1A Stock Assessment of Aleutian Islands Region Pollock

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Executive Summary

Development of a detailed age-structured stock assessment for the Aleutian Islands Region pollock began in 2003 (Barbeaux et al. 2003) and has since been developed further (Barbeaux et al. 2007). In the initial study the near shore areas of the Aleutian chain island were isolated and identified as the Near, Rat, and Andreanof Island (NRA) sub-area. In 2006 and 2007 the stock assessment data set was further refined to exclude fisheries data from the area east of 174°W to address data consistency issues. The Council supported this proposal and urged continuing development of an age-structured assessment model using data from the area west of 174°W (and omitting deep-water areas where survey data are unavailable).

A review of the 2007 Aleutian Islands region pollock stock assessment was conducted by the Center for Independent Experts (CIE). In previous assessments data from the eastern boundary of the Aleutian Islands region (between 174°W and 170°W) were excluded from all of the age-structured assessment models, but summer Aleutian Islands bottom trawl (AIBT) survey data from this area were used. The CIE review panel had concerns with the approach of using different area partitions for the survey and fisheries data. To address these concerns we ran two sets of models; one with all fisheries and survey data for the NRA subarea, and with all survey data for the NRA subarea and fisheries data from the NRA area west of 174°W (preferred model from 2007). Additionally, the CIE panel suggested that survey selectivity should not vary inter-annually. In this year's assessment we conducted model runs with both varying and fixed survey selectivity. In previous year's models the maximum age at which fisheries selectivity was allowed to change was set at 12 years, the panel suggested that this could be set earlier and model runs with the maximum set at 8 years were investigated.

Summary of major changes

- A bootstrap method (described in the 2008 Atka Mackerel Assessment; Lowe et al 2008) was used for computing annual catch-at-age and average weight-at-age. This method also produced new estimates of the multinomial catch-at-age sample sizes used in the assessment model. Previous years employed the Delta method to obtain variance estimates that were then used to compute the multinomial sample sizes.
- A constant value of 100 was used for the multinomial sample size for survey catch-at-age, except for the 1991 survey which was down-weighted due to issues with pollock age structure sampling locations not being representative of the entire survey.
- The maturity schedule used in this year's model is the mean percentage mature for 1983-2006 from the 2007 Gulf of Alaska pollock model instead of that estimated for the Bering Sea in 1984 by Westpestad and Terry.
- Unlike previous years survey selectivity is not allowed to change inter-annually. Model runs with changing selectivity were tested and it was found that the improvements to the model did not outweigh the cost of the additional parameters.
- Steepness is no longer estimated within the model, but set at 0.7 with a CV of 0.2. Previous years' MCMC runs that attempted to fit steepness in the model show a nearly uniform distribution between the parameter bounds which were previously mistaken to be the edge of a wider

distribution. Model runs with different steepness parameters (0.5-0.8) showed little difference in the results with approximately 4% difference from 2009 estimates of spawning and total biomass (± 2,900 t spawning biomass;).

- In last year's assessment fisheries selectivity was allowed to vary each year with a medium constraint on change (CV = 0.3), in this year's models fisheries selectivity can only vary between 1991 and 1992 and 2005 and 2006 with a low constraint on change (CV = 0.6) or not at all. Model runs not presented were conducted which showed little to no difference between the two configurations, but the new configuration greatly increased parsimony of the model.
- For both fisheries and survey selectivity the constraint on changes to selectivity between ages was increased (from CV = 0.6 to CV = 0.2) allowing for a smoother selectivity curve than in previous years' models.
- In response to the CIE panel suggestions the ages selected to have average catchability equal to 1.0 was changed from 8-10 years to 5-12 years and the time range for estimating mean recruitment was changed from 1990-2007 to 1978-2006.
- In response to the CIE panel the reference model uses all NRA fishery and survey data. In previous assessments the reference model was based on fishery catch data clipped at 174° W and all survey data. This was thought by the CIE panel to be inconsistently treating the two data sources without proper justification.
- In response to the CIE review panel we chose a different fishery selectivity-at-age vector for the projection model. In previous assessments the most current Bering Sea pollock fishery selectivity-at-age was used in the projection model, for this year we used the average selectivity curve fit in the Aleutian Islands pollock model for 2003 - 2007. In the case of the reference model fishery selectivity does not vary inter-annually and therefore the projection model uses the fitted selectivity-at-age vector.

Changes in the assessment results

- The use of all NRA catch data in the reference model greatly inflates the estimated biomass in the 1980's, thus inflating the reference points such that the decline in the stock in the 1990's is exaggerated compared to previous years. In the reference model the 1999 spawning biomass was estimated to be at $B_{20.7\%}$. In this year's reference model $B_{100\%}$ is 282,820 t while in last year's it was 100,945t.
- The GOA maturity schedule used in this year's assessment results in a lower proportion mature at age for younger fish, therefore reducing the estimated female spawning biomass from last year's assessment. When the maturity schedule is the only factor changed, total biomass decreases by 5%, but the spawning biomass estimate decreases by 20% .
- Changes to the fishery selectivity-at-age vector used in the projection model impacts the older aged fish (10+) relative to last year's assessment resulting in changes in $F_{40\%}$ (from 0.196 to 0.288) and $F_{35\%}$ (from 0.38 to 0.357).
- The maximum permissible ABC for 2009 and 2010 under Tier 3b are 26,873 t and 30,363 t, respectively. The OFL for 2009 and 2010 under Tier 3b are 32,553 t and 36,769 t respectively. The maximum permissible ABC under Tier 5 using the 2006 bottom trawl survey for both years is 15,290 t and the OFL is 20,386 t.

Response to SSC 2007 Comments

In general the SSC asked authors to present the probability of the stock being below $B_{20\%}$ if the stock was being managed under Tier 3b. There is a 0.36% probability of the AI pollock stock being below $B_{20\%}$ in 2009.

There were no comments from the SSC in 2007 specific to the AI pollock stock assessment.

Summary Table

Model A.SF.8.8 Parameters

Natural Morality: M = 0.215

Initial Biomass (1978): B_0 = 301,200 t

2009		
Maximum permissible ABC:	Tier 3b Model A.SF.8.8 $F_{40\%}$ = 0.288	yield = 26,873 t
	Tier 5 (M=0.215)	yield = 15,290 t
	Tier 5 (M = 0.3)	yield = 21,370 t
Overfishing (OFL):	Tier 3b Model A.SF.8.8 $F_{35\%}$ = 0.357	yield = 32,553 t
	Tier 5(M = 0.215)	yield = 20,386 t
	Tier 5 (M=0.3)	yield = 28,500 t
2010		
Maximum permissible ABC:	Tier 3b Model A.SF.8.8 $F_{40\%}$ = 0.312	yield = 30,364 t
	Tier 5 (M=0.215)	yield = 15,290 t
	Tier 5 (M = 0.3)	yield = 21,370 t
Overfishing (OFL):	Tier 3b Model A.SF.8.8 $F_{35\%}$ = 0.378	yield = 36,769 t
	Tier 5(M = 0.215)	yield = 20,386 t
	Tier 5 (M=0.3)	yield = 28,500 t

Model A.SF.8.8 Equilibrium female spawning biomass

$B_{100\%}$ = 282,820 t

$B_{40\%}$ = 113,128 t

$B_{35\%}$ = 98,987 t

Model A.SF.8.8 Projected 2009 biomass

Age 3+ biomass = 266,346 t

Female spawning biomass = 85,480 t

Introduction

Walleye pollock (*Theragra chalcogramma*) are distributed throughout the Aleutian Islands with concentrations in areas and depths dependent on season. Generally, larger pollock occur in spawning aggregations during February – April. Three stocks of pollock inhabiting three regions in the Bering Sea – Aleutian Islands (BSAI) are identified in the U.S. portion of the BSAI for management purposes. These stocks are: the eastern Bering Sea pollock occupying the eastern Bering Sea shelf from Unimak Pass to the U.S.-Russia Convention line; the Aleutian Islands Region pollock encompassing the Aleutian Islands shelf region from 170°W to the U.S.-Russia Convention line; and the Central Bering Sea—Bogoslof Island pollock. These three management stocks probably have some degree of exchange. The Central Bering Sea—Bogoslof stock is a group that forms a distinct spawning aggregation that has some connection with the deep water region of the Aleutian Basin. In the Russian Exclusive Economic Zone (EEZ), pollock are thought to form two stocks, a western Bering Sea stock centered in the Gulf of Olyutorski, and a northern stock located along the Navarin shelf from 171°E to the U.S.- Russia Convention line. The northern stock is believed to be a mixture of eastern and western Bering Sea pollock with the former predominant. Bailey et al. (1999) present a thorough review of the population structure of pollock throughout the north Pacific region. Recent genetic studies using mitochondrial DNA methods have found the largest differences to be between pollock from the eastern and western sides of the north Pacific.

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 “Basin” pollock. This problem was confirmed in the 2003-2007 Aleutian Islands pollock stock assessments (Barbeaux et al. 2007).

Fishery

The nature of the pollock fishery in the Aleutian Islands Region has varied considerably since 1977 due to changes in the fleet makeup and in regulations. During the late 1970s through the 1980s the fishing fleet was primarily foreign and joint venture (JV) where US catcher vessels delivered to foreign motherships. The last JV delivery was conducted in 1989 when the domestic fleet began operating in earnest. The distribution of observed catch differed between the foreign and JV fishery (1977-1989) and the domestic fishery (1989-2008; Fig. 1A.1). The JV and foreign fishery operated in the deep basin area extending westward to Bowers Ridge and in the eastern most portions of the Aleutian Islands. Some operations took place out to the west but observer coverage was limited. In the early domestic period (1991-1998) the fishery was more dispersed along the Aleutian Islands chain with no observed catches along Bowers Ridge and fewer operations in the deep basin area. The majority of catch in the beginning of the domestic fishery came from the eastern areas along the 170°W longitude line, and around Seguam Island in both Seguam and Amukta passes. As the fishery progressed more pollock were removed from the north side of Atka Island around 174°W and later near 177°W northwest of Adak Island inside Bobrof Island. While the overall catch level was relatively low, the domestic fishery moved far to the west near Buldir Island in 1998 (Fig. 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.

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

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, in review). 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 2006 study 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 2008, through October 20, the directed pollock fishery in the Aleutian Islands region has taken 392 t and 802 t have been taken as bycatch in other fisheries, predominantly the Pacific cod and rockfish fisheries. Table 1A.1 provides a history of ABC, OFL, and catch for Aleutian Islands pollock since 1991.

Data

Catch estimates

Estimates of pollock catch in the Aleutian Islands Region are derived from a variety of data sources (Table 1A.2). During the early period, the foreign-reported database (held at AFSC) is the main source of information and was used to derive the official catch statistics until about 1980 when the observer data were introduced to provide more reliable estimates. The foreign and joint-venture (JV) blend data takes into account observer data and reported catches and formed the basis of the official catch statistics until 1990. The NMFS Observer data are the raw observed catch estimates and provide an indication of the amount of catch observed relative to the current estimates from the blend data. The foreign reported catch database was used to partition catches among areas for the period 1977-1984, and the observer data were used to apportion catches from 1985-2003. These proportions were then expanded to match the total catch. Estimates of pollock discard levels have been available since 1990. During the years when directed fishing was allowed pollock discards represented a small fraction of the total catch (Table 1A.3).

Considering the spatial distribution of the foreign and domestic fisheries, we recommended that the Aleutian Islands Region data be subdivided where apparent spatial breaks existed (Fig. 1A.4). These breaks separate data from the northern “basin” area from the Aleutian Islands chain and split the data from the eastern-most portion of the Aleutian Islands Region from the Aleutian Islands. Two regional data partitions were developed along the Aleutian Islands chain, the western NRA (for Near, Rat, and Andreanof Island groups) including data from 174°W to 170°E, and the eastern NRA including data between 174°W and 170°W longitude. The time series of catch estimates for these two groups is shown in Table 1A.5.

Fishery length frequency

The number of hauls and length samples from the NRA region west of 174°W are quite small compared with the eastern and northern (basin) areas (Table 1A.6). Differences in the length frequencies appear to be substantial between regions (Barbeaux et al. 2004). During the early period, catches from the region west of 174°W longitude were composed of smaller fish. Catches from this region also tended to have a broader range of lengths. Fishery length frequency data from the Basin region were similar to the easternmost region and the Bogoslof region (during the years when a fishery was permitted). In the 2005 stock assessment we investigated whether the changes in length frequency distributions for the NRA region west of 174°W could be attributed to seasonal differences in concentrations of fishing effort. These investigations showed that before 1990, the fishery tended to be more concentrated later in the year, but inter-annually the fishery was consistent in time between the eastern and western NRA (Barbeaux et al. 2005). We therefore concluded that differences in length distributions observed between these two regions could not be attributed to differences in the time of year in which the fishery was conducted. Intra-annual differences may show a trend that would be consistent with seasonality differences. The occurrence of larger fish later in the time series is likely due to the fishery targeting on spawning pollock. Pollock average weights-at-age from the early period are lower than the recent period (Table 1A.7). As shown in the 2005 assessment, the observed proportion of females in the catch appeared to show a slight decline over this same period (Barbeaux et al. 2005).

Fishery age composition

Catch-at-age composition estimates were calculated using a new bootstrap method developed by Ianelli and presented in this year’s Atka mackerel stock assessment. Otoliths, weight, and length samples were collected through shore-side sampling and by at-sea observers. The number of age samples and length samples was highly variable over this time period (Table 1A.8). This problem is exacerbated for samples collected from different areas and gears (Table 1A.9). Estimates of the catch-age compositions are shown in Table 1A.10. The age composition data collected in the 2006 AICASS were used as fishery data.

Survey data

Bottom trawl survey effort in the Aleutian Islands region has not been as extensive as in the eastern Bering Sea. 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 and 2006. The Aleutian Islands bottom trawl survey planned for 2008 was canceled due to budgetary contraints. Biomass estimates from surveys conducted in the 1980s ranged between 309 and 779 thousand tons (mean 546 thousand t). Biomass estimates from the five most recent RACE surveys ranged between 112 and 366 thousand tons (mean 225 thousand t; Table 1A.11). The biomass estimates from the early surveys 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. Plotted on a simple catch-per-tow basis, the relative distribution of pollock appears to be variable between years and areas (Fig. 1A.3).

The RACE Aleutian Islands bottom trawl (AIBT) surveys prior to 2004 indicate that most of the pollock biomass was located in the Eastern Aleutian Islands Area (Area 541), and along the north side of Unalaska-Umnak Islands in the eastern Bering Sea region (~165°W and 170°W). The 2004 Aleutian Islands trawl survey showed the highest density and estimated biomass levels in the Unalaska-Umnak area in the eastern Bering Sea region. However, the 2006 survey observed only low densities of pollock in the Unalaska-Umnak Islands area. If we ignore the biomass estimates from the Unalaska-Umnak area, the 2004 and 2006 AIBT surveys are very similar and show a very different pattern of biomass abundance relative to the 2002 survey (Fig. 1A.4). Within the Aleutian Islands Region (Areas 541, 542, and 543), the 2002 AIBT survey indicated the highest densities and abundance levels to be in the Central Aleutian Islands Area (Area 542), followed by the Eastern (Area 541) and Western areas (Area 543). The 1991-2000 AIBT surveys indicated the highest pollock abundance to be in Area 541 followed by Area 542 and Area 543. The earlier RACE AIBT surveys indicated a decline in pollock abundance in the portion of Area 541 east of 174°W longitude, from a high of 53,865 t in 1991 to a low of 28,985 t in the 2000 survey. This trend was reversed beginning in the 2002 survey with estimates of 53,368 t, 111,250 t, and 69,522 t from the 2002, 2004, 2006 surveys, respectively (Table 1A.11). 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 and 2006 survey estimates which indicated a low level of pollock abundance in both Area 542 and Area 543, and a much higher pollock density in Area 541. The 2004 survey revealed very few pollock throughout the NRA, except for a single large tow in Seguam Pass. The distribution of pollock in the 2006 survey revealed a similar pattern to that of the 2004 survey with high CPUE in the Seguam pass area. The 2006 survey found a higher concentration of pollock in the Delerof Islands that was not observed in 2004, but is consistent with aggregations observed in 2002. Similar to the 2004 survey, there were very few pollock observed west of 180° longitude. Given that there has not been a substantial fishery in the Aleutians since 1999, nor has there been a substantial change in survey methodology or design, the continued decrease in pollock must be attributed to either a change in catchability due to vertical migration of pollock out of the reach of the bottom trawl, increased emigration of pollock out of the surveyed area, decreased recruitment, increased natural mortality exceeding recruitment, or some combination of these factors. Since the AIBT is limited to within the 500 m isobath, the survey biomass estimates do not include mid-water pollock, nor do they include pollock located offshore of the 500 m isobath. Survey biomass estimates therefore represent an unknown portion of the total biomass. The biomass in the Aleutian Islands may be under-estimated if the on-bottom/off-bottom distribution is similar to that of the eastern Bering Sea (Ianelli et al. 2005). In addition, climatic and year class variation may cause differences in the proportion of pollock available to the bottom trawl survey.

Survey Length Frequencies and Proportion at age

The pollock length frequency collection from the 2006 AIBTS showed the primary mode between 56 and 66 cm, similar to previous years and was primarily composed of the 2000 year-class (Tables 1A.12, Table 1A.13, and Fig. 1A.4). There was a small mode between 15 and 25 cm that would be consistent with 1 or 2 year old fish, but much fewer than observed in 2004. The 2004 AIBT survey found a large proportion of small fish (between 10 and 25 cm, indicative of 1 or 2 year old fish) in the NRA area west of 174°W, but very few small fish east of 174°W. The 2002 AIBT survey did not find very many small fish anywhere in the Aleutians. There were a large number of small fish observed in the 1994 and 2000 surveys throughout the NRA . The large numbers of 1 or 2 year old size pollock observed in the these surveys were assumed to have entered the fishable population in 1996 and 2002, respectively, and should have stabilized or increased pollock biomass in the Aleutian Islands in recent years.

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; Fig. 1A.5). Due to difficulties in operating their large mid-water trawl on the steep slope area, they determined that their biological sampling in this area were insufficient for accurate species identification and biomass estimation. They did, however, present preliminary biomass estimations. For the entire area from 170°W and 178°W longitudes they estimated a biomass of 93,000 t of spawning pollock biomass with between 61,000 t estimated in the NRA east of 173°W, and 32,000 t in the remainder of the survey area to 178°W longitude (Table 1A.14). The largest aggregations of pollock in the NRA area were observed at 174°W longitude north of Atka Island. Most of the pollock echo sign was observed along the slope of the Aleutian Islands and relatively near shore.

In 2006, and 2007 acoustic survey studies were completed in the central Aleutian Islands region aboard a 32m commercial trawler (F/V Muir Milach) equipped with a 38kHz 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 were presented in last years assessment (Barbeaux et al 2007). In 2007 two acoustic surveys were conducted (Fig. 1A.6 and Fig. 1A.7), the first was completed between March 18 and 24 March 2007 and the second between 8 April and 15 April, 2007. For both 2007 surveys, the region between 173° and 179° W longitude was surveyed at 2.5 nm transect spacing perpendicular to the shelf break one mile inland from the break and five mile offshore of the break or until pollock sign was no longer observed. Acoustic data from 88 transects were collected over approximately 6,949 nm² between 173°W-179°W providing a biomass index for both survey periods (Fig. 1A.8). The pollock biomass estimate for survey 1 was 15,646 t. In Survey 2 the total pollock biomass was estimated at 12,906 t. The spatial distribution of pollock varied between surveys with apparent pollock abundance decreasing in the Tanaga and Knoll areas and increasing elsewhere. The first survey estimated there to be 9,601 t of the pollock biomass in the Tanaga area, 4,536 t in the Knoll area, 2,452 t in Atka Flats area, 1,974 t in the Adak area, and 1,046 t in the Delarofs area. The second survey survey estimated there to be 6,403 t of pollock in the Atka flats area, 3,068 t in the Adak area, 2,606 t in the Knoll area, 1,494 t in the Delarofs area, and only 3,016 t remaining in the Tanaga 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 (Fig. 1A.9). 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 208 surveys were consistent with each other with a mode between 60 and 65 cm, but were larger than the pollock observed in the 2006 and 2007 surveys (Fig. 1A.10).

Analytic Approach

The 2008 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, with some small adjustments to the model and a user-friendly graphic interface.

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

Model structure

The AMAK model models catch-at-age with the standard Baranov catch equation. The population dynamics follows numbers-at-age over the period of catch history with natural and age-specific fishing mortality occurring throughout the 14-age-groups that are modeled (ages 2-15+). Age-2 recruitment in each year is estimated as deviations from a mean value expected from an underlying stock-recruitment curve. Deviations between the observations and the expected values are quantified with a specified error model and cast in terms of a penalized log-likelihood. This overall log-likelihood (L) is the weighted sum of the calculated log-likelihoods for each data component and model penalties. The component weights are inversely proportional to the specified (or in some cases, estimated) variances. Appendix A Tables 1 – 3 provide a description of the variables used, and the basic equations describing the population dynamics of Aleutian Islands pollock and likelihood equations. The model was modified from that of Barbeaux et al. (2003). These modifications include 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). Also, in the 2003 assessment age-1 pollock were explicitly modeled, whereas in the work presented here, they were dropped from consideration because observations of age-1 pollock are irregular, and in trials where they were included, they were found to limit the flexibility to incorporate alternative model specifications such as parametric forms of selectivity functions. The quasi[1] likelihood components and the distribution assumption of the error structure are given below:

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

The age-composition components are heavily influenced by the sample size assumptions specified for the multinomial likelihood. In this assessment a bootstrap method developed by Jim Ianelli and presented in this year's Atka mackerel assessment (Lowe et al 2008) was used to estimate effective sample size for fishery catch-at-age data. A value of 200 was selected for survey catch-at-age data.

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

*2006 effective sample size was set at 100 for this assessment

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

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

Parameters

Parameters estimated independently

Natural Mortality

For all models natural mortality was estimated using a prior of 0.2 with a CV of 0.2. Previous assessments (Barbeaux et al. 2007) suggest that Aleutian Islands pollock is less productive than the Eastern Bering Sea stock and model fits suggest that M should be closer to 0.2. In this assessments we assumed a prior value of M = 0.2 based on the studies of Wespestad and Terry (1984) for the Central Bering Sea (Table 1A.15). The current assessment model does not allow for age-specific natural mortality rates. It should be noted that in general, a higher natural mortality rate for age 2 pollock may be more appropriate (e.g., Ianelli et al. 2003,) and that this model differs from the Eastern Bering Sea model in this manner. In the future, we will be investigating methods to improve AMAK to include age varying natural mortality.

Length and Weight-at-age

We estimated length and weight-at-age separately for the survey and for the fishery. We obtained survey estimates from AIBT surveys and computed fishery estimates from observer data and the 2006 AICASS. The von Bertalanffy growth curve parameters and length-weight regression parameters from the 1980 to 2006 surveys are given in Table 1A.16. Survey weight-at-age values from 1978 to 2008 are given in Table 1A.17. For the time period 1978 to 1990, survey length and weight at age estimates were derived from the 1980, 1983, and 1986 AIBT surveys. For the time period 1990 to 2008 we calculated length and weight-at-age values from the 1991, 1994, 1997, 2000, 2002, 2004, and 2006 AIBT surveys. We calculated the average length-at-age as weighted averages by age and calculated the length-weight relationships using linear regression analysis. Data for these analyses were retrieved from the Resource Assessment and Conservation Engineering Division's (RACE) survey database. For years without survey length and weight-at-age data (unshaded cells in Table 1A.17), we used the mean values at age from the two nearest surveys. Fishery weight-at-age values from 1978 to 2008 are shown in Table 1A.18 . For the fishery, we used year (when available) and age-specific estimates of average weights-at-age computed from the fishery age and length sampling programs. These values are important for converting model estimated catch-at-age (in numbers) to estimated total annual harvests (by weight).

Maturity at Age

Previous year's assessments used the maturity schedule developed for the Bering Sea by Wespestad and Terry (1984; Table 1A.19). The CIE panel commented that given the differences in size-at-age there is likely a difference in maturity-at-age between the Bering Sea and Aleutian Islands. The authors agree, but maturity study have not been conducted specifically on the Aleutian Islands pollock and given the lack of a substantial fishery, not likely to happen in the near future. Aleutian Islands pollock size at age is more similar to that observed in the Gulf of Alaska than in the Bering Sea (Fig. 1A.11). In addition, population density in the Aleutians is similar to the GOA then the Bering Sea. In this year's assessment we used the Gulf of Alaska pollock 1983-2003 average proportion mature at age our maturity Ogive in the assessment. The GOA pollock tended to mature slightly later with 50% mature at between 4 and 5 years of age while the Bering Sea pollock reach 50% mature at between 3 and 4 years of age (Table 1A.19 and Fig. 1A.12).

Recruitment

We used a re-parameterized form of the Beverton-Holt stock recruitment relationship based on Francis (1992). Values for the stock recruitment function parameters α and β are calculated from the values of R_0 (the number of 0-year-olds in the absence of exploitation and recruitment variability) and the "steepness" (h) of the stock-recruit relationship. The "steepness" parameter is the fraction of R_0 to be expected (in the absence of recruitment variability) when the mature biomass is reduced to 20% of its pristine level

(Francis 1992). As an example, a value of h = 0.7 implies that at 20% of the unfished spawning stock size will result in an expected value of 70% of the unfished recruitment level. The steepness parameter (h) was set at 0.7 and sigma r was set at 0.6 for all model runs. Model runs with different values of h were conducted but were found to have little effect on the model results.

Parameters estimated conditionally

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

Fishing Mortality

Fishing mortality in all models was parameterized to be separable with both an age component (selectivity) and a year component. In all models selectivity is conditioned so that the mean value over all ages will be equal to one. To provide regularity in the age component, a penalty was imposed on sharp shifts in selectivity between ages using the sum of squared second differences. In addition, the age component parameters are assumed constant for either the last 4 (ages 12-15) or 8 age groups (ages 8-15). Finally, selectivity was allowed to vary over time in some model configurations. The model was set with controls selecting the degree to which selectivity is allowed to change between ages and over time.

Survey Catchability

For the bottom trawl survey, survey catchability-at-age follows the parameterization similar to the fishery selectivity-at-age presented above. The catchability-at-age relationship is modeled with a smoothed non-parametric relationship that can take on any shape (with penalties controlling the degree of change and curvature specified by the user). To provide regularity in the age component, a penalty was imposed on sharp shifts in catchability-at-age between ages using the sum of squared second differences. In addition, the age component parameters are assumed constant for the last 4 age groups (ages 12-15). As noted above, the model allows specification of the age-range over which the catchability parameter is applied. For Aleutian Islands pollock, ages 5-12 were selected to have the average catchability (factoring selectivity components) equal to the catchability parameter value.

One comment by the CIE reviewers was that the assessment model should not allow for inter-annual changes in survey selectivity. In previous assessments survey selectivity was allowed to change because in conversations with the RACE division it was determined that the survey has not had constant selectivity between years and that the improvements made the survey since 1991 have been incremental. In particular the ability of the survey to stay on the bottom was improved in 1994 by the addition of ground contact sensors. In 1997 another improvement was made in allowing the net to hit bottom before starting the survey. Both of these improvements would have increased the selectivity for older pollock which tend to reside near bottom. Model configurations with and without inter-annually varying survey selectivity were compared this year.

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

Natural Mortality

For the reference model, natural mortality (*M*) was estimated within the model using an uninformative prior starting with a value of 0.2 with a *CV* of 0.2. The addition of the 2006 catch-at-age data from the 2006 AICASS in the 2006 assessment (Barbeaux et al. 2006), allowed for improved model stability while estimating natural mortality.

