# 17. Assessment of the Atka mackerel stock in the Bering Sea/Aleutian Islands

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## Executive Summary

Relative to the November 2010 SAFE report, the following substantive changes have been made in the assessment of Atka mackerel.

*Summary of Changes in Assessment Inputs*

1. Fishery catch data were updated.
2. The 2010 fishery age composition data were added.
3. 2010 fishery catch- and weight-at-age values were added.
4. For 2012 and 2013 we assume that 64% of the BSAI-wide ABC is likely to be taken under the implemented Steller Sea Lion Reasonable and Prudent Alternatives (SSL RPAs). This percentage was applied to the 2012 maximum permissible ABC, and that amount was assumed to be caught in order to estimate the 2013 ABCs and OFL values.

*Summary of Changes in the Assessment Methodology*

There were no changed in the assessment methodology; the general modeling approach remained unchanged this year

*Responses to comments by the Scientific and Statistical Committee (SSC)*

SSC Comments on Assessments in General

The SSC requested that complete runs for model alternatives be available and also that the best estimate of current-year catches be used. We used our best estimate of what the total catch is in 2011 and also can provide alternative model runs upon request.

Comments Specific to the Atka Mackerel Assessment

In the December 2010 SSC minutes they noted that the residual pattern for the survey was poor. In response, the ability to allow a random walk for any survey catchability coefficients was implemented and estimated for a three year period. This is presented below as Model 2.

*Summary of Assessment Results*

| **Quantity** | As estimated or *specified last* year for: 2011 | 2012 | As estimated or *recommended this* year for: 2012 | 2013 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.30 | 0.30 | 0.30 | 0.30 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 3+) biomass (t) | 437,600 | na | 405,347 | 375,541 |
| Female spawning biomass (t) | | | | |
| Projected | 146,000[1] | 130,500[1] | 128,813[1] | 103,848[1] |
| $B_{100\%}$ | 261,100 | 261,100 | 255,662 | 255,662 |
| $B_{40\%}$ | 104,400 | 104,400 | 102,265 | 102,265 |
| $B_{35\%}$ | 91,400 | 91,400 | 89,482 | 89,482 |
| $F_{OFL}$ | 0.468 | 0.468 | 0.469 | 0.469 |
| $maxF_{ABC}$ | 0.384 | 0.384 | 0.384 | 0.384 |
| $F_{ABC}$ | 0.384 | 0.384 | 0.384 | 0.384 |
| OFL (t) | 101,200 | 92,200[1] | 96,548 | 78,260[1] |
| maxABC (t) | 85,300 | 77,900[1] | 81,399 | 67,067[1] |
| ABC (t) | 85,300 | 77,900[1] | 81,399 | 67,067[1] |
| **Status** | As determined *last* year for: 2009 | 2010 | As determined *this* year for: 2010 | 2011 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

[1] These values were calculated assuming reduced catch levels under SSL RPAs.

*Apportionment*

The apportionments of the 2012 and 2013 recommended ABCs based on the most recent 4-survey weighted average are:

| | 2012 (t) | 2013 (t) |
|---|---|---|
| Eastern (541+S.BSea) | 38,477 | 31,703 |
| Central (542) | 22,865 | 18,839 |
| Western (543) | 20,057 | 16,525 |
| Total | 81,399 | 67,067 |

# Introduction

*Native Names:* In the Aleut languages, Atka mackerel are known as *tmadgi-{* among the Eastern and Atkan Aleuts and Atkan of Bering Island. They are also known as *tavyi-{* among the Attuan Aleuts (Sepez *et al.* 2003).

## *Distribution*

Atka mackerel (*Pleurogrammus monopterygius*) are widely distributed along the continental shelf across the North Pacific Ocean and Bering Sea from Asia to North America. On the Asian side they extend from the Kuril Islands to Provideniya Bay (Rutenburg 1962); moving eastward, they are distributed throughout the Komandorskiye and Aleutian Islands, north along the eastern Bering Sea shelf, and through the Gulf of Alaska to southeast Alaska.

