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

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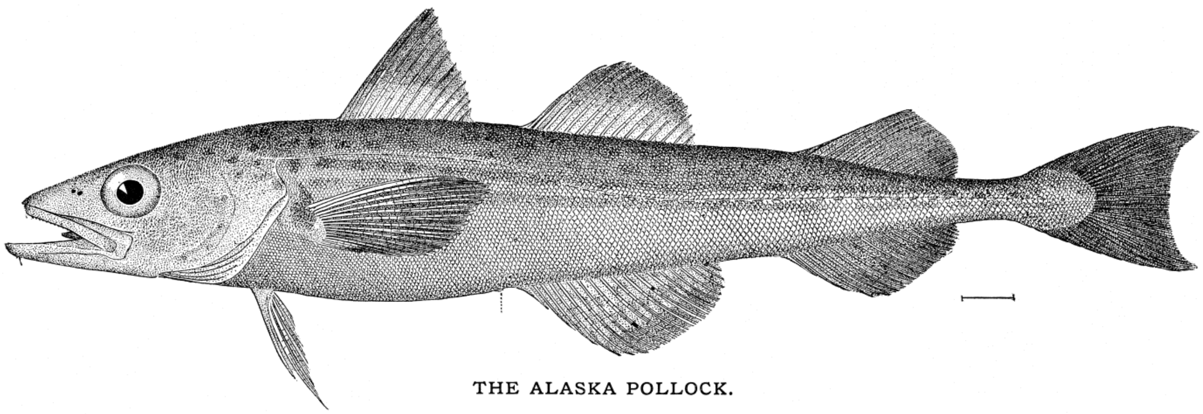


THE ALASKA POLLOCK.

Executive Summary

Model 15.1 (same as the 2015 accepted model) is presented for ABC/OFL advice. The 2014 survey age composition data, 2016 Aleutian Islands (AI) survey biomass estimate, and updated 2015 and 2016 fishery catch estimates comprised the new data for this year's assessment. As in the previous six years there has been no directed fishing for pollock in the Aleutian Islands. As of October 22, 2016 there had been only 1,245 t of bycatch, primarily in the arrowtooth flounder and Pacific cod fisheries.

Summary of Changes in Assessment Inputs

Summary of changes in assessment inputs

- Catches for 1978 to 2016 were updated to latest estimates from the catch accounting system (CAS). There were no significant changes except the addition of the 2016 estimate at 1,500 t.
- 2016 AI bottom trawl survey biomass estimated of 83,070 t was added.
- 2014 AI bottom trawl survey age composition data were added.

Summary changes in the assessment model

- There were no changes to the recommended model for ABC/OFL advice. However, Model 15.2 configuration was developed which allows for differential natural mortality with age. In this configuration, natural mortality for ages 1, 2, and 15 were modeled as deviations from the natural mortality for ages 3-14 fit with a log normal prior on *M* with a mean of 0.2 and CV of 0.2.

Summary of Results

Quantity		As estimated or *recommended this* year for: 2017	2018*
M (natural mortality rate)		0.19	
Tier		3b	
Total (age 1+) biomass (t)		250,221	271,831
Female spawning biomass (t)			
Projected		77,579	81,545
$B_{100\%}$		203,100	
$B_{40\%}$		81,240	
$B_{35\%}$		71,085	
F_{OFL}		0.378	0.397
$maxF_{ABC}$		0.304	0.319
F_{ABC}		0.304	0.319
OFL (t)		43,650	49,291
maxABC (t)		36,061	40,788
ABC (t)		36,061	40,788
Status		As determined *this* year for: 2015	2016
Overfishing		no	n/a
Overfished		n/a	no
Approaching overfished		n/a	no

* Projection based on estimated catches of 1,500 t for 2016 and 1,157 t for 2017, the five-year average *F* (2010-2015) of 0.0087, used in place of maximum permissible ABC .

** Long-term equilibrium F_{OFL} and F_{ABC} were 0.417 and 0.332, respectively.

Responses to SSC and Plan Team Comments on Assessments in General

The SSC had comments about following model numbering schemes, data-weighting issues and advice arising from the CAPAM workshop, and evaluating survey catchability research specifically regarding temperature effects. *Response: The numbering scheme is being followed in this assessment, data weighting and survey catchability issues will be addressed in future assessments. Temperature anomalies are presented below.*

Response to SSC and Plan Team comments specific to this assessment

- **The Team recommends examining alternative models with higher M (compared to the low M coming out of the estimation procedure), and further recommends exploring the unscaled estimates of selectivity with respect to the survey's low apparent catchability**. *The authors regret that time did not allow for exploration of alternative models in this assessment cycle. These issues will be addressed in the 2017 model explorations.*

Introduction

Walleye pollock (*Gadus chalcogrammus;* Coulson et al. 2006; Carr and Marshall 2008; here after pollock) 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 decreased in abundance from the mid-1980s to the mid-1990s (1986 bottom trawl survey estimate of 444,000 t to a 1994 bottom trawl survey estimate of 78,000 t). Since 1994 the abundance point estimate has been variable, but considering the variance of the survey estimates the trend appears relatively flat (Fig 1A.1). The 2012 survey abundance was a record low at 44,281 t. The 2014 survey abundance estimate at 85,316 t nearly doubled the 2012 estimate. The low 2012 estimate is thought to be anomalous due to the very low temperatures in the region affecting availability of the species to the bottom trawl survey. 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.1). This recent spatial change 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 higher 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 relationship between Aleutian Islands pollock and pollock from neighboring areas is poorly 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. At the time of that study, data from the Aleutian Islands region were unavailable. Recent genetic studies, which includes samples from the Aleutian Islands near Adak Island, have shown a lack of genetic heterogeneity among Northeast Pacific and Bering Sea pollock samples (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.

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. 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. In the stock structure presentation (Barbeaux et al. 2014) to the Council on Aleutian Islands pollock the Plan Team determined that the current management practices were of “little concern”.

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.

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.3). In 2003 through 2007 the authors' preferred stock assessment model excluded the fishery dependent data from east of 174°W longitude in the NRA. In 2007 a CIE review deemed the east-west data split as inappropriate and the authors' preferred model has since included all fisheries dependent data from the entire NRA region.

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; Barbeaux et al. 2013 Fig. 1A.4) and the domestic fishery (1989-2009; Barbeaux et al. 2013 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 (Fig. 1A.4). 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 nm 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, 2011, 2012, 2013, 2014 and 2015 50 t, 0 t, 0 t, 0 t, 0 t, and 62 t were harvested in the directed fishery. As of October 22, 2016, 0 t had been taken in the directed fishery for 2016. In 2010, 2011, 2012, 2013, 2014, and 2015 1,285 t, 1,208 t, 975 t, 2,964 t, 2,375 t and 853 t were harvested as bycatch in other fisheries. In 2016, as of October 22, 1,244 t had been taken as bycatch in other fisheries. The increase in catch in 2013 and 2014 had been primarily in the arrowtooth flounder fishery. This fishery changed fishing tactics to fish more shallow than in previous years to avoid Greenland turbot bycatch. 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

Source	Data	Years
NMFS AI Bottom Trawl Survey (AI.BIOMASS_INPFC)	Survey Biomass	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, and 2016
NMFS AI Bottom Trawl Survey (RACEBASE.SPECIMEN)	Survey Age Data	1980, 1983, 1986, 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, and 2014
AKFIN Domestic Blend (COUNCIL.COMPREHENSIVE_BLEND_CA)	Total Catch	1991-2016
Ianelli et al. 2001	Total Catch	1978-1990
Observer Program (OBSINT.DEBRIEFED_AGE)	Fishery Age Data	1978-1987, 1994-1996, and 1998
AICASS	Fishery Age Data	2006 - 2008

Catch estimates

Estimates of pollock catch in the Aleutian Islands Region are derived from a variety of data sources (Table 1A.1). The foreign-reported database (held at AFSC) is the main source of information for the early period catches, 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 take 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 1985-1990 These proportions were then expanded to match the total catch. The Alaska Fisheries Information Network (AKFIN) provides the Domestic Blend data for 1991-2016. 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). The majority of catch in the last 7 years has been as bycatch in other target fisheries (Table 1A.5).

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.6 and Table 1A.7) 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.8. Fishery average weights-at-ages are provided in Table 1A.9.

From 1983 through 1987 the 1978 year class was predominate in the fishery (Fig. 1A.5). It wasn’t until 1990s that the 1989 year class made up a larger proportion of the fishery catch at age data than 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.

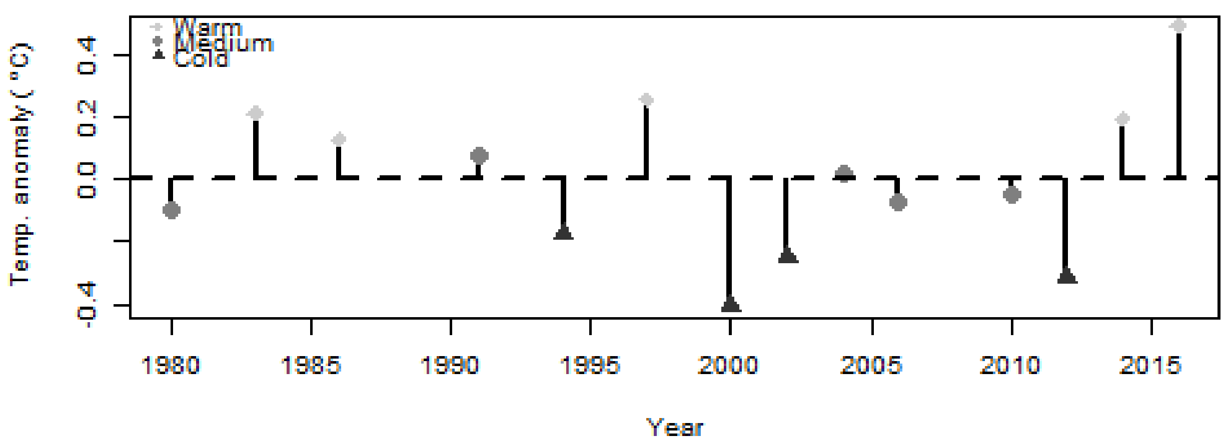
The age data collected during the 2006-2008 AICASS (Barbeaux et. al. 2011) revealed that the 1999 and 2000 year class made up a large portion of the adult population and were relatively large recruitment events for all three study years compared to more recent recruitments for this stock. In 2008, the 1998 year class appeared to be larger than previous years, but this may be due to a 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 otolith 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, 2012, 2014, and 2016. 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 (1991-2014) ranged from 44 to 175 thousand tons (Table 1A.10) 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.1 and 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 2016 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 Delarof Islands. The 2006 and 2010 survey found higher concentrations of pollock in the Delarof Islands than in 2004, but are consistent with the distribution of pollock in the 2002 survey. The 2012, 2014, and 2016 again show very little pollock in this area. The general trend for the 2002 through 2016 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, 2014, and 2016 surveys were observed in the Eastern Aleutians (Area 541), the surveys did not find large concentrations of pollock in the east as it had in the previous three surveys. The 2016 survey estimate was 83,070 t, a 3% decrease from 2014. However the 2014 survey estimate for the NRA area was 85,316 t, 93% higher than the 2012 estimate (Fig. 1A.1). Overall the 2016 survey distribution of pollock by area looked much like the 2014. For Area 543 was the 2016 estimate was 59,119 t, a 7% decrease from 2014, for while Area 543 showed a 38% increase, and Area 541 a 2% decrease.

Bottom temperatures continued to increase over 2014 with 2016 having the highest overall temperature in the time series. The bottom temperature anomaly for AI bottom trawl survey 1980-2016 with temperatures weighted by size of AI survey strata are shown below. In this figure "warm" is greater than and "cold" is less than 1 standard deviation from the mean. The 2014 and 2016 warm years were consistent with a warmer Bering Sea and the appearance of "The Blob" of warm water in the Northeastern Pacific Ocean (Peterson et al. 2015).



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 1997 through 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.5 and Table 1A.11). The 2010 survey had a large age-4 mode (2006 year class, followed by the age-5 (2005 year class). The 2012 survey had a dominant age-6 mode (2006 year class) and a smaller age-1 mode (2011 year class). The age-1 mode continued into 2014 as a dominant age-3 mode, and the age-6 mode (2006 year class) appears to have split into a pair of high age-7 and age-8 modes (2006 and 2007 year class). This is likely due to aging error either with age-6s in 2012 or the 7 and 8s in 2014. The AIBTS weight-at-age data are presented in Table 1A.12. 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 the 1991 age composition data have been down-weighted in the stock assessment model.

The length data for the 1980 through 2016 surveys are shown in Figure 1A.7. The 2010, 2012, and 2016 size composition show a higher proportion of fish < 20 cm than has been typical for the Aleutian Islands area. The 2014 survey had a very large mode between 20 and 40 cm which appears to correlate with a large 2011 year class at age 3. This year class continues into the 2016 data, but at much lower proportion. The 2016 survey has four separate modes in the length data with the 2006 year class as fish between 50 and 70 cm, a 2011 year class at between 40 and 50 cm, a smaller 2012 mode and another large model between 10 and 20 cm which would correlated with a 2015 year class.

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 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. In 2006 there was a high degree of variability between surveys due to the small area being surveyed, pollock movement, and potential overlap with the fishery being conducted during the survey period. In 2007 the spatial distribution of pollock varied between surveys with 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 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 (See Barbeaux et al 2013, Fig. 1A.9).

Analytic Approach

The 2016 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 x 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

AMAK 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 age groups that are modeled (ages 1-15+). Age-1 recruitment in each year is estimated as deviations from a mean value expected from an underlying stock-recruitment curve. Model 15.1 estimates natural mortality across all ages. Model 15.2 estimates natural mortality as a vector of deviations from the mean (see *Natural Mortality* in the Parameters Estimated Inside the Assessment Model section below for more detail). For all models, deviations between observations and 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).

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

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

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.

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	1983	1986	1991						
	$\dot{N}_{i,\bullet}$	1**	1**	1**						
	Year	1994	1997	2000	2002	2004	2006	2010	2012	2014
	$\dot{N}_{i,\bullet}$	100	100	100	100	100	100	100	100	100

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

**The 1983-1991 values were down-weighted because the samples collected in these years were not representative of the region considered.

Parameters Estimated Outside the Assessment Model

Weight-at-age

We estimated weight-at-age separately for the survey and 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 2016 are given in Table 1A.9 and the survey weight-at-age values are given in Table 1A.12 and Table 1A.13. All weight-at-age by year values were estimated using generalized additive models with time and age as the independent variables (Barbeaux et al. 2011). For the time component, five periods were defined (F1 = 1978-1984, F2= 1985-1989, D1=1990-1994, D2=1995-1998, D3=1999-2016). These periods correspond to the following fisheries: early foreign (F1), late foreign and joint venture (F2), early domestic (D1) late domestic (D2), and the recent period of mainly pollock as bycatch (D3). Weight-at-age values are important since they convert model estimated catch-at-age (in numbers) to estimated total annual harvests (by weight) and hence affect the measure of fishery impacts.

Maturity at Age

Prior to 2008, the maturity schedule developed for the Bering Sea by Wespestad and Terry (1984; Table 1A.14) was used. The CIE panel (at the 2007 Review) 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. Since Aleutian Islands pollock size at age is more similar to that observed in the Gulf of Alaska (GOA) than in the Bering Sea (Fig. 1A.2). and population density shares characteristics between these areas (steep slope, relatively narrow shelf areas) the maturity schedule from the GOA was adopted (Dorn et al. 2013). The difference is that maturation occurs at slightly older ages with 50% maturity at 4 - 5 years while the Bering Sea pollock reach 50% maturity at 3 - 4 years (Table 1A.15 and Fig. 1A.8).

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 both model runs. Since recruitment estimates arise from available age composition data, alternative values of h have little effect on historical estimates.

Parameters Estimated Inside the Assessment Model

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 smoothness penalty was imposed on abrupt changes 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). Selectivity was allowed to change in temporal blocks for 1978-1989, 1990-1998, and 1999-2007, and 2008-2016. The 1990 change was selected for the change from a foreign to a domestic fishery, in 1999 the directed fishery for pollock was closed, and in 2005 the data were from the AICASS experimental fishery. Another change was implemented for 2008 when the arrowtooth flounder fishery increased and affected pollock bycatch patterns. However, age data are unavailable for pollock from these fisheries.

Survey Selectivity and Catchability

In both models presented for the bottom trawl survey, survey selectivity-at-age follows the parameterization similar to the fishery selectivity-at-age presented above but is time invariant. The selectivity-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) similar to how the fishery selected is modeled. 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.

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). Based on the dynamics and the lack of informative data to "anchor" the biomass estimates, (i.e., there is relatively little "depletion" of recent cohorts to inform historical stock size) the assumption of catchability equals 1.0 was retained.

Natural Mortality

For Model 15.1 natural mortality was estimated using a prior with a mean of 0.2 with a *CV* of 0.2. Previous assessments (Barbeaux et al. 2007) suggest that Aleutian Islands pollock are 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 Model 15.1 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.14). Natural mortality can be reasonably estimated in this case using the AICASS age data because steepness (*h*), the recruitment variance (σ_R^2), and survey catchability (*q*) are assumed to be known. Model 15.2 allows for age-specific natural mortality rates. An age-specific natural mortality has been used by Ianelli et al. (2013) for the Bering Sea pollock with a higher natural mortality rate for age 1 and 2. In this model we allowed different natural mortality for ages 1, 2, and 15. These were fit as lognormal offsets from natural mortality for ages 3 through 14. In Model 15.2 we fixed the shape of the natural mortality vector iteratively by running the model with different values for 1, 2, and 15, and evaluating the likelihood of each iteration. The best fit model had the lowest –log likelihood.

Results

Model Evaluation

Model 15.1 is unchanged from the previous assessment and an alternative, Model 15.2 is the same, but has age-varying natural mortality.

Both models were configured with a survey catchability of 1.0 for ages 5-12, a stock recruitment steepness parameter (*h*) of 0.7 and recruitment variance (σ_R^2) of 0.6. Recruitment was modeled using data from 1978-2008. Natural mortality for Model 15.1 was estimated using a prior with a mean of 0.2 and *CV* of 0.2. For Model 15.2 natural mortality was age-specific and fit for ages 1, 2, and 15 as deviations from the mean value fit for ages 3-14. For both models the aging error component of the models was configured as described by Ianelli et al. (2003) in the 2003 Bering Sea pollock stock assessment (Table 1A.16).

Model fit criteria results are shown in Table 1A.17 and key results are presented in Table 1A.18 and Figure 1A.9, Figure 1A.10, Figure 1A.11, Figure 1A.12, Figure 1A.13, and Figure 1A.14. Model 15.1 and Model 15.2 can be compared directly using likelihood methods (Table 1A.17 and Table 1A.18). Model 15.2 provides only marginal improvements in fit to all data components. Similar to previous years, the model fit to the survey index was poor for all models (Fig. 1A.11), particularly for the 1991, 1994, 2012, and 2014 survey values. 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 data prior to 1991 which, for sampling reasons, were given less weight than the following years (Fig. 1A.11). The fishery age-composition data (Fig. 1A.12) were not fit as well as the survey catch-at-age data, but the fits were still relatively good. Observed and model derived mean ages matched well for all models, except for the 1995 and 2014 fishery data and 1994 survey data (Fig. 1A.13). Fishery age data was highly variable 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.14) for any of the models explored.

Like previous years, recruitment variability was high for both models presented (0.91 for Model 15.1 and 0.90 for Model 15.2. The mean natural mortality across all ages was similar for both models; 0.193 for Model 15.1 and 0.235 for Model 15.2. The iterative approach used for Model 15.2 resulted in a U-shaped natural mortality with higher values for the younger ages (1-3) and 15+ age group (Table 1A.14). Selectivity curves for both models (Fig. 1A.15) were similar for both the survey and the fishery. There is an apparent shift in fishery selectivity between Model 15.1 and Model 15.2 to higher selectivity for fish between ages 4 and 7. A shift in the survey selectivity is also apparent between Model 15.1 and Model 15.2 with an increase in selectivity for ages 3 to 8. The increase in age 1, 2, and 15+ natural mortality and decrease in natural mortality for ages 3-14 would explain the model fitting higher selectivity for the age-4 to age-7 pollock for both the fishery and survey.

Although Model 15.2 provides a marginally better fit to the data and gives qualitatively similar results to Model 15.1. However, Model 15.2 presents a substantial change in the approach to estimating natural mortality so until more research and feedback becomes available, Model 15.1 is recommended for consistency and used for evaluating stock status in the sections to follow.

Time Series Results

Abundance and exploitation trends

As indicated in the 2004 stock assessment (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.16, and Fig. 1A.17) in the 1980's for the Aleutian Islands area reached a peak of 900,367 t in 1984 primarily due to the 1978 year class which was well above average (Table 1A.20 and Table 1A.21, Fig. 1A.19, Fig. 1A.20, Fig. 1A.21). The model shows a large decline in the stock since its 1984 peak, hitting its lowest biomass levels in 2000 at 168,0.5 t. Total age 1+ biomass increased from 2000 to 2004 after cessation of directed fishing in the area. The increasing trend leveled off after 2005 due to poor recruitment after 2000. Average recruitments for 1990-1999 (67 million) and 2000-2009 (48 million) were well below the average for 1978-1989 (272 million). Biomass increased from 2007 onward due to low fishing pressure and the more prominent 2006 year class in the recent survey age data. Estimated pollock catch at age in numbers from 1978 to 2016 are given in Table 1A.22.

Female Spawning Stock Biomass (SSB) rose to 301,158 t in 1984 from 82,318 t in 1972 due to the large 1978 year class (Fig.1A.17 and Fig. 1A.18). SSB peaked in 1988 as the larger than average 1981, 1984 and 1987 year classes matured. Even though there was a higher than average 1989 year class the SSB began to drop in the early 1990s in the face of heavy fishing pressure and dipped to 60,956 t in 1999 ($B_{30\%}$ or 20% of the 1988 value) after a decade of poor recruitments and high fishing pressure. The highest full selection fishing mortality occurred in 1995 (F_{full} = 0.24 and Catch/biomass = 0.21) when the fishery harvested more than 82% of the 1994 survey biomass estimate (Fig. 1A.18 and Fig.1A.19). The authors' preferred Model 15.1 shows higher exploitation rates beginning in 1990 continuing through 1998 (F_{avg} = 0.17; Table 1A.23). The early 1990s fishery appeared to 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.19, and Fig. 1A.20). The status of AI pollock in 2015 and 2016 was assessed to be well above $B_{20\%}$ and had low exploitation rates (Fig. 1A.22).

There was a steep decline in pollock abundance in the Aleutian Islands as the 1978 year class diminished with age and relatively high fishery removals. Estimates of exploitation rates suggest they were below

F_{OFL}, during this period. However, given poor subsequent recruitment, catches near the 1990s level were unsustainable. To examine the role of the 1978 year class, estimated recruitment was projected forward from that year but in the absence of fishing mortality (to estimate the so-called "dynamic B_0". This showed that a significant decline occurred simply due to changes in recruitment and apparently environmental conditions. The "no fishing" projection suggests that the 2016 female spawning stock biomass would be at 83% of what it would have been without fishing (with a low point in 1999 at 30% of the unfished stock). Since the cessation of directed fishing in 1999 and very low removal levels since 2005, the stock has stabilized and increased (Fig.1A.23).

Recruitment

Recruitment variance (σ_R^2) was specified to be 0.6 yet the actual recruitment variability was 0.91 (the 2015 value was 0.95). The 1978 year-class is the largest (1.405 billion age-1 recruits; Table 1A.24 and Fig. 1A.21) and is highly influential with a large part of the fishery removals being composed of this year class (Fig. 1A.19 and Fig. 1A.20). The years 1976-1986 had several large year classes in comparison to more recent recruitment. The mean recruitment of age-1 pollock for 1978-1989 was 272 million, while the mean recruitment at age-1 between 1998 and 2008 was 47 million fish, with no year classes since the 1989 year class exceeding the overall 1978-2008 mean recruitment of 141 million age-1 recruits. Since the start of the domestic fishery in 1990, the two largest year classes have been the 1989 year class at 231 million age-1 recruits and the 2000 year class with 99 million age-1 recruits. The 2006 and 2011 year classes were similar to the 2000 year class at 96 and 98 million age-1 recruits. Although these year classes are higher than the surrounding year classes, they only stand out because everything else has been so low in recent years. 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 was highly influential. The mean recruitment for 1978 - 2008 without the 1978 year class was 70% (99 million) of the mean recruitment with the 1978 year class (141 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 preferred model's performance. For the past 20+ years the estimates from the data limited models are not outside of the 95% confidence intervals. However there is a trend in the more recent estimates which are consistently higher than the current model estimates (Fig. 1A.24). The large decline in the 2012 through 2016 biomass estimates would not have been anticipated in the preferred model. The performance of the Aleutian Islands pollock preferred model was reasonable given the unexpectedly low estimates of abundance in the bottom trawl survey estimates for 2012 through 2016. Mohn's rho for the authors' preferred Model 15.1 was estimated at 0.09, Woods Hole rho was 0.012, and retrospective RMSE was 0.047.