Model evaluation

Three data configurations were evaluated for this stock assessment cycle. Model Series W.x.x.x are comparable to the data configuration of the preferred model presented in 2007 with survey data for the entire NRA and fishery data from the western NRA. Model Series A.x.x.x have all data from the entire NRA. Model Series x.SV.x.x has survey selectivity variable for years 1991, 1994, and 1997, while Model Series x.SF.x.x have fixed survey selectivity. Finally, Model Series x.x.12.12 have the age at which fishery and survey selectivity becomes constant at age 12, while in Model Series x.x.8.8 these are set at age 8. All models were configured with a survey catchability of 1.0, a stock recruitment steepness parameter of 0.7 and sigma r of 0.6. In all configurations recruitment was modeled using data from 1978-2007. Natural mortality for all models was estimated within the model starting with a prior of 0.2 and CV of 0.2.

Models Evaluated	**Survey Data**	**Fishery Data**	**Inter-annual Survey Selectivity**	**Age at which Selectivity becomes Constant**	
				Fishery	**Survey**
W.SV.12.12	All NRA	Western NRA	Variable	12	12
A.SV.12.12	All NRA	All NRA	Variable	12	12
W.SF.12.12	All NRA	Western NRA	Fixed	12	12
A.SF.12.12	All NRA	All NRA	Fixed	12	12
W.SF.8.8	All NRA	Western NRA	Fixed	8	8
A.SF.8.8	All NRA	All NRA	Fixed	8	8

Relative differences in model fits are shown in Table 1A.20 and key results are presented in Table 1A.21. Besides the relative size of recruitment and increased prevalence of the 1978 year class the model fits between model series W.x.x.x and A.x.x.x show very similar patterns. The fit to the survey data is relatively poor for all models (Fig. 1A.13), but not surprisingly so, given the estimates of variance for the individual survey point estimates, the high intra-annual variability of these estimates, and given the survey estimates are from the summer while the fishery is conducted in the winter.

For both series (Model W.x.x.x and Model A.x.x.x) the fit to the survey age composition data was excellent for all models, except for the 1991 data which, for sampling reasons, was given less weight than for the other years (Fig. 1A.14, Fig. 1A.15, Fig. 1A.16, Fig. 1A.17, and Fig. 1A.18). Fits to the fishery age-composition data (Fig. 1A.16, Fig. 1A.17, Fig. 1A.18, Fig. 1A.19, and Fig. 1A.20) were worse than the survey catch-at-age fits, but still relatively good. Even with the older age at which selectivity asymptotes the models still had a difficult time matching the mean age of the fishery data for the 1990s where the population appeared to still have a large proportion of fish from the 1978 year class (Fig. 1A.18). There is high variability in the fishery age data which probably reflects the diversity in sampling locations for the fishery in different years. There doesn't appear to be any obvious or consistent patterns in the residuals for either the fishery or survey catch-at-age fits (Fig. 1A.16 and Fig. 1A.17). The time-varying fishery selectivity patterns in the x.x.12.12 model series show a relatively large shift (to older fish) after 1990 for the fishery data, coinciding with the change from a sporadic foreign fishery to a domestic fishery specifically targeting spawning aggregations and following the large 1978 year class (Fig.1A.21 and Fig.1A.22). The extreme shift in selectivity between the foreign and domestic fishery does not occur if the maximum age at which selectivity is allowed to change is moved to 8 years. In this case (Model series x.x.8.8) the selectivity patterns between years is very similar and was reset in presented models to be constant over time for all years(Fig. 1A.23). Changing the age fishery selectivity becomes constant from 8 to 12 years and making selectivity constant for all years for both the fishery and the survey removes thirty-two pseudo-parameters from the model, but does degrade the fit to both the survey and fishery data somewhat, primarily due to the older age classes and in particular the fit to the 1978 year class in the late 1980s and early 1990s. Because these are not true parameters, but rather coefficients in this model configuration, we cannot rely on the AIC to determine best fit model and must rely on logical arguments to determine which scenario is most biologically relevant. There are two reasons why 8 years appears more sound than 12 years: Aleutian pollock appear to asymptote in size at approximately 8 years of age, the length of fish at 8 years of age corresponds to $0.9 \times L_{inf}$ from a von Bertalanffy growth curve fit to fishery and survey length at age data, and pollock are thought to aggregate by size not by age and therefore no mechanism can be thought of that would allow the fishery to preferentially select one age over another once fish reach maximum size. For both data series Models x.x.8.8 are preferred with the maximum age at which selectivity is allowed to change set at 8 years, not because of a better fit to the model, but on assumptions on how pollock behave at size.

Estimated survey selectivity at age for the two data series (W.x.x.x and A.x.x.x) were functionally identical (Fig. 1A.24) for comparable model specifications. Allowing the survey selectivity to vary by year (x.SV.x.x and x.SF.x.x series) does not improve the fit to the survey age data in either the Model W.x.x.x series and A.SF.x.x series, only marginally improve the fit to the survey index (<1.0 for both), but adds 36 psuedo-parameters. The large increase in parameters and penalties can not be justified by the marginal improvement in fit to the survey data and therefore for both data series Models x.SF.x.x are preferred with non-varying survey selectivity over time.

The more difficult task was in determining whether Model W.SF.8.8 or Model A.SF.8.8 was the better choice for managing this stock and which model best describes the dynamics of this population. The CIE panel review suggested that the Model A.SF.8.8 data configuration is more easily justified simply by the fact that the catch excluded from Models A.SD.8.8 came from the Aleutian Islands management area and that the area covered by the survey and fishery data would be consistent. Work in previous assessments show apparent geographic breaks in the locations of the foreign and domestic fisheries with fish on the eastern extreme of the area somewhat separated and most likely connected with the Bogoslof stock and the eastern Bering Sea stocks. Model A.SF.8.8 is the most complete model in terms of data inclusion for the Aleutian Islands management area, but may be overly influenced by influx of pollock from further east. This is evidenced by the immense 1978 year class (8.97 times higher than the mean 1978-2006 age 2 recruitment) which greatly inflates the total biomass and spawning biomass estimates for Models A.x.x.x (Fig.1A.25). Model W.SF.8.8 is similar with the 1978 year class being 6.5 times higher than the mean 1978-2006 age 2 recruitment. Model W.SF.8.8. may best represents the population of pollock that would be exploited in a small boat fishery centered on Adak Island and is a conservative estimate that is less influenced by possible influx of pollock from other areas. Model A.SF.8.8 may better represent the entire AI pollock population that may be exploited if the Aleut Corporation chooses to lease the pollock quota to catcher processors operating further from this limited area. Although these models result in a lower natural mortality (M = 0.24 or 0.21 for W.SF.8.8 and A.SF.8.8 respectively) than estimated for the BS and GOA they are both in the range suggested by Westpesdad and Terry (1984) for the Aleutian Basin pollock (M = 0.2) and Bogoslof area pollock (M=0.26) estimated by Ianelli et al. (2005). The 1978 year class remains large in both model configurations. The survey and fishery effective sample sizes are exactly the same for the two data configurations. Fits to the survey catch-at-age data are slightly better in Model A.SF.8.8, while fits to the survey index and fishery catch-at-age are somewhat degraded in comparison. But again this comparison is not really appropriate because it is a different data configuration, not simply a change to the parameterization. We must again decide between the two data configurations based on best practices, therefore to be in agreement with expert opinion from the CIE review panel Model A.SF.8.8 would be the best data configuration pick. Although Model A.SF.8.8 is the preferred model, figures and tables for Model W.SF.8.8 will be presented in tandem for comparison.

Results

Abundance and exploitation trends

As indicated in the 2004 stock assessment analysis (Barbeaux et al, 2004), the abundance trend is highly conditioned on the assumptions made about the area-swept survey trawl catchability. Even with catchability fixed at 1.0, the uncertainty in the trend and level is very high. Bearing in mind the high degree of uncertainty, the total biomass trend (Table 1A.22. Table 1A.23, and Fig.1A.26) appears to have increased steeply from 1999 to 2004 after cessation of directed fishing in the area, and increase at a slower rate from 2005 to 2008. This later increase may be an artifact of a lack of age data since 2006, resulting in the model estimating recruitment since 2006 near the median value. Estimated pollock numbers at age from 1978 to 2008 for reference Model A.SF.8.8 and competing Model E.SF.8.8 are given in Table 1A.24 and Table 1A.25. The reference Model A.SF.8.8 which includes the eastern NRA catch suggests that the 1978 year class was much higher and biomass in the 1980's for the Aleutian Islands area reached 1,585,100 t at its peak in 1982. Model W.SF.8.8 has a much smaller, but still very large, 1978 year class with total biomass reaching its peak in 1983 with 498,550 t. Both models show a large decline in the stock since its peak with both hitting its minimum spawning stock biomass in 1999 (58,489t and 42,791 t for models A.SF.8.8 and W.SF.8.8 respectively).

Female Spawning Stock biomass (SSB) appears to have been greatly influence by the high exploitation in the late 1990s (Fig.1A.26). The 2007 and 2008 assessments estimate very similar total biomass levels but differ in their estimates of SSB. This can be explained by the difference in the maturity Ogives used in the two assessments. The highest fishing mortality occurred in 1995 (F = 0.279 and Catch/biomass = 0.196) when the fishery harvested more than 75% of the 1994 survey biomass estimate (Table 1A.26, Fig.1A.27, and Fig.1A.28). The reference model shows high exploitation rates beginning in 1990 (F = 0.136) continuing through 1998 (Table 1A.27). In Model A.SF.8.8 the early 1990s fishery appears to be concentrating on the older fish, particularly the 1978 year class, this is consistent with a switch in the domestic fishery to concentrating on spawning aggregations for roe. In the reference model female spawning biomass reached its lowest point in 1999 at 58,489 t ($B_{20.7\%}$ or 10% of its peak value in 1984; 42,791 t in 1999 for Model W.SF.8.8, $B_{39.3\%}$ or 25% of its peak value in 1984), but has since increased and appears to be remaining somewhat stable to increasing between 81,000 and 88,000 t since 2005. Again this may be an artifact of the model since age data and survey estimates have not been available since 2006.

All models agree that there was a steep decline in pollock abundance in the Aleutian Islands in association with the senescence of the 1978 year class without another as large year class to replace it and high fishery removals. It is reasonable to conclude that the amount of removals taken in the 1990s would not have been sustainable given recent recruitment and was largely supported by the 1978 year class. We simulated the expected total biomass under no fishing by taking the raw numbers at age from 1978 and the 1979-2008 number of recruits at age 2 and projected them forward using the model derived natural mortality rate (Fig.1A.29). This exercise reveals that under Model A.SF.8.8 there was a significant decline in the abundance of pollock due to fishing, but since the cessation of fishing in 1999 and very low removal levels since 2005 the stock has stabilized. The simulation of A.SF.8.8 shows the stock to be at 23% of what it would have been without fishing in 2008, but had a low at 16% of the unfished stock in 1999. Similarly, the simulation using numbers from Model W.SF.8.8 shows a decline with fishing in the Aleutian Islands but at a much lower extent with a low of 62% of unfished in 1999 and at 95% of unfished in 2008 after rebounding with the cessation of fishing.

Recruitment

Recruitment (at age 2) is estimated with high variance (Table 1A.28 and Table 1A.29, Fig.1A.30). Sigma R was set at 0.6, and the reference model A.SF.8.8 estimates recruitment variability at 0.88. The 1978 year-class is the largest (1.64 billion age 2 recruits) and is highly influential with a large part of the fishery removals being composed of this year class (Fig. 1A.30). 1976-1986 had several large year classes in comparison to more recent recruitment. The mean recruitment of age 2 pollock for 1978-1988 was 367.1 million, while the mean recruitment at age 2 between 1996 and 2006 was 56.6 million fish with no year classes exceeding the overall 1978-2006 mean recruitment of 182.5 million age 2 recruits. Since the start of the domestic fishery in 1990 the two largest year classes have been the 1989 year class at 164.2 million recruits and the 2000 year class with 132.5 million recruits at age 2. In the reference model no year class has exceeded the mean recruitment for 1978-2006 since the 1984 year class. Given our limited time series we are unable to determine whether the larger year classes in the late 1970’s and early 1980’s were anomalous or whether they are part of a larger cycle. The bottom line is that the system appears to have been much less productive in the 1990’s and 2000’s than in the previous decade leading to a lower abundance of pollock in the Aleutian Islands, even without substantial local fishing pressure over the previous nine years.

The 1978 year class in particular is highly influential in both models. In Model A.SF.8.8 the mean recruitment for 1978 - 2006 without the 1978 year class was 72% (130.5 million) of the mean recruitment with the 1978 year class (182.5 million). In Model W.SF.8.8 the mean recruitment for 1978 - 2006 without the 1978 year class was 80% (69.7 million) of the mean recruitment with the 1978 year class (86.7 million). If the 1978 year class is anomalous, it may be inflating the biological reference points in both models (28% in Model A.SF.8.8 and 20% in Model W.SF.8.8) 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 extent to which adjacent stocks interact is an active area of research.

Projections and harvest alternatives

For management purposes we use the yield projections estimated for reference Model A.SF.8.8 but also provide results of projections estimated for Model W.SF.8.8. We used the model estimated fishery selectivity at age (Table 1A.30 and Fig. 1A.21) for all projections. Catchability for both models is fixed at 1.0.

Reference fishing mortality rates and yields

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines “overfishing level” (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC (*max* F_{ABC}). The fishing mortality rate used to set ABC (F_{ABC}) may be less than or equal to this maximum permissible level. The overfishing and maximum allowable ABC fishing mortality rates are given in terms of percentages of unfished female spawning biomass ($F_{SPR\%}$), on fully selected age groups. The associated long-term average female spawning biomass that would be expected under average estimated recruitment from 1978-2006 for Model A.SF.8.8 (182.5 million age 2 fish) and F equal to $F_{40\%}$ and $F_{35\%}$ are denoted $B_{40\%}$ and $B_{35\%}$, respectively. The Tiers require reference point estimates for biomass level determinations. We present the following reference points for NRA pollock for Tier 3 of Amendment 56. For our analyses, we estimated the following values from Model A.SF.8.8 and Model W.SF.8.8:

Female spawning biomass	Model A.SF.8.8	Model W.SF.8.8
$B_{100\%}$	282,820 t	109,011 t
$B_{40\%}$	113,128 t	43,605 t
$B_{35\%}$	98,987 t	38,154 t
B_{09}	85,480 t	42,577 t

Specification of OFL and Maximum Permissible ABC

For the reference model, Model A.SF.8.8, the projected year 2009 female spawning biomass (SB_{09}) is estimated to be 85,480 t, below the $B_{40\%}$ value of 113,128 t placing NRA pollock in Tier 3b. The maximum permissible ABC and OFL values under Tier 3b are:

Model A.SF.8.8 Tier 3b:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2009 Projected yield (t)
max F_{ABC}	$F_{40\%}$	0.288	26,873 t
F_{OFL}	$F_{35\%}$	0.357	32,553 t

For the comparison model, Model W.SF.8.8, the projected year 2009 female spawning biomass (SB_{09}) is estimated to be 42,577 t, also below the $B_{40\%}$ value of 43,605 t and would place NRA pollock in Tier 3b. The maximum permissible ABC and OFL values under Tier 3b in this model are:

Model W.SF.8.8 Tier 3b:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2009 Projected yield (t)
max F_{ABC}	$F_{40\%}$	0.482	20,380 t
F_{OFL}	$F_{35\%}$	0.598	24,345 t

If the estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ are not reliable, then under Tier 5 with new model estimated natural mortality of 0.2146, the 2009 ABC would be 15,289 t (94,992 t x 0.75 x 0.2146 = 15,289 t) and under Tier 5 with an assumed natural mortality of 0.3 the 2009 ABC would be 21,370 t.

ABC Considerations and Recommendation

ABC Considerations

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

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

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

3) No AIBT surveys have been conducted since 2006 and estimates of biomass from previous surveys are uncertain with an average CV of 0.36. The 2002, 2004, and 2006 estimates are especially uncertain with CVs of 0.38, 0.78, and 0.48 respectively. This results in considerable uncertainty in the projections.

4) Age data have not been collected since 2006 in either the fishery or the survey and recruitment for the past two years have been estimated at the median recruitment values for the entire time series, somewhat higher than the median that has been observed for the past decade.

5) The Model A.SF.8.8 suggests that currently a large proportion of the stock in the Aleutians is composed of much older fish (9.3% 10+ by number) and would make up a large proportion of the catch (32% age 10+ by weight). This is highly reliant on the chosen selectivity curves.

ABC Recommendations

The pollock spawning stock biomass in the NRA appears to be relatively stable. It should be noted that this may be an artifact of a lack of recent data since no fishery or survey age data have been available since 2006 and the model is assuming average recruitment in recent years. The total biomass appears to be stable. The estimated female spawning biomass projected for 2009 is 85,480 t. The projected total age 3+ biomass for 2009 is 266,346 t. The maximum permissible 2009 ABC based on $F_{40\%}$ = 0.288 is 26,873 t and OFL based on $F_{40\%}$ = 0.357 is 32,553 t which is the authors recommended ABC and OFLs. Assuming a catch of 2,000 t in 2009 the 2010 authors recommended ABC based on $F_{40\%}$ = 0.312 is 30,364 t and OFL based on $F_{40\%}$ = 0.378 is 36,769 t.

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 2008 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008. 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 2009, are as follows (a "*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2009 recommended in the assessment to the *max* F_{ABC} for 2009. (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 2004-2008 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 FOFL. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2009 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2009 and 2010, *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 2021 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 2009 through 2021 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

The projected yields, female spawning biomass, and the associated fishing mortality rates for the eight harvest strategies for the reference model are shown in Table 1A.31 for Model A.SF.8.8 and Table 1A.32 for Model W.SF.8.8. Under a harvest strategy of $F_{40\%}$ (Scenario 1), female spawning biomass is projected to be below $B_{35\%}$ through 2013, be below $B_{40\%}$ through 2018, then be above $B_{40\%}$ for the remainder of the projection (Fig.1A.31 and Fig.1A.32). Female spawning biomass is projected be below $B_{35\%}$ when fishing at F_{OFL} (Fig.1A.33) through 2016 and remain below $B_{40\%}$ through the end of the projection for both Scenario 6 and Scenario 7 . Please note again that the fishing mortality rates are prescribed on the basis of the harvest scenario and the spawning biomass in each year. Thus, fishing mortality rates may not be constant within the projection if spawning biomass drops below $B_{40\%}$ in any run.

The associated long-term average female spawning biomass that would be expected under average estimated recruitment from 1978-2006 (182.5 million age 2 fish) and $F = F_{35\%}$, denoted $B_{35\%}$ is estimated to be 98,987 t. This value ($B_{35\%}$), is used in the status determination criteria. Female spawning biomass for 2009 (85,480 t) is projected to be above 1/2 $B_{35\%}$ thus, the NRA pollock stock would be determined to be *above* its minimum stock size threshold (MSST) and is *not overfished*. Female spawning biomass for 2021 is projected to be above $B_{35\%}$ in scenario 7, and is expected to be above $B_{35\%}$ in 2019 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.31 , Fig.1A.33, and Table 1A.26), show that the stock could support a constant catch of 19,000 t . Currently the stock is at $B_{31\%}$ and the long-term expected yield at $B_{40\%}$ is 42,369 t and at $B_{35\%}$.is 45,695 t, well above the 19,000t cap.

The SSC asked that the probability of the spawning stock biomass being below $B_{20\%}$ in 2009 be computed for stocks in Tier 3b. We computed the number of standard deviations the 2009 spawning biomass (B_{09}) was from $B_{20\%}$, assuming B_{09} was normally distributed. B_{09} is estimated in the stock assessment model (non-projected) to be at 88,930 t with a standard deviation of 12,050 t and $B_{20\%}$ is estimated at 56,564 t, therefore B_{09} is 2.68 standard deviations from $B_{20\%}$. Under the assumption of a normal error distribution there is a 0.36% chance of the AI pollock stock currently being below $B_{20\%}$.

Ecosystem Considerations

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

In the AI, pollock diet data reflects a closer connection with open oceanic environments than in either the Eastern Bering Sea (EBS) or the GOA. Similar to the other ecosystems, euphausiids and copepods together make up the largest proportion of AI adult pollock diet (29% and 19%, respectively); however, it is only in the AI that adult pollock rely on mesopelagic forage fish in the family Myctophidae for 24% of their diet, and AI juvenile pollock have a lower proportion of euphausiids and a higher proportion of gelatinous filter feeders than in the GOA or EBS (Fig.1A.34, left panels). We can take 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. in review), which incorporates information on pollock consumption derived from the stock assessment (see Appendix A, "ration calculations" for detailed methods), as well as uncertainty in all other food web model parameters. As estimated by the Sense routine, AI adult pollock consumed between 100 and 900 thousand metric tons of euphausiids annually during the early 1990s, with similar ranges of myctophid and copepod consumption. Juvenile AI pollock consumed an additional estimated 100 to 900 thousand tons of copepods per year (Fig.1A.34, right panels).

Using diet data for all predators of pollock and consumption estimates for those predators, as well as fishery catch data, we next estimate the sources of pollock mortality in the AI. Sources of mortality are 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.35, 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 in review) ranged from 8 to 27 thousand tons consumed by cod annually during the early 1990s, while Atka mackerel were estimated to consume between 75 and 410 thousand tons of juvenile pollock annually in the AI ecosystem (Fig.1A.35 , right panels).

After reviewing the diet compositions and mortality sources of pollock in the AI, we shift 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.36) is a relatively high trophic level (TL) predator which interacts mostly with adult pollock, but also with many other species (in green; Fig. 1A.36). 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.37). No single bycatch species accounted for more than 1% of the catch. Although these catches are small in terms of percentage, the high volume pollock fisheries still account for the majority of bycatch of pelagic species in the BSAI management areas, including smelts, salmon sharks, and squids (Gaichas et al 2004).

The intended target of the pollock trawl fishery is also a very important prey species in the wider AI food web. When both adult and juvenile pollock food web relationships are included, over two thirds of all species groups turn out to be directly linked to pollock either as predators or prey in the food web model (Fig.1A.38). 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 can investigate 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 use 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.39 shows the resulting percent change in the biomass of each species after 30 for 50% of feasible ecosystems with 95% confidence intervals (error bars in Figure1A.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.39 , upper panel). Along with the decrease in pollock biomass predicted in this simulation is a decrease in pollock fishery catch. The next largest median effect is on juvenile pollock, which are predicted to decrease in 50% of feasible ecosystems, but he 95% interval includes zero, suggesting that the decrease is uncertain. The simulation further suggests the possibility that herring, Atka mackerel, and other miscellaneous deepwater fish might increase slightly as a result of a decrease in pollock survival; however, for all of these species groups the 95% intervals cross zero, so the direction of change is uncertain. Therefore, this analysis suggests that in the AI ecosystem during the early 1990’s, pollock were most important to themselves, and to the pollock fishery.

To determine which groups were most important to pollock in each ecosystem, we conducted the inverse of the analysis presented above. In this simulation, each species group in the ecosystem had survival reduced by 10% and the system was allowed to adjust over 30 years. The strongest median effects on AI adult pollock are presented in Fig. 1A.39 (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.39, 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.35, 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.33.

Prey availability/abundance trends

Adult walleye pollock in the Aleutian Islands consume a variety of prey, primarily large zooplankton, copepods, and myctophids. Figure 1A.37 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 are showing declines, and Steller sea lions have shown some slight increases. Declining trends in predator abundance could lead to possible decreases in walleye pollock mortality. The population trends of seabirds are mixed, some increases, some decreases, and others stable. Seabird population trends could affect young-of-the-year mortality.

Changes in habitat quality

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

AI pollock fishery effects on the ecosystem

AI pollock fishery contribution to bycatch

The 2007 and 2006 AI pollock fishery were conducted in conjunction with the AICASS, Pacific Ocean perch (POP) was the most substantial bycatch species and made up 3% of the catch in 2006 and 11% in 2007. The AI pollock fishery opening in 2005 was limited to only four hauls, within these four hauls the bycatch level of POP was very high (~50%). Besides the lack of commercially harvestable levels of pollock, the high levels of POP bycatch convinced fishers to discontinue the fishery in 2005. 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.

Concentration of AI pollock catches in time and space

Since no EFP is propose for 2009 there is expected to only be a very limited fishery in 2009. The State of Alaska may begin a 3,000 t AI pollock fishery in state waters, but participation is limited to vessels under 58 ft. There are very few vessels less than 58' that can safely equip themselves for a deep water pollock fisher and therefore catch is expected to be much less than 3,000 t even if the state opens this fishery. The impacts of this fishery due to temporal and spatial concentration are not expected be substantial due to the relatively low fishing mortality expected.

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), and 2008 (382 t). Year to year differences observed in the previous eight years can not be attributed to the fishery and must be attributed to natural fluctuations in recruitment. Fishers have indicated that the larger pollock in the Aleutian Islands will be targeted. But the low level of fishing mortality is not expected to greatly affect the size distribution of pollock in the AI.

AI pollock fishery contribution to discards and offal production

The 2009 Aleutian Islands pollock fishery, if pursued, is expected to be conducted by catcher vessels delivering unsorted catch to the Adak Fisheries LLC processing plant, and therefore very little discard or offal production is expected from this fishery.

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.

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. Genetic work on the relationship of NRA pollock to other stocks in the North Pacific is essential for further assessment work. Tissue samples were collected during the 2006 and 2007 AICASS for this analysis but genetic analysis of these samples are waiting on funding. In addition, 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 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 stock and whether there have been any changes in life history parameters over time would be informative.

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Tables

Table 1A.1. Time series of ABC, TAC, and total catch for Aleutian Islands Region walleye pollock fisheries 1991-2008. Units are in metric tons. Note: There was no OFL level set in 1991 and the 1993 harvest specifications were not available

YEAR	ABC	TAC	OFL	CATCH	CATCH/TAC
1991	101,460	72,250	NA	98,604	136%
1992	51,600	47,730	62,400	52,352	110%
1993				57,132	
1994	56,600	56,600	60,400	58,659	104%
1995	56,600	56,600	60,400	64,925	115%
1996	35,600	35,600	47,000	29,062	82%
1997	28,000	28,000	38,000	25,940	93%
1998	23,800	23,800	31,700	23,822	100%
1999	23,800	2,000	31,700	1,010	51%
2000	23,800	2,000	31,700	1,244	62%
2001	23,800	2,000	31,700	824	41%
2002	23,800	1,000	31,700	1,156	116%
2003	39,400	1,000	52,600	1,653	165%
2004	39,400	1,000	52,600	1,150	115%
2005	29,400	19,000	39,100	1,556	8%
2006	29,400	19,000	39,100	1,736	9%
2007	44,500	19,000	54,500	2,519	12%
2008	28,160	19,000	34,040	1,178	6%

* As of October 28, 2008

Table 1A.2. Estimates of walleye pollock catches from the entire Aleutian Islands Region by source, 1977-2008. Units are in metric tons.

Year	Official Foreign & JV Blend	Domestic Blend	Foreign Reported	NMFS Observer Data	Current estimates
1977	7,367		7,827	5	7,367
1978	6,283		6,283	234	6,283
1979	9,446		9,505	58	9,446
1980	58,157		58,477	883	58,157
1981	55,517		57,056	2,679	55,517
1982	57,753		62,624	11,847	57,753
1983	59,021		44,544	12,429	59,021
1984	77,595		67,103	48,538	77,595
1985	58,147		48,733	43,844	58,147
1986	45,439		14,392	29,464	45,439
1987	28,471			17,944	28,471
1988	41,203			21,987	41,203
1989	10,569			5,316	10,569
1990		79,025		51,137	79,025
1991		98,604		20,493	98,604
1992		52,352		20,853	52,352
1993		57,132		22,804	57,132
1994		58,659		37,707	58,659
1995		64,925		18,023	64,925
1996		29,062		5,982	29,062
1997		25,940		5,580	25,940
1998		23,822		1,882	23,822
1999		1,010		24	1,010
2000		1,244		75	1,244
2001		824		88	824
2002		1,156		144	1,156
2003		1,653			1,653
2004		1,150			1,150
2005		1,610			1,610
2006		1,736			1,736
2007		2,519			2,519
2008		1,178			1,178

Table 1A.3. Estimated walleye pollock catch discarded and retained for the Aleutian Islands Region based on NMFS blend data, 1991-2008.

