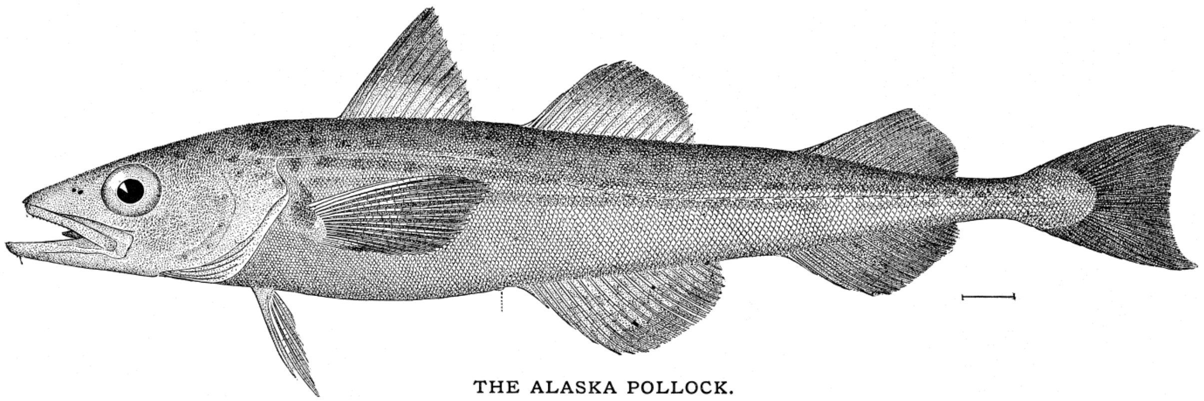
Chapter 1A: Assessment of the pollock stock in the Aleutian Islands



THE ALASKA POLLOCK.

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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 using the AMAK stock assessment model (Barbeaux et al. 2011). As presented in the 2011 stock assessment document, this assessment concerns the pollock stock located in the near shore areas of the Aleutian chain island west of 170°W identified as the Near, Rat, and Andreanof Island (NRA) sub-area of the Aleutian Islands. We continue with the same assessment model presented last year. The only differences in the model is a change in how the fishery age composition sample sizes were determined and a new set of GAMs for estimating the year specific weight-at-age. In addition we include the 2012 summer bottom trawl survey estimate and 2012 fishery catch estimate. It should be noted here that the 2012 summer bottom trawl estimate was the lowest on record with only 44,281 t estimated for the area west of 170° w longitude.

Summary of changes in assessment inputs

- Inclusion of the 2012 pollock catch estimate
- Inclusion of the 2012 Summer bottom trawl survey biomass estimate
- Catches for 1978 to 2012 were updated to latest estimates from the catch accounting system (CAS)
- A generalized additive model was used for estimating year specific weight-at-age data

Summary of changes in the assessment results

- The maximum permissible ABC for 2013 and 2014 (assuming the five year average catch in 2013) under Tier 3b are 37,295 t and 39,818 t, respectively. The OFL for 2013 and 2014 under Tier 3b are 45,588 t and 48,596 t respectively.
- Due to the historic low survey biomass estimate of 44,281 t the Tier 5 values were much lower this year than last with a Tier 5 ABC for 2013 and 2014 assuming M = 0.2 would be 6,642 t and OFL would be 8,856 t.

Summary Table

Quantity	As estimated or *specified last* year for: 2012	2013	As estimated or *recommended this* year for: 2013	2014*
M (natural mortality rate)	0.19		0.18	
Tier	3b		3b	
Projected total (age 2+) biomass (t)	250,905	285,228	265,591	292,824
Female spawning biomass (t)				
Projected	70,894	73,033	85,240	86,168
$B_{100\%}$	234,074		249,513	
$B_{40\%}$	93,630		99,805	
$B_{35\%}$	81,926		87,330	
F_{OFL}	0.33	0.33	0.34	0.34
$maxF_{ABC}$	0.27	0.27	0.27	0.28
F_{ABC}	0.27	0.27	0.27	0.28
OFL (t)	39,607	39,607	45,588	48,596
maxABC (t)	32,454	32,454	37,295	39,818
ABC (t)	32,454	32,454	37,295	39,818
Status	As determined *last* year for: 2010	2011	As determined *this* year for: 2011	2012
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

* After 2013 catch of the five year average catch of 1,614 t. If the 2013 catch is max TAC of 19,000 t the 2014 projected total age 2+ biomass would be 276,980 t, the female spawning biomass would be **78,786** t, the maximum permissible ABC would be 33,827 t and the 2014 OFL would be 41,410 t. In which case the 2014 F_{OFL} would be 0.32 and the max F_{ABC} would be 0.26.

Responses to SSC and Plan Team Comments on Assessments in General

<u>Retrospective analysis</u>

From the December 2011 SSC minutes: The SSC is pleased to see that many assessment authors have examined retrospective bias in the assessment and encourages the authors and Plan Teams to determine guidelines for how to best evaluate and present retrospective patterns associated with estimates of biomass and recruitment. We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments.

From the September 2012 Plan Team minutes: The Teams recommend that authors conduct a retrospective analysis back 10 years (thus, back to 2002 for the 2012 assessments), and show the patterns for spawning biomass (both the time series of estimates and the time series of proportional changes relative to the 2012 run). This is consistent with a December 2011 NPFMC SSC request for stock assessment authors to conduct a retrospective analysis. The base model used for the retrospective analysis should be the author's recommended model, even if it differs from the accepted model from previous year.

A retrospective analysis was completed in which data were systematically removed from the model for each year back to 2002.

<u>*Total catch accounting*</u>
From the September 2012 Plan Team minutes: The Teams recommend that authors continue to include other removals in an appendix for 2012. Authors may apply those removals in estimating ABC and OFL; however, if this is done, results based on the approach used in the previous assessment much also be presented.

We present other removals in an appendix to the Aleutian Islands pollock assessment. Other catch removals for AI pollock are minimal and were not applied in the estimation of 2013 and 2014 ABC and OFL.

Response to SSC and Plan Team CommentsSpecific to this Assessment

- There were no SSC comments from 2011 specific to AI pollock stock assessment.

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 surveyed abundance between 1986 (444,000 t) and 1994 (78,000 t) with a relatively slow but steady increase in surveyed abundance through 2010 (Fig 1A.1a). The 2012 survey abundance was a record low at 44,281 t. 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 cannot 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, other evidence suggests that the AI pollock are separated from the EBS stock at smaller temporal time scales than current genetic techniques can identify, including 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*; Ormseth 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 high recruitment events 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.4). 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 area 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 through 2012 financial problems with the Adak processing plant greatly hindered the directed fishery. In 2010 and 2011 50 t and 0 t were harvested in the directed fishery, respectively. As of October 9, 2012, 0 t had been taken in the directed fishery. In 2010 and 2011, 1,235 and 1,208 t were harvested as bycatch in other fisheries. In 2012, 961 t had been taken as bycatch in other fisheries as of October 9. Table 1A.3 provides a history of ABC, OFL, TAC, 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.5). 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 1988 and 1993, 1997, and between 1999 and 2005 to construct an age distribution.

The age data collected during the 2006-2008 AICASS (Barbeaux et. al. 2011) revealed 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, 2010, and 2012. 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 (1991-2012) ranged from 44 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.6) 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 2002 through 2010 pollock distribution 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. Although the largest proportion of the pollock biomass in the 2012 survey were observed in the Eastern Aleutians (Area 541), the survey did not find large concentrations of pollock in the east as it had in the previous two surveys. The 2012 survey estimate for the NRA area was 44,275 t, 31% of the 2010 estimate. Biomass was down in all areas. The 2012 estimate for Area 543, the western Aleutians,was 68% of the 2010 estimate, Area 542 and Area 541 were 26% and 30% respectively, of the 2010 biomass estimates. A single tow in Seguam Pass made up the majority of AI pollock (~70%) in the 2012 survey (Fig. 1A.6).

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 recruitment from the time series. The 2000 and 2002 surveys don't show any particularly dominant year class, while the 2004 through 2010 survey age data show the 1999 and 2000 year classes as dominant (Fig. 1A.5b and Table 1A.10). The AIBTS weight-at-age data are presented in Table 1A.11. The 1991 survey age data is questionable since 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 2012 surveys are shown in Figure 1A.7. All of the survey length data distributions are multimodal with a mode for the age-1 pollock between 15 and 22 cm and another for pollock greater than age 4 between 50 and 70 cm. Ages 2 and 3 year old fish are generally low or missing from bottom trawl surveys as it is believed these fish are more pelagic than the adults and age 1 pollock. The 2002 and 2012 surveys shows a larger number of pollock in the age-2 size range (mode between 20 and 40 cm) compared to other years. Age data from the 2012 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 2011 year class, the small mode between 20 and 30 cm is likely age 2 fish representing the 2010 year class, and fish near the 38 cm mode are likely age-3 pollock from the 2009 year class. Fish greater than 45 cm comprise a mix of the 2000 through 2008 year classes and beyond. The mode of age 1 fish in 2012 is larger than any other survey, this may simply be the result of fewer large pollock being observed in the 2012 survey.

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.

In 2006, and 2007 acoustic survey studies (Fig. 1A.8) 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.8) 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.9).

Analytic Approach

The 2012 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 models presented since 2007 were 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 year's model the multinomial sample sizes for the fishery were calculated as the minimum of the number of sampled hauls or 100 plus the number of sampled hauls divided by the mean number of sampled hauls.   A value of 100 was specified for survey catch-at-age data.

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

Fishery data*	Year	1978	1979	1980	1981	1982	1983	1984	1985	1986
	$\dot{N}_{i,\bullet}$	100	33	100	100	101	101	104	102	101
	Year	1987	1988	1991	1992	1993	1994	1995	1996	1997
	$\dot{N}_{i,\bullet}$	101	101	101	103	103	103	103	103	101
	Year	1998	2006	2007	2008					
	$\dot{N}_{i,\bullet}$	101	100	100	100					
Survey data	Year	1980	1983	1986	1991					
	$\dot{N}_{i,\bullet}$	1**	1**	1**	1**					
	Year	1994	1997	2000	2002	2004	2006	2010		
	$\dot{N}_{i,\bullet}$	100	100	100	100	100	100	100		

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

**The 1980-1991 values were down-weighted because the samples collected in these years were not representative of the region considered.

Parameters

Parameters estimated independently

Weight-at-age

We estimated 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 fishery weight-at-age values from 1978 to 2011 are given in Table 1A.8 and the survey weight-at-age values are given in Table 1A.11. For all years and age classes for both the survey and fishery data weight at age by year were predicted using generalized additive models with time period and age as the independent variables (Barbeaux et al. 2011). Five time periods were defined (F1 = 1978-1984, F2= 1985-1989, D1=1990-1994, D2=1995-1998, D3=1999-2011). These time periods correspond to the early foreign fishery (f1), the late foreign fishery and joint venture fishery (F2), the early domestic fishery (D1) the late domestic fishery (D2), and the period of limited AI pollock fisheries (D3). These weight-at-age 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 likely is a difference in maturity-at-age between the Bering Sea and Aleutian Islands. The authors agree, but maturity studies have not been conducted specifically for Aleutian Islands pollock and given the lack of a substantial fishery, not likely to occur 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 more similar to the GOA than the Bering Sea. Both last year’s and this year’s assessment 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.10).

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 fixed at 0.7 and the recruitment variance (σ_R^2) was fixed at a value of 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.

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. The 2012 model does not 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 presented in this assessment.

Natural Mortality

For this year's model 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 value of 0.3 used in the Eastern Bering Sea and Gulf of Alaska pollock assessments (Ianelli et al. 2009; Dorn et al. 2009). In the current assessment we assume 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 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 reasonably estimated in this case using the AICASS age data because steepness (h) and the recruitment variance (σ_R^2) are assumed to be known.

Model evaluation

Only a single model configuration is presented for this stock assessment cycle. Model AI is the model presented in the 2011 assessment with 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 model was configured with a survey catchability of 1.0, a stock recruitment steepness parameter (h)of 0.7 and recruitment variance (σ_R^2) of 0.6. Recruitment was modeled using data from 1978-2010. Natural mortality for all models was estimated within the model 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	Yes	Fixed	8	8

Model fit criteria results are shown in Table 1A.16 and key results are presented in Table 1A.17. Because there was a change in the underlying data a direct comparison of fit among years is not possible.

Similar to previous years, the model fit to the survey data was relatively poor (Fig. 1A.11), particularly for the 2012 survey index. 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.

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.12). Fits to the fishery age-composition data (Fig. 1A.13) was worse than the survey catch-at-age fits, but still relatively good. The reference model had a difficult time matching the mean age of the fishery data for the early 1990s where the population appeared to still have a large proportion of fish from the 1978 year class (Fig. 1A.14). 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 (Fig. 1A.15). The estimated survey selectivities at age are presented in Table 1A.18 and Fig. 1A.16.

Like previous years, recruitment variability was high for the reference model (0.88). In addition, natural mortality was estimated to be slightly lower in this year's model (M = 0.18, CV = 0.05) versus last year (M = 0.19, CV = 0.05), affecting the estimated reference points. The 2011 reference model estimated $B_{100\%}$ at 234,074 t and $B_{35\%}$ at 81,926, while the 2012 reference model had $B_{100\%}$ at 249,513 t and $B_{35\%}$ at 87,330 t.

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 abundance trend and level is very high. Bearing in mind the high degree of uncertainty, total biomass estimates (Table 1A.19, Fig. 1A.17, Fig. 1A.18) in the 1980's for the Aleutian Islands area reached a peak of 1,101,640 t in 1984 due to the 1978 year class which was well above average (Fig. 1A.20A, and Fig. 1A.21A). The model shows a large decline in the stock since its 1984 peak, hitting its minimum biomass levels in 2000 at 156,310 t. Total age 2+ biomass increased from 1999 to 2005 after cessation of directed fishing in the area. The increasing trend leveled off between 2005 to 2007 due to poor recruitment between 2000 and 2005. Biomass increased from 2008 onward due to the appearance of a prominent 2006 year class in the 2010 survey age data. Estimated pollock numbers at age from 1978 to 2012 are given in Table 1A.20.

Female Spawning Stock Biomass (SSB) peaked in 1984 at 387,686 t as the 1978 year class reached maturity (Fig.1A.17 and Fig. 1A.18), and dipped to a low of 57,120 t in 1999 ($B_{23\%}$ or 15% of the 1984 value) after a decade of poor recruitments and high fishing pressure. The highest full selection fishing mortality occurred in 1995 (F = 0.39 and Catch/biomass = 0.22) when the fishery harvested more than 75% of the 1994 survey biomass estimate (Table 1A.21, Fig.1A.19). The reference model shows high exploitation rates beginning in 1990 (F = 0.254) continuing through 1998 (Table 1A.22). The early 1990s fishery appeared to be concentrate 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 (Fig. 1A.20B, and Fig. 1A.21B). The status of AI pollock in 2011 and 2012 was assessed to be well above $B_{20\%}$ and had a low exploitation rates (Fig. 1A.22).

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 1979-2010 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.23). The simulation shows the 2012 female spawning stock biomass to be at 76% of what it would have been without fishing, but at a low in 1999 at 27% of the unfished stock.

Recruitment

Recruitment (at age 2) is estimated with high variance (Table 1A.23 and Fig. 1A.24). The recruitment variance (σ_R^2) was fixed at a value of 0.6, and the reference model estimates recruitment variability was 0.88. For comparison the recruitment variability in the 2011 reference model was 0.992. The 1978 year-class is the largest (1.392 billion age 2 recruits) and is highly influential with a large part of the fishery removals being composed of this year class (Fig. 1A.21). The years 1976-1986 had several large year classes in comparison to more recent recruitment. The mean recruitment of age 2 pollock for 1978-1988 was 240.9 million, while the mean recruitment at age 2 between 1998 and 2010 was 39.3 million fish, with no year classes since the 1989 year class exceeding the overall 1978-2010 mean recruitment of 111.2 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 163.4 million age 2 recruits and the 2000 year class with 86.5 million age 2 recruits. 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 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. The mean recruitment for 1978 - 2010 without the 1978 year class was 63.9% (71.1 million) of the mean recruitment with the 1978 year class (111.2 million). If the 1978 year class is anomalous, it may be inflating the biological reference points 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.

Retrospective analysis

We systematically removed each year's data from the model for 10 years to evaluate the retrospective pattern in the reference model's performance. The Aleutian Islands pollock preferred model performed well in the retrospective analysis with little difference (within the 95% confidence intervals of the 2012 reference model) in spawning biomass estimates (Fig. 1A.25). There was an apparent positive bias in the results, but differences were all within the 95% confidence bounds of the Reference model.

Projections and harvest alternatives

For management purposes we use the yield projections estimated for the 2012 reference model. We used the reference model estimated fishery selectivity at age (Table 1A.18 and Fig. 1A.16) for all projections.

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 1978-2010 for the reference model (111.2 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 reference model:

Female spawning biomass	Model AI
$B_{100\%}$	249,513 t
$B_{40\%}$	99,805 t
$B_{35\%}$	87,330 t
B_{2013}	85,240 t

Specification of OFL and Maximum Permissible ABC

For the reference model, the projected year 2013 female spawning biomass (SB_{13}) is estimated to be 85,240 t, below the $B_{40\%}$ value of 99,085 t placing NRA pollock in Tier 3b. The maximum permissible ABC and OFL values under Tier 3b for 2013 are:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2013 Projected yield (t)
max F_{ABC}	*Adjusted* $F_{40\%}$	0.27	37,295 t
F_{OFL}	*Adjusted* $F_{35\%}$	0.34	45,588 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 0.18, the 2013 ABC would be 5,978 t (44,281 t x 0.75 x 0.18 = 5,978 t) and under Tier 5 with an assumed natural mortality of 0.3 the 2013 ABC would be 9,963 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 indicated 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 (1991 through 2012) AI bottom trawl surveys are highly uncertain with an average *CV* of 0.46. The 2002, 2004, 2006, 2010, and 2012 estimates of *CV* are 0.38, 0.78, 0.48, 0.33, and 0.55 respectively. This results in considerable uncertainty in the model results.

4) The reference model suggests that currently a large proportion of the stock in the Aleutians is composed of much older fish (18% age 10+ by number) which make up a large proportion of the

catch (46% age 10+ by number). These results are 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.

6) If the 1978 year class is anomalous, it may be inflating the biological reference points in and may be causing an overestimation of the expected productivity of this system, particularly if the 1978 year class originated elsewhere.

ABC Recommendations

The pollock spawning stock biomass in the NRA appears to be increasing slowly since 2008. The total biomass also appears to be increasing slowly. The projected total age 2+ biomass for 2013 is 265,591 t. Assuming the five year average catch of 1,614 t the estimated female spawning biomass projected for 2013 is 85,240 t. Under this scenario the maximum permissible 2013 ABC (F_{maxABC} = 0.27) is 37,295 t and OFL (F_{OFL} = 0.34) is 45,588 t and the 2014 ABC (F_{maxABC} = 0.28) is 39,818 t and OFL (F_{OFL} = 0.34) is 48,596 t which are the authors' recommended ABC and OFLs.

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 2012 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2013 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2012. 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 2013, are as follows (a "*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2013 recommended in the assessment to the *max* F_{ABC} for 2013. (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 2008-2012 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 2012 or 2) above 1/2 of its MSY level in 2012 and above its MSY level in 2022 under this scenario, then the stock is not overfished.)

Scenario 7: In 2013 and 2014, 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 2025 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 2013 through 2025 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 2012:

a. If spawning biomass for 2012 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2012 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2012 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 2022 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 2015 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2015 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2015 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2025. If the mean spawning biomass for 2025 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 the reference model under a Tier 3b harvest strategy of an adjusted $F_{40\%}$ (Scenario 1), female spawning biomass is projected to be below $B_{35\%}$ through 2015, be below $B_{40\%}$ through 2020, then be above $B_{40\%}$ for the remainder of the projection (Fig.1A.26 and Fig.1A.27). Female spawning biomass is projected be above ½ $B_{35\%}$, but below $B_{35\%}$ when fishing at F_{OFL} (Fig.1A.28) through 2018 in Scenario 7. The female spawning biomass is projected to 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 due to the harvest control rules.

The associated long-term average female spawning biomass that would be expected under average estimated recruitment from 1978-2010 (111.2 million age 2 fish) and $F = F_{35\%}$, denoted $B_{35\%}$ is estimated to be 87,330 t. This value ($B_{35\%}$), is used in the status determination criteria. Female spawning biomass for 2012 (83,614 t) 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 2025 is projected to be above $B_{35\%}$ in Scenario 7, and is expected to be above $B_{35\%}$ in 2022 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.27, Fig.1A.28, and Table 1A.24), show that the stock could support a constant catch of 19,000 t. Currently the stock is at $B_{34.5\%}$ and the long-term expected yield at $B_{40\%}$ is 47,884 t and at $B_{35\%}$.is 50.664 t, well above the 19,000 t cap.

The SSC asked that the probability of the spawning stock biomass being below $B_{20\%}$ in 2013 be computed for stocks in Tier 3b. We computed the number of standard deviations the 2013 spawning biomass (B_{2013}) was from $B_{20\%}$, assuming B_{2013} was normally distributed. B_{2013} is estimated in the stock assessment model (non-projected) to be at 85,479 t with a standard deviation of 10,957 t and $B_{20\%}$ is estimated at 49,903 t, therefore B_{2013} is 3.25 standard deviations from $B_{20\%}$. Under the assumption of a normal error distribution there is a 0.20 % chance of the AI pollock stock currently being below $B_{20\%}$.

Ecosystem Considerations

Pollock is a commercially important species. It is also 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, 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. 29, 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 from Barbeaux et al. 2006, "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.29, 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.30, 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 Pacific 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.30, 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.31) is a relatively high trophic level (TL) predator which interacts mostly with adult pollock, but also with many other species (in green; Fig. 1A.33). 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. 32). 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).

