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

Steve Barbeaux, James Ianelli, Sarah Gaichas, and Mark Wilkins
Alaska Fisheries Science Center
November 2009

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. 2008). In the initial study the near shore areas of the Aleutian chain island were isolated and identified as the Near, Rat, and Andreanof Island (NRA) sub-area. In 2006 and 2007 the stock assessment data set was further refined to exclude fisheries data from the area east of 174°W to address data consistency issues. The North Pacific Fishery Management Council (Council) supported this proposal and urged further development of an age-structured assessment model using data from the area west of 174°W (and omitting deep-water areas where survey data are unavailable).

A review of the 2007 Aleutian Islands region pollock stock assessment was conducted by the Center for Independent Experts (CIE). In previous assessments data from the eastern boundary of the Aleutian Islands region (between 174°W and 170°W) were excluded from all of the age-structured assessment models, but summer Aleutian Islands bottom trawl (AIBT) survey data from this area were used. The CIE review panel had concerns with the approach of using different area partitions for the survey and fisheries data. To address these concerns we ran two sets of models; one with all fisheries and survey data for the NRA subarea, and with all survey data for the NRA subarea and fisheries data from the NRA area west of 174°W. Additionally, the CIE panel suggested that survey selectivity should not vary inter-annually. In last year's assessment we conducted model runs with both varying and fixed survey selectivity. In 2008 the reference model the maximum age at which fisheries selectivity was allowed to change was set at 8 years although model runs with maximum at 12 were presented. This year there is no additional data except that of a finalized 2008 fishery catch estimate and the preliminary fishery catch estimate for 2009. There was no summer bottom trawl survey nor were there adequate numbers of pollock ages or length measurements of pollock from the fishery to use in the stock assessment. Therefore this year we only present two models; the reference model from 2008 (Model 2) with the additional 2009 catch estimate of 1,600 t and for comparison the same model but with only the catch from the NRA western region included (Model 1).

Summary of major changes

- Inclusion of the 2009 pollock catch estimates
- Catch for 2003 to 2008 was updated to latest estimates from the catch accounting system (CAS)

Changes in the assessment results

- The maximum permissible ABC for 2010 and 2011 under Tier 3b are 33,064 t and 40,005 t, respectively. The OFL for 2010 and 2011 under Tier 3b are 32,227 t and 39,088 t respectively. The maximum permissible ABC under Tier 5 using the 2006 bottom trawl survey for both years is 15,670 t and the OFL is 20,900 t.

between 174°W and 170°W longitude. The time series of catch estimates for these two groups is shown in Table 1A.4.

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.5). 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.6). 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 presented in the 2008 Atka mackerel stock assessment (Lowe et al, 2008). 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.7). This problem is exacerbated for samples collected from different areas and gears (Table 1A.8). Estimates of the catch-age compositions are shown in Table 1A.9. 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.10). 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.4).

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.11, Table 1A.12, and Fig. 1A.5). 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.6). 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.13). 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.7 and Fig. 1A. 8), 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.9). 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 2009 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 x 10^{-7}). A feature of ADMB and AMAK is that it includes post-convergence routines to calculate standard errors (or likelihood profiles) for quantities of interest.

Model structure

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 last 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 100 was selected for survey catch-at-age data.

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

Fishery data*	Year	1978	1979	1980	1981	1982	1983	1984	1985	1986
	$\dot{N}_{i,\bullet}$	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.

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.14). 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.15. Survey weight-at-age values from 1978 to 2008 are given in Table 1A.16. 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 2009 are shown in Table 1A.17 . For the fishery, we used year (when available) and age-specific estimates of average weights-at-age computed from the fishery age and length sampling programs. These values are important for converting model estimated catch-at-age (in numbers) to estimated total annual harvests (by weight).

Maturity at Age

Previous to 2008 assessments used the maturity schedule developed for the Bering Sea by Wespestad and Terry (1984; Table 1A.18). 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 last year's and this year's assessment we used the Gulf of Alaska pollock 1983-2003 average proportion mature at age for our maturity O-give. 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 an area-parameterized form of the Beverton-Holt stock recruitment relationship based on Francis (1992). Values for the stock recruitment function parameters α and β are calculated from the values of R_0 (the number of 0-year-olds in the absence of exploitation and recruitment variability) and the "steepness" (h) of the stock-recruit relationship. The "steepness" parameter is the fraction of R_0 to be expected (in the absence of recruitment variability) when the mature biomass is reduced to 20% of its pristine level (Francis 1992). As an example, a value of $h = 0.7$ implies that at 20% of the unfished spawning stock size will result in an expected value of 70% of the unfished recruitment level. The steepness parameter (h) was set at 0.7 and sigma r was set at 0.6 for all model runs. In previous assessments model runs with different values of h were conducted but were found to have little effect on the model results.

Parameters estimated conditionally

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

Fishing Mortality

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

Survey Catchability

For the bottom trawl survey, survey catchability-at-age follows the parameterization similar to the fishery selectivity-at-age presented above. The catchability-at-age relationship is modeled with a smoothed non-parametric relationship that can take on any shape (with penalties controlling the degree of change and curvature specified by the user). To provide regularity in the age component, a penalty was imposed on sharp shifts in catchability-at-age between ages using the sum of squared second differences. In addition, the age component parameters are assumed constant for the last8 age groups (ages 8 -15). As noted above, the model allows specification of the age-range over which the catchability parameter is applied. For Aleutian Islands pollock, ages 5-12 were selected to have the average catchability (factoring selectivity components) equal to the catchability parameter value.

One comment by the CIE reviewers was that the assessment model should not allow for inter-annual changes in survey selectivity. Prior to the 2008 assessment, survey selectivity was allowed to change because in conversations with the RACE division it was determined that the survey 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. In 2008 model configurations with and without inter-annually varying survey selectivity were compared. The reference model in 2008 did not have inter-annually varying survey selectivity and therefore neither of the 2009 models have inter-annually varying survey selectivity.

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

Natural Mortality

For both models reviewed this year, 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 and for the model to estimate natural mortality.

Model evaluation

Two data configurations were evaluated for this stock assessment cycle. Model 1 is 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 2, is the same as the reference model from 2008, and has all data from the entire NRA. Both 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 both 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
Model 1	All NRA	Western NRA	Fixed	8	8
Model 2	All NRA	All NRA	Fixed	8	8

Relative differences in model fits are shown in Table 1A.19 and key results are presented in Table 1A.20. Besides the relative size of recruitment and increased prevalence of the 1978 year class the model fits between models show very similar patterns. The fit to the survey data is relatively poor for both 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 models 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. The models had a difficult time matching the mean age of the fishery data for the 1990s where the population appeared to still have a large proportion of fish from the 1978 year class (Fig. 1A.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 selectivity patterns between years is very similar and was constant over time for all years for both models (Fig. 1A.21).

Estimated survey selectivity at age between the two models were functionally identical (Fig. 1A.22 and Fig. 1A.23) for comparable model specifications

The more difficult task was in determining whether Model 1 or Model 2 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 2 data configuration is more easily justified simply by the fact that the catch excluded from Models 2 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 2 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 (8.9 times higher than the mean 1978-2006 age 2 recruitment) which greatly inflates the total biomass and spawning biomass estimates for Models 2 (Fig.1A.24). Model 1 is similar with the 1978 year class being 6.5 times higher than the mean 1978-2006 age 2 recruitment. Model 1 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 2 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 = 0.25 or 0.22 for 1 and 2 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 2, 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 2 would be the best data configuration pick and consistent with the reference model selected in 2008. Although Model 2 is the preferred model, figures and tables for Model 1 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.21. Table 1A.22, and Fig.1A.25) appears to have

increased from 1999 to 2004 after cessation of directed fishing in the area, and increase at a slower rate from 2005 to 2009. 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 2009 for reference Model 2 and competing Model 1 are given in Table 1A.23 and Table 1A.24. The reference Model 2 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 1,649,900 t at its peak in 1982. Model 1 has a much smaller, but still very large, 1978 year class with total biomass reaching its peak in 1983 with 520,850 t. Both models show a large decline in the stock since its peak with both hitting its minimum spawning stock biomass in 1999 (62,670 t and 44,875 t for Models 2 and 1 respectively).

Female Spawning Stock biomass (SSB) appears to have been greatly influence by the high exploitation in the late 1990s (Fig.1A.26).

The highest fishing mortality occurred in 1995 (F = 0.273 and Catch/biomass = 0.189) when the fishery harvested more than 75% of the 1994 survey biomass estimate (Table 1A.25, Fig.1A.26, and Fig.1A.27). The reference model shows high exploitation rates beginning in 1990 (F = 0.137) continuing through 1998 (Table 1A.26). In Model 2 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 62,620 t ($B_{21\%}$ or 11% of its peak value in 1984; 44,875 t in 1999 for Model 1, $B_{40.6\%}$ or 25% of its peak value in 1984; Fig.1A.28), but has since increased and appears to be remaining somewhat stable to increasing between 87,000 and 101,000 t since 2005. Again this may be an artifact of the model since age data and survey estimates have not been available since 2006.

Both 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 1979-2009 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 2 there was a significant decline in the abundance of pollock due to fishing, but since the cessation of fishing in 1999 and very low removal levels since 2005 the stock has stabilized and increased. The simulation of Model 2 shows the stock to be at 88% of what it would have been without fishing in 2009, but had a low at 39.8% of the unfished stock in 1999. Similarly, the simulation using numbers from Model 1 shows a decline with fishing in the Aleutian Islands but at a much lower extent with a low of 55% of unfished in 1999 and at 89% of unfished in 2009 after rebounding with the cessation of fishing.

Recruitment

Recruitment (at age 2) is estimated with high variance (Table 1A.27 and Table 1A.28, Fig.1A.30). Sigma R was set at 0.6, and the reference Model 2 estimates recruitment variability at 0.85. The 1978 year-class is the largest (1.74 billion age 2 recruits) and is highly influential with a large part of the fishery removals being composed of this year class (Fig. 1A.27). 1976-1986 had several large year classes in comparison to more recent recruitment. The mean recruitment of age 2 pollock for 1978-1988 was 388.4 million, while the mean recruitment at age 2 between 1996 and 2006 was 62.8 million fish with no year classes exceeding the overall 1978-2006 mean recruitment of 194.5 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 175.9 million recruits and the 2000 year class with 148.1 million recruits at age 2. In the reference model no year class has exceeded the mean recruitment for 1978-2006 since the 1983 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 2 the mean recruitment for 1978 - 2006 without the 1978 year class was 72% (139.5 million) of the mean recruitment with the 1978 year class (194.5 million). In Model 1 the mean recruitment for 1978 - 2006 without the 1978 year class was 80% (73.8 million) of the mean recruitment with the 1978 year class (91.8 million). If the 1978 year class is anomalous, it may be inflating the biological reference points in both models (28% in Model 2 and 20% in Model 1) and may be causing an overestimation of the expected productivity of this system, particularly if the 1978 year class originated elsewhere. Whether AI pollock recruitment is synchronous with other areas is an open question (e.g., the 1978, 1989, and 2000 year classes are also strong in the EBS region, Ianelli et al. 2005). The AI recruitment appears to be more correlated with the Gulf of Alaska (GOA) stock with a Spearman's rank correlation rho of 0.64 (P-value = 0.0002439) between the AI and GOA and a rho of 0.27 (P-value = 0.1615) between the AI and EBS (Fig. 1A. 31). Even after removing the linear downward trend for the log recruitments the Pearson's correlation coefficient for the residuals remained at 0.39 (P-value = 0.03). The extent to which these adjacent stocks interact is an active area of research.

Projections and harvest alternatives

For management purposes we use the yield projections estimated for reference Model 2 but also provide results of projections estimated for Model 1. We used the model estimated fishery selectivity at age (Table 1A.29 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 2 (194,500 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 2 and Model 1:

Female spawning biomass	Model 2	Model 1
$B_{100\%}$	298,000 t	110,480 t
$B_{40\%}$	119,200 t	44,192 t
$B_{35\%}$	104,300 t	38,668 t
B_{2010}	97,486 t	46,058 t

Specification of OFL and Maximum Permissible ABC

For the reference model, Model 2, the projected year 2010 female spawning biomass (SB_{10}) is estimated to be 97,486 t, below the $B_{40\%}$ value of 119,200 t placing NRA pollock in Tier 3b. The maximum permissible ABC and OFL values under Tier 3b are:

Model 2 Tier 3b:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2010 Projected yield (t)
max F_{ABC}	$F_{40\%}$	0.329	33,064 t
F_{OFL}	$F_{35\%}$	0.408	40,005 t

For the comparison model, Model 1, the projected year 2010 female spawning biomass (SB_{10}) is estimated to be 49,453 t, also below the $B_{40\%}$ value of 44,192 t and would place NRA pollock in Tier 3b. The maximum permissible ABC and OFL values under Tier 3b in this model are:

Model 1 Tier 3b:

Harvest Strategy	FSPR%	Fishing Mortality Rate	2010 Projected yield (t)
max F_{ABC}	$F_{40\%}$	0.512	22,214 t
F_{OFL}	$F_{35\%}$	0.647	26,887 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 0.220, the 2010 ABC would be 15,670 t (94,992 t x 0.75 x 0.2200 = 15,670 t) and under Tier 5 with an assumed natural mortality of 0.3 the 2010 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. 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 of CV are 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 three years have been estimated at the median recruitment values for the entire time series which is somewhat higher than the median that has been observed for the past decade.

5) The Model 2 suggests that currently a large proportion of the stock in the Aleutians is composed of much older fish (10% age 10+ by number) and would make up a large proportion of the catch (32% age 10+ by weight). This is highly reliant on the estimated selectivity curves.

ABC Recommendations

The pollock spawning stock biomass in the NRA appears to be relatively stable. 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 also appears to be stable. The estimated female spawning biomass projected for 2010 is 101,470 t. The projected total age 3+ biomass

for 2010 is 307,046 t. The maximum permissible 2010 ABC based on $F_{40\%}$ = 0.329 is 33,064 t and OFL based on $F_{40\%}$ = 0.408 is 40,005 t which is the authors recommended ABC and OFLs. Assuming a catch of 19,000 t in 2010 the 2011 authors recommended ABC based on $F_{40\%}$ = 0.326 is 32,227 t and OFL based on $F_{40\%}$ = 0.395 is 39,088 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 2009 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2010, 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 2010 recommended in the assessment to the *max* F_{ABC} for 2010. (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 2005-2009 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

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

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2009 or 2) above 1/2 of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2010 and 2011, 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 2022 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 2010 through 2022 the TAC is increased to 19,000 t or *max* F_{ABC} whichever is lower. (Rationale: 19,000 is the AI pollock cap set by Congressional mandate).

Projections and status determination

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2009:

a. If spawning biomass for 2009 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2009 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2009 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 1A.31). If the mean spawning biomass for 2019 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

a. If the mean spawning biomass for 2012 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2012 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2012 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2022. If the mean spawning biomass for 2022 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

The projected yields, female spawning biomass, and the associated fishing mortality rates for the eight harvest strategies for the reference model are shown in Table 1A.30 for Model 2 and Table 1A.31 for Model 1. In the reference model (Model 2) 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.32 and Fig.1A.33). Female spawning biomass is projected be below $B_{35\%}$ when fishing at F_{OFL} (Fig.1A.34) through 2017 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 (194.5 million age 2 fish) and $F = F_{35\%}$, denoted $B_{35\%}$ is estimated to be 104,300 t. This value ($B_{35\%}$), is used in the status determination criteria. Female spawning biomass for 2010 (101,470 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 2022 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.32, 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 $B_{33\%}$ and the long-term expected yield at $B_{40\%}$ is 45,966 t and at $B_{35\%}$.is 49,606 t, well above the 19,000t cap.

The SSC asked that the probability of the spawning stock biomass being below $B_{20\%}$ in 2010 be computed for stocks in Tier 3b. We computed the number of standard deviations the 2010 spawning biomass (B_{2010}) was from $B_{20\%}$, assuming B_{2010} was normally distributed. B_{2010} is estimated in the stock assessment model (non-projected) to be at 101,470 t with a standard deviation of 15,000 t and $B_{20\%}$ is estimated at 59,600 t, therefore B_{2010} is 2.79 standard deviations from $B_{20\%}$. Under the assumption of a normal error distribution there is a 0.27 % chance of the AI pollock stock currently being below $B_{20\%}$. Using the posterior distribution from an MCMC with 1,000,000 iterations thinned at 200 the probability of being at or below $B_{20\%}$ was estimated at 0.06%.

Ecosystem Considerations

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

In the AI, pollock diet data reflects a closer connection with open oceanic environments than in either the Eastern Bering Sea (EBS) or the GOA. Similar to the other ecosystems, euphausiids and copepods together make up the largest proportion of AI adult pollock diet (29% and 19%, respectively); however, it is only in the AI that adult pollock rely on mesopelagic forage fish in the family Myctophidae for 24% of their diet, and AI juvenile pollock have a lower proportion of euphausiids and a higher proportion of gelatinous filter feeders than in the GOA or EBS (Fig.1A. 35, left panels). We took this diet composition information and convert it to broad ranges of tons consumed annually by pollock in the AI using the Sense routine (Aydin et al. 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.35, right panels).

Using diet data for all predators of pollock and consumption estimates for those predators, as well as fishery catch data, we next estimated the sources of pollock mortality in the AI. Sources of mortality were compared against the total production of pollock as estimated in the AI pollock stock assessment model. In the AI, integration of this single species information with predation within the food web model suggests that most adult pollock mortality was caused by the pollock trawl fishery during the early 1990s (48%; Fig.1A. 36, 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.36 , right panels).

After reviewing the diet compositions and mortality sources of pollock in the AI, we shifted focus slightly to view pollock and the pollock fishery within the context of the larger AI food web. When viewed within the AI food web, the pollock trawl fishery (in red; Fig.1A. 37) is a relatively high trophic level (TL) predator which interacts mostly with adult pollock, but also with many other species (in green; Fig. 1A.37). 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. 38). 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. 39). In the AI, the significant predators of pollock (blue boxes joined by blue lines) include halibut, cod, Alaska skates, Steller sea lions, and the pollock trawl fishery. Significant prey of pollock (green boxes joined by green lines) are myctophids, euphausiids, copepods, benthic shrimps, and amphipods, with juveniles preying on the euphausiids and copepods.

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

First, the importance of pollock to other groups within the AI ecosystem was assessed using a model simulation analysis where pollock survival was decreased (mortality was increased) by a small amount, 10%, over 30 years to determine the potential effects on other living groups. This analysis also incorporated the uncertainty in model parameters using the Sense routines, resulting in ranges of possible outcomes. Figure 1A. 40 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.40. 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.40 , 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.40 (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. 40, 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.36, 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.38 highlights the trophic level of pollock in relation to its prey and predators. No time series of information is available on Aleutian Islands for large zooplankton, copepod, or myctophid abundance.

Predator population trends

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

Changes in habitat quality

The 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 2010 there is expected to only be a very limited fishery in 2010. The only shore-based plant capable of processing the Aleutian Islands' pollock catch has filed for Chapter 11 and it is not known at this time if the plant will be in operation in 2010, but seems unlikely.

AI pollock fishery effects on amount of large size walleye pollock

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

AI pollock fishery contribution to discards and offal production

The 2010 Aleutian Islands pollock fishery, if pursued, is expected to be conducted by catcher vessels delivering unsorted catch to the processing plant in Adak, and therefore very little discard or offal production is expected from this fishery.

