# Chapter 1: Assessment of the Walleye Pollock Stock in the Gulf of Alaska

Martin Dorn[1], Kerim Aydin[1], Darin Jones[1],
Wayne Palsson[1] and Kally Spalinger[2]

[1] National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA
[2] Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak, AK

## Executive Summary

### Summary of Changes in Assessment Model Inputs

#### *Changes in input data*

1. Fishery: 2012 total catch and catch at age.

2. Shelikof Strait acoustic survey: 2013 biomass and age composition.

3. NMFS bottom trawl survey: 2013 biomass and length composition.

4. ADFG crab/groundfish trawl survey: 2012 age composition, 2013 biomass.

#### *Changes in assessment methodology*

The age-structured assessment model is similar to the model used for the 2012 assessment and was developed using AD Model Builder (a C++ software language extension and automatic differentiation library). The 2013 model implemented the following changes based on the 2012 CIE review and other considerations: 1) removing two years of Biosonics acoustic survey time series (1992 and 1993) that were actually produced using the EK500 with the acoustic data analyzed at a higher noise threshold, 2) setting the CVs for the Biosonics acoustic survey estimates equal to the nominal value (0.2) of later acoustic surveys, and 3) removing the ADGF survey length data and increasing the input sample sizes for the ADFG survey age data.

### Summary of Results

The base model projection of female spawning biomass in 2014 is 308,541 t, which is 42.5% of unfished spawning biomass (based on average post-1977 recruitment) and above $B_{40\%}$ (290,000 t), thereby placing Gulf of Alaska pollock in sub-tier “a” of Tier 3. There were three surveys in 2013: the Shelikof Strait acoustic survey, the NMFS bottom trawl survey, and ADFG crab/groundfish survey. The 2013 Shelikof Strait acoustic survey biomass estimate is 2.7 times the biomass estimate for 2012, and is largest biomass estimate in Shelikof Strait since 1985. The 2013 NMFS bottom trawl survey biomass estimate is the highest in the time series, and is an increase of 43% from the 2011 estimate. In contrast, the ADFG crab/groundfish survey biomass estimate decreased by 40% from the 2012 estimate, but is close to the 2011 estimate. The estimated abundance of mature fish is projected to remain stable or to decrease gradually to 2015, and then to increase in subsequent years.

The author’s 2014 ABC recommendation for pollock in the Gulf of Alaska west of 140° W lon. (W/C/WYK) is 167,657 t, which is an increase of 48% from the 2013 ABC. This recommendation is based on a more conservative alternative to the maximum permissible $F_{ABC}$ introduced in the 2001 SAFE applied to the base model. In 2015, the ABC based an adjusted $F_{40\%}$ harvest rate is 185,830 t. The OFL in 2014 is 211,998 t, and the OFL in 2015 if the recommended ABC is taken in 2014 is 248,384 t.

An exempted fishing permit (EFP) has been granted to evaluate the effect of salmon excluder devices in the pollock fishery in 2013 and 2014. Pollock catches under the EFP were 2,285 t in 2013 (John Gauvin, pers. comm. Oct. 28, 2013) and are projected to be 2,304 t in 2014. We followed the Gulf of Alaska Plan Team recommendation, and used a projection model that accounted for the EFP catches by removing the actual EFP pollock catch in 2013, and the projected 2014 EFP catch at the start of year in 2014. This resulted in a 2014 ABC of 166,514 t (1,143 t reduction).

For pollock in southeast Alaska (East Yakutat and Southeastern areas), the ABC recommendation for both 2014 and 2015 is 12,625 t (see Appendix A) and the OFL recommendation for both 2014 and 2015 is 16,833 t. These recommendations are based a Tier 5 assessment using the estimated biomass in 2014 and 2015 from a random effects model fit to the 1990-2013 bottom trawl survey biomass estimates in Southeast Alaska.

### Status Summary for Gulf of Alaska Pollock in W/C/WYK

| | As estimated or specified *last* year for | | As estimated or specified *this* year for | |
|---|---|---|---|---|
| **Quantity/Status** | 2013 | 2014 | 2014 | 2015 |
| *M* (natural mortality rate) | 0.3 | 0.3 | 0.3 | 0.3 |
| Tier | 3b | 3b | 3a | 3a |
| Projected total (age 3+) biomass (t) | 981,791 | 885,420 | 972,750 | 1,723,060 |
| Female spawning biomass (t) | | | | |
| Projected | | | | |
| Upper 95% confidence interval | | | 379,861 | 319,342 |
| Point estimate | 259,843 | 247,699 | 308,541 | 267,477 |
| Lower 95% confidence interval | | | 250,611 | 224,035 |
| $B_{100\%}$ | 741,000 | 741,000 | 726,000 | 726,000 |
| $B_{40\%}$ | 297,000 | 297,000 | 290,000 | 290,000 |
| $B_{35\%}$ | 259,000 | 259,000 | 254,000 | 254,000 |
| $F_{OFL}$ | 0.20 | 0.18 | 0.26 | 0.22 |
| $maxF_{ABC}$ | 0.18 | 0.16 | 0.22 | 0.20 |
| $F_{ABC}$ | 0.15 | 0.14 | 0.20 | 0.17 |
| OFL (t) | 150,817 | 138,610 | 211,998 | 248,384 |
| maxABC (t) | 131,630 | 115,977 | 183,943 | 210,071 |
| ABC (t) | 113,586 | 104,157 | 167,657 | 185,830 |
| | As determined *last* year for | | As determined *this* year for | |
| **Status** | 2011 | 2012 | 2012 | 2013 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

### *Responses to SSC and Plan Team Comments in General*

*The SSC recommended in its December 2012 minutes that the authors consider whether it is possible to estimate M with at least two significant digits in all future stock assessments to increase validity of the estimated OFL.*

The assessment authors would like to defer our response to this comment to the 2014 assessment.

*The SSC recommended in its December 2012 minutes that assessment authors of stocks managed in Tier 5 consider the recommendations found in the draft survey averaging workgroup report.*

Results are provided for the preferred approach of the survey averaging workgroup, the random effects model, for the Tier 5 Southeast Alaska pollock assessment. The method seemed to work well. We did not use this approach for apportioning the ABC by region for Western and Central stocks, but will be considering it in future assessments pending further guidance from the survey averaging workgroup.

### *Responses to SSC and Plan Team Comments Specific to this Assessment*

*The GOA plan team suggested in its November 2012 minutes that inter-annual smoothing be used instead of blocks to avoid the undesirable effect of highly correlated recruitments between years. SSC in its December 2012 minutes agreed with the Plan Team and recommended that the assessment authors explore whether there is a tradeoff between parsimony and introduction of retrospective error when using time blocks versus a penalized random walk for time varying selectivity.*

The assessment authors would like to defer our response to this comment to the 2014 assessment.

*The GOA plan team noted in its November 2012 minutes that the assumption of the multinomial error assumption for all ages is questionable. The Team suggested that younger ages, age-1 and possibly age-2, might be better treated separately, similar to the approach used for the eastern Bering Sea pollock model for both acoustic and bottom-trawl surveys. The SSC in its December 2012 minutes concurred with the plan team recommendation.*

The assessment authors would like to defer our response to this comment to the 2014 assessment.

*The SSC in its December 2012 minutes recommended that the assessment authors explore if there are variations in female relative abundance that may explain variations in spatial distributions by management areas.*

The assessment authors would like to defer our response to this comment to the 2014 assessment.

## Introduction

Walleye pollock (*Theragra chalcogramma*) is a semi-pelagic schooling fish widely distributed in the North Pacific Ocean. Pollock in the Gulf of Alaska are managed as a single stock independently of pollock in the Bering Sea and Aleutian Islands. The separation of pollock in Alaskan waters into eastern Bering Sea and Gulf of Alaska stocks is supported by analysis of larval drift patterns from spawning locations (Bailey et al. 1997), genetic studies of allozyme frequencies (Grant and Utter 1980), mtDNA variability (Mulligan et al. 1992), and microsatellite allele variability (Bailey et al. 1997).

The results of studies of stock structure in the Gulf of Alaska are equivocal. There is evidence from allozyme frequency and mtDNA that spawning populations in the northern part of the Gulf of Alaska (Prince William Sound and Middleton Island) may be genetically distinct from the Shelikof Strait spawning population (Olsen et al. 2002). However significant variation in allozyme frequency was found between Prince William Sound samples in 1997 and 1998, indicating a lack of stability in genetic structure for this spawning population. Olsen et al. (2002) suggest that interannual genetic variation may be due to variable reproductive success, adult philopatry, source-sink population structure, or utilization of the same spawning areas by genetically distinct stocks with different spawning timing. An evaluation of stock structure for Gulf of Alaska pollock following the template developed by NPFMC stock structure working group was provided as an appendix to the 2012 assessment (Dorn et al., 2012). Evidence tended to support the current approach of treating pollock in the eastern portion of the Gulf of Alaska separately from pollock in the central and western portions of the Gulf of Alaska.

## Fishery

The commercial fishery for walleye pollock in the Gulf of Alaska started as a foreign fishery in the early 1970s (Megrey 1989). Catches increased rapidly during the late 1970s and early 1980s (Table 1.1). A large spawning aggregation was discovered in Shelikof Strait in 1981, and a fishery developed for which pollock roe was an important product. The domestic fishery for pollock developed rapidly in the Gulf of Alaska with only a short period of joint venture operations in the mid-1980s. The fishery was fully domestic by 1988.

The pollock target fishery in the Gulf of Alaska is entirely shore-based with approximately 90% of the catch taken with pelagic trawls. During winter, fishing effort targets pre-spawning aggregations in Shelikof Strait and near the Shumagin Islands (Fig. 1.1). Fishing in summer is less predictable, but typically occurs in deep-water troughs on the east side of Kodiak Island and along the Alaska Peninsula.

Incidental catch in the Gulf of Alaska directed pollock fishery is low. For tows classified as pollock targets in the Gulf of Alaska between 2008 and 2012, on average about 95% of the catch by weight of FMP species consisted of pollock (Table 1.2). Nominal pollock targets are defined by the dominance of pollock in the catch, and may include tows where other species were targeted, but pollock were caught instead. The most common managed species in the incidental catch are arrowtooth flounder, Pacific cod, flathead sole, shallow-water flatfish, squid, and Pacific ocean perch. The most common non-target species are eulachon and other osmerids, jellyfish, and grenadiers. Bycatch estimates for prohibited species over the period 2008-2012 are given in Table 1.3. Chinook salmon are the most important prohibited species caught as bycatch in the pollock fishery. The peak in Chinook salmon bycatch in 2010 led the Council to adopt management measures to reduce Chinook salmon bycatch, including cap of 25,000 Chinook salmon bycatch in directed pollock fishery.

Kodiak is the major port for pollock in the Gulf of Alaska, accounting for about 67% of recent landings. In the western Gulf of Alaska, Sand Point, Dutch Harbor, King Cove, and Akutan are important ports, sharing 32% of recent landings. Secondary ports, including Cordova, Homer, Juneau, Ketchikan, Seward, and Sitka account for less than 1% of recent landings.

Since 1992, the Gulf of Alaska pollock Total Allowable Catch (TAC) has been apportioned spatially and temporally to reduce potential impacts on Steller sea lions. The details of the apportionment scheme have evolved over time, but the general objective is to allocate the TAC to management areas based on the distribution of surveyed biomass, and to establish three or four seasons between mid-January and fall during which some fraction of the TAC can be taken. The Steller Sea Lion Protection Measures implemented in 2001 established four seasons in the Central and Western GOA beginning January 20, March 10, August 25, and October 1, with 25% of the total TAC allocated to each season. Allocations to management areas 610, 620 and 630 are based on the seasonal biomass distribution as estimated by groundfish surveys. In addition, a new harvest control rule was implemented that requires suspension of directed pollock fishing when spawning biomass declines below 20% of the reference unfished level.

## Data Used in the Assessment

The data used in the assessment model consist of estimates of annual catch in tons, fishery age composition, NMFS summer bottom trawl survey estimates of biomass and age composition, acoustic survey estimates of biomass and age composition in Shelikof Strait, and ADFG bottom trawl survey estimates of biomass and age composition. Binned length composition data are used in the model only when age composition estimates are unavailable, such as the fishery in the early part of the modeled time period and the most recent surveys. The following table specifies the data that were used in the GOA pollock assessment:

| *Source* | *Type* | *Years* |
|---|---|---|
| Fishery | Total catch biomass | 1964-2012 |
| Fishery | Length composition | 1964-1971 |
| Fishery | Age composition | 1972-2012 |
| Shelikof Strait acoustic survey | Biomass | 1981-2013 |
| Shelikof Strait acoustic survey | Age composition | 1981-2013 |
| NMFS bottom trawl survey | Area-swept biomass | 1984-2013 |
| NMFS bottom trawl survey | Age composition | 1984-2011 |
| NMFS bottom trawl survey | Length composition | 2013 |
| ADFG trawl survey | Area-swept biomass | 1989-2013 |
| ADFG survey | Age composition | 2000, 2002, 2004, 2006, 2008, 2010, 2012 |

### *Total Catch*

Estimated catch was derived by the NMFS Regional Office from shoreside electronic logbooks and observer estimates of at-sea discards (Table 1.4). Catches include the state-managed pollock fishery in Prince William Sound (PWS). Non-commercial catches are reported in Appendix D. Since 1996 the pollock Guideline Harvest Level (GHL) for the PWS fishery has been deducted from the Acceptable Biological Catch (ABC) by the NPFMC Gulf of Alaska Plan Team for management purposes.

### *Fishery Age Composition*

Estimates of fishery age composition were derived from at-sea and port sampling of the pollock catch for length and ageing structures (otoliths). Pollock otoliths collected during the 2012 fishery were aged using the revised criteria described in Hollowed et al. (1995), which involved refinements in the criteria to define edge type. Catch age composition was estimated using methods described by Kimura and Chikuni (1989). Age samples were used to construct age-length keys by sex and stratum. These keys were applied to sex and stratum specific length frequency data to estimate age composition, which were then weighted by the catch in numbers in each stratum to obtain an overall age composition. Age and length samples from the 2012 fishery were stratified by half year and statistical area as follows:

| Time strata | | Shumagin-610 | Chirikof-620 | Kodiak-630 | W. Yakutat and PWS-640 and 649 |
|---|---|---|---|---|---|
| 1st half (A and B seasons) | No. ages | 209 | 401 | 322 | 102 |
| | No. lengths | 951 | 7060 | 1686 | 731 |
| | Catch (t) | 9,108 | 31,200 | 7,826 | 5,008 |
| 2nd half (C and D seasons) | No. ages | 404 | 405 | 414 | ---- |
| | No. lengths | 2040 | 3104 | 5934 | ---- |
| | Catch (t) | 18,785 | 13,877 | 18,187 | ---- |

The catch-at-age in 2012 was primarily ages 4-7, with the age-5 fish (2007 year class) dominant (Fig. 1.2). Fishery catch at age in 1976-2012 is presented in Table 1.5 (See also Fig. 1.3). Sample sizes for ages and lengths are given in Table 1.6.

### *Gulf of Alaska Bottom Trawl Survey*

Trawl surveys have been conducted by Alaska Fisheries Science Center (AFSC) every three years (beginning in 1984) to assess the abundance of groundfish in the Gulf of Alaska (Table 1.7). Starting in 2001, the survey frequency was increased to every two years. The survey uses a stratified random design, with 49 strata based on depth, habitat, and management area (Martin 1997). Area-swept biomass estimates are obtained using mean CPUE (standardized for trawling distance and mean net width) and stratum area. The survey is conducted from chartered commercial bottom trawlers using standardized poly-Nor'eastern high opening bottom trawls rigged with roller gear. In a typical survey, 800 tows are completed. On average, 70% of these tows contain pollock (Table 1.8).

The time series of pollock biomass used in the assessment model is based on the surveyed area in the Gulf of Alaska west of 140° W lon., obtained by adding the biomass estimates for the Shumagin, Chirikof, Kodiak INPFC areas, and the western portion of Yakutat INPFC area. Biomass estimates for the west Yakutat region were obtained by splitting strata and survey CPUE data at 140° W lon. (M. Martin, AFSC, Seattle, WA, pers. comm. 2011). For surveys in 1984 and 1987, the average percent in West Yakutat in the 1990-99 surveys was used. The average was also used in 2001, when West Yakutat was not surveyed.

An adjustment was made to the survey time series to account for unsurveyed pollock in Prince William Sound. This adjustment was derived from an area-swept biomass estimate for PWS from a trawl survey conducted by ADFG in 1999, using a standard ADFG 400 mesh eastern trawl. The 1999 biomass estimate for PWS was 6,304 t ± 2,812 t (95% CI) (W. Bechtol, ADFG, 1999, pers. comm.). The PWS biomass estimate should be considered a minimum estimate because ADFG survey gear is less effective at catching pollock compared to the NMFS survey gear (von Szalay and Brown 2001). For 1999, the biomass estimates for the NMFS bottom trawl survey and the PWS survey were simply added to obtain a total biomass estimate. The adjustment factor for the 1999 survey, (PWS + NMFS)/NMFS, was applied to other triennial surveys, and increased biomass by 1.05%.

The Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering (RACE) Division conducted the thirteenth comprehensive bottom trawl survey since 1984 during the summer of 2013 (Fig. 1.4). The 2013 gulfwide biomass estimate of pollock was 1,014,846 t, which is the highest biomass in the time series, and is an increase of 43% from the 2011 estimate. The biomass estimate for the portion of the Gulf of Alaska west of 140º W long. used in the assessment model is 957,817 t. The coefficient of variation (CV) of this estimate was 0.21, which higher than the CV for the last five surveys (median = 0.15), possibly reflecting the reduced sampling effort in the 2013 survey.

*Bottom Trawl Survey Age Composition*

Estimates of numbers at age from the bottom trawl survey are obtained from random otolith samples and length frequency samples (Table 1.9). Numbers at age are estimated by INPFC area (Shumagin, Chirikof, Kodiak, Yakutat and Southeastern) using a global age-length key and CPUE-weighted length frequency data by INPFC area. The combined Shumagin, Chirikof and Kodiak age composition is used in the assessment model. Since ages are not yet available for the 2013 survey, the model is fit to binned size composition. Estimates of size composition show relatively high estimates of age-1 pollock abundance in all areas (Fig. 1.5). At lower mode at 30 cm (representing age-2 fish) is apparent only in the Kodiak area. A mode of larger fish (>45 cm) is present in all areas except for the Yakutat INPFC area.

### *Shelikof Strait Acoustic Survey*

Acoustic surveys to assess the biomass of pollock in the Shelikof Strait area have been conducted annually since 1981 (except 1982 and 1999). Survey methods and results for 2013 are presented in a NMFS processed report (Jones et. al. in review). Biomass estimates using the Simrad EK echosounder from 1992 onwards were re-estimated to take into account recently published work of eulachon acoustic target strength (Gauthier and Horne 2004). Previously, acoustic backscatter was attributed to eulachon based on the percent composition of eulachon in trawls, and it was assumed that eulachon had the same target strength as pollock. Since Gauthier and Horne (2004) determined that the target strength of eulachon was much lower than pollock, the acoustic backscatter could be attributed entirely to pollock even when eulachon were known to be present. In 2008, the noise-reduced *R/V Oscar Dyson* became the designated survey vessel for acoustic surveys in the Gulf of Alaska. In winter of 2007, a vessel comparison experiment was conducted between the *R/V Miller Freeman* (MF) and the *R/V Oscar Dyson* (OD), which obtained an OD/MF ratio of 1.132 for the acoustic backscatter detected by the two vessels in Shelikof Strait.

The 2013 biomass estimate for Shelikof Strait is 891,261 t, which 2.7 times the biomass estimate for 2012, and is largest biomass estimate in Shelikof Strait since 1985. The biomass of pollock ≥43 cm (a proxy for spawning biomass) is 2.2 times the 2012 estimate. Additional acoustic surveys in winter 2013 covered the Shumagin Islands spawning area, Sanak Gully, Morzhovoi Bay, Marmot Gully, and the shelf beak near Chirikof Island. More extensive surveys had been planned in winter of 2013, including Pavlof Bay, Kenai Peninsula, and Prince William Sound, but were unable to be completed due to equipment failure. The following table provides results from the 2013 winter acoustic surveys:

| Area | Biomass ≥43 cm (t) | Percent | Total biomass (t) | Percent |
|---|---|---|---|---|
| Morzhovoi Bay | 1,518 | 0.2% | 2,476 | 0.2% |
| Sanak Gully | 12,900 | 1.9% | 13,282 | 1.2% |
| Shumagin Islands | 46,856 | 7.0% | 91,295 | 8.4% |
| Marmot Gully | 19,019 | 2.8% | 19,942 | 1.8% |
| Shelikof Strait | 525,998 | 78.6% | 891,261 | 82.4% |
| Chirikof Island | 63,008 | 9.4% | 63,008 | 5.8% |
| Total | 669,299 | | 1,081,264 | |

In comparison to 2012, biomass estimates were much higher with the exception of Sanak Gully, which declined by 45% (Fig. 1.6).

*Acoustic Survey Age Composition*

Estimates of numbers at age from the Shelikof Strait acoustic survey (Table 1.10, Fig. 1.7) were obtained using an age-length key compiled from random otolith samples and applied to weighted length frequency samples. Otoliths collected during the 1994-2013 acoustic surveys were aged using the criteria described in Hollowed et al. (1995). Sample sizes for ages and lengths are given Table 1.11.

### Egg Production Estimates of Spawning Biomass

Estimates of spawning biomass in Shelikof Strait based on egg production methods were produced during 1981-92 (Table 1.7). A complete description of the estimation process is given in Picquelle and Megrey (1993). The annual egg production spawning biomass estimate for 1981 is questionable because of sampling deficiencies during the egg surveys for that year (Kendall and Picquelle 1990). Egg production estimates were discontinued in 1992 because the Shelikof Strait acoustic survey provided similar information. The egg production estimates are not used in the assessment model because the surveys are no longer being conducted, and the acoustic surveys in Shelikof Strait show a similar trend over the period when both were conducted.

### Alaska Department of Fish and Game Crab/Groundfish Trawl Survey

The Alaska Department of Fish and Game (ADFG) has conducted bottom trawl surveys of nearshore areas of the Gulf of Alaska since 1987. Although these surveys are designed to monitor population trends of Tanner crab and red king crab, walleye pollock and other fish are also sampled. Standardized survey methods using a 400-mesh eastern trawl were employed from 1987 to the present. The survey is designed to sample a fixed number of stations from mostly nearshore areas from Kodiak Island to Unimak Pass, and does not cover the entire shelf area. The average number of tows completed during the survey is 360. Details of the ADFG trawl gear and sampling procedures are in Blackburn and Pengilly (1994).

The 2013 biomass estimate for pollock for the ADFG crab/groundfish survey was 102,406 t, down 40% from the 2012 biomass estimate, but close to 2011 estimate (Table 1.7).

*ADFG Survey Length Frequency*

Pollock length-frequencies for the ADFG survey in 1989-2013 (excluding 1991 and 1995) typically show a mode at lengths greater than 45 cm (Fig. 1.8). The predominance of large fish in the ADFG survey is likely due to the selectivity of the gear, and the greater abundance of large pollock in the areas surveyed. Length composition in 2013 shows an unusual mode at 17 cm, which is likely age-1 age pollock, but the overall mean length is 50.5 cm, similar to previous surveys.

*ADFG Survey Age Composition*

Ages were determined by age readers in the AFSC age and growth unit from samples of pollock otoliths collected during the 2000, 2002, 2004, 2006, 2008, 2010, and 2012 ADFG surveys (N = 559, 538, 591,588, 597, 585, and 562). Comparison with fishery age composition shows that older fish (> age-8) are more common in the ADFG crab/groundfish survey. This is consistent with the assessment model, which estimates a domed-shaped selectivity pattern for the fishery, but an asymptotic selectivity pattern for the ADFG survey.

### Pre-1984 bottom trawl surveys

Considerable survey work was carried out in the Gulf of Alaska prior to the start of the NMFS triennial bottom trawl surveys in 1984. Between 1961 and the mid-1980s, the most common bottom trawl used for surveying was the 400-mesh eastern trawl. This trawl (or variants thereof) was used by IPHC for juvenile halibut surveys in the 1960s, 1970s, and early 1980s, and by NMFS for groundfish surveys in the 1970s. Von Szalay and Brown (2001) estimated a fishing power correction (FPC) for the ADFG 400-mesh eastern trawl of 3.84 (SE = 1.26), indicating that 400-mesh eastern trawl CPUE for pollock would need to be multiplied by this factor to be comparable to the NMFS poly-Nor'eastern trawl.

In most cases, earlier surveys in the Gulf of Alaska were not designed to be comprehensive, with the general strategy being to cover the Gulf of Alaska west of Cape Spencer over a period of years, or to survey a large area to obtain an index for group of groundfish, i.e., flatfish or rockfish. For example, Ronholt et al. (1978) combined surveys for several years to obtain gulfwide estimates of pollock biomass for 1973-6. There are several difficulties with such an approach, including the possibility of double-counting or missing a portion of the stock that happened to migrate between surveyed areas. Due the difficulty in constructing a consistent time series, the historical survey estimates are no longer used in the assessment model.

Multi-year combined survey estimates indicate a large increase in pollock biomass in the Gulf of Alaska occurred between the early 1960s and the mid 1970s. Increases in pollock biomass between the1960s and 1970s were also noted by Alton et al. (1987). In the 1961 survey, pollock were a relatively minor component of the groundfish community with a mean CPUE of 16 kg/hr (Ronholt et al. 1978). Arrowtooth flounder was the most common groundfish with a mean CPUE of 91 kg/hr. In the 1973-76 surveys, the CPUE of arrowtooth flounder was similar to the 1961 survey (83 kg/hr), but pollock CPUE had increased 20-fold to 321 kg/hr, and was by far the dominant groundfish species in the Gulf of Alaska. Meuter and Norcross (2002) also found that pollock was low in the relative abundance in 1960s, became the dominant species in Gulf of Alaska groundfish community in the 1970s, and subsequently declined in relative abundance.

Questions concerning the comparability of pollock CPUE data from historical trawl surveys with later surveys probably can never be fully resolved. However, because of the large magnitude of the change in CPUE between the surveys in the 1960s and the early 1970s using similar trawling gear, the conclusion that there was a large increase in pollock biomass seems robust. Early speculation about the rise of pollock in the Gulf of Alaska in the early 1970s implicated the large biomass removals of Pacific ocean perch, a potential competitor for euphausid prey (Somerton 1979, Alton et al. 1987). More recent work has focused on role of climate change (Anderson and Piatt 1999, Bailey 2000). Model results suggest that population biomass in the 1960s, prior to large-scale commercial exploitation of the stock, may have been lower than at any time since then.

### *Qualitative trends*

To assess qualitatively recent trends in abundance, each survey time series was standardized by dividing the annual estimate by the average since 1987. Shelikof Strait acoustic survey estimates prior to 2008 were rescaled to be comparable to subsequent surveys conducted by the *R/V Oscar Dyson*. Although there is considerable variability in each survey time series, a fairly clear downward trend is evident to 2000, followed by a stable, though variable, trend to 2008 (Fig. 1.9). All surveys indicate a strong increase since 2008.

Indices derived from fisheries catch data were also evaluated for trends in biological characteristics (Fig. 1.10). The percent of females in the catch is close to 50-50, but shows a slight downward trend, which may be related to changes in the seasonal distribution of the catch. The percent female was 46.6% in 2012. The mean age shows interannual variability due to strong year classes passing through the population, but no downward trends that would suggest excessive mortality rates. The percent of old fish in the catch (nominally defined as age 8 and older) is also highly variable due to variability in year class strength. The percent of old fish increased to a peak in 1997, declined due to weaker recruitment in the 1990s and increases in total mortality (both from fishing and predation), but increased from 2005 to 2008 as the large 1999 and 2000 year classes entered the old fish category. The percent of old fish has been decreasing since 2008 as the fishery began to catch greater numbers of young fish from year classes recruiting to the fishery. Under a constant $F_{40\%}$ harvest rate, the mean percent of age 8 and older fish in the catch is approximately 7%. An index of catch at age diversity was computed using the Shannon-Wiener information index,

$$-\sum p_a \ln p_a ,$$

where $p_a$ is the proportion at age. Increases in fishing mortality would tend to reduce age diversity, but year class variability would also influence age diversity. The index of age diversity is relatively stable during 1976-2012 (Fig. 1.10).

### *McKelvey Index*

McKelvey (1996) found a significant correlation between the abundance of age-1 pollock in the Shelikof Strait acoustic survey and subsequent estimates of year-class strength. The McKelvey index is defined as the estimated abundance of 9-16 cm fish in the Shelikof Strait acoustic survey, and is an index of year class strength in the previous year (Table 1.12). The correlation between the abundance of age-1 pollock in the Shelikof Strait acoustic survey and subsequent estimates of year-class strength remains relatively strong based on surveys conducted after 1992, and there is a stronger correlation between the abundance of age-1 pollock in the Shumagin Islands survey and year-class strength (Fig. 1.11). The estimate of age-1 pollock abundance in 2013 is 6.3 billion fish, which is the second highest in the time series. In addition, 6.6 billion age-1 pollock were estimated for the acoustic survey of the Shumagin Islands in 2013.

## Analytic Approach

### *Model Structure*

An age-structured model covering the period from 1964 to 2013 (50 yrs) was used to assess Gulf of Alaska pollock. The modeled population includes individuals from age 1 to age 10, with age 10 defined as a "plus" group, i.e., all individuals age 10 and older. Population dynamics were modeled using standard formulations for mortality and fishery catch (e.g. Fournier and Archibald 1982, Deriso et al. 1985, Hilborn and Walters 1992). Year- and age-specific fishing mortality was modeled as a product of a year effect, representing the full-recruitment fishing mortality, and an age effect, representing the selectivity of that age group to the fishery. The age effect was modeled using a double-logistic function with time-varying parameters (Dorn and Methot 1990, Sullivan et al. 1997). The model was fit to time series of catch biomass, survey indices of abundance, and estimates of age and length composition from the fishery and surveys. Details of the population dynamics and estimation equations are presented in Appendix B.

Based on recommendations of the July 2012 CIE review of the Gulf of Alaska pollock assessment, several changes were implemented in the 2012 assessment model: the model includes ages 1-10 rather than ages 2-10 in previous assessments; an accumulator age was added to initial age composition and stronger equilibrium assumptions were used to initialize the model; mean unbiased log-normal likelihoods are used for survey biomass indices; the historical trawl data (pre-1984) was removed from the model; six selectivity blocks were used for fishery selectivity rather than allowing selectivity parameters to vary annually with a random walk; reduced weights (input sample size) were used for the fishery age composition data. Finally, the model begins in 1964 rather than 1961.

Model parameters were estimated by maximizing the log likelihood of the data, viewed as a function of the parameters. Mean-unbiased log-normal likelihoods were used for survey biomass and total catch estimates, and multinomial likelihoods were used for age and length composition data.

| *Likelihood component* | *Statistical model for error* | *Variance assumption* |
|---|---|---|
| Fishery total catch (1964-2012) | Log-normal | CV = 0.05 |
| POP fishery length comp. (1964-71) | Multinomial | Sample size = 60 |
| Fishery age comp. (1972-2012) | Multinomial | Year-specific sample size = 20-200 |
| Shelikof acoustic survey biomass (1981-2013) | Log-normal | CV = 0.20 |
| Shelikof acoustic survey age comp. (1981-2013) | Multinomial | Sample size = 60 |
| NMFS bottom trawl survey biom. (1984-2013) | Log-normal | Survey-specific CV = 0.12-0.38 |
| NMFS bottom trawl survey age comp. (1984-2011) | Multinomial | Survey-specific sample size = 38-74 |
| NMFS bottom trawl survey length comp. (2013) | Multinomial | Sample size = 60 |
| ADFG trawl survey biomass (1989-2013) | Log-normal | CV = 0.25 |
| ADFG survey age comp. (2000, 2002, 2004, 2006, 2008, 2010, 2012) | Multinomial | Sample size = 30 |
| Recruit process error (1964-1971, 2012, 2013) | Log-normal | $\sigma_R$ =1.0 |

*Recruitment*

In most years, year-class abundance at age 1 was estimated as a free parameter. Initial age composition was estimated with a single log deviation for recruitment abundance, which was then decremented by natural mortality to fill out the initial age vector. A penalty was added to the log likelihood so that the log deviation in recruitment for 1964-71, and in 2012 and 2013 would have the same variability as recruitment during the data-rich period ($\sigma_R$ =1.0). Log deviations from mean log recruitment were estimated as free parameters in other years. These relatively weak constraints were sufficient to obtain fully converged parameter estimates while retaining an appropriate level of uncertainty.

*Modeling fishery data*

To accommodate changes in selectivity we estimated six selectivity blocks, starting in 1964, 1972, 1982, 1989, 2001, and 2007. These periods roughly correspond to the foreign fishery targeting Pacific ocean perch, the foreign target fishery, the joint venture fishery, the three periods of the domestic fishery. Previous modeling with random walk changes in selectivity also suggested that these breaks were reasonable.

*Modeling survey data*

Survey abundance was assumed to be proportional to total abundance as modified by the estimated survey selectivity pattern. Expected population numbers at age for the survey were based on the mid-date of the survey, assuming constant fishing and natural mortality throughout the year. Standard deviations in the log-normal likelihood were set equal to the sampling error CV (coefficient of variation) associated with each survey estimate of abundance (Kimura 1991).

Survey catchability coefficients can be fixed or freely estimated. The base model fixed the NMFS bottom trawl survey catchability at one as in previous assessments. Catchability coefficients for other surveys were estimated as free parameters. Egg production estimates of spawning stock biomass were included in the model by setting the age-specific selectivity equal to the estimated percent mature at age estimated by Hollowed et al. (1991).

The Simrad EK acoustic system has been used to estimate biomass in the acoustic surveys since 1992.

Earlier surveys (1981-91) were obtained with an older Biosonics acoustic system (Table 1.7). The Shelikof Strait acoustic survey time series was split into two periods corresponding to the two acoustic systems, and separate survey catchability coefficients were estimated for each period.

A vessel comparison (VC) experiment was conducted in March 2007 during the Shelikof Strait acoustic survey. The VC experiment involved the *R/V Miller Freeman* (MF, the survey vessel used to conduct Shelikof Strait surveys since the mid-1980s), and the *R/V Oscar Dyson* (OD), a noise-reduced survey vessel designed to conduct surveys that have traditionally been done with the *R/V Miller Freeman*. The vessel comparison experiment was designed to collect data either with the two vessels running beside one another at a distance of 0.7 nmi, or with one vessel following nearly directly behind the other at a distance of about 1 nmi. The methods were similar to those used during the 2006 Bering Sea VC experiment (De Robertis et al. 2008). Results indicate that the ratio of 38 kHz pollock backscatter from the *R/V Oscar Dyson* relative to the *R/V Miller Freeman* was significantly greater than one (1.13), as would be expected if the quieter OD reduced the avoidance response of the fish. Because this difference was significant, several methods were evaluated in the 2008 assessment for incorporating this result in the assessment model. The method that was adopted was to treat the MF and the OD time series as independent survey time series, and to include the vessel comparison results directly in the log likelihood of the assessment model. This likelihood component is given by

$$\log L = -\frac{1}{2\left(\sigma_S^2\right)}\left[\log(q_{OD}) - \log(q_{MF}) - \delta_{OD:MF}\right]^2,$$

where $log(q_{OD})$ is the log catchability of the *R/V Oscar Dyson*, $log(q_{MF})$ is the log catchability of the *R/V Oscar Dyson*, $\delta_{OD:MF}$ = 0.1240 is the mean of log scale paired difference in backscatter, mean[log($s_A$OD)-log($s_A$MF)] obtained from the vessel comparison, and $\sigma_S$ = 0.0244 is the standard error of the mean.

*Ageing error*

An ageing error conversion matrix is used in the assessment model to translate model population numbers at age to expected fishery and survey catch at age (Table 1.13). Dorn et al. (2003) estimated this matrix using an ageing error model fit to the observed percent reader agreement at ages 2 and 9. Mean percent agreement is close to 100% at age 1 and declines to 40% at age 10. Annual estimates of percent agreement are variable, but show no obvious trend; hence a single conversion matrix for all years in the assessment model was adopted. The model is based on a linear increase in the standard deviation of ageing error and the assumption that ageing error is normally distributed. The model predicts percent agreement by taking into account the probability that both readers are correct, both readers are off by one year in the same direction, and both readers are off by two years in the same direction (Methot 2000). The probability that both agree and were off by more than two years was considered negligible. A recent study evaluated pollock ageing criteria using radiometric methods and found them to be unbiased (Kastelle and Kimura 2006).

*Length frequency data*

The assessment model was fit to length frequency data from various sources by converting predicted age distributions (as modified by age-specific selectivity) to predicted length distributions using an age-length conversion matrix. Because seasonal differences in pollock length at age are large, several conversion matrices were used. For each matrix, unbiased length distributions at age were estimated for several years using age-length keys, and then averaged across years. A conversion matrix estimated by Hollowed et al. (1998) was used for length-frequency data from the early period of the fishery. A conversion matrix was estimated using 1992-98 Shelikof Strait acoustic survey data and used for winter survey length frequency data. The following length bins were used: 5-16, 17 - 27, 28 - 35, 36 - 42, 43 - 50, 51 - 55, 56 - 70 (cm).

Finally, a conversion matrix was estimated using second and third trimester fishery age and length data during the years (1989-98) and was used the bottom trawl survey data when age composition data are unavailable. The following length bins were used: 5-16,25 - 34, 35 - 41, 42 - 45, 46 - 50, 51 - 55, 56 - 70 (cm), so that the first four bins would capture most of the summer length distribution of the age-1, age-2, age-3 and age-4 fish, respectively. Bin definitions were different for the summer and the winter conversion matrices to account for the seasonal growth of the younger fish (ages 1-4).

### *Parameters Estimated Outside the Assessment Model*

Pollock life history characteristics, including natural mortality, weight at age, and maturity at age, were estimated independently outside the assessment model. These parameters are used in the model to estimate spawning and population biomass and obtain predictions of fishery catch and survey biomass. Pollock life history parameters include:

- Natural mortality (*M*)
- Proportion mature at age
- Weight at age and year by fishery and by survey

*Natural mortality*

Hollowed and Megrey (1990) estimated natural mortality (*M*) using a variety of methods including estimates based on: a) growth parameters (Alverson and Carney 1975, and Pauly 1980), b) GSI (Gunderson and Dygert, 1988), c) monitoring cohort abundance, and d) estimation in the assessment model. These methods produced estimates of natural mortality that ranged from 0.24 to 0.30. The maximum age observed was 22 years. For the assessment modeling, natural mortality was assumed to be 0.3 for all ages.

Hollowed et al. (2000) developed a model for Gulf of Alaska pollock that accounted for predation mortality. The model suggested that natural mortality declines from 0.8 at age 2 to 0.4 at age 5, and then remains relatively stable with increasing age. In addition, stock size was higher when predation mortality was included. In a simulation study, Clark (1999) evaluated the effect of an erroneous *M* on both estimated abundance and target harvest rates for a simple age-structured model. He found that “errors in estimated abundance and target harvest rate were always in the same direction, with the result that, in the short term, extremely high exploitation rates can be recommended (unintentionally) in cases where the natural mortality rate is overestimated and historical exploitation rates in the catch-at-age data are low.” He proposed that the chance of this occurring could be reduced by using an estimate of natural mortality on the lower end of the credible range, which is the approach used in this assessment. However, it should be emphasized that the role of pollock as prey in the Gulf of Alaska ecosystem cannot be fully evaluated using a single species assessment model (Hollowed et al. 2000).

*Maturity at age*

Maturity stages for female pollock describe a continuous process of ovarian development between immature and post-spawning. For the purposes of estimating a maturity vector (the proportion of an age group that has been or will be reproductively active during the year) for stock assessment, all fish greater than or equal to a particular maturity stage are assumed to be mature, while those less than that stage are assumed to be immature. Maturity stages in which ovarian development had progressed to the point where ova were distinctly visible were assumed to be mature (i.e., stage 3 in the 5-stage pollock maturity scale). Maturity stages are qualitative rather than quantitative, so there is subjectivity in assigning stages, and a potential for different technicians to apply criteria differently. Because the link between pre-spawning maturity stages and eventual reproductive activity later in the season is not well established, the division between mature and immature stages is problematic. Changes in the timing of spawning could also affect maturity at age estimates. Merati (1993) compared visual maturity stages with ovary histology and a blood assay for vitellogenin and found general consistency between the different approaches. Merati (1993) noted that ovaries classified as late developing stage (i.e., immature) may contain yolked eggs, but it was unclear whether these fish would have spawned later in the year. The average sample size of female pollock maturity stage data per year since 2000 from winter acoustic surveys in the Gulf of Alaska is 358 (Table 1.14).

Estimates of maturity at age in 2013 from winter acoustic surveys were above the long-term average for ages 5-10, but slightly below average for age 4 (Fig. 1.12). Inter-annual changes in maturity at age may reflect environmental conditions, pollock population biology, effect of strong year classes moving through the population, or simply ageing error. Because there did not appear to be an objective basis for excluding data, the 1983-2013 average maturity at age was used in the assessment.

Logistic regression (McCullagh and Nelder 1983) was also used to estimate the age and length at 50% maturity at age for each year. Annual estimates of age at 50% maturity are highly variable and range from 3.5 years in 1983 to 6.1 years in 1991, with an average of 4.9 years. Length at 50% mature is less variable than the age at 50% mature, suggesting that at least some of the variability in the age at maturity can be attributed to changes in length at age (Fig 1.13). Changes in year-class dominance could also potentially affect estimates of maturity at age. There is less evidence of trends in the length at 50% mature, with only the 1983 and 1984 estimates as unusually low values. The average length at 50% mature for all years is approximately 43 cm.

*Weight at age*

Year-specific weight-at-age estimates are used in the model to obtain expected catches in biomass. Where possible, year and survey-specific weight-at-age estimates are used to obtain expected survey biomass. For each data source, unbiased estimates of length at age were obtained using year-specific age-length keys. Bias-corrected parameters for the length-weight relationship, $W = a L^b$ , were also estimated. Weights at age were estimated by multiplying length at age by the predicted weight based on the length-weight regressions. A plot of weight-at-age from the Shelikof Strait acoustic survey indicates that there has been a substantial increase in weight at age for older pollock (Fig. 1.14). For pollock greater than age 6, weight-at-age has nearly doubled since 1983-1990. Further analyses are proposed to evaluate whether these changes are a density-dependent response to declining pollock abundance, or whether they are environmentally forced. Since these changes are highly auto-correlated, a fairly sophisticated analysis would be needed to attribute causation. Changes in weight-at-age have potential implications for status determination and harvest policy.

## *Parameters Estimated Inside the Assessment Model*

A large number of parameters are estimated when using this modeling approach. More than half of these parameters are year-specific deviations in fishery selectivity coefficients. Parameters were estimated using AD Model Builder (Version 10.1), a C++ software language extension and automatic differentiation library (Fournier et al. 2012). Parameters in nonlinear models are estimated in ADModel Builder using automatic differentiation software extended from Greiwank and Corliss (1991) and developed into C++ class libraries. The optimizer in AD Model Builder 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 $1 \times 10^{-6}$). AD Model Builder includes post-convergence routines to calculate standard errors (or likelihood profiles) for any quantity of interest.

A list of model parameters is shown below:

| *Population process modeled* | *Number of parameters* | *Estimation details* |
|---|---|---|
| Recruitment | Years 1964-2013 = 50 | Estimated as log deviances from the log mean; recruitment in 1964-71, and 2012 and 2013 constrained by random deviation process error. |
| Natural mortality | Age- and year-invariant = 1 | Not estimated in the model |
| Fishing mortality | Years 1964-2013 = 50 | Estimated as log deviances from the log mean |
| Mean fishery selectivity | 4 | Slope parameters estimated on a log scale, intercept parameters on an arithmetic scale |
| Selectivity blocks | 6 * 4 = 24 | Estimated as deviations from mean selectivity |
| Survey catchability | No. of surveys + 2 = 5 | AFSC bottom trawl survey catchability not estimated, other catchabilities estimated on a log scale. Three catchability periods were estimated for the acoustic survey. |
| Survey selectivity | 8 (acoustic survey: 2, BT survey: 4, ADFG survey: 2) | Slope parameters estimated on a log scale. |
| Total | 140 estimated parameters + 2 fixed parameters = 142 | |

## Results

### *Model selection and evaluation*

*Model Selection*

Three models were compared: a model with last year's configuration updated with recent fishery and survey data (Model 0), a new base model with several minor changes (Model 1) and a model with 2013 recruitment (2012 year class) set to the average value for yield projections (Model 1A). The technical changes implemented in Model 1 included: 1) removing two years of Biosonics acoustic survey estimates (1992 and 1993) that were actually produced using the EK500 with the acoustic data analyzed at a higher noise threshold, 2) setting the CVs for the Biosonics acoustic survey estimates equal to the nominal value (0.2) of later acoustic surveys, and 3) removing the ADGF survey length data and increasing the input sample sizes for the ADFG survey age data. Some of the Biosonics survey CV were very low (0.1) and methods used to obtain these variances are no longer considered appropriate for acoustic surveys. With respect to the different treatment of the ADFG composition data, there are now sufficient age composition data (7 years) to define the selectivity characteristics of this survey.

Including the recent survey and fishery data had the effect the increasing the biomass in 2011-2013 compared to 2012 assessment due the high survey biomass estimates for both the NMFS bottom trawl and Shelikof Strait acoustic surveys in 2013 (Fig. 1.15). The minor changes in Model 1 compared to Model 0 had had almost no effect on biomass in 2013 (Table 1.15). Historical biomass trends were similar with the exception of the period 1980-1990 (Fig. 1.15) due to the lower weights given the Biosonics acoustic survey estimates during this time period. Model 1A, where recruitment in 2013 was set to the average value had no effect on model fits or spawning biomass because this change was implemented only in stock projection model. Model 1 was considered the base model for the purposes of model evaluation and reporting of time series estimates.