Pollock 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.33). 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.34 shows the resulting percent change in the biomass of each species after 30 years for 50% of feasible ecosystems with 95% confidence intervals (error bars in Figure1A.34. 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.34, 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 the 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.34 (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.34, 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.30, 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.31 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 2012 Aleutian Islands summer bottom temperatures indicated that water temperatures were cooler than the 2002-2010 surveys (Lowe et. al. 2012). 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%). In addition to 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 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. There was no directed pollock fishery in the Aleutians in 2011 or 2012.

Concentration of AI pollock catches in time and space

Since no EFP is proposed for 2013 there is expected to only be a very limited fishery in 2013, if any at all. The only shore-based plant capable of processing the Aleutian Islands' pollock catch in Adak is currently not configured to do so and no pollock processing is expected there in 2013.

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), 2010 (50 t), 2011 (0 t), 2012 (0 t). Year to year differences observed in the previous decade cannot 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 2013 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 recent years.

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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Tables

Table 1A.1. Estimates of walleye pollock catches from the entire Aleutian Islands Region by source, 1977-2012. 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	31,258
1982	57,753		62,624	11,847	50,322
1983	59,021		44,544	12,429	44,442
1984	77,595		67,103	48,538	42,901
1985	58,147		48,733	43,844	47,070
1986	45,439		14,392	29,464	23,810
1987	28,471			17,944	26,257
1988	41,203			21,987	36,864
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		1,409	1,729
2010		1,238		1,261	1,238
2011		1,208		1,198	1,208
2012		961		613	961

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

** as of October 14, 2012

Table 1A.2. Estimates of Aleutian Islands Region walleye pollock catch by the three management sub-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	1995	28,109	36,714	102	64,925
1978	5,267	712	305	6,283	1996	9,226	19,574	261	29,062
1979	1,488	1,756	6,203	9,446	1997	8,110	16,799	1,031	25,940
1980	28,284	7,097	22,775	58,157	1998	1,837	3,858	18,127	23,822
1981	43,461	10,074	1,982	55,517	1999	484	420	105	1,010
1982	54,173	1,205	2,376	57,753	2000	615	461	169	1,244
1983	56,577	1,250	1,194	59,021	2001	332	386	105	824
1984	64,172	5,760	7,663	77,595	2002	842	180	133	1,156
1985	19,885	38,163	100	58,147	2003	577	760	329	1,666
1986	38,361	7,078	0	45,439	2004	397	513	248	1,158
1987	28,086	386	0	28,471	2005	689	415	517	1,621
1988	40,685	517	0	41,203	2006	1,036	488	220	1,745
1989	10,569	0	0	10,569	2007	1,919	476	124	2,519
1990	69,170	9,425	430	79,025	2008	872	290	116	1,278
1991	98,032	561	11	98,604	2009	1,086	400	243	1,729
1992	52,140	206	6	52,352	2010	737	369	132	1,238
1993	54,512	2,536	83	57,132	2011	695	447	66	1,208
1994	58,091	554	15	58,659	2012*	450	419	42	961

*as of October 14, 2012

Table 1A.3. Time series of ABC, TAC, OFL, and total catch for Aleutian Islands Region walleye pollock fisheries 1991-2012. Units are in metric tons.

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	58,700	51,600	NA	57,132	111%
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	1,282	7%
2011	36,700	19,000	44,500	1,208	6%
2012	32,454	19,000	39,607	961*	5%

* As of October 12, 2012

Table 1A.4. Estimated walleye pollock catch discarded and retained for the Aleutian Islands Region based on NMFS blend data, 1990-2011.

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	1,142	140	1,282	11%
2011	1,133	75	1,208	6%

Table 1A.5. Sampling levels in Aleutian Islands Region sub-regions based on foreign, J.V., and domestic walleye pollock observer data 1978 - 2011.

	NRA Area			**Aleutian Islands Area Basin**		
Year	Fish Measured	Hauls Sampled	Vessels Sampled	Fish Measured	Hauls Sampled	Vessels Sampled
1978	6,229	112	11	0	0	0
1979	2,294	33	6	0	0	0
1980	6,779	116	10	0	0	0
1981	11,143	94	13	1,913	15	3
1982	36,932	331	25	11,151	84	7
1983	27,474	240	21	20,744	174	21
1984	54,980	527	35	157,388	1,223	81
1985	29,185	228	25	68,923	460	58
1986	22,918	193	15	39,875	268	48
1987	47,138	352	26	2,665	26	8
1988	23,376	192	18	4,528	37	14
1989	7,431	57	7	0	0	0
1990	67,280	582	35	55	35	11
1991	3,957	34	13	24,025	396	24
1992	22,120	185	40	26,525	234	26
1993	23,559	214	30	26,218	225	31
1994	20,838	203	41	19,524	205	35
1995	31,082	350	34	340	32	16
1996	18,745	194	40	90	1	1
1997	17,722	190	31	77	1	1
1998	10,494	123	15	93	1	1
1999	135	6	4	0	0	0
2000	186	10	5	0	0	0
2001	119	6	3	0	0	0
2002	112	4	4	0	0	0
2003	544	25	7	21	1	1
2004	331	15	4	34	2	1
2005	559	27	8	10	1	1
2006	59	3	3	30	2	1
2007	830	21	9	330	12	1
2008	129	7	3	0	0	0
2009	622	28	10	25	1	1
2010	529	17	7	0	0	0
2011	694	62	6	3	1	1
Total	496,525	4,781	564	404,587	3,473	393

Table 1A.6. Number of aged and weighed fish in the NRA pollock fishery used to estimate fishery age composition. Age data from the AICASS used in the model for 2006, 2007, and 2008 are in bold.

	Number Aged			Number Weighed		
Year	Males	Females	Total	Males	Females	Total
1978	167	273	440	187	294	481
1979	124	178	302	126	183	309
1980	93	167	260	188	291	479
1981	117	143	260	246	270	516
1982	464	519	983	572	642	1214
1983	60	63	123	278	308	586
1984	80	65	145	139	151	290
1985	77	113	190	295	355	650
1986	140	147	287	323	324	647
1987	131	142	273	136	147	283
1988	34	33	67	66	65	131
1989	0	0	0	112	147	259
1990	0	0	0	340	410	750
1991	5	5	10	20	30	50
1992	9	19	28	34	45	79
1993	38	45	83	48	56	104
1994	84	78	162	102	106	208
1995	64	70	134	147	158	305
1996	70	60	130	93	83	176
1997	15	15	30	15	15	30
1998	124	143	267	126	145	271
1999	0	0	0	0	0	0
2000	0	1	1	3	17	20
2001	0	1	1	12	7	19
2002	0	0	0	1	1	2
2003	1	0	1	33	31	64
2004	0	0	0	4	15	19
2005	2	2	4	21	9	30
2006	**150**/0	**183**/0	**333**/0	**1,315**/0	**1,630**/0	**2,945**/0
2007	**542**/0	**526**/0	**1,068**/0	**701**/71	**605**/58	**1,306**/129
2008	**366**/0	**359**/0	**725**/0	**1,142**/1	**1,031**/1	**2,173**/2
2009	0	5	15	50	40	90
2010	0	0	0	32	42	74
2011	0	0	0	37	37	74

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	0.0000	0.0200	0.0930	0.0530	0.3310	0.0830	0.1010	0.1170	0.1000	0.0730	0.0180	0.0080	0.0010	0.0040
1979	0.0040	0.1180	0.1400	0.1330	0.1800	0.1490	0.0780	0.0810	0.0460	0.0320	0.0290	0.0020	0.0010	0.0060
1980	0.1270	0.0600	0.0480	0.0900	0.1940	0.1460	0.1440	0.0790	0.0710	0.0240	0.0080	0.0040	0.0040	0.0010
1981	0.0000	0.1160	0.0940	0.0660	0.0960	0.1610	0.1570	0.1170	0.0950	0.0380	0.0280	0.0160	0.0140	0.0030
1982	0.0000	0.0010	0.6860	0.0950	0.0190	0.0280	0.0510	0.0540	0.0340	0.0140	0.0070	0.0050	0.0030	0.0020
1983	0.0000	0.0000	0.0000	0.5680	0.1190	0.0740	0.0560	0.0790	0.0630	0.0360	0.0000	0.0000	0.0050	0.0000
1984	0.0020	0.0930	0.0000	0.0410	0.5440	0.1290	0.1070	0.0620	0.0170	0.0010	0.0000	0.0010	0.0000	0.0000
1985	0.0050	0.0160	0.2260	0.0510	0.1280	0.4270	0.0820	0.0380	0.0210	0.0030	0.0030	0.0000	0.0010	0.0000
1986	0.0000	0.0870	0.0060	0.1310	0.0180	0.0950	0.3330	0.1340	0.0560	0.0940	0.0180	0.0260	0.0000	0.0000
1987	0.0000	0.0000	0.2470	0.0680	0.0690	0.0110	0.0340	0.4280	0.0410	0.0420	0.0030	0.0230	0.0150	0.0190
1988	0.0000	0.0000	0.0000	0.0340	0.0950	0.1370	0.0600	0.0890	0.4190	0.0640	0.0130	0.0270	0.0130	0.0480
1991	0.0000	0.0000	0.0000	0.0000	0.1960	0.0000	0.0890	0.2920	0.0000	0.1020	0.0890	0.0000	0.2320	0.0000
1992	0.0000	0.0000	0.0000	0.0000	0.0800	0.0340	0.0260	0.0340	0.0000	0.0000	0.1390	0.1440	0.3240	0.2180
1993	0.0000	0.0000	0.0710	0.0430	0.0510	0.0990	0.0530	0.1330	0.0280	0.0990	0.0400	0.0260	0.0440	0.3130
1994	0.0000	0.0000	0.0180	0.2840	0.0580	0.1030	0.1070	0.0670	0.0540	0.0320	0.0800	0.0340	0.0200	0.1420
1995	0.0000	0.0180	0.0490	0.0000	0.2680	0.0140	0.1100	0.1120	0.0220	0.0660	0.0460	0.0870	0.0200	0.1880
1996	0.0000	0.0000	0.0140	0.0570	0.0740	0.2820	0.1300	0.1020	0.0880	0.0390	0.0340	0.0130	0.0590	0.1090
1997	0.0000	0.0000	0.0000	0.0000	0.0000	0.0260	0.2630	0.0820	0.0820	0.1710	0.0410	0.0130	0.1790	0.1440
1998	0.0000	0.0150	0.0030	0.2670	0.0850	0.0550	0.0380	0.0740	0.0640	0.0520	0.1440	0.0620	0.0700	0.0700
2006	0.0000	0.0110	0.0000	0.0210	0.3650	0.1520	0.0270	0.0110	0.0430	0.0560	0.0400	0.0290	0.0880	0.1570
2007	0.0000	0.0040	0.0110	0.0070	0.0450	0.2730	0.2490	0.0730	0.0410	0.0400	0.0630	0.0230	0.0390	0.1300
2008	0.0000	0.0000	0.0060	0.0110	0.0180	0.0350	0.2070	0.2050	0.1050	0.0200	0.0740	0.0740	0.0680	0.1780

Table 1A.8. NRA pollock fishery average weight-at-age in kilograms used in reference model.

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.191	0.375	0.557	0.679	0.758	0.841	0.953	1.086	1.202	1.275	1.315	1.364	1.468	1.655
1979	0.174	0.359	0.538	0.639	0.686	0.735	0.814	0.913	0.994	1.030	1.030	1.026	1.047	1.099
1980	0.213	0.472	0.739	0.890	0.946	0.991	1.071	1.174	1.256	1.285	1.268	1.236	1.204	1.170
1981	0.141	0.329	0.544	0.682	0.738	0.771	0.818	0.876	0.922	0.936	0.922	0.891	0.842	0.770
1982	0.140	0.319	0.538	0.704	0.791	0.841	0.889	0.938	0.972	0.979	0.962	0.927	0.866	0.771
1983	0.155	0.321	0.521	0.694	0.809	0.886	0.948	0.998	1.025	1.024	0.999	0.962	0.897	0.794
1984	0.207	0.373	0.552	0.712	0.838	0.941	1.029	1.092	1.123	1.122	1.099	1.064	0.996	0.910
1985	0.305	0.477	0.631	0.760	0.876	0.992	1.102	1.186	1.231	1.241	1.230	1.202	1.156	1.105
1986	0.352	0.490	0.584	0.651	0.719	0.803	0.893	0.969	1.018	1.038	1.037	1.020	0.996	0.988
1987	0.469	0.631	0.714	0.753	0.796	0.862	0.944	1.023	1.079	1.103	1.094	1.056	1.010	0.998
1988	0.328	0.471	0.563	0.602	0.630	0.668	0.715	0.764	0.800	0.805	0.769	0.698	0.618	0.570
1989	0.248	0.394	0.566	0.703	0.784	0.848	0.923	0.996	1.037	1.047	1.044	1.030	0.986	0.915
1990	0.248	0.394	0.566	0.703	0.784	0.848	0.923	0.996	1.037	1.047	1.044	1.030	0.986	0.915
1991	0.761	0.858	0.971	1.098	1.232	1.358	1.461	1.532	1.572	1.588	1.593	1.592	1.586	1.574
1992	0.653	0.741	0.847	0.971	1.104	1.229	1.329	1.391	1.420	1.425	1.420	1.412	1.402	1.388
1993	0.606	0.691	0.796	0.924	1.066	1.200	1.305	1.368	1.391	1.390	1.378	1.366	1.352	1.334
1994	0.537	0.613	0.711	0.833	0.972	1.106	1.213	1.276	1.300	1.297	1.284	1.269	1.253	1.232
1995	0.636	0.725	0.842	0.993	1.167	1.340	1.482	1.571	1.609	1.611	1.597	1.579	1.556	1.525
1996	0.115	0.223	0.404	0.660	0.955	1.214	1.386	1.464	1.467	1.423	1.367	1.330	1.327	1.349
1997	0.198	0.350	0.574	0.857	1.149	1.386	1.552	1.652	1.698	1.699	1.672	1.641	1.627	1.633
1998	0.224	0.367	0.558	0.777	0.984	1.146	1.260	1.336	1.382	1.401	1.397	1.385	1.378	1.388
1999	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2000	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2001	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2002	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2003	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2004	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2005	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2006	0.223	0.395	0.661	1.018	1.384	1.652	1.789	1.841	1.874	1.925	1.986	2.024	2.005	1.926
2007	0.218	0.381	0.634	0.968	1.304	1.544	1.659	1.700	1.733	1.790	1.862	1.910	1.896	1.818
2008	0.244	0.412	0.666	0.991	1.317	1.559	1.689	1.749	1.798	1.865	1.941	1.992	1.983	1.911
2009	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2010	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2011	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735
2012	0.256	0.370	0.558	0.858	1.238	1.541	1.652	1.650	1.670	1.748	1.825	1.834	1.785	1.735

Table 1A.9. Pollock biomass estimates from the Aleutian Islands Groundfish Survey, 1980-2012.

	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
2012	31,487	7,433	5,360	13,237	44,281

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

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1983	0.061	0.029	0.056	0.559	0.107	0.039	0.036	0.035	0.023	0.022	0.01	0.006	0.007	0.013
1986	0.016	0.076	0.078	0.123	0.046	0.071	0.391	0.099	0.025	0.019	0.017	0.012	0.013	0.015
1991	0.081	0.036	0.069	0.111	0.081	0.052	0.103	0.08	0.077	0.031	0.047	0.141	0.058	0.035
1994	0.034	0.049	0.057	0.232	0.081	0.083	0.097	0.061	0.034	0.051	0.039	0.035	0.04	0.106
1997	0.056	0.058	0.139	0.104	0.09	0.073	0.178	0.065	0.045	0.043	0.026	0.015	0.034	0.074
2000	0.048	0.046	0.081	0.128	0.096	0.142	0.093	0.068	0.052	0.091	0.038	0.023	0.033	0.062
2002	0.124	0.126	0.079	0.056	0.074	0.097	0.072	0.098	0.062	0.04	0.032	0.051	0.034	0.057
2004	0.027	0.054	0.205	0.164	0.082	0.049	0.058	0.073	0.053	0.061	0.04	0.026	0.031	0.078
2006	0.032	0.049	0.053	0.08	0.218	0.154	0.074	0.043	0.045	0.051	0.038	0.042	0.043	0.079
2010	0.038	0.083	0.159	0.123	0.063	0.056	0.044	0.058	0.116	0.081	0.037	0.02	0.035	0.088

Table 1A.11. Aleutian Islands bottom trawl survey pollock average weight-at-age in kilograms used in reference model.

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.174	0.387	0.624	0.760	0.847	0.935	0.999	1.054	1.114	1.164	1.303	1.607	1.782	1.578
1979	0.174	0.387	0.624	0.760	0.847	0.935	0.999	1.054	1.114	1.164	1.303	1.607	1.782	1.578
1980	0.174	0.387	0.624	0.760	0.847	0.935	0.999	1.054	1.114	1.164	1.303	1.607	1.782	1.578
1981	0.174	0.387	0.624	0.760	0.847	0.935	0.999	1.054	1.114	1.164	1.303	1.607	1.782	1.578
1982	0.174	0.387	0.624	0.760	0.847	0.935	0.999	1.054	1.114	1.164	1.303	1.607	1.782	1.578
1983	0.163	0.457	0.643	0.715	0.827	0.932	1.026	1.016	1.161	1.206	1.069	1.764	2.073	1.419
1984	0.174	0.387	0.624	0.760	0.847	0.935	0.999	1.054	1.114	1.164	1.303	1.607	1.782	1.578
1985	0.174	0.387	0.624	0.760	0.847	0.935	0.999	1.054	1.114	1.164	1.303	1.607	1.782	1.578
1986	0.211	0.460	0.575	0.693	0.852	0.870	0.955	1.058	1.069	0.861	1.058	0.849	0.829	0.803
1987	0.243	0.369	0.524	0.682	0.818	0.922	0.989	1.020	1.016	0.988	0.946	0.897	0.847	0.799
1988	0.243	0.369	0.524	0.682	0.818	0.922	0.989	1.020	1.016	0.988	0.946	0.897	0.847	0.799
1989	0.243	0.369	0.524	0.682	0.818	0.922	0.989	1.020	1.016	0.988	0.946	0.897	0.847	0.799
1990	0.243	0.369	0.524	0.682	0.818	0.922	0.989	1.020	1.016	0.988	0.946	0.897	0.847	0.799
1991	0.207	0.531	0.749	0.828	0.944	1.050	1.203	1.194	1.185	1.321	1.046	1.288	1.118	1.074
1992	0.205	0.445	0.732	0.942	1.071	1.194	1.320	1.399	1.421	1.439	1.480	1.496	1.435	1.317
1993	0.205	0.445	0.732	0.942	1.071	1.194	1.320	1.399	1.421	1.439	1.480	1.496	1.435	1.317
1994	0.205	0.462	0.822	0.960	1.125	1.342	1.422	1.757	1.702	1.553	1.619	2.723	1.417	1.683
1995	0.205	0.445	0.732	0.942	1.071	1.194	1.320	1.399	1.421	1.439	1.480	1.496	1.435	1.317
1996	0.160	0.413	0.699	0.906	1.050	1.177	1.295	1.373	1.418	1.483	1.553	1.562	1.544	1.559
1997	0.211	0.381	0.700	0.894	1.001	1.151	1.329	1.303	1.356	1.461	1.510	1.499	1.506	1.481
1998	0.160	0.413	0.699	0.906	1.050	1.177	1.295	1.373	1.418	1.483	1.553	1.562	1.544	1.559
1999	0.160	0.413	0.699	0.906	1.050	1.177	1.295	1.373	1.418	1.483	1.553	1.562	1.544	1.559
2000	0.166	0.447	0.724	0.927	0.967	1.211	1.351	1.410	1.420	1.535	1.621	1.655	1.523	1.664
2001	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647
2002	0.226	0.464	0.700	1.030	1.164	1.342	1.272	1.730	1.946	1.699	1.875	1.758	1.830	1.775
2003	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647
2004	0.222	0.486	0.787	0.939	0.993	1.347	1.292	1.735	1.554	1.703	1.594	1.595	1.575	1.505
2005	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647
2006	0.182	0.468	0.621	0.920	1.217	1.247	1.297	1.514	1.832	1.733	1.598	1.663	1.662	1.574
2007	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647
2008	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647
2009	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647
2010	0.213	0.454	0.722	0.948	1.029	1.529	1.357	1.545	1.678	1.863	1.913	1.738	1.749	1.725
2011	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647
2012	0.190	0.478	0.719	0.935	1.153	1.276	1.389	1.583	1.739	1.759	1.729	1.708	1.683	1.647

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
2010	65.01	0.267	-0.279	0.0000083	2.974

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 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. Evaluation of 2012 Aleutian Islands pollock model.