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, 2007, and 2008 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.

Acknowledgements

We thank the AFSC survey personnel, observer program staff, and fisheries observers for the collection of data and providing biomass estimates. We also thank the staff of the AFSC Age and Growth Unit for the ageing of otoliths used to determine the age compositions in the assessment.

Literature Cited

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. In review. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA NMFS Tech Memo. 250 p.

Barbeaux, S., J.N. Ianelli, s. Gaichas, and M. Wilkins. 2008. Aleutian Islands walleye pollock SAFE. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 1A

Barbeaux, S., J.N. Ianelli, s. Gaichas, and M. Wilkins. 2007. Aleutian Islands walleye pollock SAFE. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 1A

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

Barbeaux, S., J.N. Ianelli, s. Gaichas, and M. Wilkins. 2005. Aleutian Islands walleye pollock SAFE. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, Section 1A.

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

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

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

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

Hilborn, R. and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York, N.Y. 570 p.

Hilborn, R. and M. Mangel. 1997. The Ecological Detective – confronting models with data. Princeton University Press, Princeton, New Jersey. pp.315

Ianelli, J.N., S. Barbeaux, T. Honkalehto, N. Williamson and G. Walters. 2005. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2005. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:32-124.

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

Ianelli, J.N., S. Barbeaux, T. Honkalehto, N. Williamson and G. Walters. 2003. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2003. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:39-126.

Ianelli, J.N., S. Barbeaux, T. Honkalehto, N. Williamson and G. Walters. 2002. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2003. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:33-120.

Ianelli, J.N., T. Buckley, T. Honkalehto, N. Williamson and G. Walters. 2001. Bering Sea-Aleutian Islands Walleye Pollock Assessment for 2002. In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 1:1-89

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

Lowe, S., J. Ianelli, and H. Zenger. 2003. Assessment of Aleutian Islands Atka Mackerel . In: Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions. North Pac. Fish. Mgmt. Council, Anchorage, AK, section 14:1-123.

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

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

NMFS. 2002. Alaska Groundfish Fisheries: Draft Programmatic Supplemental Environmental Impact Statement. NMFS, Alaska Region, NOAA, U.S. DOC.

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

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

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

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

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	1,666	167%
2004	39,400	1,000	52,600	1,158	116%
2005	29,400	19,000	39,100	1,621	9%
2006	29,400	19,000	39,100	1,745	9%
2007	44,500	19,000	54,500	2,519	13%
2008	28,160	19,000	34,040	1,278	7%
2009	26,873	19,000	32,553	1,500	8%

* As of October 3, 2009

Table 1A.2. Estimates of walleye pollock catches from the entire Aleutian Islands Region by source, 1977-2009. Units are in metric tons.

Year	Official Foreign & JV Blend	Domestic Blend	Foreign Reported	NMFS Observed Catch*	Total Best Estimates
1977	7,367		7,827	5	7,367
1978	6,283		6,283	234	6,283
1979	9,446		9,505	58	9,446
1980	58,157		58,477	883	58,157
1981	55,517		57,056	2,679	55,517
1982	57,753		62,624	11,847	57,753
1983	59,021		44,544	12,429	59,021
1984	77,595		67,103	48,538	77,595
1985	58,147		48,733	43,844	58,147
1986	45,439		14,392	29,464	45,439
1987	28,471			17,944	28,471
1988	41,203			21,987	41,203
1989	10,569			5,316	10,569
1990		79,025		59,935	79,025
1991		98,604		53,305	98,604
1992		52,352		36,581	52,352
1993		57,132		44,552	57,132
1994		58,659		43,430	58,659
1995		64,925		53,647	64,925
1996		29,062		23,482	29,062
1997		25,940		19,623	25,940
1998		23,822		21,032	23,822
1999		1,010		492	1,010
2000		1,244		573	1,244
2001		824		477	824
2002		1,156		519	1,156
2003		1,666		1,562	1,666
2004		1,158		1,074	1,158
2005		1,621		1,359	1,621
2006		1,745		540	1,745
2007		2,519		1,182	2,519
2008		1,278		995	1,278
2009		1,500		1,121	1,500

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

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	1,196	470	1,666	28%
2004	871	287	1,158	24%
2005	1,297	324	1,621	20%
2006	1,434	311	1,745	18%
2007	2,094	425	2,519	17%
2008	1,196	81	1,278	6%
2009	1,274	226	1,500	15%

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	577	760	329	1,666
2004	397	513	248	1,158
2005	689	415	517	1,621
2006	1,036	488	220	1,745
2007	1,919	476	124	2,519
2008	872	290	116	1,278
2009	1,111	315	74	1,500

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- 2009 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	1,666	1,442	0	224
2004	1,158	969	0	189
2005	1,621	1,339	0	282
2006	1,745	1,666	0	79
2007	2,519	1,408	0	1,111
2008	1,278	817	0	461
2008	1,500	389	0	1,111

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
2009	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 that had greater than 1 t of pollock catch, 1990-2007.

	Catcher Processor		Mothership		Catcher Only	
Year	Vessels	Hauls	Vessels	Hauls	Vessels	Hauls
1990	26	752	3	118	5	68
1991	23	585	2	2	3	38
1992	31	432	3	38	16	155
1993	20	458	3	12	20	85
1994	25	376	4	15	24	213
1995	24	489	4	28	17	162
1996	24	202	3	8	18	100
1997	16	131	2	5	14	91
1998	4	123	0	0	12	61
2005	2	6	0	0	0	0
2006	0		0	0	0	0
2007	1	5	0	0	1	4

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

Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total
1978	0.05	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
2009	0.171	0.486	0.667	0.950	1.205	1.294	1.396	1.572	1.930	2.052	1.955	2.030	1.936	1.970

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
2008	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
2009	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
2007	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
2008	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
2009	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 1	Model 2
Number of Parameters	102	102
Survey Catchability	1.00	1.00
Fishery Average Effective N	39	39
Survey Average Effective N	112	112
RMSE Survey	0.69	1.05
-Log Likelihoods		
Survey Index	21.73	43.93
Fishery Age Comp	440.10	453.61
Survey Age Comp	50.77	52.61
Catch	1.26	1.17
Sub Total	513.86	551.32
-log Penalties		
Recruitment	23.80	45.55
Selectivity Constraint	25.14	25.09
Prior	0.03	0.01
Fpen	0.00	0.00
Total	562.83	621.97

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

	Model 1	Model 2
Model Conditions		
Survey Catchability	1.00	1.00
Natural Mortality	0.25	0.22
Fishing Mortalities		
Max F 1978 - 2009	0.28	0.27
F 2009	0.03	0.01
Stock Abundance		
Initial Biomass (1978; thousands of tons)	312.66	898.86
CV	13%	9%
2010 Total Biomass (thousands of tons)	163.21	333.00
CV	18%	17%
2010 Age 3+ biomass (thousands of tons)	176.26	307.05
1978 Year Class (at age 2)	0.60	1.74
CV	17%	12%
Recruitment Variability	0.67	0.85
Specified Sigma R	0.6	0.6
Steepness (h)	0.7	0.7
Projected Catch (unadjusted)		
F50% 2010 catch	0.21	0.18
CV	8%	8%
F40% 2010 catch	0.33	0.27
CV	9%	8%
F35% 2010 catch	0.42	0.34
CV	9%	9%

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

Model 2	Total Biomass (Age 2+)			Biomass	Female
Year		LCI	UCI	Age 3+	SSB
1978	898,860	729,538	1,068,182	832,062	241,490
1979	1,014,200	830,950	1,197,450	922,408	284,420
1980	1,381,600	1,131,080	1,632,120	1,034,468	316,490
1981	1,556,000	1,272,420	1,839,580	1,504,668	332,390
1982	1,649,900	1,361,260	1,938,540	1,628,451	421,530
1983	1,637,700	1,360,900	1,914,500	1,581,888	517,700
1984	1,561,900	1,309,920	1,813,880	1,515,271	565,550
1985	1,474,500	1,247,200	1,701,800	1,402,945	538,660
1986	1,361,900	1,162,590	1,561,210	1,323,684	498,950
1987	1,267,800	1,097,712	1,437,888	1,240,450	472,780
1988	1,175,900	1,032,978	1,318,822	1,139,512	443,730
1989	1,049,300	931,360	1,167,240	1,023,341	405,670
1990	969,100	873,052	1,065,148	949,500	371,160
1991	807,610	727,616	887,604	772,437	296,880
1992	623,570	556,932	690,208	610,805	224,340
1993	516,190	459,000	573,380	505,453	184,720
1994	424,430	373,494	475,366	410,778	151,830
1995	344,330	296,168	392,492	326,656	119,080
1996	271,750	225,640	317,860	263,592	90,898
1997	239,600	193,800	285,400	228,684	78,846
1998	213,770	167,436	260,104	201,932	69,144
1999	189,600	143,270	235,930	182,255	62,620
2000	194,700	147,554	241,846	183,466	65,321
2001	204,250	154,356	254,144	188,101	67,286
2002	230,930	172,368	289,492	201,310	68,730
2003	247,220	182,658	311,782	238,505	71,394
2004	253,920	186,030	321,810	246,975	79,180
2005	258,890	188,864	328,916	245,688	87,636
2006	261,400	189,828	332,972	247,372	91,568
2007	273,540	196,810	350,270	250,063	91,012
2008	291,310	204,424	378,196	267,833	90,682
2009	315,080	214,556	415,604	291,610	94,206
2010	333,000	222,156	443,844	307,046	101,470

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

Model 1	Total Biomass (Age 2+)			Biomass	Female
Year		LCI	UCI	Age 3+	SSB
1978	312,660	234,314	391,006	289,274	84,073
1979	345,290	259,550	431,030	313,830	96,054
1980	454,990	333,578	576,402	335,725	100,020
1981	490,870	350,836	630,904	472,131	97,224
1982	507,220	362,378	652,062	498,812	123,250
1983	520,850	379,222	662,478	498,838	160,390
1984	513,620	381,806	645,434	494,267	180,810
1985	495,590	372,702	618,478	463,727	174,710
1986	486,020	374,006	598,034	466,905	170,040
1987	468,850	368,984	568,716	453,476	165,810
1988	452,390	363,456	541,324	429,335	160,840
1989	436,680	358,278	515,082	418,388	156,190
1990	419,650	351,090	488,210	404,245	149,120
1991	401,230	338,914	463,546	371,623	138,490
1992	388,950	333,378	444,522	377,960	132,950
1993	359,280	310,170	408,390	349,794	124,780
1994	322,450	278,414	366,486	310,564	116,020
1995	302,800	261,532	344,068	287,781	105,020
1996	230,160	191,948	268,372	223,654	77,416
1997	197,580	160,768	234,392	189,333	65,118
1998	165,050	129,008	201,092	156,516	53,115
1999	136,110	101,198	171,022	131,078	44,875
2000	135,720	101,288	170,152	128,207	45,687
2001	137,830	102,590	173,070	127,295	45,720
2002	150,630	110,678	190,582	131,753	45,293
2003	156,630	114,056	199,204	151,295	45,632
2004	155,430	112,094	198,766	151,289	48,582
2005	152,340	109,024	195,656	144,905	51,563
2006	147,990	105,180	190,800	140,568	51,941
2007	148,340	104,162	192,518	136,305	49,663
2008	151,350	103,328	199,372	139,313	47,428
2009	158,190	104,570	211,810	146,160	47,277
2010	163,210	105,518	220,902	147,405	49,002

Table 1A.24. Reference Model 2 estimated pollock numbers at age in millions, 1978-2009.

Model 2	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% of 15+
1978	334	265	254	171	138	52	39	25	19	13	5	4	3	22	1,343	1.63%
1979	459	268	212	202	136	110	41	31	19	15	10	4	3	19	1,530	1.26%
1980	1736	368	215	169	160	108	86	32	24	15	11	8	3	17	2,952	0.58%
1981	257	1391	293	165	128	119	78	61	22	16	10	8	5	13	2,565	0.52%
1982	107	206	1110	229	128	98	90	58	44	16	11	7	5	13	2,124	0.63%
1983	279	86	164	865	176	97	73	66	41	31	11	8	5	13	1,915	0.70%
1984	233	224	69	129	670	135	74	54	48	30	22	8	6	13	1,714	0.78%
1985	358	187	178	54	99	512	102	54	39	34	21	16	6	14	1,674	0.82%
1986	191	287	149	140	42	76	386	75	39	28	24	15	11	14	1,477	0.94%
1987	137	153	229	118	110	33	59	297	57	29	21	18	11	19	1,293	1.48%
1988	182	110	123	182	93	86	25	46	227	44	22	16	14	23	1,193	1.96%
1989	130	146	88	96	142	72	66	19	33	166	32	16	12	27	1,045	2.62%
1990	98	104	117	70	77	112	57	52	15	26	130	25	13	31	926	3.31%
1991	176	79	83	89	52	56	81	39	34	10	17	85	16	28	846	3.36%
1992	64	141	62	62	64	37	38	51	23	20	6	10	49	26	650	3.96%
1993	54	51	112	47	46	47	26	26	32	14	12	4	6	47	524	9.05%
1994	68	43	41	85	35	33	33	17	16	20	9	8	2	33	442	7.53%
1995	88	55	34	30	61	24	22	21	10	9	12	5	4	21	396	5.18%
1996	41	71	43	25	21	41	16	13	11	5	5	6	3	13	314	4.23%
1997	55	33	56	33	18	15	29	10	8	7	3	3	4	10	284	3.51%
1998	59	44	26	42	24	13	11	19	6	5	4	2	2	8	266	3.19%
1999	37	47	35	20	31	17	9	7	12	4	3	3	1	6	231	2.73%
2000	56	29	38	28	16	25	14	7	6	9	3	2	2	6	241	2.48%
2001	81	45	24	30	22	12	20	11	6	4	7	2	2	6	273	2.32%
2002	148	65	36	19	24	18	10	16	9	5	3	6	2	7	366	1.79%
2003	44	119	52	29	15	19	14	8	12	7	4	3	5	7	337	2.00%
2004	35	35	95	41	23	12	15	11	6	10	5	3	2	9	303	2.93%
2005	66	28	28	76	33	18	10	12	9	5	8	4	2	9	308	2.83%
2006	70	53	22	22	61	26	15	8	10	7	4	6	3	9	316	2.74%
2007	117	56	42	18	18	48	21	12	6	8	5	3	5	9	369	2.56%
2008	117	94	45	34	14	14	38	16	9	5	6	4	2	11	411	2.71%
2009	117	94	75	36	27	11	11	30	13	7	4	5	3	11	446	2.40%

Table 1A.25. Model 1 estimated pollock numbers at age in millions, 1978-2009.

Model 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	% of 15+
1978	117	92	87	59	48	19	14	9	7	5	2	1	1	8	467	1.66%
1979	157	91	72	68	46	38	14	11	7	5	4	1	1	7	521	1.28%
1980	596	123	71	55	52	34	28	11	8	5	4	2	1	5	994	0.54%
1981	94	465	95	52	39	36	23	17	6	4	3	2	1	4	840	0.43%
1982	42	73	361	71	39	28	25	16	11	4	3	2	1	3	679	0.47%
1983	110	33	57	280	55	30	22	19	12	8	3	2	1	3	636	0.54%
1984	97	86	26	44	218	43	23	17	15	9	7	2	2	4	592	0.61%
1985	159	76	67	20	34	165	32	17	12	11	7	5	2	4	609	0.62%
1986	96	124	59	52	15	26	129	25	13	9	8	5	4	4	571	0.73%
1987	77	75	97	46	41	12	21	100	19	10	7	6	4	6	522	1.17%
1988	115	60	58	76	36	32	9	16	77	15	8	6	5	8	520	1.48%
1989	91	90	47	46	59	28	25	7	12	60	12	6	4	10	497	1.99%
1990	77	71	70	37	36	46	22	19	6	10	47	9	5	11	466	2.39%
1991	148	60	56	54	28	27	35	16	14	4	7	34	7	12	502	2.32%
1992	55	116	47	43	42	22	21	27	13	11	3	5	27	14	447	3.18%
1993	47	43	90	36	33	32	17	16	20	9	8	2	4	30	388	7.70%
1994	59	37	33	69	27	25	24	12	11	14	6	6	2	24	349	6.79%
1995	75	46	29	26	53	21	19	18	9	8	10	5	4	19	343	5.53%
1996	33	59	36	21	18	35	13	11	9	5	4	5	2	12	262	4.49%
1997	41	25	45	27	15	13	24	9	7	6	3	3	3	9	229	3.80%
1998	43	32	20	33	19	10	8	15	5	4	3	2	1	7	202	3.31%
1999	25	33	25	14	23	13	7	5	8	3	2	2	1	4	165	2.65%
2000	38	20	26	19	11	18	10	5	4	6	2	2	1	4	166	2.42%
2001	53	29	15	20	15	9	14	8	4	3	5	2	1	4	182	2.26%
2002	94	41	23	12	16	12	7	11	6	3	2	4	1	4	236	1.74%
2003	27	74	32	18	9	12	9	5	8	5	2	2	3	4	211	1.96%
2004	21	21	58	25	14	7	9	7	4	6	3	2	1	5	184	2.89%
2005	37	16	16	45	19	11	6	7	5	3	5	3	1	5	179	2.82%
2006	37	29	13	13	35	15	8	4	5	4	2	4	2	5	176	2.77%
2007	60	29	23	10	10	27	11	6	3	4	3	2	3	5	196	2.65%
2008	60	47	23	18	8	7	20	9	5	2	3	2	1	6	211	2.81%
2009	60	47	37	18	14	6	6	16	7	4	2	2	2	5	224	2.46%

Table 1A.26. Reference Model 2 estimates of full-selection fishing mortality and exploitation rates for NRA pollock.

Model 2		
Year	F[a]	Catch/Biomass Rate[b]
1978	0.017	0.007
1979	0.025	0.009
1980	0.120	0.042
1981	0.072	0.020
1982	0.087	0.031
1983	0.070	0.027
1984	0.076	0.027
1985	0.075	0.032
1986	0.038	0.017
1987	0.033	0.021
1988	0.061	0.031
1989	0.016	0.010
1990	0.137	0.082
1991	0.220	0.122
1992	0.155	0.084
1993	0.171	0.111
1994	0.219	0.138
1995	0.273	0.189
1996	0.169	0.107
1997	0.176	0.108
1998	0.182	0.111
1999	0.008	0.005
2000	0.010	0.006
2001	0.006	0.004
2002	0.008	0.005
2003	0.014	0.007
2004	0.009	0.005
2005	0.012	0.006
2006	0.013	0.007
2007	0.017	0.009
2008	0.009	0.004
2009	0.010	0.005

[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 1 estimates of full-selection fishing mortality and exploitation rates for NRA pollock.

Model 1		
Year	F[a]	Catch/Biomass Rate[b]
1978	0.008	0.003
1979	0.066	0.023
1980	0.212	0.066
1981	0.125	0.030
1982	0.020	0.006
1983	0.009	0.003
1984	0.053	0.018
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	0.045	0.025
1991	0.003	0.001
1992	0.042	0.022
1993	0.071	0.045
1994	0.029	0.019
1995	0.280	0.192
1996	0.161	0.101
1997	0.218	0.130
1998	0.242	0.141
1999	0.007	0.005
2000	0.010	0.007
2001	0.007	0.004
2002	0.004	0.002
2003	0.019	0.009
2004	0.020	0.010
2005	0.020	0.010
2006	0.023	0.012
2007	0.031	0.016
2008	0.017	0.008
2009	0.020	0.010

[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 2 estimates of age-2 pollock recruitment (in millions).

