1. Assessment of Alaska Pollock Stock in the Eastern Bering Sea

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

Alaska Fisheries Science Center
National Marine Fisheries Service

Executive Summary

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

Changes in the input data
The 2006 NMFS summer bottom-trawl survey (BTS) abundance at age estimates were computed and included for this assessment. Additionally, a time series of estimates was created that included two additional north-west strata. Previously, only the standard 6 strata were included since the additional strata were not covered in 1982-1984 and 1986. Another change to the BTS data included a correction on the assumed standard errors for the annual abundance estimates from 1982-1998.

Estimates of pollock biomass from near the surface down to 3m above the bottom were added to the assessment based on the 2006 echo-integration trawl (EIT) survey. Age composition estimates were derived from the population-at-length estimates using the 2006 BTS age-length key.

Observer data for age and size composition and average weight-at-age were evaluated for the 2005 fishery and were included in the analyses. The catch-at-age data were recompiled for 1991-2005 to reflect a minor change in the timing of stratification (one stratum running till the end of May instead of the end of June). Total pollock catch for 2005 was estimated from the NMFS Alaska Region data. The 2006 catch was projected to be 1,496,800 t.

Changes in the assessment model
No major changes were made to the assessment model this year. Alternative output values for diagnostic purposes were created including a “replay” of the estimated time series of spawning biomass and age 3+ biomass given recruitments as estimated and omitting the fishing mortality component. The projection aspect of the model was modified to more easily accommodate Tier 1, 2-year forecasts for ABC and OFL levels.

Changes in the assessment results
The BTS biomass estimate from the standard area (strata 1-6) was 2.85 million t, down by 45% from the 2005 estimate of 5.13 million. This survey estimate is about 59% of the average of all BTS estimates since 1982. The 2006 echo-integration trawl (EIT) survey numbers-at-age estimates were also low with a biomass estimate (1.56 million t) nearly as low as the 1991 value (1.45 million t).

Projections for 2007 indicate that the stock is close to or slightly below the B_{msy} level and will continue to drop given the current age structure estimate. The survey data do indicate that the 2005 year class may be near or above average, but this is highly uncertain.

The 2007 maximum ABC alternatives based on the $F_{40\%}$ and F_{msy} are 1,394 and **1,512** thousand tons, respectively for the reference model (F_{msy} harvests based on the harmonic mean value). These values differ substantively from last year (the 2006 values were 1,876 and 1,931 for Tier 3 and Tier 1). In 2005, the projected Tier 1 ABC for 2007 was 1,786 thousand t. This 15% drop in the 2007 Tier 1 ABC reflects the lower than expected survey estimates in 2006. The 2007 overfishing level (OFL) alternatives are

1,680 and **1,641** thousand tons corresponding to $F_{35\%}$ and F_{msy} (arithmetic mean). The 2008 $F_{40\%}$ (Tier 3) harvest level is projected to drop below 1 million t whereas the 2008 Tier 1 value is 1,257 thousand t.

Response to SSC and Plan Team comments

Juvenile pollock: Large numbers of age 1 and 2 fish were observed in early EIT surveys, with an apparent reduction in these ages more recently and relative scarcity in all but a few years. These ages of pollock are important prey for marine birds, mammals, and adult pollock. The authors should discuss if these observations are meaningful and whether the scarcity of these prey may lead to shifts in the trophic structure in the eastern Bering Sea.

> *An evaluation of current age-structure estimates is compared with historical patterns.*

Diet data: The document addresses the diets of pollock and the importance of cannibalism. If zooplankton prey become scarce in the southeastern Bering Sea, adult pollock may become more cannibalistic. The authors should examine diet data from the past 30+ years to see if there has been a season-adjusted shift in pollock diets.

> *Seasonal stomach-content data is sparse. An examination of trends in cannibalism is evaluated, in particular, the apparent increasing role of arrowtooth flounder as a major predator of pollock is considered.*

Juvenile weight-at-age: Accurate data on weights of age-1 fish and condition indices of age-0 and age-1 fish in summer or fall would be useful as indicators of prey availability and robustness of individual fish. These data may give early warning of when foraging conditions in the eastern Bering Sea deteriorate sufficiently to have a negative impact on pollock condition. Currently [in 2005 document], an average value over years is used. The authors should determine what it would take to obtain reliable annual estimates of weight-at-age of age-0 and age-1 pollock.

> *A project to examine this using BASIS survey data has been initiated in the past year.*

Bycatch categories: Data indicate that there has been a change in the categories by which bycatch is tabulated. The authors should describe what categories would be most useful for timely retrieval of information on species of concern.

> *There are several new initiatives addressing species of concern that are beyond the scope of this assessment. The higher-profile species (e.g., salmon, squid) are presented. While bycatch species in the pollock fishery are proportionately small compared to the pollock catch, the magnitude of removals of currently non-managed species will be more closely monitored, particularly if there are trends that warrant closer examination.*

Lists of ecosystem considerations of BSAI pollock are presented in a table. Given the recent very low abundances of zooplankton, especially the copepod *Calanus marshallae,* on the middle shelf of the southeastern Bering Sea, it would seem that there should be either moderate or high concern about these low levels. Either here or in the Ecosystem SAFE, it should be discussed whether warming temperatures in the southern Bering Sea are adversely affecting the production of large species of zooplankton.

> *As discussed below, 2006 exhibited some colder conditions. The extent of ice during the winter was higher than in recent years and during the summer, bottom temperatures were colder than normal. Additionally, non-pollock backscatter was extracted from EIT surveys over past years and compared with 2006 levels.*

Model evaluation: The SSC appreciates the discussion on model selection and agrees with the author's recommended approach to evaluate the performance of the current model(s) in the context of a management strategy evaluation (MSE). As the authors note, the approach that has been used in the past tried to balance concerns about biological realism, process errors, observation errors, and conservation. Many of the choices about model structure and the various assumptions made in developing the models are invariably subjective due to model complexity. There remains a great deal of (often unacknowledged) model uncertainty and decisions about appropriate harvest levels are made conditional on the final model choice, assuming that it is the "best" model for the job. The MSE approach uses many of the same assumptions that underlie the model to test the model's performance in a management context, but may not address the underlying assumptions themselves and uncertainty about model structure. Therefore, it remains important to continually examine important aspects of model structure such as the choices for the coefficient of variation for various data components, sample sizes for length and age composition data, the assumed error distributions (multinomial, log-normal, etc), the shape and flexibility of selectivity curves, and changes over time in selectivity. As the authors of this and other assessments continue to explore alternative models they should clearly lay out the rationale and criteria used for choosing the "best" model, in particular when subjective criteria are used to "overrule" objective criteria based on traditional significance tests or model selection criteria.

> *Sensitivity analyses to different aspects of model configurations were conducted and presented. A rationale for selecting the preferred model is given based on objective reasoning. Nonetheless, subjective decisions are still required. Where these occur will be made more explicit. Using the MSE approach allows for a number of assumptions to be tested. The operating model can (and should) be quite different than the estimating or ABC/TAC setting model. In order to determine the "'best' model for the job" objectives would need to be more clearly specified in order to evaluate performance. As a step in the direction on understanding how the current model version of the assessment model performs, a 13-year retrospective analysis was undertaken (i.e., the current selected model was run starting in 1992 and successively adding "new" data in each year and re-running the model).*

Russian catches: The SSC appreciates the efforts to formally include Russian catches in the pollock model. If or when additional data become available (such as Russian CPUEs from pelagic surveys done by TINRO), we encourage the authors to evaluate the consequences of possibly missing a substantial portion of the pollock stock that may reside outside the historical assessment area. That this has been the case, at least in recent years, is clearly indicated in the 2004 EIT survey and in recent BASIS surveys, which suggest a continuous distribution of age-0 pollock throughout the Eastern Bering Sea as far north as St. Lawrence Island (Ecosystem chapter, p. 131). If current climate conditions in the eastern Bering Sea persist, we may expect an increasing portion of the stock to reside in Russian waters (at least during the summer).

> *Correspondence with Russian scientists has continued and age-composition data from the Polish fleet fishing in Russian waters during 1995-98 was obtained. Extending the BTS data to include the NW strata also encompasses pollock that are more likely to be related to pollock that straddles the convention line. On preliminary examination, the Polish catch-age data appears to be substantively different than data from a similar period on the US side of the convention line. This may be due to differences in age-structure interpretation. Further investigation is required to ensure similar ageing criteria were used.*

Temporal stratification for age-composition estimates: The current stratification scheme uses temporal strata for Jan-Jun and Jul-Dec, respectively, primarily to stratify with respect to the A and B seasons. The SSC notes that in recent years the B season has started in mid June. Therefore, the SSC recommends that the authors modify their stratification scheme to separate A-season from B-season samples.

> *This was done and recalculated for all years since 1991.*

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. The northern stock is believed to 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, these 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

The fishery pattern has been to focus on winter spawning-aggregations of pollock. This so-called "A-season" opens on January 20th and extends into early-mid April. This first season typically lasts about 4-6 weeks, depending on the catch rates. A second season opening has occurred on September 1st (though 1995 opened on Aug 15th). This has changed considerably since 1998. Currently, the first season generally extends into the middle of March and the summer season begins in mid-late June (Fig. 1.2).

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 2004 - 2006 (Fig. 1.3), especially compared to the 2003 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. 1.4). 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. 1.5).

After 1992, the "B-season" (typically September – October) fishery has been conducted to a much greater extent west of 170°W than it had been prior to 1992 (Ianelli *et al.* 1998). This shift was due to the implementation of the CVOA (Catcher Vessel Operational Area) in 1992 and also the geographic distribution of pollock by size. The pattern in the past few years show consistent concentrations of catch around the Unimak Island area and along the 100 m depth contour to the northwest of the Pribilof Islands. (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 (preliminary data). This is consistent with an indication of a strong 2000 year class (with some possible confounding of the 1999 year class).

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

In response to continuing concerns over the possible impacts groundfish fisheries may have on rebuilding populations of Steller sea lions, NMFS and the NPFMC have made changes to the Atka mackerel (mackerel) and pollock fisheries in the Bering Sea/Aleutian Islands (BSAI) and Gulf of Alaska (GOA). These have been 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 had disproportionately high seasonal harvest rates within critical habitat that *could* lead to reduced sea lion prey densities. Consequently, the management measures were designed to redistribute the fishery both temporally and spatially according to pollock biomass distributions. The underlying assumption in this approach was that the independently derived area-wide and annual exploitation rate for pollock would not reduce local prey densities for sea lions. Work continues on evaluating the effectiveness of these measures and the potential for adverse fishery and Steller sea lion (or other marine mammal) interactions. These are presented in the ecosystem considerations section below.

Three types of measures were implemented in the pollock fisheries:

- Pollock fishery exclusion zones around sea lion rookery or haulout sites,
- Phased-in reductions in the seasonal proportions of TAC that can be taken from critical habitat, and
- 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. 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.

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.

In 2000, further reductions in seasonal pollock catches from BSAI Steller sea lion Conservation Area (SCA) were realized by closing the entire Aleutian Islands region to pollock fishing and by phased-in reductions in the proportions of seasonal TAC that could be caught from the SCA, an area which overlaps considerably with sea lion critical habitat. In 1998, over 22,000 t of pollock were caught in the Aleutian Island regions, with over 17,000 t caught in AI critical habitat. Since 1998 directed fishery removals of pollock have been prohibited.

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,” this figure increases to 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. In 2005 and 2006 the proportion of catch within the SCA has dropped considerably with about 30% of the catch taken in this area. The pattern of catch since 1998 is shown below:

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	530	45%
	Jul-Dec	558	673	17%
	Jan-Dec	851	1,204	29%
2006	Jan-Jun	262	533	51%
	Jul-Dec	620	706	12%
	Jan-Dec	851	1,239	31%

Note: Pollock catches (thousands of tons) are as reported by at-sea observers only, 2006 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. 1.3).

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 Chinook and chum salmon in 2005 were the highest on record. Bycatch to date for Chinook salmon in 2006 remains high while chum salmon bycatch is lower than in 2005 but still higher then long term averages. Given information indicating that 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 exempt vessels participating in a voluntary rolling hot spot (VRHS) closure system. This system is believed to be more responsive and dynamic to changing conditions in the fishery compared to static area closures. Since this amendment is pending the Chinook salmon savings area closed February 13, 2006. This was the first time in a closure was triggered during the A-season due to high levels of bycatch. An exempted fishing permit (EFP) was issued during the 2006 B season to test the efficacy of the VRHS system to provide insight for designing regulations in amendment 84. Additional salmon bycatch management measures including new regulatory closures are also under consideration by the Council.

Catch data

Since 2001, the total allowable catch (TAC) for EBS pollock has been at record levels over 1.4 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 1991-2004 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 a low of 1.3% in 2001. These recent low values reflect the implementation of the Council's Improved Utilization and Improved Retention program. Discard rates 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, 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). In the past year, all age-composition estimates were re-evaluated. This research is part of a project in collaboration with researchers at the University of Alaska Fairbanks, Juneau. An area-specific catch-age model for pollock around the Bering Sea is being developed which uses the spatially disaggregated data. This model, among other uses, will help in the design and analyses of pollock-tagging programs.

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.

The time series of the catch proportions-at-age suggests that during 1999-2005 a broad range of age groups were harvested. In 2005 (new data presented in this assessment) the age ranges appear to be focused primarily on age pollock age 4-7 with 5 year-olds (2000 year class) making up the majority of the catch (Fig. 1.8). The values used in the age-structured 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 following table documents annual research catches (1977 - 2005) from NMFS surveys in the Bering Sea and Aleutian Islands Region (tons):

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Bering Sea	15	94	458	139	466	682	508	208	435	163	174	467	393	369
Aleutian Is.				193		40	454			292				

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Bering Sea	465	156	221	267	249	206	262	121	162	164	149	179	236		NA
Aleutian Is.	51			48			36			40		79			

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 1.7.

Between 1983 and 1990 the BTS biomass estimates were relatively high and showed a slightly increasing trend (Table 1.8; Fig. 1.9). Between 1991 and 2005 the BTS biomass estimates ranged from 2.21 to 8.14 million t. The 2006 estimate is 2.85 million tons, down by 45% from the 2005 estimate of 5.13 million. This survey estimate is about 59% of the average of all BTS estimates since 1982 and reflects a decline in the stock since 2003. In 2006 the distribution of pollock from the BTS showed the highest concentrations in the northwestern area of the surveys and closer to the shelf break compared to the 2005 pattern (Fig. 1.10).

In general, the interannual variability of survey estimates is due to the effect of year class variability. Survey abundance-at-age estimates reflect the impact of this variability (Fig. 1.11). 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 current assessment, the estimate is about 31 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 subsequent section below, the characteristics of how strong year-class estimates change over time are illustrated.

Beginning in 1987 NMFS expanded the standard survey area farther to the northwest (Fig. 1.12). 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 1.9). 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 also evaluated using the retrospective approach described below in a subsequent section. The estimated numbers-at-age from the BTS for the standard strata (1-6) and for the northern strata included as used in Models 1 and 2 below are presented in Table 1.10.

The survey age composition information provides insights on temporal patterns in length-at-age. In particular, when converted to weight-at-age it appears that in recent years the average size (ages 4-8) has recovered to about average compared with the below-average sizes observed from 1995-2002 (Fig. 1.13). Since 1982, the pattern in size at age shows a weak periodic trend about every 10 years. This pattern seems to be inversely related (approximately) to pollock abundance and may suggest that density dependent processes may be involved.

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. 1.14). Total mortality estimates by cohort are difficult to interpret—here we take them as average mortality over the life of the cohort (since we know that harvest rates varied 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).

Effect of temperature

Using an innovative approach to link temperature with pollock density patterns, Kotwicki et al. (2005) were able to develop hypotheses about seasonal movement. They suggest that younger pollock respond to temperature and tend to be distributed farther north than the larger age-3 and older pollock. This may be related to changes in diet as pollock age and get larger (becoming less planktivorous and more piscivorous) since zooplankton tend to be more abundant in the northwestern region of the Eastern Bering Sea.

This year, the effect on pollock weight given length was evaluated for annual differences within our survey data. Variability in length-weight relationship between years was studied for all years where length and weight data were available. The relationship between total length (*L*) and total weight (*W*) was expressed by the equation:

$$W = aL^b$$

Log-transformation of this equation yielded the following coefficients for each year treated independently:

Year	log(a)	*b*	R^2
1991	2.984	-11.814	0.9896
1999	3.043	-12.260	0.9914
2000	2.984	-11.860	0.9920
2001	3.041	-12.207	0.9937
2002	2.991	-11.871	0.9932
2003	2.989	-11.852	0.9914
2004	2.966	-11.740	0.9884
2005	2.930	-11.530	0.9756
2006	3.053	-12.288	0.9946

Year-effects among slopes and intercepts were tested and found to be statistically significant ($p<0.0001$). Multiple regression methods were used to assess the impact on mean bottom temperature and survey timing on these parameters. The timing of the survey was found to be insignificant for the length-weight relationships. However, mean bottom temperature proved to be effective in predicting both slope and intercept of length-weight relationship (Fig. 1.15). While these parameters are correlated, from this cursory investigation, it appears that, for example, a 25cm pollock may vary in mean weight by between 15-20% in weight depending on temperature alone (with colder temperatures resulting in less weight given length). Further studies on these patterns using simple means tests and incorporating extensive fishery data are planned.

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 shows a fairly extensive cold pool similar to that observed in 1999 (Fig. 1.16). It should be noted that the timing of the survey can affect the estimate of “cold” years (Fig. 1.17). Rather than using simple global average temperatures as a driving force affecting survey catchability, this year a refinement was attempted. Based on examinations of the proportion of tows with pollock and the density of pollock observed as a function of temperature at each station (Fig. 1.18), a time series on the area of habitat that falls in the range of 0.5° and 4.5° C was calculated (Fig. 1.19). This shows that the amount of area considered prime for pollock was lower in 2006 and this index was tested for the effect on survey catchability (i.e., Model 3 presented below).

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 1.8). The 2006 echo-integration trawl (EIT) survey estimates was low with a biomass estimate (1.56 million t) nearly as low as the 1991 value (1.45 million t). The geographic concentration and extent of pollock from the 2006 survey is low compared to that from 2004 (Fig. 1.20). Note that these figures show that the EIT survey often found pollock in local areas where they were less abundant in the bottom-trawl survey.

The 2006 EIT survey population numbers at age estimates were done using geographically split age-length keys (E and W of 170°W). 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. The population-at-length shows a bimodal length frequency and when mapped with the age-length keys, suggested that the 2002 and 2001 year-classes were relatively abundant compared to the 2000 year class (Figs. 1.21 and 1.22).

The number of trawl hauls and sampling quantities for lengths and ages from the EIT survey are presented in Table 1.11.

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 2006 (Table 1.12). Compared to 2004, the relative abundance of pollock in 2006 was much lower overall with the biggest difference being the relative lack of pollock (and other, non-pollock biota, Boldt et al., 2006) 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 1964-2006. 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 are:

- the 2006 EBS bottom trawl survey estimate of population numbers-at-age was added;
- the 2006 EBS EIT survey estimate of population numbers-at-age were included using age-length keys from the 2006 BTS survey data; and
- the 2005 fishery age composition data were added.

Changes to the model included developing 2-year ahead projections to facilitate Tier 1 OFL and ABC determinations. For the purpose of these projections, catch in 2007 (for deriving the 2008 ABC and OFL) were assumed to be equal to the average of the three most recent years (2004-2006). Also, 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 $f\left(\widehat{S}_t\right)$ representing the stock-recruitment function given spawning biomass under no fishing and under the fishing scenario, respectively.

Finally, the original capability of the assessment model to easily conduct retrospective analyses (e.g., Parma 1993, and Ianelli and Fournier 1998) was upgraded. In addition to having the ability to examine how estimates evolve over time, specific issues related to how recruitment patterns (and their uncertainty) have changed was included along with 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. This also was applied to Models 1 and 2 below to assist in selecting between these two model configurations.

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. For this assessment, the maturity schedule presented above appears to be reasonable.

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 1.13).

Parameters estimated conditionally

A total of 664 parameters were estimated were estimated for the reference model. Initial age composition, subsequent recruitment values and stock-recruitment parameters account for 66 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 1964-2006 and projected recruitment variability (using the variance of past recruitments) for five years (2007-2011). 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 three years with the three most recent years (2004-2006) 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 year component of fishing mortality result in 44 parameters and the age-time forms an 11x15 matrix of 165 parameters bringing the total fishing mortality parameters to 209. This compares 40x15 or 600 implied fishing mortality parameters in cohort analysis (e.g., Pope 1972) which assumes total catch-at-age estimates are known perfectly.

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 78 parameters. For the EIT survey, which began in 1979, 308 parameters are used to specify age-time specific availability. Estimates for changes in EIT selectivity sometimes occur for years when the survey was not conducted increasing the number of parameters estimated, but avoiding problems associated with irregularly spaced surveys over time. Time-varying survey selectivity is estimated to account for the uncertain availability of pollock to the survey gear.

A new approach on evaluating the effect of temperature on the survey catchability was developed. First, data from the BTS surveys for all years (1982-2006) was compiled and station-specific pollock catch records were compared with bottom temperatures at each station. The distribution of tows available for analyses and the relative abundance (in proportion of tows and in CPUE) of pollock by different water temperature was shown in Fig. 1.18. This lead to the decision to characterize preferred pollock "habitat" as being from between 0.5°C and 4.5°C. With this information, a GIS technique was used to estimate the proportion of the survey area that contained water mass between these two temperatures for each survey year. This area was then normalized to have a mean of zero and annual values by year represented percentage-anomalies from the mean. Thus, in year t survey catchability was modeled as a function of habitat area (H_t) as:

$$q_t = \mu_q + \beta_q H_t$$

where μ_q is the mean catchability and β_q represents the slope parameter. This formulation and the time series presented above (Fig. 1.16) was used in Model 3 below.

For other models, the catchability coefficient for the bottom-trawl survey is estimated in the same manner as is done for the other two indices (early CPUE data and the EIT survey). These three catchability coefficients (one for each index) are estimated as free parameters.

Finally, three additional fishing mortality rates are estimated conditionally. These are the values corresponding to the $F_{40\%}$, $F_{35\%}$ and the $F_{30\%}$ harvest rates. These rates satisfy the constraint that given selectivity-at-age vector (we used the mean selectivities based on model configuration), proportion-mature-at-age, natural mortality rate, and weight at age, there are unique values 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. 1.9; 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 1.14).
- 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

In this year's assessment, new treatment of survey data is one of the main developments in the past year. These include:

1) The standard survey area for all years (1982-2006), **Model 1**.
2) Including the stations that were done in strata 8 and 9 (NW of standard strata). This required specifying a separate survey catchability for the years 1982-84 and in 1986 since the survey was restricted to strata 1-6, **Model 2**.
3) As in 2) above, with an added ecosystem index of "suitable habitat" that affects bottom-trawl survey catchability, **Model 3**.

Rather than having an objective selection where all models are considered equally plausible apriori, our approach has been to balance likely levels of process errors (e.g., recruitment variability, survey age-specific availability) with observation errors (e.g., the estimates of age composition derived from expanding samples from surveys and fisheries). Conservation concerns may also affect model selection. For example, some models may fit the data equally well, but are rejected for ABC recommendations due to conservation concerns. If alternative models indicate ABC levels substantially lower than the reference model, then given the precautionary approach and evidence of a conservation concern, an alternative model might be selected in favor of a "reference" model.

In model selection, perhaps model performance should be judged for setting ABC when other factors (e.g., migration, growth changes, productivity shifts) are ignored. A precisely selected model still fails to assuage structural assumptions about the model. Development of a management strategy evaluation (MSEs) approach continues. In an MSE, an "assessment model" is evaluated based on "known" simulation tests where alternative hypotheses about the stock dynamics (typically much more complex) are run through a feedback scenario. This year's developments have focused on evaluating historical patterns (via retrospective analyses presented below) to develop reasonable hypotheses for constructing operating models. Also, an area-specific movement model is being developed which also may serve as a framework for evaluating our management practices.

This year, the model evaluations revolve principally around treatment of the NMFS bottom trawl survey as discussed above. Also, the "suitable habitat" index was included (i.e., Fig. 1.19) a limited set of sensitivity models is presented. These are presented to exhibit behavior and responses to data and assumptions. However, for management purposes the reference model that uses the entire survey data

(Model 2) is recommended since it seems to characterize the key aspects of uncertain processes and observations.

The models presented are:

Model	Description
1	Standard bottom-trawl survey strata (1-6 only) for the entire time series (1982-2006), future selectivity based on most recent (3-year) estimate (short-term selectivity estimate).
2	As in Model 1 but including the stations that were done in strata 8 and 9 (NW of standard strata). This required specifying a separate survey catchability for the years 1982-84 and in 1986 since the survey was restricted to strata 1-6.
3	As in Model 2 above, with an added ecosystem index of “suitable habitat” that affects bottom-trawl survey catchability

This year Model 2 was selected over Model 1 since the area of the survey covers the distribution of pollock more fully. As with Model 1, it seems to characterize key aspects of the uncertain processes and observations and is sufficiently responsive to detected population changes.

In Model 3, the effect of bottom temperature on habitat definition was refined over past years. However, this refinement failed to contribute significantly to explain added components of survey catchability variability. Mean “habitat area” effect is slightly positively correlated with survey availability (β=0.039 and standard error 0.121). As before, the significance of this fit is low given this standard error, and the overall fit is virtually identical to Model 2 (Table 1.15; Fig. 1.23). Mean bottom temperature alone fails to provide a strong indicator for changes in survey availability. Presumably availability also is affected by the current age-structure of the population (younger pollock may be more or less sensitive than older pollock) and perhaps the vertical distribution of pollock.

Retrospective analyses
As part of this year’s model evaluation, a 15- year retrospective analyses of Models 1 and 2 were undertaken. This meant conducting an additional 30 model runs (two for each “terminal” year since 1991). In general, the retrospective pattern appears to show a tendency to under-estimate terminal year biomass levels even though the estimated uncertainty is quite high (Fig. 1.24). Examined more closely, the evolution of biomass estimates for selected years shows that they can be biased high for a number of years or be relatively stable (Fig. 1.25). This type of analyses is useful for critically analyzing model assumptions. For example, the fact that some strong year-class estimates evolve quite differently as additional data is added in each year suggest that unaccounted processes are occurring (Fig. 1.26). The 1992 year-class was estimated to be near average for 6 years whereas for the past 6 years it has been estimated to be among the strongest year-classes. Conversely, the 1996 year-class was estimated early-on to be about 3 times larger than average recruitment whereas in the last 4 years, subsequent data indicate that it was only about twice as large as average. The algorithm for calculating harmonic-mean catches (using the delta-method approximation for variance terms) was applied in the retrospective model runs for Tier 1 and Tier 3. Between Models 1 and 2, Model 2 (which uses more data) appeared to have less variability in the ABC recommendation (Fig. 1.27). For this reason, and since including the data from the NW strata seems reasonable since fishing and pollock extend into this area, Model 2 is recommended for management and assessment purposes.

The new diagnostic measure introduced this year examines the current stock status relative to where it may have been under no fishing (since 1978). The impact of adding in the stock-recruitment curve (as described above in the “Model Structure” section, is illustrated in Figure 1.28.

Results

The two models brought forward this year (Models 1 and 2) tend to fit all age compositions and survey indices better than last year's model (Table 1.15). This could be due to refinements made in the data and also in correcting some early BTS survey variances that were found to be in error. The spawning biomass is anticipated to be well below $B_{40\%}$ in 2007 (85% of the value) but be above the B_{msy} level (Table 1.16). The new diagnostic introduced this year is that the current spawning stock is about 58% of the predicted value had no fishing occurred since 1978. This compares with the 34% of $B_{100\%}$ (based on the SPR expansion from mean recruitment since 1978) and 40% of B_0 (as from the estimated stock-recruitment curve). Comparisons of yields for the two models are quite similar (Table 1.17).

Comparing the current and projected age structure for Model 2 relative to the last year's assessment indicates that this year's abundance estimate of 2006 numbers at age is about 91% of last year's estimates (Fig. 1.29). The 2000 year class remains relatively prominent and estimates of subsequent year classes (i.e., the 2001 and 2002) are higher than estimated previously.

The estimated selectivity pattern changes over time to become slightly more dome-shaped since 2000 (Fig. 1.30). This may be due in part to older fish becoming more bottom-oriented and dispersed and thus less available to the fishery. The model fits the fishery age-composition data quite well and strong year classes are clearly evident (Fig. 1.31). The model fit to the early Japanese fishery CPUE data (Low and Ikeda, 1980) is consistent with the population trends for this period (Fig. 1.32).

As in previous assessments, the selectivity was specified so that it could vary slightly over time for both survey types (EIT and BTS). This was done to account for potential changes in fish distribution. For example, it seems reasonable to assume that the presence of 1-year-olds available to the bottom-trawl gear on the shelf might be variable, even when the abundance is the same (Fig. 1.33). The bottom trawl survey age composition data continue to indicate the 2000 year class as being relatively abundant and that the 2005 year class was present in reasonably good numbers (Fig. 1.34). .

The EIT survey selectivity dramatically changed over time (Fig. 1.35) possibly due in part to changes in age-specific pollock distributions over time. Also, the number of hauls sampled has generally increased over time—presumably this trend affects the overall estimate of the age composition of pollock available to the survey. These patterns are also illustrated in the model fit to the EIT survey age composition data (Fig. 1.36). The proportions at age observed in the survey are generally consistent with what appeared later in the bottom-trawl survey and fishery. Estimated numbers-at-age for Model 2 are presented in Table 1.18 and estimated catch-at-age presented in Table 1.19. Estimated summary biomass (age 3+), female spawning biomass, and age-1 recruitment for Model 2 is given in Table 1.20.

To explore the multidimensional parameter uncertainty, the posterior distribution was integrated using Monte-Carlo Markov Chain methods. This involved generating 1 million simulations drawn from the posterior distribution. This chain was then "thinned" to reduce potential serial correlation to 5,000 parameter draws from the posterior distribution. Selected model parameters (Model 2) are 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; Fig. 1.37). The population was projected assuming fixed catches of 1.2 and 1.4 million tons. The probability that the 2006 stock size is below $B_{40\%}$ level is higher than in recent years (~53% estimated chance that the 2006 spawning biomass is below the $B_{40\%}$ level). By 2009, the expectation is that the stock size will drop below the $B_{40\%}$ stock size level (with about 89% probability), and then increase (with considerable uncertainty) to similar levels by 2011 (Fig. 1.38).

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 1.21, Fig. 1.39). 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. Peak biomass occurred in 1985 and then the population declined to about 4 million t by 1991 as these above-average year classes decreased in abundance with age and were replaced by weaker year classes. In 1992 an upturn in abundance began with the recruitment of a strong 1989 year class. This was followed by the 1992, 1996 and 2000 year classes that have kept the stock at relatively high levels. From 1992 to 2003, the age 3 and older biomass had been variable at around 8 million tons[1]. As predicted in last year's assessment, the stock has declined substantially since 2003 and is projected to continue the current decline in 2007.

Compared with past year's assessments, the estimates of age 3+ pollock biomass are slightly lower in the current assessment for recent years and nearly identical before 2002 (Table 1.21). 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. 1.40).

The abundance and exploitation pattern estimated from Model 2 shows that the spawning exploitation rate (SER, defined as the percent removal of spawning-aged females in any given year) has averaged about 14% in the past 10 years and for 2006 has increased to 21% (Fig. 1.41). This compares to an overall average SER of 17% (1964 – 2006) and is equal to the highest level seen in the past 20 years (1990). The observed variation in pollock abundance is primarily due to natural variation in the survival of individual year classes.

One way to evaluate past management and assessment performance is to plot estimated fishing mortality relative to the (current) maximum permissible 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 51% of $F_{40\%}$ (Fig. 1.42).

Recruitment

The 2000 year class is well above average and represents a major component of the population (about 20% of the total biomass projected for 2007, or 36% of the "exploitable" biomass—that is adjusted by selectivity). Of the exploitable stock, the 2007 fishery is expected to be comprised of about 82% of the pollock coming from the 1999-2002 year classes.

As seen in the retrospective analysis presented above, the coefficients of variation or "CV" (reflecting uncertainty) on year classes can change dramatically as information is added. Currently, there is some indication that the 2005 year classes will be average or well above (Fig. 1.43, top panel). The uncertainty in the magnitude of this year class propagates into future stock size uncertainty and makes future survey information critical for providing appropriate 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 (Fig. 1.43, 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, the extent of their

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

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, we selected the following values from Model 2 results computed based on recruitment from post-1976 spawning events:

$B_{100\%}$ = 6,381 thousand t female spawning biomass[2]

$B_{40\%}$ = **2,552** thousand t female spawning biomass

$B_{35\%}$ = 2,233 thousand t female spawning biomass

B_{msy} = **2,061** thousand t female spawning biomass

Specification of OFL and Maximum Permissible ABC

For Model 2, the year 2007 spawning biomass is estimated to be 2,172 thousand tons (at the time of spawning, assuming the stock is fished at average level of catch from 2004-2006). This is above the B_{msy} value of **2,061**. Under Amendment 56, Tier 1a, the harmonic mean value is considered a risk-averse policy provided reliable estimates of F_{msy} and its pdf are available. A simplified exploitation-rate type value that corresponds to the F_{msy} levels as applied to the age 3+ biomass was used for computing ABC levels under Tier 1 (Ianelli et al. 2004).

The 2007 estimate of female spawning biomass (at time of spawning assuming 2007 Tier 3 catch levels) is **2,170** thousand t. This is below the $B_{40\%}$ value of **2,552** but above the B_{msy} value estimated under Tier 1. The OFL's and maximum permissible ABC values by Tier are thus:

Tier	Year	OFL	Max ABC
1a	2007	**1,641** thousand t	**1,512** thousand t
1b	2008	1,365 thousand t	1,257 thousand t
3b	2007	1,680 thousand t	1,394 thousand t
3b	2008	1,115 thousand t	913 thousand t

ABC Recommendation

This year's estimated 2006 abundance levels is 9% lower than last year's estimate which reflects survey estimates that were lower than expected. The biomass of Eastern Bering Sea pollock is projected to continue declining from the 2003 peak until 2008. The rate of decline over this period has averaged about 19% per year. The spawning exploitation rate has consequently increased by 15% from 2003-2006. Under Tier 3 projections, the spawning stock biomass is expected drop below B_{msy} (**2,061** thousand t) by 2008, then level off and increase (Fig. 1.44).

Given the rapidly declining stock and the recent increases in harvest rates, 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 unknown stock removals in Russian waters. Setting the ABC below the maximum permissible value can provide opportunities reduce the projected declines (e.g., constant catch scenarios of 1.4 and 1.2 million t; Fig. 1.45). Since the projections suggest that the stock is currently headed for higher spawning biomass exploitation rates than have been estimated for the past 20 years, an ABC level that stabilizes this rate is recommended. Figure 1.46 shows that if 1.2 million t is taken next year, the rate drops below 20% whereas if 1.4 million t is taken, the rate rises above 25% (and the highest observed in the past 20 years is 21%). Therefore, an ABC for 2007 of 1.3 million t is recommended. While this may seem to be an

---

[2] Note that another theoretical "unfished spawning biomass level" (based on stock-recruitment relationship $\tilde{B}_0$) is somewhat lower (**5,452** t).

arbitrary adjustment, the rationale for this recommendation is based on the fact that fishing conditions and stock productivity have been excellent at exploitation rates that have been considerably lower than recent levels. Increasing the exploitation rate for a stock that is declining at the present rate (~19% per year since 2003 based on age 3+ biomass) seems likely to increase the risk of the fishery's catch stability. That is, higher catches in 2007 may result in considerably lower catches in 2008. Catch rates experienced by the fleet are also likely to drop as pollock stock densities reach lower levels. This may impact the economic viability of the fishery as a whole and some sectors in particular.

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}. Due to this and other complications, an option to have projections based on Tier 1 has been delayed. For this section, we thus treat this stock as if it were managed under Tier 3 for projections, but provide a proxy ABC and OFL value under Tier 1 rules (by using the same harmonic and arithmetic mean values for MSYR as applied to the age 3+ biomass).

For each scenario, the projections begin with the vector of 2006 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2007 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch assumed for 2006. 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 2007 and 2008, 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 constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2006 and 2007 recommended in the assessment to the *max* F_{ABC} for 2006. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to the 2001-2005 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 $F_{75\%}$. (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 2006 or 2) above ½ of its MSY level in 2007 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2007 and 2008, *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 2019 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 1.22). 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. 1.44).

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 2007:

a) If spawning biomass for 2007 is estimated to be below ½ $B_{35\%}$ the stock is below its MSST.

b) If spawning biomass for 2007 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c) If spawning biomass for 2007 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 1.22). If the mean spawning biomass for 2017 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 2009 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2009 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2009 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2019. If the mean spawning biomass for 2019 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 2007, nor is it expected to be approaching an overfished condition based on Scenario 7 (the mean spawning biomass in 2009 is above the $B_{35\%}$ level; Table 1.22). For harvest recommendations, Tier 3 and a proxy for Tier 1 calculations were made that give ABC and OFL values for 2007 and 2008 (assuming catch is 1,394,000 t in 2007 Table 1.23).