*Model Evaluation*

Model fit to age composition data was evaluated using plots of observed and predicted age composition in the fishery (Fig. 1.16), Shelikof Strait acoustic survey (Fig. 1.17), the NMFS trawl survey (Fig. 1.18), and the ADFG trawl survey (Fig. 1.19). Model fits to fishery age composition data are adequate in most years. The largest residuals tended to be at ages 1-2 for the Shelikof Strait acoustic survey and the NMFS bottom trawl survey due to inconsistencies between the initial estimates of abundance and subsequent information about year class size.

Model fits are similar to previous assessments, and general trends in survey time series are fit reasonably well (Figs. 1.20-1.21). The discrepancy between the NMFS trawl survey and the Shelikof Strait acoustic survey biomass estimates in the 1980s accounts for the poor model fit to both time series during those years. It is difficult for the model to fit the rapid increase in the Shelikof Strait acoustic survey and the NMFS survey in 2013 since an age-structured pollock population cannot increase as rapidly as is indicated by these surveys. In contrast, the model expectation is close to the ADFG survey in 2013.

### *Time series results*

Parameter estimates and model output are presented in a series of tables and figures. Estimated survey selectivity and fishery selectivity for different periods given in Table 1.16 (see also Figure 1.22). Table 1.17 gives the estimated population numbers at age for the years 1961-2012. Table 1.18 gives the estimated time series of age 3+ population biomass, age-1 recruitment, and harvest rate (catch/3+ biomass) for 1977-2012 (see also Fig. 1.23). Table 1.19 gives coefficients of variation and 95% confidence intervals for age-1 recruitment and spawning stock biomass. Stock size peaked in the early 1980s at approximately 80% of the proxy for unfished stock size ($B_{100\%}$ = mean 1979-2012 recruitment multiplied by the spawning biomass per recruit in the absence of fishing (SPR@*F*=0)). In 1997, the stock dropped below the $B_{40\%}$ for the first time since the early 1980s, reached a minimum in 2003 of 18% of unfished stock size. Over the last five years (2009-2013) stock size has shown a strong upward trend from 22% to 47% of unfished stock size.

### *Retrospective comparison of assessment results*

A retrospective comparison of assessment results for the years 1993-2013 indicates the current estimated trend in spawning biomass for 1990-2013 is consistent with previous estimates (Fig. 1.24, top panel). All time series show a similar pattern of decreasing spawning biomass in the 1990s, a period of greater stability in 2000s, followed by an increase starting in 2008. There appear to be no consistent pattern of bias in estimates of ending year biomass, but assessment errors are clearly correlated over time, such that there are runs of over estimates and under estimates. Because of the high survey biomass estimates in 2013, a moderate retrospective pattern is evident between the current assessment and the last two assessments, where the spawning biomass has been revised upwards with each assessment. The estimated 2013 age composition from the current assessment is reasonably consistent with the projected 2013 age composition in the 2012 assessment (Fig. 1.24, bottom panel), although the 2013 assessment estimates slightly higher abundance for pollock age four and older, and lower abundance for younger pollock. The largest change is the estimate of the age-1 fish (2012 year class), which is four times the projected value in last year’s assessment. In the 2012 assessment, the age-1 abundance would have been equal to average recruitment, but in this year’s assessment this estimate is informed by survey estimates from the 2013 acoustic and bottom trawl surveys. The CV of the recruitment estimate of the 2012 year class is 0.24, but past experience suggests that the actual uncertainty of initial recruitment estimates tends to greater than indicated by the assessment model.

### *Stock productivity*

Recruitment of Gulf of Alaska pollock is more variable (CV = 1.13) than Eastern Bering Sea pollock (CV = 0.62). Other North Pacific groundfish stocks, such as sablefish and Pacific ocean perch, also have high recruitment variability. However, unlike sablefish and Pacific ocean perch, pollock have a short generation time (~8 yrs), so that large year classes do not persist in the population long enough to have a buffering effect on population variability. Because of these intrinsic population characteristics, the typical pattern of biomass variability for Gulf of Alaska pollock will be sharp increases due to strong recruitment, followed by periods of gradual decline until the next strong year class recruits to the population. Gulf of Alaska pollock is more likely to show this pattern than any other groundfish stock in the North Pacific due to the combination of a short generation time and high recruitment variability.

Since 1980, strong year classes have occurred every four to six years, although this pattern appears much weaker since 2004 (Fig. 1.23). Because of high recruitment variability, the functional relationship between spawning biomass and recruitment is difficult to estimate despite good contrast in spawning biomass. Strong and weak year classes have been produced at high and low level of spawning biomass. Spawner productivity is higher on average at low spawning biomass compared to high spawning biomass, indicating that survival of eggs to recruitment is density-dependent (Fig. 1.25). However, this pattern of density-dependent survival only emerges on a decadal scale, and could be confounded with environmental variability on the same temporal scale. These decadal trends in spawner productivity have produced the pattern of increase and decline in the GOA pollock population. The last two decades have been a period of relatively low spawner productivity, though some increase is apparent since 2004.

## Harvest Recommendations

### *Reference fishing mortality rates and spawning biomass levels*

Since 1997, Gulf of Alaska pollock have been managed under Tier 3 of NPFMC harvest guidelines. In Tier 3, reference mortality rates are based on the spawning biomass per recruit (SPR), while biomass reference levels are estimated by multiplying the SPR by average recruitment. Estimates of the $F_{SPR}$ harvest rates were obtained using the life history characteristics of Gulf of Alaska pollock (Table 1.20). Spawning biomass reference levels were based on mean 1978-2012 age-1 recruitment (931 million), which is about 5% lower than the post-1977 mean in the 2012 assessment. Spawning was assumed to occur on March 15th, and female spawning biomass was calculated using mean weight at age for the Shelikof Strait acoustic surveys in 2008-2013 to estimate current reproductive potential. A substantial increase in pollock weight-at-age has been observed (Fig. 1.14), which may be a density-dependent response to low abundance or due to environmental forcing. The SPR at F=0 was estimated as 0.780 kg/recruit at age one. $F_{SPR}$ rates depend on the selectivity pattern of the fishery. Selectivity has changed as the fishery evolved from a foreign fishery occurring along the shelf break to a domestic fishery on spawning aggregations and in nearshore waters (Fig. 1.1). For SPR calculations, selectivity was based on the average for 2008-2012 to reflect current selectivity patterns. Gulf of Alaska pollock $F_{SPR}$ harvest rates are given below:

| | | *Equilibrium under average 1978-2012 recruitment* | | | | |
|---|---|---|---|---|---|---|
| *$F_{SPR}$ rate* | *Fishing mortality* | *Avg. Recr. (Million)* | *Total 3+ biom. (1000 t)* | *Female spawning biom. (1000 t)* | *Catch (1000 t)* | *Harvest rate* |
| 100.0% | 0.000 | 931 | 2247 | 726 | 0 | 0.0% |
| 40.0% | 0.221 | 931 | 1253 | 290 | 201 | 16.0% |
| 35.0% | 0.259 | 931 | 1162 | 254 | 215 | 18.5% |

The $B_{40\%}$ estimate of 290,000 t represents a 2% decrease from the $B_{40\%}$ estimate of 297,000 t in the 2012 assessment, which is a mostly a result of the decrease in mean recruitment. The base model projection of spawning biomass in 2014 is 308,541 t, which is 42.5% of unfished spawning biomass (based on average post-1977 recruitment) and above $B_{40\%}$ (290,000 t), thereby placing Gulf of Alaska pollock in sub-tier “a” of Tier 3.

### 2014 acceptable biological catch

The definitions of OFL and maximum permissible $F_{ABC}$ under Amendment 56 provide a buffer between the overfishing level and the intended harvest rate, as required by NMFS national standard guidelines. Since estimates of stock biomass from assessment models are uncertain, the buffer between OFL and ABC provides a margin of safety so that assessment error will not result in the OFL being inadvertently exceeded. For Gulf of Alaska pollock, the maximum permissible $F_{ABC}$ harvest rate is 85.6% of the OFL harvest rate. In the 2001 assessment, based on an analysis that showed that the buffer between the maximum permissible $F_{ABC}$ and OFL decreased when the stock is below approximately $B_{50\%}$ , we developed a more conservative alternative that maintains a constant buffer between ABC and $F_{ABC}$ at all stock levels (Table 1.21). While there is always some probability of exceeding $F_{OFL}$ due to imprecise stock assessments, it seemed unreasonable to reduce safety margin as the stock declines.

This alternative is given by the following

*Define* $B^* = B_{40\%} \dfrac{F_{35\%}}{F_{40\%}}$

*Stock status:* $B / B^* > 1$ *, then* $F = F_{40\%}$

*Stock status:* $0.05 < B / B^* \le 1$ *, then* $F = F_{40\%} \times (B/ B^* - 0.05) / (1 - 0.05)$

*Stock status:* $B / B^* \le 0.05$ *, then* $F = 0$

This alternative has the same functional form as the maximum permissible $F_{ABC}$; the only difference is that it declines linearly from $B^*$ ( $= B_{47\%}$) to $0.05B^*$ (Fig. 1.26).

Projections for 2014 for $F_{OFL}$, the maximum permissible $F_{ABC}$, and an adjusted $F_{40\%}$ harvest rate with a constant buffer between $F_{ABC}$ and $F_{OFL}$ are given in Table 1.22.

### ABC recommendation

There were three surveys in 2013, the Shelikof Strait acoustic survey, the NMFS bottom trawl survey, and ADFG crab/groundfish survey. The 2013 Shelikof Strait acoustic survey biomass estimate is 2.7 times the biomass estimate for 2012, and is largest biomass estimate in Shelikof Strait since 1985. The 2013 NMFS bottom trawl biomass estimate is the highest in the time series, and is an increase of 43% from the 2011 estimate. In contrast, the ADFG crab/groundfish survey biomass estimate decreased by 40% from the 2012 estimate, but is close to the 2011 estimate. The estimated abundance of mature fish is projected to projected remain stable or to decrease gradually to 2015, and to increase in subsequent years. We considered the few minor changes in this assessment to be improvements to the model, however further changes to the assessment should be anticipated as other recommendations on the 2012 CIE review are incorporated in the assessment.

The following information is available on the magnitude of the 2012 year class. The 2013 Shelikof Strait acoustic survey estimate is 6.3 billion, the second highest in time series. Although the abundance of age-1 pollock in the NMFS bottom trawl survey has relatively low correlation with year class strength, the 2013 estimate of age-1 pollock was more than two times higher than the next highest estimate. This information is included in the model, and produces an initial estimate of 4.1 billion, which is about four times average recruitment. The 2013 Shumagin acoustic survey estimate, which is not used in the model, is 6.6 billion—more than three times higher than the next highest estimate. Although previous pollock assessments have taken the approach of setting large initial year classes equal the average for one or more years, in this case, given the multiple observations of high age-1 abundance, this approach does not seem warranted. One advantage of beginning the model at age one is that the initial estimate of a year class has less influence on projected yields in the next year, since pollock have low selectivity at age 2. The 2014 ABC is reduced by 10% if the 2012 year class is set equal to the average (Table 1.15).

The recommended ABC was based on a model projection using the base model and the more conservative adjusted $F_{40\%}$ harvest rate described above. The author's recommended 2014 ABC is therefore 167,657 t, which is an increase of 48% from the 2013 ABC. In 2015, the ABC based an adjusted $F_{40\%}$ harvest rate is 185,830 t (Table 1.22). The OFL in 2014 is 211,998 t, and the OFL in 2015 if the recommended ABC is taken in 2014 is 248,384 t.

An exempted fishing permit (EFP) has been granted to evaluate the effect of salmon excluder devices in the pollock fishery in 2013 and 2014. Pollock catches under the EFP were 2,285 t in 2013 (John Gauvin, pers. comm. Oct. 28, 2013) and are projected to be 2,304 t in 2014. We followed the Gulf of Alaska Plan Team recommendation, and used a projection model that accounted for the EFP catches by removing the actual EFP pollock catch in 2013, and the projected 2014 EFP catch at the start of year in 2014. This resulted in a 2014 ABC of 166,514 t (1,143 t difference).

To evaluate the probability that the stock will drop below the $B_{20\%}$ threshold, we projected the stock forward for five years and removed catches based on the spawning biomass in each year and the author's recommended fishing mortality schedule. This projection incorporates uncertainty in stock status, uncertainty in the estimate of $B_{20\%}$, and variability in future recruitment. We then sampled from the likelihood of future spawning biomass using Markov chain Monte Carlo (MCMC) (Fig. 1.27). A chain of 1,000,000 samples was thinned by selecting every 200th sample. Analysis of the thinned MCMC chain indicates that probability of the stock dropping below $B_{20\%}$ will be negligible in all years.

### *Projections and Status Determination*

A standard set of projections is required for stocks managed under Tier 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For each scenario, the projections begin with the 2013 numbers at age at the start of the year as estimated by the assessment model, and assume the 2013 catch will be equal to the TAC of 113,099 t. In each year, the fishing mortality rate is determined by the spawning biomass in that year and the respective harvest scenario. Recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments during 1978-2012 as estimated by the assessment model. Spawning biomass is computed in each year based on the time of peak spawning (March 15) using the maturity and weight schedules in Table 1.20. 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 are 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 2014, are as follows ("*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 the $F_{ABC}$ recommended in the assessment.

*Scenario 3*: In all future years, *F* is set equal to the five-year average *F* (2009-2013). (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 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 2013 or 2) above 1/2 of its MSY level in 2013 and above its MSY level in 2023 under this scenario, then the stock is not overfished)

*Scenario 7*: In 2014 and 2015, *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 1) above its MSY level in 2016, or 2) above 1/2 of its MSY level in 2016 and above its MSY level in 2026 under this scenario, then the stock is not approaching an overfished condition.)

Results from scenarios 1-5 are presented in Table 1.22. Under all harvest policies, mean spawning biomass is projected remain stable or to decrease gradually to 2015, and to increase in subsequent years (Fig. 1.28). Plots of individual projection runs are highly variable (Fig. 1.29), and may provide a more realistic view of potential pollock abundance in the future.

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

The catch estimate for the most recent complete year (2012) is 103,991 t, which is less than the 2012 OFL of 143,716 t. Therefore, the stock is not being subject to overfishing.

Scenarios 6 and 7 are used to make the MSFCMA's other required status determination as follows:

Under scenario 6, spawning biomass is estimated to be 329,732 t in 2013, which is above $B_{35\%}$ (254,000 t). Therefore, Gulf of Alaska pollock is not currently overfished.

Under scenario 7, projected mean spawning biomass in 2016 is 308,515 t, which is above $B_{35\%}$ (254,000 t). Therefore, Gulf of Alaska pollock is not approaching an overfished condition.

## Ecosystem considerations

### *Prey of pollock*

An ECOPATH model was assembled to characterize food web structure in Gulf of Alaska using diet data and population estimates during 1990-93. We use ECOPATH here simply as a tool to integrate diet data and stock abundance estimates in a consistent way to evaluate ecosystem interactions. We focus primarily on first-order trophic interactions: prey of pollock and the predators of pollock.

Pollock trophic interactions occur primarily in the pelagic pathway in the food web, which leads from phytoplankton through various categories of zooplankton to planktivorous fish species such as capelin and sandlance (Fig. 1.30); the primary prey of pollock are euphausiids. Pollock also consume shrimp, which are more associated with the benthic pathway, and make up approximately 18% of age 2+ pollock diet. All ages of GOA pollock are primarily zooplanktivorous during the summer growing season (>80% by weight zooplankton in diets for juveniles and adults; Fig 1.31). While there is an ontogenetic shift in diet from copepods to larger zooplankton (primarily euphausiids) and fish, cannibalism is not as prevalent in the Gulf of Alaska as in the Eastern Bering Sea, and fish consumption is low even for large pollock (Yang and Nelson 2000).

There are no extended time series of zooplankton abundance for the shelf waters of the Gulf of the Alaska. Brodeur and Ware (1995) provide evidence that biomass of zooplankton in the center of the Alaska Gyre was twice as high in the 1980s than in the 1950s and 1960s, consistent with a shift to positive values of the PDO since 1977. The percentage of zooplankton in diets of pollock is relatively constant throughout the 1990s (Fig. 1.31). While indices of stomach fullness exist for these survey years, a more detailed bioenergetics modeling approach would be required to examine if feeding and growth conditions have changed over time, especially given the fluctuations in GOA water temperature in recent years, as water temperature has a considerable effect on digestion and other energetic rates.

### *Predators of pollock*

Initial ECOPATH model results show that the top five predators on pollock >20 cm by relative importance are arrowtooth flounder, Pacific halibut, Pacific cod, Steller sea lion (SSL), and the directed pollock fishery (Fig. 1.32). For pollock less than 20cm, arrowtooth flounder represent close to 50% of total mortality. All major predators show some diet specialization, and none depend on pollock for more than 50% of their total consumption (Fig. 1.33). Pacific halibut is most dependent on pollock (48%), followed by SSL (39%), then arrowtooth flounder (24% for juvenile and adult pollock combined), and lastly Pacific cod (18%). It is important to note that although arrowtooth flounder is the largest single source of mortality for both juvenile and adult pollock (Fig 1.33), arrowtooth depend less on pollock in their diets then do the other predators.

Arrowtooth consume a greater number of smaller pollock than do Pacific cod or Pacific halibut, which consume primarily adult fish. However, by weight, larger pollock are important to all three predators (Fig. 1.34). Length frequencies of pollock consumed by the western stock of Steller sea lions tend towards larger fish, and generally match the size frequencies of cod and halibut (Zeppelin et al. 2004). The diet of Pacific cod and Pacific halibut are similar in that the majority of their diet besides pollock is from the benthic pathway of the food web. Alternate prey for Steller sea lions and arrowtooth flounder are similar, and come primarily from the pelagic pathway.

Predation mortality, as estimated by ECOPATH, is extremely high for GOA pollock >20cm. Estimates for the 1990-1993 time period indicate that known sources of predation sum to 90%-120% of the total production of walleye pollock calculated from 2004 stock assessment growth and mortality rates; estimates greater than 100% may indicate a declining stock (as shown by the stock assessment trend in the early 1990s; Fig 1.35, top), or the use of mortality rates which are too low. Conversely, as >20cm pollock include a substantial number of 2-year olds, it may be that mortality rate estimates for this age range is low. In either case, predation mortality for pollock in the GOA is much greater a proportion of pollock production than as estimated by the same methods for the Bering Sea, where predation mortality (primarily pollock cannibalism) was up to 50% of total production.

Aside from long-recognized decline in Steller sea lion abundance, the major predators of pollock in the Gulf of Alaska are stable to increasing, in some cases notably so since the 1980s (Fig. 1.35, top). This high level of predation is of concern in light of the declining trend of pollock with respect to predator increases. To assess this concern, it is important to determine if natural mortality may have changed over time (e.g. the shifting control hypothesis; Bailey 2000). To examine predator interactions more closely than in the initial model, diet data of major predators in trawl surveys were examined in all survey years since 1990.

Trends in total consumption of walleye pollock were calculated by the following formula:

$$Consumption = \sum B_{pred,size,subregion} \cdot DC_{pred,size,subregion} \cdot WLF_{pred,size,GOA} \cdot Ration_{pred,size}$$

where B(pred, size, subregion) is the biomass of a predator size class in the summer groundfish surveys in a particular survey subregion; DC is the percentage by weight of pollock in that predator group as measured from stomach samples, WLF is the weight frequency of pollock in the stomachs of that predator group pooled across the GOA region, calculated from length frequencies in stomachs and length-weight relationships from the surveys. Finally, ration is an applied yearly ration for that predator group calculated by fitting weight-at-age to the generalized von Bertalanffy growth equations as described in Essington et al. (2001). Ration is assumed fixed over time for a given size class of predator.

Fig. 1.35 (bottom) shows annual total estimates of consumption of pollock (all age classes) in survey years by the four major fish predators. Other predators, shown as constant, are taken from ECOPATH modeling results and displayed for comparison. Catch is shown as reported in Table 1.1. In contrast, the line in the figure shows the historical total production (tons/year) plus yearly change in biomass (positive or negative) from the stock assessment results. In a complete accounting of pollock mortality, the height of the bars should match the height of the line. As shown, estimates of consumption greatly surpass estimates of production; fishing mortality is a relatively small proportion of total consumption. Overestimates in consumption rates could arise through seasonal differences in diets; while ration is seasonally adjusted, diet proportions are based on summer data. Also, better energetic estimates of consumption would improve these estimates. In terms of the stock assessment, underestimates of production could result from underestimating natural mortality, especially at ages 2-3, underestimating the rate of decline which occurred between 1990-present, or underestimates of the total biomass of pollock; this analysis should be revisited using higher mortality at younger ages than assumed in the current stock assessment.

To better judge natural mortality, consumption was calculated for two size groups of pollock, divided at 30cm fork length. This size break, which differs from the break in the ECOPATH analysis, is based on finding minima between modes of pollock in predator diets (Fig. 1.36). This break is different from the conversion matrices used in the stock assessment; perhaps due to differences in size selection between predators and surveys. For this analysis, it is assumed that pollock<30cm are ages 0-2 while pollock ≥30cm are age 3+ fish.

Consumption of age 0-2 pollock per unit predator biomass (using survey biomass) varied considerably through survey years, although within a year all predators had similar consumption levels (Fig. 1.37, top). Correlation coefficients of consumption rates were 0.98 between arrowtooth and halibut, and 0.90 for both of these species with pollock. Correlation coefficients of these three species with cod were ~0.55 for arrowtooth and halibut and ~0.20 with pollock. The majority of this predation by weight occurred on age 2 pollock.

Plotted against age 2 pollock numbers calculated from the stock assessment, consumption/biomass and total consumption by predator shows a distinct pattern (Fig. 1.37, lower two graphs). In "low" recruitment years consumption is consistently low, while in high recruitment years consumption is high, but does not increase linearly, rather consumptions seems to level out at high numbers of juvenile pollock, resembling a classic "Type II" functional response. This suggests the existence bottom-up control of juvenile consumption, in which strong year classes of pollock "overwhelm" feeding rates of predators, resulting in potentially lower juvenile mortality in good recruitment years which may amplify the recruitment. However, this result should be examined iteratively within the stock assessment, as the back-calculated numbers at age 2 assume a constant natural mortality rate. Assuming a lower mortality rate due to predator satiation would lead to lower estimates of age 2 numbers, which would make the response appear more linear.

Consumption of pollock ≥30cm shows a different pattern over time. A decline of consumption per unit biomass is evident for halibut and cod (Fig. 1.37, top). Arrowtooth shows an insignificant decline; it is possible that the noise in the arrowtooth trend, mirroring the consumption of <30cm fish, is due to the choice of 30cm as an age cutoff. As a function of age 3+ assessment biomass, consumption per unit biomass and total consumption remained constant as the stock declined, and then fell off rapidly at low biomass levels in recent years (Fig. 1.37, middle and bottom). Again, this result should be approached iteratively, but it suggests increasing predation mortality on age 3+ pollock during 1990-2005, possibly requiring increased foraging effort from predators.

There has been a marked decline in Pacific halibut weight at age since the 1970s that Clark et al. (1999) attributed to the 1977 regime shift without being able to determine the specific biological mechanisms that produced the change. Possibilities suggested by Clark et al. (1999) include the physiological effect of an increase in temperature, intra- and interspecific competition for prey, or a change in prey quality. The two species most dependent on pollock in the early 1990s (Pacific halibut and Steller sea lion) have both shown an exceptional biological response during the post-1977 period consistent with a reduction in carrying capacity (growth for Pacific halibut, survival for Steller sea lions). In contrast, the dominant predator on pollock in the Gulf of Alaska (arrowtooth flounder) has increased steadily in abundance over the same period and shows no evidence of decline in size at age. Given that arrowtooth flounder has a range of potential prey types to select from during periods of low pollock abundance (Fig. 1.33), we do not expect that arrowtooth would decline simply due to declines in pollock.

Taken together, Figs. 1.36 and 1.37 suggest that recruitment remains bottom-up controlled even under the current estimates of high predation mortality, and may lead to strong year classes. However, top-down control seems to have increased on age 3+ pollock in recent years, perhaps as predators have attempted to maintain constant pollock consumption during a period of declining abundance. It is possible that natural mortality on adult pollock will remain high in the ecosystem in spite of decreasing pollock abundance.

### *Ecosystem modeling*

To examine the relative role of pollock natural versus fishing mortality within the GOA ecosystem, a set of simulations were run using the ECOPATH model shown in Fig. 1.30. Following the method outlined in Aydin et al. (2005), 20,000 model ecosystems were drawn from distributions of input parameters; these parameter sets were subjected to a selection/rejection criteria of species persistence resulting in approximately 500 ecosystems with nondegenerate parameters. These models, which did not begin in an equilibrium state, were projected forward using ECOSIM algorithms until equilibrium conditions were reached. For each group within the model, a perturbation experiment was run in all acceptable ecosystems by reducing the species survival (increasing mortality) by 10%, or by reducing gear effort by 10%, and reporting the percent change in equilibrium of all other species or fisheries catches. The resulting changes are reported as ranges across the generated ecosystems, with 50% and 95% confidence intervals representing the distribution of percent change in equilibrium states for each perturbation.

Fig. 1.38 shows the changes in other species when simulating a 10% decline in adult pollock survival (top graph), a 10% decline in juvenile pollock survival (middle graph), and a 10% decline in pollock trawl effort. Fisheries in these simulations are governed by constant fishing mortality rates rather than harvest control rules. Only the top 20 effects are shown in each graph; note the difference in scales between each graph.

The model results indicate that the largest effects of declining adult pollock survival would be declines in halibut and Steller sea lion biomass. Declines in juvenile survival would have a range of effects, including halibut and Steller sea lions, but also releasing a range of competitors for zooplankton including rockfish and shrimp. The pollock trawl itself has a lesser effect throughout the ecosystem (recall that fishing mortality is small in proportion to predation mortality for pollock); the strongest modeled effects are not on competitors for prey but on incidentally caught species (Table 1.2), with the strongest effects being on sharks.

The results presented above are taken from Gulfwide weighted averages of consumption; Steller sea lions and the fishing fleet are central place foragers, making foraging trips from specific locations (ports in the case of the fishing fleet, and rookeries or haulouts for Steller sea lions). Foraging bouts (or trawl sets) begin at the surface, and foragers attack their prey from the top down. For such species, directed and local changes in fishing may have a disproportionate effect compared to the results shown here.

In contrast, predation by groundfish is not as constrained geographically, and captures are likely to occur when the predator swims upwards from the bottom. Changes in the vertical distribution of pollock may tend to favor one mode of foraging over another. For example, if pollock move deeper in the water column due to surface warming, foraging groundfish might obtain an advantage over surface foragers. Alternatively, pollock may respond adaptively to predation risks from groundfish or surface foragers by changing its position in the water column.

Of species affecting pollock (Fig. 1.39), arrowtooth have the largest impact on adult pollock, while bottom-up processes (phytoplankton and zooplankton) have the largest impact on juvenile pollock. It is interesting to note that the link between juvenile and adult pollock is extremely uncertain (wide error bars) within these models.

Finally, of the four major predators of pollock (Fig 1.40), all are affected by bottom-up forcing; Steller sea lions, Pacific cod, and Pacific halibut are all affected by pollock perturbations, while pollock effects on arrowtooth are much more minor.

Pair-wise correlations in predator trends were examined for consistent patterns (Fig. 1.41). For each pair-wise comparison, we used the maximum number of years available. Time series for Steller sea lions and Pacific cod begin in mid 1970s, while other time series extend back to the early 1960s. We make no attempt to evaluate statistical significance (biomass trends are highly autocorrelated), and emphasize that correlation does not imply causation. If two populations are strongly correlated in time, there are many possible explanations: both populations are responding to similar forcing, one or other is causative agent, etc.

Pollock abundance, fishery catches, and Steller sea lions are positively correlated (Fig. 1.41). Since the harvest policy for pollock is modified fixed harvest rate strategy, a positive correlation between catch and abundance would be expected. The Steller sea lion trend is more strongly correlated with pollock abundance than pollock catches, but this correlation is based on data since 1976, and does not include earlier years of low pollock abundance. The only strong inverse correlation is between arrowtooth flounder and Steller sea lions. A strong positive correlation exists between Pacific cod and Pacific halibut, and, from the 1960s to the present, between Pacific halibut and arrowtooth flounder.

Several patterns are apparent in abundance trends and the diet data. First, the two predators with alternate prey in the benthic pathway, Pacific cod and Pacific halibut, covary and have been relatively stable in the post-1977 period. Second, the long term increases in both Pacific halibut and arrowtooth flounder (with quite different diets apart from pollock) may be linked to similarities in their reproductive behavior. Both spawn offshore in late winter, and conditions that enhance onshore advection, such as El Niños, may play an important role in recruitment to nursery areas for these species (Bailey and Picquelle 2002).

Finally, it is apparent that the potential for competition between Steller sea lions and arrowtooth flounder is underappreciated, perhaps because arrowtooth flounder seem poorly designed to compete as forager in the pelagic zone. However, arrowtooth flounder consume both the primary prey of Steller sea lions (pollock), and alternate pelagic prey also utilized by Steller sea lions (capelin, herring, sandlance, salmon). Arrowtooth predation on pollock occurs at a smaller size than pollock targeted by Steller sea lions. The arrowtooth flounder population is nearly unexploited, is increasing in abundance, may be increasing it's per unit consumption of pollock, and shows no evidence of density-dependent growth. And lastly, since 1976 there has been a strong inverse correlation between arrowtooth flounder and Steller sea lion abundance that is at least consistent with competition between these species.

## Data Gaps and Research Priorities

Based on the 2012 CIE review of the Gulf of Alaska pollock assessment, the following research priorities are identified. Additional details on recommended pollock research are included in a document provided to the GOA Plan Team in September 2013 that summarized and responded to the CIE review.

- Reduce data sets to those that are informative about current status by removing earlier and more questionable data sets, and reducing the influence of the inconsistent data earlier in the time series.
- Improve relative weightings given to different data sets.
- Consider alternative modeling platforms.
- Conduct research to develop informative priors on acoustic and trawl survey selectivity and catchability, and consider different ways to model selectivity.
- Evaluate alternative ways to model fishery and survey selectivity (including asymptotic selectivity).
- Explore implications of non-constant natural mortality on pollock assessment and management.

## Literature Cited

Alton, M. S., M. O. Nelson, and B. A. Megrey. 1987. Changes in the abundance and distribution of walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska. Fish. Res. 5: 185-197.

Alverson, D. L. And M. J. Carney. 1975. A graphic review of the growth and decay of population cohorts. Cons. int. Explor. Mer, 133-143.

Anderson, P. J. and J. F. Piatt 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Mar. Ecol. Prog. Ser. 189:117-123.

Aydin, K., GA. McFarlane, JR. King, BA. Megrey, and KW. Myers. 2005. Linking oceanic food webs to coastal production and growth rates of Pacific salmon (*Oncorhynchus* spp.), using models on three scales. Deep-sea Res, II. 52: 757-780.

Bailey, K.M., P.J. Stabeno, and D.A. Powers. 1997. The role of larval retention and transport features in mortality and potential gene flow of walleye pollock. J. Fish. Biol. 51(Suppl. A):135-154.

Bailey, K.M., T.J. Quinn II, P. Bentzen, and W.S. Grant. 1999. Population structure and dynamics of walleye pollock, *Theragra chalcogramma*. Advances in Mar. Biol. 37: 179-255.

Bailey, K.M. 2000. Shifting control of recruitment of walleye pollock *Theragra chalcogramma* after a major climatic and ecosystem change. Mar. Ecol. Prog. Ser 198:215-224.

Bailey, K. M and S. J. Picquelle. 2002. Larval distribution of offshore spawning flatfish in the Gulf of Alaska: potential transport pathways and enhanced onshore transport during ENSO events. Mar. Ecol. Prog. Ser. 236:205-217.

Baranov, F.I. 1918. On the question of the biological basis of fisheries. Nauchn. Issed. Ikhtiologicheskii Inst. Izv. 1:81-128.

Blackburn, J. and D. Pengilly. 1994. A summary of estimated population trends of seven most abundant groundfish species in trawl surveys conducted by Alaska Department of Fish and Game in the Kodiak and Alaska Peninsula areas, 1988 through 1993. Alaska Department of Fish and Game, Regional Information Report No. 4K94-31. 19p.

Brodeur, R. D. and Ware, D.M. 1995. Interdecadal variability in distribution and catch rates of epipelagic nekton in the Northeast Pacific Ocean. pp. 329-356 in R. J. Beamish [Ed.] Climate change and northern fish populations. Canadian Special Publication of Fisheries and Aquatic Sciences 121. National Research Council of Canada, Ottawa.

Clark, W.G. 1999. Effects of an erroneous natural mortality rate on a simple age-structured model. Can. J. Fish. Aquat. Sci. 56:1721-1731.

Clark, W. G., S. R. Hare, A. M. Parma, P. J. Sullivan, and R. J. Trumble. 1999. Decadal changes in growth and recruitment of Pacific halibut (*Hippoglossus stenolepis*). Can. J. Fish. Aquat. Sci. 56(2): 242-252.

Deriso, R.B., T.J. Quinn II, and P.R. Neal. 1985. Catch-age analysis with auxiliary information. Can. J. Fish. Aquat. Sci. 42: 815-824.

De Robertis, A., Hjellvik, V., Williamson, N. J., and Wilson, C. D. 2008. Silent ships do not always encounter more fish: comparison of acoustic backscatter recorded by a noise-reduced and a conventional research vessel. – ICES Journal of Marine Science, 65: 623–635.

Dorn, M. W., and R. D. Methot. 1990. Status of the coastal Pacific whiting resource in 1989 and recommendation to management in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-182, 84 p.

Dorn, M.W., S. Barbeaux, B, M. Guttormsen, B. Megrey, A. Hollowed, M. Wilkins, and K. Spalinger. 2003. Assessment of the walleye pollock stock in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Dorn, M.W., K. Aydin, S. Barbeaux, D. Jones, K. Spalinger, and W. Palsson. 2012. Assessment of the walleye pollock stock in the Gulf of Alaska. *In* Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Doubleday, W.G. 1976. A least-squares approach to analyzing catch at age data. Res. Bull. Int. Comm. Northw. Atl. Fish. 12:69-81.

Fournier, D. and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 39:1195-1207.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.
Fritz, L. W. 1993. Trawl locations of walleye pollock and Atka mackerel fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska from 1977-92. AFSC Processed Report 93-08. NMFS, AFSC, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 p.

Gauthier, S. and J. K. Horne 2004. Acoustic characteristics of forage fish species in the Gulf of Alaska and Bering Sea. Can. J. Aquat. Fish. Sci. 61: 1839-1850.

Grant, W.S. and F.M. Utter. 1980. Biochemical variation in walleye pollock *Theragra chalcogramma*: population structure in the southeastern Bering Sea and Gulf of Alaska. Can. J. Fish. Aquat. Sci. 37:1093-1100.

Greiwank, A., and G.F. Corliss (eds.) 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan. 6-8, Breckenridge, CO. Soc. Indust. and Applied Mathematics, Philadelphia.

Gunderson, D. R. and P. H. Dygert. 1988. Reproductive effort as a predictor of natural mortality rate. J. Cons. int. Mer, 44:200-209.

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

Hollowed, A.B. and B.A. Megrey. 1990. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1991 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Hollowed, A.B., B.A. Megrey, P. Munro, and W. Karp. 1991. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for the 1992 Gulf of Alaska Groundfish Fishery. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Hollowed, A.B., E. Brown, P. Livingston, B.A. Megrey and C. Wilson. 1995. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for Gulf of Alaska As Projected for 1996. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Hollowed, A.B., E. Brown, J. Ianelli, B.A. Megrey and C. Wilson. 1998. Walleye pollock. In Stock Assessment and Fishery Evaluation Report for Groundfish Resources of the Gulf of Alaska. Prepared by the Gulf of Alaska Groundfish Plan Team, North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510. North Pacific Fisheries Management Council, Anchorage, AK.

Hollowed, A.B., J.N. Ianelli, P. Livingston. 2000. Including predation mortality in stock assessments: a case study for Gulf of Alaska pollock. ICES J. Mar. Sci. 57:279-293.

Jones, D., M.A, Guttormsen, A. McCarthy. In review. Results of the February-March 2012 Echo Integration-Trawl Surveys of Walleye Pollock (Theragra chalcogramma) Conducted in the Gulf of Alaska, Cruises MF2012-01 and MF2012-04. AFSC Processed Rep. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Kastelle, C. R. and D. K. Kimura. 2006. Age validation of walleye pollock (*Theragra chalcogramma*) from the Gulf of Alaska using the disequilibrium of Pb-210 and Ra-226. ICES Journal of Marine Science 63:1520-1529.

Kendall, A.W. Jr. and S.J. Picquelle. 1990. Egg and larval distributions of walleye pollock *Theragra chalcogramma* in Shelikof Strait, Gulf of Alaska. Fish. Bull., U.S. 88:133-154.

Kimura, D.K. 1989. Variability, tuning, and simulation for the Doubleday-Deriso catch-at-age model. Can. J. Fish. Aquat. Sci. 46:941-949.

Kimura, D.K. 1990. Approaches to age-structured separable sequential population analysis. Can. J. Fish. Aquat. Sci. 47:2364-2374.

Kimura, D.K. 1991. Improved methods for separable sequential population analysis. Unpublished. Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, Washington 98115.

Kimura, D. K. and S. Chikuni. 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 of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Can. Spec. Publ. Fish. Aquat. Sci. 108:57-66.

McCullagh, P., and J. A. Nelder. 1983. Generalized linear models. Chapman and Hall, London. 261 p.
McKelvey, D. 1996. Juvenile walleye pollock, *Theragra chalcogramma*, distribution and abundance in Shelikof Strait–What can we learn from acoustic survey results? p. 25-34. *In* U.S. Dep. Commer. NOAA Tech. Rep. NMFS 126.

McKelvey, D.R. 1996. Juvenile walleye pollock, *Theragra chalcogramma*, distribution and abundance in Shelikof Strait—what can we learn from acoustic surveys. Ecology of Juvenile Walleye Pollock, *Theragra chalcogramma*. NOAA Technical Report NMFS 126, p 25-34.

Martin, M.H. 1997. Data Report: 1996 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-82, 235 p.

Megrey, B.A. 1989. Exploitation of walleye pollock resources in the Gulf of Alaska, 1964-1988: portrait of a fishery in transition. Proc. International Symp. on the Biology and Management of Walleye Pollock, Lowell Wakefield Fisheries Symp., Alaska Sea Grant Rep. 89-1, 33-58.

Merati, N. 1993. Spawning dynamics of walleye pollock, *Theragra chalcogramma*, in Shelikof Strait, Gulf of Alaska. Unpublished MS thesis. University of Washington. 134 p.

Methot, R.D. 2000. Technical description of the stock synthesis assessment program. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-43, 46 p.

Meuter, F.J. and B.L. Norcross. 2002. Spatial and temporal patterns in the demersal fish community on the shelf and upper slope regions of the Gulf of Alaska. Fish. Bull. 100:559-581.

Mulligan, T.J., Chapman, R.W. and B.L. Brown. 1992. Mitochondrial DNA analysis of walleye pollock, *Theragra chalcogramma*, from the eastern Bering Sea and Shelikof Strait, Gulf of Alaska. Can. J. Fish. Aquat. Sci. 49:319-326.

Olsen, J.B., S.E. Merkouris, and J.E. Seeb. 2002. An examination of spatial and temporal genetic variation in walleye pollock (*Theragra chalcogramma*) using allozyme, mitochondrial DNA, and microsatellite data. Fish. Bull. 100:752-764.

Pauly, D.. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. int. Explor. Mer, 39(2):175-192.

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

Picquelle, S.J., and B.A. Megrey. 1993. A preliminary spawning biomass estimate of walleye pollock, *Theragra chalcogramma*, in Shelikof Strait, Gulf of Alaska, based on the annual egg production method. Bulletin of Marine Science 53(2):728:749.

Ronholt, L. L., H. H. Shippen, and E. S. Brown. 1978. Demersal fish and shellfish resources of the Gulf of Alaska from Cape Spencer to Unimak Pass 1948 - 1976 (A historical review). Northwest and Alaska Fisheries Center Processed Report.

Saunders, M.W., G.A. McFarlane, and W. Shaw. 1988. Delineation of walleye pollock (*Theragra chalcogramma*) stocks off the Pacific coast of Canada. Proc. International Symp. on the Biology and Management of Walleye Pollock, Lowell Wakefield Fisheries Symp., Alaska Sea Grant Rep. 89-1, 379-402.

Somerton, D. 1979. Competitive interaction of walleye pollock and Pacific ocean perch in the northern Gulf of Alaska. *In* S. J. Lipovsky and C.A. Simenstad (eds.) Gutshop '78, Fish food habits studies: Proceedings of the second Pacific Northwest Technical Workshop, held Maple Valley, WA (USA), 10-13 October, 1978., Washington Sea Grant, Seattle, WA.

Sullivan, P.J., A.M. Parma, and W.G. Clark. 1997. Pacific halibut assessment: data and methods. Int. Pac. Halibut Comm. SCI.

Rept. 97. 84 p.

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

von Szalay, P. G., and E. Brown. 2001. Trawl comparisons of fishing power differences and their applicability to National Marine Fisheries Service and the Alaska Department of Fish and Game trawl survey gear. Alaska Fishery Research Bulletin 8:85-95.

Yang, M-S. and M. W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

Zeppelin, TK., DJ. Tollit, KA. Call, TJ. Orchard, and CJ. Gudmundson. 2004. Sizes of walleye pollock (Theragra chalcogramma) and Atka mackerel (Pleurogrammus monopterygius) consumed by the western stock of Steller sea lions (Eumetopias jubatus) in Alaska from 1998 to 2000. Fish. Bull. 102:509-521.

Table 1.1. Walleye pollock catch (t) in the Gulf of Alaska. The ABC for 2013 is for the area west of 140° W lon. (Western, Central and West Yakutat management areas) and includes the guideline harvest level for the state-managed fishery in Prince William Sound (2,827 t). Research catches are reported in Appendix D.

| *Year* | *Foreign* | *Joint Venture* | *Domestic* | *Total* | *ABC/TAC* |
|---|---|---|---|---|---|
| 1964 | 1,126 | | | 1,126 | --- |
| 1965 | 2,749 | | | 2,749 | --- |
| 1966 | 8,932 | | | 8,932 | --- |
| 1967 | 6,276 | | | 6,276 | --- |
| 1968 | 6,164 | | | 6,164 | --- |
| 1969 | 17,553 | | | 17,553 | --- |
| 1970 | 9,343 | | | 9,343 | --- |
| 1971 | 9,458 | | | 9,458 | --- |
| 1972 | 34,081 | | | 34,081 | --- |
| 1973 | 36,836 | | | 36,836 | --- |
| 1974 | 61,880 | | | 61,880 | --- |
| 1975 | 59,512 | | | 59,512 | --- |
| 1976 | 86,527 | | | 86,527 | --- |
| 1977 | 117,834 | | 522 | 118,356 | 150,000 |
| 1978 | 96,392 | 34 | 509 | 96,935 | 168,800 |
| 1979 | 103,187 | 566 | 1,995 | 105,748 | 168,800 |
| 1980 | 112,997 | 1,136 | 489 | 114,622 | 168,800 |
| 1981 | 130,324 | 16,857 | 563 | 147,744 | 168,800 |
| 1982 | 92,612 | 73,917 | 2,211 | 168,740 | 168,800 |
| 1983 | 81,358 | 134,131 | 119 | 215,608 | 256,600 |
| 1984 | 99,260 | 207,104 | 1,037 | 307,401 | 416,600 |
| 1985 | 31,587 | 237,860 | 15,379 | 284,826 | 305,000 |
| 1986 | 114 | 62,591 | 25,103 | 87,809 | 116,000 |
| 1987 | | 22,823 | 46,928 | 69,751 | 84,000 |
| 1988 | | 152 | 65,587 | 65,739 | 93,000 |
| 1989 | | | 78,392 | 78,392 | 72,200 |
| 1990 | | | 90,744 | 90,744 | 73,400 |
| 1991 | | | 100,488 | 100,488 | 103,400 |
| 1992 | | | 90,857 | 90,857 | 87,400 |
| 1993 | | | 108,908 | 108,908 | 114,400 |
| 1994 | | | 107,335 | 107,335 | 109,300 |
| 1995 | | | 72,618 | 72,618 | 65,360 |
| 1996 | | | 51,263 | 51,263 | 54,810 |
| 1997 | | | 90,130 | 90,130 | 79,980 |
| 1998 | | | 125,098 | 125,098 | 124,730 |
| 1999 | | | 95,590 | 95,590 | 94,580 |
| 2000 | | | 73,080 | 73,080 | 94,960 |
| 2001 | | | 72,076 | 72,076 | 90,690 |
| 2002 | | | 51,937 | 51,937 | 53,490 |
| 2003 | | | 50,666 | 50,666 | 49,590 |
| 2004 | | | 63,934 | 63,934 | 65,660 |
| 2005 | | | 80,846 | 80,846 | 86,100 |
| 2006 | | | 71,976 | 71,976 | 81,300 |
| 2007 | | | 53,062 | 53,062 | 63,800 |
| 2008 | | | 52,500 | 52,500 | 53,590 |
| 2009 | | | 44,003 | 44,003 | 43,270 |
| 2010 | | | 76,860 | 76,860 | 77,150 |
| 2011 | | | 81,307 | 81,307 | 88,620 |
| 2012 | | | 103,991 | 103,991 | 108,440 |
| 2013 | | | | | 113,099 |
| *Average (1977-2012)* | | | | 101,971 | 116,706 |

Sources: 1964-85--Megrey (1988); 1986-90--Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission. Domestic catches in 1986-90 were adjusted for discard as described in Hollowed et al. (1991). 1991-2012--NMFS Alaska Regional Office.

