Chapter 1A: Assessment of the Pollock stock in the Aleutian Islands

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Executive Summary

Development of a detailed age-structured stock assessment for the Aleutian Islands Region pollock began in 2003 (Barbeaux et al. 2003) and has since been developed further (Barbeaux et al. 2009). In the initial study the near shore areas of the Aleutian chain island were isolated and identified as the Near, Rat, and Andreanof Island (NRA) sub-area. In 2006 and 2007 the stock assessment data set was further refined to exclude fisheries data from the area east of 174°W to address data consistency issues. The North Pacific Fishery Management Council (Council) supported this proposal and urged further development of an age-structured assessment model using data from the area west of 174°W (and omitting deep-water areas where survey data are unavailable). A review of the 2007 Aleutian Islands region pollock stock assessment was conducted by the Center for Independent Experts (CIE). In previous assessments data from the eastern boundary of the Aleutian Islands region (between 174°W and 170°W) were excluded from all of the age-structured assessment models, but summer Aleutian Islands bottom trawl (AIBT) survey data from this area were used. The CIE review panel had concerns with the approach of using different area partitions for the survey and fisheries data. To address these concerns we ran two sets of models; one with all fisheries and survey data for the NRA subarea, and another with all survey data for the NRA subarea and fisheries data from just the NRA area west of 174°W. We repeated this partition for the 2008 and 2009 assessments with the SSC and plan team selecting the model with all data as the reference model each time. To simplify the stock assessment process and allow more space for alternative model configurations we will no longer be presenting the alternative smaller fishery area model.

This year we have added the 2007 and 2008 AICASS age data as fishery catch-at-age, the 2010 pollock catch, and the 2010 summer bottom trawl survey biomass estimate to the model. There was a considerable amount of disagreement among age readers on AI pollock otoliths. For this reason this year we explored the addition of an aging error matrix to our model. We present two models, one configured the same as the reference model from 2009 (Model AI), and one with the addition of an ageing error matrix (Model AI_AE).

Summary of major changes

- Inclusion of the 2010 pollock catch estimates
- Catches for 2003 to 2010 were updated to latest estimates from the catch accounting system (CAS)
- Inclusion of catch at age from the 2007 and 2008 AICASS as fishery catch at age
- Inclusion of the 2010 summer bottom trawl survey biomass estimates
- Reduction in the natural mortality rate from 0.22 to 0.20
- Reduction in $F_{35\%}$ from 104,300 t to 94,771 t
- Inclusion of an aging error matrix in reference model (Model AI_AE)

Changes in the assessment results

- The maximum permissible ABC for 2011 and 2012 (assuming a 19,000 t catch in 2011) under Tier 3b are 36,668 t and 35,617 t, respectively. The OFL for 2011 and 2012 under Tier 3b are 44,497 t and 43,295 t respectively.
- Adding aging error increased estimated recruitment variability and lowered reference values and the current biomass estimates.

Response to SSC 2009 Comments

- There were no SSC comments from 2009 specific to AI pollock stock assessment.

Summary Table

	Last year		This year	
Quantity/Status	2010	2011	**2011**	2012*
M (natural mortality)	0.22		**0.20**	
Specified/recommended Tier	3b		**3b**	
Projected biomass (ages 2+)	343,226	366,107	**298,034**	327,293
Female spawning biomass (t)				
Projected	97,486	89,780	**80,867**	82,106
$B_{100\%}$	298,000		**270,774**	
$B_{40\%}$	119,200		**108,310**	
$B_{35\%}$	104,300		**94,771**	
F_{OFL}	0.41	0.40	**0.32**	0.31
$maxF_{ABC}$	0.33	0.32	**0.26**	0.26
Specified/recommended F_{ABC}	0.33	0.32	**0.26**	0.26
Specified/recommended OFL (t)	40,005	39,088	**44,497**	43,295
Specified/recommended ABC (t)	33,064	32,227	**36,668**	35,617
Is the stock being subjected to overfishing?	No	No	**No**	No
Is the stock currently overfished?	No	No	**No**	No
Is the stock approaching a condition of being overfished?	No	No	**No**	No

* After 2011catch of the max TAC of 19,000 t. If the 2011 catch is only 1.09 t (i.e., equal to the five year average), the 2012 projected total age 2+ biomass would be 343,607 t, the female spawning biomass would be 87,115 t, the maximum permissible ABC would be 41,606 t and the 2012 OFL would be 50,438 t. In which case the 2010 F_{OFL} would be 0.32 and the max F_{ABC} would be 0.28.

Introduction

Walleye pollock (*Theragra chalcogramma*) are distributed throughout the Aleutian Islands (AI) with concentrations in areas and depths dependent on diel and seasonal migration. The population of pollock in the AI is characterized by a sharp drop in abundance between 1986 (444,000 t) and 1994 (78,000 t) with a relatively slow but steady increase in abundance since (Fig 1A.1a). The precipitous decline between 1986 and 1991 may be in part due to undocumented fishing by foreign vessels claiming catch from the Central Bering Sea (CBS) as the documented fishing levels alone can not account for the decline (Table 1A.1). A number of foreign fishing vessels were observed fishing in the AI during this time period (Egan 1988a; Egan 1988b) while claiming catch from the CBS. The most recent surveys show that the AI pollock population is predominantly concentrated in the eastern portion of the Aleutian Island chain, closer to the Eastern Bering Sea shelf. Surveys from the 1980's and 1990's estimated higher proportions of pollock biomass in the central and western Aleutians (Fig 1A.1b). This recent spatial imbalance in population abundance may reflect a spatial contraction of the stock in the Eastern Bering Sea after the collapse of the Central Bering Sea population in the early 1990's, low AI pollock recruitments since the mid 1980's, documented high exploitation rate of the AI pollock in the mid to late 1990's, and possibly a high undocumented exploitation rate in the late 1980's by foreign fishers.

The degree of independence of the Aleutian Islands pollock from pollock of other areas is not well understood. Bailey et al. (1999) presented a review of the meta-population structure of pollock throughout the north Pacific region identifying possible meta-populations in the Eastern Bering Sea, but little data from the Aleutian Islands region were available at the time and therefore his population model doesn't consider these fish. Recent genetic studies, which included samples from the Aleutian Islands near Adak Island, have shown a lack of genetic heterogeneity among Northeast Pacific and Bering Sea pollock that could be used for stock definition (Grant et al. 2010). Grant et al. (2006) found and later confirmed (Grant et al.2010) the greatest genetic differences occurred between samples from Asia and the Eastern North Pacific with mirror-image haplogroup clines between them. Grant et al (2010) interpreted that the genetic differences across the Pacific Ocean and mirror-image haplogroup clines likely reflect divergence during ice-age isolations and subsequent expansion into the central North Pacific on each side with gene flow across the contact zone. The pollock in the AI therefore are most likely a mixed population from both Asian and North American and the result of re-colonization from both sides of the Pacific post ice-age.

For management purposes, the pollock population in the Eastern Bering Sea and Aleutian Islands (BSAI) has been split into three stocks. These stocks are: Eastern Bering Sea (EBS) pollock occupying the eastern Bering Sea shelf from Unimak Pass to the U.S.-Russia Convention line, Aleutian Islands (AI) pollock encompassing the pollock in the Aleutian Islands shelf region from 170°W to the U.S.-Russia Convention line; and the Central Bering Sea-Bogoslof Island (CBS-BI) pollock. These three management stocks probably have some degree of exchange. The CBS-BI stock is a group that forms a distinct spawning aggregation that has some connection with the deep water region of the Aleutian Basin. This stock assessment concentrates on the pollock of the Aleutian Islands and assumes that these fish are distinct enough from the CBS-BI and EBS meta-populations to model their dynamics separately.

Although the genetics evidence points to a mixed population, evidence to suggest that the AI pollock are separated from the EBS stock at smaller temporal time scales than current genetic techniques can identify include disparate size at age and asynchrony in high recruitment events. It appears that the AI pollock are much more similar to the Gulf of Alaska (GOA) pollock than the EBS pollock in size at age, with the GOA pollock being significantly larger than the EBS fish and AI pollock being significantly larger than the GOA pollock (Fig.1A.2). This may be a latitudinal effect with the more southern AI pollock encountering a longer summer growing period. Similar latitudinal differences have been observed in both Pacific and Atlantic cod (Gadus *macrocephalus* and *morhua*; Orsmeth and Norcross 2009). Although the AI and EBS shared some larger-than-the-mean (normalized at post-1979) recruitment events (1977, 1978, 1982, 1989, and 2000) the AI shared more with the GOA (1976, 1977, 1978, 1985, 1989, and 2000). All three regions shared four of these higher recruitment events (1977, 1978, 1989, and 2000). In addition the AI had unique highs in 1981, 1983, 1986, and 1987 (Fig. 1A.3). Although the evidence is rather weak and not by any means conclusive the size at age and asynchronous recruitments suggest some degree of separation between the EBS and the pollock of these three regions.

Previously, Ianelli et al. (1997) developed a model for Aleutian Islands pollock and concluded that the spatial overlap and the nature of the fisheries precluded a clearly defined "stock" since much of the catch was removed very close to the eastern edge of the region and appeared continuous with catch further to the east. In some years, a large portion of the pollock removed in the Aleutian Islands Region was from deep-water regions and appeared to be most aptly assigned as CBS-BI pollock. Since 2003 these deep-water catches have been excluded from the stock assessment data and only the area designated as the Near-Rat-Andreanof Islands area (NRA) or the area closest to the Aleutian Islands have been used in the stock assessment (Fig 1A.4). In 2003 through 2007 the reference stock assessment model excluded the fishery dependent data from east of 174°W longitude. In 2007 a CIE review deemed the east-west data split as inappropriate and the reference model has since included all fisheries dependent data from the NRA region.

The current AI pollock stock assessment model has been developed within the NOAA fisheries stock assessment Toolbox model AMAK and is a catch-at-age model with the standard Baranov catch equation. The population dynamics follows numbers-at-age over the period of catch history with natural and age-specific fishing mortality occurring throughout the 14-age-groups that are modeled (ages 2-15+). Age-2 recruitment in each year is estimated as deviations from a mean value expected from an underlying stock-recruitment curve. In the model we assume a single fishery (which includes both targeted catch and bycatch from other fisheries) and a single summer bottom trawl survey index of abundance. Catch at age is available from both the survey and the fishery, although in the latter years (2006-2008) age data collected during a cooperative acoustic survey conducted in the Central Aleutians has been incorporated into the model as fishery age data.

Fishery

The nature of the pollock fishery in the Aleutian Islands Region has varied considerably since 1977 due to changes in the fleet makeup and in regulations. During the late 1970s through the 1980s the fishing fleet was primarily foreign and joint venture (JV) where US catcher vessels delivered to foreign motherships. The last JV delivery was conducted in 1989 when the domestic fleet began operating in earnest. The distribution of observed catch differed between the foreign and JV fishery (1977-1989) and the domestic fishery (1989-2009; Fig. 1A.5). The JV and foreign fishery operated in the deep basin area extending westward to Bowers Ridge and in the eastern most portions of the Aleutian Islands. Some operations took place out to the west but observer coverage was limited. In the early domestic period (1991-1998) the fishery was more dispersed along the Aleutian Islands chain with no observed catches along Bowers Ridge and fewer operations in the deep basin area. The majority of catch in the beginning of the domestic fishery came from the eastern areas along the 170°W longitude line, and around Seguam Island in both Seguam and Amukta passes. As the fishery progressed more pollock were removed from the north side of Atka Island around 174°W and later near 177°W northwest of Adak Island inside Bobrof Island. While the overall catch level was relatively low, the domestic fishery moved far to the west near Buldir Island in 1998 (Table 1A.2). In 1999 the North Pacific Fishery Management Council (NPFMC) closed the Aleutian Islands region to directed pollock fishing due to concerns for Steller sea lion recovery.

In 2003 the entire AI pollock quota was allocated to the Aleut Corporation and in 2005 the directed fishery was reopened. The fishery was still restricted to areas outside of 20 nmi of Steller Sea lion rookeries and haulouts, limiting fishing to two small areas with commercial concentrations of pollock within easy delivery distance to Adak Island. One is a 4 mile stretch of shelf break located northwest of Atka Island between Koniuji Island and North Cape of Atka Island, the other is a 7 mile stretch located east of Nazan Bay in an area referred to as Atka flats. Bycatch of Pacific Ocean perch (POP) can be very high in both these areas and it appears that pollock and POP share these areas intermittently; depending on time of day, season, and tide. Although there may be other areas further west that may have commercial concentrations of pollock, to date there have been no attempts by the reopened directed fishery to explore these areas.

Two catcher processor vessels attempted directed fishing for pollock in February 2005, but failed to find commercially harvestable quantities outside of Steller sea lion critical habitat closure areas and in the end removed less than 200 t of pollock. In addition, bycatch rates of Pacific Ocean perch were prohibitively high in areas where pollock aggregations were observed. The 2005 fishery is thought to have resulted in a net loss of revenue for participating vessels. Data on specific bycatch and discard rates for the 2005 fishery are not presented due to issues of data confidentiality.

In 2006 and 2007 the Aleut Corporation, in partnership with the Alaska Fisheries Science Center (AFSC), Adak Fisheries LLC and the owners and operators of the F/V Muir Milach, conducted the Aleutian Islands Cooperative Acoustic Survey Study (AICASS) to test the technical feasibility of conducting acoustic surveys of pollock in the Aleutian Islands using small (<32 m) commercial fishing vessels (Barbeaux and Fraser 2009). This work was supported under an exempted fishing permit that allowed directed pollock fishing within Steller sea lion critical habitat. A total of 932 t and 1,100 t of pollock were harvested during these studies in 2006 and 2007 respectively, and biological data collected during the studies were treated in the stock assessment as fishery data. In 2008 additional surveys of Aleutian Islands region pollock in the same area were conducted on board the R/V Oscar Dyson and in cooperation with the F/V Muir Milach; the work was funded through a North Pacific Research Board grant and less than 10 t of groundfish were taken for the study. In 2009 the directed pollock fishery in the Aleutian Islands region took 403 t and 1,326 t were taken as bycatch in other fisheries, predominantly the Pacific cod and rockfish fisheries. In 2010 financial problems with the Adak processing plant greatly hindered the directed fishery and as of October 2, only 50 t had been taken in the directed fishery while 1,055 t were taken as bycatch in other fisheries. Table 1A.3 provides a history of ABC, OFL, and catch for Aleutian Islands pollock since 1991. Since 2005 the TAC has been constrained to 19,000 t or the ABC, whichever is lower, by statute.

Data

Catch estimates

Estimates of pollock catch in the Aleutian Islands Region are derived from a variety of data sources (Table 1A.1). During the early period, the foreign-reported database (held at AFSC) is the main source of information and was used to derive the official catch statistics until about 1980 when the observer data were introduced to provide more reliable estimates. The foreign and joint-venture (JV) blend data takes into account observer data and reported catches and formed the basis of the official catch statistics until 1990. The NMFS Observer data are the raw observed catch estimates and provide an indication of the amount of catch observed relative to the current estimates from the blend data. The foreign reported catch database was used to partition catches among areas for the period 1977-1984, and the observer data were used to apportion catches from 1985-2003. These proportions were then expanded to match the total catch. Estimates of pollock discard levels have been available since 1990. During the years when directed fishing was allowed pollock discards represented a small fraction of the total catch (Table 1A.4).

Fishery age composition

Otoliths, weight, and length samples were collected through shore-side sampling and by at-sea observers. The number of age samples and length samples were highly variable (Table 1A.5 and Table 1A.6) and sampling effort in the directed fishery was very low after 1998. The age composition data collected in the 2006, 2007, and 2008 AICASS were used as fishery data. Estimates of the catch-age compositions used in this assessment are shown in Table 1A.7. The multinomial catch-at-age sample sizes were calculated using the bootstrap method presented in the 2008 Atka mackerel stock assessment (Lowe et al, 2008).

From 1983 through 1995 the 1978 year class was predominate in the fishery (Fig. 1A.6a). It wasn't until 1996 that the 1989 year class outpaced the 1978 year class. Although the 1981 and 1983 year classes were large in comparison to recent recruitments they were dwarfed by the 1978 recruitment event. There were insufficient age data collected from the fishery between 1999 and 2005 to construct an age distribution.

The age data collected during the 2006-2008 AICASS (Fig. 6a) show that the 1999 and 2000 year class made up a large portion of the adult population and were relatively large recruitment events for all three study years compared to more recent recruitments for this stock. In 2008 the 1998 year class appeared to be larger than previous years, but this may be due to high level of aging error as the agreement between age readers was only between 20.5% and 43.6% for this study. The low level of agreement between age readers compared to Bering Sea pollock was due to the high number of older fish in this stock and the low definition of the annuli in the AI pollock. This has been a consistent problem for the AICASS data with aging agreement averaging less than 50% across all years of data.

Survey data

The National Marine Fisheries Service in conjunction with the Fisheries Agency of Japan conducted bottom trawl surveys in the Aleutian Islands region (from ~165°W to ~170°E) in 1980, 1983, and 1986. The Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering Division (RACE) conducted bottom trawl surveys in this region in 1991, 1994, 1997, 2000, 2002, 2004, 2006, and 2010. The Aleutian Islands bottom trawl survey planned for 2008 was canceled due to budgetary constraints. The earlier cooperative survey biomass estimates are not comparable with biomass estimates obtained from the RACE trawl surveys because of differences in the nets, fishing power of the vessels, and sampling design. In the early surveys, biomass estimates were computed using relative fishing power coefficients (RFPC) and were based on the most efficient trawl during each survey. Such methods result in pollock biomass estimates that are higher than those obtained using the standard methods employed in the RACE surveys. In the NRA area, the early survey (1980-1986) abundance ranged from 267 to 440 thousand tons and the later surveys (1991-2010) ranged from 78 to 175 thousand tons (Table 1A.9) with a peak in survey abundance in 2002. Plots of CPUE by tow show the relative distribution of pollock to be variable between years and areas (Fig. 1A.7) but with an obvious decreasing trend in the Western and Central AI.

The RACE Aleutian Islands bottom trawl (AIBT) surveys prior to 2004 indicate that most of the pollock biomass was distributed roughly equally between the Eastern (541) and Central Aleutian Islands area (542). The 2004 Aleutian Islands trawl survey showed a significant decline in the Central Aleutian Islands area and a near doubling of the Eastern Aleutians Islands pollock abundance estimate from the 2002 survey. In the 2006 AIBT survey the Central and Western biomass estimates remained stable while the Eastern population was nearly half the 2004 estimate and back to 2002 levels, but the CV for this estimate was 90.2%. The 2010 survey shows an increase in abundance throughout the survey area with a larger increase in the Eastern area and slight increases in the Central and Western area. The Eastern portion of the survey continues to have by far the highest abundance levels, but the CV for the Eastern area remains high at 64%. During the 1991-2002 surveys, a number of large to medium-sized tows were encountered throughout the Aleutians indicating a fairly well distributed population. This is very different from the 2004 through 2010 survey estimates which indicated a low level of pollock abundance in both Central and Western areas, and a much higher pollock density in the Eastern area with only a few large hauls making up the majority of the abundance. The 2004 survey encountered a single large tow near Seguam pass that when expanded to the entire stratum made up the majority of the estimated pollock biomass. The 2006 and 2010 surveys revealed very few pollock throughout the NRA, except for large tows in Seguam Pass and in the Delerof Islands. The 2006 and 2010 survey found higher concentrations of pollock in the Delerof Islands than in 2004, but are consistent with the distribution of pollock in the 2002 survey. The general trend for the more recent surveys (2002-2010) is a low level of pollock abundance in the Central and Western Aleutians with a more abundant, but patchy distribution of pollock in the Eastern Aleutians resulting in highly imprecise survey estimates.

Survey proportion at age and length frequencies

The survey data from 1994 and 1997 are consistent with the fishery data in that the 1989 year class was larger than the mean. The 2000 and 2002 surveys don't show any particularly dominant year class, while the 2004 and 2006 survey age data show the 2000 year class as dominant with the 1999 year class playing a much smaller role in the proportion at age than observed in the fishery data (Fig. 1A.6b and Table 1A.10). The AIBTS weight-at-age data are presented in Table 1A.11. The 1991 survey age data is questionable since the most of the age data were collected in only a few survey hauls in the Western Aleutians area. For this reason these data have been down weighted in the stock assessment model.

The length data for the 2002 through 2010 surveys are shown in Figure 1A.8. The 2002 through 2006 length data are bimodal, with a small mode for the age-1 pollock at between 15 and 22 cm and another for the adult pollock between 55 and 70cm. The age 2 and 3 are generally missing from bottom trawl surveys as it is believed these fish are more pelagic than the adults and age 1 pollock. The 2002 survey shows a large number of pollock in this size range compared to other years. The pollock length frequency collection from the 2010 AIBTS is tri-modal with peaks at 19 cm, 45 cm, and 59 cm . The 19 cm mode is much larger than previous surveys and the middle 45 cm mode is unique to the 2010 survey. Age data from the 2010 AIBTS data are not yet available, but given the length at age for AI pollock (Fig. 1A.2) we can speculate on the age composition of the modes. The 19 cm mode most likely corresponds to age -1 pollock from the 2009 year class, the 45 cm peak is most likely composed of age 4 fish representing the 2006 year classes, while the fish around the 59 cm mode are most likely a mix of older fish from the 1998 through 2000 year classes and beyond.

Other Surveys

In addition to the bottom trawl survey there has been one echo integration-trawl survey in a portion of the NRA. The R/V Kaiyo Maru conducted a survey between 170°W and 178°W longitude in the winter of 2002 after completing a survey of the Bogoslof region (Nishimura et al. 2002). Due to difficulties in operating their large mid-water trawl on the steep slope area, they determined that their biological sampling in this area were insufficient for accurate species identification and biomass estimation. They did, however, present preliminary biomass estimations. For the entire area from 170°W and 178°W longitudes they estimated a biomass of 93,000 t of spawning pollock biomass with between 61,000 t estimated in the NRA east of 173°W, and 32,000 t in the remainder of the survey area to 178°W longitude (Barbeaux et al. 2009). The largest aggregations of pollock in the NRA area were observed at 174°W north of Atka Island. Most of the pollock echo sign was observed along the slope of the Aleutian Islands and relatively near shore.

In 2006, and 2007 acoustic survey studies (Fig. 1A.9) were completed in the central Aleutian Islands region aboard a 32m commercial trawler (F/V Muir Milach) equipped with a 38 kHz SIMRAD ES-60 acoustic system. The Aleutian Islands Cooperative Acoustic Survey Study (AICASS) was conducted to assess the feasibility of using a small commercial fishing vessel to estimate the abundance of pollock in waters off the central Aleutian Islands. In 2008 this survey was expanded to include the R/V Oscar Dyson to survey the same area as the F/V Muir Milach. The results of the 2006 survey are presented in an AFSC technical memorandum (Barbeaux and Fraser 2009) and the 2007 survey results were described in the 2009 Aleutian Islands pollock stock assessment (Barbeaux et al. 2009). In summary both surveys were able to conduct scientific quality acoustic surveys in the Aleutian Islands during the winter months using commercially available echosounders and a commercial fishing vessel. For 2006 there was a high degree of variability between surveys due to the small area being surveyed, pollock movement, and potentially the fishery being conducted during the survey period. In 2007 the spatial distribution of pollock varied between surveys with apparent pollock abundance decreasing in an area inside Boborof Island near Ship Rock and in an area north of Atka Island known as the Knoll and increasing elsewhere in the study area.

The 2008 AICASS (Fig. 1A.9) was conducted to investigate whether cooperative biomass assessments and surveys could be an effective way to manage fisheries at the local scales that are important to predators such as Steller sea lions. The study included two acoustic surveys one conducted by the R/V Oscar Dyson and the other by the F/V Muir Milach. The first acoustic survey conducted 16-29 February by the R/V Oscar Dyson between 173° W and 178° W resulted in a pollock biomass estimate of 36,135 t for the surveyed area. The second survey conducted 23-27 March between 174.17°W and 178° W resulted in a biomass estimate of 29,041 t. For the same area the R/V Oscar Dyson survey had a biomass estimate of 27,128 t, each of the estimates for the smaller area are within the margin of error of the other. The later F/V Muir Milach survey showed fewer pollock in the Tanaga area and more pollock in the Knoll area. The size of the pollock from the two 2008 surveys were consistent with each other with a mode between 60 and 65 cm, but were larger than the pollock observed in the 2006 and 2007 surveys (Fig. 1A.10).

Analytic Approach

The 2010 Aleutian Islands walleye pollock stock assessment uses the same modeling approach as in last year’s assessment; implemented through the Assessment Model for Alaska (here referred to as AMAK). AMAK is a variation of the “Stock Assessment Toolbox” model presented to the plan team in the 2002 Atka mackerel stock assessment (Lowe et al. 2002), with some small adjustments to the model and a user-friendly graphic interface.

The abundance, mortality, recruitment, and selectivity of the Aleutian Islands pollock were assessed with a stock assessment model constructed with AMAK as implemented using the ADMB software. The ADMB is a C++ software language extension and automatic differentiation library. It allows for estimation of large numbers of parameters in non-linear models using automatic differentiation software developed into C++ libraries (Fournier 1998). The optimizer in ADMB is a quasi-Newton routine (Press et al. 1992). The model is determined to have converged when the maximum parameter gradient is less than a small constant (set to 1×10^{-7}). A feature of ADMB and AMAK is that it includes post-convergence routines to calculate standard errors (or likelihood profiles) for quantities of interest.

Model structure

The AMAK model models catch-at-age with the standard Baranov catch equation. The population dynamics follows numbers-at-age over the period of catch history with natural and age-specific fishing mortality occurring throughout the 14-age-groups that are modeled (ages 2-15+). Age-2 recruitment in each year is estimated as deviations from a mean value expected from an underlying stock-recruitment curve. Deviations between the observations and the expected values are quantified with a specified error model and cast in terms of a penalized log-likelihood. This overall log-likelihood (L) is the weighted sum of the calculated log-likelihoods for each data component and model penalties. The component weights are inversely proportional to the specified (or in some cases, estimated) variances. Appendix A Tables 1 – 3 provide a description of the variables used, and the basic equations describing the population dynamics of Aleutian Islands pollock and likelihood equations. The model was modified from that of Barbeaux et al. (2003). These modifications include:

- The addition of a feature that allows a user-specified age-range for which to apply the survey (or other abundance index) catchability. For example, specifying the age-range of 5-12 (as was done for this assessment) means that the average age-specific catchability of the survey is set to the parametric value (either specified as fixed, as in this assessment, or estimated).
- In the 2003 assessment age-1 pollock were explicitly modeled, whereas in the work presented here, they were dropped from consideration because observations of age-1 pollock are irregular, and in trials where they were included, they were found to limit the flexibility to incorporate alternative model specifications such as parametric forms of selectivity functions.

The quasi[1] likelihood components and the distribution assumption of the error structure are given below:

Likelihood Component	Distribution Assumption
Catch biomass	Lognormal
Catch age composition	Multinomial
Survey catch biomass	Lognormal
Survey catch age composition	Multinomial
Recruitment deviations	Lognormal
Stock recruitment curve	Lognormal
Selectivity smoothness (in age-coefficients, survey and fishery)	Lognormal
Selectivity change over time (fishery only)	Lognormal
Priors (where applicable)	Lognormal

The age-composition components are heavily influenced by the sample size assumptions specified for the multinomial likelihood. In this assessment a bootstrap method developed by Jim Ianelli and presented in last year's Atka mackerel assessment (Lowe et al 2008) was used to estimate effective sample size for fishery catch-at-age data. In brief, the 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. In summary, estimates of the proportion of catch-at-age are derived from the mean of the bootstrap sampling of the revised catch-at-age estimates. The bootstrap method also allows evaluation of sample-size scalings that better reflect inter-annual differences in sampling and observer coverage (Lowe et al 2008). A value of 100 was selected for survey catch-at-age data.

Fishery data*	Year	1978	1979	1980	1981	1982	1983	1984	1985	1986
	$\dot{N}_{i,\bullet}$	177	103	131	99	670	125	288	155	220
	Year	1987	1988	1991	1992	1993	1994	1995	1996	1998
	$\dot{N}_{i,\bullet}$	269	51	53	35	70	159	75	84	187
	Year	2006	2007	2008						
	$\dot{N}_{i,\bullet}$	100	100	100						
Survey data										
	Year	1991	1994	1997	2000	2002	2004	2006		
	$\dot{N}_{i,\bullet}$	1**	100	100	100	100	100	100		

*2006, 2007, and 2008 effective sample sizes were set at 100 for this assessment

**The 1991 value was down-weighted because the samples collected in that year were not representative of the region considered.

Parameters

Parameters estimated independently

Length and Weight-at-age

We estimated length and weight-at-age separately for the survey and for the fishery. We obtained survey estimates from AIBT surveys and computed fishery estimates from observer data and the 2006-2008 AICASS. The von Bertalanffy growth curve parameters and length-weight regression parameters from the

[1] The likelihood is *quasi* because model penalties (e.g., non-parametric smoothers) are included.

1980 to 2006 surveys are given in Table 1A.13. Survey weight-at-age values from 1978 to 2010 are given in Table 1A.11. For the time period 1978 to 1990, survey length and weight at age estimates were derived from the 1980, 1983, and 1986 AIBT surveys. For the time period 1990 to 2010 we calculated length and weight-at-age values from the 1991, 1994, 1997, 2000, 2002, 2004, and 2006 AIBT surveys. The 2010 AIBT survey age data are not yet available. We calculated the average length-at-age as weighted averages by age and calculated the length-weight relationships using linear regression analysis. Data for these analyses were retrieved from the Resource Assessment and Conservation Engineering Division's (RACE) survey database. For years without survey length and weight-at-age data (unshaded cells in Table 1A.11), we used the mean values at age from the two nearest surveys. Fishery weight-at-age values from 1978 to 2010 are shown in Table 1A.8. For the fishery, we used year (when available) and age-specific estimates of average weights-at-age computed from the fishery age and length sampling programs. These values are important for converting model estimated catch-at-age (in numbers) to estimated total annual harvests (by weight).

Maturity at Age

Previous to 2008, assessments used the maturity schedule developed for the Bering Sea by Wespestad and Terry (1984; Table 1A.14). The CIE panel commented that given the differences in size-at-age there is likely a difference in maturity-at-age between the Bering Sea and Aleutian Islands. The authors agree, but maturity studies have not been conducted specifically on the Aleutian Islands pollock and given the lack of a substantial fishery, not likely to happen in the near future. Aleutian Islands pollock size at age is more similar to that observed in the Gulf of Alaska than in the Bering Sea (Fig. 1A.2). In addition, population density in the Aleutians is similar to the GOA then the Bering Sea. In last year's and this year's assessment we used the Gulf of Alaska pollock 1983-2003 average proportion mature at age for our maturity O-give (Dorn et al 2008). The GOA pollock tended to mature slightly later with 50% mature at between 4 and 5 years of age while the Bering Sea pollock reach 50% mature at between 3 and 4 years of age (Table 1A.14 and Fig. 1A.11).