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 have been greatly reduced in this fishery.

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. 1.47). 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. 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; Figs. 1.48). 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; Fig. 1.49).

Regarding specific small-scale ecosystems of the EBS, Cianelli 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 1.24. 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” backscatterers 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 and 2006 (Fig. 1.50). They represent 38-kHz acoustic backscatter (sA, m2/nmi2) attributed to an undifferentiated invertebrate-fish species mixture, along with unidentified fish. For the 1999, 2000 and 2002 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 necessarily always performed as rigorously as classification of pollock, so non-pollock backscatter may contain small amounts of non-biological scatter. Trawl data suggest that biological components include jellyfish such as Chrysaora sp., macrozooplankton, age 0 pollock, and other fishes. Some scatterers, such as swimbladdered fishes and large medusae, are more easily detected at 38 kHz than small and poorly reflective organisms such as macrozooplankton (e.g. copepods and euphausiids). Because these scatterers all reflect sound at different target strengths, comparison of backscatter both within and between years is not strictly possible. However, it is obvious from the data presented below that the contribution from non-pollock scatterers in 2006 was quite a bit lower than that of preceding years. This suggests that the ecosystem, particularly in the southeastern region of the EBS, was anomalously different in the summer of 2006, 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.

Furthermore, several other ecosystem indicators may give cause for concern. Zooplankton and non-pollock forage 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 larger 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. (Fig. 4A in Ecosystem Considerations). 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, according to length frequencies in summer diet data (Figure 1.51). 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 in the Bering Sea and the Gulf of Alaska shows that arrowtooth are truly a top predator in the Gulf of Alaska. However, in the Bering Sea, pollock, skates, and sharks all prey on arrowtooth, giving the species a relatively high predation mortality (Fig 1.52).

The predation on small arrowooth 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, Fig. 1.53). 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; we are currently collaborating in the development of a detailed, age-structured, multispecies statistical model (MSM; Jurado-Molina et al. 2005) to more completely model this complex interaction for pollock and arrowtooth; this model will be applied to the question in the near future.

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 1.25). 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 1.26). 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 1.27). 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 1.28.

Acknowledgements

Grant Thompson provided the methodology used for the standard harvest scenarios and the associated text. Terry Hiatt compiled the catch and bycatch records. We thank the staff of the AFSC age-and-growth department for their excellent work in promptly processing the samples used in this assessment. The work of many individuals involved in collecting and processing survey and observer data is greatly appreciated.

References

Arsenev, V.S. 1967. Currents and water masses in the Bering Sea. Nauka Press, Moscow. English translation by S. Pearson, 1968, U.S. Dept. Commerce, NMFS, Seattle, 147 pp.

Aydin, K. Y., et al.2002. A comparison of the Eastern Bering and western Bering Sea shelf and slope ecosystems through the use of mass-balance food web models. U.S. Department of Commerce, Seattle, WA. (NOAA Technical Memorandum NMFS-AFSC-130) 78p.

Bailey, K.M., T.J. Quinn, P. Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, *Theragra chalcogramma*. Advances in Mar. Biol. 37:179-255.

Barbeaux, S. J., S. Gaichas, J. N. Ianelli, and M. W. Dorn. 2005. Evaluation of biological sampling protocols for at-sea groundfish observers in Alaska. Alaska Fisheries Research Bulletin 11(2):82-101.

Barbeaux, S.J., M. Dorn, J. Ianelli, and J. Horne. 2005. Visualizing Alaska pollock (*Theragra chalcogramma*) aggregation dynamics. ICES CM 2005/U:01.

Beverton, R. J. H. and S. J. Holt. 1957. On the dynamics of exploited fish populations. Fish. Invest., Lond., Ser. 2, 19.

Boldt, J. 2006. Ecosystem considerations chapter for 2006. http://access.afsc.noaa.gov/reem/ecoweb

Butterworth, D.S., J.N. Ianelli, and R. Hilborn. 2003. A statistical model for stock assessment of southern bluefin tuna with temporal changes in selectivity. Afr. J. mar. Sci. 25: 331-361.

Canino, M.F., and P. Bentzen (2004). Evidence for positive selection at the pantophysin (Pan I) locus in walleye pollock, *Theragra chalcogramma*. *Molecular Biology and Evolution*, Volume 21, No. 7, pp. 1391-1400 (July 2004).

Canino, M.F., P.T. O'Reilly, L. Hauser, and P. Bentzen. 2005. Genetic differentiation in walleye pollock (*Theragra chalcogramma*) in response to selection at the pantophysin (*Pan* I) locus. Can. J. Fish. Aquat. Sci. 62:2519-2529.

Ciannelli, L., B.W. Robson, R.C. Francis, K. Aydin, and R.D. Brodeur (2004). Boundaries of open marine ecosystems: an application to the Pribilof Archipelago, southeast Bering Sea. *Ecological Applications*, Volume 14, No. 3. pp. 942-953.

Clark, W.G. 1999. Effects of an erroneous natural mortality rate on a simple age-structured model. Can. J. Fish. Aquat. Sci. 56:1721-1731.

Cotter, A.J.R., L. Burt, C.G.M Paxton, C. Fernandez, S.T. Buckland, and J.X Pan. 2004. Are stock assessment methods too complicated? Fish and Fisheries, 5:235-254.

Deriso, R. B., T. J. Quinn II, and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Can J. Fish. Aquat. Sci. 42:815-824.

Dorn, M.W. 1992. Detecting environmental covariates of Pacific whiting *Merluccius productus* growth using a growth-increment regression model. Fish. Bull. 90:260-275.

Fadeev N.S., Wespestad V. Review of walleye Pollock fishery// Izv. TINRO.-2001.- Vol.128.- p.75-91.

Fair, L.F. 1994. Eastern Bering Sea walleye pollock: revised estimates of population parameters, relation of recruitment to biological and environmental variables, and forecasting. M.S. Thesis, University of Alaska Fairbanks, Fairbanks AK. 131 p.

Fair, L.F. and T.J. Quinn II, (In prep.). Eastern Bering Sea walleye pollock: a comparison of forecasting methods. Draft MS. Juneau Center, School of Fish. And Ocean Sci. Univ. Alaska Fairbanks. 32 p.

Fournier, D. 1998. An Introduction to AD model builder for use in nonlinear modeling and statistics. Otter Research Ltd. PO Box 2040, Sidney BC V8L3S3, Canada, 53p.

Fournier, D.A. and C.P. Archibald. 1982. A general theory for analyzing catch-at-age data. Can. J. Fish. Aquat. Sci. 39:1195-1207.

Francis, R.C., K. Aydin, R.L. Merrick, and S. Bollens. 1999. Modeling and Management of the Bering Sea Ecosystem. *In* "Dynamics of the Bering Sea"

Francis, R.I.C.C. 1992. Use of risk analysis to assess fishery management strategies: a case study using orange roughy (*Hoplostethus atlanticus*) on the Chatham Rise, New Zealand. Can. J. Fish. Aquat. Sci. 49: 922-930.

Greiwank, A., and G.F. Corliss (eds.) 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan. 6-8, Breckenridge, CO. Soc. Indust. And Applied Mathematics, Philadelphia.

Harrison, R. C. 1993. Data Report: 1991 bottom trawl survey of the Aleutian Islands area. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS-AFSC-12.

Hinckley, S. 1987. The reproductive biology of walleye pollock, *Theragra chalcogramma*, in the Bering Sea, with reference to spawning stock structure. Fish. Bull. 85:481-498.

Hollowed, A. B., J. N. Ianelli, and P. A. Livingston. 2000. Including predation mortality in stock assessments: A case study involving Gulf of Alaska walleye pollock. ICES Journal of Marine Science, 57, pp. 279-293.

Honkalehto, T. N. Williamson, D. Hanson, D. McKelvey, and S. de Blois. 2002b. Results of the Echo Integration-trawl Survey of walleye Pollock (*Theragra chalcogramma*) Conducted on the Southeastern Bering Sea Shelf and in the Southeastern Aleutian Basin Near Bogoslof Island in February and March 2002. AFSC Processed Report 2002-02. 49p.

Honkalehto, T. N. Williamson, D. McKelvey, and S. Stienessen. 2002a. Results of the Echo Integration-trawl Survey for Walleye Pollock (*Theragra chalcogramma*) on the Bering Sea Shelf and Slope in June and July 2002. AFSC Processed Report 2002-04. 38p.

Honkalehto, T., D. Mckelvey, and N. Williamson. 2005. Results of the echo integration-trawl survey of walleye pollock (/Theragra chalcogramma/) on the U.S. and Russian Bering Sea shelf in June and July 2004. AFSC Processed Rep. 2005-02, 43 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, Seattle WA 98115.Ianelli, J.N. 1996. An alternative stock assessment model of the Eastern Bering Sea pollock fishery. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, Appendix Section 1:1-73.

Ianelli, J.N. 1997. An alternative stock assessment analysis for Gulf of Maine cod. SARC-24 Working Paper A2. 29p.

Ianelli, J.N. and D.A. Fournier. 1998. Alternative age-structured analyses of the NRC simulated stock assessment data. *In* Restrepo, V.R. [ed.]. Analyses of simulated data sets in support of the NRC study on stock assessment methods. NOAA Tech. Memo. NMFS-F/SPO-30. 96 p.

Ianelli, J.N., L. Fritz, T. Honkalehto, N. Williamson and G. Walters 1998. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 1999. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-79.

Ianelli, J.N., L. Fritz, T. Honkalehto, N. Williamson and G. Walters. 2000. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2001. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-79.

Ianelli, J.N., S. Barbeaux, G. Walters, T. Honkalehto, and N. Williamson. 2004. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2005. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:37-126.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, N. Williamson and G. Walters. 2002. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2003. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-101.

Ianelli, J.N., T. Buckley, T. Honkalehto, G Walters, and N. Williamson 2001. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2002. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/ Aleutian Islands regions. North Pac. Fish. Mgmt. Council Anchorage, AK, Section 1:1-79

Ianelli, J.N., T. Buckley, T. Honkalehto, N. Williamson and G. Walters. 2001. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2002. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-105.

Ingraham, W. J., Jr., and Miyahara, R. K. 1988. Ocean surface current simulations in the North Pacific Ocean and Bering Sea (OSCURS -Numerical Model). U.S. Department of Commerce, National Oceanic and Atmospheric Adminstration, Technical Memorandum, National Marine Fisheries Service F/NWC-130, 155 pp.

Jurado-Molina J., P. A. Livingston and J. N. Ianelli. 2005. Incorporating predation interactions to a statistical catch-at-age model for a predator-prey system in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences. 62(8): 1865-1873.

Kastelle, C. R., and Kimura, D. K. 2006. Age validation of walleye pollock (*Theragra chalcogramma*) from the Gulf of Alaska using the disequilibrium of Pb-210 and Ra-226. e ICES Journal of Marine Science, 63: 1520e1529.

Kimura, D.K. 1989. Variability in estimating catch-in-numbers-at-age and its impact on cohort analysis. *In* R.J. Beamish and G.A. McFarlane (eds.), Effects on ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aq. Sci. 108:57-66.

Kimura, D.K., J.J. Lyons, S.E. MacLellan, and B.J. Goetz. 1992. Effects of year-class strength on age determination. Aust. J. Mar. Freshwater Res. 43:1221-8.

Kotwicki, S., T.W. Buckley, T. Honkalehto, and G. Walters. 2005. Variation in the distribution of walleye pollock (*Theragra chalcogramma*) with temperature and implications for seasonal migration. Fish. Bull 103:574–587.

Lauth, R.R., J.N. Ianelli, and W.W. Wakefield. 2004. Estimating the size selectivity and catching efficiency of a survey bottom trawl for thornyheads, *Sebastolobus spp.* using a towed video camera sled. Fisheries Research. 70:39-48.

Livingston, P. A., and Methot, R. D. (1998). “Incorporation of predation into a population assessment model of Eastern Bering Sea walleye pollock. *In* Fishery Stock Assessment Models.” NOAA Technical Report 126, *NMFS F/NWC-54*, Alaska Sea Grant Program, 304 Eielson Building, University of Alaska Fairbanks, Fairbanks, AK 99775. pp. 663-678.

Low, L.L., and Ikeda. 1980. Average density index of walleye pollock in the Bering Sea. NOAA Tech. Memo. SFRF743.

Mace, P., L. Botsford, J. Collie, W. Gabriel, P. Goodyear J. Powers, V. Restrepo, A. Rosenberg, M. Sissenwine, G. Thompson, J. Witzig. 1996. Scientific review of definitions of overfishing in U.S. Fishery Management Plans. NOAA Tech. Memo. NMFS-F/SPO-21. 20 p.

McAllister, M.K. and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Can. J. Fish. Aquat. Sci. 54:284-300.

Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. *In* Proceedings of the symposium on applications of stock assessment techniques to Gadids. L. Low [ed.]. Int. North Pac. Fish. Comm. Bull. 50: 259-277.

Miller, T.J. 2005. Estimation of catch parameters from a fishery observer program with multiple objectives. PhD Dissertation. Univ. of Washington. 419p.

Mueter, F. J., M.C. Palmer, and B.L. Norcross. 2004. Environmental predictors of walleye pollock recruitment on the Eastern Bering Sea shelf. Final Report to the Pollock Conservation Cooperative Research Center. June 2004. 74p.

O’Reilly, P.T., M.F. Canino, K.M. Bailey and P. Bentzen. 2004. Inverse relationship between F_{ST} and microsatellite polymorphism in the marine fish, walleye pollock (*Theragra chalcogramma*): implications for resolving weak population structure. *Molecular Ecology (2004) 13, 1799–1814*

Parma, A.M. 1993. Retrospective catch-at-age analysis of Pacfic halibut: implications on assessment of harvesting policies. *In* Proceedings of the International Symposium on Management Strategies of Exploited Fish Populations. Alaska Sea Grant Rep. No. 93-02. Univ. Alaska Fairbanks.

Pope, J. G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Res. Bull. Int. Commn. NW Atlant. Fish. 9: 65-74.

Press, W.H., S.A. Teukolsky, W.T. Vetterling, B.P. Flannery. 1992. Numerical Recipes in C. Second Ed. Cambridge University Press. 994 p.

Quinn II, T. J. and J. S. Collie. 1990. Alternative population models for Eastern Bering Sea pollock. INPFC Symposium on application of stock assessment techniques to gadids. Int. North Pac. Fish. Comm. Bull. 50:243-258.

Quinn, T.J. and R.B. Deriso 1999. Quantitative Fish Dynamics. Oxford University Press, New York. 542 p.

Restrepo, V.R., G.G. Thompson, P.M Mace, W.L Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade, and J.F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Tech. Memo. NMFS-F/SPO-31. 54 p.

Ronholt, L. L., K. Teshima, and D. W. Kessler. 1994. The groundfish resources of the Aleutian Islands region and southern Bering Sea, 1980, 1983, and 1986. Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS-AFSC-31.

Schnute, J.T. 1994. A general framework for developing sequential fisheries models. Can. J. Fish. Aquat. Sci. 51:1676-1688.

Schnute, J.T. and Richards, L.J. 1995. The influence of error on population estimates from catch-age models. Can. J. Fish. Aquat. Sci. 52:2063-2077.

Shuntov, V. P., A. F. Volkov, O. S. Temnykh, and E. P. Dulepova. 1993. Pollock in the ecosystems of the Far East Seas. TINRO, Vladivostok.

Smith, G.B. 1981. The biology of walleye pollock. *In* Hood, D.W. and J.A. Calder, The Eastern Bering Sea Shelf: Oceanography and Resources. Vol. I. U.S. Dep. Comm., NOAA/OMP 527-551.

Stahl, J. 2004. Maturation of walleye pollock, *Theragra chalcogramma*, in the Eastern Bering Sea in relation to temporal and spatial factors. Masters thesis. School of Fisheries and Ocean Sciences, Univ. Alaska Fairbanks, Juneau. 000p.

Stepanenko, M.A. 1997. Variations from year to year in the spatial differentiation of the walleye pollock, *Theragra chalcogramma*, and the cod, *Gadus macrocephalus*, in the Bering Sea. Journ. of Ichthyol. 37:14-20.

Swartzman, G.L., A.G. Winter, K.O. Coyle, R.D. Brodeur, T. Buckley, L. Ciannelli, G.L. Hunt, Jr., J. Ianelli, and S.A. Macklin (2005). Relationship of age-0 pollock abundance and distribution around the Pribilof Islands with other shelf regions of the Eastern Bering Sea. /Fisheries Research/, Vol. 74, pp. 273-287.

Thompson, G.G. 1996. Risk-averse optimal harvesting in a biomass dynamic model. Unpubl. Manuscr., 54 p. Alaska Fisheries Science Center, 7600 Sand Pt. Way NE, Seattle WA, 98115. Distributed as Appendix B to the Environmental Analysis Regulatory Impact Review of Ammendments 44/44 to the Fishery Management Plans for the Groundfish Fisheries of the Bering Sea and Aleutian Islands Area and the Gulf of Alaska.

Thompson, G.G. 1996. Spawning exploitation rate: a useful and general measure of relative fishing mortality. Alaska Fisheries Science Center contribution. Unpubl. Manuscr., 7 p.

Thompson, G.G. and M.W. Dorn. 2004. Chapter 2: assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands area. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 2. p185-302.

Traynor J. J. and M. O. Nelson. 1985. Results of the U.S. hydroacoustic survey of pollock on the continental shelf and slope. In: R.G. Bakkala and K. Wakabayashi (eds.), Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. Int. North Pac. Fish. Comm. Bull. 44: 192-199.

Walters, C. J. 1969. A generalized computer simulation model for fish population studies. Trans. Am. Fish. Soc. 98:505 -512.

Walters, C. J., and J. F. Kitchell. 2001. Cultivation/depensation effects on juvenile survival and recruitment. Can. J. Fish. Aquat. Sci. 58:39-50.

Wespestad, V. G. 1990. Walleye pollock. Condition of groundfish resources in the Bering Sea-Aleutian Islands region as assessed in 1989. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/AKC.

Wespestad, V. G. and J. M. Terry. 1984. Biological and economic yields for Eastern Bering Sea walleye pollock under differing fishing regimes. N. Amer. J. Fish. Manage., 4:204-215.

Wespestad, V. G. and J. Traynor. 1989. Walleye pollock. In: L-L. Low and R. Narita (editors), Condition of groundfish resources in the Bering Sea-Aleutian Islands region as assessed in 1988. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., NOAA Tech. Memo. NMFS F/AKC-178.

Wespestad, V. G., J. Ianelli, L. Fritz, T. Honkalehto, G. Walters. 1996. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 1997. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-73.

Wespestad, V.G., L.W. Fritz, W.J. Ingraham, and B.A. Megrey. 1997. On Relationships between Cannibalism, climate variability, physical transport and recruitment success of Bering Sea Walleye Pollock, *Theragra chalcogramma.* ICES International Symposium, Recruitment Dynamics of exploited marine populations: physical-biological interactions. Baltimore, MD, Sept 22-24.

Winter, A.G., G.L. Swartzman, and L. Ciannelli (2005). Early- to late-summer population growth and prey consumption by age-0 pollock (*Theragra chalcogramma*), in two years of contrasting pollock abundance near the Pribilof Islands, Bering Sea. /Fisheries Oceanography/, Vol. 14, No. 4, pp. 307-320.

Tables

Table 1.1 Catch from the Eastern Bering Sea by area, the Aleutian Islands, the Donut Hole, and the Bogoslof Island area, 1979-2006. (2006 values set equal to TAC). 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			1,496,710			

1979-1989 data are from Pacfin.

1990-2005 data are from NMFS Alaska Regional Office, includes discards.
2006 EBS catch assuming full TAC will be taken

Table 1.2. Time series of ABC, TAC, and catch levels for EBS pollock, 1977-2006. Source: compiled from NMFS Regional office web site and various NPFMC reports.

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	1,496,710
1977-2005 average	1,418,586	1,205,457	1,181,995

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, 1991-2004. 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%)	(0%)	2,723 (1%)	20,302 (2%)	23,783 (2%)	1,156	923	390,414	1,089,880	1,482,373

Table 1.4. Eastern Bering Sea pollock catch at age estimates based on observer data, 1979-2005. 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
Average	4.9	73.2	240.8	365.8	373.6	313.2	204.4	118.6	70.4	37.6	26.3	13.2	8.8	12.1	1,862.9
Median	0.1	33.0	92.3	312.9	365.7	238.0	156.6	98.9	59.7	25.8	18.2	10.2	4.2	8.2	1,883.0

Table 1.5. Numbers of pollock fishery samples measured for lengths and for length-weight by sex and strata, 1977-2005, as sampled by the NMFS observer program.

	A Season		B Season SE		B Season NW		
Lengths							
	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
Length-weight samples							
	A Season		B Season SE		B Season NW		
	Males	Females	Males	Females	Males	Females	Total
1977	1,222	1,338	137	166	1,461	1,664	5,988
1978	1,991	2,686	409	516	2,200	2,623	10,425
1979	2,709	3,151	152	209	1,469	1,566	9,256
1980	1,849	2,156	99	144	612	681	5,541
1981	1,821	2,045	51	52	1,623	1,810	7,402
1982	2,030	2,208	181	176	2,852	3,043	10,490
1983	1,199	1,200	144	122	3,268	3,447	9,380
1984	980	1,046	117	136	1,273	1,378	4,930
1985	520	499	46	55	426	488	2,034
1986	689	794	518	501	286	286	3,074
1987	1,351	1,466	25	33	72	63	3,010
1991	2,712	2,781	2,339	2,496	1,065	1,169	12,562
1992	1,517	1,582	1,911	1,970	588	566	8,134
1993	1,201	1,270	1,448	1,406	435	450	6,210
1994	1,552	1,630	1,569	1,577	162	171	6,661
1995	1,215	1,259	1,320	1,343	223	232	5,592
1996	2,094	2,135	1,409	1,384	1	1	7,024
1997	628	627	616	665	511	523	3,570
1998	1,852	1,946	959	923	327	350	6,357
1999	5,318	4,798	7,797	7,054	3,532	3,768	32,267
2000	12,421	11,318	12,374	7,809	7,977	7,738	59,637
2001	14,882	14,369	10,778	10,378	8,777	9,079	68,263
2002	14,004	13,541	12,883	12,942	7,202	7,648	68,220
2003	14,780	15,495	9,401	10,092	9,994	10,261	70,023
2004	7,690	7,890	6,819	6,847	4,603	4,321	38,170
2005	7,390	7,033	5,109	4,115	6,927	6,424	36,998

Table 1.6. Numbers of pollock fishery samples used for age determination estimates by sex and strata, 1977-2005, 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

Table 1.7. Sampling effort for pollock in the EBS based on the NMFS bottom trawl survey 1982-2006. Total haul numbers including those beyond the standard 1-6 strata are shown in parentheses.

Year	Number of Hauls	Lengths	Aged	Year	Number of Hauls	Lengths	Aged
1982	329	40,001	1,611	1994	355 (375)	38,901	1,141
1983	354	78,033	1,931	1995	356 (376)	25,673	1,156
1984	355	40,530	1,806	1996	355 (375)	40,789	1,387
1985	430 (434)	48,642	1,913	1997	356 (376)	35,536	1,193
1986	354	41,101	1,344	1998	355 (375)	37,673	1,261
1987	342 (356)	40,144	1,607	1999	353 (373)	32,532	1,385
1988	353 (373)	40,408	1,173	2000	352 (372)	41,762	1,545
1989	353 (373)	38,926	1,227	2001	355 (375)	47,335	1,641
1990	351 (371)	34,814	1,257	2002	355 (375)	43,361	1,695
1991	351 (371)	43,406	1,083	2003	356 (376)	46,480	1,638
1992	336 (356)	34,024	1,263	2004	355 (375)	44,102	1,660
1993	355 (375)	43,278	1,385	2005	353 (373)	33,842 (35,976)	1,676
				2006	356 (376)	37,350 (39,211)	1,573

Table 1.8. Biomass (age 1+) of Eastern Bering Sea walleye 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 and that the value for the 1979 bottom trawl survey was omitted from use in the model since a different gear configuration was used.

Year	Bottom trawl Survey (t)	EIT Survey (t)	EIT Percent age 3+	Total[3] (t)	Near bottom biomass
1979	3.20	7.46	(22%)	10.66	30%
1980	1.00				
1981	2.30				
1982	2.86	4.90	(95%)	7.76	46%
1983	6.26				
1984	4.89				
1985	4.63	4.80	(97%)	9.43	54%
1986	4.90				
1987	5.11				
1988	7.11	4.68	(97%)	11.79	63%
1989	5.93				
1990	7.13				
1991	5.11	1.45	(46%)	6.56	79%
1992	4.37				
1993	5.52				
1994	4.98	2.89	(85%)	7.87	64%
1995	5.41				
1996	3.20	2.31	(97%)	5.51	60%
1997	3.03	2.59	(70%)	5.62	54%
1998	2.21				
1999	3.60	3.29[4]	(95%)	6.86	52%
2000	5.13	3.05	(95%)	8.19	63%
2001	4.15				
2002	4.83	3.62	(82%)	8.39	57%
2003	8.14				
2004	3.76	3.31	(99%)	7.06	53%
2005	5.13				
2006	2.85	1.56		4.41	65%

[3] 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).

[4] 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 1.9. 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%
Avg.	4,808,839	303,397	5,128,040	6%

Table 1.10. Bottom-trawl survey estimated numbers at age (millions) used for the stock assessment model, 1982-2006 based on strata 1-6 (top set) and on strata 1-6, with 8 and 9 (bottom set). Shaded cells represent years where the NW regions were not surveyed and were thus treated as having a separate survey catchability.

Std area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	StdErr	CV
1982	896	2,129	2,385	3,076	1,044	140	97	47	29	18	12	7	2	1	0	9,885	1,269	13%
1983	3,978	529	1,277	2,266	5,051	1,552	286	157	71	61	46	16	6	5	2	15,303	1,198	8%
1984	363	269	399	1,153	1,459	3,427	652	145	68	24	16	6	4	5	2	7,992	795	10%
1985	4,062	291	1,115	520	2,001	1,532	1,150	229	62	50	17	6	7	1	0	11,043	1,420	13%
1986	2,130	316	358	1,338	816	1,382	1,219	1,122	357	55	26	11	1	3	0	9,134	838	9%
1987	251	522	682	508	3,062	849	824	337	1,097	175	55	22	4	2	1	8,392	1,044	12%
1988	703	416	1,157	2,206	980	3,200	967	759	443	1,075	103	62	12	16	7	12,106	1,417	12%
1989	611	199	310	1,038	2,581	583	2,331	359	456	177	564	97	86	43	57	9,491	944	10%
1990	1,422	207	69	526	1,077	3,656	741	1,864	192	361	56	526	45	34	45	10,822	1,306	12%
1991	2,291	637	229	66	452	426	1,416	533	1,154	302	415	86	261	37	31	8,336	811	10%
1992	1,209	288	1,654	266	290	484	446	654	296	572	205	259	114	90	70	6,897	775	11%
1993	2,092	266	635	2,882	632	511	270	377	518	320	281	205	162	90	106	9,346	896	10%
1994	1,027	350	377	1,107	3,007	527	139	121	137	260	160	225	83	80	123	7,723	962	12%
1995	1,014	76	233	1,178	1,569	2,529	1,071	282	174	113	213	87	162	65	93	8,860	1,768	20%
1996	1,317	279	107	213	721	1,047	976	334	84	91	62	119	39	71	94	5,555	458	8%
1997	2,152	303	69	77	1,106	759	564	734	131	68	51	57	93	31	106	6,301	863	14%
1998	575	520	250	141	246	1,416	412	292	237	60	28	10	22	26	61	4,298	495	12%
1999	787	681	643	693	394	695	1,737	478	237	222	83	36	15	22	76	6,799	802	12%
2000	874	279	352	1,178	1,198	628	550	1,801	711	382	168	112	35	16	72	8,356	1,026	12%
2001	1,441	832	438	403	1,023	1,081	469	237	709	513	200	161	58	24	62	7,650	687	9%
2002	615	283	585	842	864	1,140	596	295	410	772	385	174	104	32	35	7,133	728	10%
2003	350	104	659	1,116	1,324	1,205	1,604	890	402	521	1,054	456	173	88	66	10,011	1,802	18%
2004	297	189	121	979	975	748	440	477	236	148	148	268	115	28	22	5,191	478	9%
2005	301	91	164	759	2,230	1,526	812	375	288	223	57	122	198	76	79	7,300	723	10%
2006	741	30	31	206	699	941	621	302	174	150	72	45	65	87	86	4,252	396	9%
Avg	1,260	403	572	990	1,392	1,279	816	528	347	269	179	127	75	39	52	8,327	956	11%

Incl. NW area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	StdErr	CV
1982	896	2,129	2,385	3,076	1,044	140	97	47	29	18	12	7	2	1	0	9,885	1,269	13%
1983	3,978	529	1,277	2,266	5,051	1,552	286	157	71	61	46	16	6	5	2	15,303	1,198	8%
1984	363	269	399	1,153	1,459	3,427	652	145	68	24	16	6	4	5	2	7,992	795	10%
1985	4,675	649	2,600	858	2,958	1,865	1,283	254	65	53	18	6	7	1	0	15,294	1,967	13%
1986	2,130	316	358	1,338	816	1,382	1,219	1,122	357	55	26	11	1	3	0	9,134	838	9%
1987	308	550	724	539	3,247	915	926	373	1,209	191	58	23	4	2	1	9,070	1,129	12%
1988	797	436	1,196	2,285	1,012	3,318	1,001	786	462	1,118	107	64	13	16	7	12,618	1,477	12%
1989	662	223	429	1,388	3,156	643	2,482	379	470	181	579	100	88	44	58	10,882	1,083	10%
1990	1,730	212	71	552	1,110	3,755	759	1,907	198	373	58	545	46	36	46	11,399	1,375	12%
1991	2,443	649	232	69	465	435	1,436	539	1,165	305	420	87	265	37	31	8,578	835	10%
1992	1,260	296	1,702	285	319	536	478	689	310	595	212	268	117	92	72	7,230	812	11%
1993	2,154	286	714	2,975	648	521	276	384	527	325	286	208	164	91	107	9,665	927	10%
1994	1,054	354	382	1,115	3,025	530	140	123	140	265	162	229	84	82	126	7,811	973	12%
1995	1,021	86	269	1,224	1,601	2,554	1,080	285	176	114	216	88	164	66	94	9,037	1,803	20%
1996	1,411	339	157	311	790	1,101	1,009	344	86	93	64	122	40	73	97	6,036	498	8%
1997	2,173	327	152	189	2,272	1,033	631	785	137	70	53	59	96	31	110	8,118	1,111	14%
1998	620	546	282	190	368	2,104	544	348	272	68	31	11	24	28	64	5,502	634	12%
1999	800	686	645	700	401	725	1,846	515	260	244	91	39	16	24	81	7,071	834	12%
2000	906	283	355	1,190	1,217	643	566	1,865	733	393	172	116	36	16	74	8,565	1,052	12%
2001	1,463	837	441	407	1,034	1,093	475	240	720	521	203	163	59	24	63	7,742	695	9%
2002	642	295	618	894	922	1,202	627	306	421	793	396	179	106	33	37	7,471	763	10%
2003	373	123	728	1,183	1,379	1,250	1,662	923	415	542	1,092	474	180	90	69	10,484	1,887	18%
2004	313	225	142	1,045	1,011	766	451	489	243	152	153	276	119	30	23	5,438	501	9%
2005	346	124	183	790	2,300	1,570	835	386	297	229	59	126	206	81	84	7,616	754	10%
2006	757	35	47	295	785	1,005	647	312	179	155	75	47	68	91	90	4,587	427	9%
Avg	1,353	446	699	1,082	1,581	1,384	861	551	361	278	184	131	77	40	54	9,080	1,134	12%

Table 1.11. Number of 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	NA	2,741
	Midwater, east of St Paul	13	1,725		783
	Midwater, west of St Paul	31	6,689		1,958
	Bottom	4	273		0
1985	**Total** (Legs1 &2)	73	19,872	NA	2,739
1988	**Total**	25	6,619	1,519	1,471
1991	**Total**	62	16,343	2,065	1,663
1994	**Total**	77	21,506	4,973	1,770
	East of 170 W				612
	West of 170 W				1,158
1996	**Total**	57	16,910	1,950	1,926
	East of 170 W				815
	West of 170 W				1,111
1997	**Total**	86	30,535	3,635	2,285
	East of 170 W				936
	West of 170 W				1,349
1999	**Total**	122	42,364	4,946	2,446
	East of 170 W	45	13,842	1,945	946
	West of 170 W	77	28,522	3,001	1,500
2000	**Total**	128	43,729	3,459	2,253
	East of 170 W	32	7,721	850	850
	West of 170 W	96	36,008	2,609	1,403
2002	**Total**	126	40,234	3,233	2,200
	East of 170 W	48	14,601	1,424	1,000
	West of 170 W	78	25,633	1,809	1,200
2004	**Total (US zone)**	139	29,934	3,251	2,351
	East of 170 W	45	8,881	1,152	798
	West of 170 W	94	21,053	2,099	1,192
	Russian zone	15	5,893	461	461
2006	**Total**	104	24,979	2,711	NA
	East of 170 W	27	4,830	822	NA
	West of 170 W	77	20,149	1,889	NA

Table 1.12. Distribution of pollock between areas from summer echo integration-trawl surveys on the Bering Sea shelf, 1994-2006. Data are estimated pollock biomass from 14 m below the surface down to 3 m off bottom for survey years 1994-2002. For survey years 2004 and 2006, data collection began at 12 m from the surface.

			Biomass (million mt)			
	Dates	**Area** (nmi)^2	**SCA**	**(percent)** **E170-SCA**	**W170**	**Total Biomass (million mt)**
1994	Jul 9-Aug 19	78,251	0.312	0.399	2.18	2.89
			(11%)	(14%)	(75%)	
1996	Jul 20-Aug 30	93,810	0.215	0.269	1.83	2.31
			(9%)	(12%)	(79%)	
1997	Jul 17-Sept 4	102,770	0.246	0.527	1.82	2.59
			(10%)	(20%)	(70%)	
1999	Jun 7-Aug 5	103,670	0.299	0.579	2.41	3.29
			(9%)	(18%)	(73%)	
2000	Jun 7- Aug 2	106,140	0.393	0.498	2.16	3.05
			(13%)	(16%)	(71%)	
2002	Jun 4 – Jul 30	99,526	0.647	0.797	2.178	3.622
			(18%)	(22%)	(60%)	
2004	Jun 4 – Jul 29	99,659	0.498	0.516	2.293	3.307
			(15 %)	(16%)	(69%)	
2006	Jun 3 – Jul 25	89,550	0.131	0.254	1.175	1.560
			(8%)	(16%)	(75%)	

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

Table 1.13. 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: 2006 weight-at-age is treated as the three-year average of values from 2003-2005.*

	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*	*0.413*	*0.546*	*0.643*	*0.759*	*0.877*	*0.943*	*1.058*	*1.178*	*1.218*	*1.241*	*1.378*	*1.269*	*1.479*

Table 1.14. Pollock sample sizes assumed for the age-composition data likelihoods from the fishery, bottom-trawl survey, and EIT surveys, 1964-2006. Note that for the 2006 assessment, the 2006 EIT sample size was half of the value (104) specified here since the BTS age-length key was used.

Year	Fishery	Year	Fishery	BTS	EIT
1964	10	1979	50		25
1965	10	1980	50		
1966	10	1981	50		
1967	10	1982	50	100	48
1968	10	1983	50	100	
1969	10	1984	50	100	
1970	10	1985	50	100	73
1971	10	1986	50	100	
1972	10	1987	50	100	
1973	10	1988	50	100	25
1974	10	1989	50	100	
1975	10	1990	50	100	
1976	10	1991	200	100	62
1977	10	1992	200	100	
1978	50	1993	200	100	
		1994	200	100	77
		1995	200	100	
		1996	200	100	57
		1997	200	100	86
		1998	200	100	
		1999	200	100	122
		2000	200	100	128
		2001	200	100	
		2002	200	100	126
		2003	200	100	
		2004	200	100	139
		2005	200	100	
		2006	200	100	52*

Table 1.15. Results comparing fits Models 1 from last years assessment with Models 1 and 2 from the present assessment.