Number of Parameters		123
Survey Catchability		1.00
Fishery Average Effective *N*		70.38
Survey Average Effective *N*		43.23
RMSE Survey		0.471
	-Log Likelihoods	
Survey Index		34.924
Fishery Age Comp		472.901
Survey Age Comp		59.732
Catch		1.198
Sub Total		568.755
	-log Penalties	
Recruitment		48.617
Selectivity Constraints		
	Survey	3.454
	Fishery	19.735
Prior		0.180
Fpen		0.001
Residual		0.026
Total		640.768

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

Model Conditions	
Survey Catchability	1
Natural Mortality	0.18
Fishing Mortalities	
Max $F_{1978-2012}$	0.39
F_{2012}	0.01
Stock Abundance	
Initial Biomass (1978; thousands of tons)	493.75
CV	8%
2012 Total Biomass (thousands of tons)	235.24
CV	13%
2012 Age 3+ biomass (thousands of tons)	225.29
1978 Year Class (billions at age 2)	1.39
CV	10%
Recruitment Variability	0.88
Recruitment variance (σ_R^2)	0.60
Steepness (*h*)	0.70

Table 1A.18 Estimates of 2012 fishery, and survey selectivity-at-age.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
2012 Fishery	0.016	0.044	0.113	0.256	0.492	0.689	0.854	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Survey	0.174	0.306	0.471	0.618	0.731	0.814	0.901	1.000	1.000	1.000	1.000	1.000	1.000	1.000

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

Model AI	**Total Biomass (Age 2+)**			**Female SSB**		
Year		**LCI**	**UCI**		**LCI**	**UCI**
1978	493,750	416,776	570,724	154,340	129,520	179,160
1979	524,750	446,596	602,904	170,960	144,838	197,082
1980	768,010	659,610	876,410	178,120	151,216	205,024
1981	976,490	832,536	1,120,444	169,950	142,440	197,460
1982	1,079,000	923,694	1,234,306	240,510	206,200	274,820
1983	1,096,300	941,346	1,251,254	326,340	281,284	371,396
1984	1,101,600	951,600	1,251,600	387,690	335,640	439,740
1985	1,058,700	922,062	1,195,338	380,600	331,780	429,420
1986	997,950	876,442	1,119,458	372,210	327,090	417,330
1987	974,280	865,566	1,082,994	382,600	340,204	424,996
1988	931,760	837,026	1,026,494	370,710	333,172	408,248
1989	819,890	740,922	898,858	330,270	299,026	361,514
1990	752,940	688,268	817,612	295,720	270,526	320,914
1991	613,970	558,700	669,240	233,410	212,838	253,982
1992	513,190	464,322	562,058	188,170	170,905	205,435
1993	443,690	400,382	486,998	161,390	146,301	176,479
1994	367,110	328,342	405,878	134,640	120,986	148,294
1995	294,800	258,328	331,272	107,790	94,953	120,627
1996	232,600	197,676	267,524	82,957	71,021	94,893
1997	202,480	167,998	236,962	71,512	59,734	83,290
1998	182,160	147,638	216,682	63,638	51,628	75,648
1999	156,900	122,862	190,938	57,120	44,806	69,434
2000	156,310	123,190	189,430	58,733	46,418	71,048
2001	161,590	127,814	195,366	59,147	46,986	71,308
2002	179,380	141,880	216,880	59,166	47,196	71,136
2003	194,970	153,874	236,066	61,047	48,786	73,308
2004	200,830	158,184	243,476	67,098	53,503	80,693
2005	201,320	158,442	244,198	73,798	58,579	89,017
2006	197,290	155,090	239,490	76,764	60,636	92,892
2007	194,930	152,980	236,880	75,326	59,306	91,346
2008	202,620	157,592	247,648	73,512	57,641	89,383
2009	216,360	166,032	266,688	74,120	57,928	90,312
2010	223,530	169,156	277,904	76,972	59,673	94,271
2011	228,420	171,208	285,632	80,957	61,788	100,126
2012	235,240	174,104	296,376	83,637	62,745	104,529
2013	241,540	176,604	306,476	85,479	63,565	107,393

Table 1A.20. Reference Model estimates of pollock numbers at age in millions, 1978-2012.

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% 10+
1978	108	104	116	64	95	24	24	18	13	9	4	3	3	26	611	4.2%
1979	142	91	87	97	53	78	19	20	14	11	7	3	3	23	647	3.6%
1980	1392	119	76	72	79	43	63	16	16	11	8	6	3	21	1,924	1.1%
1981	49	1160	98	60	54	57	30	42	10	10	7	5	4	15	1,603	0.9%
1982	78	41	960	79	47	41	43	22	30	7	7	5	4	13	1,377	1.0%
1983	253	65	34	769	61	35	30	30	15	21	5	5	4	12	1,339	0.9%
1984	150	211	54	28	611	47	27	23								
1985	200	126	175	44	22	483	37	21	17	17	8	11	3	11	1,175	1.0%
1986	56	167	104	143	36	18	377	28	16	13	13	6	9	11	996	1.1%
1987	97	47	140	86	118	29	14	301	22	12	10	10	5	15	906	1.7%
1988	124	81	39	115	71	95	23	11	238	18	10	8	8	16	858	1.9%
1989	75	104	67	32	92	55	74	18	8	177	13	7	6	18	747	2.4%
1990	45	63	87	56	26	76	46	60	14	7	144	11	6	19	660	2.9%
1991	163	37	52	70	43	19	54	31	39	9	4	94	7	16	641	2.6%
1992	29	136	31	42	54	32	14	37	20	25	6	3	61	15	505	3.0%
1993	39	24	113	25	33	42	24	10	26	14	18	4	2	53	426	12.3%
1994	38	33	20	92	20	24	30	16	6	17	9	11	3	35	354	10.0%
1995	55	31	27	16	69	14	16	19	10	4	10	5	7	23	306	7.4%
1996	26	46	26	22	12	48	9	10	11	5	2	6	3	17	241	6.9%
1997	39	22	38	21	17	9	34	6	7	7	4	1	4	13	220	5.8%
1998	25	32	18	31	16	13	6	24	4	4	5	2	1	11	193	5.7%
1999	18	21	27	14	24	12	9	4	15	3	3	3	1	8	161	4.7%
2000	28	15	17	22	12	20	10	7	4	12	2	2	2	7	163	4.6%
2001	61	24	12	15	19	10	16	8	6	3	10	2	2	8	196	4.2%
2002	87	51	20	10	12	16	8	14	7	5	2	9	1	8	250	3.3%
2003	25	72	42	17	9	10	13	7	11	6	4	2	7	8	233	3.5%
2004	20	21	61	35	14	7	8	11	6	9	5	3	2	13	215	5.9%
2005	25	17	17	51	30	12	6	7	9	5	8	4	3	12	204	5.8%
2006	23	21	14	14	42	25	10	5	6	7	4	6	3	12	193	6.3%
2007	50	20	18	12	12	35	20	8	4	5	6	3	5	13	211	6.0%
2008	73	42	16	15	10	10	29	17	7	3	4	5	3	15	248	6.0%
2009	46	61	35	14	12	8	8	24	14	5	3	3	4	15	253	5.7%
2010	31	38	51	29	11	10	7	7	20	12	4	2	3	15	242	6.4%
2011	55	26	32	43	25	10	8	6	6	17	10	4	2	15	257	5.9%
2012	57	46	22	27	36	21	8	7	5	5	14	8	3	14	271	5.2%

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

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1978	0.06	0.22	0.81	0.74	1.59	0.49	0.61	0.53	0.39	0.26	0.13	0.10	0.08	0.77	6.78
1979	0.13	0.32	1.00	1.86	1.45	2.66	0.80	0.97	0.70	0.52	0.34	0.17	0.13	1.13	12.18
1980	6.13	1.94	4.02	6.28	9.74	6.42	11.30	3.24	3.29	2.38	1.76	1.17	0.57	4.28	62.52
1981	0.15	12.74	3.50	3.54	4.58	5.93	3.71	6.15	1.46	1.48	1.07	0.79	0.53	2.18	47.81
1982	0.26	0.51	38.60	5.21	4.39	4.77	5.89	3.49	4.82	1.14	1.16	0.84	0.62	2.13	73.83
1983	0.58	0.56	0.95	35.75	4.04	2.86	2.97	3.48	1.72	2.37	0.56	0.57	0.41	1.35	58.17
1984	0.27	1.42	1.21	1.02	32.13	3.07	2.10	2.08	2.04	1.01	1.39	0.33	0.34	1.03	49.44
1985	0.34	0.81	3.71	1.56	1.11	29.81	2.75	1.80	1.50	1.47	0.72	1.00	0.24	0.98	47.80
1986	0.05	0.62	1.27	2.91	1.04	0.63	16.38	1.45	0.80	0.66	0.65	0.32	0.44	0.54	27.76
1987	0.09	0.17	1.66	1.71	3.34	1.02	0.60	15.05	1.12	0.62	0.51	0.50	0.25	0.76	27.40
1988	0.25	0.60	0.95	4.68	4.09	6.79	2.00	1.14	23.96	1.79	0.98	0.82	0.80	1.61	50.46
1989	0.04	0.19	0.41	0.32	1.35	1.00	1.61	0.46	0.22	4.59	0.34	0.19	0.16	0.46	11.34
1990	0.17	0.69	2.61	3.81	2.81	10.24	7.67	12.43	2.98	1.41	29.81	2.23	1.22	4.01	82.09
1991	0.63	0.42	1.58	4.87	4.72	2.65	9.29	6.52	8.19	1.96	0.93	19.64	1.47	3.45	66.32
1992	0.08	1.11	0.69	2.13	4.38	3.24	1.76	5.83	3.17	3.98	0.95	0.45	9.54	2.39	39.70
1993	0.15	0.27	3.43	1.74	3.60	5.65	4.05	2.08	5.36	2.92	3.66	0.88	0.42	10.97	45.18
1994	0.20	0.50	0.82	8.46	2.82	4.40	6.61	4.41	1.75	4.52	2.46	3.08	0.74	9.60	50.37
1995	0.32	0.53	1.23	1.63	10.99	2.74	4.05	5.59	2.85	1.13	2.93	1.59	2.00	6.69	44.27
1996	0.10	0.51	0.78	1.48	1.28	6.48	1.54	2.11	2.22	1.13	0.45	1.16	0.63	3.46	23.33
1997	0.13	0.21	1.01	1.27	1.60	1.05	5.13	1.15	1.22	1.28	0.65	0.26	0.67	2.36	17.99
1998	0.10	0.40	0.59	2.32	1.93	1.85	1.17	5.37	0.93	0.99	1.04	0.53	0.21	2.46	19.89
1999	0.00	0.01	0.03	0.03	0.11	0.08	0.07	0.04	0.14	0.02	0.03	0.03	0.01	0.07	0.67
2000	0.00	0.01	0.02	0.06	0.06	0.15	0.09	0.08	0.04	0.14	0.02	0.03	0.03	0.08	0.81
2001	0.01	0.01	0.01	0.03	0.06	0.05	0.10	0.06	0.04	0.02	0.07	0.01	0.01	0.06	0.54
2002	0.01	0.02	0.02	0.03	0.06	0.10	0.07	0.13	0.07	0.05	0.02	0.08	0.01	0.08	0.75
2003	0.01	0.04	0.07	0.06	0.06	0.10	0.15	0.09	0.16	0.08	0.06	0.03	0.10	0.11	1.12
2004	0.00	0.01	0.06	0.09	0.06	0.05	0.07	0.10	0.05	0.09	0.04	0.03	0.02	0.12	0.79
2005	0.00	0.01	0.02	0.16	0.18	0.10	0.06	0.08	0.11	0.06	0.09	0.05	0.03	0.14	1.09
2006	0.00	0.01	0.02	0.04	0.23	0.18	0.09	0.05	0.06	0.08	0.04	0.07	0.03	0.13	1.03
2007	0.01	0.01	0.03	0.05	0.09	0.39	0.28	0.13	0.07	0.08	0.10	0.05	0.08	0.20	1.57
2008	0.01	0.01	0.01	0.03	0.04	0.05	0.19	0.13	0.05	0.03	0.03	0.04	0.02	0.12	0.76
2009	0.01	0.03	0.05	0.04	0.07	0.07	0.08	0.29	0.17	0.06	0.03	0.04	0.05	0.17	1.16
2010	0.00	0.01	0.05	0.07	0.05	0.06	0.05	0.06	0.18	0.10	0.04	0.02	0.02	0.13	0.84
2011	0.01	0.01	0.03	0.09	0.10	0.05	0.06	0.05	0.05	0.13	0.08	0.03	0.02	0.12	0.83
2012	0.01	0.01	0.01	0.04	0.11	0.08	0.04	0.04	0.03	0.03	0.08	0.05	0.02	0.08	0.63

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

Year	F[a]	Catch/Biomass Rate[b]
1978	0.033	0.013
1979	0.054	0.018
1980	0.257	0.076
1981	0.172	0.032
1982	0.193	0.047
1983	0.134	0.041
1984	0.105	0.039
1985	0.100	0.044
1986	0.057	0.024
1987	0.056	0.027
1988	0.116	0.040
1989	0.029	0.013
1990	0.254	0.105
1991	0.258	0.161
1992	0.188	0.102
1993	0.257	0.129
1994	0.349	0.160
1995	0.389	0.220
1996	0.257	0.125
1997	0.225	0.128
1998	0.281	0.131
1999	0.010	0.006
2000	0.012	0.008
2001	0.008	0.005
2002	0.010	0.006
2003	0.015	0.008
2004	0.010	0.006
2005	0.013	0.008
2006	0.012	0.009
2007	0.017	0.013
2008	0.009	0.006
2009	0.013	0.008
2010	0.010	0.006
2011	0.009	0.005
2012*	0.007	0.004

[a] Average fishing mortality rates over all ages
[b] Catch/biomass rate is the ratio of catch to beginning year age 2+ biomass.
* As of October 14, 2012

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

2011 Reference Model		2012 Reference Model		
Year	**Index at age 2**	**Year**	**Index at age 2**	**St. Dev**
1978	189.4	1978	108.3	22.72
1979	201.1	1979	141.8	33.64
1980	1,176.0	1980	1,392.5	141.83
1981	40.8	1981	49.3	19.09
1982	33.3	1982	78.4	22.29
1983	208.8	1983	252.6	39.63
1984	79.6	1984	150.3	29.99
1985	502.9	1985	200.1	31.65
1986	66.1	1986	55.6	15.90
1987	96.1	1987	96.7	18.31
1988	187.8	1988	124.2	19.06
1989	78.6	1989	74.8	13.50
1990	52.3	1990	44.8	9.97
1991	142.2	1991	163.4	18.42
1992	37.6	1992	28.8	6.59
1993	49.6	1993	39.4	7.27
1994	49.1	1994	37.7	7.45
1995	96.2	1995	55.3	9.64
1996	21.7	1996	25.9	5.94
1997	52.5	1997	38.9	7.48
1998	30.9	1998	25.0	5.56
1999	12.3	1999	17.8	4.25
2000	25.7	2000	28.4	5.96
2001	78.8	2001	60.5	10.73
2002	117.7	2002	86.5	14.23
2003	14.2	2003	24.6	5.84
2004	21.6	2004	20.1	5.10
2005	21.8	2005	25.0	6.58
2006	17.9	2006	23.5	6.34
2007	21.7	2007	50.3	14.21
2008	35.7	2008	72.7	19.97
2009	58.7	2009	45.9	14.99
2010	59.2	2010	30.8	11.52
2011	59.3	2011	55.2	25.92
		2012	56.9	27.07
Ave 78-08	121.3	Ave 1978-2010	118.9	
Med 78-08	52.3	Med 1978-2010	55.4	

Table 1A.24. Projections of Reference Model AI female spawning biomass (in thousands of t), fishing mortality (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=234.07 kt, B_{40}=93.63 kt, B_{35}=81.93 kt, and ½ B_{35}=40.96 kt).*

Sp.Biomass	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2012	83.61	83.61	83.61	83.61	83.61	83.61	83.61	83.61
2013	82.42	82.42	85.29	83.84	85.36	81.69	82.42	83.93
2014	72.05	72.05	88.52	79.56	88.98	68.50	72.05	80.01
2015	71.24	71.24	97.04	81.59	97.87	66.74	70.75	81.92
2016	76.32	76.32	109.79	88.69	110.99	71.38	73.59	88.71
2017	84.65	84.65	125.48	99.34	127.02	79.20	80.36	99.34
2018	92.35	92.35	141.22	110.11	143.12	86.08	86.65	110.90
2019	98.33	98.33	156.52	119.97	158.80	91.02	91.26	122.56
2020	101.88	101.88	170.53	127.95	173.24	93.53	93.62	133.34
2021	103.84	103.84	183.12	134.25	186.29	94.62	94.65	143.20
2022	105.33	105.33	194.35	139.47	197.98	95.51	95.52	152.23
2023	106.68	106.68	204.07	143.79	208.14	96.51	96.51	160.30
2024	107.00	107.00	211.44	146.39	215.91	96.63	96.63	166.49
2025	106.66	106.66	216.89	147.71	221.74	96.14	96.14	171.14
F	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2012	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2013	0.27	0.27	0.01	0.14	0.00	0.34	0.27	0.13
2014	0.23	0.23	0.01	0.14	0.00	0.28	0.23	0.14
2015	0.23	0.23	0.01	0.14	0.00	0.27	0.29	0.14
2016	0.24	0.24	0.01	0.14	0.00	0.28	0.29	0.14
2017	0.25	0.25	0.01	0.14	0.00	0.30	0.31	0.13
2018	0.26	0.26	0.01	0.14	0.00	0.32	0.32	0.13
2019	0.27	0.27	0.01	0.14	0.00	0.33	0.33	0.12
2020	0.28	0.28	0.01	0.14	0.00	0.34	0.34	0.11
2021	0.28	0.28	0.01	0.14	0.00	0.34	0.34	0.10
2022	0.28	0.28	0.01	0.14	0.00	0.34	0.34	0.09
2023	0.29	0.29	0.01	0.14	0.00	0.34	0.34	0.09
2024	0.29	0.29	0.01	0.14	0.00	0.34	0.34	0.09
2025	0.29	0.29	0.01	0.14	0.00	0.34	0.34	0.08
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2012	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
2013	37.30	37.30	0.97	20.14	0.00	45.59	37.30	19.00
2014	28.01	28.01	1.01	18.96	0.00	31.41	28.01	19.00
2015	25.48	25.48	1.05	18.29	0.00	27.60	31.34	19.00
2016	26.89	26.89	1.14	18.64	0.00	29.16	31.16	19.00
2017	31.18	31.18	1.28	20.44	0.00	34.34	35.39	19.00
2018	36.39	36.39	1.47	23.10	0.00	40.25	40.77	19.00
2019	40.94	40.94	1.67	25.80	0.00	44.88	45.11	19.00
2020	44.07	44.07	1.86	28.11	0.00	47.77	47.86	19.00
2021	45.68	45.68	2.01	29.78	0.00	49.06	49.08	19.00
2022	46.43	46.43	2.14	30.96	0.00	49.40	49.41	19.00
2023	47.04	47.04	2.26	31.93	0.00	49.77	49.77	19.00
2024	47.34	47.34	2.36	32.76	0.00	50.11	50.10	19.00
2025	47.50	47.50	2.44	33.30	0.00	50.13	50.13	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 in central, decreasing in West.**	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 2012 AI summer bottom temperature was colder than average**	Cooling 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 2005-2009 fishery had 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. 2013 fishery not expected to be significant.**	Unknown	Unknown
Fishery effects on age-at-maturity and fecundity	**Unknown**	Unknown	Unknown

Figures

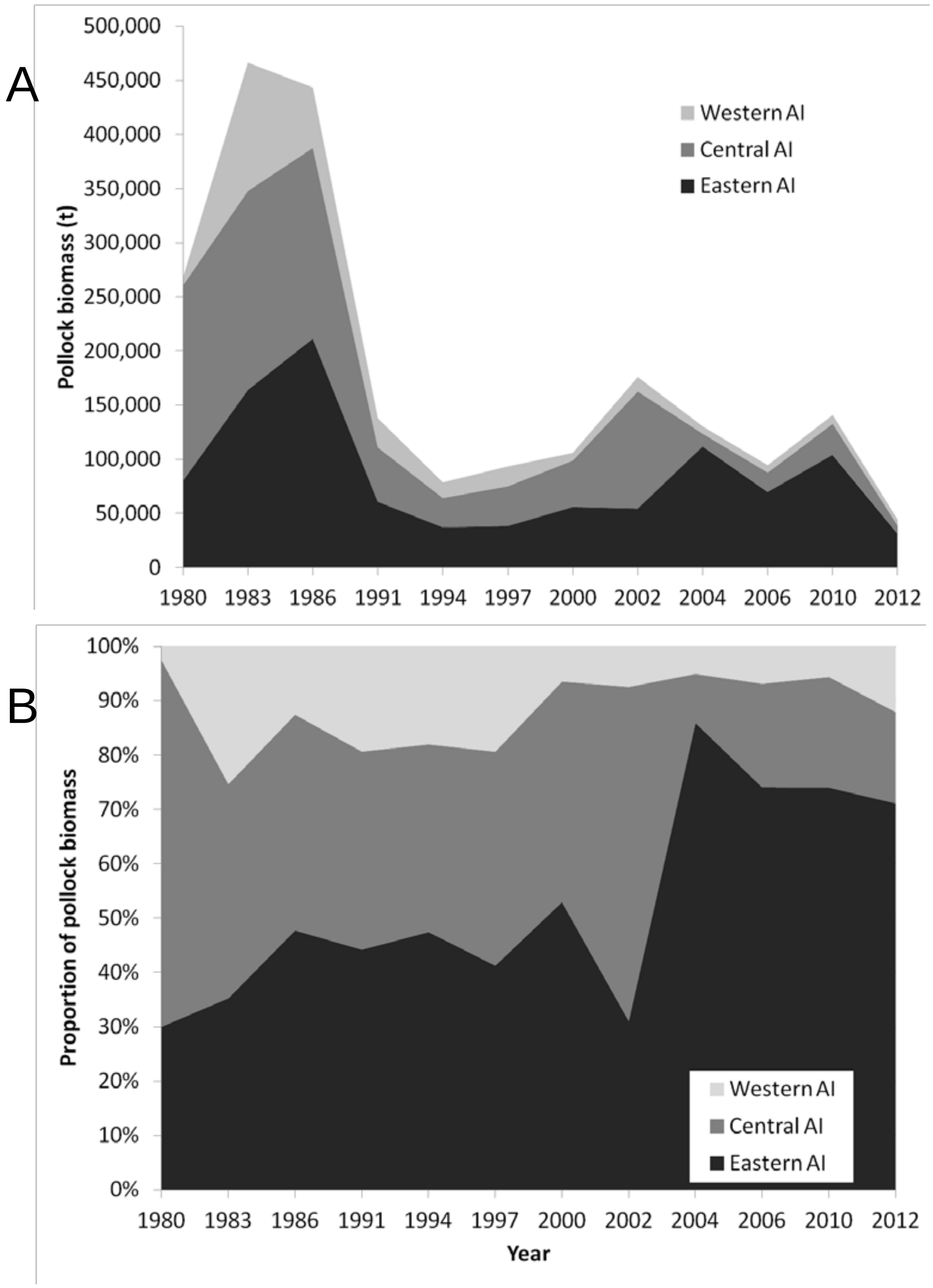

Figure 1A.1 Aleutian Islands bottom trawl survey pollock biomass (A; top) and proportion of biomass (B; bottom) for the three Aleutian Island management regions.