Recruitment

We used an area-parameterized form of the Beverton-Holt stock recruitment relationship based on Francis (1992). 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" (h) of the stock-recruit relationship. The "steepness" parameter 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). As an example, a value of $h = 0.7$ implies that at 20% of the unfished spawning stock size will result in an expected value of 70% of the unfished recruitment level. The steepness parameter (h) was set at 0.7 and sigma r was set at 0.6 for all model runs. In previous assessments model runs with different values of h were conducted but were found to have little effect on the model results.

Parameters estimated conditionally

Deviations between the observations and the expected values are quantified with a specified error structure. Lognormal error is assumed for estimates of survey and fishery catch, and a multinomial error structure is assumed for analysis of the survey and fishery age compositions. These error structures are used to estimate the following parameters conditionally within the model.

Fishing Mortality

Fishing mortality in all models was parameterized to be separable with both an age component (selectivity) and a year component. In all models selectivity is conditioned so that the mean value over all ages will be equal to one. To provide regularity in the age component, a penalty was imposed on sharp shifts in selectivity between ages using the sum of squared second differences. In addition, the age component parameters are assumed constant for the last 8 age groups (ages 8-15). Finally, selectivity was fixed over time for all model configurations. The model was set with controls selecting the degree to which selectivity is allowed to change between ages and over time.

Survey Catchability

For the bottom trawl survey, survey catchability-at-age follows the parameterization similar to the fishery selectivity-at-age presented above. The catchability-at-age relationship is modeled with a smoothed non-parametric relationship that can take on any shape (with penalties controlling the degree of change and curvature specified by the user). To provide regularity in the age component, a penalty was imposed on sharp shifts in catchability-at-age between ages using the sum of squared second differences. In addition, the age component parameters are assumed constant for the last 8 age groups (ages 8 -15). As noted above, the model allows specification of the age-range over which the catchability parameter is applied. For Aleutian Islands pollock, ages 5-12 were selected to have the average catchability (factoring selectivity components) equal to the catchability parameter value.

One comment by the CIE reviewers was that the assessment model should not allow for inter-annual changes in survey selectivity. Prior to the 2008 assessment, survey selectivity was allowed to change because in conversations with the RACE division it was determined that the survey selectivity was not constant between years and that the improvements made to the survey since 1991 have been incremental. In particular, both measuring the amount of time the gear was on bottom and the ability of the survey to stay on the bottom was improved in 1994 by the addition of ground contact sensors. In 1997 another improvement was made in allowing the net to hit bottom before starting the survey. Both of these improvements would have increased the selectivity for older pollock which tend to reside near bottom. In 2008 we compared configurations with and without inter-annually varying survey selectivity. After reviewing the results, the authors recommended and the Groundfish Plan Team and Scientific and Statistical Committee agreed that the best model should not have inter-annual varying survey selectivity. Neither of the 2010 models presented have inter-annually varying survey selectivity.

In the 2004 Aleutian Islands pollock stock assessment the focus of our analysis was to evaluate a key model assumption: the extent to which the NMFS summer bottom trawl survey catchability should be estimated by the available data (resulting in very high stock sizes) or constrained to be close to a value of 1.0 (implying that the area-swept survey method during the summer months reasonably applies to a fishery that will likely occur during the winter). We provided evidence that suggests that fixing the value of survey catchability to 1.0 is unreasonable. However, recognizing that no other information is available to “anchor” the assessment model to an absolute biomass level, the authors were reluctant to proceed with specifying influential prior distributions on catchability values. The effects of the fishery on the pollock population dynamics appear to be poorly determined given the available data. This could be due to a number of factors including: characteristics of Aleutian Islands pollock relative to adjacent regions, poor quality data, and the possibility that the fishing effects are minor relative to other factors. The latter point is likely to be true at least for the recent period since 1999 when the fishery removals have been minor. Therefore, we assumed a fixed catchability value of 1.00 for models evaluated in this assessment.

Natural Mortality

For all models natural mortality was estimated using a prior of 0.2 with a CV of 0.2. Previous assessments (Barbeaux et al. 2007) suggest that Aleutian Islands pollock is less productive than the Eastern Bering Sea stock and model fits suggest that M should be closer to 0.2 than the 0.3 used in the Eastern Bering Sea and Gulf of Alaska pollock assessments (Ianelli et al 2009l; Dorn et al 2009). In this assessments we assumed a prior value of $M = 0.2$ based on the studies of Wespestad and Terry (1984) for the Central Bering Sea (Table 1A.12). Although the current assessment model does not allow for age-specific natural mortality rates, it should be noted that in general, a higher natural mortality rate for age 2 pollock may be more appropriate (Ianelli et al. 2003). The addition of the catch-at-age data from the AICASS in recent assessments has improved model stability. Natural mortality can be estimated in this case using the

AICASS age data because steepness and Sigma R are assumed to be known and the data show an increasing abundance with very low levels of harvest.

Model evaluation

Two model configurations were evaluated for this stock assessment cycle. Model AI is comparable to the model configuration of the preferred model presented in 2009. Model AI_AE is the same as the reference model from 2009 but with the addition of an aging error matrix developed from age-specific estimates of the standard deviation of ageing errors (assuming unbiased age-determinations) from AFSC aging validation results (Table 1A.15). The aging error component of the model was configured as described by Ianelli et al. (2003) in the 2003 Bering Sea pollock stock assessment.

The two models were configured with a survey catchability of 1.0, a stock recruitment steepness parameter of 0.7 and sigma r of 0.6. Recruitment was modeled using data from 1978-2007. Natural mortality for all models was estimated within the model starting with a prior of 0.2 and CV of 0.2.

Models Evaluated	**Fishery and Survey Data**	**Aging Error Matrix**	**Inter-annual Survey Selectivity**	**Age at which Selectivity becomes Constant**	
				Fishery	**Survey**
Model AI	All NRA	No	Fixed	8	8
Model AI_AE	All NRA	Yes	Fixed	8	8

Relative differences in model fits are shown in Table 1A.16 and key results are presented in Table 1A.17.

The relative fits of the two models are very similar, but as would be expected Model AI_AE with aging error provided a better fit to both the fishery and survey age composition data. The fit to the survey data, although marginally better in the model with aging error, was relatively poor for both (Fig. 1A.12). This is not surprising given the high level of variance in the survey point estimates, the high intra-annual variability of the estimates, and the fact that the survey estimates are from the summer while the fishery is conducted in the winter.

For both models the fit to the survey age composition data was good, except for the 1991 data which, for sampling reasons, was given less weight than for the other years (Fig. 1A.13 and Fig. 1A.14). The effective sample size for the Model AI_AE with aging error was higher than that of the model without aging error and the negative log-likelihood was lower suggesting a better fit for the aging error model (Table 1A.16). Fits to the fishery age-composition data (Fig. 1A.15 and Fig. 1A.16) worse than the survey catch-at-age fits, but still relatively good for both models, but again the model with aging error out-performed the model without aging error. Both models had a difficult time matching the mean age of the fishery data for the 1990s where the population appeared to still have a large proportion of fish from the 1978 year class (Fig. 1A.17). There is high variability in the fishery age data which probably reflects the diversity in sampling locations for the fishery in different years. There doesn't appear to be any obvious or consistent patterns in the residuals for either the fishery or survey catch-at-age fits for the two models (Fig. 1A.18 and Fig. 1A.19). The estimated survey selectivities at age for the two models are presented in Table 1A.18 and Fig. 1A.20.

Although recruitment variability was high in both models, Model AI_AE had slightly higher recruitment variability (0.957) than Model AI (0.917). In addition natural mortality was estimated to be slightly lower in Model AI_AE (M = 0.20, CV = 0.05) versus Model AI (M = 0.21, CV = 0.05), effecting the estimated reference points. Model AI had $B_{100\%}$ at 272,207 t and $B_{35\%}$ at 95,272, while model AI_AE had $B_{100\%}$ at 270,774 t and $B_{35\%}$ at 94,771.

Given the high degree of disagreement among age readers and better fit to the data, Model AI_AE with aging error was clearly the best choice of models. From here forward only results from Model AI_AE will be presented.

Results

Abundance and exploitation trends

As indicated in the 2004 stock assessment analysis (Barbeaux et al, 2004), the abundance trend is highly conditioned on the assumptions made about the area-swept survey trawl catchability. Even with catchability fixed at 1.0, the uncertainty in the trend and level is very high. Bearing in mind the high degree of uncertainty, the total biomass trend (Table 1A.19, Fig. 1A.21, Fig. 1A.22, Fig. 1A.23, Fig. 1A.24A, and Fig. 1A.25A) appears to have increased from 1999 to 2004 after cessation of directed fishing in the area, and increase at a slower rate from 2005 to 2010. Estimated pollock numbers at age from 1978 to 2010 for the reference Model AI_AE are given in Table 1A.20. The biomass estimates from the reference Model AI_AE indicate that the 1978 year class was well above average and biomass in the 1980's for the Aleutian Islands area reached 1,469,900 t at its peak in 1983. The model shows a large decline in the stock since its peak, hitting its minimum biomass levels in 1999 at 174,020 t. Since the cessation of directed pollock fishing in 1999 and low catches after it was reopening in 2005, the stock biomass has been slowly increasing at an average rate of 5% per year. The stock did appear to decline slightly between 2005 and 2007 due to poor recruitment in the late 1990's, but has since begun increasing again as the fish from the 2000 and 1999 year classes have matured.

Female Spawning Stock biomass (SSB) peaked in 1984 at 547,400 t as the 1978 year class reached maturity (Fig.1A.21 and Fig. 1A.22), and dipped to a low of 58,490 t in 1999 ($B_{22\%}$ or 11% of the 1984 value) after a decade of poor recruitments and high fishing pressure. The highest full selection fishing mortality occurred in 1995 (*F* = 0.41 and Catch/biomass = 0.178) when the fishery harvested more than 75% of the 1994 survey biomass estimate (Table 1A.21, Fig.1A.23, Fig. 1A.24B, Fig. 1A.25B, and Fig. 1A.26). The reference model shows high exploitation rates beginning in 1990 (*F* = 0.208) continuing through 1998 (Table 1A.22). The early 1990s fishery appears to be concentrating on the older fish, particularly the 1978 year class, this is consistent with a switch in the domestic fishery to concentrating on spawning aggregations for roe.

There was a steep decline in pollock abundance in the Aleutian Islands in association with the senescence of the 1978 year class without another as large year class to replace it and high fishery removals. It is reasonable to conclude that the amount of removals taken in the 1990s would not have been sustainable given recent recruitment and was largely supported by the 1978 year class. We simulated the expected total biomass under no fishing by taking the raw numbers at age from 1978 and the 1979-2009 number of recruits at age 2 and projected them forward using the model derived natural mortality rate This exercise reveals that under the reference model there was a significant decline in the abundance of pollock due to fishing, but since the cessation of fishing in 1999 and very low removal levels since 2005 the stock has stabilized and increased (Fig.1A.27). The simulation shows the stock to be at 85% in 2010 of what it would have been without fishing, but had a low at 35% of the unfished stock in 1999.

Recruitment

Recruitment (at age 2) is estimated with high variance (Table 1A.23 and Fig. 1A.28). Sigma R was set at 0.6, and the reference estimates recruitment variability at 0.957. For comparison the recruitment variability in Model AI without the aging error matrix was 0.917. The 1978 year-class is the largest (1.75 billion age 2 recruits) and is highly influential with a large part of the fishery removals being composed of this year class (Fig. 1A.24). 1976-1986 had several large year classes in comparison to more recent recruitment. The mean recruitment of age 2 pollock for 1978-1988 was 327.0 million, while the mean recruitment at age 2 between 1998 and 2008 was 50.6 million fish with no year classes exceeding the overall 1978-2008 mean recruitment of 155.6 million age 2 recruits. Since the start of the domestic fishery in 1990 the two largest year classes have been the 1989 year class at 180.9 million recruits and the 2000 year class with 130.8 million recruits at age 2. No year class has exceeded the mean recruitment for 1978-2008 since the 1989 year class. Given our limited time series we are unable to determine whether the larger year classes in the late 1970's and early 1980's were anomalous or whether they are part of a larger cycle. The bottom line is that pollock year class strength has been much lower in the 1990's and 2000's than in the previous decade leading to a lower abundance of pollock in the Aleutian Islands, even without substantial local fishing pressure over the previous nine years.

The 1978 year class in particular is highly influential in both models. The mean recruitment for 1978 - 2008 without the 1978 year class was 65.8% (102.4 million) of the mean recruitment with the 1978 year class (155.6 million). If the 1978 year class is anomalous, it may be inflating the biological reference points in both models and may be causing an overestimation of the expected productivity of this system, particularly if the 1978 year class originated elsewhere. Whether AI pollock recruitment is synchronous with other areas is an open question (e.g., the 1978, 1989, and 2000 year classes are also strong in the EBS region, Ianelli et al. 2005). The AI recruitment appears to be just as, or even more, correlated with the Gulf of Alaska (GOA) stock (Fig. 1A.3; Barbeaux et al. 2009) and the extent to which these adjacent stocks interact is an active area of research.

Projections and harvest alternatives

For management purposes we use the yield projections estimated for reference Model AI_AE. We used the reference model (Model AI_AE) estimated fishery selectivity at age (Table 1A.18 and Fig. 1A.20) for all projections. Catchability in the projection was fixed at 1.0.

Reference fishing mortality rates and yields

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 (*max* F_{ABC}). The fishing mortality rate used to set ABC (F_{ABC}) may be less than or equal to this maximum permissible level. The overfishing and maximum allowable ABC fishing mortality rates are given in terms of percentages of unfished female spawning biomass ($F_{SPR\%}$), on fully selected age groups. The associated long-term average female spawning biomass that would be expected under average estimated recruitment from 1978-2006 for Model AI_AE (162 million age 2 fish) and F equal to $F_{40\%}$ and $F_{35\%}$ are denoted $B_{40\%}$ and $B_{35\%}$, respectively. The Tiers require reference point estimates for biomass level determinations. We present the following reference points for NRA pollock for Tier 3 of Amendment 56. For our analyses, we estimated the following values from the authors' choice model (Model AI_AE) and Model AI:

Female spawning biomass	Model AI_AE	Model AI
$B_{100\%}$	270,774 t	272,205 t
$B_{40\%}$	108,310 t	108,882 t
$B_{35\%}$	94,771 t	95,272 t
B_{2011}	80,867 t	84,819 t

Specification of OFL and Maximum Permissible ABC

For the reference model, Model AI_AE, the projected year 2011 female spawning biomass (SB_{11}) is estimated to be 80,867 t, below the $B_{40\%}$ value of 108,310 t placing NRA pollock in Tier 3b. The maximum permissible ABC and OFL values under Tier 3b are:

Model AI_AE Tier 3b:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2011 Projected yield (t)
max F_{ABC}	$F_{40\%}$	0.26	36,668 t
F_{OFL}	$F_{35\%}$	0.32	44,497 t

If the estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ were deemed not reliable, then under Tier 5 with new model estimated natural mortality of 0.20, the 2011 ABC would be 20,950 t (139,666 t x 0.75 x 0.20 = 20,950 t) and under Tier 5 with an assumed natural mortality of 0.3 the 2011 ABC would be 31,425 t.

ABC Considerations and Recommendation

ABC Considerations

There remains considerable uncertainty in the Aleutian Islands pollock assessment. We've noted some concerns below:

1) The level of interaction between the Aleutian stock and the Eastern Bering Sea stock is unknown. It is evident that some interaction does occur and that the abundance and composition of the eastern portion of the Aleutian Islands stock is highly confounded with that of the Eastern Bering Sea stock. Overestimation of the Aleutian Islands pollock stock productivity due to an influx of Eastern Bering Sea stock is a significant risk.

2) As assessed in the 2004 AI pollock stock assessment (Barbeaux et al. 2004), AIBT survey catchability is probably less than 1.0, but we have no data to concretely anchor the value at anywhere less than 1.0. We therefore employ a default value for catchability of 1.00. This provides a conservative total biomass estimate.

3) Recent AI bottom trawl surveys are highly uncertain with an average CV of 0.36. The 2002, 2004, 2006, and 2010 estimates of CV are 0.38, 0.78, 0.48, and 0.33 respectively. This results in considerable uncertainty in the projections.

4) The reference model suggests that currently a large proportion of the stock in the Aleutians is composed of much older fish (19% age 10+ by number) and make up a large proportion of the catch (58% age 10+ by weight). This is highly reliant on the estimated selectivity curves.

5) Aging error is a significant concern for this stock with aging comparisons for the 2006 through 2008 age data at between 20% and 47% agreement.

ABC Recommendations

The pollock spawning stock biomass in the NRA appears to be increasing slowly. The total biomass also appears to be increasing slowly. The estimated female spawning biomass projected for 2011 is 84,819 t. The projected total age 3+ biomass for 2011 is 241,698 t. The maximum permissible 2011 ABC based on F_{maxABC} = 0.26 is 36,668 t and OFL based on F_{OFL} = 0.32 is 44,497 t which is the authors recommended ABC and OFLs. Assuming a catch of 19,000 t in 2011 the 2012 authors' recommended ABC based on F_{maxABC} = 0.26 is 35,617 t and OFL based on F_{OFL} = 0.31 is 43,295 t. If the 2011 catch is only 1.09 t (i.e., equal to the five year average), the 2012 projected total age 2+ biomass would be 343,607 t, the female spawning biomass would be 87,115 t, the maximum permissible ABC would be 41,606 t and the 2012 OFL would be 50,438 t. In which case the 2010 F_{OFL} would be 0.32 and the max F_{ABC} would be 0.28.

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 eight 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).

For each scenario, the projections begin with the vector of 2010 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2011 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2010. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. 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 1000 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 2011, are as follows (a "*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2011 recommended in the assessment to the *max* F_{ABC} for 2011. (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 2006-2010 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 4: In all future years, F is set equal to $F_{75\%}$. (Rationale: This scenario represents a very conservative harvest rate and was requested by the Alaska Regional Office based on public comment.)

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 2010 or 2) above 1/2 of its MSY level in 2010 and above its MSY level in 2020 under this scenario, then the stock is not overfished.)

Scenario 7: In 2011 and 2012, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2023 under this scenario, then the stock is not approaching an overfished condition.)

The author included one more scenario in order to take into consideration the congressionally mandated TAC cap on pollock harvest from the Aleutian Islands area.

Scenario 8: In 2011 through 2023 the TAC is increased to 19,000 t or *max* F_{ABC} whichever is lower. (Rationale: 19,000 is the AI pollock cap set by Congressional mandate).

Projections and status determination

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2010:

a. If spawning biomass for 2010 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2010 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2010 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6. If the mean spawning biomass for 2020 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

a. If the mean spawning biomass for 2013 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2013 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2013 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2023. If the mean spawning biomass for 2023 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

The projected yields, female spawning biomass, and the associated fishing mortality rates for the eight harvest strategies for the reference model are shown in Table 1A.24. In Model AI_AE under a harvest strategy of $F_{40\%}$ (Scenario 1), female spawning biomass is projected to be below $B_{35\%}$ through 2014, be below $B_{40\%}$ through 2016, then be above $B_{40\%}$ for the remainder of the projection (Fig.1A.27 and Fig.1A.28). Female spawning biomass is projected be below $B_{35\%}$ when fishing at F_{OFL} (Fig.1A.29) through 2015 and remain below $B_{40\%}$ through the end of the projection for both Scenario 6 and Scenario 7. Please note again that the fishing mortality rates are prescribed on the basis of the harvest scenario and the spawning biomass in each year. Thus, fishing mortality rates may not be constant within the projection if spawning biomass drops below $B_{40\%}$ in any run.

The associated long-term average female spawning biomass that would be expected under average estimated recruitment from 1978-2008 (155.6 million age 2 fish) and $F = F_{35\%}$, denoted $B_{35\%}$ is estimated to be 95,272 t. This value ($B_{35\%}$), is used in the status determination criteria. Female spawning biomass for 2010 (79,680t) is projected to be above 1/2 $B_{35\%}$ thus, the NRA pollock stock is *above* its minimum stock size threshold (MSST) and is *not overfished*. Female spawning biomass for 2023 is projected to be above $B_{35\%}$ in scenario 7, and is expected to be above $B_{35\%}$ in 2020 in Scenario 6, therefore the NRA pollock stock is *not* expected to fall below its MSST in two years and is *not approaching an overfished condition*.

Projections under Scenario 8 (Fig.1A.30, Fig.1A.31, and Table 1A.24), show that the stock could support a constant catch of 19,000 t . Currently the stock is at $B_{30\%}$ and the long-term expected yield at $B_{40\%}$ is 62,698 t and at $B_{35\%}$.is 66,100 t, well above the 19,000 t cap.

The SSC asked that the probability of the spawning stock biomass being below $B_{20\%}$ in 2011 be computed for stocks in Tier 3b. We computed the number of standard deviations the 2011 spawning biomass (B_{2011}) was from $B_{20\%}$, assuming B_{2011} was normally distributed. B_{2011} is estimated in the stock assessment model (non-projected) to be at 83,561 t with a standard deviation of 10,400 t and $B_{20\%}$ is estimated at 54,441t, therefore B_{2011} is 2.8 standard deviations from $B_{20\%}$. Under the assumption of a normal error distribution there is a 0.27 % chance of the AI pollock stock currently being below $B_{20\%}$. Using the posterior distribution from an MCMC with 1,000,000 iterations thinned at 1000, B_{2011} is estimated to be at 69,968 t and the probability of being at or below $B_{20\%}$ was estimated at 0.012%. From the projection model B_{2011} is estimated to be at 84,819 t with a standard deviation of 18 t, under an assumption of a normal error distribution there is <<0.01% probability of being below $B_{20\%}$.

Ecosystem Considerations

Pollock is a commercially important species. It is also an important as prey to other fish, birds, and marine mammals, and has been the focus of substantial research in Alaskan ecosystems, especially in the Gulf of Alaska (GOA; Hollowed et al. 2000). To determine the ecosystem relationships of juvenile and adult pollock in the Aleutian Islands (AI), we first examined the diet data collected for pollock. Diet data are collected aboard NMFS bottom trawl surveys in the AI ecosystem during the summer (May – August). In the AI, a total of 1,458 pollock stomachs were collected between the 1991 and 1994 bottom trawl surveys (n=688 and 770, respectively) and used in this analysis. The diet compositions reported here reflect the size and spatial distribution of pollock in each survey (see Appendix A, "Diet calculations" for detailed methods from Barbeaux et al 2006). Juvenile pollock were defined as fish less than 20 cm in length, which roughly corresponds to 0 and 1 year old fish in the stock assessment, and adult pollock were defined as fish 20 cm in length or greater, roughly corresponding to age 2+ fish.

In the AI, pollock diet data reflects a closer connection with open oceanic environments than in either the Eastern Bering Sea (EBS) or the GOA. Similar to the other ecosystems, euphausiids and copepods together make up the largest proportion of AI adult pollock diet (29% and 19%, respectively); however, it is only in the AI that adult pollock rely on mesopelagic forage fish in the family Myctophidae for 24% of their diet, and AI juvenile pollock have a lower proportion of euphausiids and a higher proportion of gelatinous filter feeders than in the GOA or EBS (Fig.1A. 32, left panels). We took this diet composition information and convert it to broad ranges of tons consumed annually by pollock in the AI using the Sense routine (Aydin et al. 1997), which incorporates information on pollock consumption derived from the stock assessment (see Appendix A, "ration calculations" for detailed methods), as well as uncertainty in all other food web model parameters. As estimated by the Sense routine, AI adult pollock consumed between 100 and 900 thousand metric tons of euphausiids annually during the early 1990s, with similar ranges of myctophid and copepod consumption. Juvenile AI pollock consumed an additional estimated 100 to 900 thousand tons of copepods per year (Fig.1A.32, right panels).

Using diet data for all predators of pollock and consumption estimates for those predators, as well as fishery catch data, we next estimated the sources of pollock mortality in the AI. Sources of mortality were compared against the total production of pollock as estimated in the AI pollock stock assessment model. In the AI, integration of this single species information with predation within the food web model suggests that most adult pollock mortality was caused by the pollock trawl fishery during the early 1990s (48%; Fig.1A.33, left panels). (Fishery catch of pollock in the AI has subsequently declined to less than half the early 1990s catch by the late 1990s, and the directed fishery was closed in 1999 (Ianelli et al 2005). Therefore, AI pollock likely now experience predation mortality exceeding fishing mortality as in the EBS and GOA ecosystems.) The major predators of AI adult pollock are Pacific cod, Steller sea lions, pollock themselves, halibut, and skates. In the AI, juvenile pollock have a very different set of predators from adult pollock; Atka mackerel cause most juvenile pollock mortality (71%). Estimates of the tonnage of adult pollock consumed by predators from the Sense routines (Aydin et al.1997) ranged from 8 to 27 thousand tons consumed by cod annually during the early 1990s, while Atka mackerel were estimated to consume between 75 and 410 thousand tons of juvenile pollock annually in the AI ecosystem (Fig.1A.33 , right panels).

After reviewing the diet compositions and mortality sources of pollock in the AI, we shifted focus slightly to view pollock and the pollock fishery within the context of the larger AI food web. When viewed within the AI food web, the pollock trawl fishery (in red; Fig.1A.34) is a relatively high trophic level (TL) predator which interacts mostly with adult pollock, but also with many other species (in green; Fig. 1A.34). The diverse pollock fishery bycatch ranges from high TL predators such as salmon sharks, sleeper sharks, and arrowtooth flounder, to mid TL pelagic forage fish and squid, to low TL benthic invertebrates such as crabs and shrimp, but all of these catches represent extremely small flows. Because the pollock trawl fishery contributes significant fishery offal and discards back into each ecosystem, these flows to fishery detritus groups are represented as the only "predator consumption" flows from the fishery; the biomass of retained catch represents a permanent removal from the system.

In the AI food web model, we included detailed information on bycatch for each fishery. This data was collected in the early 1990s when the AI pollock fishery was much larger than it is at present. During the early 1990's, the pollock trawl fishery was extremely species-specific in the AI ecosystem, with pollock representing over 90% of its total catch by weight (Fig.1A. 35). No single bycatch species accounted for more than 1% of the catch. Although these catches are small in terms of percentage, the high volume pollock fisheries still account for the majority of bycatch of pelagic species in the BSAI management areas, including smelts, salmon sharks, and squids (Gaichas et al 2004).

The intended target of the pollock trawl fishery is also a very important prey species in the wider AI food web. When both adult and juvenile pollock food web relationships are included, over two thirds of all species groups turn out to be directly linked to pollock either as predators or prey in the food web model (Fig.1A.36). In the AI, the significant predators of pollock (blue boxes joined by blue lines) include halibut, cod, Alaska skates, Steller sea lions, and the pollock trawl fishery. Significant prey of pollock (green boxes joined by green lines) are myctophids, euphausiids, copepods, benthic shrimps, and amphipods, with juveniles preying on the euphausiids and copepods.

We investigated whether these differences in pollock diet, mortality, and relationships between the EBS and AI might suggest different ecosystem roles for pollock in these areas. We used the diet and mortality results integrated with information on uncertainty in the food web using the Sense routines (Aydin et al in review) and a perturbation analysis with each model food web to explore the ecosystem relationships of pollock further. Two questions are important in determining the ecosystem role of pollock: which species groups are pollock important to, and which species groups are important to pollock?

First, the importance of pollock to other groups within the AI ecosystem was assessed using a model simulation analysis where pollock survival was decreased (mortality was increased) by a small amount, 10%, over 30 years to determine the potential effects on other living groups. This analysis also incorporated the uncertainty in model parameters using the Sense routines, resulting in ranges of possible outcomes. Figure 1A.37 shows the resulting percent change in the biomass of each species after 30 for 50% of feasible ecosystems with 95% confidence intervals (error bars in Figure1A.37. Species showing the largest median changes from baseline conditions are presented in descending order from left to right. Therefore, the largest change resulting from a 10% decrease in pollock survival in both ecosystems is a decrease in adult pollock biomass, as might have been expected from such a perturbation. However, the decrease in pollock biomass resulting from the 10% survival reduction is uncertain in AI: the 50% intervals range from a 5-37% decrease in the AI (Fig.1A.37, upper panel). Along with the decrease in pollock biomass predicted in this simulation is a decrease in pollock fishery catch. The next largest median effect is on juvenile pollock, which are predicted to decrease in 50% of feasible ecosystems, but he 95% interval includes zero, suggesting that the decrease is uncertain. The simulation further suggests the possibility that herring, Atka mackerel, and other miscellaneous deepwater fish might increase slightly as a result of a decrease in pollock survival; however, for all of these species groups the 95% intervals cross zero, so the direction of change is uncertain. Therefore, this analysis suggests that in the AI ecosystem during the early 1990's, pollock were most important to themselves, and to the pollock fishery.

To determine which groups were most important to pollock in each ecosystem, we conducted the inverse of the analysis presented above. In this simulation, each species group in the ecosystem had survival reduced by 10% and the system was allowed to adjust over 30 years. The strongest median effects on AI adult pollock are presented in Fig. 1A.37 (lower panel). The largest effect on adult pollock was the reduction in biomass resulting from the reduced survival of juvenile pollock, although the 95% intervals include zero change, indicating considerable uncertainty in this result. (The same caution applies to the interpretation of all of the results of this simulation as all of the 95% intervals contain zero). It is interesting, however, that reduced survival of juvenile Atka mackerel had a larger median effect on adult pollock biomass than the direct effect of reduced adult pollock survival itself (Fig. 1A. 37, lower panel), and that the effect is positive. Adult Atka mackerel show the same pattern, which is likely explained by the amount of mortality caused by Atka mackerel on juvenile pollock in the AI food web model (see Fig. 1A.34, lower panels). Reduced survival of Atka mackerel adults or juveniles apparently relieves considerable mortality on juvenile pollock in this model, accounting for the increases in pollock biomass predicted (which is similar in magnitude to the increase predicted from reducing the pollock fishery catch by 10%). Although this result is uncertain, it does indicate an important interaction between two commercially important species in the AI ecosystem which might be further investigated.

Ecosystem effects on Aleutian Islands Walleye Pollock

The following ecosystem considerations are summarized in Table 1A.25.

Prey availability/abundance trends

Adult walleye pollock in the Aleutian Islands consume a variety of prey, primarily large zooplankton, copepods, and myctophids. Figure 1A.34 highlights the trophic level of pollock in relation to its prey and predators. No time series of information is available on Aleutian Islands for large zooplankton, copepod, or myctophid abundance.

Predator population trends

The abundance trend of Aleutian Islands Pacific cod is decreasing, and the trend for Aleutian Islands arrowtooth flounder is relatively stable. Northern fur seals and Steller sea lions west of 178°W longitude are showing declines, while Steller sea lions east of 178°W longitude have shown some slight increases. Declining trends in predator abundance could lead to possible decreases in walleye pollock mortality. The population trends of seabirds are mixed, some increases, some decreases, and others stable. Seabird population trends could affect young-of-the-year mortality.