	Model 1 (2005)	Model 1	Model 2
-ln(Likelihoods)			
Priors	9.16	9.34	9.13
CPUE	1.95	2.71	2.70
Bottom Trawl Survey	9.92	7.09	7.94
EIT Survey	-5.45	-6.19	-6.36
Fishery Age Comp	-862.30	-867.09	-866.60
Bottom Trawl Age Comp	-384.05	-404.05	-407.15
EIT Age Comp	-255.88	-275.62	-276.11
Stock-recruitment curve	2.73	3.21	2.79
Recruitment deviations	18.96	17.15	16.25
Catch	0.00	0.00	0.00
Fishery selectivity penalty/prior	22.59	13.23	14.07
BTS penalty/prior	13.73	18.17	15.79
EIT penalty/prior	29.21	28.26	28.81
Total –ln(likelihood)	-1399.43	-1444.59	-1449.37
Number of parameters	640	664	665
Age Composition data			
Average effective N Fishery	194	249	286
Average effective N Bottom trawl survey	134	205	212
Average effective N Hydro acoustic survey	204	239	244

Survey abundance estimates, RMSE*	Model 1 (2005)	Model 1	Model 2
Trawl Survey	0.237	0.135	0.141
EIT survey	0.341	0.337	0.335

Recruitment Residuals	Model 1 (2005)	Model 1	Model 2
Due to Stock	0.24	0.24	0.25
Residual RMSE	0.39	0.39	0.37
Total	0.63	0.63	0.61

Notes: Effective N (sample size) computations are as presented in McAllister and Ianelli (1997).

RMSE = $\sqrt{\frac{\sum \ln\left(obs/pred\right)^2}{n}}$

Table 1.16. Summary model results showing the stock condition for EBS pollock. Values in parentheses are coefficients of variation (CV's) of values immediately above.

	Model 1	**Model 2**
Biomass (thousands of t)		
Year 2007 spawning biomass[5]	2,080	**2,170**
(CV)	(20%)	**(20%)**
2006 spawning biomass	2,733	**2,837**
B_{msy}	1,956	**2,061**
(CV)	(25%)	**(26%)**
$B_{40\%}$	2,508	**2,552**
(CV)	(4%)	**(4%)**
$B_{35\%}$	2,195	**2,228**
B_0 (stock-recruitment curve)	5,219	**5,452**
2007 Percent of B_{msy} spawning biomass	106%	**105%**
2007 Percent of $B_{40\%}$ spawning biomass	83%	**85%**
Ratio of B2006 over B2006 if no fishing since 1978	58%	**59%**
2007 Age 3+ Biomass	6,100	6,361
Ratio B2007/B2006 (3+ biomass)	80%	**80%**
Recruitment (millions of pollock at age 1)		
Steepness parameter (*h*)	0.66	0.65
Average recruitment (all yrs)	21,997	**22,325**
(CV)	63%	**63%**
Average recruitment (since 1978)	23,893	**24,258**
(CV since 1978)	67%	**66%**
2000 year class	44,022	**44,575**
(CV 2000 year class)	14%	**15%**
Natural Mortality (age 3 and older)	0.3	**0.3**

Table 1.17. Results relating to yield for Models 1 and 2.

	Model 1	**Model 2**
Yield projections		
B_{msy} (age 3+)	7,941	8,226
2007 Age 3+ biomass (GM)	5,962	6,218
MSYR (HM)	0.252	0.243
2007 MSYR yield (Tier 1 ABC)	1,501	**1,512**
MSYR (AM)	0.272	0.264
2007 MSYR OFL	1,622	**1,641**
MSY (long-term expectation)	2,105	2,114

Notes: MSYR = exploitation rate relative to begin-year age 3+ biomass corresponding to F_{msy}. F_{msy} yields calculated within the model (i.e., including uncertainty in both the estimate of F_{msy} and in projected stock size). HM = Harmonic mean, GM = Geometric mean, AM = Arithmetic mean

Table 1.18 Estimates of numbers at age for the EBS pollock stock under Model 2 (millions).

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	**Total**
1964	4,676	3,599	2,280	577	222	374	153	63	31	197	12,172
1965	21,767	1,897	2,265	1,605	371	135	228	96	40	153	28,556
1966	13,266	8,838	1,190	1,553	995	234	88	150	64	131	26,509
1967	26,980	5,387	5,548	818	967	632	153	58	100	132	40,774
1968	25,021	10,945	3,340	3,592	444	544	372	92	36	147	44,532
1969	29,092	10,151	6,712	2,075	2,073	263	332	227	56	112	51,094
1970	22,834	11,803	6,224	4,166	1,196	1,227	160	202	139	104	48,053
1971	10,117	9,259	7,169	3,703	2,260	671	713	93	118	143	34,247
1972	11,722	4,102	5,525	4,043	1,879	1,138	346	374	49	139	29,318
1973	27,189	4,750	2,419	2,966	1,916	883	550	171	187	94	41,124
1974	20,552	11,009	2,746	1,196	1,254	801	383	244	77	128	38,389
1975	18,031	8,326	6,021	1,058	468	513	336	161	103	87	35,104
1976	13,185	7,310	4,697	2,649	471	216	242	159	76	90	29,096
1977	13,989	5,348	4,202	2,238	1,276	234	109	122	80	85	27,683
1978	27,778	5,678	3,174	2,311	1,157	620	118	56	62	85	41,039
1979	65,508	11,274	3,363	1,731	1,183	556	309	59	28	75	84,087
1980	25,313	26,591	6,714	1,876	910	587	285	160	31	54	62,523
1981	28,684	10,283	16,634	4,382	994	414	270	135	77	41	61,913
1982	15,292	11,656	6,478	11,379	2,630	542	227	151	76	66	48,496
1983	52,698	6,215	7,379	4,575	7,430	1,621	336	142	94	89	80,580
1984	12,712	21,421	3,944	5,298	3,122	4,759	1,000	206	86	110	52,658
1985	34,636	5,167	13,592	2,833	3,621	2,005	2,943	617	126	119	65,659
1986	13,281	14,079	3,279	9,766	1,936	2,325	1,240	1,816	375	147	48,244
1987	7,751	5,399	8,928	2,360	6,694	1,271	1,466	749	1,131	315	36,063
1988	4,881	3,151	3,429	6,481	1,654	4,551	840	939	490	928	27,344
1989	10,519	1,984	1,998	2,468	4,441	1,086	2,867	507	584	859	27,313
1990	49,350	4,276	1,259	1,454	1,661	2,869	682	1,699	311	885	64,446
1991	28,380	20,061	2,707	908	930	997	1,649	359	945	665	57,601
1992	21,881	11,537	12,696	1,949	575	550	564	848	196	869	51,663
1993	52,985	8,895	7,323	8,808	1,119	340	284	267	402	539	80,961
1994	13,663	21,540	5,655	5,200	5,533	717	199	157	148	543	53,356
1995	9,905	5,554	13,695	4,017	3,273	3,552	421	111	88	402	41,019
1996	22,291	4,027	3,533	10,039	2,824	2,163	1,967	206	58	287	47,395
1997	31,988	9,062	2,563	2,595	7,125	1,906	1,263	1,037	114	212	57,864
1998	15,237	13,004	5,768	1,883	1,848	4,843	1,134	684	587	201	45,189
1999	17,042	6,194	8,270	4,167	1,301	1,218	2,999	674	397	472	42,735
2000	26,833	6,928	3,940	5,984	2,892	864	763	1,809	398	534	50,944
2001	44,575	10,909	4,404	2,838	4,100	1,880	524	442	1,022	554	71,248
2002	19,678	18,121	6,943	3,186	1,962	2,525	1,024	285	244	934	54,902
2003	11,092	8,000	11,530	5,005	2,181	1,175	1,314	532	151	688	41,667
2004	5,861	4,509	5,089	8,292	3,401	1,281	593	661	273	487	30,447
2005	9,411	2,383	2,870	3,689	5,417	2,081	714	323	363	450	27,701
2006	22,415	3,826	1,517	2,079	2,400	3,294	1,149	385	175	474	37,714
Median	20,115	8,163	4,893	2,902	1,864	940	473	217	116	150	44,860
Average	22,325	9,062	5,655	3,755	2,326	1,361	766	425	238	318	46,231

Table 1.19. Estimated catch-at-age of EBS pollock for Model 2 (millions).

Year	1	2	3	4	5	6	7	8	9	10+	Total
1964	6.6	37.8	98.0	66.8	35.0	57.7	20.5	7.1	3.1	16.4	349.0
1965	18.5	24.4	146.1	227.2	47.1	14.5	22.1	8.4	3.2	10.9	522.3
1966	11.0	110.6	74.8	214.3	123.3	24.6	8.3	12.8	5.0	9.1	593.7
1967	39.8	119.9	606.3	189.6	202.6	113.0	24.7	8.5	13.5	16.1	1,333.9
1968	34.9	336.7	467.3	690.0	77.2	83.5	57.0	13.8	5.2	21.4	1,787.1
1969	40.9	314.5	945.4	401.3	362.5	40.7	51.2	34.4	8.4	16.5	2,215.6
1970	39.7	450.7	1,064.1	970.2	252.5	229.7	30.0	37.1	25.0	18.5	3,117.5
1971	18.4	479.3	1,489.0	1,017.2	631.4	177.3	181.4	23.1	28.9	34.9	4,080.9
1972	25.1	249.4	1,325.4	1,272.6	601.2	345.1	101.2	106.6	13.9	39.1	4,079.7
1973	73.2	359.2	702.0	1,115.0	731.5	320.3	192.9	58.4	63.2	32.0	3,647.6
1974	48.4	1,269.2	1,156.8	495.0	492.0	304.5	144.4	92.1	28.9	47.4	4,078.9
1975	33.9	775.7	2,139.3	368.9	154.1	163.5	106.1	51.0	32.5	26.9	3,851.9
1976	21.0	582.1	1,464.5	809.8	135.8	60.1	66.7	43.8	21.0	24.5	3,229.3
1977	15.3	299.1	942.1	589.6	382.3	65.3	29.7	33.3	21.8	22.5	2,401.0
1978	31.3	326.0	728.4	622.8	354.4	177.1	32.8	15.5	17.3	23.0	2,328.5
1979	68.4	601.4	722.6	437.6	340.6	149.0	80.8	15.5	7.3	19.0	2,442.2
1980	14.6	406.0	692.3	465.3	306.9	194.7	90.6	50.0	9.5	16.7	2,246.4
1981	10.4	99.1	1,102.6	723.0	228.3	93.5	58.0	28.4	16.0	8.5	2,367.8
1982	3.3	67.4	261.2	1,169.6	382.6	77.4	30.9	20.0	9.9	8.6	2,030.9
1983	7.6	24.6	195.7	312.2	872.8	236.2	49.5	22.4	14.8	15.1	1,751.1
1984	1.8	83.4	102.7	355.2	360.5	681.8	144.9	32.0	13.3	18.5	1,794.1
1985	4.9	20.1	354.3	190.1	418.3	287.4	427.0	95.7	19.3	20.1	1,837.2
1986	1.3	61.4	80.4	632.4	191.2	300.9	198.8	251.5	59.7	24.6	1,802.2
1987	0.5	16.7	156.1	109.6	476.9	119.3	171.4	75.4	131.1	36.6	1,293.6
1988	0.5	13.8	84.4	421.0	163.9	590.6	135.0	130.5	78.3	145.9	1,763.9
1989	0.7	7.3	30.2	195.6	492.8	143.4	497.9	75.0	91.5	125.4	1,659.9
1990	5.1	24.2	29.0	172.7	273.5	558.5	172.2	368.8	71.3	188.5	1,863.9
1991	3.1	121.2	66.6	114.6	162.4	205.7	440.1	82.4	228.8	151.6	1,576.5
1992	2.4	41.7	697.5	381.1	100.2	145.8	177.9	267.1	58.8	234.9	2,107.2
1993	3.7	20.8	263.2	1,161.1	130.9	61.8	62.2	58.3	83.5	96.5	1,941.9
1994	0.9	49.8	200.9	678.1	640.1	128.8	43.3	34.1	30.4	98.4	1,904.8
1995	0.5	10.6	123.8	177.8	305.9	780.7	125.5	29.0	19.1	69.5	1,642.3
1996	0.9	6.3	26.1	364.5	217.6	397.7	494.8	45.2	10.5	41.2	1,604.8
1997	1.2	13.0	17.5	87.1	508.4	326.1	296.7	212.2	19.3	28.1	1,509.6
1998	0.7	28.3	123.8	109.8	176.8	689.7	194.3	127.7	102.0	28.3	1,581.4
1999	0.7	12.6	166.2	227.8	117.0	163.1	484.3	118.7	65.0	64.1	1,419.6
2000	1.3	16.9	94.4	388.4	307.4	136.2	144.4	373.0	76.4	84.0	1,622.4
2001	2.1	16.4	89.1	163.7	601.1	432.7	121.3	97.8	190.8	83.7	1,798.6
2002	1.1	31.3	161.1	210.2	326.5	654.4	267.1	71.0	51.5	164.6	1,938.9
2003	0.7	15.1	291.2	358.5	391.8	327.2	368.0	142.5	34.2	123.9	2,053.1
2004	0.3	6.1	94.5	849.6	513.6	276.2	136.7	149.1	55.3	76.7	2,158.2
2005	0.5	3.3	55.0	389.4	841.9	461.2	169.3	74.8	75.6	75.0	2,146.2
2006	1.3	5.9	31.7	238.6	404.3	788.1	293.9	96.3	39.5	86.6	1,986.2
Median	4.3	45.8	198.3	384.7	316.9	186.0	130.2	54.6	27.0	30.2	1,884.4
Average	14.2	179.8	467.4	473.7	343.6	257.1	158.4	85.6	45.6	57.3	2,082.8

Table 1.20. Estimated EBS pollock Model 2 age 3+ biomass, female spawning biomass, and age 1 recruitment for 1964-2006. 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	1,810	526	4,676	1986	11,486	3,926	13,281
1965	2,231	641	21,767	1987	12,077	4,045	7,751
1966	2,252	734	13,266	1988	11,330	4,020	4,881
1967	3,518	902	26,980	1989	9,584	3,603	10,519
1968	3,881	1,098	25,021	1990	7,603	2,889	49,350
1969	5,058	1,345	29,092	1991	5,929	2,145	28,380
1970	5,929	1,614	22,834	1992	9,270	2,259	21,881
1971	6,617	1,781	10,117	1993	11,795	3,166	52,985
1972	6,265	1,731	11,722	1994	11,407	3,536	13,663
1973	4,751	1,413	27,189	1995	13,658	3,824	9,905
1974	3,460	997	20,552	1996	11,480	3,840	22,291
1975	3,585	834	18,031	1997	10,056	3,656	31,988
1976	3,577	867	13,185	1998	9,973	3,340	15,237
1977	3,582	921	13,989	1999	10,872	3,325	17,042
1978	3,438	940	27,778	2000	10,052	3,343	26,833
1979	3,323	921	65,508	2001	9,800	3,369	44,575
1980	4,320	1,046	25,313	2002	10,197	3,193	19,678
1981	8,364	1,749	28,684	2003	13,320	3,517	11,092
1982	9,476	2,675	15,292	2004	12,055	3,709	5,861
1983	10,443	3,274	52,698	2005	9,759	3,348	9,411
1984	10,088	3,457	12,712	2006	7,950	2,837	22,415
1985	12,285	3,703	34,636	2007	6,361	2,170	-
				2008	6,420	1,867	-

Table 1.21. Estimates of begin-year age 3 and older biomass (thousands of tons) and coefficients of variation (CV) for Model 2 (current assessment) compared to estimates from the 2005-2000 assessments for EBS pollock. NOTE: see Ianelli et al. (2001) for a discussion on the interpretation of age-3+ biomass estimates.

	Current		2005		2004		2003		2002		2001		2000	
	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV	Assess.	CV
1964	1,810	23%	1,779	23%	1,789	23%	1,822	23%	1,784	23%	1,726	23%	751	18%
1965	2,231	21%	2,222	21%	2,272	20%	2,312	20%	2,266	20%	2,196	20%	976	18%
1966	2,252	21%	2,288	21%	2,326	20%	2,372	20%	2,324	20%	2,251	21%	1,001	20%
1967	3,518	17%	3,483	17%	3,514	17%	3,575	17%	3,511	17%	3,420	17%	1,957	17%
1968	3,881	17%	3,881	17%	3,976	17%	4,049	17%	3,976	17%	3,876	17%	2,312	18%
1969	5,058	16%	5,323	16%	5,258	16%	5,340	16%	5,252	16%	5,137	16%	3,379	15%
1970	5,929	16%	6,447	15%	6,211	15%	6,296	15%	6,201	15%	6,079	15%	3,998	13%
1971	6,617	13%	7,145	13%	6,714	14%	6,797	14%	6,702	14%	6,580	14%	4,372	11%
1972	6,265	13%	6,692	13%	6,204	13%	6,282	13%	6,194	13%	6,078	14%	3,984	10%
1973	4,751	16%	5,055	15%	4,632	16%	4,705	16%	4,626	16%	4,520	16%	2,873	13%
1974	3,460	19%	3,635	19%	3,288	19%	3,356	19%	3,287	19%	3,193	20%	1,648	21%
1975	3,585	13%	3,666	14%	3,440	14%	3,489	14%	3,436	14%	3,366	13%	2,536	12%
1976	3,577	11%	3,614	11%	3,497	11%	3,538	11%	3,492	11%	3,434	11%	2,694	9%
1977	3,582	10%	3,548	10%	3,504	10%	3,541	10%	3,496	10%	3,444	10%	2,701	7%
1978	3,438	10%	3,361	10%	3,385	10%	3,422	10%	3,375	10%	3,327	10%	2,608	7%
1979	3,323	9%	3,273	10%	3,341	10%	3,380	10%	3,329	10%	3,280	10%	2,640	8%
1980	4,320	8%	4,373	8%	4,409	8%	4,462	8%	4,385	8%	4,322	8%	3,723	8%
1981	8,364	7%	8,289	7%	8,301	7%	8,414	7%	8,239	7%	8,127	7%	7,834	6%
1982	9,476	6%	9,446	7%	9,472	7%	9,614	7%	9,388	7%	9,261	7%	9,021	7%
1983	10,443	6%	10,536	7%	10,552	7%	10,728	7%	10,441	7%	10,298	7%	9,958	6%
1984	10,088	6%	10,244	7%	10,263	7%	10,456	7%	10,143	7%	10,000	7%	9,518	7%
1985	12,285	5%	12,435	6%	12,492	6%	12,771	6%	12,344	6%	12,181	6%	11,182	5%
1986	11,486	5%	11,609	6%	11,677	6%	11,973	6%	11,538	6%	11,381	6%	10,277	5%
1987	12,077	5%	12,106	5%	12,226	5%	12,596	5%	12,116	5%	11,951	5%	10,636	5%
1988	11,330	5%	11,153	5%	11,243	5%	11,633	5%	11,317	5%	11,159	5%	9,910	4%
1989	9,584	5%	9,384	5%	9,466	5%	9,850	5%	9,540	5%	9,394	5%	8,251	5%
1990	7,603	5%	7,392	6%	7,454	6%	7,811	6%	7,524	6%	7,393	6%	6,473	5%
1991	5,929	6%	5,454	6%	5,637	7%	5,977	7%	5,708	7%	5,582	6%	4,859	6%
1992	9,270	5%	8,905	5%	9,120	5%	9,614	5%	9,227	5%	8,898	5%	7,920	5%
1993	11,795	4%	11,669	5%	11,721	6%	12,363	6%	12,110	5%	11,503	5%	10,233	5%
1994	11,407	5%	11,000	5%	10,998	6%	11,696	6%	11,358	6%	10,590	6%	9,285	5%
1995	13,658	4%	13,605	6%	13,554	6%	14,474	6%	13,848	6%	12,617	7%	10,267	6%
1996	11,480	5%	11,826	6%	11,772	7%	12,630	7%	11,988	7%	10,752	7%	8,556	7%
1997	10,056	5%	9,966	6%	9,949	8%	10,775	8%	10,142	8%	8,984	8%	7,057	9%
1998	9,973	5%	9,915	7%	9,943	8%	11,110	8%	10,466	9%	9,335	10%	7,448	11%
1999	10,872	5%	10,998	6%	11,093	10%	13,339	10%	12,712	11%	12,593	14%	10,772	15%
2000	10,052	5%	9,947	7%	10,036	12%	12,498	12%	11,807	12%	11,680	17%	10,490	17%
2001	9,800	6%	9,566	8%	9,675	14%	12,394	14%	11,511	14%	11,145	20%		
2002	10,197	7%	9,824	9%	9,899	16%	12,930	16%	11,118	17%				
2003	13,320	10%	13,073	13%	12,239	19%	12,688	19%						
2004	12,055	12%	10,972	15%	9,894	21%	11,217	21%						
2005	9,759	14%	9,277	18%	8,573									
2006	7,950	17%	8,232	21%										
2007	6,361	21%												
2008	6,420	27%												

Table 1.22 Projections of Model 1 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 6,381; **2,552**; and 2,233 thousand t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2006	1,497	1,497	1,497	1,497	1,497	1,497	1,497
2007	1,394	1,394	696	389	0	1,680	1,394
2008	913	913	612	364	0	986	913
2009	993	993	624	382	0	1,077	1,218
2010	1,215	1,215	705	434	0	1,349	1,400
2011	1,424	1,424	822	509	0	1,575	1,591
2012	1,561	1,561	929	583	0	1,701	1,705
2013	1,605	1,605	998	635	0	1,725	1,726
2014	1,609	1,609	1,034	667	0	1,712	1,713
2015	1,606	1,606	1,054	687	0	1,703	1,703
2016	1,610	1,610	1,066	699	0	1,709	1,709
2017	1,620	1,620	1,077	709	0	1,724	1,724
2018	1,636	1,636	1,089	719	0	1,738	1,738
2019	1,622	1,622	1,090	722	0	1,720	1,720
Fishing M.	***Scenario 1***	***Scenario 2***	***Scenario 3***	***Scenario 4***	***Scenario 5***	***Scenario 6***	***Scenario 7***
2006	0.347	0.347	0.347	0.347	0.347	0.347	0.347
2007	0.427	0.427	0.195	0.105	0.000	0.536	0.427
2008	0.363	0.363	0.195	0.105	0.000	0.432	0.363
2009	0.398	0.398	0.195	0.105	0.000	0.476	0.504
2010	0.430	0.430	0.195	0.105	0.000	0.522	0.531
2011	0.446	0.446	0.195	0.105	0.000	0.544	0.547
2012	0.455	0.455	0.195	0.105	0.000	0.555	0.556
2013	0.456	0.456	0.195	0.105	0.000	0.555	0.556
2014	0.457	0.457	0.195	0.105	0.000	0.555	0.555
2015	0.458	0.458	0.195	0.105	0.000	0.555	0.555
2016	0.458	0.458	0.195	0.105	0.000	0.555	0.555
2017	0.459	0.459	0.195	0.105	0.000	0.557	0.557
2018	0.459	0.459	0.195	0.105	0.000	0.556	0.556
2019	0.458	0.458	0.195	0.105	0.000	0.556	0.556
Spawning biomass	***Scenario 1***	***Scenario 2***	***Scenario 3***	***Scenario 4***	***Scenario 5***	***Scenario 6***	***Scenario 7***
2006	2,837	2,837	2,837	2,837	2,837	2,837	2,837
2007	2,172	2,172	2,273	2,314	2,362	2,126	2,172
2008	1,868	1,868	2,197	2,357	2,564	1,740	1,868
2009	2,051	2,051	2,462	2,702	3,036	1,914	2,022
2010	2,327	2,327	2,842	3,150	3,601	2,171	2,213
2011	2,531	2,531	3,192	3,571	4,142	2,342	2,357
2012	2,641	2,641	3,462	3,917	4,620	2,417	2,422
2013	2,663	2,663	3,625	4,156	4,998	2,416	2,418
2014	2,653	2,653	3,719	4,318	5,292	2,394	2,395
2015	2,657	2,657	3,801	4,460	5,563	2,394	2,395
2016	2,672	2,672	3,865	4,569	5,777	2,408	2,409
2017	2,695	2,695	3,924	4,662	5,954	2,429	2,430
2018	2,698	2,698	3,956	4,723	6,085	2,430	2,430
2019	2,680	2,680	3,959	4,747	6,163	2,410	2,410

Table 1.23 Tier 1 and Tier 3 EBS pollock ABC and OFL projections from Model 2 for 2007 and for 2008 under various 2007 assumed catches. Tier 1 levels use projected age-3+ biomass levels and the associated harmonic mean F_{msy} value.

Units are thousands of tons.

		Tier 1		Tier 3	
Year		ABC	OFL	ABC	OFL
2007		**1,512**	**1,641**	1,394	1,680
	Assumed 2007 catch	ABC	OFL	ABC	OFL
2008	1,488	1,257	1,365	877	1,072
2008	1,394	1,318	1,431	913	1,115
2008	1,300	1,380	1,498	950	1,159
2008	1,200	1,447	1,570	990	1,206

Table 1.24. 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	New study initiated in 2002	NA	Possible concern

Table 1.25 Bycatch estimates (mt) of non-target species caught in the BSAI directed pollock fishery, 1997-2002 based on observer data, 2003-2005 based on observer data as processed through the catch accounting system (NMFS Regional Office, Juneau, Alaska).

	1997	1998	1999	2000	2001	2002
Jellyfish	6,632	6,129	6,176	9,361	3,095	1,530
Squid	1,487	1,210	474	379	1,776	1,708
Skates	348	406	376	598	628	870
Misc Fish	207	134	156	236	156	134
Sculpins	109	188	67	185	199	199
Sleeper shark	105	74	77	104	206	149
Smelts	19.5	30.2	38.7	48.7	72.5	15.3
Grenadiers	19.7	34.9	79.4	33.2	11.6	6.5
Salmon shark	6.6	15.2	24.7	19.5	22.5	27.5
Starfish	6.5	57.7	6.8	6.2	12.8	17.4
Shark	15.6	45.4	10.3	0.1	2.3	2.3
Benthic inverts.	2.5	26.3	7.4	1.7	0.6	2.1
Sponges	0.8	21.0	2.4	0.2	2.1	0.3
Octopus	1.0	4.7	0.4	0.8	4.8	8.1
Crabs	1.0	8.2	0.8	0.5	1.8	1.5
Anemone	2.6	1.8	0.3	5.8	0.1	0.6
Tunicate	0.1	1.5	1.5	0.4	3.7	3.8
Unident. inverts	0.2	2.9	0.1	4.4	0.1	0.2
Echinoderms	0.8	2.6	0.1	0.0	0.2	0.1
Seapen/whip	0.1	0.2	0.5	0.9	1.5	2.1
Birds	0.2	2.1	0.7	0.2	0.3	0.3
Lanternfish	0.4	0.2	0.0	0.1	0.3	2.7
Coral	0.0	0.2	0.0	0.1	0.0	0.0
Dogfish	0.0	0.1	0.0	0.0	0.1	0.0
Sandfish	0.0	0.0	0.1	0.4	0.1	0.3
Sandlance	0.0	0.0	0.0	0.0	0.0	0.2
Shrimp	0.1	0.3	0.3	0.0	0.1	0.2
Sticheidae	0.1	0.0	0.0	0.0	0.3	0.0

	2003	2004	2005
Jellyfish	5,644	6,040	5,183
Squid	1,151	855	1,041
Skate	452	673	718
Misc fish	101	77	154
Large Sculpins	42.6	116	137
Shark	81.8	107	84
Sea star	89.4	6.77	9.22
Other Sculpins	59.2	15.5	10.8
Grenadier	20.4	9.40	8.99
Eulachon	2.49	18.8	8.98
Other osmerids	7.51	1.97	3.38
Snails	1.26	0.94	6.91
Eelpouts	7.03	0.61	1.33
Giant Grenad.	0.31	3.50	5.02
Octopus	1.10	2.58	1.16
Sea pens/whips	0.58	0.95	1.65
Birds	0.13	0.11	2.42
Anemone	0.40	0.41	0.29
Misc crabs	0.75	0.03	0.26
Lanternfish	0.29	0.07	0.63
Capelin	0.01	0.32	0.35
Urochordate	0.00	0.01	0.49
Pandal. shrimp	0.01	0.01	0.43
Corals Bryozo.	0.01	0.04	0.35
Brittle star	0.26	0.01	0.02
Invertebrate	0.04	0.12	0.09
Stichaeidae	0.08	0.07	0.04
Sponge	0.10	0.05	0.03
Other	0.09	0.08	0.07

Table 1.26 Bycatch estimates (t) of target species caught in the BSAI directed pollock fishery, 1997-2005 based on then NMFS Alaska Regional Office reports from observers.

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

Table 1.27 Bycatch estimates of prohibited species caught in the BSAI directed pollock fishery, 1997-2005 based on then NMFS Alaska Regional Office reports from observers, (n=numbers, t=metric tons).

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Herring (t)	1,089	821	785	482	224	105	895	963	442
Red king crab (n)	0	5,098	0	0	38	6	53	10	0
Other king crab (n)	156	1,832	2	104	5,135	81	9	6	6
Bairdi crab (n)	6,525	35,594	1,078	173	86	651	784	1,200	585
Other tanner crab (n)	88,588	45,623	12,778	1,807	2,179	1,667	761	740	1,932
Chinook salmon (n)	43,336	49,373	10,187	3,966	30,107	32,222	46,044	53,343	65,344
Other salmon (n)	61,504	62,276	44,585	56,707	52,835	76,998	190,146	436,176	690,322
Halibut (t)	127	144	69	80	164	127	97	92	190

Table 1.28. Summary results for Model 2, EBS pollock. Tonnage units are thousands of metric tons.

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	0.009	0.121	0.699	1.062	1.582	1.711	1.668	1.474	1.275	1.080	1.080	1.080	1.080	1.080

Base model	Model 2
Tier (2007)	1a
Age 3+ 2007 begin-year biomass	6,361 t
2007 Spawning biomass	**2,837** t
B_{msy}	**2,061** t
$B_{40\%}$	**2,552** t
$B_{35\%}$	2,233 t
$B_{100\%}$	6,381 t
B_0	**5,452** t

Yield Considerations		2007	2008*
ABC:	Harmonic Mean F_{msy}	**1,512** t	1,257 t
ABC:	Yield $F_{40\%}$ (Tier 3)	1,394 t	913 t
OFL:	Arithmetic Mean F_{msy} Yield	1,365 t	1,365 t
OFL:	Yield $F_{35\%}$ (Tier 3)	1,680 t	1,115 t
	Full Selection F's		
	F_{msy}	0.919	
	$F_{40\%}$	0.506	
	$F_{35\%}$	0.650	

* Assuming 2007 catches equal 1,488,000 t

Figures

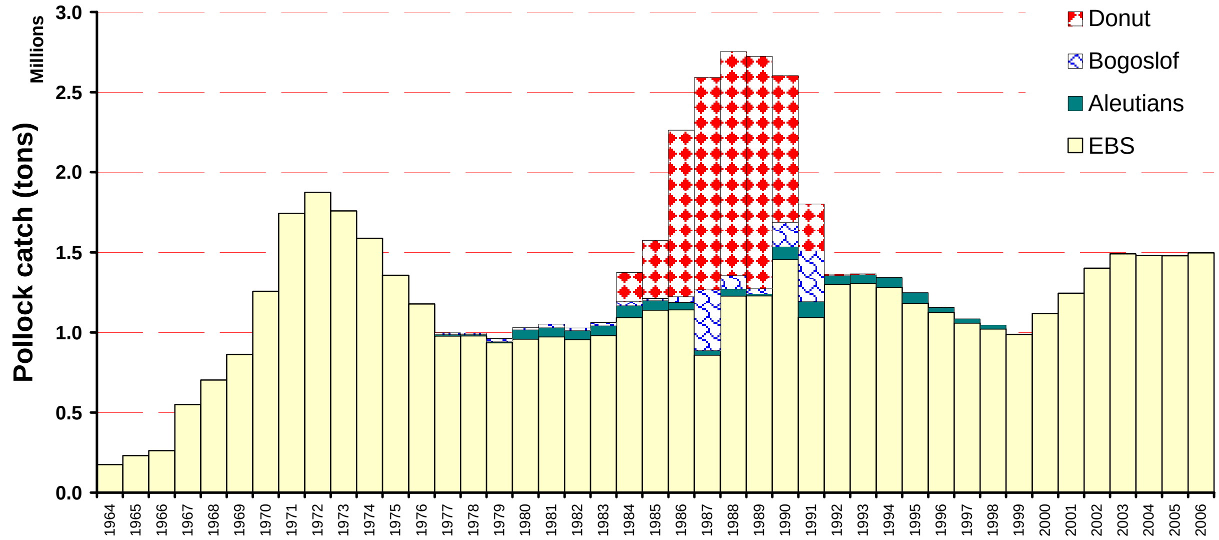


Figure 1.1. Walleye pollock catch in the Eastern Bering Sea, Aleutian Islands, Bogoslof Island, and Donut Hole, 1964-2005

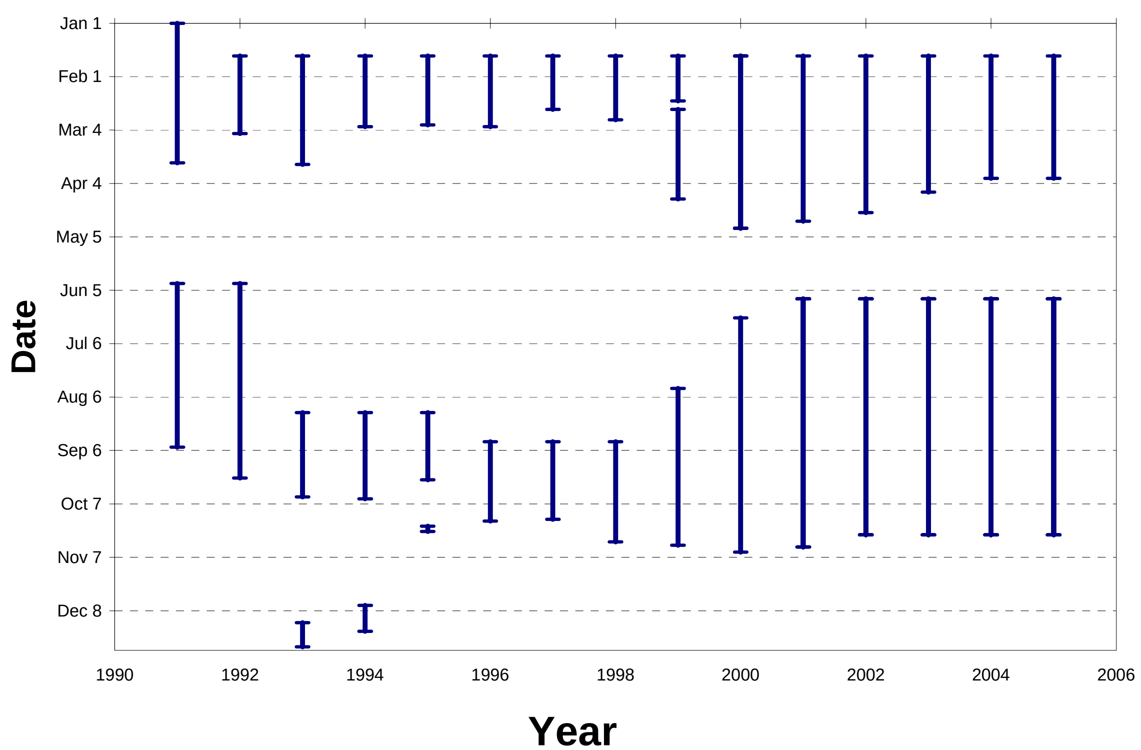


Figure 1.2. Period length and timing of the main EBS pollock fishing seasons 1991-2005 (some fishery sectors had variable openings).