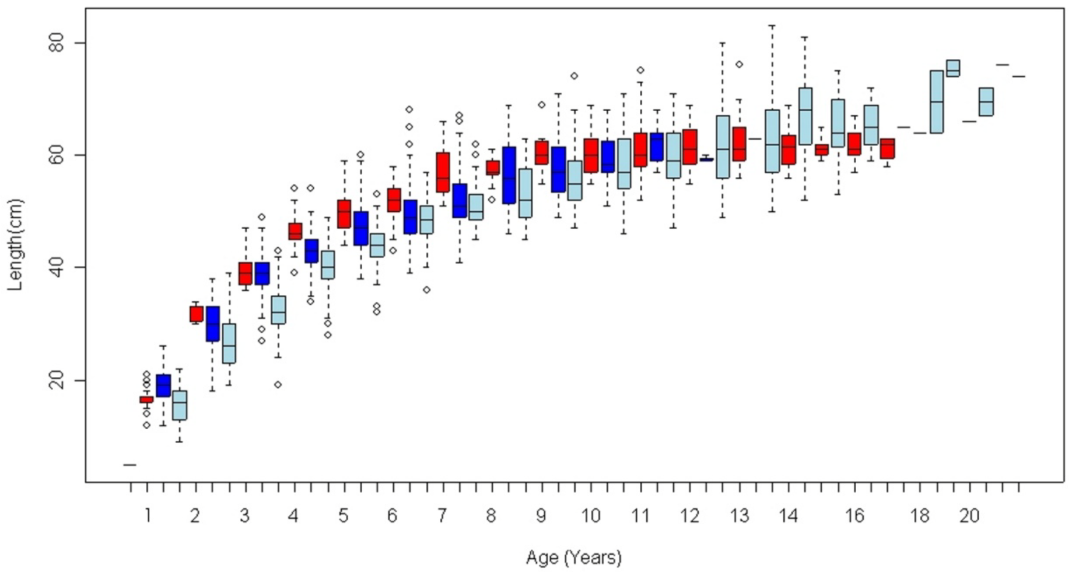

Figure 1A.2. Length at age for Aleutian Islands (red), Gulf of Alaska (blue), and Bering Sea (grey) pollock from the 2004 Aleutian Islands, 2004 Bering Sea, and 2005 Gulf of Alaska bottom trawl surveys.

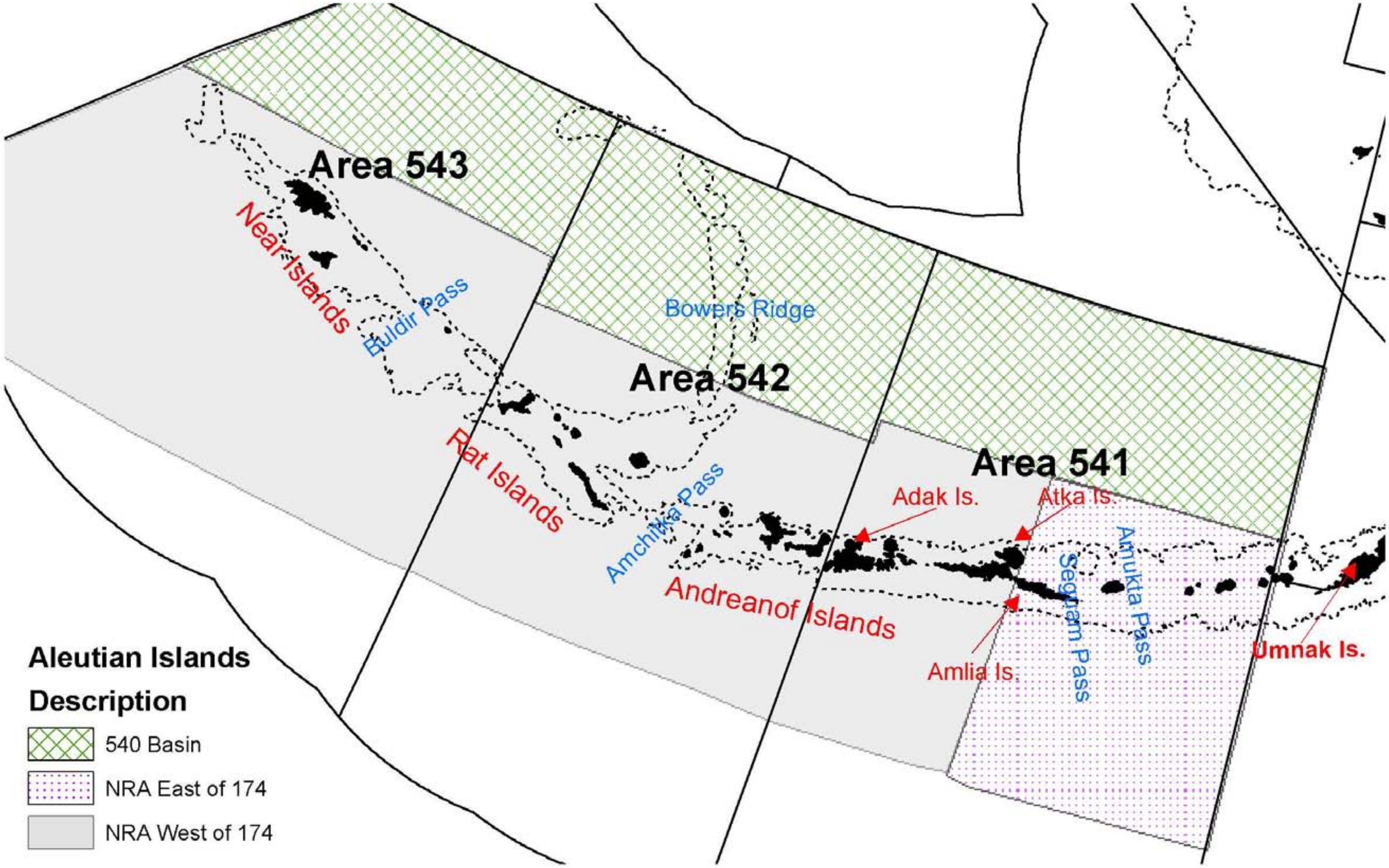

Figure 1A. 3. Regions defined for consideration of alternative data partitions for Aleutian Islands Region pollock. The abbreviation "NRA" represents the Near, Rat, and Andreanof Island group.

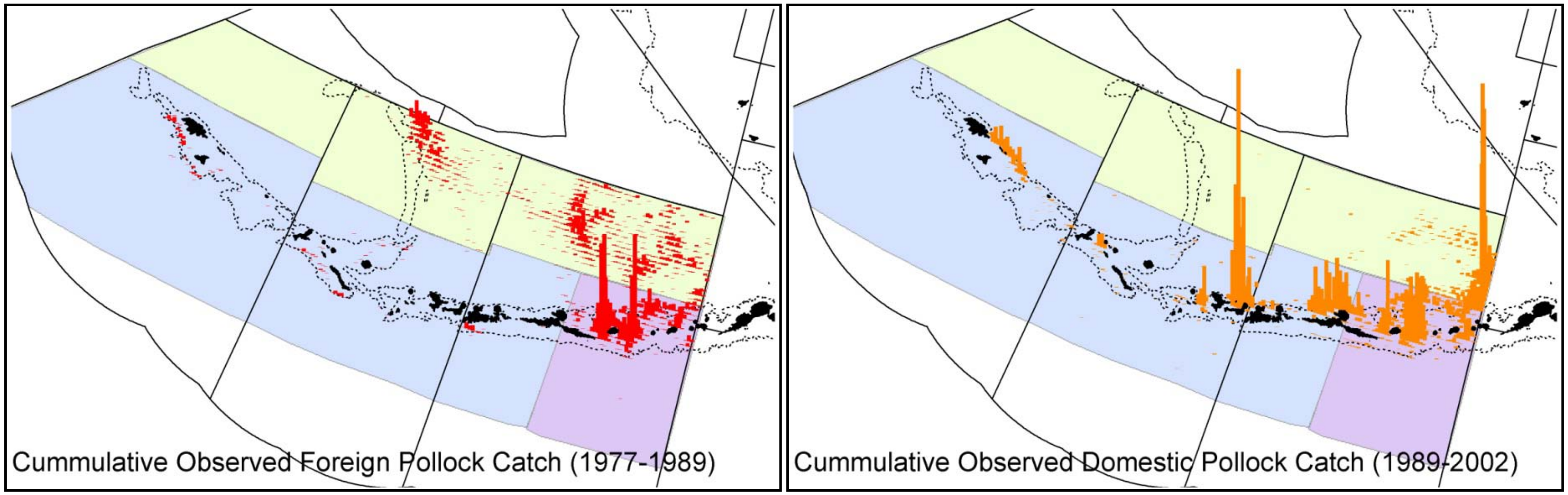

Figure 1A.4. Top figures are observed foreign and J.V. (1978-1989; left), early domestic (1989-2002; right) pollock catch in the Aleutian Islands Area summed over all years and 10 minute latitude and longitude blocks. The two top maps use the same scale (maximum observed catch per 10 minute block: foreign and J.V. 8,000 t and Domestic 19,000 t). Catches of less than 1 t were excluded from cumulative totals.

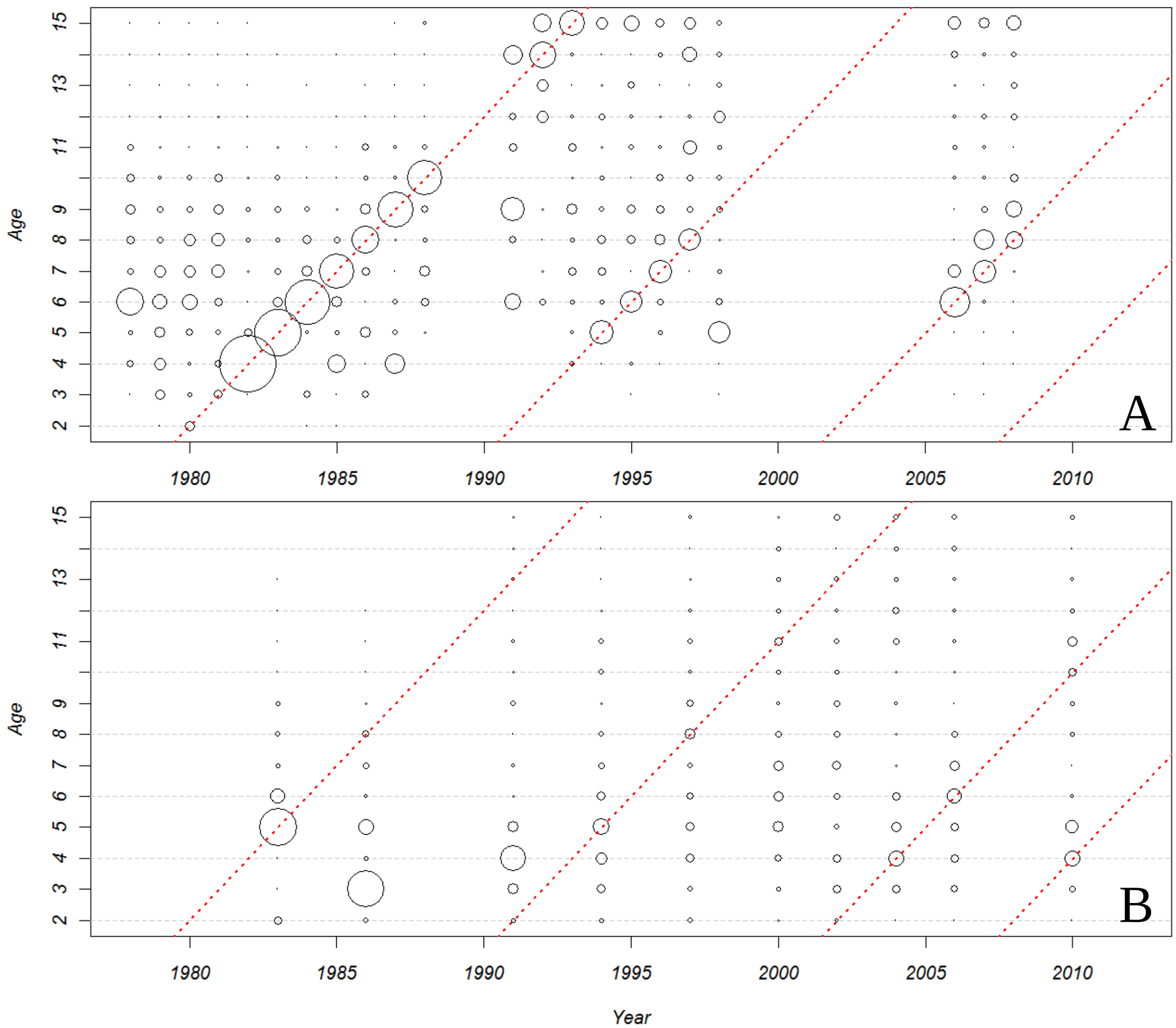

Figure 1A.5. Age distributions for 1978-2008 Aleutian Islands pollock fishery (A; top) and 1980 - 2010 Aleutian Islands Bottom Trawl surveys (B; bottom). The 1978, 1989, 2000, and 2006 year classes are indicated by the diagonal dashed lines.

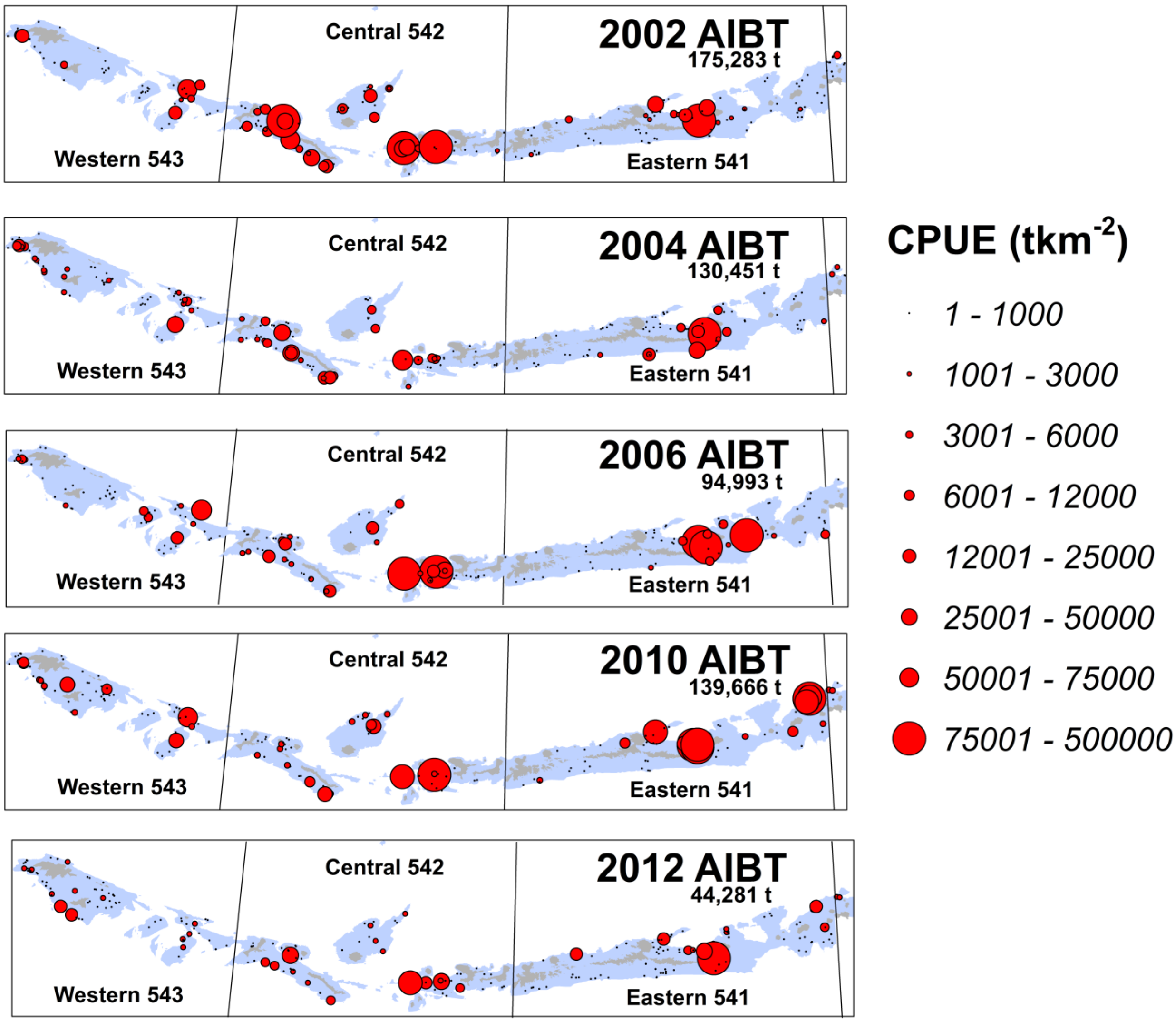

Figure 1A.6. Catch per unit effort (tkm^{-2}) for surveys of pollock in the Aleutian Islands Region, 2002-2012. The shaded area is the Aleutian Islands shelf area less than 300m depth.

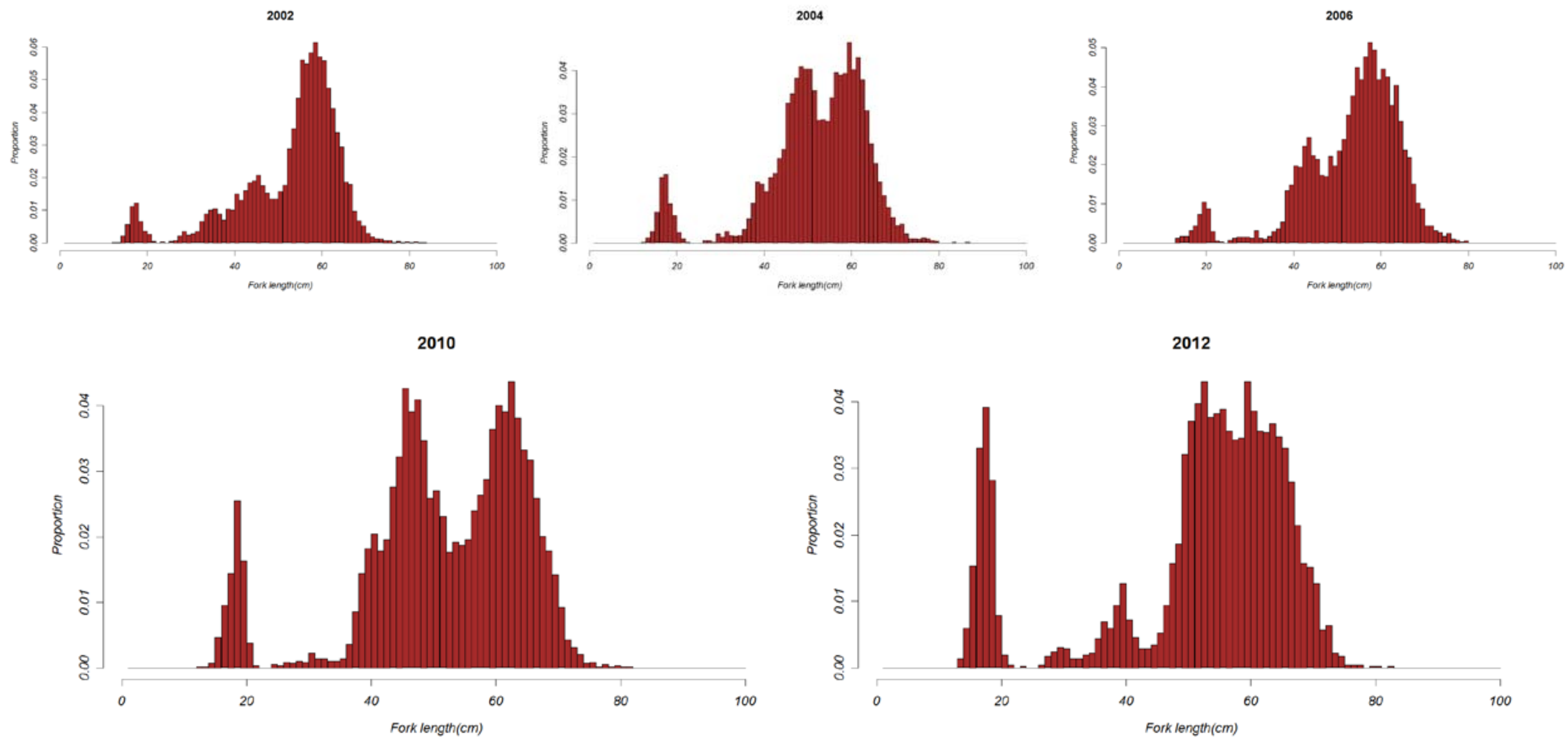

Figure 1A.7. Length distributions for 2002-2012 Aleutian Islands bottom trawl surveys.