Changes in habitat quality

The 2010 and 2006 Aleutian Islands summer bottom temperatures indicated that water temperatures were slightly cooler at shallower depths than 2004, but was otherwise an average year. Bottom temperatures could possibly affect fish distribution, but there have been no directed studies, and there is no time series of data which demonstrates the effects on Aleutian Islands walleye pollock.

AI pollock fishery effects on the ecosystem

AI pollock fishery contribution to bycatch

Prior to 1998, levels of bycatch in the pollock fishery of prohibited species, forage, HAPC biota, marine mammals and birds, and other sensitive non-target species was very low compared to other fisheries in the region. The AI pollock fishery opening in 2005 was limited to only four hauls, within these four hauls the bycatch level of POP was very high (~50%). Besides the lack of commercially harvestable levels of pollock, the high levels of POP bycatch convinced fishers to discontinue the fishery in 2005. The 2006 and 2007 AI pollock fisheries were conducted in conjunction with the AICASS, Pacific Ocean perch (POP) was the most substantial bycatch species and made up 3% of the catch in 2006 and 11% in 2007. The 2008 directed pollock fishery had an observed bycatch rate of 1% with 97% of this being POP. In

2009 there was no observer coverage of the directed fishery and in 2010 there was less than 1% bycatch in the directed fishery which caught less than 50 tons of pollock.

Concentration of AI pollock catches in time and space

Since no EFP is propose for 2011 there is expected to only be a very limited fishery in 2011. The only shore-based plant capable of processing the Aleutian Islands' pollock catch is currently in legal contention and it is not known at this time if the plant will be in operation for pollock in 2011, but seems unlikely.

AI pollock fishery effects on amount of large size walleye pollock

The AI pollock fishery in the Aleutian Islands was closed between 1999 and 2005. There was only a very limited fishery in 2005 (< 200t), 2006 (932 t), 2007 (1,300 t), 2008 (382 t), 2009 (400 t), and 2010 (50 t). Year to year differences observed in the previous decade can not be attributed to the fishery and must be attributed to natural fluctuations in recruitment. Fishers have indicated that the larger pollock in the Aleutian Islands will be targeted. But the low level of fishing mortality is not expected to greatly affect the size distribution of pollock in the AI.

AI pollock fishery contribution to discards and offal production

The 2011 Aleutian Islands pollock fishery, if pursued, is expected to be conducted by catcher vessels delivering unsorted catch to the processing plant in Adak, and therefore very little discard or offal production is expected from this fishery. Currently the plant is out of operation and therefore no fishery is expected.

AI Pollock fishery effects on AI pollock age-at-maturity and fecundity

The effects of the fishery on the age-at-maturity and fecundity of AI pollock are unknown. No studies on AI pollock age-at-maturity or fecundity have been conducted. Studies are needed to determine if there have been changes over time and whether changes could be attributed to the fishery. Little impact is expected if the fishery continues to be conducted in the limited capacity it has been over.

Data gaps and research priorities

Very little is known about the AI pollock stock structure and their relation to Western Bering Sea, Eastern Bering Sea, Gulf of Alaska, Bogoslof and Central Bering Sea pollock. Studies on the migration of pollock in the North Pacific should be explored in order to obtain an understanding of how the stocks relate spatially and temporally and how neighboring fisheries affect local abundances. Time series data sets on prey species abundance in the Aleutian Islands would be useful for a more clear understanding of ecosystem affects. Studies to determine the impacts of environmental indicators such as temperature regime on AI Aleutian pollock are needed. Currently, we rely on studies from the eastern Bering Sea and Gulf of Alaska for our estimates of life history parameters (e.g. maturity-at-age, fecundity, and natural mortality) for the NRA pollock. Studies specific to the NRA to determine whether there are any differences from the eastern Bering Sea and Gulf of Alaska stocks and whether there have been any changes in life history parameters over time would be informative.

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Literature Cited

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling, 298 p. NTIS No. PB2008-107111. At: http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-178.pdf

Bailey, K. M., T. J. Quinn, P., Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, Theragra chalcogramma. Advances in Marine Biology, 37, 179–255.

Barbeaux, S. J., and D. Fraser. 2009. Aleutian Islands cooperative acoustic survey study for 2006. U. S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-198, 91 p. http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-198.pdf

Barbeaux, S., J. Ianelli, S. Gaichas, and M. Wilkins. 2009. Aleutian Islands walleye pollock SAFE. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510., Section 1A

Barbeaux, S., J. Ianelli, S. Gaichas, and M. Wilkins. 2006. Aleutian Islands walleye pollock SAFE. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 1A

Barbeaux, S., J. Ianelli, E. Brown. 2004. Aleutian Islands walleye pollock SAFE. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 1A.

Barbeaux, S., J. Ianelli, E. Brown. 2003. Aleutian Islands walleye pollock SAFE. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 1A:839-888.

Dorn, M.W., K. Aydin, S. Barbeaux, M. Guttormsen, B. Megrey, K. Spalinger, and M. Wilkins. 2009. Assessment of the walleye pollock stock in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 1: 61-164

Dorn, M.W., S. Barbeaux, B, M. Guttormsen, B. Megrey, A. Hollowed, M. Wilkins, and K. Spalinger. 2003. Assessment of the walleye pollock stock in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 1: 61-164

Egan, T. 1988a. Foreign trawlers accused of violating U.S. zone. New York Times. 21 Jan 1988

Egan, T. 1988b. Japanese, Reacting to Allegations Of Illegal Fishing, Plan New Rules. New York Times. 5 Feb1988

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.

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.

Gaichas, S. D. Courtney, T. TenBrink, M. Nelson1, S. Lowe, J. Hoff, B. Matta, and J. Boldt. 2004. Bering Sea Aleutian Islands Squid and Other Species Stock Assessment. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 16: 927-1008

Grant, W. S., Spies, I. B., and Canino, M. F. 2006. Biogeographic evidence for selection on mitochondrial DNA in North Pacific walleye pollock Theragra chalcogramma. Journal of Heredity, 97: 571–580.

Grant, W. S., Spies, I., and Canino, M. F. 2010. Shifting-balance stock structure in North Pacific walleye pollock (*Gadus chalcogrammus*). – ICES Journal of Marine Science, 67: 1687–1696.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.

Hollowed, A. B., Bax, N., Beamish, R., Collie, J., Fogarty, M., Livingston, P., Pope, J., et al. 2000. Are multispecies models an improvement on single-species models for measuring fishing impacts on marine ecosystems? ICES Journal of Marine Science, 57: 707–719.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, S. Kotwicki, K. Aydin, and N. Williamson. 2009. 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 1:49-148.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, N. Williamson and G. Walters. 2005. 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 1:32-124.

Ianelli, J.N., S. Barbeaux, G. Walters, and N. Williamson. 2003. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2004. 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 1:39-126.

Ianelli, J.N., L. Fritz, T. Honkalehto, N. Williamson and G. Walters 1997. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 1998. *In*: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 1:1-79.

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.

Lowe, S., J.N. Ianelli, H. Zenger, K. and R Rueter 2002. Assessment of Aleutian Islands Atka Mackerel . In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 14:609-668

Lowe, S., J.N. Ianelli, M. Wilkins, K. Aydin, R. Lauth, and I. Spies. 2008. Assessment of Aleutian Islands Atka Mackerel . In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, P.O. Box 103136, Anchorage, AK 99510. Section 16:979-1054

Nishimura, A., T. Yanagimoto, Y. Takoa. 2002. Cruise results of the winter 2002 Bering Sea pollock survey (Kaiyo Maru), Document for the 2002 statistical meeting, Central Bering Sea Convention, September 2002. Available: Hokkaido National Fisheries Research Institute, Hokkaido, Japan

Ormseth, O. A., and Norcross, B. L. 2009. Causes and consequences of life-history variation in North American stocks of Pacific cod. – ICES Journal of Marine Science, 66: 349–357.

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

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., 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, P.O. Box 103136, Anchorage, AK 99510.Section 1:1-73.

Tables

Table 1A.1. Estimates of walleye pollock catches from the entire Aleutian Islands Region by source, 1977-2010. Units are in metric tons.

Year	Official Foreign & JV Blend	Domestic Blend	Foreign Reported	NMFS Observed Catch*	Total Best Estimates
1977	7,367		7,827	5	7,367
1978	6,283		6,283	234	6,283
1979	9,446		9,505	58	9,446
1980	58,157		58,477	883	58,157
1981	55,517		57,056	2,679	55,517
1982	57,753		62,624	11,847	57,753
1983	59,021		44,544	12,429	59,021
1984	77,595		67,103	48,538	77,595
1985	58,147		48,733	43,844	58,147
1986	45,439		14,392	29,464	45,439
1987	28,471			17,944	28,471
1988	41,203			21,987	41,203
1989	10,569			5,316	10,569
1990		79,025		59,935	79,025
1991		98,604		53,305	98,604
1992		52,352		36,581	52,352
1993		57,132		44,552	57,132
1994		58,659		43,430	58,659
1995		64,925		53,647	64,925
1996		29,062		23,482	29,062
1997		25,940		19,623	25,940
1998		23,822		21,032	23,822
1999		1,010		492	1,010
2000		1,244		573	1,244
2001		824		477	824
2002		1,156		519	1,156
2003		1,666		1,562	1,666
2004		1,158		1,074	1,158
2005		1,621		1,359	1,621
2006		1,745		540	1,745
2007		2,519		1,182	2,519
2008		1,278		995	1,278
2009		1,729		1,121	1,729
2010		1,238		1,231	1,238

*Extrapolated catch from observed fishing not a total catch estimate.

Table 1A.2. Estimates of Aleutian Islands Region walleye pollock catch by the three management sub-areas. Foreign reported data were used from 1977-1984, from 1985-2010 observer data were used to partition catches among the areas. Units are in metric tons.

Year	East 541	Central 542	West 543	Total		Year	East 541	Central 542	West 543	Total
1977	4,402	0	2,965	7,367		1994	58,091	554	15	58,659
1978	5,267	712	305	6,283		1995	28,109	36,714	102	64,925
1979	1,488	1,756	6,203	9,446		1996	9,226	19,574	261	29,062
1980	28,284	7,097	22,775	58,157		1997	8,110	16,799	1,031	25,940
1981	43,461	10,074	1,982	55,517		1998	1,837	3,858	18,127	23,822
1982	54,173	1,205	2,376	57,753		1999	484	420	105	1,010
1983	56,577	1,250	1,194	59,021		2000	615	461	169	1,244
1984	64,172	5,760	7,663	77,595		2001	332	386	105	824
1985	19,885	38,163	100	58,147		2002	842	180	133	1,156
1986	38,361	7,078	0	45,439		2003	577	760	329	1,666
1987	28,086	386	0	28,471		2004	397	513	248	1,158
1988	40,685	517	0	41,203		2005	689	415	517	1,621
1989	10,569	0	0	10,569		2006	1,036	488	220	1,745
1990	69,170	9,425	430	79,025		2007	1,919	476	124	2,519
1991	98,032	561	11	98,604		2008	872	290	116	1,278
1992	52,140	206	6	52,352		2009	1,086	400	243	1,729
1993	54,512	2,536	83	57,132		2010	737	369	132	1,238

Table 1A.3. Time series of ABC, TAC, and total catch for Aleutian Islands Region walleye pollock fisheries 1991-2010. Units are in metric tons. Note: There was no OFL level set in 1991 and the 1993 harvest specifications were not available

YEAR	ABC	TAC	OFL	CATCH	CATCH/TAC
1991	101,460	72,250	NA	98,604	136%
1992	51,600	47,730	62,400	52,352	110%
1993				57,132	
1994	56,600	56,600	60,400	58,659	104%
1995	56,600	56,600	60,400	64,925	115%
1996	35,600	35,600	47,000	29,062	82%
1997	28,000	28,000	38,000	25,940	93%
1998	23,800	23,800	31,700	23,822	100%
1999	23,800	2,000	31,700	1,010	51%
2000	23,800	2,000	31,700	1,244	62%
2001	23,800	2,000	31,700	824	41%
2002	23,800	1,000	31,700	1,156	116%
2003	39,400	1,000	52,600	1,666	167%
2004	39,400	1,000	52,600	1,158	116%
2005	29,400	19,000	39,100	1,621	9%
2006	29,400	19,000	39,100	1,745	9%
2007	44,500	19,000	54,500	2,519	13%
2008	28,160	19,000	34,040	1,278	7%
2009	26,873	19,000	32,553	1,729	9%
2010	33,100	19,000	40,000	1,238*	7%

* As of October 24, 2010

Table 1A.4. Estimated walleye pollock catch discarded and retained for the Aleutian Islands Region based on NMFS blend data, 1990-2010.

Year	Catch Retained	Discard	Total	Discard Percentage
1990	69,682	9,343	79,025	12%
1991	93,059	5,441	98,500	6%
1992	49,375	2,986	52,361	6%
1993	55,399	1,740	57,138	3%
1994	57,308	1,373	58,681	2%
1995	63,545	1,380	64,925	2%
1996	28,067	994	29,062	3%
1997	25,323	617	25,940	2%
1998	23,657	164	23,822	1%
1999	361	446	807	55%
2000	455	790	1,244	64%
2001	445	380	824	46%
2002	398	758	1,156	66%
2003	1,196	470	1,666	28%
2004	871	287	1,158	24%
2005	1,297	324	1,621	20%
2006	1,434	311	1,745	18%
2007	2,094	425	2,519	17%
2008	1,196	81	1,278	6%
2009	1,384	345	1,729	20%
2010	1,097	141	1,238	11%

Table 1A.5. Sampling levels in Aleutian Islands Region sub-regions based on foreign, J.V., and domestic walleye pollock observer data 1978 – 1998.

	NRA Area			Aleutian Islands Area Basin		
Year	Fish Measured	Hauls Sampled	Vessels Sampled	Fish Measured	Hauls Sampled	Vessels Sampled
1978	6,334	199	15	0	0	0
1979	2,294	49	10	0	0	0
1980	6,907	172	14	0	0	0
1981	11,399	133	21	1,913	15	3
1982	37,262	433	43	11,151	84	7
1983	27,770	277	39	20,744	174	21
1984	56,881	652	71	157,388	1,223	81
1985	34,251	268	39	68,923	460	58
1986	22,939	195	18	39,875	268	48
1987	47,138	378	34	2,665	26	8
1988	28,801	252	26	4,528	37	14
1989	7,424	57	8	0	0	0
1990	68,140	718	61	55	1	1
1991	26,035	212	33	24,025	194	26
1992	26,176	237	65	20,769	179	27
1993	26,735	267	49	22,022	185	30
1994	34,830	352	82	5,314	56	16
1995	32,033	536	65	1,922	19	7
1996	18,769	339	76	0	0	0
1997	17,303	311	59	77	1	1
1998	10,587	229	27	0	0	0
1999	135	6	4	0	0	0
2000	186	10	5	0	0	0
2001	119	6	3	0	0	0
2002	80	4	4	0	0	0
2003	544	23	7	0	0	0
2004	365	17	5	0	0	0
2005	569	25	9	0	0	0
2006	89	5	4	0	0	0
2007	1,160	31	11	0	0	0
2008	205	10	5	0	0	0
2009	694	31	11	0	0	0
2010	493	14	7	0	0	0
Total	554,647	6,448	930	381,371	2,922	348

Table 1A.6. Number of aged and measured fish in the NRA pollock fishery used to estimate fishery age composition. Shaded values were not used in assessment. Age data from the AICASS used in the model for 2006, 2007, and 2008 are in bold.

	Number Aged			Number Measured		
Year	Males	Females	Total	Males	Females	Total
1978	209	322	531	490	1,013	1,503
1979	124	178	302	611	706	1,317
1980	93	167	260	971	1,183	2,154
1981	124	152	276	2,226	2,556	4,782
1982	564	640	1,204	3,655	4,058	7,713
1983	132	145	277	1,493	1,484	2,977
1984	294	312	606	5,273	5,571	10,844
1985	210	265	475	349	431	780
1986	77	113	190	0	0	0
1987	131	142	273	1,670	2,375	4,045
1988	34	33	67	188	190	378
1989	0	0	0	0	0	0
1990	267	327	594	5,209	7,094	12,303
1991	178	183	361	0	0	80
1992	135	154	289	3,755	3,650	7,405
1993	85	90	175	7,701	5,770	13,471
1994	190	197	387	2,644	2,381	5,025
1995	171	214	385	16,518	12,552	29,070
1996	96	84	180	8,933	6,374	15,307
1997	36	34	70	9,232	8,007	17,239
1998	121	141	262	5,992	4,447	10,439
1999	0	0	0	75	60	135
2000	3	7	20	70	114	184
2001	12	7	19	52	106	158
2002	1	1	2	46	61	107
2003	33	27	60	0	0	0
2004	4	15	19	153	212	365
2005	9	21	30	309	260	569
2006	**150**/3	**183**/2	**333**/5	**1,315**/55	**1,630**/62	**2,945**/117
2007	**542**/70	**526**/84	**1,068**/154	**701**/523	**605**/636	**1,306**/1,159
2008	**366**/24	**359**/13	**725**/37	**1,142**/90	**1,031**/115	**2,173**/206
2009	54	41	95	364	330	694
2010*	32	21	53	286	207	493

*as of 24 October 2010

Table 1A.7. Estimates at catch-age composition from the Aleutian Islands commercial fishery, 1978-1998, and the Aleutian Islands cooperative acoustic surveys for 2006-2008.

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.000	0.016	0.099	0.052	0.329	0.088	0.096	0.114	0.107	0.069	0.016	0.009	0.001	0.004
1979	0.000	0.088	0.129	0.153	0.194	0.156	0.085	0.094	0.043	0.021	0.029	0.001	0.001	0.005
1980	0.038	0.038	0.061	0.116	0.236	0.181	0.149	0.067	0.077	0.022	0.007	0.002	0.006	0.001
1981	0.000	0.083	0.088	0.081	0.099	0.157	0.176	0.125	0.093	0.044	0.022	0.011	0.018	0.004
1982	0.000	0.001	0.523	0.101	0.046	0.062	0.092	0.082	0.044	0.020	0.012	0.008	0.005	0.004
1983	0.000	0.000	0.000	0.390	0.144	0.083	0.069	0.121	0.128	0.034	0.022	0.004	0.003	0.001
1984	0.001	0.023	0.000	0.063	0.287	0.146	0.185	0.124	0.084	0.061	0.014	0.008	0.005	0.001
1985	0.003	0.006	0.091	0.031	0.105	0.321	0.143	0.098	0.095	0.060	0.026	0.015	0.004	0.004
1986	0.000	0.047	0.004	0.106	0.025	0.116	0.320	0.159	0.066	0.087	0.049	0.014	0.002	0.004
1987	0.000	0.000	0.243	0.078	0.072	0.012	0.038	0.419	0.039	0.046	0.002	0.020	0.012	0.020
1988	0.000	0.000	0.000	0.045	0.104	0.142	0.049	0.113	0.367	0.068	0.023	0.034	0.015	0.041
1991	0.000	0.000	0.014	0.011	0.071	0.105	0.048	0.092	0.013	0.066	0.054	0.199	0.106	0.222
1992	0.000	0.000	0.000	0.000	0.048	0.032	0.042	0.014	0.068	0.000	0.133	0.114	0.269	0.279
1993	0.000	0.000	0.027	0.064	0.105	0.066	0.038	0.107	0.016	0.067	0.035	0.045	0.078	0.352
1994	0.000	0.000	0.010	0.199	0.061	0.099	0.094	0.094	0.056	0.026	0.067	0.024	0.025	0.245
1995	0.000	0.004	0.012	0.000	0.230	0.021	0.136	0.119	0.027	0.070	0.045	0.091	0.021	0.225
1996	0.000	0.000	0.009	0.039	0.057	0.306	0.102	0.120	0.074	0.078	0.032	0.010	0.051	0.123
1998	0.000	0.003	0.005	0.275	0.087	0.053	0.048	0.073	0.067	0.048	0.140	0.058	0.078	0.067
2006	0.000	0.006	0.000	0.025	0.335	0.151	0.031	0.012	0.049	0.055	0.046	0.034	0.099	0.157
2007	0.000	0.006	0.014	0.010	0.052	0.278	0.252	0.076	0.041	0.038	0.058	0.024	0.037	0.116
2008	0.000	0.002	0.007	0.010	0.021	0.040	0.197	0.206	0.109	0.023	0.074	0.073	0.066	0.174

Table 1A.8. NRA pollock fishery average weight-at-age in kilograms used in reference model. Shaded cells had missing observations and were filled with their mean values

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.047	0.404	0.794	0.709	0.837	0.965	0.984	1.060	0.977	1.101	1.320	1.271	0.726	0.469
1979	0.047	0.378	0.515	0.766	0.635	0.789	0.938	0.898	1.024	1.179	1.103	1.052	0.656	0.646
1980	0.159	0.607	0.807	0.896	0.892	0.935	1.026	1.098	1.071	1.036	1.052	0.467	0.418	0.606
1981	0.189	0.425	0.565	0.649	0.696	0.707	0.750	0.832	0.901	0.825	1.016	0.975	0.767	0.415
1982	0.189	0.277	0.564	0.645	0.653	0.695	0.742	0.785	0.885	0.875	0.856	0.900	0.806	0.856
1983	0.189	0.368	0.596	0.676	0.623	0.713	0.812	0.814	0.831	0.862	0.812	0.596	0.643	0.492
1984	0.186	0.321	0.596	0.522	0.608	0.647	0.723	0.751	0.766	0.782	0.845	0.860	0.843	0.417
1985	0.363	0.494	0.630	0.597	0.679	0.717	0.711	0.798	0.817	0.803	0.945	0.950	1.089	0.973
1986	0.189	0.536	0.494	0.647	0.658	0.702	0.768	0.767	0.853	0.783	0.879	0.779	0.490	0.386
1987	0.189	0.368	0.717	0.748	0.831	0.501	0.799	0.966	1.117	1.000	1.075	1.165	0.994	1.079
1988	0.189	0.368	0.596	0.641	0.749	0.815	0.650	0.819	0.942	0.769	0.365	0.485	0.329	0.619
1989	0.189	0.368	0.596	0.719	0.834	0.906	0.954	0.995	1.006	1.072	1.085	0.994	0.956	0.890
1990	0.189	0.368	0.596	0.719	0.834	0.906	0.954	0.995	1.006	1.072	1.085	0.994	0.956	0.890
1991	0.189	0.368	0.657	0.634	0.734	0.791	1.014	0.957	0.866	1.188	1.137	1.060	1.088	1.012
1992	0.189	0.368	0.596	0.719	0.739	0.999	1.081	0.661	0.408	1.072	1.389	1.188	1.262	1.159
1993	0.189	0.368	0.790	0.937	1.130	1.244	1.089	1.166	0.925	1.246	1.231	1.233	1.145	1.151
1994	0.189	0.368	0.584	0.831	0.970	1.156	1.120	1.116	1.189	1.388	1.228	1.080	1.047	1.178
1995	0.189	0.484	0.558	0.719	1.185	1.237	1.428	1.398	1.194	1.458	1.460	1.504	1.576	1.331
1996	0.189	0.368	0.360	0.738	1.081	1.251	1.209	1.385	1.531	1.211	1.296	0.901	1.460	1.303
1997	0.189	0.309	0.421	0.775	1.072	1.200	1.165	1.340	1.451	1.332	1.303	1.106	1.430	1.374
1998	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
1999	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
2000	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
2001	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
2002	0.189	0.390	0.638	1.416	1.487	1.524	1.769	1.305	1.961	2.156	2.157	2.089	2.091	1.739
2003	0.189	0.390	0.638	1.416	1.487	1.524	1.769	1.305	1.961	2.156	2.157	2.089	2.091	1.739
2004	0.189	0.390	0.638	1.416	1.487	1.524	1.769	1.305	1.961	2.156	2.157	2.089	2.091	1.739
2005	0.189	0.390	0.638	1.416	1.487	1.524	1.769	1.305	1.961	2.156	2.157	2.089	2.091	1.739
2006	0.189	0.390	0.638	1.416	1.487	1.524	1.769	1.305	1.961	2.156	2.157	2.089	2.091	1.739
2007	0.189	0.405	0.628	0.914	1.329	1.681	1.653	1.770	1.685	2.053	2.013	1.889	1.927	1.731
2008	0.189	0.430	0.648	0.930	1.099	1.802	1.873	1.836	1.714	1.938	2.040	2.014	1.950	1.803
2009	0.189	0.430	0.648	0.930	1.099	1.802	1.873	1.836	1.714	1.938	2.040	2.014	1.950	1.803
2010	0.189	0.430	0.648	0.930	1.099	1.802	1.873	1.836	1.714	1.938	2.040	2.014	1.950	1.803

Table 1A.9. Pollock biomass estimates from the Aleutian Islands Groundfish Survey, 1980-2010.

	Eastern Area 541	Central Area 542	Western Area 543	Unalaska-Umnak Area (~165W-170W)	NRA 170W - 170E
1980	80,242	180,227	6,890	56,732	243,695
1983	165,681	186,690	118,234	282,648	495,775
1986	212,608	175,886	55,732	102,379	439,461
1991	60,632	50,065	26,701	51,644	137,202
1994	37,355	27,174	13,683	39,696	77,502
1997	38,541	36,764	18,207	65,400	97,512
2000	56,084	42,969	6,547	22,462	105,598
2002	54,634	108,244	12,442	181,334	175,283
2004	112,040	11,627	6,605	235,658	130,451
2006	69,996	18,482	6,514	18,006	94,993
2010	103,748	28,108	7,810	106,194	139,666

Table 1A.10. Aleutian Islands bottom trawl survey pollock proportion-at-age used in reference model. Shaded cells the highest proportion for the year.

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1991	0.067	0.092	0.215	0.110	0.037	0.054	0.034	0.091	0.040	0.057	0.024	0.077	0.052	0.051
1994	0.016	0.083	0.154	0.195	0.084	0.060	0.044	0.020	0.046	0.037	0.026	0.004	0.010	0.016
1997	0.023	0.030	0.084	0.115	0.093	0.090	0.184	0.124	0.050	0.057	0.037	0.033	0.019	0.039
2000	0.010	0.041	0.109	0.122	0.107	0.099	0.073	0.036	0.043	0.082	0.034	0.031	0.031	0.019
2002	0.034	0.106	0.152	0.106	0.134	0.118	0.079	0.058	0.042	0.044	0.029	0.038	0.016	0.036
2004	0.003	0.048	0.245	0.128	0.100	0.050	0.082	0.057	0.031	0.048	0.061	0.033	0.039	0.041
2006	0.005	0.046	0.059	0.087	0.209	0.125	0.081	0.027	0.046	0.041	0.040	0.042	0.062	0.050

Table 1A.11. Aleutian Islands bottom trawl survey pollock average weight-at-age in kilograms used in reference model, shaded cells are averaged from surrounding years.

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.307	0.492	0.646	0.764	0.848	0.907	0.948	0.975	0.993	1.006	1.014	1.019	1.023	1.025
1979	0.307	0.492	0.646	0.764	0.848	0.907	0.948	0.975	0.993	1.006	1.014	1.019	1.023	1.025
1980	0.307	0.492	0.646	0.764	0.848	0.907	0.948	0.975	0.993	1.006	1.014	1.019	1.023	1.025
1981	0.248	0.433	0.597	0.728	0.826	0.897	0.947	0.982	1.006	1.022	1.033	1.041	1.046	1.050
1982	0.248	0.433	0.597	0.728	0.826	0.897	0.947	0.982	1.006	1.022	1.033	1.041	1.046	1.050
1983	0.190	0.374	0.548	0.693	0.805	0.887	0.947	0.989	1.018	1.039	1.053	1.063	1.069	1.074
1984	0.214	0.399	0.571	0.711	0.817	0.896	0.952	0.991	1.018	1.037	1.050	1.059	1.065	1.069
1985	0.214	0.399	0.571	0.711	0.817	0.896	0.952	0.991	1.018	1.037	1.050	1.059	1.065	1.069
1986	0.239	0.425	0.593	0.728	0.830	0.904	0.956	0.993	1.018	1.035	1.047	1.055	1.061	1.065
1987	0.232	0.456	0.665	0.767	0.894	0.973	1.020	1.067	1.117	1.141	1.088	1.107	1.110	1.090
1988	0.232	0.456	0.665	0.767	0.894	0.973	1.020	1.067	1.117	1.141	1.088	1.107	1.110	1.090
1989	0.232	0.456	0.665	0.767	0.894	0.973	1.020	1.067	1.117	1.141	1.088	1.107	1.110	1.090
1990	0.232	0.456	0.665	0.767	0.894	0.973	1.020	1.067	1.117	1.141	1.088	1.107	1.110	1.090
1991	0.224	0.505	0.690	0.787	1.015	1.154	1.259	1.205	1.268	1.208	1.156	1.118	1.156	1.098
1992	0.212	0.511	0.778	0.891	1.076	1.220	1.249	1.326	1.356	1.317	1.349	1.329	1.346	1.223
1993	0.212	0.511	0.778	0.891	1.076	1.220	1.249	1.326	1.356	1.317	1.349	1.329	1.346	1.223
1994	0.199	0.517	0.866	0.995	1.138	1.286	1.238	1.446	1.443	1.426	1.542	1.540	1.537	1.349
1995	0.224	0.476	0.823	0.971	1.067	1.238	1.264	1.379	1.440	1.450	1.531	1.525	1.567	1.474
1996	0.224	0.476	0.823	0.971	1.067	1.238	1.264	1.379	1.440	1.450	1.531	1.525	1.567	1.474
1997	0.249	0.435	0.779	0.948	0.996	1.190	1.291	1.311	1.438	1.473	1.519	1.510	1.596	1.599
1998	0.208	0.473	0.774	0.919	0.949	1.168	1.275	1.314	1.425	1.497	1.616	1.591	1.533	1.649
1999	0.208	0.473	0.774	0.919	0.949	1.168	1.275	1.314	1.425	1.497	1.616	1.591	1.533	1.649
2000	0.166	0.512	0.769	0.890	0.903	1.146	1.260	1.317	1.412	1.522	1.713	1.673	1.469	1.698
2001	0.189	0.490	0.737	1.021	1.033	1.234	1.288	1.426	1.532	1.564	1.736	1.681	1.576	1.671
2002	0.212	0.469	0.705	1.152	1.164	1.323	1.315	1.534	1.652	1.605	1.758	1.689	1.683	1.643
2003	0.212	0.469	0.705	1.152	1.164	1.323	1.315	1.534	1.652	1.605	1.758	1.689	1.683	1.643
2004	0.234	0.494	0.788	0.906	1.015	1.251	1.215	1.499	1.526	1.696	1.627	1.643	1.546	0.870
2005	0.234	0.494	0.788	0.906	1.015	1.251	1.215	1.499	1.526	1.696	1.627	1.643	1.546	0.934
2006	0.171	0.486	0.667	0.950	1.205	1.294	1.396	1.572	1.930	2.052	1.955	2.030	1.936	1.970
2007	0.171	0.486	0.667	0.950	1.205	1.294	1.396	1.572	1.930	2.052	1.955	2.030	1.936	1.970
2008	0.171	0.486	0.667	0.950	1.205	1.294	1.396	1.572	1.930	2.052	1.955	2.030	1.936	1.970
2009	0.171	0.486	0.667	0.950	1.205	1.294	1.396	1.572	1.930	2.052	1.955	2.030	1.936	1.970
2010	0.171	0.486	0.667	0.950	1.205	1.294	1.396	1.572	1.930	2.052	1.955	2.030	1.936	1.970

Table 1A.12. Estimated instantaneous natural mortality rates (M) by age from Wespestad and Terry (1984).