Projections and harvest alternatives

For management purposes we use the yield projections estimated from the 2016 authors' preferred Model 15.1. We used the estimated terminal (2008-2016) fishery selectivity at age (Table 1A.20 and Fig. 1A.15) 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 1978-2008 for the authors' preferred model (130.6 million age 1 fish) and F equal to $F_{40\%}$ and $F_{35\%}$ are denoted $B_{40\%}$ and $B_{35\%}$, respectively. The Tiers require reference point estimates for biomass level determinations. We present the following reference points for NRA pollock for Tier 3 of Amendment 56. For our analyses, we estimated the following values from the authors' preferred model:

Female spawning biomass	Model 15.1
$B_{100\%}$	203,100 t
$B_{40\%}$	81,240 t
$B_{35\%}$	71,085 t
B_{2017}	77,579 t

Specification of OFL and Maximum Permissible ABC

For the authors' preferred Model 15.1, the projected year 2017 female spawning biomass (SB_{17}) is estimated to be 74,690 t, below the $B_{40\%}$ value of 81,240 t placing NRA pollock in Tier 3b. The maximum permissible ABC and OFL values under Tier 3b for 2017 are:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2017 Projected yield (t)
$max\ F_{ABC}$	Adjusted $F_{40\%}$	0.30	36,061 t
F_{OFL}	Adjusted $F_{35\%}$	0.38	43,650 t

If the estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ were deemed not reliable, then under Tier 5 with estimated natural mortality of 0.194 and the 2016 AIBT survey biomass, the 2017 ABC would be 12,081 t (83,070 t x 0.75 x 0.194 = 12,081 t) and under Tier 5 with an assumed natural mortality of 0.3 the 2017 ABC would be 18,691 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 2016) AI bottom trawl surveys are highly uncertain with an average *CV* of 0.36. The 2002, 2004, 2006, 2010, 2012, 2014, and 2016 estimates of *CV* are 0.38, 0.78, 0.48, 0.33, 0.55, 0.24, and 0.33 respectively. This results in considerable uncertainty in the model results.

4) The authors' preferred model suggests that currently a large proportion of the stock in the Aleutians is composed of much older fish (11% age 10+ by number) which make up a large proportion of the catch (37% 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, and in turn may be causing an overestimation of the expected productivity of this system, particularly if the 1978 year class originated elsewhere.

7) The low 2012 through 2016 bottom trawl survey estimates can't be explained by estimated natural mortality or catch. The availability of pollock to the survey may not be static and therefore the index could be unreliable. Migration of pollock outside the survey area could also explain this decline, but less likely.

ABC Recommendations

The pollock spawning stock biomass and total age 1+ biomass in the NRA appears to have been increasing slightly (+1.2% and +1.9% annually) since 1999. The projected total age 1+ biomass for 2017 is 250,221 t. Assuming the five year average F of 0.009, the estimated female spawning biomass projected for 2017 is 77,579 t. Under this scenario the maximum permissible Tier 3b 2017 ABC (F_{maxABC} = 0.304) is 36,061 t and OFL (F_{OFL} = 0.378) is 43,650 t and the 2018 ABC (F_{maxABC} = 0.319) is 40,788 t and OFL (F_{OFL} = 0.397) is 49,291 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 2016 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2017 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2016 of 1500 t. For 2017 the five-year average F (2011-2015) of 0.0087, used in place of maximum permissible ABC resulting in a catch estimate of 1,157 t. 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 2017 and 2018, 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 2017 recommended in the assessment to the *max* F_{ABC} for 2017. (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 2011-2015 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 2016 or 2) above 1/2 of its MSY level in 2016 and above its MSY level in 2026 under this scenario, then the stock is not overfished.)

Scenario 7: In 2017 and 2018, *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 2029 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 2017 through 2028 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 2016:

a. If spawning biomass for 2016 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2016 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2016 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 2026 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 2019 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.

b. If the mean spawning biomass for 2019 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c. If the mean spawning biomass for 2019 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2029. If the mean spawning biomass for 2028 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 authors' preferred model are shown in Table 1A.25. In the authors' preferred 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 2022, be below $B_{40\%}$ through 2024, then be above $B_{40\%}$ for the remainder of the projection (Fig.1A.25 and Fig.1A.26). Female spawning biomass is projected be above ½ $B_{35\%}$, but below $B_{35\%}$ when fishing at F_{OFL} (Fig.1A.27) through 2022 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 1978-2008 (126 million age 1 fish) and $F = F_{35\%}$, denoted $B_{35\%}$ is estimated to be 71,085 t. This value ($B_{35\%}$), is used in the status determination criteria. Female spawning biomass for 2016 (74,999 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 2029 is projected to be above $B_{35\%}$ in Scenario 7, and is expected to be above $B_{35\%}$ in 2026 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.25, Fig.1A.26, and Table 1A.25), show that the stock could support a constant catch of 19,000 t. The stock is currently at $B_{36.9\%}$ and the long-term expected yield at $B_{40\%}$ is 40,770 t and at $B_{35\%}$.is 43,027 t, well above the 19,000 t cap.

The SSC asked that the probability of the spawning stock biomass being below $B_{20\%}$ in 2017 be computed for stocks in Tier 3b. We computed the number of standard deviations the 2017 spawning biomass (B_{2017}) was from $B_{20\%}$, assuming B_{2017} was normally distributed. B_{2017} is estimated in the stock assessment model (non-projected) to be at 74,056 t with a standard deviation of 8,752 t and $B_{20\%}$ is estimated at 40,620 t, therefore B_{2017} is 3.8 standard deviations from $B_{20\%}$. Under the assumption of a normal error distribution there is a 0.00007 % 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 from 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. 28, 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.28, 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.29, 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.29, 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.30) is a relatively high trophic level (TL) predator which interacts mostly with adult pollock, but also with many other species (in green; Fig. 1A.32). 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. 31). 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.32). 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.33 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.33. 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.33, 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.33 (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.33, 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.29, 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.26.

Prey availability/abundance trends

Adult walleye pollock in the Aleutian Islands consume a variety of prey, primarily large zooplankton, copepods, and myctophids. Figure 1A.32 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

Water temperature in the Aleutian Islands is variable among survey years particularly for bottom depth at the preferred depth range of pollock (Fig. 1A.34, Fig. 1A.35, and Fig. 1A 36). The 2012 Aleutian Islands summer bottom temperatures indicated that water temperatures were substantially cooler than the 2004-2010 surveys (Lowe et. al. 2012). Bottom temperatures could possibly affect fish distribution. The 2014 and 2016 AI bottom trawl surveys show a swing of bottom and surface temperature values to above the means for the entire time series (1991-2016) and similar to the 2004-2010 bottom temperatures.

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 through 2014, a limited fishery of 62 t in 2015, and no directed fishery so far in 2016.

Concentration of AI pollock catches in time and space

Since no EFP is proposed for 2017 there is expected to only be a very limited fishery in 2017, 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 2017.

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), 2013 (0 t), 2014 (0 t), 2015 (62 t), and 2016 (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 2017 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, 1977-2016. 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		53,647	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		23,798		21,032	23,798
1999		1,010		492	1,010
2000		1,244		573	1,244
2001		1,010		477	1,010
2002		1,177		519	1,177
2003		1,649		1,562	1,649
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		996	1,278
2009		1,662		1,409	1,662
2010		1,285		1,261	1,285
2011		1,208		1,198	1,208
2012		975		927	975
2013		2,964		2,953	2,964
2014		2,375		2,369	2,375
2015		916		914	916
2016*		1,244		980	1,244

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

** as of October 31, 2016

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	1997	8,110	16,799	1,031	25,940
1978	5,267	712	305	6,283	1998	1,374	2,603	19,821	23,798
1979	1,488	1,756	6,203	9,446	1999	484	420	105	1,010
1980	28,284	7,097	22,775	58,157	2000	615	461	169	1,244
1981	43,461	10,074	1,982	55,517	2001	333	387	105	1,010
1982	54,173	1,205	2,376	57,753	2002	862	182	133	1,177
1983	56,577	1,250	1,194	59,021	2003	565	758	326	1,649
1984	64,172	5,760	7,663	77,595	2004	397	513	248	1,158
1985	19,885	38,163	100	58,147	2005	689	415	517	1,621
1986	38,361	7,078	0	45,439	2006	1,036	488	220	1,745
1987	28,086	386	0	28,471	2007	1,919	476	124	2,519
1988	40,685	517	0	41,203	2008	872	293	112	1,278
1989	10,569	0	0	10,569	2009	1,020	400	243	1,662
1990	69,170	9,425	430	79,025	2010	754	382	150	1,285
1991	98,032	561	11	98,604	2011	695	447	66	1,208
1992	52,140	206	6	52,352	2012	503	427	45	975
1993	54,512	2,536	83	57,132	2013	2,342	309	313	2,964
1994	58,091	554	15	58,659	2014	2,088	176	111	2,375
1995	28,109	36,714	102	64,925	2015	565	264	87	916
1996	9,226	19,574	261	29,062	2016	887	195	162	1,244

*as of October 22, 2016

Table 1A.3. Time series of ABC, TAC, OFL, and total catch for Aleutian Islands Region walleye pollock fisheries 1991-2016. 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	23,798	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	825	41%
2002	23,800	1,000	31,700	1,177	116%
2003	39,400	1,000	52,600	1,649	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	1,662	9%
2010	33,100	19,000	40,000	1,285	7%
2011	36,700	19,000	44,500	1,208	6%
2012	32,500	19,000	39,600	975	5%
2013	37,300	19,000	45,600	2,964	16%
2014	35,048	19,000	42,811	2,375	13%
2015	29,659	19,000	36,005	916	5%
2016*	32,227	19,000	39,075	1,244	7%

* As of October 31, 2016

Table 1A.4. Estimated walleye pollock catch discarded and retained for the Aleutian Islands Region based on NMFS blend data, 1990-2016.

Year	Catch Retained	Discard	Total	Discard Percentage
1990	69,682	9,343	79,025	12%
1991	93,373	5,231	98,604	5%
1992	49,369	2,983	52,352	6%
1993	55,399	1,733	57,132	3%
1994	57,286	1,373	58,659	2%
1995	63,545	1,380	64,925	2%
1996	28,067	994	29,062	3%
1997	25,323	618	25,940	2%
1998	23,636	162	23,798	1%
1999	529	480	1,010	48%
2000	455	790	1,244	63%
2001	445	380	825	46%
2002	398	779	1,177	66%
2003	1,181	468	1,649	28%
2004	871	287	1,158	25%
2005	1,297	324	1,621	20%
2006	1,434	311	1,745	18%
2007	2,094	425	2,519	17%
2008	1,197	81	1,278	6%
2009	1,268	395	1,662	24%
2010	1,143	142	1,285	11%
2011	1,133	75	1,208	6%
2012	880	95	975	10%
2013	2,856	107	2,964	4%
2014	2,237	138	2,375	6%
2015	896	20	916	2%
2016	1,186	59	1,244	5%

* As of October 31, 2016

Table 1A.5. Catch of pollock in the Aleutian Islands for other target fisheries 2012-2016. 2016 data are through October 22, 2016.

Target Fishery	**2012**	**2013**	**2014**	**2015**	**2016**	**Total**
Arrowtooth Flounder	102.74	710.05	693.39	1.30	144.44	1,651.92
Atka Mackerel	370.21	492.70	633.18	145.83	424.74	2,066.67
Greenland Turbot - BSAI		0.03				0.03
Halibut		0.02	0.16	0.17	0.38	0.73
Kamchatka Flounder - BSAI	120.76	440.02	132.99	168.12	100.39	962.28
Pacific Cod	85.93	23.41	11.24	7.49	17.16	145.24
Rockfish	295.44	1,152.32	903.64	537.87	486.59	3,375.86
Sablefish	0.02	0.12	0.01			0.16
Total	975.10	2,818.67	2,374.63	860.79	1,173.70	8,202.89

Table 1A.6. Sampling levels in Aleutian Islands Region sub-regions based on foreign, J.V., and domestic walleye pollock observer data 1978 - 2016.

	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	647	29	10	0	0	0
2010	529	17	7	0	0	0
2011	697	63	6	0	0	0
2012	154	13	5	0	0	0
2013	930	42	9	0	0	0
2014	527	26	6	0	0	0
2015	811	31	5	0	0	0
2016	183	5	3	0	0	0
Total	499,158	4,900		404,559	3,435	

Table 1A.7. 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
1987	131	142	273	136	147	283
1988	34	33	67	66	65	131
1989	0	0	0	112	147	259
1990	46	49	95	340	410	750
1991	80	77	157	20	30	50
1992	110	121	231	34	45	79
1993	81	82	163	48	56	104
1994	157	151	308	102	106	208
1995	74	106	180	147	158	305
1996	95	84	179	93	83	176
1997	15	15	30	15	15	30
1998	144	170	314	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**/1	**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	20	10	30	50	40	90
2010	0	0	0	29	38	67
2011	0	0	0	37	37	74
2012	0	0	0	8	9	17
2013	0	0	0	57	87	144
2014	0	0	0	18	41	59
2015	0	0	0	57	84	141
2016	0	0	0	7	13	20

Table 1A.8. Estimates of catch-age composition from the Aleutian Islands commercial fishery 1978-1987, 1994-1996, 1998, and the Aleutian Islands cooperative acoustic surveys for 2006-2008. Shaded cells are the highest proportion for the year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.014	0.000	0.020	0.092	0.052	0.326	0.082	0.099	0.115	0.098	0.072	0.018	0.007	0.001	0.004
1979	0.010	0.004	0.118	0.138	0.133	0.178	0.148	0.078	0.080	0.045	0.032	0.028	0.002	0.001	0.006
1980	0.000	0.127	0.060	0.049	0.090	0.194	0.146	0.144	0.079	0.070	0.024	0.007	0.004	0.004	0.001
1981	0.031	0.000	0.113	0.091	0.064	0.093	0.156	0.152	0.113	0.093	0.036	0.027	0.015	0.013	0.003
1982	0.001	0.000	0.001	0.685	0.095	0.019	0.028	0.051	0.054	0.034	0.014	0.007	0.005	0.003	0.002
1983	0.060	0.000	0.000	0.000	0.534	0.112	0.069	0.053	0.074	0.059	0.034	0.000	0.000	0.005	0.000
1984	0.071	0.002	0.087	0.000	0.038	0.506	0.120	0.100	0.058	0.016	0.001	0.000	0.001	0.000	0.000
1985	0.002	0.005	0.016	0.225	0.051	0.128	0.426	0.082	0.038	0.021	0.003	0.003	0.000	0.001	0.000
1986	0.002	0.000	0.087	0.006	0.131	0.018	0.095	0.333	0.134	0.056	0.094	0.018	0.026	0.000	0.000
1987	0.012	0.000	0.000	0.245	0.068	0.068	0.010	0.033	0.423	0.040	0.042	0.002	0.022	0.015	0.018
1994	0.006	0.000	0.000	0.018	0.282	0.057	0.102	0.107	0.067	0.054	0.032	0.080	0.034	0.020	0.141
1995	0.006	0.000	0.018	0.049	0.000	0.267	0.014	0.110	0.111	0.022	0.065	0.045	0.086	0.020	0.187
1996	0.030	0.000	0.000	0.013	0.055	0.072	0.273	0.126	0.099	0.085	0.037	0.033	0.013	0.057	0.106
1998	0.004	0.000	0.015	0.003	0.265	0.085	0.055	0.038	0.074	0.064	0.052	0.144	0.062	0.070	0.070
2006	0.023	0.000	0.010	0.000	0.021	0.349	0.146	0.034	0.010	0.044	0.047	0.042	0.031	0.091	0.151
2007	0.001	0.000	0.003	0.010	0.007	0.047	0.274	0.248	0.074	0.040	0.039	0.064	0.023	0.040	0.130
2008	0.001	0.000	0.001	0.006	0.010	0.018	0.034	0.201	0.209	0.109	0.021	0.072	0.073	0.069	0.175

Table 1A.9. NRA pollock fishery average weight-at-age in kilograms used in authors' preferred model.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.160	0.122	0.358	0.568	0.675	0.753	0.856	0.986	1.106	1.187	1.249	1.341	1.467	1.497	1.243
1979	0.160	0.146	0.383	0.555	0.620	0.663	0.731	0.825	0.912	0.963	0.991	1.045	1.145	1.196	1.025
1980	0.160	0.197	0.510	0.762	0.878	0.937	0.999	1.088	1.183	1.244	1.262	1.285	1.348	1.374	1.196
1981	0.160	0.126	0.335	0.546	0.681	0.744	0.773	0.812	0.873	0.924	0.929	0.905	0.894	0.879	0.787
1982	0.160	0.125	0.316	0.535	0.717	0.817	0.845	0.871	0.934	0.997	0.989	0.917	0.867	0.866	0.864
1983	0.160	0.149	0.318	0.508	0.698	0.829	0.879	0.911	0.981	1.048	1.016	0.899	0.851	0.933	1.133
1984	0.160	0.215	0.380	0.534	0.698	0.845	0.932	0.993	1.080	1.146	1.092	0.961	0.939	1.157	1.752
1985	0.160	0.319	0.512	0.616	0.735	0.877	0.996	1.098	1.209	1.278	1.211	1.075	1.082	1.403	2.453
1986	0.160	0.248	0.493	0.579	0.636	0.720	0.807	0.895	0.994	1.066	1.033	0.927	0.907	1.158	1.734
1987	0.160	0.096	0.430	0.697	0.817	0.870	0.886	0.912	0.991	1.111	1.194	1.180	1.126	1.105	1.060
1988	0.160	0.253	0.395	0.564	0.704	0.791	0.855	0.926	1.000	1.049	1.065	1.060	1.045	1.011	0.950
1989	0.160	0.253	0.395	0.564	0.704	0.791	0.855	0.926	1.000	1.049	1.065	1.060	1.045	1.011	0.950
1990	0.160	0.253	0.395	0.564	0.704	0.791	0.855	0.926	1.000	1.049	1.065	1.060	1.045	1.011	0.950
1991	0.416	0.494	0.588	0.706	0.855	1.029	1.202	1.340	1.423	1.457	1.465	1.463	1.453	1.431	1.396
1992	0.416	0.494	0.588	0.706	0.855	1.029	1.202	1.340	1.423	1.457	1.465	1.463	1.453	1.431	1.396
1993	0.416	0.494	0.588	0.706	0.855	1.029	1.202	1.340	1.423	1.457	1.465	1.463	1.453	1.431	1.396
1994	0.416	0.508	0.583	0.683	0.813	0.962	1.107	1.221	1.290	1.317	1.319	1.309	1.295	1.275	1.247
1995	0.416	0.602	0.691	0.813	0.976	1.165	1.351	1.495	1.578	1.607	1.606	1.594	1.579	1.557	1.525
1996	0.179	0.177	0.248	0.405	0.649	0.954	1.219	1.372	1.441	1.471	1.467	1.420	1.346	1.293	1.299
1997	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
1998	0.179	0.277	0.383	0.552	0.774	0.995	1.157	1.253	1.312	1.362	1.400	1.413	1.400	1.385	1.397
1999	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2000	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2001	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2002	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2003	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2004	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2005	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2006	0.179	0.319	0.459	0.705	1.048	1.392	1.621	1.722	1.772	1.844	1.951	2.052	2.085	2.021	1.893
2007	0.179	0.251	0.375	0.610	0.963	1.327	1.561	1.643	1.665	1.710	1.801	1.898	1.939	1.892	1.784
2008	0.179	0.223	0.345	0.575	0.930	1.316	1.589	1.706	1.744	1.789	1.869	1.958	2.003	1.974	1.890
2009	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2010	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2011	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2012	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2013	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2014	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2015	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740
2016	0.179	0.256	0.371	0.558	0.859	1.238	1.540	1.652	1.650	1.670	1.748	1.827	1.840	1.791	1.740

Table 1A.10. Pollock biomass estimates (t) from the Aleutian Islands Groundfish Survey, 1980-2014.

	Eastern Area 541	Central Area 542	Western Area 543	Unalaska-Umnak Area (~165W-170W)	NRA 170W - 170E Biomass	CV
1980	80,242	180,227	6,884	6,770	267,353	0.34
1983	164,286	183,542	118,234	104,515	466,063	0.17
1986	211,589	175,886	55,732	40,059	443,208	0.23
1991	60,932	50,259	26,701	51,644	137,891	0.19
1994	37,355	27,174	14,213	39,696	78,741	0.19
1997	38,541	36,764	18,115	65,400	93,420	0.22
2000	56,084	42,969	6,870	22,462	105,922	0.28
2002	54,634	108,179	13,140	181,334	175,953	0.38
2004	112,040	11,763	6,605	235,658	130,408	0.78
2006	69,996	18,002	6,514	18,006	94,512	0.48
2010	104,320	28,675	7,938	110,986	140,932	0.33
2012	31,488	7,433	5,360	13,237	44,281	0.55
2014	63,723	6,807	14,787	69,168	85,316	0.24
2016	59,119	9,404	14,547	10,047	83,070	0.33

Table 1A.11. Aleutian Islands bottom trawl survey pollock proportion-at-age used in authors' preferred model (top panel). Shaded cells are the highest proportion for the year. Aleutian Islands bottom trawl survey pollock proportion-at-age sample sizes (bottom panel).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1983	0.001	0.107	0.046	0.019	0.448	0.173	0.055	0.059	0.049	0.024	0.011	0.004	0.001	0.000	0.000
1986	0.002	0.058	0.367	0.031	0.140	0.054	0.071	0.152	0.086	0.023	0.006	0.007	0.002	0.000	0.000
1991	0.061	0.049	0.128	0.298	0.125	0.029	0.036	0.021	0.063	0.027	0.043	0.014	0.045	0.031	0.028
1994	0.144	0.046	0.096	0.123	0.172	0.092	0.068	0.054	0.026	0.058	0.051	0.032	0.004	0.012	0.020
1997	0.042	0.067	0.070	0.106	0.110	0.082	0.060	0.122	0.083	0.040	0.067	0.044	0.035	0.025	0.046
2000	0.105	0.024	0.045	0.084	0.119	0.106	0.108	0.071	0.037	0.045	0.090	0.046	0.048	0.046	0.027
2002	0.043	0.046	0.095	0.093	0.068	0.073	0.106	0.076	0.075	0.056	0.068	0.046	0.058	0.026	0.071
2004	0.064	0.009	0.091	0.176	0.117	0.094	0.031	0.034	0.043	0.033	0.069	0.081	0.052	0.047	0.059
2006	0.039	0.006	0.083	0.093	0.093	0.171	0.117	0.080	0.023	0.034	0.042	0.041	0.046	0.069	0.064
2010	0.076	0.007	0.071	0.177	0.143	0.046	0.019	0.051	0.053	0.095	0.109	0.051	0.040	0.005	0.056
2012	0.129	0.018	0.053	0.018	0.075	0.236	0.106	0.016	0.015	0.038	0.053	0.108	0.080	0.042	0.016
2014	0.094	0.066	0.167	0.028	0.089	0.019	0.168	0.168	0.063	0.019	0.002	0.01	0.021	0.036	0.049

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1983	11	663	173	668	2892	1107	345	228	171	78	36	16	4	1	0
1986	31	130	729	88	344	152	185	376	194	50	14	16	6	0	0
1991	0	25	60	198	93	26	38	23	60	28	41	15	52	34	14
1994	162	112	125	91	127	62	50	41	25	61	51	33	17	10	7
1997	97	106	114	118	105	75	58	112	69	39	49	38	33	23	22
2000	107	59	60	84	88	78	77	58	29	37	70	39	33	29	9
2002	119	116	183	122	75	104	103	77	81	74	61	54	75	34	24
2004	43	7	26	134	65	51	29	42	32	21	29	39	19	22	10
2006	41	4	26	33	48	121	72	45	17	29	27	22	23	34	20
2010	39	5	37	80	66	20	8	20	27	39	38	18	13	2	8
2012	82	8	13	16	42	138	58	14	11	31	29	53	34	19	5
2014	85	100	94	14	42	33	93	115	52	16	2	8	14	21	28