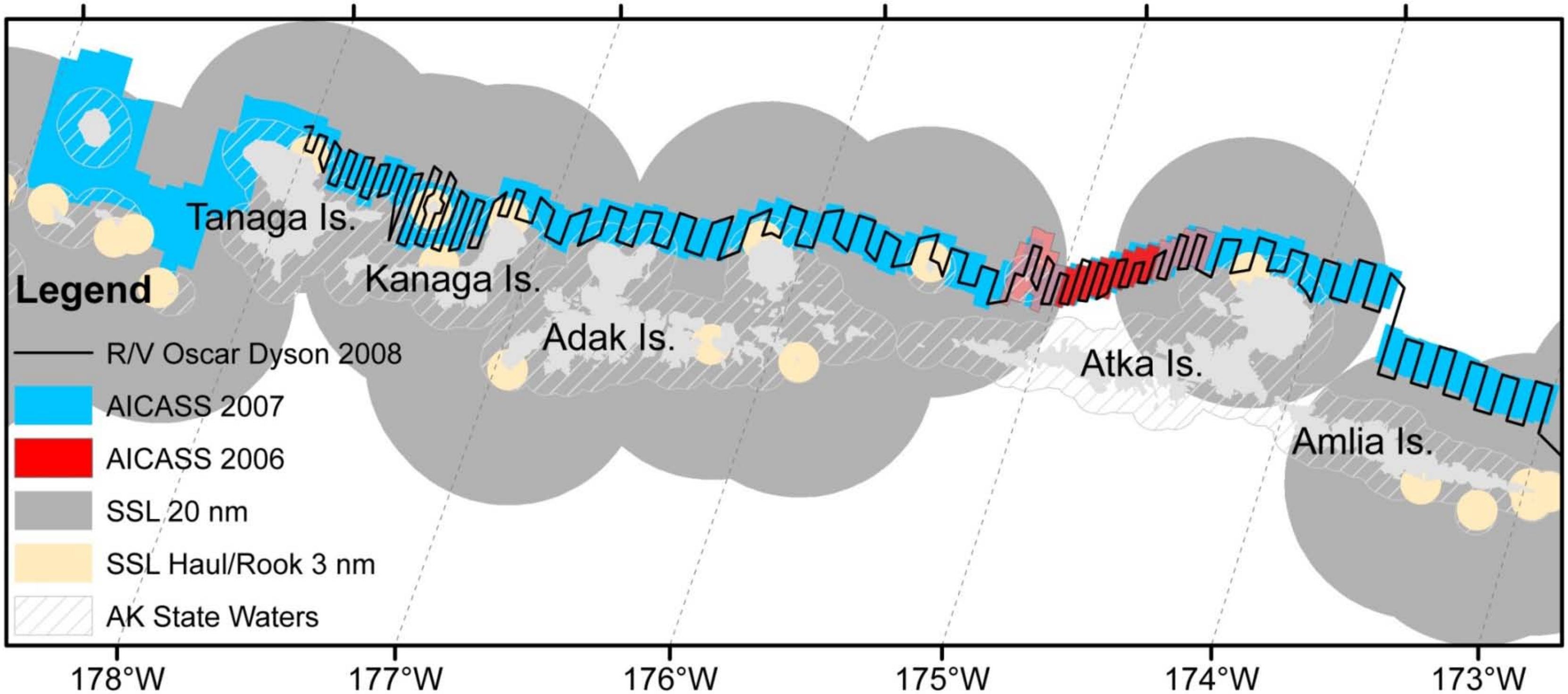

Figure 1A.8. 2006, 2007, and 2008 Aleutian Islands Cooperative Acoustic Survey Study (AICASS) sites within the central Aleutian Islands with pertinent Steller sea lion (SSL) areas.

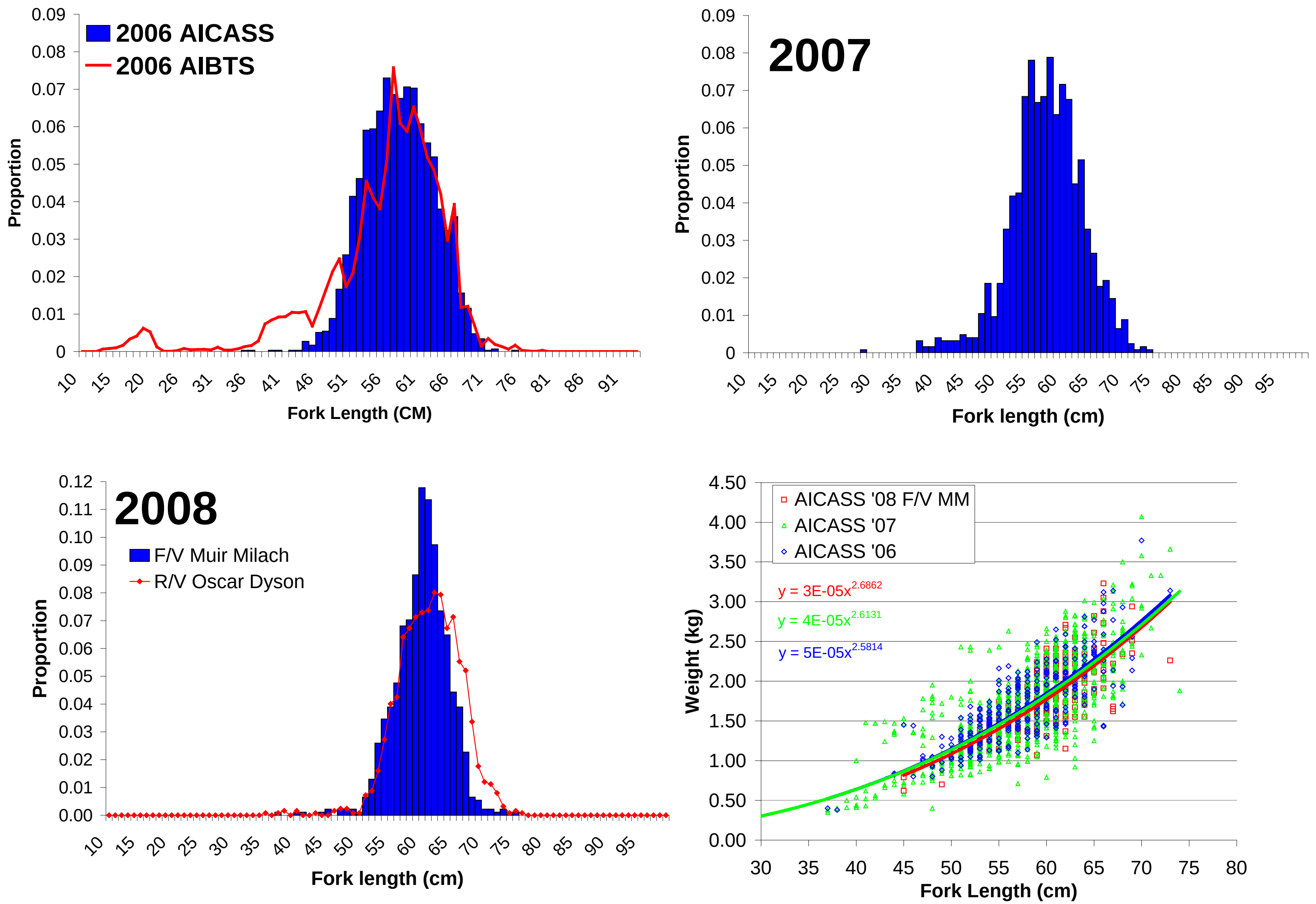

Figure 1A.9. Length distributions for the 2006, 2007, and 2008 Aleutian Islands Cooperative Acoustic Survey studies.

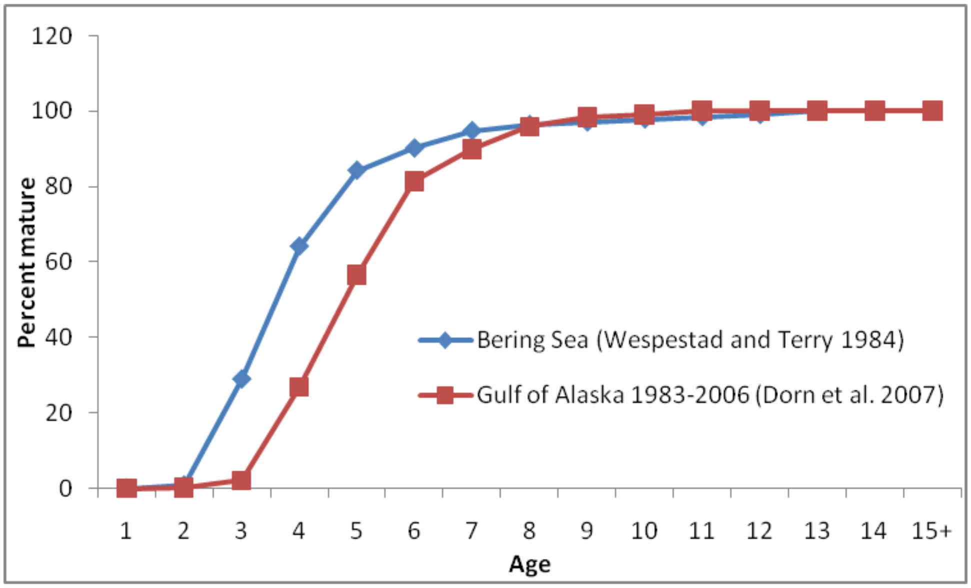

Figure 1A.10. Percentage mature at age for Bering Sea pollock (Wespestad and Terry 1984) and the mean percentage mature at age for 1983-2006 for Gulf of Alaska pollock (Dorn et al. 2007).

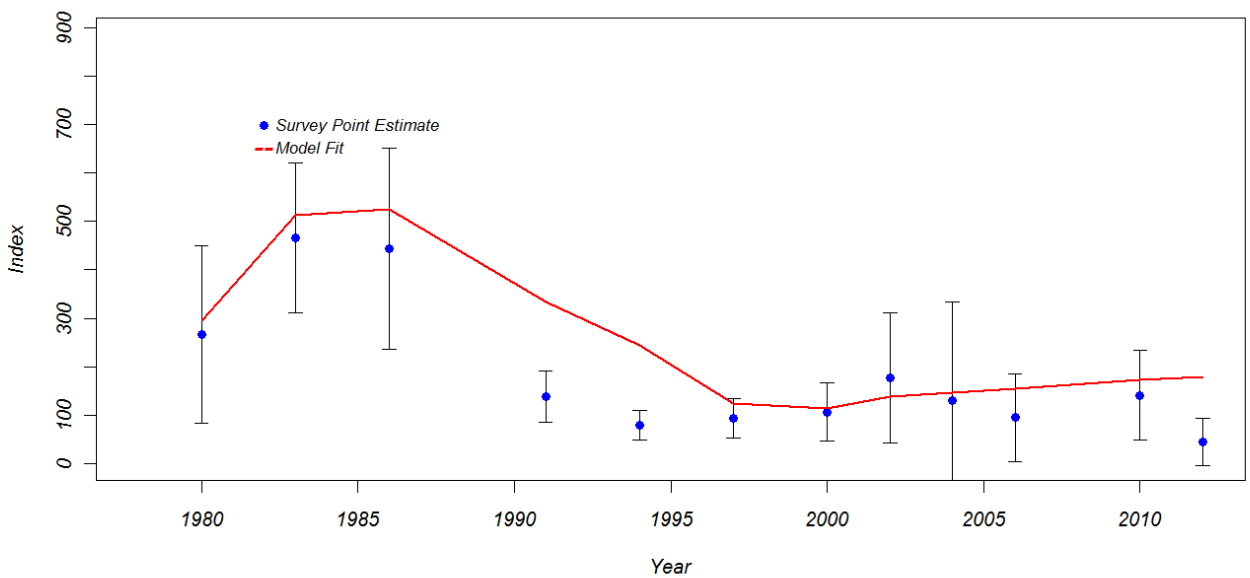

Figure 1A.11. Reference model fit (solid line) to NMFS summer bottom trawl survey (dots)..

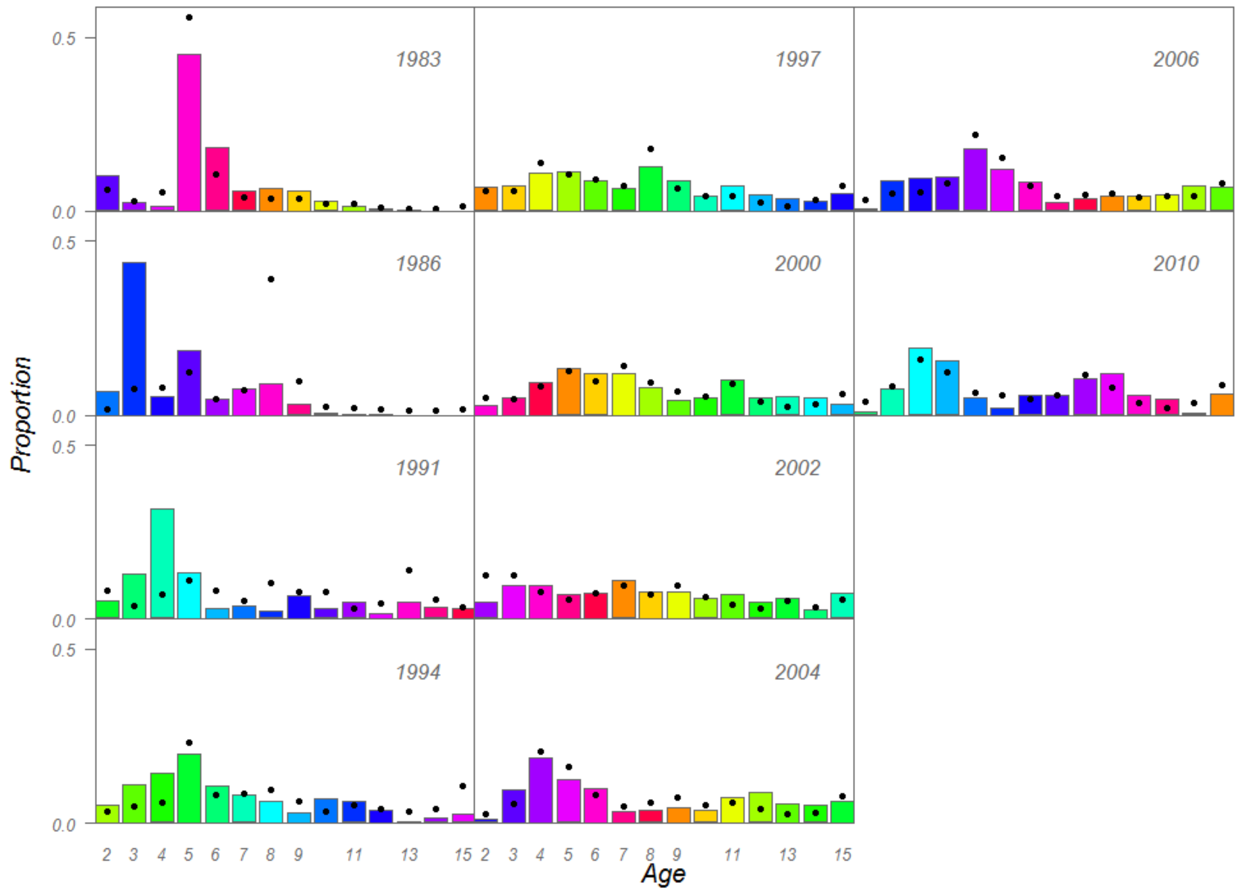

Figure 1A.12. Aleutian Islands pollock reference model fit to NMFS summer bottom trawl survey age composition data. The "•" symbol are the model predictions and columns are the observed proportions at age (with colors corresponding to cohorts).

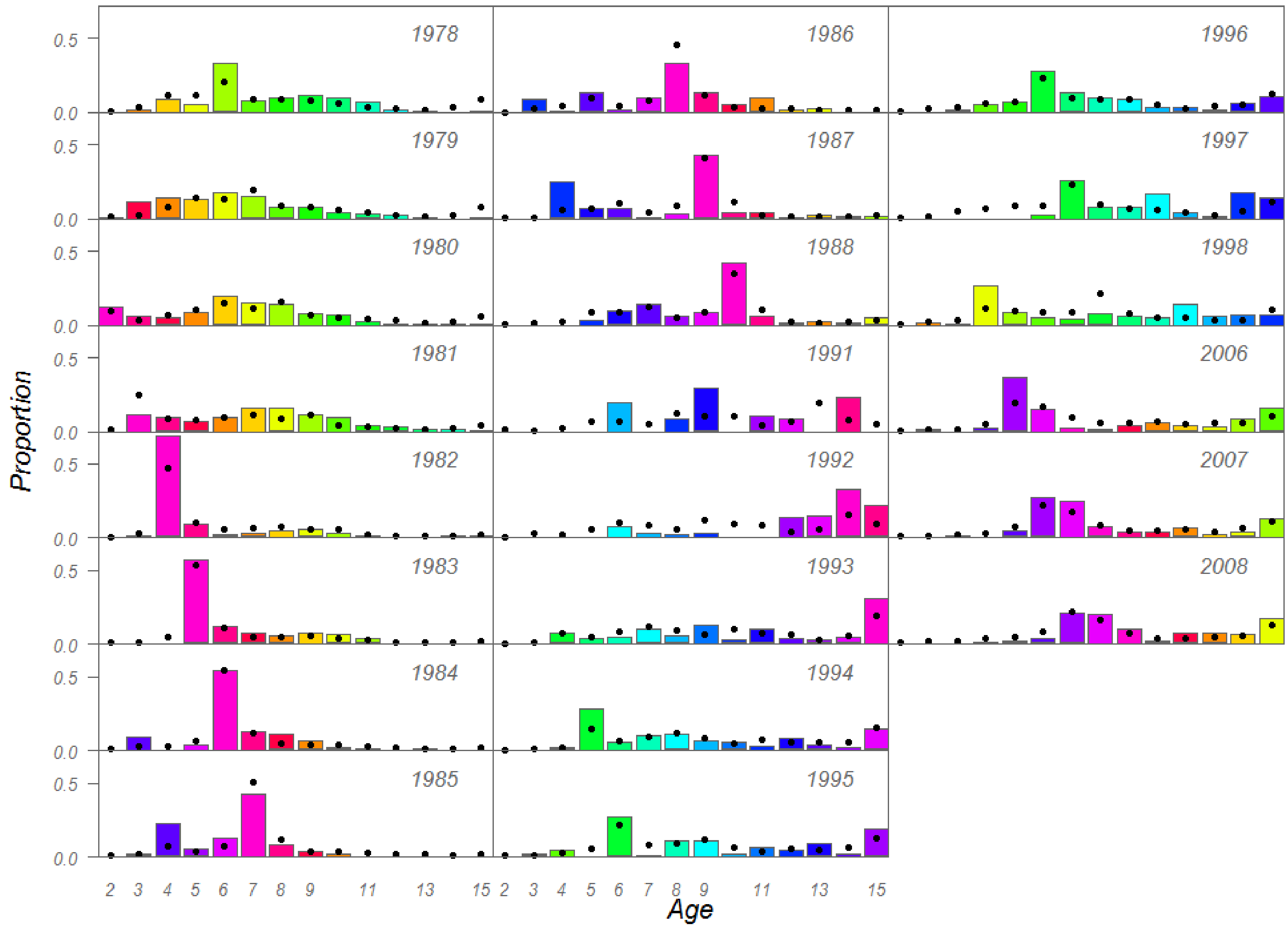

Figure 1A.13. Fit to fishery age composition data for Aleutian Islands pollock. The "•" symbol are the model predictions and columns are the observed proportions at age (with colors corresponding to cohorts).

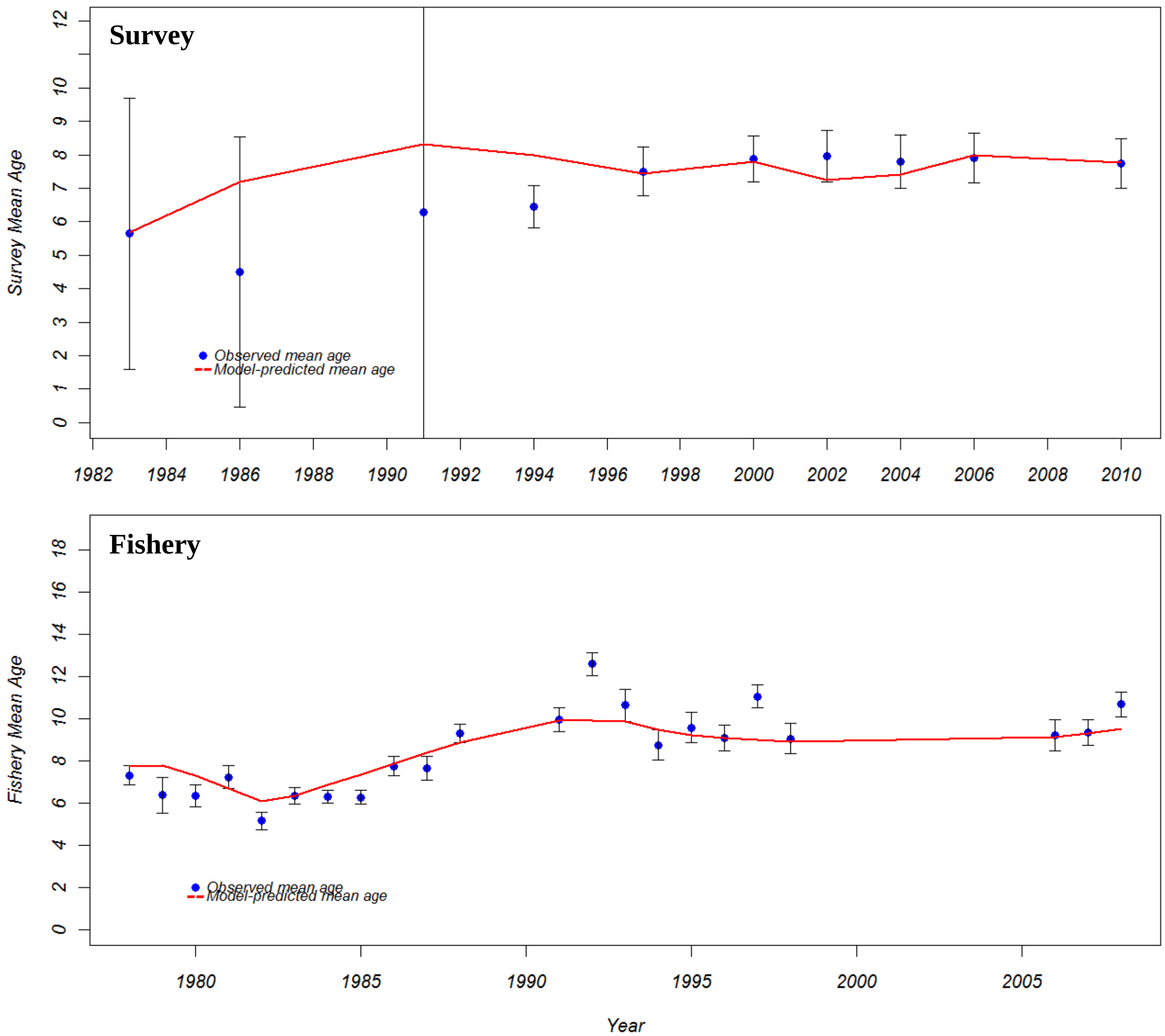

Figure 1A.14. Observed mean age and model derived mean age from the AIBTS (top) and fishery catch at age data (bottom) for the reference model. The confidence intervals are adjusted by the multinomial sample sizes used in reference model.