## *Early life history*

Atka mackerel are a substrate-spawning fish with male parental care. Single or multiple clumps of adhesive eggs are laid on rocky substrates in individual male territories within nesting colonies where males brood eggs for a protracted period. Nesting colonies are widespread across the continental shelf of the Aleutian Islands and western GOA down to bottom depths of 144 m (Lauth *et al*. 2007b). Historical data from ichthyoplankton tows done on the outer shelf and slope off Kodiak Island in the 1970's and 1980's (Kendall and Dunn 1985) suggest that nesting colonies may have existed at one time in the central Gulf of Alaska. Possible factors limiting the upper and lower depth limit of Atka mackerel nesting habitat include insufficient light penetration and the deleterious effects of unsuitable water temperatures, wave surge, or high densities of kelp and green sea urchins (Gorbunova 1962, Lauth *et al.* 2007b, Zolotov 1993).

Incubation times for developing eggs decrease logarithmically with an increase in water temperature and range from 39 days at a water temperature of 12.2° to 169 days at 1.6 °C, however, an incubation water temperature of 15°C was lethal to developing embryos (Guthridge and Hillgruber 2008). In the eastern and central Aleutian Islands, larvae hatch from October to January with maximum hatching in late November (Lauth *et al.* 2007a). After hatching, larvae are neustonic and about 10 mm in length (Kendall and Dunn 1985). Along the outer shelf and slope of Kodiak Island, larvae caught in the fall were about 10.3 mm compared to larvae caught the following spring which were about 17.6 (Kendall and Dunn 1985). Larvae and fry have been observed in coastal areas and at great distances offshore (>500 km) in the Bering Sea and North Pacific Ocean (Gorbunova 1962, Materese *et al*. 2003, Mel'nikow and Efimkin 2003).

The Bering-Aleutian Salmon International Survey (BASIS) project studies salmon during their time at the high seas, and has conducted standardized surveys of the upper pelagic layer in the eastern Bering Sea (EBS) shelf using a surface trawl. In addition to collecting data pertaining to salmon species, BASIS also collected and recorded information for many other Alaskan fish species, including juvenile Atka mackerel. The EBS shelf was sampled during the mid-August through September time period from 2004 to 2006 and juvenile Atka mackerel with lengths ranging from 150-200 mm were distributed along the outer shelf in the southern EBS shelf and along the outer middle shelf between St. George and St Matthew Islands (Appendix B in Lowe et al. 2007). The fate or ecological role of these juveniles is unknown since adult Atka mackerel are much less common or absent in annual standardized bottom trawl surveys in the EBS shelf (Lauth and Acuna 2009)

## *Reproductive ecology*

Male Atka mackerel exhibit elaborate color patterns during mating. The reproductive cycle consists of three phases: 1) establishing territories; 2) spawning, and 3) brooding (Lauth *et al*. 2007a). In early June,

a fraction of the adult males end schooling and diurnal behavior and begin aggregating and establishing territories on rocky substrate in nesting colonies (Lauth *et al*. 2007a). The widespread distribution and broad depth range of nesting colonies suggests that previous conjecture of a concerted nearshore spawning migration by males in the Aleutian Islands is not accurate (Lauth *et al.* 2007b). Geologic, oceanographic, and biotic features vary considerably among nesting colonies, however, nesting habitat is invariably rocky and perfused with moderate or strong currents (Lauth *et al.* 2007b). Many nesting sites in the Aleutian Islands are inside fishery trawl exclusion zones which may serve as *de facto* marine reserves for protecting Atka mackerel (Cooper and McDermott 2008).

The spawning phase begins in late July, peaks in early September, and ends in mid-October (Lauth *et al*. 2007a). Mature females spawn an average of 4.6 separate batches of eggs during the 12-week spawning period or about one egg batch every 2.5 weeks (McDermott *et al*. 2007). After spawning ends, territorial males with nests continue to brood egg masses until hatching. Higher water temperatures in the range of water temperatures observed in nesting colonies, 3.9°C to 10.5°C (Gorbunova 1962, Lauth *et al*. 2007b), can result in long incubation times extending the male brooding phase into January or February (Lauth *et al*. 2007a).

