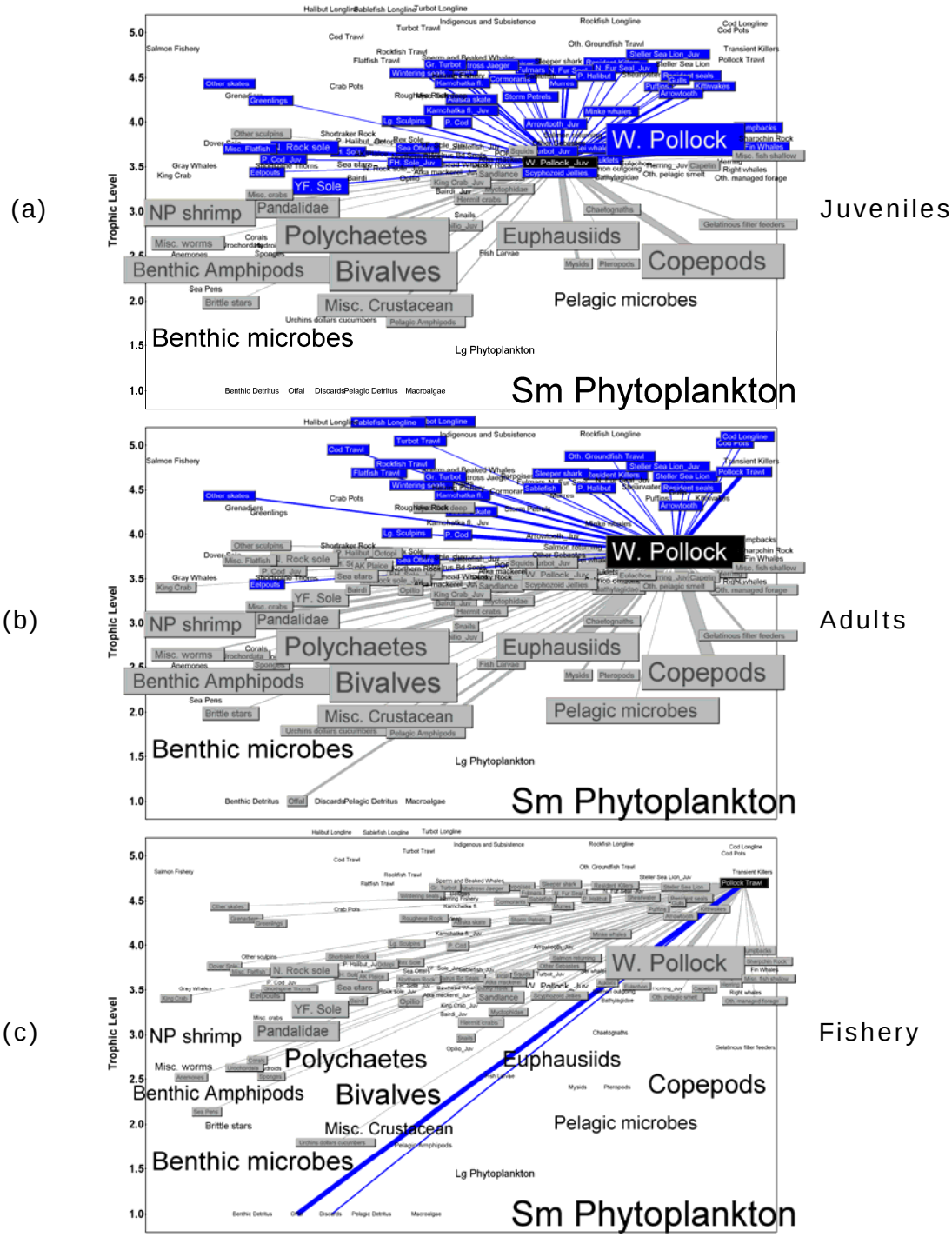


Figure 1.45. Food web pathways for the EBS region based on data from 1990-1994 emphasizing the position of EBS pollock juveniles (a), adults (b) and the pollock fishery (c). Outlined species and fisheries represent predators of pollock (dark box with light text) and prey of pollock (light boxes with dark text). Labels without boxes indicate no direct connection. Box and text size is proportional to each species' standing stock biomass, while the widths are proportional to the consumption between boxes (tons/year).