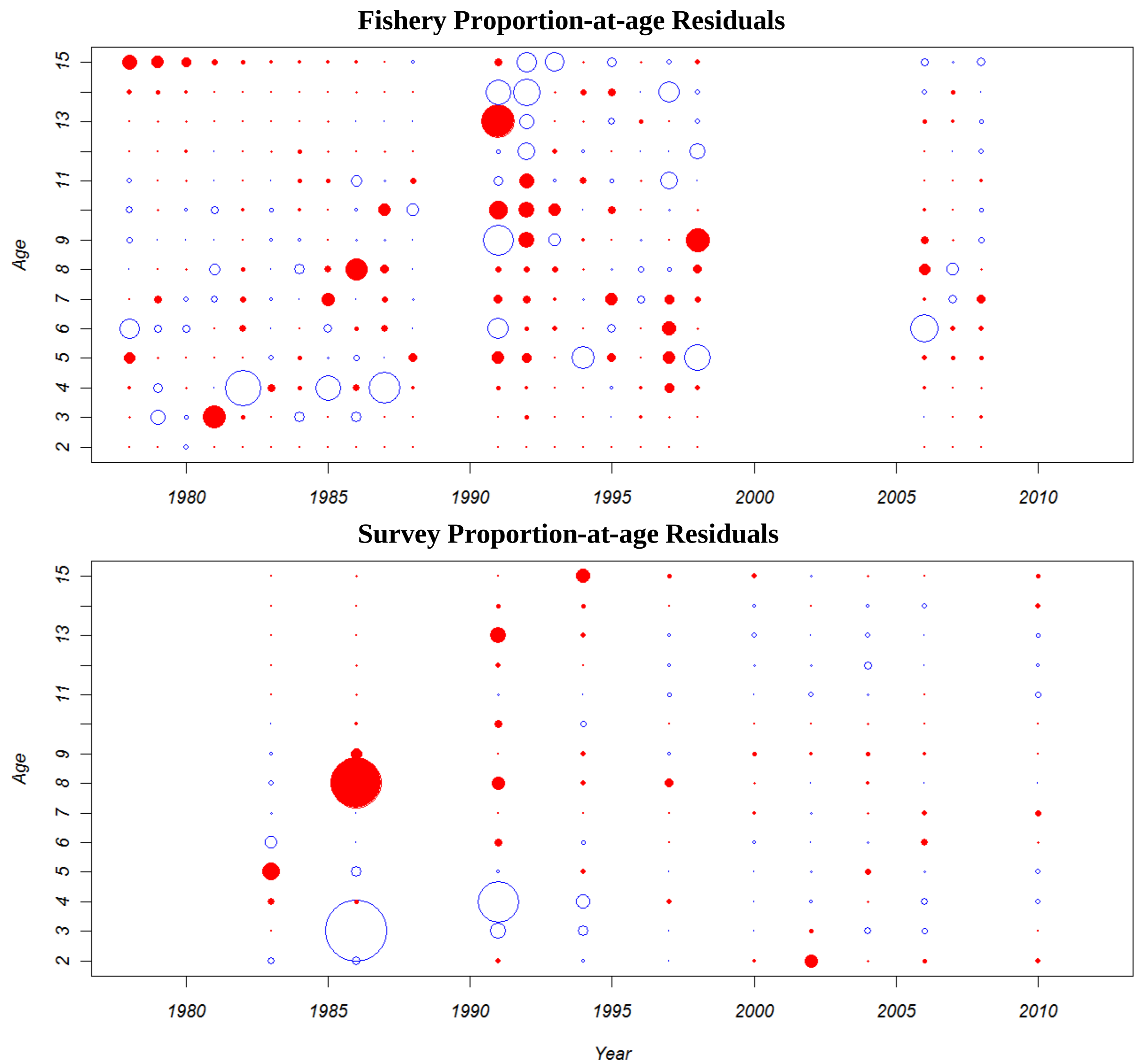

Figure 1A.15. Standardized residuals for fits to the fishery (top) and survey (bottom) proportion-at-age data for the AI pollock reference model.

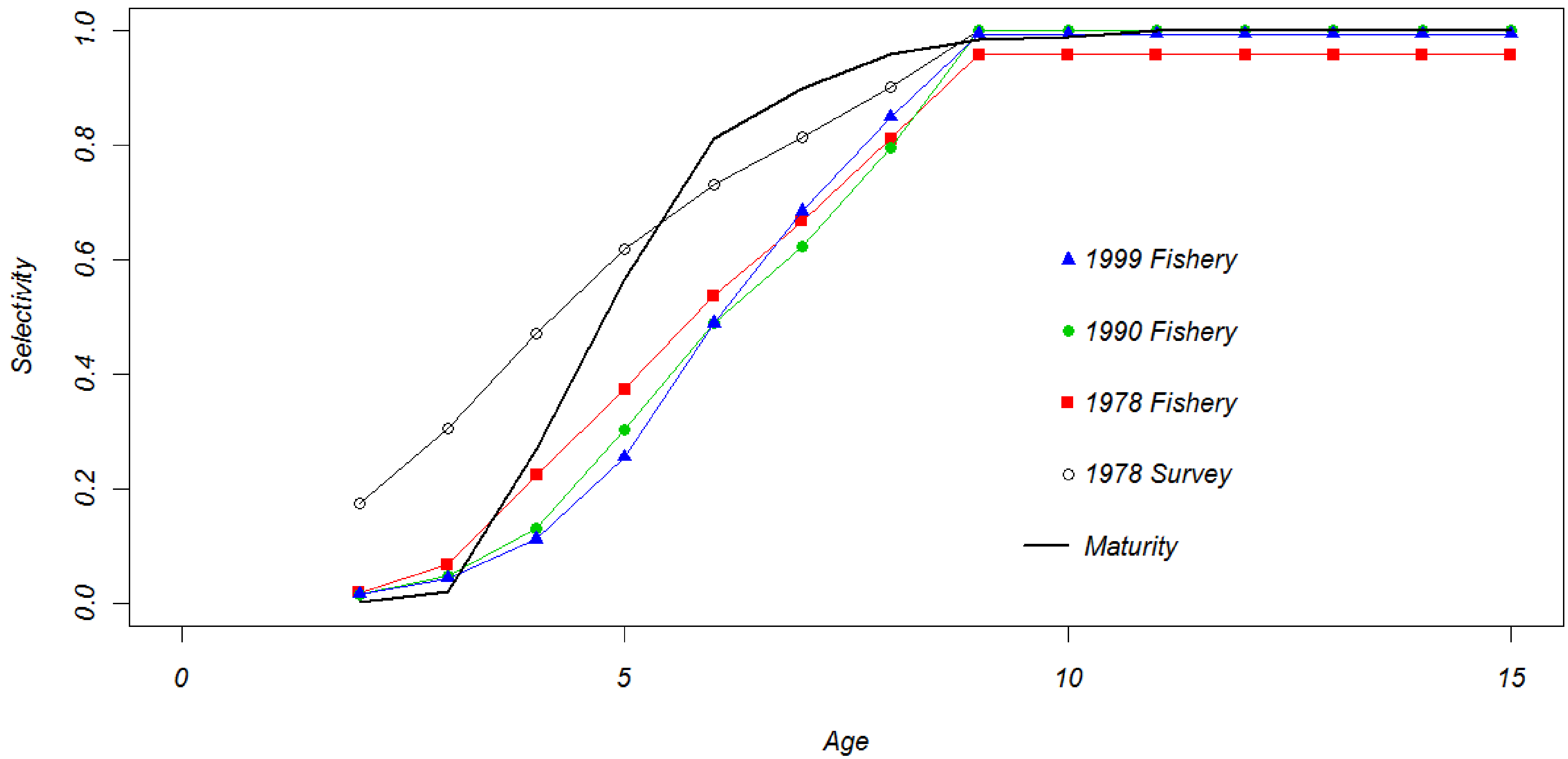

Figure 1A.16. Fishery and survey selectivity estimates with maturity at age for Aleutian Islands pollock reference model. The maximum age at which the selectivity is allowed to change in the model is set to 8.

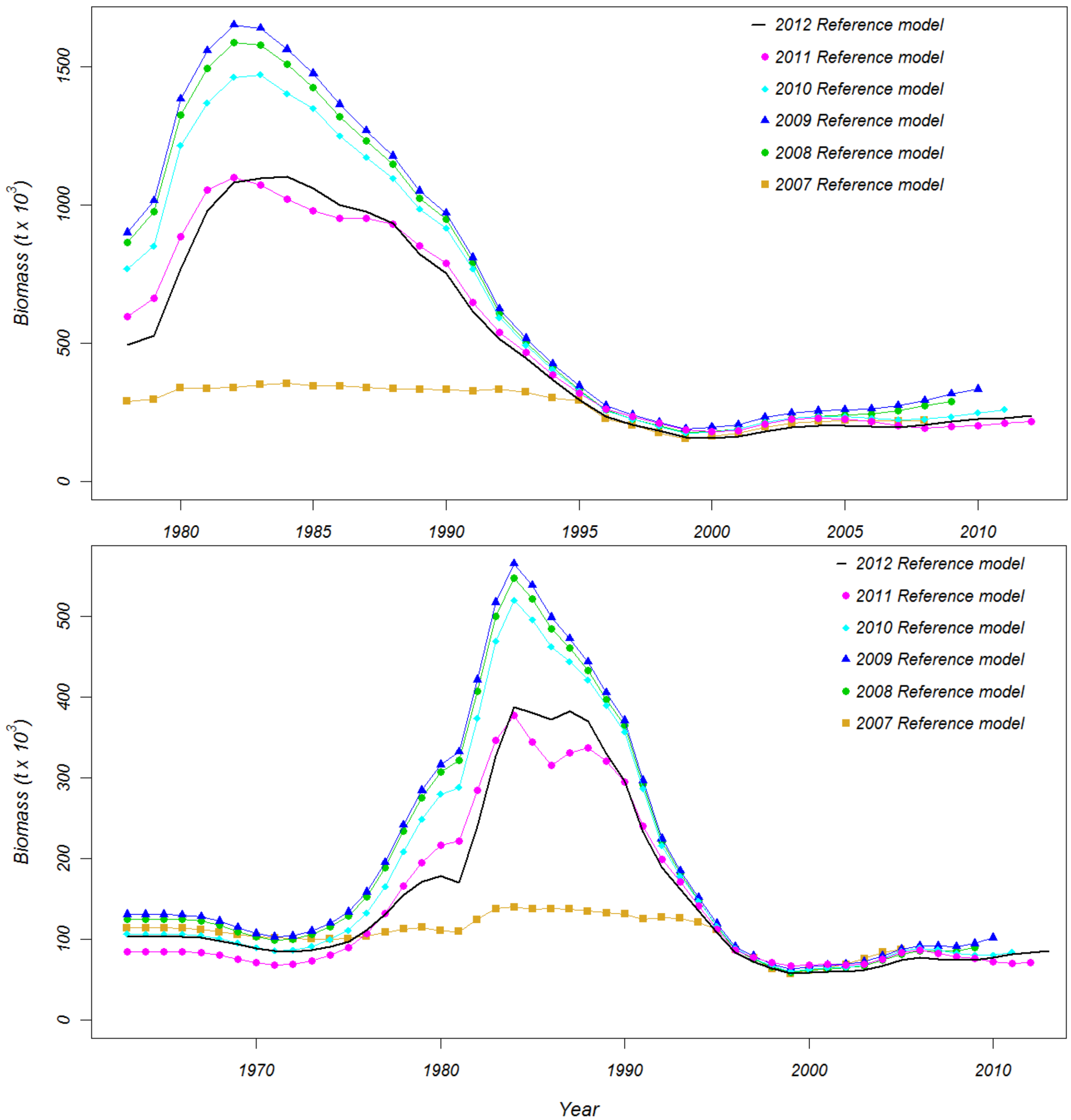

Figure 1A.17. Age 2+ (top) and spawning (bottom) biomass trajectories for the 2012 model compared with the 2007 through 2011 reference models.

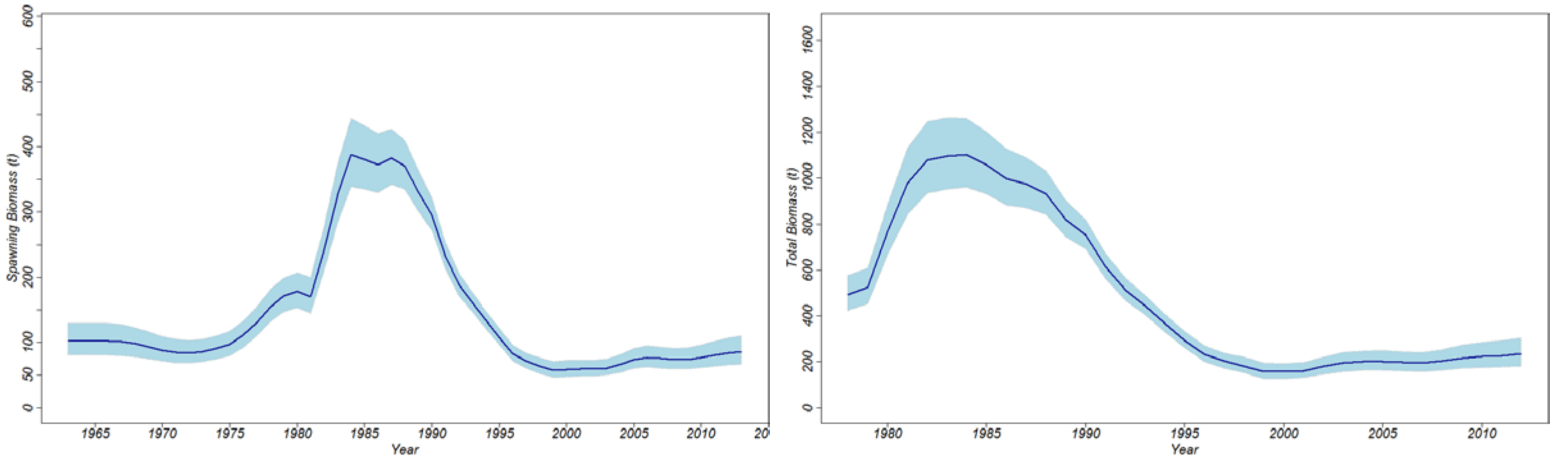

Figure 1A.18. Estimates of Aleutian Islands pollock spawning biomass (left) and age 2+ total biomass (right) in 1,000s of tons from the reference model. Confidence intervals are two standard deviations.

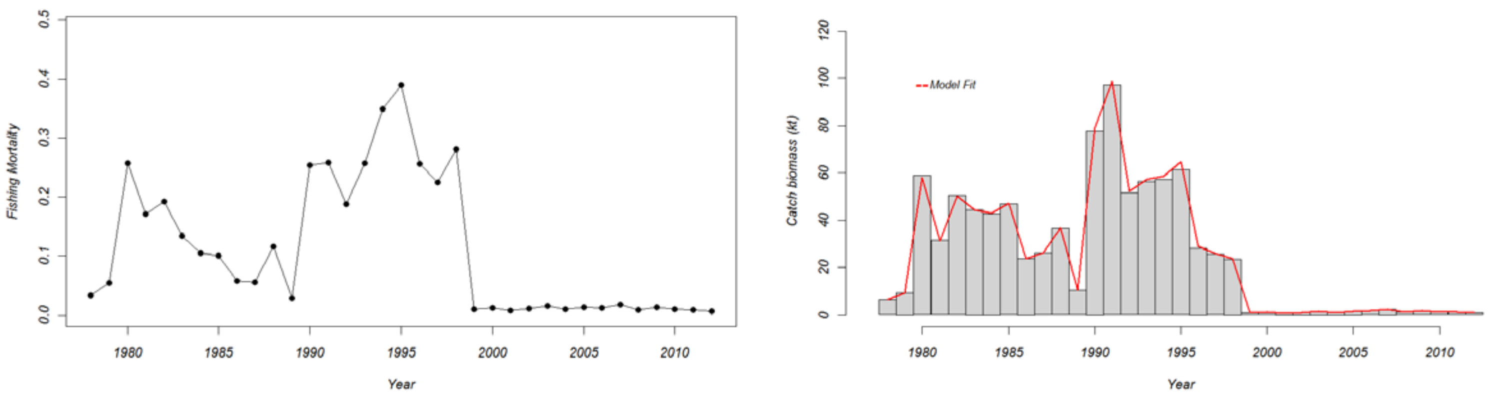

Figure 1A.19 Fishing mortality rates (left) and fits to total catch in 1,000s of tons (right) for AI pollock over time 1978-2012. Fishing mortality rates are based on the average over ages 2-15.

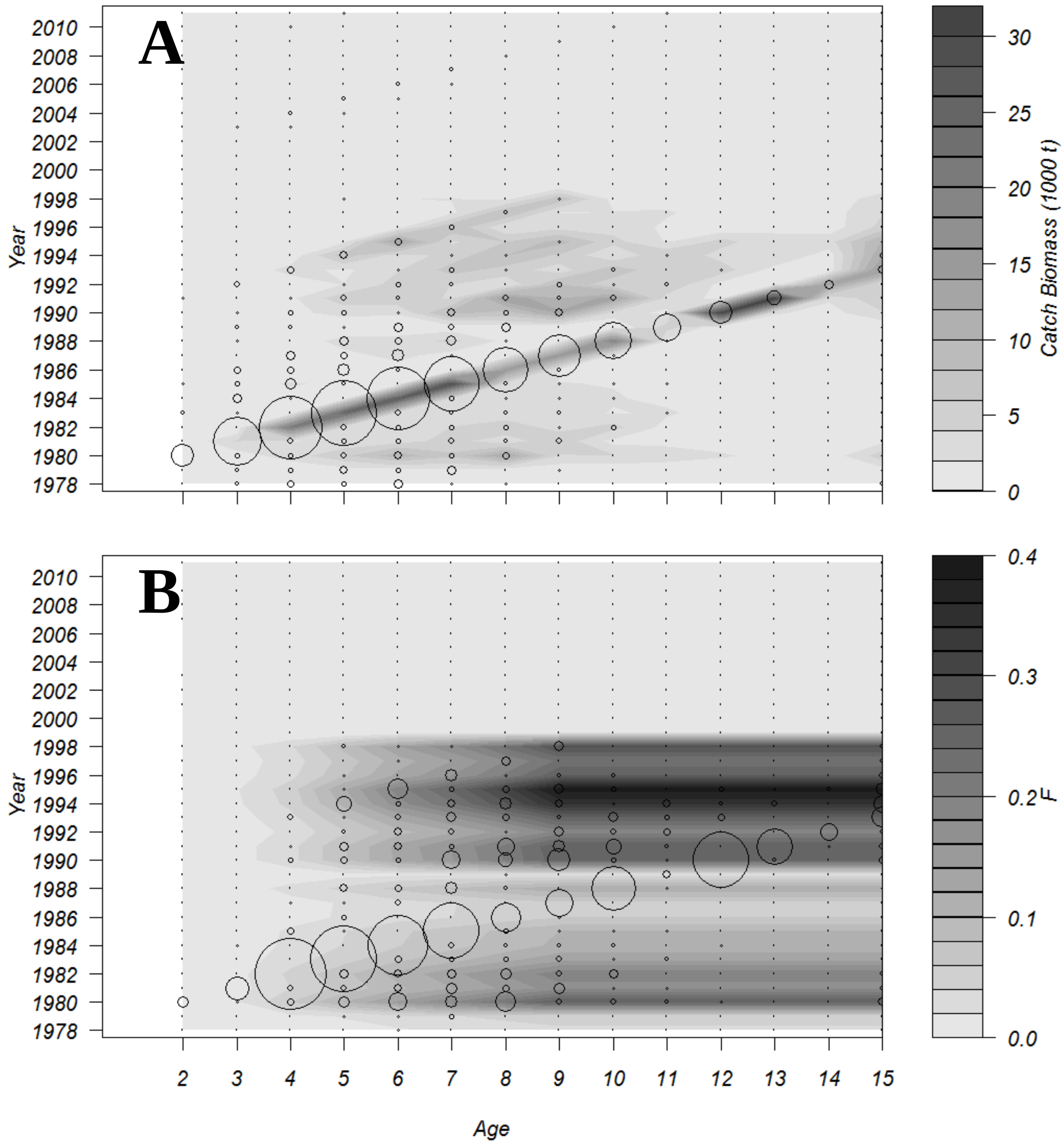

Figure 1A.20 AI pollock reference model (A-contour) catch biomass in 1,000s of tons and (A-bubbles) total biomass and (B-contour) fishing mortality rates and (B-bubbles) catch biomass by age. Total biomass is scaled to 1/20th of the catch biomass in the bubble plots