Table 1A.12. Aleutian Islands bottom trawl survey pollock average weight-at-age in kilograms used in authors' preferred model.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.068	0.173	0.374	0.608	0.763	0.855	0.936	1.005	1.069	1.130	1.172	1.235	1.361	1.479	1.503
1979	0.068	0.173	0.374	0.608	0.763	0.855	0.936	1.005	1.069	1.130	1.172	1.235	1.361	1.479	1.503
1980	0.068	0.173	0.374	0.608	0.763	0.855	0.936	1.005	1.069	1.130	1.172	1.235	1.361	1.479	1.503
1981	0.068	0.173	0.374	0.608	0.763	0.855	0.936	1.005	1.069	1.130	1.172	1.235	1.361	1.479	1.503
1982	0.068	0.173	0.374	0.608	0.763	0.855	0.936	1.005	1.069	1.130	1.172	1.235	1.361	1.479	1.503
1983	0.063	0.163	0.458	0.642	0.715	0.824	0.919	1.031	1.023	1.194	1.199	1.081	1.443	1.593	1.430
1984	0.068	0.173	0.374	0.608	0.763	0.855	0.936	1.005	1.069	1.130	1.172	1.235	1.361	1.479	1.503
1985	0.068	0.173	0.374	0.608	0.763	0.855	0.936	1.005	1.069	1.130	1.172	1.235	1.361	1.479	1.503
1986	0.056	0.196	0.457	0.588	0.709	0.798	0.875	0.970	1.036	1.134	1.026	1.017	1.277	1.189	1.279
1987	0.065	0.181	0.391	0.602	0.736	0.818	0.891	0.970	1.038	1.065	1.067	1.095	1.163	1.232	1.274
1988	0.065	0.181	0.391	0.602	0.736	0.818	0.891	0.970	1.038	1.065	1.067	1.095	1.163	1.232	1.274
1989	0.065	0.181	0.391	0.602	0.736	0.818	0.891	0.970	1.038	1.065	1.067	1.095	1.163	1.232	1.274
1990	0.065	0.181	0.391	0.602	0.736	0.818	0.891	0.970	1.038	1.065	1.067	1.095	1.163	1.232	1.274
1991	0.109	0.207	0.531	0.749	0.828	0.944	1.051	1.208	1.196	1.186	1.322	1.047	1.289	1.118	1.078
1992	0.078	0.206	0.450	0.737	0.941	1.066	1.189	1.320	1.401	1.418	1.433	1.478	1.499	1.438	1.315
1993	0.078	0.206	0.450	0.737	0.941	1.066	1.189	1.320	1.401	1.418	1.433	1.478	1.499	1.438	1.315
1994	0.049	0.205	0.462	0.821	0.960	1.124	1.340	1.416	1.753	1.697	1.544	1.613	2.718	1.417	1.682
1995	0.078	0.206	0.450	0.737	0.941	1.066	1.189	1.320	1.401	1.418	1.433	1.478	1.499	1.438	1.315
1996	0.044	0.161	0.418	0.701	0.902	1.045	1.174	1.295	1.373	1.414	1.480	1.553	1.560	1.539	1.559
1997	0.051	0.211	0.381	0.700	0.894	0.999	1.150	1.327	1.300	1.355	1.455	1.504	1.497	1.499	1.480
1998	0.044	0.161	0.418	0.701	0.902	1.045	1.174	1.295	1.373	1.414	1.480	1.553	1.560	1.539	1.559
1999	0.044	0.161	0.418	0.701	0.902	1.045	1.174	1.295	1.373	1.414	1.480	1.553	1.560	1.539	1.559
2000	0.030	0.166	0.447	0.724	0.927	0.967	1.210	1.351	1.410	1.422	1.535	1.623	1.655	1.523	1.664
2001	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2002	0.037	0.226	0.464	0.700	1.029	1.165	1.341	1.273	1.725	1.945	1.698	1.874	1.755	1.830	1.775
2003	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2004	0.031	0.222	0.486	0.787	0.939	0.993	1.346	1.292	1.735	1.555	1.703	1.595	1.594	1.574	1.506
2005	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2006	0.047	0.181	0.468	0.621	0.919	1.217	1.247	1.299	1.517	1.830	1.733	1.600	1.665	1.661	1.574
2007	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2008	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2009	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2010	0.047	0.213	0.454	0.722	0.948	1.029	1.529	1.409	1.545	1.678	1.863	1.913	1.737	1.748	1.725
2011	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2012	0.035	0.167	0.458	0.784	1.039	1.157	1.367	1.672	1.724	1.562	1.735	1.943	1.707	1.666	1.666
2013	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2014	0.040	0.206	0.448	0.602	0.876	1.091	1.352	1.461	1.543	1.799	1.953	1.559	1.437	1.717	1.685
2015	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664
2016	0.041	0.186	0.474	0.711	0.925	1.158	1.309	1.431	1.607	1.740	1.761	1.729	1.687	1.661	1.664

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, 2006, 2010, 2012, and 2014 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	2.981
2012	66.70	0.260	-0.144	0.0000069	3.005
2014	NA	NA	NA	0.0000072	2.996

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. (2009) 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. Estimated instantaneous natural mortality rates (*M*) by age from Wespestad and Terry (1984) for the Bering Sea and natural mortality rates in Model 15.1 (M1) and Model 15.2 (M2).

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
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
M1	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
M2	0.90	0.71	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.38

Table 1A.16. Aging error matrix used in the authors' preferred model developed from aging validation tests for 2006-2008.

Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1	0.9744	0.0256	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0256	0.9488	0.0256	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0389	0.9222	0.0389	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0537	0.8927	0.0537	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0692	0.8615	0.0692	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0851	0.8299	0.0851	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0001	0.1007	0.7985	0.1007	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.1159	0.7678	0.1159	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.1305	0.7383	0.1305	0.0004	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.1442	0.7100	0.1442	0.0007	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013	0.1571	0.6832	0.1571	0.0013	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.1689	0.6577	0.1689	0.0022	0.0000
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0034	0.1798	0.6337	0.1798	0.0034
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.1896	0.6110	0.1945
15+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0068	0.1985	0.7948

Table 1A.17. Evaluation of 2016 Aleutian Islands pollock models.

		Model 15.1	Model 15.2
Number of Parameters		139	139
Survey Catchability		1.00	1.00
Fishery Average Effective *N*		46.02	46.64
Survey Average Effective *N*		77.14	94.95
RMSE Survey		0.53	0.55
-Log Likelihoods			
	Survey Index	32.10	32.88
	Fishery Age Comp	271.97	265.95
	Survey Age Comp	74.13	60.31
	Catch	0.81	0.72
Sub Total		379.01	359.86
-log Penalties			
Recruitment		55.00	52.86
Selectivity Constraints			
	Survey	1.71	1.75
	Fishery	15.79	17.16
	Prior	0.01	2.46
	Fpen	0.00	0.00
	Residual	0.01	0.00
Total		451.53	434.09

Table 1A.18. Key results for the evaluations of Aleutian Islands pollock models.

	Model 15.1	Model 15.2
Model Conditions		
Survey Catchability	1.00	1.00
Mean Natural Mortality	0.19	0.24
Fishing Mortalities		
Max $F_{1978-2016}$	0.236	0.242
F_{2015}	0.005	0.005
Stock Abundance		
Initial Biomass (1978; thousands of tons)	493.39	393.55
CV	8%	7%
2016 Total Biomass 1+ (thousands of tons)	223.98	205.53
CV	12%	12%
2016 Female SSB (thousands of tons)	72.52	70.19
CV	11%	11%
1978 Year Class (billions at age 1)	1.40	3.26
	11%	16%
Recruitment Variability (1978-2010)	0.98	0.97
Recruitment variance (σ_R^2)	0.60	0.60
Steepness (*h*)	0.70	0.70

Table 1A.19. The 2015 and 2016 authors' preferred model estimates of pollock biomass with 2016 Model 15.1 approximate lower (LCI) and upper (UCI) 95% confidence bounds for age 1+ biomass and female spawning stock biomass (SSB) estimates.

	Total Biomass (Age 1+)				Female SSB			
Year	2015 Model	2016 Model	LCI	UCI	2015 Model	2016 Model	LCI	UCI
1978	482,340	493,391	420,903	578,364	152,394	128,791	180,323	180,323
1979	547,510	562,407	484,692	652,583	166,195	141,509	195,186	195,186
1980	677,620	705,603	612,714	812,574	170,912	145,708	200,477	200,477
1981	816,050	847,374	731,242	981,948	157,657	132,551	187,518	187,518
1982	881,750	896,532	774,778	1,037,420	205,435	175,953	239,858	239,858
1983	866,360	887,257	765,946	1,027,780	262,038	225,301	304,766	304,766
1984	865,960	900,367	779,021	1,040,620	301,158	258,894	350,322	350,322
1985	847,990	881,654	767,394	1,012,930	289,754	249,461	336,555	336,555
1986	846,250	876,688	768,365	1,000,280	279,903	241,619	324,253	324,253
1987	851,080	874,987	774,328	988,731	296,881	259,761	339,304	339,304
1988	826,220	846,861	757,368	946,927	301,533	267,429	339,987	339,987
1989	771,530	792,353	714,422	878,784	293,307	262,419	327,831	327,831
1990	741,140	757,957	691,313	831,025	274,952	248,983	303,629	303,629
1991	608,380	621,416	564,598	683,951	220,683	199,617	243,973	243,973
1992	508,140	519,638	468,721	576,086	179,869	162,063	199,631	199,631
1993	447,970	455,936	410,452	506,461	159,241	143,518	176,686	176,686
1994	378,280	384,423	343,403	430,342	135,665	121,529	151,445	151,445
1995	307,010	312,838	274,654	356,331	110,256	97,137	125,146	125,146
1996	247,100	250,997	214,837	293,243	85,390	73,458	99,261	99,261
1997	216,620	218,594	183,831	259,929	74,626	63,038	88,345	88,345
1998	196,040	197,260	163,441	238,077	67,590	56,032	81,533	81,533
1999	169,190	169,374	137,156	209,160	60,956	49,435	75,162	75,162
2000	168,540	168,035	137,015	206,078	62,049	50,702	75,935	75,935
2001	173,270	172,488	141,381	210,440	61,985	50,956	75,402	75,402
2002	185,530	183,829	151,246	223,431	60,864	50,311	73,629	73,629
2003	197,820	193,882	159,887	235,105	61,347	50,913	73,921	73,921
2004	201,210	195,416	161,492	236,467	65,827	54,738	79,162	79,162
2005	198,190	192,129	159,157	231,932	70,777	58,882	85,077	85,077
2006	190,960	184,952	153,474	222,886	72,220	60,054	86,850	86,850
2007	184,670	178,706	148,570	214,955	69,581	57,851	83,689	83,689
2008	185,590	180,669	150,188	217,336	65,920	54,745	79,377	79,377
2009	192,920	189,224	157,055	227,982	63,581	52,795	76,570	76,570
2010	195,210	192,027	158,930	232,016	64,300	53,411	77,408	77,408
2011	193,580	190,857	157,471	231,322	67,632	56,063	81,587	81,587
2012	193,150	191,162	156,982	232,785	69,745	57,528	84,557	84,557
2013	195,600	193,328	157,767	236,905	68,919	56,588	83,936	83,936
2014	203,720	201,052	161,904	249,666	66,877	54,526	82,025	82,025
2015	215,680	211,465	168,107	266,005	68,773	55,599	85,067	85,067
2016	228,000	223,984	176,063	284,947	72,520	58,017	90,648	90,648
2017					77,674	61,212	98,562	98,562

Table 1A.20 Model 15.1 estimate of 2016 fishery and survey selectivity-at-age used in projections.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Survey	0.179	0.231	0.328	0.463	0.622	0.785	0.912	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Fishery	0.013	0.029	0.064	0.139	0.279	0.497	0.761	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 1A.21. Authors' preferred Model 15.1 estimates of pollock numbers at age in billions (10^9).

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% of 15+
1978	0.13	0.12	0.09	0.12	0.06	0.09	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.02	0.74	2.9%
1979	1.40	0.11	0.10	0.08	0.09	0.05	0.08	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.02	2.01	1.0%
1980	0.05	1.16	0.09	0.08	0.06	0.08	0.04	0.06	0.01	0.02	0.01	0.01	0.01	0.00	0.02	1.69	1.0%
1981	0.06	0.04	0.94	0.07	0.06	0.05	0.05	0.03	0.04	0.01	0.01	0.01	0.01	0.00	0.01	1.39	0.9%
1982	0.34	0.05	0.03	0.77	0.06	0.05	0.03	0.04	0.02	0.03	0.01	0.01	0.01	0.00	0.01	1.44	0.8%
1983	0.13	0.28	0.04	0.03	0.60	0.04	0.04	0.02	0.03	0.01	0.02	0.00	0.00	0.00	0.01	1.25	0.8%
1984	0.52	0.11	0.23	0.03	0.02	0.46	0.03	0.03	0.02	0.02	0.01	0.01	0.00	0.00	0.01	1.50	0.6%
1985	0.10	0.43	0.09	0.19	0.03	0.02	0.35	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01	1.29	0.7%
1986	0.10	0.09	0.35	0.07	0.15	0.02	0.01	0.26	0.02	0.01	0.01	0.01	0.00	0.01	0.01	1.12	0.7%
1987	0.23	0.08	0.07	0.29	0.06	0.12	0.02	0.01	0.20	0.01	0.01	0.01	0.01	0.00	0.01	1.13	1.0%
1988	0.13	0.19	0.07	0.06	0.23	0.05	0.09	0.01	0.01	0.16	0.01	0.01	0.01	0.01	0.01	1.03	1.1%
1989	0.06	0.11	0.15	0.06	0.05	0.18	0.04	0.07	0.01	0.01	0.12	0.01	0.01	0.00	0.01	0.87	1.5%
1990	0.23	0.05	0.09	0.13	0.05	0.04	0.15	0.03	0.06	0.01	0.00	0.09	0.01	0.00	0.01	0.94	1.4%
1991	0.04	0.19	0.04	0.07	0.10	0.03	0.03	0.10	0.02	0.04	0.00	0.00	0.06	0.00	0.01	0.74	1.6%
1992	0.06	0.04	0.15	0.03	0.05	0.07	0.02	0.02	0.06	0.01	0.02	0.00	0.00	0.04	0.01	0.60	1.6%
1993	0.05	0.05	0.03	0.13	0.03	0.04	0.05	0.02	0.01	0.04	0.01	0.02	0.00	0.00	0.03	0.51	6.2%
1994	0.09	0.04	0.04	0.02	0.10	0.02	0.03	0.04	0.01	0.01	0.03	0.01	0.01	0.00	0.02	0.47	4.5%
1995	0.03	0.07	0.04	0.03	0.02	0.07	0.01	0.02	0.02	0.01	0.00	0.02	0.00	0.01	0.01	0.37	3.6%
1996	0.05	0.03	0.06	0.03	0.03	0.01	0.05	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.32	3.6%
1997	0.03	0.04	0.02	0.05	0.02	0.02	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.27	3.2%
1998	0.02	0.03	0.04	0.02	0.04	0.02	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.23	4.4%
1999	0.03	0.02	0.02	0.03	0.01	0.03	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.21	3.6%
2000	0.08	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.24	2.8%
2001	0.10	0.06	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.30	2.7%
2002	0.03	0.08	0.05	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.01	0.28	3.0%
2003	0.02	0.02	0.07	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.25	3.2%
2004	0.03	0.02	0.02	0.06	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.23	5.0%
2005	0.02	0.02	0.02	0.02	0.05	0.03	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.21	5.2%
2006	0.05	0.01	0.02	0.01	0.01	0.04	0.02	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.21	5.1%
2007	0.10	0.04	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.27	4.2%
2008	0.05	0.08	0.03	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.27	5.0%
2009	0.02	0.04	0.06	0.03	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.25	5.4%
2010	0.05	0.02	0.04	0.05	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.25	5.6%
2011	0.03	0.04	0.01	0.03	0.04	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.23	5.7%
2012	0.10	0.02	0.03	0.01	0.02	0.04	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.29	4.2%
2013	0.06	0.08	0.02	0.03	0.01	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.29	4.1%
2014	0.07	0.05	0.07	0.02	0.02	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.31	4.5%
2015	0.07	0.06	0.04	0.05	0.01	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.02	0.33	5.3%
2016	0.07	0.06	0.05	0.03	0.05	0.01	0.01	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.02	0.34	4.7%

Table 1A.22. Authors' preferred Model 15.1 estimated NRA region pollock catch at age in millions (10^6). **2016** catch numbers estimated with the 2016 total year end catch estimate of 1,500 t.

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**
1978	0.07	0.13	0.25	0.89	0.8	1.74	0.56	0.73	0.55	0.4	0.26	0.12	0.09	0.08	0.64	7.31
1979	1.1	0.18	0.43	0.95	1.92	1.47	2.9	0.88	0.91	0.69	0.5	0.33	0.16	0.12	0.9	13.44
1980	0.18	8.71	1.77	4.64	5.79	9.73	6.64	12.04	2.93	3.04	2.29	1.67	1.1	0.52	3.38	64.43
1981	0.15	0.21	13.13	2.91	4.21	4.34	6.41	3.97	5.66	1.38	1.43	1.08	0.78	0.52	1.84	48.02
1982	1.06	0.3	0.54	36.66	4.5	5.41	4.93	6.64	3.26	4.64	1.13	1.17	0.88	0.64	1.93	73.69
1983	0.3	1.3	0.48	0.92	34.65	3.54	3.76	3.13	3.32	1.63	2.32	0.56	0.59	0.44	1.29	58.23
1984	0.96	0.41	2.27	0.91	0.98	30.98	2.82	2.76	1.82	1.93	0.95	1.35	0.33	0.34	1.01	49.82
1985	0.18	1.53	0.83	4.99	1.12	1.02	28.81	2.42	1.89	1.25	1.32	0.65	0.93	0.22	0.92	48.08
1986	0.1	0.18	1.9	1.14	3.85	0.73	0.6	15.68	1.05	0.82	0.54	0.57	0.28	0.4	0.5	28.34
1987	0.24	0.18	0.39	4.68	1.59	4.56	0.78	0.6	12.54	0.84	0.65	0.43	0.46	0.23	0.72	28.89
1988	0.2	0.61	0.58	1.41	9.46	2.72	7.01	1.12	0.68	14.36	0.96	0.75	0.49	0.53	1.08	41.96
1989	0.03	0.1	0.38	0.41	0.56	3.17	0.82	1.98	0.25	0.15	3.23	0.22	0.17	0.11	0.36	11.94
1990	0.82	0.4	1.51	5.36	4.15	5.1	25.96	6.05	11.72	1.49	0.91	19.14	1.28	1	2.8	87.69
1991	0.17	1.58	0.83	3.28	9.87	5.05	5.02	22.25	4.2	8.13	1.03	0.63	13.27	0.89	2.64	78.84
1992	0.16	0.19	1.93	1.06	3.61	7.21	3.01	2.61	9.34	1.76	3.41	0.43	0.26	5.57	1.48	42.03
1993	0.18	0.35	0.46	4.86	2.29	5.21	8.55	3.14	2.22	7.94	1.5	2.9	0.37	0.23	6	46.2
1994	0.39	0.41	0.88	1.2	10.77	3.35	6.18	8.82	2.63	1.86	6.65	1.26	2.43	0.31	5.21	52.35
1995	0.16	0.75	0.86	1.91	2.2	12.86	3.2	5.08	5.84	1.74	1.23	4.4	0.83	1.61	3.65	46.32
1996	0.17	0.18	0.92	1.1	2.08	1.58	7.43	1.6	2.04	2.34	0.7	0.49	1.76	0.33	2.11	24.83
1997	0.08	0.24	0.28	1.5	1.53	1.94	1.21	5	0.87	1.11	1.28	0.38	0.27	0.96	1.33	17.98
1998	0.08	0.19	0.59	0.74	3.36	2.3	2.39	1.31	4.41	0.77	0.98	1.13	0.34	0.24	2.03	20.86
1999	0	0	0.01	0.04	0.04	0.14	0.09	0.08	0.03	0.12	0.02	0.03	0.03	0.01	0.06	0.7
2000	0.01	0.01	0.01	0.03	0.07	0.07	0.19	0.1	0.07	0.03	0.11	0.02	0.02	0.03	0.07	0.84
2001	0.01	0.01	0.01	0.01	0.03	0.07	0.05	0.12	0.05	0.04	0.02	0.06	0.01	0.01	0.05	0.55
2002	0	0.02	0.03	0.03	0.03	0.06	0.12	0.07	0.14	0.06	0.05	0.02	0.07	0.01	0.07	0.78
2003	0	0.01	0.06	0.08	0.07	0.07	0.11	0.17	0.08	0.16	0.07	0.05	0.02	0.08	0.1	1.13
2004	0	0.01	0.01	0.08	0.1	0.07	0.05	0.07	0.09	0.05	0.09	0.04	0.03	0.01	0.1	0.8
2005	0	0.01	0.01	0.03	0.17	0.2	0.11	0.07	0.08	0.1	0.05	0.1	0.04	0.03	0.13	1.13
2006	0.01	0	0.01	0.02	0.05	0.24	0.21	0.09	0.05	0.06	0.07	0.04	0.07	0.03	0.12	1.07
2007	0.02	0.02	0.01	0.04	0.05	0.11	0.41	0.3	0.11	0.06	0.07	0.09	0.05	0.09	0.18	1.61
2008	0.01	0.02	0.02	0.01	0.03	0.04	0.06	0.21	0.13	0.05	0.03	0.03	0.04	0.02	0.12	0.82
2009	0	0.02	0.05	0.04	0.03	0.06	0.07	0.09	0.25	0.15	0.06	0.03	0.04	0.05	0.16	1.1
2010	0.01	0	0.02	0.07	0.06	0.03	0.06	0.06	0.06	0.16	0.1	0.04	0.02	0.02	0.13	0.84
2011	0	0.01	0.01	0.04	0.12	0.08	0.04	0.06	0.04	0.05	0.13	0.08	0.03	0.02	0.12	0.83
2012	0.01	0	0.01	0.01	0.05	0.13	0.08	0.03	0.04	0.03	0.03	0.08	0.05	0.02	0.09	0.66
2013	0.02	0.05	0.03	0.08	0.05	0.21	0.47	0.24	0.07	0.09	0.06	0.07	0.18	0.11	0.25	1.98
2014	0.02	0.02	0.07	0.04	0.1	0.06	0.2	0.39	0.15	0.05	0.06	0.04	0.04	0.12	0.23	1.59
2015	0.01	0.01	0.02	0.05	0.02	0.06	0.03	0.09	0.13	0.05	0.02	0.02	0.01	0.01	0.11	0.64
2016	0.01	0.01	0.03	0.04	0.11	0.05	0.1	0.04	0.1	0.14	0.05	0.02	0.02	0.01	0.14	0.87

Table 1A.23. Authors' preferred Model 15.1 estimates of full-selection fishing mortality and exploitation rates for NRA pollock.

Year	F[a]	Catch/Biomass Rate[b]
1978	0.023	0.013
1979	0.036	0.017
1980	0.169	0.082
1981	0.119	0.037
1982	0.144	0.056
1983	0.105	0.050
1984	0.085	0.048
1985	0.080	0.053
1986	0.046	0.027
1987	0.048	0.030
1988	0.073	0.044
1989	0.021	0.013
1990	0.175	0.104
1991	0.193	0.159
1992	0.125	0.101
1993	0.159	0.125
1994	0.211	0.153
1995	0.236	0.208
1996	0.153	0.116
1997	0.125	0.119
1998	0.166	0.121
1999	0.006	0.006
2000	0.007	0.007
2001	0.005	0.005
2002	0.007	0.006
2003	0.009	0.009
2004	0.007	0.006
2005	0.009	0.008
2006	0.008	0.009
2007	0.012	0.014
2008	0.006	0.007
2009	0.009	0.009
2010	0.007	0.006
2011	0.007	0.006
2012	0.005	0.005
2013	0.015	0.015
2014	0.012	0.012
2015	0.005	0.004
2016*	0.006	0.006

[a] Average fishing mortality rates over all ages
[b] Catch/biomass rate is the ratio of catch to beginning year age 1+ biomass.
* Assuming catch of 1,500 t

Table 1A.24. Authors' preferred model estimates of age 1 pollock recruitment (in millions) for 2015 and 2016 author's preferred models.