### *Prey and predators*

Adult Atka mackerel in the Aleutians consume a variety of prey, but principally calanoid copepods and euphausiids (Yang 1999), and are consumed by a variety of piscivores, including groundfish (e.g., Pacific cod and arrowtooth flounder, Livingston *et al.* unpubl. manuscr.), marine mammals (e.g., northern fur seals and Steller sea lions, Kajimura 1984, NMFS 1995, Sinclair and Zeppelin 2002), and seabirds (e.g., thick-billed murres, tufted puffins, and short-tailed shearwaters, Springer *et al.* 1999).

Predation on Atka mackerel eggs by cottids and other hexagrammids is prevalent during the spawning season as is cannibalism by other Atka mackerel of both sexes (heterocannibalism) and by males from their own nest (filial cannibalism; Canino *et al*. 2008, Yang 1999, Zolotov 1993). Filial egg cannibalism is a common phenomenon in species with extended paternal care.

Nichol and Somerton (2002) examined the diurnal vertical migrations of Atka mackerel using archival tags and related these movements to light intensity and current velocity. Atka mackerel displayed strong diel behavior, with vertical movements away from the bottom occurring almost exclusively during daylight hours, presumably for feeding, and little to no movement at night (where they were closely associated with the bottom).

### *Stock structure*

A morphological and meristic study suggests there may be separate populations in the Gulf of Alaska and the Aleutian Islands (Levada 1979). This study was based on comparisons of samples collected off Kodiak Island in the central Gulf, and the Rat Islands in the Aleutians. Lee (1985) also conducted a morphological study of Atka mackerel from the Bering Sea, Aleutian Islands and Gulf of Alaska. The data showed some differences (although not consistent by area for each characteristic analyzed), suggesting a certain degree of reproductive isolation. Results from an allozyme genetics study comparing Atka mackerel samples from the western Gulf of Alaska with samples from the eastern, central, and western Aleutian Islands showed no evidence of discrete stocks (Lowe *et al.* 1998). A survey of genetic variation in Atka mackerel using microsatellite DNA markers provided little evidence of genetic structuring over the species range, although slight regional heterogeneity was evident in comparisons between some areas (Canino *et al*. 2010). Samples collected from the Aleutian Islands, Japan, and the Gulf of Alaska did not exhibit genetic isolation by distance or a consistent pattern of differentiation. Examination of these results over time (2004, 2006) showed temporal stability in Stalemate Bank but not at Seguam Pass. These results indicate a lack of structuring in Atka mackerel over a large portion of the

species range, perhaps reflecting high dispersal, a recent population expansion and large effective population size, or some combination of all these factors (Canino *et al*. 2010).

The question remains as to whether the Aleutian Island (AI) and Gulf of Alaska populations of Atka mackerel should be managed as a unit stock or separate populations given that there is a lack of consistent genetic stock structure over the species range. There are significant differences in population size, distribution, recruitment patterns, and resilience to fishing suggesting that management as separate stocks is appropriate. Bottom trawl surveys and fishery data suggest that the Atka mackerel population in the GOA is smaller and much more patchily distributed than that in the AI, and composed almost entirely of fish >30 cm in length. There are also more areas of moderate Atka mackerel density in the AI than in the GOA. The lack of small fish in the GOA suggests that Atka mackerel recruit to that region differently than in the AI. Nesting sites have been located in the Gulf of Alaska in the Shumagin Islands (Lauth *et al.* 2007a), and historical ichthyoplankton data from the 1970's around Kodiak Island indicate there was a spawning and nesting population even further to the east (Kendall and Dunn 1985), but the source of these spawning populations is unknown. They may be migrant fish from strong year classes in the Aleutian Islands or a self-perpetuating population in the Gulf, or some combination of the two. The idea that the western GOA is the eastern extent of their geographic range might also explain the greater sensitivity to fishing depletion in the GOA as reflected by the history of the GOA fishery since the early 1970s. Catches of Atka mackerel from the GOA peaked in 1975 at about 27,000 t. Recruitment to the AI population was low from 1980-1985, and catches in the GOA declined to 0 in 1986. Only after a series of large year classes recruited to the AI region in the late 1980s, did the population and fishery reestablish in the GOA beginning in the early 1990s. After passage of these year classes through the population, the GOA population, as sampled in the 1996 and 1999 GOA bottom trawl surveys, has declined and is very patchy in its distribution. Most recently, the strong 1998 and 1999 year classes documented in the Aleutian Islands showed up in the Gulf of Alaska. Leslie depletion analyses using historical AI and GOA fishery data suggest that catchability increased from one year to the next in the GOA fished areas, but remained the same in the AI areas (Lowe and Fritz 1996; 1997). These differences in population resilience, size, distribution, and recruitment support separate assessments and management of the GOA and AI stocks and a conservative approach to management of the GOA portion of the population.