Year	Catch Retained	Discard	Total	Discard Percentage
1990	69,682	9,343	79,025	12%
1991	93,059	5,441	98,500	6%
1992	49,375	2,986	52,361	6%
1993	55,399	1,740	57,138	3%
1994	57,308	1,373	58,681	2%
1995	63,545	1,380	64,925	2%
1996	28,067	994	29,062	3%
1997	25,323	617	25,940	2%
1998	23,657	164	23,822	1%
1999	361	446	807	55%
2000	455	790	1,244	64%
2001	445	380	824	46%
2002	398	758	1,156	66%
2003	1184	468	1,653	28%
2004	871	278	1,150	24%
2005	200	1,410	1,610	88%
2006	897	839	1,736	48%
2007	1,429	930	2,519	39%
2008	1,148	30	1,178	3%

Table 1A.4. Estimates of Aleutian Islands Region walleye pollock catch by the three management sub-areas. Foreign reported data were used from 1977-1984, from 1985-2008 observer data were used to partition catches among the areas. Units are in metric tons.

Year	East (541)	Central (542)	West (543)	Total
1977	4,402	0	2,965	7,367
1978	5,267	712	305	6,283
1979	1,488	1,756	6,203	9,446
1980	28,284	7,097	22,775	58,157
1981	43,461	10,074	1,982	55,517
1982	54,173	1,205	2,376	57,753
1983	56,577	1,250	1,194	59,021
1984	64,172	5,760	7,663	77,595
1985	19,885	38,163	100	58,147
1986	38,361	7,078	0	45,439
1987	28,086	386	0	28,471
1988	40,685	517	0	41,203
1989	10,569	0	0	10,569
1990	69,170	9,425	430	79,025
1991	98,032	561	11	98,604
1992	52,140	206	6	52,352
1993	54,512	2,536	83	57,132
1994	58,091	554	15	58,659
1995	28,109	36,714	102	64,925
1996	9,226	19,574	261	29,062
1997	8,110	16,799	1,031	25,940
1998	1,837	3,858	18,127	23,822
1999	484	420	105	1,010
2000	615	461	169	1,244
2001	332	386	105	824
2002	842	180	133	1,156
2003	574	758	329	1,661
2004	383	505	248	1,135
2005	670	386	517	1,572
2006	1032	277	220	1,529
2007	1760	475	124	2,359
2008	796	269	113	1,178

Table 1A.5. Estimates of pollock catch (metric tons) by new area definitions. “NRA” stands for Near, Rat, and Andreanof island groups, “NRA w/o E” signifies the NRA region without the area east of 174°W, “Basin” represents the northern portions of areas 541 and 542. See Fig. 1A. for locations on a map. (*Note: 1977-1984 area assignments are based on foreign reported data, 1985- 2008 are based on observer data).*

Year	NRA	NRA w/o E	Basin	Basin + E
1977	7,367	2,965	0	4,402
1978	6,283	1,016	0	5,267
1979	9,446	7,959	0	1,488
1980	58,157	29,873	0	28,284
1981	31,258	14,811	24,259	40,706
1982	50,322	3,149	7,863	54,605
1983	44,442	1,669	15,354	57,352
1984	42,901	9,171	39,140	68,424
1985	47,070	870	48,472	57,278
1986	23,810	704	28,003	44,735
1987	26,257	2,720	2,251	25,752
1988	36,864	574	4,339	40,628
1989	10,569	0	0	10,569
1990	79,025	10,477	0	68,548
1991	98,604	561	230	98,043
1992	52,352	8,519	29,455	43,833
1993	57,132	16,162	22,404	40,970
1994	58,659	5,965	26,288	52,694
1995	64,925	58,203	3,015	6,723
1996	29,062	23,187	899	5,875
1997	25,940	25,774	0	166
1998	23,822	23,335	67	486
1999	1,010	631	0	378
2000	1,244	891	0	354
2001	824	575	0	249
2002	1,156	351	1	805
2003	1,653	1,430	0	222
2004	1,150	962	0	188
2005	1,610	1,330	0	280
2006	1,736	1,657	0	79
2007	2,359	1,319	0	1,040
2008	1,178	753	0	425

Table 1A.6. Sampling levels in Aleutian Islands Region sub-regions based on foreign, J.V., and domestic walleye pollock observer data 1978 – 1998.

	NRA West of 174° Longitude			NRA East of 174° Longitude			Aleutian Islands Area Basin		
Year	Fish Measured	Hauls Sampled	Vessels Sampled	Fish Measured	Hauls Sampled	Vessels Sampled	Fish Measured	Hauls Sampled	Vessels Sampled
1978	1,503	64	4	4,831	135	11	0	0	0
1979	1,317	16	4	977	33	6	0	0	0
1980	2,154	53	4	4,753	119	10	0	0	0
1981	4,782	37	7	6,617	96	14	1,913	15	3
1982	7,713	102	13	29,549	331	30	11,151	84	7
1983	2,977	35	12	24,793	242	27	20,744	174	21
1984	10,844	111	22	46,037	541	49	157,388	1,223	81
1985	780	9	2	33,471	259	37	68,923	460	58
1986	0	0	0	22,939	195	18	39,875	268	48
1987	4,045	26	5	43,093	352	29	2,665	26	8
1988	378	3	2	28,423	249	24	4,528	37	14
1989	0	0	0	7,424	57	8	0	0	0
1990	12,303	131	14	55,837	587	47	55	1	1
1991	0	1	1	26,035	211	32	24,025	194	26
1992	7,405	59	15	18,771	178	50	20,769	179	27
1993	13,471	130	15	13,264	137	34	22,022	185	30
1994	5,025	47	18	29,805	305	64	5,314	56	16
1995	29,070	324	34	2,963	212	31	1,922	19	7
1996	15,307	160	35	3,462	179	41	0	0	0
1997	17,239	189	33	64	122	26	77	1	1
1998	10,439	122	15	148	107	12	0	0	0
Total	146,752	1,619	255	403,256	4,647	600	381,371	2,922	348

Table 1A.7. NRA pollock fishery average weight-at-age in kilograms used in reference model. Shaded cells had missing observations and were filled with their mean values

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.047	0.404	0.794	0.709	0.837	0.965	0.984	1.060	0.977	1.101	1.320	1.271	0.726	0.469
1979	0.047	0.378	0.515	0.766	0.635	0.789	0.938	0.898	1.024	1.179	1.103	1.052	0.656	0.646
1980	0.159	0.607	0.807	0.896	0.892	0.935	1.026	1.098	1.071	1.036	1.052	0.467	0.418	0.606
1981	0.189	0.425	0.565	0.649	0.696	0.707	0.750	0.832	0.901	0.825	1.016	0.975	0.767	0.415
1982	0.189	0.277	0.564	0.645	0.653	0.695	0.742	0.785	0.885	0.875	0.856	0.900	0.806	0.856
1983	0.189	0.368	0.596	0.676	0.623	0.713	0.812	0.814	0.831	0.862	0.812	0.596	0.643	0.492
1984	0.186	0.321	0.596	0.522	0.608	0.647	0.723	0.751	0.766	0.782	0.845	0.860	0.843	0.417
1985	0.363	0.494	0.630	0.597	0.679	0.717	0.711	0.798	0.817	0.803	0.945	0.950	1.089	0.973
1986	0.189	0.536	0.494	0.647	0.658	0.702	0.768	0.767	0.853	0.783	0.879	0.779	0.490	0.386
1987	0.189	0.368	0.717	0.748	0.831	0.501	0.799	0.966	1.117	1.000	1.075	1.165	0.994	1.079
1988	0.189	0.368	0.596	0.641	0.749	0.815	0.650	0.819	0.942	0.769	0.365	0.485	0.329	0.619
1989	0.189	0.368	0.596	0.719	0.834	0.906	0.954	0.995	1.006	1.072	1.085	0.994	0.956	0.890
1990	0.189	0.368	0.596	0.719	0.834	0.906	0.954	0.995	1.006	1.072	1.085	0.994	0.956	0.890
1991	0.189	0.368	0.657	0.634	0.734	0.791	1.014	0.957	0.866	1.188	1.137	1.060	1.088	1.012
1992	0.189	0.368	0.596	0.719	0.739	0.999	1.081	0.661	0.408	1.072	1.389	1.188	1.262	1.159
1993	0.189	0.368	0.790	0.937	1.130	1.244	1.089	1.166	0.925	1.246	1.231	1.233	1.145	1.151
1994	0.189	0.368	0.584	0.831	0.970	1.156	1.120	1.116	1.189	1.388	1.228	1.080	1.047	1.178
1995	0.189	0.484	0.558	0.719	1.185	1.237	1.428	1.398	1.194	1.458	1.460	1.504	1.576	1.331
1996	0.189	0.368	0.360	0.738	1.081	1.251	1.209	1.385	1.531	1.211	1.296	0.901	1.460	1.303
1997	0.189	0.309	0.421	0.775	1.072	1.200	1.165	1.340	1.451	1.332	1.303	1.106	1.430	1.374
1998	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
1999	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
2000	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
2001	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
2002	0.189	0.250	0.482	0.812	1.064	1.149	1.121	1.294	1.370	1.454	1.310	1.311	1.399	1.446
2003	0.332	0.393	0.760	0.688	0.810	0.915	0.907	0.972	0.928	1.061	1.167	1.187	1.615	1.073
2004	0.332	0.393	0.760	0.688	0.810	0.915	0.907	0.972	0.928	1.061	1.167	1.187	1.615	1.073
2005	0.332	0.393	0.760	0.688	0.810	0.915	0.907	0.972	0.928	1.061	1.167	1.187	1.615	1.073
2006	0.332	0.393	0.760	0.688	0.810	0.915	0.907	0.972	0.928	1.061	1.167	1.187	1.615	1.073
2007	0.332	0.393	0.760	0.688	0.810	0.915	0.907	0.972	0.928	1.061	1.167	1.187	1.615	1.073
2008	0.332	0.393	0.760	0.688	0.810	0.915	0.907	0.972	0.928	1.061	1.167	1.187	1.615	1.073

Table 1A.8. Number of aged and measured fish in the NRA pollock fishery used to estimate fishery age composition. Shaded values were not used in assessment. Data for 2006 from 2006 AICASS.

	Number Aged			Number Measured		
Year	Males	Females	Total	Males	Females	Total
1978	209	322	531	490	1,013	1,503
1979	124	178	302	611	706	1,317
1980	93	167	260	971	1,183	2,154
1981	124	152	276	2,226	2,556	4,782
1982	564	640	1,204	3,655	4,058	7,713
1983	132	145	277	1,493	1,484	2,977
1984	294	312	606	5,273	5,571	10,844
1985	210	265	475	349	431	780
1986	77	113	190	0	0	0
1987	131	142	273	1,670	2,375	4,045
1988	34	33	67	188	190	378
1989	0	0	0	0	0	0
1990	46	49	95	5,209	7,094	12,303
1991	36	47	83	0	0	80
1992	110	121	231	3,755	3,650	7,405
1993	81	82	163	7,701	5,770	13,471
1994	157	151	308	2,644	2,381	5,025
1995	74	106	180	16,518	12,552	29,070
1996	95	84	179	8,933	6,374	15,307
1997	15	15	30	9,232	8,007	17,239
1998	144	170	314	5,992	4,447	10,439
1999	0	0	0	75	60	135
2000	0	1	1	70	114	184
2001	0	1	1	52	106	158
2002	0	0	0	46	61	107
2003	0	0	0	0	0	0
2004	0	0	0	153	212	365
2005	0	0	0	309	260	569
2006	74	87	161	1,315	1,630	2,945
2007	0	0	0	523	636	1,159

Table 1A.9. Number of individual vessels and hauls sampled by observers in the NRA pollock fishery west of 174°W longitude, 1990-2007. For 2005-2007 many of the sampled vessels were not directly targeting pollock.

	NRA Area 541 West of 174W				NRA Area 542				NRA Area 543			
	Catcher Processor		Catcher Only		Catcher Processor		Catcher Only		Catcher Processor		Catcher Only	
Year	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls
1990	12	50	0	0	16	132	0	0	2	4	0	0
1991	2	3	0	0	2	2	0	0	0	0	0	0
1992	18	126	0	0	4	5	0	0	0	0	0	0
1993	18	195	0	0	6	25	0	0	3	5	0	0
1994	18	76	0	0	3	6	0	0	0	0	0	0
1995	22	200	8	39	15	272	11	77	0	0	0	0
1996	5	12	7	15	25	198	10	38	0	0	0	0
1997	13	66	11	30	14	93	10	60	1	6	0	0
1998	4	6	5	16	3	24	5	19	2	97	4	24
2005	1	2	1	2	3	4	0	0	3	6	0	0
2006	0	0	1	1	1	2	0	0	1	1	0	0
2007	1	1	1	3	5	14	0	0	1	2	0	0

Table 1A.10. Reference Model A.SF.8.8 Estimated NRA region pollock catch at age (millions).

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1978	0.05	0.27	1.30	1.31	1.32	0.65	0.64	0.56	0.42	0.29	0.11	0.08	0.06	0.51	7.57
1979	0.11	0.40	1.58	2.24	1.90	1.98	0.99	1.00	0.63	0.48	0.33	0.13	0.09	0.65	12.51
1980	2.00	2.63	7.62	8.85	10.52	9.11	9.51	4.76	3.52	2.22	1.69	1.17	0.44	2.60	66.64
1981	0.18	5.97	6.29	5.24	5.09	6.15	5.31	5.54	1.98	1.47	0.93	0.70	0.49	1.27	46.61
1982	0.09	1.07	28.88	8.81	6.15	6.09	7.36	6.38	4.81	1.72	1.27	0.80	0.61	1.52	75.56
1983	0.19	0.36	3.42	26.72	6.83	4.87	4.82	5.86	3.66	2.76	0.99	0.73	0.46	1.22	62.89
1984	0.17	1.02	1.56	4.32	28.35	7.40	5.28	5.26	4.62	2.88	2.17	0.78	0.57	1.33	65.71
1985	0.26	0.84	4.01	1.78	4.13	27.59	7.21	5.18	3.72	3.27	2.04	1.54	0.55	1.35	63.47
1986	0.07	0.67	1.73	2.40	0.89	2.12	14.30	3.78	1.96	1.41	1.24	0.77	0.58	0.72	32.64
1987	0.04	0.30	2.26	1.73	2.01	0.77	1.85	12.70	2.44	1.27	0.91	0.80	0.50	0.84	28.42
1988	0.11	0.41	2.28	4.97	3.19	3.81	1.47	3.59	17.93	3.45	1.79	1.29	1.13	1.89	47.31
1989	0.02	0.14	0.43	0.71	1.30	0.86	1.04	0.41	0.72	3.59	0.69	0.36	0.26	0.60	11.13
1990	0.13	0.85	4.73	4.20	5.73	10.75	7.09	8.58	2.47	4.35	21.76	4.19	2.17	5.23	82.23
1991	0.37	1.02	5.30	8.42	6.17	8.45	15.50	9.92	8.55	2.46	4.34	21.69	4.18	7.37	103.74
1992	0.09	1.27	2.81	4.11	5.37	3.95	5.29	9.41	4.21	3.63	1.04	1.84	9.20	4.90	57.12
1993	0.09	0.51	5.51	3.46	4.19	5.51	3.98	5.20	6.56	2.93	2.53	0.73	1.28	9.83	52.31
1994	0.14	0.55	2.55	7.80	4.03	4.89	6.26	4.37	4.04	5.09	2.28	1.96	0.56	8.63	53.15
1995	0.22	0.86	2.62	3.41	8.53	4.37	5.10	6.21	3.03	2.80	3.53	1.58	1.36	6.37	49.99
1996	0.06	0.70	2.09	1.79	1.90	4.75	2.36	2.64	2.22	1.08	1.00	1.26	0.56	2.76	25.17
1997	0.09	0.33	2.84	2.42	1.71	1.83	4.47	2.16	1.71	1.43	0.70	0.65	0.81	2.15	23.30
1998	0.10	0.47	1.37	3.29	2.32	1.64	1.71	4.06	1.38	1.09	0.92	0.45	0.41	1.90	21.11
1999	0.00	0.02	0.09	0.07	0.14	0.10	0.07	0.08	0.13	0.04	0.03	0.03	0.01	0.07	0.88
2000	0.01	0.02	0.11	0.12	0.09	0.18	0.13	0.09	0.07	0.12	0.04	0.03	0.03	0.08	1.12
2001	0.00	0.02	0.04	0.08	0.08	0.06	0.12	0.09	0.05	0.04	0.06	0.02	0.02	0.06	0.74
2002	0.01	0.03	0.09	0.07	0.11	0.11	0.08	0.17	0.10	0.05	0.04	0.07	0.02	0.08	1.03
2003	0.01	0.10	0.21	0.18	0.12	0.19	0.19	0.14	0.23	0.12	0.07	0.05	0.08	0.13	1.82
2004	0.00	0.02	0.24	0.16	0.11	0.08	0.13	0.13	0.07	0.11	0.06	0.03	0.03	0.11	1.28
2005	0.01	0.02	0.10	0.40	0.22	0.16	0.11	0.19	0.14	0.08	0.12	0.07	0.04	0.14	1.80
2006	0.01	0.04	0.08	0.12	0.42	0.24	0.18	0.13	0.16	0.12	0.07	0.10	0.06	0.15	1.88
2007	0.02	0.06	0.21	0.13	0.16	0.57	0.32	0.25	0.13	0.16	0.12	0.07	0.11	0.21	2.52
2008	0.01	0.05	0.11	0.12	0.06	0.08	0.29	0.17	0.10	0.05	0.06	0.05	0.03	0.12	1.30

Table 1A.11. Pollock biomass estimates from the Aleutian Islands Groundfish Survey, 1980-2006.

	Aleutian Islands Region NRA West (174W-170E)	NRA East (170W-174W)	NRA total	Unalaska-Umnak area (~165W-170W)	Combined
1980			243,695	56,732	300,427
1983			495,775	282,648	778,423
1986			439,461	102,379	541,840
1991	83,337	53,865	137,202	51,644	188,846
1994	47,623	29,879	77,502	39,696	117,199
1997	57,577	39,935	97,512	65,400	158,912
2000	76,613	28,985	105,598	22,462	128,060
2002	121,915	53,368	175,283	181,334	356,617
2004	19,201	111,250	130,451	235,658	366,110
2006	25,471	69,522	94,993	18,006	112,999

Table 1A.12. Aleutian Islands bottom trawl survey pollock proportion-at-age used in reference model. Shaded cells the highest proportion for the year.

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

Table 1A.13. Aleutian Islands bottom trawl survey pollock average weight-at-age in kilograms used in reference model, shaded cells are averaged from surrounding years.

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

Table 1A.14. Results of the 2002 Aleutian Islands echo integration-trawl survey conducted by the R/V Kaiyo Maru.

	Leg 2-1	Leg 2-2	Leg 2-3	Leg 2-4
Area (km^2)	27,902	10,433	4,045	1,413
Density (t/km^2)	2.18	1.82	2.46	1.79
Population (10^6)	37	12	6	2
Biomass (10^3 t)	61	19	10	3
CV	0.31	0.33	0.21	0.76

Table 1A.15. Estimated instantaneous natural mortality rates (M) by age from Wespestad and Terry (1984).

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

Table 1A.16. Estimated von Bertalanffy growth curve parameters and length-weight regression parameters for walleye pollock sampled during the U.S.-Japan 1980, 1983, and 1986 groundfish surveys and the 1991, 1994, 1997, 2000, 2002, and 2006 RACE groundfish surveys.

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

Table 1A.17. Average weight-at-age for Aleutian Islands pollock as estimated from NMFS summer bottom trawl survey estimates. Values between survey years (shaded) were set to the mean of the nearest two surveys (or single year for 1978-79, 2003-07).

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.31	0.49	0.65	0.76	0.85	0.91	0.95	0.98	0.99	1.01	1.01	1.02	1.02	1.03
1979	0.31	0.49	0.65	0.76	0.85	0.91	0.95	0.98	0.99	1.01	1.01	1.02	1.02	1.03
1980	0.31	0.49	0.65	0.76	0.85	0.91	0.95	0.98	0.99	1.01	1.01	1.02	1.02	1.03
1981	0.25	0.43	0.60	0.73	0.83	0.90	0.95	0.98	1.01	1.02	1.03	1.04	1.05	1.05
1982	0.25	0.43	0.60	0.73	0.83	0.90	0.95	0.98	1.01	1.02	1.03	1.04	1.05	1.05
1983	0.19	0.37	0.55	0.69	0.80	0.89	0.95	0.99	1.02	1.04	1.05	1.06	1.07	1.07
1984	0.21	0.40	0.57	0.71	0.82	0.90	0.95	0.99	1.02	1.04	1.05	1.06	1.07	1.07
1985	0.21	0.40	0.57	0.71	0.82	0.90	0.95	0.99	1.02	1.04	1.05	1.06	1.07	1.07
1986	0.24	0.42	0.59	0.73	0.83	0.90	0.96	0.99	1.02	1.04	1.05	1.06	1.06	1.06
1987	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1988	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1989	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1990	0.23	0.46	0.67	0.77	0.89	0.97	1.02	1.07	1.12	1.14	1.09	1.11	1.11	1.09
1991	0.22	0.51	0.69	0.79	1.01	1.15	1.26	1.21	1.27	1.21	1.16	1.12	1.16	1.10
1992	0.21	0.51	0.78	0.89	1.08	1.22	1.25	1.33	1.36	1.32	1.35	1.33	1.35	1.22
1993	0.21	0.51	0.78	0.89	1.08	1.22	1.25	1.33	1.36	1.32	1.35	1.33	1.35	1.22
1994	0.20	0.52	0.87	1.00	1.14	1.29	1.24	1.45	1.44	1.43	1.54	1.54	1.54	1.35
1995	0.22	0.48	0.82	0.97	1.07	1.24	1.26	1.38	1.44	1.45	1.53	1.52	1.57	1.47
1996	0.22	0.48	0.82	0.97	1.07	1.24	1.26	1.38	1.44	1.45	1.53	1.52	1.57	1.47
1997	0.25	0.43	0.78	0.95	1.00	1.19	1.29	1.31	1.44	1.47	1.52	1.51	1.60	1.60
1998	0.21	0.47	0.77	0.92	0.95	1.17	1.28	1.31	1.43	1.50	1.62	1.59	1.53	1.65
1999	0.21	0.47	0.77	0.92	0.95	1.17	1.28	1.31	1.43	1.50	1.62	1.59	1.53	1.65
2000	0.17	0.51	0.77	0.89	0.90	1.15	1.26	1.32	1.41	1.52	1.71	1.67	1.47	1.70
2001	0.19	0.49	0.74	1.02	1.03	1.23	1.29	1.43	1.53	1.56	1.74	1.68	1.58	1.67
2002	0.21	0.47	0.70	1.15	1.16	1.32	1.32	1.53	1.65	1.61	1.76	1.69	1.68	1.64
2003	0.21	0.47	0.70	1.15	1.16	1.32	1.32	1.53	1.65	1.61	1.76	1.69	1.68	1.64
2004	0.23	0.49	0.79	0.91	1.02	1.25	1.22	1.50	1.53	1.70	1.63	1.64	1.55	0.87
2005	0.23	0.49	0.79	0.91	1.02	1.25	1.22	1.50	1.53	1.70	1.63	1.64	1.55	0.93
2006	0.17	0.49	0.67	0.95	1.20	1.29	1.40	1.57	1.93	2.05	1.96	2.03	1.94	1.97
2007	0.17	0.49	0.67	0.95	1.20	1.29	1.40	1.57	1.93	2.05	1.96	2.03	1.94	1.97

Table 1A.18. Average weight-at-age for Aleutian Islands pollock as estimated from fishery data.

	Age													
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
1978	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
1979	0.23	0.35	0.53	0.73	0.67	0.83	0.94	0.95	1.04	1.16	1.06	1.52	1.58	1.02
1980	0.24	0.55	0.77	0.84	0.86	0.91	1.00	1.09	1.06	1.02	1.16	1.10	0.85	1.52
1981	0.34	0.48	0.55	0.73	0.76	0.78	0.81	0.90	0.90	0.86	1.02	1.03	0.89	0.91
1982	0.34	0.42	0.54	0.64	0.78	0.82	0.84	0.89	0.98	1.00	0.96	0.95	0.91	0.97
1983	0.34	0.47	0.66	0.73	0.78	0.80	0.93	0.96	1.01	0.90	1.19	1.15	0.97	1.14
1984	0.43	0.45	0.66	0.74	0.81	0.87	0.97	1.00	1.27	1.64	1.14	1.22	1.19	1.14
1985	0.47	0.57	0.67	0.69	0.80	0.85	0.86	1.09	1.23	1.60	1.66	1.15	1.64	1.14
1986	0.34	0.51	0.60	0.75	0.83	0.87	0.95	0.93	1.01	0.94	1.07	0.90	1.19	1.14
1987	0.34	0.47	0.69	0.76	0.83	0.85	0.87	0.98	1.07	0.99	1.34	1.15	1.01	1.09
1988	0.34	0.47	0.66	0.80	0.79	0.82	0.93	0.89	0.98	0.89	0.78	0.72	0.90	1.06
1989	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
1990	0.34	0.48	0.55	0.73	0.76	0.78	0.81	0.90	0.90	0.86	1.02	1.03	0.89	0.91
1991	0.34	0.47	0.67	0.66	0.80	0.96	1.08	1.17	1.10	1.22	1.16	1.10	1.29	1.09
1992	0.34	0.47	0.64	0.74	0.73	0.80	0.94	1.25	1.03	1.00	1.25	1.15	1.05	1.10
1993	0.34	0.47	0.89	0.82	1.03	1.03	1.14	1.08	1.16	1.19	1.20	1.33	1.14	1.14
1994	0.34	0.47	0.64	0.84	0.97	1.14	1.14	1.12	1.19	1.24	1.27	1.06	1.09	1.15
1995	0.34	0.55	0.85	0.75	1.13	1.33	1.40	1.36	1.43	1.42	1.50	1.45	1.66	1.32
1996	0.34	0.54	0.48	0.93	1.03	1.18	1.28	1.39	1.47	1.35	1.38	1.36	1.46	1.30
1997	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
1998	0.34	0.40	0.76	0.74	0.98	1.06	1.09	1.25	1.31	1.48	1.28	1.30	1.36	1.45
1999	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2000	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2001	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2002	0.34	0.47	0.66	0.75	0.85	0.93	0.99	1.06	1.11	1.15	1.19	1.15	1.19	1.14
2003	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
2004	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
2005	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07
2006	0.33	0.39	0.76	0.69	0.81	0.92	0.91	0.97	0.93	1.06	1.17	1.19	1.61	1.07

Table 1A.19. Percentage mature females at age from Wespestad and Terry (1984) for the BSAI and mean percentage of mature females at age for the Gulf of Alaska from Dorn et al (2007) for 1983-2006 (GOA 3).

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.20. Comparisons of fits for the evaluations of Aleutian Islands pollock models.