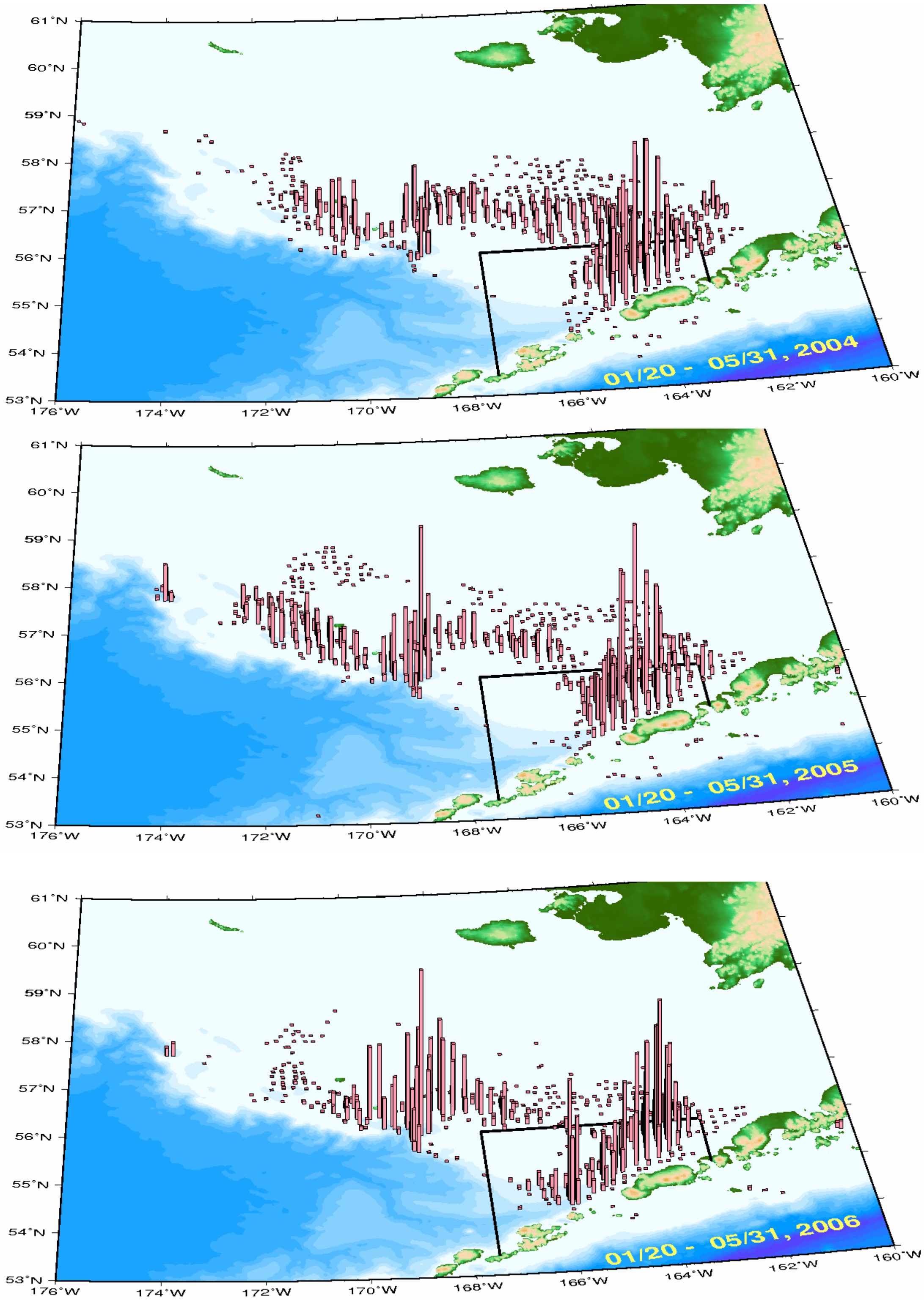


Figure 1.3. Concentrations of the pollock fishery 2004-2006, January – May on the EBS shelf. Line delineates catcher-vessel operational area (CVOA). The column height represents relative removal on the same scale in all years.

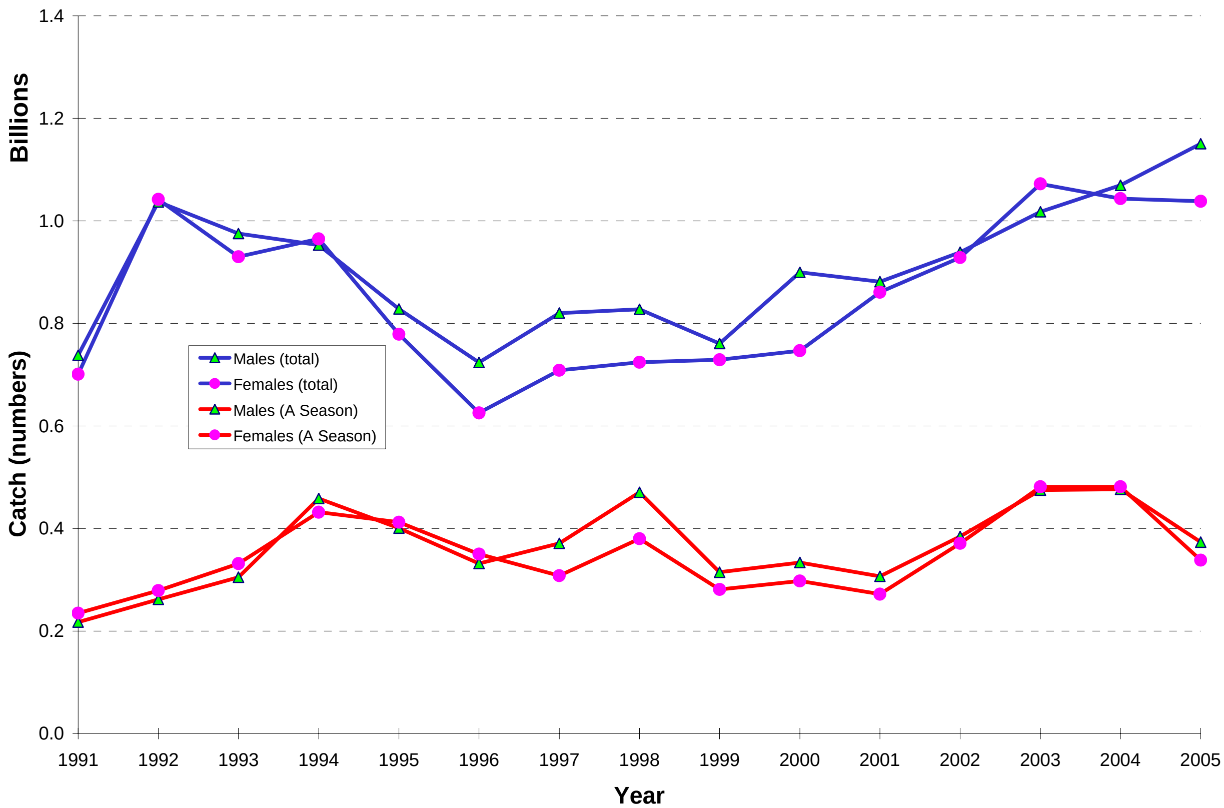


Figure 1.4. Estimate of EBS pollock catch numbers by sex for the "A season" (January-June) and for the entire annual fishery, 1991-2005.

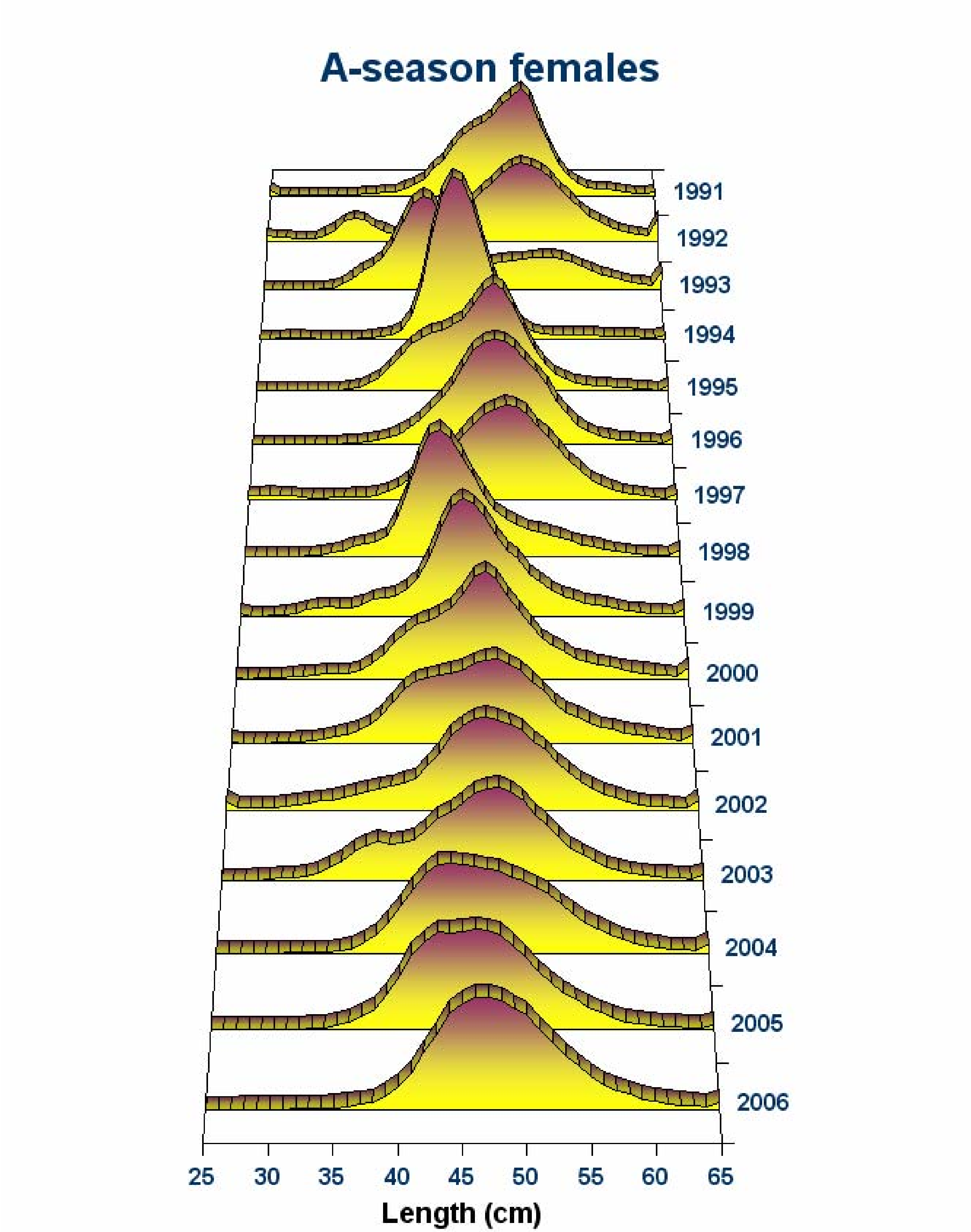


Figure 1.5. Fishery length frequency for the "A season" (January-May) female EBS pollock, 1991-2006. Data for 2006 are preliminary.

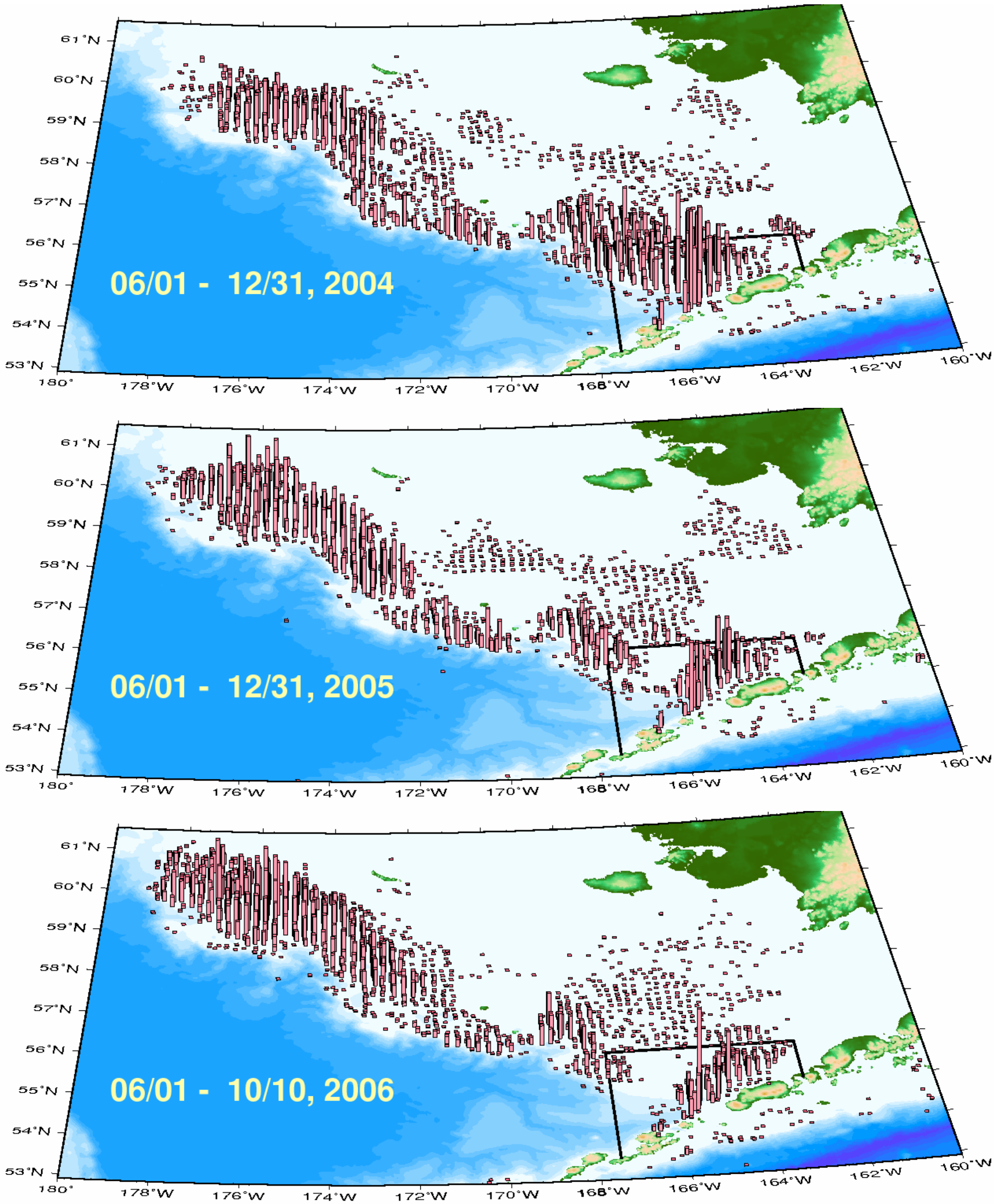


Figure 1.6. Concentrations of the EBS pollock fishery 2004-2006, July – December on the EBS shelf. Line delineates the catcher-vessel operational area (CVOA). The height of the bars represents relative removal on the same scale over all years.

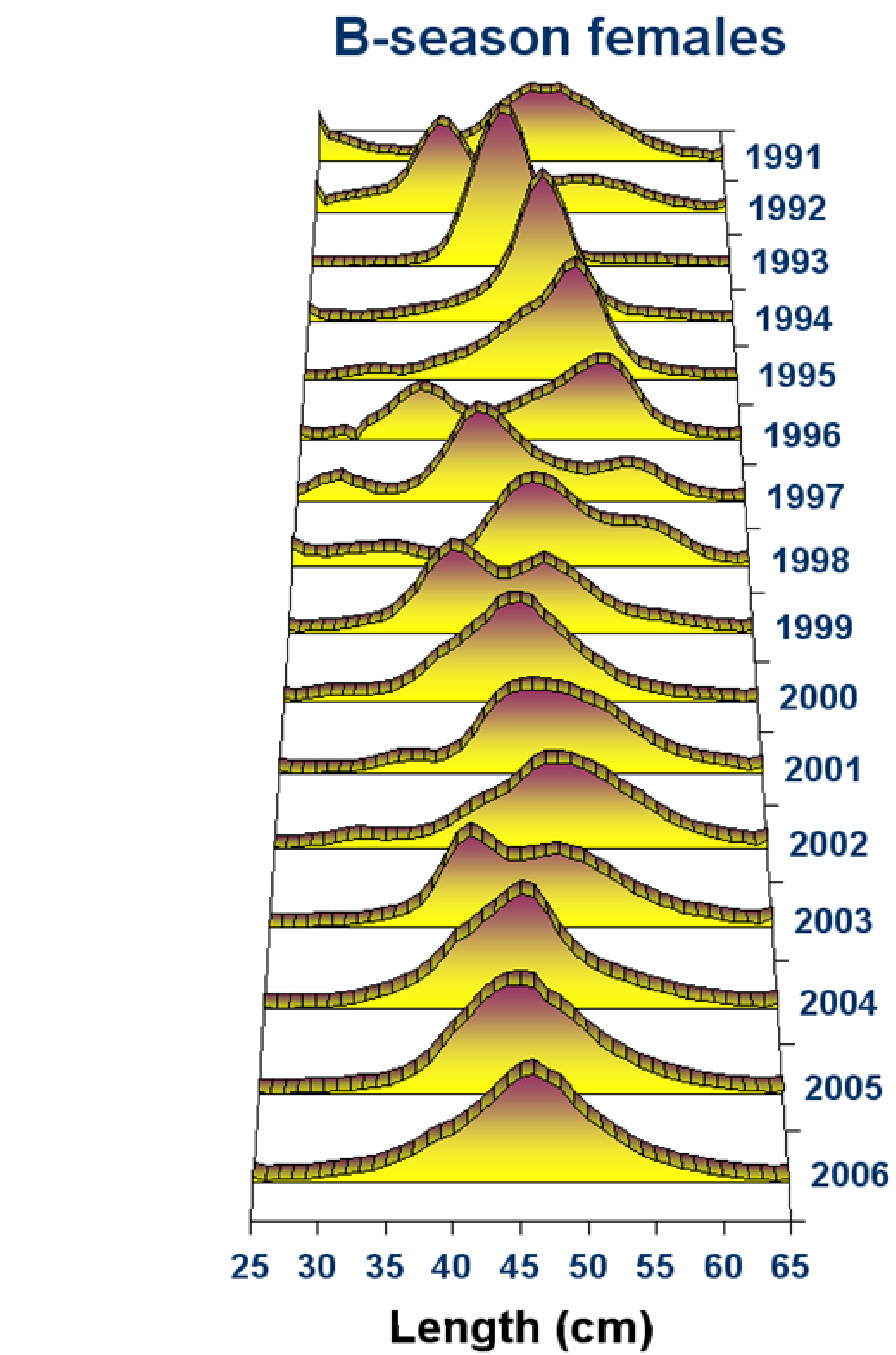


Figure 1.7. Length frequency of EBS pollock observed in period July-December for 1991-2006. Data for 2006 are preliminary.

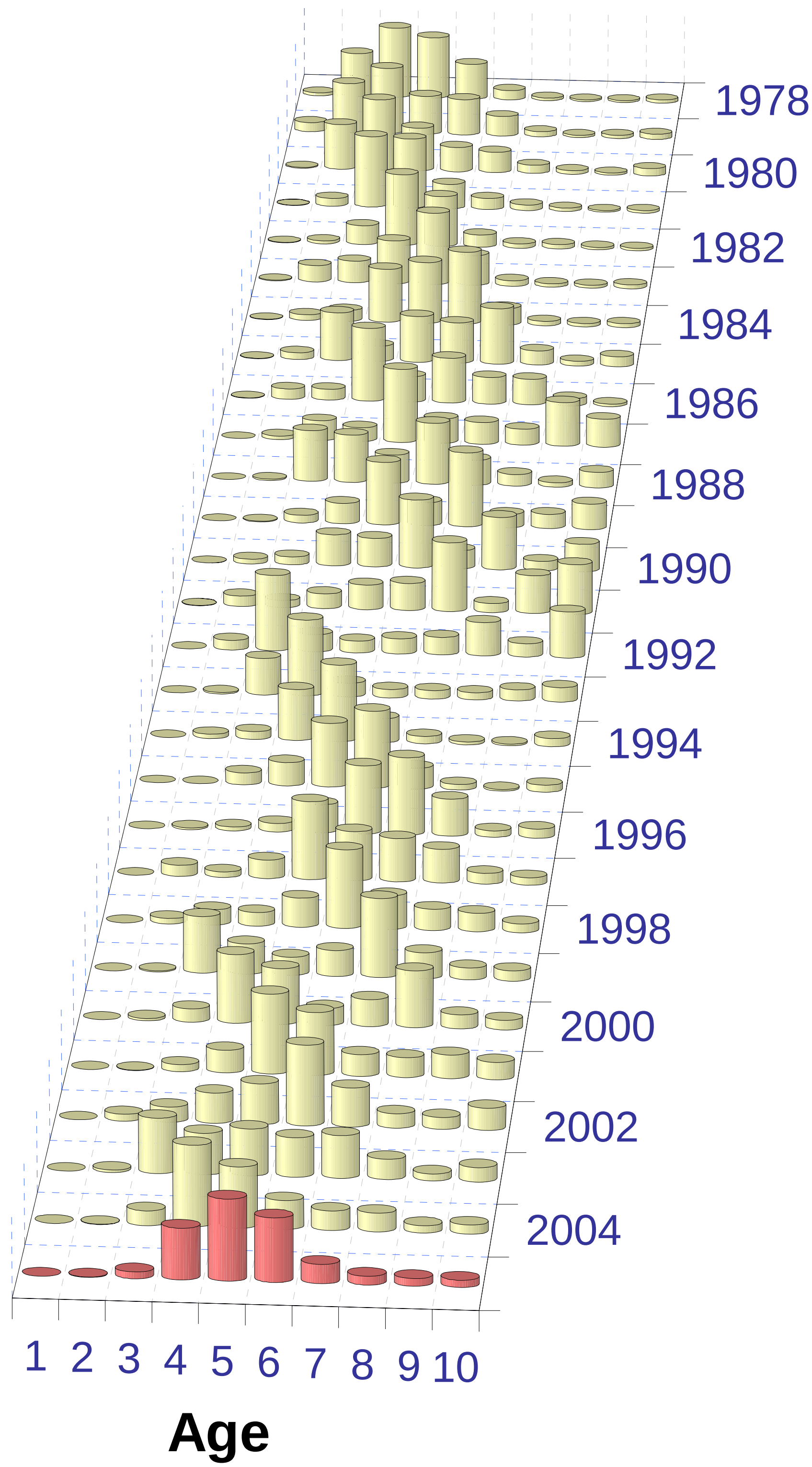


Figure 1.8. EBS pollock fishery estimated catch-at-age data (proportions) for 1978-2005. Age 10 represents pollock age 10 and older.

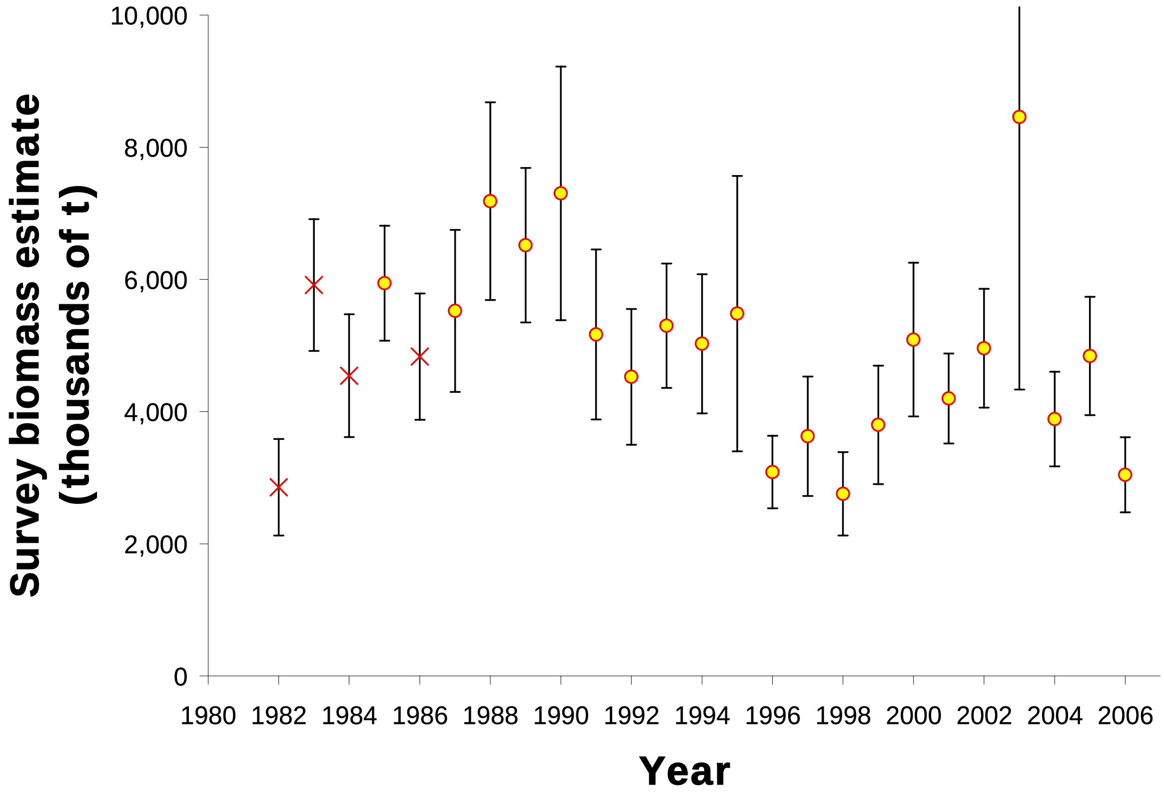


Figure 1.9. Bottom-trawl survey biomass estimates with approximate 95% confidence bounds (based on sampling error) for EBS walleye pollock, 1982-2006. These estimates **include** the northern strata except for 1982-84, and 1986 (indicated by cross symbols).

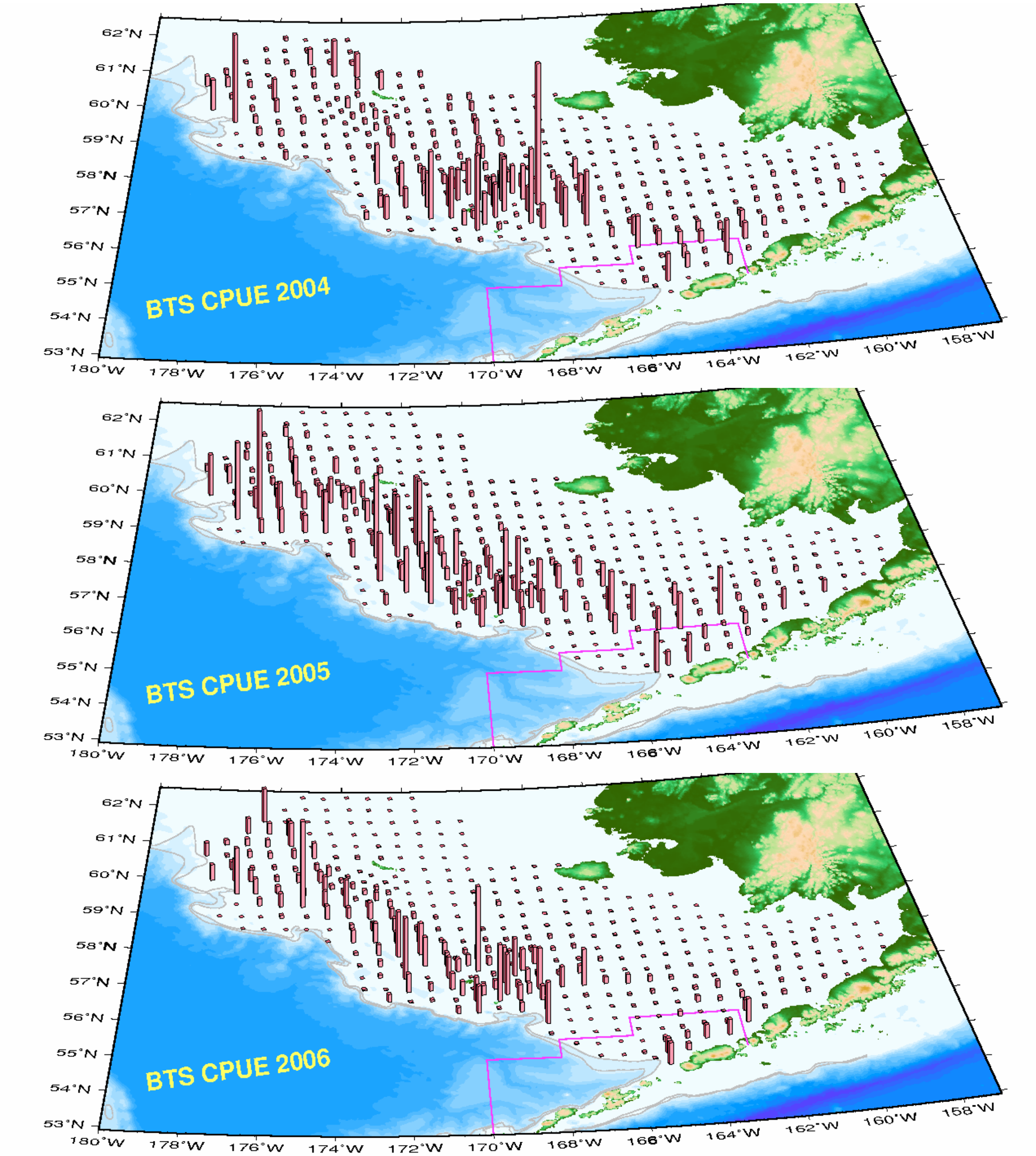


Figure 1.10. Maps showing the walleye catch-per-unit effort observed from the 2004 - 2006 NMFS EBS shelf bottom-trawl surveys.

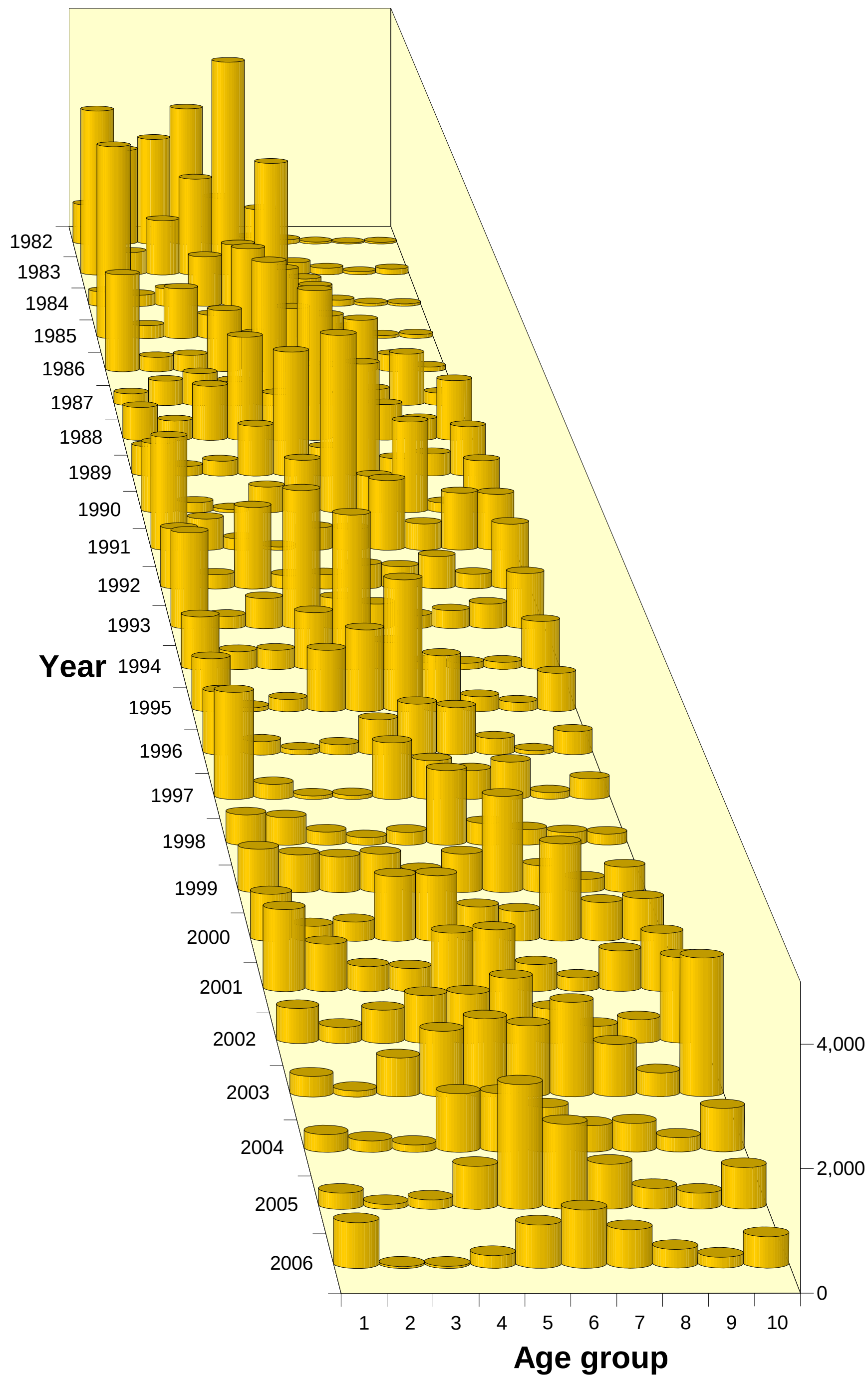


Figure 1.11. Pollock abundance levels by age and year plotted over time (top) and by individual cohorts (year classes) as estimated directly from the NMFS bottom-trawl surveys (1982-2006).

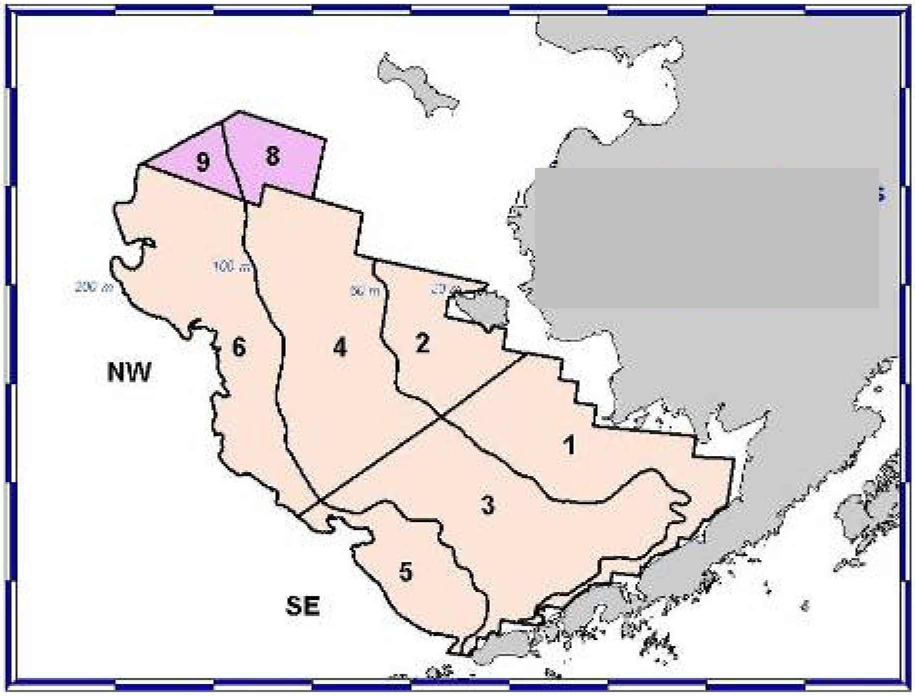


Figure 1.12. Map showing the standard NMFS bottom-trawl survey strata (1-6) and the additional strata (8 and 9). The standard survey area (done each year since 1982) measures 463,374 km^2 and includes about 356 stations. Including the expanded area (done each year since 1987) the number of stations typically totals 376.

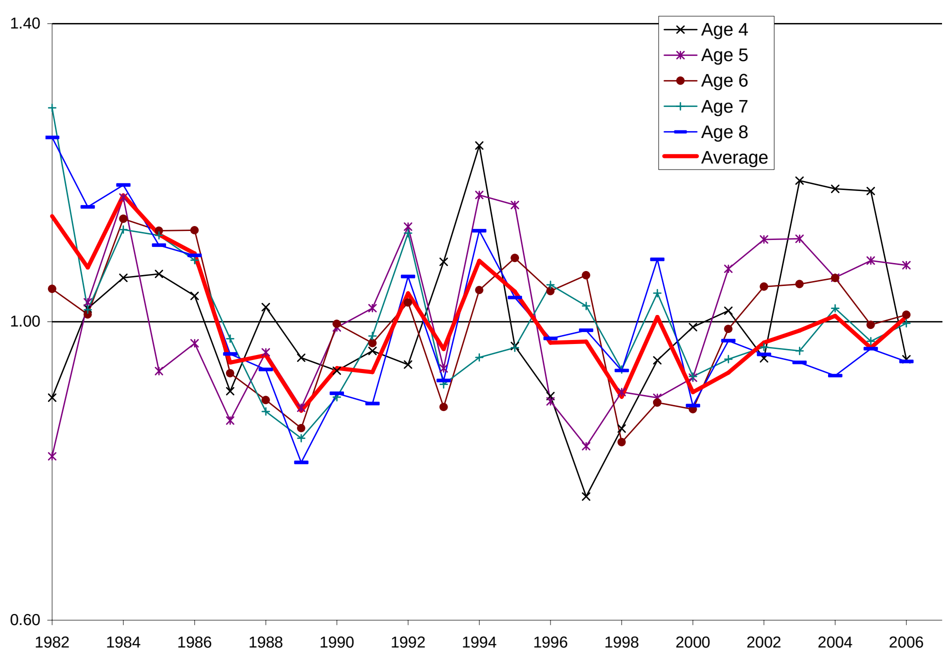


Figure 1.13. Trends in pollock average weights-at-age based on NMFS bottom trawl survey estimates, 1982-2006. Values are shown relative to their mean within each age or age group. Note that the length-weight relationship used here is constant; hence, the differences are how average lengths-at-age vary over time in terms of weight.