Table 1.2. Incidental catch (t) of FMP species (upper table) and non-target species (bottom table) in the walleye pollock directed fishery in the Gulf of Alaska in 2008-2012. Species are ordered according to the cumulative catch during the period. Incidental catch estimates include both retained and discarded catch.

| *Managed species/species group* | *2008* | *2009* | *2010* | *2011* | *2012* |
|---|---|---|---|---|---|
| Pollock | 47383.1 | 39334.5 | 73033.1 | 77293.9 | 99643.6 |
| Arrowtooth flounder | 1592.1 | 761.0 | 2071.8 | 1992.7 | 1326.9 |
| Pacific cod | 579.2 | 557.0 | 1497.9 | 1500.5 | 1266.5 |
| Flathead sole | 438.1 | 215.7 | 360.1 | 217.4 | 189.5 |
| Shallow water flatfish | 230.0 | 17.0 | 78.5 | 289.2 | 171.2 |
| Squid | 91.8 | 320.9 | 129.0 | 209.1 | 6.6 |
| Pacific ocean perch | 49.9 | 36.1 | 96.6 | 172.3 | 294.5 |
| Shark | 113.5 | 55.9 | 279.2 | 27.1 | 84.7 |
| Rex sole | 59.4 | 35.5 | 60.7 | 90.0 | 48.8 |
| Big skate | 21.7 | 33.8 | 47.1 | 92.6 | 47.8 |
| Shortraker rockfish | 70.3 | 26.2 | 9.4 | 24.4 | 21.8 |
| Rougheye rockfish | 42.9 | 12.9 | 30.5 | 34.5 | 21.2 |
| Longnose skate | 23.6 | 35.1 | 9.8 | 35.0 | 9.0 |
| Sculpin | 15.3 | 5.0 | 6.1 | 53.4 | 20.2 |
| Northern rockfish | 7.9 | 11.7 | 2.2 | 13.7 | 47.0 |
| Sablefish | 1.3 | 0.1 | 1.3 | 32.5 | 7.2 |
| Dusky rockfish | 4.1 | 1.5 | 5.8 | 19.1 | 4.1 |
| Deep water flatfish | 5.8 | 2.4 | 3.1 | 14.6 | 3.1 |
| Other skate | 5.9 | 2.6 | 7.0 | 1.9 | 5.5 |
| Other rockfish | 4.5 | 0.2 | 0.4 | 6.8 | 0.8 |
| Octopus | 0.0 | 0.1 | 0.8 | 2.3 | 0.4 |
| Thornyhead rockfish | 0.2 | 0.1 | 0.1 | 1.8 | 0.5 |
| Atka mackerel | 0.1 | 0.0 | 0.4 | 0.1 | 0.2 |
| *Percent non-pollock* | *6.6%* | *5.1%* | *6.0%* | *5.9%* | *3.5%* |

| *Non target species/species group* | *2008* | *2009* | *2010* | *2011* | *2012* |
|---|---|---|---|---|---|
| Eulachon | 762.23 | 214.65 | 226.88 | 308.83 | 193.81 |
| Other osmerids | 401.88 | 146.33 | 6.78 | 78.60 | 88.45 |
| Jellyfish | 193.72 | 11.31 | 121.72 | 7.69 | 132.49 |
| Giant Grenadier | 217.09 | 26.30 | 1.93 | 109.32 | 15.76 |
| Misc fish | 35.36 | 42.07 | 42.38 | 43.47 | 49.89 |
| Grenadier | 26.81 | 0.00 | 9.23 | 7.98 | 70.89 |
| Sea star | 6.44 | 0.00 | 4.74 | 3.63 | 0.75 |
| Capelin | 0.00 | 0.01 | 0.00 | 7.94 | 0.02 |
| Pandalid shrimp | 0.83 | 0.17 | 1.12 | 0.12 | 0.07 |
| Sea anemone unidentified | 0.26 | 0.00 | 0.47 | 0.55 | 0.00 |
| Snails | 0.33 | 0.01 | 0.00 | 0.06 | 0.01 |
| Hermit crab unidentified | 0.01 | 0.00 | 0.09 | 0.00 | 0.14 |
| Eelpouts | 0.00 | 0.13 | 0.09 | 0.00 | 0.01 |
| Miscellaneous crabs | 0.07 | 0.00 | 0.01 | 0.11 | 0.00 |
| Surf smelt | 0.16 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bivalves | 0.05 | 0.00 | 0.05 | 0.04 | 0.00 |
| Stichaeidae | 0.00 | 0.00 | 0.07 | 0.00 | 0.07 |
| Urochordata | 0.00 | 0.00 | 0.00 | 0.09 | 0.02 |
| Sea urchins, sand dollars, sea cucumbers | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
| Brittle star unidentified | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 1.3. Bycatch of prohibited species for trawls where pollock was the predominant species in the catch in the Gulf of Alaska during 2008-2012. Herring and halibut bycatch is reported in metric tons, while crab and salmon are reported in number of fish.

| *Species/species group* | *2008* | *2009* | *2010* | *2011* | *2012* |
|---|---|---|---|---|---|
| Bairdi Tanner Crab (nos.) | 1,740 | 6,633 | 108 | 10,035 | 727 |
| Blue King Crab (nos.) | 0 | 0 | 0 | 0 | 0 |
| Chinook Salmon (nos.) | 10,633 | 3,195 | 44,808 | 14,787 | 18,851 |
| Golden (Brown) King Crab (nos.) | 0 | 0 | 0 | 0 | 0 |
| Halibut (t) | 118.9 | 63.6 | 49.2 | 191.6 | 94.5 |
| Herring (t) | 0.9 | 8.1 | 0.9 | 10.7 | 1.3 |
| Non-Chinook Salmon (nos.) | 847 | 333 | 752 | 1247 | 283 |
| Opilio Tanner (Snow) Crab (nos.) | 0 | 0 | 0 | 0 | 0 |
| Red King Crab (nos.) | 0 | 0 | 0 | 0 | 0 |

Table 1.4. Catch (retained and discarded) of walleye pollock (t) by management area in the Gulf of Alaska during 2002-2012 compiled by the Alaska Regional Office.

| *Year* | *Utilization* | *Shumagin 610* | *Chirikof 620* | *Kodiak 630* | *West Yakutat 640* | *Prince William Sound 649 (state waters)* | *Southeast and East Yakutat 650 & 659* | *Total* | *Percent discard* |
|---|---|---|---|---|---|---|---|---|---|
| 2002 | Retained | 17,046 | 20,106 | 10,615 | 1,808 | 1,216 | 0 | 50,791 | |
| | Discarded | 416 | 425 | 287 | 10 | 6 | 2 | 1,146 | 2.2% |
| | Total | 17,462 | 20,531 | 10,902 | 1,818 | 1,222 | 2 | 51,937 | |
| 2003 | Retained | 16,347 | 18,972 | 12,225 | 940 | 1,118 | 0 | 49,603 | |
| | Discarded | 161 | 658 | 210 | 2 | 31 | 0 | 1,063 | 2.1% |
| | Total | 16,508 | 19,630 | 12,435 | 943 | 1,149 | 0 | 50,666 | |
| 2004 | Retained | 23,226 | 24,221 | 13,896 | 215 | 1,100 | 0 | 62,658 | |
| | Discarded | 342 | 438 | 459 | 11 | 26 | 0 | 1,276 | 2.0% |
| | Total | 23,568 | 24,659 | 14,355 | 226 | 1,127 | 0 | 63,934 | |
| 2005 | Retained | 30,791 | 27,286 | 18,986 | 1,876 | 740 | 0 | 79,680 | |
| | Discarded | 136 | 621 | 350 | 9 | 50 | 0 | 1,166 | 1.4% |
| | Total | 30,927 | 27,908 | 19,336 | 1,885 | 790 | 0 | 80,846 | |
| 2006 | Retained | 24,489 | 26,409 | 16,127 | 1,570 | 1,475 | 0 | 70,070 | |
| | Discarded | 203 | 750 | 951 | 2 | 1 | 0 | 1,906 | 2.6% |
| | Total | 24,691 | 27,159 | 17,078 | 1,572 | 1,476 | 0 | 71,976 | |
| 2007 | Retained | 17,694 | 18,846 | 13,777 | 84 | NA | 0 | 50,401 | |
| | Discarded | 262 | 516 | 701 | 3 | NA | 1 | 1,483 | 2.8% |
| | Total | 17,956 | 19,362 | 14,478 | 87 | 1,179 | 1 | 53,062 | |
| 2008 | Retained | 15,100 | 18,691 | 13,335 | 1,155 | NA | 0 | 48,281 | |
| | Discarded | 2,157 | 367 | 1,052 | 6 | NA | 2 | 3,584 | 6.8% |
| | Total | 17,257 | 19,058 | 14,387 | 1,161 | 635 | 2 | 52,500 | |
| 2009 | Retained | 14,475 | 13,579 | 10,974 | 1,190 | NA | 0 | 40,219 | |
| | Discarded | 461 | 421 | 1,263 | 31 | NA | 0 | 2,177 | 4.9% |
| | Total | 14,936 | 14,000 | 12,238 | 1,221 | 1,608 | 0 | 44,003 | |
| 2010 | Retained | 25,960 | 28,015 | 18,373 | 1,625 | 1,660 | 2 | 75,635 | |
| | Discarded | 91 | 330 | 783 | 12 | 9 | 1 | 1,226 | 1.6% |
| | Total | 26,051 | 28,345 | 19,156 | 1,637 | 1,669 | 3 | 76,860 | |
| 2011 | Retained | 20,472 | 36,072 | 19,014 | 2,268 | 1,535 | 0 | 79,360 | |
| | Discarded | 122 | 1,110 | 710 | 3 | 1 | 0 | 1,946 | 2.4% |
| | Total | 20,594 | 37,183 | 19,724 | 2,271 | 1,536 | 0 | 81,307 | |
| 2012 | Retained | 27,355 | 44,578 | 25,107 | 2,353 | 2,622 | 0 | 102,014 | |
| | Discarded | 538 | 499 | 907 | 28 | 5 | 0 | 1,978 | 1.9% |
| | Total | 27,893 | 45,077 | 26,014 | 2,381 | 2,627 | 0 | 103,991 | |
| *Average (2002-2012)* | | 21,622 | 25,719 | 16,373 | 1,382 | 1,365 | 1 | 66,462 | |

Table 1.5. Catch at age (millions) of walleye pollock in the Gulf of Alaska in 1976-2012.

| | Age | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Year* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *Total* |
| 1976 | 0.00 | 1.91 | 24.21 | 108.69 | 39.08 | 16.37 | 3.52 | 2.25 | 1.91 | 0.31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 198.25 |
| 1977 | 0.01 | 2.76 | 7.06 | 23.83 | 89.68 | 30.35 | 8.33 | 2.13 | 1.79 | 0.67 | 0.44 | 0.10 | 0.02 | 0.00 | 0.00 | 167.17 |
| 1978 | 0.08 | 12.11 | 48.32 | 18.26 | 26.39 | 51.86 | 12.83 | 4.18 | 1.36 | 1.04 | 0.32 | 0.04 | 0.01 | 0.00 | 0.00 | 176.80 |
| 1979 | 0.00 | 2.53 | 48.83 | 76.37 | 14.15 | 10.13 | 16.70 | 5.02 | 1.27 | 0.60 | 0.16 | 0.04 | 0.00 | 0.00 | 0.00 | 175.81 |
| 1980 | 0.25 | 19.01 | 26.50 | 58.31 | 36.63 | 11.31 | 8.61 | 8.00 | 3.89 | 1.11 | 0.50 | 0.21 | 0.08 | 0.03 | 0.00 | 174.42 |
| 1981 | 0.14 | 2.59 | 31.55 | 73.91 | 47.97 | 20.29 | 4.87 | 4.83 | 2.73 | 0.26 | 0.03 | 0.02 | 0.00 | 0.00 | 0.00 | 189.19 |
| 1982 | 0.01 | 10.67 | 55.55 | 100.77 | 71.73 | 54.25 | 10.46 | 1.33 | 0.93 | 0.55 | 0.03 | 0.02 | 0.02 | 0.00 | 0.00 | 306.31 |
| 1983 | 0.00 | 3.64 | 20.64 | 110.03 | 137.31 | 67.41 | 42.01 | 7.38 | 1.24 | 0.06 | 0.28 | 0.07 | 0.00 | 0.00 | 0.00 | 390.07 |
| 1984 | 0.34 | 2.37 | 33.00 | 38.80 | 120.80 | 170.72 | 62.55 | 19.31 | 5.42 | 0.10 | 0.07 | 0.03 | 0.03 | 0.00 | 0.00 | 453.54 |
| 1985 | 0.04 | 12.74 | 5.53 | 33.22 | 42.22 | 86.02 | 128.95 | 41.19 | 10.84 | 2.20 | 0.70 | 0.00 | 0.00 | 0.00 | 0.00 | 363.64 |
| 1986 | 0.66 | 8.63 | 20.34 | 10.12 | 19.13 | 7.32 | 8.70 | 9.78 | 2.13 | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 87.59 |
| 1987 | 0.00 | 8.83 | 14.03 | 8.00 | 6.89 | 6.44 | 7.18 | 4.19 | 9.95 | 1.94 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 67.44 |
| 1988 | 0.17 | 3.05 | 20.80 | 26.95 | 11.94 | 5.10 | 3.45 | 1.62 | 0.34 | 3.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 76.62 |
| 1989 | 1.08 | 0.27 | 1.47 | 19.39 | 28.89 | 16.96 | 8.09 | 4.76 | 1.69 | 1.10 | 3.62 | 0.43 | 0.01 | 0.00 | 0.00 | 87.77 |
| 1990 | 0.00 | 2.77 | 2.40 | 2.99 | 9.49 | 40.39 | 13.06 | 4.90 | 1.08 | 0.41 | 0.01 | 0.56 | 0.01 | 0.07 | 0.06 | 78.20 |
| 1991 | 0.00 | 0.59 | 9.68 | 5.45 | 2.85 | 5.33 | 26.67 | 3.12 | 16.10 | 0.87 | 5.65 | 0.42 | 2.19 | 0.21 | 0.77 | 79.90 |
| 1992 | 0.05 | 3.25 | 5.57 | 50.61 | 14.13 | 4.02 | 8.77 | 19.55 | 1.02 | 1.49 | 0.20 | 0.73 | 0.00 | 0.00 | 0.00 | 109.41 |
| 1993 | 0.02 | 1.97 | 9.43 | 21.83 | 47.46 | 15.72 | 6.55 | 6.29 | 8.52 | 1.81 | 2.07 | 0.49 | 0.72 | 0.13 | 0.24 | 123.25 |
| 1994 | 0.06 | 1.26 | 4.49 | 9.63 | 35.92 | 31.32 | 12.20 | 4.84 | 4.60 | 6.15 | 1.44 | 1.02 | 0.29 | 0.09 | 0.08 | 113.37 |
| 1995 | 0.00 | 0.06 | 1.01 | 5.11 | 11.52 | 25.83 | 12.09 | 2.99 | 1.52 | 2.00 | 1.82 | 0.19 | 0.28 | 0.03 | 0.15 | 64.61 |
| 1996 | 0.00 | 1.27 | 1.37 | 1.12 | 3.50 | 5.11 | 12.87 | 10.60 | 3.14 | 1.53 | 0.80 | 1.43 | 0.35 | 0.23 | 0.16 | 43.48 |
| 1997 | 0.00 | 1.07 | 6.72 | 3.77 | 3.28 | 6.60 | 10.09 | 16.52 | 12.24 | 5.06 | 2.06 | 0.79 | 0.54 | 0.17 | 0.02 | 68.92 |
| 1998 | 0.31 | 0.27 | 26.44 | 36.44 | 15.06 | 6.65 | 7.50 | 11.36 | 14.96 | 10.76 | 3.75 | 0.75 | 0.38 | 0.21 | 0.11 | 134.95 |
| 1999 | 0.00 | 0.42 | 2.21 | 22.74 | 36.10 | 8.99 | 6.89 | 3.72 | 5.71 | 7.27 | 4.01 | 1.07 | 0.56 | 0.12 | 0.10 | 99.92 |
| 2000 | 0.08 | 0.98 | 2.84 | 3.47 | 14.65 | 24.63 | 6.24 | 5.05 | 2.30 | 1.24 | 3.00 | 1.52 | 0.30 | 0.14 | 0.04 | 66.48 |
| 2001 | 0.74 | 10.13 | 6.59 | 7.34 | 9.42 | 12.59 | 14.44 | 4.73 | 2.70 | 1.35 | 0.65 | 0.83 | 0.61 | 0.00 | 0.04 | 72.14 |
| 2002 | 0.16 | 12.31 | 20.72 | 6.76 | 4.47 | 8.75 | 5.37 | 6.06 | 1.33 | 0.82 | 0.43 | 0.30 | 0.33 | 0.22 | 0.13 | 68.16 |
| 2003 | 0.14 | 2.69 | 21.47 | 22.95 | 5.33 | 3.25 | 4.66 | 3.76 | 2.58 | 0.54 | 0.19 | 0.04 | 0.09 | 0.04 | 0.05 | 67.79 |
| 2004 | 0.85 | 6.28 | 11.91 | 31.84 | 25.09 | 5.98 | 2.43 | 2.63 | 0.77 | 0.22 | 0.25 | 0.00 | 0.00 | 0.00 | 0.00 | 88.24 |
| 2005 | 1.14 | 1.21 | 5.33 | 6.85 | 41.25 | 21.73 | 6.10 | 0.74 | 0.91 | 0.35 | 0.18 | 0.13 | 0.00 | 0.00 | 0.00 | 85.91 |
| 2006 | 2.20 | 7.79 | 4.16 | 2.75 | 5.97 | 27.38 | 12.80 | 2.45 | 0.83 | 0.46 | 0.23 | 0.10 | 0.07 | 0.03 | 0.00 | 67.22 |
| 2007 | 0.82 | 18.89 | 7.46 | 2.51 | 2.31 | 3.58 | 10.19 | 6.70 | 1.59 | 0.29 | 0.23 | 0.09 | 0.00 | 0.00 | 0.01 | 54.68 |
| 2008 | 0.32 | 6.29 | 21.94 | 6.76 | 2.15 | 1.16 | 2.27 | 5.60 | 2.84 | 0.87 | 0.36 | 0.21 | 0.06 | 0.04 | 0.02 | 50.89 |
| 2009 | 0.24 | 6.38 | 14.84 | 13.47 | 3.82 | 1.19 | 0.72 | 0.95 | 1.90 | 1.45 | 0.47 | 0.06 | 0.01 | 0.00 | 0.00 | 45.50 |
| 2010 | 0.01 | 5.29 | 23.35 | 21.32 | 18.14 | 3.68 | 1.11 | 0.73 | 0.92 | 1.02 | 0.64 | 0.05 | 0.06 | 0.01 | 0.00 | 76.31 |
| 2011 | 0.00 | 2.49 | 12.18 | 26.78 | 20.88 | 13.12 | 2.97 | 0.61 | 0.38 | 0.21 | 0.36 | 0.35 | 0.07 | 0.00 | 0.00 | 80.40 |
| 2012 | 0.03 | 0.66 | 4.64 | 13.49 | 29.83 | 21.43 | 8.94 | 1.95 | 0.43 | 0.18 | 0.23 | 0.16 | 0.04 | 0.07 | 0.08 | 82.15 |

Table 1.6. Number of aged and measured fish in the Gulf of Alaska pollock fishery used to estimate fishery age composition (1989-2012).

| | *Number aged* | | | *Number measured* | | |
|---|---|---|---|---|---|---|
| *Year* | *Males* | *Females* | *Total* | *Males* | *Females* | *Total* |
| 1989 | 882 | 892 | 1,774 | 6,454 | 6,456 | 12,910 |
| 1990 | 453 | 689 | 1,142 | 17,814 | 24,662 | 42,476 |
| 1991 | 1,146 | 1,322 | 2,468 | 23,946 | 39,467 | 63,413 |
| 1992 | 1,726 | 1,755 | 3,481 | 31,608 | 47,226 | 78,834 |
| 1993 | 926 | 949 | 1,875 | 28,035 | 31,306 | 59,341 |
| 1994 | 136 | 129 | 265 | 24,321 | 25,861 | 50,182 |
| 1995 | 499 | 544 | 1,043 | 10,591 | 10,869 | 21,460 |
| 1996 | 381 | 378 | 759 | 8,581 | 8,682 | 17,263 |
| 1997 | 496 | 486 | 982 | 8,750 | 8,808 | 17,558 |
| 1998 | 924 | 989 | 1,913 | 78,955 | 83,160 | 162,115 |
| 1999 | 980 | 1,115 | 2,095 | 16,304 | 17,964 | 34,268 |
| 2000 | 1,108 | 972 | 2,080 | 13,167 | 11,794 | 24,961 |
| 2001 | 1,063 | 1,025 | 2,088 | 13,731 | 13,552 | 27,283 |
| 2002 | 1,036 | 1,025 | 2,061 | 9,924 | 9,851 | 19,775 |
| 2003 | 1,091 | 1,119 | 2,210 | 8,375 | 8,220 | 16,595 |
| 2004 | 1,217 | 996 | 2,213 | 4,446 | 3,622 | 8,068 |
| 2005 | 1,065 | 968 | 2,033 | 6,837 | 6,005 | 12,842 |
| 2006 | 1,127 | 969 | 2,096 | 7,248 | 6,178 | 13,426 |
| 2007 | 998 | 1,064 | 2,062 | 4,504 | 5,064 | 9,568 |
| 2008 | 961 | 1,090 | 2,051 | 7,430 | 8,536 | 15,966 |
| 2009 | 1,011 | 1,034 | 2,045 | 9,913 | 9,447 | 19,360 |
| 2010 | 1,195 | 1,055 | 2,250 | 14,958 | 13,997 | 28,955 |
| 2011 | 1,197 | 1,025 | 2,222 | 9,625 | 11,023 | 20,648 |
| 2012 | 1,160 | 1,097 | 2,257 | 11,045 | 10,430 | 21,475 |

Table 1.7. Biomass estimates (t) of walleye pollock from acoustic surveys in Shelikof Strait, NMFS bottom trawl surveys (west of 140 W. long.), egg production surveys in Shelikof Strait, and ADFG crab/groundfish trawl surveys. An adjustment of +1.05% was made to the NMFS bottom trawl biomass time series to account for unsurveyed biomass in Prince William Sound. In 2001, when the NMFS bottom trawl survey did not extend east of 147° W lon., an expansion factor of 2.7% derived from previous surveys was used for West Yakutat.

| | *Shelikof Strait acoustic survey* | | | | | |
|---|---|---|---|---|---|---|
| | *R/V Miller Freeman* | | *R/V Oscar* | *NMFS bottom trawl west of* | *Shelikof Strait egg* | *ADFG crab/groundfish* |
| *Year* | *Biosonics* | *EK500* | *Dyson* | *140° W lon.* | *production* | *survey* |
| 1981 | 2,785,755 | | | | 1,788,908 | |
| 1982 | | | | | | |
| 1983 | 2,278,172 | | | | | |
| 1984 | 1,757,168 | | | 720,548 | | |
| 1985 | 1,175,823 | | | | 768,419 | |
| 1986 | 585,755 | | | | 375,907 | |
| 1987 | | | | 732,660 | 484,455 | |
| 1988 | 301,709 | | | | 504,418 | |
| 1989 | 290,461 | | | | 433,894 | 214,434 |
| 1990 | 374,731 | | | 825,609 | 381,475 | 114,451 |
| 1991 | 380,331 | | | | 370,000 | |
| 1992 | | 713,429 | | | 616,000 | 127,359 |
| 1993 | | 435,753 | | 755,786 | | 132,849 |
| 1994 | | 492,593 | | | | 103,420 |
| 1995 | | 763,612 | | | | |
| 1996 | | 777,172 | | 666,521 | | 122,477 |
| 1997 | | 583,017 | | | | 93,728 |
| 1998 | | 504,774 | | | | 81,215 |
| 1999 | | | | 607,409 | | 53,587 |
| 2000 | | 448,638 | | | | 102,871 |
| 2001 | | 432,749 | | 219,072 | | 86,967 |
| 2002 | | 256,743 | | | | 96,237 |
| 2003 | | 317,269 | | 398,469 | | 66,989 |
| 2004 | | 330,753 | | | | 99,358 |
| 2005 | | 356,117 | | 358,017 | | 79,089 |
| 2006 | | 293,609 | | | | 69,044 |
| 2007 | | 180,881 | | 282,356 | | 76,674 |
| 2008 | | | 208,032 | | | 83,476 |
| 2009 | | | 265,971 | 669,505 | | 145,438 |
| 2010 | | | 429,730 | | | 124,110 |
| 2011 | | | | 667,131 | | 100,839 |
| 2012 | | | 335,836 | | | 172,007 |
| 2013 | | | 891,261 | 957,817 | | 102,406 |

Table 1.8. Survey sampling effort and biomass coefficients of variation (CV) for pollock in the NMFS bottom trawl survey. The number of measured pollock is approximate due to subsample expansions in the database. The total number measured includes both sexed and unsexed fish. Ages for the 2013 are not yet available.

| *Year* | *No. of tows* | *No. of tows with pollock* | *Survey biomass CV* | *Number aged* | | | *Number measured* | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Males* | *Females* | *Total* | *Males* | *Females* | *Total* |
| 1984 | 929 | 536 | 0.14 | 1,119 | 1,394 | 2,513 | 8,985 | 13,286 | 25,990 |
| 1987 | 783 | 533 | 0.20 | 672 | 675 | 1,347 | 15,843 | 18,101 | 34,797 |
| 1990 | 708 | 549 | 0.12 | 503 | 560 | 1,063 | 15,014 | 20,053 | 42,631 |
| 1993 | 775 | 628 | 0.16 | 879 | 1,013 | 1,892 | 14,681 | 18,851 | 35,219 |
| 1996 | 807 | 668 | 0.15 | 509 | 560 | 1,069 | 17,698 | 19,555 | 46,668 |
| 1999 | 764 | 567 | 0.38 | 560 | 613 | 1,173 | 10,808 | 11,314 | 24,080 |
| 2001 | 489 | 302 | 0.30 | 395 | 519 | 914 | 9,135 | 10,281 | 20,272 |
| 2003 | 807 | 508 | 0.12 | 514 | 589 | 1,103 | 10,561 | 12,706 | 25,052 |
| 2005 | 839 | 516 | 0.15 | 639 | 868 | 1,507 | 9,108 | 10,893 | 27,114 |
| 2007 | 820 | 554 | 0.14 | 646 | 675 | 1,321 | 10,018 | 11,638 | 24,768 |
| 2009 | 823 | 563 | 0.15 | 684 | 870 | 1,554 | 13,084 | 14,697 | 30,876 |
| 2011 | 670 | 492 | 0.15 | 705 | 941 | 1,646 | 11,852 | 13,832 | 27,327 |
| 2013 | 548 | 439 | 0.21 | NA | NA | NA | 14,941 | 16,680 | 31,880 |

Table 1.9. Estimated number at age (millions) from the NMFS bottom trawl survey. Estimates are for the Western and Central Gulf of Alaska only (Management areas 610-630). Estimates are not available for the 2013 survey.

| *Year* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *Total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1984 | 0.93 | 10.02 | 67.81 | 155.78 | 261.17 | 474.57 | 145.10 | 24.80 | 16.59 | 1.66 | 0.21 | 1.32 | 0.00 | 0.00 | 0.00 | 1159.96 |
| 1987 | 25.45 | 363.02 | 172.99 | 138.97 | 91.13 | 168.27 | 78.14 | 43.99 | 175.39 | 22.41 | 7.81 | 3.51 | 1.82 | 0.00 | 0.00 | 1292.88 |
| 1989 | 208.88 | 63.49 | 47.56 | 243.15 | 301.09 | 104.43 | 54.47 | 28.39 | 26.14 | 5.98 | 10.66 | 0.00 | 0.00 | 0.00 | 0.00 | 1094.23 |
| 1990 | 64.04 | 251.21 | 48.34 | 46.68 | 209.77 | 240.82 | 74.41 | 110.41 | 26.13 | 34.23 | 5.03 | 27.73 | 5.70 | 1.07 | 1.63 | 1147.19 |
| 1993 | 139.31 | 71.15 | 50.94 | 182.96 | 267.12 | 91.51 | 33.12 | 68.98 | 76.62 | 26.36 | 11.85 | 6.29 | 3.82 | 1.82 | 4.41 | 1036.25 |
| 1996 | 194.23 | 128.79 | 17.30 | 26.13 | 50.04 | 63.18 | 174.41 | 87.62 | 52.37 | 27.73 | 12.10 | 18.46 | 7.16 | 9.68 | 19.70 | 888.90 |
| 1999 | 109.73 | 19.17 | 20.94 | 66.76 | 118.94 | 56.80 | 59.04 | 47.71 | 56.40 | 81.97 | 65.18 | 9.67 | 8.28 | 2.50 | 0.76 | 723.85 |
| 2001 | 412.83 | 117.03 | 34.42 | 33.39 | 25.05 | 33.45 | 37.01 | 8.20 | 5.74 | 0.59 | 4.48 | 2.52 | 1.28 | 0.00 | 0.18 | 716.19 |
| 2003 | 75.46 | 18.40 | 128.41 | 140.74 | 73.27 | 44.72 | 36.10 | 25.27 | 14.51 | 8.61 | 3.23 | 1.79 | 1.26 | 0.00 | 0.00 | 571.77 |
| 2005 | 270.37 | 33.72 | 34.41 | 35.86 | 91.78 | 78.82 | 45.24 | 20.86 | 9.61 | 9.98 | 4.81 | 0.57 | 0.64 | 0.00 | 0.00 | 636.68 |
| 2007 | 174.01 | 95.96 | 88.59 | 37.11 | 19.23 | 18.90 | 54.98 | 31.11 | 6.64 | 3.04 | 2.78 | 1.00 | 1.13 | 0.00 | 0.00 | 534.48 |
| 2009 | 222.94 | 87.33 | 106.82 | 129.35 | 101.26 | 27.21 | 17.59 | 26.60 | 53.90 | 29.46 | 9.68 | 7.00 | 2.78 | 1.61 | 0.00 | 823.53 |
| 2011 | 249.43 | 96.71 | 110.68 | 101.79 | 163.62 | 107.99 | 33.24 | 7.14 | 5.69 | 8.61 | 19.29 | 6.62 | 0.00 | 0.00 | 0.55 | 911.36 |

Table 1.10. Estimated number at age (millions) for the acoustic survey in Shelikof Strait. For the acoustic survey in 1987, when total abundance could not be estimated, the percent at age is given.

| *Year* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *Total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 77.65 | 3,481.18 | 1,510.77 | 769.16 | 2,785.91 | 1,051.92 | 209.93 | 128.52 | 79.43 | 25.19 | 1.73 | 0.00 | 0.00 | 0.00 | 0.00 | 10,121.37 |
| 1983 | 1.21 | 901.77 | 380.19 | 1,296.79 | 1,170.81 | 698.13 | 598.78 | 131.54 | 14.48 | 11.61 | 3.92 | 1.71 | 0.00 | 0.00 | 0.00 | 5,210.93 |
| 1984 | 61.65 | 58.25 | 324.49 | 141.66 | 635.04 | 988.21 | 449.62 | 224.35 | 41.03 | 2.74 | 0.00 | 1.02 | 0.00 | 0.00 | 0.00 | 2,928.07 |
| 1985 | 2,091.74 | 544.44 | 122.69 | 314.77 | 180.53 | 347.17 | 439.31 | 166.68 | 42.72 | 5.56 | 1.77 | 1.29 | 0.00 | 0.00 | 0.00 | 4,258.67 |
| 1986 | 575.36 | 2,114.83 | 183.62 | 45.63 | 75.36 | 49.34 | 86.15 | 149.36 | 60.22 | 10.62 | 1.29 | 0.00 | 0.00 | 0.00 | 0.00 | 3,351.78 |
| 1987 | 7.5% | 25.5% | 55.8% | 2.9% | 1.7% | 1.2% | 1.6% | 1.2% | 2.1% | 0.4% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| 1988 | 17.44 | 109.93 | 694.32 | 322.11 | 77.57 | 16.99 | 5.70 | 5.60 | 3.98 | 8.96 | 1.78 | 1.84 | 0.20 | 0.00 | 0.00 | 1,266.41 |
| 1989 | 399.48 | 89.52 | 90.01 | 222.05 | 248.69 | 39.41 | 11.75 | 3.83 | 1.89 | 0.55 | 10.66 | 1.42 | 0.00 | 0.00 | 0.00 | 1,119.25 |
| 1990 | 49.14 | 1,210.17 | 71.69 | 63.37 | 115.92 | 180.06 | 46.33 | 22.44 | 8.20 | 8.21 | 0.93 | 3.08 | 1.51 | 0.79 | 0.24 | 1,782.08 |
| 1991 | 21.98 | 173.65 | 549.90 | 48.11 | 64.87 | 69.60 | 116.32 | 23.65 | 29.43 | 2.23 | 4.29 | 0.92 | 4.38 | 0.00 | 0.00 | 1,109.32 |
| 1992 | 228.03 | 33.69 | 73.54 | 188.10 | 367.99 | 84.11 | 84.99 | 171.18 | 32.70 | 56.35 | 2.30 | 14.67 | 0.90 | 0.30 | 0.00 | 1,338.85 |
| 1993 | 63.29 | 76.08 | 37.05 | 72.39 | 232.79 | 126.19 | 26.77 | 35.63 | 38.72 | 16.12 | 7.77 | 2.60 | 2.19 | 0.49 | 1.51 | 739.61 |
| 1994 | 185.98 | 35.77 | 49.30 | 31.75 | 155.03 | 83.58 | 42.48 | 27.23 | 44.45 | 48.46 | 14.79 | 6.65 | 1.12 | 2.34 | 0.57 | 729.49 |
| 1995 | 10,689.87 | 510.37 | 79.37 | 77.70 | 103.33 | 245.23 | 121.72 | 53.57 | 16.63 | 10.72 | 14.57 | 5.81 | 2.12 | 0.44 | 0.00 | 11,931.45 |
| 1996 | 56.14 | 3,307.21 | 118.94 | 25.12 | 53.99 | 71.03 | 201.05 | 118.52 | 39.80 | 13.01 | 11.32 | 5.32 | 2.52 | 0.03 | 0.38 | 4,024.36 |
| 1997 | 70.37 | 183.14 | 1,246.55 | 80.06 | 18.42 | 44.04 | 51.73 | 97.55 | 52.73 | 14.29 | 2.40 | 3.05 | 0.93 | 0.46 | 0.00 | 1,865.72 |
| 1998 | 395.47 | 88.54 | 125.57 | 474.36 | 136.12 | 14.22 | 31.93 | 36.30 | 74.08 | 25.90 | 14.30 | 6.88 | 0.27 | 0.56 | 0.56 | 1,425.05 |
| 2000 | 4,484.41 | 755.03 | 216.52 | 15.83 | 67.19 | 131.64 | 16.82 | 12.61 | 9.87 | 7.84 | 13.87 | 6.88 | 1.88 | 1.06 | 0.00 | 5,741.46 |
| 2001 | 288.93 | 4,103.95 | 351.74 | 61.02 | 41.55 | 22.99 | 34.63 | 13.07 | 6.20 | 2.67 | 1.20 | 1.91 | 0.69 | 0.50 | 0.24 | 4,931.27 |
| 2002 | 8.11 | 162.61 | 1,107.17 | 96.58 | 16.25 | 16.14 | 7.70 | 6.79 | 1.46 | 0.66 | 0.35 | 0.34 | 0.15 | 0.13 | 0.00 | 1,424.45 |
| 2003 | 51.19 | 89.58 | 207.69 | 802.46 | 56.58 | 7.69 | 4.14 | 1.58 | 1.46 | 0.85 | 0.28 | 0.00 | 0.10 | 0.00 | 0.00 | 1,223.60 |
| 2004 | 52.58 | 93.94 | 57.58 | 159.62 | 356.33 | 48.78 | 2.67 | 3.42 | 3.32 | 0.52 | 0.42 | 0.00 | 0.66 | 0.00 | 0.00 | 779.84 |
| 2005 | 1,626.13 | 157.49 | 55.54 | 34.63 | 172.74 | 162.40 | 36.02 | 3.61 | 2.39 | 0.00 | 0.76 | 0.00 | 0.00 | 0.00 | 0.00 | 2,251.71 |
| 2006 | 161.69 | 835.96 | 40.75 | 11.54 | 17.42 | 55.98 | 74.97 | 32.25 | 6.90 | 0.83 | 0.75 | 0.53 | 0.00 | 0.00 | 0.00 | 1,239.57 |
| 2007 | 53.54 | 231.73 | 174.88 | 29.66 | 10.14 | 17.27 | 34.39 | 20.85 | 1.54 | 1.05 | 0.69 | 0.00 | 0.00 | 0.00 | 0.00 | 575.74 |
| 2008 | 1,368.02 | 391.20 | 249.56 | 53.18 | 12.01 | 2.16 | 4.07 | 10.66 | 6.69 | 2.01 | 0.53 | 0.00 | 0.00 | 0.00 | 0.00 | 2,100.10 |
| 2009 | 331.94 | 1,204.50 | 110.22 | 98.69 | 60.21 | 9.91 | 2.90 | 0.86 | 5.07 | 6.13 | 1.37 | 0.24 | 0.00 | 0.00 | 0.00 | 1,832.03 |
| 2010 | 90.04 | 305.57 | 531.65 | 84.46 | 78.93 | 28.52 | 11.78 | 5.46 | 5.25 | 10.82 | 9.36 | 3.45 | 0.00 | 0.00 | 0.00 | 1,165.29 |
| 2012 | 94.94 | 851.52 | 43.49 | 76.89 | 95.78 | 46.24 | 29.21 | 4.49 | 1.14 | 0.27 | 0.09 | 0.53 | 0.00 | 0.00 | 0.00 | 1,244.57 |
| 2013 | 6,324.25 | 149.42 | 803.34 | 60.86 | 68.82 | 114.18 | 65.16 | 49.14 | 11.92 | 5.40 | 5.74 | 0.61 | 1.69 | 4.82 | 2.61 | 7,667.95 |

Table 1.11. Survey sampling effort and estimation uncertainty for pollock in the Shelikof Strait acoustic survey. Survey CVs based on a cluster sampling design are reported for 1981-91, while relative estimation error using a geostatistical method are reported for 1992-2013.

| Year | No. of midwater tows | No. of bottom trawl tows | Survey biomass CV | Number aged Males | Number aged Females | Number aged Total | Number measured Males | Number measured Females | Number measured Total |
|---|---|---|---|---|---|---|---|---|---|
| 1981 | 38 | 13 | 0.12 | 1,921 | 1,815 | 3,736 | NA | NA | NA |
| 1983 | 40 | 0 | 0.16 | 1,642 | 1,103 | 2,745 | NA | NA | NA |
| 1984 | 45 | 0 | 0.18 | 1,739 | 1,622 | 3,361 | NA | NA | NA |
| 1985 | 57 | 0 | 0.14 | 1,055 | 1,187 | 2,242 | NA | NA | NA |
| 1986 | 39 | 0 | 0.22 | 642 | 618 | 1,260 | NA | NA | NA |
| 1987 | 27 | 0 | --- | 557 | 643 | 1,200 | NA | NA | NA |
| 1988 | 26 | 0 | 0.17 | 537 | 464 | 1,001 | NA | NA | NA |
| 1989 | 21 | 0 | 0.10 | 582 | 545 | 1,127 | NA | NA | NA |
| 1990 | 28 | 13 | 0.17 | 1,034 | 1,181 | 2,215 | NA | NA | NA |
| 1991 | 16 | 2 | 0.35 | 468 | 567 | 1,035 | NA | NA | NA |
| 1992 | 17 | 8 | 0.04 | 784 | 765 | 1,549 | NA | NA | NA |
| 1993 | 22 | 2 | 0.05 | 583 | 624 | 1,207 | NA | NA | NA |
| 1994 | 44 | 9 | 0.05 | 553 | 632 | 1,185 | NA | NA | NA |
| 1995 | 22 | 3 | 0.05 | 599 | 575 | 1,174 | NA | NA | NA |
| 1996 | 30 | 8 | 0.04 | 724 | 775 | 1,499 | NA | NA | NA |
| 1997 | 16 | 14 | 0.04 | 682 | 853 | 1,535 | 5,380 | 6,104 | 11,484 |
| 1998 | 22 | 9 | 0.04 | 863 | 784 | 1,647 | 5,487 | 4,946 | 10,433 |
| 2000 | 31 | 0 | 0.05 | 422 | 363 | 785 | 6,007 | 5,196 | 11,203 |
| 2001 | 17 | 9 | 0.05 | 314 | 378 | 692 | 4,531 | 4,584 | 9,115 |
| 2002 | 18 | 1 | 0.07 | 278 | 326 | 604 | 2,876 | 2,871 | 5,747 |
| 2003 | 17 | 2 | 0.05 | 288 | 321 | 609 | 3,554 | 3,724 | 7,278 |
| 2004 | 13 | 2 | 0.09 | 492 | 440 | 932 | 3,838 | 2,552 | 6,390 |
| 2005 | 22 | 1 | 0.04 | 543 | 335 | 878 | 2,714 | 2,094 | 4,808 |
| 2006 | 17 | 2 | 0.04 | 295 | 487 | 782 | 2,527 | 3,026 | 5,553 |
| 2007 | 9 | 1 | 0.06 | 335 | 338 | 673 | 2,145 | 2,194 | 4,339 |
| 2008 | 10 | 2 | 0.06 | 171 | 248 | 419 | 1,641 | 1,675 | 3,316 |
| 2009 | 9 | 3 | 0.06 | 254 | 301 | 555 | 1,583 | 1,632 | 3,215 |
| 2010 | 13 | 2 | 0.03 | 286 | 244 | 530 | 2,590 | 2,358 | 4,948 |
| 2012 | 8 | 3 | 0.08 | 235 | 372 | 607 | 1,727 | 1,989 | 3,716 |
| 2013 | 29 | 5 | 0.05 | 376 | 386 | 778 | 2,198 | 2,436 | 8,158 |

Table 1.12. Predictions of Gulf of Alaska pollock year-class strength. The McKelvey index is the estimated abundance of 9-16 cm pollock (billions) from the Shelikof Strait acoustic survey.

| *Year class* | *Year of acoustic survey* | *McKelvey index* | *Rank abundance of McKelvey index* |
|---|---|---|---|
| 1980 | 1981 | 0.078 | 17 |
| 1981 | | | |
| 1982 | 1983 | 0.001 | 29 |
| 1983 | 1984 | 0.062 | 20 |
| 1984 | 1985 | 2.092 | 4 |
| 1985 | 1986 | 0.579 | 7 |
| 1986 | | | |
| 1987 | 1988 | 0.017 | 27 |
| 1988 | 1989 | 0.399 | 8 |
| 1989 | 1990 | 0.049 | 25 |
| 1990 | 1991 | 0.022 | 26 |
| 1991 | 1992 | 0.228 | 12 |
| 1992 | 1993 | 0.063 | 19 |
| 1993 | 1994 | 0.186 | 13 |
| 1994 | 1995 | 10.688 | 1 |
| 1995 | 1996 | 0.061 | 21 |
| 1996 | 1997 | 0.070 | 18 |
| 1997 | 1998 | 0.395 | 9 |
| 1998 | | | |
| 1999 | 2000 | 4.484 | 3 |
| 2000 | 2001 | 0.291 | 11 |
| 2001 | 2002 | 0.008 | 28 |
| 2002 | 2003 | 0.051 | 24 |
| 2003 | 2004 | 0.053 | 23 |
| 2004 | 2005 | 1.626 | 5 |
| 2005 | 2006 | 0.162 | 14 |
| 2006 | 2007 | 0.054 | 22 |
| 2007 | 2008 | 1.368 | 6 |
| 2008 | 2009 | 0.332 | 10 |
| 2009 | 2010 | 0.090 | 16 |
| 2010 | | | |
| 2011 | 2012 | 0.095 | 15 |
| 2012 | 2013 | 6.324 | 2 |

Table 1.13. Ageing error transition matrix used in the Gulf of Alaska pollock assessment model.

| | | *Observed Age* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *True Age* | *St. dev.* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| 1 | 0.18 | 0.9970 | 0.0030 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2 | 0.23 | 0.0138 | 0.9724 | 0.0138 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | 0.27 | 0.0000 | 0.0329 | 0.9342 | 0.0329 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 0.32 | 0.0000 | 0.0000 | 0.0571 | 0.8858 | 0.0571 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 5 | 0.36 | 0.0000 | 0.0000 | 0.0000 | 0.0832 | 0.8335 | 0.0832 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6 | 0.41 | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.1090 | 0.7817 | 0.1090 | 0.0001 | 0.0000 | 0.0000 |
| 7 | 0.45 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.1333 | 0.7325 | 0.1333 | 0.0004 | 0.0000 |
| 8 | 0.50 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.1554 | 0.6868 | 0.1554 | 0.0012 |
| 9 | 0.54 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0028 | 0.1747 | 0.6450 | 0.1775 |
| 10 | 0.59 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0052 | 0.1913 | 0.8035 |

Table 1.14. Proportion mature at age for female pollock based on maturity stage data collected during winter acoustic surveys in the Gulf of Alaska (1983-2013).