	Model W.			Model A.		
	SV.12.12	SF.12.12	SF.8.8	SV.12.12	SF.12.12	SF.8.8
Number of Parameters	168	132	100	168	132	100
Survey Catchability	1.00	1.00	1.00	1.00	1.00	1.00
Fishery Average Effective N	51	51	39	50	50	39
Survey Average Effective N	130	149	109	127	144	109
RMSE Survey	0.82	0.81	0.71	1.32	1.29	1.06
-Log Likelihoods						
Survey Index	20.96	21.67	23.57	38.47	39.23	47.18
Fishery Age Comp	335.79	336.14	439.68	345.59	345.77	452.44
Survey Age Comp	44.39	44.09	51.65	43.18	43.14	50.72
Catch	0.80	0.83	1.40	0.79	0.80	1.26
Sub Total	401.93	402.73	516.30	428.03	428.95	551.60
-log Penalties						
Recruitment	3.18	3.13	25.48	22.13	21.88	48.82
Selectivity Constraint	69.58	65.11	25.00	75.34	70.74	24.91
Prior	0.02	0.02	0.02	0.01	0.01	0.00
Fpen	0.00	0.00	0.00	0.00	0.00	0.00
Total	474.70	471.00	566.80	525.50	521.58	625.32

Table 1A.21. Key results for the evaluations of Aleutian Islands pollock models.

	Model W.			Model A.		
	SV.12.12	SF.12.12	SF.8.8	SV.12.12	SF.12.12	SF.8.8
Model Conditions						
Survey Catchability	1.00	1.00	1.00	1.00	1.00	1.00
Natural Mortality	0.24	0.24	0.25	0.18	0.18	0.22
Fishing Mortalities						
Max F 1978 - 2008	0.33	0.32	0.28	0.34	0.33	0.28
F 2008	0.03	0.03	0.02	0.01	0.01	0.01
Stock Abundance						
Initial Biomass (1978; thousands of tons)	367.97	366.26	366.49	1015.20	1010.70	1016.90
CV	0.13	0.13	0.14	0.10	0.10	0.10
2008 Total Biomass (thousands of tons)	211.39	211.47	182.46	392.37	392.63	358.60
CV	17%	17%	17%	15%	15%	16%
2009 Age 3+ biomass (thousands of tons)	192.58	192.72	164.64	370.00	370.40	330.85
1978 Year Class (at age 2)	0.45	0.45	0.62	1.06	1.05	1.71
CV	18%	18%	17%	13%	13%	12%
Recruitment Variability	0.55	0.55	0.63	0.72	0.72	0.81
Specified Sigma R	0.60	0.60	0.60	0.60	0.60	0.60
Steepness (h)	0.70	0.70	0.70	0.70	0.70	0.70
Projected Catch (unadjusted)						
F50% 2009 catch	0.31	0.30	0.25	0.18	0.18	0.20
CV	19%	19%	13%	16%	16%	12%
F40% 2009 catch	0.50	0.50	0.42	0.29	0.29	0.33
CV	20%	20%	16%	17%	17%	14%
F35% 2009 catch	0.65	0.64	0.55	0.38	0.37	0.44
CV	21%	21%	17%	18%	18%	16%

Table 1A.22. Ther reference Model A.SF.8.8 estimates of pollock biomass with approximate lower (LCI) and upper (UCI) 95% confidence bounds for age 2+ biomass. Also included are the age 3+ biomass and female spawning stock biomass (SSB) estimates.

A.SF.8.8	Total Biomass (Age 2+)			Biomass	Female
Year		LCI	UCI	Age 3+	SSB
1978	863,180	705,900	1,020,460	800,200	233,660
1979	975,370	805,062	1,145,678	888,760	275,640
1980	1,325,300	1,093,740	1,556,860	997,716	307,090
1981	1,491,800	1,229,480	1,754,120	1,443,471	322,120
1982	1,585,100	1,317,380	1,852,820	1,564,911	407,610
1983	1,576,000	1,318,540	1,833,460	1,523,447	500,320
1984	1,506,400	1,271,320	1,741,480	1,462,306	547,400
1985	1,424,400	1,211,900	1,636,900	1,356,481	522,420
1986	1,318,100	1,131,362	1,504,838	1,281,636	484,920
1987	1,230,900	1,071,138	1,390,662	1,204,647	460,710
1988	1,145,100	1,010,634	1,279,566	1,110,485	433,600
1989	1,024,100	913,050	1,135,150	999,528	397,490
1990	948,890	858,438	1,039,342	930,386	364,920
1991	790,030	715,104	864,956	757,198	292,150
1992	608,130	546,164	670,096	596,271	220,580
1993	502,380	449,486	555,274	492,477	181,340
1994	411,400	364,596	458,204	398,963	148,450
1995	330,790	286,846	374,734	314,716	115,560
1996	258,350	216,498	300,202	250,981	87,432
1997	225,910	184,470	267,350	216,128	75,164
1998	199,720	157,926	241,514	189,077	65,231
1999	175,420	133,666	217,174	168,816	58,489
2000	180,200	137,778	222,622	170,118	61,012
2001	188,830	144,110	233,550	174,439	62,867
2002	212,870	160,718	265,022	186,359	64,253
2003	227,740	170,262	285,218	219,945	66,689
2004	234,090	173,476	294,704	227,803	73,750
2005	239,180	176,384	301,976	227,097	81,504
2006	242,290	177,714	306,866	229,278	85,205
2007	254,550	184,776	324,324	232,716	84,887
2008	272,370	192,642	352,098	250,534	84,936

Table 1A.23. Model W.SF.8.8 estimates of pollock biomass with approximate lower (LCI) and upper (UCI) 95% confidence bounds for age 2+ biomass. Also included are the age 3+ biomass and female spawning stock biomass (SSB) estimates.

W.SF.8.8 Year	Total Biomass (Age 2+)	LCI	UCI	Biomass Age 3+	Female SSB
1978	301,200	228,180	374,220	279,078	81,555
1979	332,680	252,772	412,588	302,978	93,220
1980	436,100	323,434	548,766	323,630	96,917
1981	468,830	338,762	598,898	451,174	93,722
1982	484,420	349,572	619,268	476,507	118,320
1983	498,550	366,380	630,720	477,773	154,070
1984	492,870	369,554	616,186	474,551	174,010
1985	476,040	360,874	591,206	445,764	168,410
1986	468,070	362,884	573,256	449,814	164,350
1987	452,810	358,814	546,806	438,078	160,650
1988	438,030	354,190	521,870	415,918	156,190
1989	423,980	349,986	497,974	406,415	152,100
1990	408,560	343,814	473,306	393,754	145,610
1991	390,860	332,178	449,542	362,583	135,490
1992	379,540	327,336	431,744	369,092	130,410
1993	350,830	304,808	396,852	341,874	122,510
1994	314,600	273,480	355,720	303,509	113,930
1995	295,020	256,668	333,372	281,052	103,120
1996	222,680	187,338	258,022	216,654	75,646
1997	190,130	156,186	224,074	182,493	63,255
1998	157,680	124,548	190,812	149,749	51,140
1999	128,880	96,812	160,948	124,211	42,791
2000	128,590	97,006	160,174	121,615	43,556
2001	130,550	98,324	162,776	120,808	43,603
2002	142,420	106,066	178,774	124,946	43,230
2003	148,090	109,356	186,824	143,162	43,556
2004	147,020	107,504	186,536	143,162	46,283
2005	144,210	104,590	183,830	137,258	49,058
2006	140,300	100,982	179,618	133,311	49,422
2007	140,850	100,086	181,614	129,498	47,296
2008	143,910	99,342	188,478	132,553	45,232

Table 1A.24. Reference Model A.SF.8.8 estimated pollock numbers at age in millions, 1978-2008.

A.SF.8.8	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% of 15+
1978	315	252	242	164	133	50	38	24	18	13	5	4	3	22	1,282	1.72%
1979	433	254	203	194	131	106	40	30	19	14	10	4	3	19	1,460	1.33%
1980	1638	349	205	162	155	104	84	31	23	15	11	8	3	17	2,805	0.61%
1981	242	1320	279	158	123	115	76	59	21	16	10	8	5	14	2,445	0.55%
1982	101	195	1059	220	123	95	88	57	43	15	11	7	5	14	2,032	0.66%
1983	263	81	156	829	170	94	71	64	40	30	11	8	5	13	1,835	0.73%
1984	221	212	65	123	645	131	71	53	46	29	22	8	6	13	1,645	0.81%
1985	339	178	170	51	95	495	99	53	38	33	21	16	6	14	1,608	0.85%
1986	182	274	143	134	40	73	375	73	38	27	24	15	11	14	1,423	0.98%
1987	131	147	220	114	106	31	57	289	56	29	21	18	11	19	1,250	1.53%
1988	173	106	118	176	90	84	25	44	222	43	22	16	14	23	1,156	2.03%
1989	123	140	85	94	137	70	64	19	33	163	31	16	12	27	1,014	2.71%
1990	93	99	113	68	75	110	56	51	15	26	128	25	13	31	901	3.43%
1991	164	75	79	87	51	55	79	39	33	10	17	84	16	29	817	3.50%
1992	59	132	59	59	62	36	37	50	22	19	6	10	49	26	626	4.14%
1993	50	48	105	45	44	45	25	25	32	14	12	4	6	48	504	9.44%
1994	62	40	38	80	33	32	32	17	16	20	9	8	2	33	422	7.93%
1995	80	50	32	28	58	23	21	20	10	9	11	5	4	21	373	5.51%
1996	37	65	40	23	20	39	15	13	11	5	5	6	3	13	293	4.52%
1997	49	30	52	30	17	14	27	10	8	7	3	3	4	10	263	3.77%
1998	53	39	24	39	22	12	10	18	6	5	4	2	2	8	245	3.43%
1999	33	43	31	18	29	16	8	6	11	4	3	2	1	6	212	2.92%
2000	50	27	35	25	14	23	13	7	5	9	3	2	2	6	220	2.67%
2001	72	41	21	28	20	11	18	10	5	4	7	2	2	6	249	2.50%
2002	133	58	33	17	22	16	9	15	8	4	3	5	2	6	333	1.94%
2003	39	107	47	26	14	18	13	7	12	6	3	3	4	7	306	2.16%
2004	31	31	86	38	21	11	14	10	6	9	5	3	2	9	277	3.13%
2005	60	25	25	69	30	17	9	11	8	5	7	4	2	9	283	3.02%
2006	65	49	20	20	56	24	14	7	9	7	4	6	3	8	292	2.90%
2007	109	52	39	16	16	44	19	11	6	7	5	3	5	9	343	2.69%
2008	109	88	42	32	13	13	35	15	8	4	6	4	2	11	384	2.83%

Table 1A.25. Model W.SF.8.8 estimated pollock numbers at age in millions, 1978-2008.

W.SF.8.8	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% of 15+
1978	111	87	84	57	47	18	13	8	6	4	2	1	1	8	447	1.73%
1979	149	87	68	65	44	36	14	10	6	5	3	1	1	7	498	1.34%
1980	562	116	68	53	50	33	27	10	7	5	3	2	1	5	944	0.57%
1981	88	440	90	50	37	34	22	17	6	4	3	2	1	4	799	0.45%
1982	40	69	343	68	37	27	24	15	11	4	3	2	1	3	647	0.49%
1983	104	31	54	267	53	29	21	19	11	8	3	2	1	3	607	0.56%
1984	92	82	24	42	209	41	22	16	14	9	6	2	2	4	566	0.63%
1985	151	72	64	19	32	159	31	16	12	10	6	5	2	4	583	0.64%
1986	91	119	56	50	15	25	124	24	13	9	8	5	4	4	548	0.75%
1987	74	72	93	44	39	12	20	97	19	10	7	6	4	6	503	1.20%
1988	111	58	56	73	35	31	9	15	75	15	8	6	5	8	502	1.52%
1989	88	87	45	44	57	27	24	7	12	59	11	6	4	10	481	2.04%
1990	74	69	68	36	35	45	21	19	6	9	46	9	5	11	452	2.45%
1991	141	58	54	53	27	26	34	16	14	4	7	34	7	12	486	2.38%
1992	52	111	46	42	41	21	21	27	12	11	3	5	26	14	433	3.27%
1993	45	41	87	35	33	32	16	15	19	9	8	2	4	30	376	7.90%
1994	55	35	32	67	27	24	23	12	11	14	6	6	2	24	337	7.01%
1995	70	44	27	25	52	21	19	18	9	8	10	5	4	19	330	5.75%
1996	30	55	34	20	17	34	13	11	9	5	4	5	2	12	250	4.70%
1997	38	24	42	25	14	12	24	9	7	6	3	3	3	9	217	3.99%
1998	40	30	18	31	18	10	8	15	5	4	3	2	1	7	190	3.48%
1999	23	31	23	13	22	12	6	5	8	3	2	2	1	4	155	2.78%
2000	35	18	24	18	10	17	9	5	4	6	2	2	1	4	156	2.55%
2001	49	27	14	19	14	8	13	7	4	3	5	2	1	4	170	2.38%
2002	87	38	21	11	15	11	6	10	6	3	2	4	1	4	221	1.85%
2003	25	69	30	17	9	12	9	5	8	4	2	2	3	4	197	2.07%
2004	19	19	54	23	13	7	9	7	4	6	3	2	1	5	173	3.05%
2005	35	15	15	42	18	10	5	7	5	3	5	3	1	5	169	2.97%
2006	35	27	12	12	33	14	8	4	5	4	2	4	2	5	166	2.91%
2007	57	27	21	9	9	25	11	6	3	4	3	2	3	5	185	2.76%
2008	57	45	21	17	7	7	19	8	4	2	3	2	1	6	200	2.91%

Table 1A.26. Reference Model A.SF.8.8 estimates of full-selection fishing mortality and exploitation rates for NRA pollock.

A.SF.8.8		Catch/Biomass
Year	F[a]	Rate[b]
1978	0.017	0.007
1979	0.025	0.010
1980	0.122	0.044
1981	0.073	0.021
1982	0.089	0.032
1983	0.071	0.028
1984	0.078	0.028
1985	0.077	0.033
1986	0.039	0.018
1987	0.033	0.021
1988	0.063	0.032
1989	0.017	0.010
1990	0.138	0.083
1991	0.223	0.125
1992	0.157	0.086
1993	0.173	0.114
1994	0.224	0.143
1995	0.279	0.196
1996	0.175	0.112
1997	0.183	0.115
1998	0.192	0.119
1999	0.009	0.006
2000	0.010	0.007
2001	0.007	0.004
2002	0.009	0.005
2003	0.015	0.007
2004	0.009	0.005
2005	0.013	0.007
2006	0.013	0.007
2007	0.017	0.009
2008	0.008	0.004

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

Table 1A.27. Model W.SF.8.8 estimates of full-selection fishing mortality and exploitation rates for NRA pollock.

W.SF.8.8		Catch/Biomass
Year	F[a]	Rate[b]
1978	0.009	0.003
1979	0.068	0.024
1980	0.218	0.068
1981	0.129	0.032
1982	0.020	0.007
1983	0.009	0.003
1984	0.055	0.019
1985	0.004	0.002
1986	0.003	0.001
1987	0.010	0.006
1988	0.003	0.001
1989	0.000	0.000
1990	0.046	0.026
1991	0.003	0.001
1992	0.043	0.022
1993	0.072	0.046
1994	0.029	0.019
1995	0.283	0.197
1996	0.164	0.104
1997	0.222	0.136
1998	0.250	0.148
1999	0.008	0.005
2000	0.011	0.007
2001	0.007	0.004
2002	0.004	0.002
2003	0.020	0.010
2004	0.021	0.011
2005	0.021	0.011
2006	0.024	0.012
2007	0.032	0.017
2008	0.016	0.008

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

Table 1A.28. Reference Model A.SF.8.8 estimates of age-2 pollock recruitment (in millions).

Year	Index at age 2	Year	Index at age 2
1978	314.9	1995	80.4
1979	433.1	1996	36.8
1980	1637.8	1997	48.9
1981	241.5	1998	53.2
1982	100.9	1999	33.0
1983	263.0	2000	50.4
1984	220.6	2001	72.0
1985	339.4	2002	132.5
1986	182.5	2003	39.0
1987	131.2	2004	31.5
1988	173.3	2005	60.4
1989	123.1	2006	65.0
1990	92.5	2007	109.2
1991	164.2	2008	109.2
1992	59.3	2009	73.4
1993	49.5	Ave 78-06	182.5
1994	62.2	Med 78-06	92.5

Table 1A.29. Model W.SF.8.8 estimates of age-2 pollock recruitment (in millions).

Year	Index at age 2	Year	Index at age 2
1978	110.6	1995	69.9
1979	148.5	1996	30.2
1980	562.3	1997	38.2
1981	88.3	1998	39.6
1982	39.6	1999	23.4
1983	103.9	2000	34.9
1984	91.6	2001	48.7
1985	151.4	2002	87.4
1986	91.3	2003	24.7
1987	73.7	2004	19.3
1988	110.5	2005	34.8
1989	87.8	2006	34.9
1990	74.0	2007	56.8
1991	141.4	2008	56.8
1992	52.2	2009	43.4
1993	44.8	Ave 78-06	86.7
1994	55.5	Med 78-06	69.9

Table 1A.30 Estimates of 2008 fishery, 2003-2007 mean fishery, and survey selectivity-at-age.

	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Model A.SF.8.8														
2008 Fishery	0.007	0.046	0.230	0.341	0.428	0.555	0.734	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ave2003-2007	0.007	0.046	0.230	0.341	0.428	0.555	0.734	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Survey	0.062	0.188	0.416	0.621	0.740	0.797	0.886	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Model W.SF.8.8														
2008 Fishery	0.006	0.038	0.195	0.300	0.392	0.518	0.706	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ave2003-2007	0.006	0.038	0.195	0.300	0.392	0.518	0.706	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Survey	0.066	0.199	0.435	0.636	0.748	0.804	0.894	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 1A.31. Projections of Model A.SF.8.8 female spawning biomass (in thousands of t), *F*, and catch (in thousands of t) for NRA pollock for the 8 scenarios. Fishing mortality rates given are based on the *average* fishing mortality over all ages.

Sp.Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2008	84.90	84.90	84.90	84.90	84.90	84.90	84.90	84.90
2009	85.48	85.48	88.54	86.83	88.68	84.73	85.48	86.47
2010	78.59	78.59	96.07	85.69	96.95	74.97	78.59	83.55
2011	82.36	82.36	110.15	92.54	111.75	77.67	81.80	88.61
2012	90.69	90.69	128.35	104.13	130.65	85.19	87.39	99.26
2013	98.94	98.94	147.61	116.68	150.65	92.44	93.50	111.84
2014	103.77	103.77	163.92	126.28	167.73	96.16	96.60	122.38
2015	105.70	105.70	177.16	132.83	181.78	97.02	97.16	130.75
2016	107.05	107.05	188.81	138.11	194.23	97.55	97.57	138.38
2017	109.82	109.82	200.95	144.28	207.18	99.95	99.94	147.50
2018	112.90	112.90	212.67	150.38	219.67	102.81	102.80	156.81
2019	114.62	114.62	222.20	154.81	229.94	104.33	104.32	164.44
2020	114.78	114.78	229.03	157.14	237.46	104.20	104.20	169.87
2021	115.73	115.73	235.75	159.87	244.80	104.99	104.98	175.59
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2008	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2009	0.29	0.29	0.01	0.16	0.00	0.36	0.29	0.20
2010	0.26	0.26	0.01	0.16	0.00	0.31	0.26	0.21
2011	0.28	0.28	0.01	0.16	0.00	0.32	0.34	0.21
2012	0.29	0.29	0.01	0.16	0.00	0.35	0.36	0.20
2013	0.31	0.31	0.01	0.16	0.00	0.37	0.37	0.19
2014	0.31	0.31	0.01	0.16	0.00	0.38	0.38	0.18
2015	0.32	0.32	0.01	0.16	0.00	0.38	0.38	0.18
2016	0.32	0.32	0.01	0.16	0.00	0.39	0.39	0.16
2017	0.33	0.33	0.01	0.16	0.00	0.39	0.39	0.15
2018	0.34	0.34	0.01	0.16	0.00	0.40	0.40	0.14
2019	0.34	0.34	0.01	0.16	0.00	0.40	0.40	0.14
2020	0.34	0.34	0.01	0.16	0.00	0.40	0.40	0.13
2021	0.34	0.34	0.01	0.16	0.00	0.40	0.40	0.13
Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2008	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2009	26.87	26.87	1.25	16.08	0.00	32.55	26.87	19.00
2010	22.03	22.03	1.31	15.36	0.00	24.79	22.03	19.00
2011	24.80	24.80	1.49	16.55	0.00	27.47	30.29	19.00
2012	28.02	28.02	1.68	17.86	0.00	31.02	32.50	19.00
2013	30.91	30.91	1.87	19.23	0.00	34.21	34.93	19.00
2014	33.02	33.02	2.09	20.82	0.00	36.37	36.70	19.00
2015	33.78	33.78	2.23	21.72	0.00	37.15	37.26	19.00
2016	35.95	35.95	2.46	23.34	0.00	38.92	38.95	19.00
2017	37.39	37.39	2.64	24.51	0.00	40.14	40.14	19.00
2018	38.07	38.07	2.78	25.17	0.00	40.67	40.66	19.00
2019	38.73	38.73	2.93	25.96	0.00	41.63	41.62	19.00
2020	38.93	38.93	3.02	26.37	0.00	41.62	41.62	19.00
2021	40.30	40.30	3.18	27.36	0.00	43.09	43.09	19.00

Table 1A.32. Projections of Model W.SF.8.8 female spawning biomass (in thousands of t), *F*, and catch (in thousands of t) for NRA pollock for the 8 scenarios. Fishing mortality rates given are based on the *average* fishing mortality over all ages.

Sp.Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2008	45.20	45.20	45.20	45.20	45.20	45.20	45.20	45.20
2009	42.58	42.58	45.10	44.08	45.23	41.96	42.58	42.78
2010	34.37	34.37	46.98	41.15	47.79	32.02	34.37	35.09
2011	34.42	34.42	51.89	42.53	53.27	31.93	34.11	34.75
2012	37.21	37.21	58.50	46.29	60.42	34.62	35.58	37.36
2013	40.16	40.16	65.52	50.64	67.96	37.26	37.63	40.22
2014	41.62	41.62	71.16	53.75	74.11	38.33	38.43	41.64
2015	42.04	42.04	75.64	55.78	79.10	38.40	38.40	42.04
2016	42.28	42.28	79.46	57.36	83.42	38.46	38.45	42.28
2017	43.13	43.13	83.35	59.20	87.80	39.24	39.23	43.13
2018	44.11	44.11	86.97	60.99	91.89	40.15	40.15	44.11
2019	44.63	44.63	89.81	62.23	95.15	40.58	40.58	44.63
2020	44.71	44.71	91.88	62.92	97.59	40.59	40.59	44.71
2021	44.91	44.91	93.76	63.63	99.80	40.74	40.74	44.91
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2008	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2009	0.48	0.48	0.02	0.20	0.00	0.60	0.48	0.44
2010	0.38	0.38	0.02	0.20	0.00	0.45	0.38	0.39
2011	0.38	0.38	0.02	0.20	0.00	0.45	0.48	0.39
2012	0.40	0.40	0.02	0.20	0.00	0.48	0.49	0.40
2013	0.42	0.42	0.02	0.20	0.00	0.50	0.51	0.42
2014	0.43	0.43	0.02	0.20	0.00	0.51	0.52	0.43
2015	0.44	0.44	0.02	0.20	0.00	0.52	0.52	0.44
2016	0.44	0.44	0.02	0.20	0.00	0.52	0.52	0.44
2017	0.44	0.44	0.02	0.20	0.00	0.52	0.52	0.44
2018	0.44	0.44	0.02	0.20	0.00	0.53	0.53	0.44
2019	0.45	0.45	0.02	0.20	0.00	0.53	0.53	0.45
2020	0.45	0.45	0.02	0.20	0.00	0.53	0.53	0.45
2021	0.45	0.45	0.02	0.20	0.00	0.54	0.54	0.45
Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2008	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2009	20.38	20.38	1.14	9.55	0.00	24.35	20.38	19.00
2010	12.83	12.83	1.14	8.54	0.00	13.78	12.83	13.37
2011	12.86	12.86	1.24	8.69	0.00	13.84	15.70	13.11
2012	13.92	13.92	1.35	9.03	0.00	15.17	15.98	14.03
2013	15.08	15.08	1.46	9.51	0.00	16.59	16.90	15.13
2014	15.89	15.89	1.60	10.08	0.00	17.34	17.45	15.90
2015	16.31	16.31	1.69	10.44	0.00	17.65	17.66	16.31
2016	16.85	16.85	1.83	11.04	0.00	18.06	18.05	16.85
2017	17.19	17.19	1.93	11.41	0.00	18.41	18.40	17.18
2018	17.43	17.43	2.01	11.66	0.00	18.67	18.67	17.43
2019	17.70	17.70	2.09	11.88	0.00	18.94	18.94	17.69
2020	17.87	17.87	2.15	12.07	0.00	19.07	19.07	17.87
2021	18.16	18.16	2.22	12.33	0.00	19.48	19.48	18.16

Table 1A.33. **Ecosystem effects on AI walleye pollock**

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Zooplankton	Stomach contents, ichthyoplankton surveys	None	Unknown
Predator population trends			
Marine mammals	Fur seals declining, Steller sea lions increasing slightly	Possibly lower mortality on walleye pollock	No concern
Birds	Stable, some increasing some decreasing	May affect young-of-year mortality	Unknown
Fish (Pacific cod, arrowtooth flounder)	Pacific cod—decreasing, arrowtooth--stable	Possible decreases to walleye pollock mortality	No concern
Changes in habitat quality			
Temperature regime	The 2004 and 2006AI summer bottom temperature was near average. A warming since 2000 and 2002 were coldest and second coldest survey years respectively.	Warming from 2002 could affect apparent distribution.	Unknown

***The AI walleye pollock* effects on ecosystem**

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Expected to be heavily monitored	Likely to be a minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Expected to be heavily monitored.	Bycatch levels should be low.	Unknown
HAPC biota (seapens/whips, corals, sponges, anemones)	Very low bycatch levels of seapens/whips, sponge and coral catches expected in the pelagic fishery	Bycatch levels and destruction of benthic habitat expected to be minor given the pelagic fishery.	No concern
Marine mammals and birds	Very minor direct-take expected	Likely to be very minor contribution to mortality	No concern
Sensitive non-target species	Expected to be heavily monitored	Unknown given that this fishery was closed between 1999 and 2005. The 2006 AICASS had 3% POP bycatch, the only significant bycatch. The 2005 fishery had a high bycatch of POP, but bycatch of other species was very low in fishery prior to 1999.	No concern
Other non-target species	Very little bycatch.	Unknown	No concern
Fishery concentration in space and time	Steller sea lion protection measures may concentrate fishery spatially to very small areas between 20 nm closures	Depending on concentration of pollock outside of critical habitat could possibly have an effect.	Possible concern
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Possible Concern
Fishery contribution to discards and offal production	Offal production—unknown. Fishery in 2005 expected to be conducted by CPs which may have fish meal production capabilities	Unknown	Unknown
Fishery effects on age-at-maturity and fecundity	Unknown	Unknown	Unknown

Figures

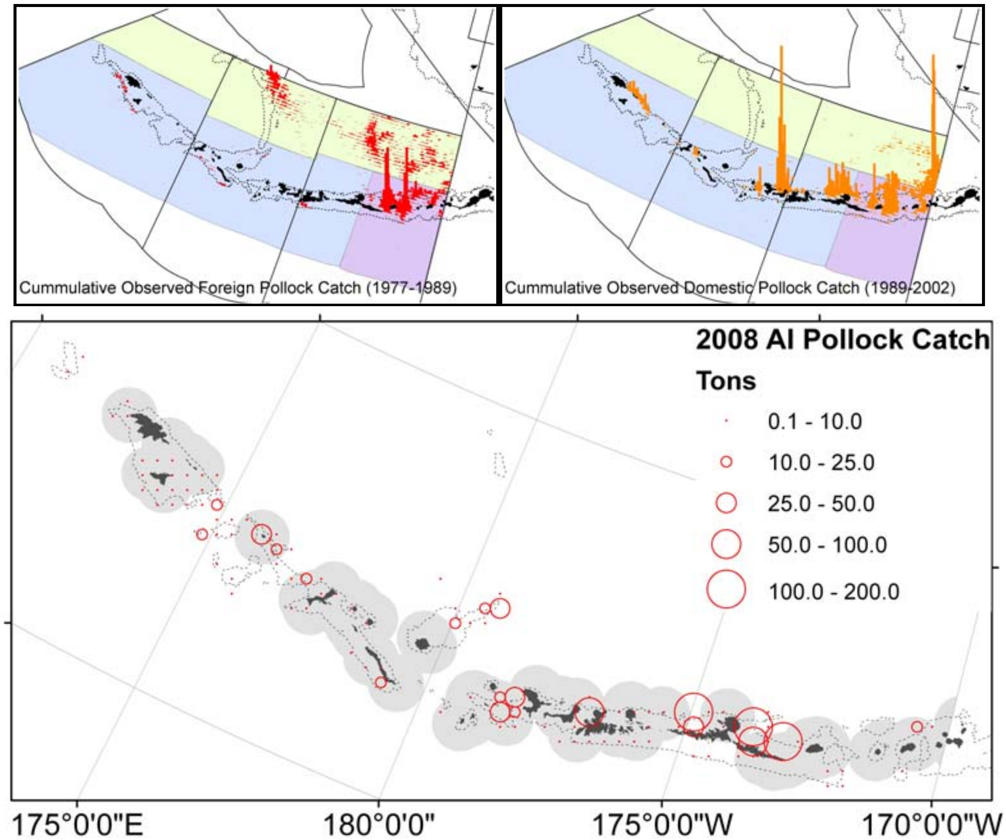

Figure 1A.1. Top figures are Observed foreign and J.V. (1978-1989; left), early domestic (1989-2002; right) pollock catch in the Aleutian Islands Area summed over all years and 10 minute latitude and longitude blocks. The two top maps use the same scale (maximum observed catch per 10 minute block: foreign and J.V. 8,000 t and Domestic 19,000 t). Catches of less than 1 t were excluded from cumulative totals. The bottom figure is observed pollock catch location in 2008 aggregated in 20 X 20 km cells, shaded areas are the directed pollock fishing exclusion zone and dotted line is the 300m isobath.