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
M	0.85	0.45	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6

Table 1A.13. Estimated von Bertalanffy growth curve parameters and length-weight regression parameters for walleye pollock sampled during the U.S.-Japan 1980, 1983, and 1986 groundfish surveys and the 1991, 1994, 1997, 2000, 2002, and 2006 RACE groundfish surveys.

	L_{inf}	K	t_0	A	b
1980	51.92	0.414	-0.525	0.0132	2.858
1983	53.26	0.383	0.002	0.0178	2.768
1986	51.02	0.443	-0.084	0.0142	2.831
1991	54.55	0.392	-0.361	0.0104	2.912
1994	61.58	0.330	-0.102	0.0069	3.022
1997	61.41	0.286	-0.397	0.0081	2.983
2000	62.58	0.306	-0.048	0.0064	3.019
2002	64.36	0.289	-0.127	0.0066	3.018
2004	61.76	0.332	-0.189	0.0065	3.022
2006	64.45	0.271	-0.278	0.0000075	2.991

Table 1A.14. Percentage mature females at age from Wespestad and Terry (1984) for the BSAI and mean percentage of mature females at age for the Gulf of Alaska from Dorn et al (2007) for 1983-2006 (GOA).

Age	1	2	3	4	5	6	7	8	9	10	11	12	13-15
BSAI	0.0	0.8	28.9	64.1	84.2	90.1	94.7	96.3	97.0	97.8	98.4	99.0	100
GOA	0.0	0.1	2.1	26.9	56.5	81.3	89.9	95.9	98.4	99.0	100	100	100

Table 1A.15. Aging error matrix used in the reference model, Model AI_AE developed from aging validation tests for 2006-2008.

Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2	0.974	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.039	0.922	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.054	0.893	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.069	0.862	0.069	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.085	0.830	0.085	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.101	0.799	0.101	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.116	0.768	0.116	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.131	0.738	0.131	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.144	0.710	0.144	0.001	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.157	0.683	0.157	0.001	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.169	0.658	0.169	0.002	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.180	0.634	0.180	0.003
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.190	0.611	0.195
15+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.199	0.795

Table 1A.16. Comparisons of fits for the evaluations of Aleutian Islands pollock models.

	Model AI	Model AI_AE
Number of Parameters	103	103
Survey Catchability	1.00	1.00
Fishery Average Effective N	40.90	40.39
Survey Average Effective N	92.86	99.83
RMSE Survey	1.09	1.07
-Log Likelihoods		
Survey Index	42.12	41.01
Fishery Age Comp	470.30	442.44
Survey Age Comp	51.38	48.61
Catch	1.23	1.14
Sub Total	565.02	533.21
-log Penalties		
Recruitment	55.76	62.55
Selectivity Constraint	24.78	22.80
Prior	0.00	1.42E-05
Fpen	0.00	0.00116
Total	645.56	618.57

Table 1A.17. Key results for the evaluations of Aleutian Islands pollock models.

	Model AI	Model AI_AE
Model Conditions		
Survey Catchability	1	1
Natural Mortality	0.21	0.20
Fishing Mortalities		
Max F 1978 - 2010	0.27	0.28
F 2010	0.00	0.00
Stock Abundance		
Initial Biomass (1978; thousands of tons)	814.08	767.97
CV	9%	9%
2010 Total Biomass (thousands of tons)	281.81	258.78
CV	15%	14%
2010 Age 3+ biomass (thousands of tons)	261.26	241.51
1978 Year Class (at age 2)	1.57	1.75
CV	11%	11%
Recruitment Variability	0.92	0.96
Specified Sigma R	0.60	0.60
Steepness (h)	0.70	0.70
Projected Catch (unadjusted)		
F50% 2010 catch	0.17	0.15
CV	8%	8%
F40% 2010 catch	0.26	0.24
CV	8%	8%
F35% 2010 catch	0.32	0.30
CV	8%	9%

Table 1A.18 Estimates of 2010 fishery, and survey selectivity-at-age.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Model AI_AE	0.008	0.047	0.230	0.351	0.427	0.570	0.787	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010 Fishery	0.008	0.047	0.230	0.351	0.427	0.570	0.787	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Survey	0.080	0.226	0.460	0.649	0.780	0.822	0.898	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Model AI	0.007	0.044	0.221	0.329	0.418	0.548	0.729	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010 Fishery	0.007	0.044	0.221	0.329	0.418	0.548	0.729	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Survey	0.073	0.209	0.435	0.599	0.718	0.771	0.872	1.00	1.00	1.00	1.00	1.00	10.0	1.00

Table 1A.19. The reference Model AI_AE estimates of pollock biomass with approximate lower (LCI) and upper (UCI) 95% confidence bounds for age 2+ biomass. Also included are the age 3+ biomass and female spawning stock biomass (SSB) estimates.

Model 2	Total Biomass (Age 2+)			Biomass	Female
Year		LCI	UCI	Age 3+	SSB
1978	767,970	636,104	899,836	713,160	208,620
1979	850,470	710,662	990,278	799,853	248,760
1980	1,212,800	1,010,640	1,414,960	862,360	279,730
1981	1,366,300	1,135,660	1,596,940	1,353,166	287,840
1982	1,459,700	1,222,240	1,697,160	1,448,657	373,650
1983	1,469,000	1,236,820	1,701,180	1,409,982	469,520
1984	1,402,000	1,189,440	1,614,560	1,377,106	520,070
1985	1,347,100	1,151,326	1,542,874	1,264,543	495,690
1986	1,248,300	1,075,280	1,421,320	1,230,485	462,140
1987	1,171,400	1,022,358	1,320,442	1,148,083	444,500
1988	1,094,900	968,624	1,221,176	1,063,328	421,630
1989	984,440	879,332	1,089,548	960,221	389,410
1990	915,510	829,468	1,001,552	902,416	356,860
1991	767,570	695,348	839,792	731,399	286,340
1992	591,940	531,720	652,160	582,729	215,650
1993	492,310	440,370	544,250	482,860	178,060
1994	403,230	357,318	449,142	393,607	146,980
1995	327,010	283,604	370,416	309,739	116,120
1996	255,560	214,374	296,746	250,333	88,107
1997	224,610	183,710	265,510	214,723	76,131
1998	198,740	157,588	239,892	189,312	66,295
1999	174,020	133,250	214,790	168,870	59,827
2000	177,450	136,614	218,286	169,018	62,353
2001	187,510	144,496	230,524	171,530	64,141
2002	213,080	163,354	262,806	186,926	65,039
2003	228,650	174,674	282,626	223,149	67,823
2004	235,100	179,162	291,038	231,014	76,207
2005	233,890	178,178	289,602	228,693	85,045
2006	227,470	173,458	281,482	220,892	88,817
2007	223,000	170,440	275,560	212,510	86,498
2008	224,130	170,894	277,366	209,715	82,540
2009	233,070	175,292	290,848	216,883	79,689
2010	246,830	180,636	313,024	230,312	79,680

Table 1A.20. Reference Model AI_AE estimated pollock numbers at age in millions, 1978-2009.

M 2	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% 15+
1978	274	220	227	131	138	32	35	21	17	10	4	3	2	21	1,136	1.9%
1979	253	224	180	184	106	111	26	28	17	13	8	3	2	19	1,175	1.6%
1980	1752	207	183	146	149	85	89	21	22	13	10	6	3	17	2,702	0.6%
1981	66	1431	168	143	111	112	62	62	14	15	9	7	4	13	2,216	0.6%
1982	55	54	1164	133	112	86	85	46	45	10	11	6	5	12	1,825	0.7%
1983	295	45	44	921	104	86	65	62	33	32	7	8	5	12	1,719	0.7%
1984	125	241	37	35	725	81	66	49	46	24	23	5	6	12	1,475	0.8%
1985	413	102	196	29	27	562	62	49	35	33	17	17	4	13	1,560	0.8%
1986	89	337	83	156	23	21	430	46	36	26	24	13	12	12	1,308	0.9%
1987	117	73	275	67	125	18	17	336	35	28	20	19	10	19	1,157	1.6%
1988	158	95	60	222	54	100	14	13	261	28	21	15	14	22	1,079	2.1%
1989	121	129	78	48	176	42	78	11	10	194	21	16	11	27	962	2.8%
1990	65	99	106	63	39	142	34	62	9	8	155	16	13	31	842	3.7%
1991	181	53	80	82	48	29	103	24	41	6	5	103	11	29	796	3.6%
1992	46	148	43	61	60	34	20	65	14	24	3	3	60	23	604	3.9%
1993	47	38	119	33	46	44	24	13	42	9	16	2	2	54	490	11.0%
1994	48	39	30	92	25	33	31	16	8	26	6	10	1	35	401	8.8%
1995	86	39	31	23	67	18	23	20	10	5	16	3	6	21	367	5.9%
1996	26	70	31	23	16	46	11	13	11	5	3	8	2	15	282	5.3%
1997	49	21	57	24	17	12	32	8	8	7	3	2	5	10	257	4.1%
1998	47	40	17	44	18	13	8	22	5	5	4	2	1	10	237	4.2%
1999	26	38	33	13	33	13	9	6	13	3	3	3	1	7	200	3.4%
2000	42	21	31	27	11	26	11	7	4	11	2	3	2	7	205	3.2%
2001	80	34	17	26	22	9	21	9	6	4	9	2	2	7	247	2.8%
2002	131	65	28	14	21	18	7	17	7	5	3	7	2	7	332	2.2%
2003	28	107	53	23	11	17	14	6	14	6	4	2	6	7	298	2.4%
2004	20	23	87	44	19	9	14	12	5	11	5	3	2	10	263	4.0%
2005	26	17	18	71	36	15	8	11	9	4	9	4	2	10	241	4.2%
2006	33	21	14	15	58	29	12	6	9	8	3	7	3	10	229	4.4%
2007	52	27	17	11	12	47	24	10	5	7	6	2	6	11	239	4.5%
2008	72	43	22	14	9	10	38	19	8	4	6	5	2	13	266	5.1%
2009	81	59	35	18	12	7	8	31	15	7	3	5	4	13	298	4.2%
2010	83	66	48	29	15	9	6	7	25	12	5	3	4	13	325	4.1%

Table 1A.21. Reference Model Estimated NRA region pollock catch at age (millions).

Model10AE	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1978	0.06	0.27	1.36	1.19	1.52	0.48	0.72	0.54	0.43	0.26	0.11	0.08	0.06	0.55	7.63
1979	0.07	0.4	1.54	2.4	1.68	2.34	0.75	1.03	0.61	0.49	0.29	0.12	0.09	0.69	12.50
1980	2.46	1.76	7.46	8.93	11	8.32	11.73	3.39	3.63	2.15	1.71	1.04	0.42	2.76	66.76
1981	0.06	7.39	4.17	5.38	5.05	6.74	5.12	6.41	1.42	1.53	0.91	0.72	0.44	1.34	46.68
1982	0.05	0.32	33.51	5.8	5.89	6	8.08	5.49	5.34	1.19	1.27	0.75	0.6	1.48	75.77
1983	0.23	0.21	1	31.8	4.34	4.78	4.93	5.93	3.12	3.04	0.68	0.72	0.43	1.18	62.39
1984	0.11	1.28	0.93	1.34	33.79	5.01	5.58	5.15	4.83	2.54	2.47	0.55	0.59	1.31	65.48
1985	0.34	0.52	4.79	1.07	1.22	33.34	4.99	4.99	3.58	3.35	1.76	1.72	0.38	1.32	63.37
1986	0.04	0.85	1.01	2.89	0.51	0.63	17.64	2.38	1.85	1.33	1.24	0.65	0.64	0.63	32.29
1987	0.04	0.16	2.86	1.05	2.39	0.46	0.59	14.86	1.57	1.22	0.87	0.82	0.43	0.84	28.16
1988	0.1	0.38	1.16	6.57	1.92	4.76	0.94	1.08	21.34	2.26	1.75	1.26	1.18	1.82	46.52
1989	0.02	0.14	0.4	0.38	1.69	0.54	1.37	0.25	0.22	4.35	0.46	0.36	0.26	0.61	11.05
1990	0.1	0.88	4.48	4.03	2.98	14.46	4.67	10.62	1.5	1.33	26.46	2.8	2.17	5.27	81.75
1991	0.42	0.76	5.39	8.26	5.79	4.56	21.78	6.11	10.7	1.51	1.34	26.65	2.82	7.49	103.58
1992	0.08	1.48	2.07	4.38	5.2	3.89	3.01	12.44	2.64	4.63	0.65	0.58	11.53	4.46	57.04
1993	0.09	0.42	6.39	2.68	4.42	5.62	4.15	2.8	8.87	1.89	3.3	0.46	0.41	11.41	52.91
1994	0.11	0.54	2.02	9.1	2.96	5.2	6.47	4.13	2.13	6.75	1.43	2.51	0.35	8.99	52.69
1995	0.25	0.68	2.55	2.81	9.77	3.36	5.7	6.04	2.92	1.51	4.77	1.01	1.78	6.61	49.76
1996	0.05	0.77	1.64	1.8	1.53	5.66	1.9	2.75	2.19	1.06	0.55	1.73	0.37	3.04	25.04
1997	0.09	0.24	3.04	1.95	1.67	1.52	5.53	1.61	1.79	1.42	0.69	0.36	1.12	2.21	23.24
1998	0.09	0.47	0.96	3.65	1.82	1.66	1.49	4.71	1.05	1.16	0.93	0.45	0.23	2.17	20.84
1999	0	0.02	0.09	0.05	0.16	0.09	0.08	0.06	0.15	0.03	0.04	0.03	0.01	0.08	0.89
2000	0	0.01	0.1	0.12	0.06	0.2	0.11	0.1	0.06	0.14	0.03	0.04	0.03	0.09	1.09
2001	0.01	0.01	0.03	0.08	0.08	0.04	0.15	0.07	0.05	0.03	0.08	0.02	0.02	0.06	0.73
2002	0.01	0.03	0.06	0.04	0.08	0.09	0.05	0.15	0.06	0.04	0.03	0.06	0.01	0.06	0.77
2003	0	0.06	0.14	0.09	0.05	0.11	0.13	0.06	0.16	0.06	0.04	0.03	0.06	0.08	1.07
2004	0	0.01	0.14	0.11	0.06	0.04	0.08	0.08	0.03	0.08	0.03	0.02	0.01	0.08	0.77
2005	0	0.01	0.04	0.23	0.14	0.08	0.05	0.1	0.09	0.03	0.08	0.03	0.02	0.09	0.99
2006	0	0.01	0.03	0.05	0.24	0.16	0.1	0.06	0.09	0.07	0.03	0.07	0.03	0.1	1.04
2007	0.01	0.02	0.06	0.06	0.07	0.38	0.26	0.14	0.07	0.1	0.09	0.04	0.09	0.15	1.54
2008	0	0.01	0.03	0.03	0.03	0.04	0.21	0.13	0.06	0.03	0.04	0.03	0.01	0.09	0.74
2009	0.01	0.03	0.08	0.06	0.05	0.04	0.06	0.3	0.15	0.06	0.03	0.05	0.04	0.12	1.08
2010	0	0.02	0.07	0.06	0.04	0.03	0.03	0.04	0.16	0.08	0.03	0.02	0.02	0.09	0.69

Table 1A.22. Reference Model AI_AE estimates of full-selection fishing mortality and exploitation rates for NRA pollock.

Model 2		Catch/Biomass
Year	F[a]	Rate[b]
1978	0.029	0.001
1979	0.041	0.009
1980	0.200	0.025
1981	0.121	0.011
1982	0.140	0.002
1983	0.111	0.001
1984	0.124	0.007
1985	0.119	0.001
1986	0.059	0.001
1987	0.050	0.002
1988	0.094	0.001
1989	0.025	0.000
1990	0.208	0.011
1991	0.334	0.001
1992	0.236	0.014
1993	0.264	0.033
1994	0.330	0.015
1995	0.411	0.178
1996	0.256	0.091
1997	0.264	0.115
1998	0.275	0.117
1999	0.013	0.004
2000	0.015	0.005
2001	0.010	0.003
2002	0.010	0.002
2003	0.012	0.006
2004	0.008	0.007
2005	0.010	0.007
2006	0.011	0.008
2007	0.016	0.011
2008	0.008	0.005
2009	0.011	0.007
2010	0.007	0.000

[a] Average fishing mortality rates over all ages
[b] Catch/biomass rate is the ratio of catch to beginning year age 3+ biomass.

Table 1A.23. Reference Model AI_AE estimates of age-2 pollock recruitment (in millions).

Year	Index at age 2	Year	Index at age 2
1978	274.1	1996	26.1
1979	253.1	1997	49.4
1980	1752.4	1998	47.1
1981	65.7	1999	25.8
1982	55.0	2000	42.2
1983	295.2	2001	79.9
1984	124.6	2002	130.8
1985	412.9	2003	27.5
1986	89.3	2004	20.4
1987	116.6	2005	26.0
1988	158.1	2006	32.9
1989	121.1	2007	52.5
1990	65.5	2008	72.1
1991	180.9	2009	80.9
1992	46.1	2010	82.6
1993	47.3		
1994	48.1	Ave 78-08	178.2
1995	86.3	Med 78-08	83.1

Table 1A.24. Projections of Model AI_AE female spawning biomass (in thousands of t), *F*, and catch (in thousands of t) for NRA pollock for the 8 scenarios. Fishing mortality rates given are based on the *average* fishing mortality over all ages *(B_0=270.77 kt, B_{40}=108.31 kt, B_{35}=94.77 kt, and ½ B_{35}=47.39 kt).*

Sp.Biomass	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2010	79.68	79.68	79.68	79.68	79.68	79.68	79.68	79.68
2011	80.87	80.87	83.50	81.98	83.57	80.23	80.87	82.23
2012	74.72	74.72	90.03	80.73	90.52	71.53	74.72	82.11
2013	77.94	77.94	102.56	86.69	103.43	73.71	77.45	88.79
2014	86.47	86.47	120.25	98.17	121.52	81.40	83.50	101.32
2015	96.84	96.84	141.15	112.57	142.86	90.67	91.78	117.61
2016	105.66	105.66	161.45	126.14	163.61	98.23	98.75	133.97
2017	111.88	111.88	180.24	137.75	182.91	103.14	103.35	149.53
2018	114.36	114.36	195.31	145.49	198.51	104.50	104.56	162.01
2019	114.28	114.28	206.82	149.91	210.57	103.71	103.73	171.57
2020	114.16	114.16	216.79	153.33	221.07	103.20	103.19	180.07
2021	114.98	114.98	226.03	156.73	230.81	103.78	103.77	188.26
2022	116.35	116.35	234.59	160.14	239.84	105.13	105.13	196.07
2023	117.43	117.43	241.67	162.73	247.34	106.14	106.14	202.65
F	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2010	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2011	0.26	0.26	0.01	0.15	0.00	0.32	0.26	0.13
2012	0.24	0.24	0.01	0.15	0.00	0.28	0.24	0.13
2013	0.25	0.25	0.01	0.15	0.00	0.29	0.31	0.13
2014	0.26	0.26	0.01	0.15	0.00	0.31	0.31	0.12
2015	0.27	0.27	0.01	0.15	0.00	0.33	0.33	0.11
2016	0.29	0.29	0.01	0.15	0.00	0.34	0.34	0.10
2017	0.29	0.29	0.01	0.15	0.00	0.35	0.35	0.09
2018	0.30	0.30	0.01	0.15	0.00	0.36	0.36	0.08
2019	0.31	0.31	0.01	0.15	0.00	0.36	0.36	0.08
2020	0.30	0.30	0.01	0.15	0.00	0.36	0.36	0.07
2021	0.31	0.31	0.01	0.15	0.00	0.36	0.36	0.07
2022	0.30	0.30	0.01	0.15	0.00	0.36	0.36	0.07
2023	0.30	0.30	0.01	0.15	0.00	0.36	0.36	0.06
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2010	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09
2011	36.68	36.68	1.10	22.26	0.00	44.50	36.68	19.00
2012	30.13	30.13	1.15	21.21	0.00	33.98	30.13	19.00
2013	32.13	32.13	1.28	22.11	0.00	35.46	39.24	19.00
2014	36.85	36.85	1.46	24.18	0.00	40.74	42.81	19.00
2015	41.59	41.59	1.66	26.55	0.00	46.01	47.12	19.00
2016	49.12	49.12	1.95	30.65	0.00	54.06	54.60	19.00
2017	53.86	53.86	2.23	34.04	0.00	58.71	58.92	19.00
2018	57.05	57.05	2.49	37.00	0.00	61.22	61.28	19.00
2019	58.35	58.35	2.68	38.76	0.00	61.98	61.99	19.00
2020	58.59	58.59	2.86	40.20	0.00	62.20	62.19	19.00
2021	59.00	59.00	2.99	41.06	0.00	61.76	61.75	19.00
2022	58.68	58.68	3.09	41.56	0.00	61.62	61.61	19.00
2023	59.22	59.22	3.19	42.28	0.00	62.19	62.19	19.00

Table 1A.25. **Ecosystem effects on AI walleye pollock**

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton	Stomach contents, ichthyoplankton surveys	None	Unknown
Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	Possibly lower mortality on walleye pollock	No concern
Birds	Stable, some increasing some decreasing	May affect young-of-year mortality	Unknown
Fish (Pacific cod, arrowtooth flounder)	Pacific cod—decreasing, arrowtooth--stable	Possible decreases to walleye pollock mortality	No concern
Changes in habitat quality			
Temperature regime	The 2004 and 2006AI summer bottom temperature was near average.	Cooling from 2004 could affect apparent distribution.	Unknown

The AI walleye pollock **effects on ecosystem**

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Expected to be heavily monitored	Likely to be a minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Expected to be heavily monitored.	Bycatch levels should be low.	Unknown
HAPC biota (seapens/whips, corals, sponges, anemones)	Very low bycatch levels of seapens/whips, sponge and coral catches expected in the pelagic fishery	Bycatch levels and destruction of benthic habitat expected to be minor given the pelagic fishery.	No concern
Marine mammals and birds	Very minor direct-take expected	Likely to be very minor contribution to mortality	No concern
Sensitive non-target species	Expected to be heavily monitored	Unknown given that this fishery was closed between 1999 and 2005. The 2006 AICASS had 3% POP bycatch, the only significant bycatch. The 2005 fishery had a high bycatch of POP, but bycatch of other species was very low in fishery prior to 1999.	No concern
Other non-target species	Very little bycatch.	Unknown	No concern
Fishery concentration in space and time	Steller sea lion protection measures may concentrate fishery spatially to very small areas between 20 nm closures	Depending on concentration of pollock outside of critical habitat could possibly have an effect.	Possible concern
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Possible Concern
Fishery contribution to discards and offal production	Offal production—unknown. 2011 fishery not expected to be significant.	Unknown	Unknown
Fishery effects on age-at-maturity and fecundity	Unknown	Unknown	Unknown

Figures

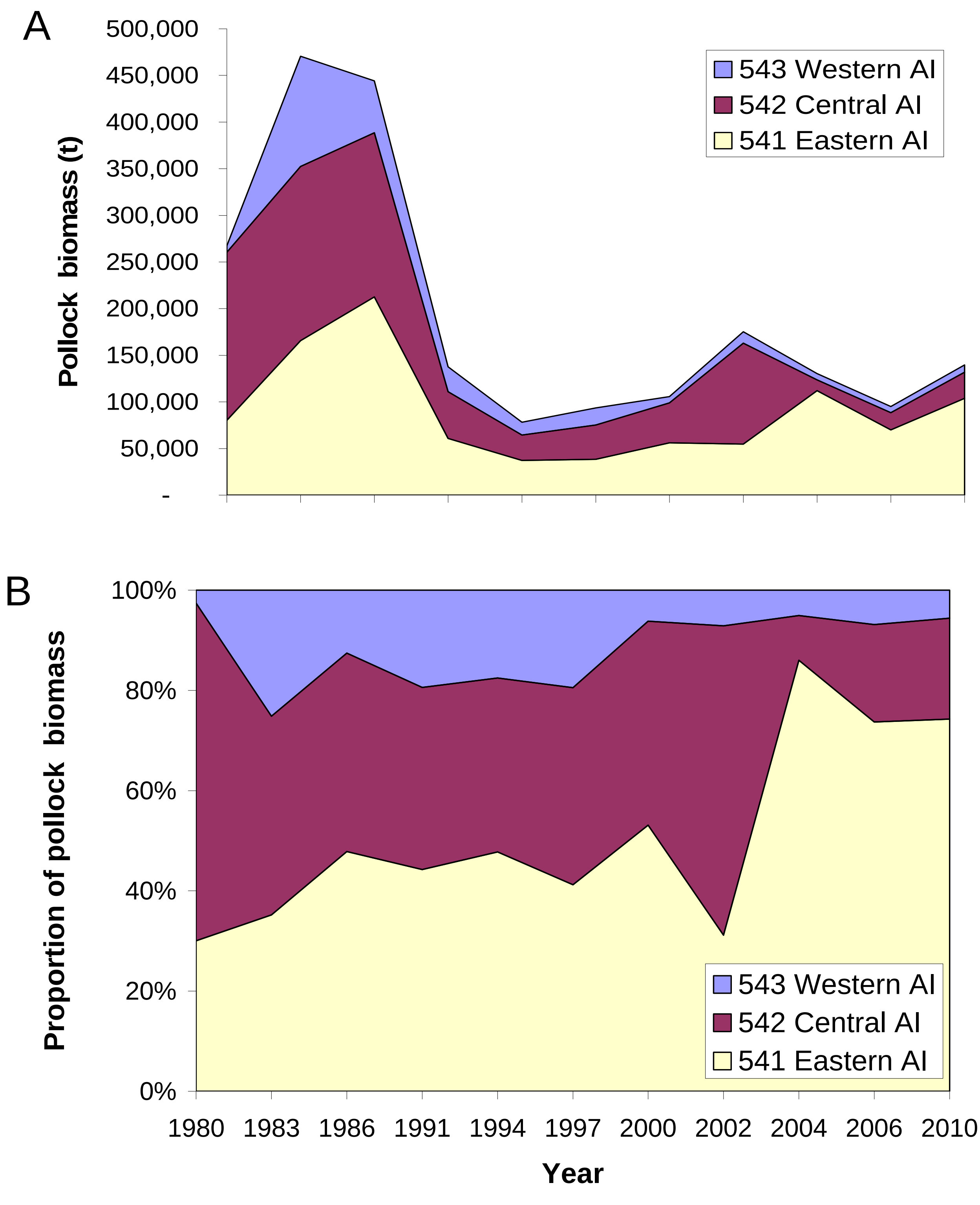


Figure 1A.1 Aleutian Islands bottom trawl survey pollock biomass (A; top) and proportion of biomass (B; bottom) for the three Aleutian Island management regions.

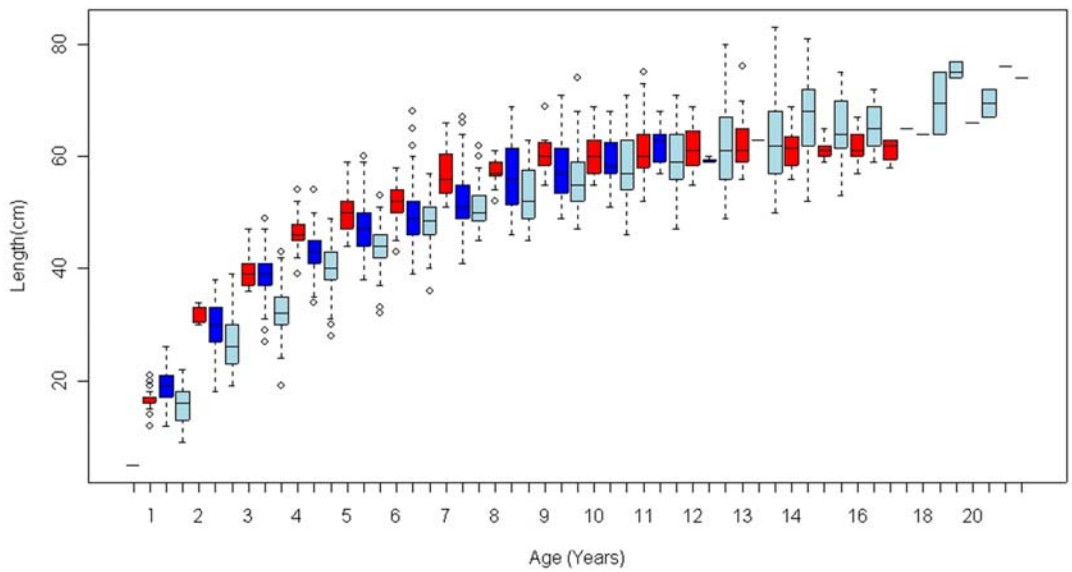


Figure 1A.2. Length at age for Aleutian Islands (red), Gulf of Alaska (blue), and Bering Sea (grey) pollock from the 2004 Aleutian Islands, 2004 Bering Sea, and 2005 Gulf of Alaska bottom trawl surveys.