| Year | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10+ | Sample size |
|---|---|---|---|---|---|---|---|---|---|---|
| 1983 | 0.000 | 0.165 | 0.798 | 0.960 | 0.974 | 0.983 | 0.943 | 1.000 | 1.000 | 1333 |
| 1984 | 0.000 | 0.145 | 0.688 | 0.959 | 0.990 | 1.000 | 0.992 | 1.000 | 1.000 | 1621 |
| 1985 | 0.015 | 0.051 | 0.424 | 0.520 | 0.929 | 0.992 | 0.992 | 1.000 | 1.000 | 1183 |
| 1986 | 0.000 | 0.021 | 0.105 | 0.849 | 0.902 | 0.959 | 1.000 | 1.000 | 1.000 | 618 |
| 1987 | 0.000 | 0.012 | 0.106 | 0.340 | 0.769 | 0.885 | 0.950 | 0.991 | 1.000 | 638 |
| 1988 | 0.000 | 0.000 | 0.209 | 0.176 | 0.606 | 0.667 | 1.000 | 0.857 | 0.964 | 464 |
| 1989 | 0.000 | 0.000 | 0.297 | 0.442 | 0.710 | 0.919 | 1.000 | 1.000 | 1.000 | 796 |
| 1990 | 0.000 | 0.000 | 0.192 | 0.674 | 0.755 | 0.910 | 0.945 | 0.967 | 0.996 | 1844 |
| 1991 | 0.000 | 0.000 | 0.111 | 0.082 | 0.567 | 0.802 | 0.864 | 0.978 | 1.000 | 628 |
| 1992 | 0.000 | 0.000 | 0.040 | 0.069 | 0.774 | 0.981 | 0.990 | 1.000 | 0.983 | 765 |
| 1993 | 0.000 | 0.016 | 0.120 | 0.465 | 0.429 | 0.804 | 0.968 | 1.000 | 0.985 | 624 |
| 1994 | 0.000 | 0.007 | 0.422 | 0.931 | 0.941 | 0.891 | 0.974 | 1.000 | 1.000 | 872 |
| 1995 | 0.000 | 0.000 | 0.153 | 0.716 | 0.967 | 0.978 | 0.921 | 0.917 | 0.977 | 805 |
| 1996 | 0.000 | 0.000 | 0.036 | 0.717 | 0.918 | 0.975 | 0.963 | 1.000 | 0.957 | 763 |
| 1997 | 0.000 | 0.000 | 0.241 | 0.760 | 1.000 | 1.000 | 0.996 | 1.000 | 1.000 | 843 |
| 1998 | 0.000 | 0.000 | 0.065 | 0.203 | 0.833 | 0.964 | 1.000 | 1.000 | 0.989 | 757 |
| 2000 | 0.000 | 0.012 | 0.125 | 0.632 | 0.780 | 0.579 | 0.846 | 1.000 | 0.923 | 356 |
| 2001 | 0.000 | 0.000 | 0.289 | 0.308 | 0.825 | 0.945 | 0.967 | 0.929 | 1.000 | 374 |
| 2002 | 0.000 | 0.026 | 0.259 | 0.750 | 0.933 | 0.974 | 1.000 | 1.000 | 1.000 | 499 |
| 2003 | 0.000 | 0.029 | 0.192 | 0.387 | 0.529 | 0.909 | 0.750 | 1.000 | 1.000 | 301 |
| 2004 | 0.000 | 0.000 | 0.558 | 0.680 | 0.745 | 0.667 | 1.000 | 1.000 | 1.000 | 444 |
| 2005 | 0.000 | 0.000 | 0.706 | 0.882 | 0.873 | 0.941 | 1.000 | 1.000 | 1.000 | 321 |
| 2006 | 0.000 | 0.000 | 0.043 | 0.483 | 0.947 | 0.951 | 0.986 | 1.000 | 1.000 | 476 |
| 2007 | 0.000 | 0.000 | 0.333 | 0.667 | 0.951 | 0.986 | 0.983 | 1.000 | 1.000 | 313 |
| 2008 | 0.000 | 0.000 | 0.102 | 0.241 | 0.833 | 1.000 | 0.968 | 0.952 | 1.000 | 240 |
| 2009 | 0.000 | 0.000 | 0.140 | 0.400 | 0.696 | 1.000 | 1.000 | 1.000 | 1.000 | 296 |
| 2010 | 0.000 | 0.000 | 0.357 | 0.810 | 0.929 | 1.000 | 1.000 | 1.000 | 1.000 | 314 |
| 2012 | 0.000 | 0.000 | 0.204 | 0.659 | 0.885 | 1.000 | 1.000 | 1.000 | 1.000 | 372 |
| 2013 | 0.000 | 0.000 | 0.240 | 0.896 | 0.941 | 0.950 | 0.939 | 1.000 | 1.000 | 622 |
| *Average* | | | | | | | | | | |
| *All years* | 0.001 | 0.017 | 0.260 | 0.574 | 0.825 | 0.918 | 0.963 | 0.986 | 0.992 | |
| *2003-2013* | 0.000 | 0.003 | 0.287 | 0.611 | 0.833 | 0.940 | 0.962 | 0.995 | 1.000 | |
| *2008-2013* | 0.000 | 0.000 | 0.209 | 0.601 | 0.857 | 0.990 | 0.981 | 0.990 | 1.000 | |

Table 1.15. Results comparing model fits, stock status, and 2014 yield for different model configurations.

| | *Last year* | *Model 0* | *Model 1* | *Model 1A* |
|---|---|---|---|---|
| **Model fits** | | | | |
| Total log(Likelihood) | -1049.71 | -1097.91 | -1037.14 | -1037.14 |
| Catch | -0.65 | -0.61 | -0.37 | -0.37 |
| Fishery age and length comp | -421.98 | -437.33 | -435.26 | -435.26 |
| Acoustic survey biomass | -98.01 | -106.97 | -77.37 | -77.37 |
| Acoustic survey age and length comp | -345.09 | -352.26 | -355.40 | -355.40 |
| Bottom trawl survey biomass | -30.65 | -31.26 | -20.87 | -20.87 |
| Bottom trawl survey age and length comp | -99.24 | -110.62 | -107.16 | -107.16 |
| ADFG trawl survey biomass | -10.31 | -9.22 | -8.47 | -8.47 |
| ADFG trawl survey age and length comp | -38.81 | -42.46 | -24.57 | -24.57 |
| Penalties | -4.96 | -7.17 | -7.66 | -7.66 |
| NMFS trawl q | 1.00 | 1.00 | 1.00 | 1.00 |
| Composition data | | | | |
| Fishery age comp. effective N | 108 | 111 | 108 | 108 |
| Shelikof Strait acoustic age comp. effective N | 22 | 24 | 26 | 26 |
| NMFS bottom trawl age comp. effective N | 40 | 37 | 38 | 38 |
| ADF&G trawl age and length comp. effective N | 38 | 35 | 34 | 34 |
| Survey abundance | | | | |
| Shelikof Strait Acoustic RMSE | | | | |
| Biosonics | 0.48 | 0.49 | 0.56 | 0.56 |
| EK500 | 0.36 | 0.36 | 0.35 | 0.35 |
| Dyson | 0.51 | 0.56 | 0.55 | 0.55 |
| NMFS bottom trawl RMSE | 0.36 | 0.36 | 0.31 | 0.31 |
| ADF&G trawl RMSE | 0.24 | 0.22 | 0.21 | 0.21 |
| **Stock status (t)** | | | | |
| 2014 Spawning biomass | 247,699 | 308,465 | 308,541 | 308,135 |
| (CV) | (10%) | (12%) | (11%) | (11%) |
| Depletion (B2014/B0) | 33% | 40% | 42% | 42% |
| $B_{40\%}$ | 296,519 | 308,975 | 290,460 | 290,460 |
| **2014 yield (000 t)** | | | | |
| Author's recommended ABC | 104.16 | 154.43 | 167.66 | 151.05 |
| MaxABC | 115.98 | 178.79 | 183.94 | 165.81 |

Model descriptions (see text for details):

Last year--2012 assessment model

Model 0--2012 assessment model updated with new fishery and survey data

Model 1--Revised model with limited changes

Model 1A--Revised model with limited changes AND 2012 year class set equal to the average for catch projections

Table 1.16. Estimated selectivity at age for Gulf of Alaska pollock fisheries and surveys. The fisheries and surveys were modeled using double logistic selectivity functions.

| *Age* | *POP fishery (1964-71)* | *Foreign (1972-81)* | *Foreign and JV (1982-1988)* | *Domestic (1989-2000)* | *Domestic (2001-2006)* | *Recent domestic (2007-2013)* | *Acoustic survey* | *Bottom trawl survey* | *ADF&G bottom trawl* |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000 | 0.002 | 0.015 | 0.004 | 0.029 | 0.025 | 0.573 | 0.341 | 0.009 |
| 2 | 0.000 | 0.019 | 0.070 | 0.022 | 0.102 | 0.125 | 1.000 | 0.189 | 0.056 |
| 3 | 0.003 | 0.175 | 0.282 | 0.112 | 0.304 | 0.442 | 0.911 | 0.296 | 0.290 |
| 4 | 0.441 | 0.702 | 0.687 | 0.413 | 0.634 | 0.815 | 0.813 | 0.453 | 0.738 |
| 5 | 1.000 | 0.969 | 0.949 | 0.803 | 0.883 | 0.962 | 0.709 | 0.661 | 0.951 |
| 6 | 0.801 | 1.000 | 1.000 | 0.967 | 0.983 | 0.994 | 0.603 | 0.878 | 0.993 |
| 7 | 0.511 | 0.980 | 0.909 | 1.000 | 1.000 | 1.000 | 0.501 | 1.000 | 0.999 |
| 8 | 0.256 | 0.867 | 0.620 | 0.984 | 0.930 | 0.994 | 0.407 | 0.948 | 1.000 |
| 9 | 0.107 | 0.521 | 0.256 | 0.849 | 0.615 | 0.888 | 0.324 | 0.766 | 1.000 |
| 10 | 0.041 | 0.158 | 0.071 | 0.437 | 0.190 | 0.307 | 0.253 | 0.560 | 1.000 |

Table 1.17. Total estimated abundance at age (millions) of Gulf of Alaska pollock from the age-structured assessment model.

| | *Age* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* |
| 1964 | 240 | 178 | 132 | 98 | 72 | 54 | 40 | 29 | 22 | 62 |
| 1965 | 126 | 178 | 132 | 98 | 72 | 53 | 39 | 29 | 22 | 62 |
| 1966 | 170 | 93 | 132 | 98 | 71 | 52 | 38 | 29 | 22 | 62 |
| 1967 | 382 | 126 | 69 | 98 | 69 | 48 | 36 | 27 | 21 | 62 |
| 1968 | 709 | 283 | 93 | 51 | 70 | 48 | 34 | 25 | 20 | 61 |
| 1969 | 174 | 525 | 209 | 69 | 37 | 48 | 33 | 24 | 18 | 59 |
| 1970 | 418 | 129 | 389 | 155 | 45 | 21 | 29 | 22 | 17 | 57 |
| 1971 | 505 | 310 | 95 | 288 | 108 | 30 | 14 | 20 | 15 | 54 |
| 1972 | 503 | 374 | 229 | 71 | 206 | 74 | 21 | 10 | 14 | 51 |
| 1973 | 1,954 | 373 | 277 | 166 | 48 | 134 | 48 | 13 | 7 | 47 |
| 1974 | 480 | 1,447 | 275 | 200 | 111 | 31 | 87 | 31 | 9 | 39 |
| 1975 | 306 | 356 | 1,068 | 196 | 126 | 66 | 18 | 51 | 19 | 33 |
| 1976 | 1,902 | 226 | 263 | 766 | 127 | 78 | 41 | 11 | 32 | 37 |
| 1977 | 2,748 | 1,408 | 167 | 187 | 484 | 76 | 46 | 24 | 7 | 48 |
| 1978 | 2,947 | 2,035 | 1,039 | 119 | 117 | 285 | 44 | 27 | 15 | 38 |
| 1979 | 5,103 | 2,182 | 1,501 | 741 | 75 | 70 | 170 | 27 | 17 | 37 |
| 1980 | 2,791 | 3,780 | 1,612 | 1,081 | 489 | 48 | 44 | 107 | 17 | 38 |
| 1981 | 610 | 2,067 | 2,794 | 1,169 | 736 | 322 | 31 | 29 | 71 | 40 |
| 1982 | 839 | 452 | 1,528 | 2,031 | 803 | 491 | 214 | 21 | 20 | 79 |
| 1983 | 365 | 621 | 333 | 1,103 | 1,412 | 545 | 331 | 146 | 15 | 72 |
| 1984 | 682 | 270 | 456 | 239 | 757 | 941 | 361 | 222 | 101 | 64 |
| 1985 | 2,686 | 504 | 197 | 320 | 155 | 468 | 576 | 225 | 146 | 118 |
| 1986 | 1,003 | 1,982 | 366 | 136 | 198 | 90 | 266 | 336 | 142 | 187 |
| 1987 | 225 | 742 | 1,456 | 262 | 92 | 131 | 59 | 177 | 231 | 239 |
| 1988 | 462 | 166 | 546 | 1,048 | 181 | 62 | 88 | 40 | 123 | 342 |
| 1989 | 2,302 | 342 | 122 | 395 | 735 | 124 | 43 | 60 | 28 | 341 |
| 1990 | 1,294 | 1,705 | 253 | 90 | 283 | 510 | 85 | 29 | 41 | 263 |
| 1991 | 498 | 958 | 1,260 | 185 | 64 | 195 | 345 | 57 | 20 | 215 |
| 1992 | 305 | 369 | 708 | 920 | 130 | 43 | 127 | 225 | 38 | 164 |
| 1993 | 196 | 226 | 272 | 518 | 650 | 88 | 28 | 84 | 149 | 141 |
| 1994 | 253 | 145 | 167 | 199 | 364 | 434 | 58 | 18 | 55 | 197 |
| 1995 | 1,289 | 187 | 107 | 122 | 140 | 245 | 287 | 38 | 12 | 175 |
| 1996 | 451 | 954 | 138 | 78 | 87 | 97 | 166 | 194 | 26 | 133 |
| 1997 | 202 | 334 | 706 | 102 | 56 | 60 | 66 | 114 | 133 | 113 |
| 1998 | 227 | 149 | 247 | 513 | 70 | 36 | 38 | 41 | 71 | 162 |
| 1999 | 222 | 168 | 110 | 176 | 333 | 40 | 20 | 20 | 22 | 145 |
| 2000 | 1,184 | 164 | 124 | 79 | 117 | 200 | 23 | 11 | 12 | 109 |
| 2001 | 948 | 877 | 121 | 90 | 54 | 74 | 122 | 14 | 7 | 81 |
| 2002 | 152 | 698 | 636 | 84 | 58 | 33 | 45 | 73 | 9 | 62 |
| 2003 | 131 | 112 | 509 | 448 | 56 | 37 | 21 | 28 | 47 | 50 |
| 2004 | 103 | 97 | 82 | 361 | 303 | 37 | 24 | 13 | 18 | 68 |
| 2005 | 472 | 76 | 71 | 58 | 240 | 194 | 23 | 15 | 9 | 61 |
| 2006 | 893 | 348 | 55 | 49 | 38 | 149 | 118 | 14 | 9 | 49 |
| 2007 | 783 | 658 | 253 | 39 | 32 | 24 | 91 | 72 | 9 | 41 |
| 2008 | 1,300 | 578 | 479 | 176 | 26 | 21 | 15 | 59 | 46 | 35 |
| 2009 | 534 | 961 | 423 | 339 | 120 | 17 | 14 | 10 | 39 | 56 |
| 2010 | 209 | 395 | 705 | 304 | 237 | 83 | 12 | 10 | 7 | 68 |
| 2011 | 758 | 154 | 289 | 501 | 208 | 160 | 56 | 8 | 6 | 54 |
| 2012 | 156 | 560 | 113 | 205 | 342 | 140 | 107 | 37 | 5 | 43 |
| 2013 | 4,084 | 115 | 409 | 79 | 138 | 227 | 92 | 71 | 25 | 34 |
| *Average* | 946 | 643 | 474 | 338 | 231 | 151 | 95 | 60 | 40 | 97 |

Table 1.18. Estimates of population biomass, recruitment, and harvest of Gulf of Alaska pollock from the age-structured assessment model. The harvest rate is the catch in biomass divided by the total biomass of age 3+ fish at the start of the year.

| | | | | | | 2012 Assessment results | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Year* | *3+ total biomass (1,000 t)* | *Female spawn. biom. (1,000 t)* | *Age 1 recruits (million)* | *Catch (t)* | *Harvest rate* | *3+ total biomass* | *Female spawn. biom.* | *Age 1 recruits* | *Harvest rate* |
| 1977 | 774 | 160 | 2,748 | 118,356 | 15% | 939 | 196 | 3,345 | 13% |
| 1978 | 966 | 162 | 2,947 | 96,935 | 10% | 1,197 | 205 | 3,542 | 8% |
| 1979 | 1,431 | 174 | 5,103 | 105,748 | 7% | 1,781 | 226 | 5,886 | 6% |
| 1980 | 1,954 | 238 | 2,791 | 114,622 | 6% | 2,426 | 307 | 3,070 | 5% |
| 1981 | 2,871 | 243 | 610 | 147,744 | 5% | 3,488 | 310 | 641 | 4% |
| 1982 | 3,284 | 352 | 839 | 168,740 | 5% | 3,931 | 442 | 856 | 4% |
| 1983 | 2,941 | 521 | 365 | 215,608 | 7% | 3,490 | 636 | 356 | 6% |
| 1984 | 2,459 | 591 | 682 | 307,401 | 13% | 2,907 | 722 | 672 | 11% |
| 1985 | 1,848 | 547 | 2,686 | 284,826 | 15% | 2,205 | 679 | 2,574 | 13% |
| 1986 | 1,483 | 462 | 1,003 | 87,809 | 6% | 1,798 | 581 | 960 | 5% |
| 1987 | 1,703 | 396 | 225 | 69,751 | 4% | 1,929 | 497 | 218 | 4% |
| 1988 | 1,714 | 380 | 462 | 65,739 | 4% | 1,876 | 463 | 448 | 4% |
| 1989 | 1,594 | 400 | 2,302 | 78,392 | 5% | 1,720 | 459 | 2,248 | 5% |
| 1990 | 1,370 | 381 | 1,294 | 90,744 | 7% | 1,455 | 418 | 1,262 | 6% |
| 1991 | 1,498 | 374 | 498 | 100,488 | 7% | 1,545 | 403 | 490 | 7% |
| 1992 | 1,795 | 341 | 305 | 90,857 | 5% | 1,805 | 355 | 309 | 5% |
| 1993 | 1,605 | 369 | 196 | 108,908 | 7% | 1,603 | 374 | 197 | 7% |
| 1994 | 1,332 | 412 | 253 | 107,335 | 8% | 1,328 | 411 | 248 | 8% |
| 1995 | 1,113 | 370 | 1,289 | 72,618 | 7% | 1,108 | 368 | 1,290 | 7% |
| 1996 | 910 | 328 | 451 | 51,263 | 6% | 905 | 325 | 455 | 6% |
| 1997 | 939 | 279 | 202 | 90,130 | 10% | 934 | 277 | 202 | 10% |
| 1998 | 849 | 213 | 227 | 125,098 | 15% | 846 | 211 | 220 | 15% |
| 1999 | 672 | 193 | 222 | 95,590 | 14% | 670 | 191 | 217 | 14% |
| 2000 | 588 | 179 | 1,184 | 73,080 | 12% | 585 | 178 | 1,211 | 12% |
| 2001 | 539 | 173 | 948 | 72,076 | 13% | 534 | 172 | 962 | 13% |
| 2002 | 679 | 144 | 152 | 51,937 | 8% | 681 | 143 | 153 | 8% |
| 2003 | 796 | 134 | 131 | 50,666 | 6% | 803 | 133 | 134 | 6% |
| 2004 | 699 | 141 | 103 | 63,934 | 9% | 706 | 141 | 102 | 9% |
| 2005 | 582 | 178 | 472 | 80,846 | 14% | 589 | 178 | 468 | 14% |
| 2006 | 496 | 182 | 893 | 71,976 | 15% | 503 | 185 | 816 | 14% |
| 2007 | 485 | 162 | 783 | 53,062 | 11% | 491 | 164 | 640 | 11% |
| 2008 | 723 | 161 | 1,300 | 52,500 | 7% | 709 | 164 | 1,042 | 7% |
| 2009 | 1,067 | 163 | 534 | 44,003 | 4% | 991 | 164 | 440 | 4% |
| 2010 | 1,269 | 230 | 209 | 76,860 | 6% | 1,113 | 219 | 163 | 7% |
| 2011 | 1,203 | 279 | 758 | 81,307 | 7% | 1,020 | 249 | 989 | 8% |
| 2012 | 1,105 | 306 | 156 | 103,991 | 9% | 909 | 257 | 201 | 11% |
| 2013 | 1,074 | 340 | 4,084 | | | | | | |
| *Average* | | | | | | | | | |
| *1977-2012* | 1,315 | 287 | 981 | 101,971 | 9% | 1,431 | 317 | 1,029 | 8% |
| *1978-2012* | | | 931 | | | | | 886 | |

Table 1.19. Uncertainty of estimates of recruitment and spawning biomass of Gulf of Alaska pollock from the age-structured assessment model.

| *Year* | *Age-1 Recruits (millions)* | *CV* | *Lower 95% CI* | *Upper 95% CI* | *Spawning biomass (1,000 t)* | *CV* | *Lower 95% CI* | *Upper 95% CI* |
|---|---|---|---|---|---|---|---|---|
| 1964 | 240 | 0.39 | 115 | 503 | 107 | 0.39 | 51 | 224 |
| 1965 | 126 | 0.48 | 52 | 306 | 106 | 0.39 | 51 | 224 |
| 1966 | 170 | 0.46 | 72 | 398 | 105 | 0.40 | 49 | 223 |
| 1967 | 382 | 0.40 | 180 | 807 | 101 | 0.41 | 46 | 220 |
| 1968 | 709 | 0.33 | 374 | 1342 | 96 | 0.42 | 44 | 212 |
| 1969 | 174 | 0.54 | 65 | 466 | 89 | 0.42 | 40 | 196 |
| 1970 | 418 | 0.33 | 223 | 782 | 82 | 0.42 | 37 | 182 |
| 1971 | 505 | 0.27 | 300 | 850 | 92 | 0.38 | 45 | 188 |
| 1972 | 503 | 0.27 | 299 | 846 | 105 | 0.35 | 54 | 203 |
| 1973 | 1954 | 0.14 | 1499 | 2548 | 108 | 0.34 | 57 | 206 |
| 1974 | 480 | 0.22 | 316 | 730 | 107 | 0.32 | 58 | 199 |
| 1975 | 306 | 0.24 | 193 | 485 | 107 | 0.31 | 59 | 192 |
| 1976 | 1902 | 0.13 | 1487 | 2432 | 134 | 0.25 | 83 | 217 |
| 1977 | 2748 | 0.11 | 2196 | 3437 | 160 | 0.22 | 104 | 248 |
| 1978 | 2947 | 0.11 | 2374 | 3658 | 162 | 0.23 | 103 | 253 |
| 1979 | 5103 | 0.09 | 4310 | 6043 | 174 | 0.22 | 114 | 266 |
| 1980 | 2791 | 0.09 | 2318 | 3361 | 238 | 0.18 | 169 | 335 |
| 1981 | 610 | 0.17 | 437 | 851 | 243 | 0.14 | 184 | 320 |
| 1982 | 839 | 0.12 | 658 | 1069 | 352 | 0.12 | 280 | 442 |
| 1983 | 365 | 0.20 | 246 | 541 | 521 | 0.10 | 427 | 635 |
| 1984 | 682 | 0.14 | 522 | 892 | 591 | 0.10 | 484 | 722 |
| 1985 | 2686 | 0.08 | 2319 | 3111 | 547 | 0.11 | 438 | 683 |
| 1986 | 1003 | 0.10 | 827 | 1216 | 462 | 0.13 | 361 | 592 |
| 1987 | 225 | 0.19 | 155 | 325 | 396 | 0.13 | 308 | 511 |
| 1988 | 462 | 0.14 | 354 | 602 | 380 | 0.12 | 300 | 483 |
| 1989 | 2302 | 0.07 | 2021 | 2622 | 400 | 0.11 | 325 | 493 |
| 1990 | 1294 | 0.08 | 1104 | 1518 | 381 | 0.10 | 314 | 462 |
| 1991 | 498 | 0.12 | 393 | 630 | 374 | 0.10 | 308 | 453 |
| 1992 | 305 | 0.13 | 237 | 394 | 341 | 0.09 | 284 | 409 |
| 1993 | 196 | 0.15 | 146 | 262 | 369 | 0.08 | 313 | 435 |
| 1994 | 253 | 0.14 | 193 | 331 | 412 | 0.08 | 353 | 481 |
| 1995 | 1289 | 0.07 | 1128 | 1472 | 370 | 0.08 | 317 | 432 |
| 1996 | 451 | 0.10 | 370 | 550 | 328 | 0.08 | 281 | 383 |
| 1997 | 202 | 0.14 | 153 | 267 | 279 | 0.08 | 238 | 327 |
| 1998 | 227 | 0.12 | 178 | 289 | 213 | 0.09 | 179 | 252 |
| 1999 | 222 | 0.12 | 174 | 282 | 193 | 0.09 | 162 | 231 |
| 2000 | 1184 | 0.06 | 1048 | 1338 | 179 | 0.09 | 149 | 215 |
| 2001 | 948 | 0.07 | 833 | 1078 | 173 | 0.10 | 142 | 211 |
| 2002 | 152 | 0.16 | 113 | 206 | 144 | 0.11 | 117 | 178 |
| 2003 | 132 | 0.14 | 101 | 172 | 134 | 0.11 | 109 | 165 |
| 2004 | 103 | 0.17 | 75 | 142 | 141 | 0.09 | 119 | 167 |
| 2005 | 472 | 0.09 | 395 | 564 | 178 | 0.08 | 151 | 209 |
| 2006 | 893 | 0.08 | 757 | 1053 | 182 | 0.09 | 154 | 216 |
| 2007 | 783 | 0.10 | 649 | 945 | 162 | 0.10 | 134 | 195 |
| 2008 | 1300 | 0.09 | 1083 | 1561 | 161 | 0.10 | 132 | 195 |
| 2009 | 534 | 0.13 | 414 | 688 | 163 | 0.10 | 135 | 197 |
| 2010 | 209 | 0.24 | 132 | 329 | 230 | 0.09 | 194 | 273 |
| 2011 | 758 | 0.17 | 541 | 1062 | 279 | 0.09 | 236 | 330 |
| 2012 | 156 | 0.40 | 74 | 329 | 306 | 0.09 | 256 | 366 |
| 2013 | 4084 | 0.24 | 2571 | 6486 | 340 | 0.10 | 279 | 413 |

Table 1.20. Gulf of Alaska pollock life history and fishery vectors used to estimate spawning biomass per recruit ($F_{SPR}$) harvest rates. Spawning weight at age is based on an average from the Shelikof Strait acoustic survey conducted in March. Population weight at age is based on a average for the bottom trawl survey conducted in June to August. Proportion mature females is the average from winter acoustic survey specimen data for 1983-2013.

| | | | *Weight at age (kg)* | | | |
|---|---|---|---|---|---|---|
| | *Natural mortality* | *Fishery selectivity (Avg. 2008-2012)* | *Spawning (Avg. 2008-2013)* | *Population (Avg. 2007-2011)* | *Fishery (Avg. 2005-2012)* | *Proportion mature females* |
| 1 | 0.3 | 0.025 | 0.010 | 0.038 | 0.125 | 0.000 |
| 2 | 0.3 | 0.125 | 0.092 | 0.222 | 0.328 | 0.001 |
| 3 | 0.3 | 0.442 | 0.277 | 0.458 | 0.635 | 0.017 |
| 4 | 0.3 | 0.815 | 0.591 | 0.816 | 0.920 | 0.260 |
| 5 | 0.3 | 0.962 | 0.942 | 1.149 | 1.253 | 0.574 |
| 6 | 0.3 | 0.994 | 1.287 | 1.436 | 1.531 | 0.825 |
| 7 | 0.3 | 1.000 | 1.692 | 1.613 | 1.716 | 0.918 |
| 8 | 0.3 | 0.994 | 1.860 | 1.734 | 1.917 | 0.963 |
| 9 | 0.3 | 0.888 | 2.011 | 1.954 | 2.084 | 0.986 |
| 10+ | 0.3 | 0.307 | 2.102 | 1.964 | 2.151 | 0.992 |

Table 1.21. Methods used to assess Gulf of Alaska pollock, 1977-2012. The basis for catch recommendation in 1977-1989 is the presumptive method by which the ABC was determined (based on the assessment and SSC minutes). The basis for catch recommendation given in 1990-2012 is the method used by the Plan Team to derive the ABC recommendation given in the SAFE summary chapter.

| *Year* | *Assessment method* | *Basis for catch recommendation in following year* | *B40% (t)* |
|---|---|---|---|
| 1977-81 | Survey biomass, CPUE trends, M=0.4 | MSY = 0.4 * M * Bzero | --- |
| 1982 | CAGEAN | MSY = 0.4 * M * Bzero | --- |
| 1983 | CAGEAN | Mean annual surplus production | --- |
| 1984 | Projection of survey numbers at age | Stabilize biomass trend | --- |
| 1985 | CAGEAN, projection of survey numbers at age, CPUE trends | Stabilize biomass trend | --- |
| 1986 | CAGEAN, projection of survey numbers at age | Stabilize biomass trend | --- |
| 1987 | CAGEAN, projection of survey numbers at age | Stabilize biomass trend | --- |
| 1988 | CAGEAN, projection of survey numbers at age | 10% of exploitable biomass | --- |
| 1989 | Stock synthesis | 10% of exploitable biomass | --- |
| 1990 | Stock synthesis, reduce *M* to 0.3 | 10% of exploitable biomass | --- |
| 1991 | Stock synthesis, assume trawl survey catchability = 1 | FMSY from an assumed SR curve | --- |
| 1992 | Stock synthesis | Max[-Pr(SB<Threshold)+Yld] | --- |
| 1993 | Stock synthesis | Pr(SB>B20)=0.95 | --- |
| 1994 | Stock synthesis | Pr(SB>B20)=0.95 | --- |
| 1995 | Stock synthesis | Max[-Pr(SB<Threshold)+Yld] | --- |
| 1996 | Stock synthesis | Amendment 44 Tier 3 guidelines | 289,689 |
| 1997 | Stock synthesis | Amendment 44 Tier 3 guidelines | 267,600 |
| 1998 | Stock synthesis | Amendment 44 Tier 3 guidelines | 240,000 |
| 1999 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 247,000 |
| 2000 | AD model builder | Amendment 56 Tier 3 guidelines | 250,000 |
| 2001 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 245,000 |
| 2002 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 240,000 |
| 2003 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 248,000 |
| 2004 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$, and stairstep approach for projected ABC increase) | 229,000 |
| 2005 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible FABC) | 224,000 |
| 2006 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible FABC) | 220,000 |
| 2007 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 221,000 |
| 2008 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 237,000 |
| 2009 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 248,000 |
| 2010 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 276,000 |
| 2011 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 271,000 |
| 2012 | AD model builder | Amendment 56 Tier 3 guidelines (with a reduction from max permissible $F_{ABC}$) | 297,000 |

Table 1.22. Projections of Gulf of Alaska pollock spawning biomass, full recruitment fishing mortality, and catch for 2013-2023 under different harvest policies. All projections begin with estimated age composition in 2013 using the base run model with a projected 2013 catch of 113,099 t. The values for $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 726,000, 290,000, 254,000 t, respectively.

| Spawning biomass (t) | Max $F_{ABC}$ | Author's recommended F | Average F | $F_{75\%}$ | F = 0 | $F_{OFL}$ | Max $F_{ABC}$ for two years, then $F_{OFL}$ |
|---|---|---|---|---|---|---|---|
| 2013 | 329,732 | 329,732 | 329,732 | 329,732 | 329,732 | 329,732 | 329,732 |
| 2014 | 307,335 | 308,541 | 314,175 | 316,425 | 320,200 | 305,223 | 307,335 |
| 2015 | 261,475 | 267,477 | 294,532 | 306,577 | 327,760 | 252,179 | 261,475 |
| 2016 | 310,417 | 321,015 | 365,106 | 387,359 | 427,940 | 296,436 | 308,515 |
| 2017 | 399,938 | 413,493 | 497,722 | 537,437 | 611,597 | 375,046 | 385,943 |
| 2018 | 442,197 | 454,587 | 591,778 | 653,857 | 773,169 | 405,216 | 414,218 |
| 2019 | 433,702 | 443,654 | 623,243 | 705,012 | 867,791 | 388,920 | 395,660 |
| 2020 | 392,570 | 399,928 | 594,457 | 685,068 | 871,617 | 347,272 | 351,732 |
| 2021 | 361,766 | 368,555 | 566,018 | 661,052 | 862,305 | 319,009 | 321,703 |
| 2022 | 339,982 | 347,160 | 538,987 | 634,454 | 840,589 | 300,842 | 302,388 |
| 2023 | 328,189 | 336,073 | 518,065 | 610,886 | 812,609 | 292,400 | 293,275 |
| 2024 | 322,759 | 331,455 | 504,549 | 595,174 | 793,073 | 289,537 | 290,010 |
| 2025 | 321,270 | 330,691 | 496,893 | 585,990 | 781,138 | 289,697 | 289,943 |
| 2026 | 319,567 | 329,500 | 490,710 | 578,795 | 772,072 | 288,906 | 289,031 |
| Fishing mortality | Max $F_{ABC}$ | Author's recommended F | Average F | $F_{75\%}$ | F = 0 | $F_{OFL}$ | Max $F_{ABC}$ for two years, then $F_{OFL}$ |
| 2013 | 0.13 | 0.13 | 0.13 | 0.13 | 0 | 0.13 | 0.13 |
| 2014 | 0.22 | 0.20 | 0.10 | 0.06 | 0 | 0.26 | 0.22 |
| 2015 | 0.20 | 0.17 | 0.10 | 0.06 | 0 | 0.22 | 0.20 |
| 2016 | 0.22 | 0.21 | 0.10 | 0.06 | 0 | 0.26 | 0.26 |
| 2017 | 0.22 | 0.22 | 0.10 | 0.06 | 0 | 0.26 | 0.26 |
| 2018 | 0.22 | 0.22 | 0.10 | 0.06 | 0 | 0.26 | 0.26 |
| 2019 | 0.22 | 0.22 | 0.10 | 0.06 | 0 | 0.26 | 0.26 |
| 2020 | 0.22 | 0.21 | 0.10 | 0.06 | 0 | 0.25 | 0.25 |
| 2021 | 0.21 | 0.20 | 0.10 | 0.06 | 0 | 0.23 | 0.24 |
| 2022 | 0.20 | 0.19 | 0.10 | 0.06 | 0 | 0.23 | 0.23 |
| 2023 | 0.20 | 0.19 | 0.10 | 0.06 | 0 | 0.22 | 0.22 |
| 2024 | 0.20 | 0.19 | 0.10 | 0.06 | 0 | 0.22 | 0.22 |
| 2025 | 0.20 | 0.19 | 0.10 | 0.06 | 0 | 0.22 | 0.22 |
| 2026 | 0.20 | 0.18 | 0.10 | 0.06 | 0 | 0.22 | 0.22 |
| Catch (t) | Max $F_{ABC}$ | Author's recommended F | Average F | $F_{75\%}$ | F = 0 | $F_{OFL}$ | Max $F_{ABC}$ for two years, then $F_{OFL}$ |
| 2013 | 113,099 | 113,099 | 113,099 | 113,099 | 113,099 | 113,099 | 113,099 |
| 2014 | 183,943 | 167,657 | 89,014 | 56,381 | 0 | 211,998 | 183,943 |
| 2015 | 210,071 | 185,830 | 118,989 | 76,743 | 0 | 230,138 | 210,071 |
| 2016 | 303,398 | 293,416 | 160,277 | 104,987 | 0 | 341,463 | 349,727 |
| 2017 | 310,427 | 317,948 | 175,119 | 117,134 | 0 | 342,210 | 348,201 |
| 2018 | 290,041 | 295,475 | 174,081 | 118,894 | 0 | 313,874 | 317,902 |
| 2019 | 266,095 | 269,631 | 166,789 | 115,738 | 0 | 284,565 | 287,125 |
| 2020 | 245,651 | 242,817 | 158,824 | 111,355 | 0 | 256,035 | 258,374 |
| 2021 | 224,394 | 218,889 | 150,040 | 105,830 | 0 | 231,366 | 232,757 |
| 2022 | 199,937 | 193,968 | 131,118 | 91,356 | 0 | 208,295 | 208,826 |
| 2023 | 198,263 | 192,603 | 130,460 | 90,827 | 0 | 208,003 | 208,230 |
| 2024 | 198,424 | 193,105 | 130,376 | 90,722 | 0 | 209,310 | 209,390 |
| 2025 | 197,690 | 192,780 | 129,454 | 90,084 | 0 | 209,236 | 209,245 |
| 2026 | 195,041 | 190,323 | 128,056 | 89,144 | 0 | 206,763 | 206,750 |

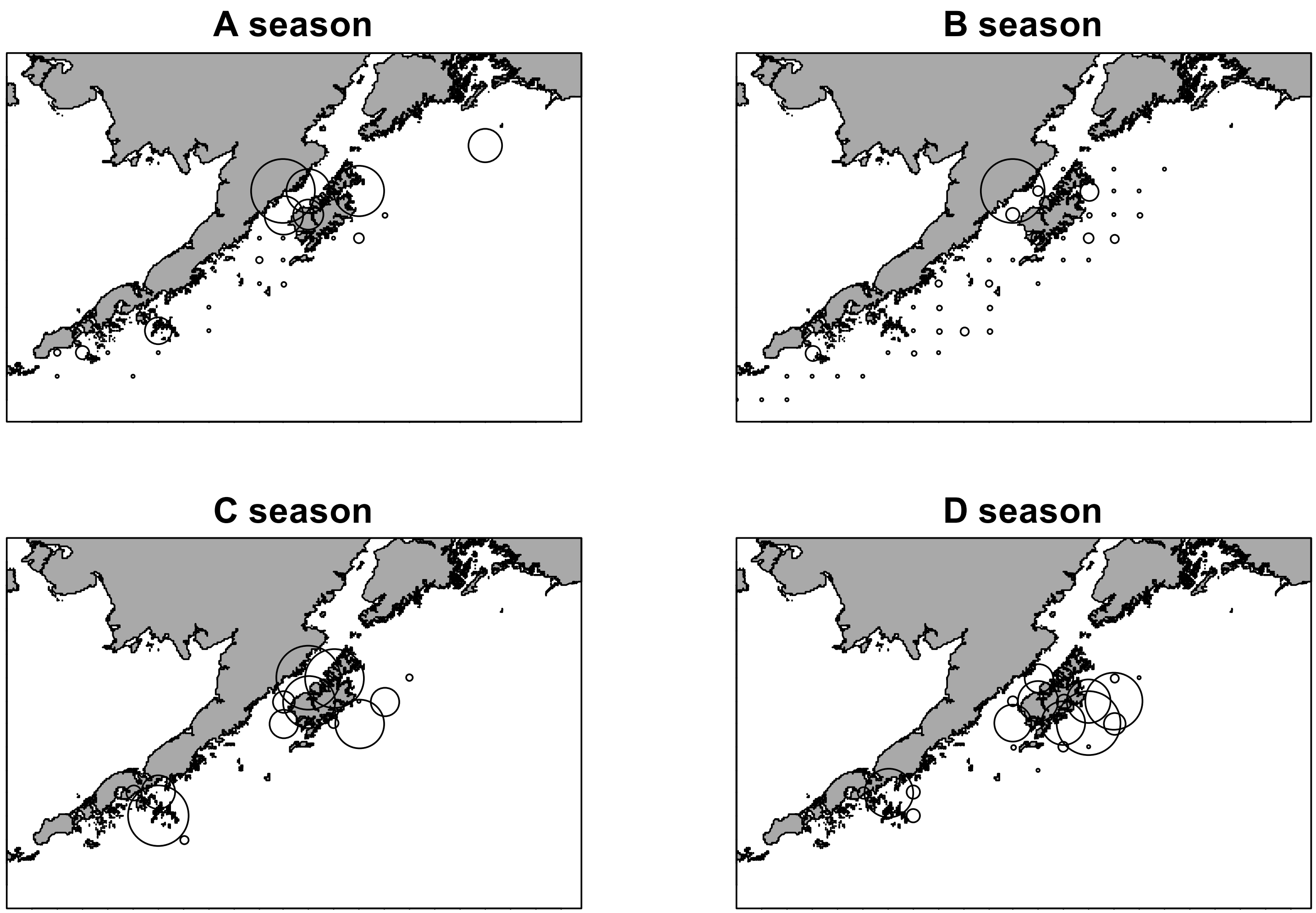



Figure 1.1. Pollock catch in 2012 for 1/2 degree latitude by 1 degree longitude blocks by season in the Gulf of Alaska as determined by fishery observer-recorded haul retrieval locations. Blocks with less than 1.0 t of pollock catch are not shown. The area of the circle is proportional to the catch.

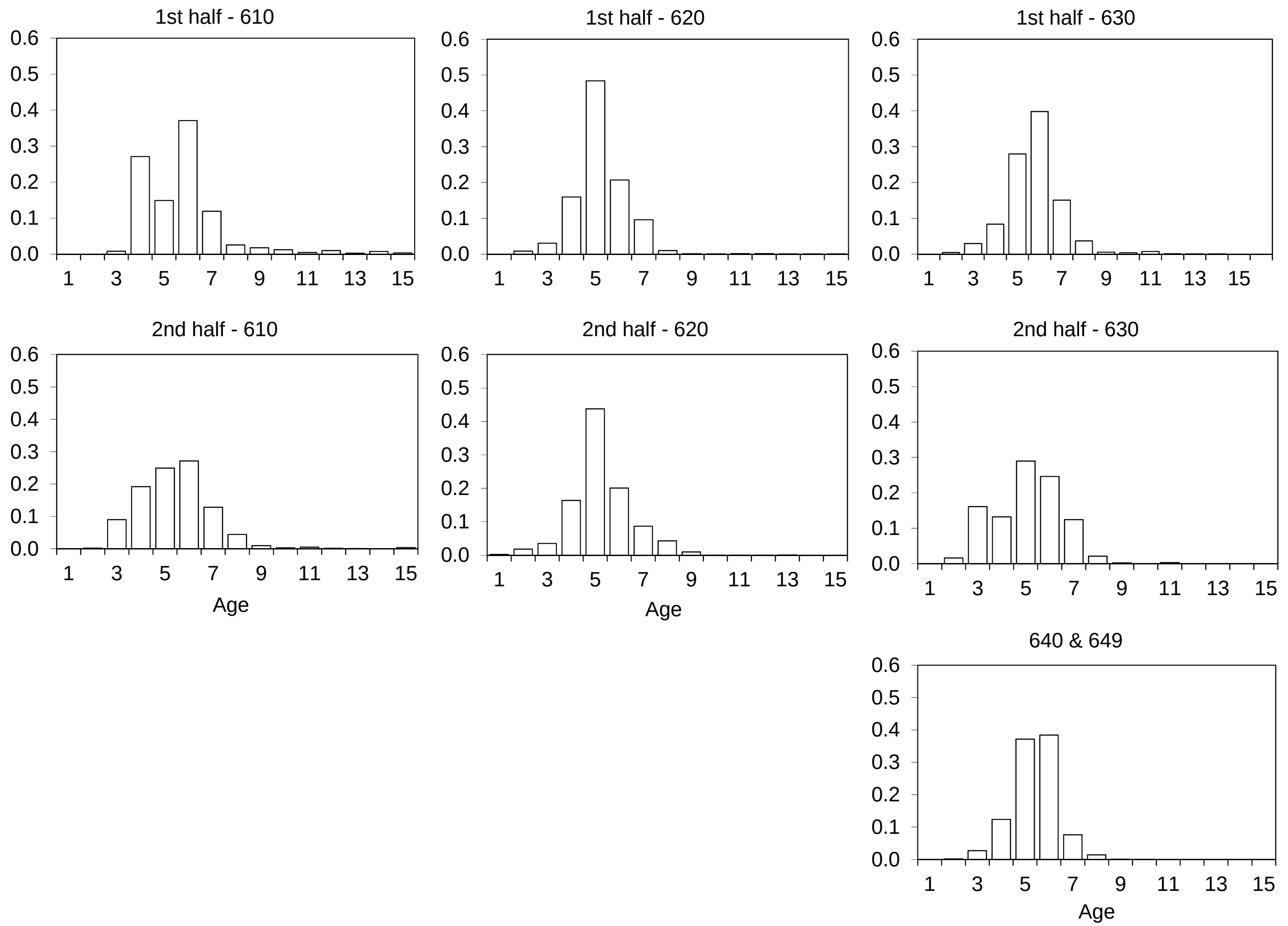



Figure 1.2. 2012 fishery age composition by half year (January-June, July-December) and statistical area.

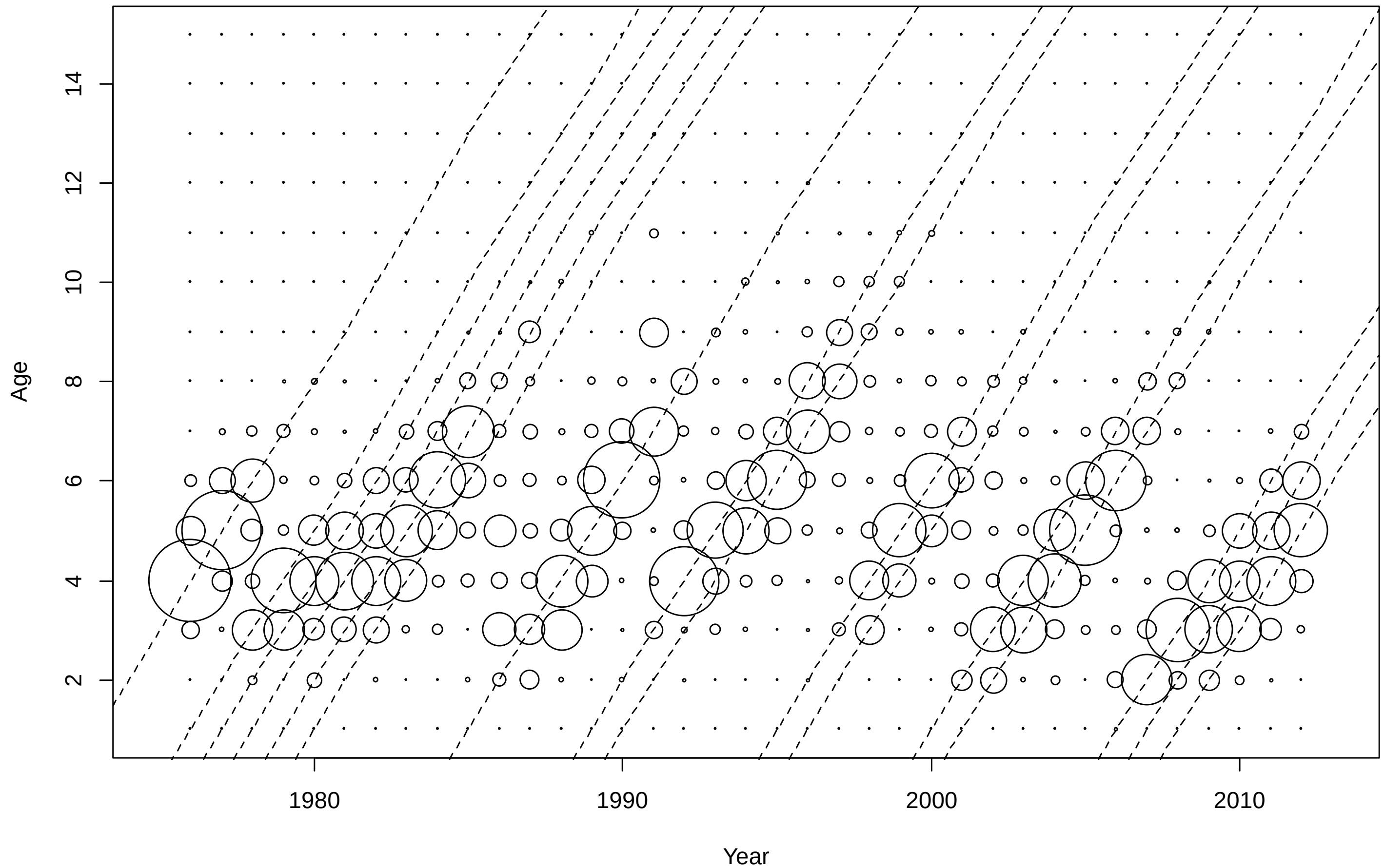



Figure 1.3. Gulf of Alaska pollock fishery age composition (1976-2012). The diameter of the circle is proportional to the catch. Diagonal lines show strong year classes (1972, 1975, 1976, 1977, 1978, 1979, 1984, 1988, 1994, 1995, 1999, 2000, 2005, 2006, and 2007).