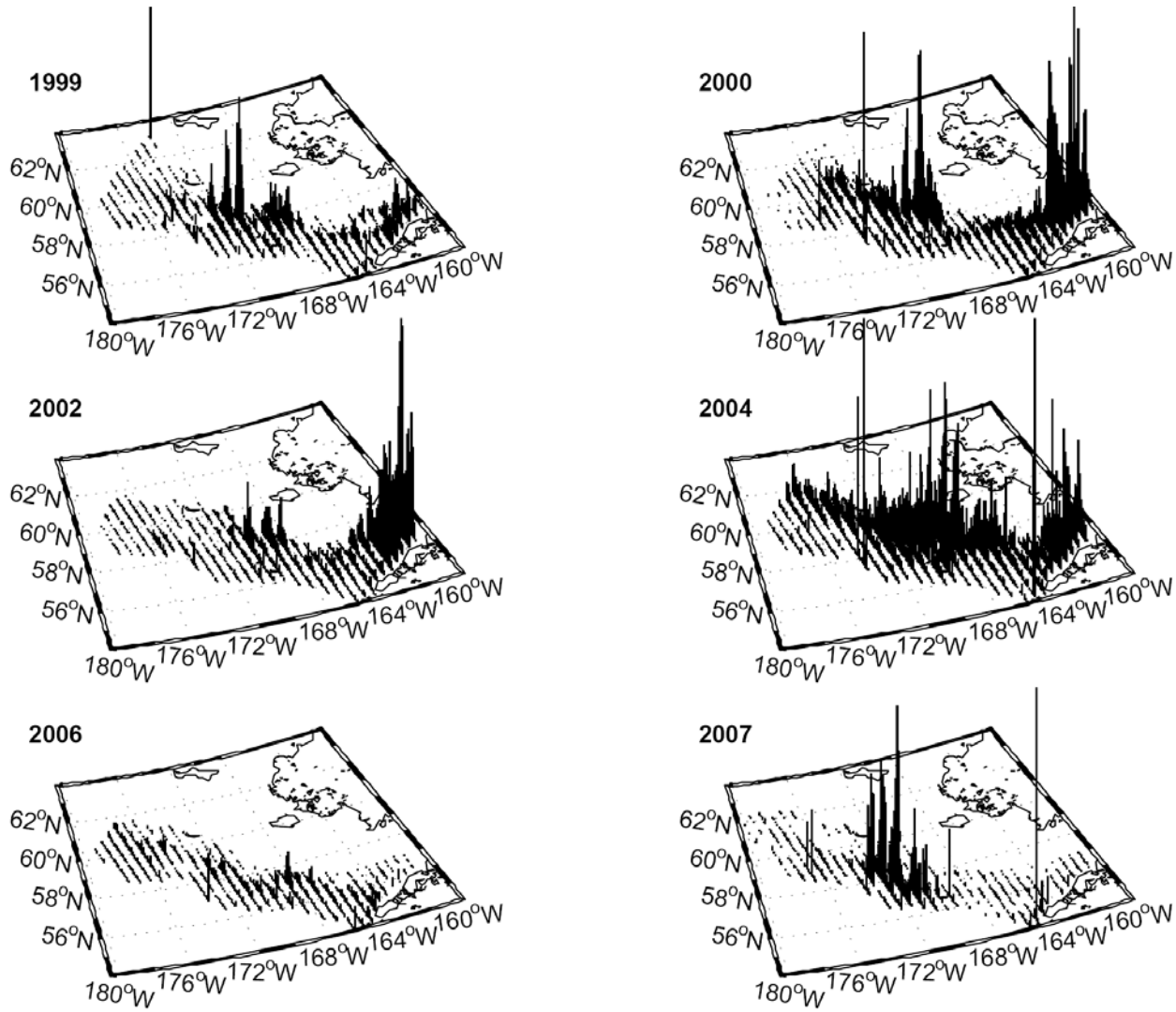


Figure 1.46. Geographic distribution of 38 kHz acoustic backscatter (s_A (m^2/nmi^2)) from species other than pollock (non-pollock, "other" backscatter) observed along tracklines during June-July eastern Bering Sea shelf acoustic-trawl surveys between 1999 and 2007.

Model details

Model structure

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). Catch in numbers at age in year t ($C_{a,t}$) and total catch biomass (Y_t) were

$$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}\left(1 - e^{-Z_{a,t}}\right)N_{t,a}, \qquad \leq t \leq T \quad 1 \leq a \leq A$$

$$N_{t+1,a+1} = N_{t,a}e^{-Z_{t,a}} \qquad 1 \leq t \leq T \quad 1 \leq a < A$$

$$N_{t+1,A} = N_{t,A-1}e^{-Z_{t,A-1}} + N_{t,A}e^{-Z_{t,A}} \quad 1 \leq t \leq T$$