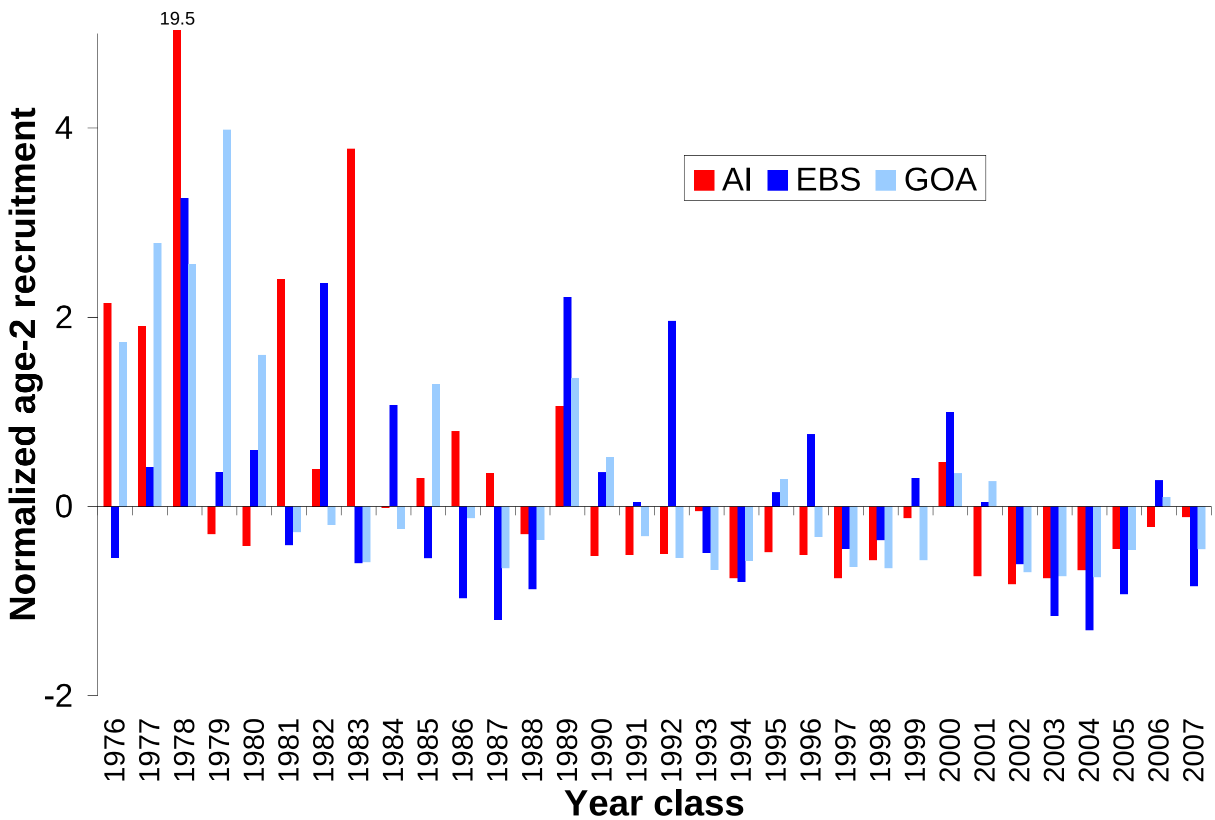


Figure 1A.3. Aleutian Islands (AI), Bering Sea (BS), and Gulf of Alaska (GOA) normalized age-2 recruitment. Data were normalized to 1979-2008 numbers. AI numbers are from the 2010 reference model, while EBS and GOA are from 2009 reference models.

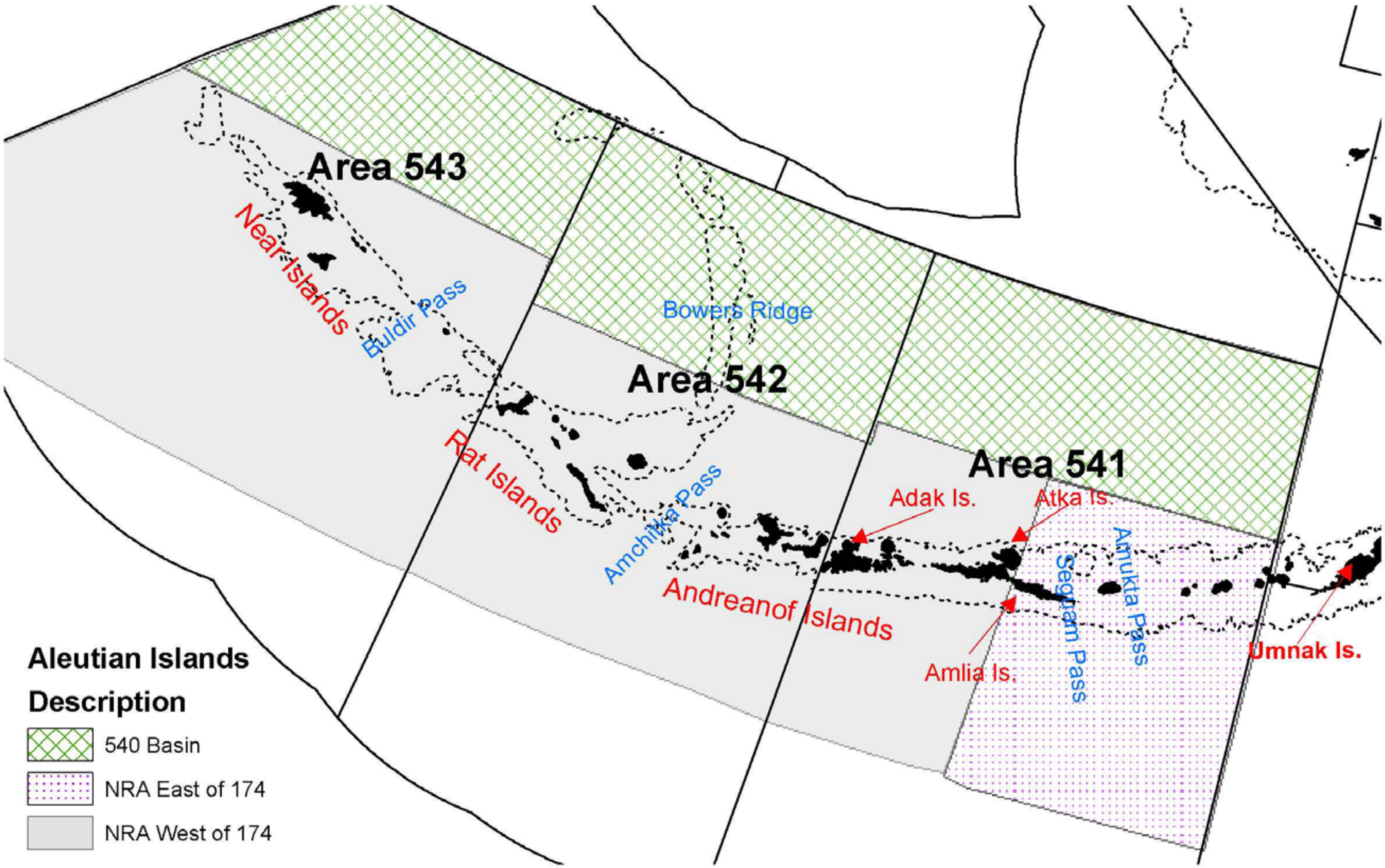


Figure 1A.4. Regions defined for consideration of alternative data partitions for Aleutian Islands Region pollock. The abbreviation "NRA" represents the Near, Rat, and Andreanof Island group.

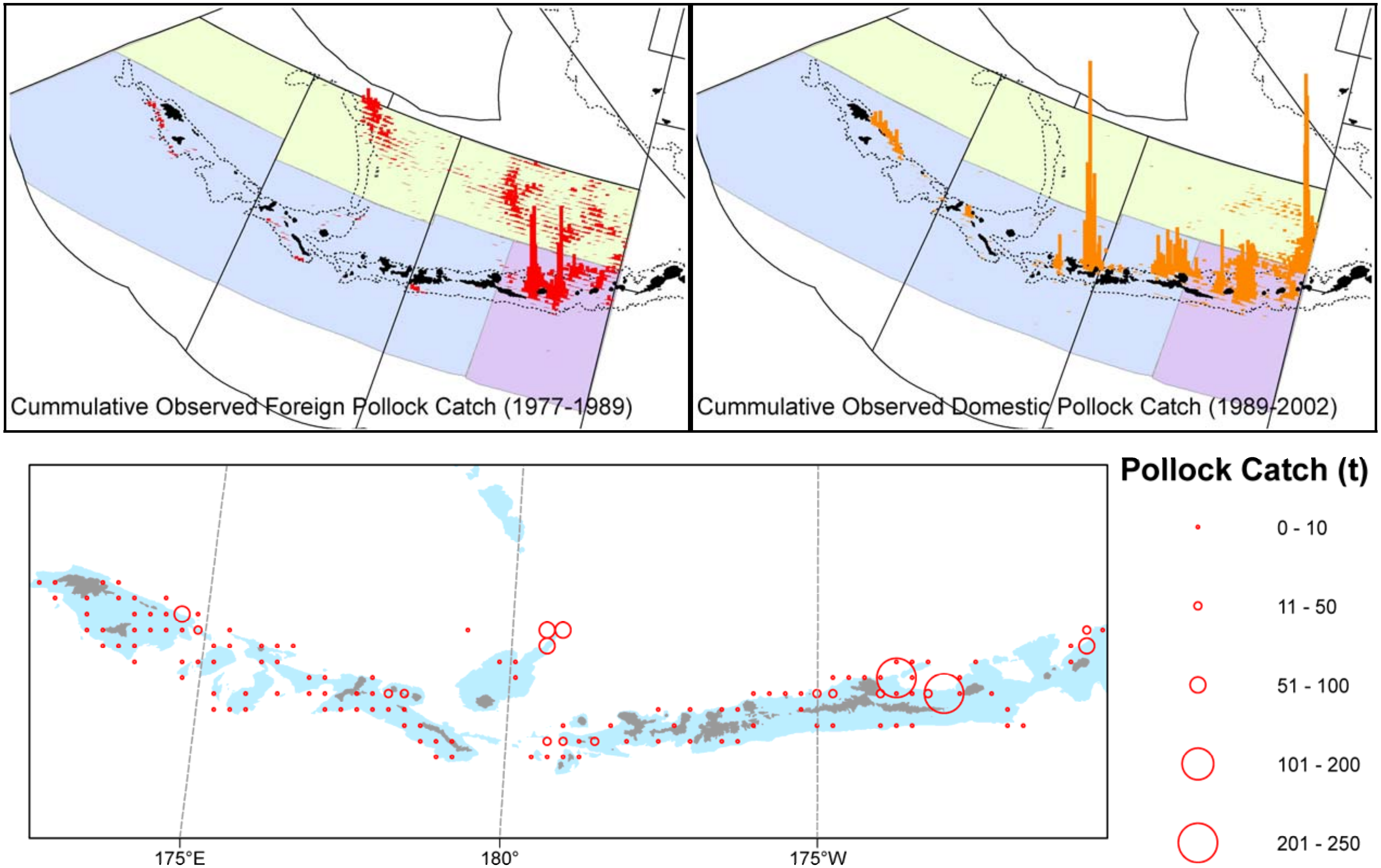


Figure 1A.5. Top figures are observed foreign and J.V. (1978-1989; left), early domestic (1989-2002; right) pollock catch in the Aleutian Islands Area summed over all years and 10 minute latitude and longitude blocks. The two top maps use the same scale (maximum observed catch per 10 minute block: foreign and J.V. 8,000 t and Domestic 19,000 t). Catches of less than 1 t were excluded from cumulative totals. The bottom figure is observed pollock catch location in 2010 (as of 21 October) aggregated in 20 km^2 cells, shaded areas is the shelf area less than 300m in depth.

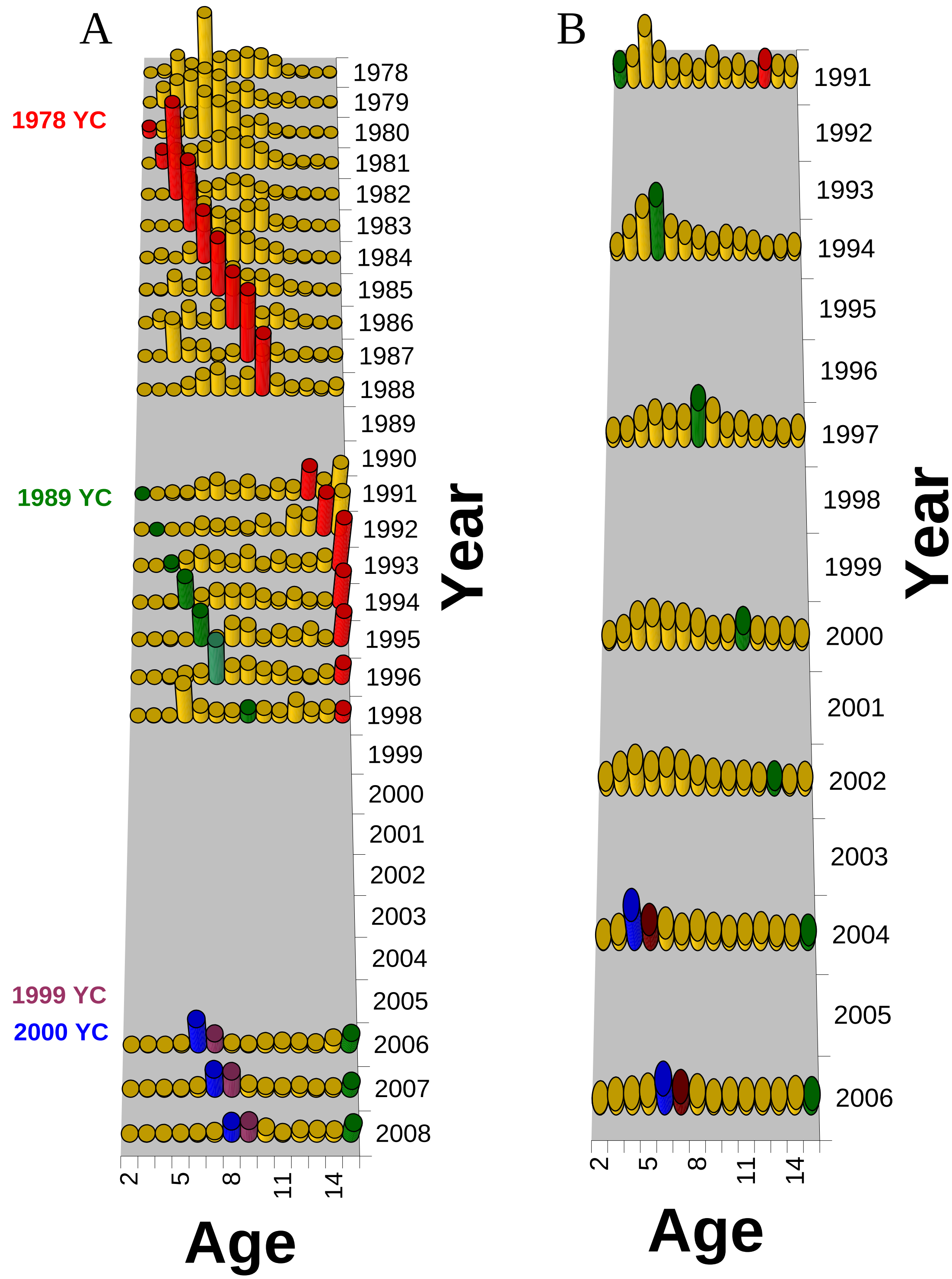


Figure 1A.6. Age distributions for 1978-2010 Aleutian Islands pollock fishery (A; left) and 1991-2006 Aleutian Islands Bottom Trawl surveys (B; right).

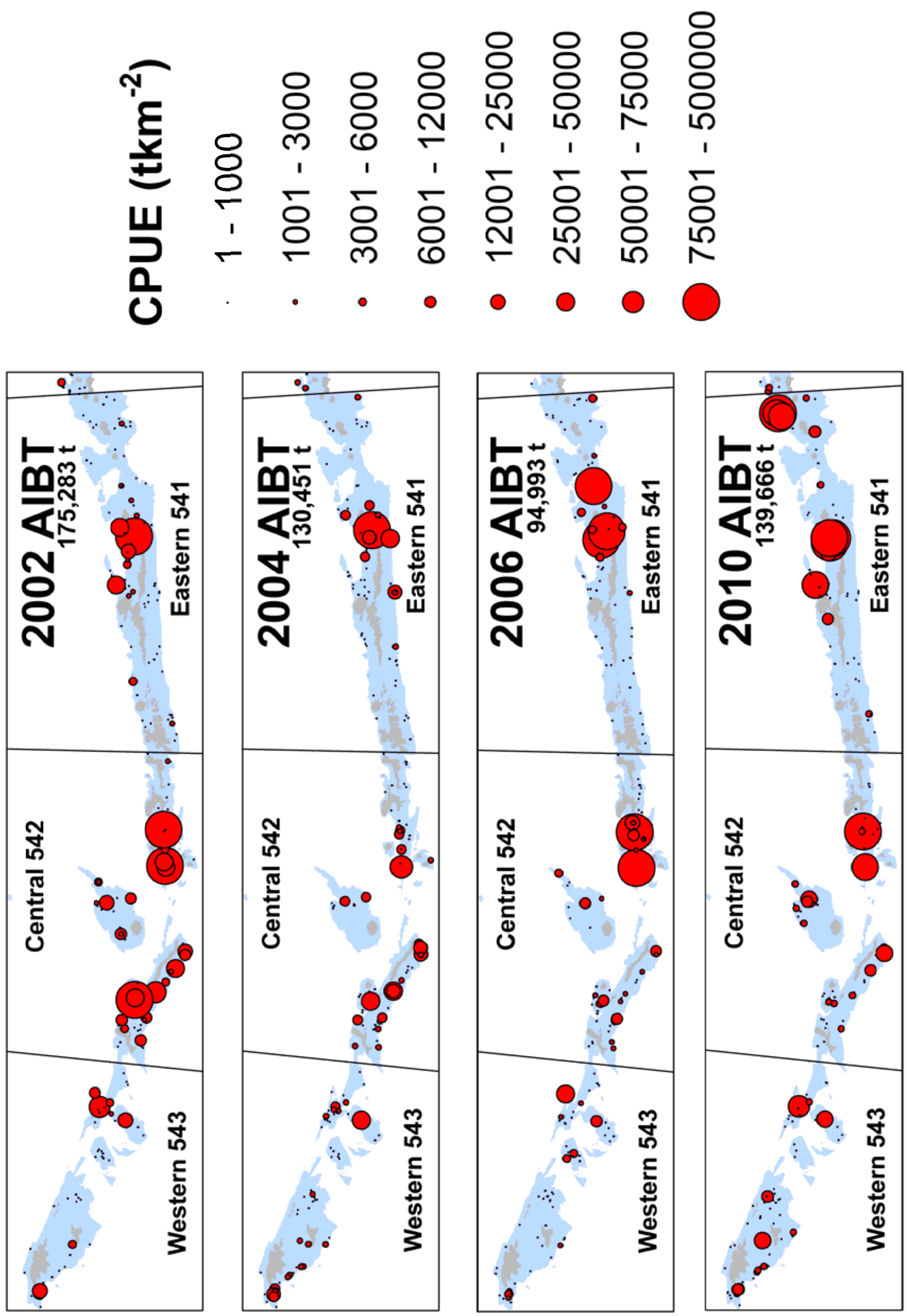


Figure 1A.7. Catch per unit effort (tkm^2) for surveys of pollock in the Aleutian Islands Region, 2002-2010. The shaded area is the Aleutian Islands shelf area at less than 300m depth.

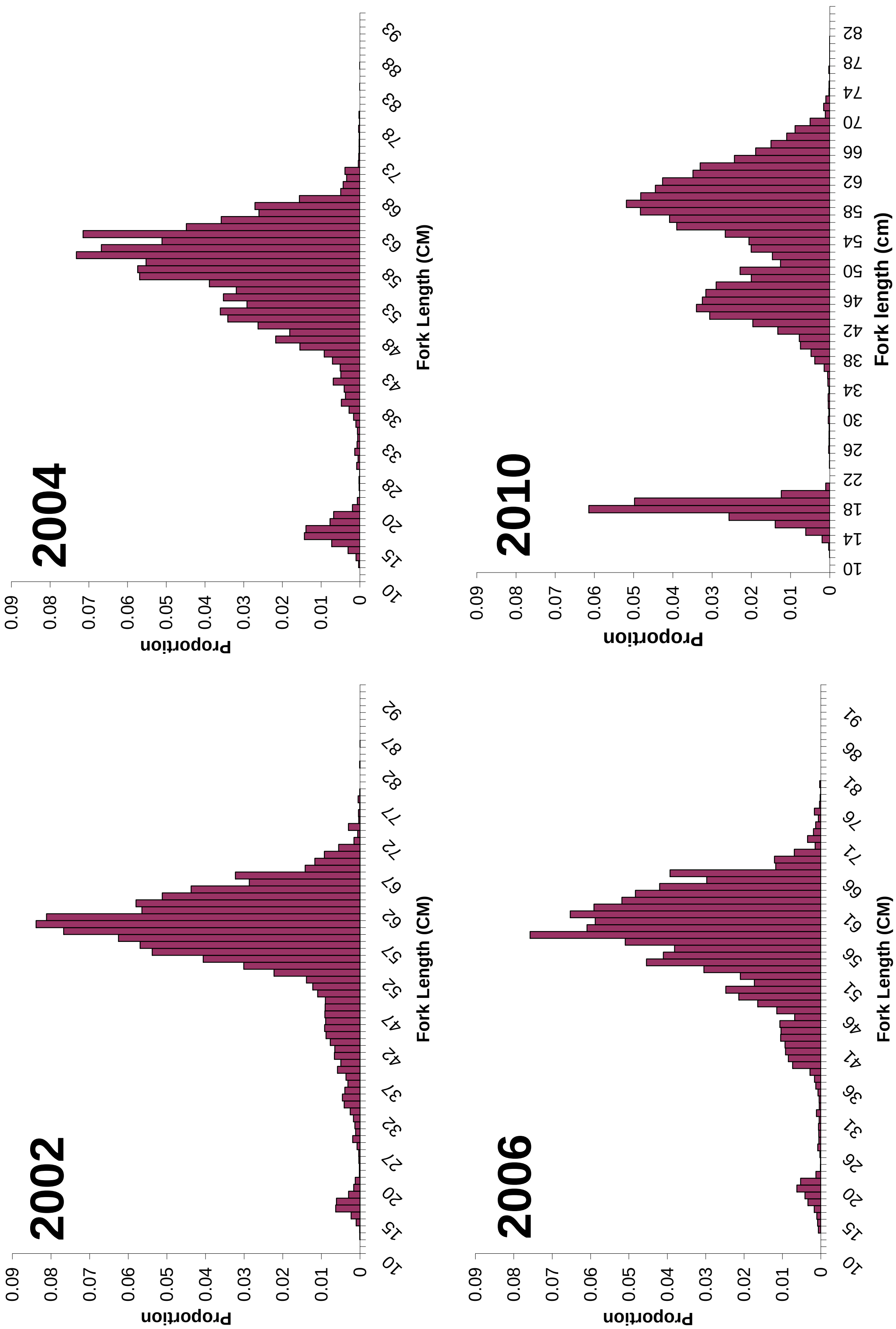


Figure 1A.8. Length distributions for 2002-2010 Aleutian Islands bottom trawl surveys and the 2006 Aleutian Islands cooperative acoustic survey study

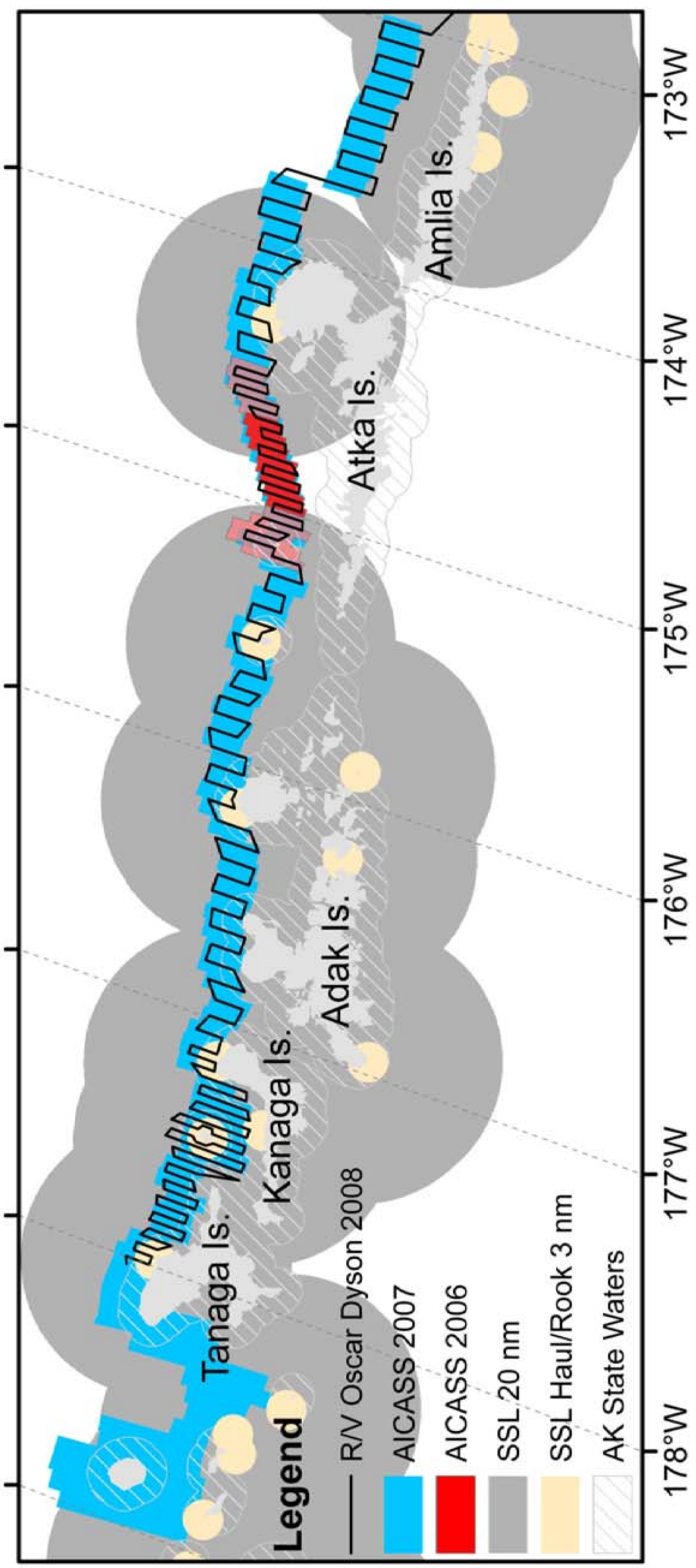


Figure 1A.9. 2006, 2007, and 2008 Aleutian Islands Cooperative Acoustic Survey Study sites within the central Aleutian Islands with pertinent Steller Sea lion areas.

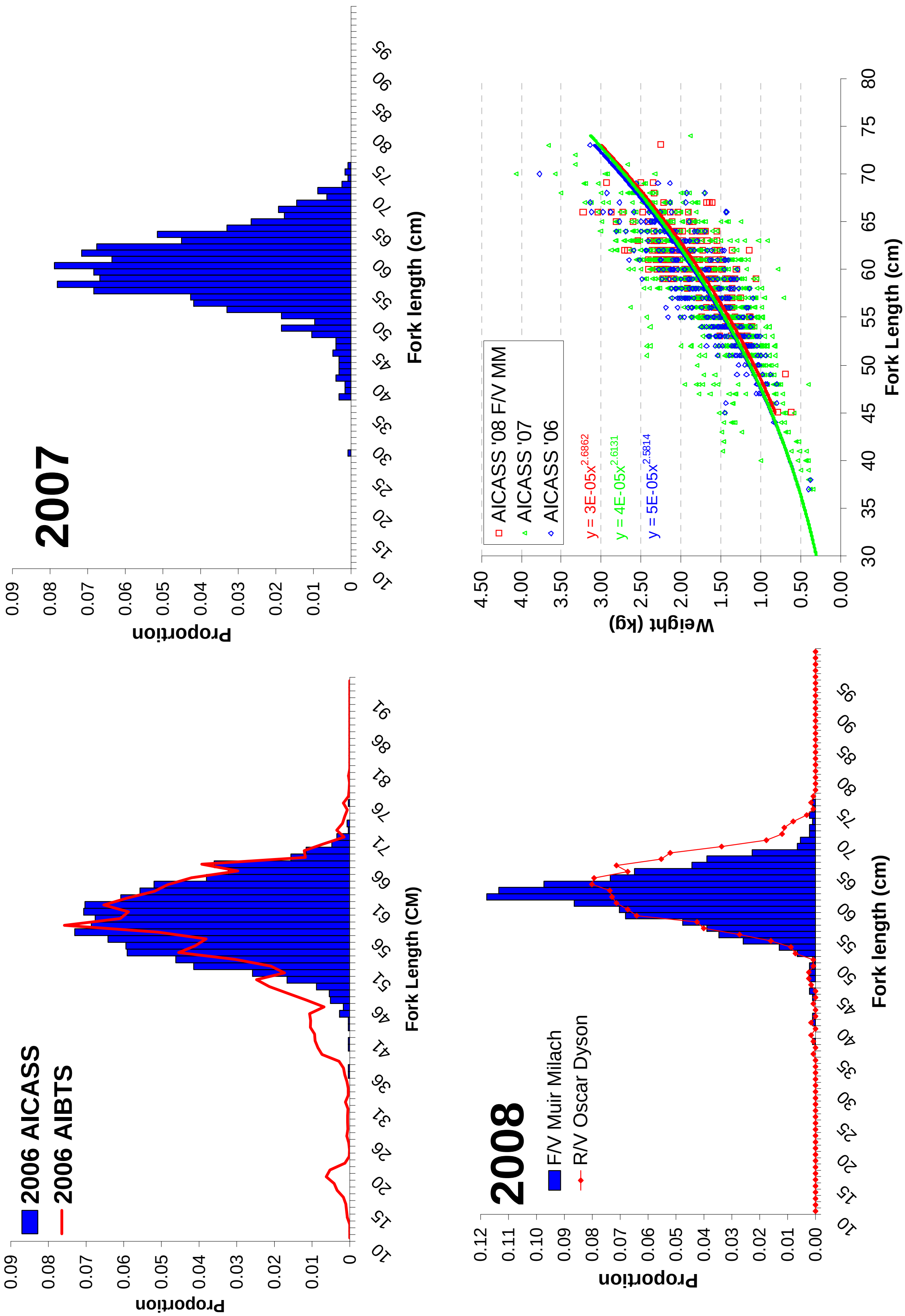


Figure 1A.10. Length distributions for the 2006, 2007, and 2008 Aleutian Islands cooperative acoustic survey studies.