*Management units*

Amendment 28 to the Bering Sea/Aleutian Islands (BSAI) Fishery Management Plan became effective in mid-1993, and divided the Aleutian subarea into three districts at 177°W and 177°E for the purposes of spatially apportioning TACs. Since 1994, the BSAI Atka mackerel TAC has been allocated to the three regions (541 Eastern Aleutians, 542 Central Aleutians, 543 Western Aleutians) based on the average distribution of biomass estimated from the Aleutian Islands bottom trawl surveys.

## Fishery

### Catch history

Annual catches of Atka mackerel in the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions increased during the 1970s reaching an initial peak of over 24,000 t in 1978 (see BSAI SAFE Table 3). Atka mackerel became a reported species group in the BSAI Fishery Management Plan in 1978. Catches (including discards and community development quota [CDQ] catches), corresponding Acceptable Biological Catches (ABC) and Total Allowable Catches (TAC) set by the North Pacific Fishery Management Council (Council) from 1978 to the present are given in Table 17.1.

From 1970-1979, Atka mackerel were landed off Alaska exclusively by the distant water fleets of the U.S.S.R., Japan and the Republic of Korea. U.S. joint venture fisheries began in 1980 and dominated the landings of Atka mackerel from 1982 through 1988. Total landings declined from 1980-1983 primarily

due to changes in target species and allocations to various nations rather than changes in stock abundance. Catches increased quickly thereafter, and from 1985-1987 Atka mackerel catches averaged 34,000 t annually, dropping to a low of 18,000 t in 1989. The last joint venture allocation of Atka mackerel off Alaska was in 1989, and since 1990, all Atka mackerel landings have been made by U.S. fishermen. Beginning in 1992, TACs increased steadily in response to evidence of a large exploitable biomass, particularly in the central and western Aleutian Islands.

### Description of the Directed Fishery

The patterns of the Atka mackerel fishery generally reflect the behavior of the species: (1) the fishery is highly localized and usually occurs in the same few locations each year; (2) the schooling semi-pelagic nature of the species makes it particularly susceptible to trawl gear fished on the bottom; and (3) trawling occurs almost exclusively at depths less than 200 m. In the early 1970s, most Atka mackerel catches were in the western Aleutian Islands (west of 180°W longitude). In the late 1970s and through the 1980s, fishing effort moved eastward, with the majority of landings occurring near Seguam and Amlia Islands. In 1984 and 1985 the majority of landings came from a single 1/2° latitude by 1° longitude block bounded by 52°30'N, 53°N, 172°W, and 173°W in Seguam Pass (73% in 1984, 52% in 1985). Areas fished by the Atka mackerel fishery from 1977 to 1992 are displayed in Fritz (1993). Areas of 2010 and 2011 fishery operations are shown in Figure 17.1.