$$Z_{t,a} = F_{t,a} + M_{t,a}$$

$$C_{t\cdot} = \sum_{a=1}^{A} C_{t,a}$$

$$p_{t,a} = C_{t,a}/C_{t\cdot}$$

$$Y_t = \sum_{a=1}^{A} w_a C_{t,a} \text{ ,and}$$

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

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

$$s_{t+1,a} = s_{t,a}\exp\left(\gamma_{t,a}\right), \qquad \gamma_{t,a} \sim N\left(0, \sigma_s^2\right)$$

where

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

If the selectivities ($s_{t,a}$) are constant over time then fishing mortality rate decomposes into an age component and a year component. This assumption creates what is known as a separable model. If selectivity in fact changes over time, then the separable model can mask important changes in fish abundance. In our analyses, we constrain the variance term (σ_s^2) to allow selectivity to change slowly

over time–thus improving our ability to estimate the $\gamma_{t,a}$. 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 every two years (previously three years were used). In this application, 2006-2007 were configured to have the same selectivity since the geographical patterns were quite similar compared to other years. The "mean" selectivity going forward for projections and ABC deliberations is the simple mean of the estimates from 2005-2007. Unlike previous years, since 2007 now has age specific information (through length frequency) allowing estimates to extend to such a recent year should help better capture how the fishery is evolving in the short term.

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

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

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

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

The parameters to be estimated in this part of the model are thus the $\overline{\alpha}, \overline{\beta}, \delta_t^{\mu}, \delta_t^{\alpha}, \text{and } \delta_t^{\beta}$ for t=1982, 1983,…2007. The variance terms for these process-error parameters were specified to be 0.04.

This year a modification was made to the EIT survey selectivity and how these data are treated. 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.

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):

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

with mature spawning biomass during year t was defined as:

$$B_t = \sum_{a=1}^{15} w_a \phi_a N_{at}$$

and ϕ_a, the proportion of mature females at age, was the same as that presented in Wespestad (1995).

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

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

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:

$$\alpha = \tilde{B}_0 \frac{1-h}{4h}$$

$$\beta = \frac{5h-1}{4hR_0}$$

where

$\tilde{B}_0$	is the total egg production (or proxy, e.g., female spawner 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 same prior distribution for steepness based on a beta distribution as in Ianelli et al. (2001) and is shown in Fig. 1.47.

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

$$R_t = f(B_{t-1}) = \frac{B_{t-1} e^{a\left(1-\frac{B_{t-1}}{\varphi_0 R_0}\right)}}{\varphi_0}.$$

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

$$h = \frac{e^a}{e^a + 4}$$

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:

$$R_t^{'} = \hat{R}_t \frac{f\left(S_t^{'}\right)}{f\left(\hat{S}_t\right)}$$

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 recruitment patterns (and uncertainty) have changed relative to Tier 1 and Tier 3 ABC calculations. The retrospective approach simply uses the current model to evaluate how it may change over time with the addition of new data based on the evolution of data collected over the past 14 years.

Parameter estimation

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

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

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

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

$$E_{ageing} = \begin{pmatrix} b_{1,1} & b_{1,2} & b_{1,3} & \cdots & b_{1,15} \\ b_{2,1} & b_{2,2} & & & \\ b_{3,1} & & \ddots & & \\ \vdots & & & \ddots & \\ b_{15,2} & & & & b_{15,15} \end{pmatrix} ,$$

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

In 2007 the ability to fit to length frequency data was added. This included 25 "bins" for length categories as follows:

Bin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Lower bound (cm)	25	27	29	31	33	35	36	37	38	39	40	41	42	43	44	45	46	48	50	52	54	56	58	60	62

The growth transition matrix (based on 2006 fishery data) was used to estimate the dispersion of pollock lengths given age and is shown in Fig. 1.22. The mean and standard deviation in length given age was fit as a function of age:

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Mean length (cm)	19.07	27.90	34.74	40.02	44.11	47.27	49.71	51.61	53.07	54.20	55.08	55.76	56.28	56.68	57.99
Std. Dev.	2.10	2.79	3.25	3.37	3.31	3.55	3.73	3.87	4.03	4.29	4.53	4.77	4.99	5.21	5.51

The length frequency data were fit in an analogous fashion to that of age-data when ageing errors were assumed—by converting the 2007 assessment model predicted catch-at-age into predicted length frequency using the growth and variability as estimated above. For the length frequency data, a multinomial likelihood was used.