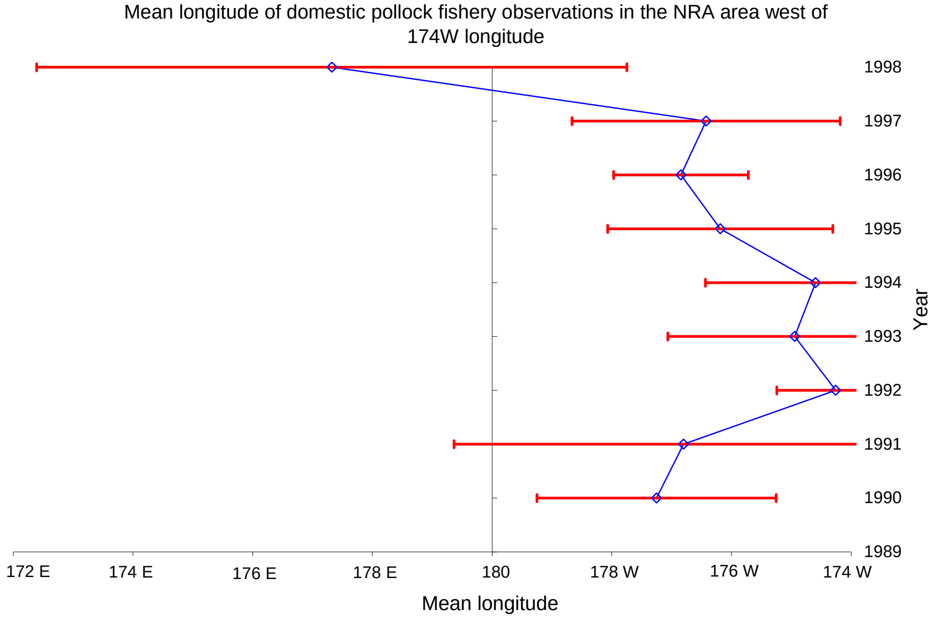

Figure 1A.2. Mean longitude of observed targeted domestic (1990-1998) pollock catch in the NRA west of 174 W longitude. Error bars indicate one standard deviation from the mean

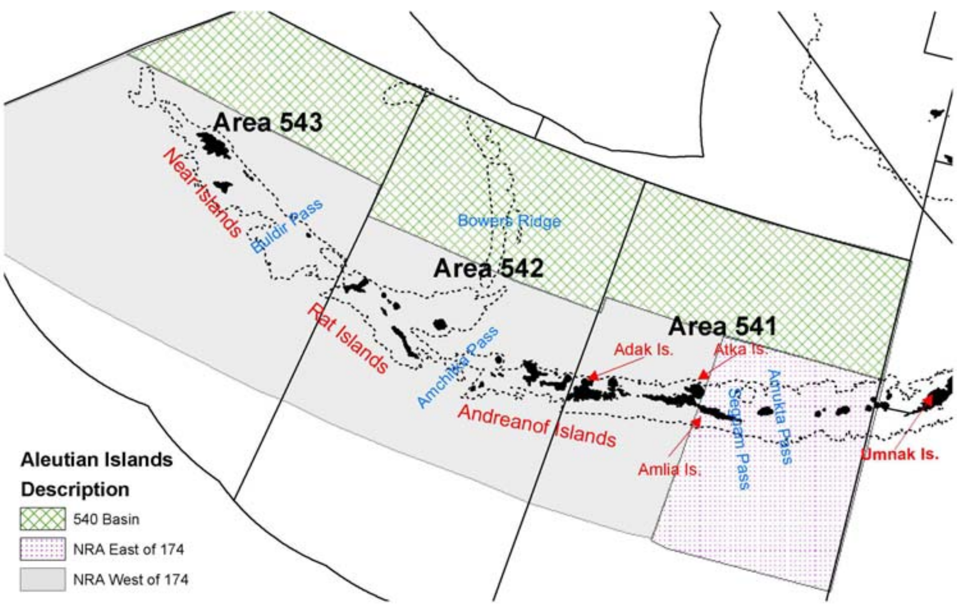

Figure 1A.3. Regions defined for consideration of alternative data partitions for Aleutian Islands Region pollock. The abbreviation "NRA" represents the Near, Rat, and Andreanof Island groups.

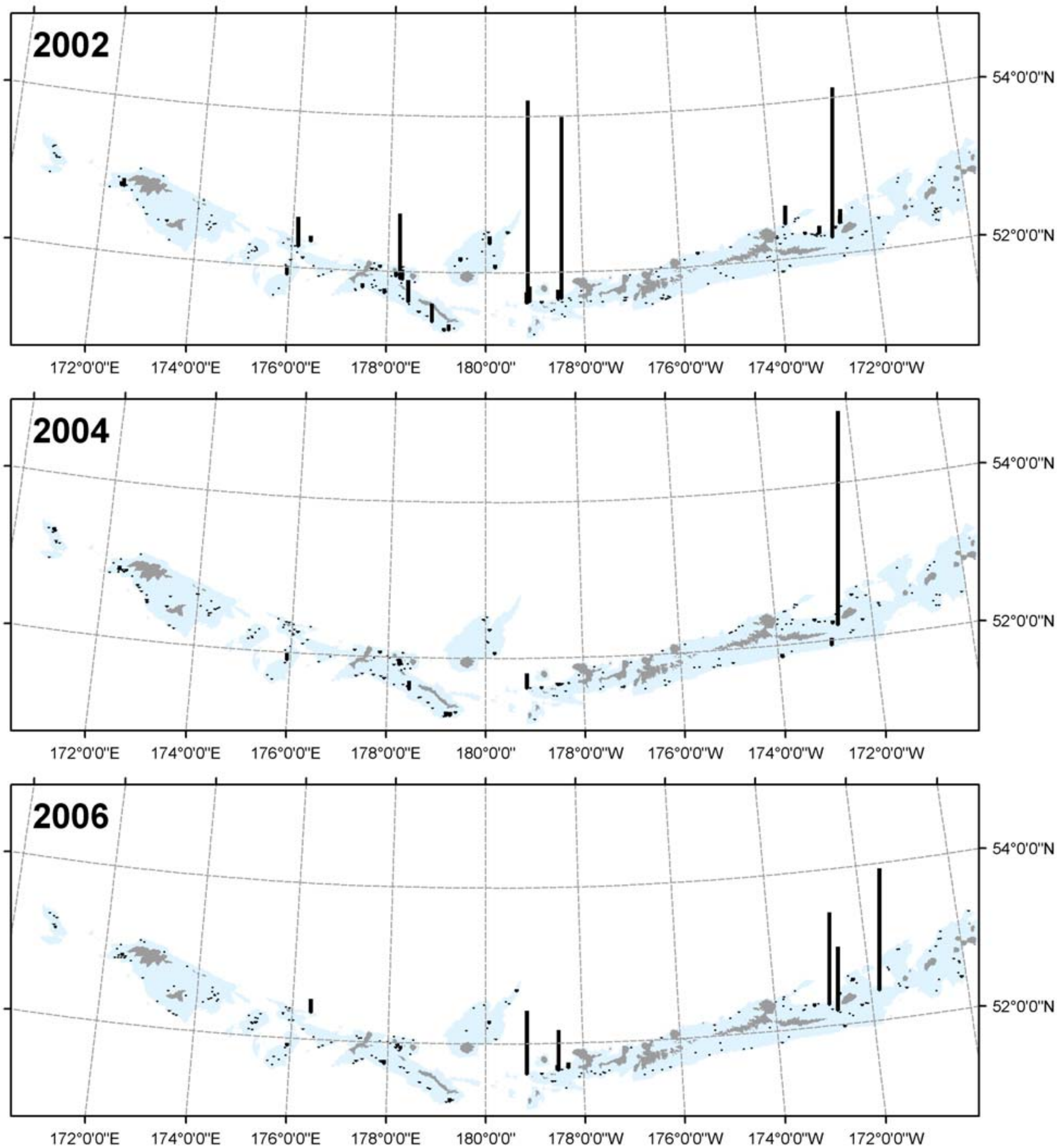

Figure 1A.4. Catch per unit effort (kg per m^3) for surveys of pollock in the Aleutian Islands Region, 2002-2006. The shaded area is the region surveyed.

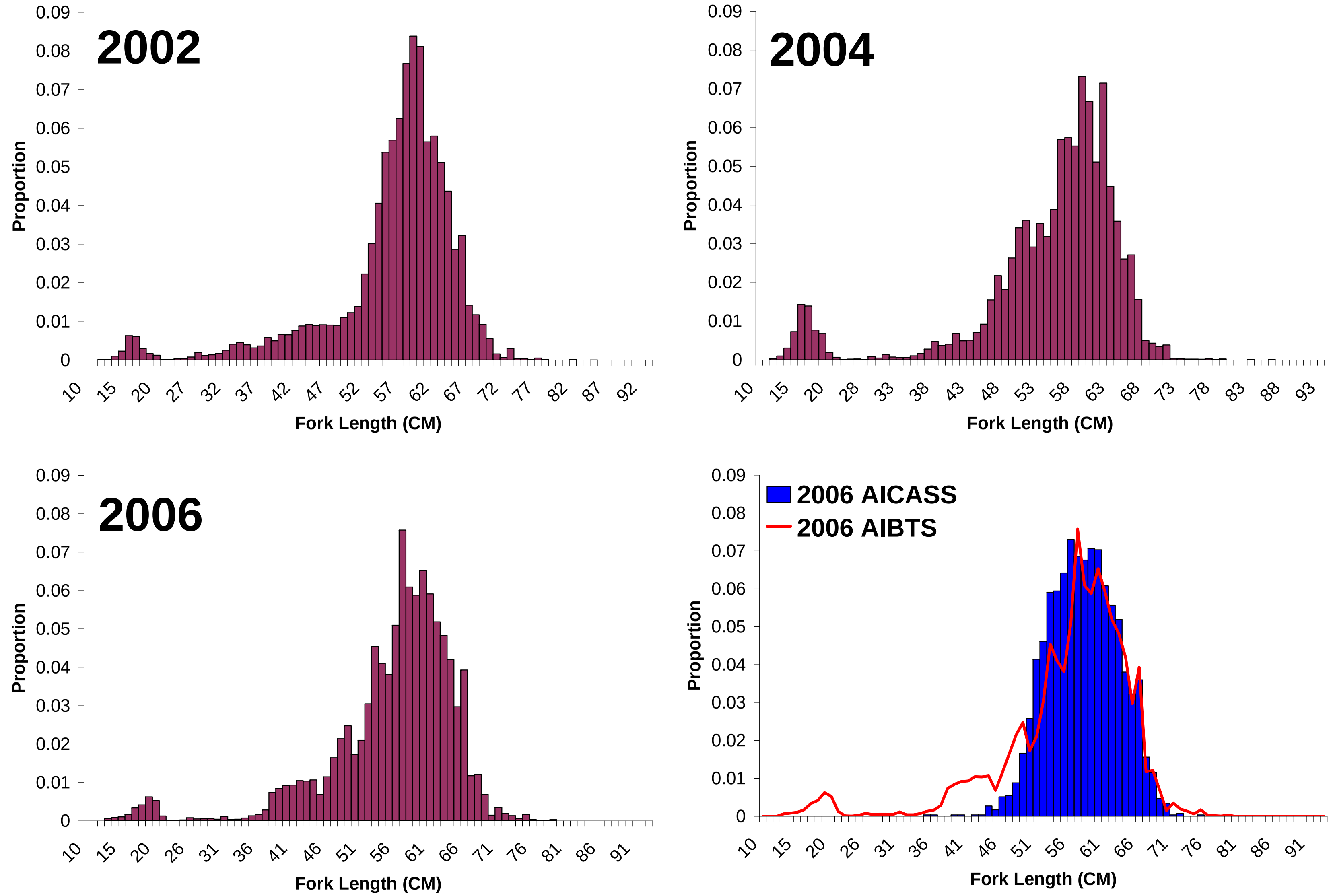

Figure 1A.5. Length distribution for 2002-2006 Aleutian Islands bottom trawl surveys and the 2006 Aleutian Islands cooperative acoustic survey study.

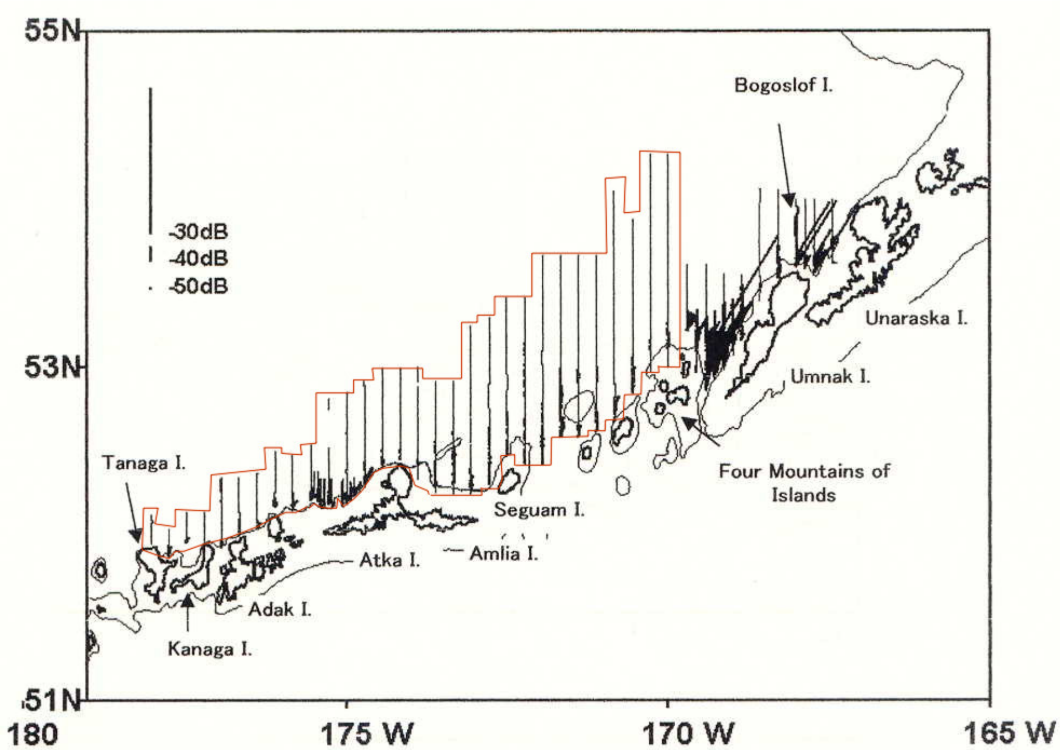

Figure 1A.6. R/V Kaiyo Maru 2002 echo integration-trawl survey (above) strata for leg2 and below observed S_A in both legs. Please note that in the bottom picture the encircled area is leg 2.

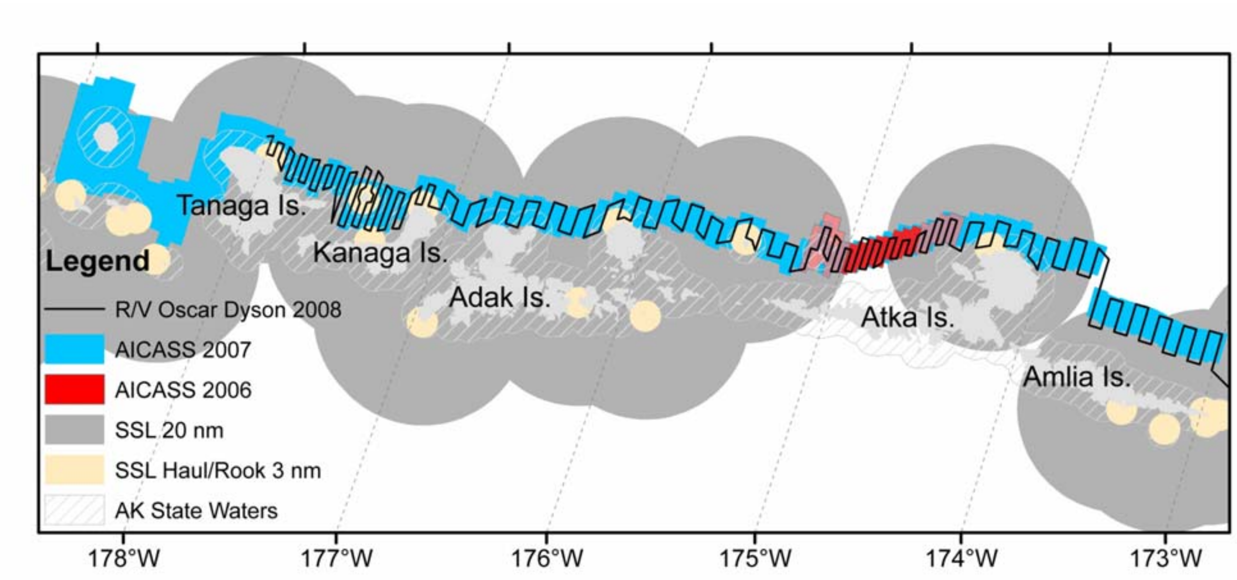

Figure 1A.7. 2006, 2007, and 2008 Aleutian Islands Cooperative Acoustic Survey Study sites within the central Aleutian Islands with pertinent Steller Sea lion areas.

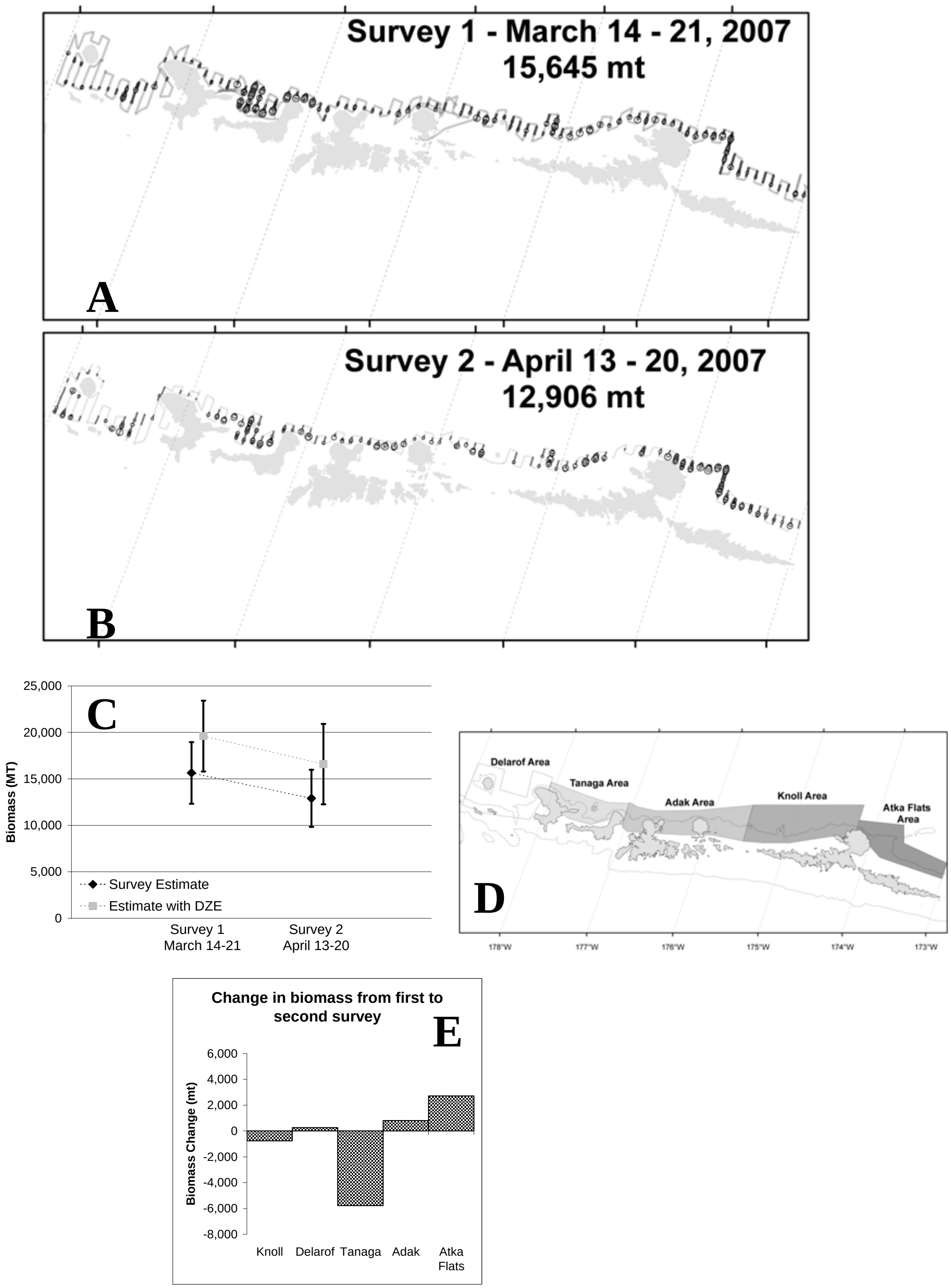

Figure 1A.8. Distribution and biomass estimate results from the 2007 Aleutian Islands Cooperative Acoustic Survey Studies. A) pollock abundance and distribution for Survey 1, B) pollock abundance and distribution for Survey 2, C) biomass estimates, and D) area delineations, and E) Change in pollock biomass between 2007 surveys by area.

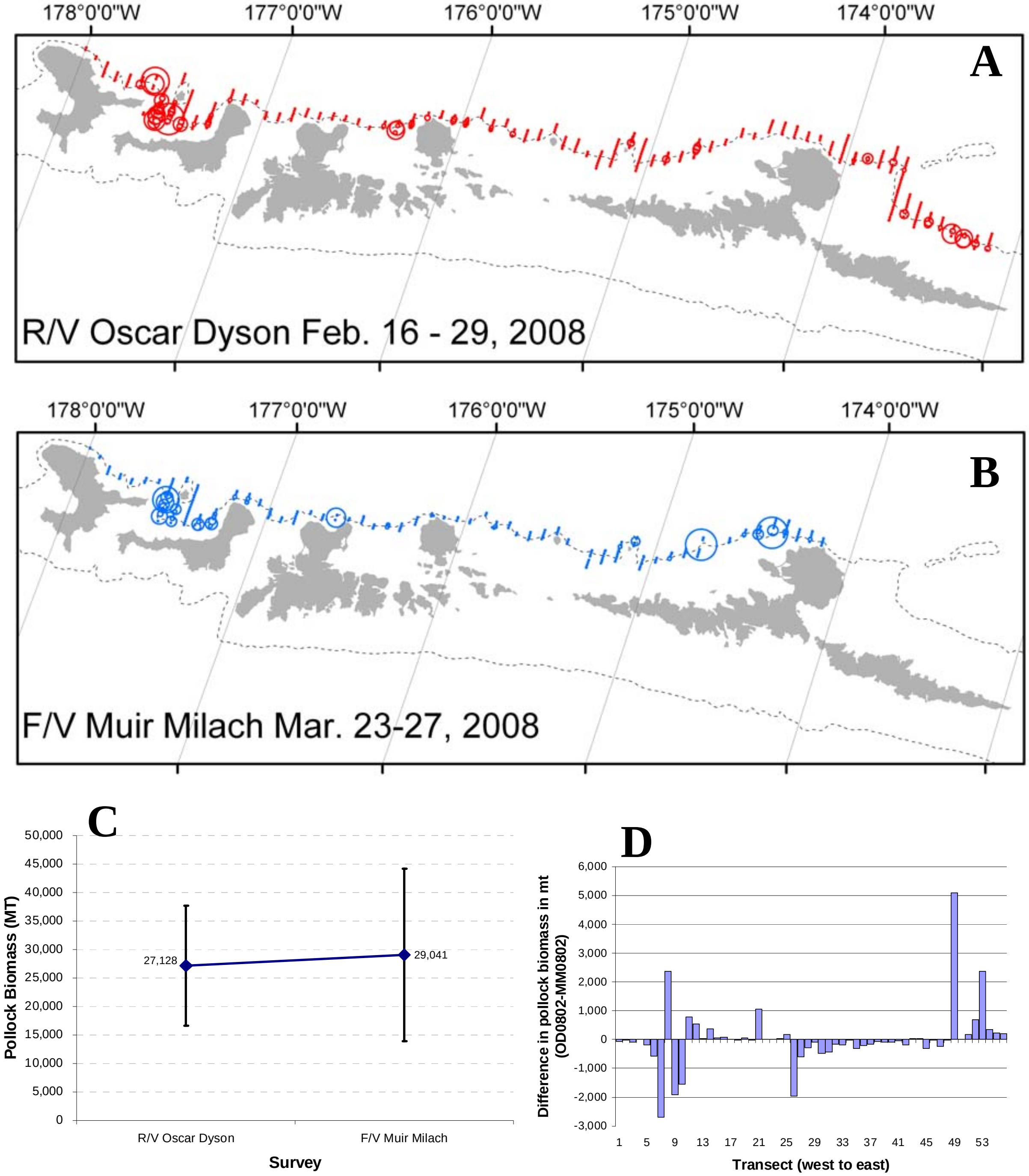

Figure 1A.9. Distribution and biomass estimate results from the 2008 Aleutian Islands Cooperative Acoustic Survey Studies, A) pollock abundance and distribution for Survey 1, B) pollock abundance and distribution for Survey 2, C) biomass estimates, and D) change in biomass distribution by transect.