Year	Index at age 2	Year	Index at age 2
1978	334.0	1996	40.8
1979	459.2	1997	54.6
1980	1735.8	1998	59.2
1981	256.6	1999	36.7
1982	107.4	2000	56.2
1983	278.9	2001	80.8
1984	233.3	2002	148.1
1985	357.5	2003	43.6
1986	191.1	2004	34.7
1987	136.9	2005	66.0
1988	181.8	2006	70.1
1989	129.7	2007	117.4
1990	98.0	2008	117.4
1991	175.9	2009	117.4
1992	63.8		
1993	53.7		
1994	68.3	Ave 78-06	194.5
1995	88.4	Med 78-06	98.0

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

Year	Index at age 2	Year	Index at age 2
1978	116.9	1996	32.5
1979	157.3	1997	41.3
1980	596.3	1998	42.7
1981	93.7	1999	25.1
1982	42.0	2000	37.5
1983	110.1	2001	52.7
1984	96.8	2002	94.4
1985	159.3	2003	26.7
1986	95.6	2004	20.7
1987	76.9	2005	37.2
1988	115.3	2006	37.1
1989	91.5	2007	60.2
1990	77.0	2008	60.2
1991	148.0	2009	60.2
1992	54.9		
1993	47.4		
1994	59.4	Ave 78-06	91.8
1995	75.1	Med 78-06	75.1

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

	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
Model 2														
2009 Fishery	0.007	0.044	0.224	0.333	0.420	0.547	0.727	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Survey	0.060	0.180	0.390	0.567	0.689	0.755	0.856	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Model 1														
2009 Fishery	0.006	0.037	0.191	0.294	0.386	0.512	0.701	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Survey	0.065	0.195	0.422	0.606	0.722	0.782	0.878	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 1A.31. Projections of Model 2 female spawning biomass (in thousands of t), *F*, and catch (in thousands of t) for NRA pollock for the 8 scenarios. Fishing mortality rates given are based on the *average* fishing mortality over all ages *(B_0=298.0 kt, B_{40}=119.2 kt, B_{35}=104.3 kt, and ½ B_{35}=52.15 kt)*.

Sp.Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2009	94.21	94.21	94.21	94.21	94.21	94.21	94.21	94.21
2010	97.49	97.49	101.23	99.32	101.38	96.57	97.49	99.23
2011	89.78	89.78	111.29	99.49	112.25	85.41	89.78	98.92
2012	91.83	91.83	126.02	105.85	127.77	86.25	91.15	104.77
2013	98.95	98.95	144.78	116.87	147.31	92.53	95.05	116.09
2014	106.36	106.36	164.40	128.80	167.75	98.94	100.12	129.15
2015	110.51	110.51	180.68	137.61	184.87	102.04	102.52	139.90
2016	112.04	112.04	193.69	143.46	198.73	102.56	102.71	148.23
2017	113.26	113.26	205.15	148.25	211.02	103.00	103.03	155.94
2018	116.26	116.26	217.32	154.27	224.02	105.63	105.62	165.38
2019	119.55	119.55	229.15	160.39	236.63	108.76	108.74	175.05
2020	121.41	121.41	238.72	164.79	246.95	110.37	110.36	182.94
2021	121.48	121.48	245.43	166.97	254.33	110.17	110.17	188.41
2022	122.20	122.20	251.87	169.43	261.39	110.75	110.75	193.97
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2009	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2010	0.33	0.33	0.01	0.17	0.00	0.41	0.33	0.18
2011	0.30	0.30	0.01	0.17	0.00	0.36	0.30	0.19
2012	0.31	0.31	0.01	0.17	0.00	0.36	0.38	0.18
2013	0.32	0.32	0.01	0.17	0.00	0.37	0.38	0.17
2014	0.33	0.33	0.01	0.17	0.00	0.39	0.39	0.16
2015	0.33	0.33	0.01	0.17	0.00	0.40	0.40	0.16
2016	0.33	0.33	0.01	0.17	0.00	0.40	0.40	0.15
2017	0.34	0.34	0.01	0.17	0.00	0.40	0.40	0.14
2018	0.35	0.35	0.01	0.17	0.00	0.41	0.41	0.14
2019	0.35	0.35	0.01	0.17	0.00	0.42	0.42	0.13
2020	0.35	0.35	0.01	0.17	0.00	0.42	0.42	0.12
2021	0.35	0.35	0.01	0.17	0.00	0.42	0.42	0.12
2022	0.36	0.36	0.01	0.17	0.00	0.42	0.42	0.11
Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2009	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
2010	33.06	33.06	1.35	18.26	0.00	40.01	33.06	19.00
2011	27.37	27.37	1.45	17.82	0.00	30.61	27.37	19.00
2012	29.91	29.91	1.68	19.39	0.00	32.91	36.50	19.00
2013	32.21	32.21	1.86	20.53	0.00	35.44	37.21	19.00
2014	34.88	34.88	2.09	22.09	0.00	38.37	39.21	19.00
2015	36.17	36.17	2.25	23.14	0.00	39.74	40.09	19.00
2016	36.99	36.99	2.42	24.19	0.00	40.57	40.69	19.00
2017	39.18	39.18	2.66	25.90	0.00	42.47	42.50	19.00
2018	40.84	40.84	2.83	27.00	0.00	43.76	43.76	19.00
2019	41.46	41.46	2.98	27.68	0.00	44.39	44.38	19.00
2020	42.25	42.25	3.11	28.39	0.00	45.39	45.39	19.00
2021	42.41	42.41	3.20	28.79	0.00	45.35	45.34	19.00
2022	43.65	43.65	3.35	29.77	0.00	46.68	46.68	19.00

Table 1A.32. Projections of Model 1 female spawning biomass (in thousands of t), *F*, and catch (in thousands of t) for NRA pollock for the 8 scenarios. Fishing mortality rates given are based on the *average* fishing mortality over all ages *(B_0=110.48 kt, B_{40}=44.19 kt, B_{35}=38.67 kt, and ½ B_{35}=19.33 kt)*.

Sp.Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2009	47.28	47.28	47.28	47.28	47.28	47.28	47.28	47.28
2010	46.06	46.06	48.76	47.69	48.89	45.35	46.06	46.52
2011	38.05	38.05	51.90	45.69	52.70	35.31	38.05	39.39
2012	37.11	37.11	56.93	46.80	58.32	34.27	36.75	36.12
2013	39.23	39.23	63.56	50.17	65.50	36.34	37.39	36.09
2014	41.72	41.72	70.44	54.06	72.93	38.56	38.94	37.14
2015	42.82	42.82	75.78	56.62	78.80	39.29	39.39	37.52
2016	42.94	42.94	79.77	58.08	83.31	39.13	39.13	37.35
2017	43.00	43.00	83.13	59.19	87.16	39.05	39.03	37.41
2018	43.71	43.71	86.59	60.66	91.08	39.74	39.72	38.37
2019	44.60	44.60	89.82	62.16	94.75	40.58	40.58	39.53
2020	45.06	45.06	92.34	63.19	97.65	40.97	40.97	40.29
2021	45.14	45.14	94.18	63.78	99.82	40.99	40.99	40.99
2022	45.37	45.37	95.89	64.43	101.84	41.17	41.17	42.90
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2009	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2010	0.51	0.51	0.02	0.21	0.00	0.65	0.51	0.43
2011	0.44	0.44	0.02	0.21	0.00	0.51	0.44	0.53
2012	0.42	0.42	0.02	0.21	0.00	0.49	0.53	0.60
2013	0.43	0.43	0.02	0.21	0.00	0.51	0.52	0.66
2014	0.44	0.44	0.02	0.21	0.00	0.53	0.53	0.71
2015	0.45	0.45	0.02	0.21	0.00	0.54	0.54	0.79
2016	0.45	0.45	0.02	0.21	0.00	0.54	0.54	0.87
2017	0.45	0.45	0.02	0.21	0.00	0.54	0.54	0.88
2018	0.45	0.45	0.02	0.21	0.00	0.54	0.54	0.89
2019	0.46	0.46	0.02	0.21	0.00	0.55	0.55	0.86
2020	0.46	0.46	0.02	0.21	0.00	0.55	0.55	0.88
2021	0.47	0.47	0.02	0.21	0.00	0.55	0.55	0.37
2022	0.47	0.47	0.02	0.21	0.00	0.56	0.56	0.42
Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*	*Scenario 8*
2009	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
2010	22.21	22.21	1.13	10.13	0.00	26.89	22.21	19.00
2011	15.32	15.32	1.16	9.37	0.00	16.33	15.32	19.00
2012	14.84	14.84	1.29	9.68	0.00	15.83	18.08	19.00
2013	15.39	15.39	1.39	9.95	0.00	16.71	17.61	19.00
2014	16.30	16.30	1.53	10.47	0.00	17.82	18.17	19.00
2015	16.66	16.66	1.61	10.73	0.00	18.13	18.24	19.00
2016	17.02	17.02	1.71	11.11	0.00	18.34	18.36	19.00
2017	17.50	17.50	1.85	11.66	0.00	18.71	18.70	19.00
2018	17.79	17.79	1.93	11.95	0.00	19.03	19.02	19.00
2019	17.99	17.99	2.00	12.15	0.00	19.25	19.24	19.00
2020	18.23	18.23	2.06	12.30	0.00	19.50	19.50	19.00
2021	18.41	18.41	2.11	12.48	0.00	19.67	19.67	15.36
2022	18.70	18.70	2.18	12.72	0.00	20.08	20.08	16.92

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

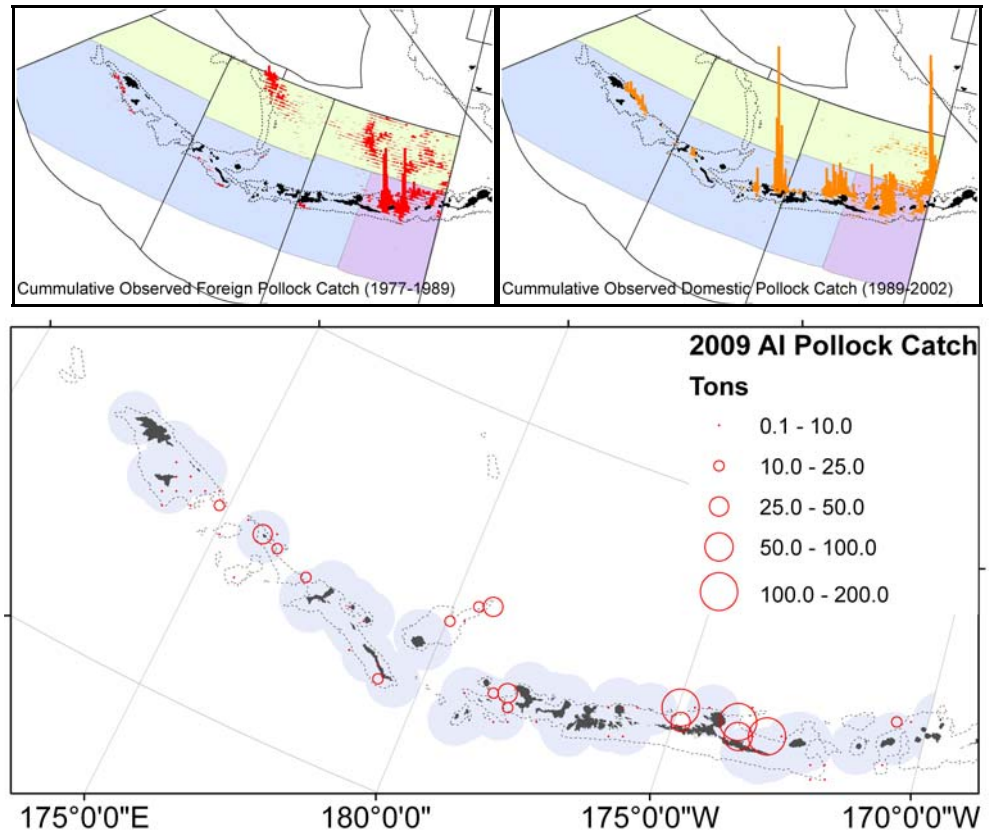

Figure 1A.1. Top figures are observed foreign and J.V. (1978-1989; left), early domestic (1989-2002; right) pollock catch in the Aleutian Islands Area summed over all years and 10 minute latitude and longitude blocks. The two top maps use the same scale (maximum observed catch per 10 minute block: foreign 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 2009 aggregated in 20 X 20 km cells, shaded areas are the directed pollock fishing exclusion zone and dotted line is the 300m isobath.

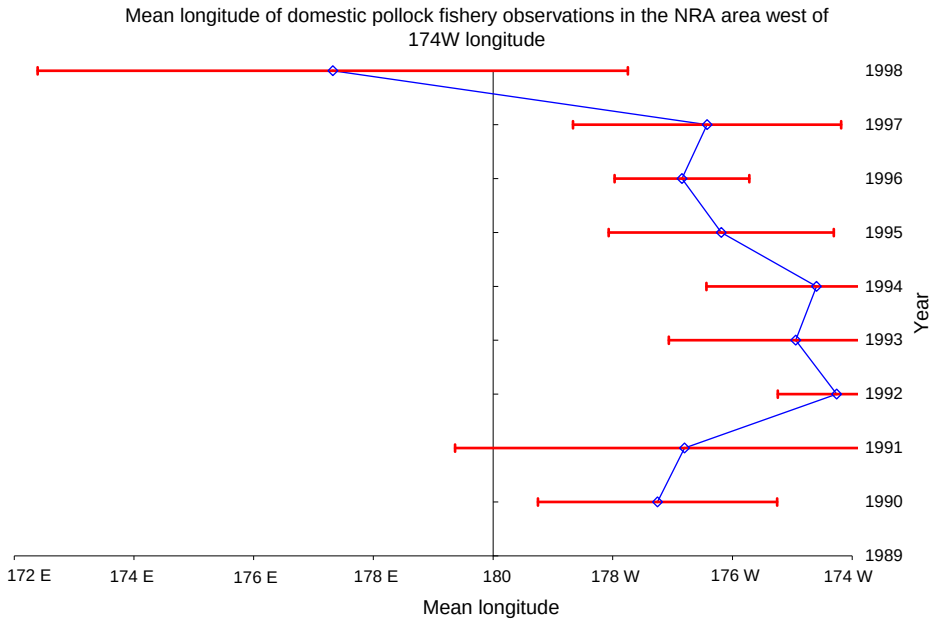

Figure 1A.2. Mean longitude of observed targeted domestic (1990-1998) pollock catch in the NRA west of 174 W longitude. Error bars indicate one standard deviation from the mean

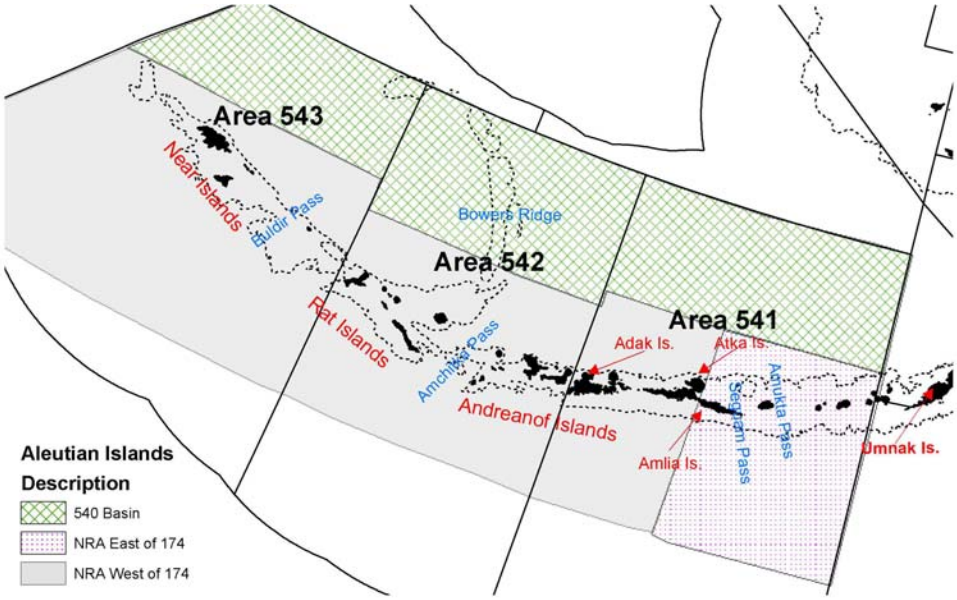

Figure 1A.3. Regions defined for consideration of alternative data partitions for Aleutian Islands Region pollock. The abbreviation "NRA" represents the Near, Rat, and Andreanof Island groups.

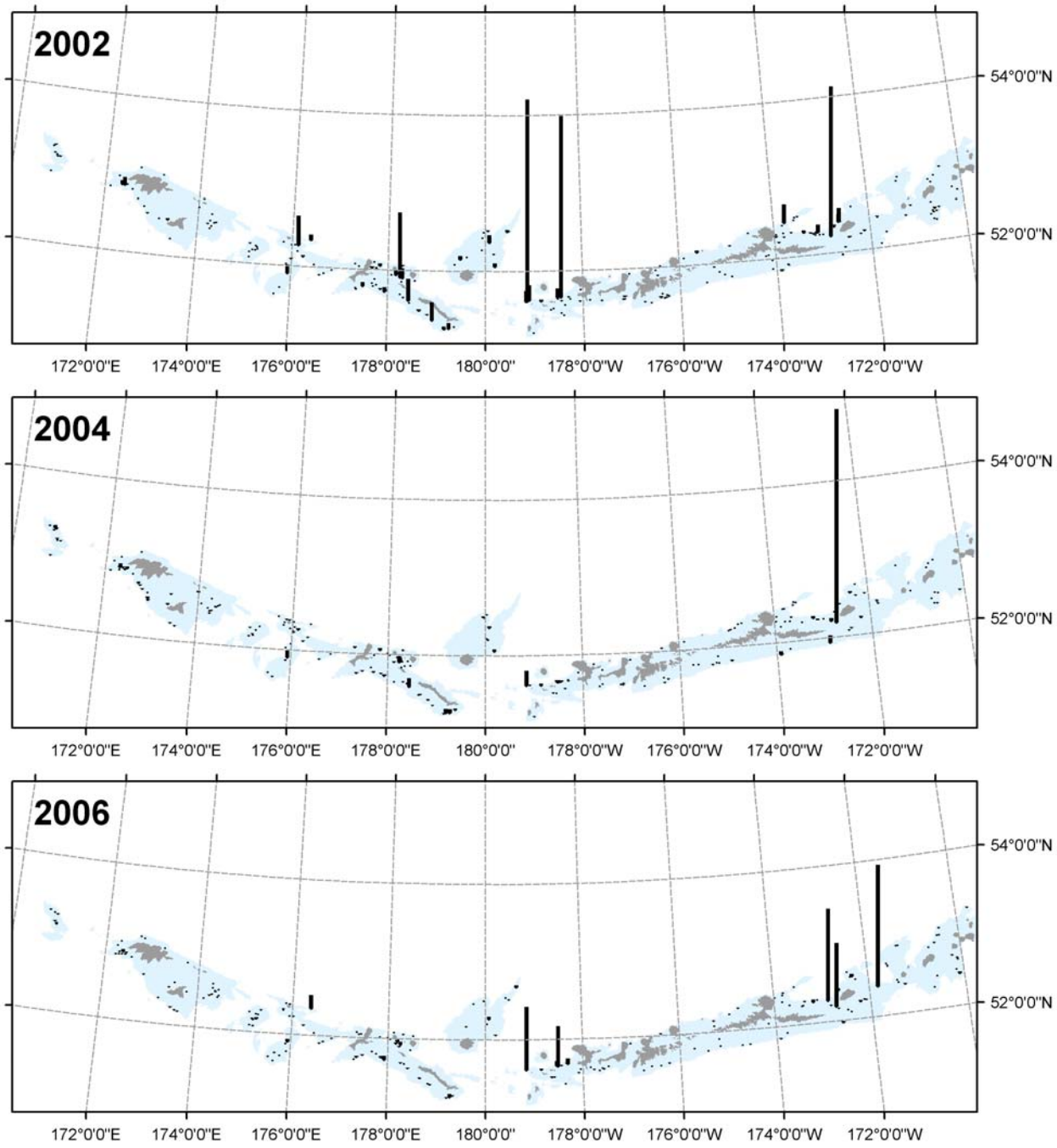

Figure 1A.4. Catch per unit effort (kg per m^3) for surveys of pollock in the Aleutian Islands Region, 2002-2006. The shaded area is the region surveyed.