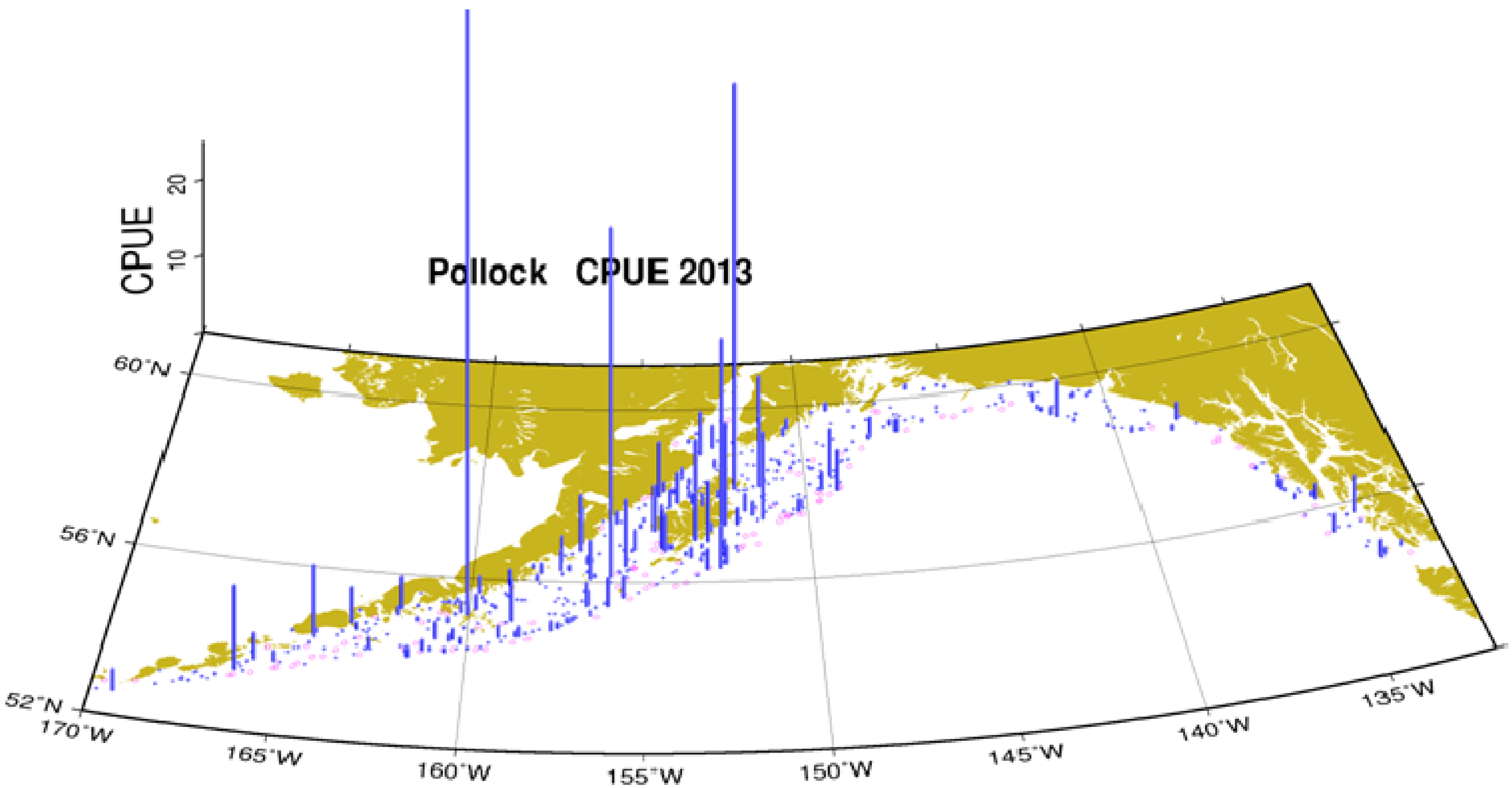



Figure 1.4. Pollock catch per unit effort (CPUE) for the 2013 NMFS bottom trawl survey in the Gulf of Alaska.

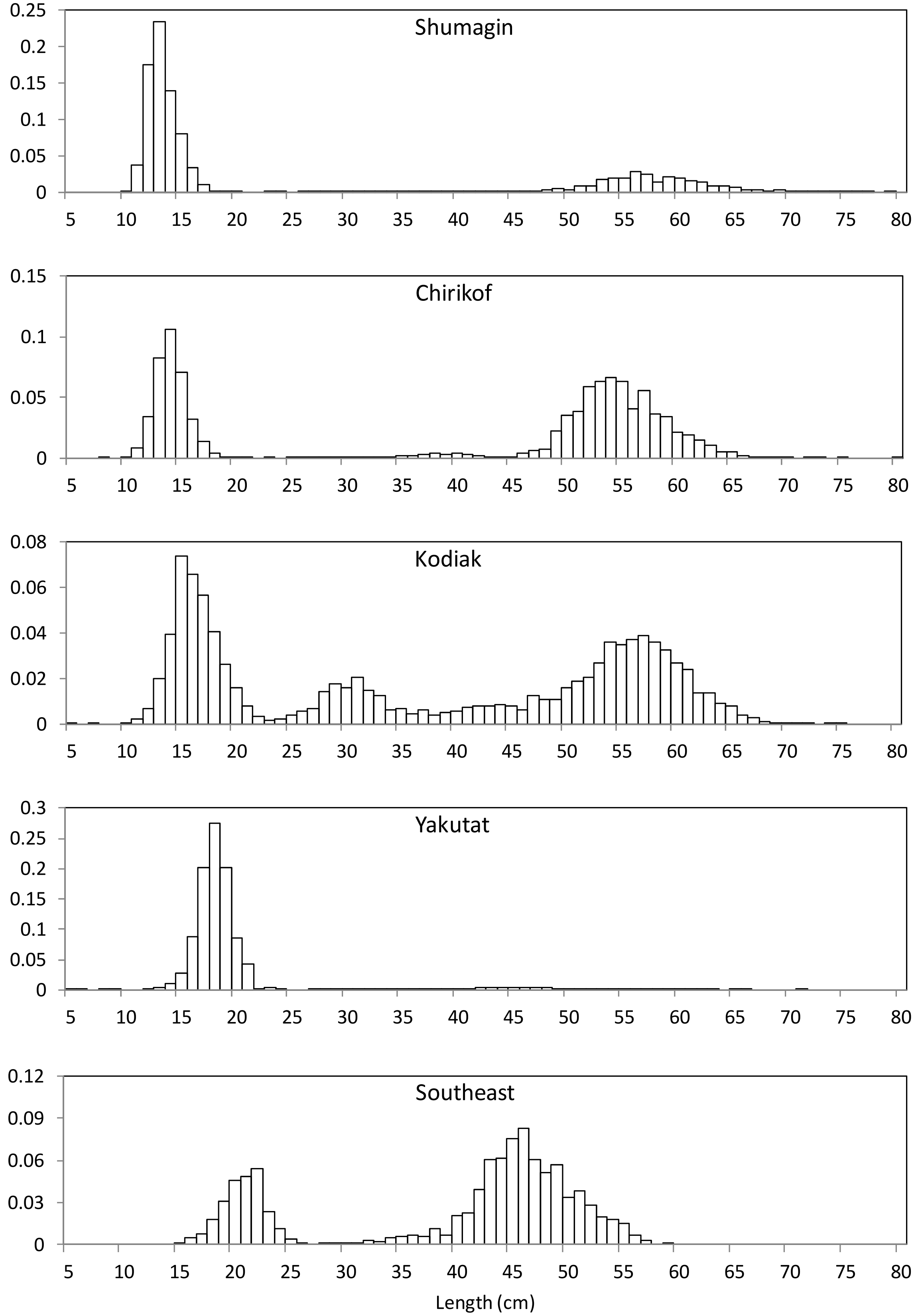



Figure 1.5. Length composition of pollock by statistical area for the 2013 NMFS bottom trawl survey.

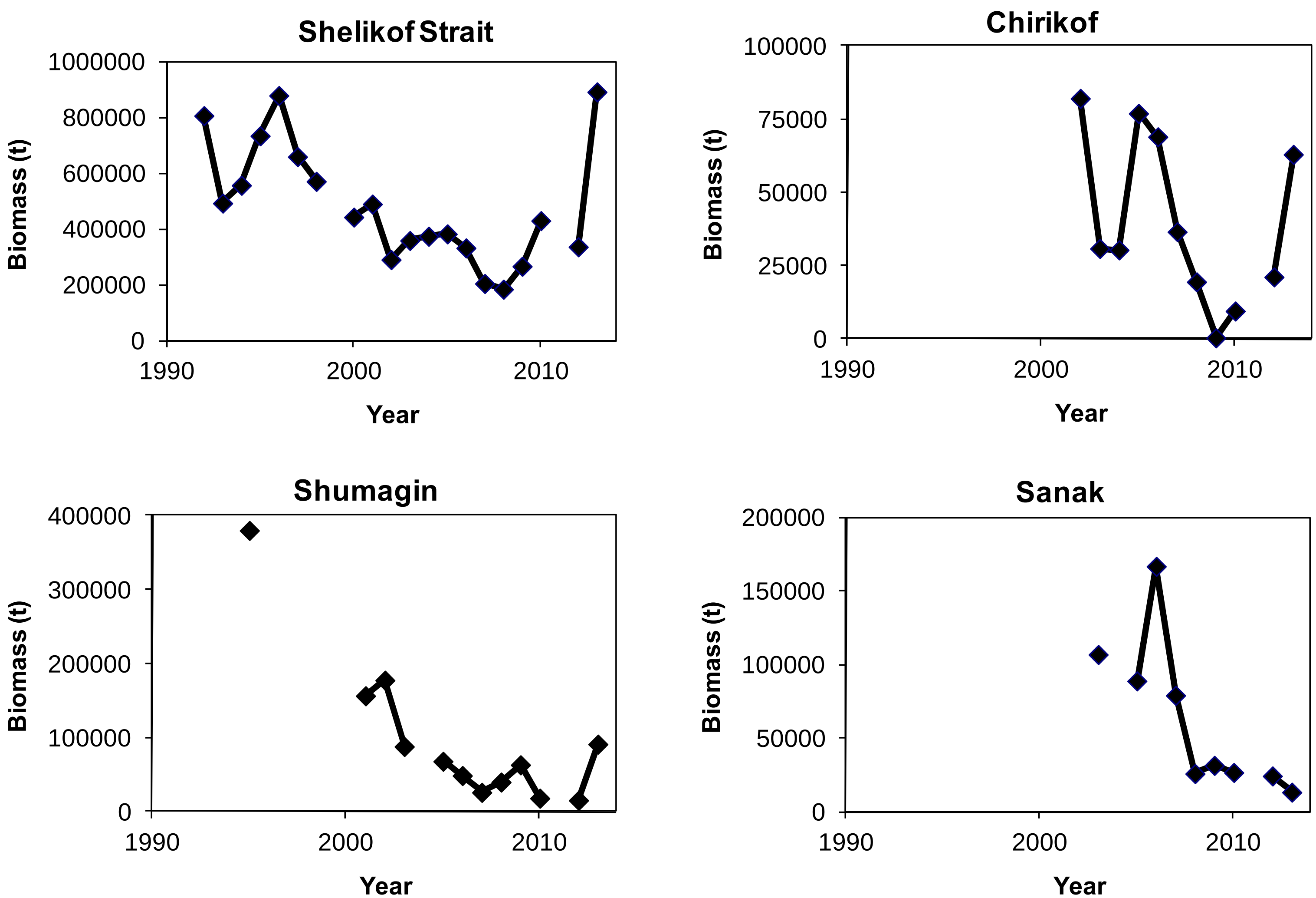



Figure 1.6. Trends in biomass estimates from winter acoustic surveys of pre-spawning aggregations of pollock in the Gulf of Alaska.

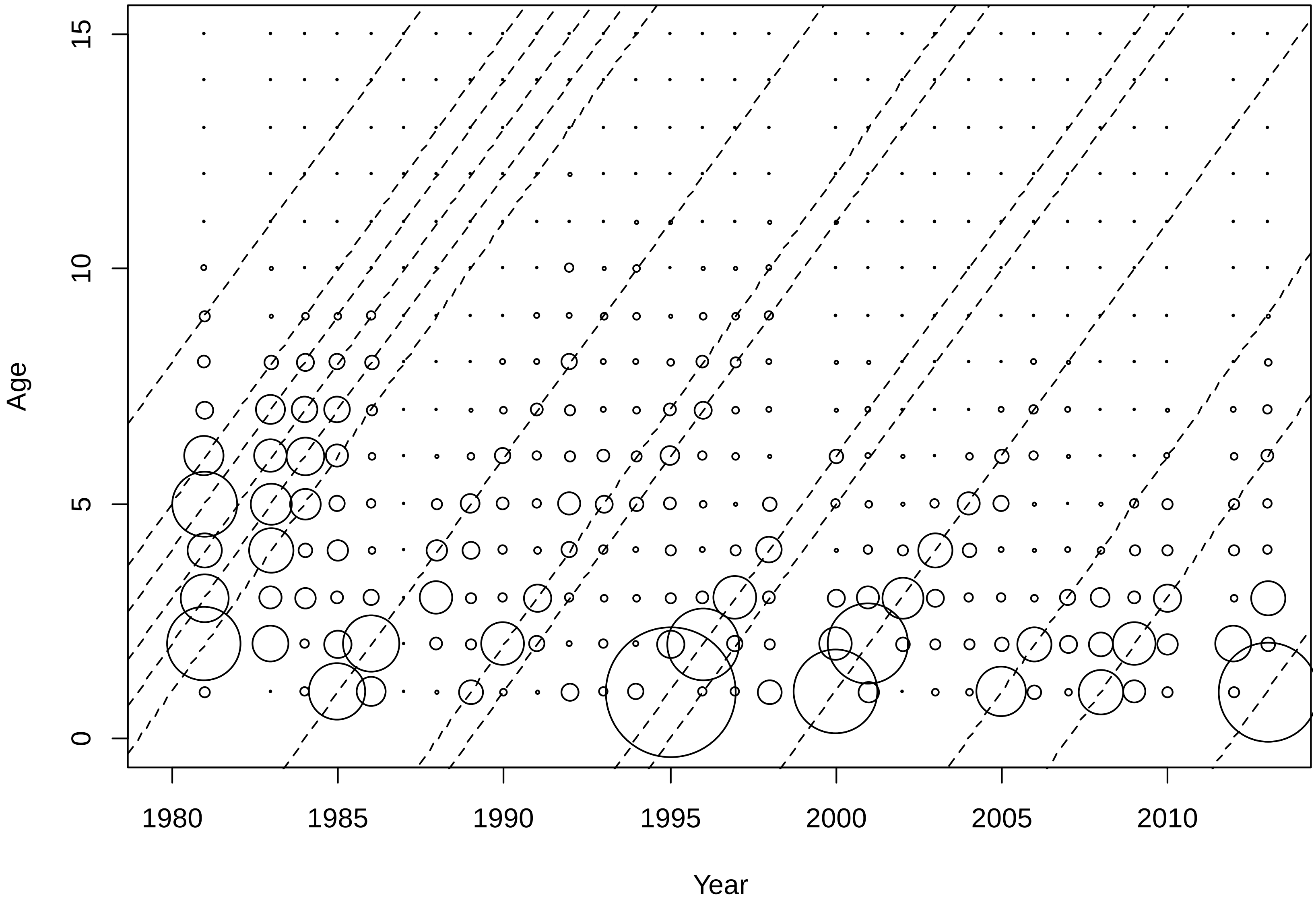



Figure 1.7. Estimated abundance at age in the Shelikof Strait acoustic survey (1981-2013, except 1982, 1987, 1999, and 2011). The area of the circle is proportional to the estimated abundance.

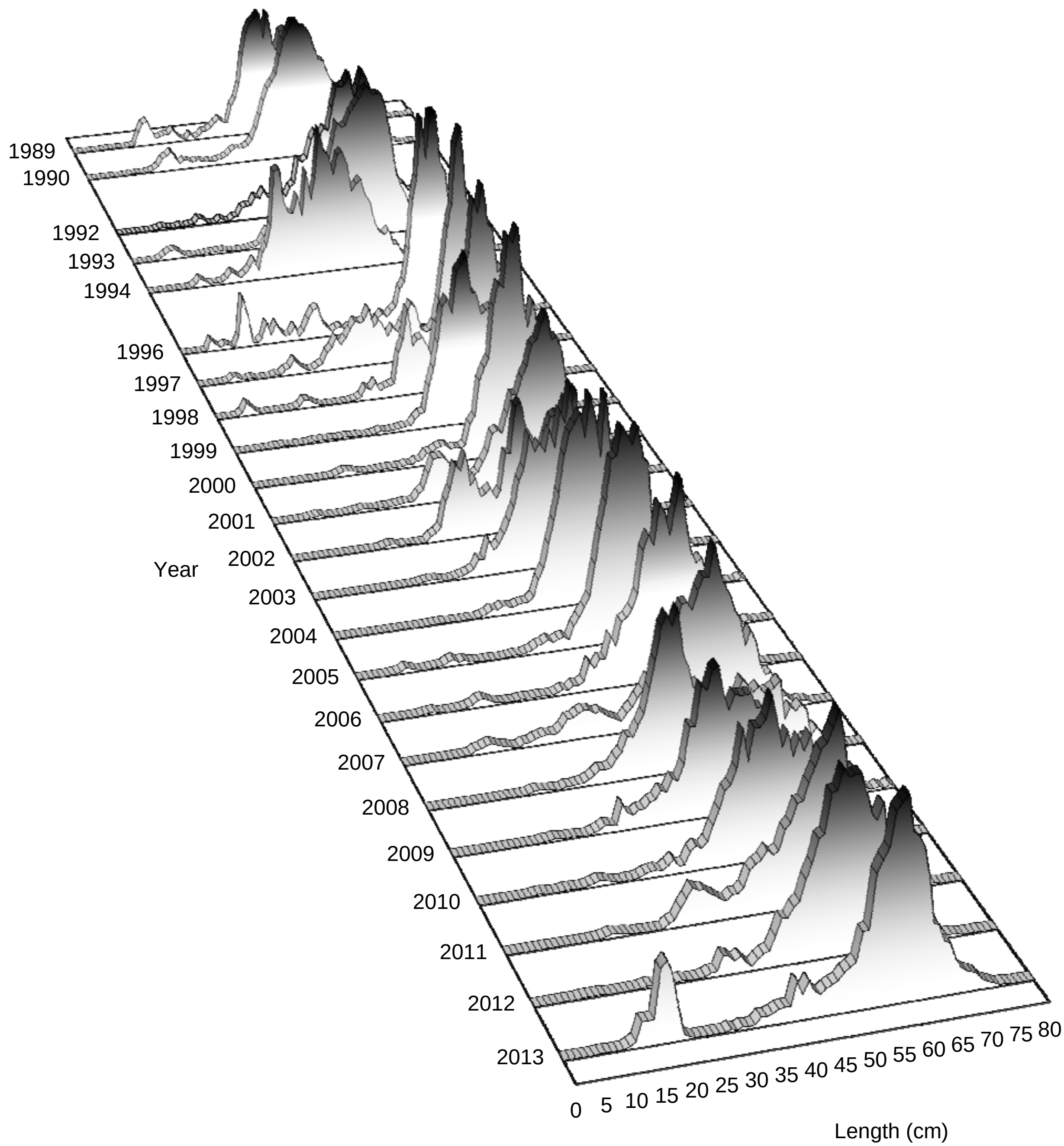



Figure 1.8. Length frequency of pollock in the ADFG crab/groundfish trawl survey (1989-2013, except 1991 and 1995).

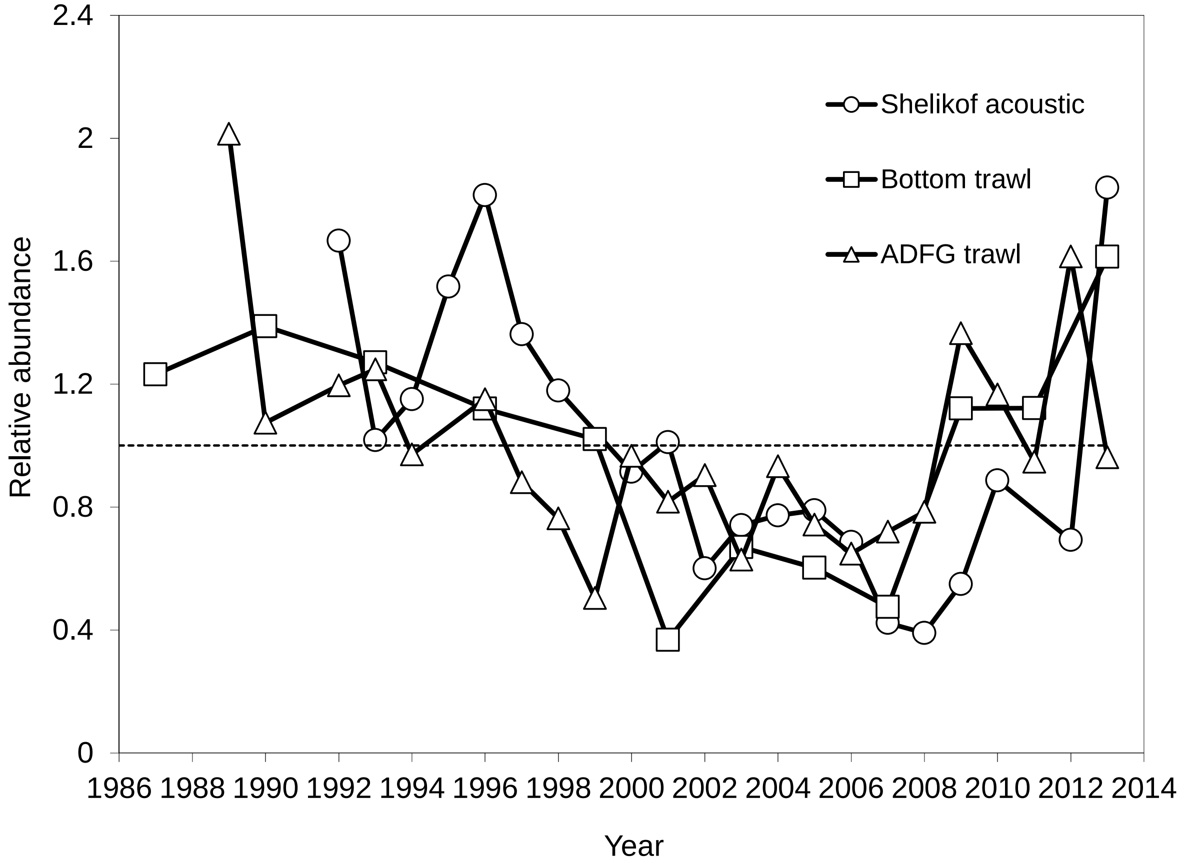



Figure 1.9. Relative trends in pollock biomass since 1987 for the Shelikof Strait acoustic survey, the NMFS bottom trawl survey, and the ADFG crab/groundfish trawl survey. Each survey biomass estimate is standardized to the average since 1987. Shelikof Strait acoustic surveys prior to 2008 were re-scaled to be comparable to the surveys conducted from 2008 onwards by the *R/V Oscar Dyson*.

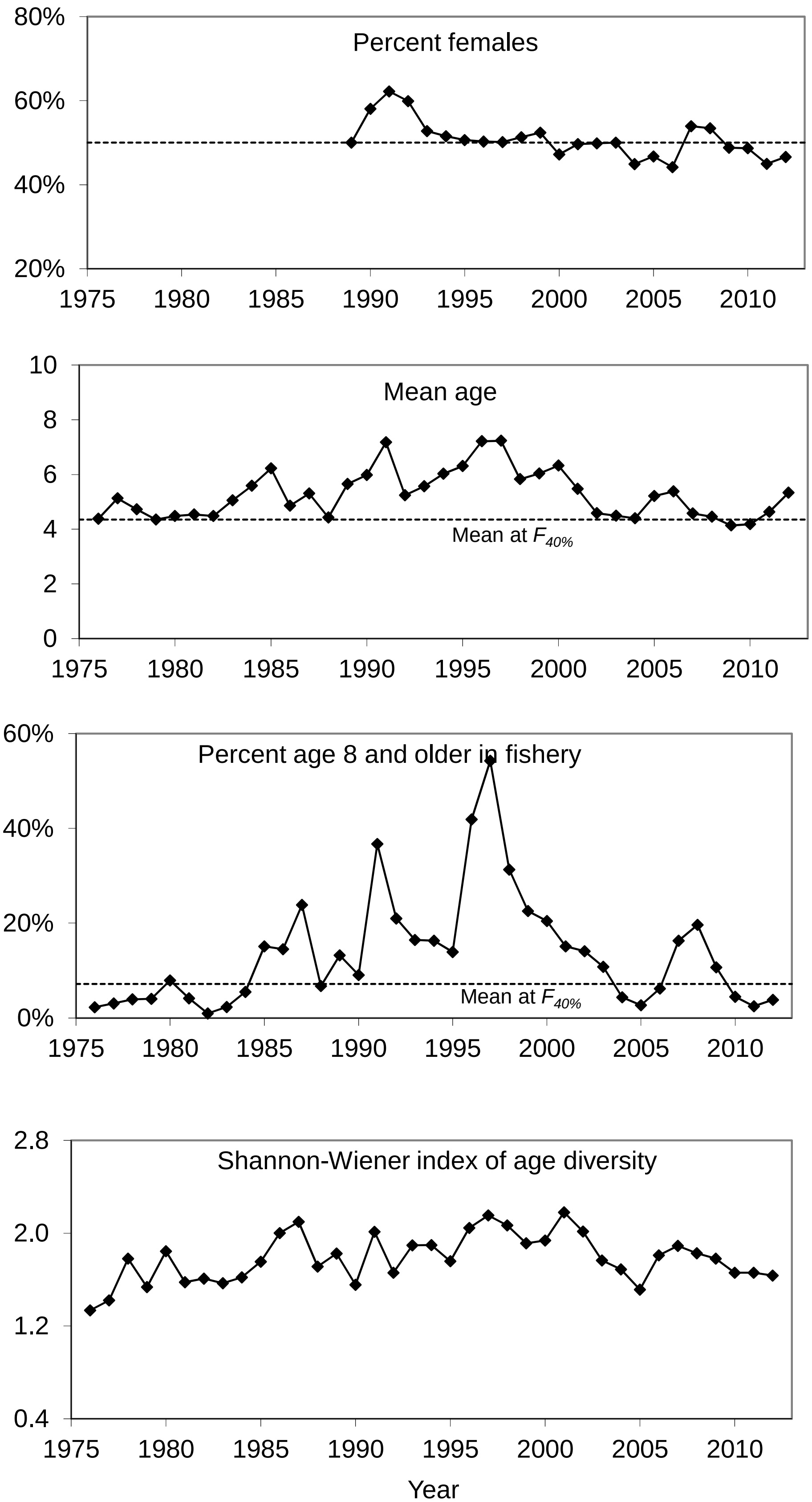



Figure 1.10. Gulf of Alaska pollock fishery catch characteristics.

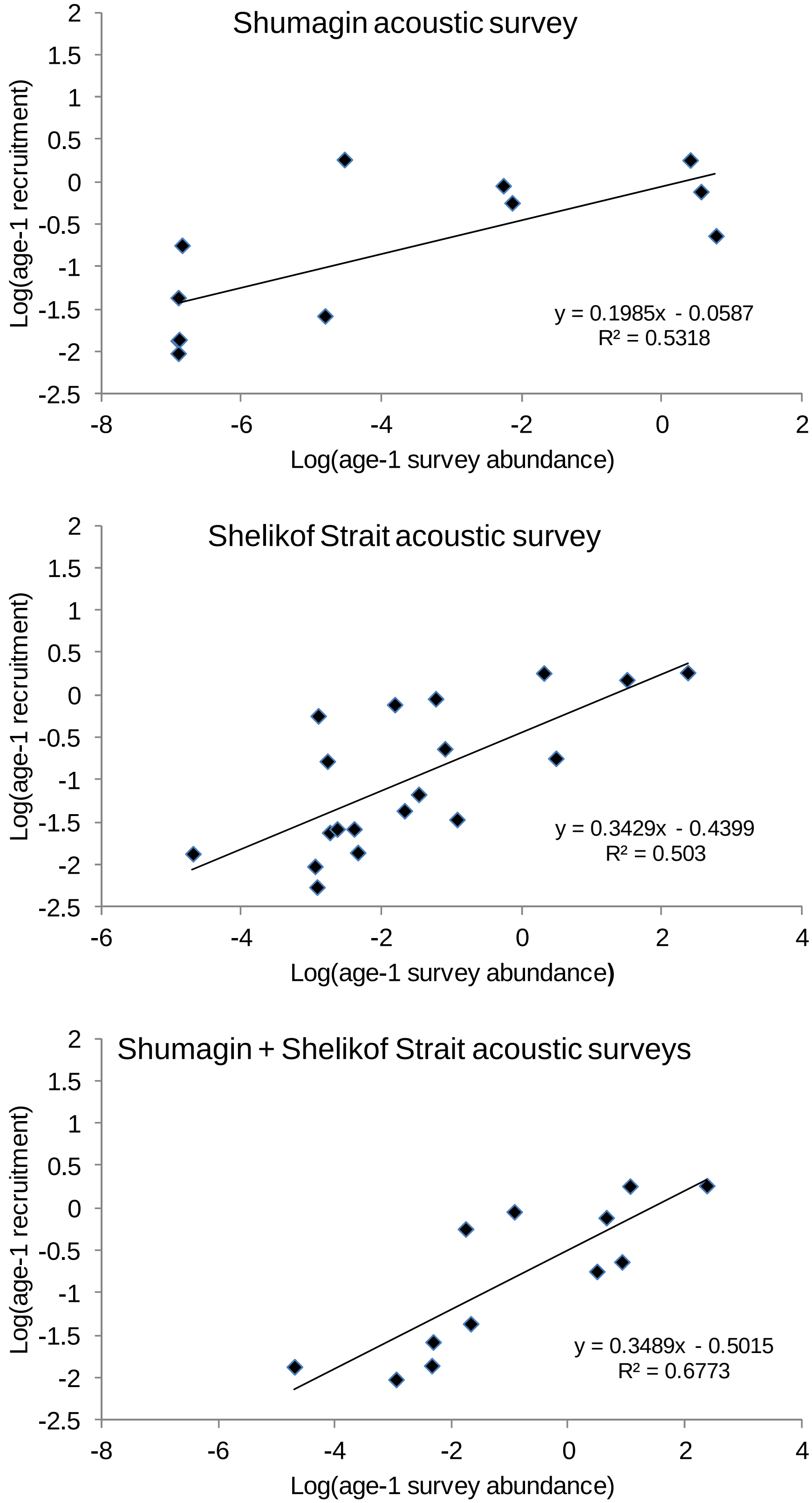



Figure 1.11. Relationship between age-1 abundance indices and assessment model estimates of recruitment for Shumagin and Shelikof Strait acoustic surveys after 1992.

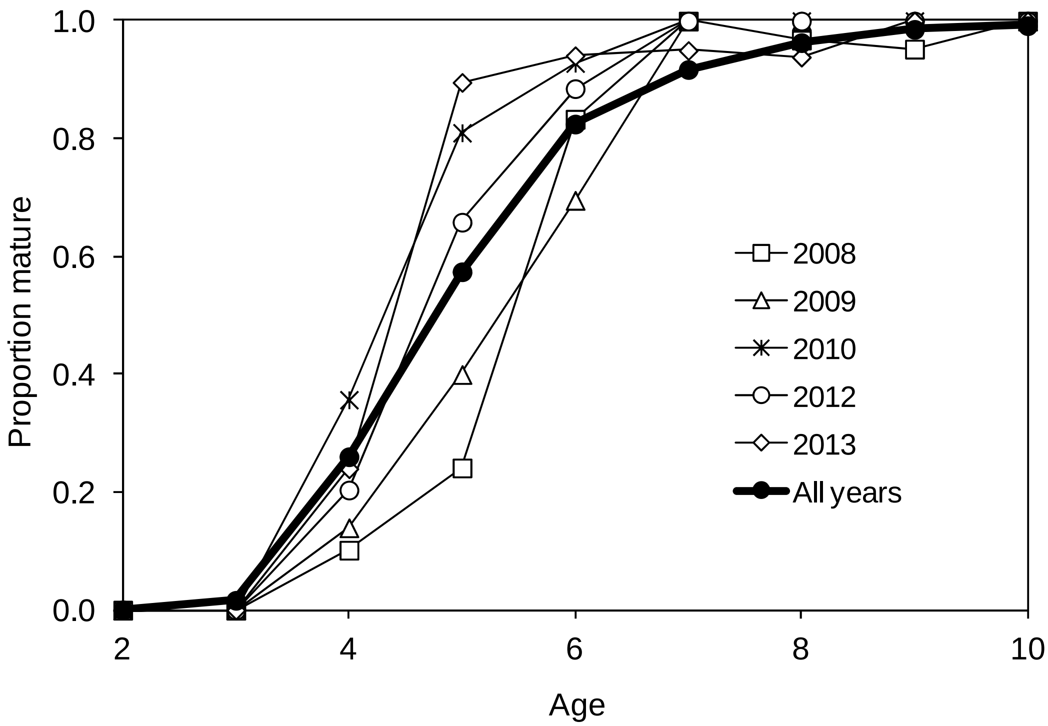



Figure 1.12. Estimates of the proportion mature at age from visual maturity data collected during 2008-2013 winter acoustic surveys in the Gulf of Alaska and long-term average proportion mature at age (1983-2013).

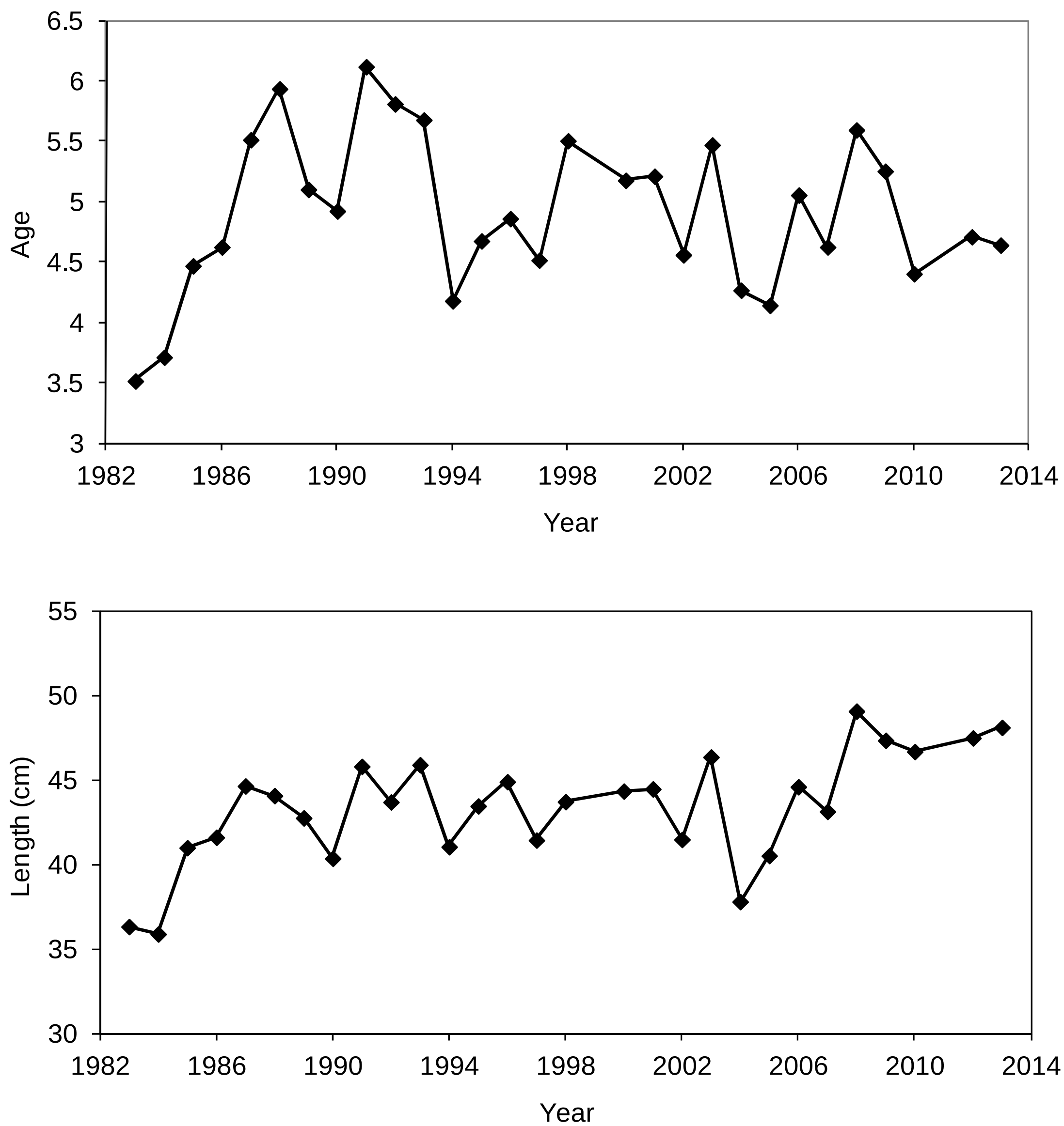



Figure 1.13. Age at 50% mature (top) and length at 50% mature (bottom) from annual logistic regressions for female pollock from winter acoustic survey data in the Gulf of Alaska, 1983-2013.

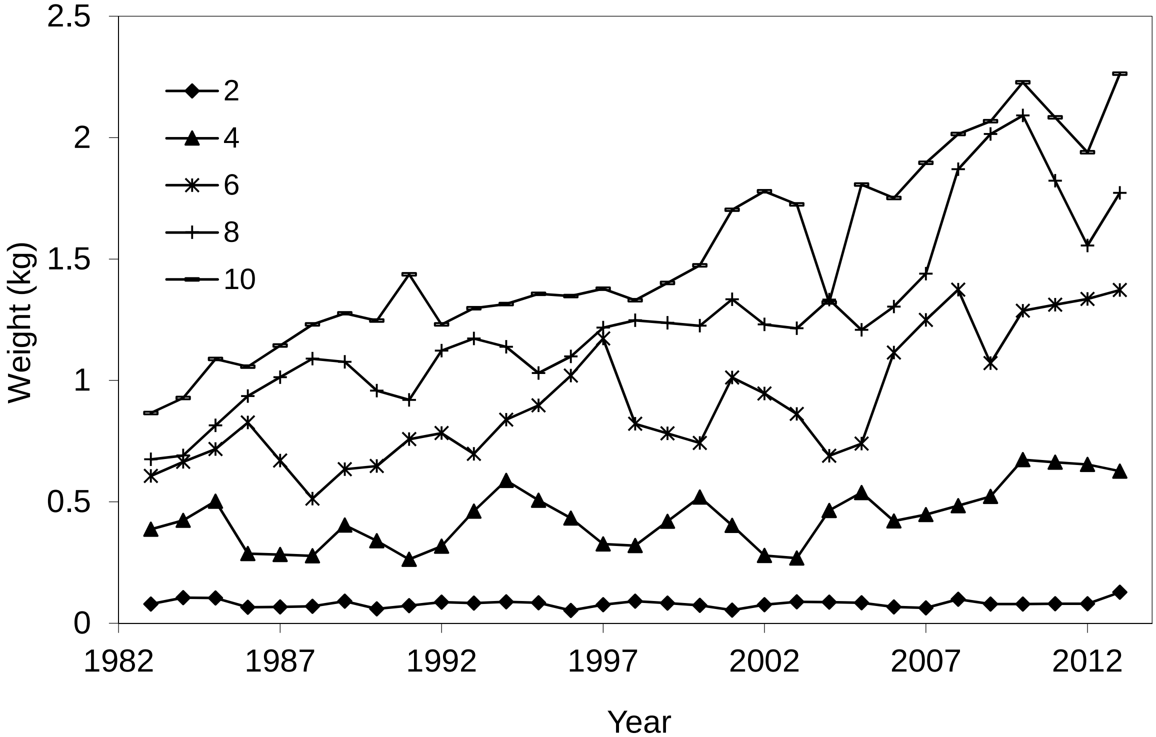



Figure 1.14. Estimated weight-at-age of Gulf of Alaska pollock (ages 2, 4, 6, and 10) from Shelikof Strait acoustic surveys in 1983-2013 used in the assessment model. In 1999 and 2011, when the acoustic survey was not conducted, weights-at-age were interpolated from adjacent years.

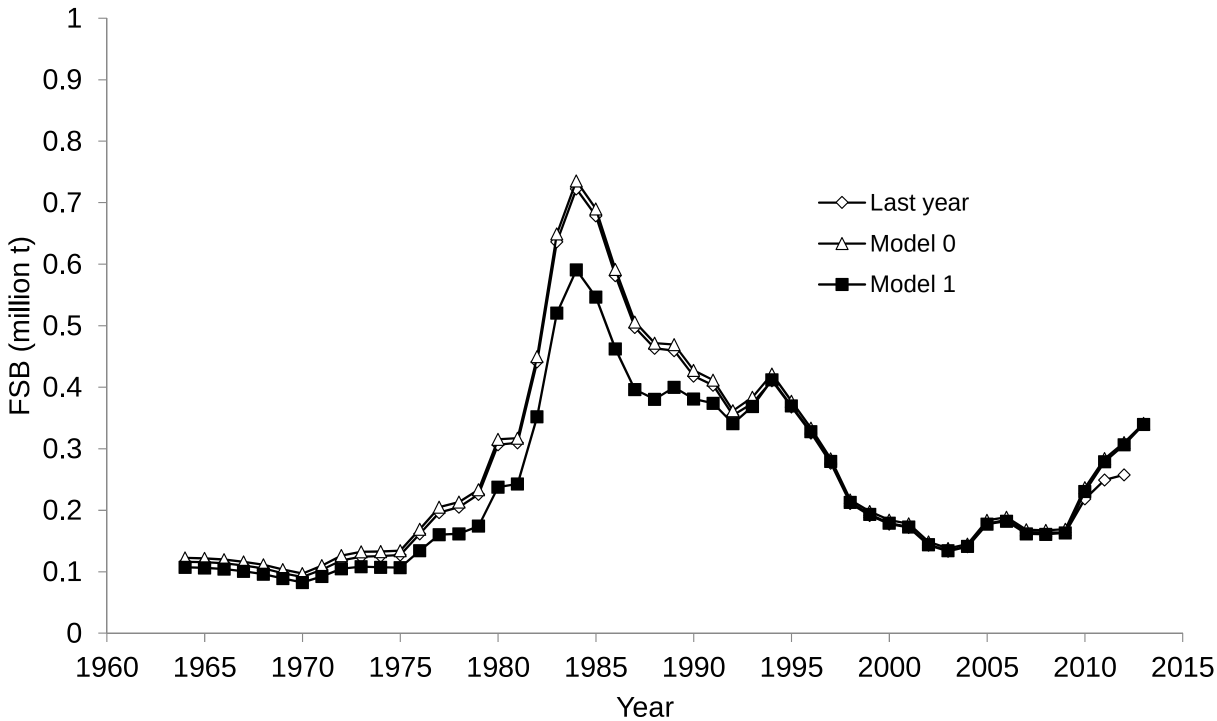



Figure 1.15. Comparison of estimated spawning biomass from the alternative models. Model 0 updates the 2012 assessment model with new data but makes no changes to the model configuration. Model 1 implements several minor changes to treatment of survey data.