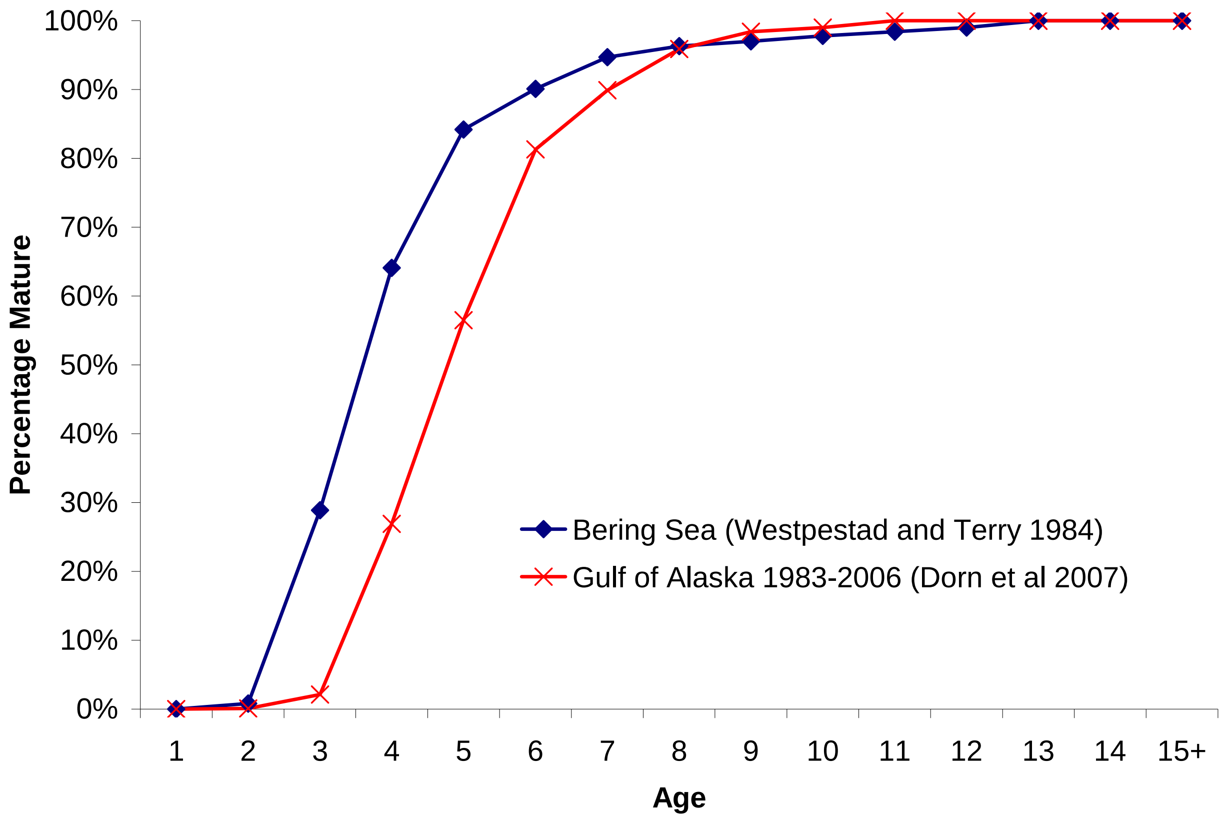


Figure 1A.11. Percentage mature at age for Bering Sea (Wespestad and Terry 1984) and the mean percentage mature at age for 1983-2006 for Gulf of Alaska pollock (Dorn et al. 2007).

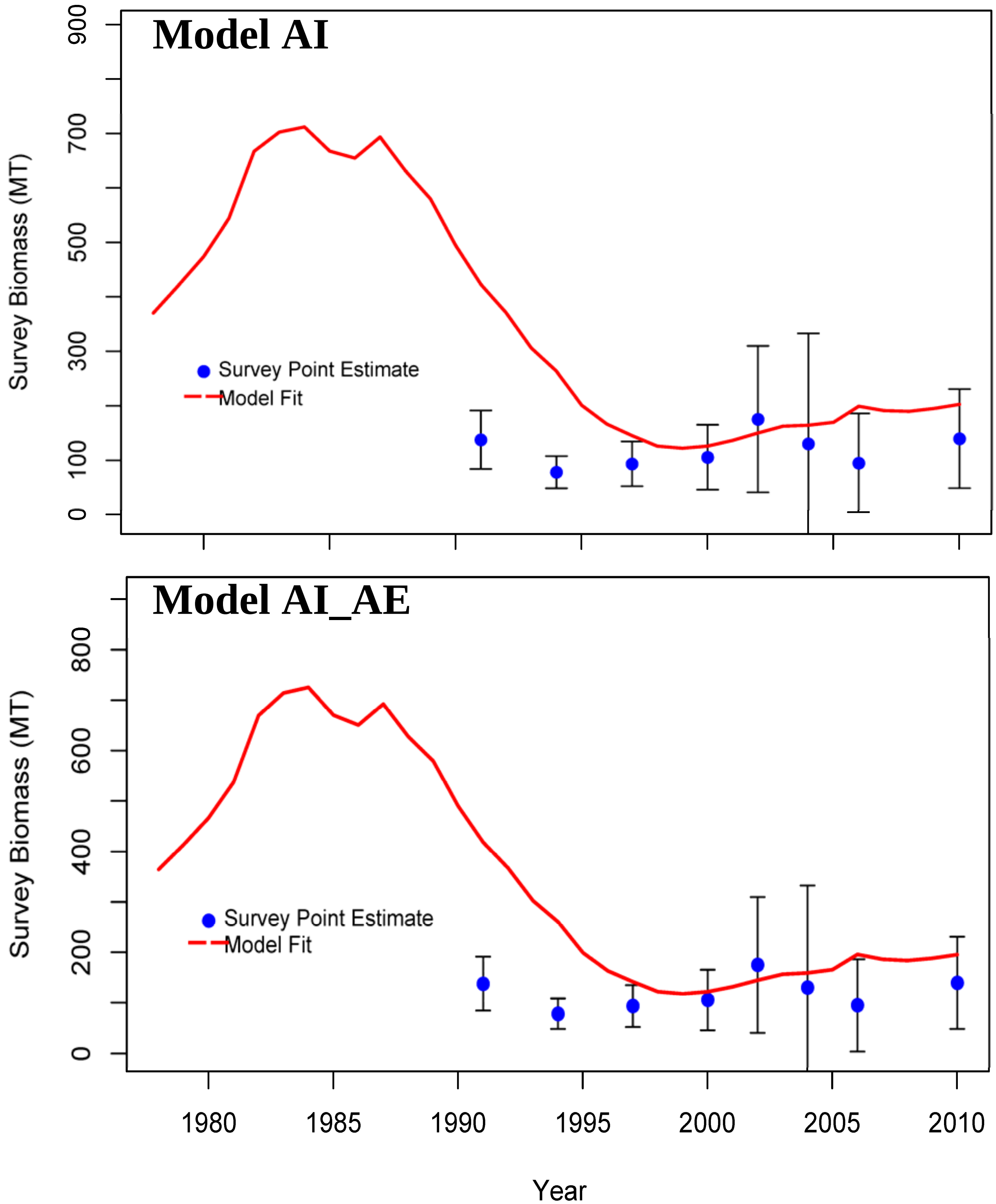


Figure 1A.12. Fit (solid line) to NMFS summer trawl survey (dots) for Model AI (top) and reference model, Model AI_AE (bottom) .

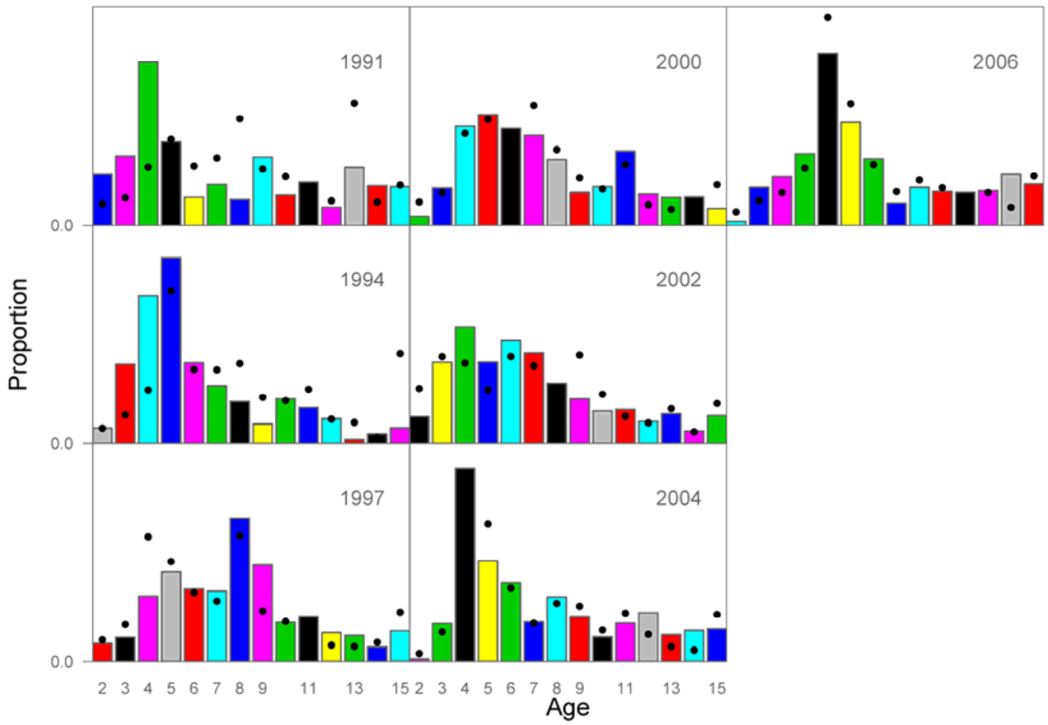


Figure 1A.13. Fits to NMFS summer trawl survey age composition data for Model AI for Aleutian Islands pollock.

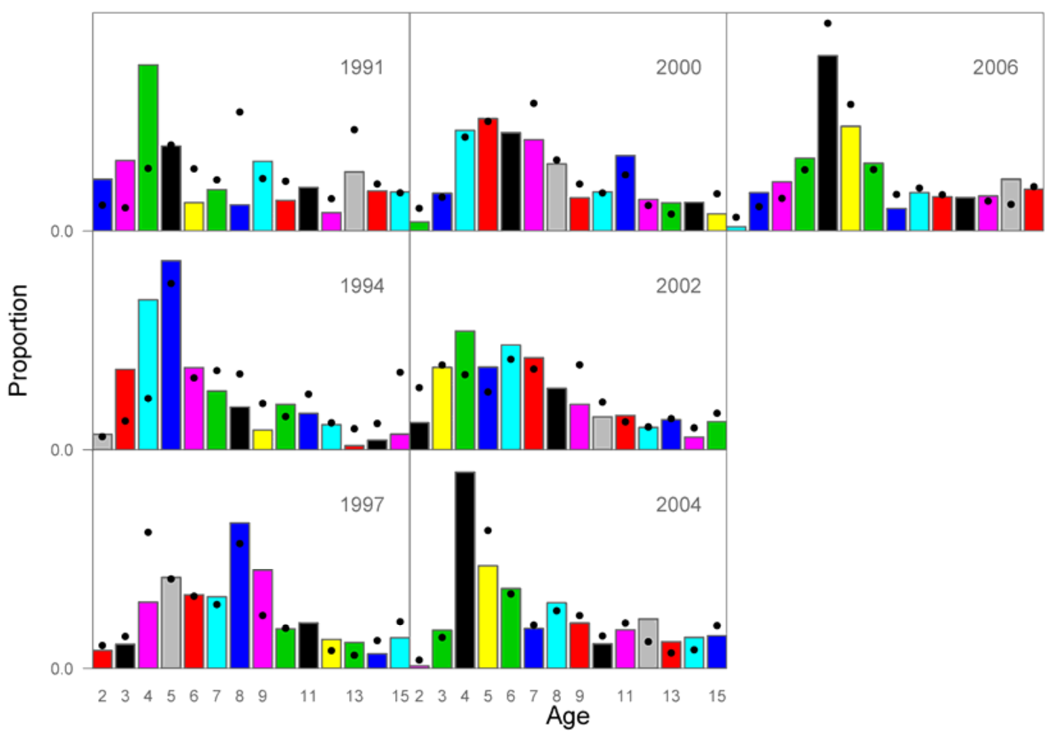


Figure 1A.14. Fits to NMFS summer trawl survey age composition data for the reference model, Model AI_AE, for Aleutian Islands pollock.

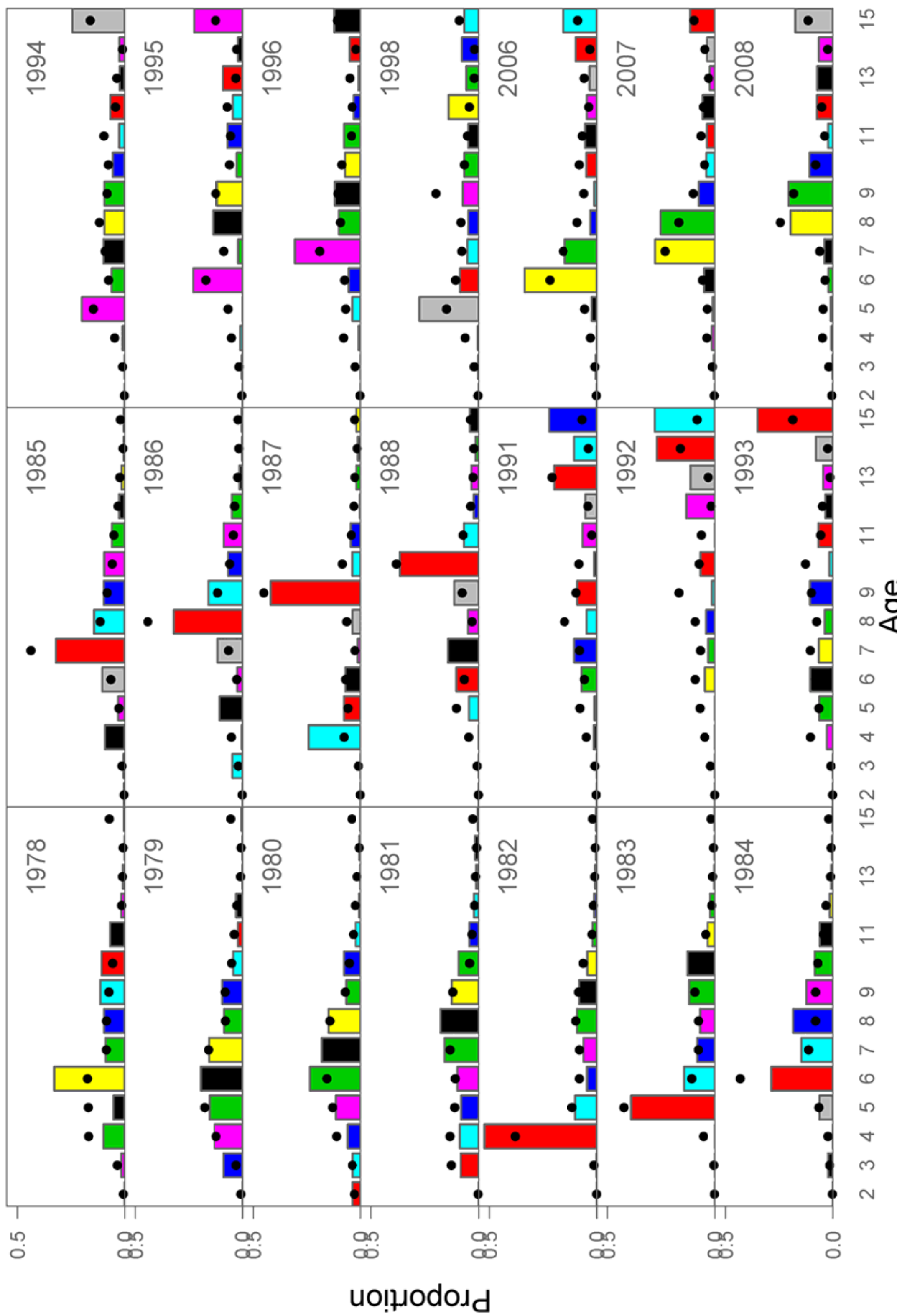


Figure 1A.15. Fit to fishery age composition data for Model AI for Aleutian Islands (NRA) pollock.

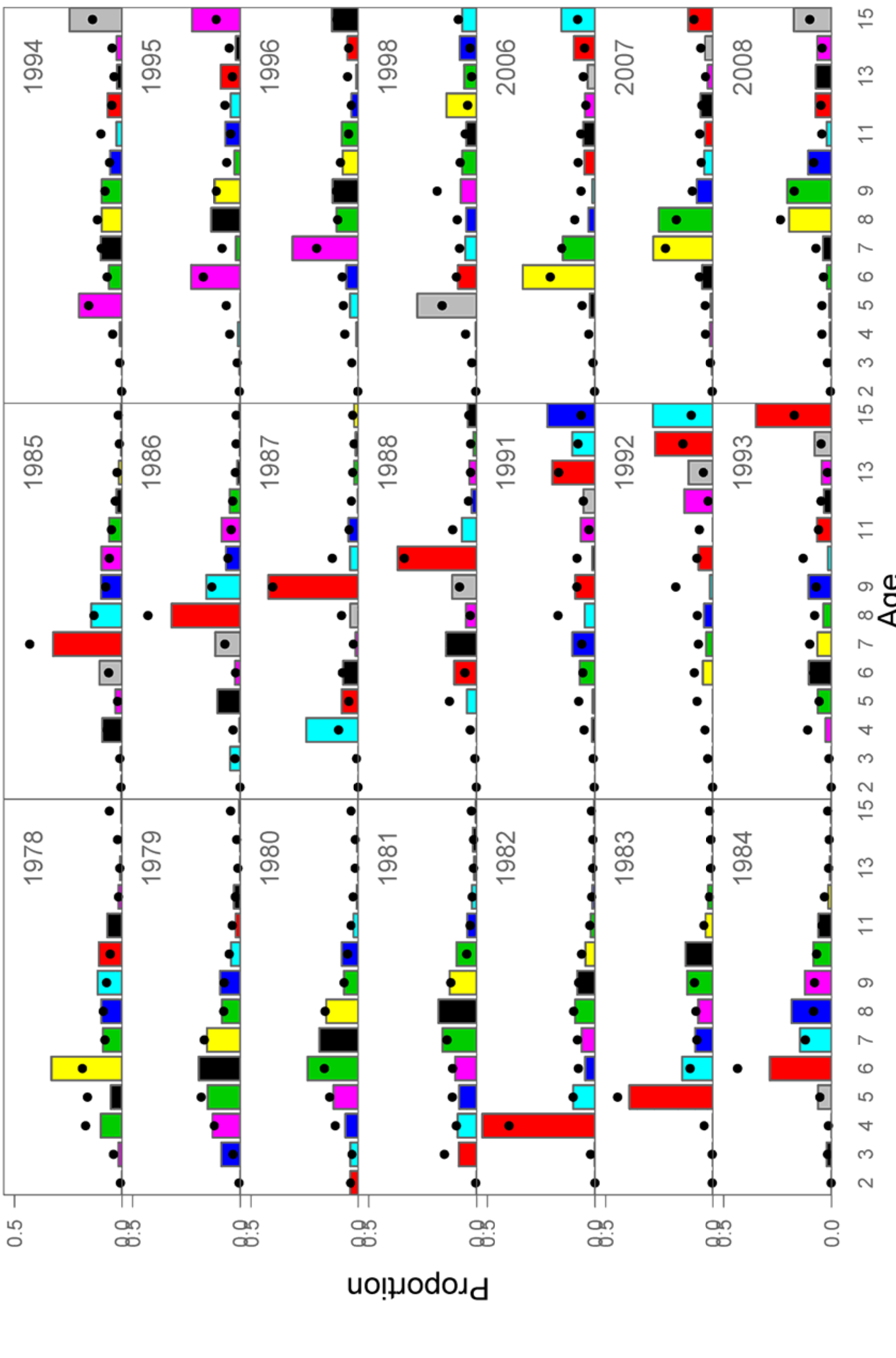


Figure 1A.16. Fit to fishery age composition data for Model AI_AE for Aleutian Islands (NRA) pollock 1978-2008

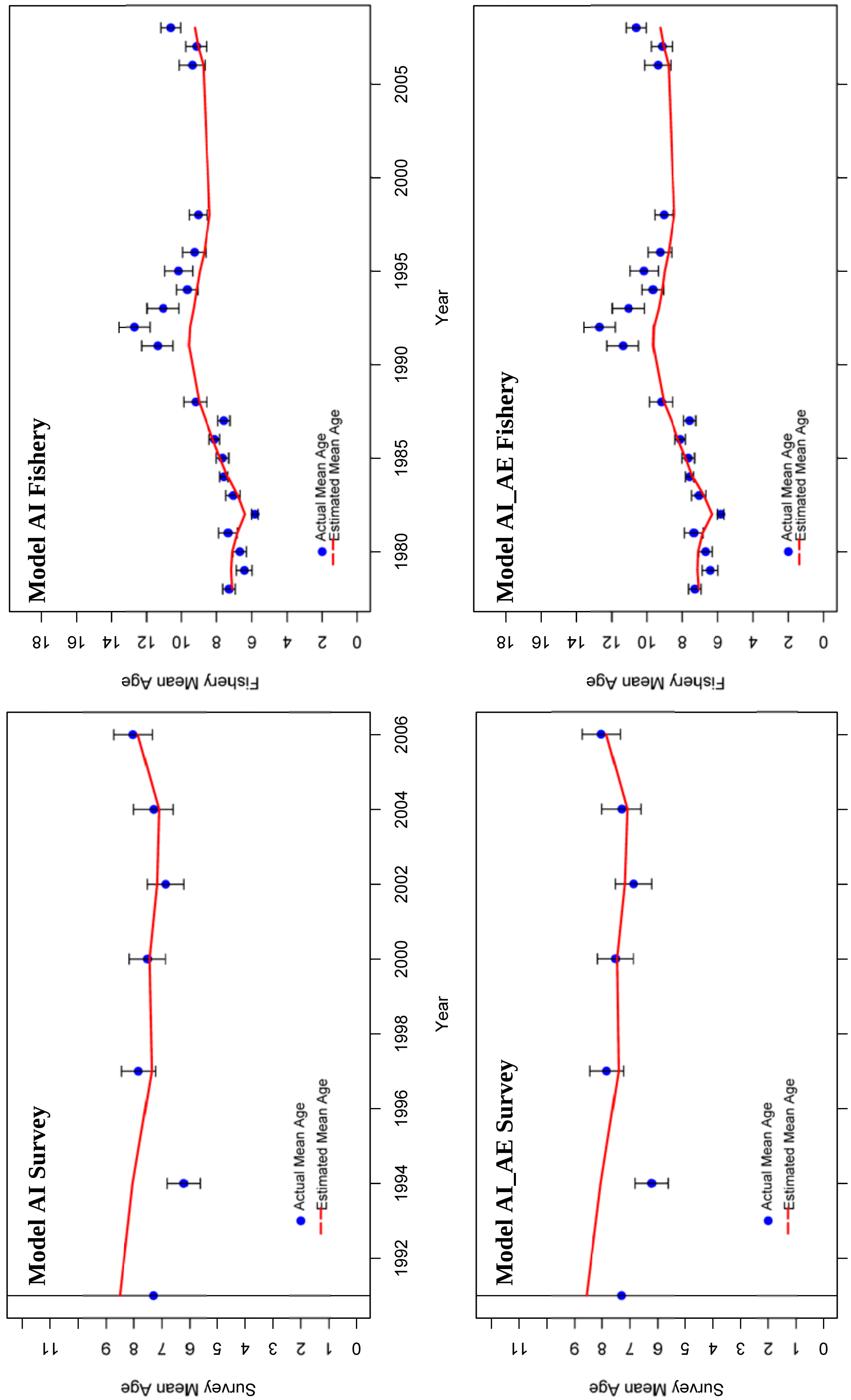


Figure 1A.17. Observed mean age and model derived mean age from the AIBTS (left) and fishery catch at age data (right) for Model AI (top) and the reference model, Model AI_AE. (bottom).

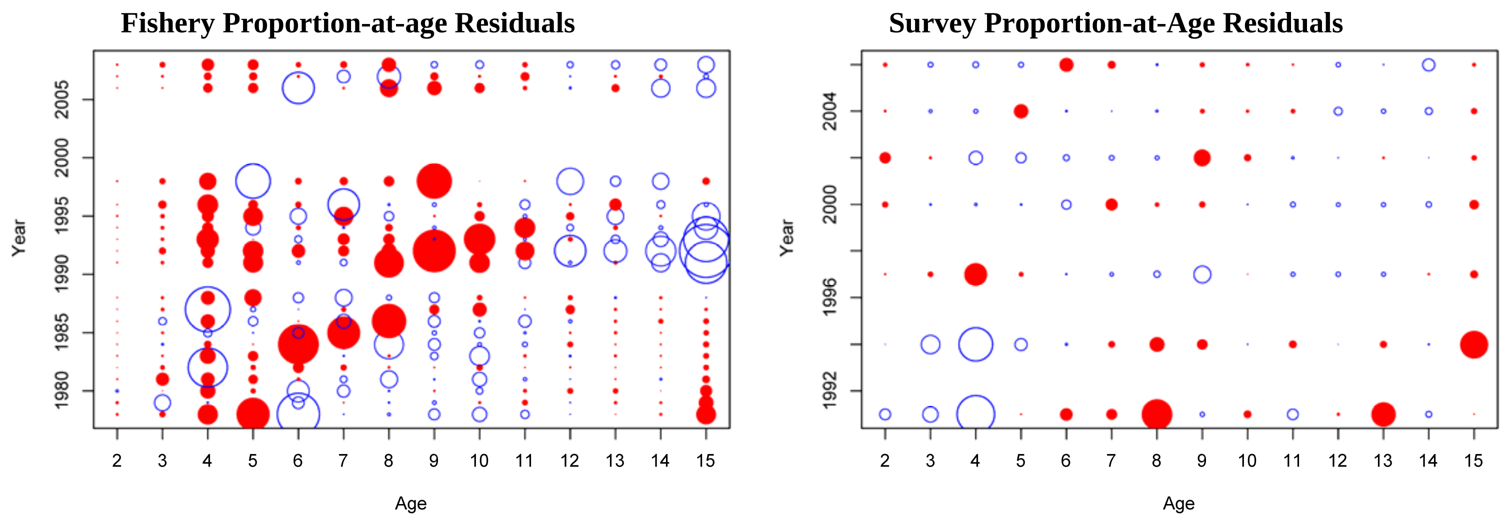


Figure 1A.18. Standardized residuals for fits to the fishery (left) and survey (right) proportion-at-age data for Model AI, solid circles are positive residuals while hollow circles are negative residuals.

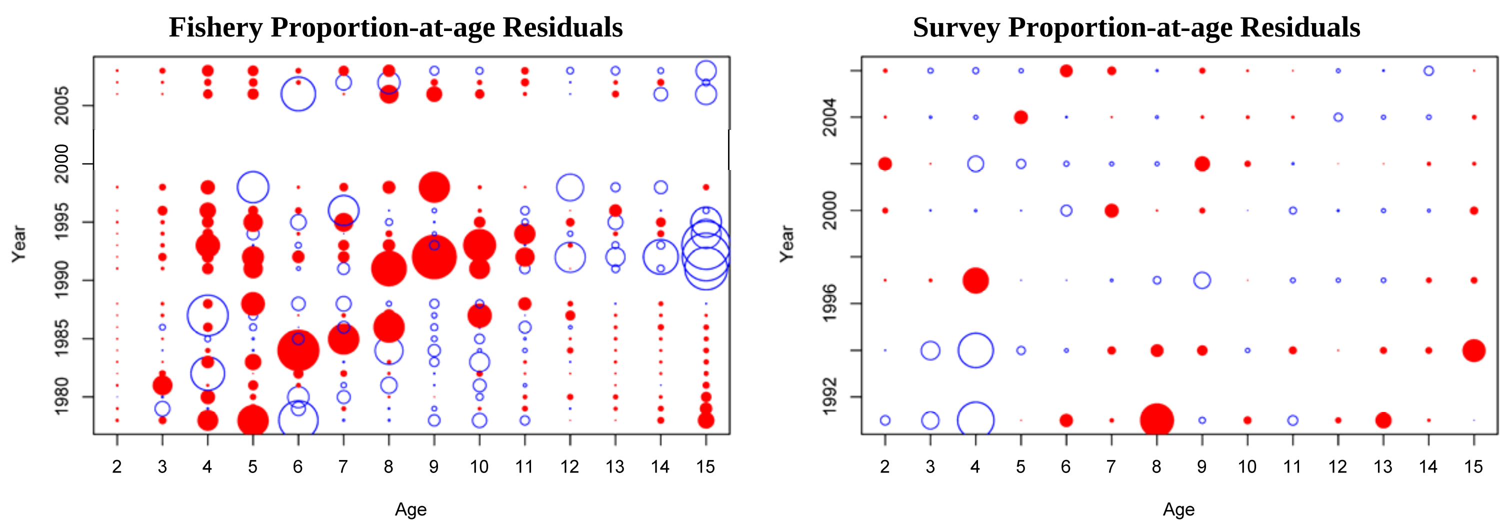


Figure 1A.19. Standardized residuals for fits to the fishery (left) and survey (right) proportion-at-age data for Model AI_AE, solid circles are positive residuals while hollow circles are negative residuals.

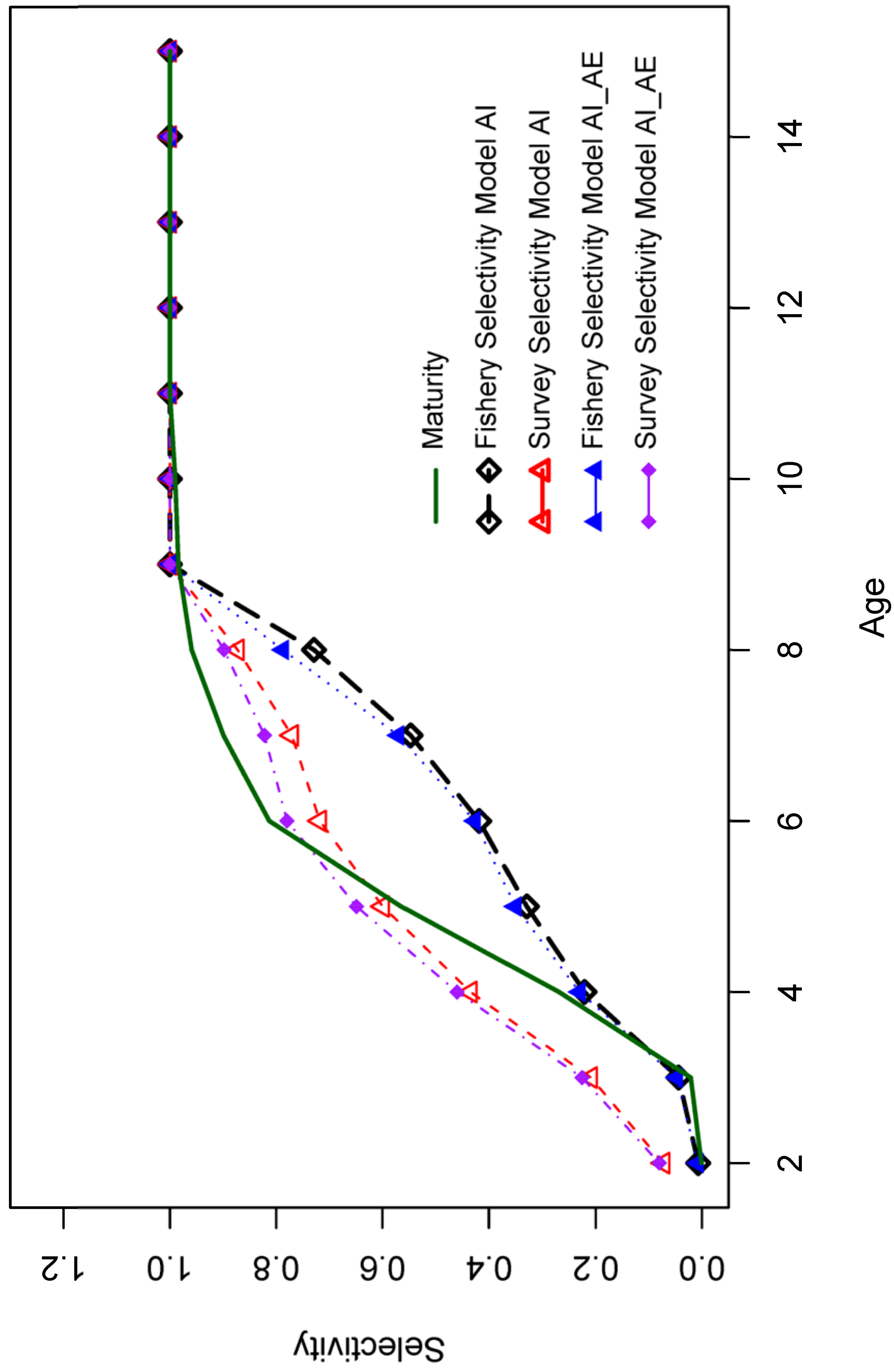


Figure 1A.20. Fishery and survey selectivity estimates with maturity at age for Aleutian Islands pollock Model AI and reference Model AI_AE with the maximum age at which the selectivity is allowed to change is set to 8.