2015 Authors' Preferred Model			2016 Model 15.1		
Year	Index at age 1	St. Dev.	Year	Index at age 1	St. Dev.
1978	127.4	30.8	1978	133.5	32.4
1979	1,330.5	143.3	1979	1,404.7	151.9
1980	45.8	16.8	1980	48.0	17.7
1981	54.9	17.7	1981	57.9	18.7
1982	318.7	56.2	1982	338.2	59.7
1983	125.6	39.3	1983	132.3	41.5
1984	491.4	79.1	1984	520.2	83.7
1985	99.2	37.1	1985	103.7	38.9
1986	96.7	33.7	1986	101.2	35.4
1987	217.6	40.4	1987	226.9	42.2
1988	123.8	25.5	1988	128.2	26.5
1989	61.6	15.9	1989	64.0	16.6
1990	222.0	27.8	1990	231.1	29.0
1991	41.6	10.0	1991	43.2	10.4
1992	59.9	11.5	1992	62.1	11.9
1993	53.1	11.0	1993	54.7	11.4
1994	88.7	14.8	1994	90.4	15.2
1995	33.1	7.9	1995	33.8	8.0
1996	52.3	10.2	1996	53.2	10.3
1997	31.8	6.9	1997	32.3	7.1
1998	22.8	5.5	1998	23.2	5.6
1999	35.1	7.4	1999	34.5	7.3
2000	74.8	12.6	2000	75.0	12.6
2001	100.1	15.8	2001	99.0	15.5
2002	29.4	6.5	2002	29.8	6.5
2003	22.9	5.6	2003	22.5	5.4
2004	27.8	6.4	2004	26.3	6.0
2005	17.9	5.1	2005	17.4	4.9
2006	46.5	10.5	2006	45.3	9.9
2007	87.7	18.5	2007	95.8	17.9
2008	42.0	10.6	2008	52.7	11.5
2009	22.7	7.2	2009	19.7	5.9
2010	46.7	12.8	2010	46.5	11.0
2011	35.1	12.4	2011	27.8	8.8
2012	88.0	26.5	2012	98.4	23.2
2013	66.3	31.3	2013	56.7	18.8
2014	67.8	32.4	2014	74.4	23.7
2015	68.2	32.7	2015	68.7	32.6
			2016	69.7	33.3
Ave 78-10	128.8		Ave 78-10	134.8	
Med 78-10	54.9		Med 78-10	57.9	

Table 1A.25. Projections of Authors' preferred Model 15.1 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=203.1 kt, B_{40}=81.240 kt, B_{35}=71.085 kt, and ½ B_{35}=35.543 kt).*

Sp.Biomass	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2016	72.50	72.50	72.50	72.50	72.50	72.50	72.50	72.50
2017	74.69	74.69	77.58	76.26	77.67	73.98	74.69	76.17
2018	65.20	65.20	81.52	73.42	82.09	61.87	65.20	72.87
2019	60.67	60.67	85.69	71.84	86.71	56.58	60.22	70.79
2020	60.96	60.96	92.54	73.63	94.00	56.65	58.57	72.11
2021	65.32	65.32	102.67	79.26	104.56	60.84	61.82	77.31
2022	72.09	72.09	115.52	87.83	117.84	67.20	67.66	85.81
2023	77.98	77.98	128.02	96.15	130.77	72.42	72.61	94.72
2024	82.17	82.17	139.49	103.30	142.68	75.79	75.85	103.30
2025	84.25	84.25	149.36	108.58	153.02	77.12	77.13	110.81
2026	85.25	85.25	157.94	112.54	162.08	77.53	77.52	117.43
2027	86.11	86.11	165.60	115.88	170.22	78.01	78.00	123.56
2028	87.12	87.12	172.46	118.86	177.53	78.80	78.80	129.24
2029	87.38	87.38	177.46	120.58	182.93	78.94	78.93	129.42
F	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2016	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2017	0.30	0.30	0.01	0.14	0.00	0.38	0.30	0.15
2018	0.26	0.26	0.01	0.14	0.00	0.31	0.26	0.15
2019	0.24	0.24	0.01	0.14	0.00	0.28	0.30	0.16
2020	0.24	0.24	0.01	0.14	0.00	0.28	0.29	0.16
2021	0.25	0.25	0.01	0.14	0.00	0.30	0.30	0.16
2022	0.26	0.26	0.01	0.14	0.00	0.31	0.32	0.15
2023	0.27	0.27	0.01	0.14	0.00	0.33	0.33	0.14
2024	0.28	0.28	0.01	0.14	0.00	0.34	0.34	0.14
2025	0.28	0.28	0.01	0.14	0.00	0.34	0.34	0.13
2026	0.29	0.29	0.01	0.14	0.00	0.34	0.34	0.12
2027	0.29	0.29	0.01	0.14	0.00	0.34	0.34	0.12
2028	0.29	0.29	0.01	0.14	0.00	0.34	0.34	0.11
2029	0.29	0.29	0.01	0.14	0.00	0.34	0.34	0.31
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
2016	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2017	36.06	36.06	1.16	17.92	0.00	43.65	36.06	19.00
2018	27.83	27.83	1.25	17.61	0.00	30.87	27.83	19.00
2019	24.43	24.43	1.36	17.61	0.00	26.12	29.82	19.00
2020	23.73	23.73	1.43	17.47	0.00	25.16	27.04	19.00
2021	25.49	25.49	1.54	18.03	0.00	27.37	28.31	19.00
2022	28.84	28.84	1.69	19.43	0.00	31.43	31.86	19.00
2023	32.94	32.94	1.90	21.58	0.00	36.08	36.27	19.00
2024	36.48	36.48	2.13	23.84	0.00	39.61	39.67	19.00
2025	38.42	38.42	2.32	25.46	0.00	41.34	41.35	19.00
2026	39.44	39.44	2.47	26.61	0.00	42.07	42.06	19.00
2027	39.78	39.78	2.59	27.33	0.00	42.10	42.09	19.00
2028	40.05	40.05	2.69	27.90	0.00	42.22	42.22	19.00
2029	40.30	40.30	2.78	28.46	0.00	42.54	42.53	19.00

Table 1A.26. 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	**Newly opened areas should spread the fishery out more than under previous SSL protection measures.**	Depending on concentration of pollock outside of critical habitat could 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. 2015 fishery not expected to be significant.**	Unknown	Unknown
Fishery effects on age-at-maturity and fecundity	**Unknown**	Unknown	Unknown

Figures

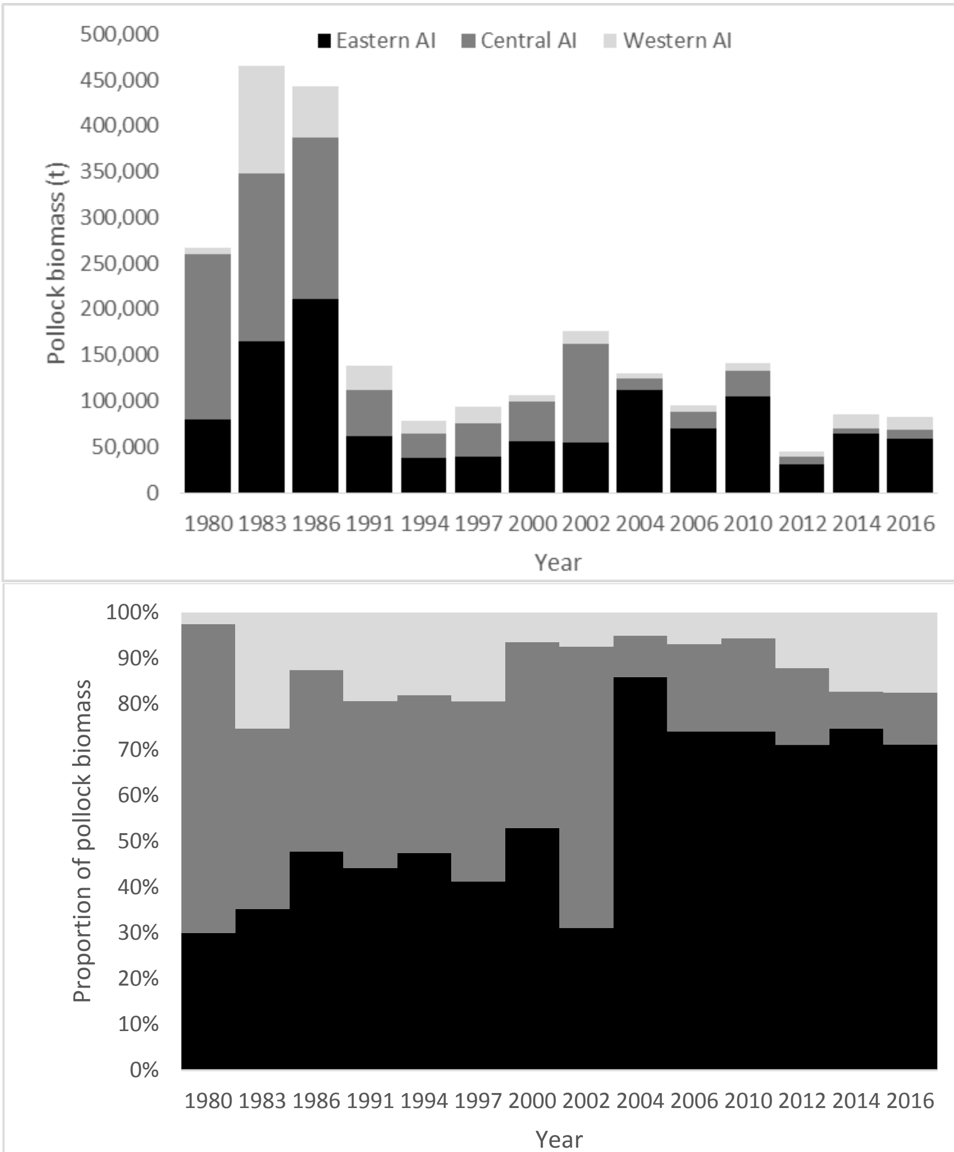

Figure 1A.1 Aleutian Islands bottom trawl survey pollock biomass (top) and proportion of biomass (bottom) for the three Aleutian Island management regions.

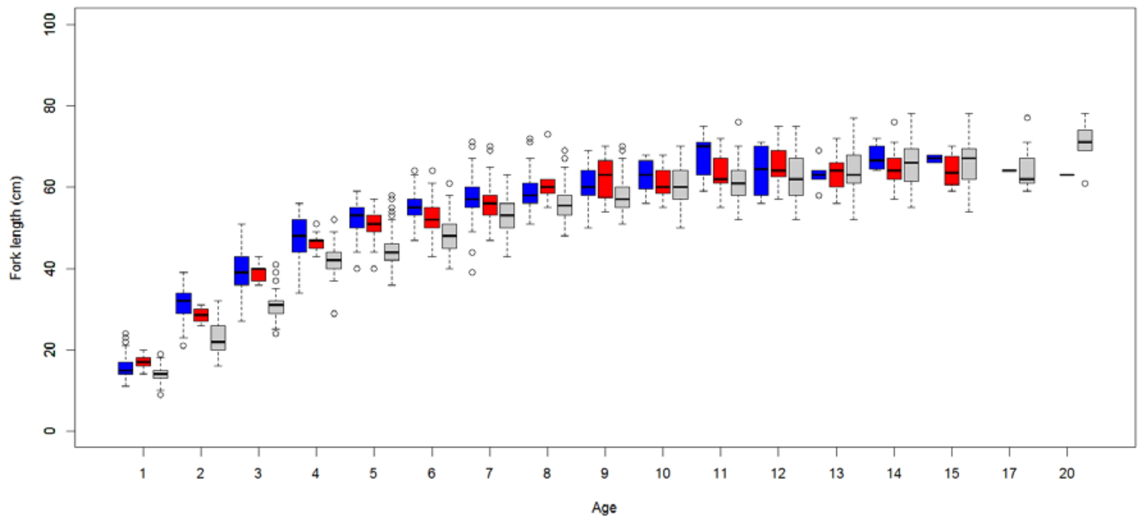

Figure 1A.2. Length at age for Aleutian Islands (red), Gulf of Alaska (blue), and Bering Sea (grey) pollock from the 2012 Aleutian Islands, 2013 Bering Sea, and 2013 Gulf of Alaska bottom trawl surveys.

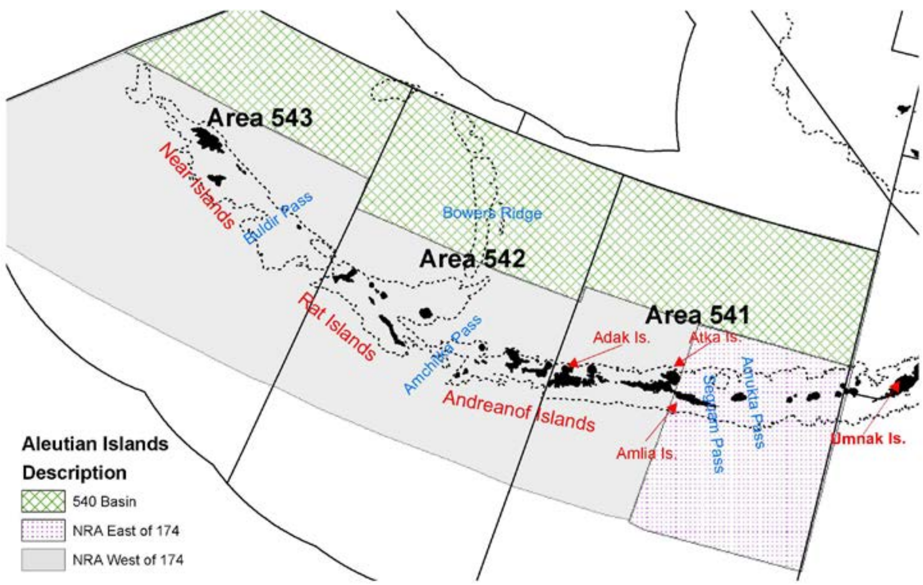

Figure 1A. 3. Regions defined for consideration of alternative data partitions for Aleutian Islands Region pollock. The abbreviation “NRA” represents the Near, Rat, and Andreanof Island group. There are no models for 2014 that consider the NRA east-west partition at 174° W.

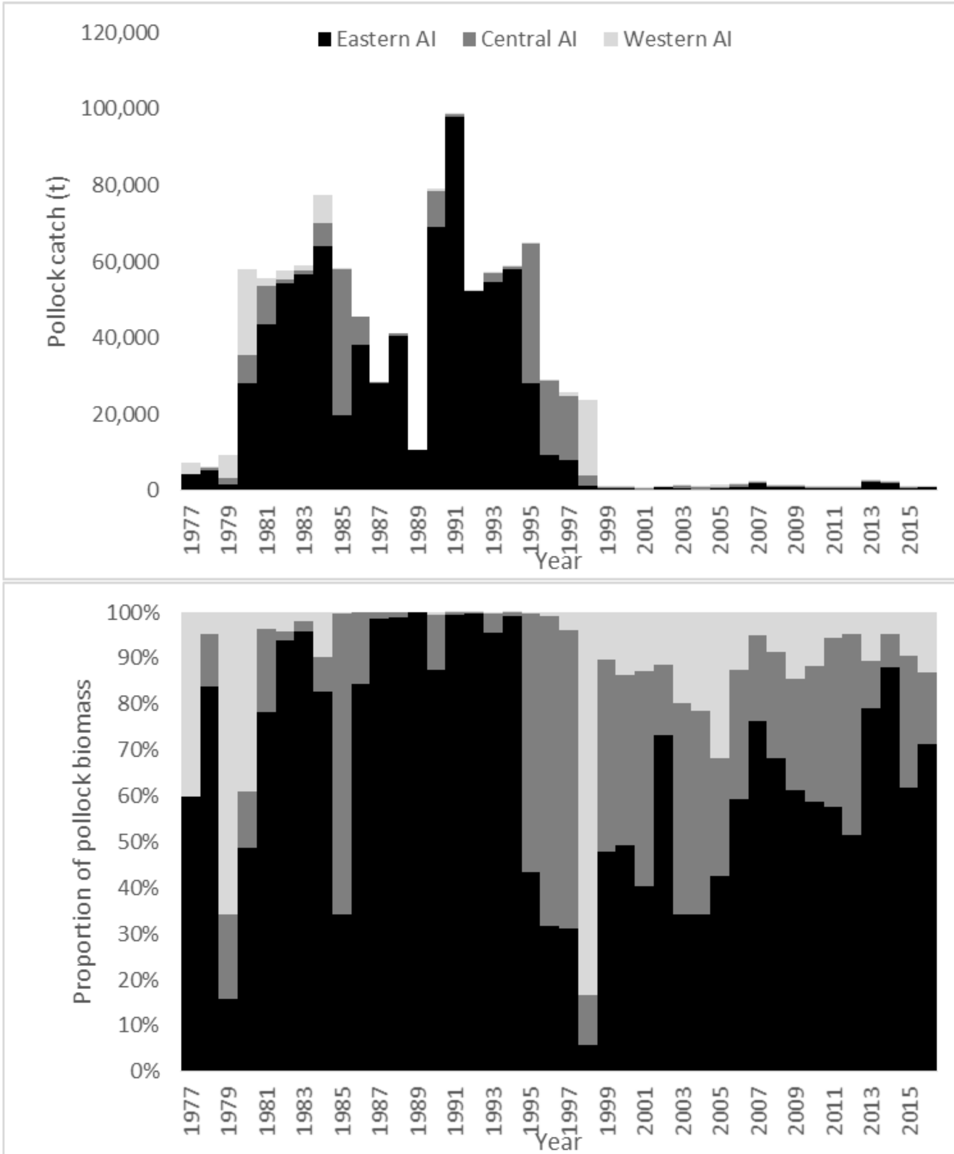

Figure 1A.4. Pollock catch by NMFS reporting area for 1977- 2015 by total catch (top) and percentage of catch by area (bottom).

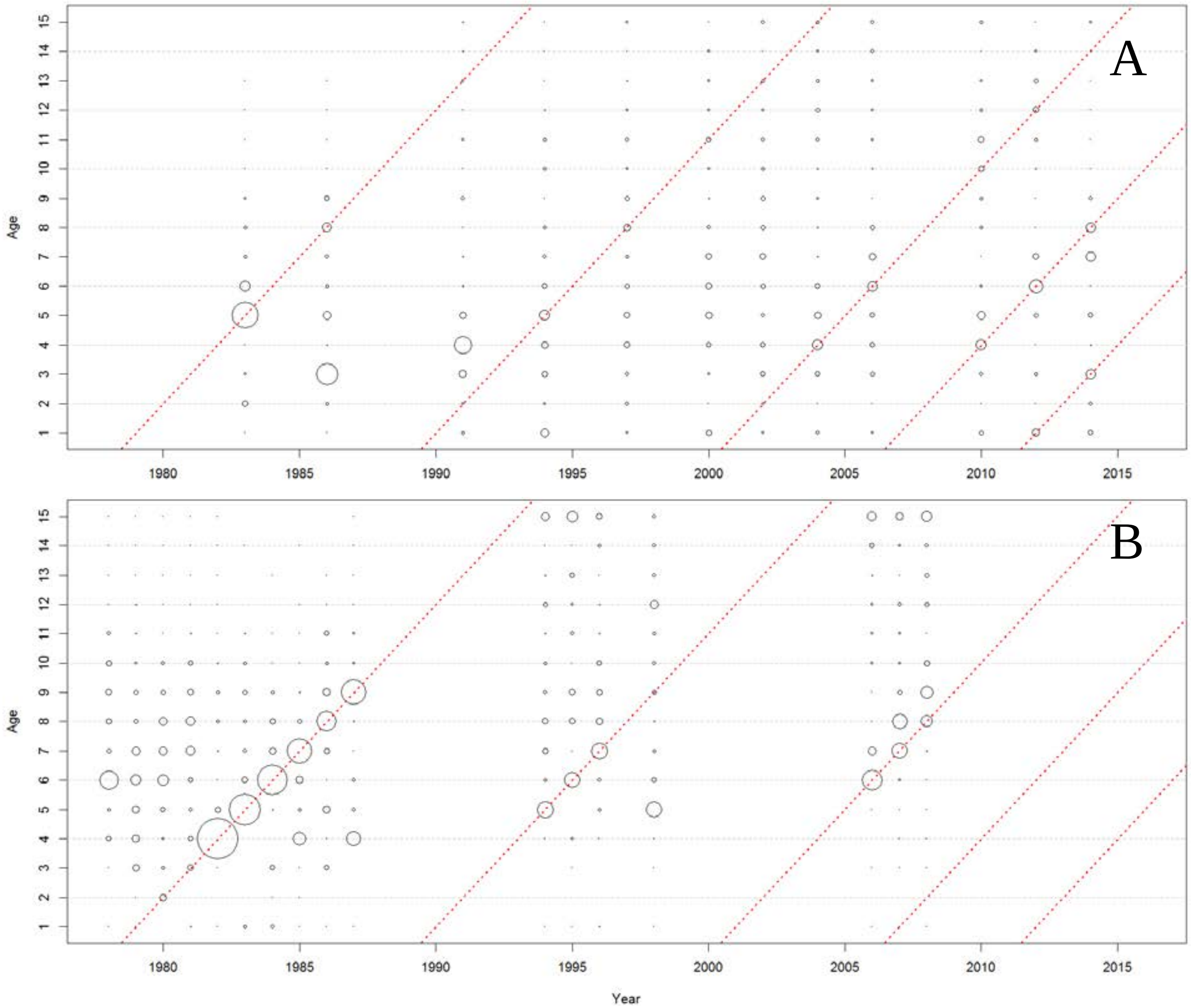

Figure 1A.5. Age distributions for 1978-2008 Aleutian Islands pollock fishery (A; top) and 1980 - 2014 Aleutian Islands Bottom Trawl surveys (B; bottom). The 1978, 1989, 2000, 2006, and 2011 year classes are indicated by the diagonal dashed lines.

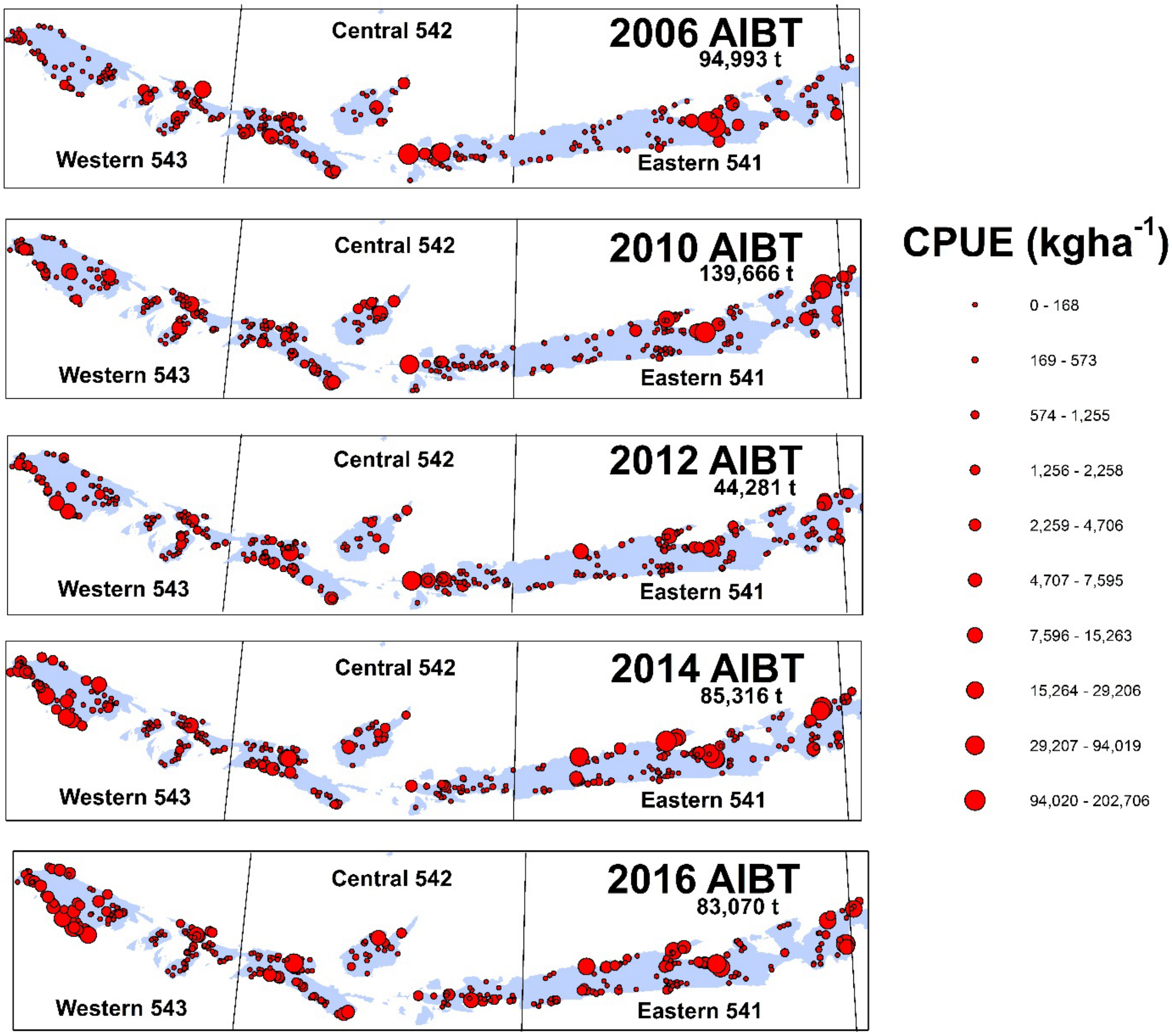

Figure 1A.6. Catch per unit effort (kgha^{-1}) for surveys of pollock in the Aleutian Islands Region, 2004-2016. The shaded area is the Aleutian Islands shelf area less than 300m depth.