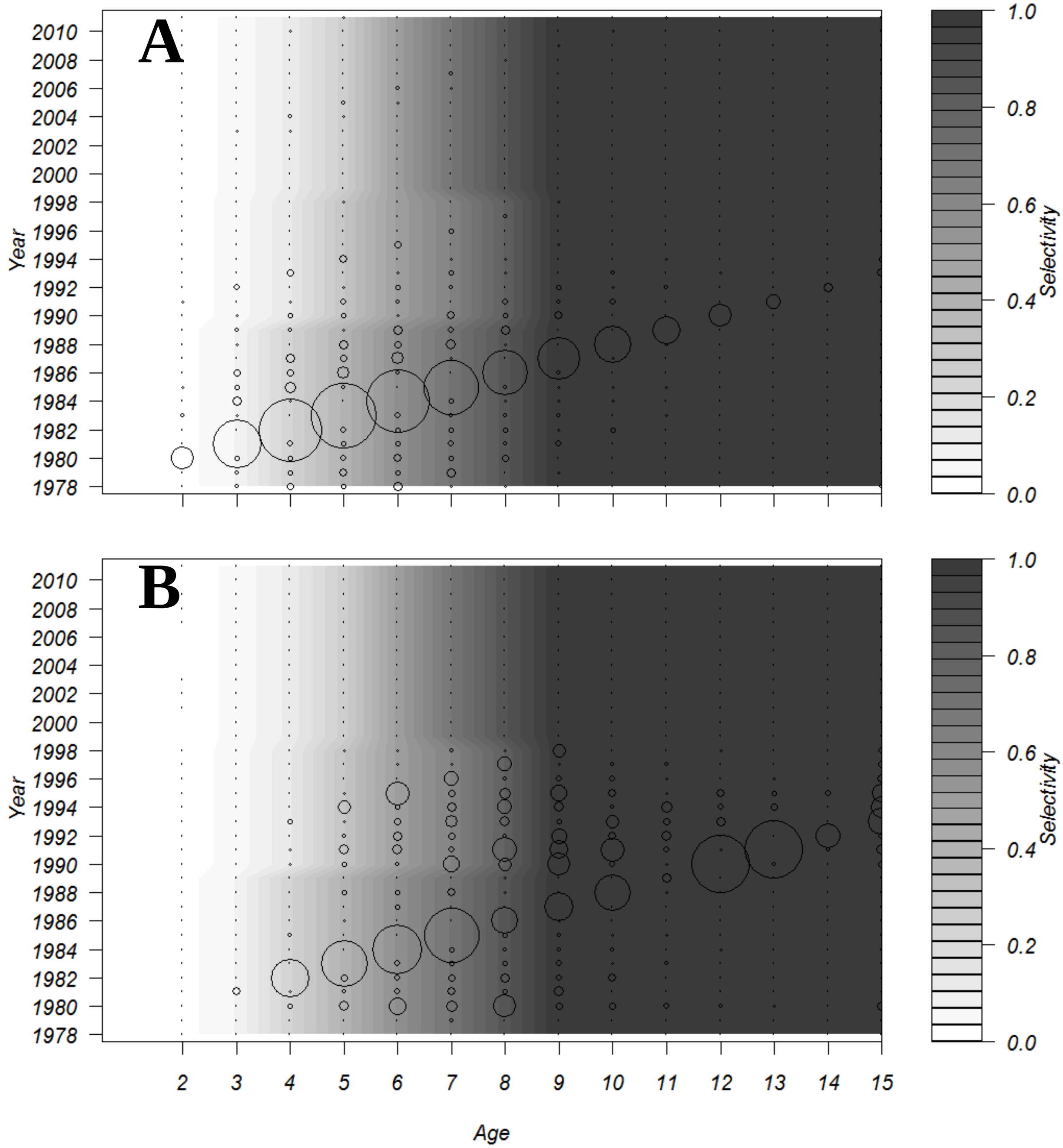

Figure 1A.21 Contour plots of fishery selectivity by age for AI pollock with bubble plots of (A) total biomass at age and (B) catch biomass at age. Total biomass is scaled to 1/20 of the catch biomass bubbles.

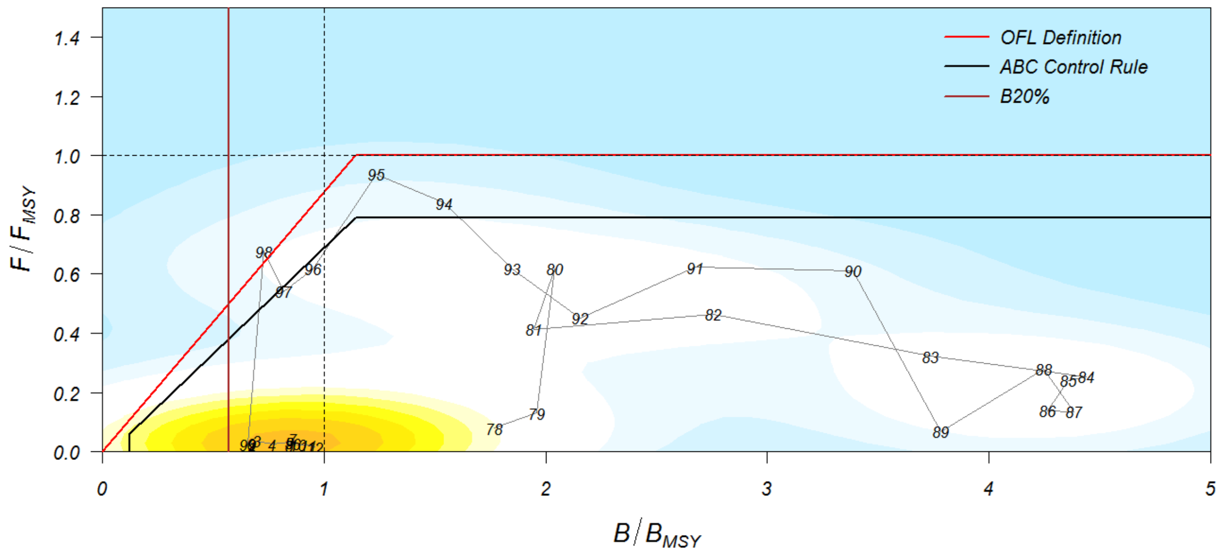

Figure 1A.22. Aleutian Islands pollock spawning biomass relative to B_{msy} and full-selection fishing mortality relative to F_{msy} (1978-2012). The ratio of fishing mortality to F_{msy} is calculated using the estimated selectivity pattern in that year. Color is scaled relative to density of points in the region from high orange to low blue.

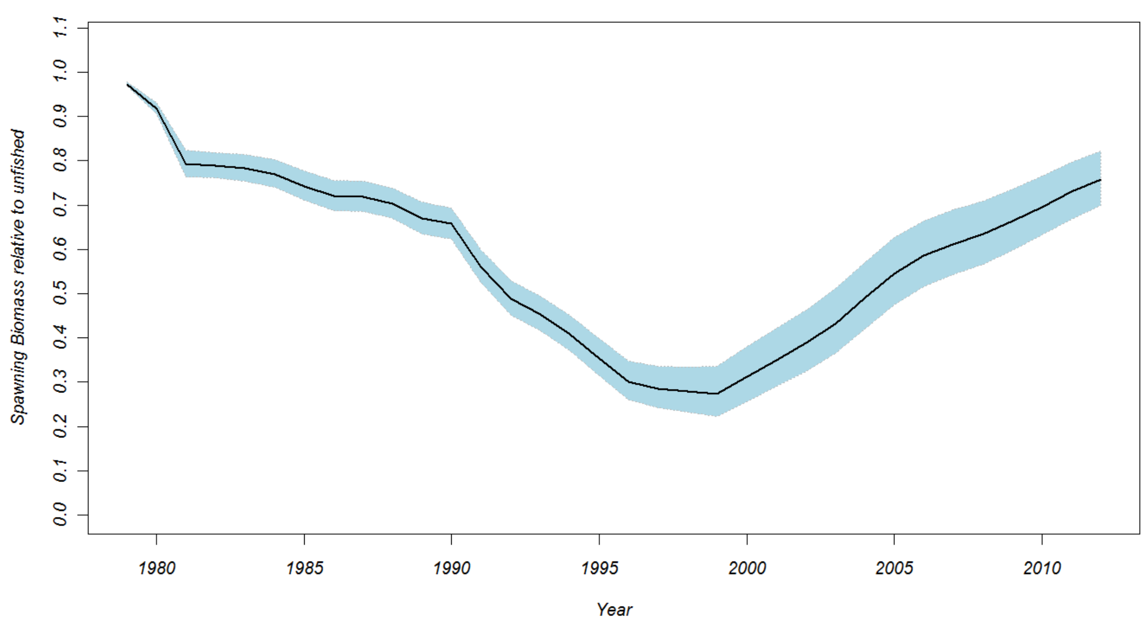

Figure 1A.23. Aleutian Islands pollock ratio of spawning biomass with fishing relative to spawning biomass without fishing for the reference model with 95% confidence interval (shaded).

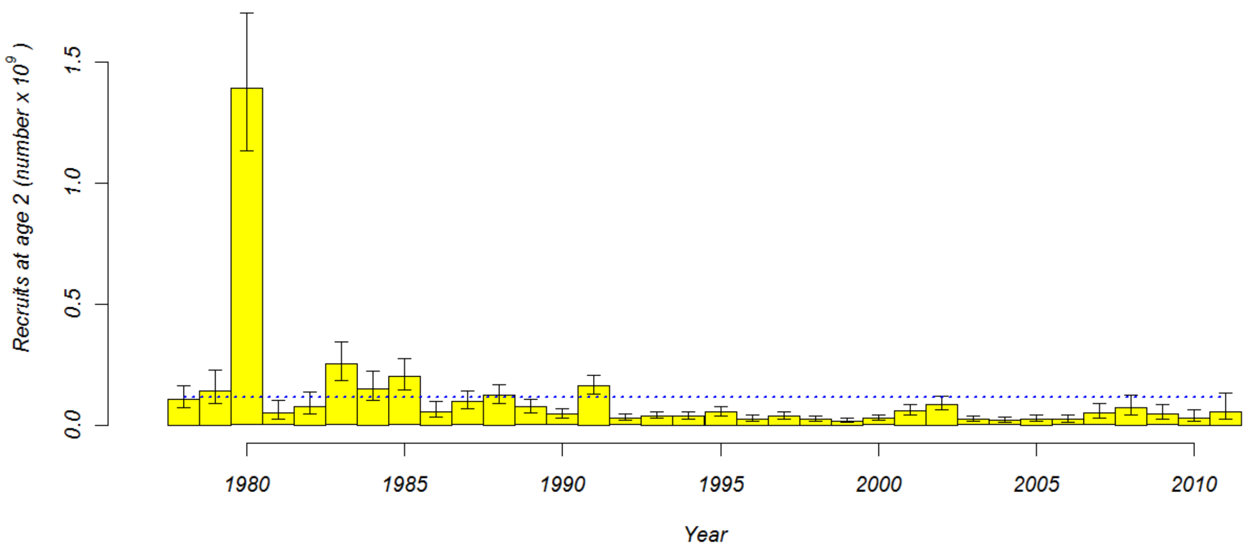

Figure 1A.24. Reference model estimates of Aleutian Islands pollock age 2 recruitment. The vertical bars represent the upper and lower 95% confidence bounds. The dotted line is the 1978-2010 mean age 2 recruitment.

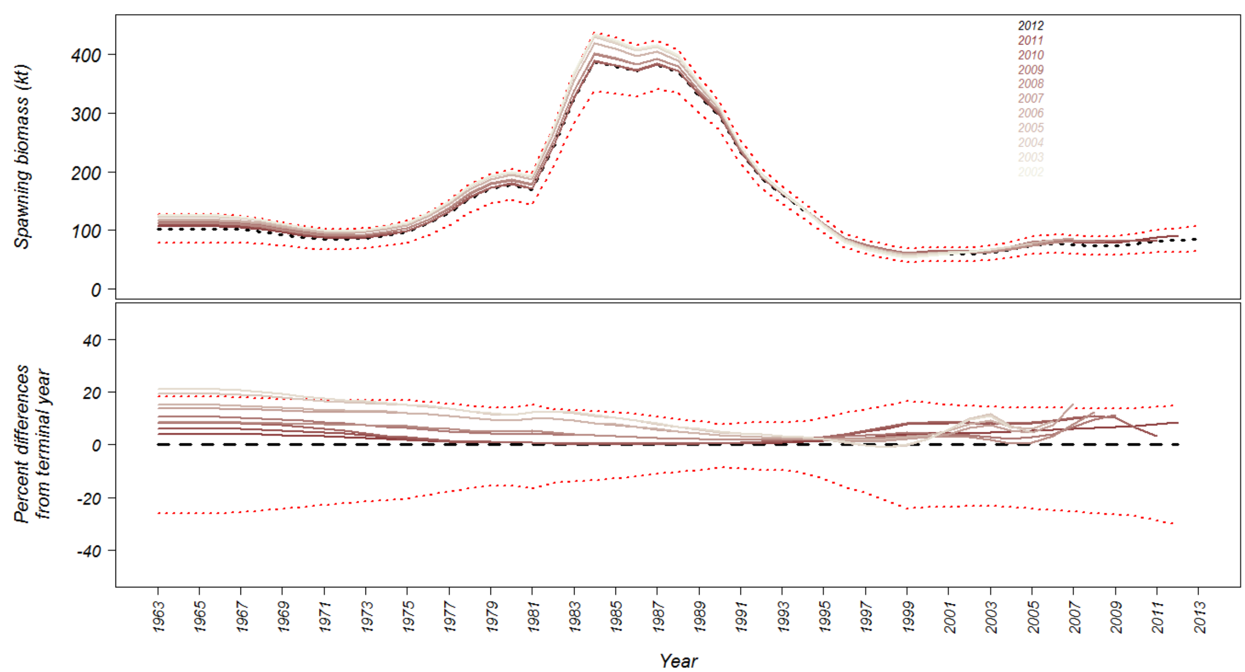

Figure 1A.25. Retrospective analysis of the AI pollock 2012 Reference model. Top figure is female spawning biomass and bottom figure is the percent difference from the reference model with all data. The black dashed line is the 2012 reference model with all data and the red dotted lines are the 95% confidence intervals for the reference model with all data.

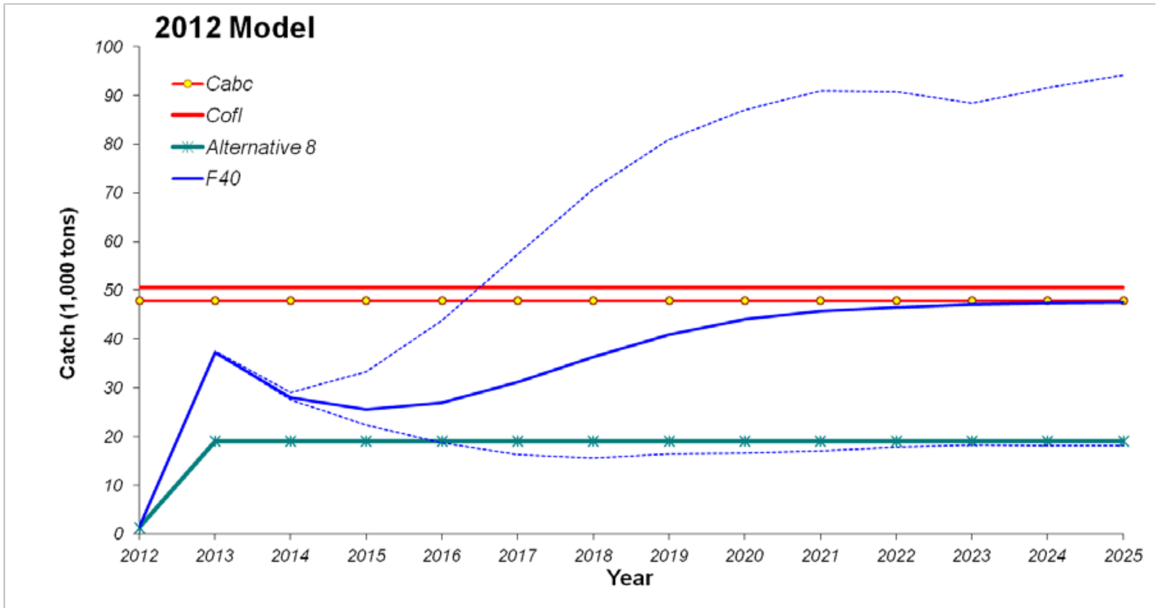

Figure 1A.26 Projected catch for $F_{40\%}$ and Alternative 8 ABC scenarios.

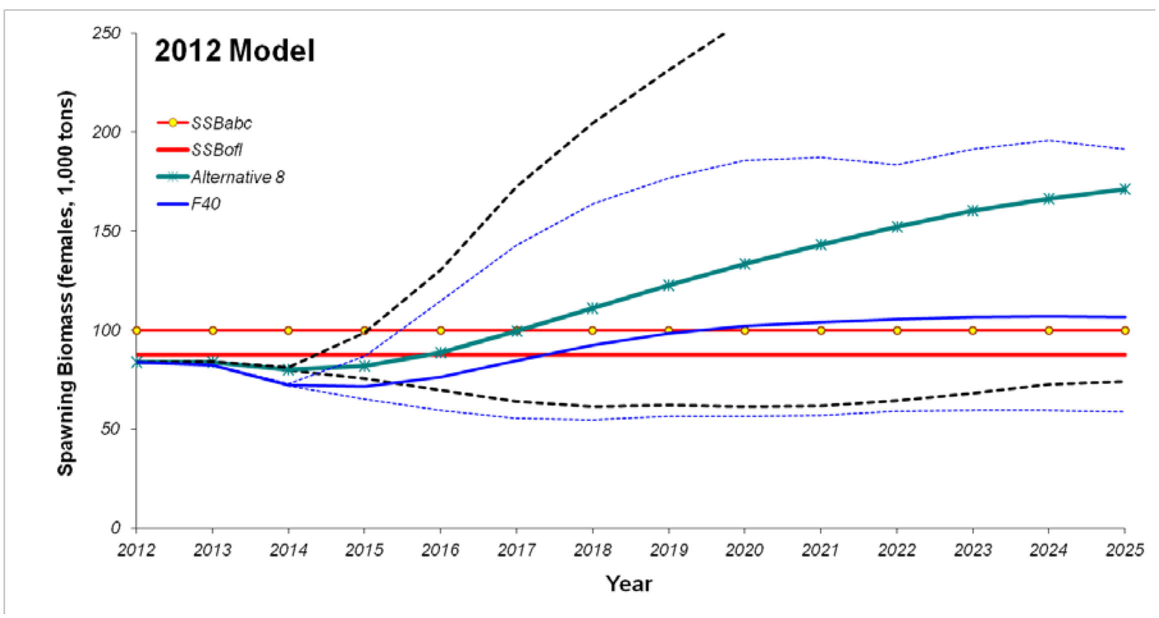

Figure 1A.27 Projected spawning biomass for $F_{40\%}$ and Alternative 8 ABC scenarios.

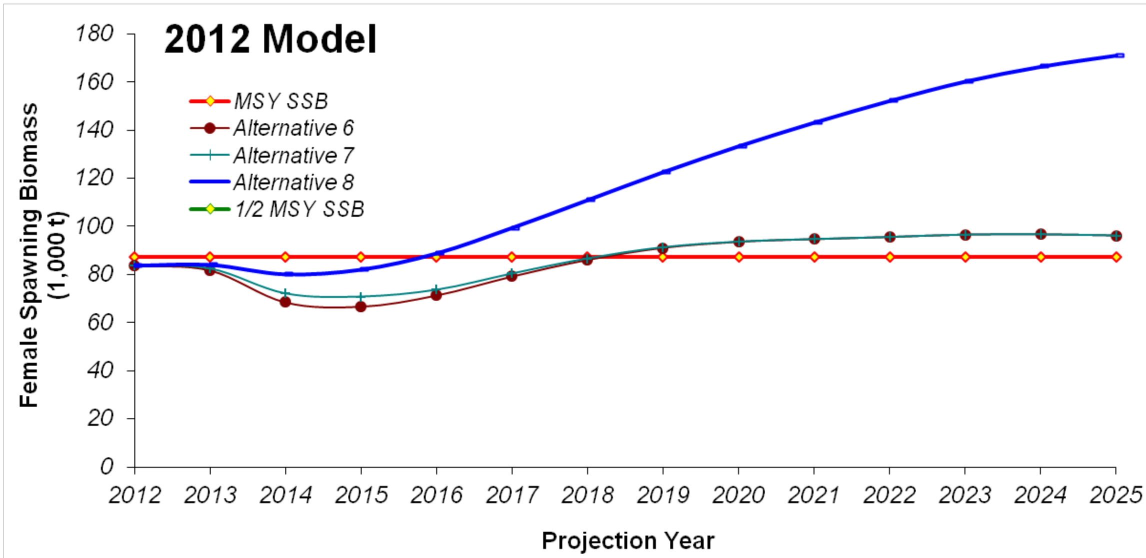

Figure 1A.28 Projected spawning biomass for MSY, ½MSY, and Alternatives 6, 7, and 8 ABC scenarios from the reference model.