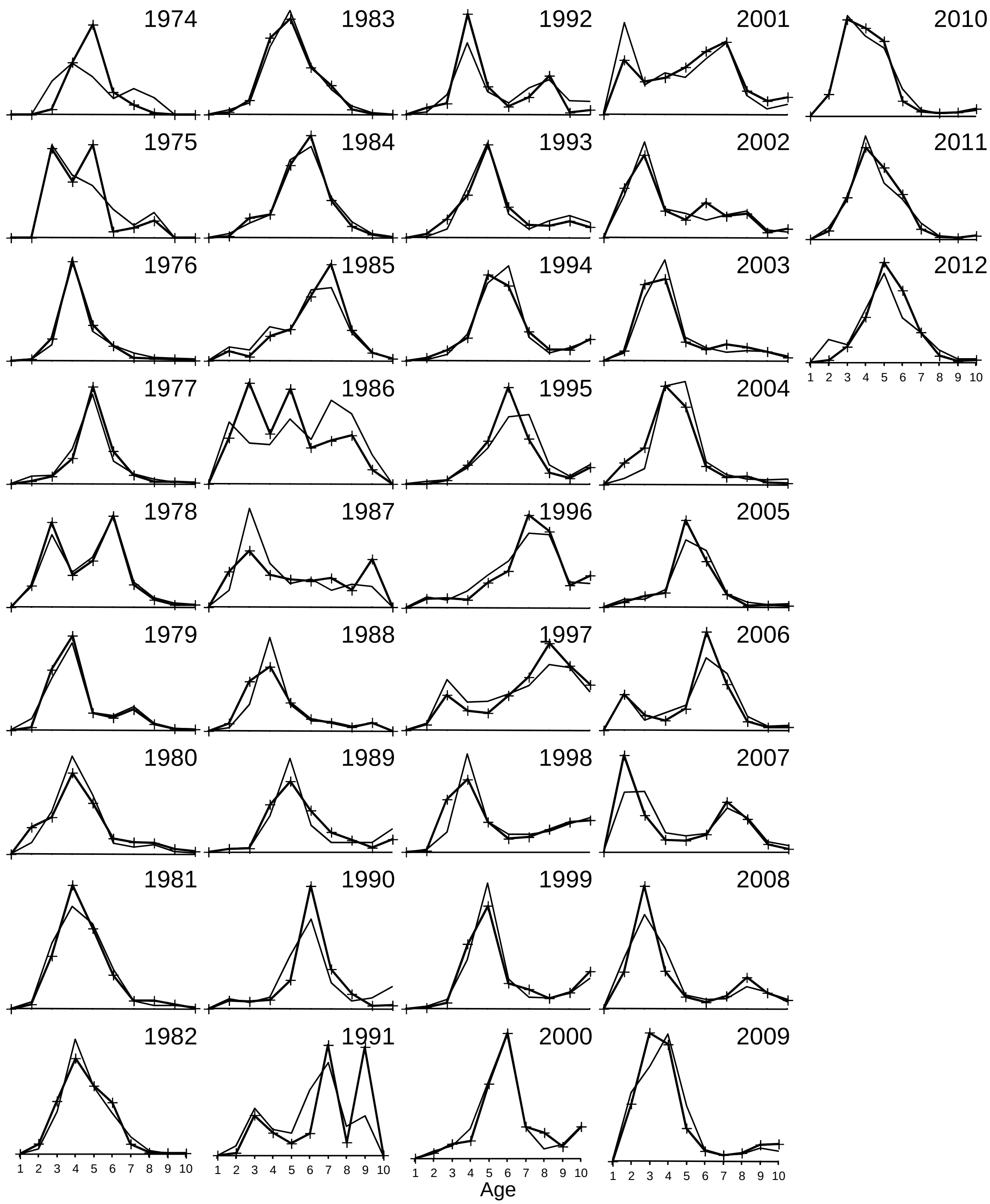



Figure 1.16. Observed and predicted fishery age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbol are observed proportions at age.

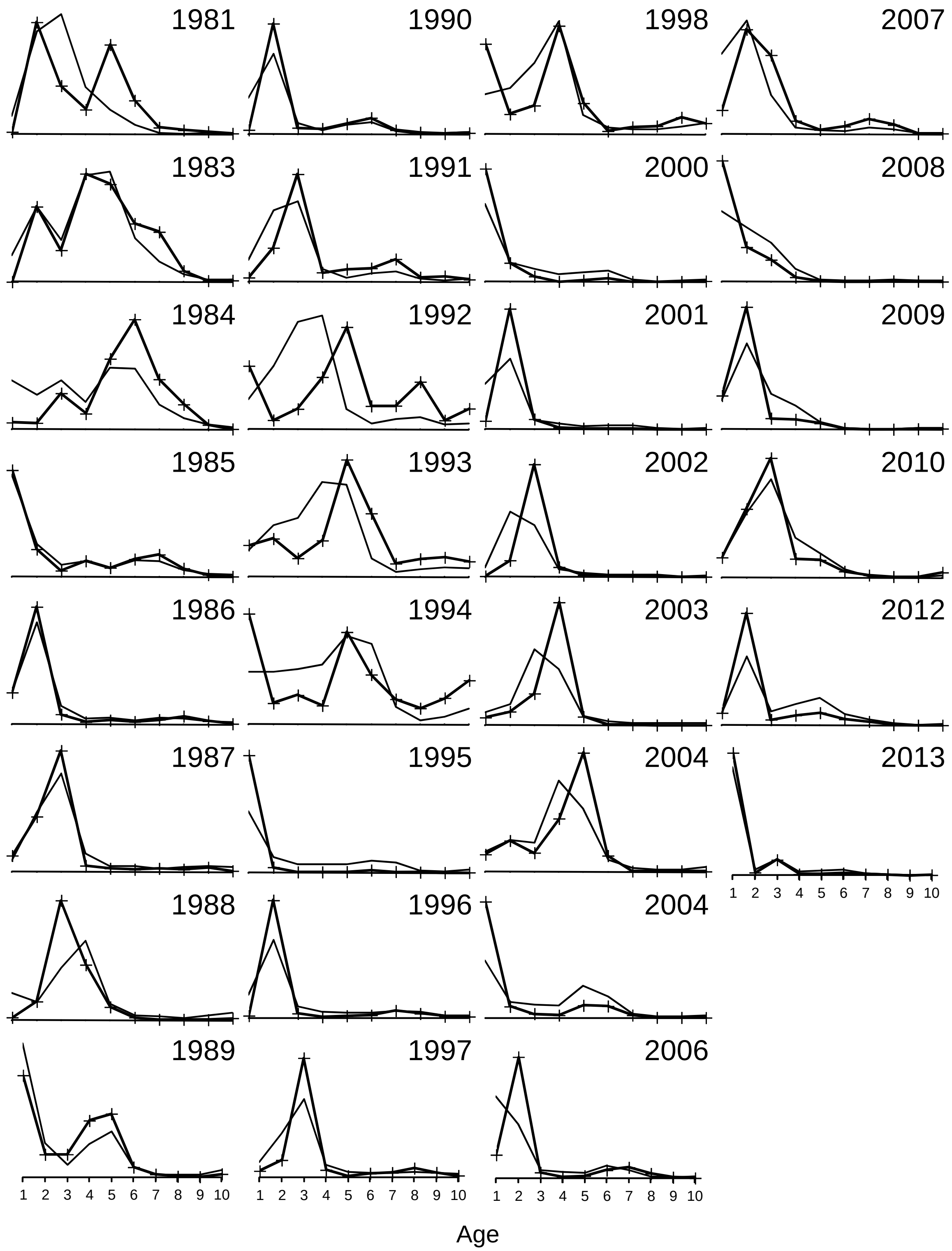



Figure 1.17. Observed and predicted Shelikof Strait acoustic survey age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbol are observed proportions at age.

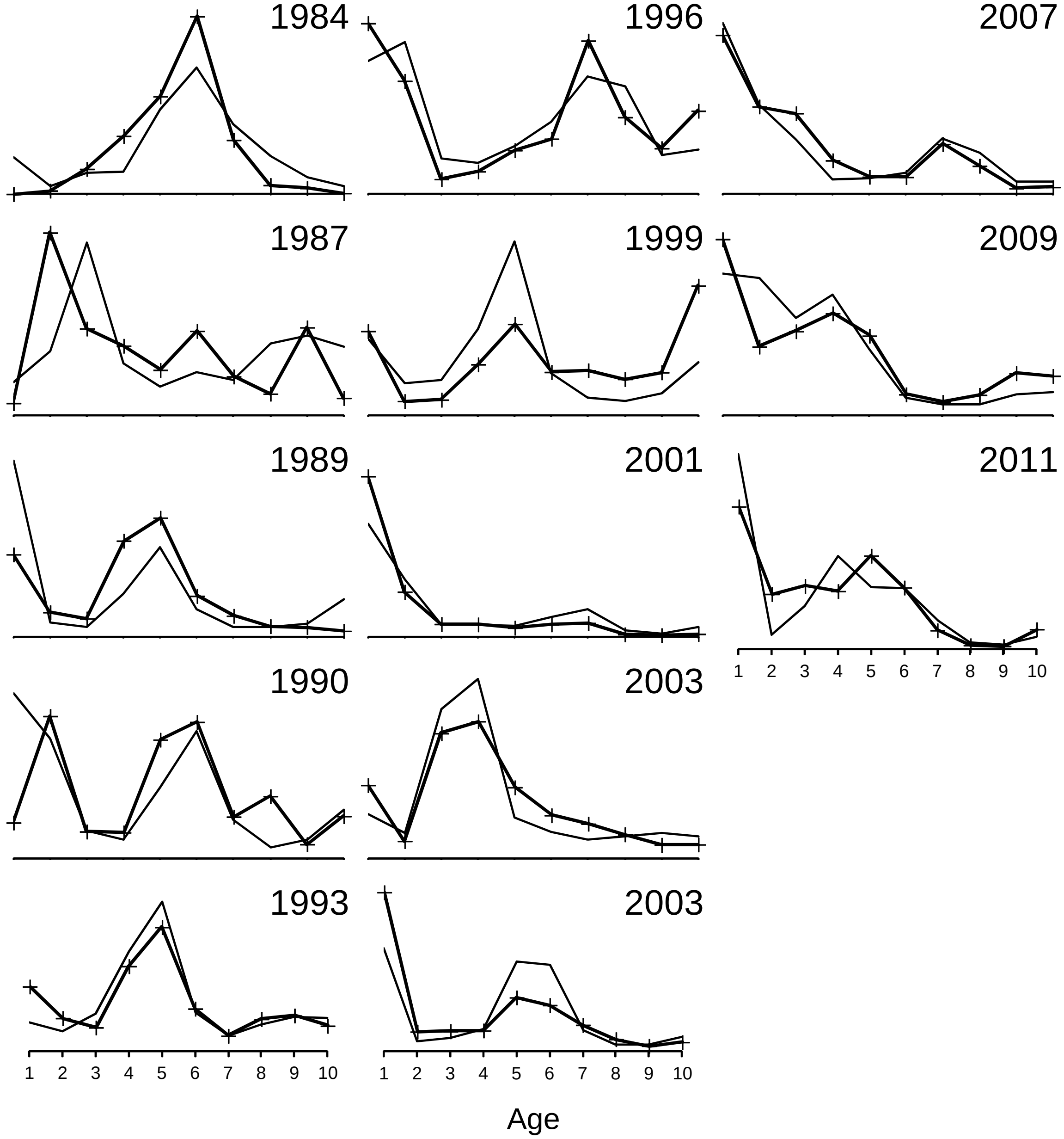



Figure 1.18. Observed and predicted NMFS bottom trawl age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbol are observed proportions at age.

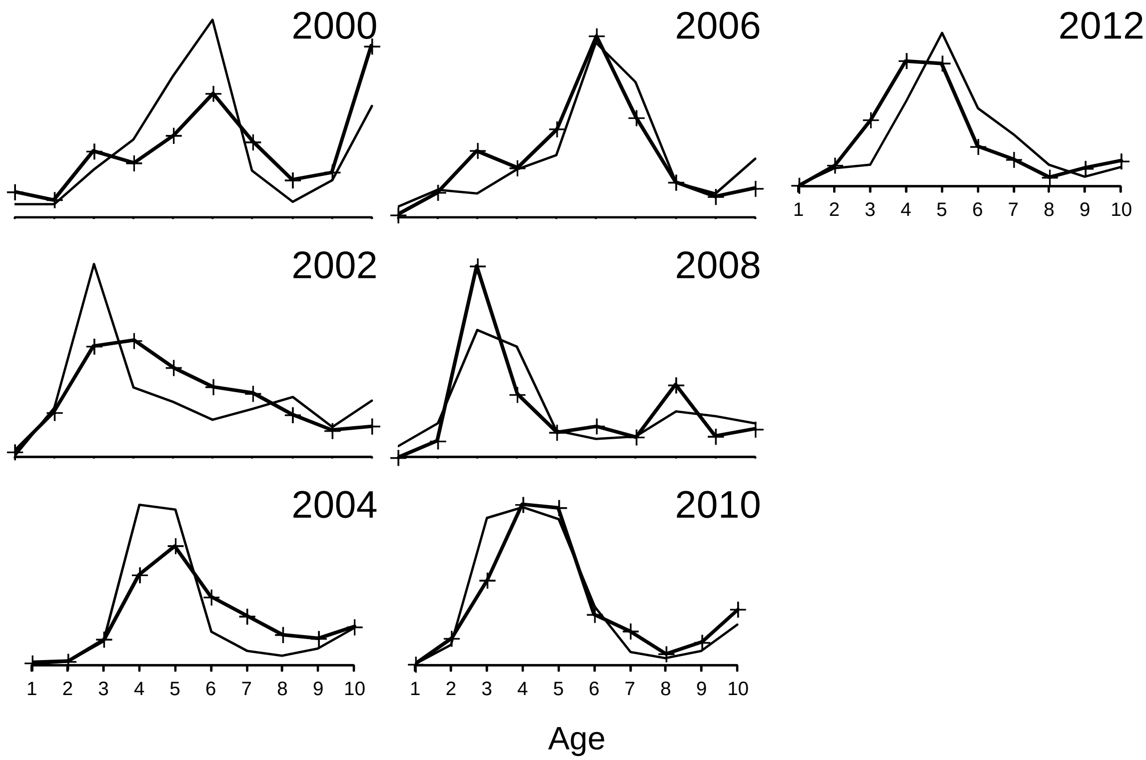



Figure 1.19. Observed and predicted ADFG crab/groundfish survey age composition for Gulf of Alaska pollock from the base model. Continuous lines are model predictions and lines with + symbol are observed proportions at age.

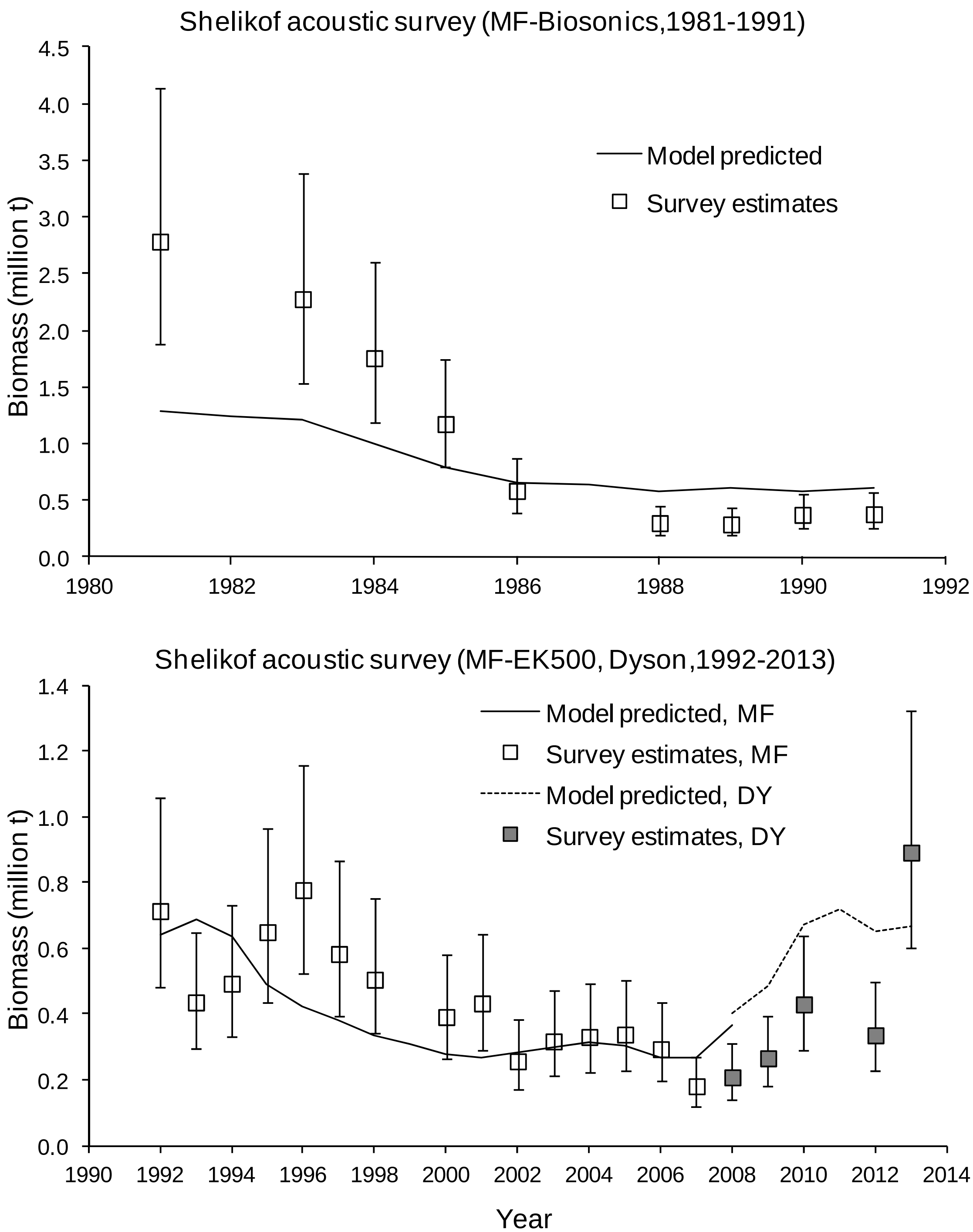



Figure 1.20. Model predicted and observed survey biomass for the Shelikof Strait acoustic survey for the base model (Model 1). The Shelikof acoustic survey is modeled with three catchability periods corresponding to the two acoustic systems used on the *R/V Miller Freeman* (MF), with an additional catchability period for the *R/V Oscar Dyson* (DY) in 2008-2013. Error bars indicate plus and minus two standard deviations. A CV of 0.2 is assumed for all acoustic surveys when fitting the model.

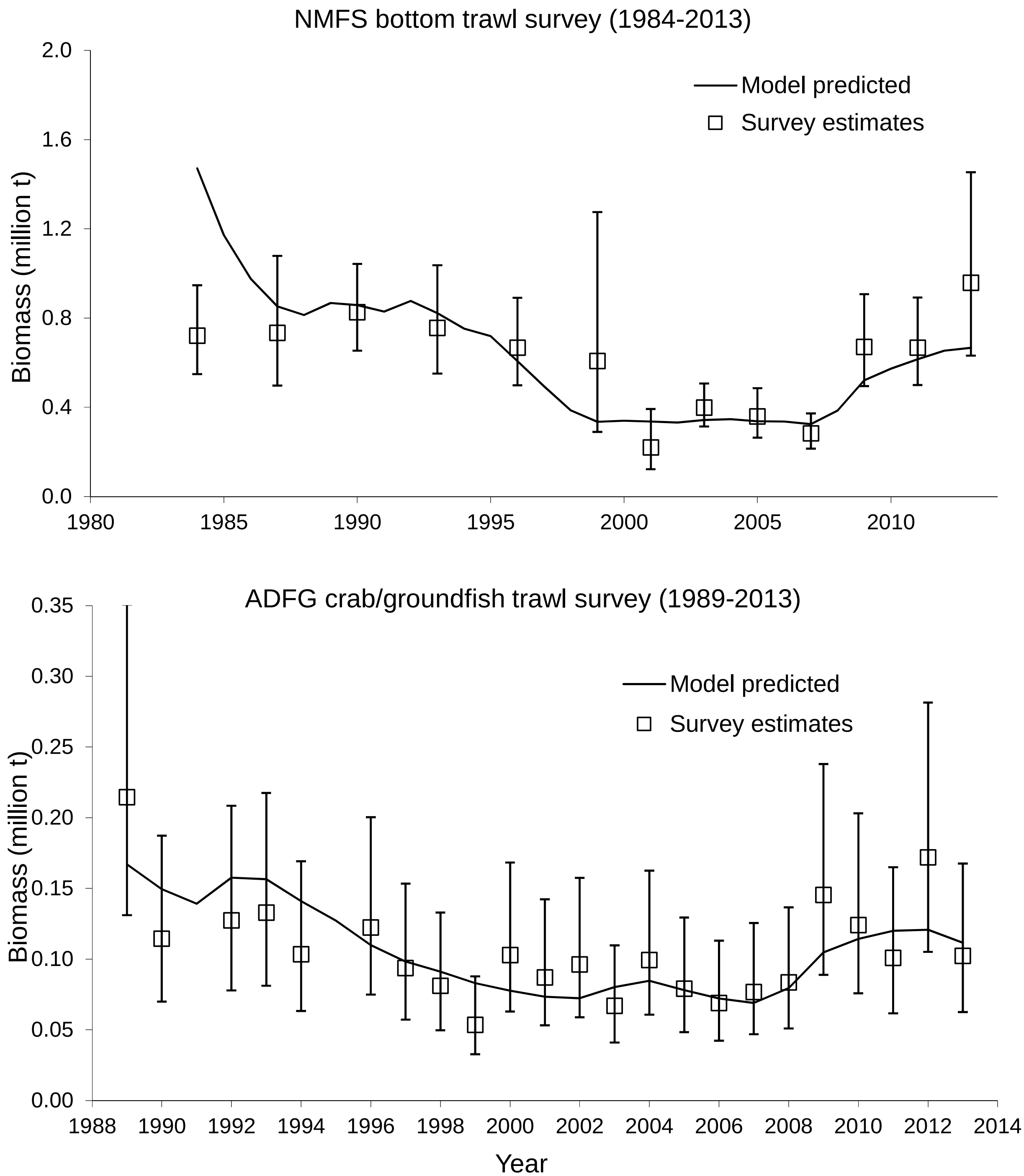



Figure 1.21. Model predicted and observed survey biomass for the NMFS bottom trawl survey (top), and the ADFG crab/groundfish survey (bottom) for the base model (Model 1). Error bars indicate plus and minus two standard deviations. Since variance estimates are unavailable for ADFG biomass estimates, an assumed CV of 0.25 is used in the assessment model.

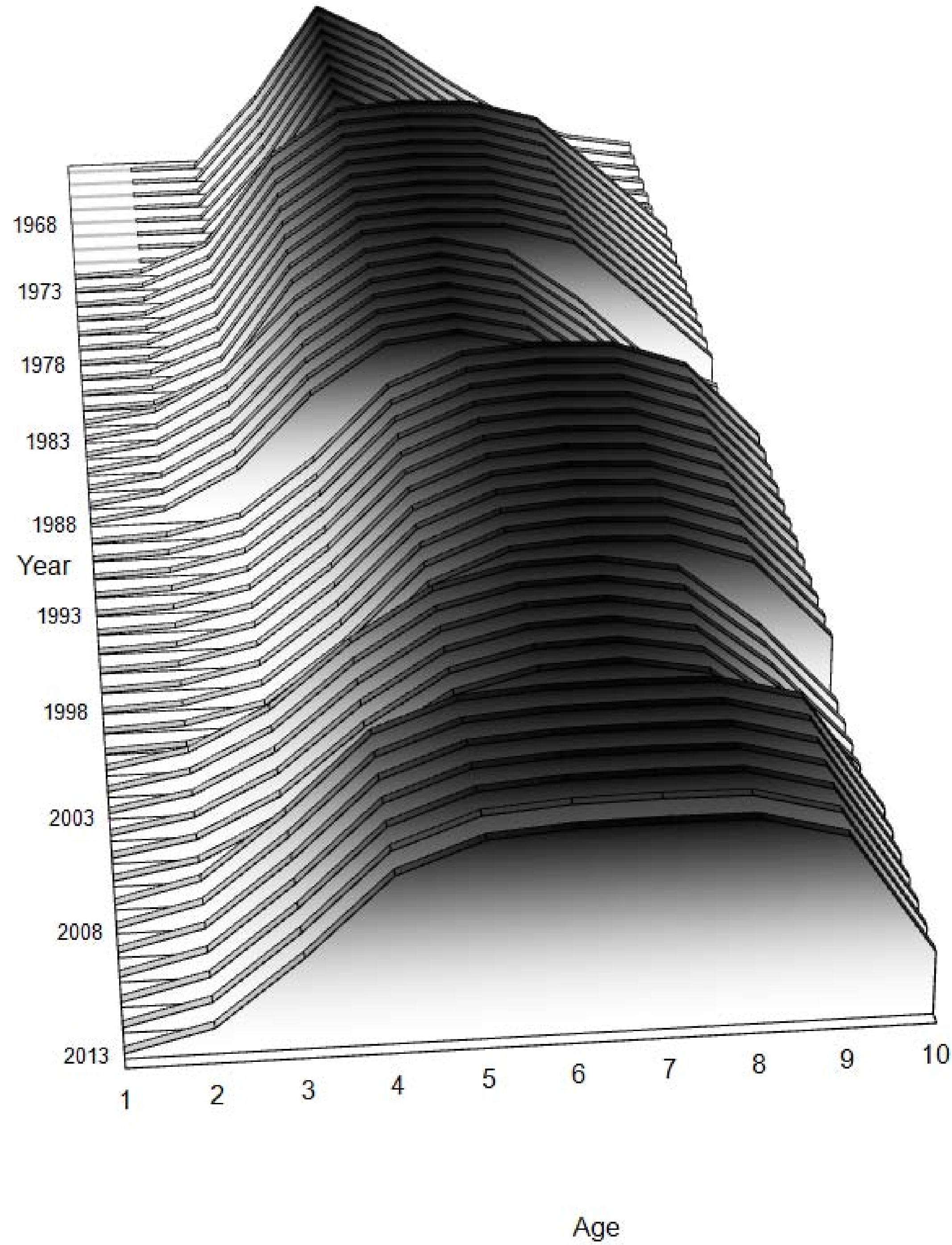



Figure 1.22. Estimates of time-varying fishery selectivity for Gulf of Alaska pollock for the base model. The selectivity is scaled so the maximum in each year is 1.0.

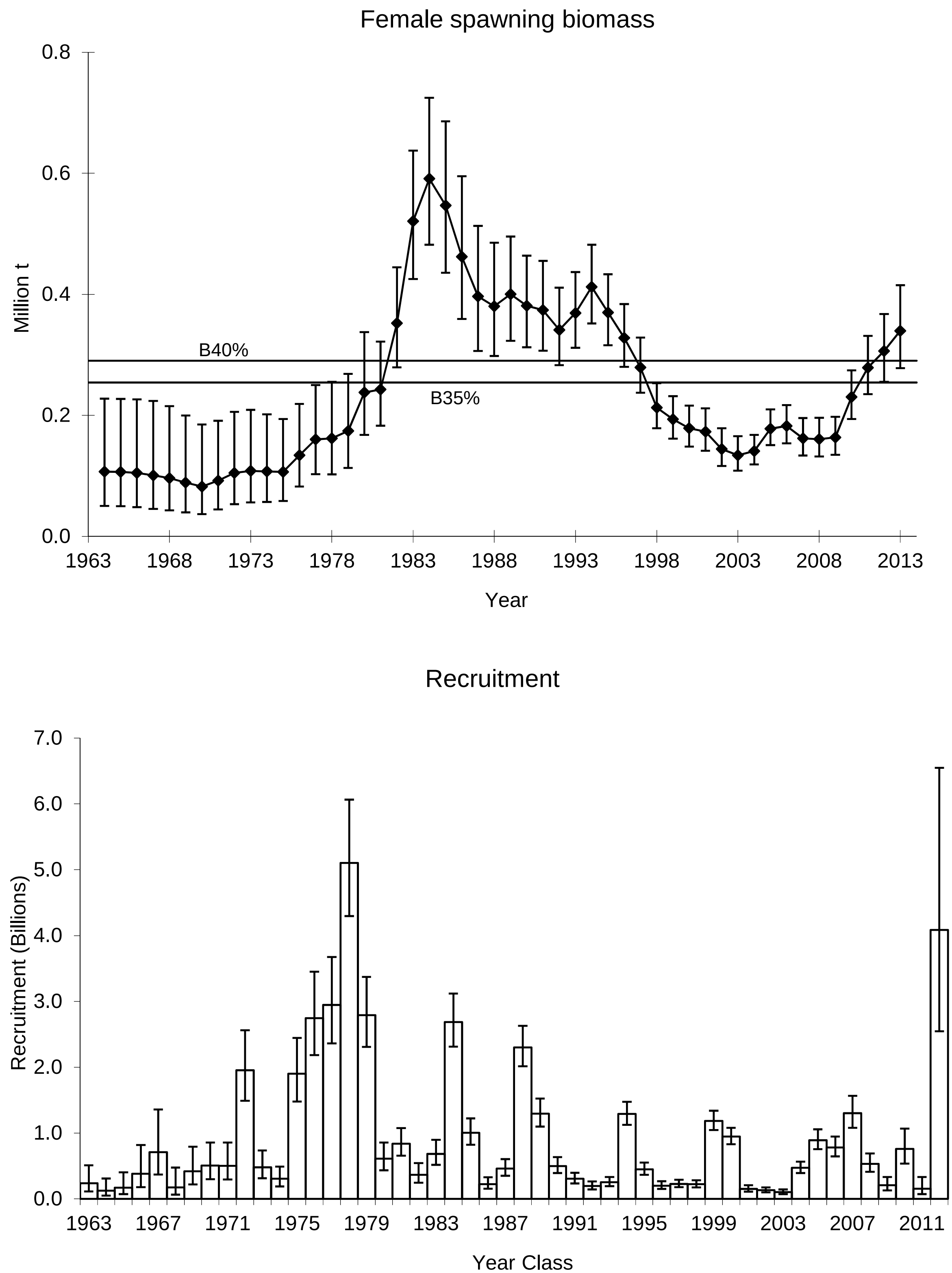
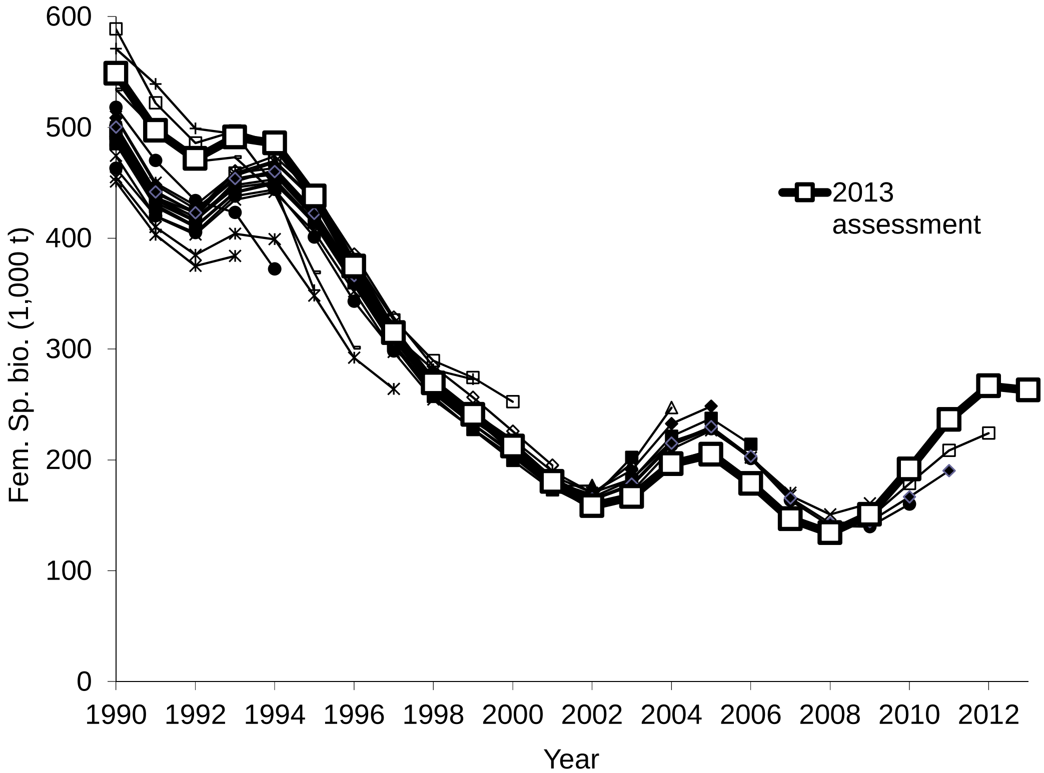



Figure 1.23. Estimated time series of Gulf of Alaska pollock spawning biomass (million t, top) and age-1 recruitment (billions of fish, bottom) from 1964 to 2013 for the base model. Vertical bars represent two standard deviations. The $B_{35\%}$ and $B_{40\%}$ lines represent the current estimate of these benchmarks.



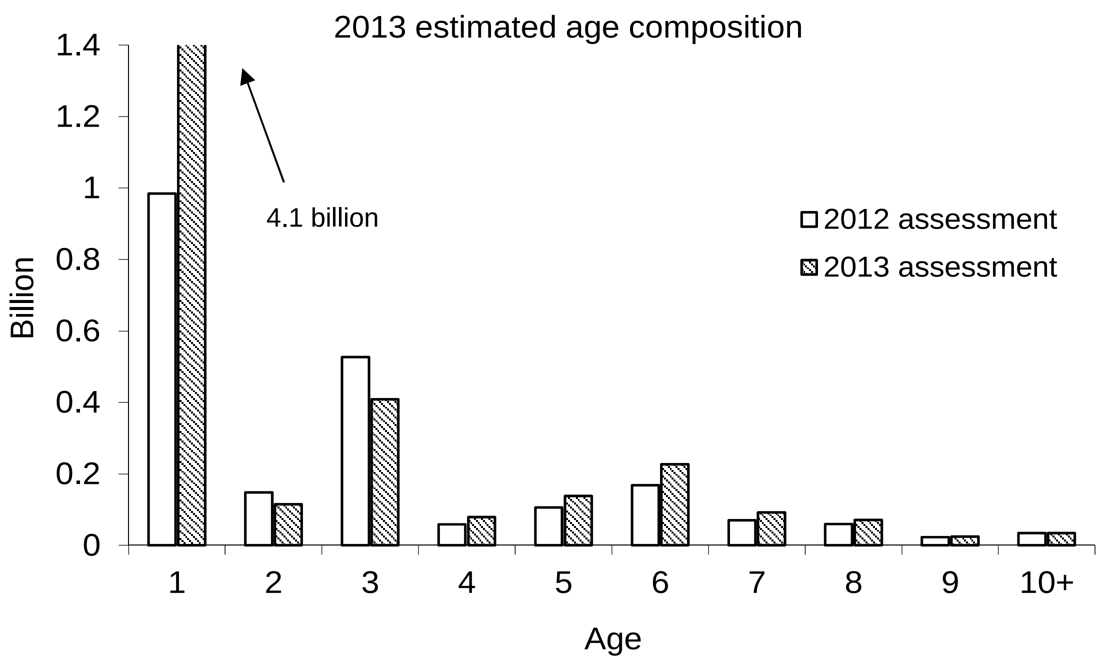
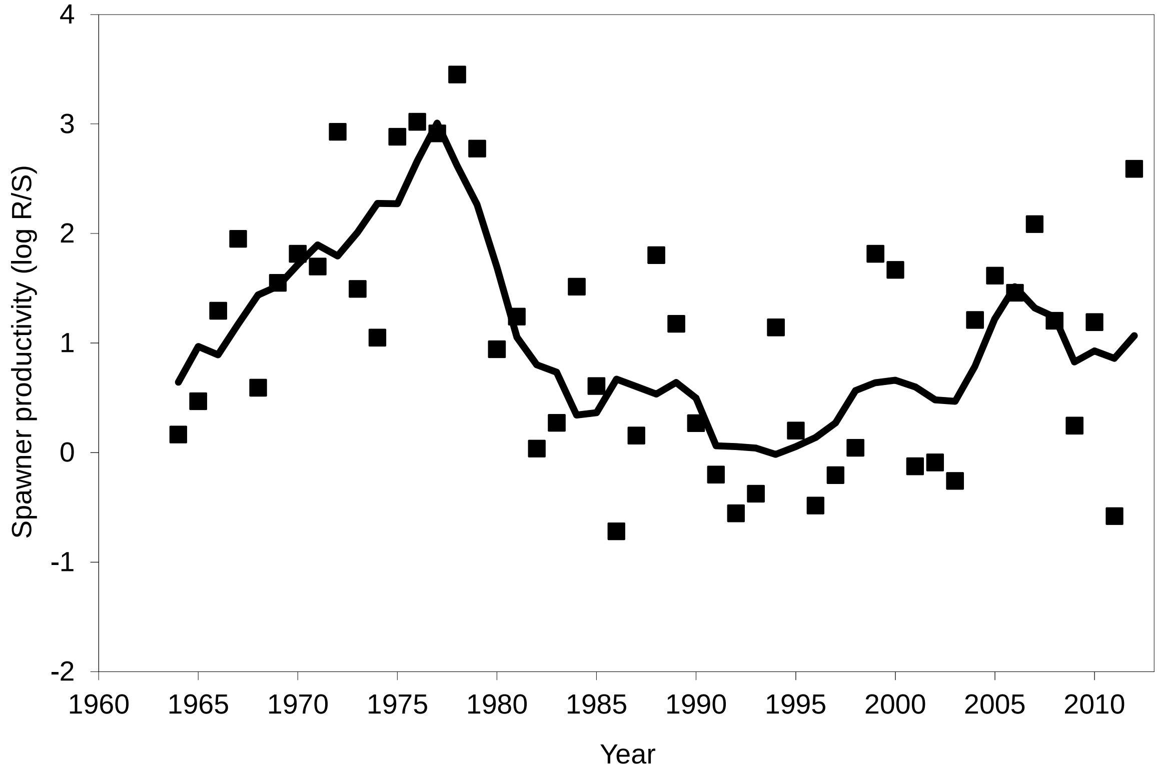




Figure 1.24. Retrospective plot of estimated Gulf of Alaska pollock female spawning biomass for stock assessments in the years 1993-2013 (top). For this figure, the time series of female spawning biomass was calculated using the same maturity and spawning weight at age for all assessments to facilitate comparison. The bottom panel shows the estimated age composition in 2013 from the 2012 and 2013 assessments.



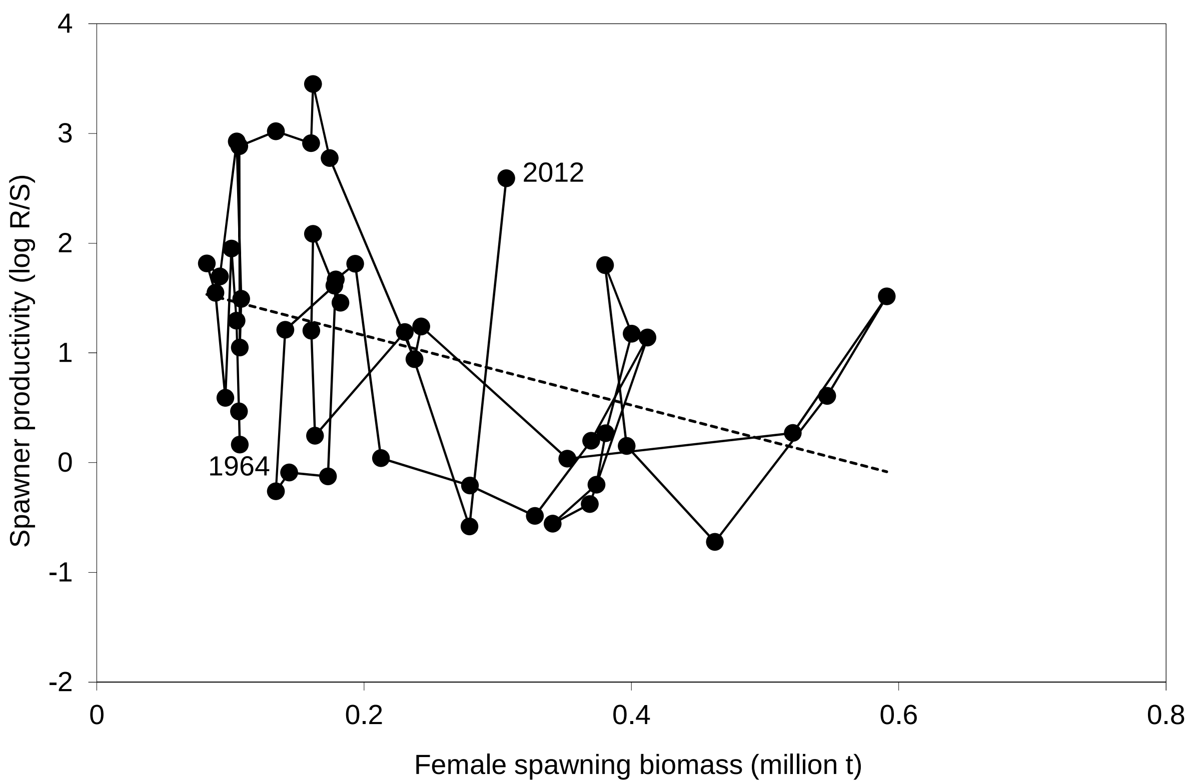
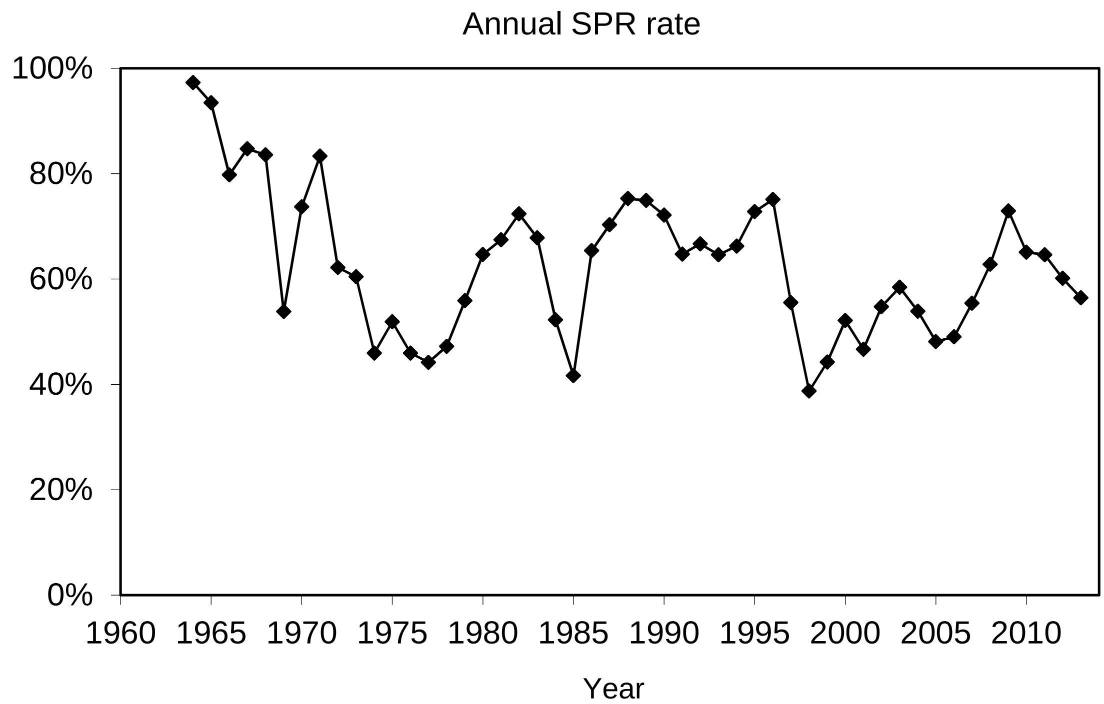




Figure 1.25. Gulf of Alaska pollock spawner productivity, *log(R/S)*, in 1964-2012 (top). A five-year running average is also shown. Spawner productivity in relation to female spawning biomass (bottom). The Ricker stock-recruit curve is linear in a plot of spawner productivity against spawning biomass.



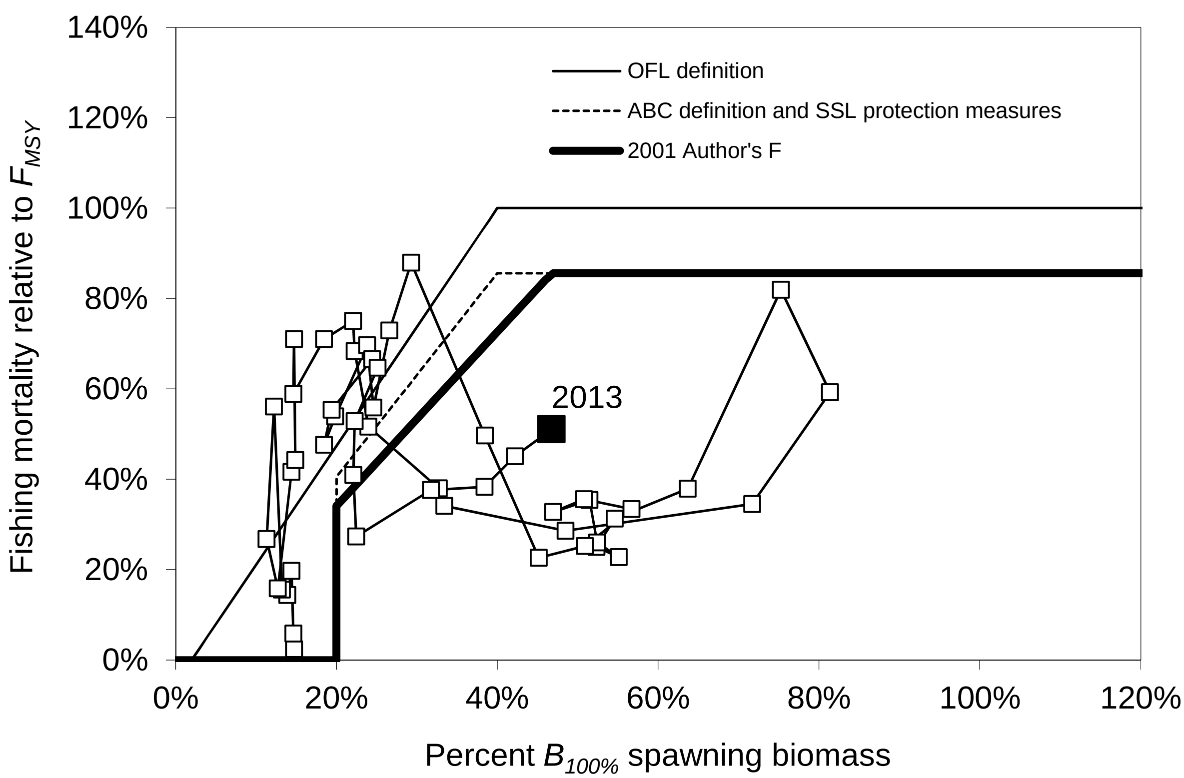




Figure 1.26. Annual fishing mortality as measured in percentage of unfished spawning biomass per recruit (top). Gulf of Alaska pollock spawning biomass relative to the unfished level and fishing mortality relative to $F_{MSY}$ (bottom). The ratio of fishing mortality to $F_{MSY}$ is calculated using the estimated selectivity pattern in that year. Estimates of $B_{100\%}$ spawning biomass are based on current estimates of maturity at age, weight at age, and mean recruitment. Because these estimates change as new data become available, this figure can only be used in a general way to evaluate management performance relative to biomass and fishing mortality reference levels.