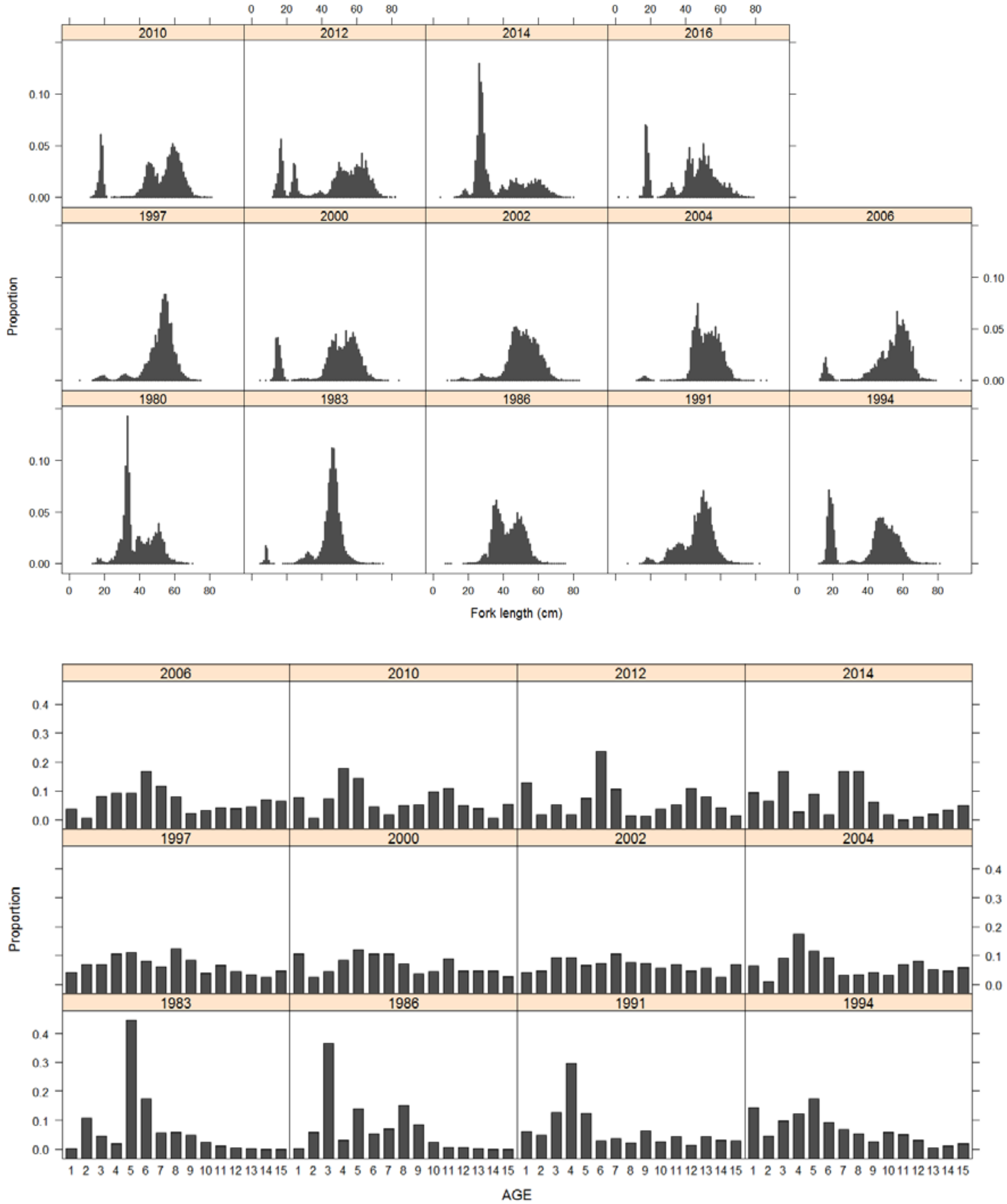

Figure 1A.7. Population distribution by length (top) for 1980-2016 and age (bottom) for 1983-2014 for the Aleutian Islands bottom trawl surveys.

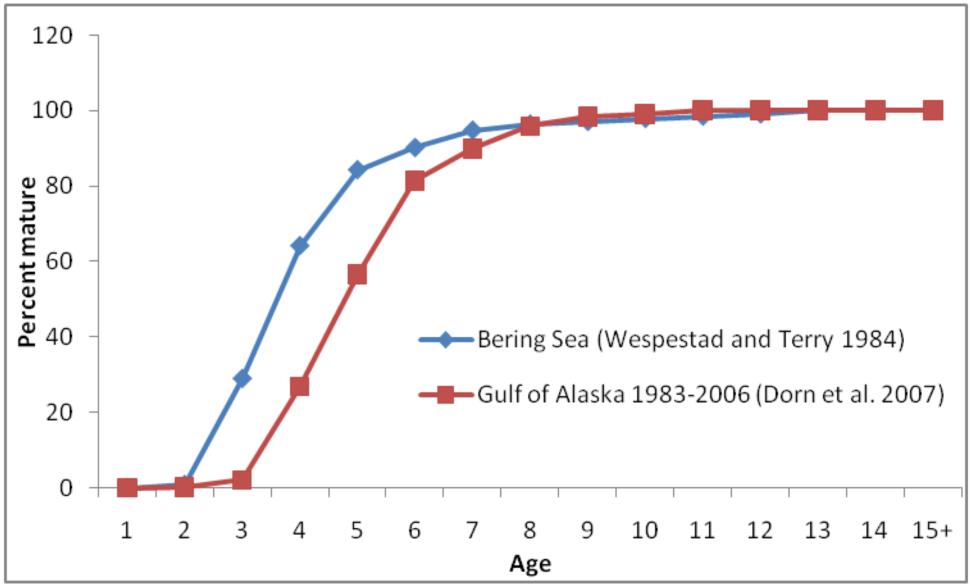

Figure 1A.8. Percent mature at age for Bering Sea pollock (Wespestad and Terry 1984) and the mean percent mature at age for 1983-2006 for Gulf of Alaska pollock (Dorn et al. 2007).

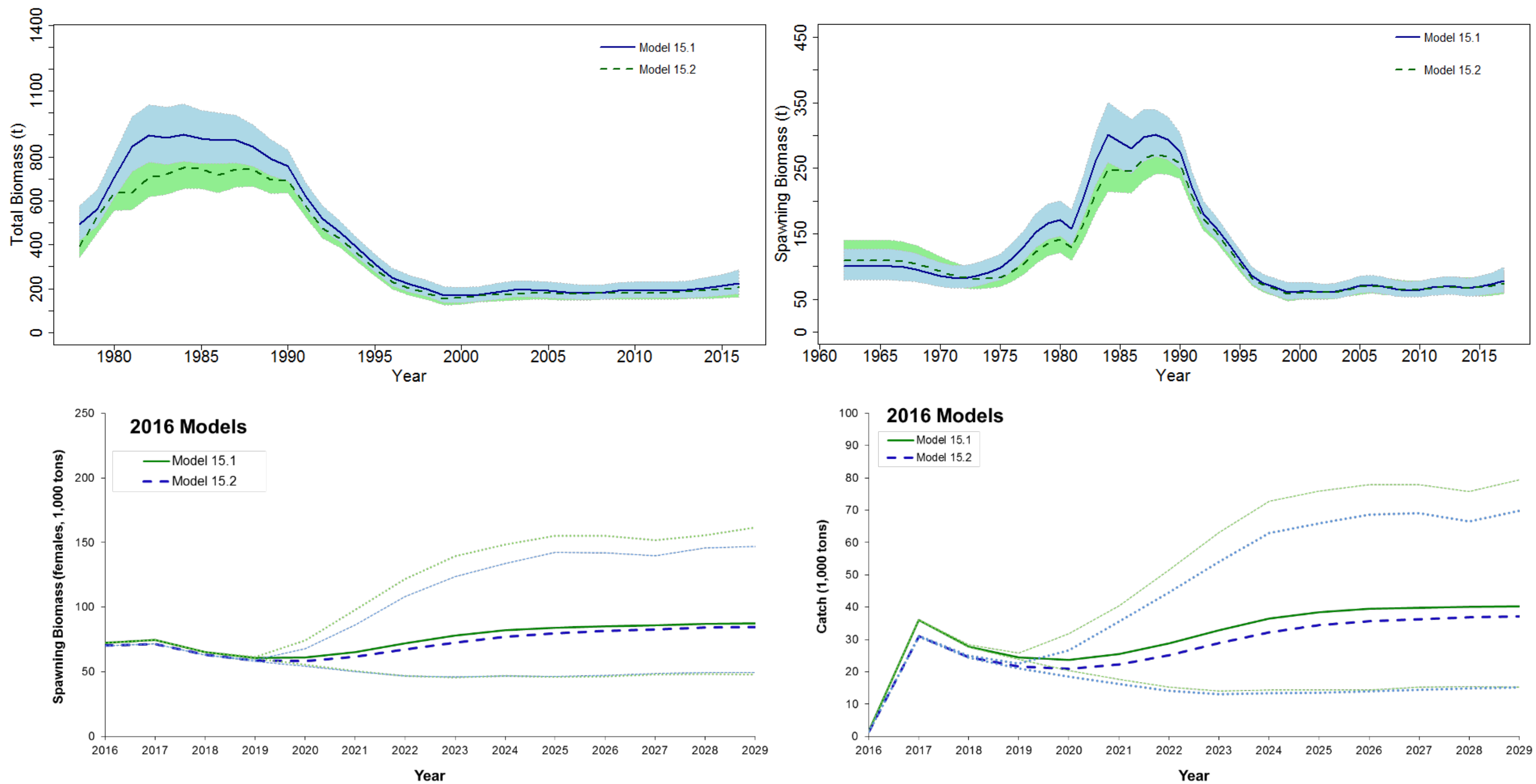

Figure 1A.9. Total biomass (top left), spawning biomass (top right), and spawning biomass projection (bottom left) and catch projection (bottom right) from Model 15.1. and Model 15.2.

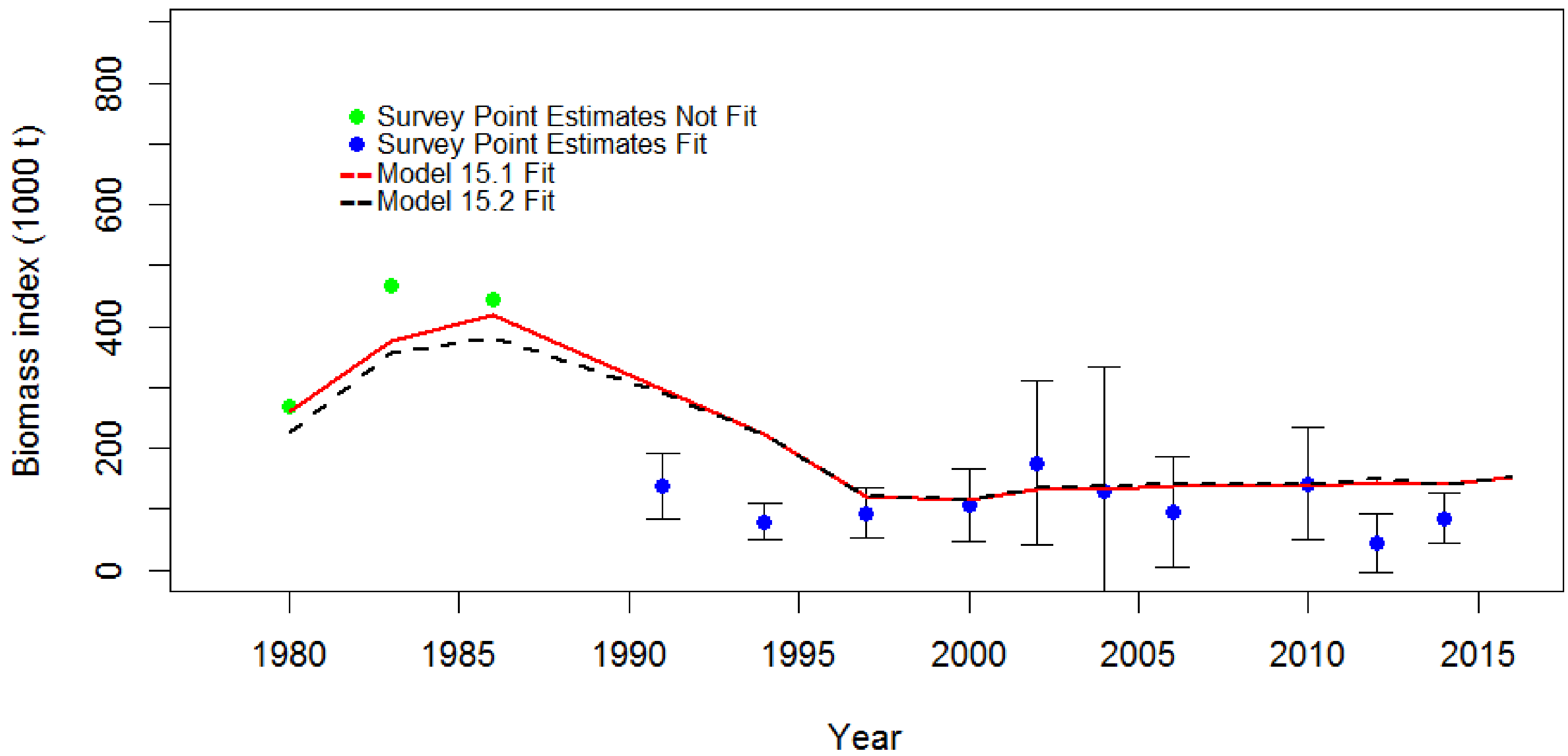

Figure 1A.10. Model fits to NMFS summer bottom trawl survey.

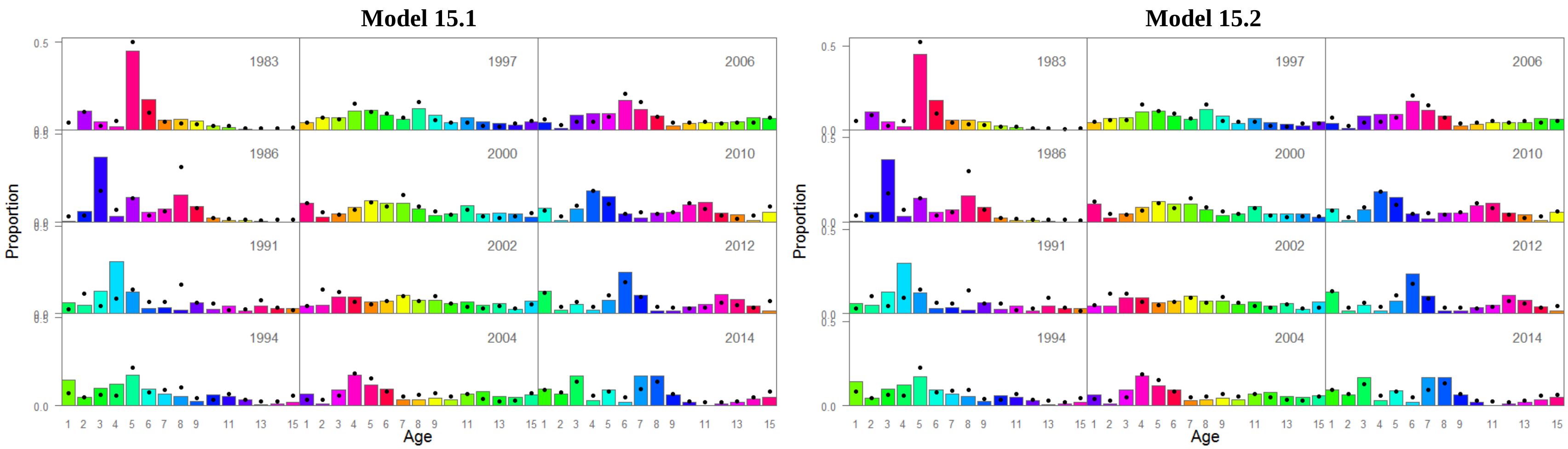

Figure 1A.11. Aleutian Islands pollock Model 15.1 and Model 15.2 fit to NMFS summer bottom trawl survey age composition data. The "•" symbol are the model predictions and columns are the observed proportions at age (with colors corresponding to cohorts).

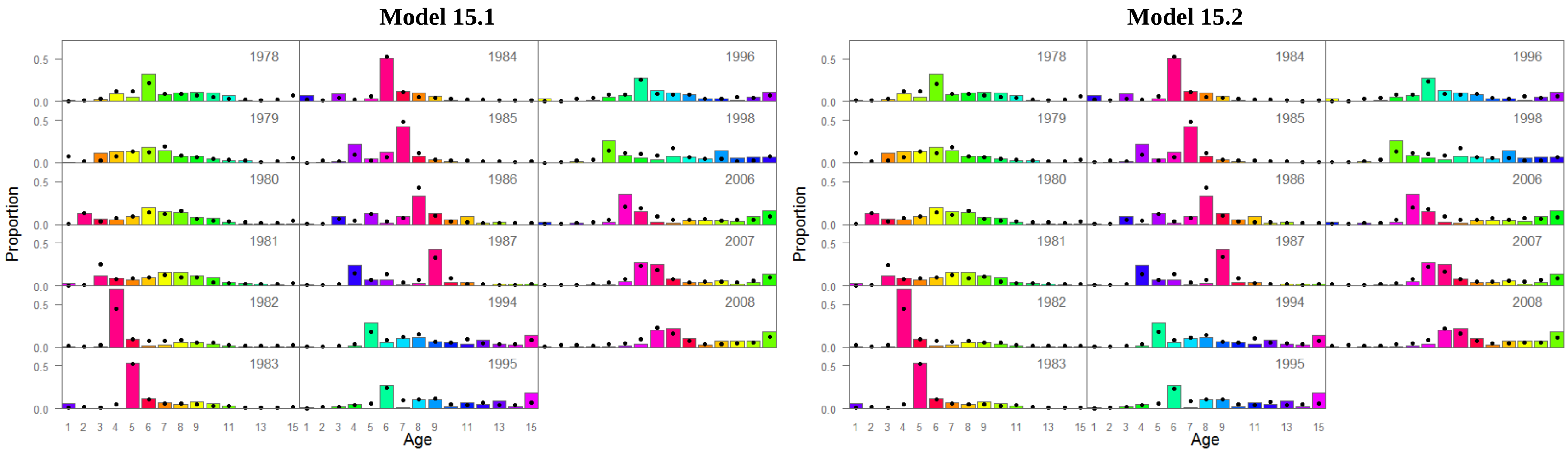

Figure 1A.12. Model 15.1 and Model 15.2. fits to fishery age composition data for Aleutian Islands pollock. The "•" symbol are the model predictions and columns are the observed proportions at age (with colors corresponding to cohorts).

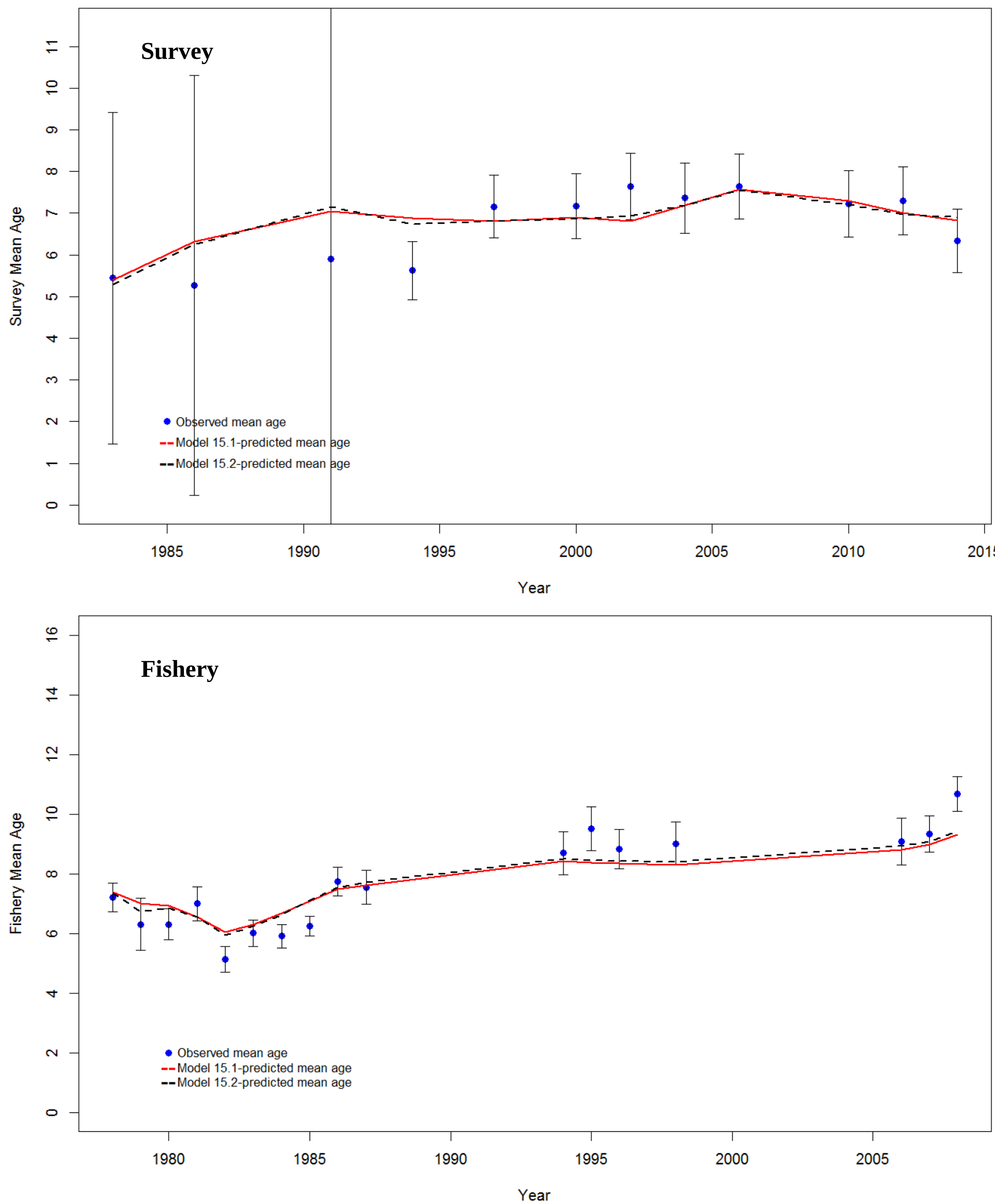

Figure 1A.13. Observed mean age and model derived mean age from the AIBTS (top) and fishery catch at age data (bottom) for Model 15.1 and Model 15.2. The confidence intervals are adjusted by the multinomial sample sizes used in the models.