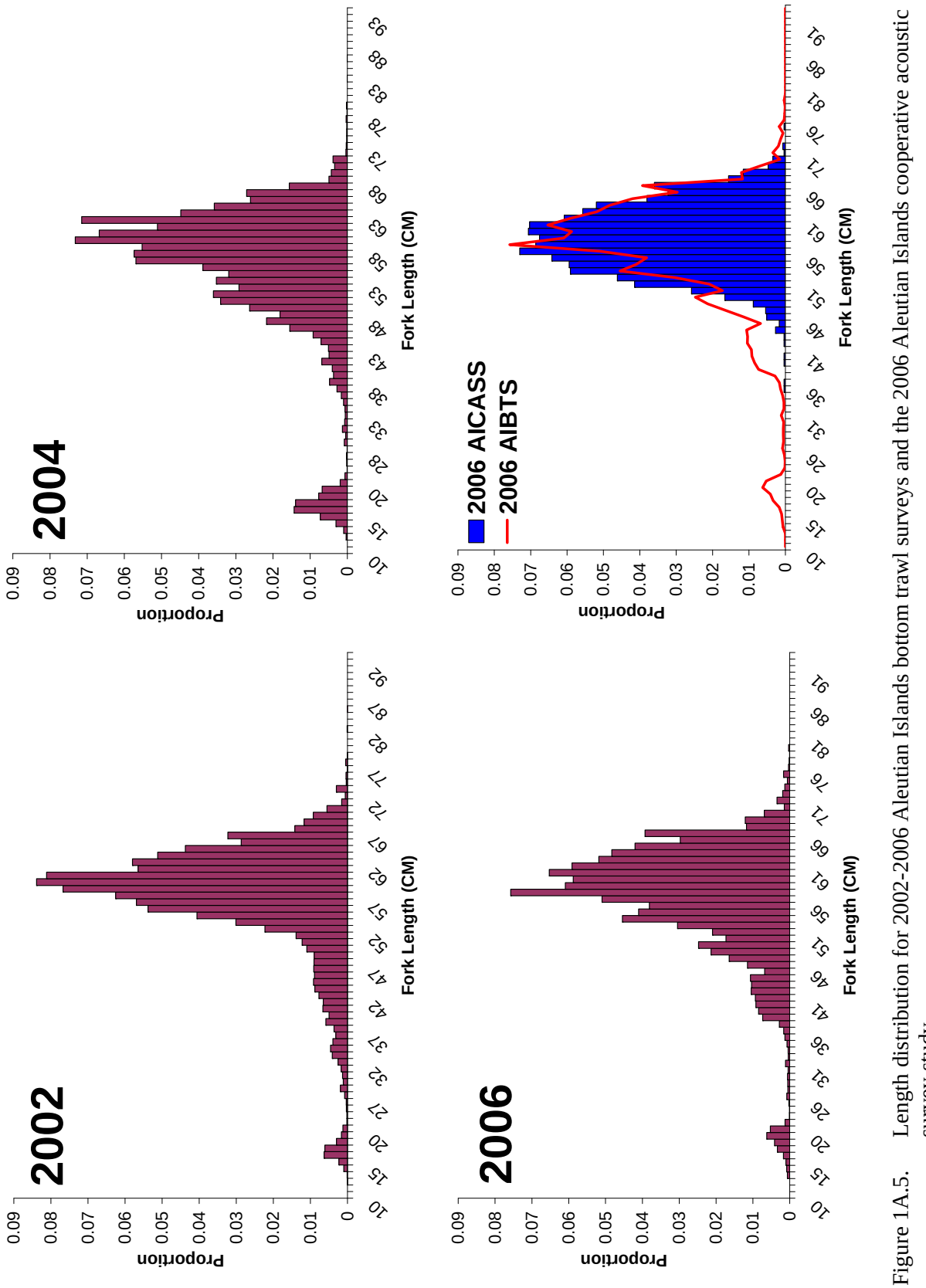

Figure 1A.5. Length distribution for 2002-2006 Aleutian Islands bottom trawl surveys and the 2006 Aleutian Islands cooperative acoustic survey study.

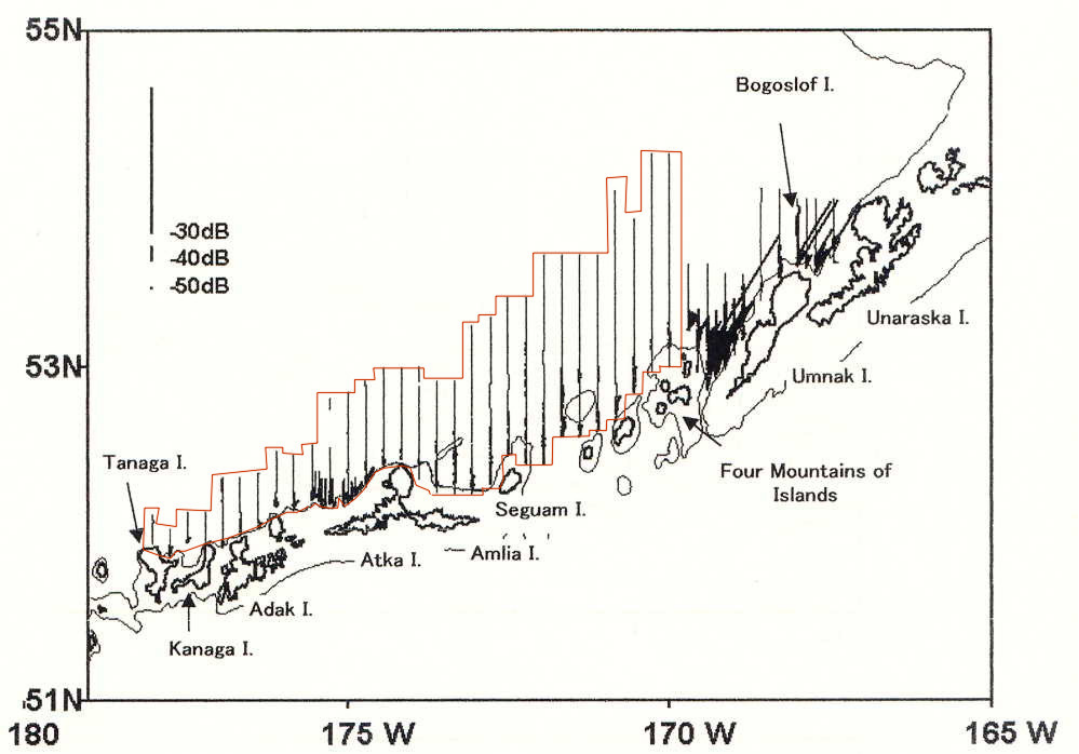

Figure 1A.6. R/V Kaiyo Maru 2002 echo integration-trawl survey (above) strata for leg2 and below observed S_A in both legs. Please note that in the bottom picture the encircled area is leg 2.

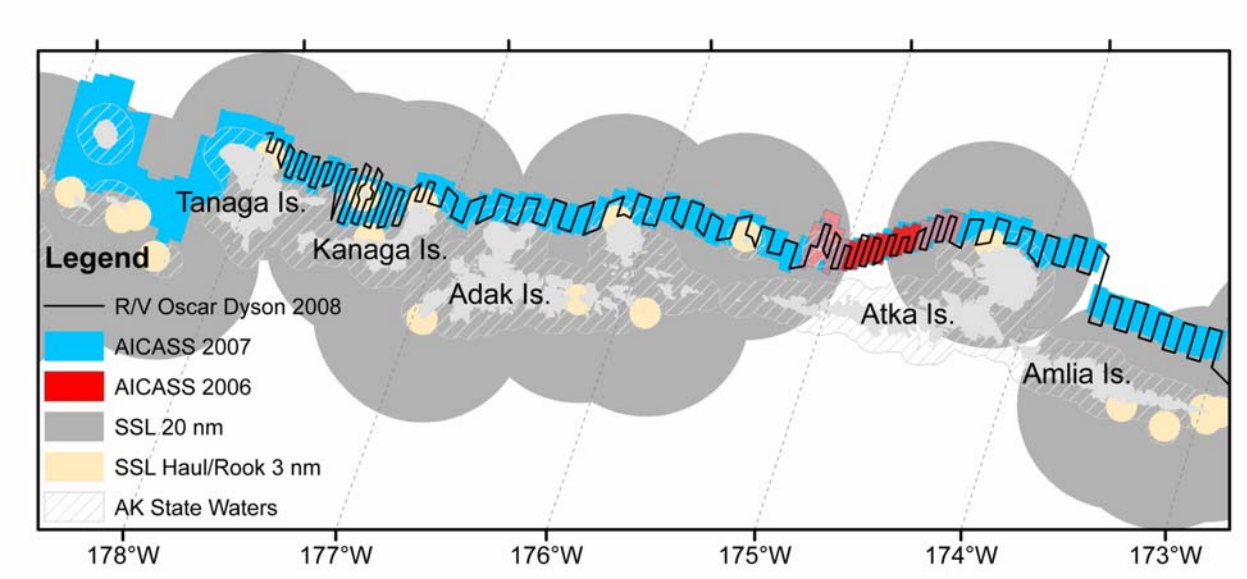

Figure 1A.7. 2006, 2007, and 2008 Aleutian Islands Cooperative Acoustic Survey Study sites within the central Aleutian Islands with pertinent Steller Sea lion areas.

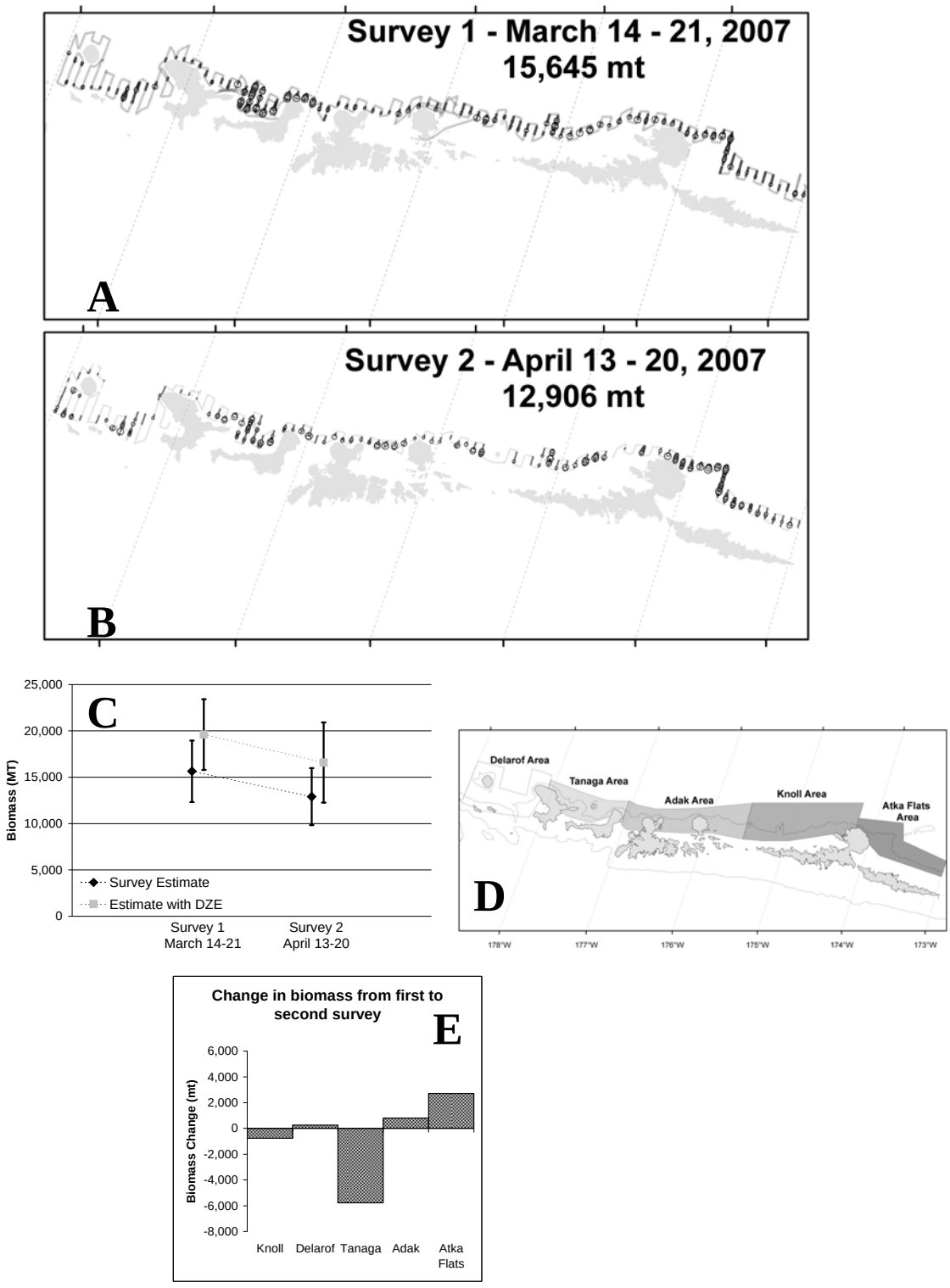

Figure 1A.8. Distribution and biomass estimate results from the 2007 Aleutian Islands Cooperative Acoustic Survey Studies. A) pollock abundance and distribution for Survey 1, B) pollock abundance and distribution for Survey 2, C) biomass estimates, and D) area delineations, and E) Change in pollock biomass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

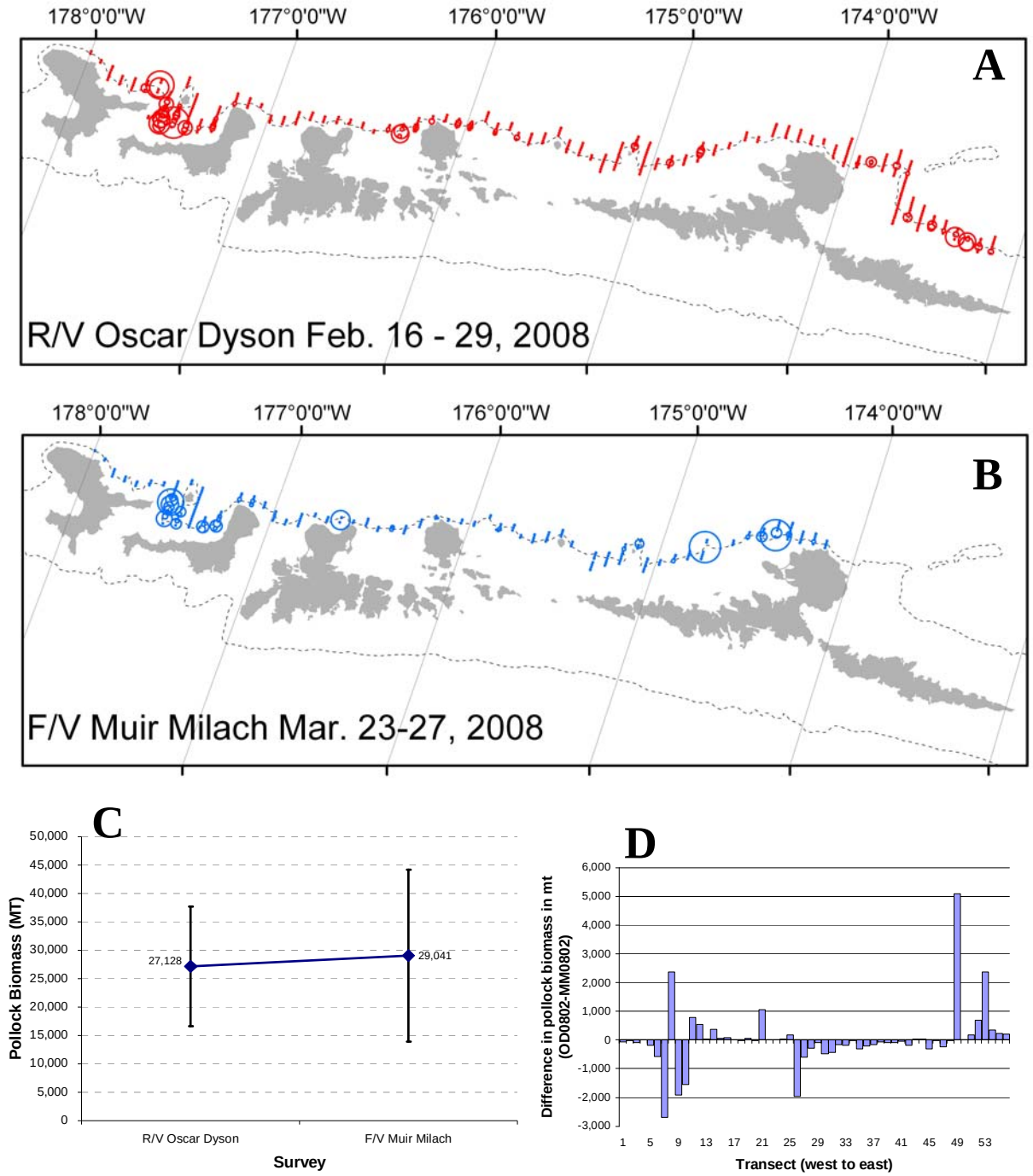

Figure 1A.9. Distribution and biomass estimate results from the 2008 Aleutian Islands Cooperative Acoustic Survey Studies, A) pollock abundance and distribution for Survey 1, B) pollock abundance and distribution for Survey 2, C) biomass estimates, and D) change in biomass distribution by transect.