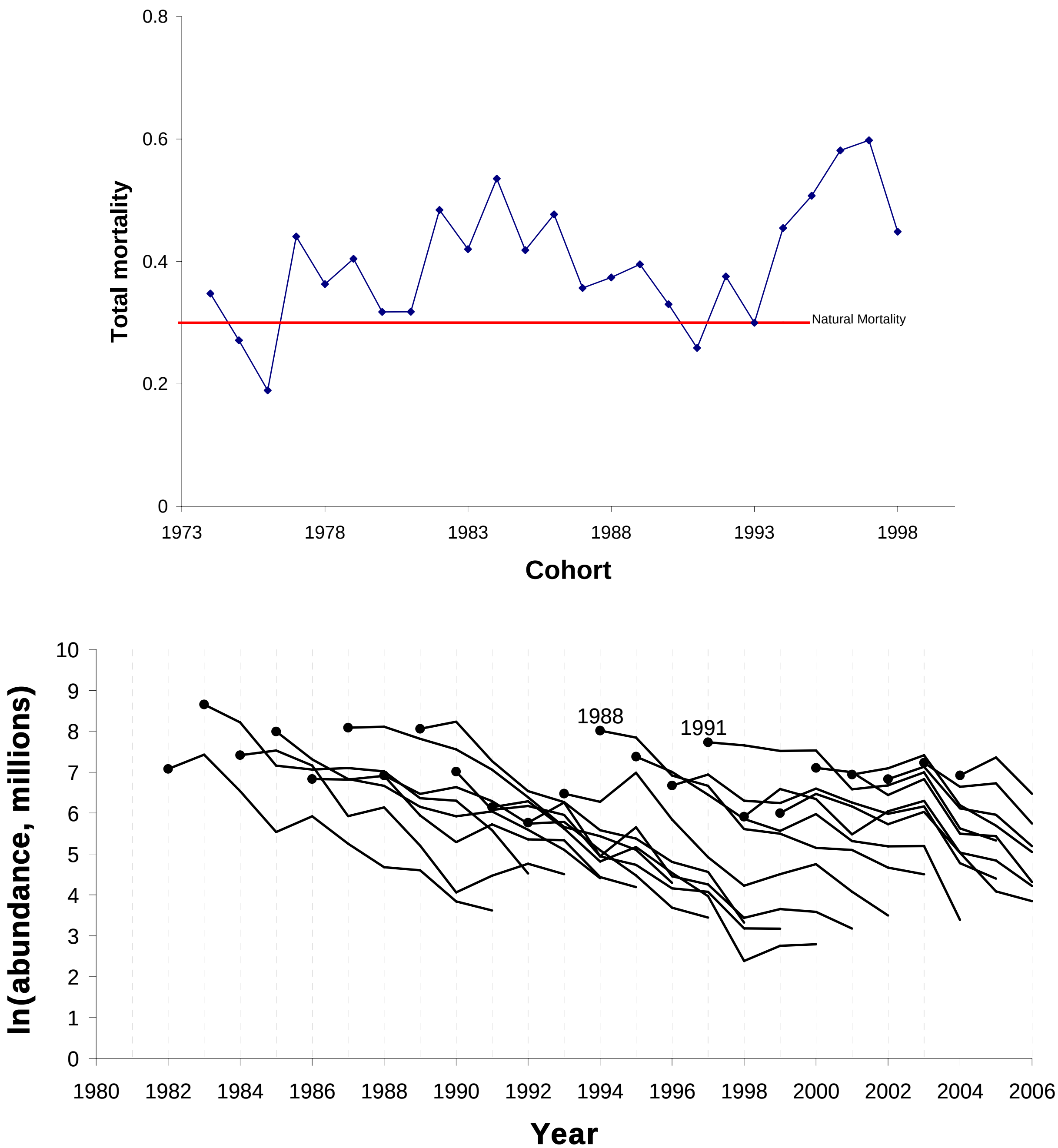


Figure 1.14. Evaluation of cohort abundances as observed for age 6 and older in the NMFS summer bottom trawl surveys. The bottom panel shows the raw log-abundances at age while the top panel shows the estimates of total mortality by cohort.

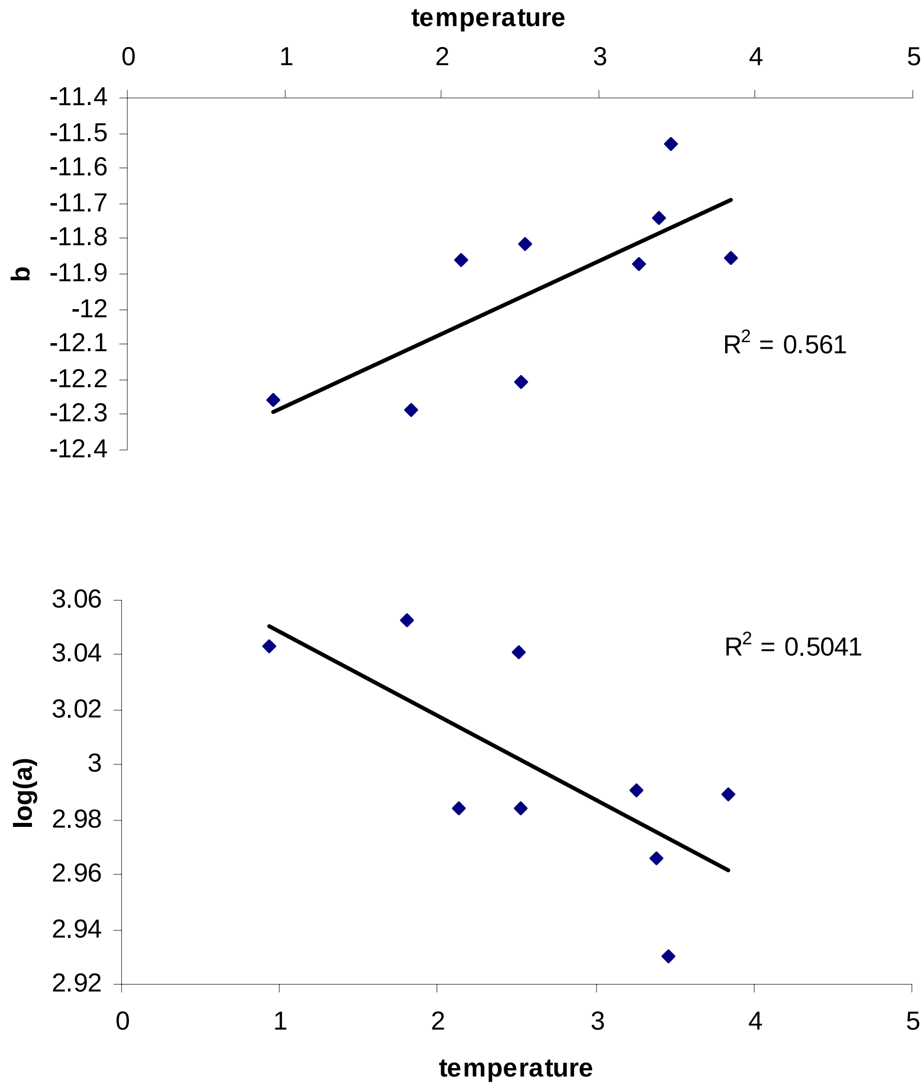


Figure 1.15. Relationship between slope (*b*) and intercept (log(a)) of linear regression log(W) = log a + b·log(L) and mean bottom temperature during 9 bottom-trawl surveys. The patterns indicate that the weight of different size (length) fish was greater during warmer years than during colder years.

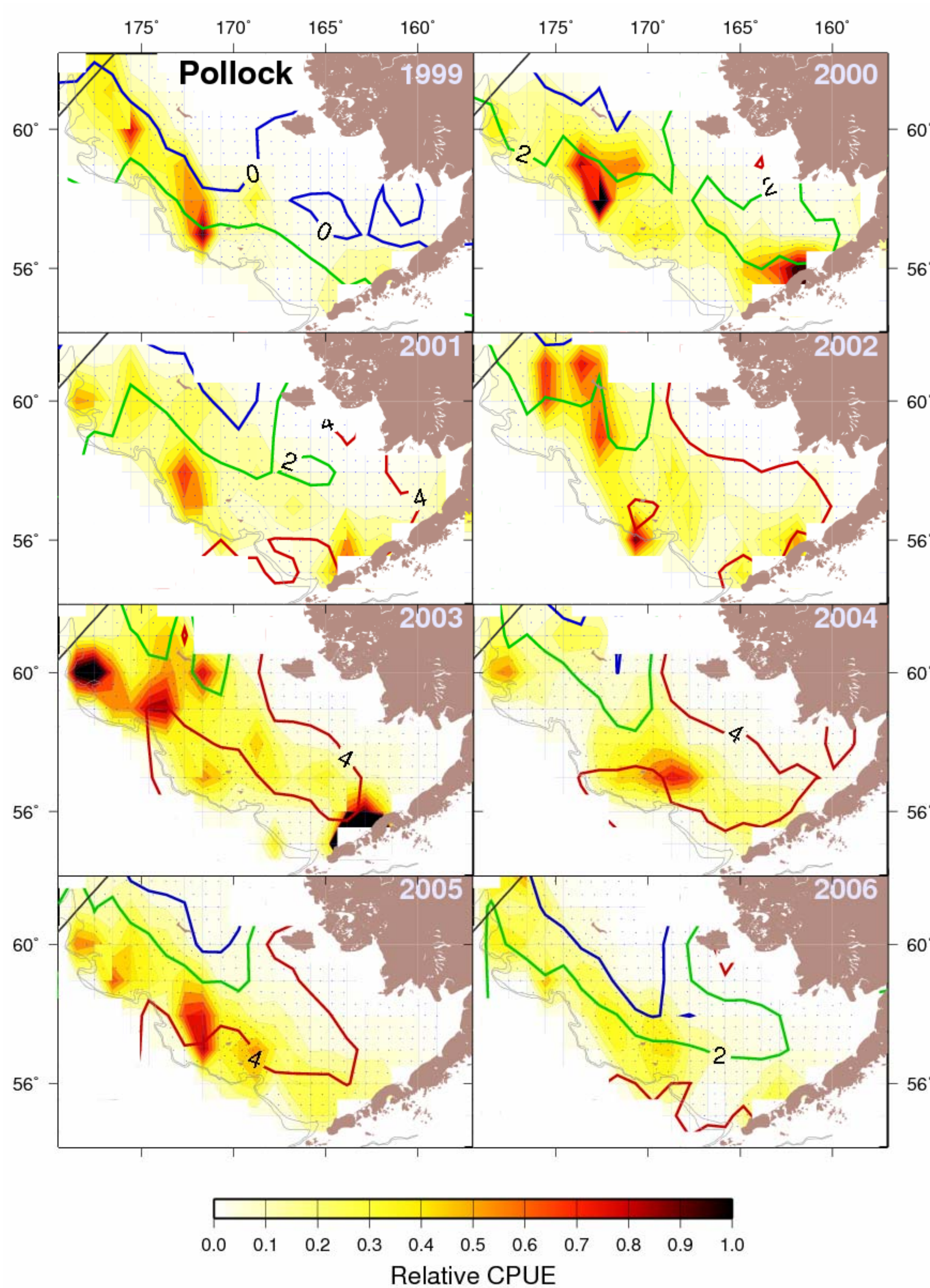


Figure 1.16. EBS pollock CPUE (shades = relative kg/hectare) and bottom temperature isotherms of 0º, 2º, and 4º Celsius from summer bottom-trawl surveys, 1999-2006.

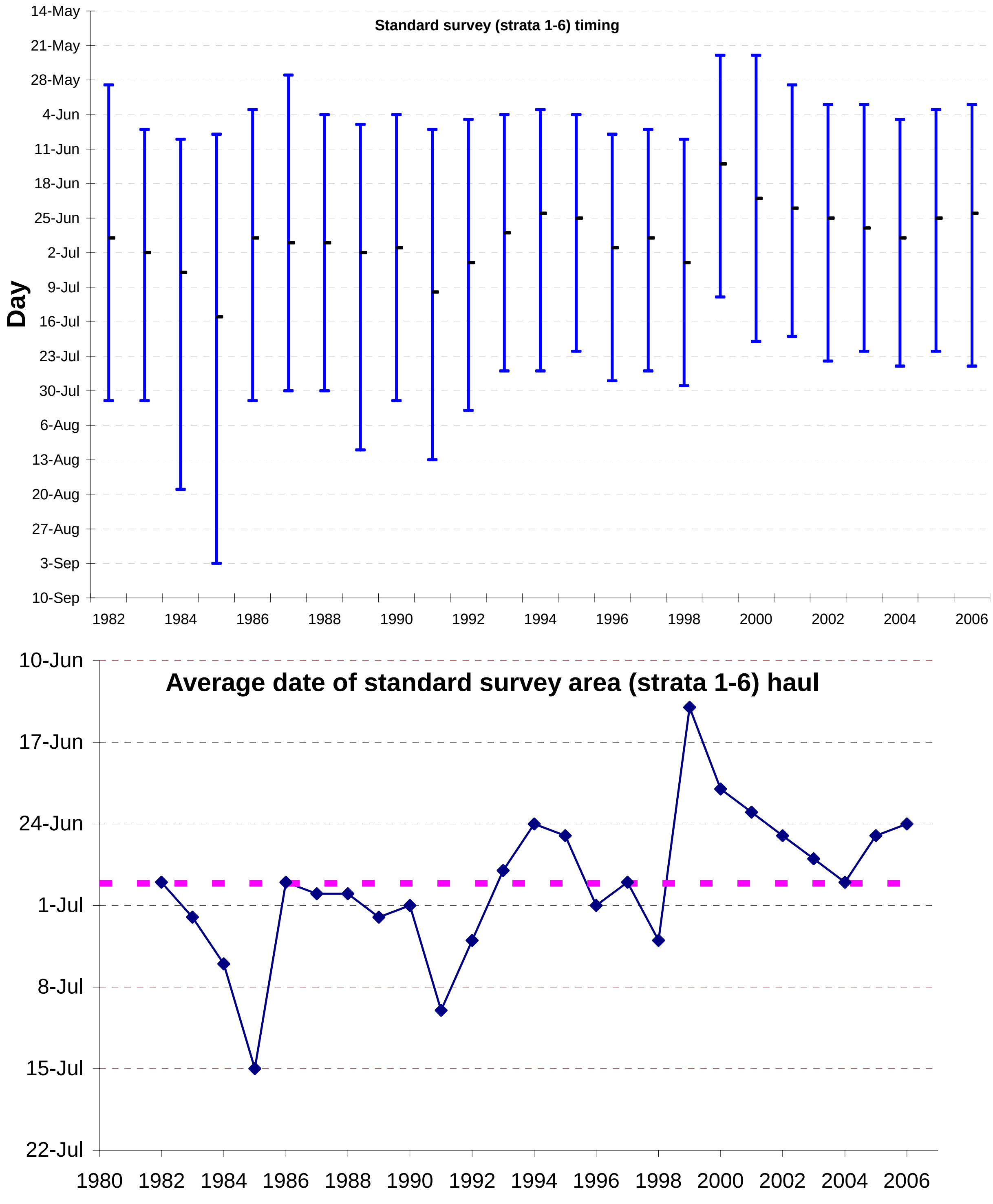


Figure 1.17. Timing of bottom-trawl surveys by year showing the range of days of operation (top panel) with start date represented by the upper bar and the end date by the lower dash for each year (the tick mark represents the mean date of all tows). The average date of tow operations (bottom panel) and mean value (dashed lane) is shown in the bottom panel.

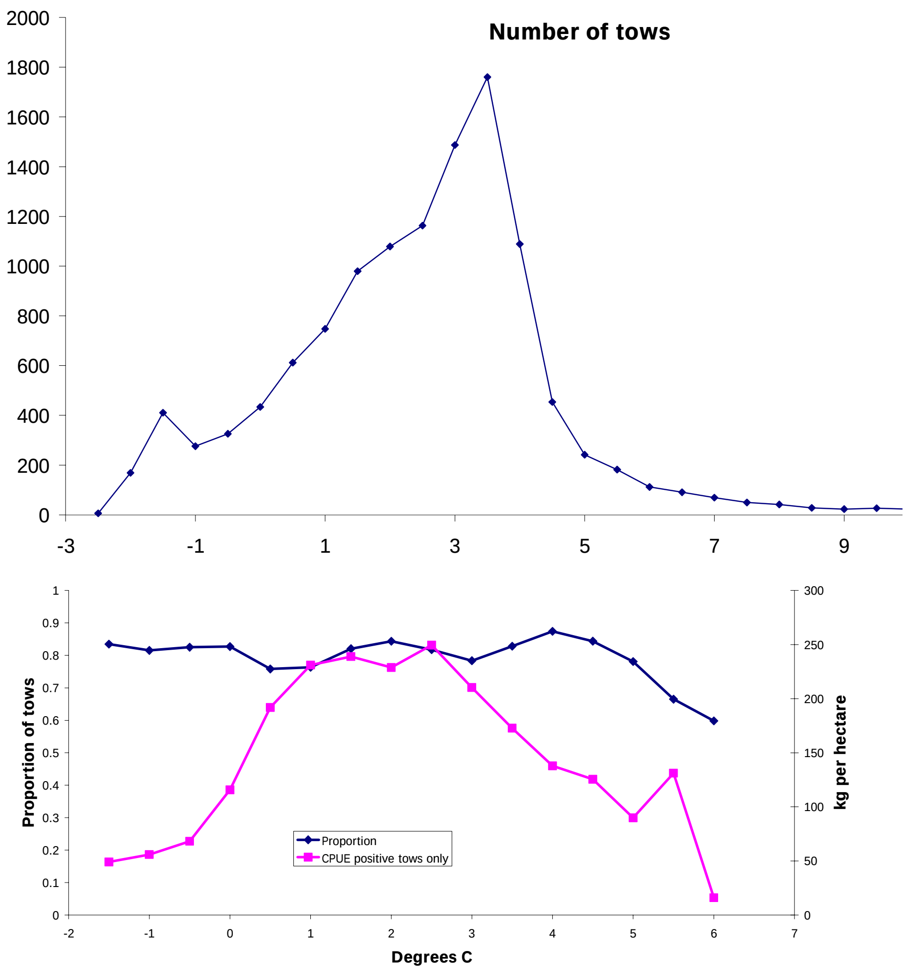


Figure 1.18. Numbers of EBS summer bottom-trawl survey tows with temperature (top panel) and proportion of those tows with pollock and the CPUE in kg per hectare (bottom panel) for all years, 1982-2006.

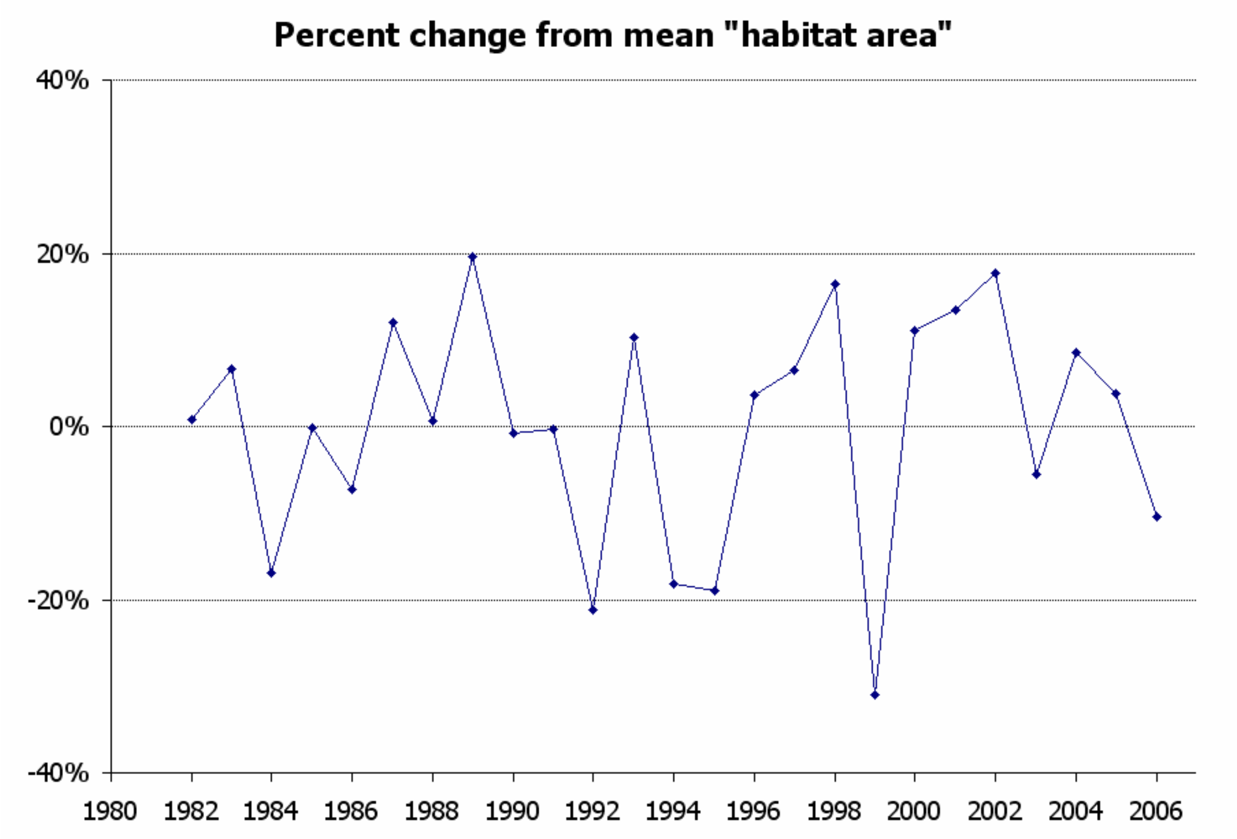


Figure 1.19. Index of suitable habitat area defined as the area of the bottom between the 0.5° and 4.5°C isotherms. This was used in Model 3 as an index affecting BTS catchability for EBS pollock.

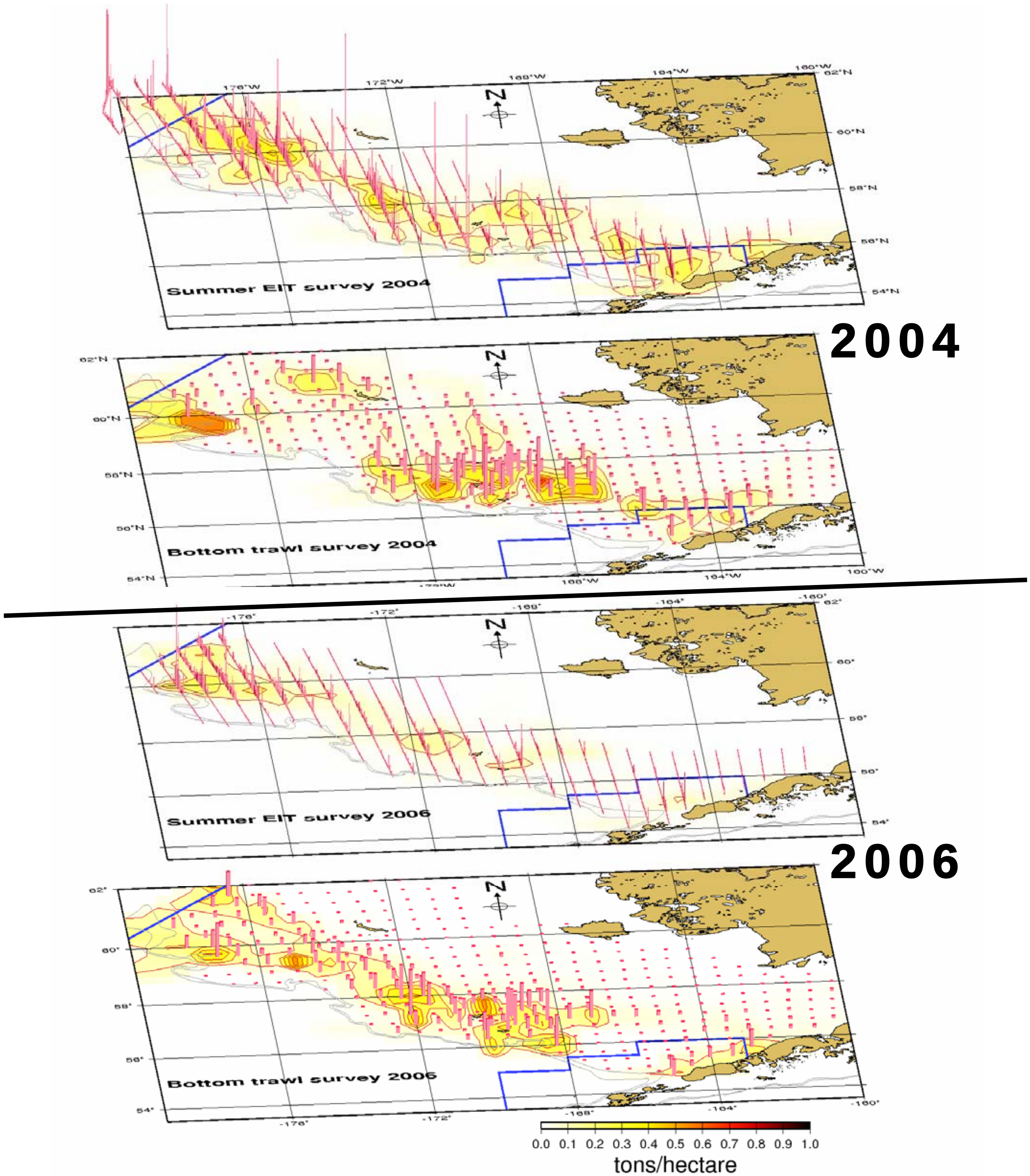
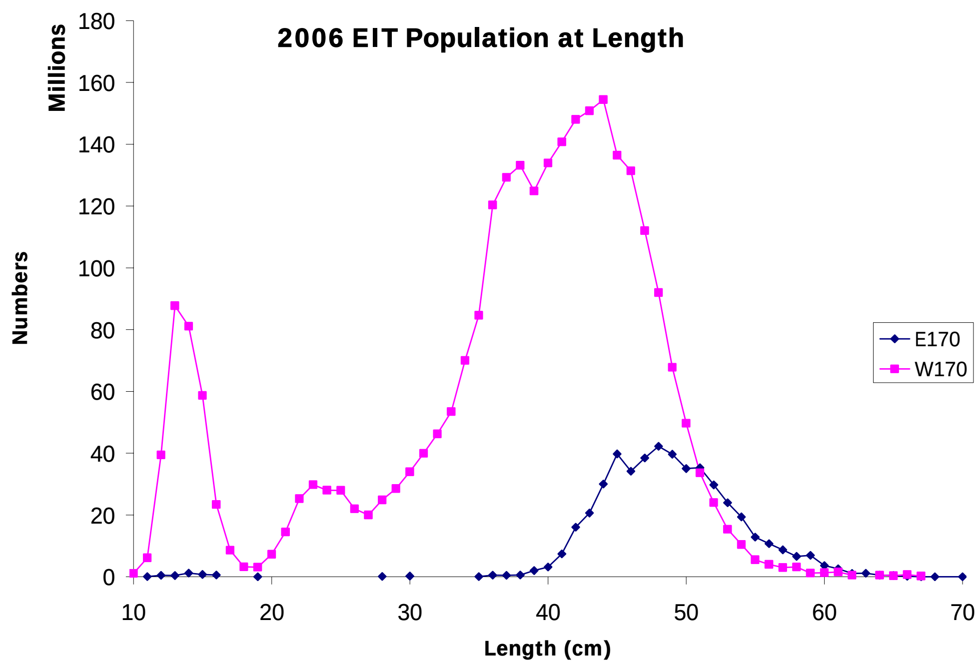


Figure 1.20. Echo-integration trawl survey results for 2004 and 2006. The lower figure is the result from the BTS data in the same years. Vertical lines represent biomass of pollock as observed in the different surveys.



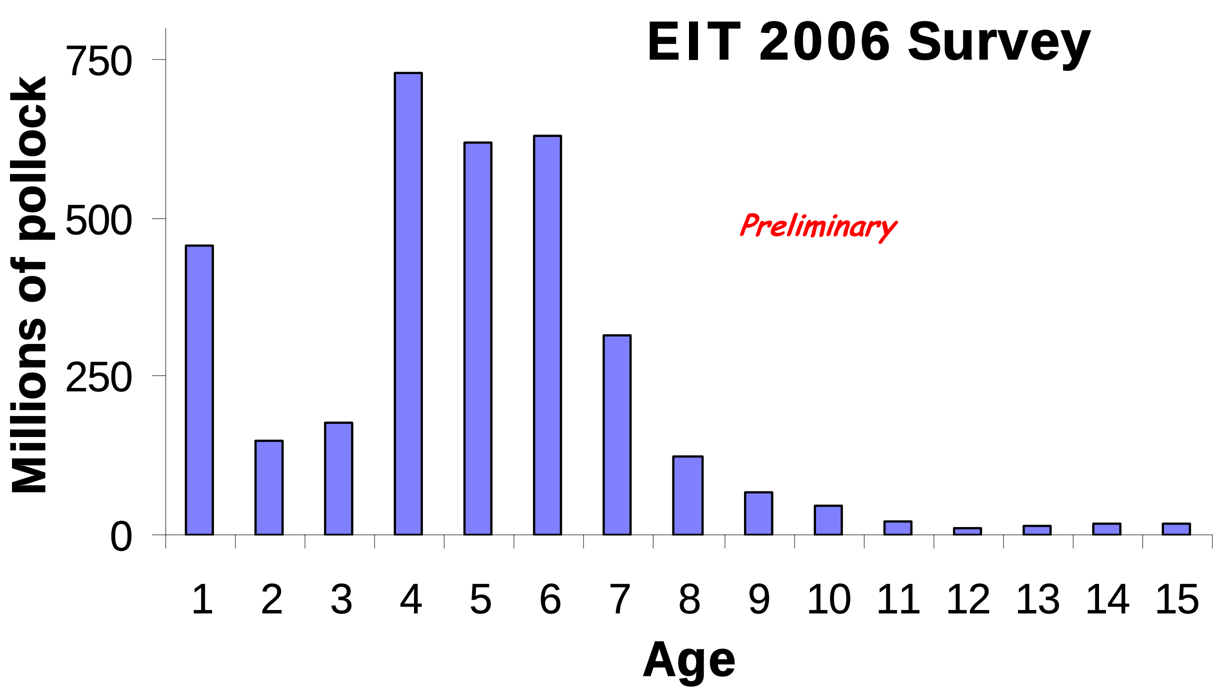


Figure 1.21. EBS pollock population at length (top) and age (bottom) estimates from the 2006 echo-integration trawl survey. These represent summed age compositions using geographically split (east and west of 170W) BTS age composition data applied to EIT population at length estimates (also geographically split). The EIT numbers at age estimates will be updated in 2007 when otoliths from that survey are interpreted for ages.

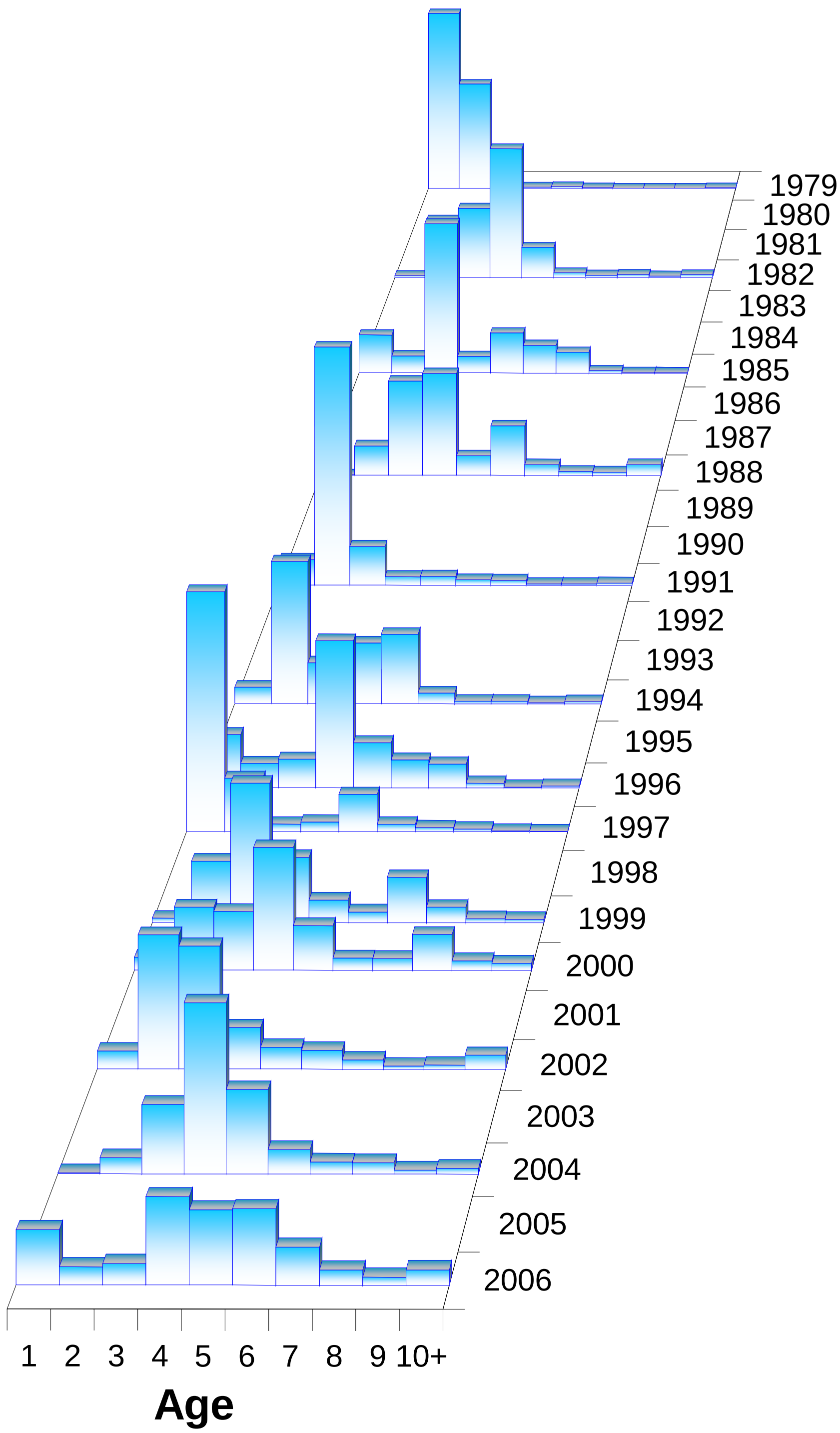


Figure 1.22. Time series of estimated proportions at age for EBS walleye pollock from the EIT surveys, 1979-2006. Note that the 2006 age compositions were computed using an age-length key derived from the 2006 BTS data and as such, are preliminary. Next year the 2006 EIT survey age data will have been processed and applied.