### Management History

Prior to 1992, ABCs were allocated to the entire Aleutian management district with no additional spatial management. However, because of increases in the ABC beginning in 1992, the Council recognized the need to disperse fishing effort throughout the range of the stock to minimize the likelihood of localized depletions. In 1993, an initial Atka mackerel TAC of 32,000 t was caught by 11 March, almost entirely south of Seguam Island. This initial TAC release represented the amount of Atka mackerel that the Council thought could be appropriately harvested in the eastern portion of the Aleutian Islands subarea (based on the assessment for the 1993 fishery; Lowe 1992). In mid-1993, however, Amendment 28 to the Bering Sea/Aleutian Islands (BSAI) Fishery Management Plan became effective, dividing the Aleutian subarea into three districts at 177°W and 177°E for the purposes of spatially apportioning TACs (Figure 17.1). On 11 August 1993, an additional 32,000 t of Atka mackerel TAC was released to the Central (27,000 t) and Western (5,000 t) districts. Since 1994, the BSAI Atka mackerel TAC has been allocated to the three regions based on the average distribution of biomass estimated from the Aleutian Islands bottom trawl surveys. Table 17.2 gives the time series of BSAI Atka mackerel catches, corresponding ABC and TAC by region.

In June 1998, the Council passed a fishery regulatory amendment that proposed a four-year timetable to temporally and spatially disperse and reduce the level of Atka mackerel fishing within Steller sea lion critical habitat (CH) in the BSAI Islands. Temporal dispersion was accomplished by dividing the BSAI Atka mackerel TAC into two equal seasonal allowances, an A-season beginning January 1 and ending April 15, and a B-season from September 1 to November 1. Spatial dispersion was accomplished through a planned 4-year reduction in the maximum percentage of each seasonal allowance that could be caught within CH in the Central and Western Aleutian Islands. This was in addition to bans on trawling within 10 nm of all sea lion rookeries in the Aleutian district and within 20 nm of the rookeries on Seguam and Agligadak Islands (in area 541), which were instituted in 1992. The goal of spatial dispersion was to reduce the proportion of each seasonal allowance caught within CH to no more than 40% by the year 2002. No CH allowance was established in the Eastern subarea because of the year-round 20 nm trawl exclusion zone around the sea lion rookeries on Seguam and Agligadak Islands that minimized effort within CH. The regulations implementing this four-year phased-in change to Atka mackerel fishery management became effective on 22 January 1999 and lasted only 3 years (through 2001). In 2002, new regulations affecting management of the Atka mackerel, pollock, and Pacific cod fisheries went into

effect. Furthermore, all trawling was prohibited in CH from 8 August 2000 through 30 November 2000 by the Western District of the Federal Court because of violations of the Endangered Species Act (ESA).

As part of the plan to respond to the Court and comply with the ESA, NMFS and the NPFMC formulated new regulations for the management of Steller sea lion and groundfish fishery interactions that went into effect in 2002. The objectives of temporal and spatial fishery dispersion, cornerstones of the 1999 regulations, were retained. Season dates and allocations remained the same (A season: 50% of annual TAC from 20 January to 15 April; B season: 50% from 1 September to 1 November). However, the maximum seasonal catch percentage from CH was raised from the goal of 40% in the 1999 regulations to 60%. To compensate, effort within CH in the Central (542) and Western (543) Aleutian fisheries was limited by allowing access to each subarea to half the fleet at a time. Vessels fishing for Atka mackerel are randomly assigned to one of two teams, which start fishing in either area 542 or 543. Vessels may not switch areas until the other team has caught the CH allocation assigned to that area. In the 2002 regulations, trawling for Atka mackerel was prohibited within 10 nm of all rookeries in areas 542 and 543; this was extended to 15 nm around Buldir Island and 3 nm around all major sea lion haulouts. Steller sea lion CH east of 178°W in the Aleutian district, including all CH in subarea 541 and a 1° longitude-wide portion of subarea 542, is closed to directed Atka mackerel fishing.