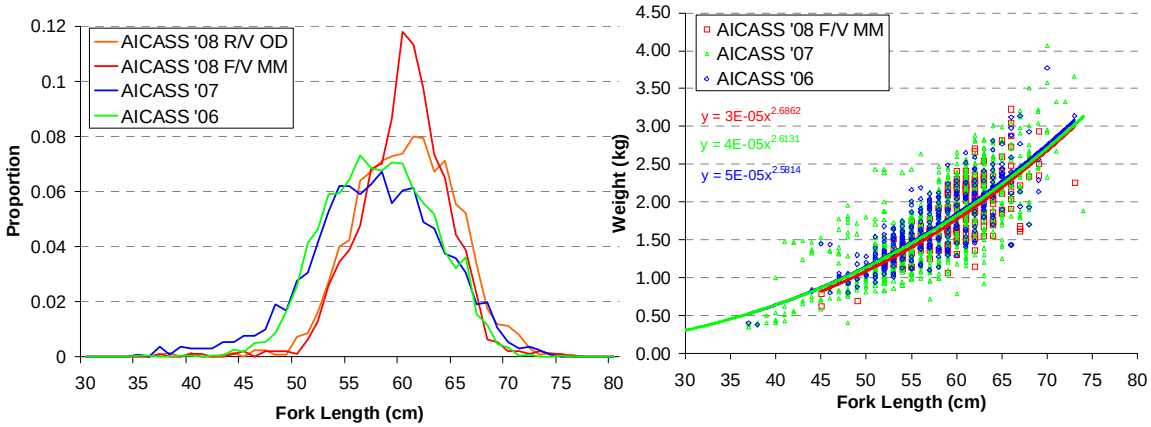

Figure 1A.10. Length distribution (left) and weight at length of Aleutian Islands pollock from the 2006, 2007, and 2008 Aleutian Islands cooperative acoustic survey studies.

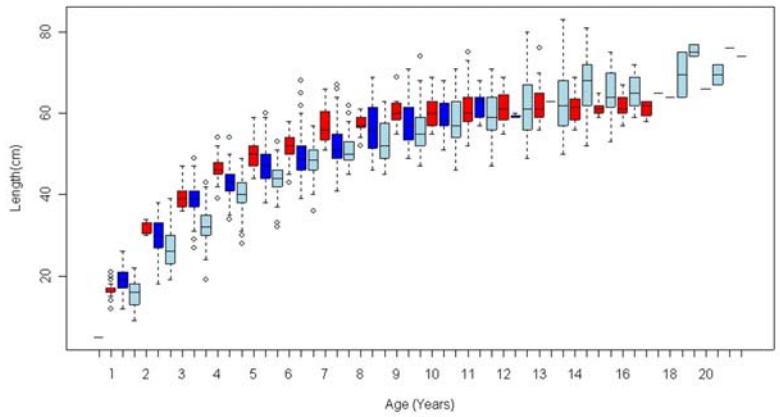

Figure 1A.11. Length at age for Aleutian Islands (red), Gulf of Alaska (blue), and Bering Sea (grey) pollock from the 2004 Aleutian Islands, 2004 Bering Sea, and 2005 Gulf of Alaska bottom trawl surveys.

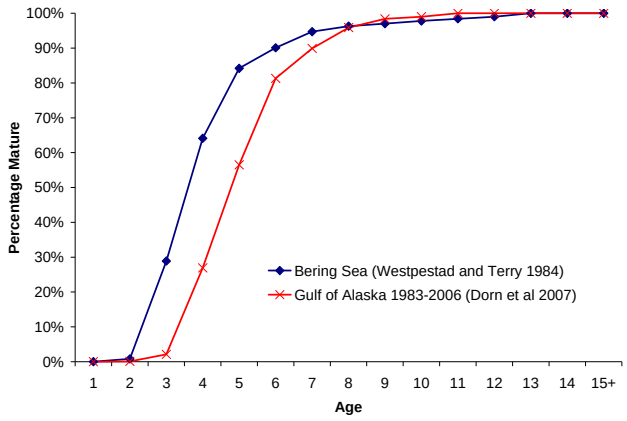

Figure 1A.12. Percentage mature at age for Bering Sea (Westpestad and Terry 1984) and the mean percentage mature at age for 1983-2006 for Gulf of Alaska pollock (Dorn et al. 2007).

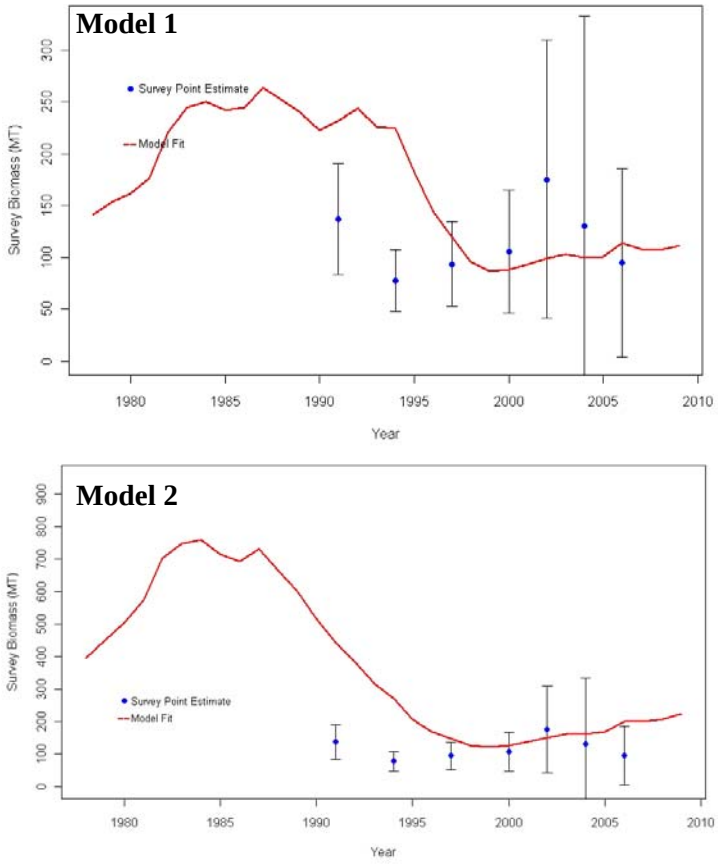

Figure 1A.13. Fit (solid line) to NMFS summer trawl survey (dots) for Model 1 (top) and Model 2 (bottom). (Note the biomass axes are not on the same scales)

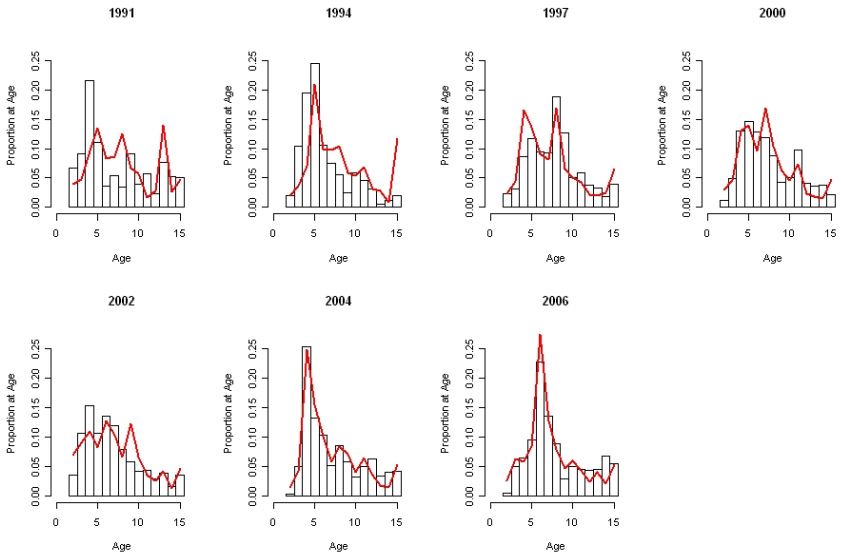

Figure 1A.14. Fits to NMFS summer trawl survey age composition data for Model 1 for Aleutian Islands pollock.

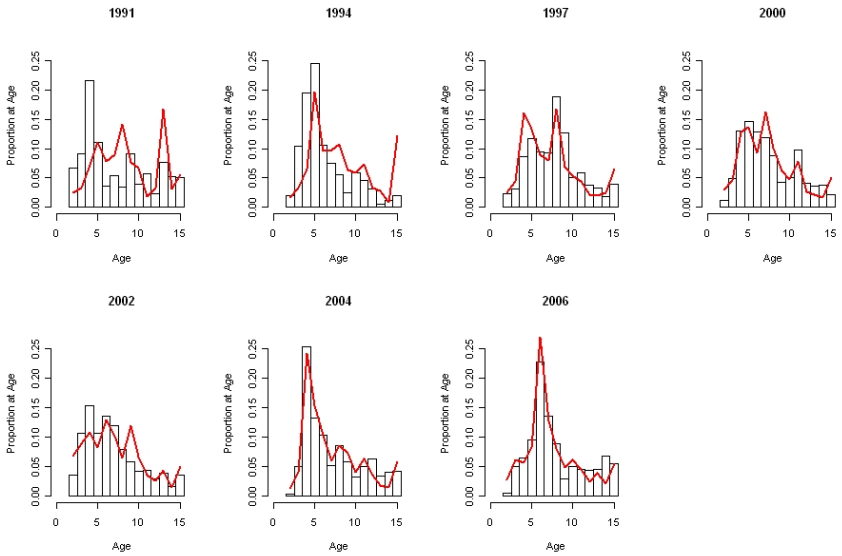

Figure 1A.15. Fits to NMFS summer trawl survey age composition data for Model 2 for Aleutian Islands pollock.

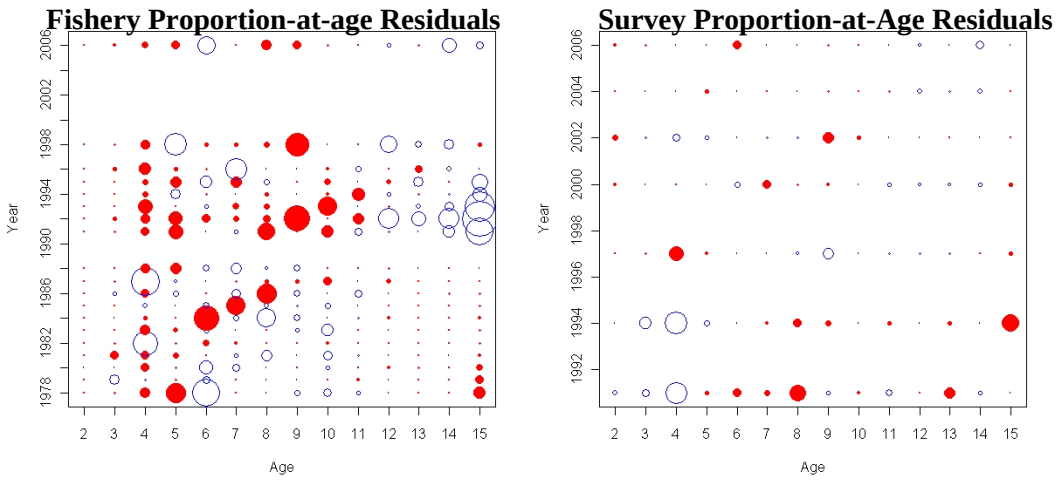

Figure 1A.16. Standardized residuals for fits to the fishery (left) and survey (right) proportion-at-age data for Model 1, solid circles are positive residuals while hollow circles are negative residuals.

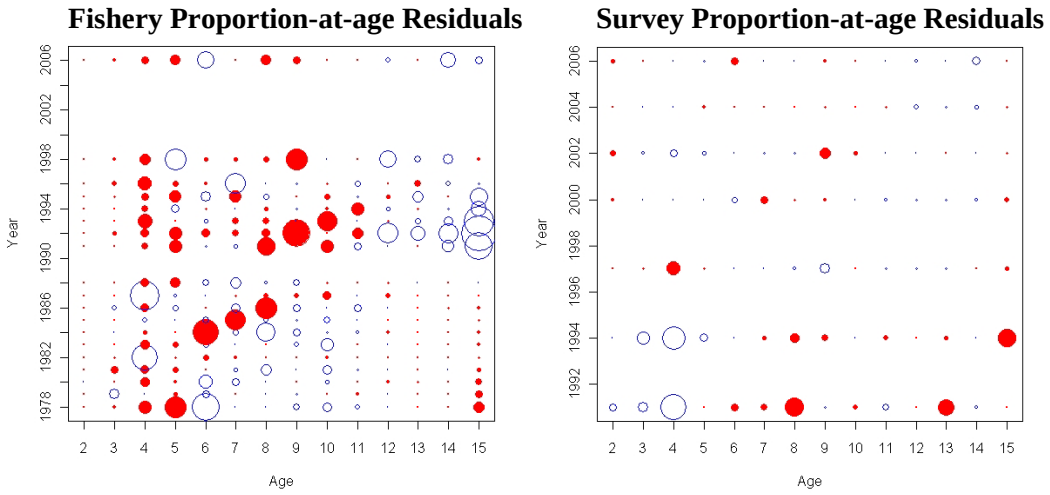

Figure 1A.17. Standardized residuals for fits to the fishery (left) and survey (right) proportion-at-age data for Model 2, solid circles are positive residuals while hollow circles are negative residuals.

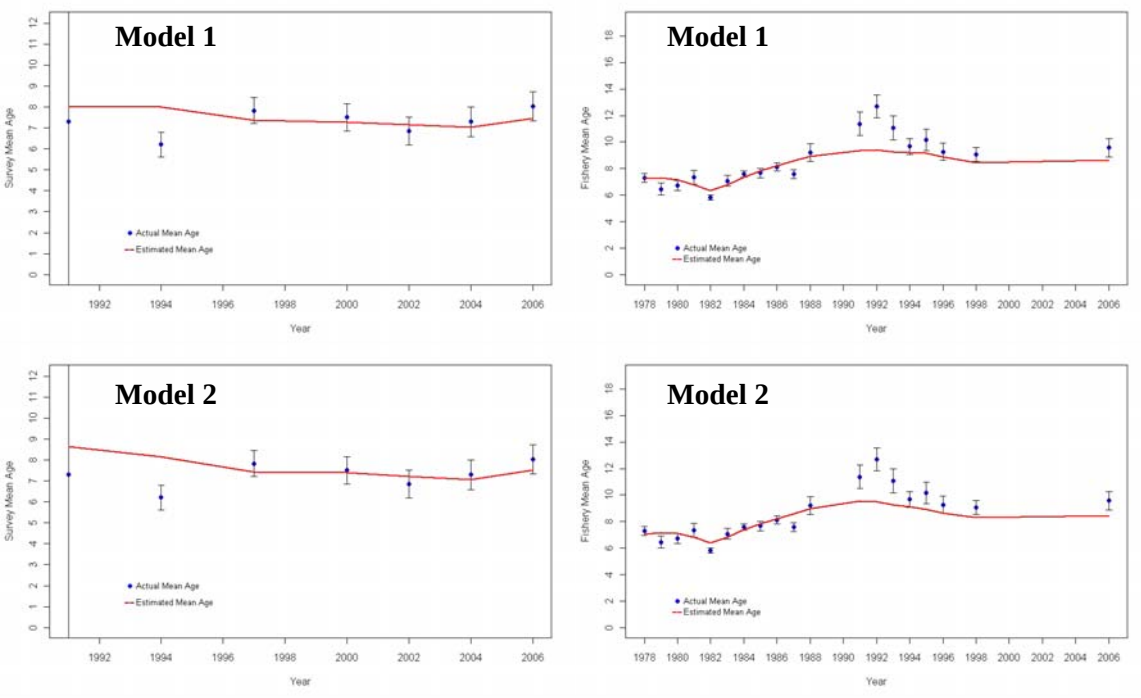

Figure 1A.18. Observed mean age and model derived mean age from the AIBTS (left) and fishery catch at age data (right) for Model 1 (top) and Model 2.

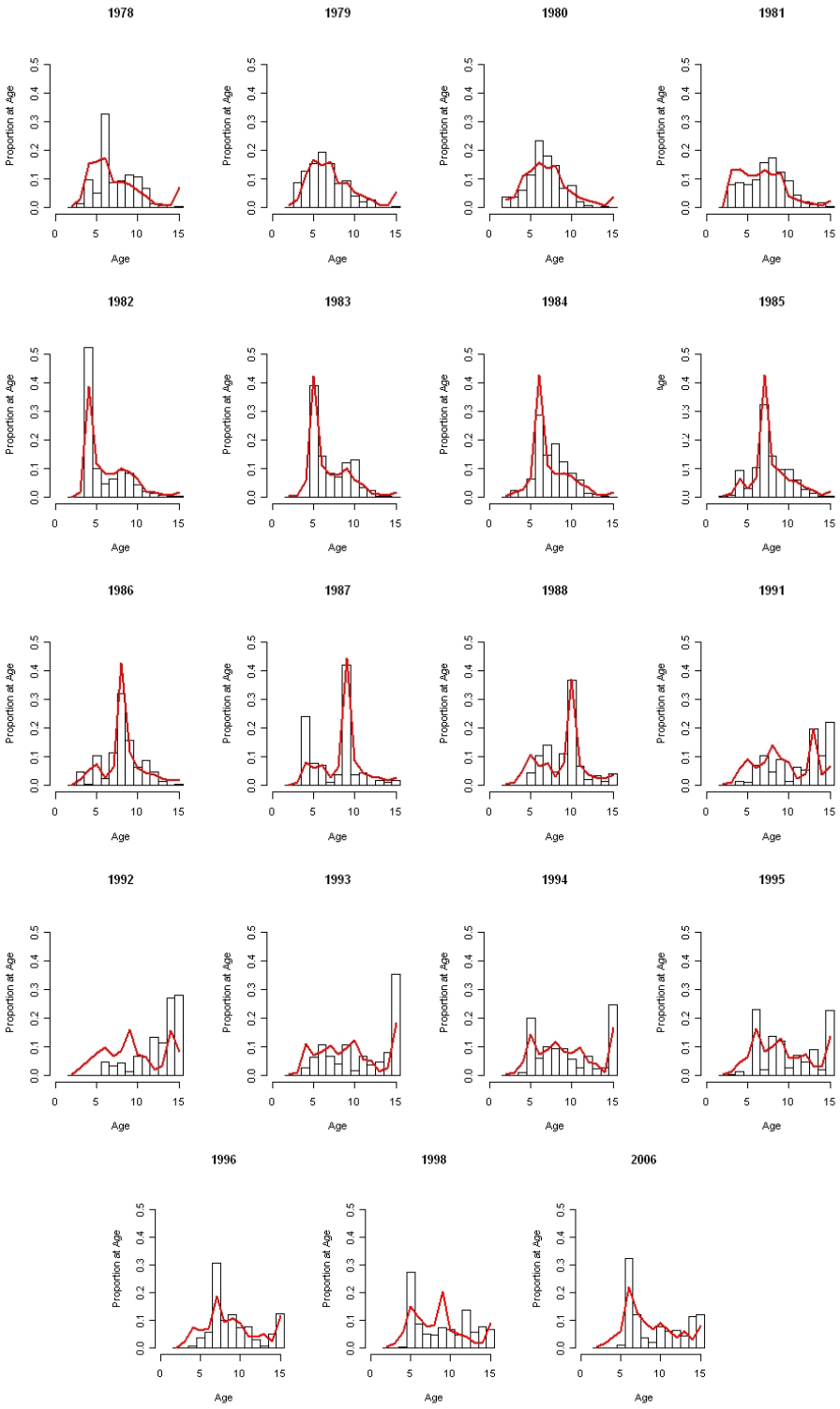

Figure 1A.19. Fit to fishery age composition data for Model 1 for Aleutian Islands (NRA) pollock.