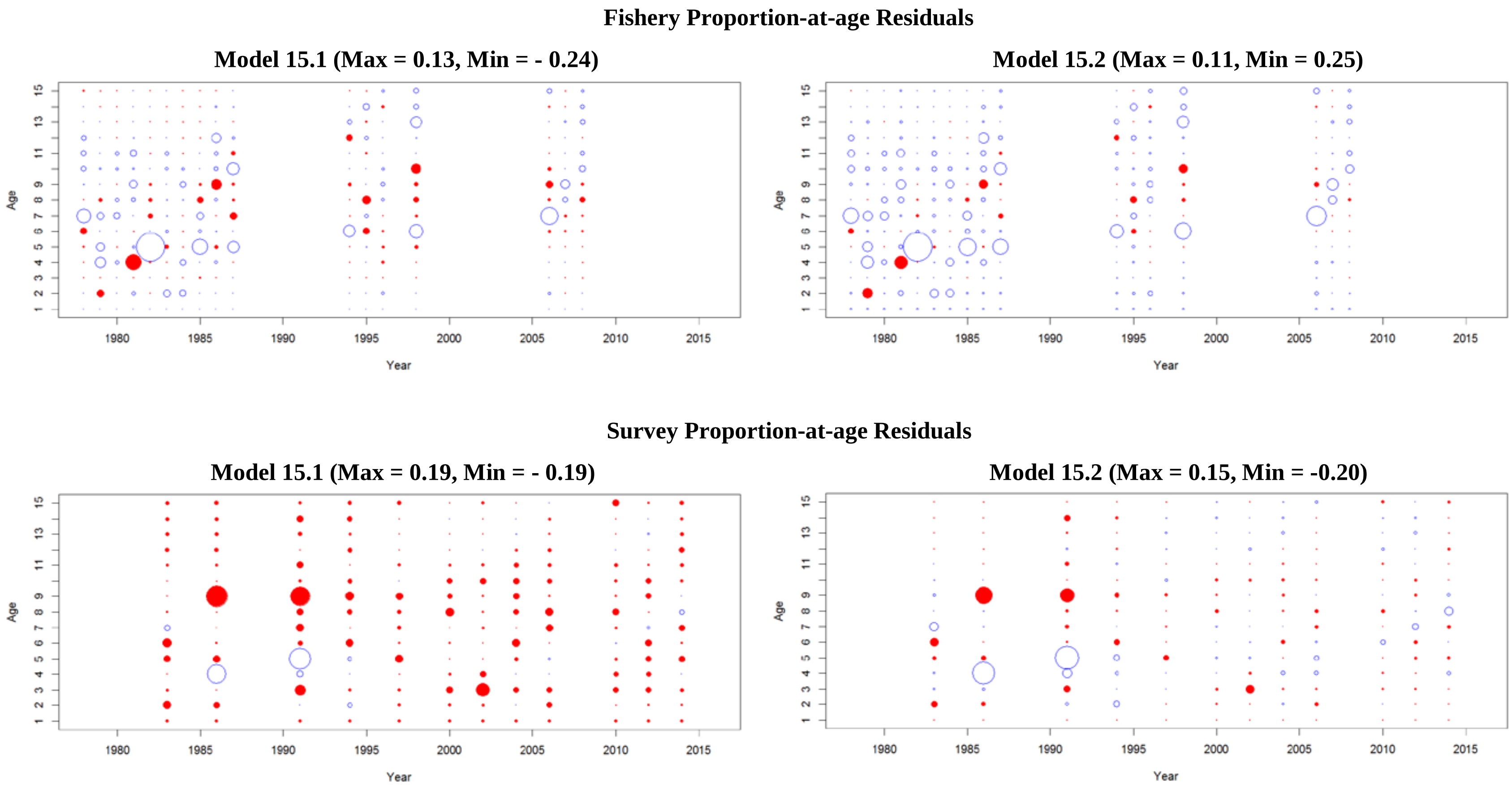

Figure 1A.14. Standardized residuals for fits to the fishery (top) and survey (bottom) proportion-at-age data for AI pollock Model 15.1 and Model 15.2..

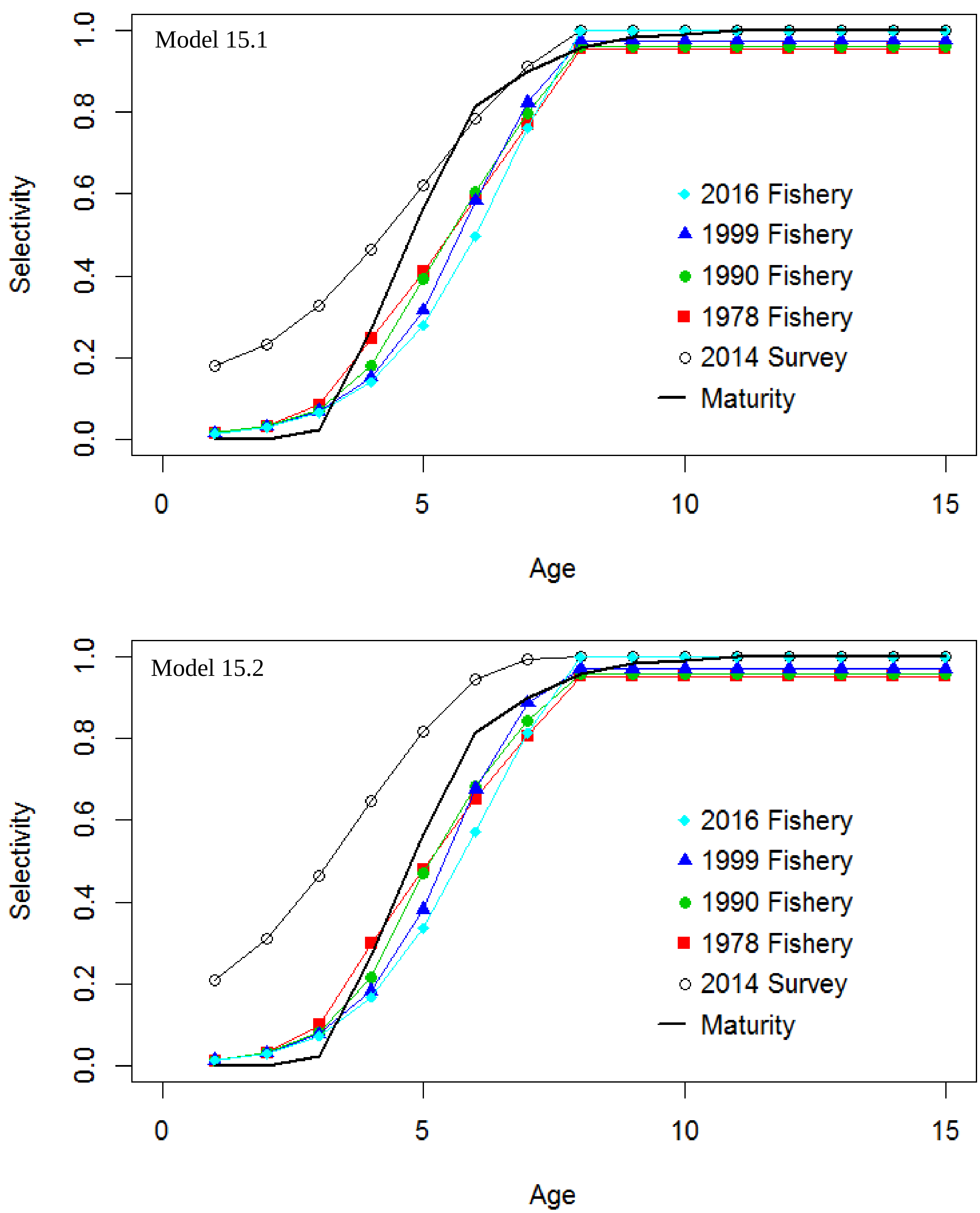

Figure 1A.15. Fishery and survey selectivity estimates with maturity at age for Aleutian Islands pollock models.

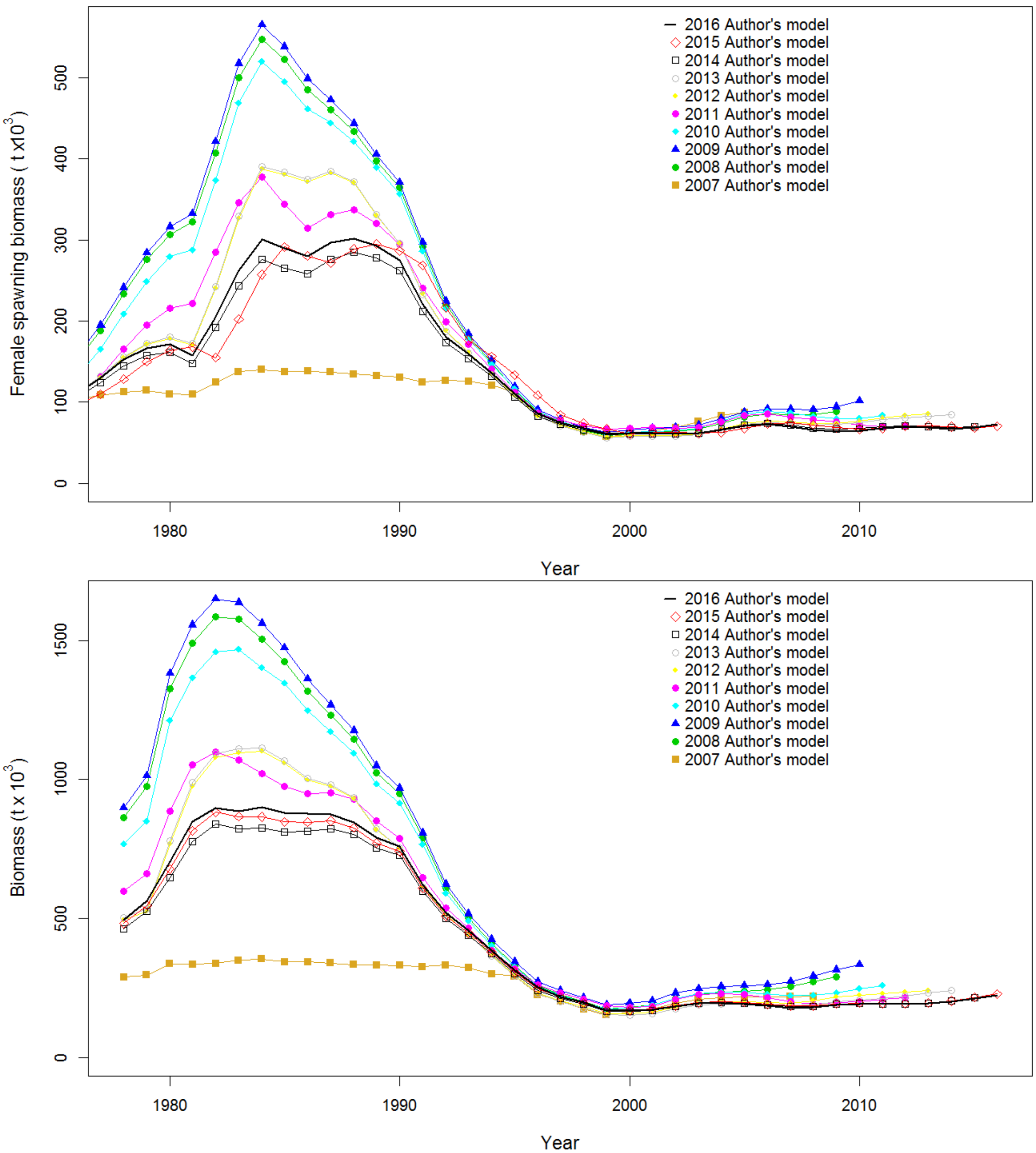

Figure 1A.16. Female spawning (top) and total (bottom) biomass trajectories for the 2016 Authors' preferred model compared with the 2007 through 2015 Authors' preferred models.

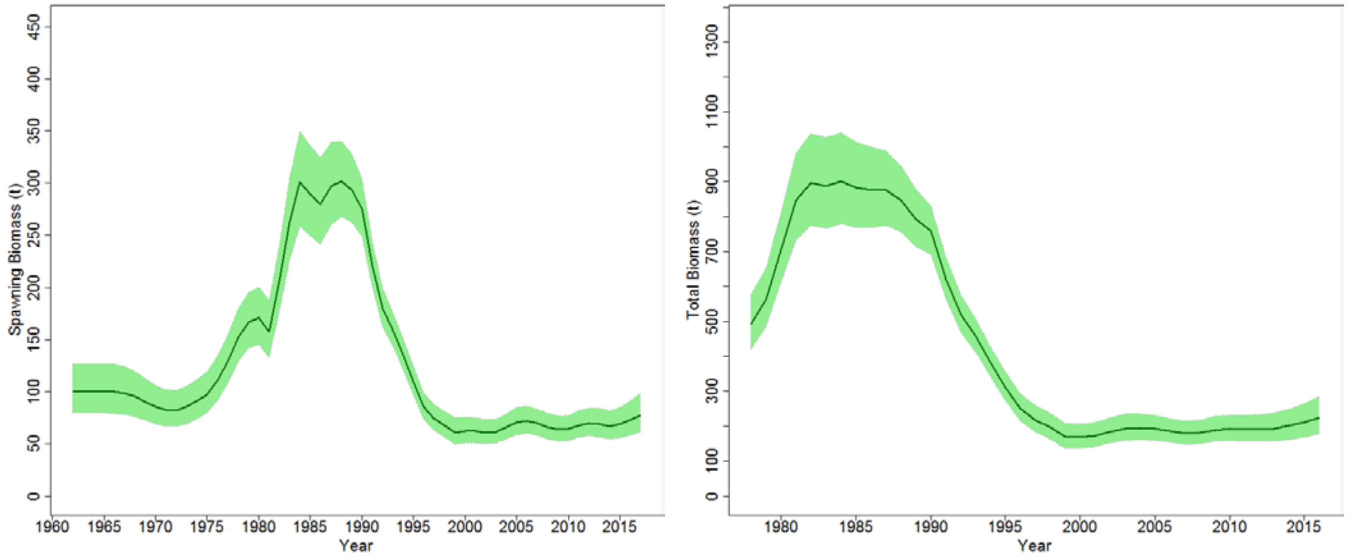

Figure 1A.17. Estimates of Aleutian Islands pollock spawning biomass (left) and age 1+ total biomass (right) in 1,000s of tons from the authors' preferred Model 15.1.. Confidence intervals are two standard deviations.

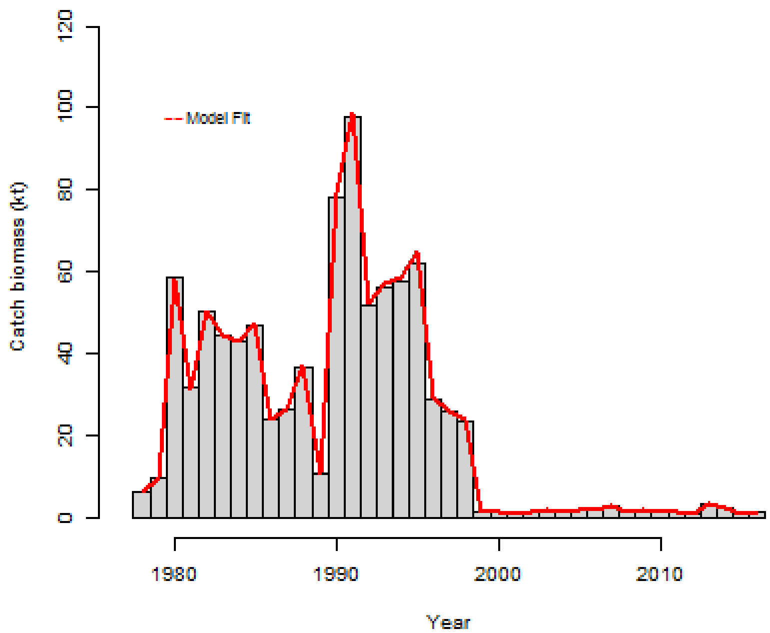

Figure 1A.18 Fits to total catch in 1,000s of tons for AI pollock over time 1978-2015.

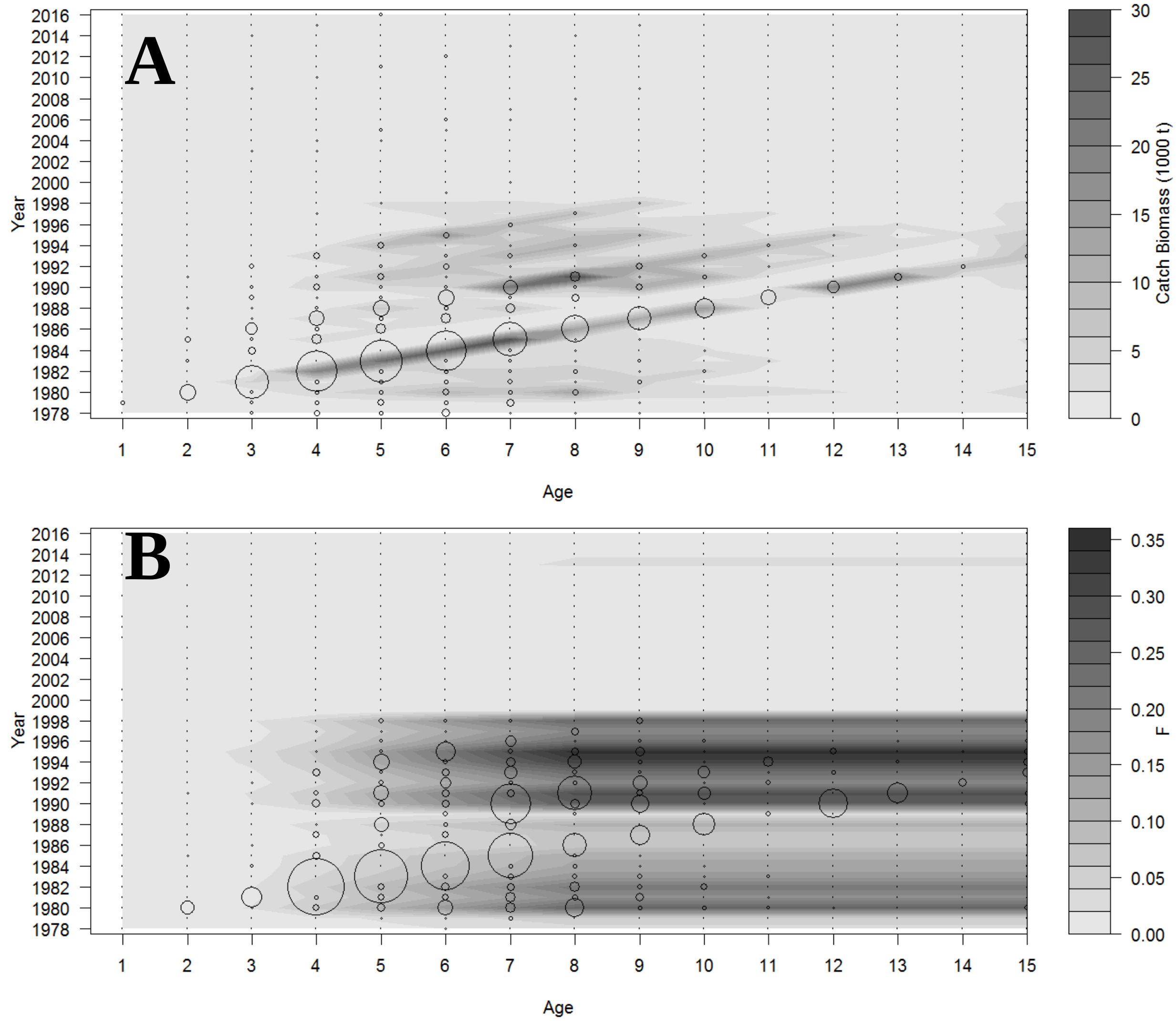

Figure 1A.19 AI pollock authors' preferred Model 15.1 (A-contour) catch biomass in 1,000s of tons and (A-bubbles) total biomass and (B-contour) fishing mortality rates and (B-bubbles) catch biomass by age. Total biomass is scaled to 1/20th of the catch biomass in the bubble plots

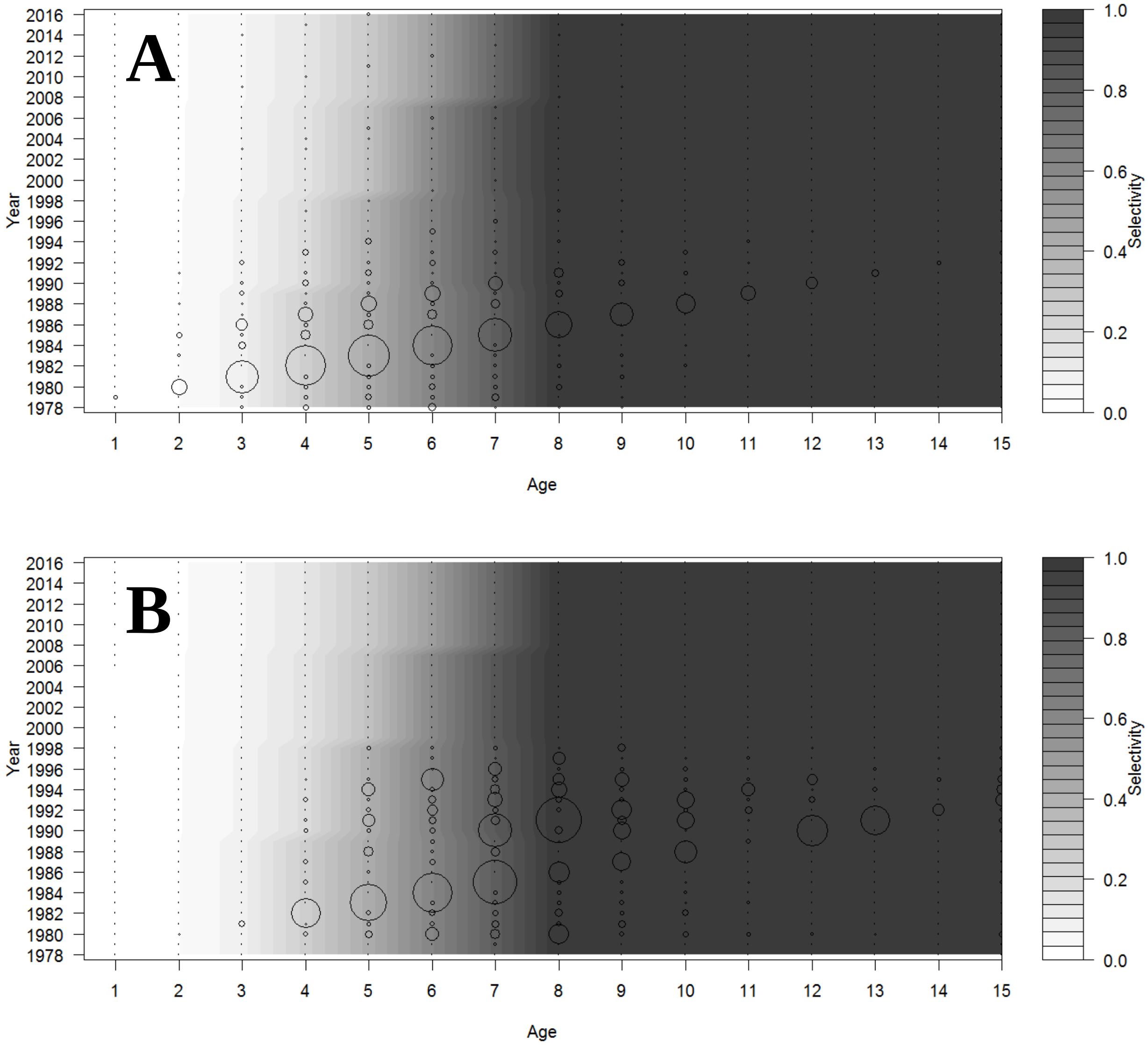

Figure 1A.20 Contour plots of fishery selectivity by age for AI pollock with bubble plots of (A) total biomass at age and (B) catch biomass at age for the Authors' preferred Model 1.0. Total biomass is scaled to 1/20 of the catch biomass bubbles.

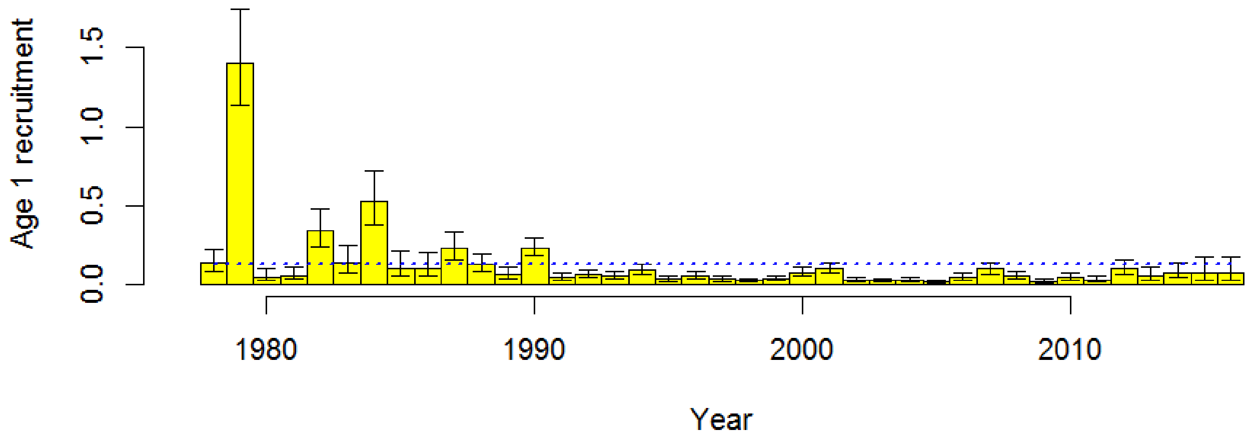

Figure 1A.21. Authors' preferred model estimates of Aleutian Islands pollock age 1 recruitment. The vertical bars represent the upper and lower 95% confidence bounds. The dotted line is the 1978-2010 mean age-1 recruitment.