Most recently, the 2010 NMFS Biological Opinion found that the fisheries for Alaska groundfish in the Bering Sea and Aleutian Islands and Gulf of Alaska, and the cumulative effects of these fisheries, are likely to jeopardize the continued existence of the western distinct population segment (DPS) of Steller sea lions, and also likely to adversely modify the designated critical habitat of the western DPS of Steller sea lions. Because this Biological Opinion found jeopardy and adverse modification of critical habitat, the agency is required to implement reasonable and prudent alternatives (RPAs) to the proposed actions (the fisheries). The Biological Opinion includes RPAs which require changes in groundfish fishery management in Management Sub-areas 543, 542, and 541 in the Aleutian Islands Management Area. NOAA Fisheries implemented the direct final rule measures before the start of the 2011 fishery in January. The RPAs specific to Atka mackerel are listed below:

<u>In Area 543</u>:

- Prohibit retention by all federally permitted vessels of Atka mackerel and Pacific cod.
- Establish a TAC for Atka mackerel sufficient to support the incidental discarded catch that may occur in other targeted groundfish fisheries (e.g., Pacific ocean perch).
- Eliminate the Atka mackerel platoon management system in the HLA.

<u>In Area 542</u>:

- Close waters from 0–3 nm around Kanaga Island/Ship Rock to directed fishing for groundfish by federally permitted vessels.
- Set TAC for Area 542 to no more than 47 percent of the acceptable biological catch (ABC).
- Between 177 E to 179 W longitude and 178 W to 177 W longitude, close critical habitat from 0–20 nm to directed fishing for Atka mackerel by federally permitted vessels year round.
- Between 179 W to 178 W longitude, close critical habitat from 0-10 nm to directed fishing for Atka mackerel by federally permitted vessels year round. Between 179 W and 178 W longitude, close critical habitat from 10-20 nm to directed fishing for Atka mackerel by federally permitted vessels not participating in a harvest cooperative or fishing a CDQ allocation.
- Add a 50:50 seasonal apportionment to the CDQ allocation to mirror seasonal apportionments for Atka mackerel harvest cooperatives.
- Limit the amount of Atka mackerel harvest allowed inside critical habitat to no more than 10 percent of the annual allocation for each harvest cooperative or CDQ group. Evenly divide the annual critical habitat harvest limit between the A and B seasons.

- Change the Atka mackerel seasons to January 20, 12:00 noon to June 10, 12:00 noon for the A season and June 10, 12:00 noon to November 1, 12:00 noon for the B season.
- Eliminate the Atka mackerel platoon management system in the HLA.

In Area 541:
- Change the Bering Sea Area 541 Atka mackerel seasons to January 20, 12:00 noon to June 10, 12:00 noon for the A season and June 10,12:00 noon to November 1, 12:00 noon for the B season.
- Close the Bering Sea subarea year round to directed fishing for Atka mackerel.

Amendment 80 to the BSAI Groundfish FMP was adopted by the Council in June 2006 and implemented for the 2008 fishing year. This action allocates several BSAI non-pollock trawl groundfish species among trawl fishery sectors, and facilitates the formation of harvesting cooperatives in the non-American Fisheries Act (non-AFA) trawl catcher/processor sector. Bering Sea/Aleutian Islands Atka mackerel is one of the groundfish species directly affected by Amendment 80. In addition, a Best Practices Cooperative has been formed under Amendment 80 which includes most of the participants in the BSAI Atka mackerel fishery.

### Bycatch and Discards

Atka mackerel are not commonly caught as bycatch in other directed Aleutian Islands fisheries. The largest amounts of discards of Atka mackerel, which are likely under-size fish, occur in the directed Atka mackerel trawl fishery. Atka mackerel are also caught as bycatch in the trawl Pacific cod and rockfish fisheries. Northern and light dusky rockfish are caught in the Aleutian Islands Atka mackerel fishery. While the 2008 and 2009 discards of northern rockfish as a total of the Atka mackerel catch were 5 and 4%, respectively, the actual amount of northern catches (discards and retained) accounts for a large portion of the AI northern TAC. The 2008 fishery caught 2,722 t of northern rockfish, about 33% of the 2008 AI northern TAC. The 2009 Atka mackerel fishery caught 2,700 t of northern rockfish which accounted for 38% of the northern TAC.