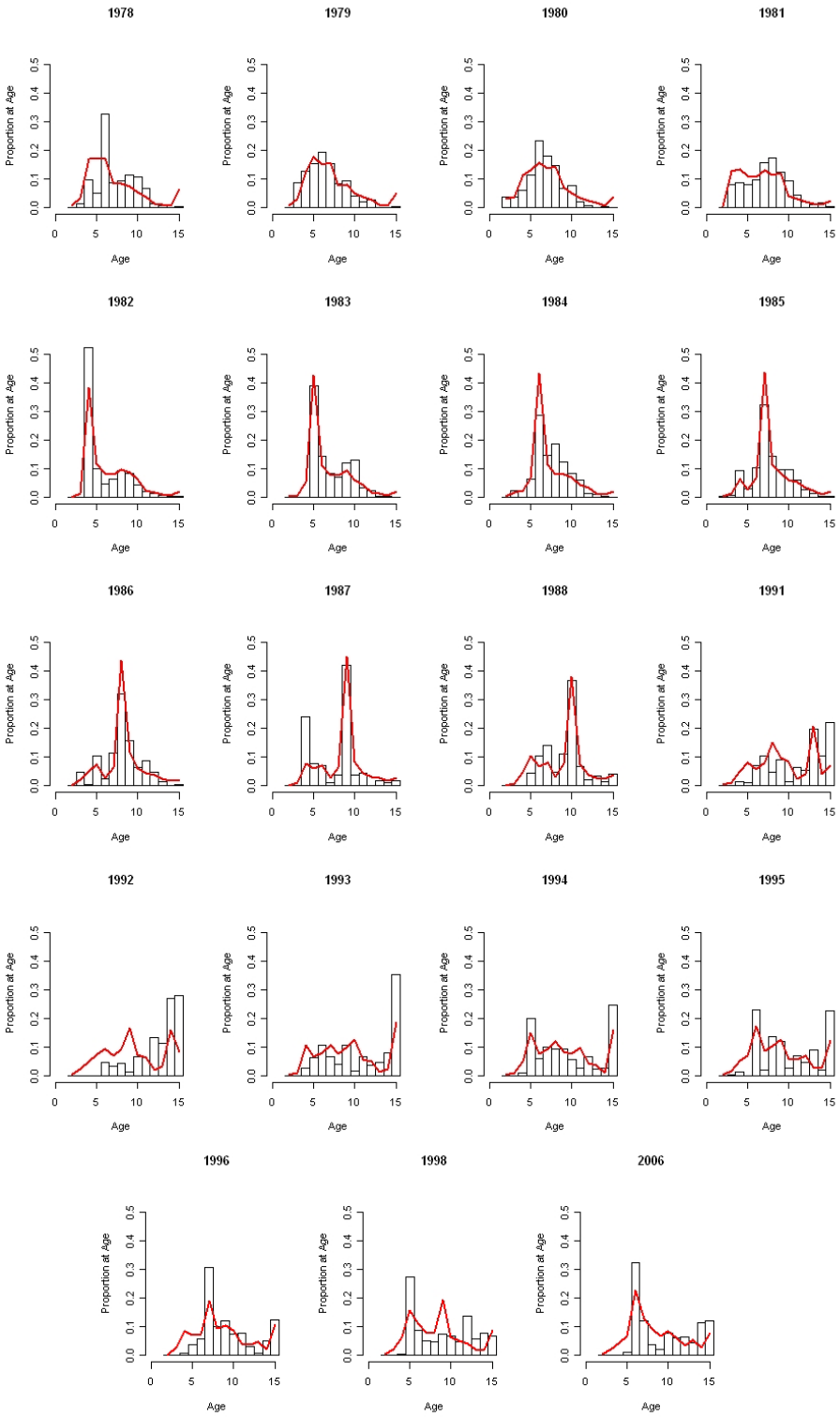

Figure 1A.20. Fit to fishery age composition data for Model 2 for Aleutian Islands (NRA) pollock.

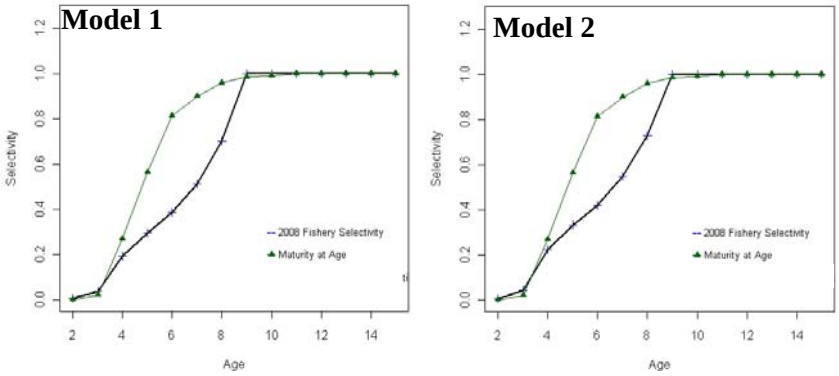

Figure 1A.21. Fishery selectivity estimates for Aleutian Islands pollock for Models 1 and 2 with the maximum age at which the selectivity is allowed to change is set to 8.

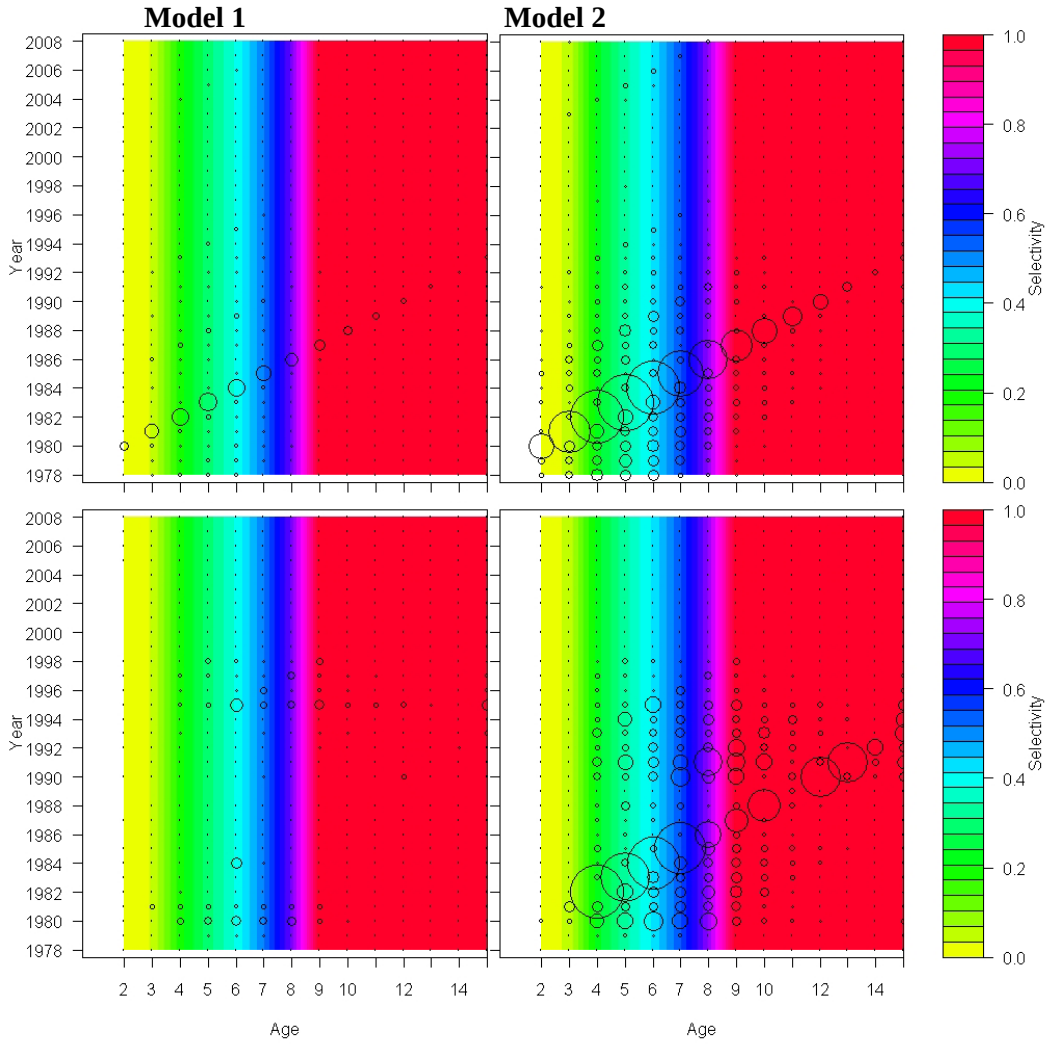

Figure 1A.22 Fishery Selectivity for Model 1 (left) and Model 2 (right) by age for AI pollock with bubble plots of total biomass at age (top) and catch biomass at age (bottom). Total biomass is scaled to 1/25 of the catch biomass bubbles.

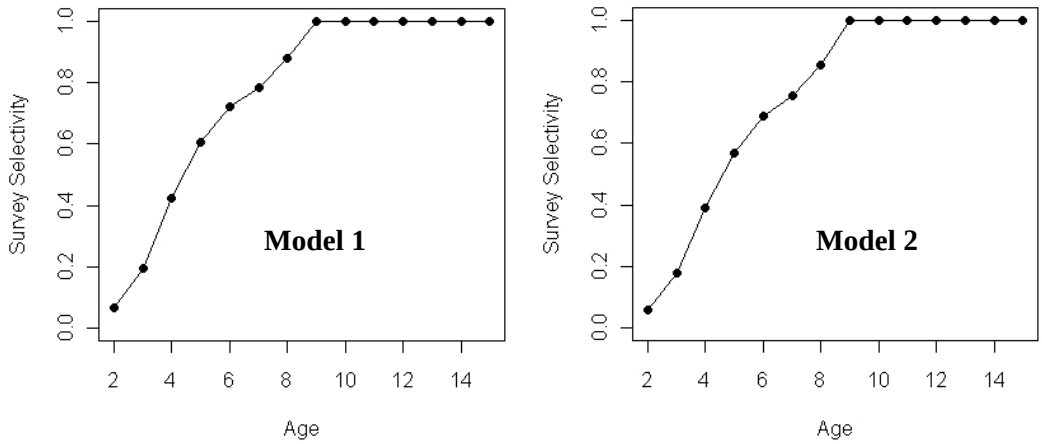

Figure 1A.23. Selectivity estimates for Aleutian Islands pollock for the bottom trawl survey.

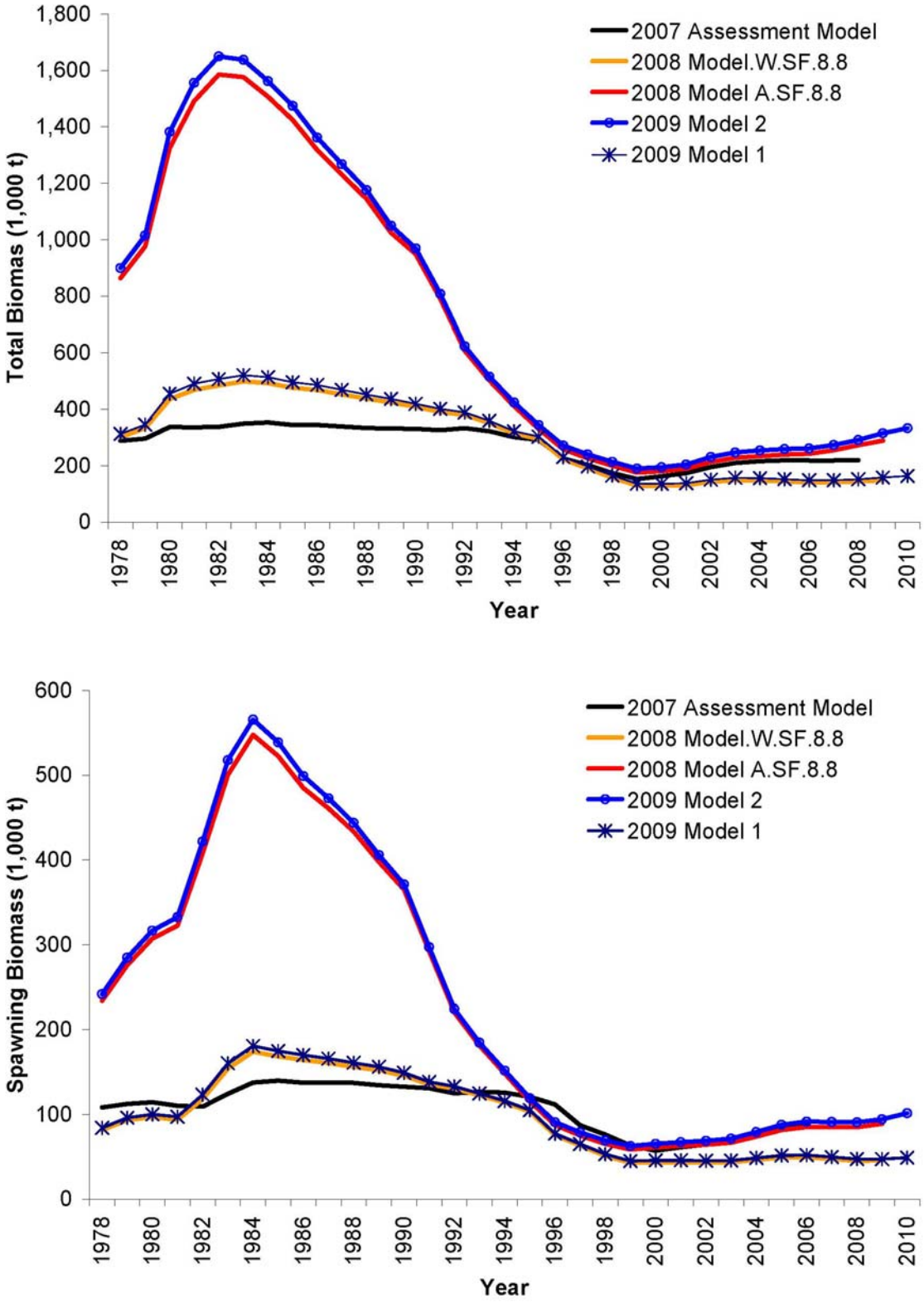

Figure 1A.24. Age 2+ (top) and spawning (bottom) biomass trajectories under four evaluated models compared with the 2008 reference model.

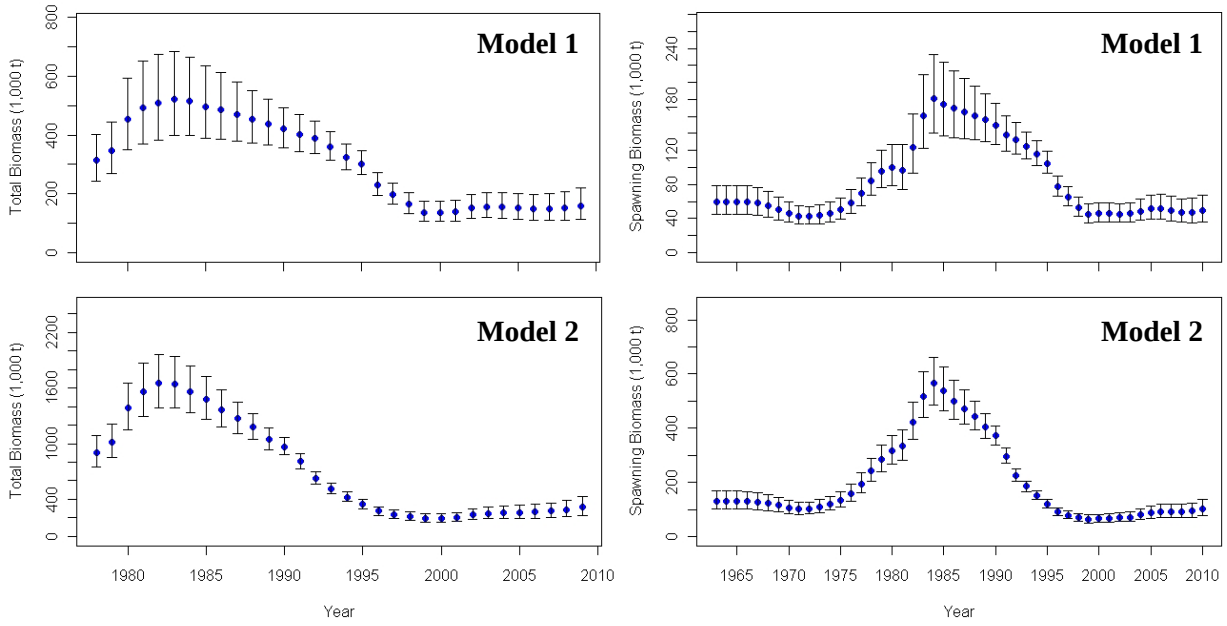

Figure 1A.25. Estimates of Aleutian Islands pollock age 2+ total biomass (Right) and Spawning Biomass (Left) in 1,000s of tons; Top are estimates from Model 1 and bottom are from Model 2 (Note: Biomass axes are not to the same scale). Error bars are two standard deviations.