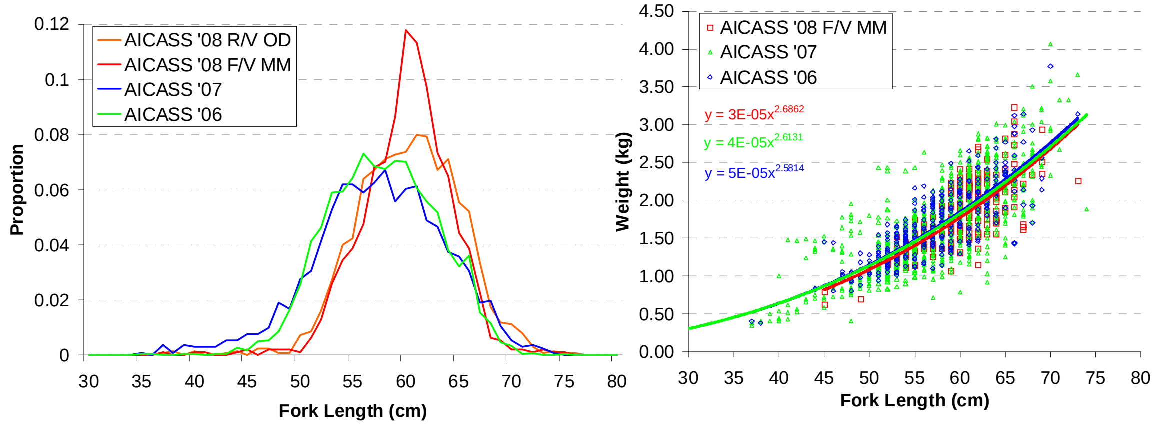

Figure 1A.10. Length distribution (left) and weight at length of Aleutian Islands pollock from the 2006, 2007, and 2008 Aleutian Islands cooperative acoustic survey studies.

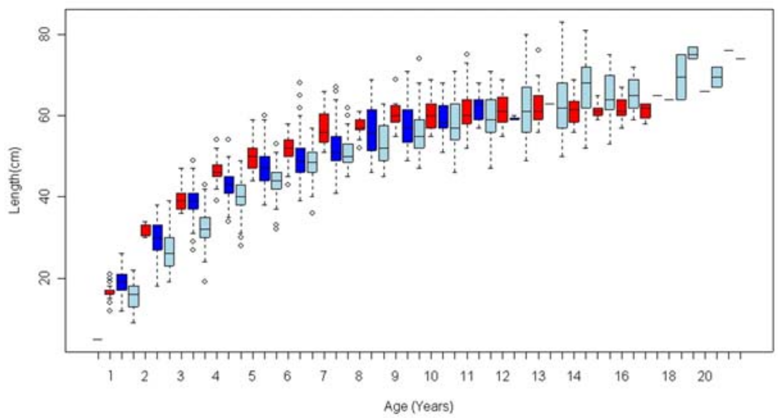

Figure 1A.11. Length at age for Aleutian Islands (red), Gulf of Alaska (blue), and Bering Sea (grey) pollock from the 2004 Aleutian Islands, 2004 Bering Sea, and 2005 Gulf of Alaska bottom trawl surveys.

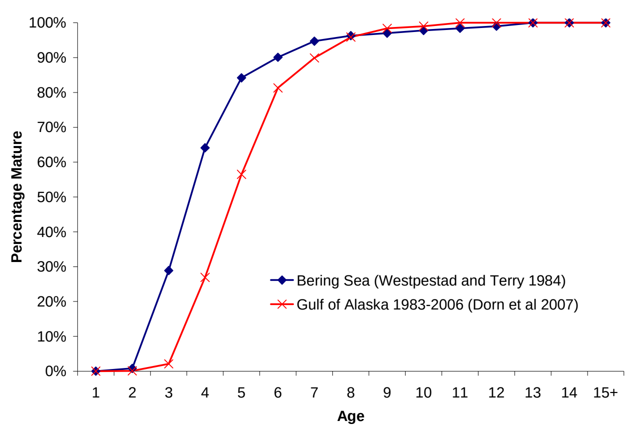

Figure 1A.12. Percentage mature at age for Bering Sea (Westpestad and Terry 1984) and the mean percentage mature at age for 1983-2006 for Gulf of Alaska pollock (Dorn et al. 2007).

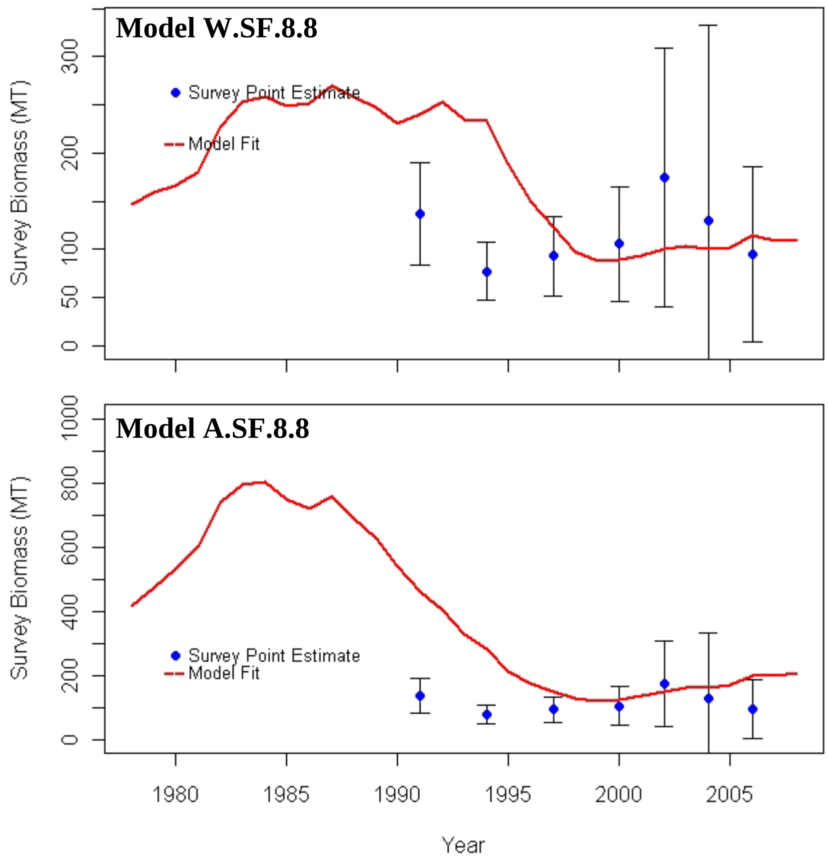

Figure 1A.13. Fit (solid line) to NMFS summer trawl survey (dots) for Model W.SF.8.8 (top) and Model A.SF.8.8 (bottom). (Note the biomass axes are not on the same scales)

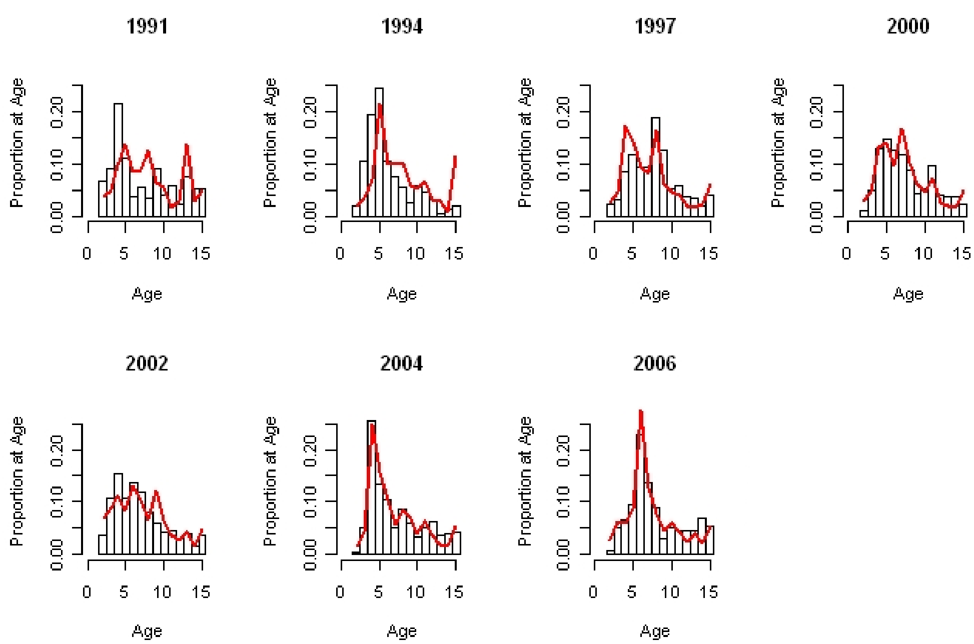

Figure 1A.14. Fits to NMFS summer trawl survey age composition data for Model W.SF.8.8 for Aleutian Islands pollock.

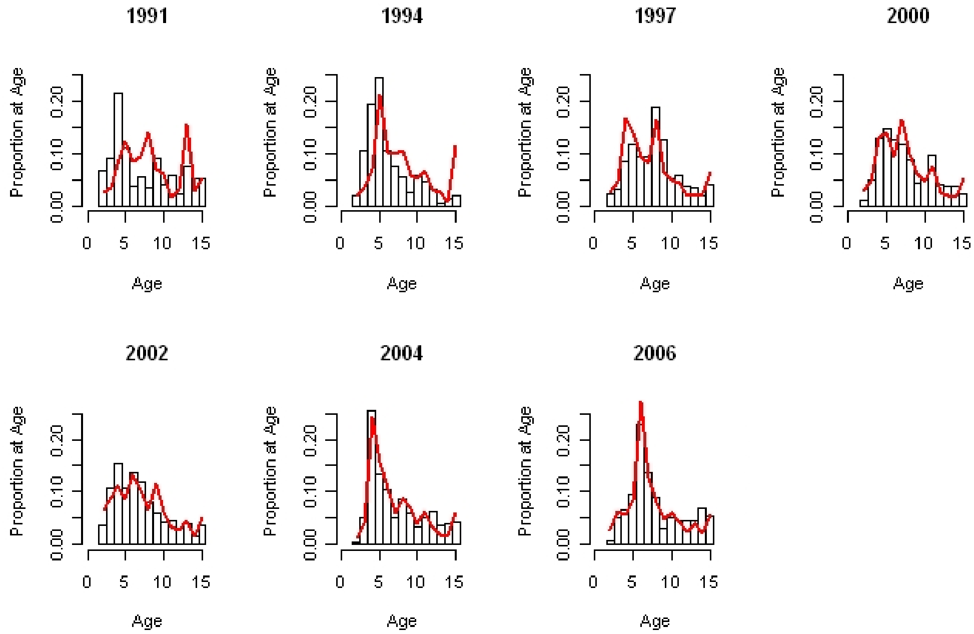

Figure 1A.15. Fits to NMFS summer trawl survey age composition data for Model A.SF.8.8 for Aleutian Islands pollock.

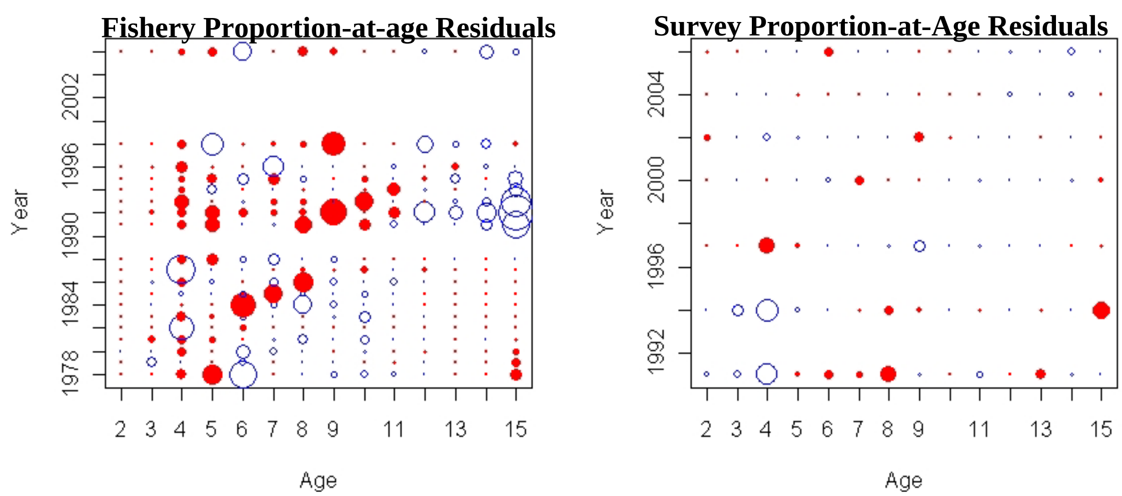

Figure 1A.16. Standardized residuals for fits to the fishery (left) and survey (right) proportion-at-age data for Model W.SF.8.8.

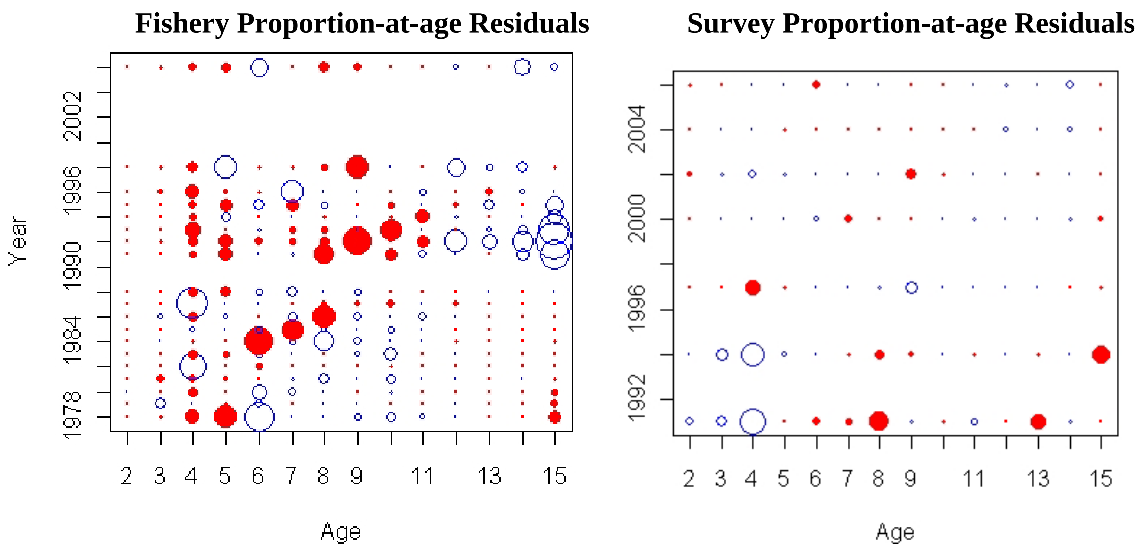

Figure 1A.17. Standardized residuals for fits to the fishery (left) and survey (right) proportion-at-age data for Model A.SF.8.8. Solid circles are positive residuals while hollow circles are negative residuals.

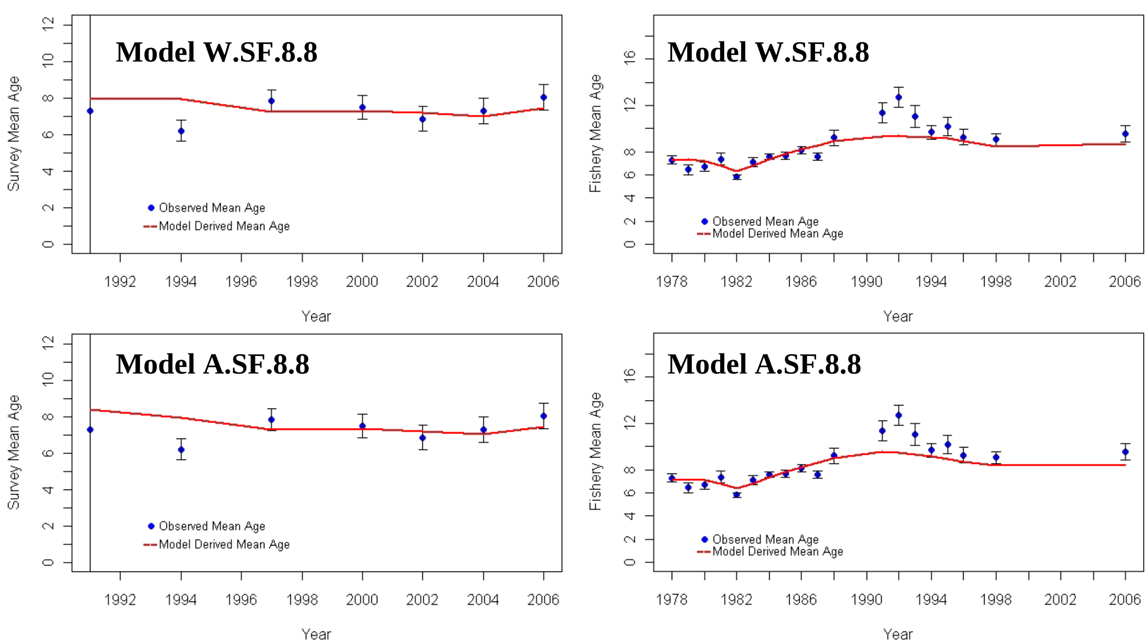

Figure 1A.18. Observed mean age and model derived mean age from the AIBTS (left) and fishery catch at age data (right) for Model W.SF.8.8 (top) and Model A.SF.8.8.

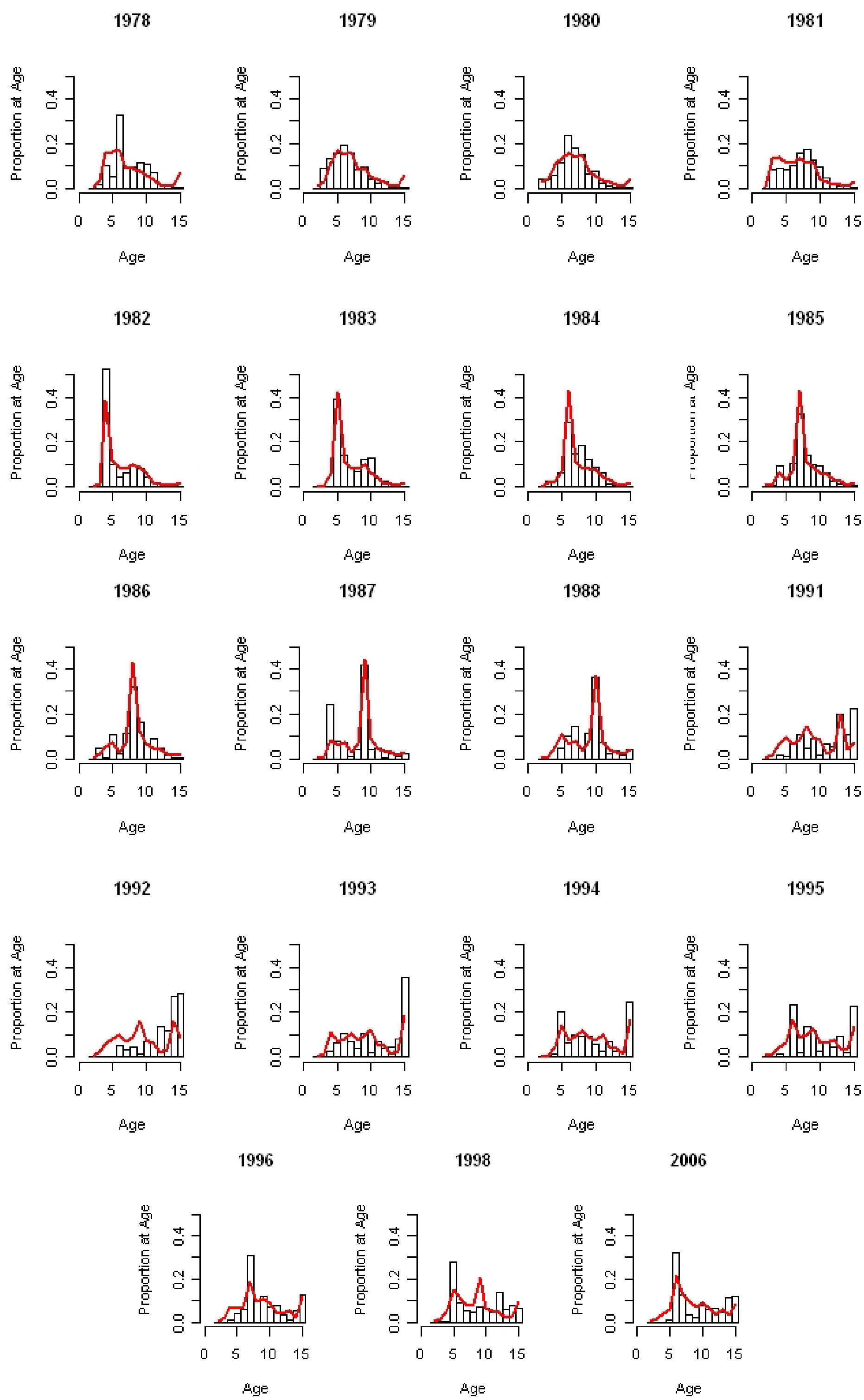

Figure 1A.19. Fit to fishery age composition data for Model W.SF.8.8 for Aleutian Islands (NRA) pollock.

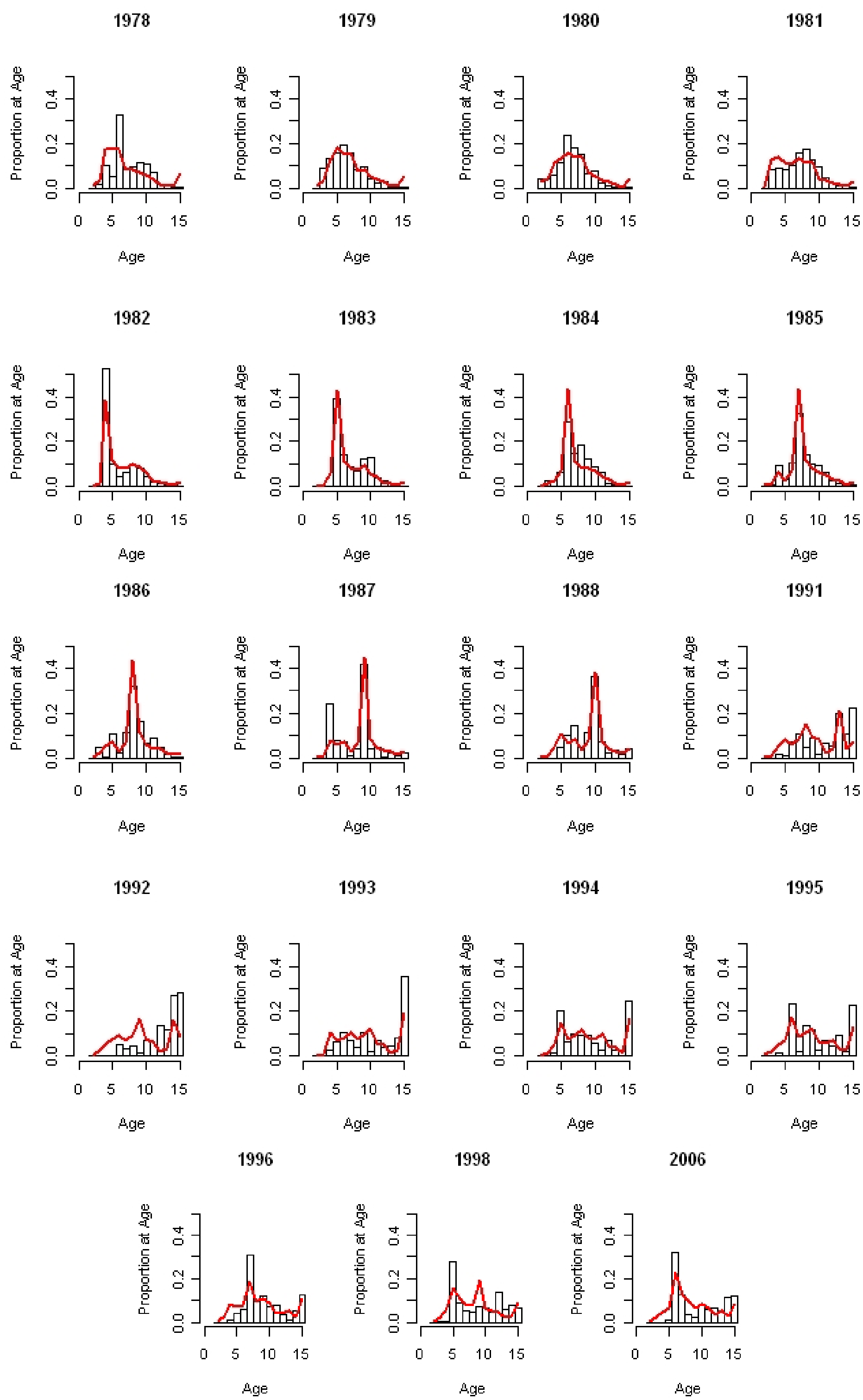

Figure 1A.20. Fit to fishery age composition data for Model A.SF.8.8 for Aleutian Islands (NRA) pollock.

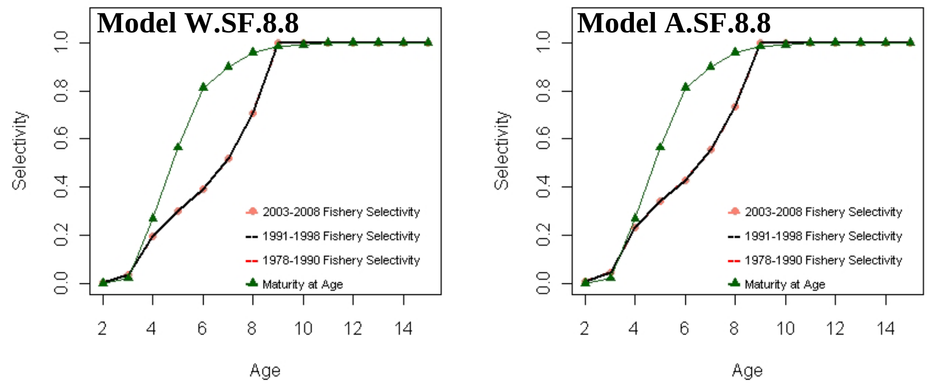

Figure 1A.21. Fishery selectivity estimates for Aleutian Islands pollock for Models W.SF.8.8 and A.SF.8.8 with the maximum age at which the selectivity is allowed to change is set to 8.