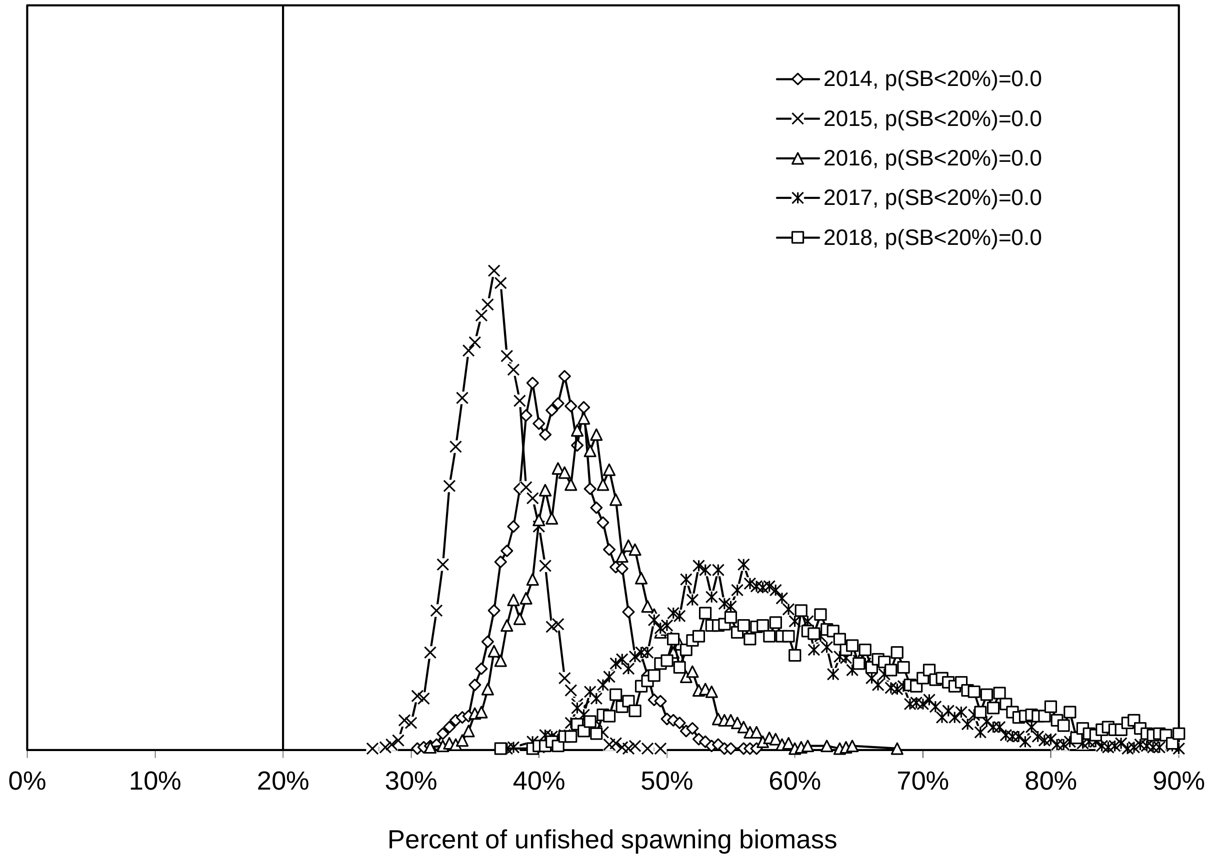
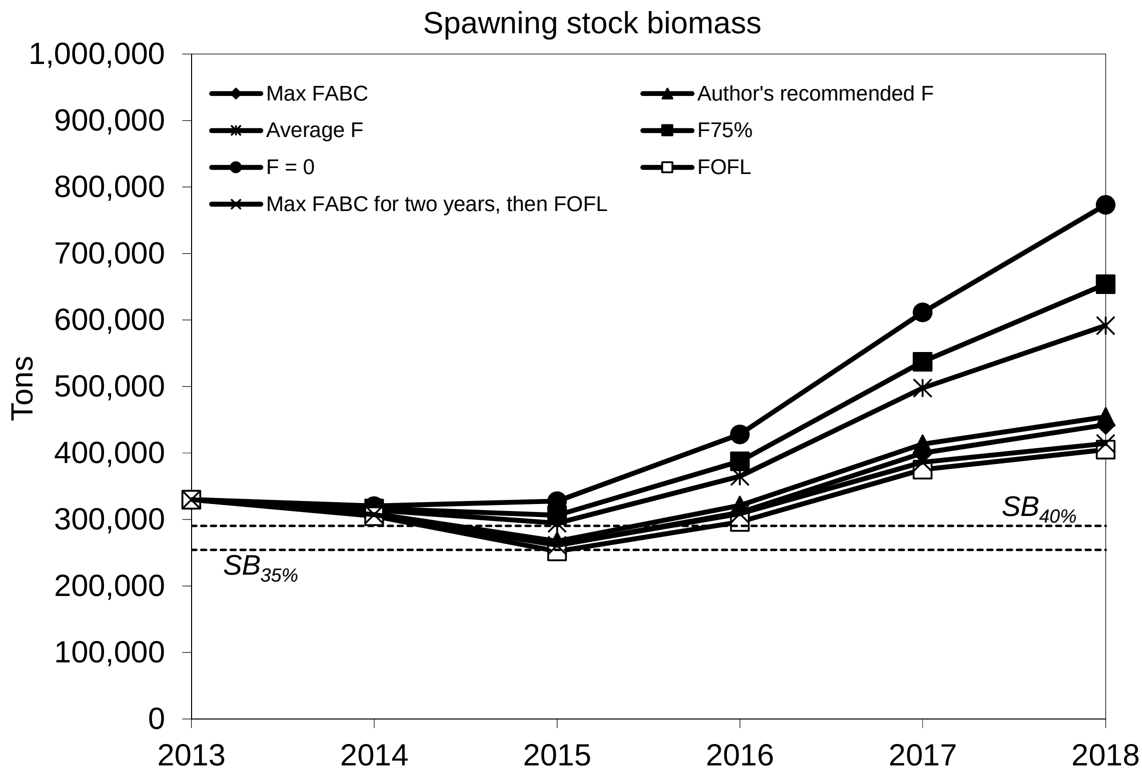



Figure 1.27. Uncertainty in spawning biomass in 2014-2018 based on a thinned MCMC chain from the joint marginal likelihood for the base model where catch is set to the author's recommended $F_{ABC}$.



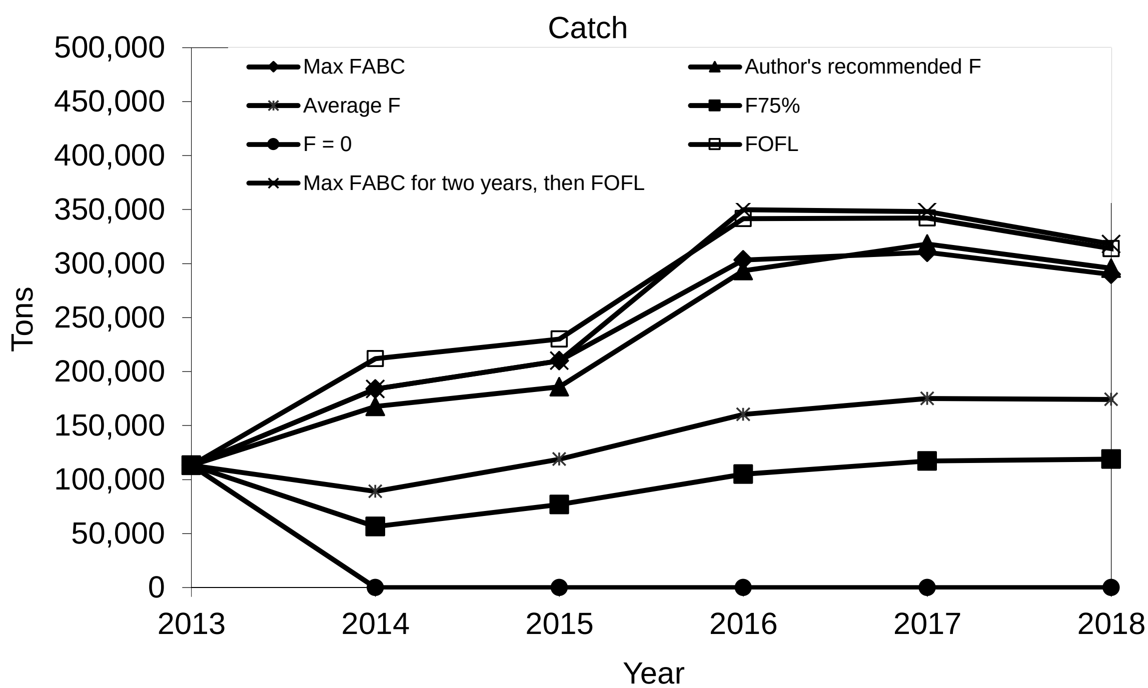




Figure 1.28. Projected spawning biomass and catches in 2014-18 under different harvest rates.

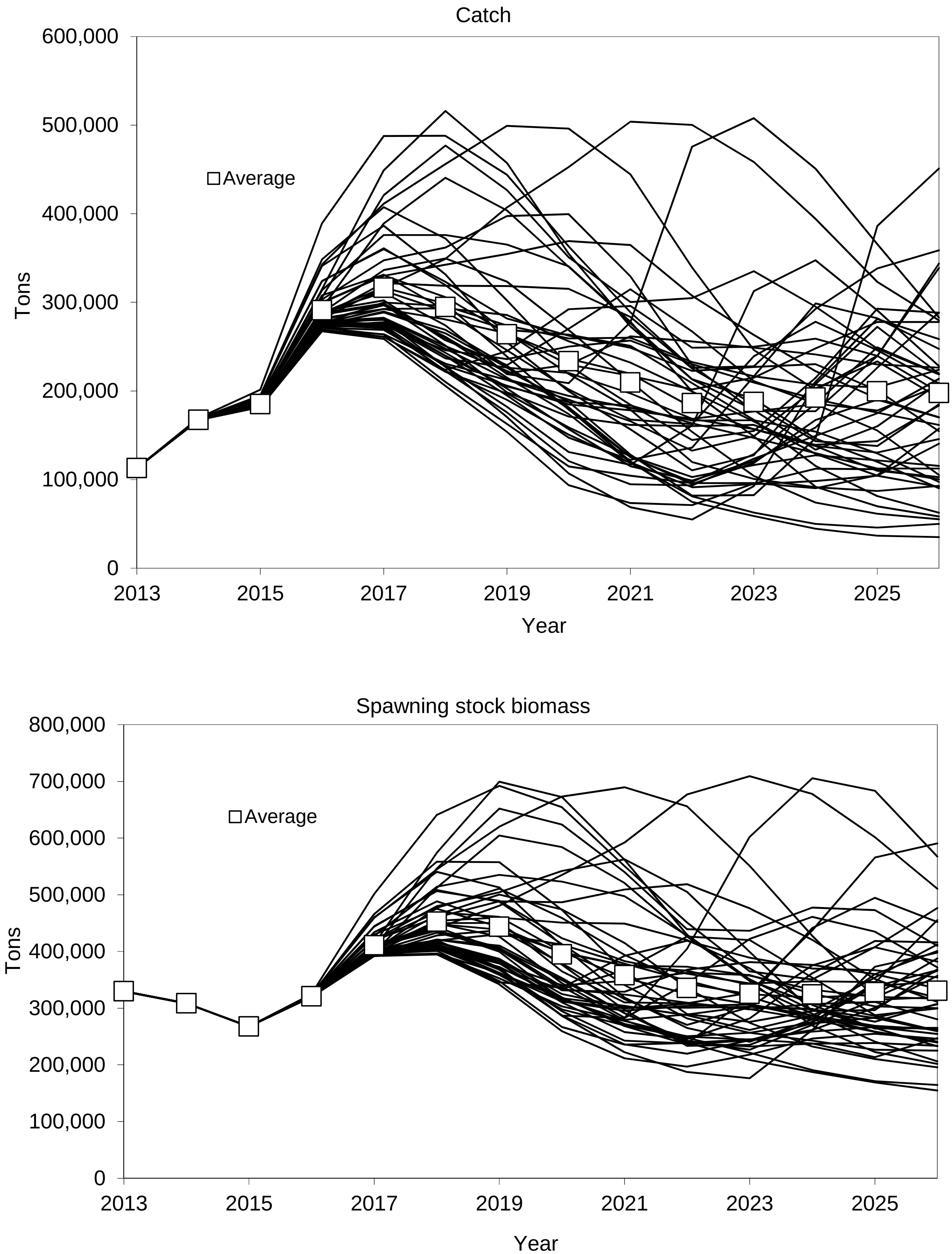



Figure 1.29. Variability in projected catch and spawning biomass in 2014-2026 for the base model under the author's recommended $F_{ABC}$.

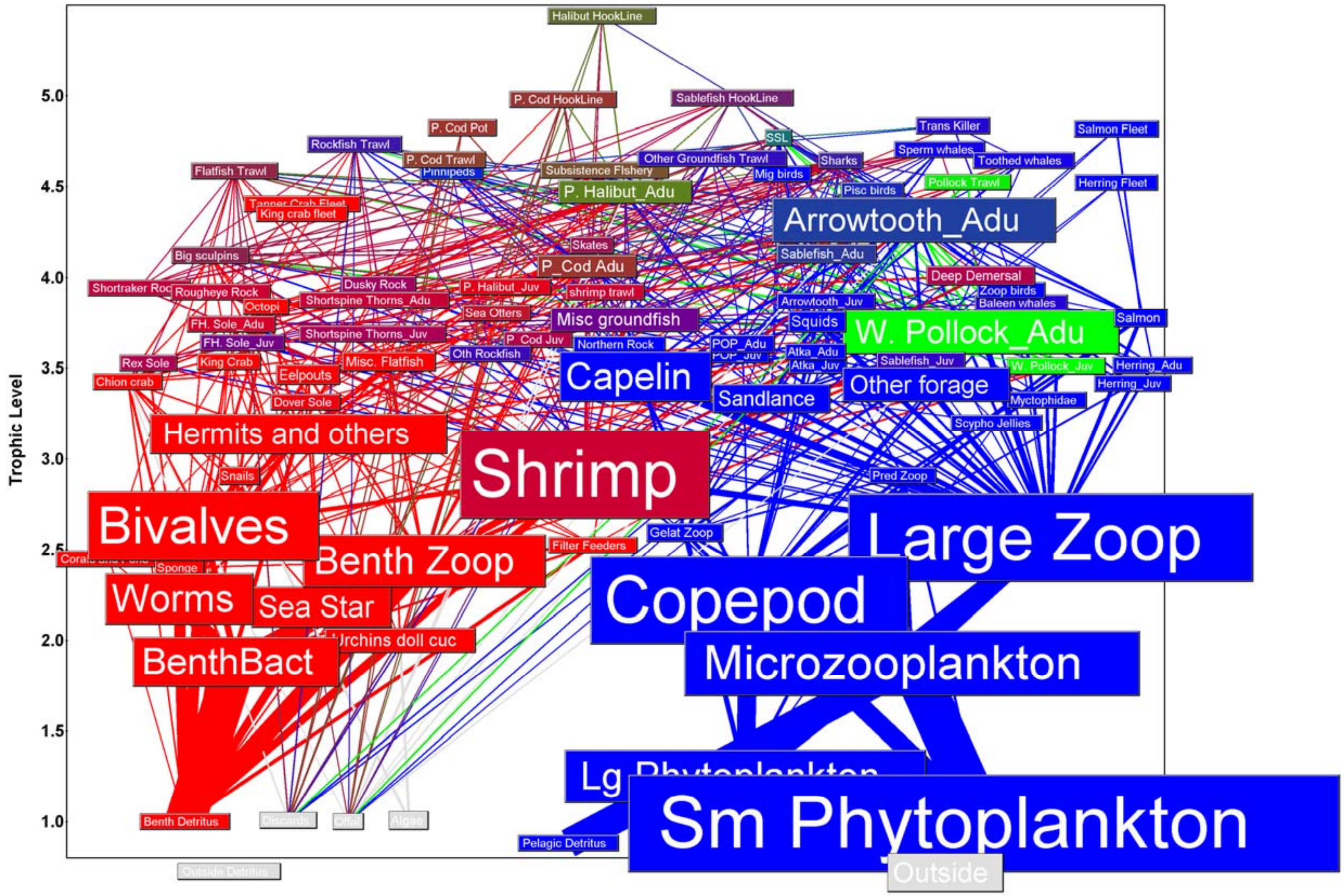
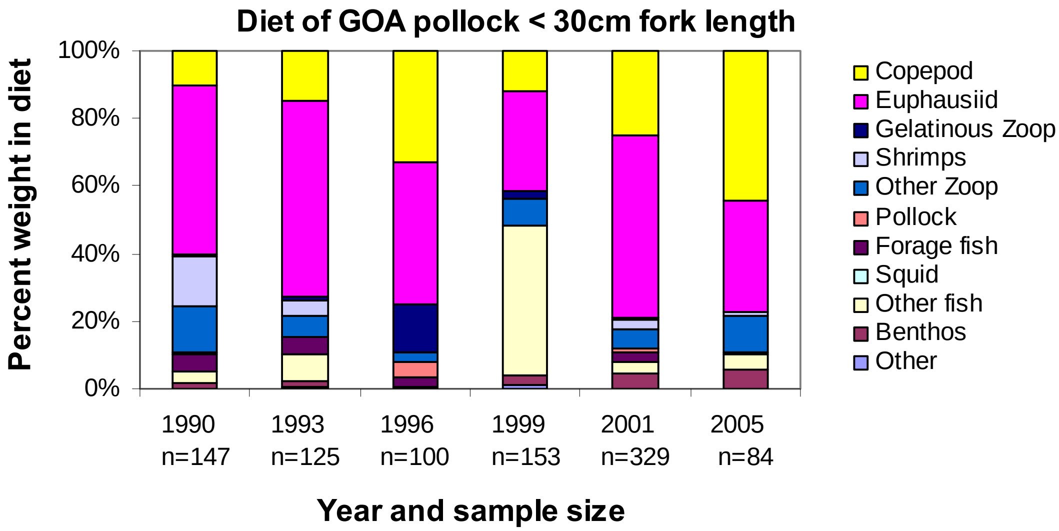



Figure 1.30. Gulf of Alaska food web showing demersal (red) and pelagic (blue) pathways. Walleye pollock is shown in green. Pollock consumers stain green according to the importance of pollock in their diet.



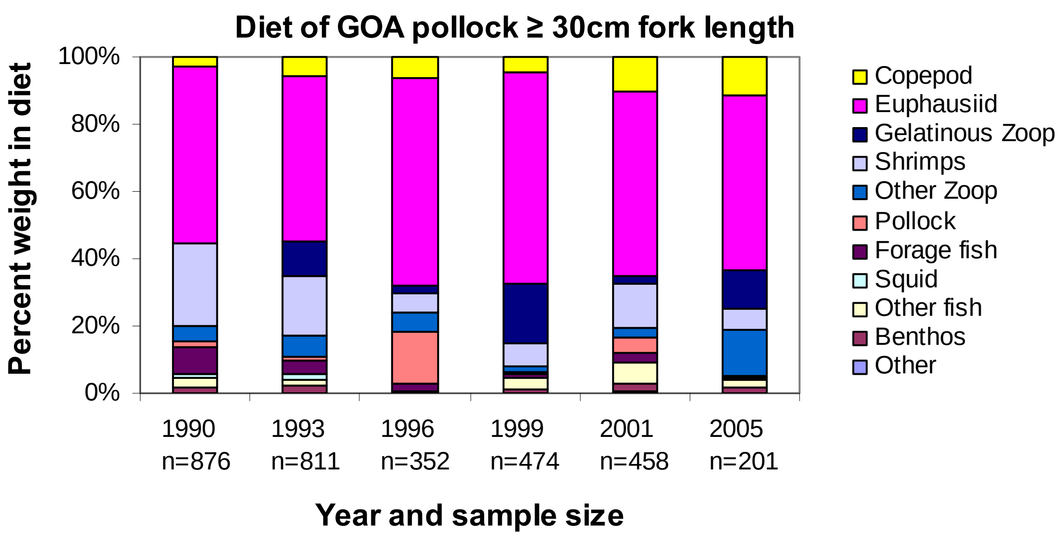
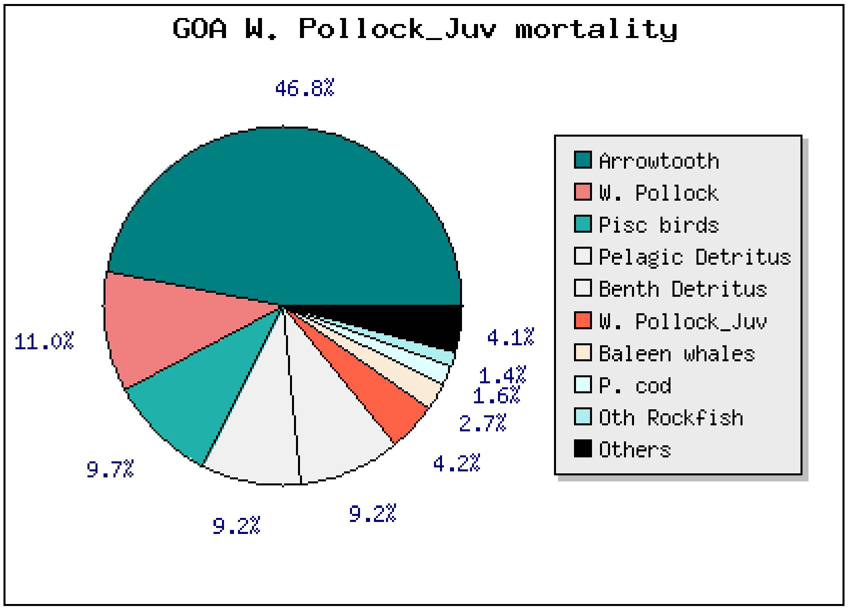




Figure 1.31. Diet (percent wet weight) of GOA walleye pollock juveniles (top) and adults (bottom) from summer food habits data collected on NMFS bottom trawl surveys, 1990-2005.



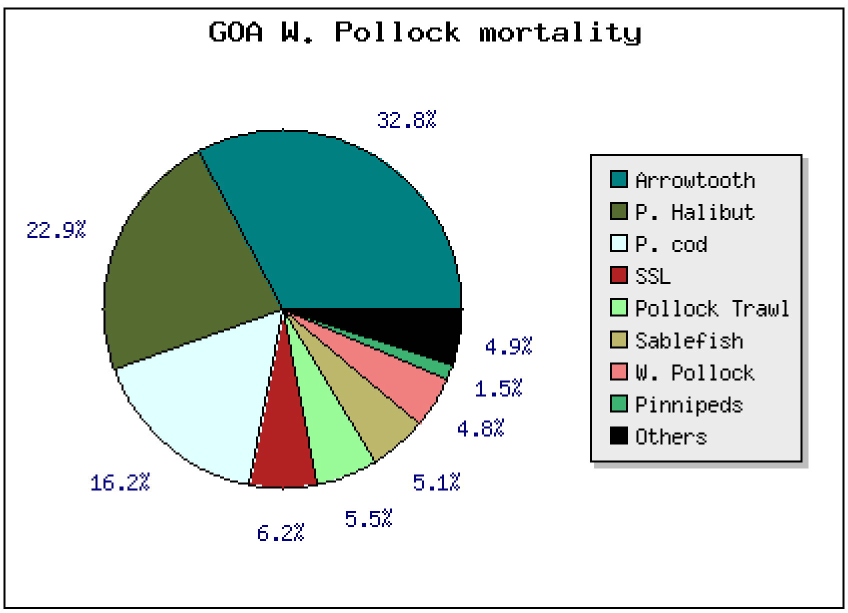




Figure 1.32. Sources of mortality for walleye pollock juveniles (top) and adults (bottom) from an ECOPATH model of the Gulf of Alaska. Pollock less than 20cm are considered juveniles.

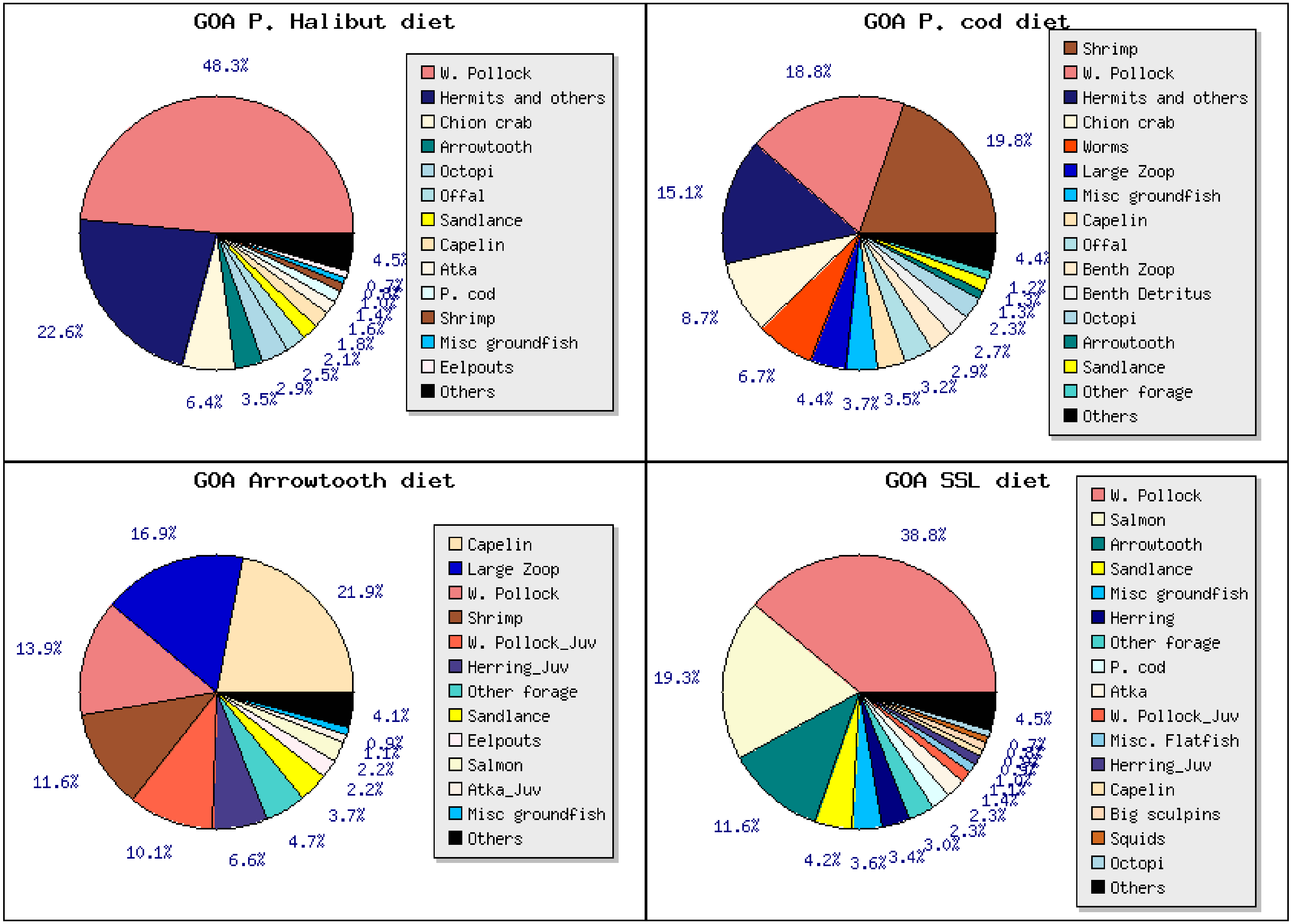



Figure 1.33. Diet diversity of major predators of walleye pollock from an ECOPATH model for Gulf of Alaska during 1990-94.

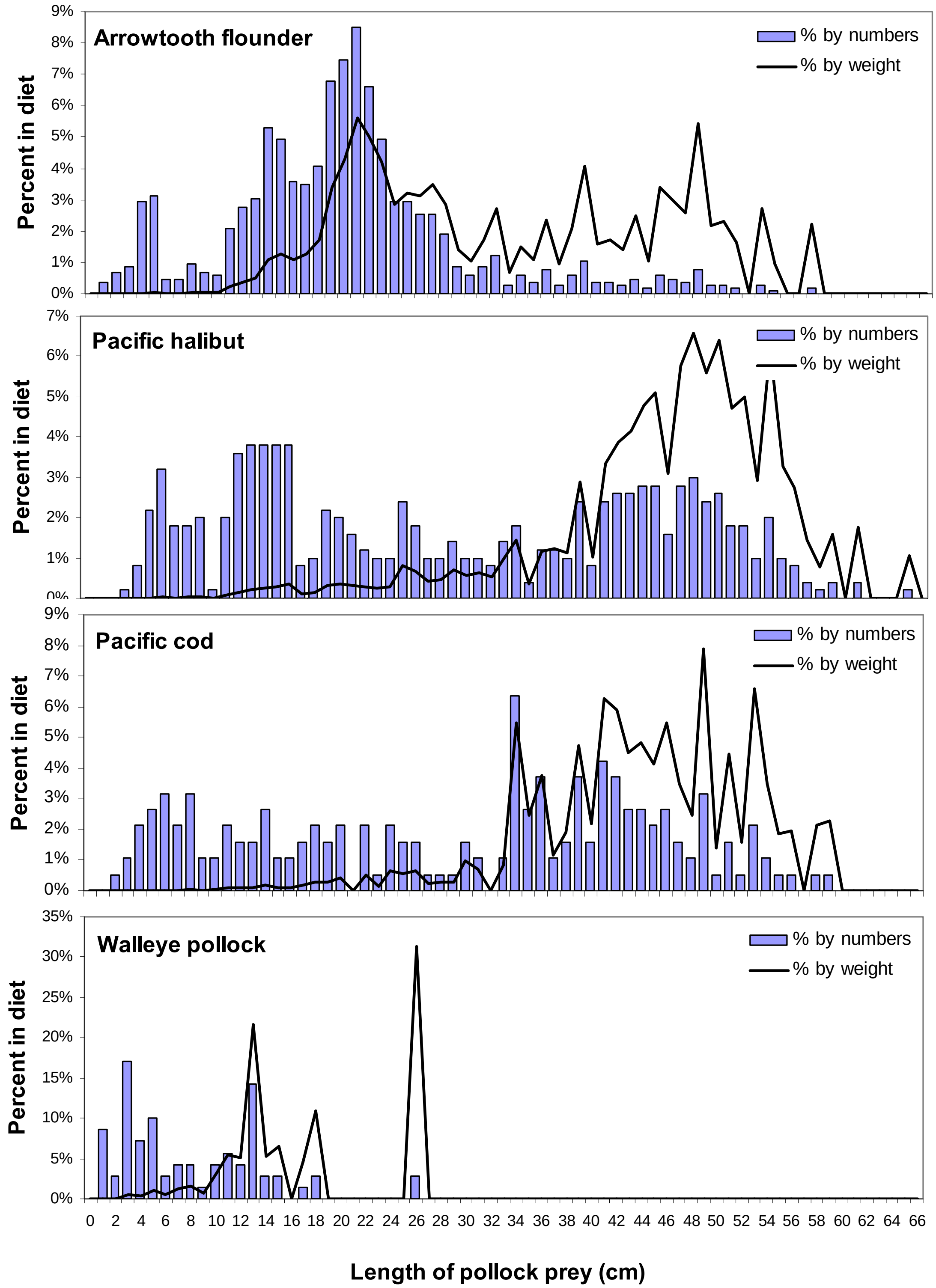
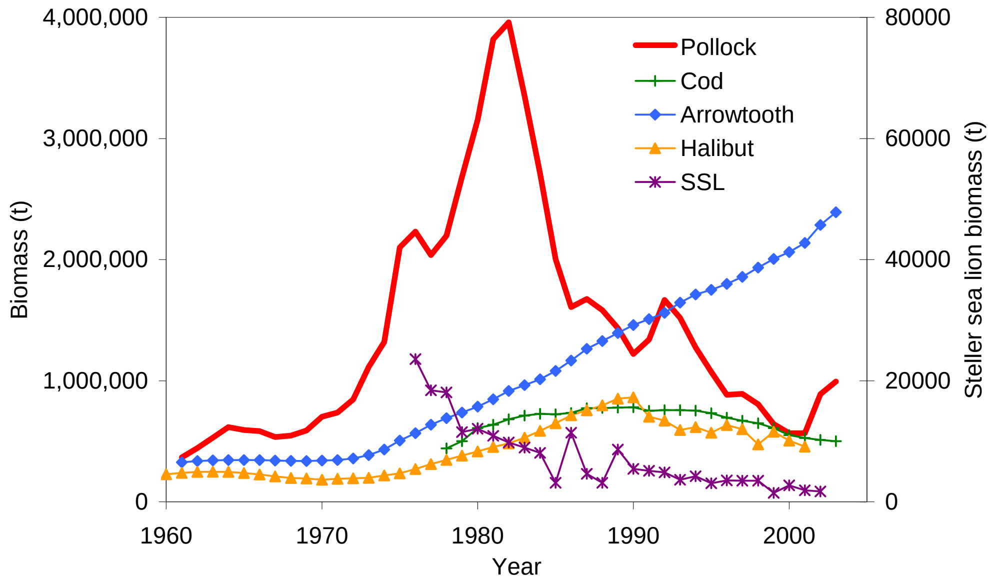



Figure 1.34. Length frequencies and percent by weight of each length class of pollock prey (cm fork length) in stomachs of four major groundfish predators, from AFSC bottom-trawl surveys 1987-2005. Length of prey is uncorrected for digestion state.



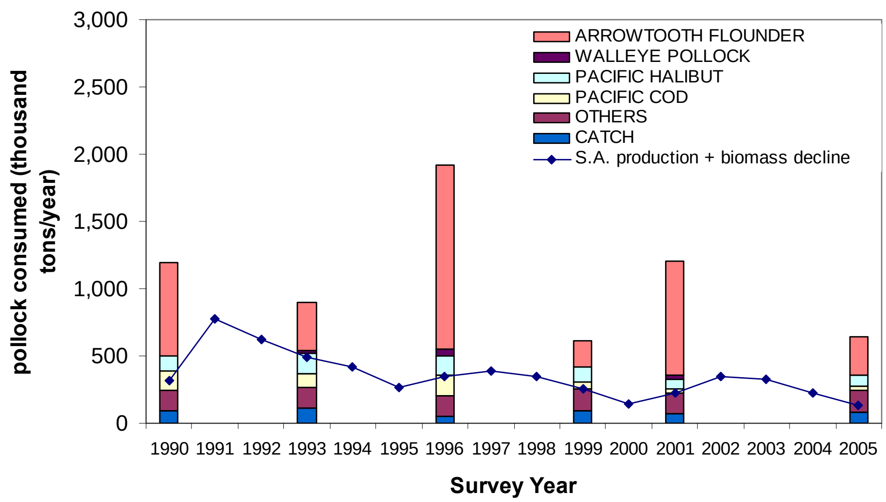




Figure 1.35. (Top) Historical trends in GOA walleye pollock, Pacific cod, Pacific halibut, arrowtooth flounder, and Steller Sea Lions, from stock asessement data. (Bottom) Total catch and consumption of walleye pollock in survey years (bars) and production + biomass change as calculated from the current stock assessment results (line). See text for calculation methods.

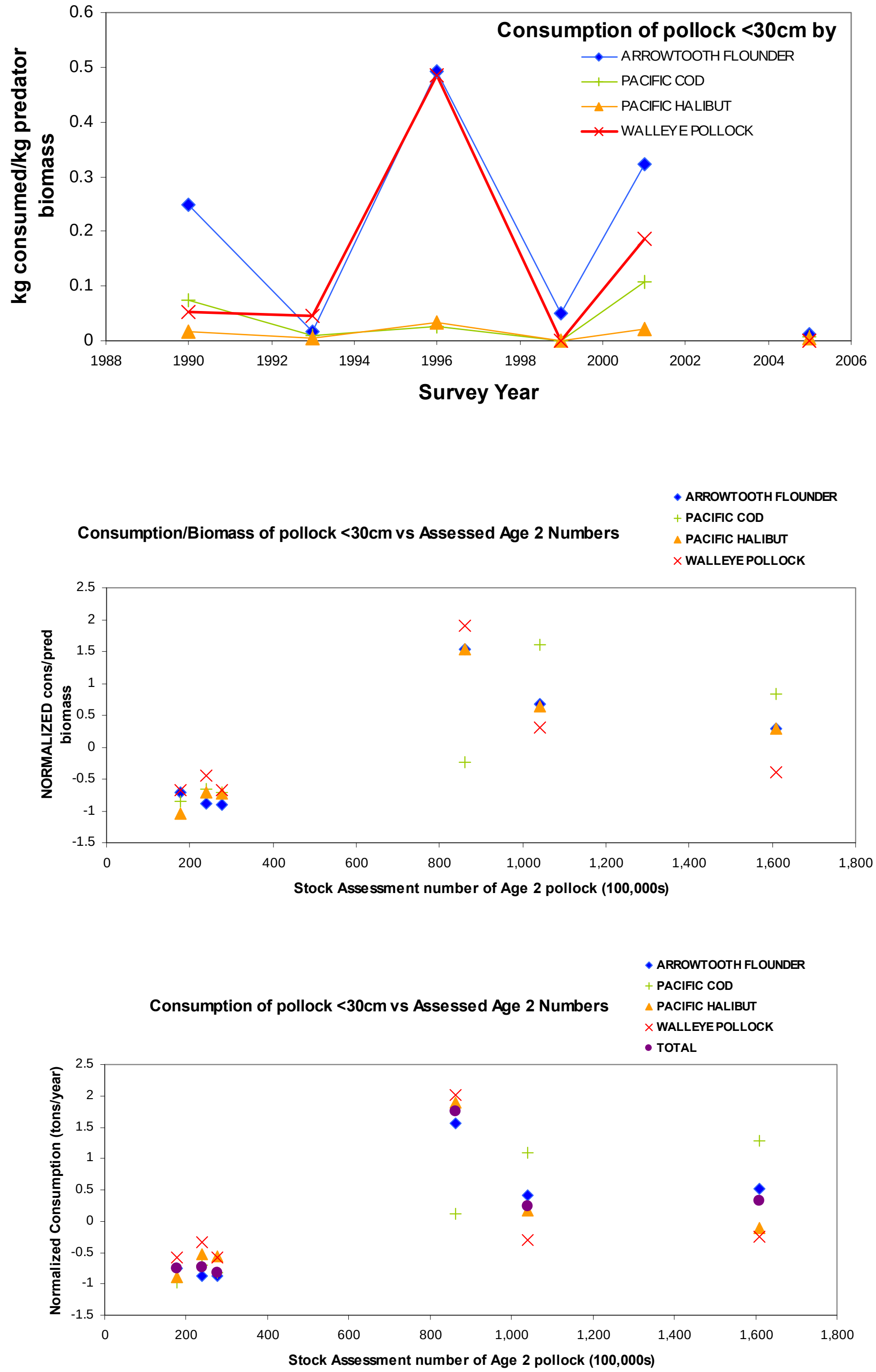



Figure 1.36. (Top) Consumption per unit predator survey biomass of GOA walleye pollock <30cm fork length in diets, shown for each survey year. (Middle and bottom) Normalized consumption/biomass and normalized total consumption of pollock <30cm fork length, plotted against age 2 pollock numbers.

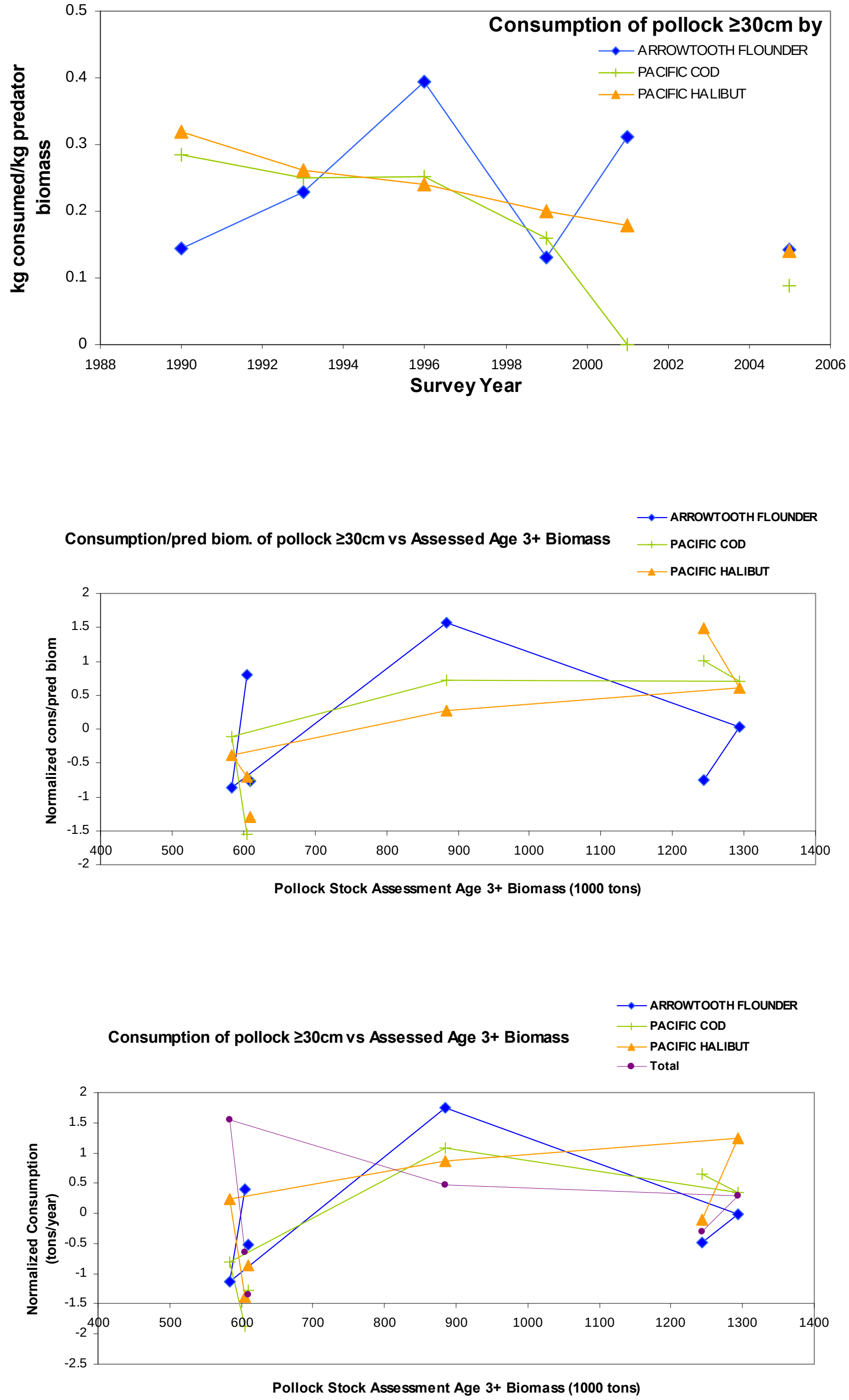



Figure 1.37. (Top) Consumption per unit predator survey biomass of GOA walleye pollock ≥30cm fork length in diets, shown for each survey year. (Middle and bottom) Normalized consumption/biomass and normalized total consumption of pollock ≥30cm fork length, plotted against age 3+ pollock biomass.