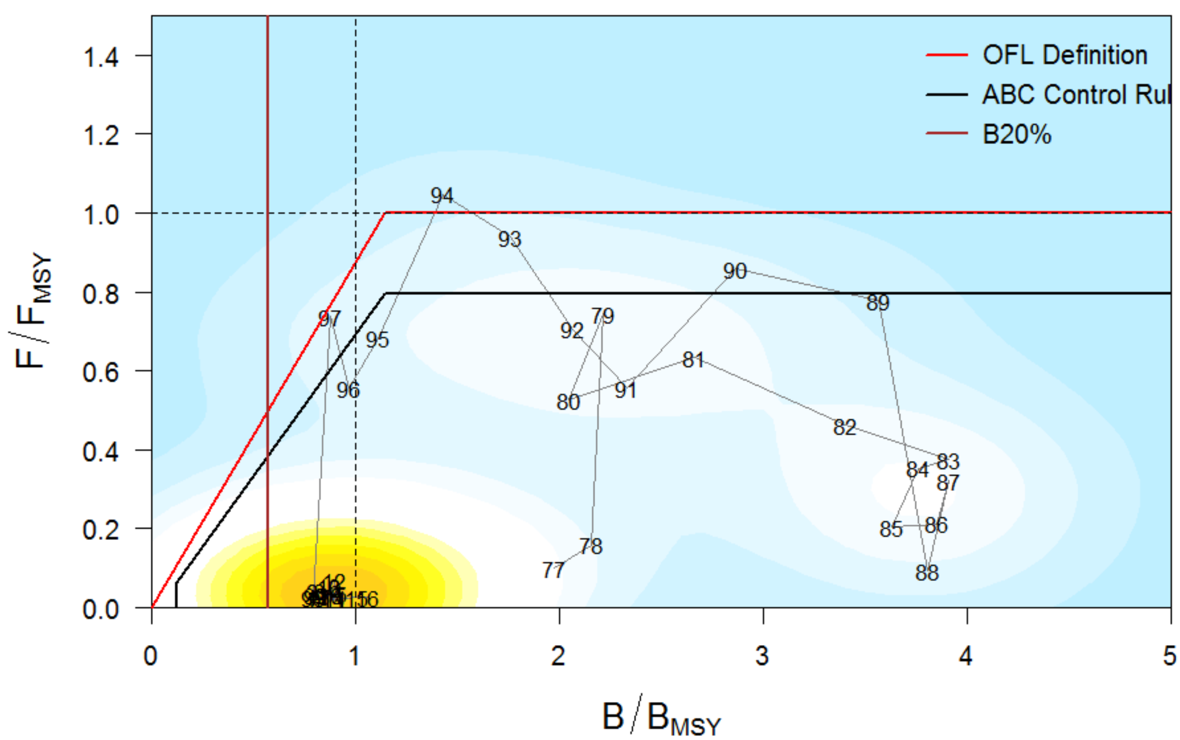

Figure 1A.22. Aleutian Islands pollock spawning biomass relative to B_{msy} and full-selection fishing mortality relative to F_{msy} (1978-2018). The ratio of fishing mortality to F_{msy} is calculated using the estimated selectivity pattern in that year. Color is scaled relative to density of points in the region from high orange to low blue. 2017 and 2018 are plotted with catch assumed to be at the five-year average F (Alternative 3).

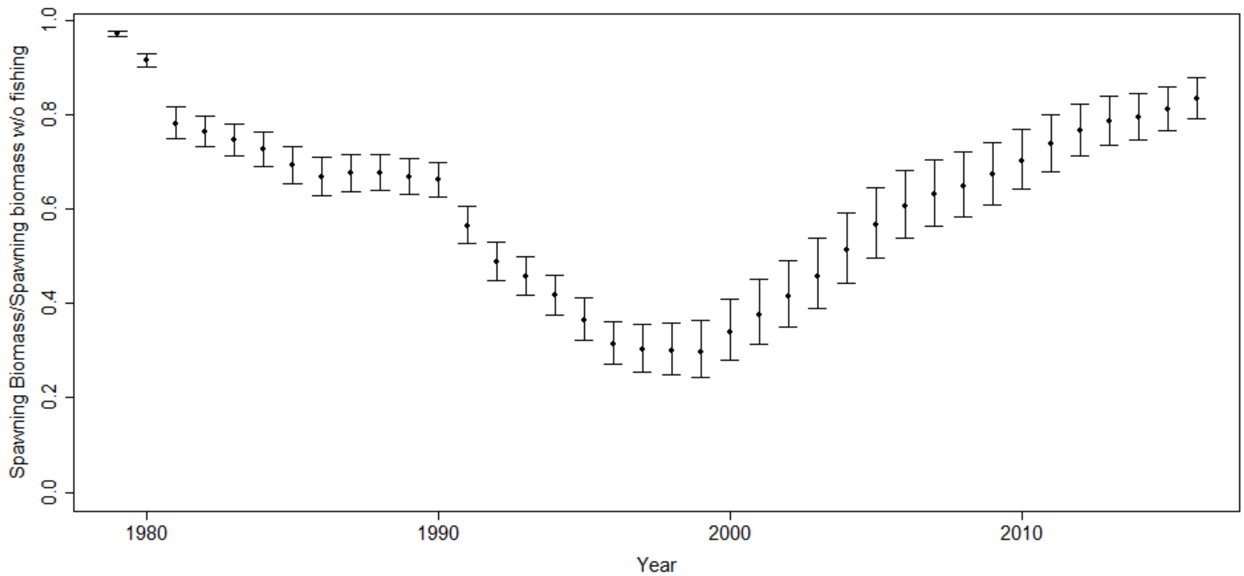

Figure 1A.23. Aleutian Islands pollock ratio of spawning biomass with fishing relative to spawning biomass without fishing for the authors' preferred model with 95% confidence interval.

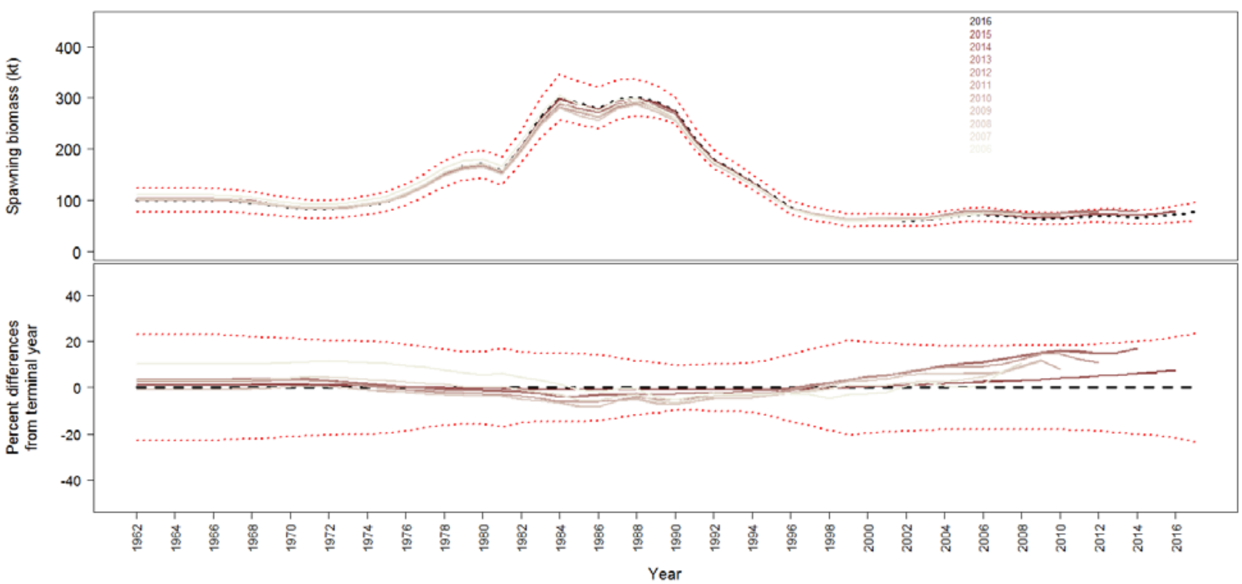

Figure 1A.24 Retrospective analysis for Authors' preferred Model 15.1 with data for the previous 10 years being systematically removed from the model. Black dashed line is the 2016 Model 15.1 estimate, the red dotted lines are the 95% confidence intervals calculated as ±1.96×standard deviation.

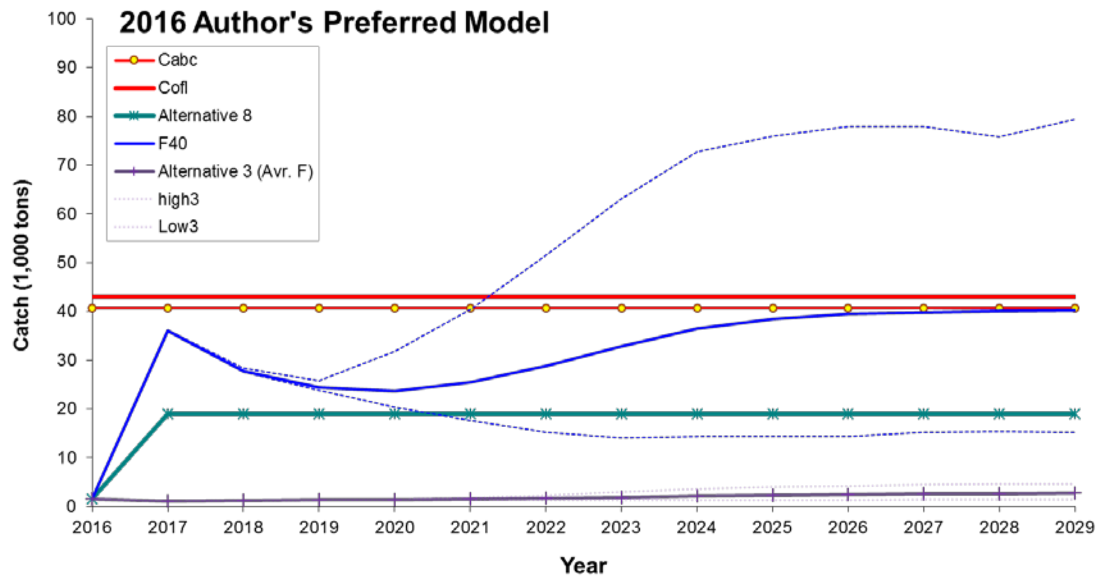

Figure 1A.25 Authors' preferred Model 15.1 projected catch for $F_{40\%}$, Alternative 3 (average F), and Alternative 8 (19,000t) ABC scenarios.

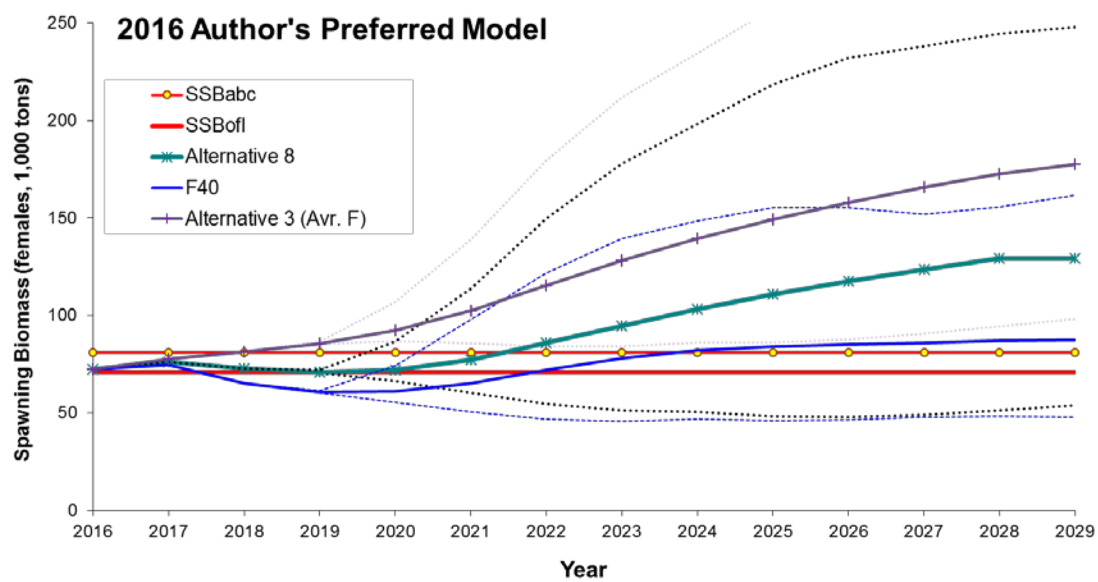

Figure 1A.26 Authors' preferred Model 15.1 projected spawning biomass for $F_{40\%}$ Alternative 3 (average F), and Alternative 8 (19,000t) ABC scenarios.

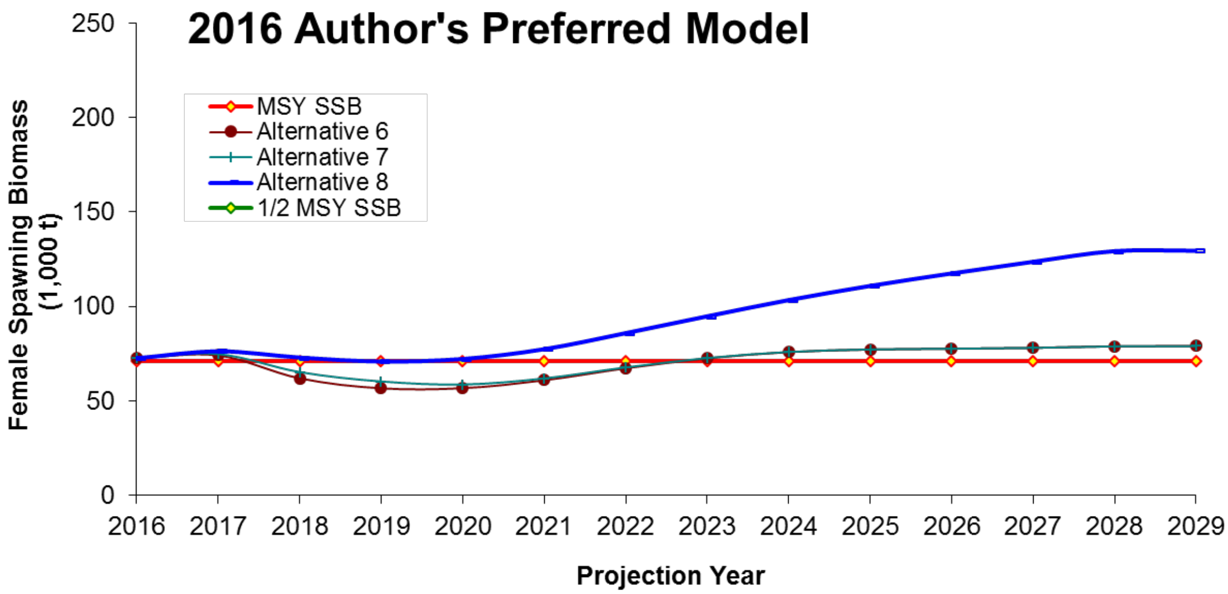

Figure 1A.27 Authors' preferred Model 15.1 projected spawning biomass for MSY, ½MSY, and Alternatives 6, 7, and 8 ABC scenarios from the authors' preferred model.

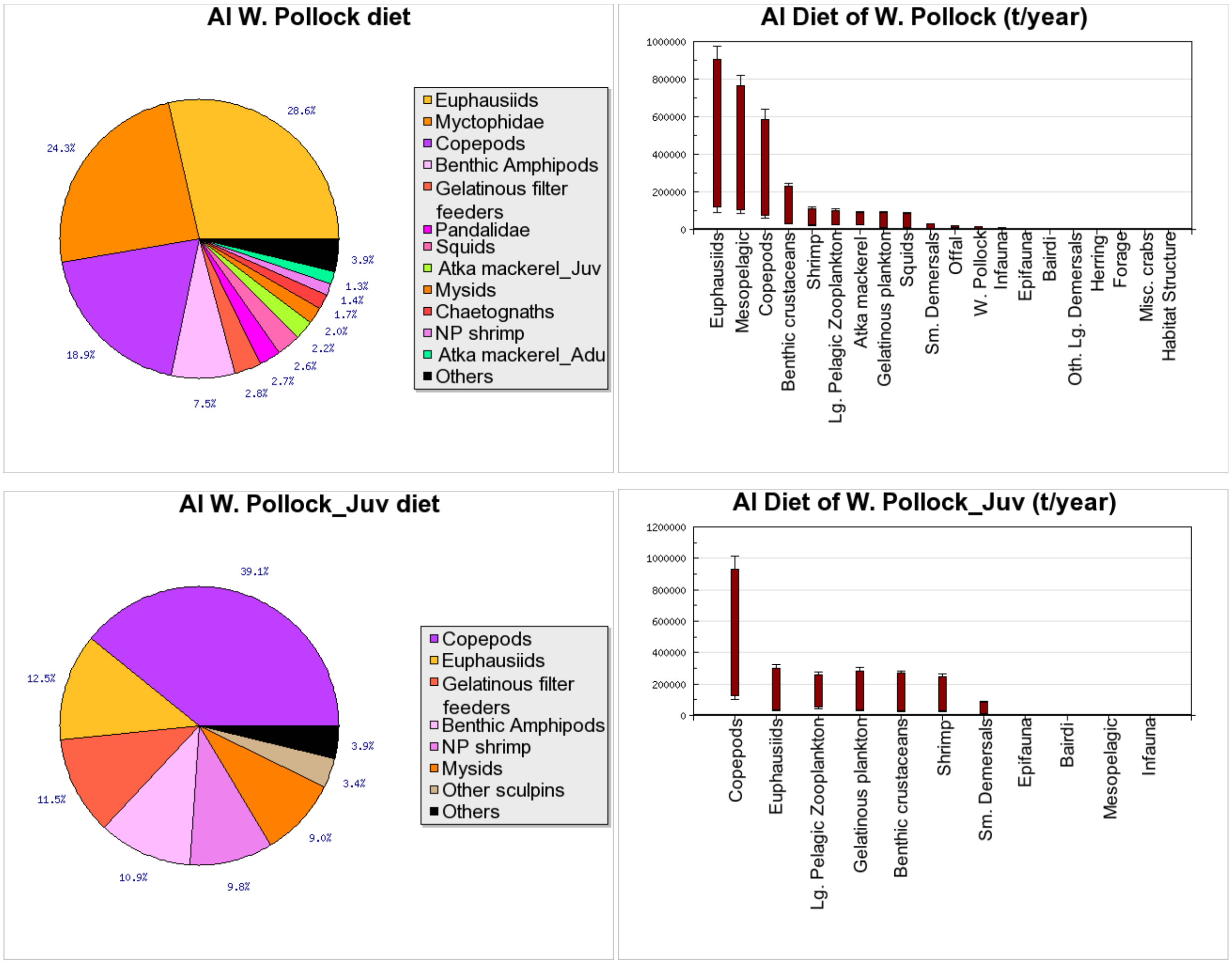

Figure 1A.28. Diet composition (left) and estimated consumption of prey (right) by AI adult (top) and juvenile (bottom) pollock. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994. See Appendix A Barbeaux et al. 2006 for detailed methods.

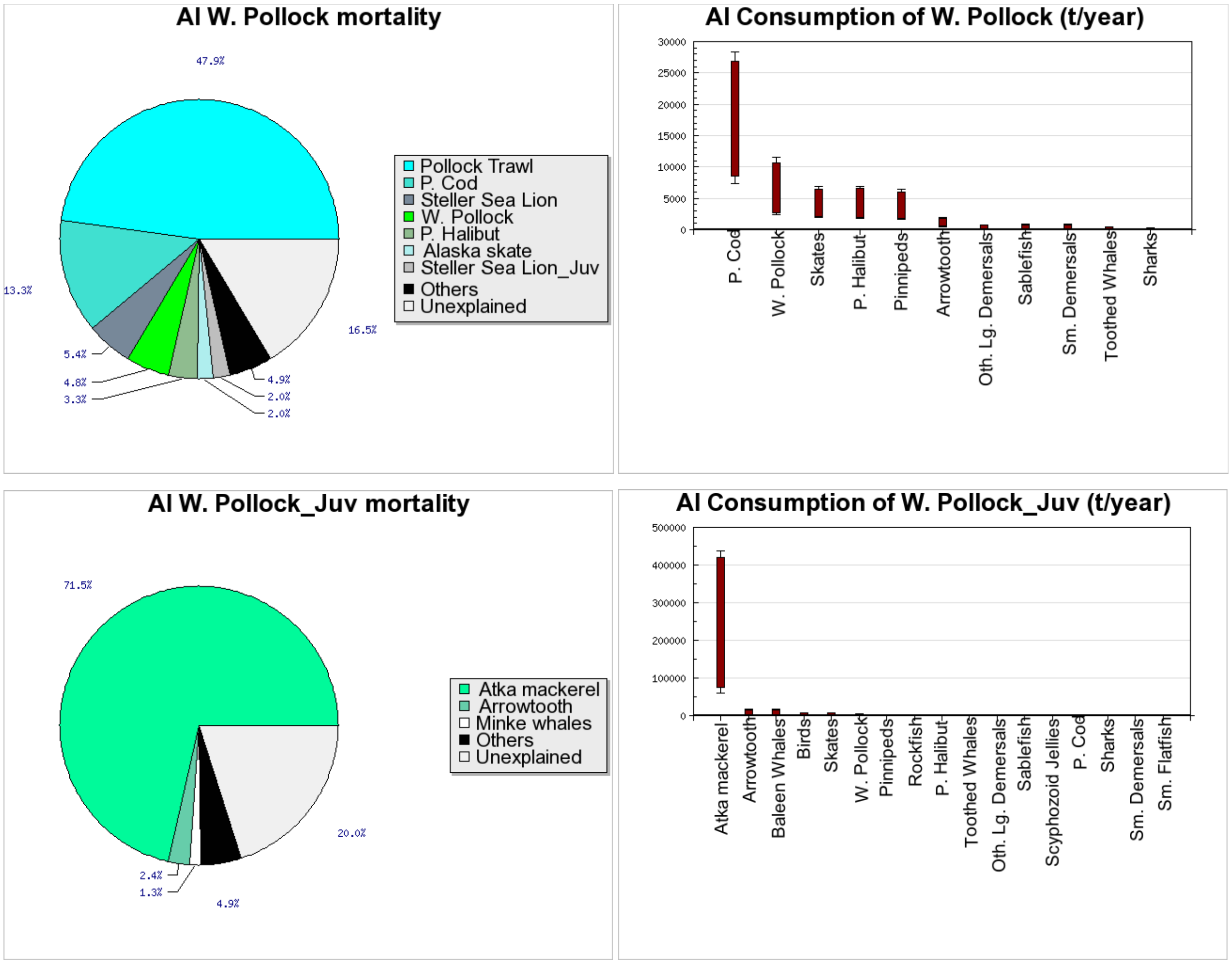

Figure 1A.29. Mortality sources (left) and estimated consumption by predators (right) of AI adult (top) and juvenile (bottom) pollock. Mortality sources reflect pollock predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994, pollock predator consumption 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.