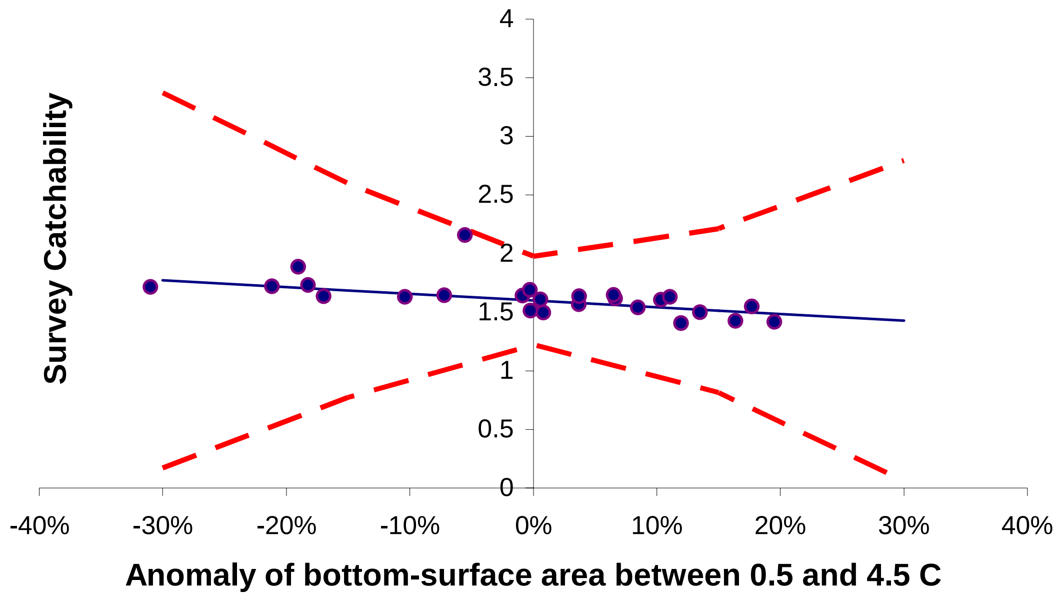
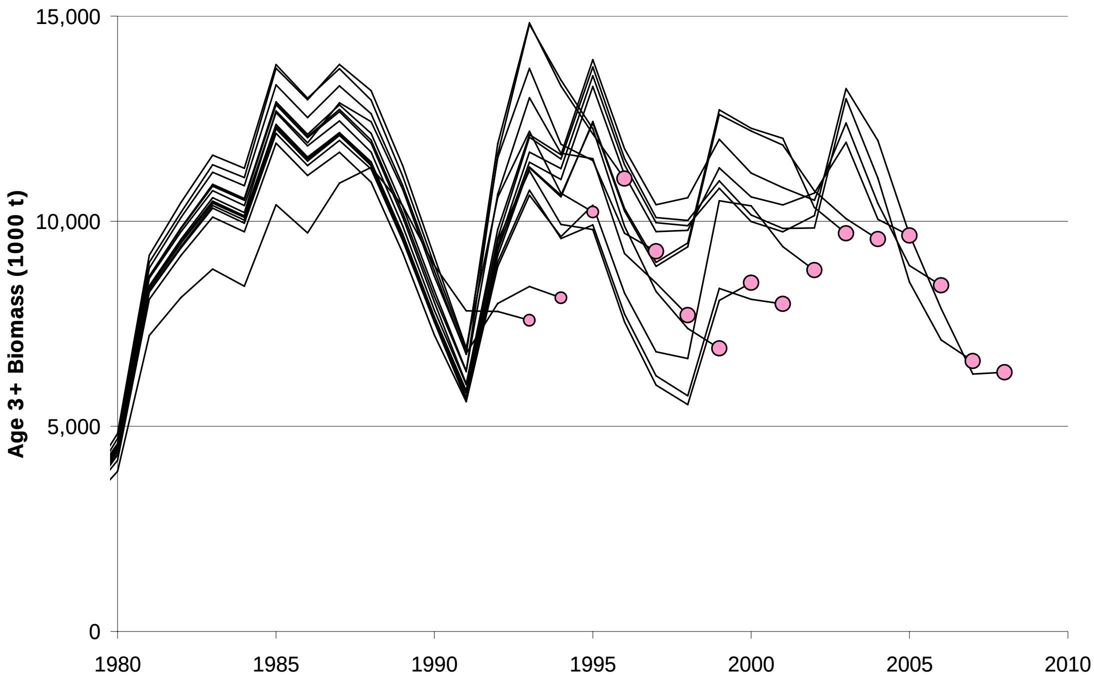


Figure 1.23. Estimated relationship between pollock bottom-trawl survey catchability and relative change in bottom surface area between 0.5° and 4.5° C (solid line). Values along horizontal axis were normalized to have a mean of 0.0 as under Model 4. Points represent residuals relative to survey estimates (i.e., $\hat{q}_t + \ln\left(\hat{I}_t / I_t\right)$ where $\hat{I}_t$ and I_t represent the predicted and observed survey indices respectively and $\hat{q}_t$ is the expected catchability given the surface area anomaly in year *t*. Dashed lines represent $\pm$ two standard deviations of the prediction given surface area anomaly. The largest positive outlier is from the 2003 survey year when the BTS estimate was over 8 million t.



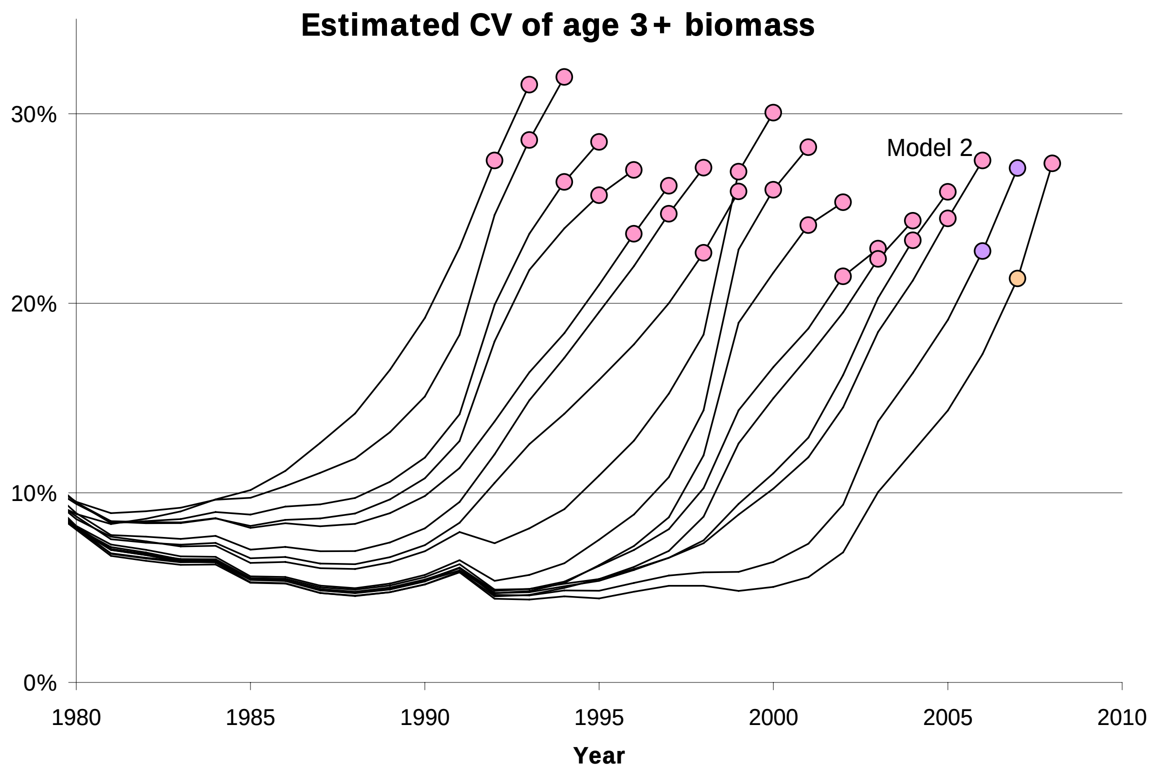


Figure 1.24. Results from retrospective analyses for **Model 2** showing the 16 individual time trajectories of age 3+ biomass (top panel) and the uncertainty as estimated in those "assessment" years. Note that the terminal two points are projected values, e.g., in the 2000 "assessment" projected age 3+ biomass values are presented for 2001 and 2002.

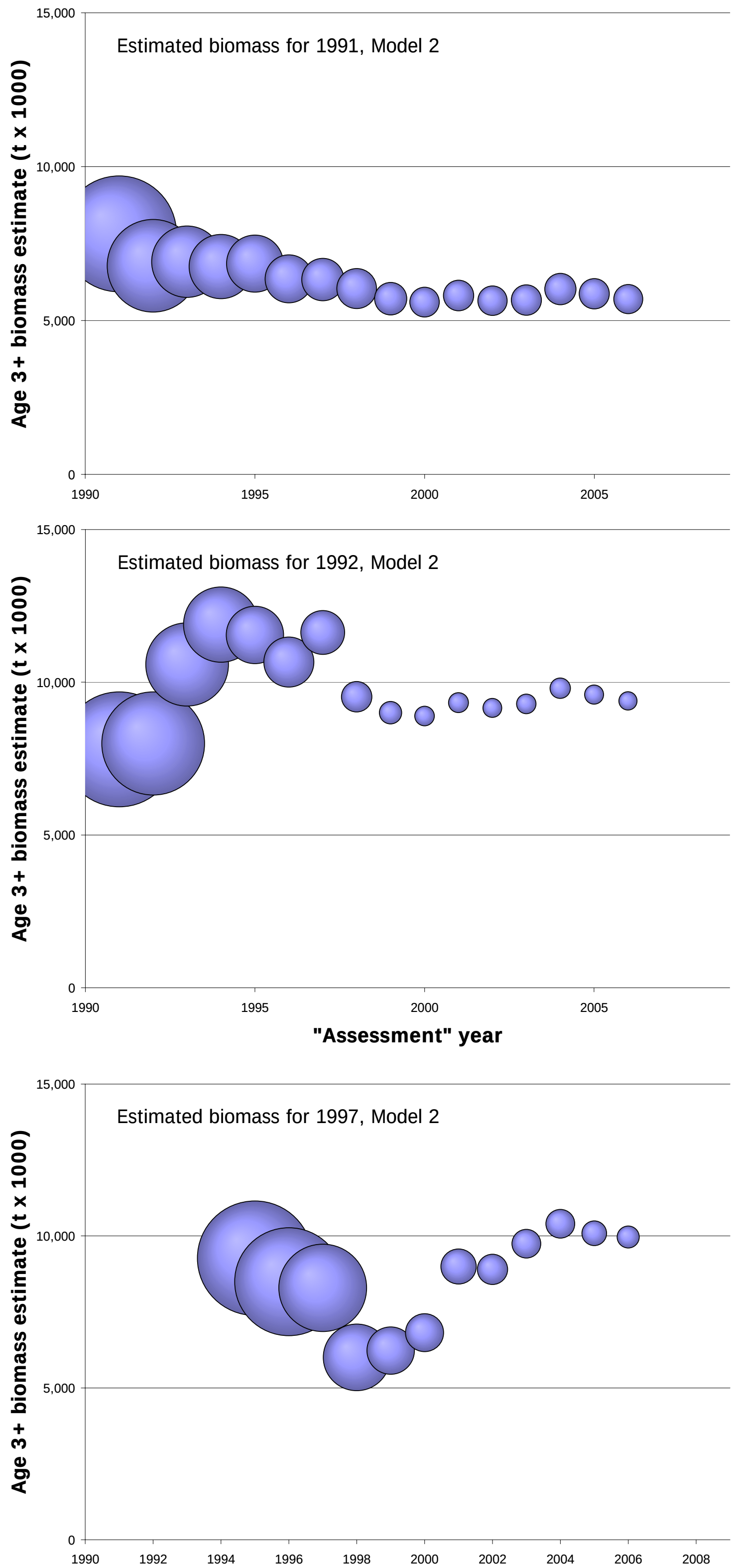


Figure 1.25. Selected results from the retrospective analyses showing how the age 3+ biomass estimates for 1991 (top), 1992 (middle) and 1997 (bottom) have evolved over time. The width of the circles is proportional to the estimated coefficient of variation.

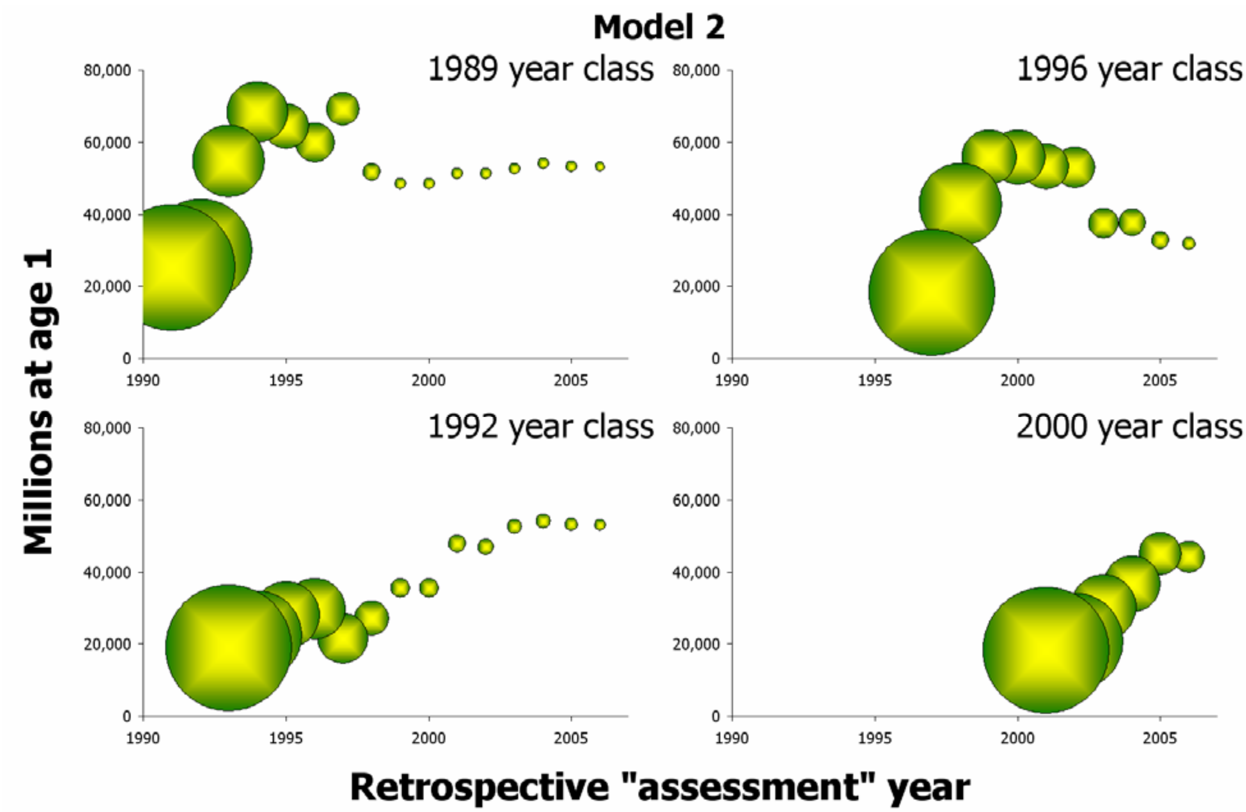


Figure 1.26. Results from the retrospective analyses (e.g., the left-most bubble in the upper left panel represents the estimate of the 1989 year class as if the assessment year was 1991—all data after 1991 were ignored) for **Model 2**) showing how estimates of strong year-classes have evolved over time. The width of the circles is proportional to the estimated coefficient of variation in each “assessment” year.

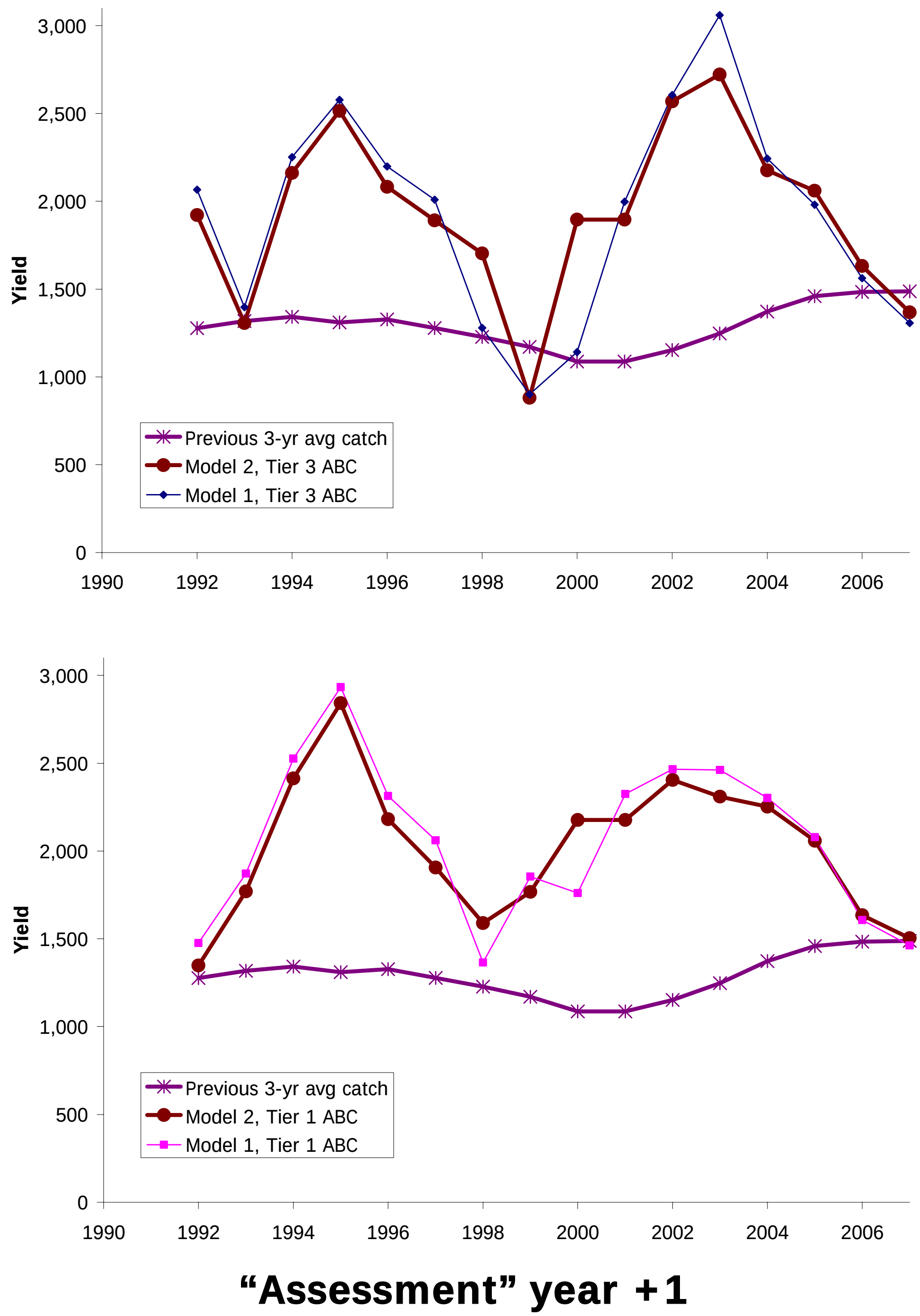


Figure 1.27. Retrospective analyses showing 1-yr ahead maximum permissible ABC values for Tier 3 (top panel) and Tier 1 (bottom) for **Models 1 and 2.** Also shown are the average catches in the three-years prior to the projected ABCs. Note that in "real" assessments, historical data are revised and updated. In these analyses, the historical data used in all years were the same as that used for the current assessment.

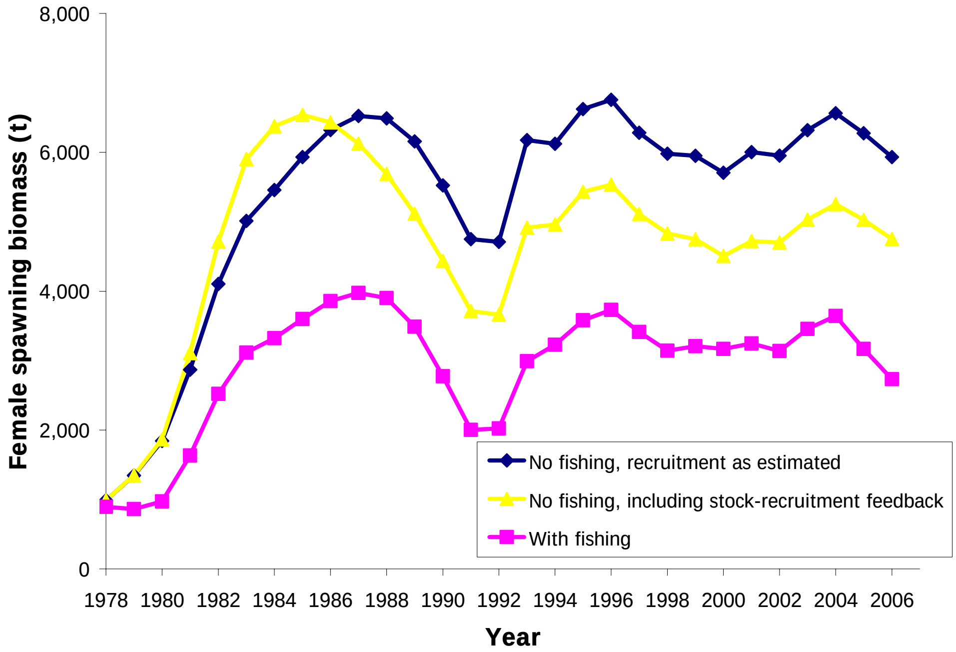


Figure 1.28. EBS pollock female spawning biomass estimates as estimated under Model 1 (lower line) compared to values based on "replaying" the estimates had fishing not occurred (with and without stock-recruitment feedback).

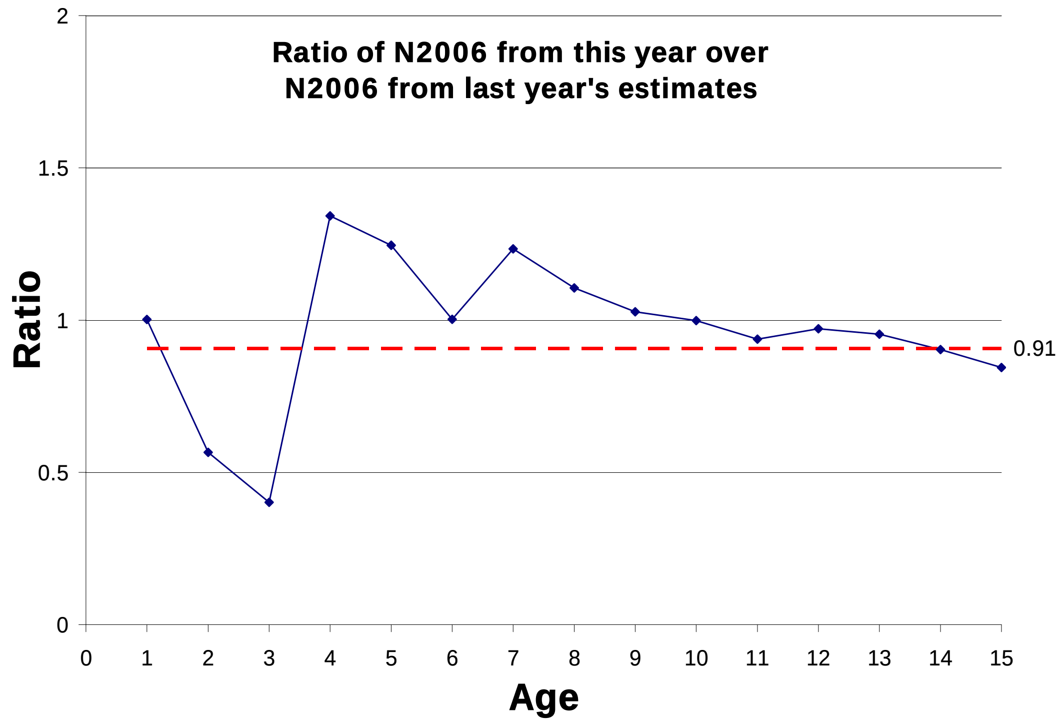


Figure 1.29. Estimates of 2006 EBS pollock population abundance from the current assessment divided by the 2005 assessment estimates. This indicates that overall, the new information changed the point estimates of 2006 population levels on average to 91% of the previous levels.

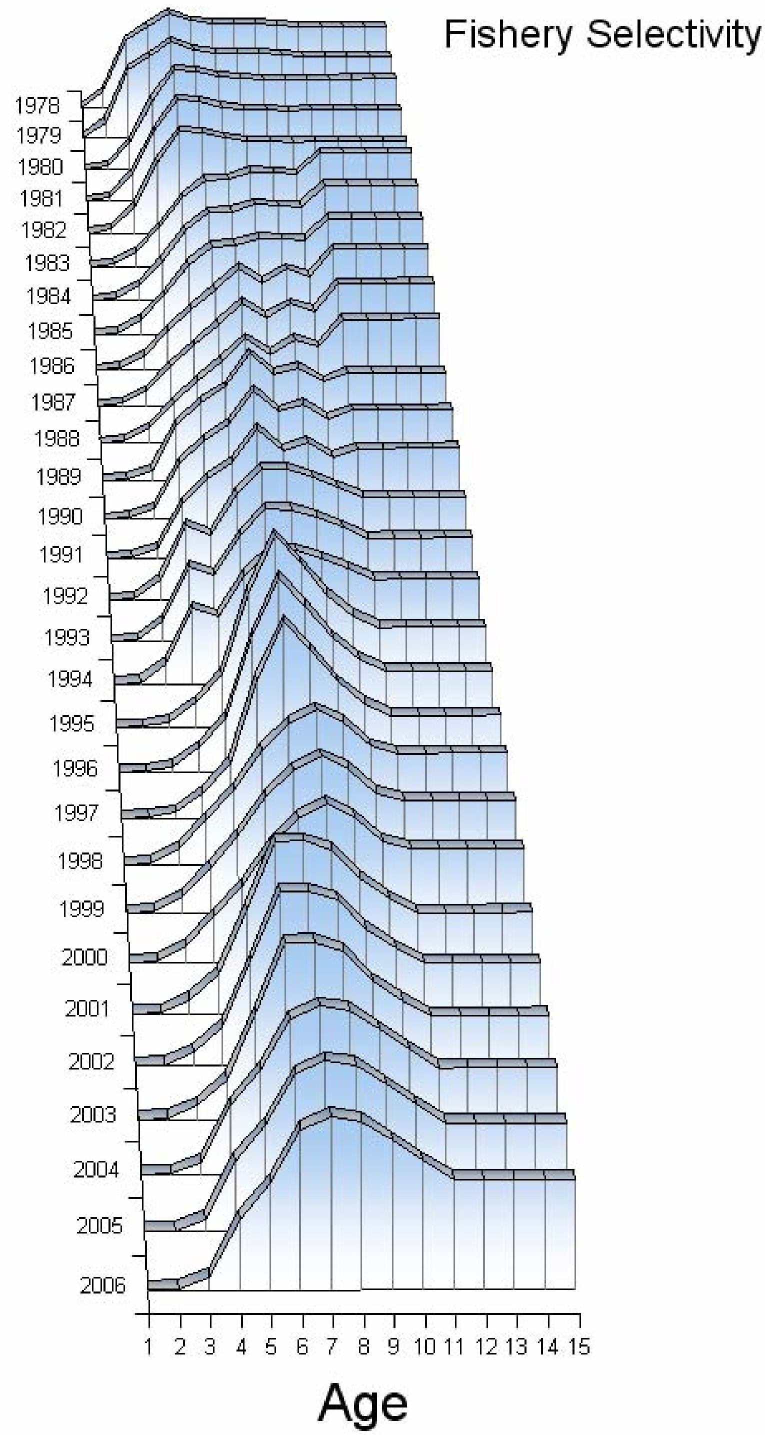


Figure 1.30. Selectivity at age estimates for the EBS walleye pollock fishery, 1978-2006 estimated for **Model 2**.

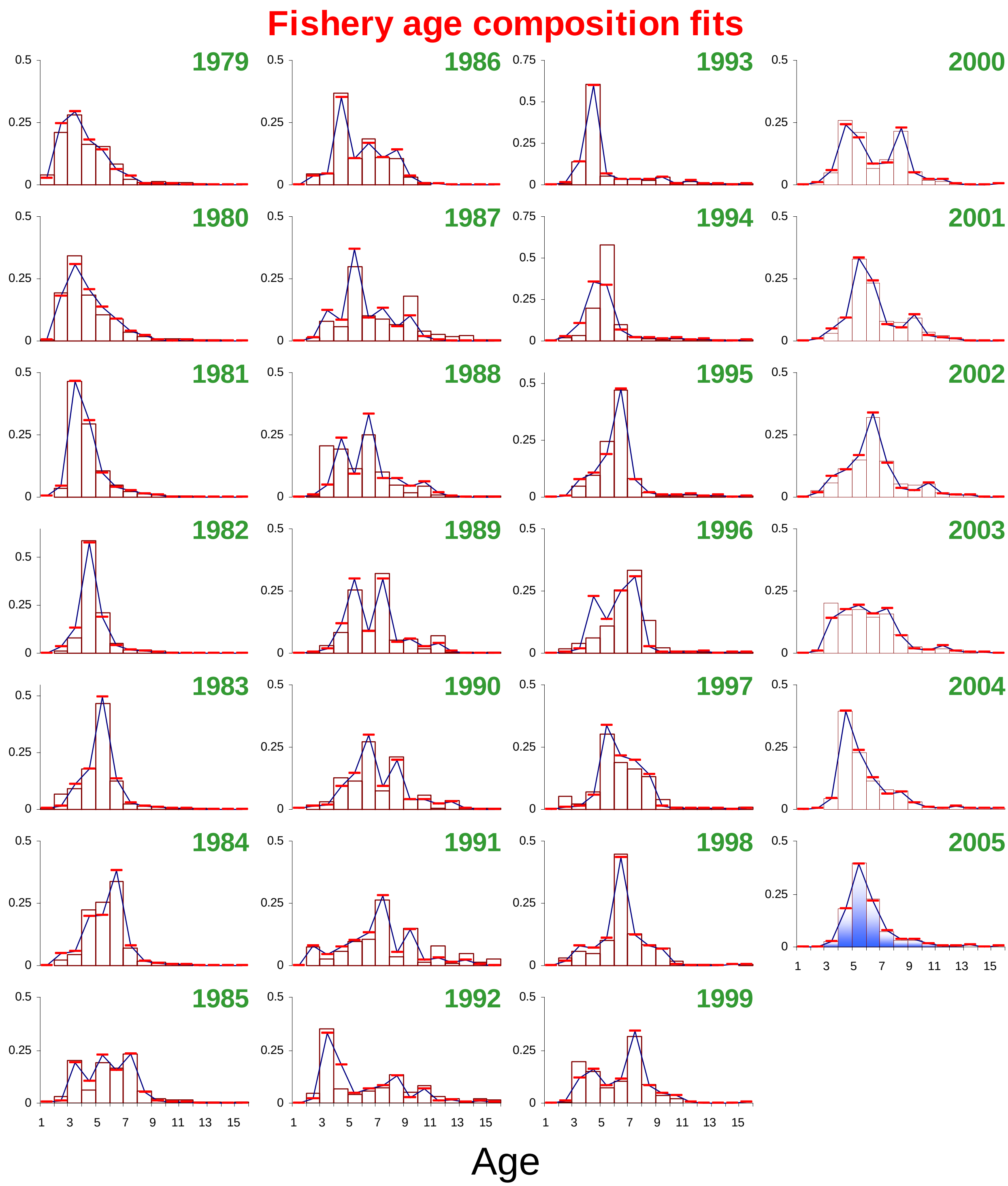


Figure 1.31. **Model 2** fit to the EBS walleye pollock fishery age composition estimates (1979-2005). Lines represent model predictions while the vertical columns represent the data. Data new to this year's assessment are shaded.

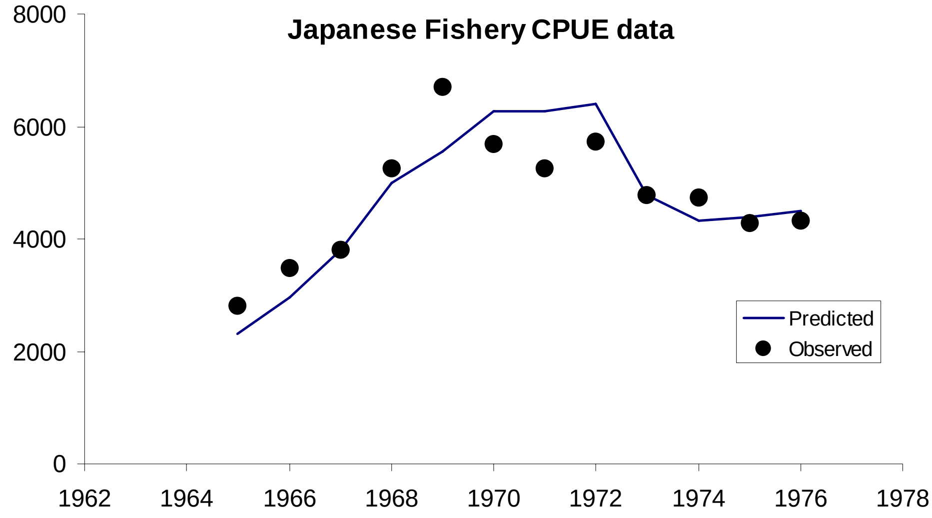


Figure 1.32. **Model 2** fit to the EBS walleye pollock fishery CPUE data from Low and Ikeda (1980).

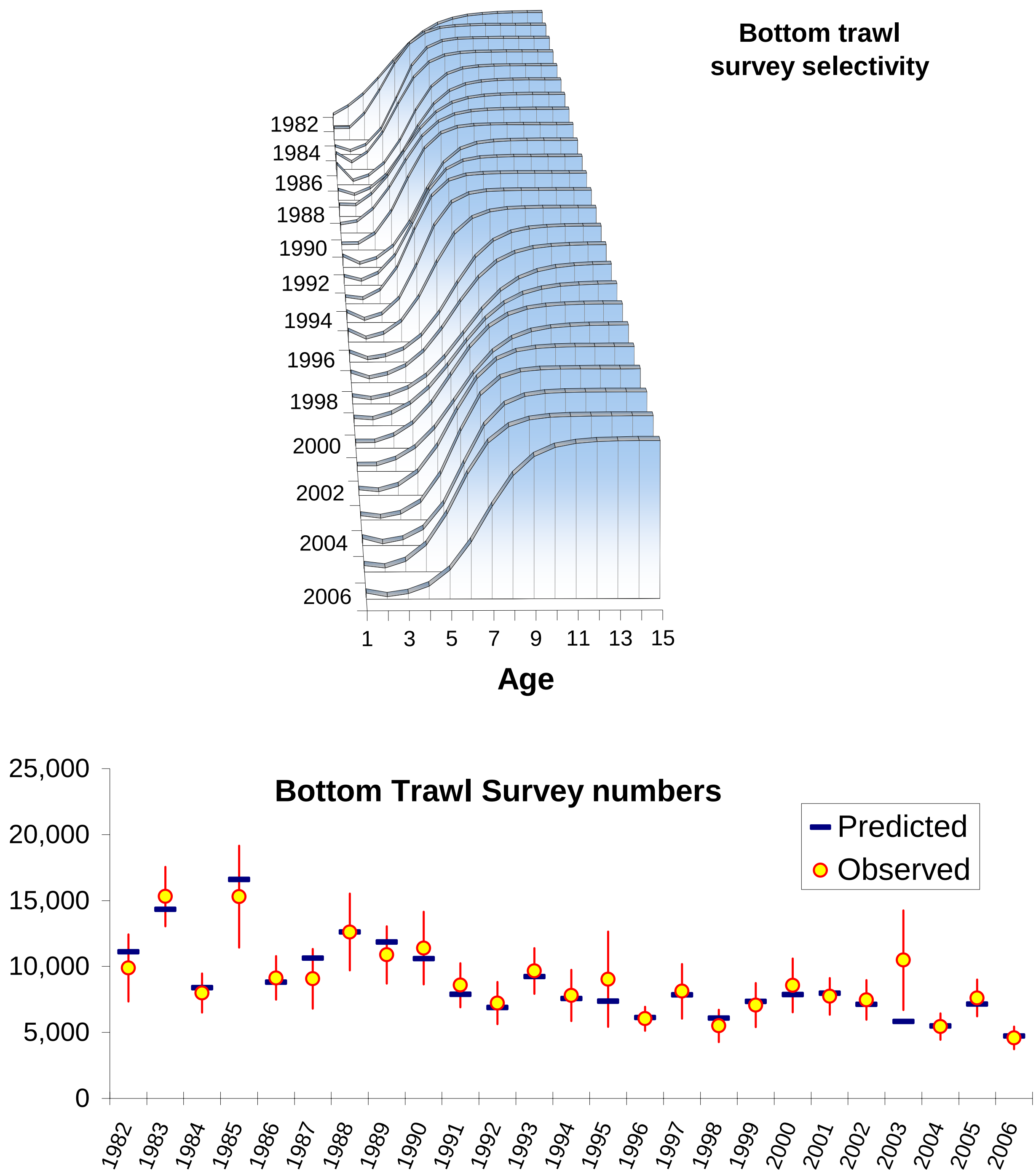


Figure 1.33. Estimates of bottom-trawl survey numbers (lower panel) and selectivity-at-age (with maximum value equal to 1.0) over time (upper panel) for EBS walleye pollock, 1982-2006, **Model 2**.