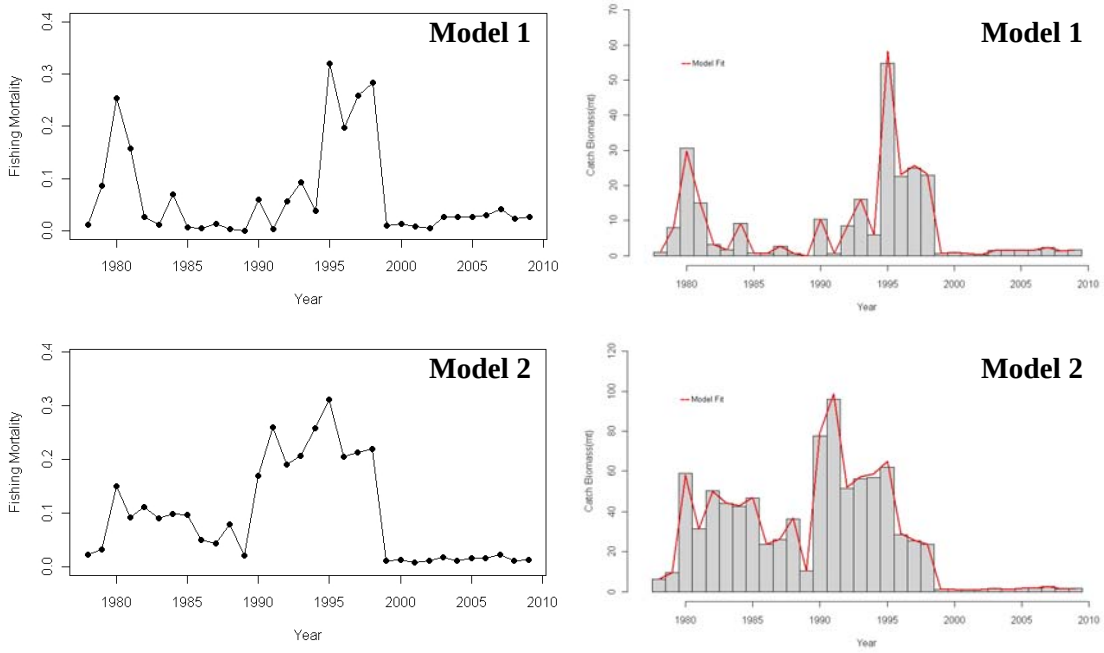

Figure 1A.26 Fishing mortality rates (left) and fits to total catch in 1,000s of tons (right) for Model 1 (top) and Model 2 (bottom) for AI pollock over time 1978-2009. Fishing mortality rates are based on the average over ages 2-15. (Note the catch biomass are not on the same scales)

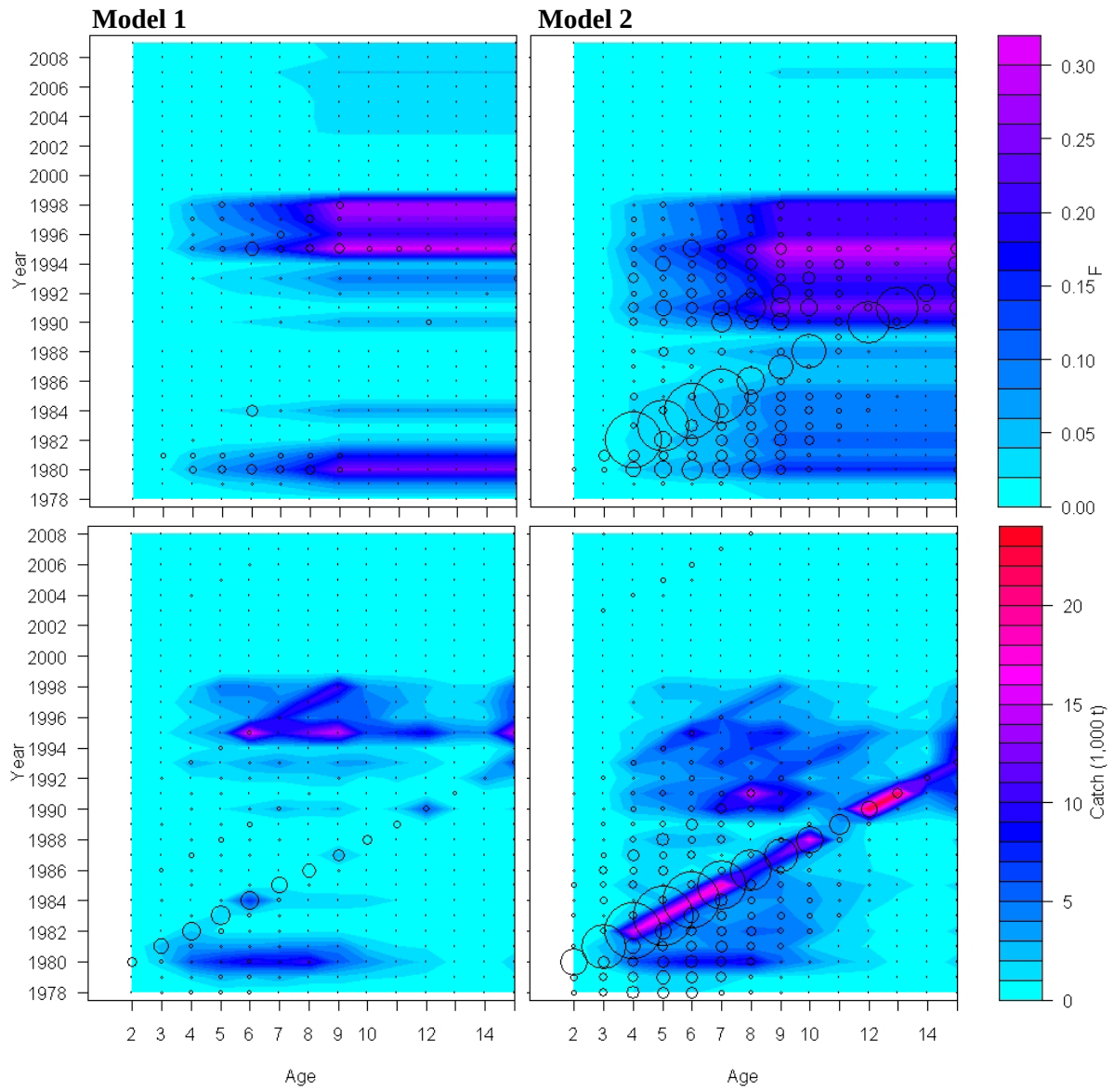

Figure 1A.27 Fishing mortality rates (top) and Catch Biomass in 1,000s of tons (bottom) for Model 1 (left) and Model 2 (right) by age for AI pollock with bubble plots of catch biomass at age (top) and total biomass at age (bottom). Total biomass bubbles are scaled to 1/25th of the catch biomass bubbles.

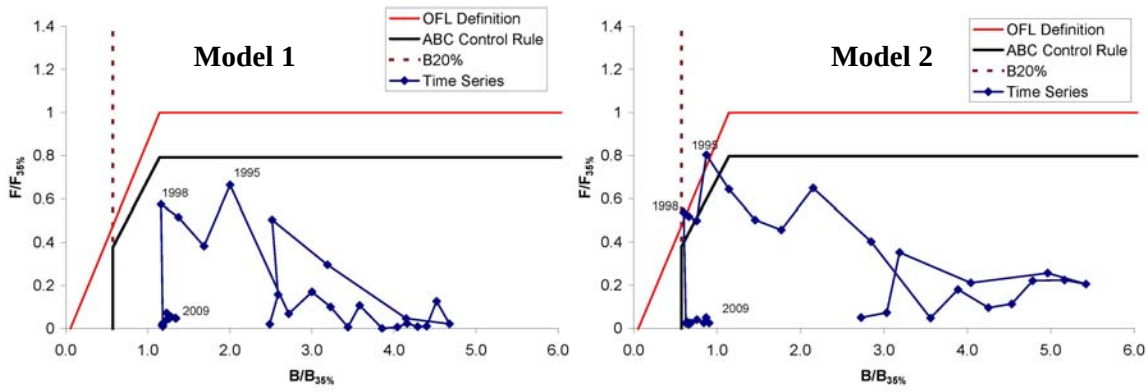

Figure 1A.28. Model 1 (left) reference model Model 2(right) Aleutian Islands pollock spawning biomass relative to $B_{35\%}$ and full-selection fishing mortality relative to F_{OFL} (1978-2009). The ratio of fishing mortality to F_{OFL} is calculated using the estimated selectivity pattern in that year.

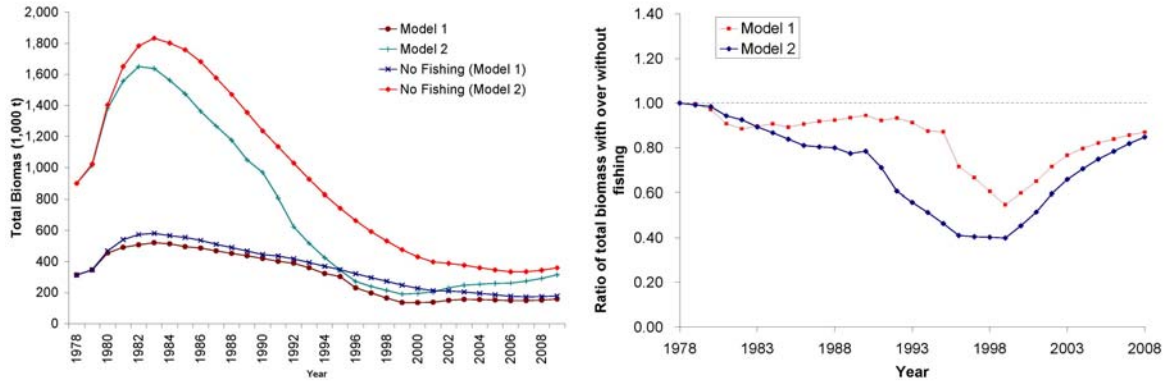

Figure 1A.29. Aleutian Islands pollock total biomass (age 2+) with and without fishing (left) and ratio of total biomass with fishing over total biomass without fishing for Model 1 and Model 2.

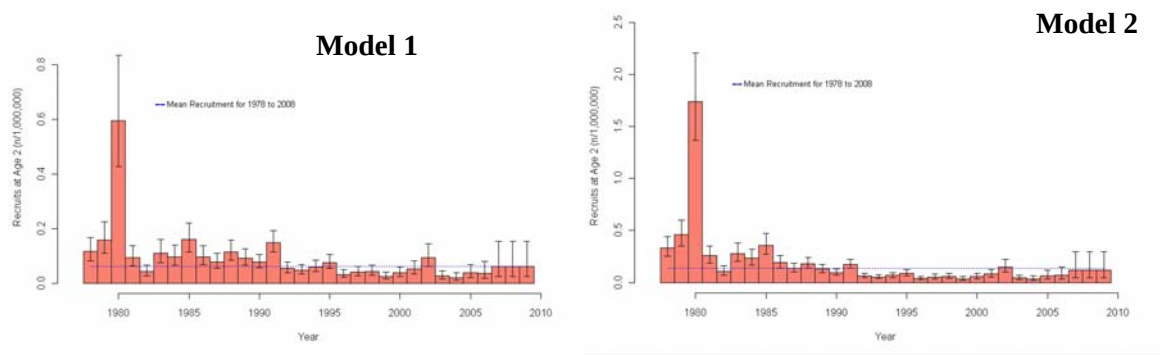

Figure 1A.30. Estimates of Aleutian Islands (NRA assessment area) pollock year-class estimates for Model 1(left) and Model 2 (right); vertical bars represent approximate upper and lower confidence bounds. (Note the Recruits axes are not the same scale.

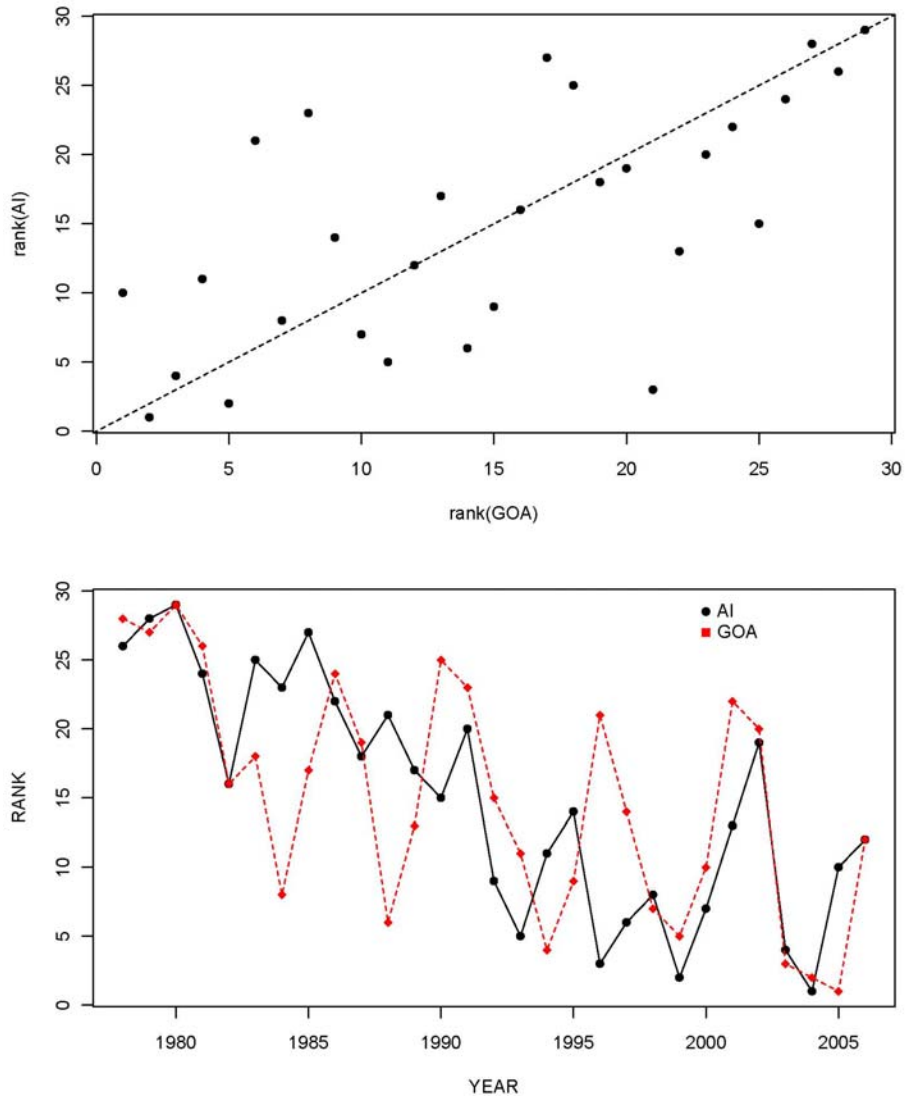

Figure 1A.31 Numbers of age 2 pollock ranked by year for the Gulf of Alaska (GOA) and Aleutian Islands (AI) plotted against each other with a 1:1 line (left) and plotted by year (right).

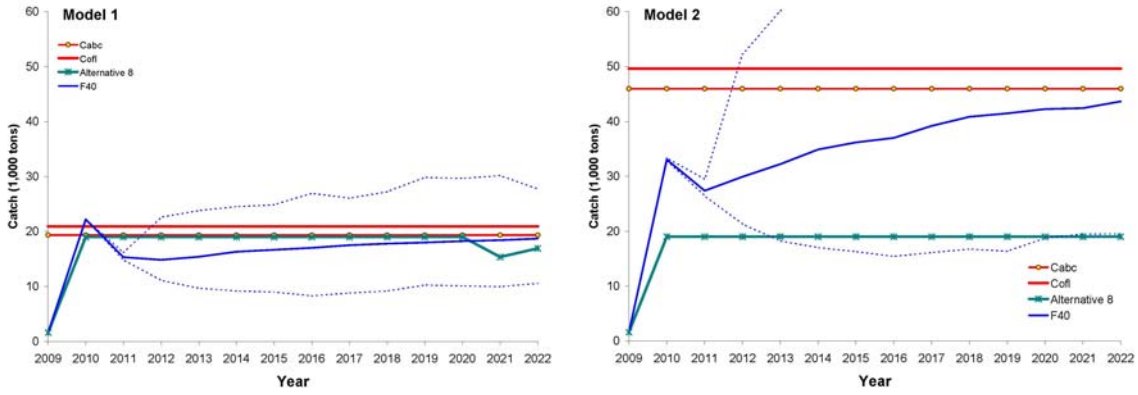

Figure 1A.32 Projected catch for $F_{40\%}$ and Alternative 8 ABC scenarios from Model 1 and Model 2.

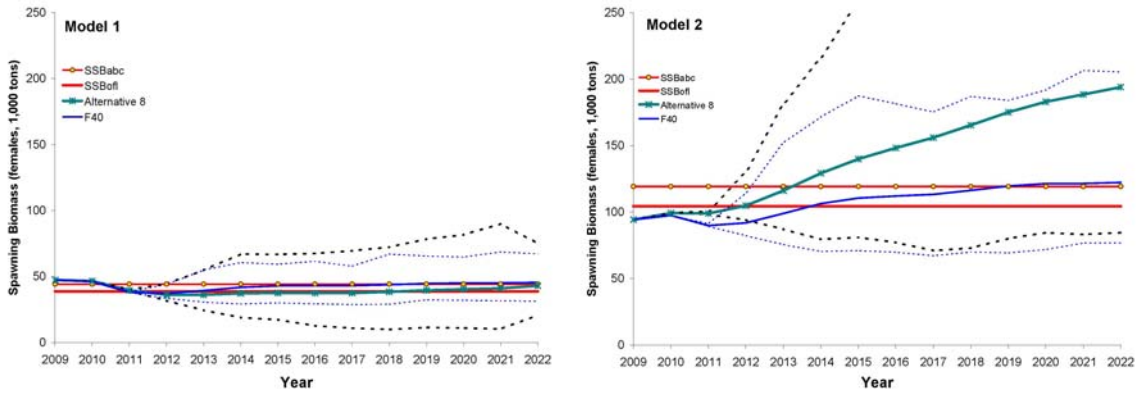

Figure 1A.33 Projected spawning biomass for $F_{40\%}$ and Alternative 8 ABC scenarios from Model 1 and Model 2.

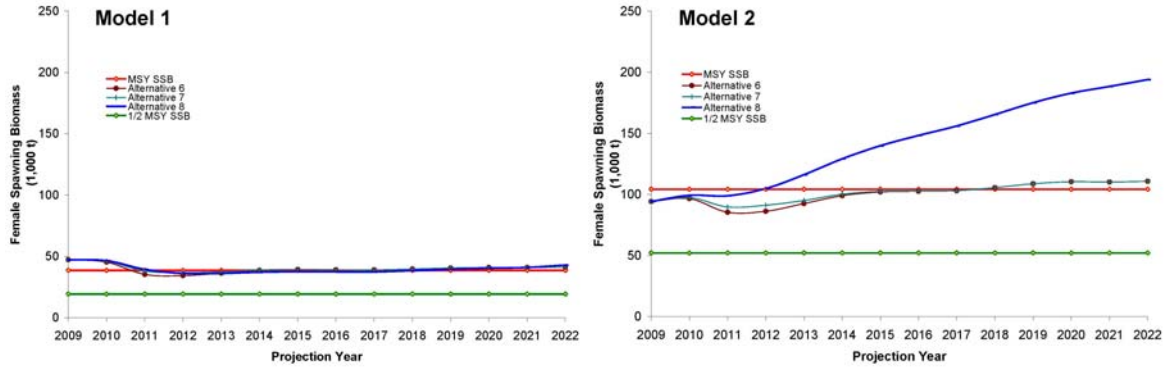

Figure 1A.34 Projected spawning biomass for and Alternatives 6, 7, and 8 ABC scenarios from Model 1 and Model 2.

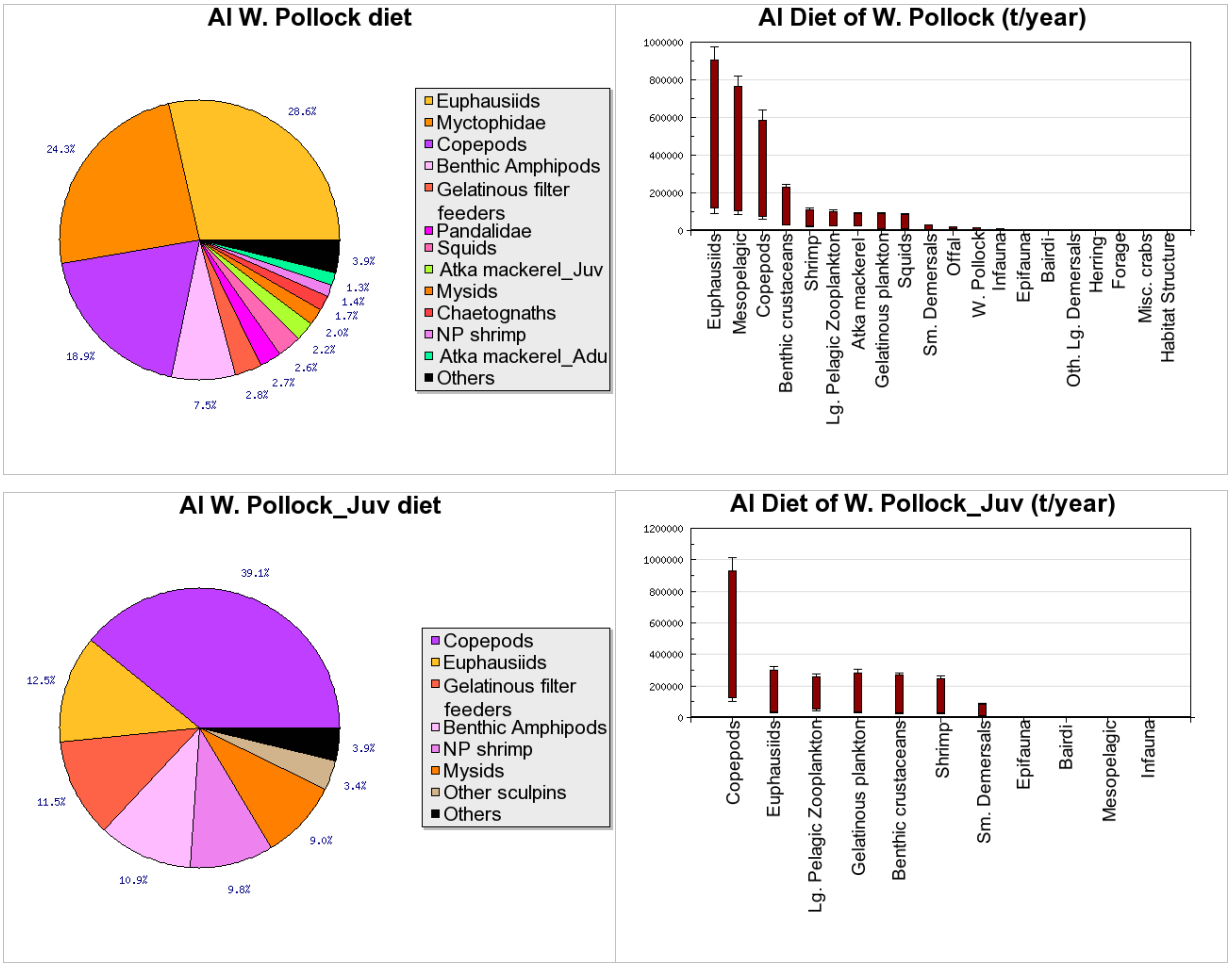

Figure 1A.35. Diet composition (left) and estimated consumption of prey (right) by AI adult (top) and juvenile (bottom) pollock. Diets are estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994. See Appendix A for detailed methods.