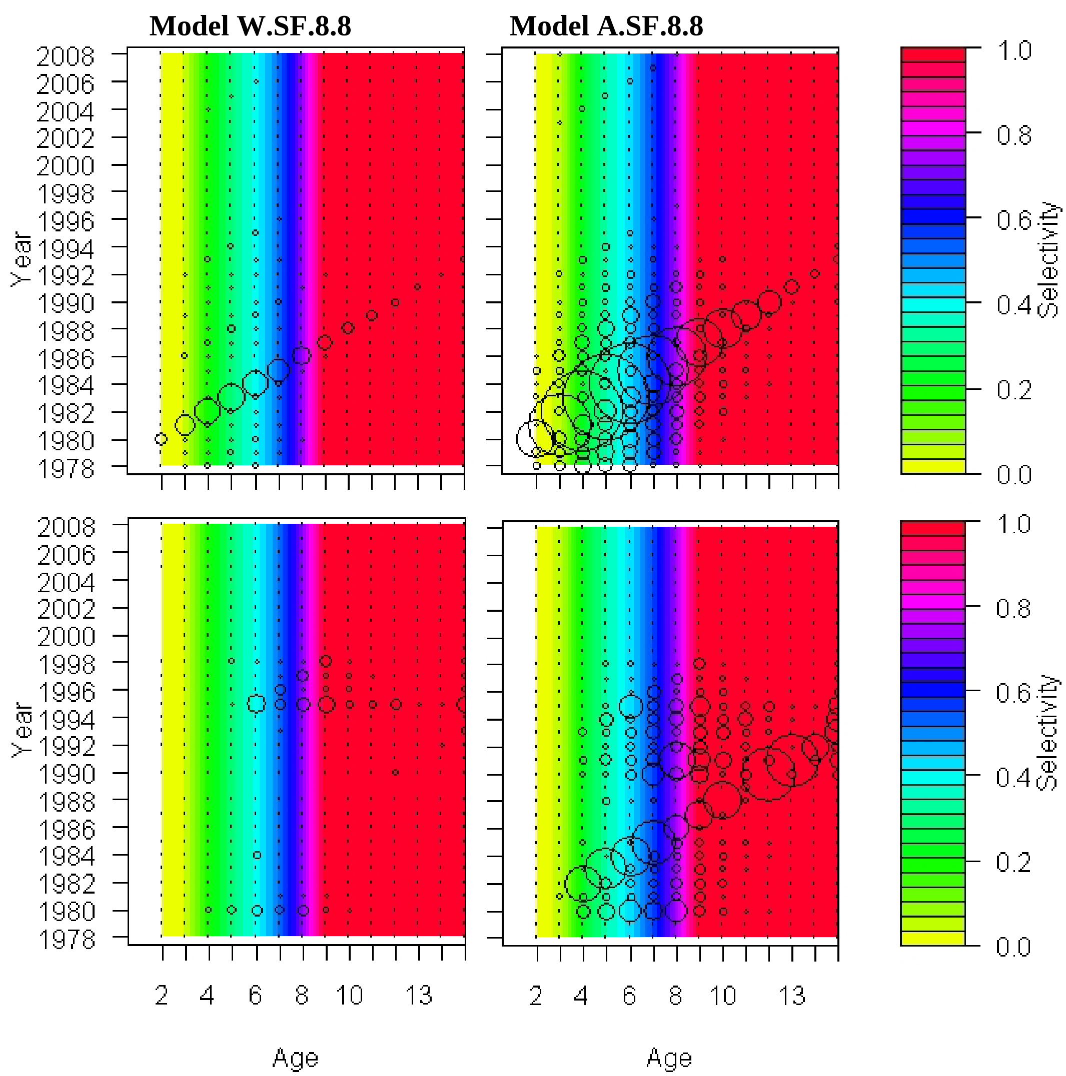

Figure 1A.22 Fishery Selectivity for Model W.SF.8.8 (left) and Model A.SF.8.8 (right) by age for AI pollock with bubble plots of total biomass at age (top) and catch biomass at age (bottom). Total biomass is scaled to 1/20th of the catch biomass bubbles.

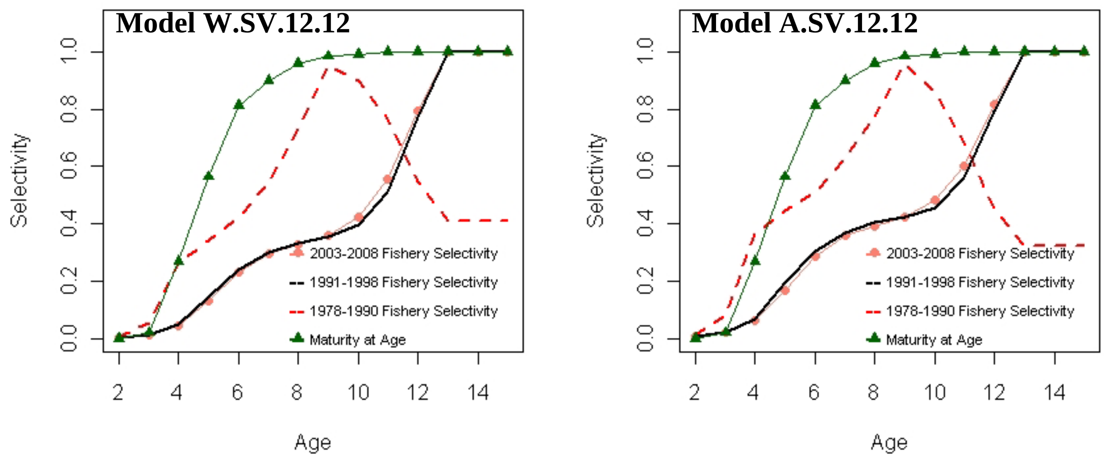

Figure 1A.23. Fishery selectivity estimates for Aleutian Islands pollock for Models W.SV.12.12 and A.SV.12.12 with the maximum age at which the fishery selectivity is allowed to change is set to 12.

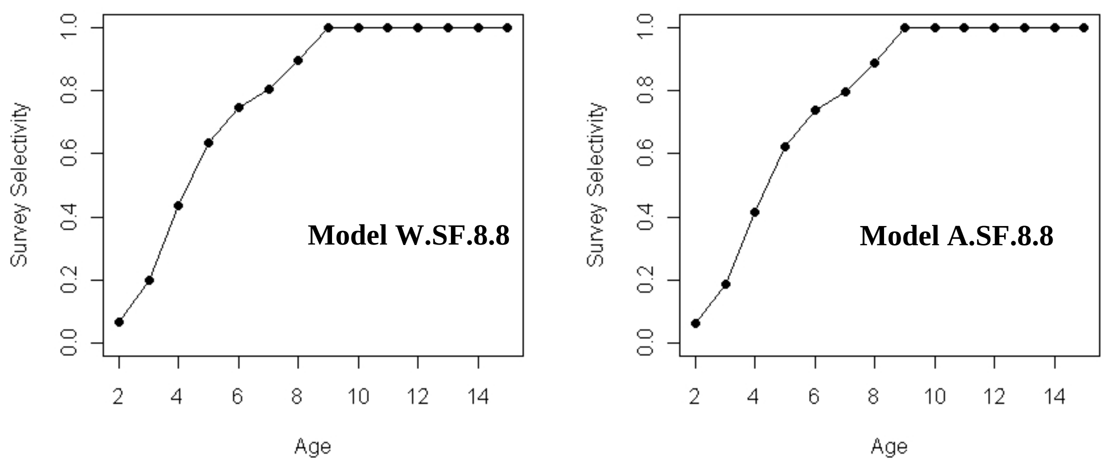

Figure 1A.24. Selectivity estimates for Aleutian Islands pollock for the bottom trawl survey.

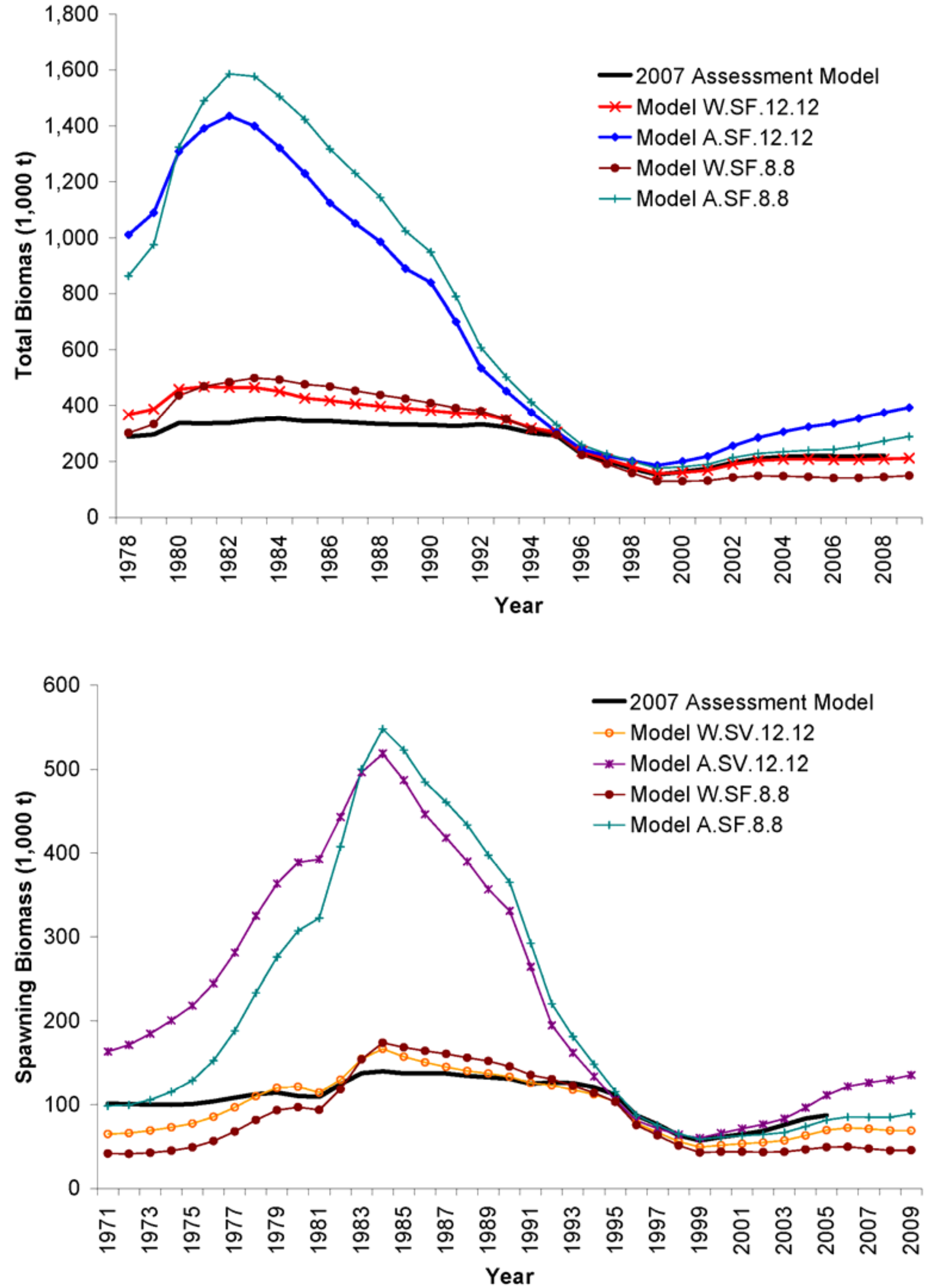

Figure 1A.25. Age 2+ (top) and spawning (bottom) biomass trajectories under four evaluated models compared with the 2007 reference model.

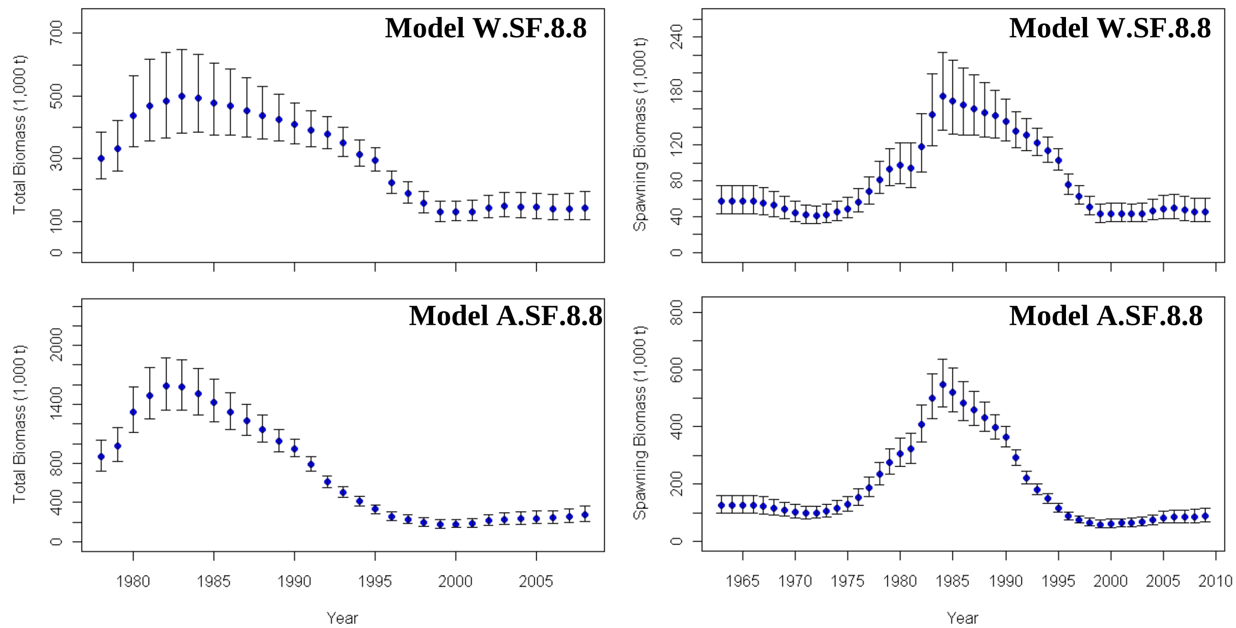

Figure 1A.26. Estimates of Aleutian Islands pollock age 2+ total biomass (Right) and Spawning Biomass (Left) in 1,000s of tons; Top are estimates from Model W.SF.8.8 and bottom are from Model A.SF.8.8 (Note: Biomass axes are not to the same scale). Error bars are two standard deviations.

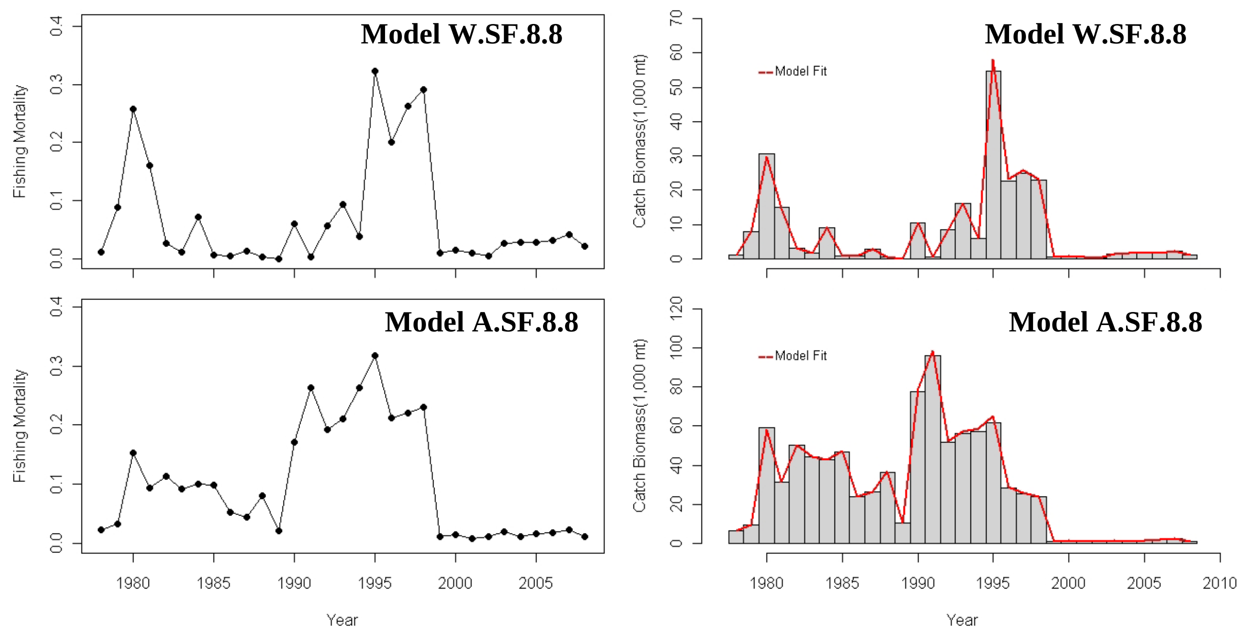

Figure 1A.27 Fishing mortality rates (left) and fits to total catch in 1,000s of tons (right) for Model W.SF.8.8 (top) and Model A.SF.8.8 (bottom) for AI pollock over time 1978-2006. Fishing mortality rates are based on the average over ages 2-15. (Note the catch biomass are not on the same scales)

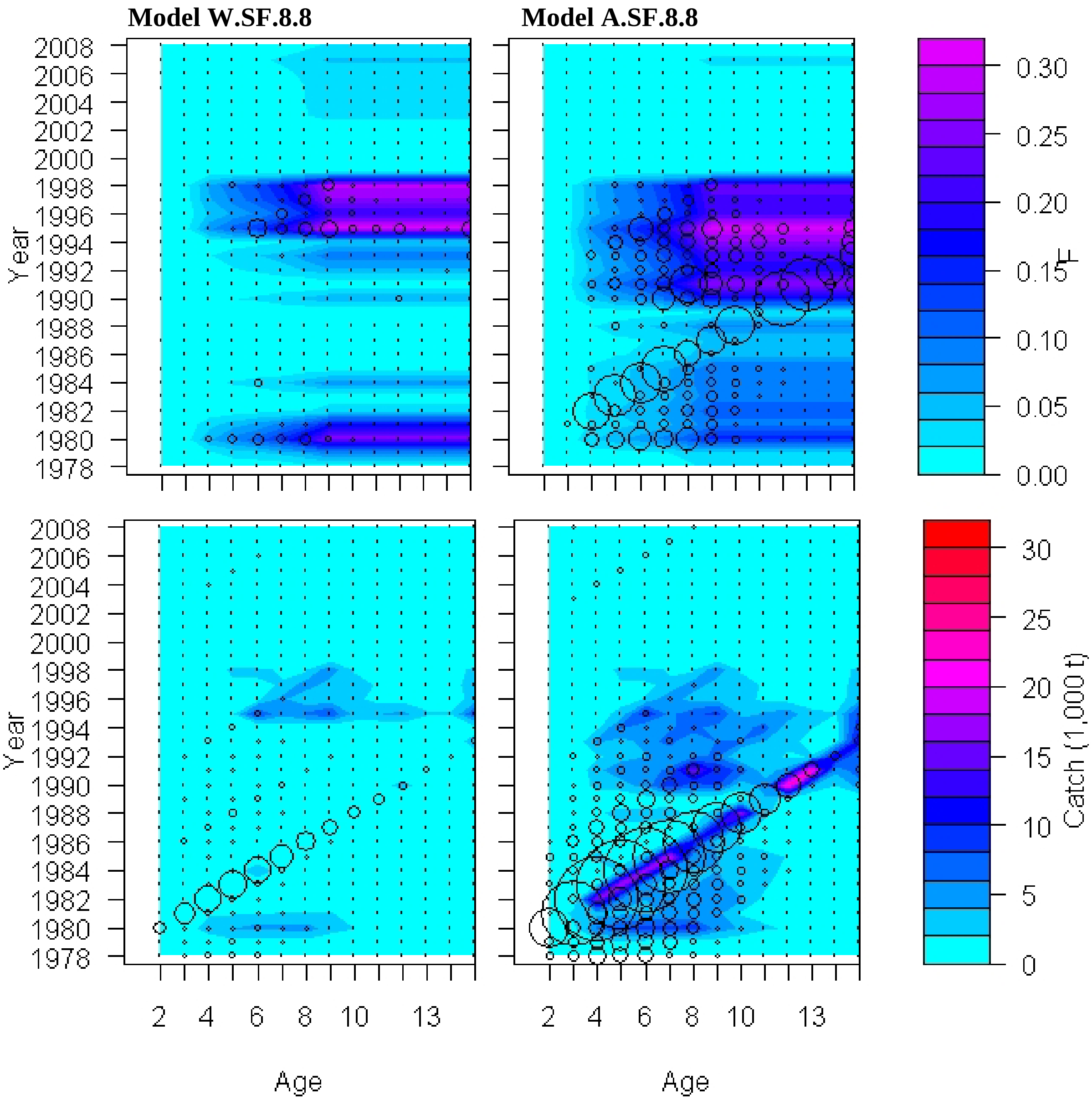

Figure 1A.28 Fishing mortality rates (top) and Catch Biomass in 1,000s of tons (bottom) for Model W.SF.8.8 (left) and Model A.SF.8.8 (right) by age for AI pollock with bubble plots of catch biomass at age (top) and total biomass at age (bottom). Total biomass bubbles are scaled to 1/20th of the catch biomass bubbles.

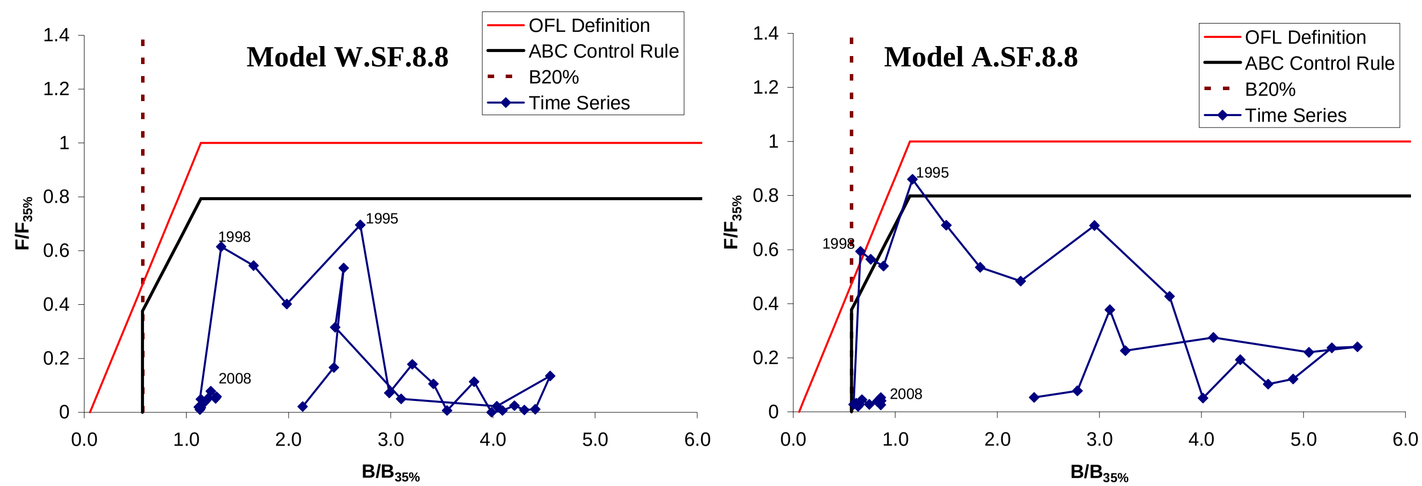

Figure 1A.29. Model W.SF.8.8 (left) reference model Model A.SF.8.8(right) Aleutian Islands pollock spawning biomass relative to $B_{35\%}$ and full-selection fishing mortality relative to F_{OFL} (1978-2008). The ratio of fishing mortality to F_{OFL} is calculated using the estimated selectivity pattern in that year.

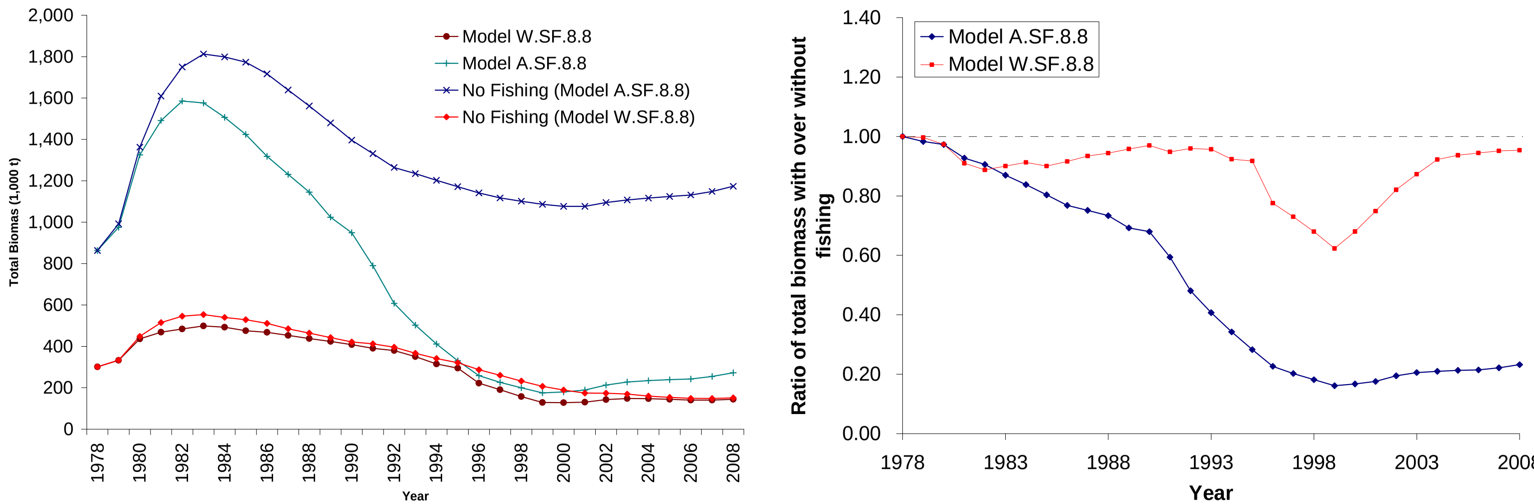

Figure 1A.30. Aleutian Islands pollock total biomass (age 2+) with and without fishing (left) and ratio of total biomass with fishing over total biomass without fishing for Model A.SF.8.8 and Model W.SF.8.8.

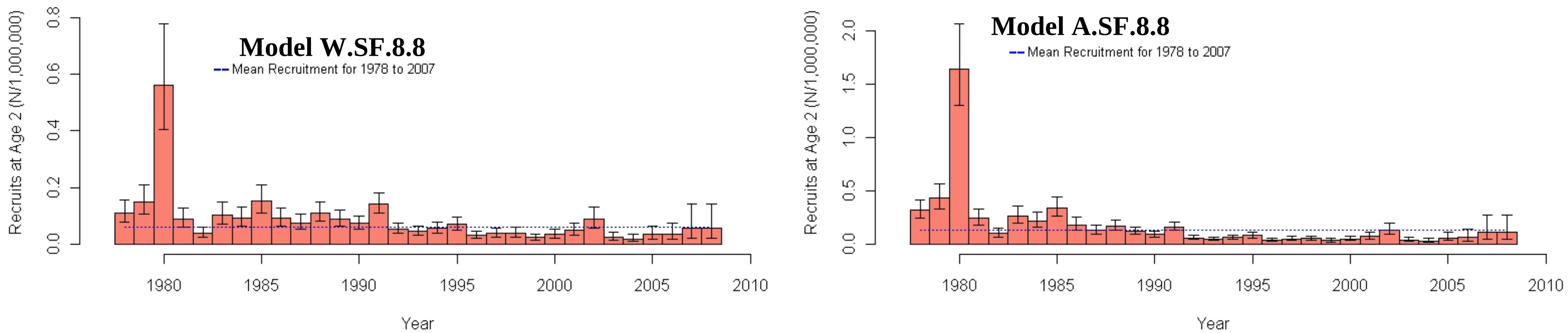

Figure 1A.31. Estimates of Aleutian Islands (NRA assessment area) pollock year-class estimates for Model W.SF.8.8 (left) and Model A.SF.8.8 (right); vertical bars represent approximate upper and lower confidence bounds. (Note the Recruits axes are not the same scale.