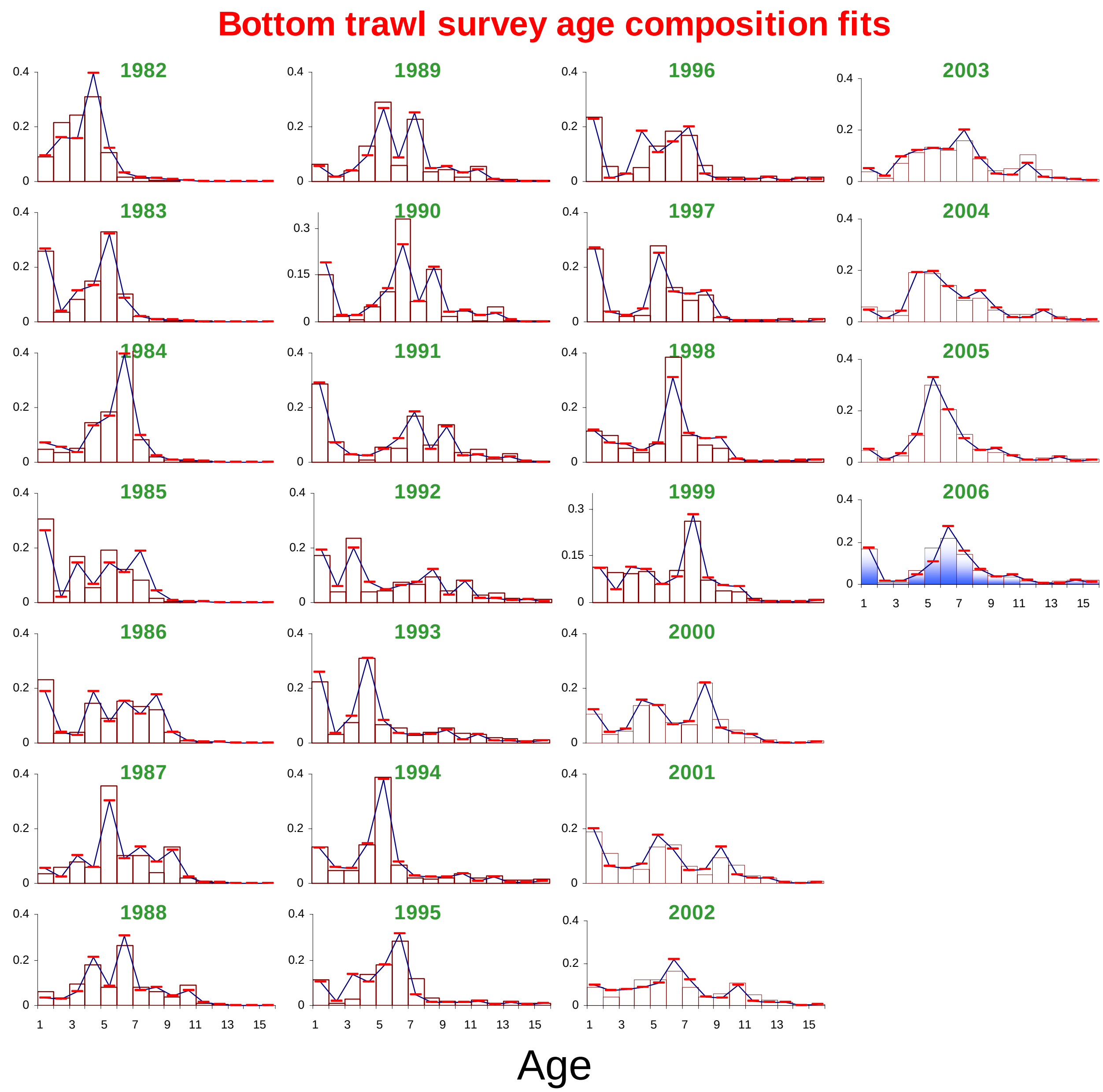
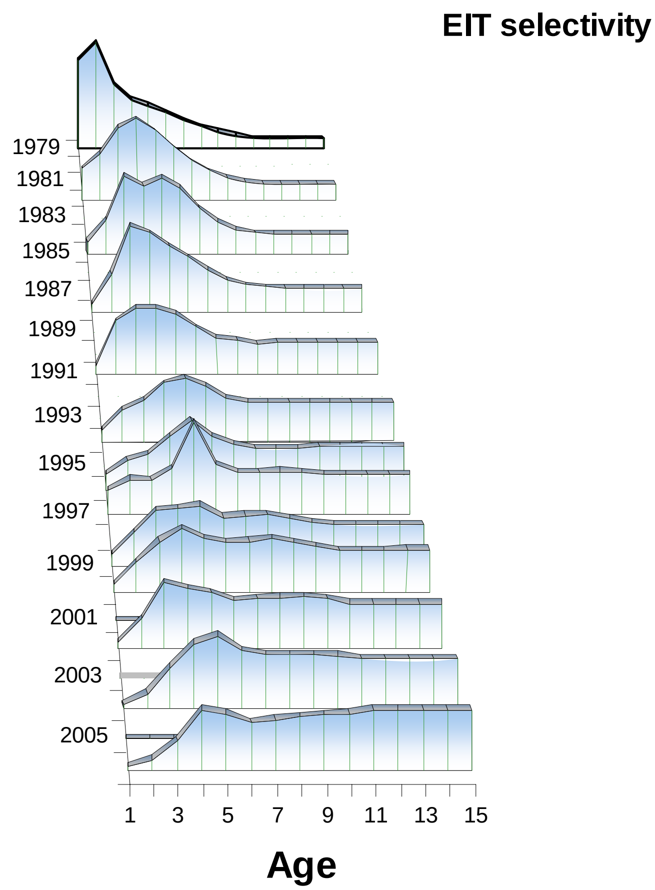


Figure 1.34. **Model 2** fit to the bottom trawl survey age composition data (proportions) for EBS walleye pollock. Lines represent model predictions while the vertical columns represent the data. Data new to this assessment are shaded (2006).



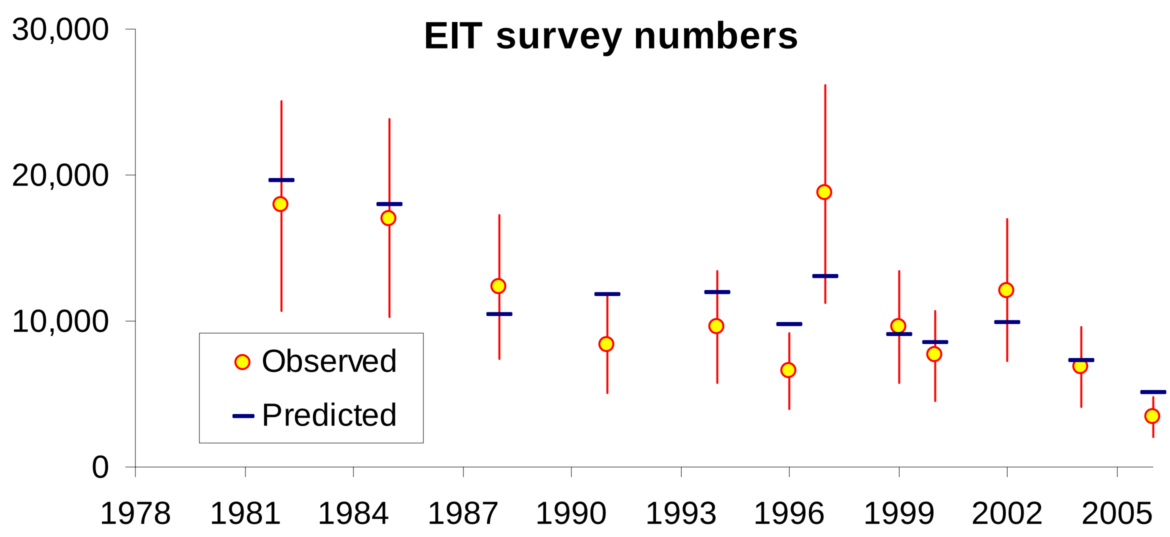


Figure 1.35. **Model 2** estimates of EIT survey numbers (lower panel) and selectivity-at-age (with mean value equal to 1.0) over time (upper panel) for EBS walleye pollock. Note that the 1979 value (observed=115,424; predicted=47,127) are not plotted.

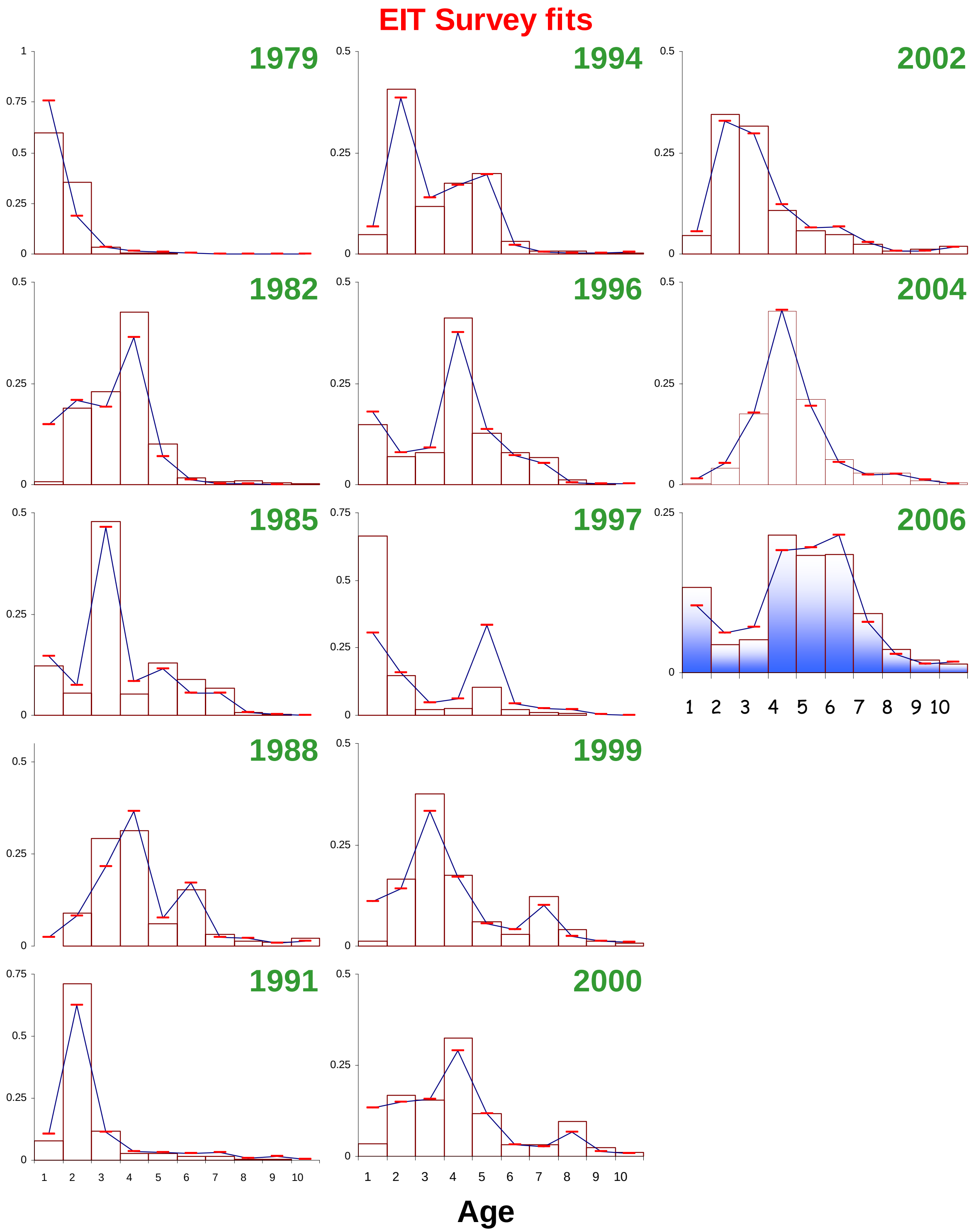


Figure 1.36. Model 2 fit to the EIT survey EBS walleye pollock age composition data (proportions). Lines represent model predictions while the vertical columns represent the data. Data new to the assessment are shaded.

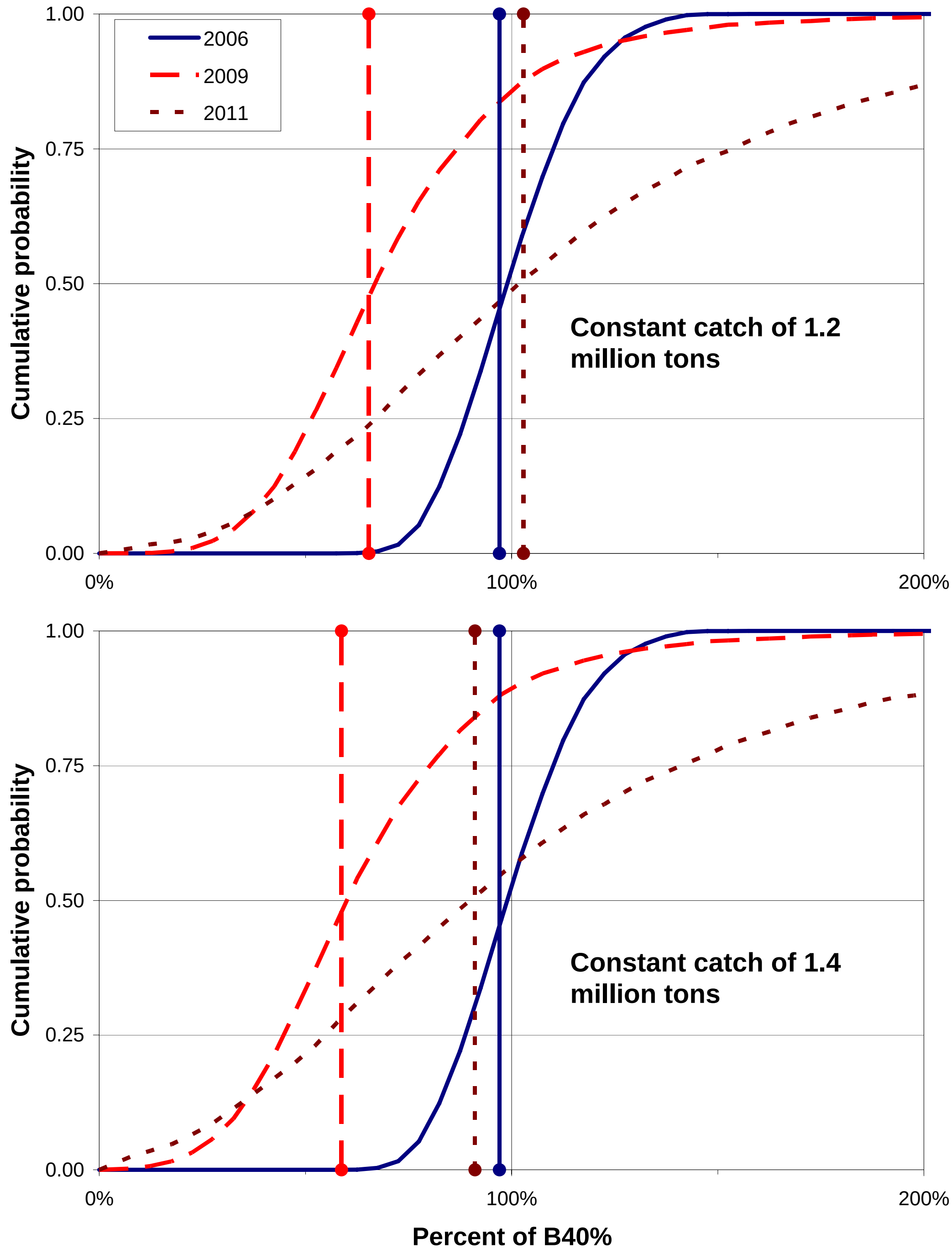


Figure 1.37. Cumulative probability that projected female spawning biomass levels will drop below $B_{40\%}$ based on fixed constant catch levels of 1.2 (top) and 1.4 (bottom) million tons. Marginal distributions of the full joint posterior distribution based on a thinned MCMC chain used for integration. Corresponding expected values (means) are shown by the vertical lines terminated with closed circles.

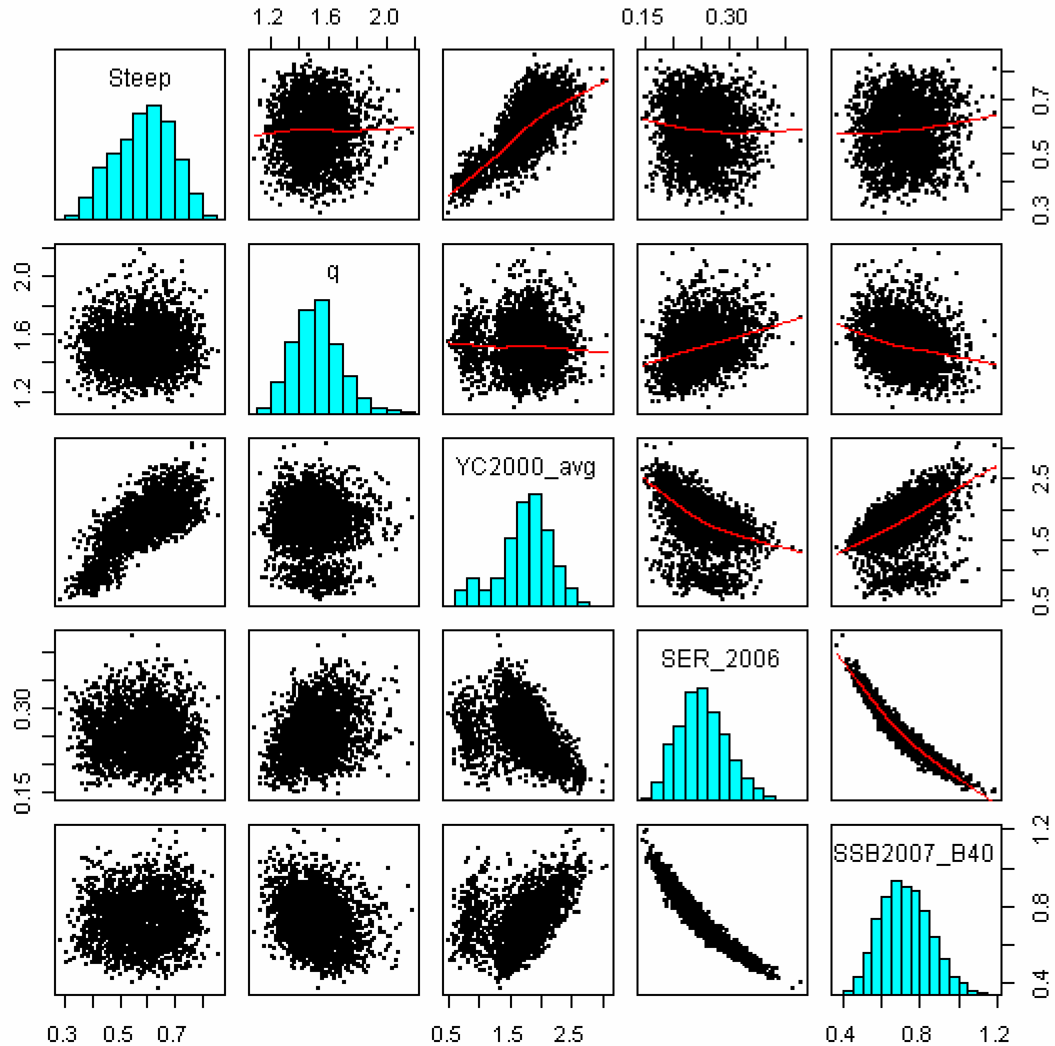


Figure 1.38. Bivariate and marginal distributions of key parameters integrated over an MCMC chain for Model 2 (length one million with every 200th sample selected and a burn-in of 4,000).

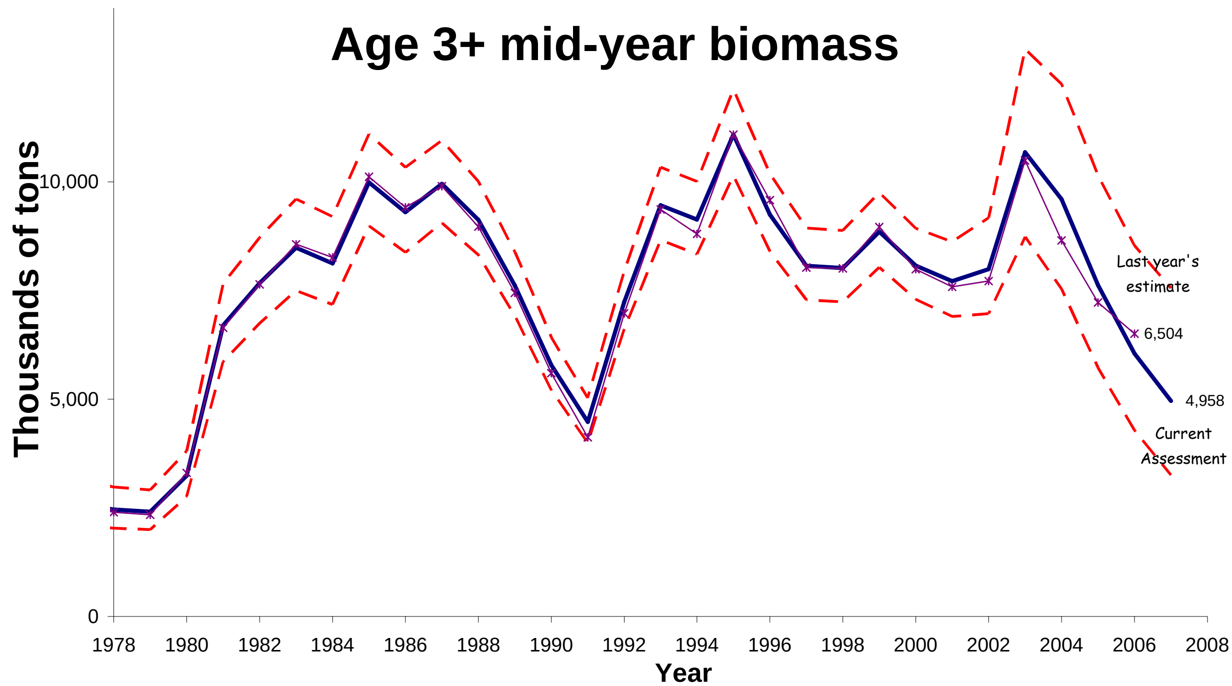


Figure 1.39. Estimated age 3+ EBS mid-year walleye pollock biomass under Model 2, 1978-2007. Approximate upper and lower 95% confidence limits are shown by dashed lines. Superimposed is the estimate of mid-year age 3+ biomass from last year's assessment

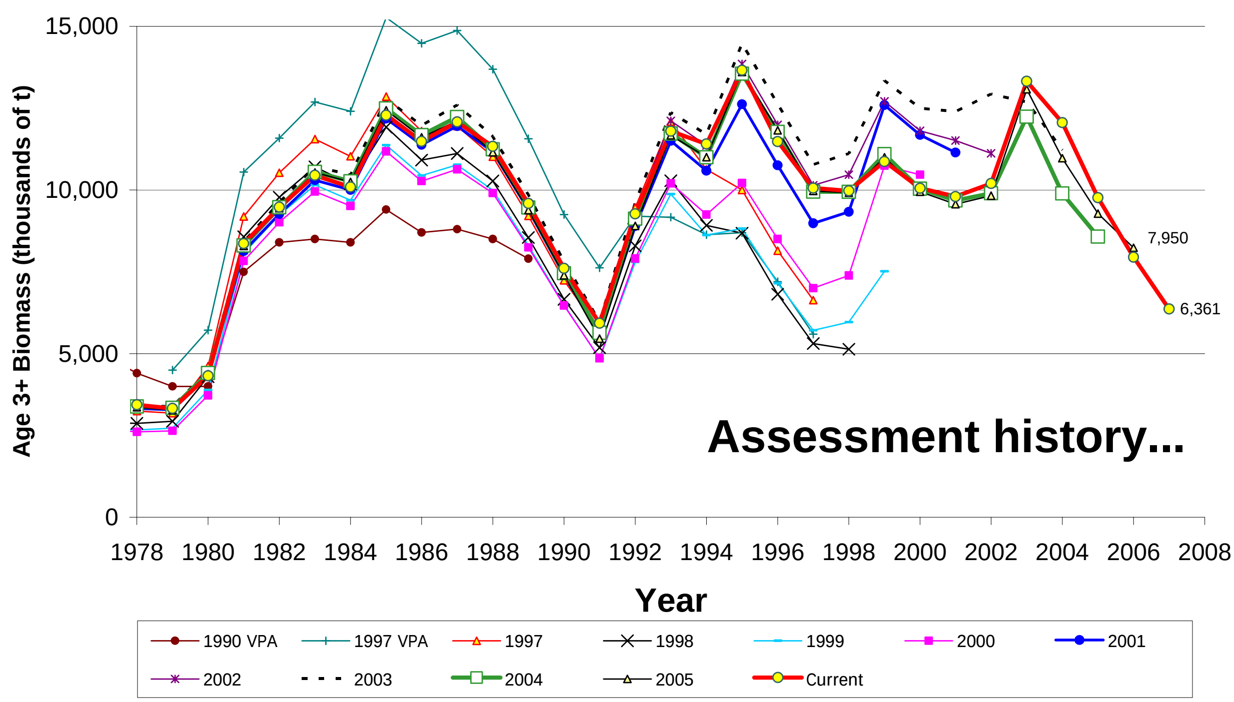


Figure 1.40. Comparison of the current assessment results with past assessments of **begin-year** EBS age-3+ pollock biomass, 1978-2006.

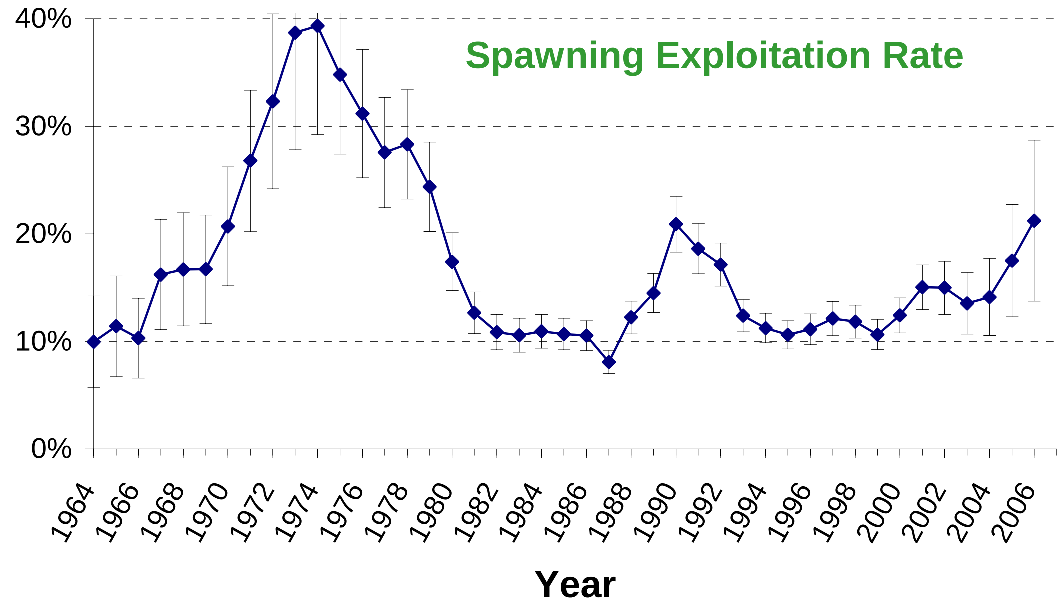


Figure 1.41. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) for EBS walleye pollock, Model 2. Error bars represent two standard deviations from the estimate.

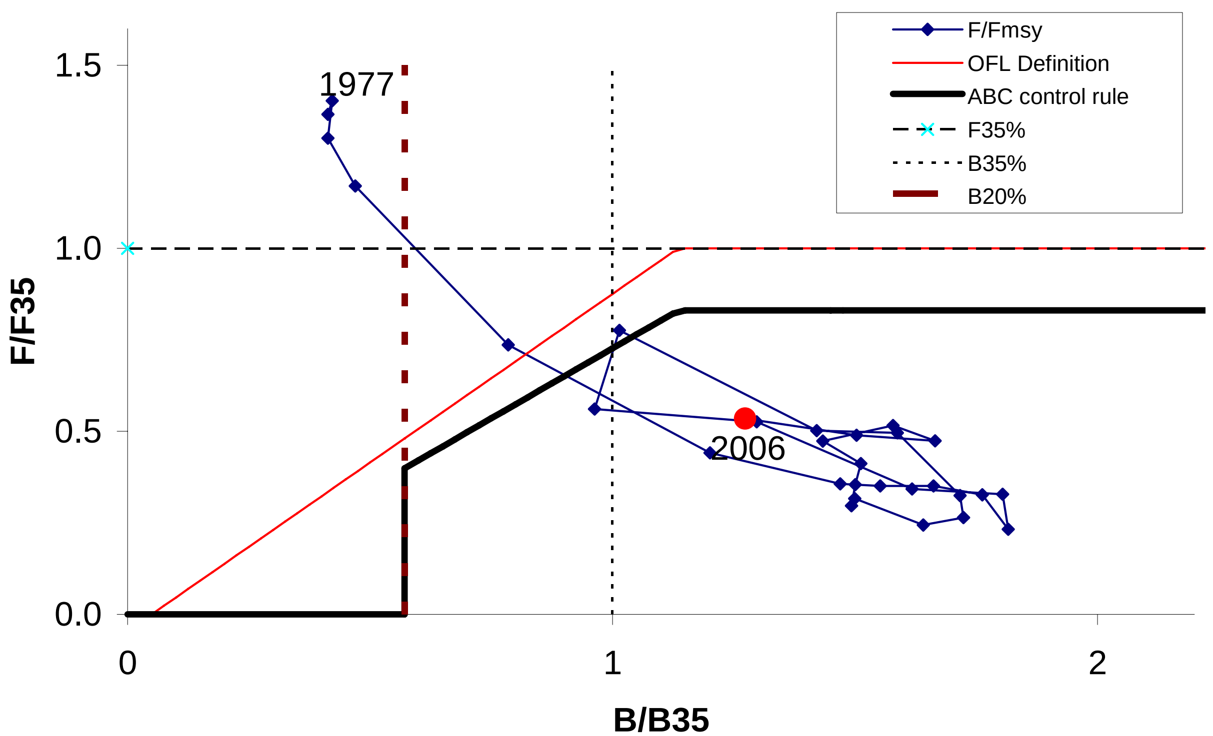


Figure 1.42. Spawning biomass relative to annually computed $F_{35\%}$ values and fishing mortality rates for Model 2, EBS pollock, 1977-2006.

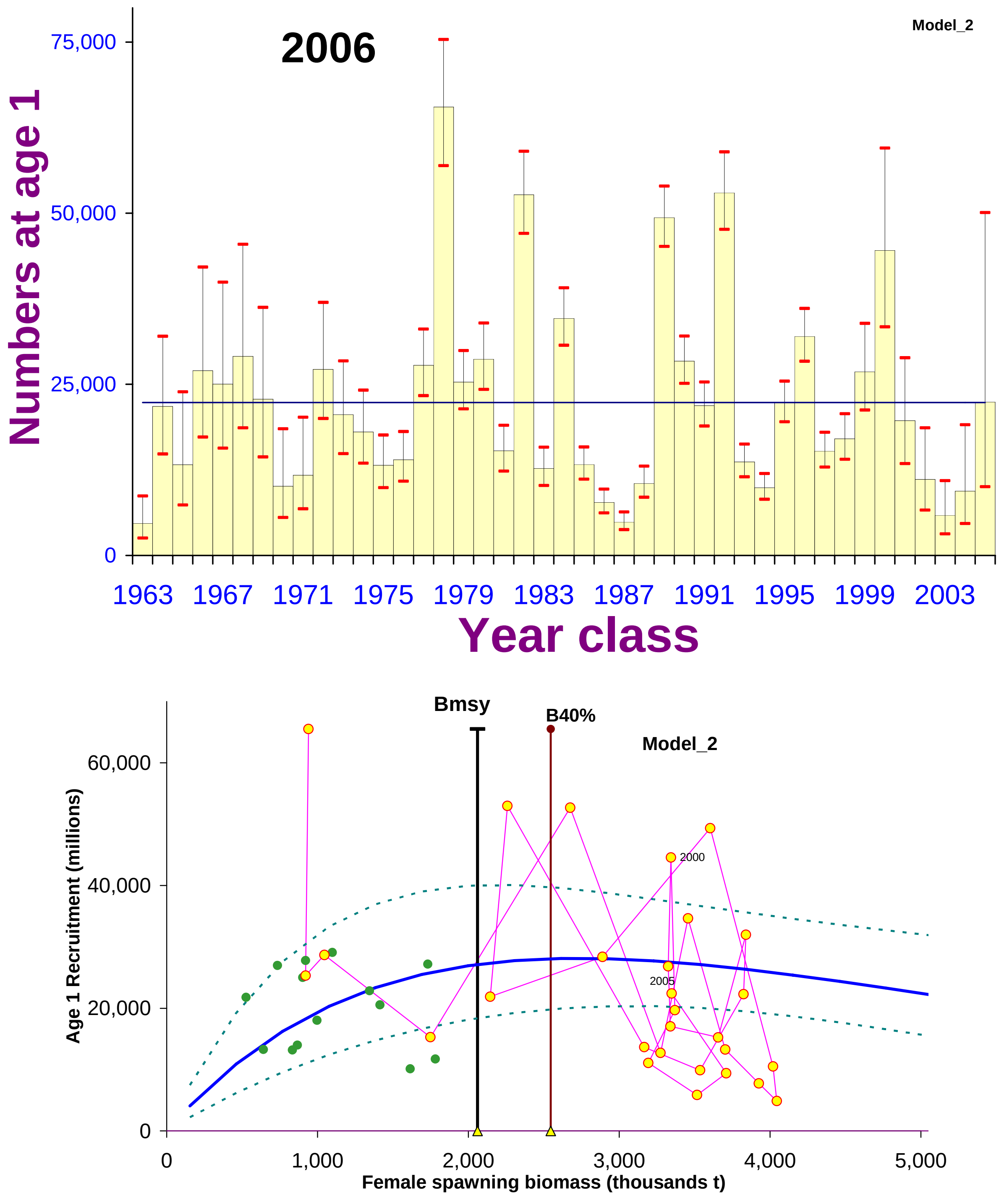


Figure 1.43. Year-class strengths by year (as age-1 recruits, upper panel) and relative to female spawning biomass (thousands of tons, lower panel) for EBS walleye pollock, **Model 2**. Solid line in upper panel represents the mean age-1 recruitment for all years since 1964 (1963-2005 year classes). Vertical lines in lower panel indicate B_{msy} and $B_{40\%}$ level, curve represents fitted stock-recruitment relationship with diagonal representing the replacement lines with no fishing. Dashed lines represent lower and upper 95% confidence limits about the curve.

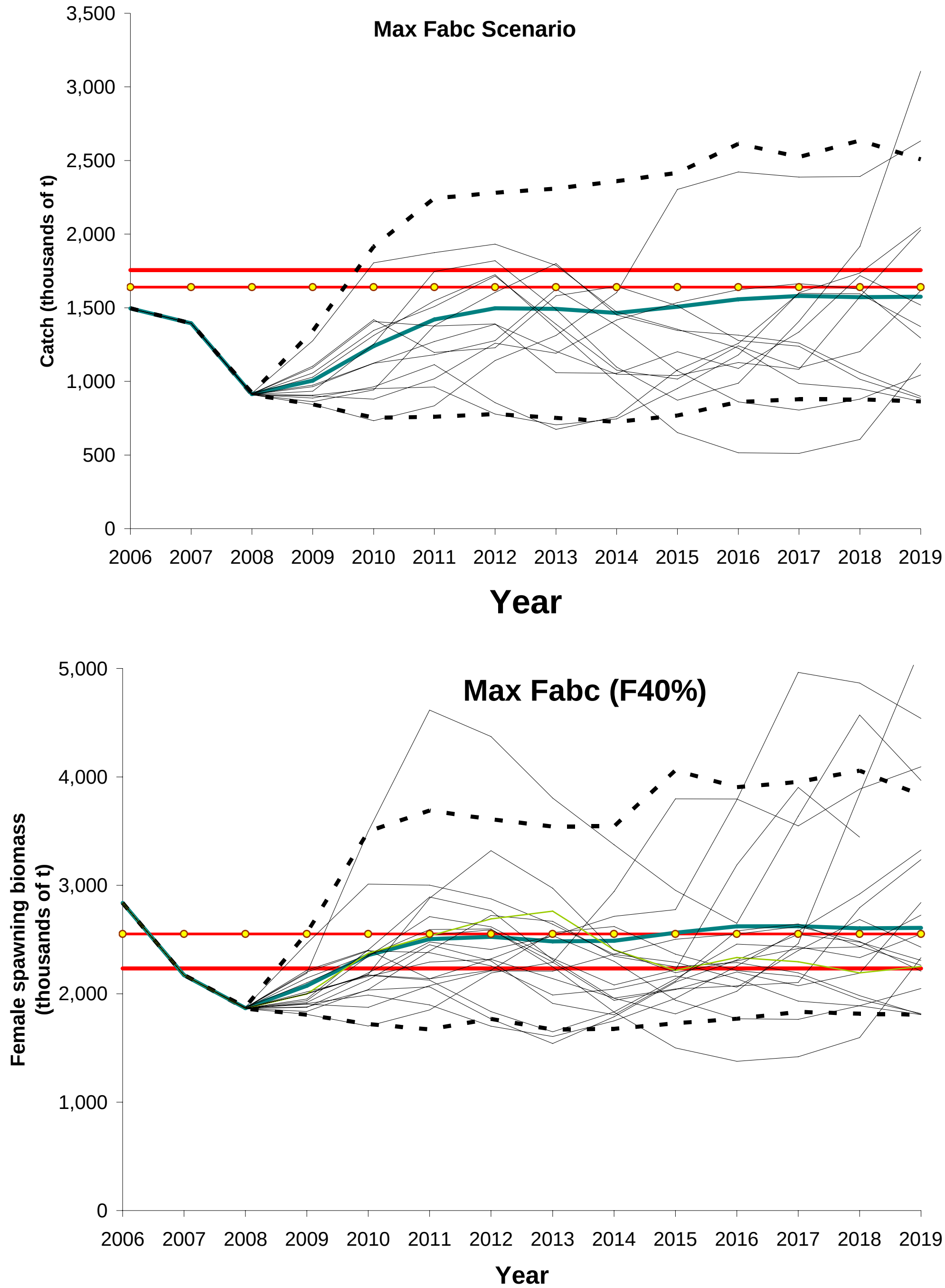


Figure 1.44. Projected EBS walleye pollock **yield** (top) and **Female spawning biomass** (bottom) relative to the long-term expected values under $F_{35\%}$ and $F_{40\%}$ (horizontal lines) for **Model 2**. $B_{40\%}$ is computed from average recruitment from 1978-2005. Future harvest rates follow the guidelines specified under Scenario 1, max F_{ABC} assuming $F_{ABC} = F_{40\%}$.