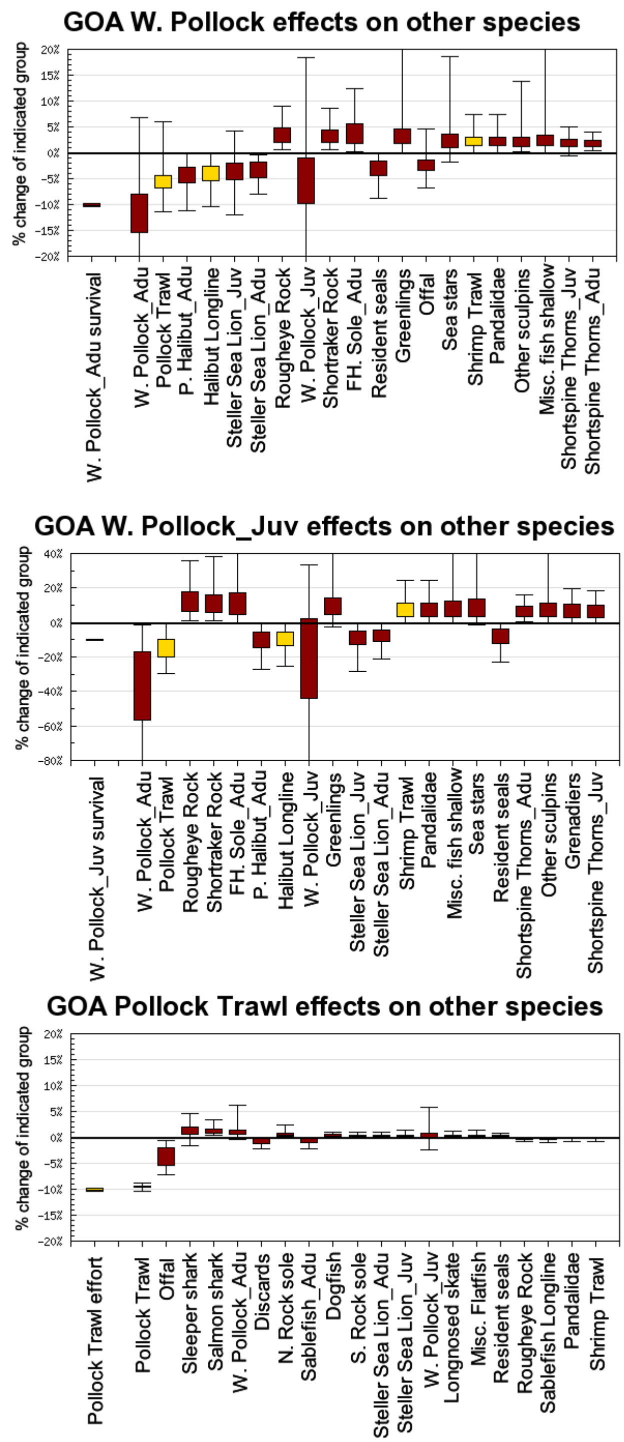



Figure 1.38. Ecosystem model output (percent change at future equilibrium of indicated groups) resulting from reducing adult pollock survival by 10% (top graph), reducing juvenile pollock survival by 10% (middle graph), and reducing pollock trawl effort by 10%. Dark bars indicate biomass changes of modeled species, while light bars indicate changes in fisheries catch (landings+discards) assuming a constant fishing rate within the indicated fishery. Graphs show 50% and 95% confidence intervals (bars and lines respectively) summarized over 20,000 ecosystems drawn from error ranges of input parameters (see Aydin et al. 2005 for methodology). Only the top 20 effects, sorted by median, are shown for each perturbation.

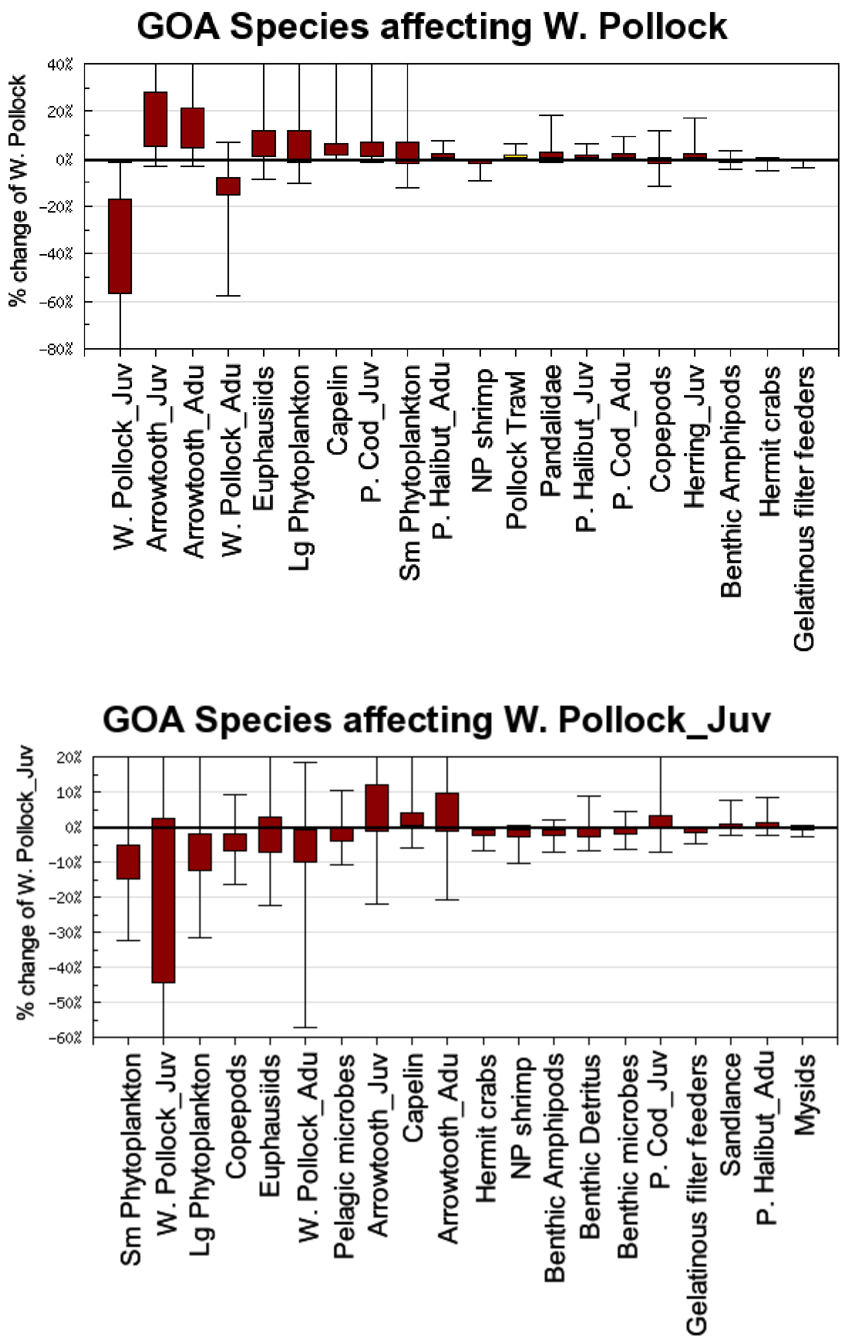



Figure 1.39. Ecosystem model output, shown as percent change at future equilibrium of adult pollock (top) and juvenile pollock, resulting from independently lowering the indicated species' survival rates by 10% (dark bars) or by reducing fishing effort of a particular gear by 10% (light bars). Graphs show 50% and 95% confidence intervals (bars and lines respectively) summarized over 20,000 ecosystems drawn from error ranges of input parameters (see Aydin et al. 2005 for methodology). Only the top 20 effects, sorted by median, are shown for each perturbation.

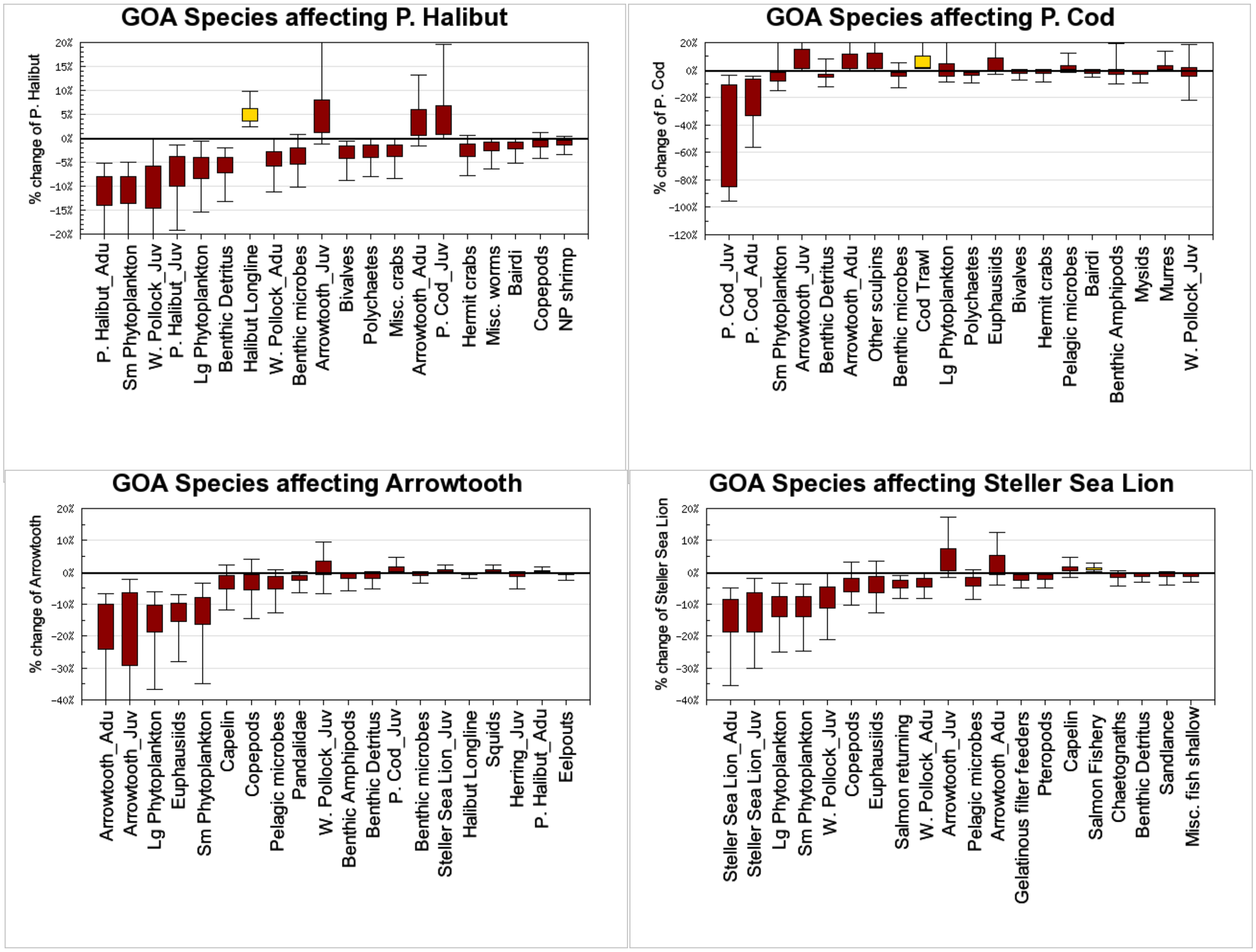



Figure 1.40. Ecosystem model output, shown as percent change at future equilibrium of four major predators on walleye pollock, resulting from independently lowering the indicated species' survival rates by 10% (dark bars) or by reducing fishing effort of a particular gear by 10% (light bars). Graphs show 50% and 95% confidence intervals (bars and lines respectively) summarized over 20,000 ecosystems drawn from error ranges of input parameters (see Aydin et al. 2005 for methodology). Only the top 20 effects, sorted by median, are shown for each perturbation.

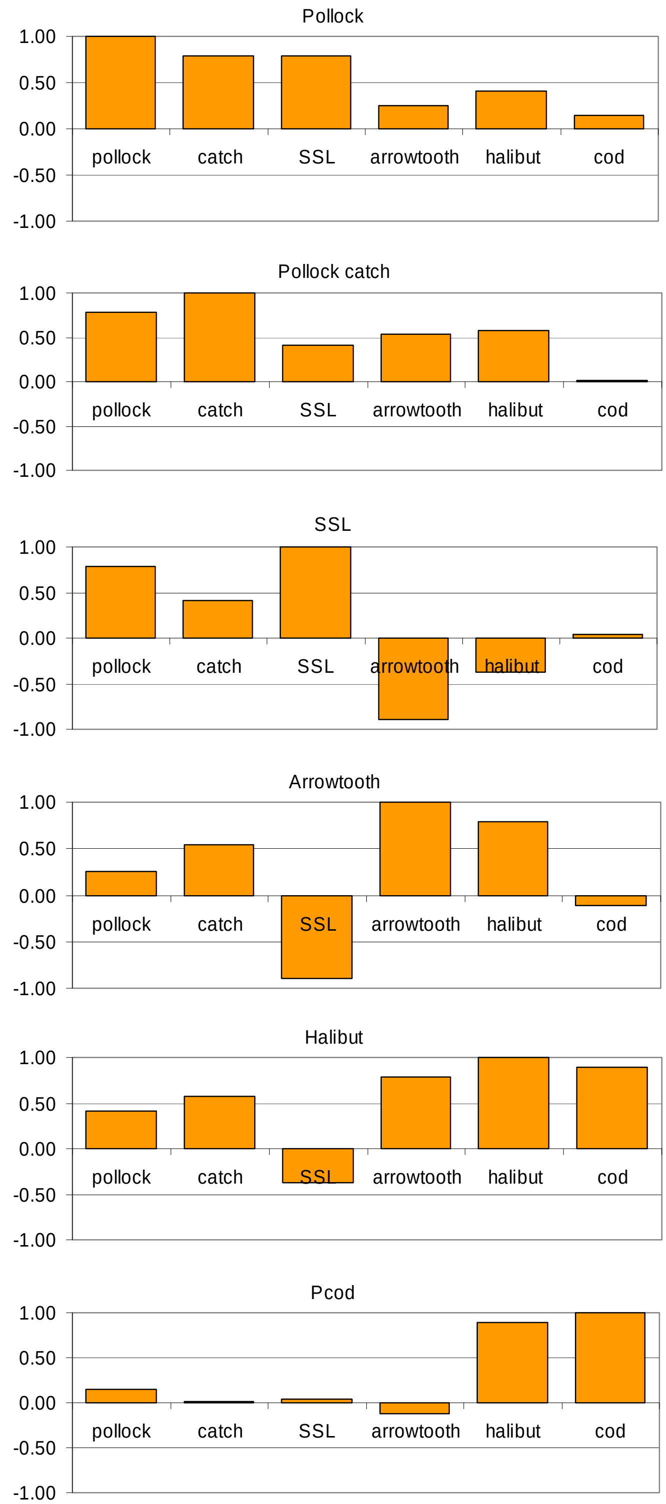


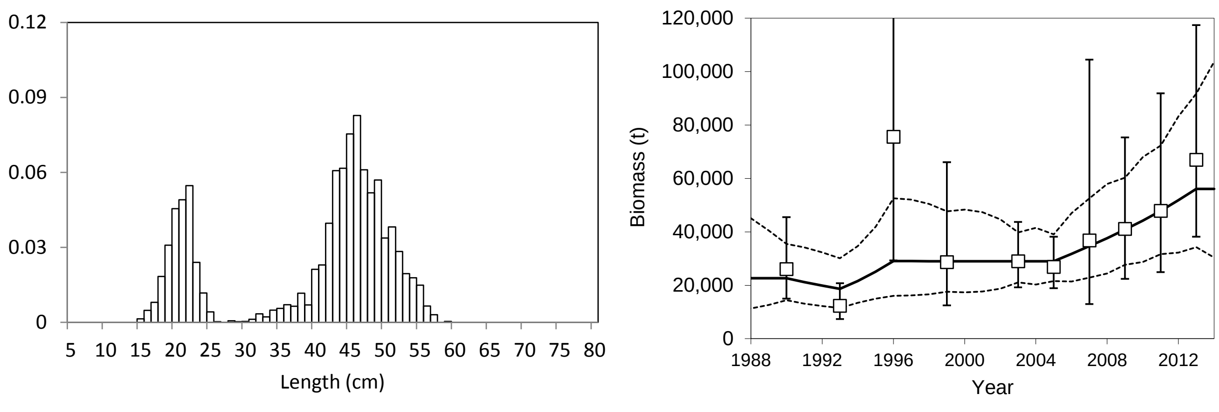

Figure 1.41. Pair-wise Spearman rank correlation between abundance trends of walleye pollock, pollock fishery catches, Steller sea lions, arrowtooth flounder, Pacific halibut, and Pacific cod in the Gulf of Alaska. Rank correlations are based on the years in which abundance estimates are available for each pair.

## Appendix A: Southeast Alaska pollock

Bottom trawl surveys indicate a substantial reduction in pollock abundance east of 140° W. lon. Stock structure in this area is poorly understood. Bailey et al. (1999) suggest that pollock metapopulation structure in southeast Alaska is characterized by numerous fiord populations. In the 2013 bottom trawl survey, higher pollock CPUE in southeast Alaska occurred primarily from Cape Ommaney to Dixon Entrance, where the shelf is more extensive. Pollock length composition in the 2013 bottom trawl survey showed a mode of age-1 pollock, and a mode at 46 cm (Appendix Fig. A.1). Larger pollock (> 55 cm) were uncommon. Juveniles in this area are unlikely to influence the population dynamics of pollock in the central and western Gulf of Alaska. Ocean currents are generally northward in this area, suggesting that juvenile settlement is a result of spawning further south. Spawning aggregations of pollock have been reported from the northern part of Dixon Entrance (Saunders et al. 1988).

Historically, there has been little directed fishing for pollock in Southeast Alaska (Fritz 1993). Pollock catch the Southeast and East Yakutat statistical areas has averaged about 1 t since 2002 (Table 1.4). The ban on trawling east of 140° W. lon. prevents the development of a trawl fishery for pollock in Southeast Alaska.

Biomass in Southeast Alaska was estimated by splitting survey strata and CPUE data in the Yakutat INPFC area at 140° W. lon. and combining the strata east of the line with comparable strata in the Southeastern INPFC area. Surveys since 1996 had the most complete coverage of shallow strata in southeast Alaska, and indicate that stock size is approximately 25-75,000 t (Appendix Fig. A.1). There is a gradual increase in biomass since 2005, but confidence intervals are large. A random effects model was fit to the 1990-2013 bottom trawl survey biomass estimates in southeast Alaska. We recommend placing southeast Alaska pollock in Tier 5 of NPFMC harvest policy, and basing the ABC and OFL on natural mortality (0.3) and the biomass estimate from the random effects model in 2014 (56,111 t). **This results in a 2014 ABC of 12,625 t (56,111 t * 0.75 M), and a 2015 OFL of 16,833 t (56,111 t * M). The same ABC and OFL is recommended for 2015.**




Appendix Figure A.1. Pollock size composition in 2013 (left) and biomass trend in southeast Alaska from NMFS bottom trawl surveys in 1990-2013 (right). Error bars indicate plus and minus two standard deviations. The solid line is the biomass trend from the random effects model, while dotted lines indicate the 95% confidence interval.

## Status Summary for Southeast Alaska Pollock

| Quantity | As estimated or *specified last* year for: 2013 | 2014 | As estimated or *recommended this* year for: 2014 | 2015 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.3 | 0.3 | 0.3 | 0.3 |
| Tier | 5 | 5 | 5 | 5 |
| Biomass (t) | | | | |
| Upper 95% confidence interval | 91,888 | 91,888 | 103,745 | 114,876 |
| Point estimate | 47,885 | 47,885 | 56,111 | 56,111 |
| Lower 95% confidence interval | 24,954 | 24,954 | 30,348 | 27,408 |
| $F_{OFL}$ | 0.30 | 0.30 | 0.30 | 0.30 |
| $maxF_{ABC}$ | 0.23 | 0.23 | 0.23 | 0.23 |
| $F_{ABC}$ | 0.23 | 0.23 | 0.23 | 0.23 |
| OFL (t) | 14,366 | 14,366 | 16,833 | 16,833 |
| maxABC (t) | 10,774 | 10,774 | 12,625 | 12,625 |
| ABC (t) | 10,774 | 10,774 | 12,625 | 12,625 |
| **Status** | As determined *last* year for: 2011 | 2012 | As determined *this* year for: 2012 | 2013 |
| Overfishing | No | n/a | No | n/a |

## Appendix B: Gulf pollock stock assessment model

### *Population dynamics*

The age-structured model for pollock describes the relationships between population numbers by age and year. The modeled population includes individuals from age 1 to age 10, with age 10 defined as a "plus" group, i.e., all individuals age 10 and older. The model extends from 1964 to 2013 (50 years). The Baranov (1918) catch equations are assumed, so that

$$c_{ij} = N_{ij} \frac{F_{ij}}{Z_{ij}} [1 - \exp(-Z_{ij})]$$

$$N_{i+1\,j+1} = N_{ij} \exp(-Z_{ij})$$

$$Z_{ij} = \sum_k F_{ij} + M$$

except for the plus group, where

$$N_{i+1,10} = N_{i,9} \exp(-Z_{i,9}) + N_{i,10} \exp(-Z_{i,10})$$

where $N_{ij}$ is the population abundance at the start of year *i* for age *j* fish, $F_{ij}$ = fishing mortality rate in year *i* for age *j* fish, and $c_{ij}$ = catch in year *i* for age *j* fish. A constant natural mortality rate, *M*, irrespective of year and age, is assumed.

Fishing mortality is modeled as a product of year-specific and age-specific factors (Doubleday 1976)

$$F_{ij} = s_j f_i$$

where $s_j$ is age-specific selectivity, and $f_i$ is the annual fishing mortality rate. To ensure that the selectivities are well determined, we require that $\max(s_j) = 1$. Following previous assessments, a scaled double-logistic function (Dorn and Methot 1990) was used to model age-specific selectivity,

$$s'_j = \left( \frac{1}{1 + \exp[-\beta_1(j - \alpha_1)]} \right) \left( 1 - \frac{1}{1 + \exp[-\beta_2(j - \alpha_2)]} \right)$$

$$s_j = s'_j / \max( s'_j )$$

where $\alpha_1$ = inflection age, $\beta_1$ = slope at the inflection age for the ascending logistic part of the equation, and $\alpha_2$ , $\beta_2$ = the inflection age and slope for the descending logistic part.

### Measurement error

Model parameters were estimated by maximum likelihood (Fournier and Archibald 1982, Kimura 1989, 1990, 1991). Fishery observations consist of the total annual catch in tons, $C_i$ , and the proportions at age in the catch, $p_{ij}$ . Predicted values from the model are obtained from

$$\hat{C}_i = \sum_j w_{ij} \, c_{ij}$$

$$\hat{p}_{ij} = c_{ij} / \sum_j c_{ij}$$

where $w_{ij}$ is the weight at age $j$ in year $i$ . Year-specific weights at age are used when available.

Log-normal measurement error in total catch and multinomial sampling error in the proportions at age give a log-likelihood of

$$\log L_k = -\sum_i [ \log( C_i ) - \log( \hat{C}_i ) ]^2 / 2\sigma_i^2 + \sum_i m_i \sum_j p_{ij} \log( \hat{p}_{ij} / p_{ij} )$$

where $\sigma_i$ is standard deviation of the logarithm of total catch (~ $CV$ of total catch) and $m_i$ is the size of the age sample. In the multinomial part of the likelihood, the expected proportions at age have been divided by the observed proportion at age, so that a perfect fit to the data for a year gives a log likelihood value of zero (Fournier and Archibald 1982). This formulation of the likelihood allows considerable flexibility to give different weights (i.e. emphasis) to each estimate of annual catch and age composition. Expressing these weights explicitly as CVs (for the total catch estimates), and sample sizes (for the proportions at age) assists in making reasonable assumptions about appropriate weights for estimates whose variances are not routinely calculated.

Survey observations consist of a total biomass estimate, $B_i$ , and survey proportions at age $\pi_{ij}$ . Predicted values from the model are obtained from

$$\hat{B}_i = q \sum_j w_{ij} \, s_j \, N_{ij} \exp[ \phi_i Z_{ij} ]$$

where $q$ = survey catchability, $w_{ij}$ is the survey weight at age *j* in year *i* (if available), $s_j$ = selectivity at age for the survey, and $\phi_i$ = fraction of the year to the mid-point of the survey. Although there are multiple surveys for Gulf pollock, a subscript to index a particular survey has been suppressed in the above and subsequent equations in the interest of clarity. Survey selectivity was modeled using a either a double-logistic function of the same form used for fishery selectivity, or simpler variant, such as single logistic function. The expected proportions at age in the survey in the *i*th year are given by

$$\hat{\pi}_{ij} = s_j N_{ij} \exp[\phi_i Z_{ij}] \,/\, \sum_j s_j N_{ij} \exp[\phi_i Z_{ij}]$$

Log-normal errors in total biomass and multinomial sampling error in the proportions at age give a log-likelihood for survey *k* of

$$\log L_k = -\sum_i [\log(B_i) - \log(\hat{B}_i) + \sigma^2/2]^2 / 2\sigma_i^2 + \sum_i m_i \sum_j \pi_{ij} \log(\hat{\pi}_{ij} / \pi_{ij})$$

where $\sigma_i$ is the standard deviation of the logarithm of total biomass (~ CV of the total biomass) and $m_i$ is the size of the age sample from the survey.

## Appendix C: Seasonal distribution and apportionment of walleye pollock among management areas in the Gulf of Alaska

Since 1992, the Gulf of Alaska pollock TAC has been apportioned between management areas based on the distribution of biomass in groundfish surveys. Both single species and ecosystem considerations provide the rationale for apportioning the TAC. From an ecosystem perspective, apportioning the TAC will spatially distribute the effects of fishing on other pollock consumers (i.e., Steller sea lions), potentially reducing the overall intensity of any adverse effects. Apportioning the TAC also ensures that no smaller component of the stock experiences higher mortality than any other. Although no sub-stock units of pollock have yet been identified in the Gulf of Alaska, it would be precautionary to manage the fishery so that if these sub-units do exist they would not be subject to high fishing mortality. Protection of sub-stock units would be most important during spawning season, when they are spatially separated. The Steller sea lion protection measures implemented in 2001 require apportionment of pollock TAC based on the seasonal distribution of biomass.

Walleye pollock in the Gulf of Alaska undergo an annual migration between summer foraging habitats and winter spawning grounds. Since surveying effort has been concentrated during the summer months and prior to spawning in late winter, the dynamics and timing of this migration are not well understood. Regional biomass estimates are highly variable, indicating either large sampling variability, large interannual changes in distribution, or, more likely, both. There is a comprehensive survey of the Gulf of Alaska in summer, but historically surveying during winter has focused on the Shelikof Strait spawning grounds. Recently there has been expanded acoustic surveying effort outside of Shelikof Strait in winter, but no acoustic survey has been comprehensive, covering all areas where pollock could potentially occur.

***Winter apportionment***

An annual acoustic survey on pre-spawning aggregations in Shelikof Strait has been conducted since 1981. Since 2000, several additional spawning areas have been surveyed multiple times, including Sanak Gully, the Shumagin Islands, the shelf break near Chirikof Island, and Marmot Bay. Although none of these spawning grounds are as important as Shelikof Strait, especially from a historical perspective, in recent years the aggregate biomass surveyed outside Shelikof Strait has been comparable to that within Shelikof Strait.

As in previous assessments, a “composite” approach was used to estimate the percent of the total stock in each management area. The estimated biomass for each survey was divided by the total biomass of pollock estimated by the assessment model in that year and then split into management areas for surveys that crossed management boundaries. The percent for each survey was added together to form a composite biomass distribution, which was then rescaled so that it summed to 100%. Model estimates of biomass at spawning took into account the total mortality between the start of the year and spawning, and used mean weight at age from Shelikof Strait surveys.

Since time series of biomass estimates for spawning areas outside of Shelikof Strait are now available, we used the four most recent surveys at each spawning area, and used a rule that a minimum of three surveys was necessary to include an area. These criteria are intended to provide estimates that reflect recent biomass distribution while at the same time providing some stability in the estimates. The biomass in these secondary spawning areas tends to be highly variable from one year to the next. Areas meeting these criteria were Shelikof Strait, the shelf break near Chirikof Island, the Shumagin area, Sanak Gully, Morzhovoi Bay, and Marmot Bay. While the spawning aggregations found in 2010 along the Kenai Peninsula and in Prince William Sound are clearly important, before including them in the apportionment calculations the surveys in these areas need to be repeated to confirm stability of spawning in these areas

There are also several potentially difficult issues that would need to dealt with, for example, whether including biomass along Kenai Peninsula would lead increased harvests on the east side of Kodiak, both of which are in area 630. In addition, the fishery inside Prince William Sound (area 649) is managed by the State of Alaska, and state management objectives for Prince William Sound need to be taken into account.

Vessel comparison experiments conducted between the *R/V Miller Freeman* and the *R/V Oscar Dyson* in Shelikof Strait in 2007, and in the Shumagin/Sanak area in 2008 found significant differences in the ratio of backscatter between the two vessels. The estimated *R/V Oscar Dyson* to *R/V Miller Freeman* ratio for the Shelikof Strait was 1.132, while the ratio for the Shumagin and Sanak areas (taken together) was 1.31. Since the *R/V Oscar Dyson* was designed to minimize vessel avoidance, biomass estimates produced by *R/V Oscar Dyson* should be considered better estimates of the true biomass than those produced by the *R/V Miller Freeman*. When calculating the distribution of biomass by area, multipliers were applied to surveys conducted by the *R/V Miller Freeman* to make them comparable to the *R/V Oscar Dyson* (Appendix Table C.1). Multipliers were needed only for Marmot Bay and Morzhovoi Bay because all other areas have been surveyed at least four times with the *R/V Oscar Dyson*. A vessel specific multiplier of 1.31 was applied in Marmot Bay and Morzhovoi Bay because the fish in these areas were at similar depths as at the Sanak and Shumagin area.

The sum of the percent biomass for all surveys combined was 64.77%, which may reflect sampling variability, or interannual variation in spawning location, but also reflects the recent trend that the aggregate biomass of pollock surveyed acoustically in winter (at least in those areas that have been surveyed repeatedly) is lower than the assessment model estimates of abundance. After rescaling, the resulting average biomass distribution was 12.18%, 78.58%, 9.23% in areas 610, 620, and 630 (Appendix Table C.1). In comparison to last year, the percentage in area 610 is 3.9 percentage points lower, is 4.4 percentage points higher in area 620, and is 0.6 percentage points lower in area 630.

### *A-season apportionment between areas 620 and 630*

In the 2002 assessment, based on evaluation of fishing patterns which suggested that the migration to spawning areas was not complete by January 20, the Gulf of Alaska plan team recommended an alternative apportionment scheme for areas 620 and 630 based on the midpoint of the summer and winter distributions in area 630. This approach was not used for area 610 because fishing patterns during the A season suggested that most of the fish captured in area 610 would eventually spawn in area 610. The resulting A season apportionment using updated survey data is: 610, 12.18%; 620, 65.79%; 630, 22.03%.

### *Summer distribution*

The NMFS bottom trawl is summer survey (typically extending from mid-May to mid-August). Because of large shifts in the distribution of pollock between management areas one survey to the next, and the high variance of biomass estimates by management area, Dorn et al. (1999) recommended that the apportionment of pollock TAC be based upon an unweighted average of four most recent NMFS summer surveys. The four-survey average was updated with 2013 survey results in an average biomass distribution of 32.61%, 30.67%, 33.80%, and 2.92% in areas 610, 620, 630, and 640 (Appendix Fig. C.1). Including the 2013 survey and deleting the 2005 survey lowered the percentage in area 610 by 3 percentage points and raised the percentage in areas 620 by 3 percentage points. The percentage in area 630 is almost unchanged.

### *Apportionment for area 640*

The apportionment for area 640, which is not managed by season, is based on the summer distribution of the biomass in the NMFS bottom trawl survey. The percentage (2.92%) of the TAC in area 640 is subtracted from the TAC before allocating the remaining TAC by season and region.

***Example calculation of 2014 Seasonal and Area TAC Allowances for W/C/WYK***

**Warning: This example is based on hypothetical ABC of 100,000 t.**

1) Deduct the Prince William Sound Guideline Harvest Level.

2) Use summer biomass distribution for the 640 allowance:

640 0.0292 x Total TAC = 2,917 t

3) Calculate seasonal apportionments of TAC for the A, B, C, and D seasons at 25 %, 25%, 25%, and 25% of the remaining annual TAC west of 140° W lon.

A season 0.25 x (Total TAC – 2,917) = 24,271 t
B season 0.25 x (Total TAC – 2,917) = 24,271 t
C season 0.25 x (Total TAC – 2,917) = 24,271 t
D season 0.25 x (Total TAC – 2,917) = 24,271 t

4) For the A season, the allocation of TAC to areas 610, 620 and 630 is based on a blending of winter and summer distributions to reflect that pollock may not have completed their migration to spawning areas by Jan. 20, when the A season opens.

610 0.1218 x 24,271 t = 2,956 t
620 0.6579 x 24,271 t = 15,968 t
630 0.2203 x 24,271 t = 5,348 t

5) For the B season, the allocation of TAC to areas 610, 620 and 630 is based on the composite estimate of winter biomass distribution1

610 0.1218 x 24,271 t = 2,956 t
620 0.7858 x 24,271 t = 19,073 t
630 0.0923 x 24,271 t = 2,241 t

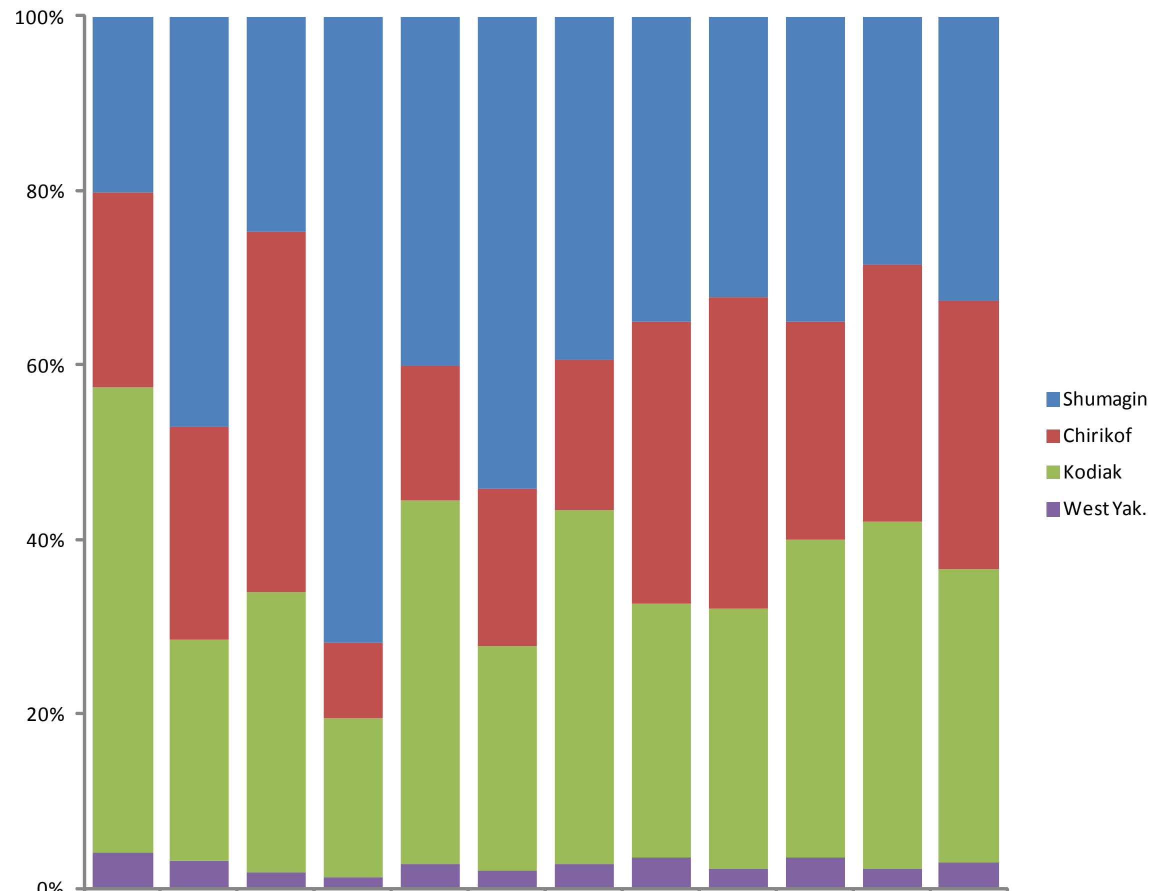
6) For the C and D seasons, the allocation of remaining TAC to areas 610, 620 and 630 is based on the average biomass distribution in areas 610, 620, 630, and 640 in the most recent four NMFS bottom trawl surveys of 32.61%, 30.67%, 33.80%, and 2.92%.

610 0.3261 / (1 – 0.0292) x 24,271 = 8,152 t
620 0.3067 / (1 – 0.0292) x 24,271 = 7,668 t
630 0.3380 / (1 – 0.0292) x 24,271 = 8,451 t

610 0.3261 / (1 – 0.0292) x 24,271 = 8,152 t
620 0.3067 / (1 – 0.0292) x 24,271 = 7,668 t
630 0.3380 / (1 – 0.0292) x 24,271 = 8,451 t

Appendix Table C.1. Estimates of percent pollock in areas 610-630 during winter acoustic surveys in the Gulf of Alaska. The biomass of age-1 fish is not included the acoustic survey biomass estimates.

| *Survey* | *Year* | *Model estimates of total 2+ biomass at spawning* | *Survey biomass estimate* | *Multiplier from vessel comparison (OD/MF)* | *Percent* | *Percent by management area* | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | *Area 610* | *Area 620* | *Area 630* |
| Shelikof | 2009 | 661,853 | 265,971 | 1.00 | 40.2% | 0.0% | 95.6% | 4.4% |
| Shelikof | 2010 | 907,160 | 429,730 | 1.00 | 47.4% | 0.0% | 93.7% | 6.3% |
| Shelikof | 2012 | 942,237 | 335,836 | 1.00 | 35.6% | 0.0% | 96.0% | 4.0% |
| Shelikof | 2013 | 984,559 | 831,486 | 1.00 | 84.5% | 0.0% | 95.0% | 5.0% |
| Shelikof | Average | | | | 51.9% | 0.0% | 95.1% | 4.9% |
| | Percent of total 2+ biomass | | | | | 0.0% | 49.4% | 2.5% |
| Chirikof | 2009 | 661,853 | 396 | 1.00 | 0.1% | 0.0% | 0.0% | 100.0% |
| Chirikof | 2010 | 907,160 | 9,544 | 1.00 | 1.1% | 0.0% | 0.0% | 100.0% |
| Chirikof | 2012 | 942,237 | 21,181 | 1.00 | 2.2% | 0.0% | 13.0% | 87.0% |
| Chirikof | 2013 | 984,559 | 63,008 | 1.00 | 6.4% | 0.0% | 70.2% | 29.8% |
| Chirikof | Average | | | | 2.4% | 0.0% | 20.8% | 79.2% |
| | Percent of total 2+ biomass | | | | | 0.0% | 0.5% | 1.9% |
| Marmot | 2007 | 454,067 | 3,157 | 1.31 | 0.9% | 0.0% | 0.0% | 100.0% |
| Marmot | 2009 | 661,853 | 19,759 | 1.00 | 3.0% | 0.0% | 0.0% | 100.0% |
| Marmot | 2010 | 907,160 | 5,585 | 1.00 | 0.6% | 0.0% | 0.0% | 100.0% |
| Marmot | 2013 | 984,559 | 19,899 | 1.00 | 2.0% | 0.0% | 0.0% | 100.0% |
| Marmot | Average | | | | 1.5% | 0.0% | 0.0% | 100.0% |
| | Percent of total 2+ biomass | | | | | 0.0% | 0.0% | 1.5% |
| Shumagin | 2009 | 661,853 | 45,955 | 1.00 | 7.3% | 61.4% | 38.6% | 0.0% |
| Shumagin | 2010 | 907,160 | 18,081 | 1.00 | 2.3% | 94.9% | 5.1% | 0.0% |
| Shumagin | 2012 | 942,237 | 15,501 | 1.00 | 1.9% | 88.0% | 12.0% | 0.0% |
| Shumagin | 2013 | 984,559 | 47,388 | 1.00 | 4.8% | 55.2% | 44.8% | 0.0% |
| Shumagin | Average | | | | 4.1% | 74.9% | 25.1% | 0.0% |
| | Percent of total 2+ biomass | | | | | 3.1% | 1.0% | 0.0% |
| Sanak | 2009 | 661,853 | 31,435 | 1.00 | 4.7% | 100.0% | 0.0% | 0.0% |
| Sanak | 2010 | 907,160 | 26,678 | 1.00 | 2.9% | 100.0% | 0.0% | 0.0% |
| Sanak | 2012 | 942,237 | 24,252 | 1.00 | 2.6% | 100.0% | 0.0% | 0.0% |
| Sanak | 2013 | 984,559 | 12,967 | 1.00 | 1.3% | 100.0% | 0.0% | 0.0% |
| Sanak | Average | | | | 3.4% | 100.0% | 0.0% | 0.0% |
| | Percent of total 2+ biomass | | | | | 3.4% | 0.0% | 0.0% |
| Mozhovoi | 2006 | 463,064 | 11,679 | 1.31 | 3.3% | 100.0% | 0.0% | 0.0% |
| Mozhovoi | 2007 | 454,067 | 2,540 | 1.31 | 0.7% | 100.0% | 0.0% | 0.0% |
| Mozhovoi | 2010 | 907,160 | 1,650 | 1.00 | 0.2% | 100.0% | 0.0% | 0.0% |
| Mozhovoi | 2013 | 984,559 | 1,520 | 1.00 | 0.2% | 100.0% | 0.0% | 0.0% |
| Mozhovoi | Average | | | | 1.4% | 100.0% | 0.0% | 0.0% |
| | Percent of total 2+ biomass | | | | | 1.4% | 0.0% | 0.0% |
| Total | | | | | 64.77% | 7.89% | 50.90% | 5.98% |
| Rescaled total | | | | | 100.00% | 12.18% | 78.58% | 9.23% |




| | 1990 | 1993 | 1996 | 1999 | 2001 | 2003 | 2005 | 2007 | 2009 | 2011 | 2013 | 4 survey avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shumagin | 20.03% | 47.08% | 24.69% | 71.90% | 40.06% | 54.09% | 39.35% | 34.94% | 32.16% | 34.93% | 28.40% | 32.61% |
| Chirikof | 22.41% | 24.27% | 41.32% | 8.55% | 15.30% | 18.14% | 17.16% | 32.42% | 35.66% | 25.04% | 29.56% | 30.67% |
| Kodiak | 53.42% | 25.44% | 32.16% | 18.23% | 41.88% | 25.62% | 40.64% | 29.06% | 29.99% | 36.38% | 39.79% | 33.80% |
| West Yak. | 4.13% | 3.20% | 1.83% | 1.32% | 2.76% | 2.15% | 2.85% | 3.59% | 2.18% | 3.65% | 2.24% | 2.92% |

Appendix Figure C.1. Percent distribution of Gulf of Alaska pollock biomass west of 140° W long. in NMFS bottom trawl surveys in 1990-2013.

## Appendix D: Supplemental catch data

To comply with the Annual Catch Limit (ACL) requirements, estimates have been developed for non-commercial catches and removals from NMFS-managed stocks in Alaska. Research catches have been routinely reported in the pollock assessment, but these catches are only for survey data that have been included in RACEBASE, and are not a comprehensive accounting of all research removals (Appendix Table D.1). One new data set is more a comprehensive accounting of research removals than had been available previously. This data set is relatively complete only for 2010 and 2011 (Appendix Table D.2). Comparison of research catches from RACEBASE with the more comprehensive information in 2010 and 2011 suggests that research catches have been substantially underreported. The estimates from RACEBACE ranged between 25% and 30% of the total research catch. Annual large-mesh and small-mesh trawl surveys conducted by ADFG account for most of the missing research catch of pollock. Even if research catches are four times those reported in RACEBACE, they would still amount to less than 1/2 of a percent on average of the ABC during 2002-2011, and would have a negligible effect on the pollock stock or the stock assessment.

An attempt was made using methods described in Tribuzio et. al (2011) to estimate the incidental catch of groundfish in the Pacific halibut fishery. Based on Plan Team recommendations, these estimates will not be continued. Estimates of pollock bycatch in the Pacific halibut fishery during 2001-2010 averaged 12.2 t, with a minimum of 0.9 t and a maximum of 62.4 t, suggesting that the bycatch of pollock (or the estimates thereof) are low and highly variable. Since some halibut fishery incidental catch as enters into the catch accounting system, it is unclear whether these catches have already been taken into account in the reported catch. However this seems unlikely for pollock. It is important to note that there is unreported incidental catch of pollock in other fisheries in Alaska, such as the salmon fishery, which, based on anecdotal reports, may be substantial on occasion.

Appendix Table D.1. Estimates of pollock research catch (t) in the Gulf of Alaska from RACEBASE during 1977-2011.

| *Year* | *Catch (t)* |
|---|---|
| 1977 | 89.2 |
| 1978 | 99.7 |
| 1979 | 52.4 |
| 1980 | 229.4 |
| 1981 | 433.3 |
| 1982 | 110.4 |
| 1983 | 213.1 |
| 1984 | 310.7 |
| 1985 | 167.2 |
| 1986 | 1201.8 |
| 1987 | 226.6 |
| 1988 | 19.3 |
| 1989 | 72.7 |
| 1990 | 158.0 |
| 1991 | 16.2 |
| 1992 | 39.9 |
| 1993 | 116.4 |
| 1994 | 70.4 |
| 1995 | 44.3 |
| 1996 | 146.9 |
| 1997 | 75.5 |
| 1998 | 63.6 |
| 1999 | 34.7 |
| 2000 | 56.3 |
| 2001 | 77.1 |
| 2002 | 77.6 |
| 2003 | 127.6 |
| 2004 | 53.0 |
| 2005 | 71.7 |
| 2006 | 63.5 |
| 2007 | 47.1 |
| 2008 | 26.2 |
| 2009 | 89.9 |
| 2010 | 37.4 |
| 2011 | 43.0 |

Appendix Table D.2. Estimates of pollock research catch (t) in the Gulf of Alaska by survey or research project in 2010 and 2011.

| | *Year* | |
|---|---|---|
| *Survey/research project* | *2010* | *2011* |
| ADFG large-mesh trawl | 83.0 | 81.3 |
| ADFG small-mesh trawl | 20.1 | 23.4 |
| IPHC annual survey | 0.8 | 0.3 |
| NMFS Shelikof Strait acoustic survey | 12.0 | |
| NMFS Shumagin Islands acoustic survey | 25.4 | |
| NMFS bottom trawl survey | | 43.0 |
| NMFS sablefish longline survey | 2.5 | 1.4 |
| GOA IERP research | 0.1 | |
| Western GOA cooperative acoustic survey | 12.4 | |
| Total | 156.3 | 149.3 |

*(This page intentionally left blank)*