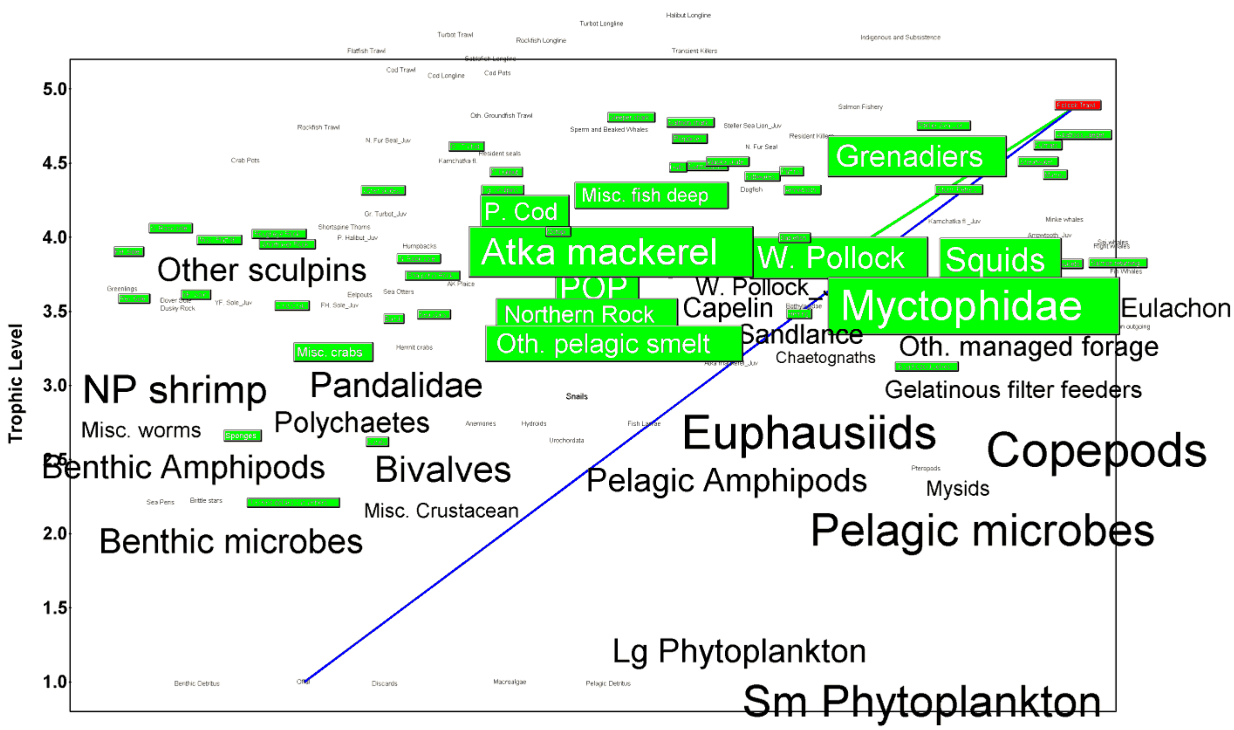

Figure 1A.30. The pollock trawl fishery in the AI food web. Species taken by the pollock fishery (in red) are highlighted in green, with the most significant flow to pollock indicated with a green line. Box size is proportional to biomass and lines between boxes represent the most significant energy flows. From Aydin et al. (2007).

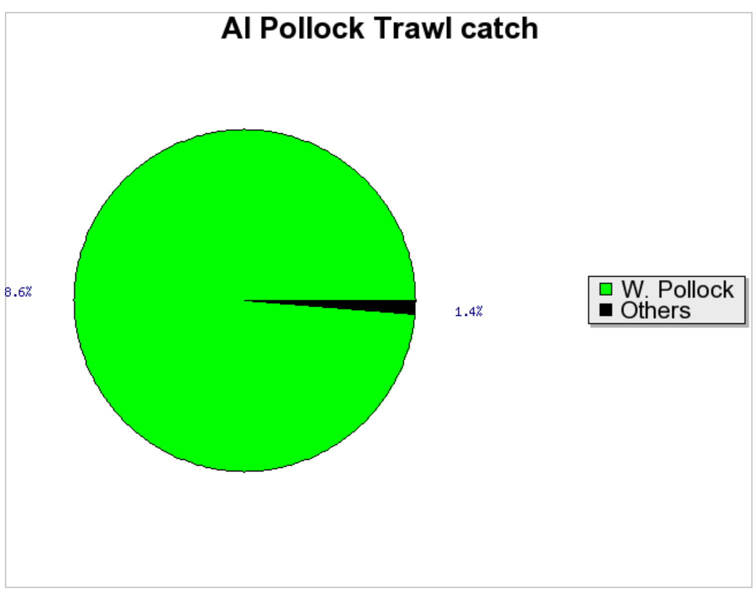

Figure 1A.31. Catch composition of the AI pollock trawl fishery during the early 1990's, as used in the food web model (Aydin et al. 2004).

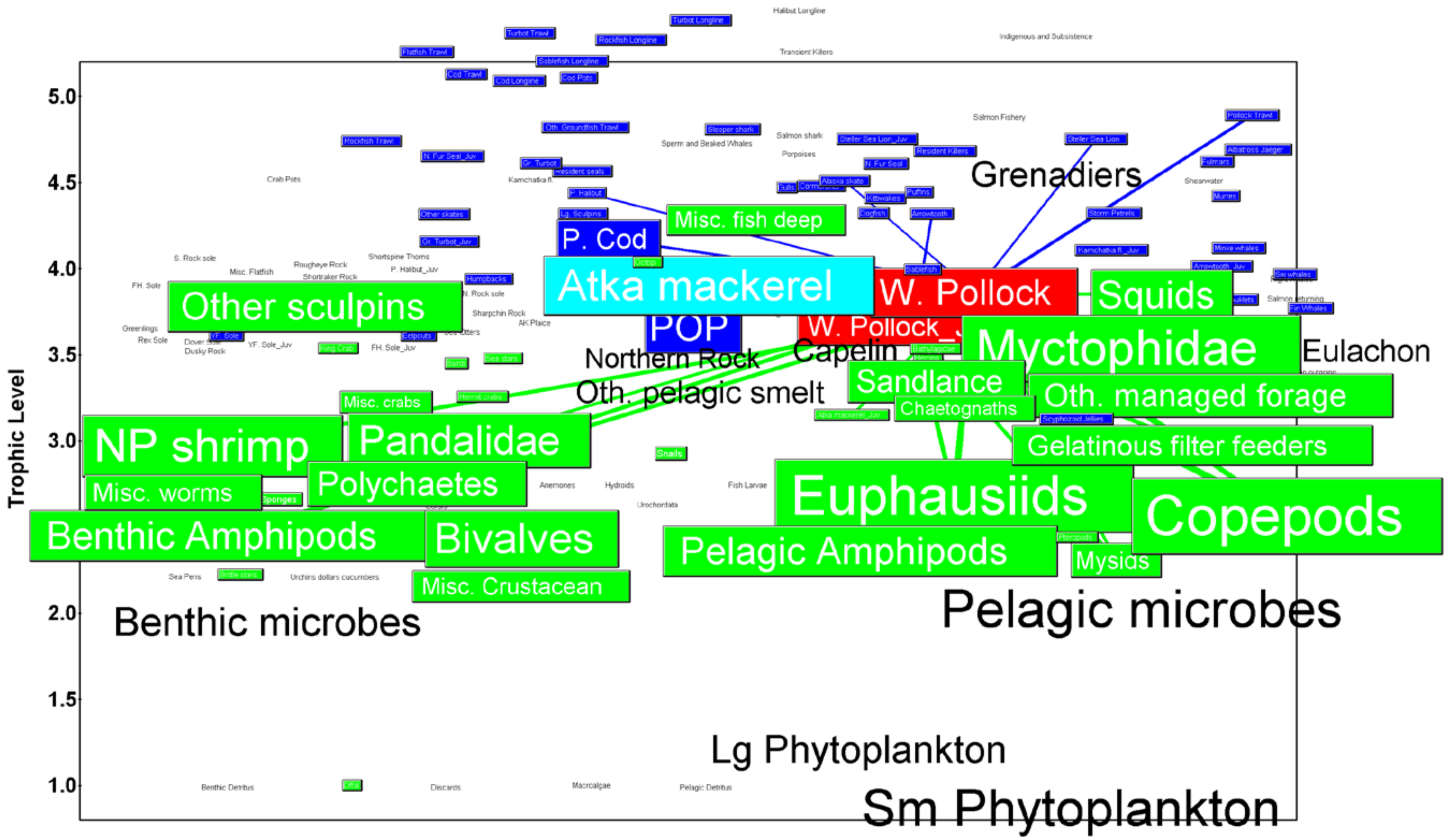

Figure 1A.32. Adult and juvenile pollock (highlighted in red) in the AI food web (Aydin et al 2004). Predators of pollock are dark blue, prey of pollock are green, and species that are both predators and prey of pollock are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.

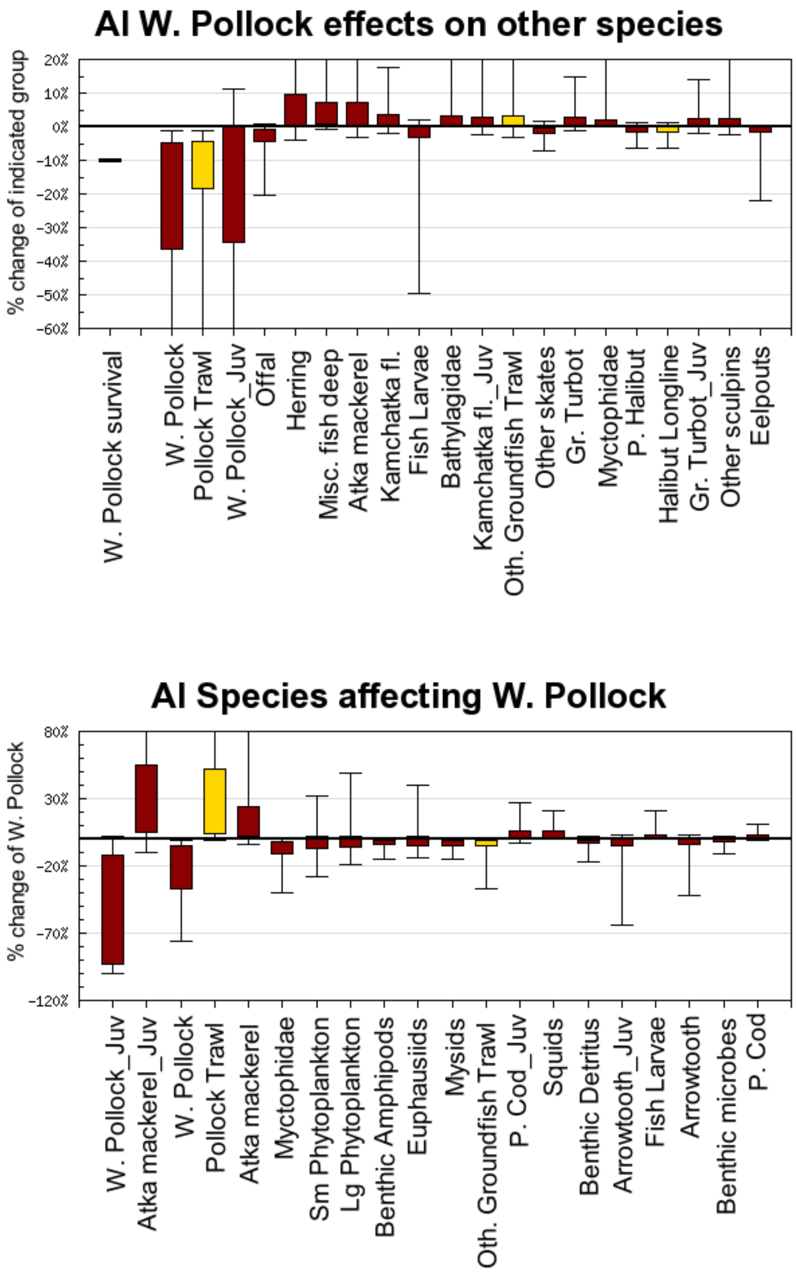

Figure 1A.33. (upper panel) Effect of changing pollock survival on fishery catch (yellow) and biomass of other species (dark red), from a simulation analysis where pollock survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. (lower panel) Effect of reducing 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. 2007 for detailed Sense methods).

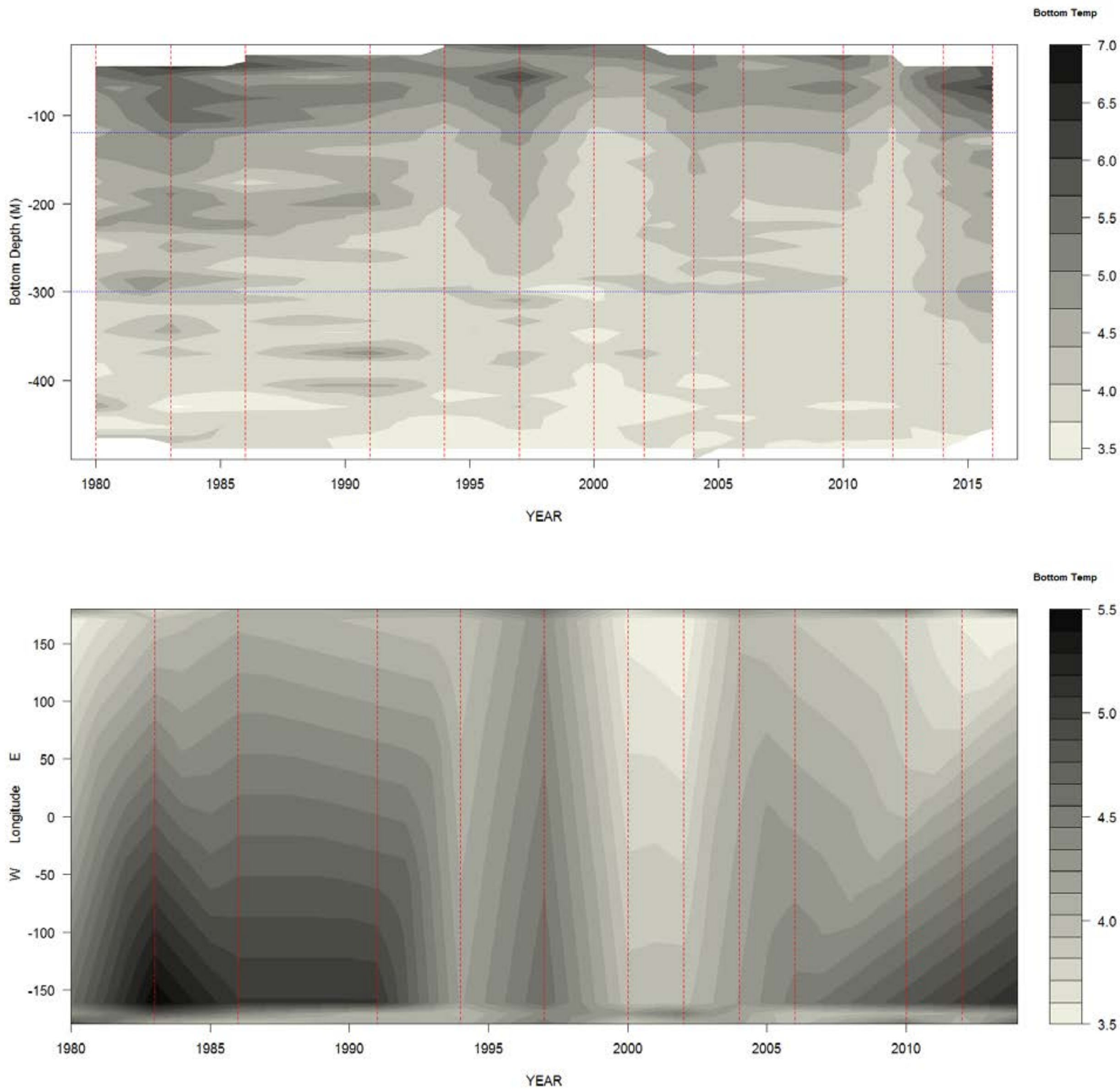

Figure 1A.34 Mean bottom temperatures by 10 m bottom depth (top) and by 1 degree longitude (bottom) by year. Red lines indicate years with survey data. Note the E longitudes (positive values) are further west in the Aleutian Islands. Blue lines are at -120 and -300, the area of highest densities for pollock in the AI.

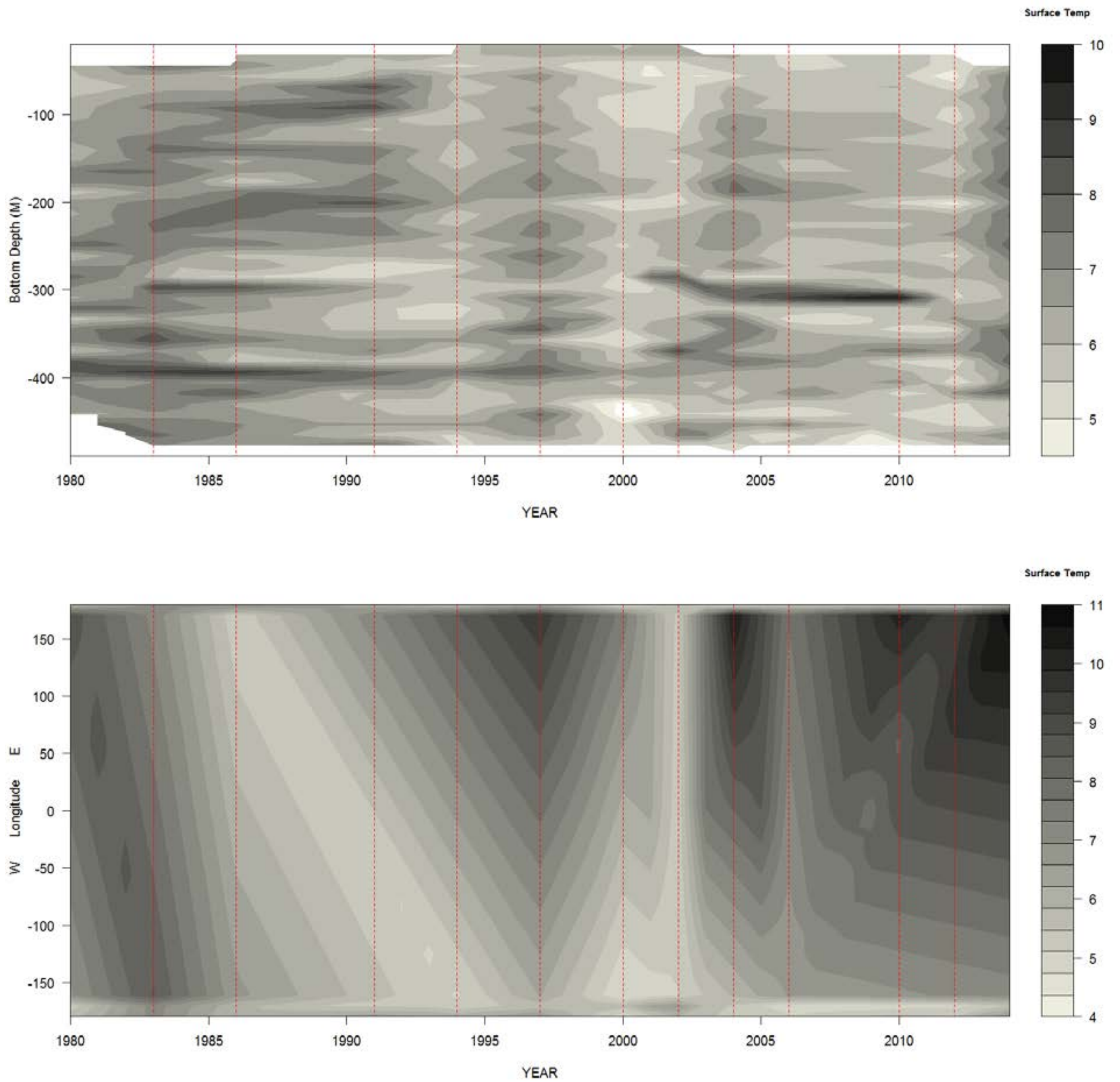

Figure 1A.35 Mean surface temperature by 10 m bottom depth (top) and 1 degree longitude (bottom) by year. Red lines indicate years with survey data. Note the E Longitudes (positive values) are further west in the Aleutian Islands

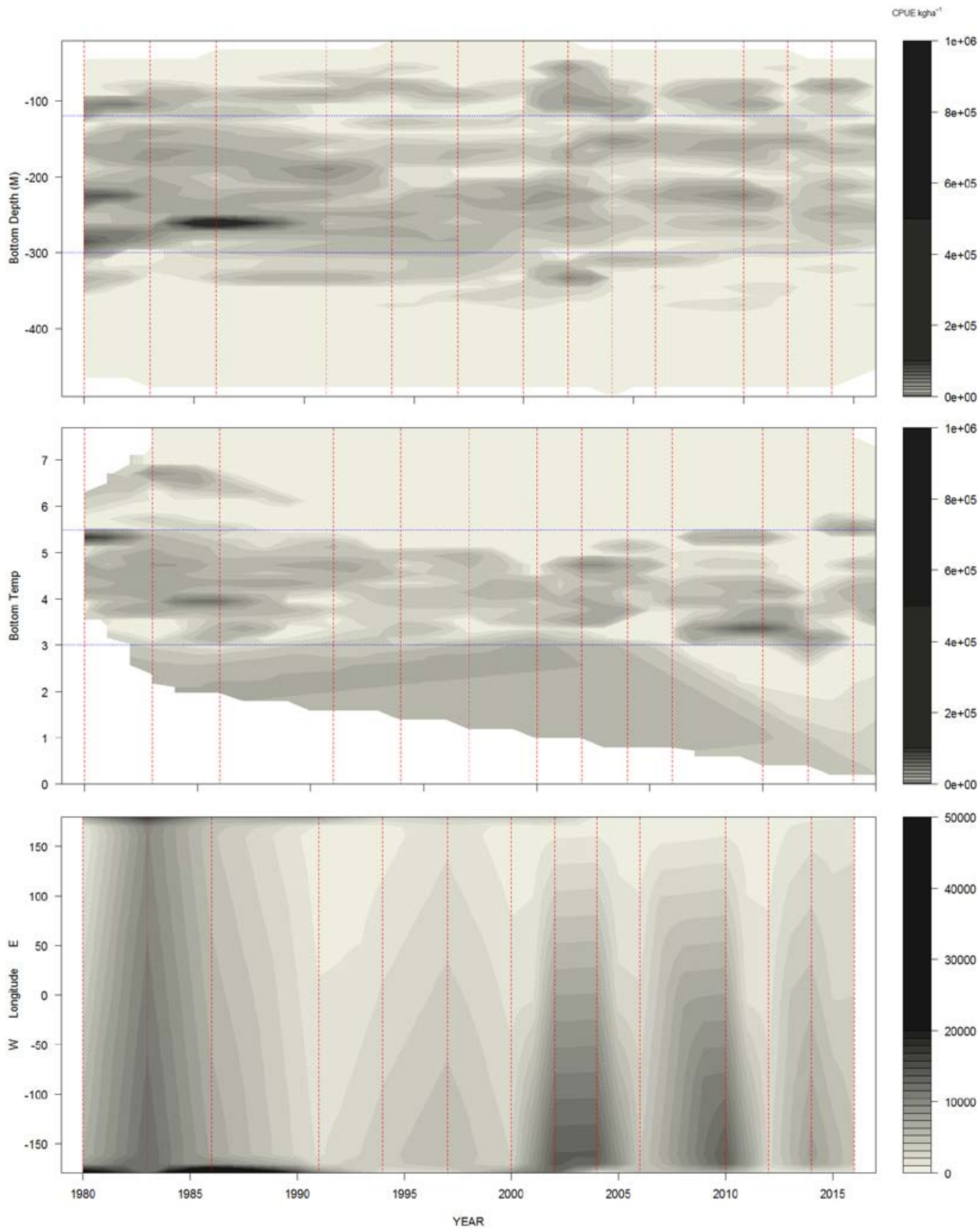

Figure 1A.36 Pollock CPUE kgha^{-1} by 10 m bottom depth (top), 0.1 °C bottom temperature (middle), and 10° longitude (bottom).

Appendix 1A-A

Table A-1. Variable descriptions and model specification for Authors' Preferred Model.

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: i = {1963, …., 2015}	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	Fit with M=0.20 and CV = 0.2, constant over all ages for Models 15.1 Model 15.2 M = vector fit as deviates from initial M.
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, …, 2015	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	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \neq$ 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	$L_1 = \lambda_1 \sum_i \ln\left(Y_i^s \big/ \hat{Y}_i^s\right)^2 \frac{1}{2\sigma_i^2}$	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	$L_4 = \lambda_4 \sum_{i=1963}^{2007} \ln\left(C_i \big/ \hat{C}_i\right)^2$	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 2016 recommended ABC of 36,061 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.

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

	NMFS Acoustic	Bottom Trawl	ABL Long Line	AICASS*	IPHC	Japanese Surveys	Atka Tagging	Total
1978								
1979								
1980	2.5	37.9				97.7		138.10
1981								
1982	5.7	0.8						6.50
1983		28.1				396.7		424.80
1984								
1985								
1986		10.6				248.1		258.70
1987								
1988								
1989								
1990								
1991		30.0						30.00
1992								
1993								
1994		26.9						26.90
1995								
1996			0.09					0.09
1997		23.2						23.20
1998			0.11					0.11
1999								
2000		30.9	0.05					30.95
2001								
2002		35.5	0.10					35.60
2003								
2004		18.2	0.06					18.26
2005								
2006		17.8	0.05					17.85
2007								
2008			0.05	7.6				7.65
2009								
2010		35.3	0.26		0.02			35.58
2011					0.06		3.2	3.26
2012		13.0	0.16		0.01			13.17
2013					0.05			0.05
2014		20.7	0.23		0.10			21.03
2015					<0.01			<0.01
2016								

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