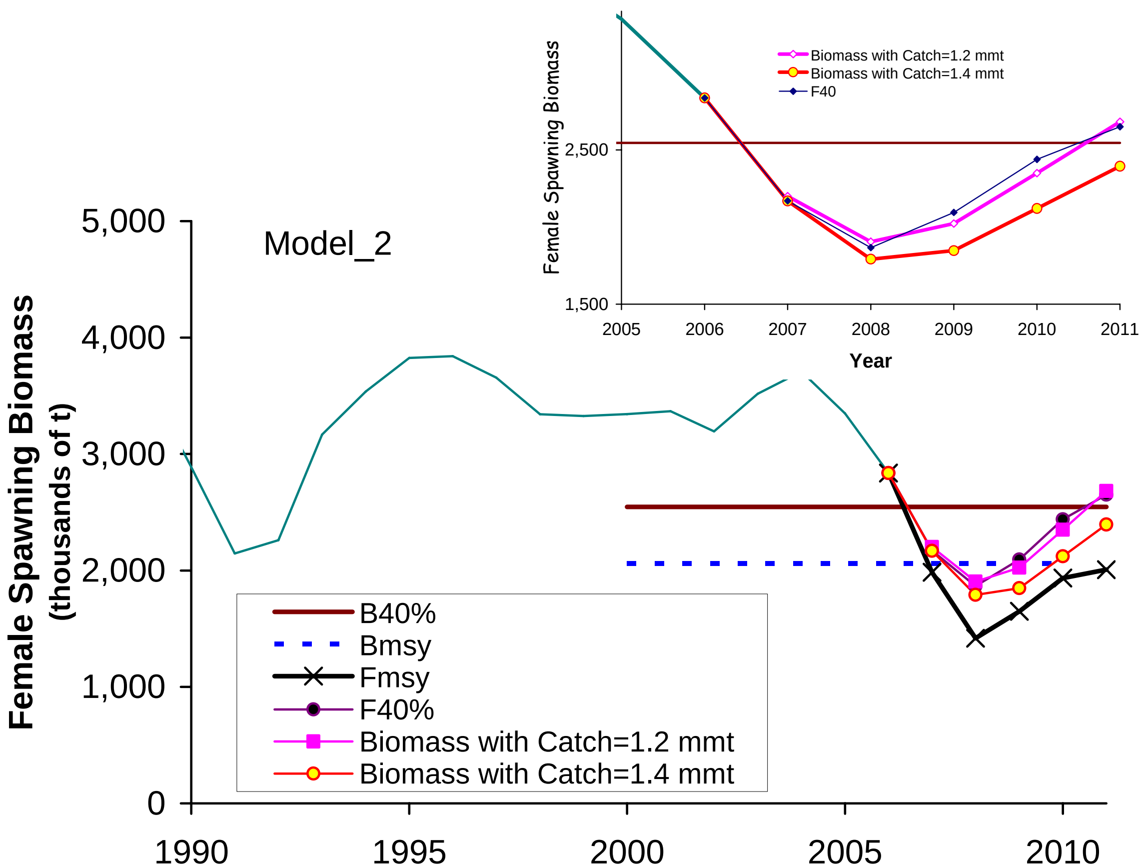


Figure 1.45. EBS walleye pollock female spawning biomass trends, 1990-2011 as estimated by Model 2 under different 2006-2010 harvest levels. Note that the F_{msy} catch levels represent unadjusted arithmetic mean fishing mortality rates. Horizontal solid and dashed lines represent the B_{msy}, and $B_{40\%}$ levels, respectively.

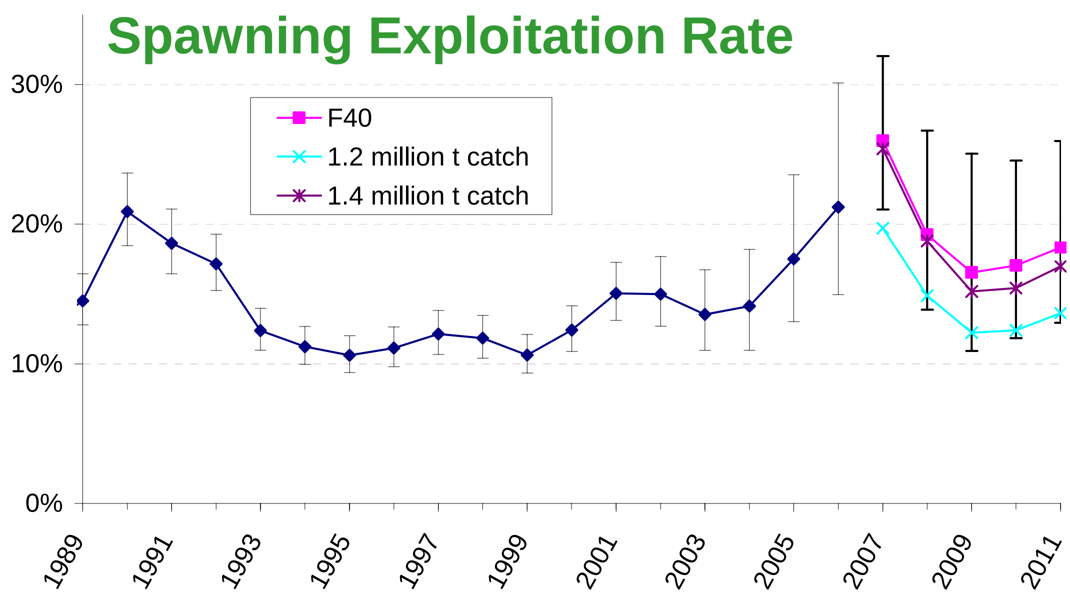


Figure 1.46. Estimated spawning exploitation rate (defined as the annual percent removals of spawning females due to the fishery) for EBS pollock, Model 2. Error bars represent two standard deviations from the estimate and projections for 2007 show the implications of different harvest levels.

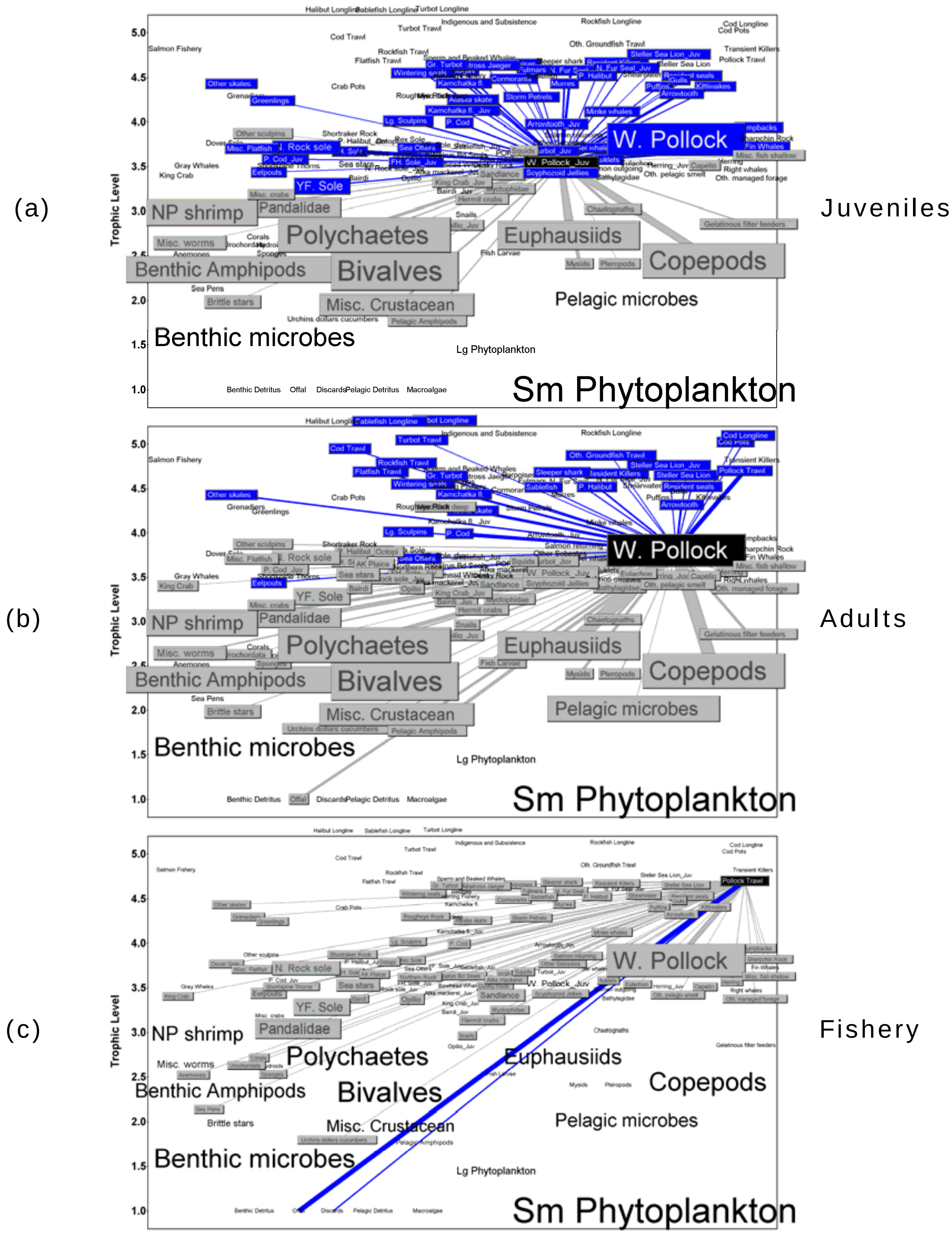


Figure 1.47. Food web pathways for the EBS region based on data from 1990-1994 emphasizing the position of EBS pollock juveniles (a), adults (b) and the pollock fishery (c). Outlined species and fisheries represent predators of pollock (dark box with light text) and prey of pollock (light boxes with 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).

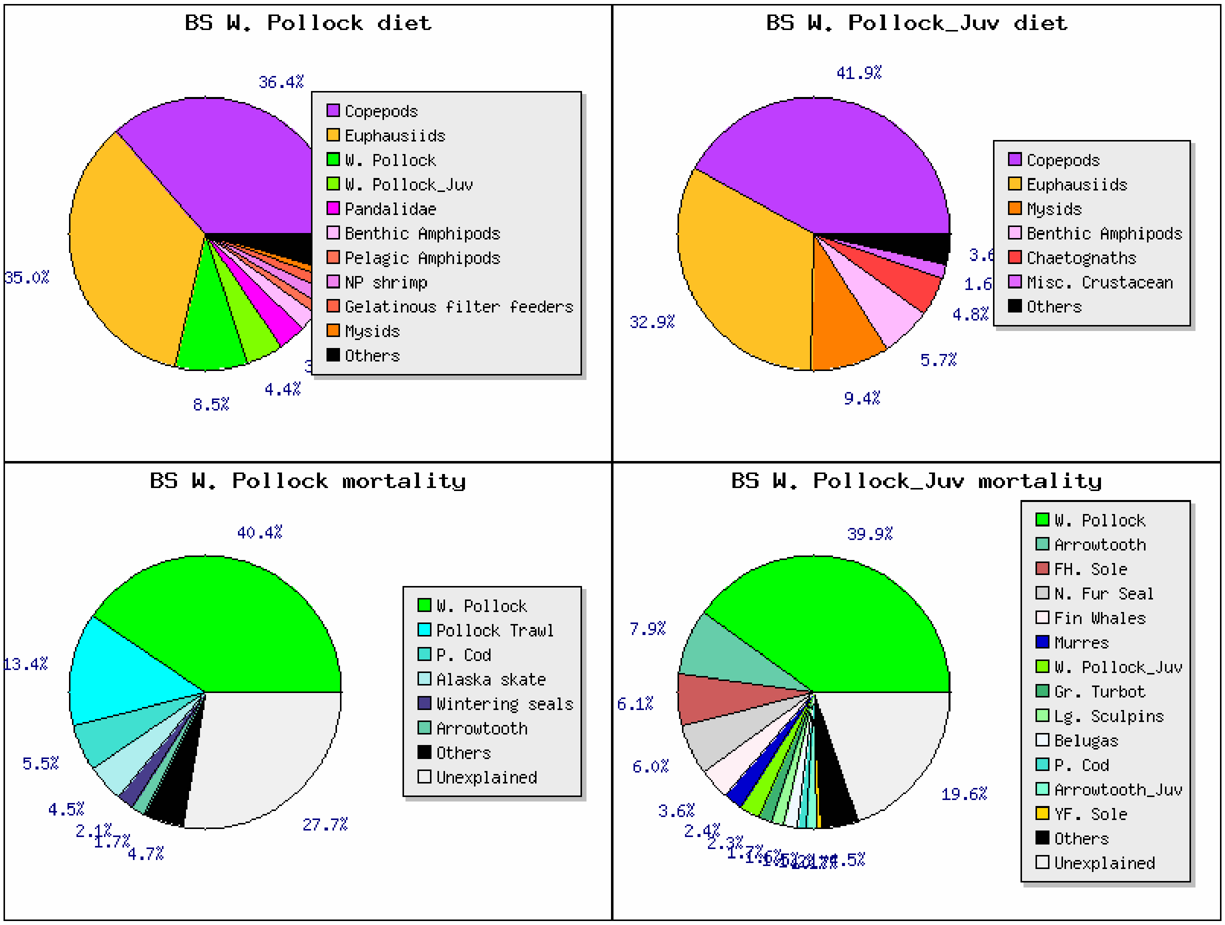


Figure 1.48. Diet (top) and mortality sources (bottom) for EBS pollock adults (left) and juveniles (right) based on data from 1990-1994. “Unexplained” mortality is the difference between the stock assessment total exploitation rate averaged for 1990-1994, and the predation and fishing mortality, which are calculated independently of the assessment, using predator diets, consumption rates, and fisheries catch.

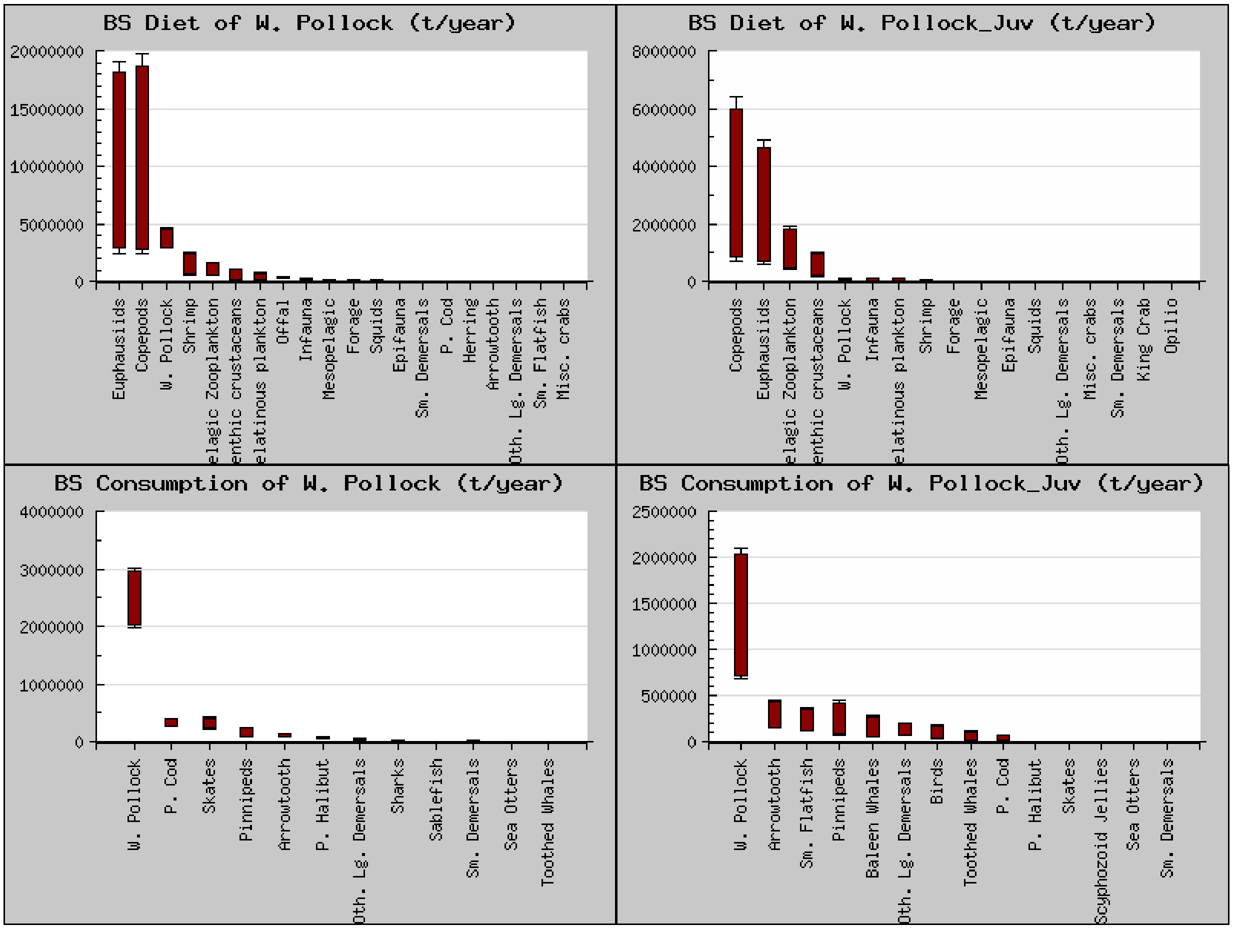


Figure 1.49. Diet (top) and mortality sources (bottom) for EBS pollock adults (left) and juveniles (right) based on data from 1990-1994. Error bars represent uncertainty of propagated consumption rates and population variance.

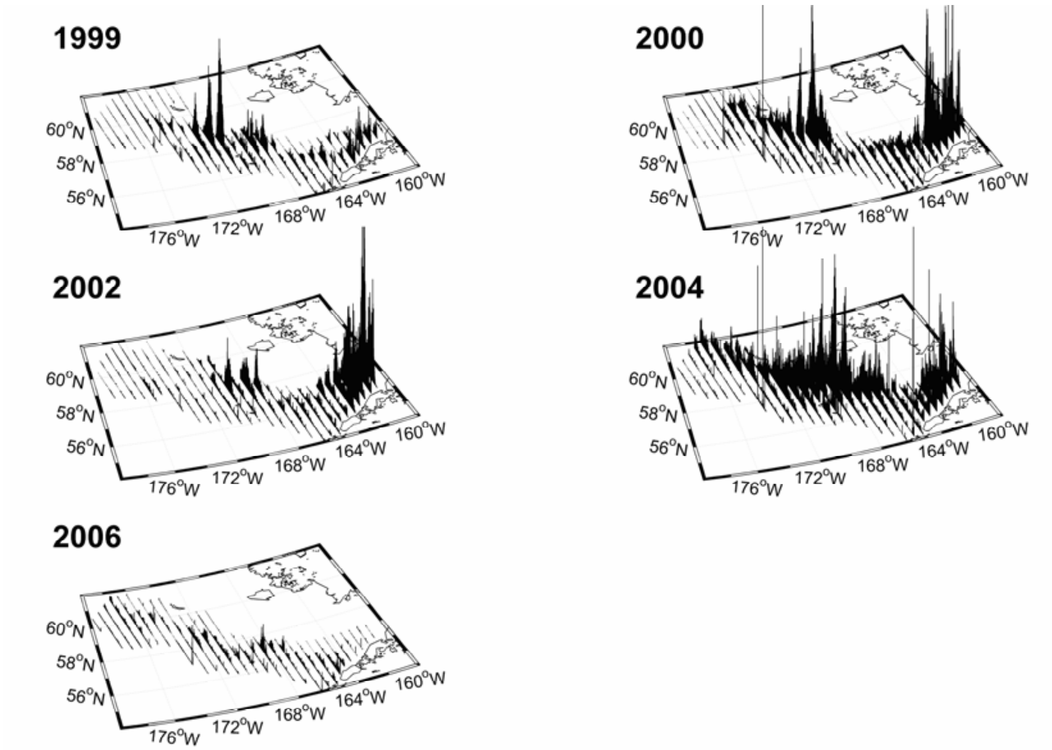


Figure 1.50. Geographic distribution of acoustic 38 kHz acoustic backscatter (s_A (m^2/nmi^2)) from species other than pollock (non-pollock, "other" backscatter) observed along tracklines during June-July eastern Bering Sea shelf acoustic-trawl surveys between 1999 and 2006.

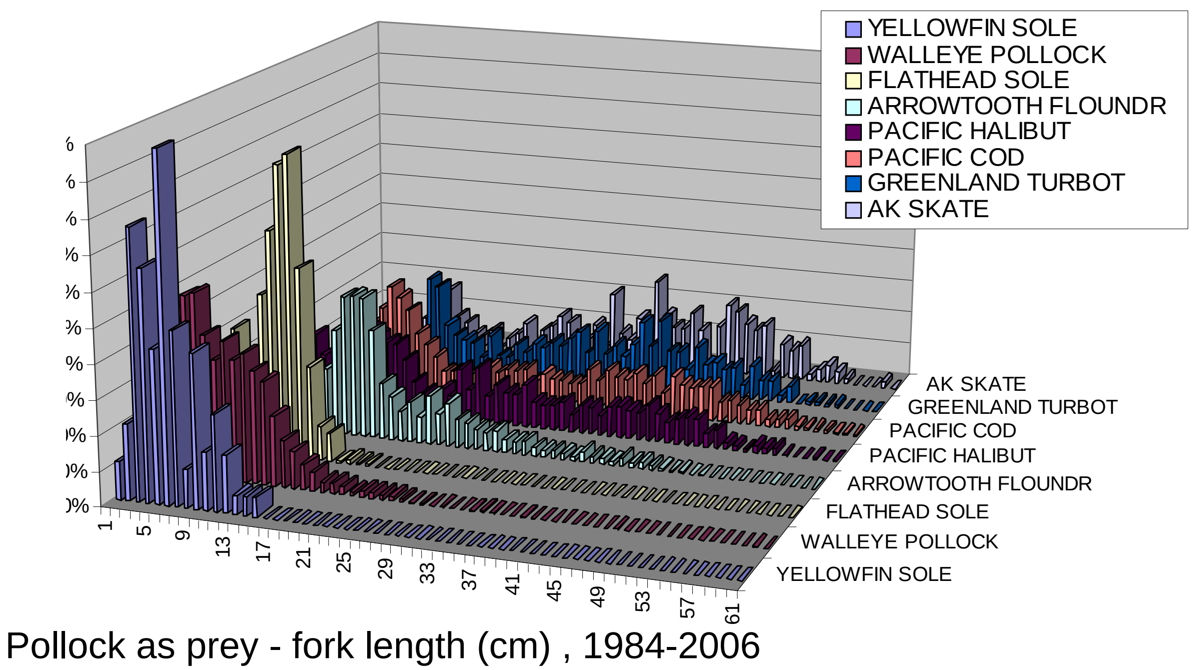


Figure 1.51. Length frequency of pollock found in stomachs, from groundfish food habits collected from 1984-2006 on AFSC summer trawl surveys in the eastern Bering Sea. Predators are sorted by median prey length of pollock in their stomachs. All lengths of predators are combined.

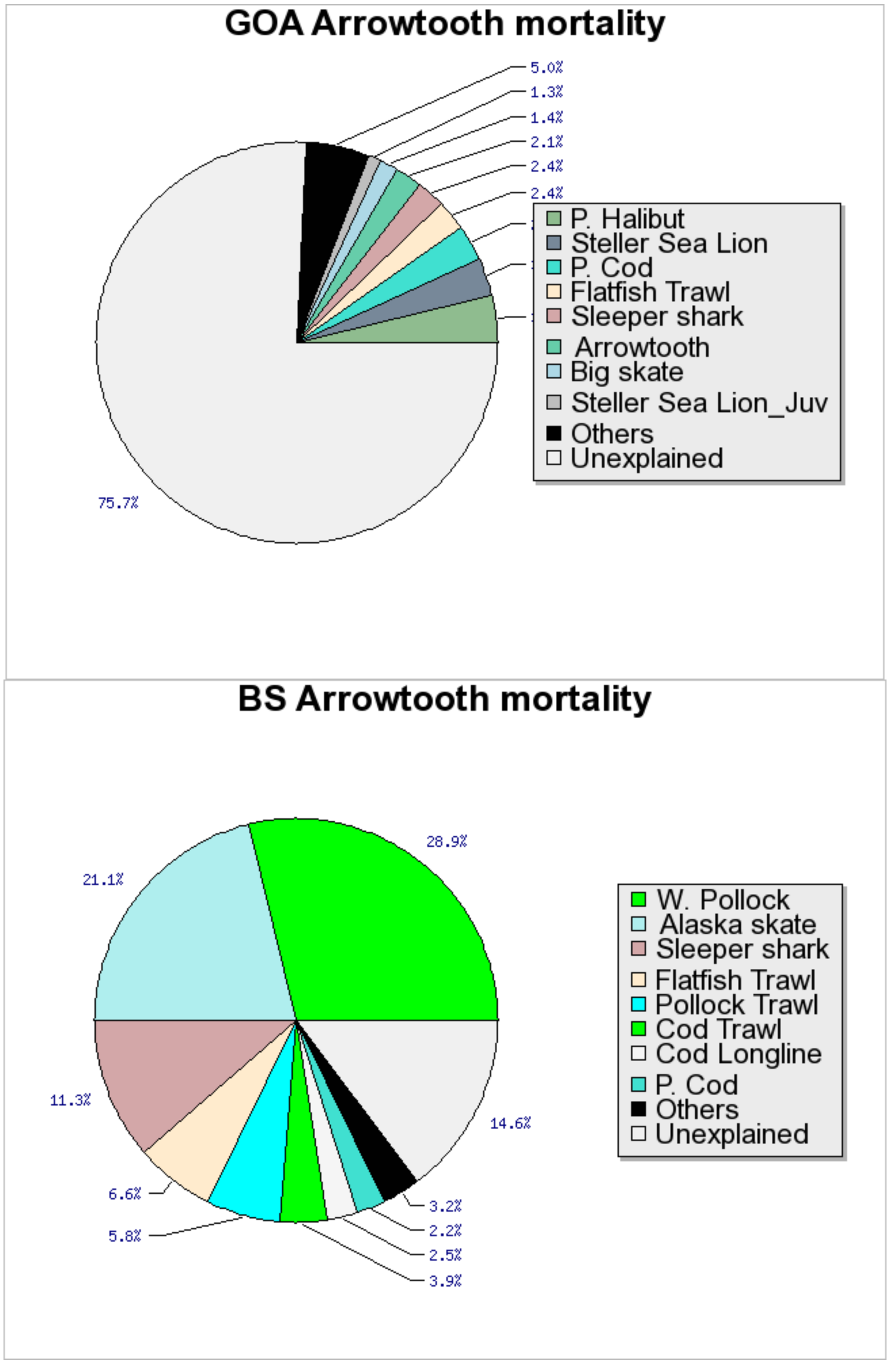


Figure 1.52. Mortality of arrowtooth flounder by predator or fishery as from predator ration and diet estimates, and fisheries catch data, 1990-94, as described in Appendix 1 of the Ecosystem Considerations chapter. “Unexplained” mortality is the difference between the stock assessment mortality and total predation; high unexplained mortality may indicate a top predator in an ecosystem. Top figure: eastern Bering Sea; Bottom figure, Gulf of Alaska.

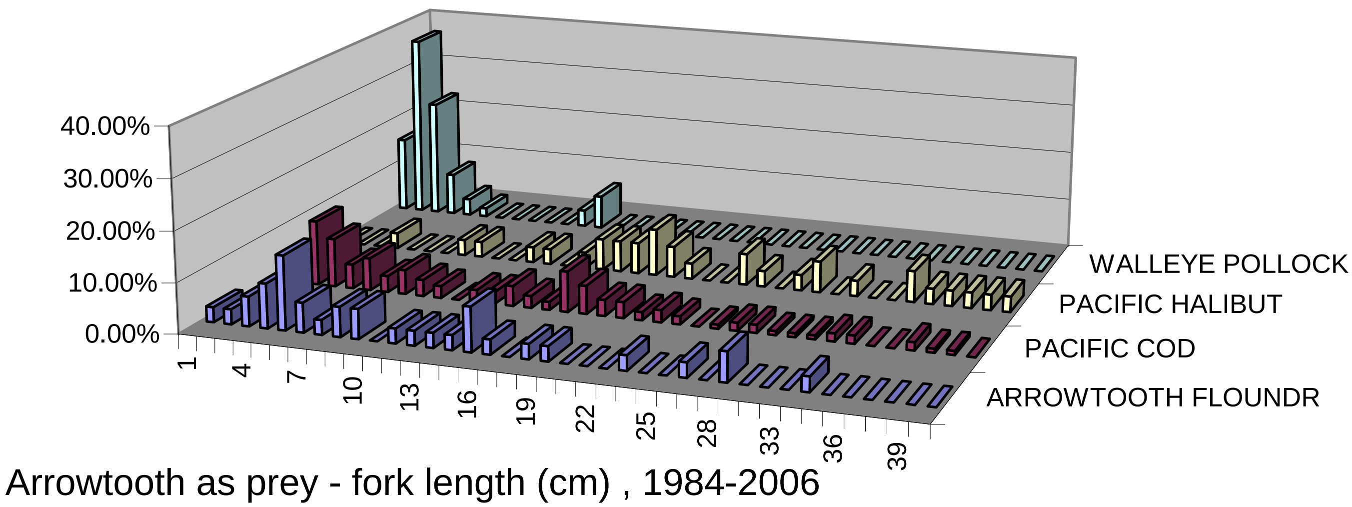


Figure 1.53. Length frequency of arrowtooth flounder found in stomachs, from groundfish food habits collected from 1984-2006 on AFSC summer trawl surveys in the eastern Bering Sea. Predators are sorted by median prey length of pollock in their stomachs. All lengths of predators are combined.

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

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

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

$$
\begin{aligned}
F_{t,a} &= s_{t,a}\mu^f \exp\left(\varepsilon_t\right) && \varepsilon_t \sim N\left(0,\sigma_E^2\right) \\
s_{t+1,a} &= s_{t,a}\exp\left(\gamma_{t,a}\right), && \gamma_{t,a} \sim N\left(0,\sigma_s^2\right)
\end{aligned}
$$

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 three years to reduce the number of parameters but retain some variability attributed to the process of selectivity variability. Specifically, the last three years of the model (in this case 2004-2006) is configured to have the same selectivity and changes are allowed in each 3-year period prior (e.g., the next most recent selectivity change would occur between the years 1999 and 2000.

One form used to model bottom-trawl survey selectivity (used in Models 1, 3-7) is to have an asymptotic yet retain the properties desired for the characteristics of this gear. Namely, that the function should allow flexibility in selecting age 1 pollock over time. The functional form of this selectivity is:

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

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 $\bar{\alpha}, \bar{\beta}, \delta_t^{\mu}, \delta_t^{\alpha}, \text{and } \delta_t^{\beta}$ for *t*=1982, 1983,…2006. The variance terms for these parameters were specified to be 0.04.

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):

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

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).

Reparameterization of the stock-recruitment function
This year we implemented a reparameterized form for the stock-recruitment relationship as by Francis (1992). 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. 1.54.

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.

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.

Sample size values were fixed at values shown in Table 1.14. Strictly speaking, the amount of data collected for this fishery indicates higher values might be warranted. However, the standard multinomial sampling process is not robust to violations of assumptions (Fournier et al. 1990). Consequently, as the model fit approached a solution, we invoke a robust likelihood function which fit proportions at age as:

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

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).

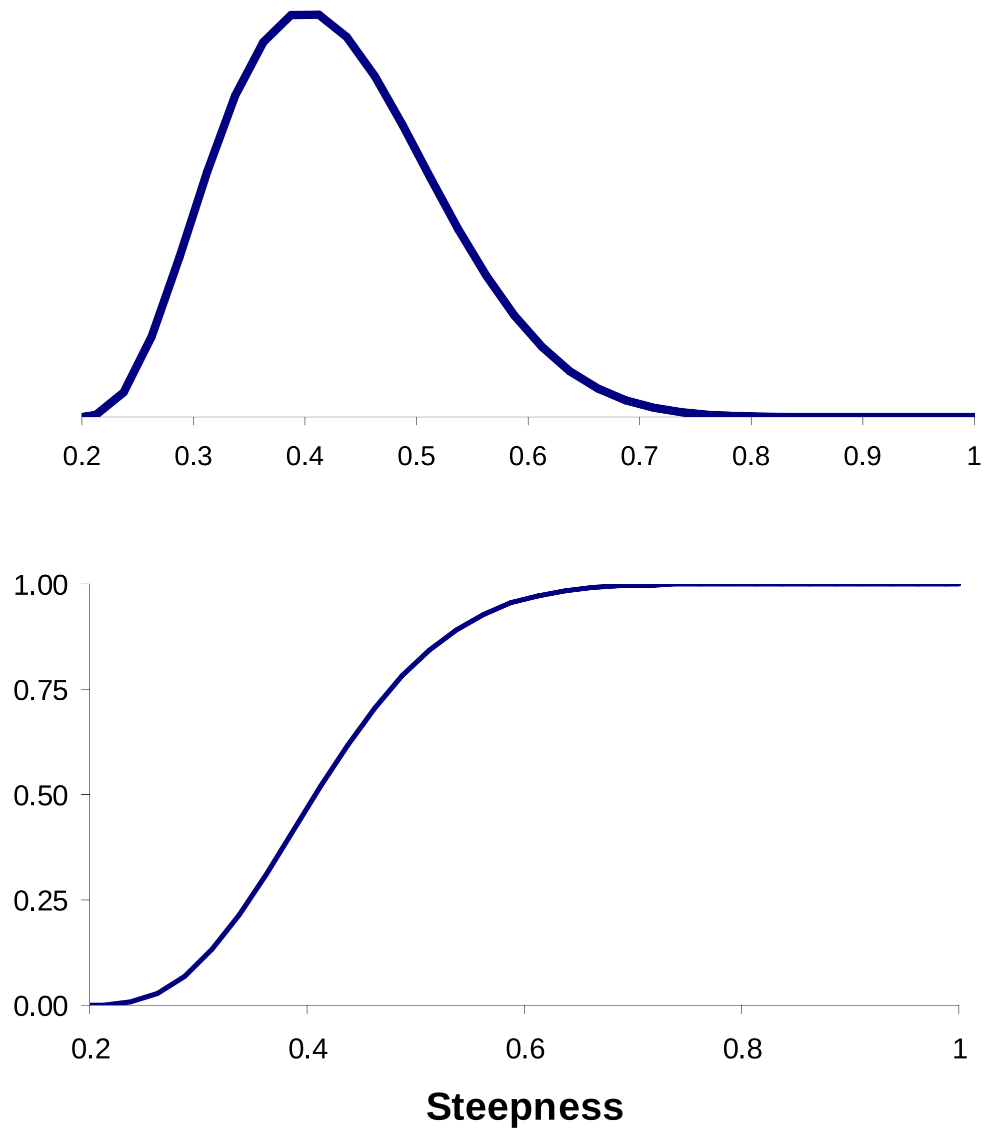


Figure 1.54. Cumulative prior probability distribution of steepness based on the beta distribution (α=4, β=10) assumed for the main model.

(This page intentionally left blank)