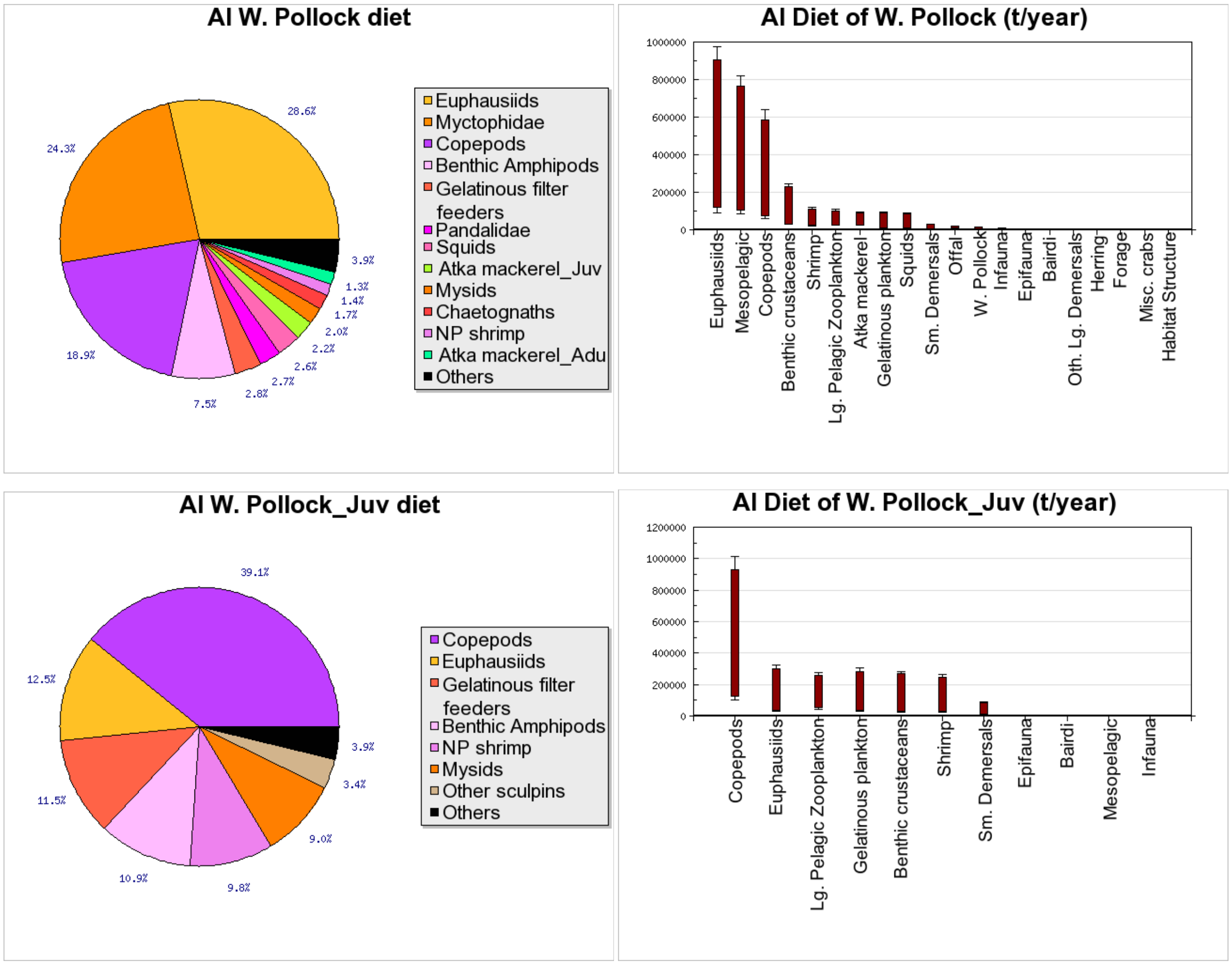

Figure 1A.29. Diet composition (left) and estimated consumption of prey (right) by AI adult (top) and juvenile (bottom) pollock. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994. See Appendix A Barbeaux et al. 2006 for detailed methods.

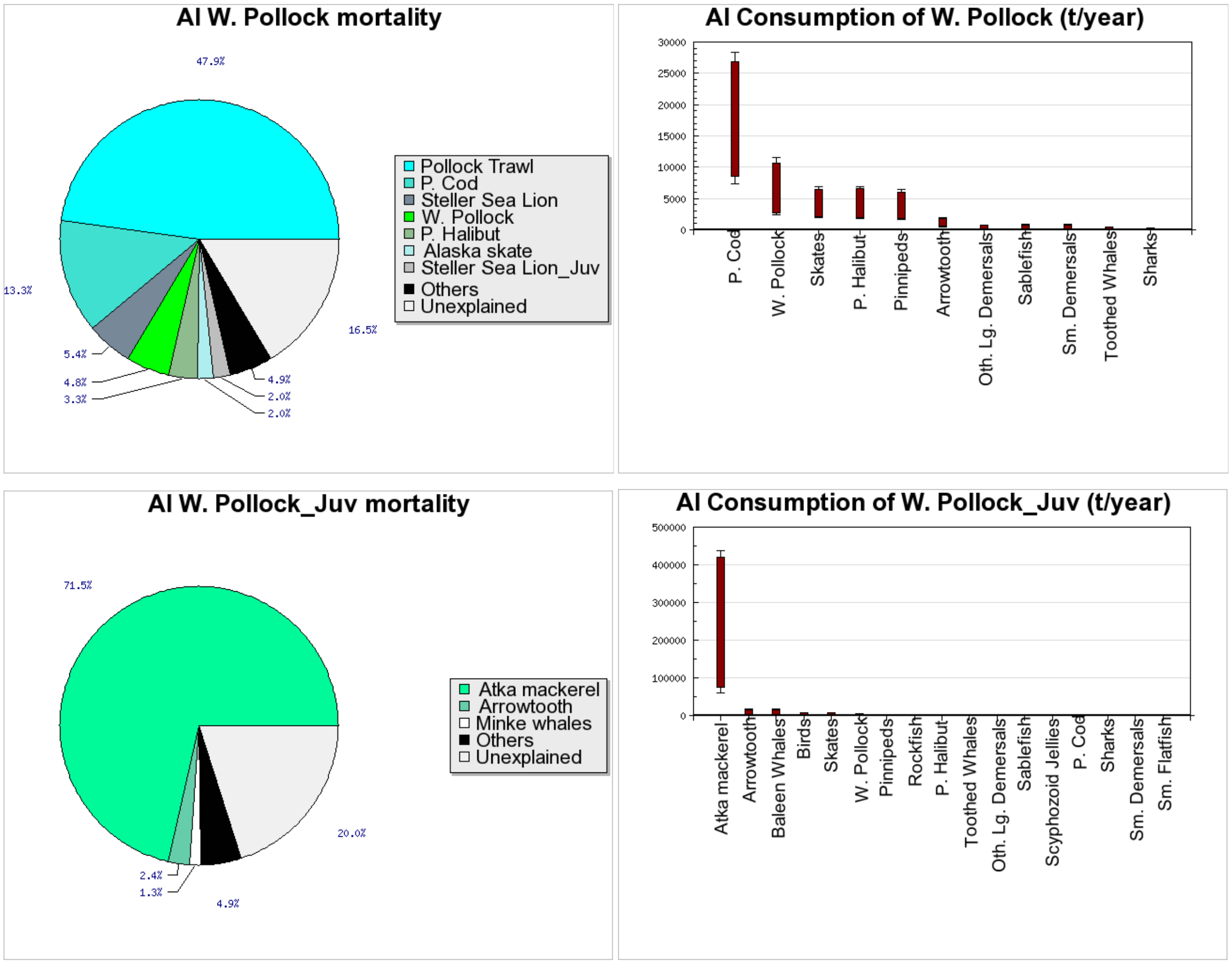

Figure 1A.30. Mortality sources (left) and estimated consumption by predators (right) of AI adult (top) and juvenile (bottom) pollock. Mortality sources reflect pollock predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994, pollock predator consumption 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 Barbeaux et al. 2006 for detailed methods.

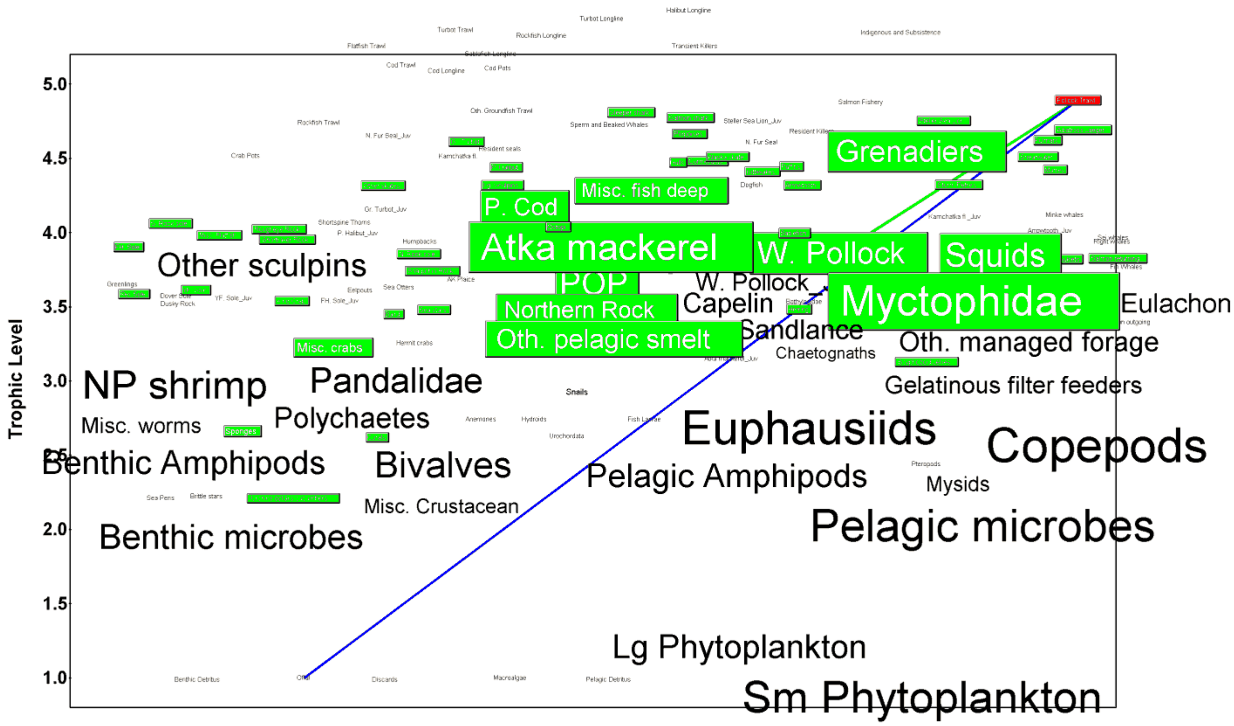

Figure 1A.31. The pollock trawl fishery in the AI food web. Species taken by the pollock fishery (in red) are highlighted in green, with the most significant flow to pollock indicated with a green line. Box size is proportional to biomass and lines between boxes represent the most significant energy flows. From Aydin et al. (2004).

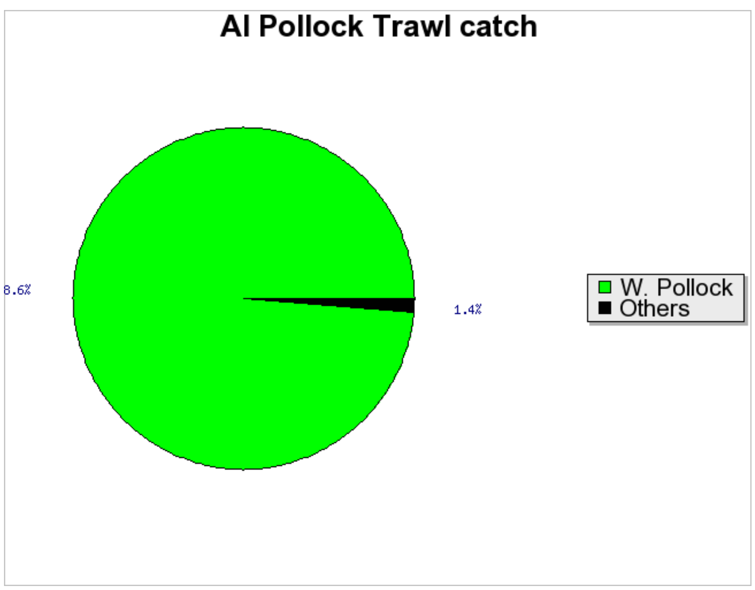

Figure 1A.32. Catch composition of the AI pollock trawl fishery during the early 1990's, as used in the food web model (Aydin et al. 2004).

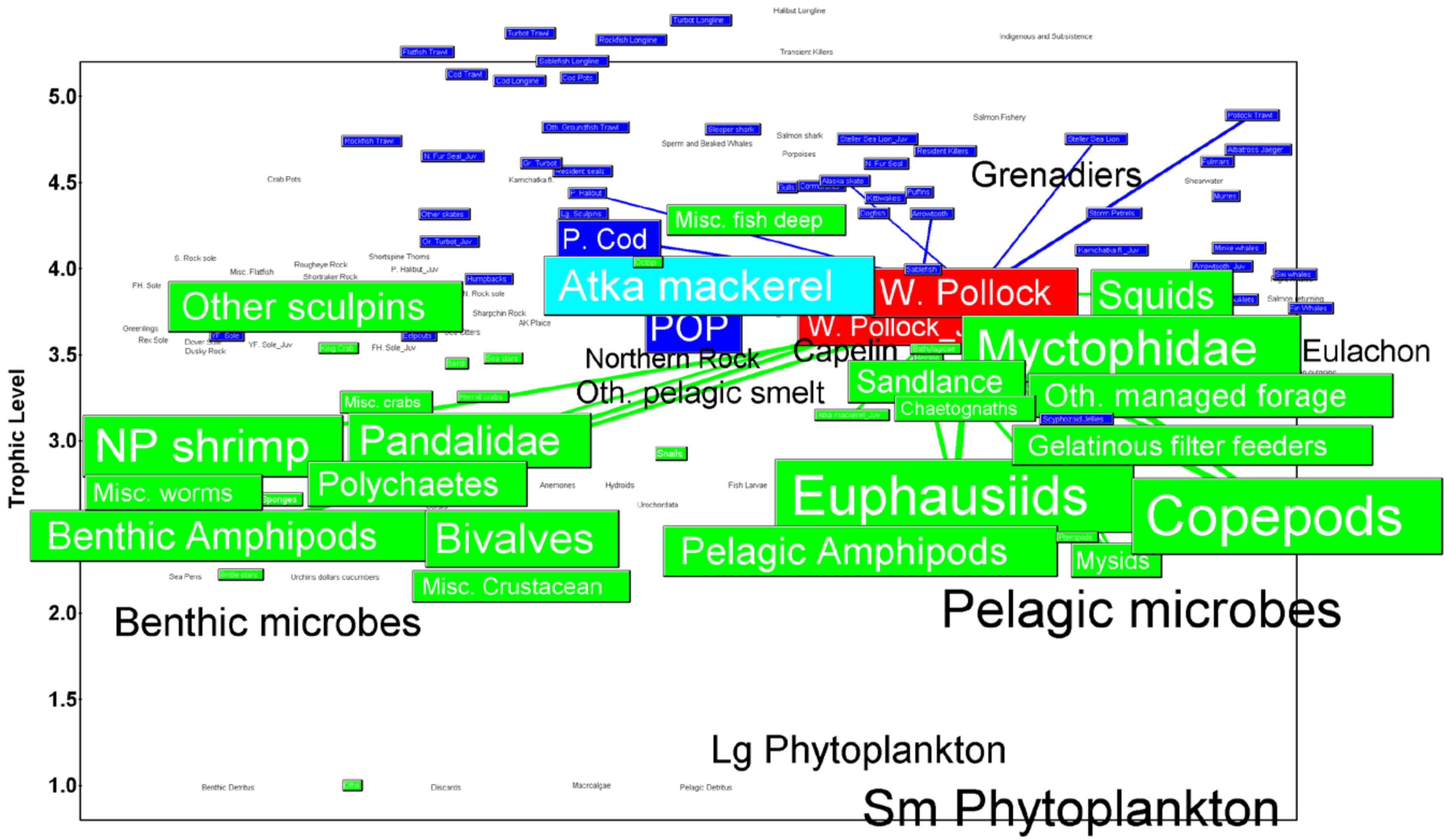

Figure 1A.33. Adult and juvenile pollock (highlighted in red) in the AI food web (Aydin et al 2004). Predators of pollock are dark blue, prey of pollock are green, and species that are both predators and prey of pollock are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.

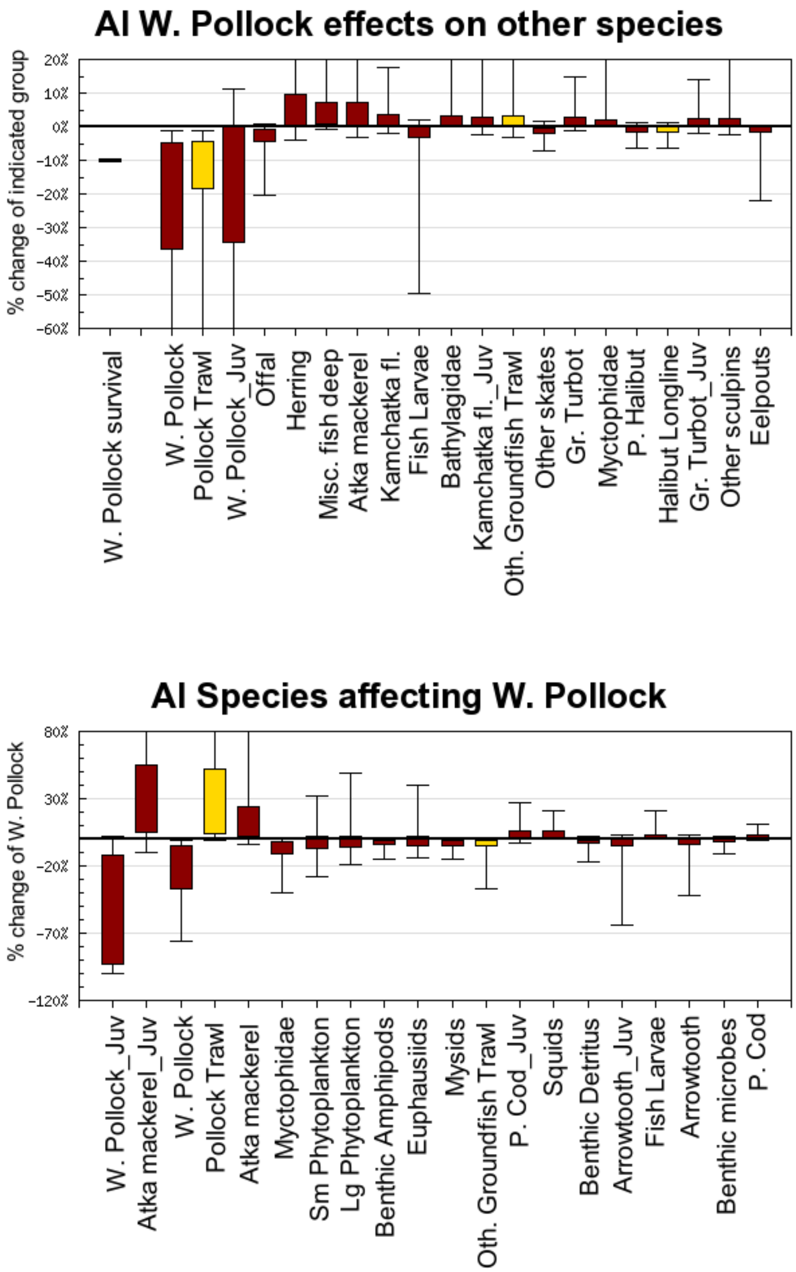

Figure 1A.34. (upper panel) Effect of changing pollock survival on fishery catch (yellow) and biomass of other species (dark red), from a simulation analysis where pollock survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. (lower panel) Effect of reducing 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 1A-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, $\sum_{j=1}^{15^+} \eta_j^s = 0$	$s_j^s = e^{\eta_j^s}$ $j \le$ maxage $s_j^s = e^{\eta_{\text{maxage}}^s}$ $j >$ 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, $\sum_{j=1}^{15^+} \eta_{ij} = 0$	$s_{ij}^f = e^{\eta_j^f}$, $j \le$ maxage $s_{ij}^f = e^{\eta_{\text{maxage}}^f}$ $j >$ 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	$\dot{L} = \sum_{i=1}^{7} L_i$	

Appendix 1A-B Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, we present non-commercial removals and estimates of pollock removals from the halibut fishery from the Halibut Fishery Incidental Catch Estimation (HFICE) to help estimate total catch and removals from NMFS managed stocks in Alaska.

Estimates of total removals that do not occur during directed groundfish fishing activities includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System (CAS) estimates. Current pollock research removals are insignificant relative to the fishery catch, being smaller than the observation error assumed for the catch estimate. Total removals from activities other than directed fishery were near 35.6 tons in 2010 (Table C-1).. This is ~0.1% of the 2013 recommended ABC of 37,295 t. There were no data available on pollock removals due to subsistence, personal use, or recreational catch. It is assumed that pollock catches during these activities would be minimal in AI management area.

The HFICE is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).   HFICE Aleutian Islands pollock catch is estimated to be insubstantial for the Aleutians, never exceeding 4.5 tons in a given year (Table C-1).

References:

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Hanselman, D. H., C. Lunsford, and C. Rodgveller. 2010. Alaskan Sablefish. In Stock assessment and fishery evaluation report for the groundfish resources of the GOA and BS/AI as projected for 2010. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.pp.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Table 1A.B-1 Total removals of walleye pollock (t) from the NRA area from activities not related to directed fishing, since 1978.

	NMFS Acoustic	NMFS Bottom Trawl	NMFS Long Line*	AICASS**	IPHC*	Japanese Surveys	HFICE***	Total
1978								
1979								
1980	2.5	37.9				97.7		138.0
1981								
1982	5.7	0.8						6.4
1983		28.1				396.7		424.8
1984								
1985								
1986		10.6				248.1		258.7
1987								
1988								
1989								
1990								
1991		30.0						30.0
1992								
1993								
1994		26.9						26.9
1995								
1996								
1997		23.2						23.2
1998								
1999								
2000		30.9						30.9
2001							1.0	1.0
2002		35.5					1.1	36.6
2003							4.5	4.5
2004		18.2					2.3	20.6
2005							0.3	0.3
2006		17.8					1.7	19.6
2007				7.6				7.6
2008								
2009								
2010		35.3	0.276		0.02		1.0	36.6
2011								
2012		13.0						

* Data only available for 2010

** Aleutian Islands Cooperative Acoustic Survey, 2008 only; 2006 and 2007 AICASS catch included in CAS

*** Estimates of pollock catch (t) from the Halibut Fishery Incidental Catch Estimation (HFICE) working group

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