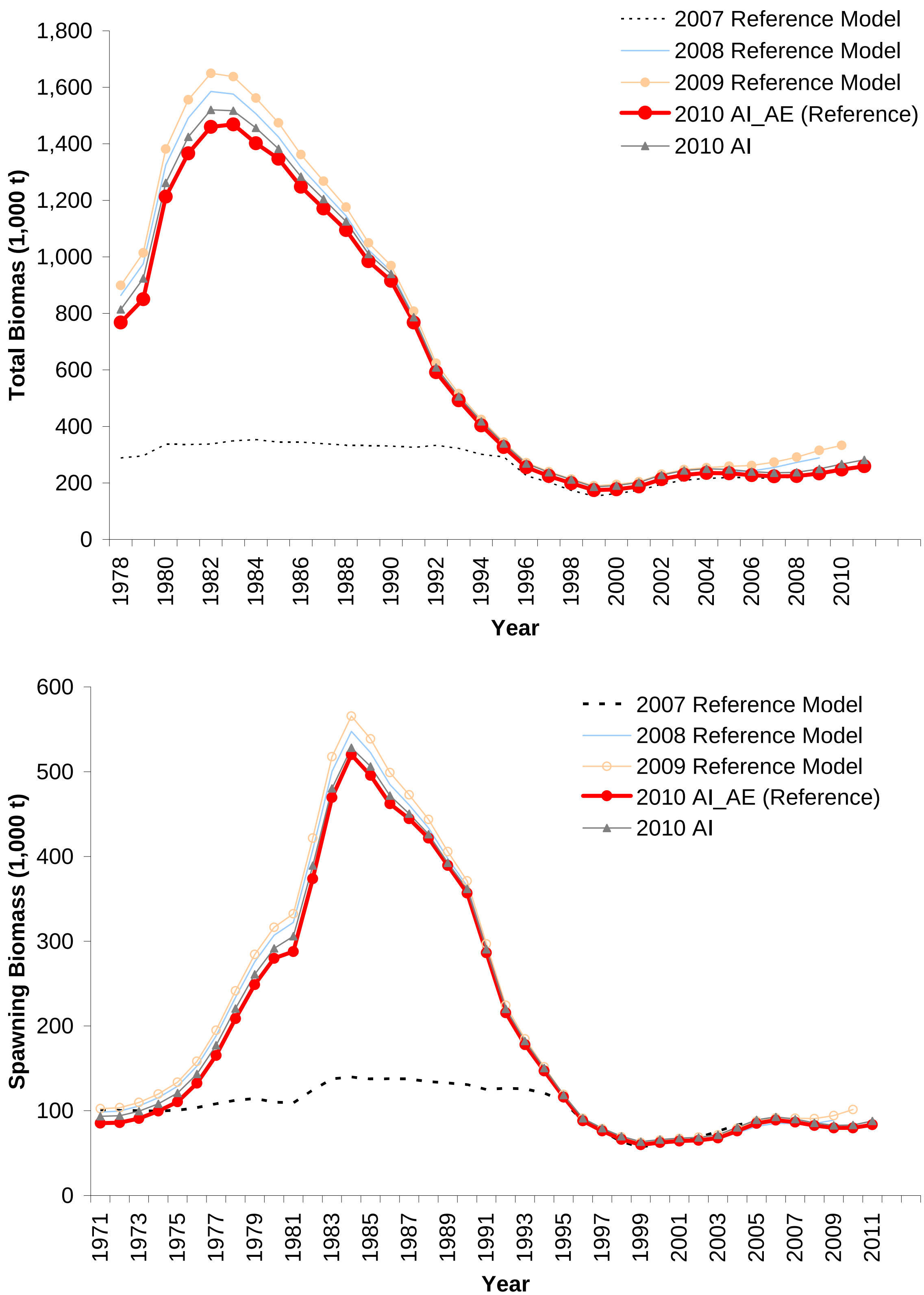


Figure 1A.21. Age 2+ (top) and spawning (bottom) biomass trajectories for the two 2010 models compared with the 2007 through 2009 reference models.

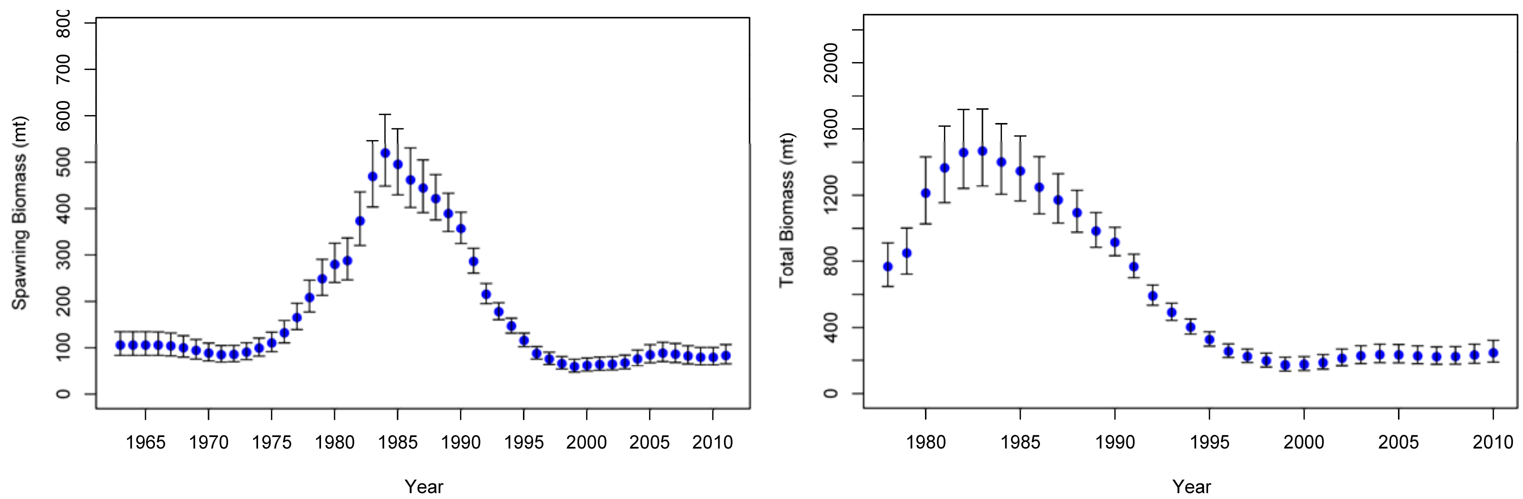


Figure 1A.22. Estimates of Aleutian Islands pollock age 2+ total biomass (Right) and Spawning Biomass (Left) in 1,000s of tons from the reference Model AI_AE. Error bars are two standard deviations.

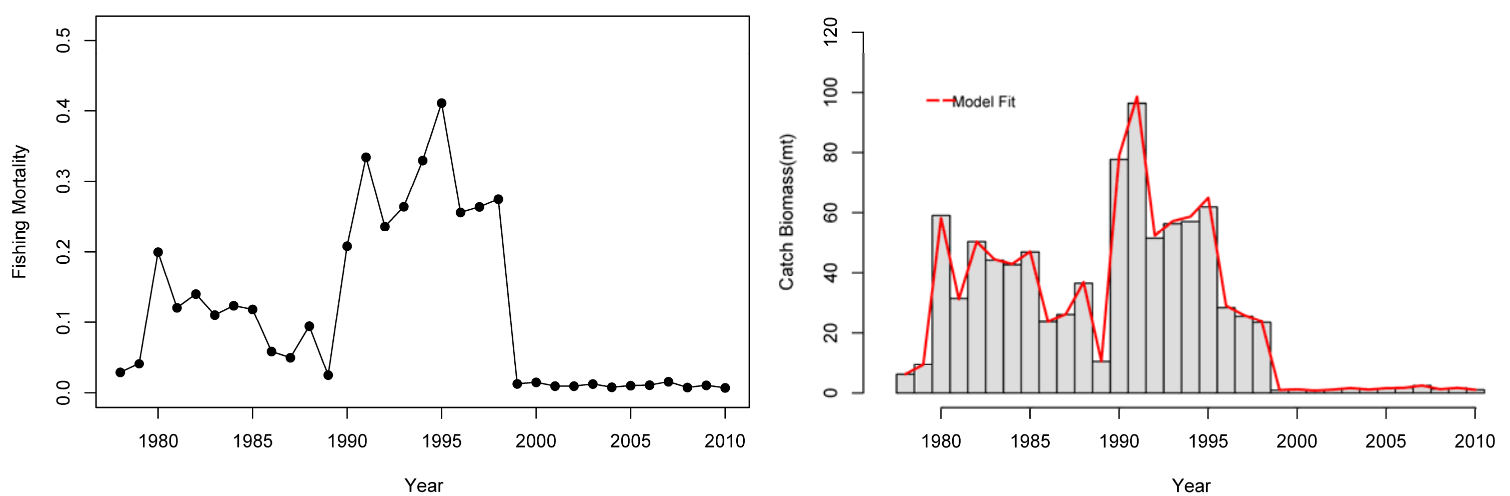


Figure 1A.23 Fishing mortality rates (left) and fits to total catch in 1,000s of tons (right) for Model AI_AE for AI pollock over time 1978-2009. Fishing mortality rates are based on the average over ages 2-15.

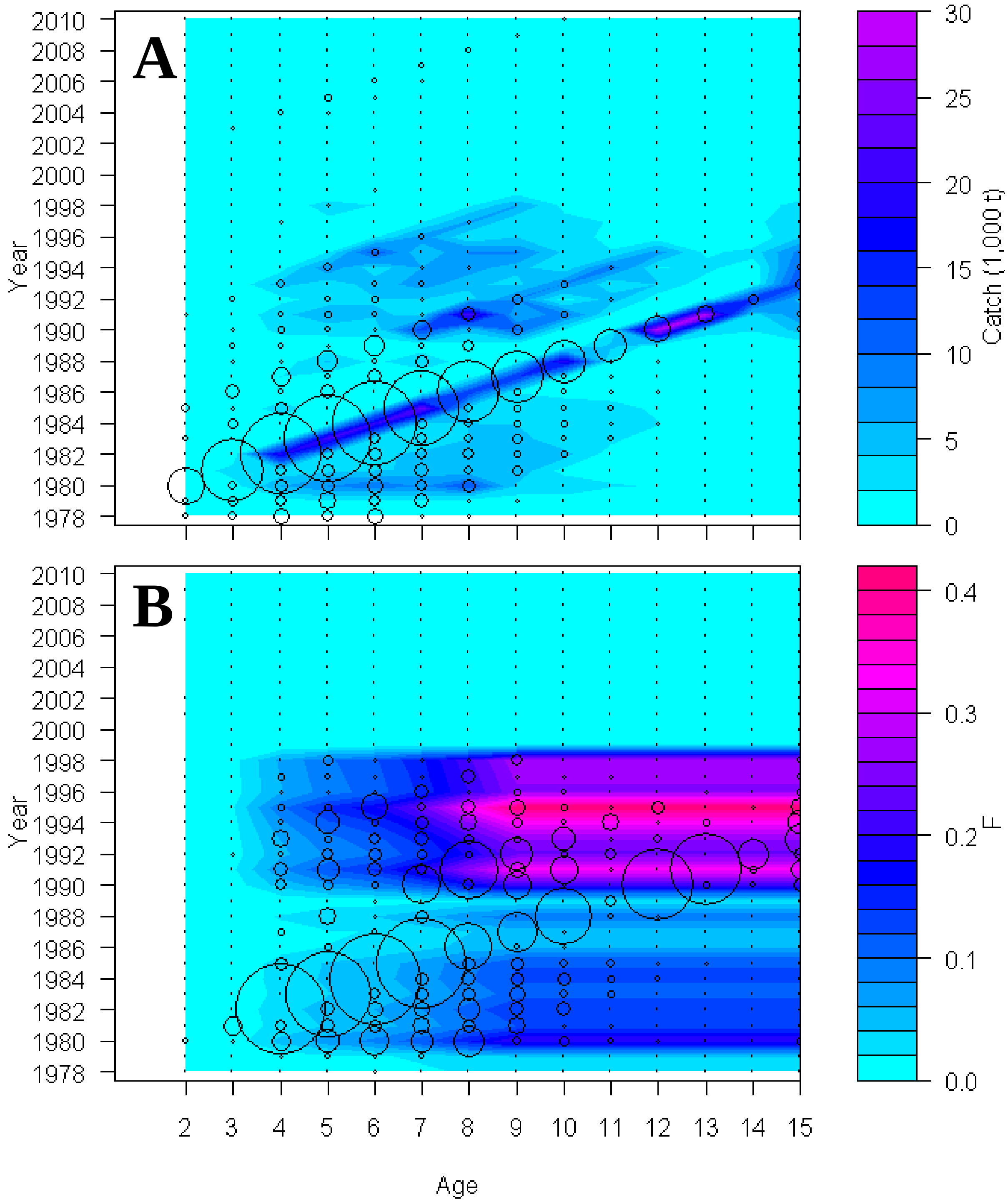


Figure 1A.24 Model AI_AE (A-contour) catch Biomass in 1,000s of tons and (A-bubbles) total biomass and (B contour) fishing mortality rates and (B-bubbles) catch biomass by age for AI pollock. Total biomass bubbles are scaled to 1/25th of the catch biomass bubbles.

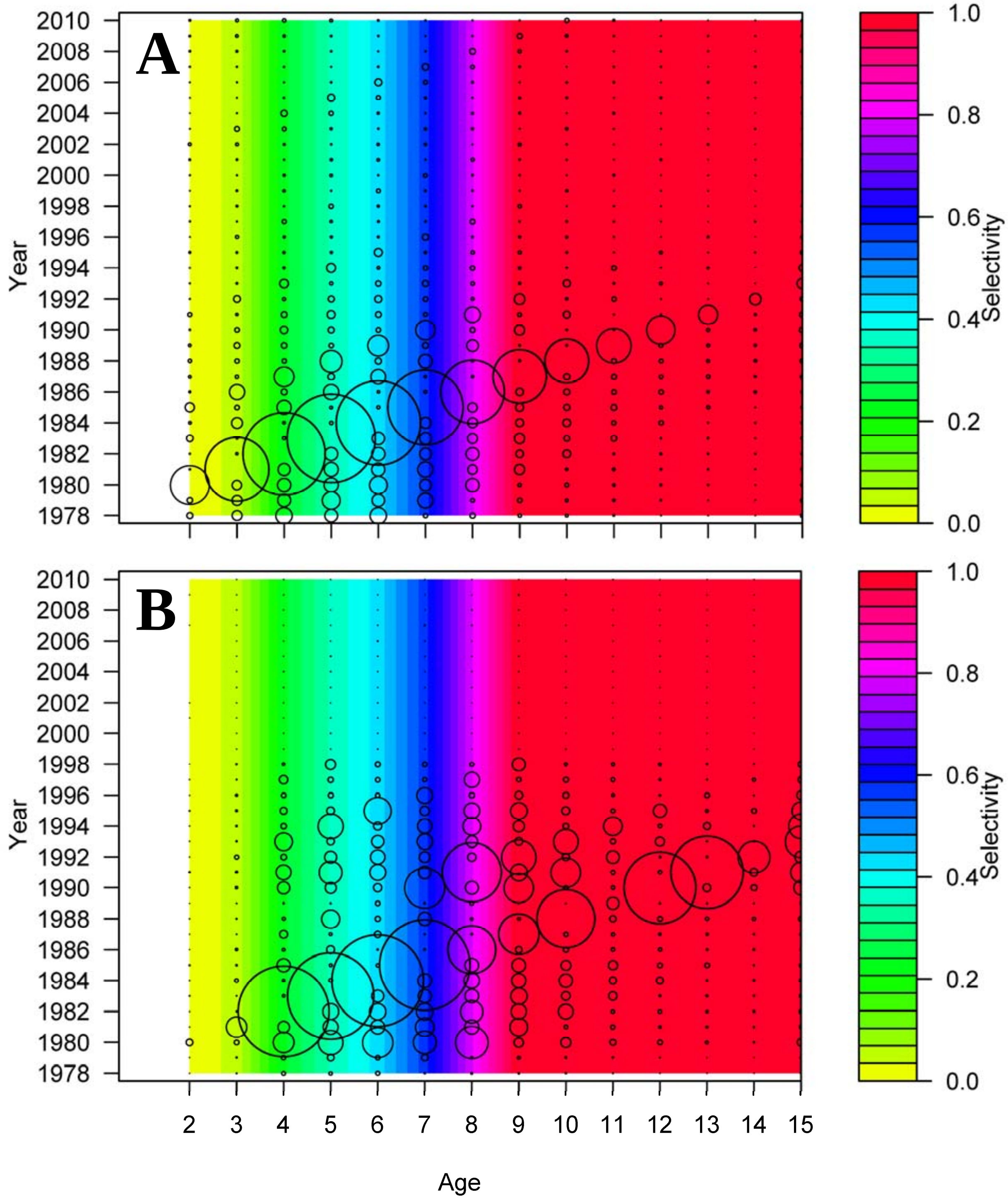


Figure 1A.25 Model AI_AE contour plots of fishery selectivity by age for AI pollock with bubble plots of (A) total biomass at age and (B) catch biomass at age. Total biomass is scaled to 1/25 of the catch biomass bubbles.

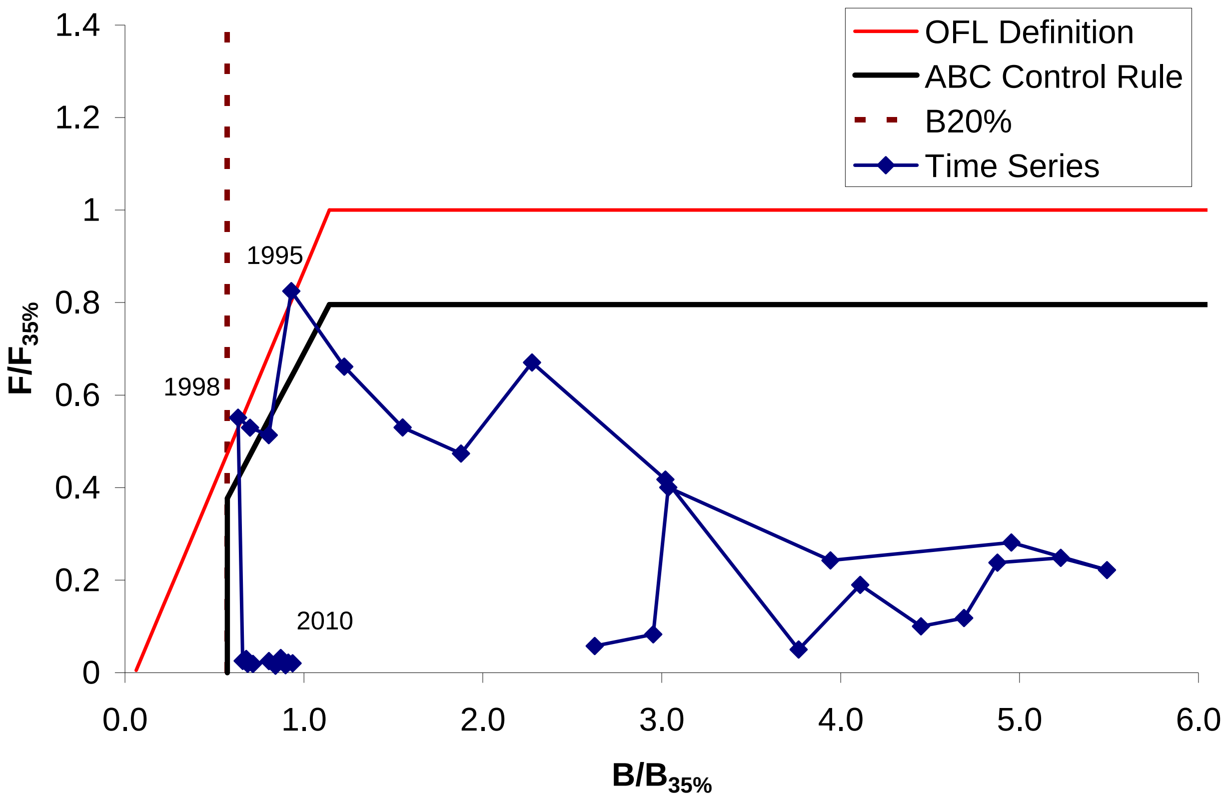


Figure 1A.26. Reference model Model AI_AE Aleutian Islands pollock spawning biomass relative to $B_{35\%}$ and full-selection fishing mortality relative to F_{OFL} (1978-2009). The ratio of fishing mortality to F_{OFL} is calculated using the estimated selectivity pattern in that year.

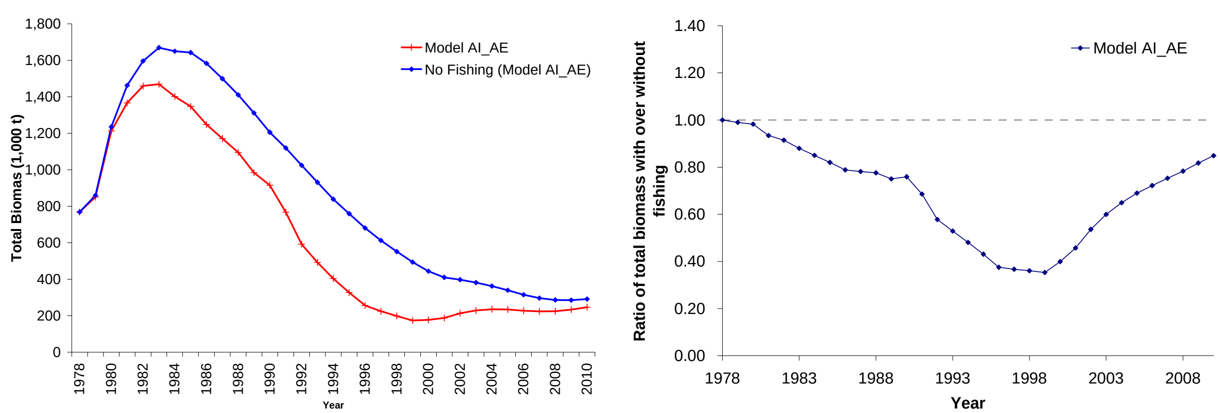


Figure 1A.27. Aleutian Islands pollock total biomass (age 2+) with and without fishing (left) and ratio of total biomass with fishing over total biomass without fishing for the reference model, Model AI_AE.

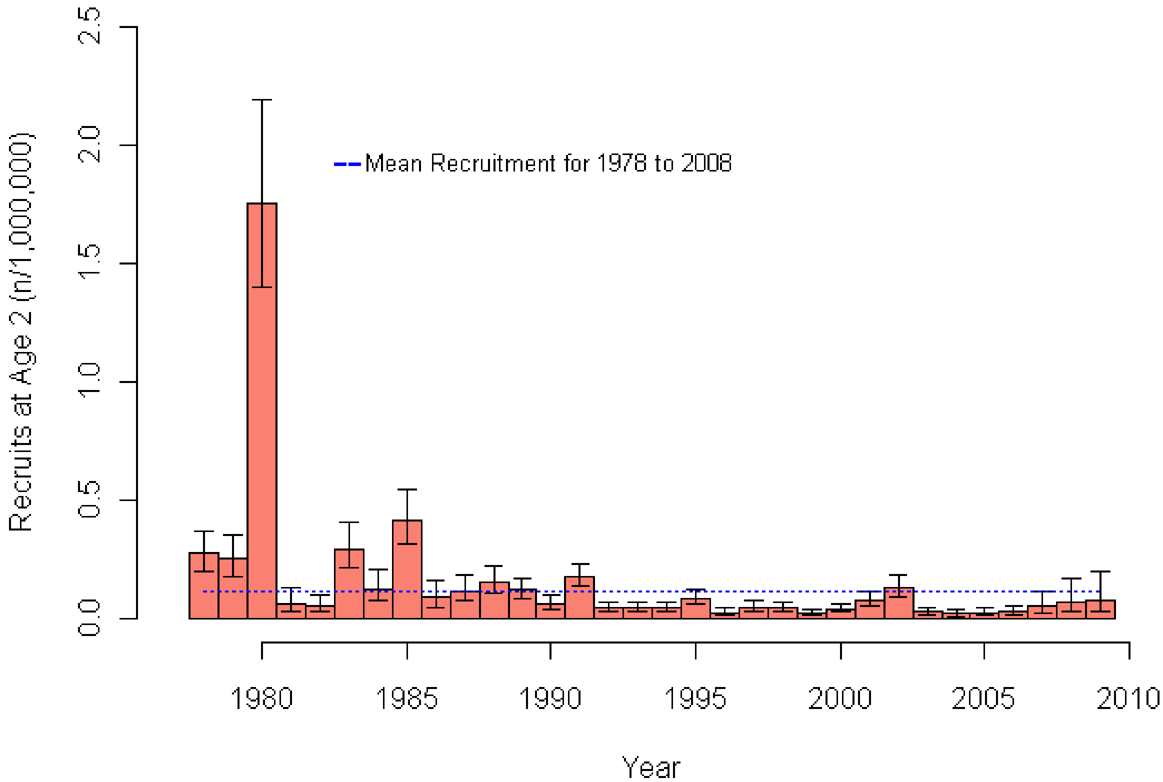


Figure 1A.28. Model AI_AE estimates of Aleutian Islands pollock year-class numbers. The vertical bars represent approximate upper and lower confidence bounds.

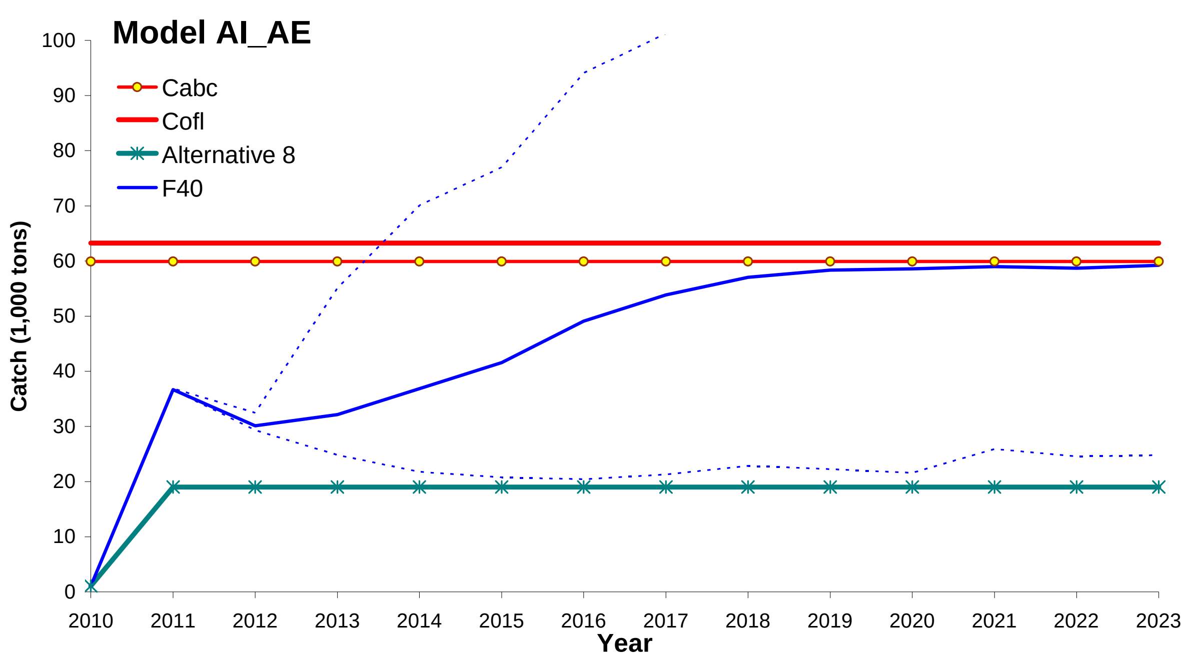


Figure 1A.29 Projected catch for $F_{40\%}$ and Alternative 8 ABC scenarios from reference Model AI_AE.