Sample size values were revised and are shown in Table 1.16. 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:

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

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

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

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

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:

$$\hat{N}^s_{t,a}=e^{-0.5Z_{t,a}}N_{t,a}q^s_t s^s_{t,a}$$

where the superscript *s* indexes the type of survey (EIT or BTS). For these analyses we chose to keep survey catchabilities constant over time (though they are estimated separately for the EIT and bottom trawl surveys). The contribution to the negative log-likelihood function from the surveys is given by

$$\sum_{t^s}\left(\frac{\ln\left(A^s_{t\cdot}/\hat{N}^s_{t\cdot}\right)^2}{2\sigma^2_{t^s}}\right)$$

where $A^s_{t\cdot}$ is the total (numerical) abundance estimate with variance $\sigma^2_{t^s}$ from survey *s* in year *t*.

The contribution to the negative log-likelihood function for the observed total catches ($O_{t\cdot}$) by the fishery is given by

$$\lambda_c\sum_t\left(\log\left(O_{t\cdot}/\hat{C}_{t\cdot}\right)^2\right)$$

where λ_c represents prior assumptions about the accuracy of the observed catch data. Similarly, the contribution of prior distributions (in negative log-density) to the log-likelihood function include $\lambda_\varepsilon\sum_t\varepsilon_t{}^2+\lambda_\gamma\sum_{ta}\gamma_{t,a}{}^2+\lambda_\delta\sum_t\delta_t{}^2$ 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 easily estimate such a large number of parameters in such a non-linear model, 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 1991-2006. The model simply computes the values of $\overline{w}_i,\sigma^2_{w_i}$ based on available data and (if this option is selected) estimates the parameters subject to the natural constraint:

$$w_i^{future}\sim N\left(\overline{w}_i,\sigma^2_{w_i}\right).$$

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.

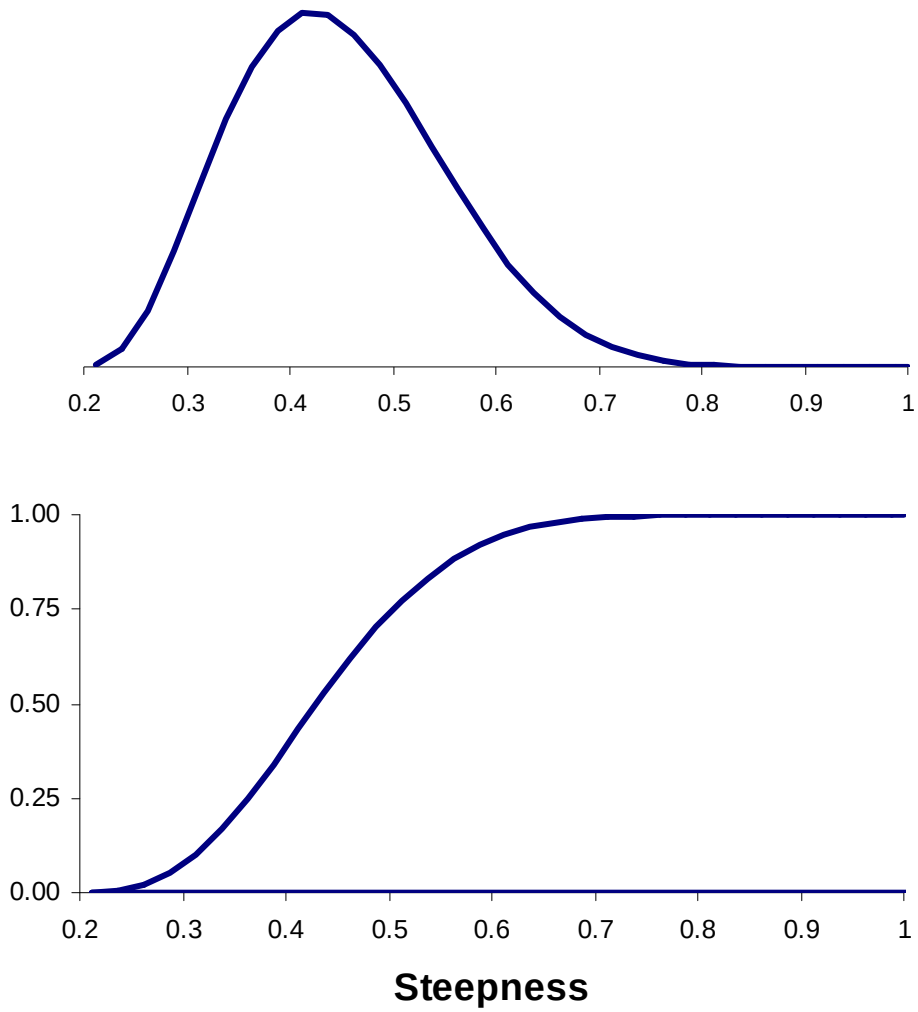


Figure 1.47. Cumulative prior probability distribution of steepness based on the beta distribution with α and β set to values which assume a mean and CV of 0.45 and 0.15, respectively. .

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