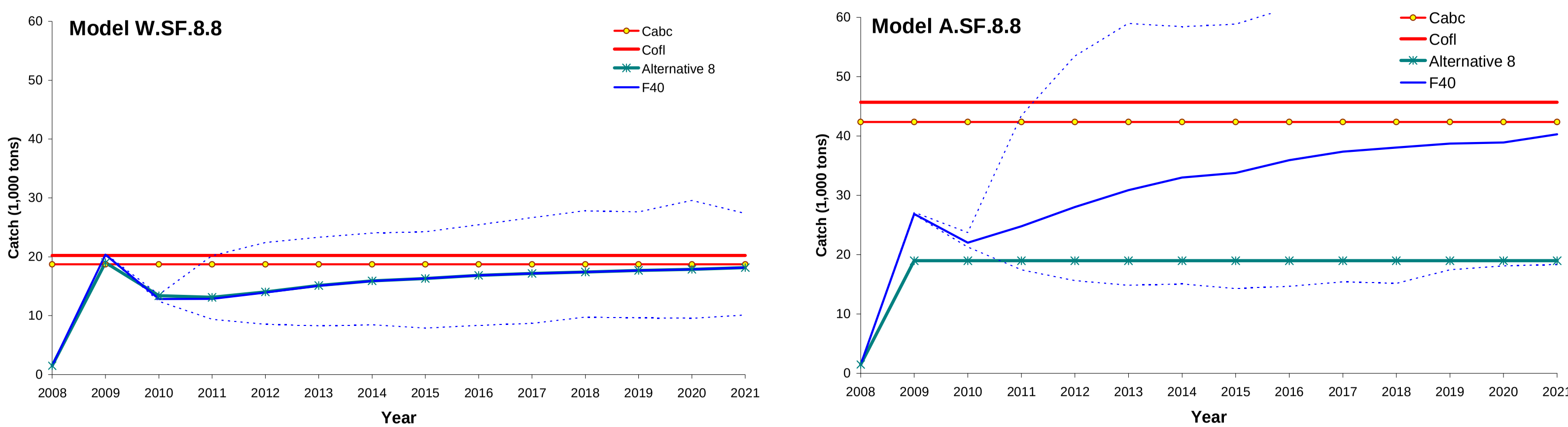

Figure 1A.32 Projected catch for $F_{40\%}$ and Alternative 8 ABC scenarios from Model W.SF.8.8 and Model A.SF8.8.

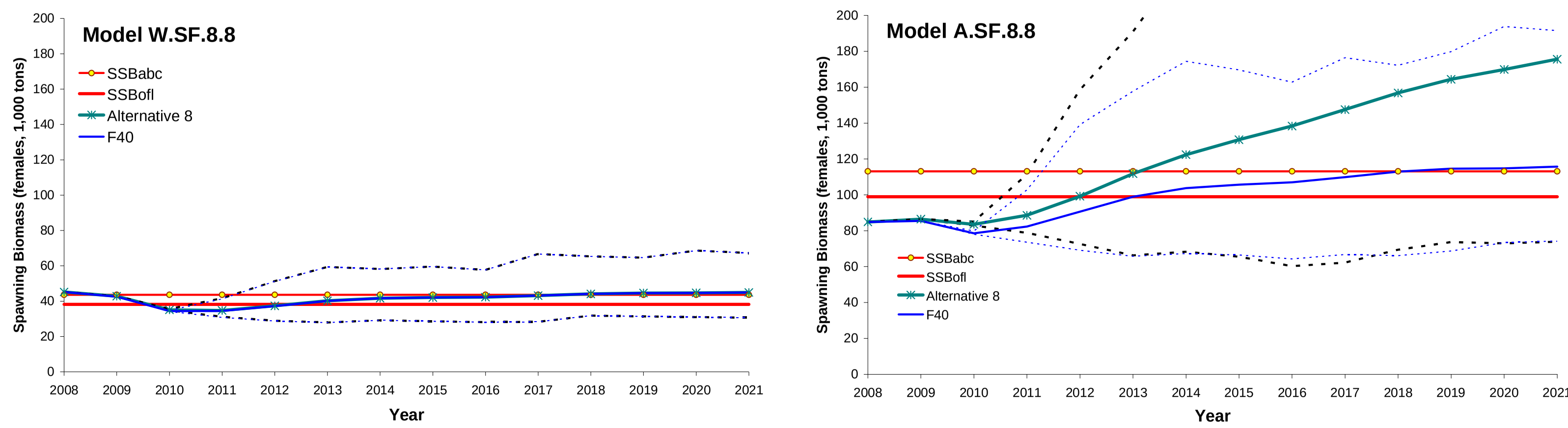

Figure 1A.33 Projected spawning biomass for $F_{40\%}$ and Alternative 8 ABC scenarios from Model W.SF.8.8 and Model A.SF.8.8.

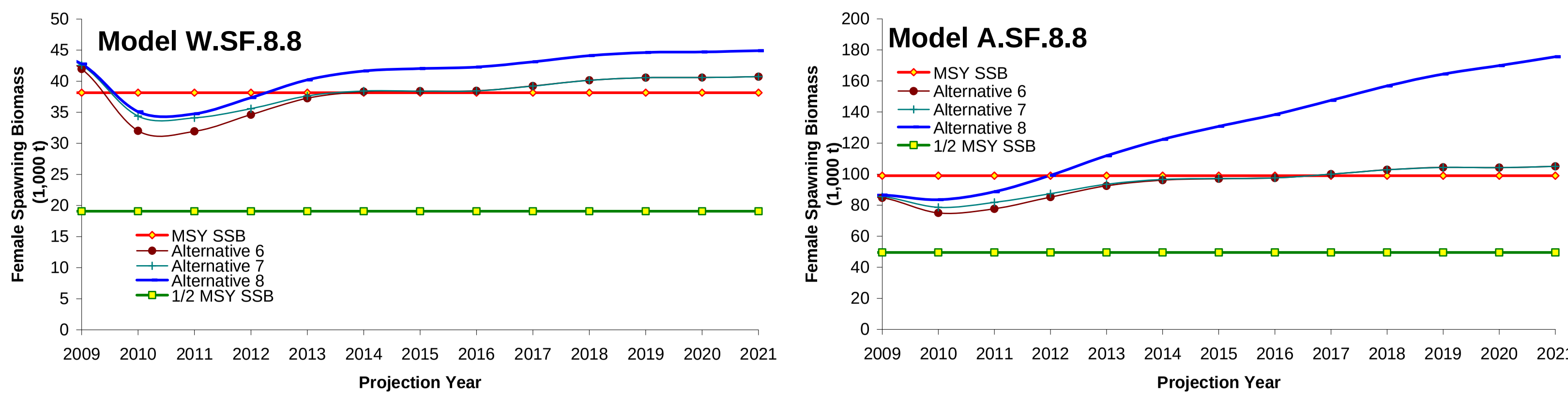

Figure 1A.34 Projected spawning biomass for and Alternatives 6, 7, and 8 ABC scenarios from Model W.SF.8.8 and Model A.SF.8.8.

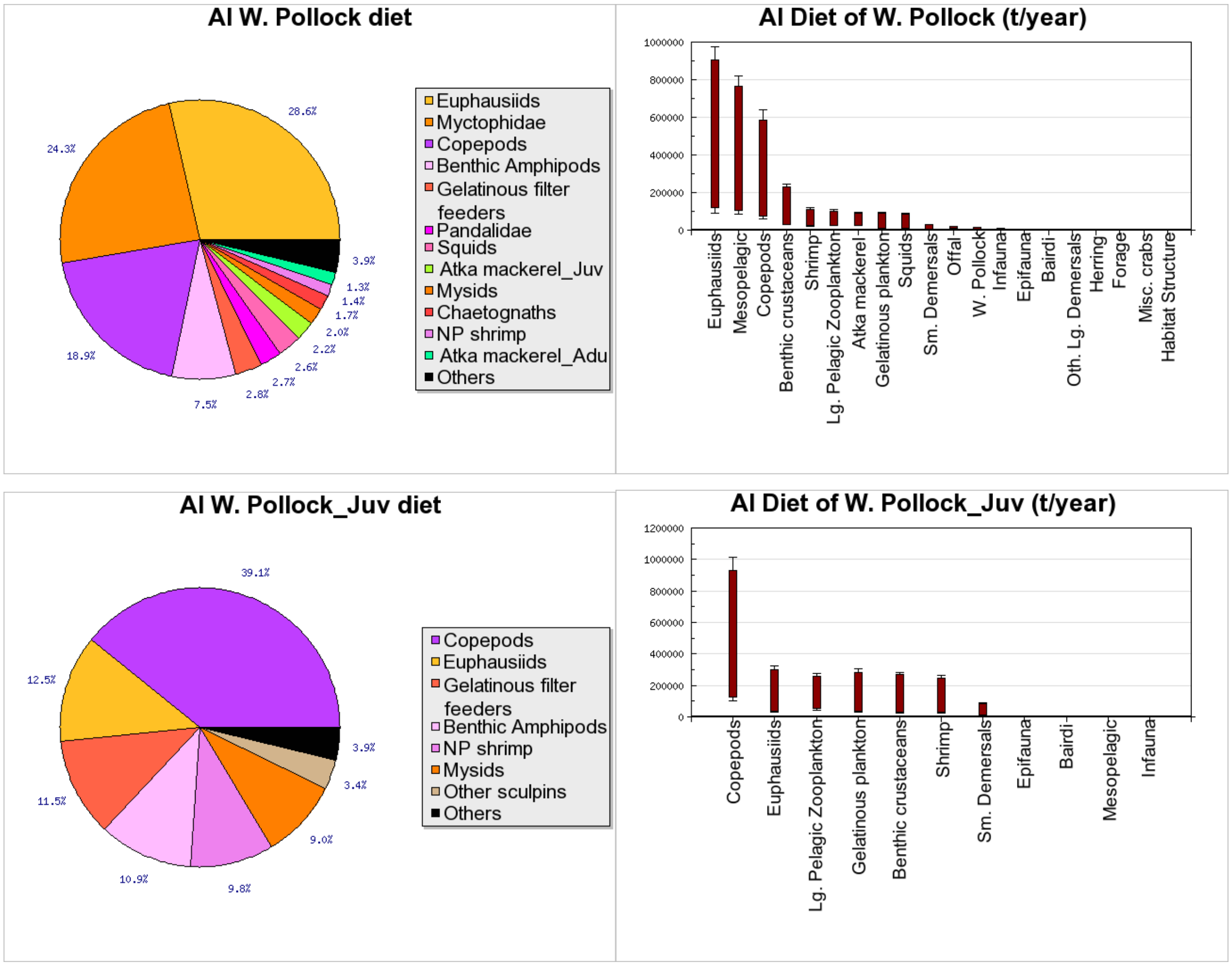

Figure 1A.35. Diet composition (left) and estimated consumption of prey (right) by AI adult (top) and juvenile (bottom) pollock. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994. See Appendix A for detailed methods.

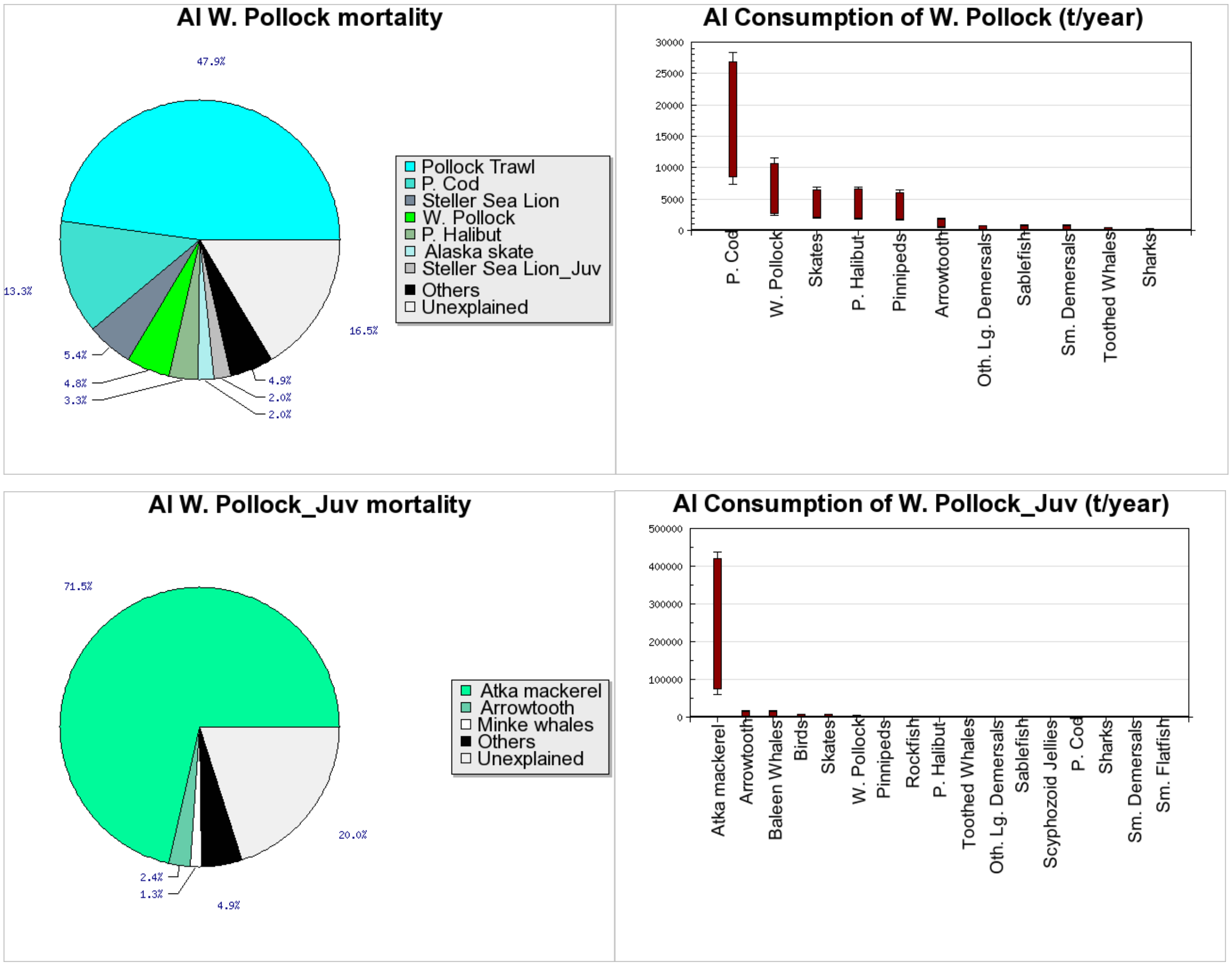

Figure 1A.36. Mortality sources (left) and estimated consumption by predators (right) of AI adult (top) and juvenile (bottom) pollock. Mortality sources reflect pollock predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994, pollock predator consumption 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 in review). See Appendix A for detailed methods.

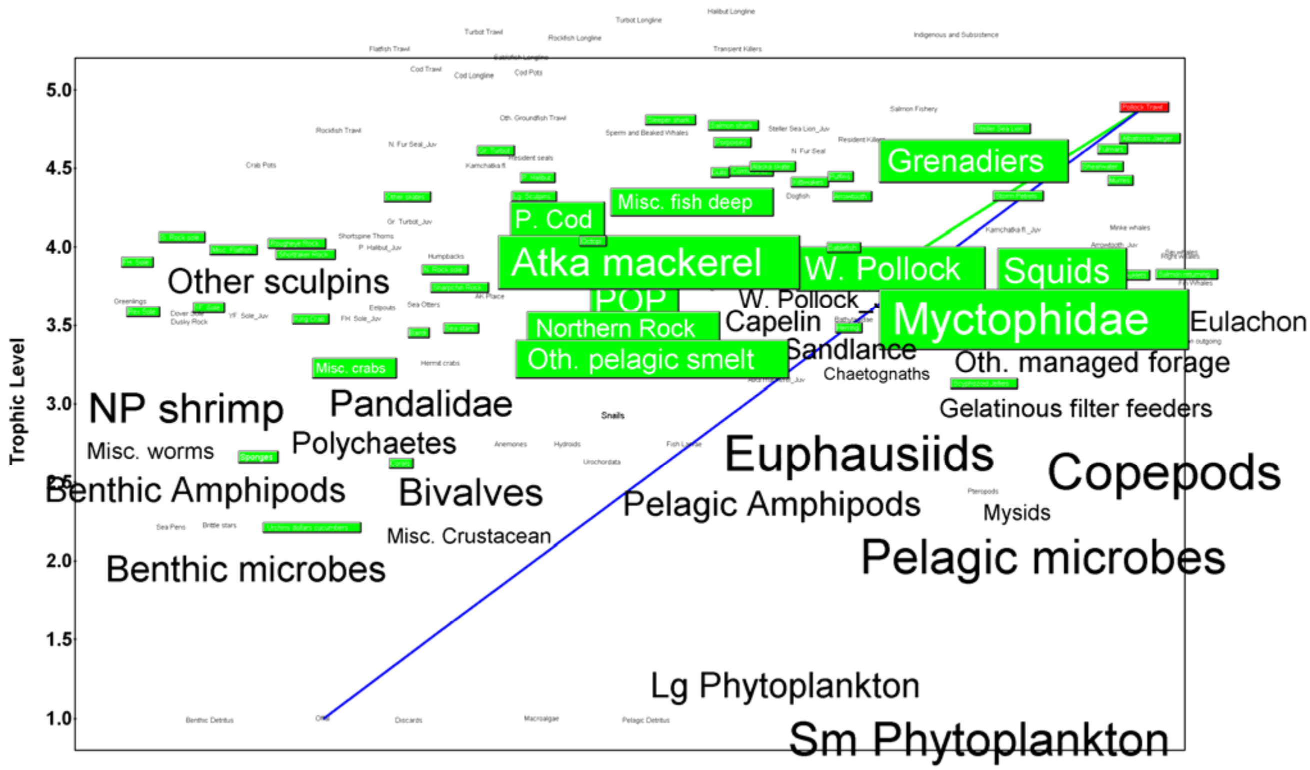

Figure 1A.37. The pollock trawl fishery in the AI food web. Species taken by the pollock fishery (in red) are highlighted in green, with the most significant flow to pollock indicated with a green line. Box size is proportional to biomass and lines between boxes represent the most significant energy flows. From Aydin et al (in review).

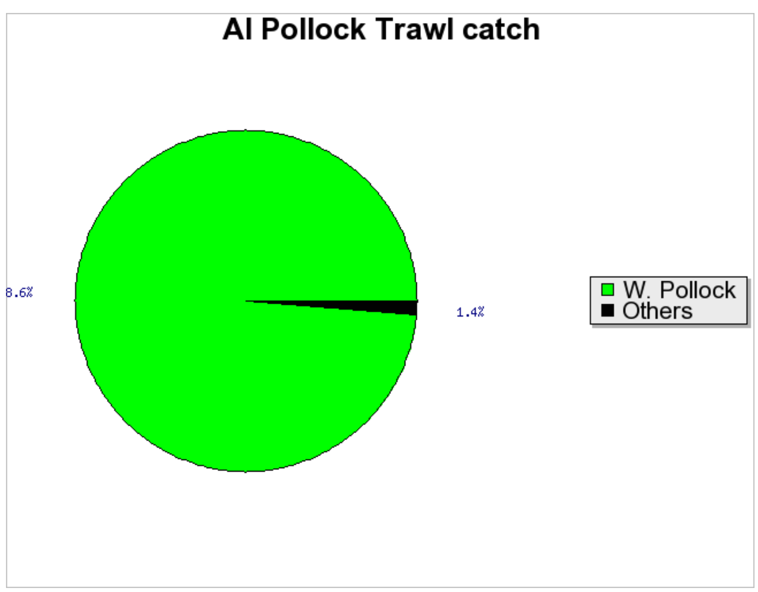

Figure 1A.38. Catch composition of the AI pollock trawl fishery during the early 1990's, as used in the food web model (Aydin et al Tech Memo).

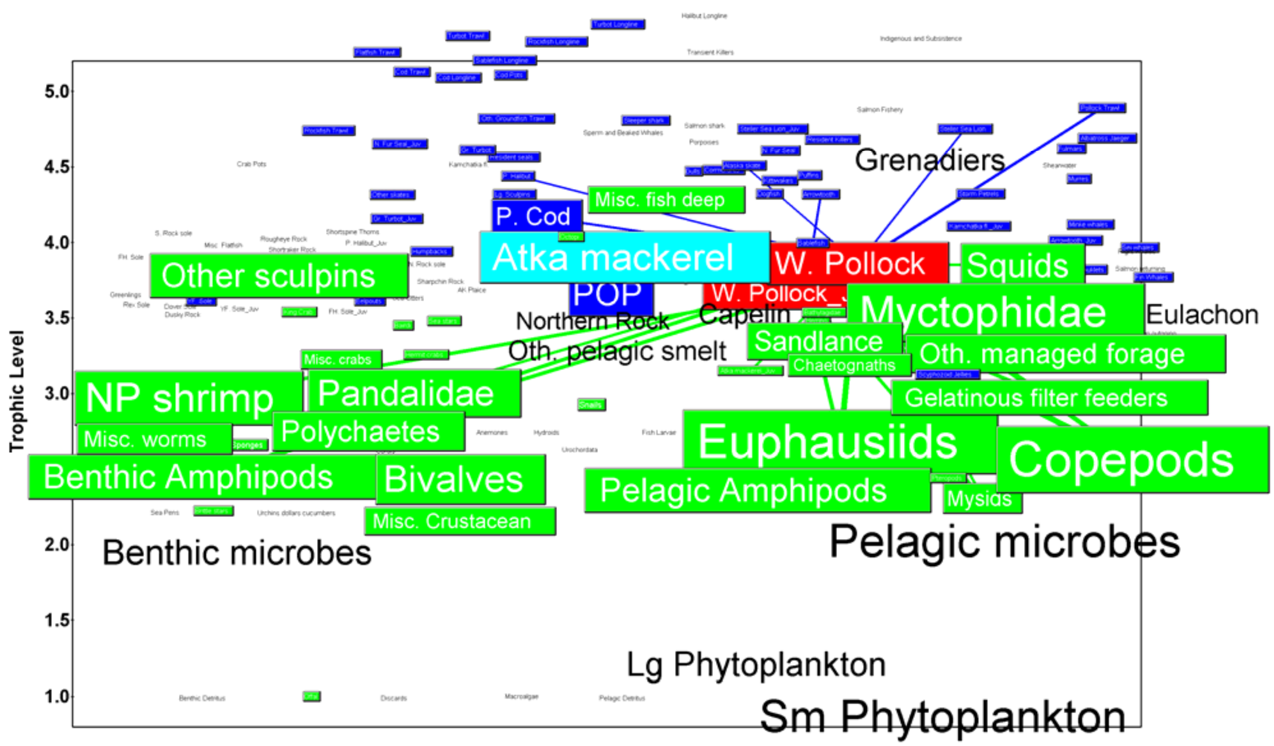

Figure 1A.39. Adult and juvenile pollock (highlighted in red) in the AI food web (Aydin et al Tech Memo). Predators of pollock are dark blue, prey of pollock are green, and species that are both predators and prey of pollock are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.

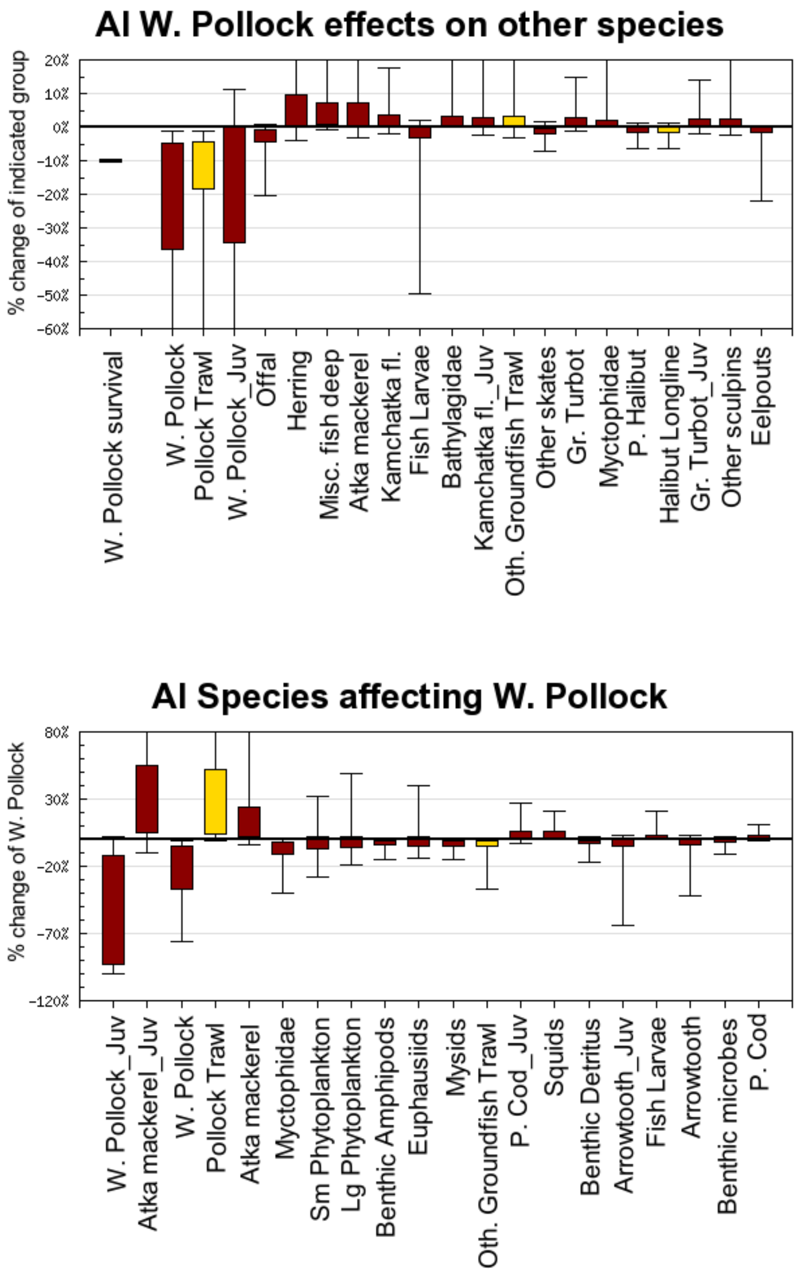

Figure 1A.40. (upper panel) Effect of changing pollock survival on fishery catch (yellow) and biomass of other species (dark red), from a simulation analysis where pollock survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. (lower panel) Effect of reducing fisheries catch (yellow) and other species survival (dark red) on pollock biomass, from a simulation analysis where survival of each X axis species group was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. In both panels, boxes show resulting percent change in the biomass of each species on the x axis after 30 years for 50% of feasible ecosystems, error bars show results for 95% of feasible ecosystems (see Aydin et al in review for detailed Sense methods).

Appendix A

Table A-1. Variable descriptions and model specification.

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

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

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

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

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

Likelihood /penalty component		Description / notes
Abundance indices	$L_1 = \lambda_1 \sum_i \ln\left(Y_i^s \big/ \hat{Y}_i^s \right)^2 \frac{1}{2\sigma_i^2}$	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	$L_7 = \left[\lambda_7 \frac{\ln\left(M \big/ \hat{M} \right)^2}{2\sigma_M^2} + \lambda_8 \frac{\ln\left(q / \hat{q} \right)^2}{2\sigma_q^2} \right]$	Prior on natural mortality, and survey catchability (reference case assumption that these are precisely known at 0.3 and 1.0, respectively).
Overall objective function to be minimized	$\dot{L} = \sum_{i=1}^{7} L_i$	

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