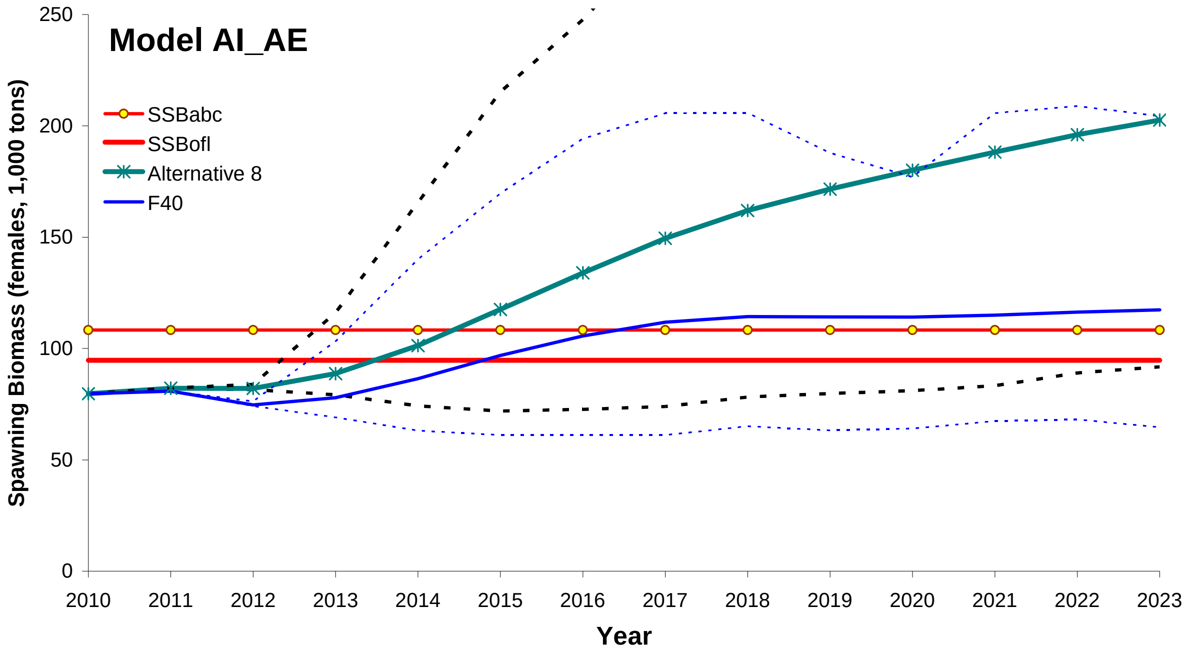


Figure 1A.30 Projected spawning biomass for $F_{40\%}$ and Alternative 8 ABC scenarios from the reference Model AI_AE.

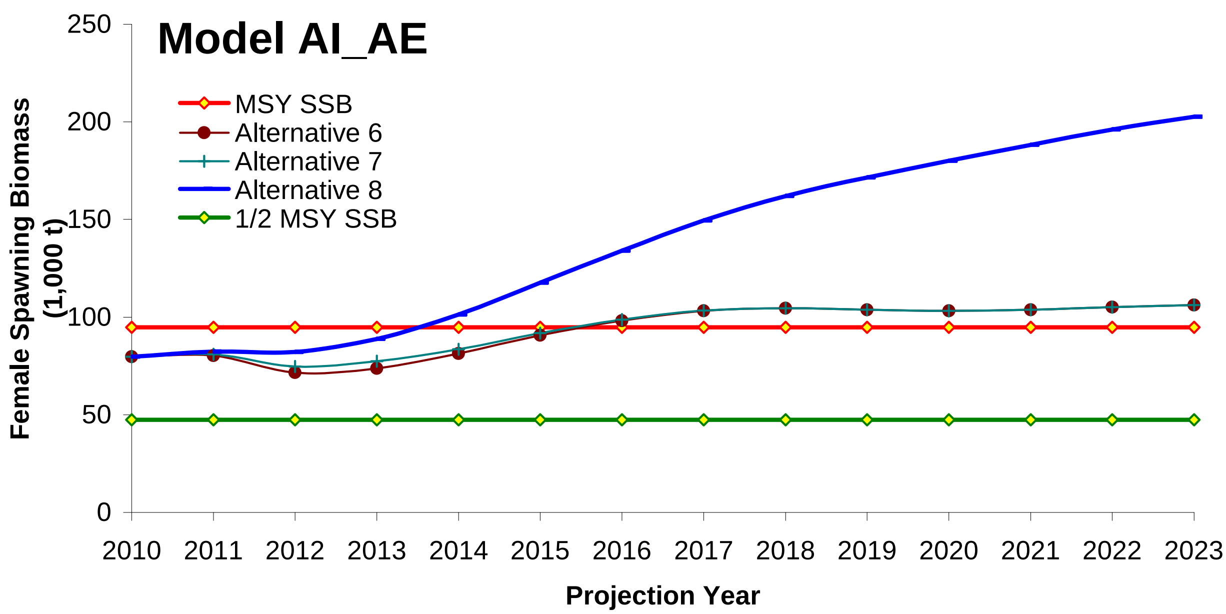


Figure 1A.31 Projected spawning biomass for and Alternatives 6, 7, and 8 ABC scenarios from the reference model, Model AI_AE.

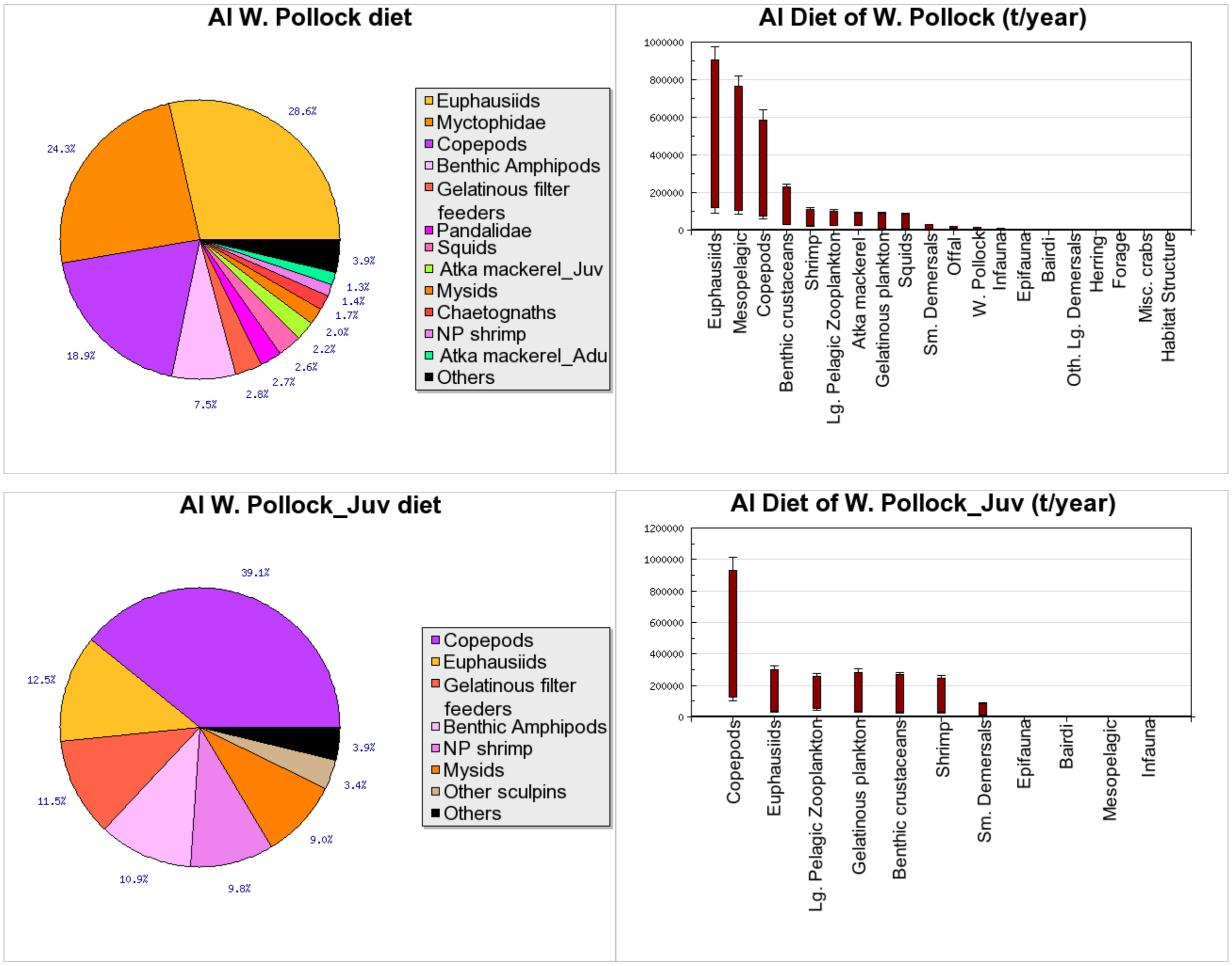


Figure 1A.32. Diet composition (left) and estimated consumption of prey (right) by AI adult (top) and juvenile (bottom) pollock. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994. See Appendix A for detailed methods.

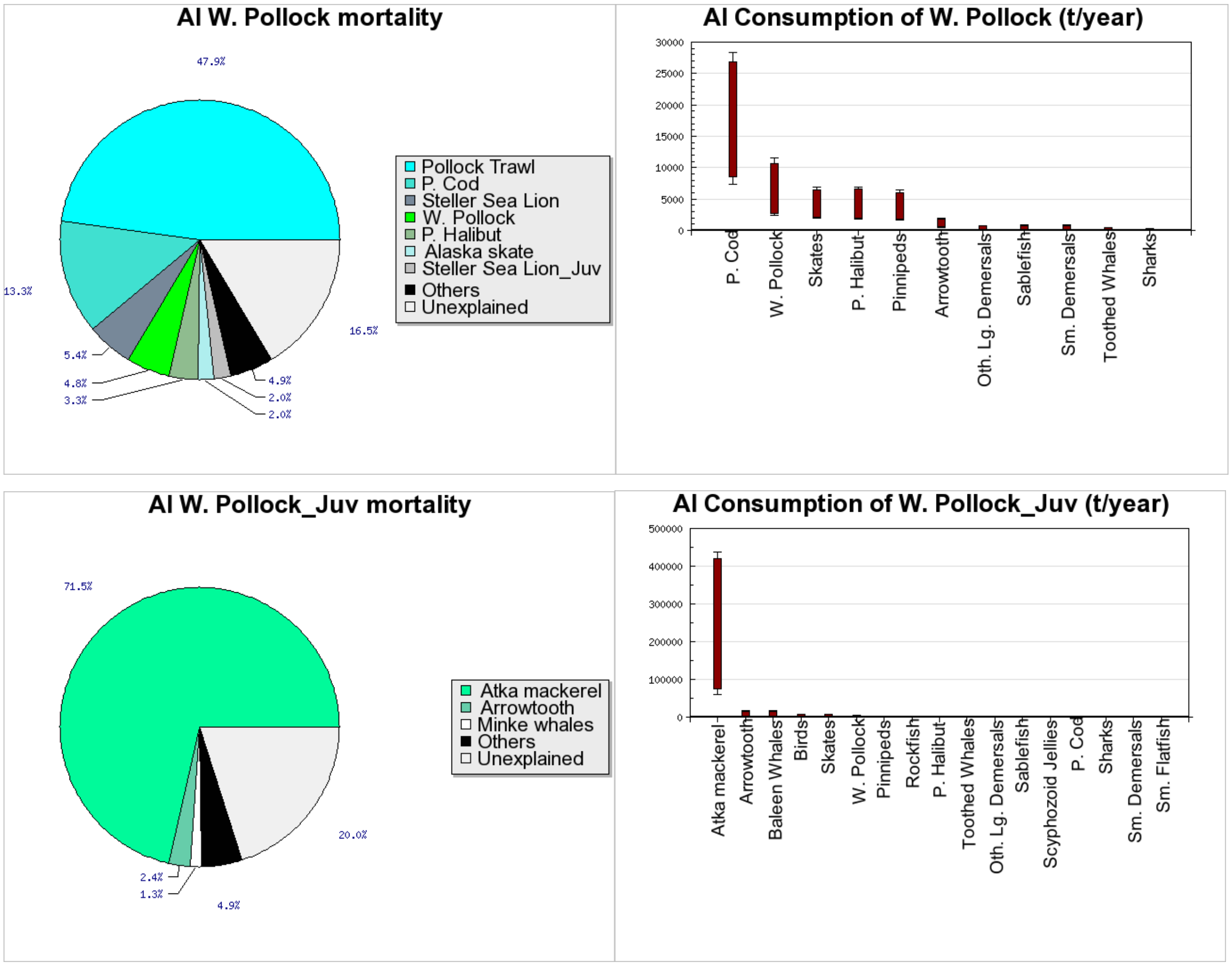


Figure 1A.33. Mortality sources (left) and estimated consumption by predators (right) of AI adult (top) and juvenile (bottom) pollock. Mortality sources reflect pollock predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994, pollock predator consumption rates estimated from stock assessments and other studies, and catch of pollock by all fisheries in the same time periods. Annual consumption ranges incorporating uncertainty in food web model parameters were estimated by the Sense routines (Aydin et al 2004). See Appendix A for detailed methods.

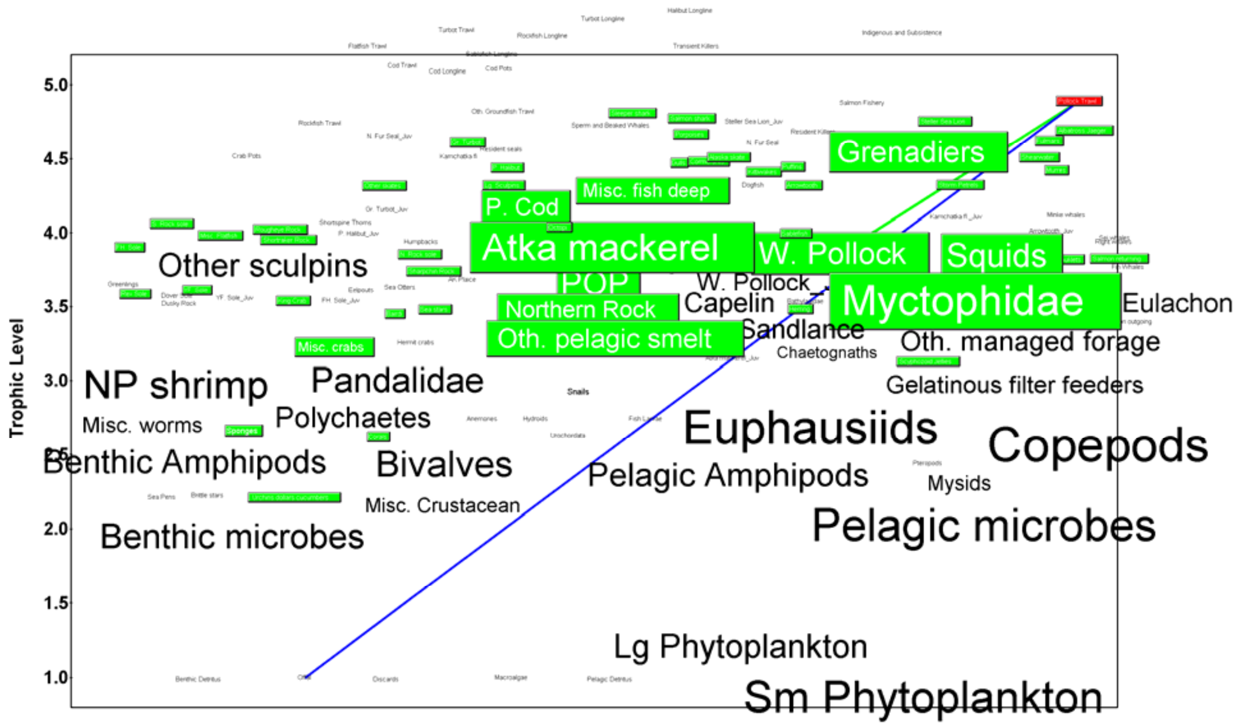


Figure 1A.34. The pollock trawl fishery in the AI food web. Species taken by the pollock fishery (in red) are highlighted in green, with the most significant flow to pollock indicated with a green line. Box size is proportional to biomass and lines between boxes represent the most significant energy flows. From Aydin et al (2004).

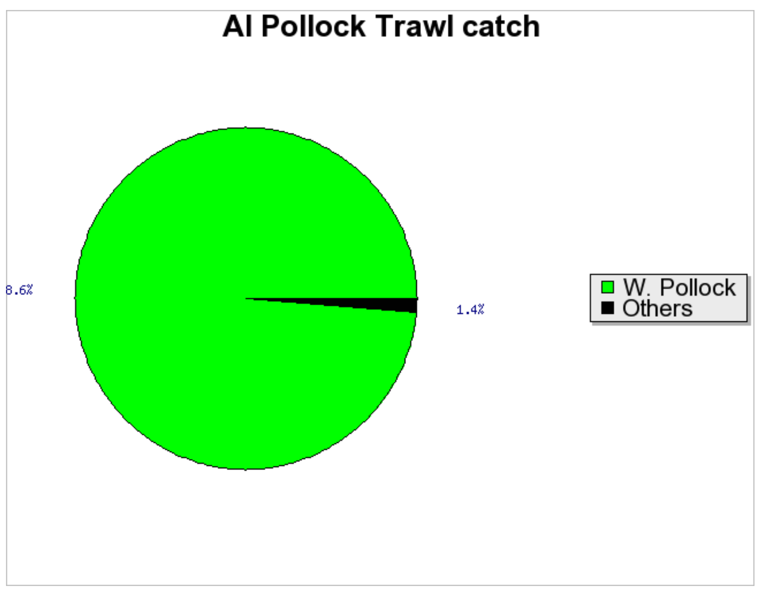


Figure 1A.35. Catch composition of the AI pollock trawl fishery during the early 1990's, as used in the food web model (Aydin et al 2004).

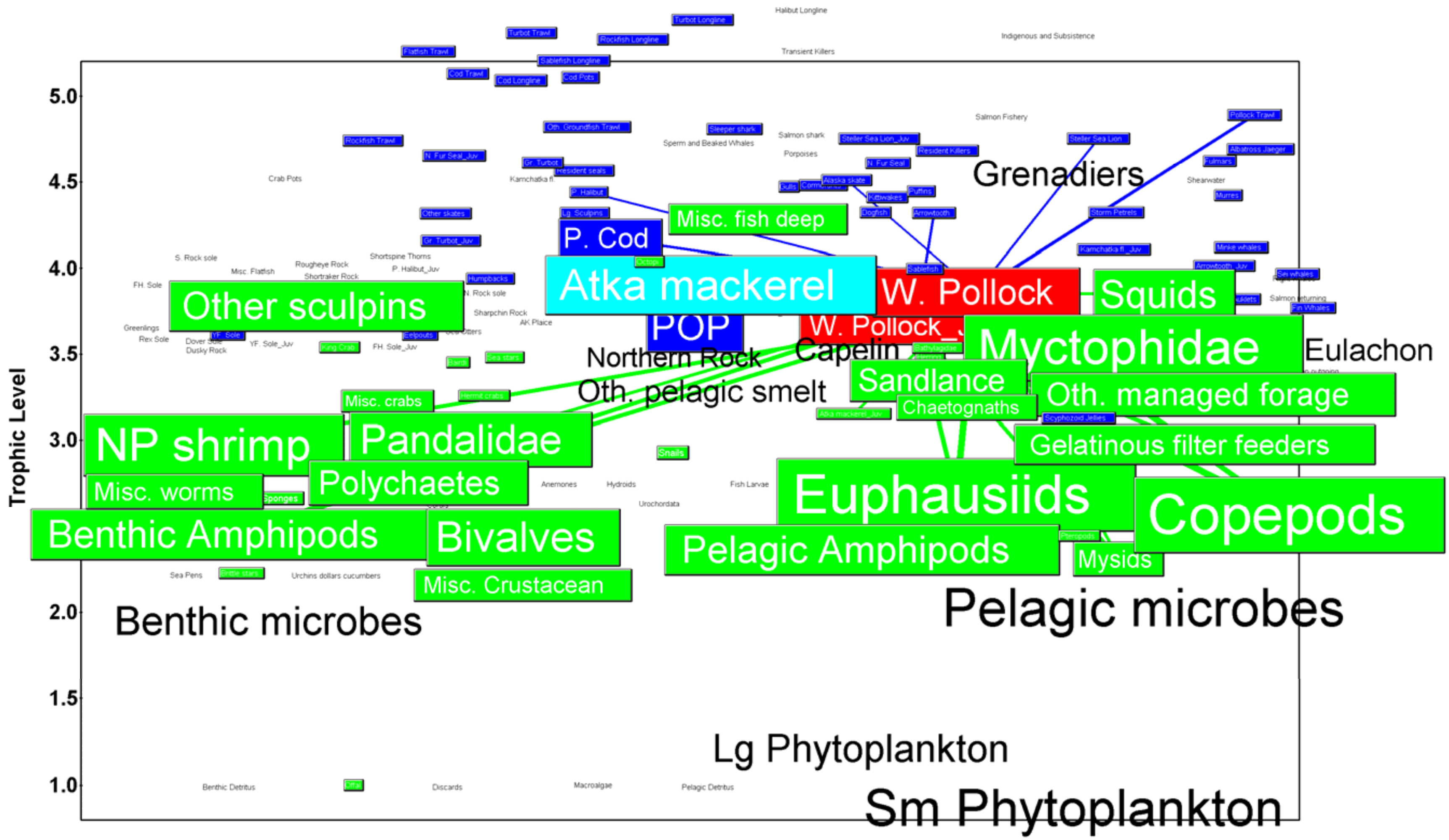
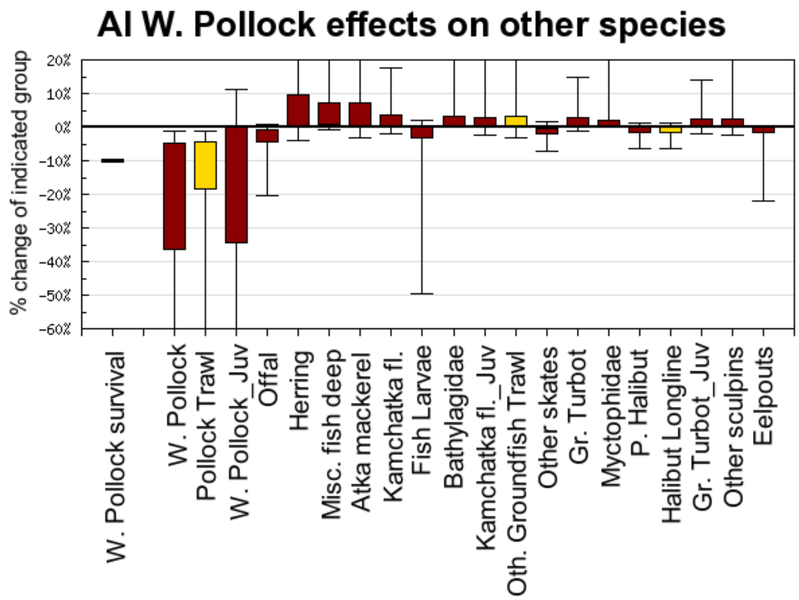


Figure 1A.36. Adult and juvenile pollock (highlighted in red) in the AI food web (Aydin et al 2004). Predators of pollock are dark blue, prey of pollock are green, and species that are both predators and prey of pollock are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.



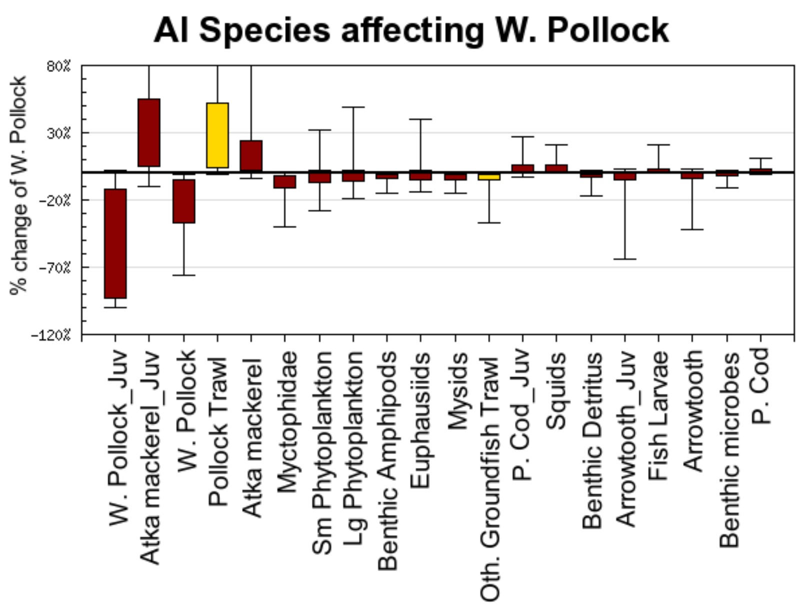


Figure 1A.37. (upper panel) Effect of changing pollock survival on fishery catch (yellow) and biomass of other species (dark red), from a simulation analysis where pollock survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. (lower panel) Effect of reducing fisheries catch (yellow) and other species survival (dark red) on pollock biomass, from a simulation analysis where survival of each X axis species group was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. In both panels, boxes show resulting percent change in the biomass of each species on the x axis after 30 years for 50% of feasible ecosystems, error bars show results for 95% of feasible ecosystems (see Aydin et al in review for detailed Sense methods).

Appendix A

Table A-1. Variable descriptions and model specification.

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: i = {1963, …., 2007}	i	
Age index: j = {1, 2, 3, …, 14$^+$}	j	
Mean weight by age j	W_j	
Maximum age beyond which selectivity is constant	*Maxage*	Selectivity parameterization
Instantaneous Natural Mortality	M	Fixed M=0.20, constant over all ages
Proportion females mature at age j	p_j	Definition of spawning biomass
Sample size for proportion at age j in year i	T_i	Scales multinomial assumption about estimates of proportion at age
Survey catchability coefficient	q^s	Prior distribution = lognormal(1.0 , σ_q^2)
Stock-recruitment parameters	R_0	Unfished equilibrium recruitment
	h	Stock-recruitment steepness
	σ_R^2	Recruitment variance
Estimated parameters		
$\phi_i(26),\ R_0,\ h,\ \varepsilon_i(41), \sigma_R^2,\ \mu^f,\ \mu^s,\ M,\ \eta_j^s(39),\ \eta_j^f c(13),\ q^s(3)$		

Note that the number of selectivity parameters estimated depends on the model configuration.

Table A-2. Variables and equations describing implementation of the Assessment Model for Alaska (AMAK).

Description	Symbol/Constraints	Key Equation(s)
Survey abundance index (s) by year	Y_i^s	$\hat{Y}_i^s = q_i^s \sum_{j=1}^{14^+} s_j^s W_{ij} e^{Z_{i,j}\frac{7}{12}} N_{ij}$
Catch biomass by year	C_i	$\hat{C}_i = \sum_j W_{ij} N_{ij} \frac{F_{ij}}{Z_{ij}} \left(1 - e^{-Z_{ij}}\right)$
Proportion at age j, in year i	P_{ij}, $\sum_{j=1}^{14} P_{ij} = 1.0$	$P_{ij} = \frac{N_{ij} s_{ij}^f}{\sum_{k=1}^{15} N_{ik} s_{ik}^f}$
Initial numbers at age	$j = 1$	$N_{1977,1} = e^{\mu_R + \varepsilon_{1977}}$
	$1 < j < 13$	$N_{1977,j} = e^{\mu_R + \varepsilon_{1978-j}} \prod_{j=1}^{j} e^{-M}$
	$j = 14^+$	$N_{1977,15} = N_{1977,14} \left(1 - e^{-M}\right)^{-1}$
Subsequent years ($i > 1963$)	$j = 1$	$N_{i,1} = e^{\mu_R + \varepsilon_i}$
	$i < j < 13$	$N_{i,j} = N_{i-1,j-1} e^{-Z_{i-1,j-1}}$
	$j = 14^+$	$N_{i,14^+} = N_{i-1,14} e^{-Z_{i-1,13}} + N_{i-1,15} e^{-Z_{i-1,14}}$
Year effect, i = 1963, …, 2007	ε_i, $\sum_{i=1963}^{2007} \varepsilon_i = 0$	$N_{i,1} = e^{\mu_R + \varepsilon_i}$
Index catchability Mean effect	μ^s, μ^f	$q_i^s = e^{\mu^s}$
Age effect	η_j^s, $\sum_{j=1}^{15^+} \eta_j^s = 0$	$s_j^s = e^{\eta_j^s}$ $\quad j \le$ maxage $s_j^s = e^{\eta_{\text{maxage}}^s}$ $\quad j >$ maxage
Instantaneous fishing mortality		$F_{ij} = e^{\mu_f + \eta_j^f + \phi_i}$
mean fishing effect	μ_f	
annual effect of fishing in year i	ϕ_i, $\sum_{i=1977}^{2007} \phi_i = 0$	
age effect of fishing (regularized) In year time variation allowed	η_{ij}^f, $\sum_{j=1}^{15^+} \eta_{ij} = 0$	$s_{ij}^f = e^{\eta_j^f}$, $\quad j \le$ maxage $s_{ij}^f = e^{\eta_{\text{maxage}}^f}$ $\quad j >$ maxage
In years where selectivity is constant over time	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \ne$ change year
Natural Mortality	M	
Total mortality		$Z_{ij} = F_{ij} + M$
Recruitment Beverton-Holt form	$\tilde{R}_i$	$\tilde{R}_i = \frac{\alpha B_i}{\beta + B_i}$, $\alpha = \frac{4hR_0}{5h-1}$ and $\beta = \frac{B_0(1-h)}{5h-1}$ where $h=0.8$ $B_0 = \tilde{R}_0 \varphi$ $\varphi = \frac{e^{-15M} W_{15} p_{15}}{1 - e^{-M}} + \sum_{j=1}^{15} e^{-M(j-1)} W_j p_j$

Table A-3. Specification of objective function that is minimized (i.e., the penalized negative of the log-likelihood).

Likelihood /penalty component		Description / notes
Abundance indices	$L_1 = \lambda_1 \sum_i \ln\left(Y_i^s / \hat{Y}_i^s \right)^2 \frac{1}{2\sigma_i^2}$	Survey abundance
Prior on smoothness for selectivities	$L_2 = \sum_l \lambda_2^l \sum_{j=1}^{15^+} \left(\eta_{j+2}^l + \eta_j^l - 2\eta_{j+1}^l \right)^2$	Smoothness (second differencing), Note: *l={s*, or *f}* for survey and fishery selectivity
Prior on recruitment regularity	$L_3 = \lambda_3 \sum_{i=1963}^{2007} \varepsilon_i^2$	Influences estimates where data are lacking (e.g., if no signal of recruitment strength is available, then the recruitment estimate will converge to median value).
Catch biomass likelihood	$L_4 = \lambda_4 \sum_{i=1963}^{2007} \ln\left(C_i / \hat{C}_i \right)^2$	Fit to catch biomass in each year (
Proportion at age likelihood	$L_5 = -\sum_{l,i,j} T_{ij}^l P_{ij}^l \ln\left(\hat{P}_{ij}^l \cdot P_{ij}^l \right)$	*L={s, f}* for survey and fishery age composition observations
Fishing mortality regularity	$L_6 = \lambda_6 \sum_{i=1963}^{2007} \phi_i^2$	(relaxed in final phases of estimation)
Priors	$L_7 = \left[\lambda_7 \frac{\ln\left(M / \hat{M} \right)^2}{2\sigma_M^2} + \lambda_8 \frac{\ln\left(q / \hat{q} \right)^2}{2\sigma_q^2} \right]$	Prior on natural mortality, and survey catchability (reference case assumption that these are precisely known at 0.3 and 1.0, respectively).
Overall objective function to be minimized	$\dot{L} = \sum_{i=1}^{7} L_i$	

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