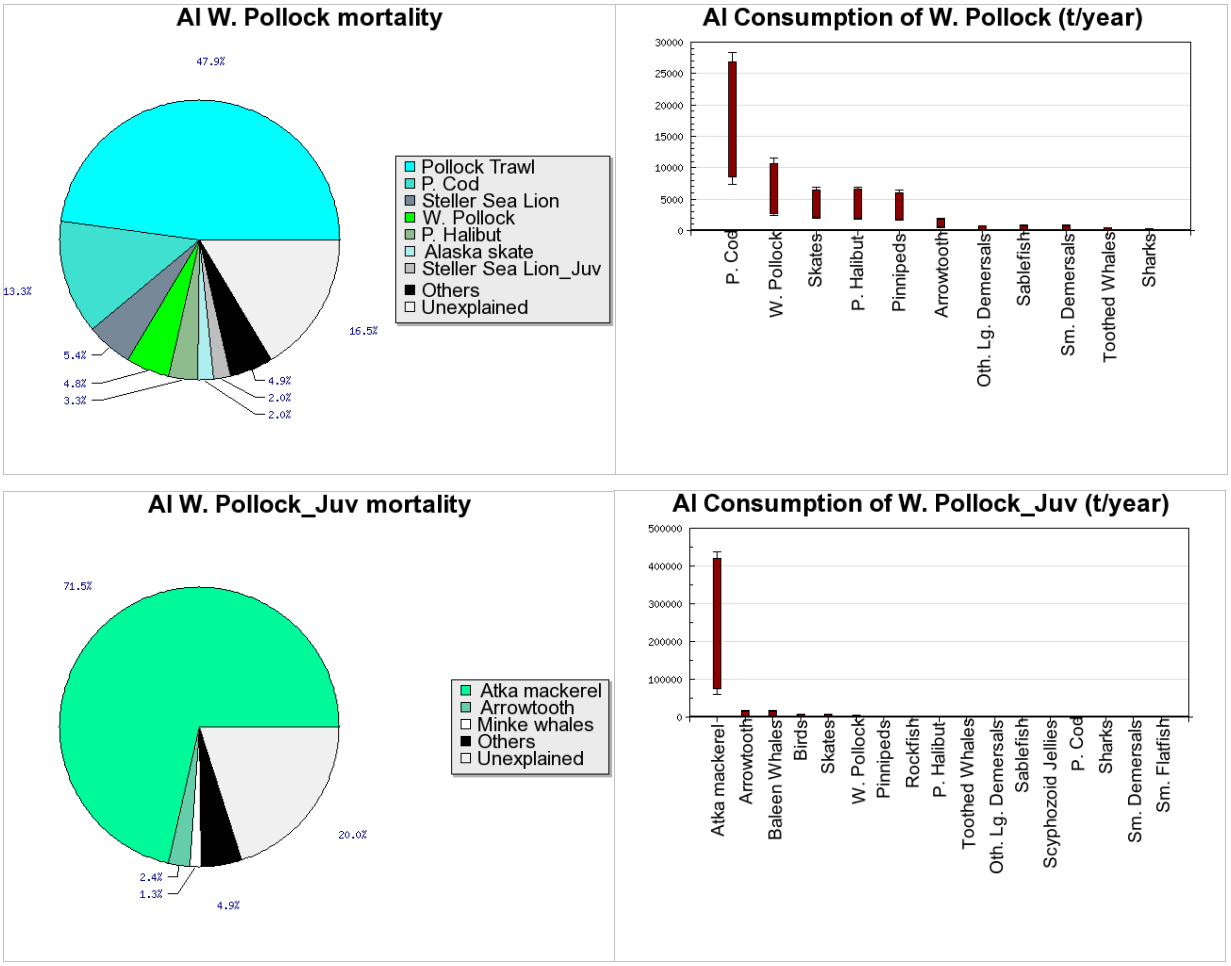

Figure 1A.36. Mortality sources (left) and estimated consumption by predators (right) of AI adult (top) and juvenile (bottom) pollock. Mortality sources reflect pollock predator diets estimated from stomach collections taken aboard NMFS bottom trawl surveys in 1991-1994, pollock predator consumption 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 2004). See Appendix A for detailed methods.

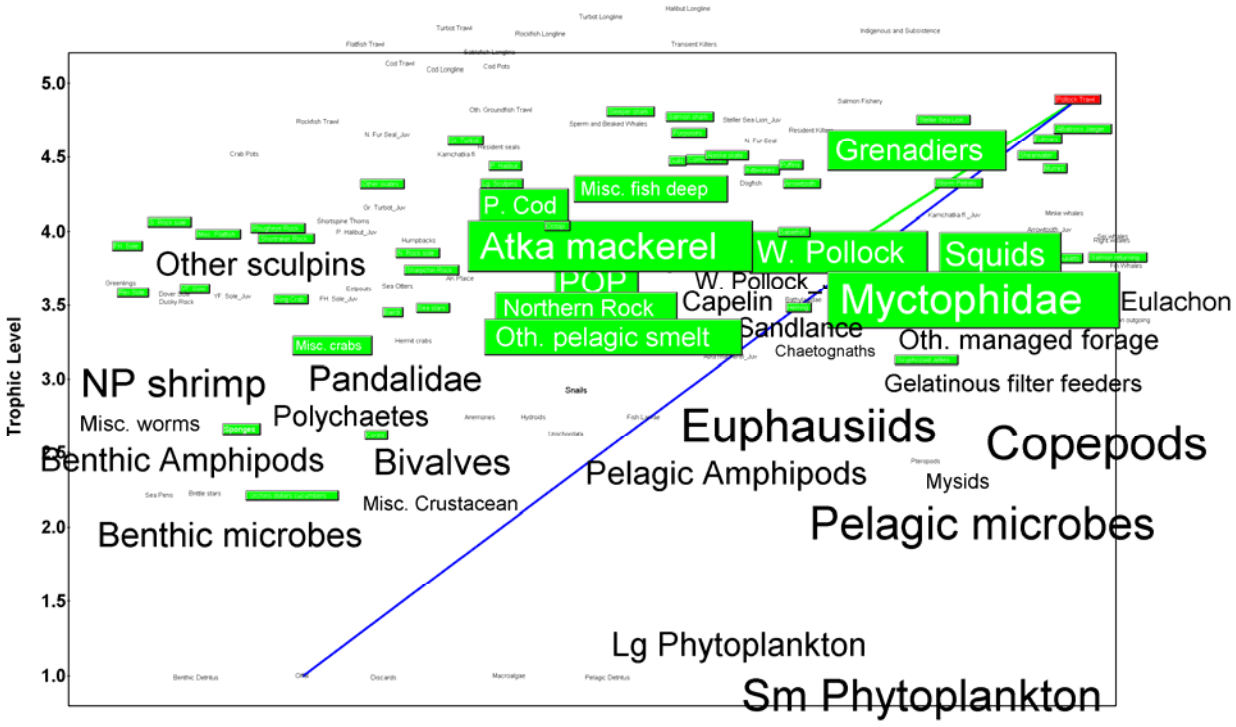

Figure 1A.37. The pollock trawl fishery in the AI food web. Species taken by the pollock fishery (in red) are highlighted in green, with the most significant flow to pollock indicated with a green line. Box size is proportional to biomass and lines between boxes represent the most significant energy flows. From Aydin et al (2004).

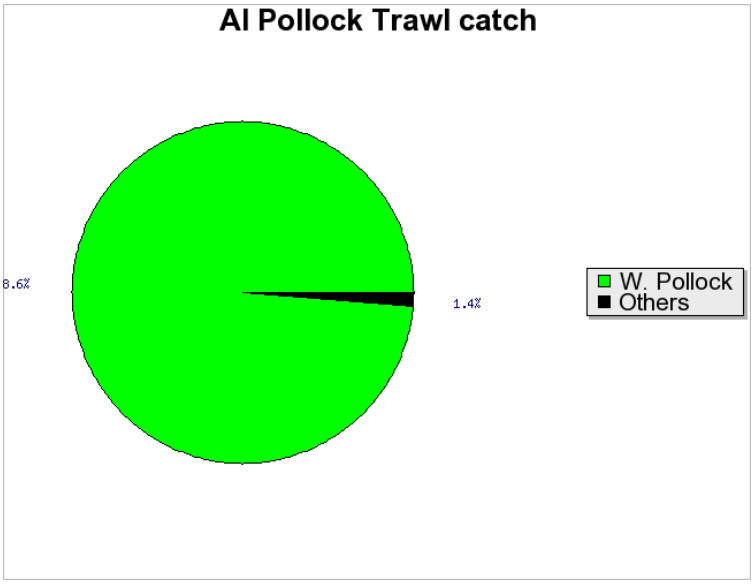

Figure 1A.38. Catch composition of the AI pollock trawl fishery during the early 1990's, as used in the food web model (Aydin et al 2004).

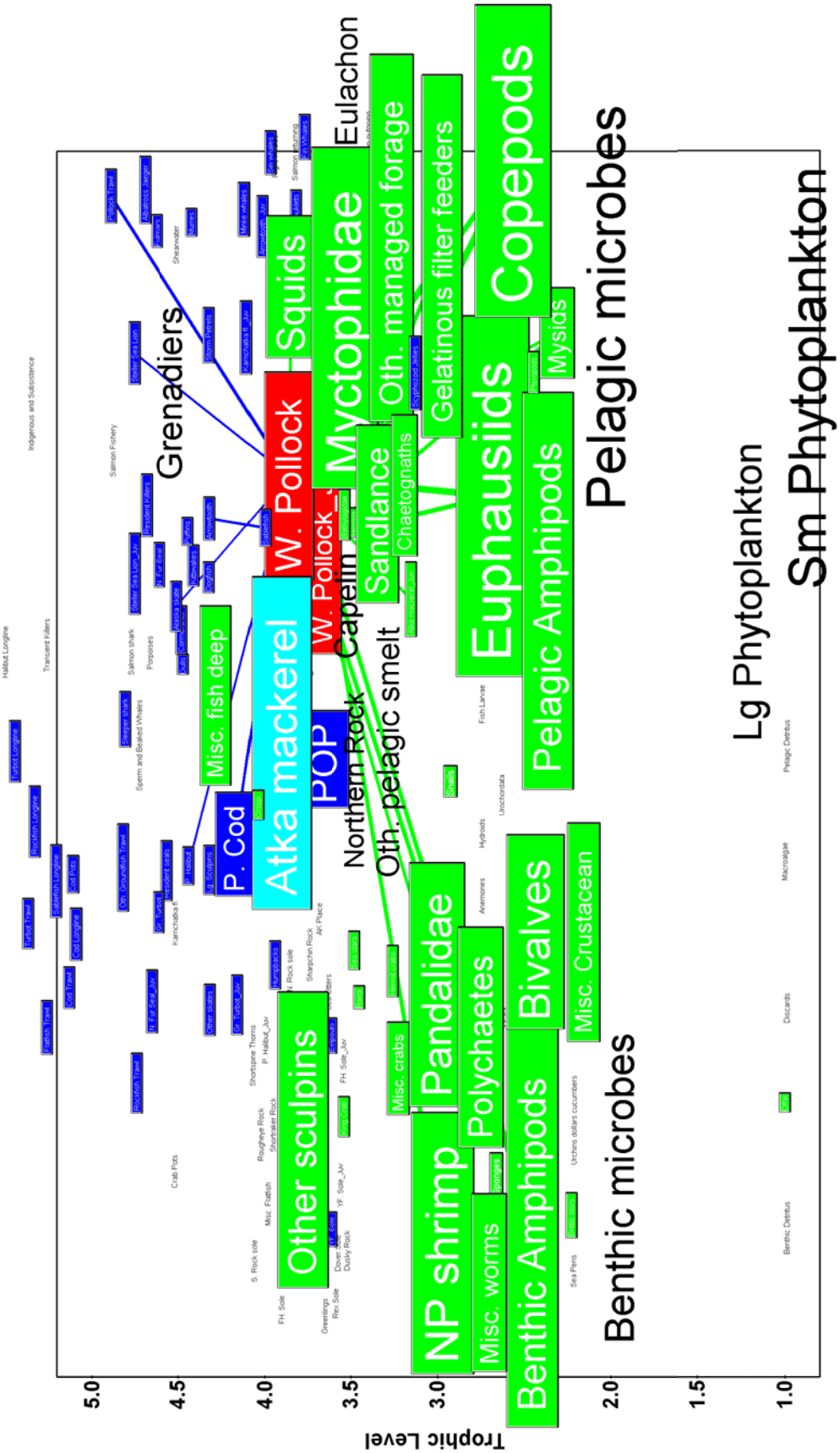

Figure 1A.39. Adult and juvenile pollock (highlighted in red) in the AI food web (Aydin et al 2004). Predators of pollock are dark blue, prey of pollock are green, and species that are both predators and prey of pollock are light blue. Box size is proportional to biomass and lines between boxes represent the most significant energy flows.

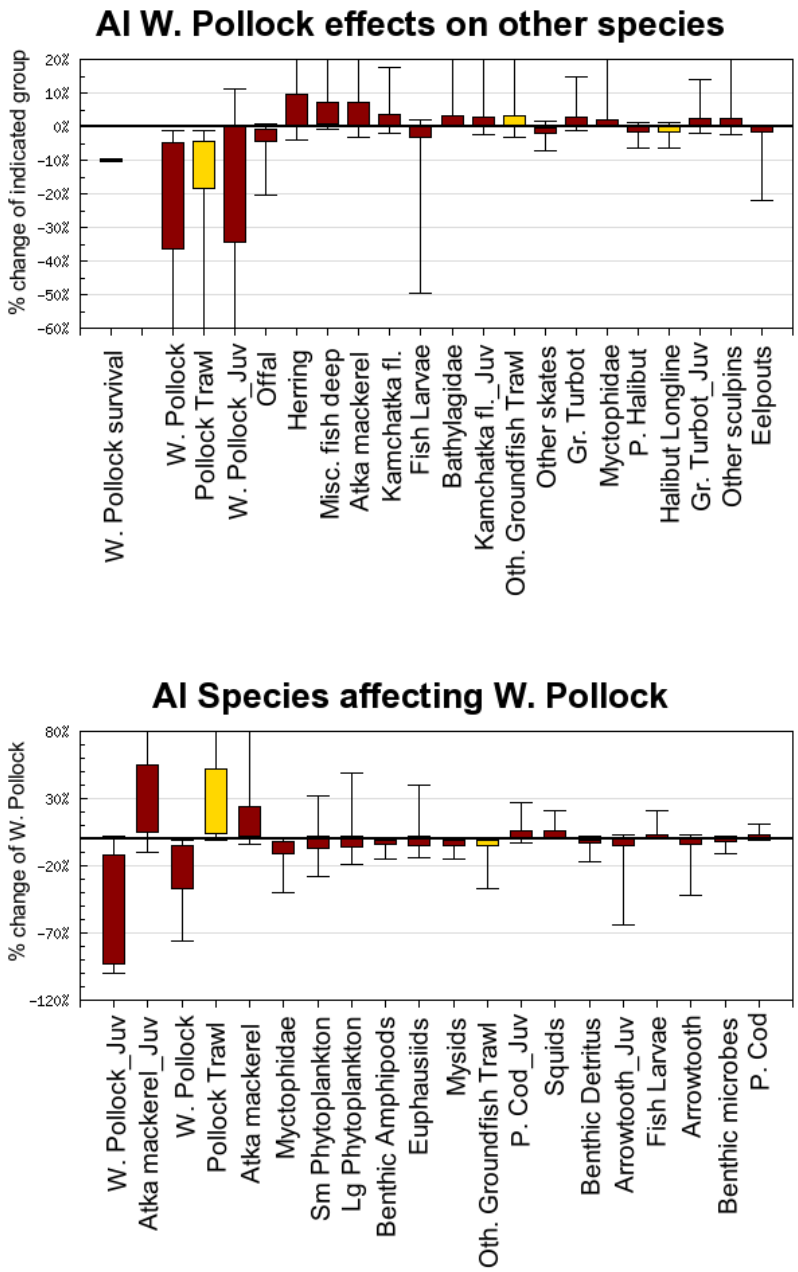

Figure 1A.40. (upper panel) Effect of changing pollock survival on fishery catch (yellow) and biomass of other species (dark red), from a simulation analysis where pollock survival was decreased by 10% and the rest of the ecosystem adjusted to this decrease for 30 years. (lower panel) Effect of reducing 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	μ^s, μ^f	$q_i^s = e^{\mu^s}$
Mean effect		
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	$\tilde{R}_i$	$\tilde{R}_i = \frac{\alpha B_i}{\beta + B_i}$,
Beverton-Holt form		$\alpha = \frac{4hR_0}{5h-1}$ 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	$L_4 = \lambda_4 \sum_{i=1963}^{2007} \ln\left(C_i / \hat{C}_i\right)^2$	Fit to catch biomass in each year (
Proportion at age likelihood	$L_5 = -\sum_{l,i,j} T_{ij}^l P_{ij}^l \ln\left(\hat{P}_{ij}^l \cdot P_{ij}^l\right)$	*L={s, f}* for survey and fishery age composition observations
Fishing mortality regularity	$L_6 = \lambda_6 \sum_{i=1963}^{2007} \phi_i^2$	(relaxed in final phases of estimation)
Priors	$L_7 = \left[\lambda_7 \frac{\ln\left(M/\hat{M}\right)^2}{2\sigma_M^2} + \lambda_8 \frac{\ln\left(q/\hat{q}\right)^2}{2\sigma_q^2}\right]$	Prior on natural mortality, and survey catchability (reference case assumption that these are precisely known at 0.3 and 1.0, respectively).
Overall objective function to be minimized	$\dot{L} = \sum_{i=1}^{7} L_i$	