Discard data have been available for the groundfish fishery since 1990. Discards of Atka mackerel for 1990-1999 have been presented in previous assessments (Lowe *et al.* 2003). Aleutian Islands Atka mackerel discard data from 2000 to the present are given below:

| Year | Fishery | Discarded (t) | Retained (t) | Total (t) | Discard Rate (%) |
|---|---|---|---|---|---|
| **2000** | Atka mackerel | 2,388 | 43,977 | 46,365 | 5.1 |
| | All others | 201 | 272 | 473 | |
| | All | 2,589 | 44,249 | 46,838 | |
| **2001** | Atka mackerel | 3,832 | 55,744 | 59,567 | 6.4 |
| | All others | 551 | 1,217 | 1,768 | |
| | All | 4,384 | 56,961 | 61,344 | |
| **2002** | Atka mackerel | 7,125 | 36,112 | 43,237 | 16.5 |
| | All others | 239 | 1,205 | 1,443 | |
| | All | 7,364 | 37,317 | 44,680 | |
| **2003** | Atka mackerel | 9,209 | 41,994 | 51,203 | 18.0 |
| | All others | 709 | 1,076 | 1,785 | |
| | All | 9,918 | 43,070 | 52,988 | |
| **2004** | Atka mackerel | 6,709 | 45,841 | 52,550 | 12.8 |
| | All others | 448 | 407 | 855 | |
| | All | 7,157 | 46,248 | 53,405 | |
| **2005** | Atka mackerel | 2,403 | 55,359 | 57,762 | 4.2 |
| | All others | 264 | 448 | 712 | |
| | All | 2,668 | 55,806 | 58,474 | |
| **2006** | Atka mackerel | 1,558 | 56,603 | 58,161 | 2.7 |
| | All others | 326 | 232 | 558 | |
| | All | 1,884 | 56,835 | 58,719 | |
| **2007** | Atka mackerel | 1,595 | 53,593 | 55,188 | 2.9 |
| | All others | 73 | 474 | 554 | |
| | All | 1,668 | 54,067 | 55,735 | |
| **2008** | Atka mackerel | 1,087 | 53,757 | 54,483 | 2.0 |
| | All others | 72 | 2,774 | 2,846 | |
| | All | 1,159 | 56,531 | 57,690 | |
| **2009** | Atka mackerel | 2,618 | 67,116 | 69,733 | 3.8 |
| | All others | 283 | 2,546 | 2,829 | |
| | All | 2,901 | 69,661 | 72,563 | |
| **2010** | Atka mackerel | 3,626 | 57,667 | 61,293 | 5.9 |
| | All others | 65 | 1,261 | 1,326 | |
| | All | 3,691 | 58,928 | 62,619 | |

The discards and discard rate of Atka mackerel in the Atka mackerel fishery increased dramatically in 2002. The 2002 fishery caught large numbers of 3 and 4 year olds from the 1998 and 1999 year classes. Small fish from the very large 1999 year class may have contributed to the increased discarding in the 2002 fishery. The discards and discard rate increased again in 2003; the 2003 fishery caught large numbers of 3 and 4 year olds from the 1999 and 2000 year classes, and small fish from the 2000 year class may have contributed to the increased discarding in the 2003 fishery. The 2004 discard rate decreased despite the appearance of the above average 2001 year class; the 2004 fishery appeared to have retained larger numbers of 3-year old fish than previous years (Lowe *et al.* 2005). The discard rate decreased dramatically in 2005. The 2006 discard rate continued to decline, and rates have been 2-3% until 2009 when the discard rate increased to nearly 4%. The increases in 2009 and 2010 may be due to large numbers of small fish from the 2006 and 2007 year classes.

Until 1998, discard rates of Atka mackerel by the target fishery have generally been greatest in the western AI (543) and lowest in the east (541, Lowe *et al.* 2003). After 1998 and up until 2003, discard rates have been higher in the central AI (542) and have remained lowest in the east (541). However, in 2003, the discard rate in the eastern (541) and western AI (543) nearly doubled, and the western rate exceeded the central area rate. In the 2004 fishery, the discard rates decreased in both the central and western Aleutians (542 & 543) while the eastern rate increased again. The 2005 discard rates dropped significantly in all three areas, contributing to the large overall drop in the 2005 discard rate shown above. Discard rates have continued to decrease in eastern AI (541) since 2005.

| | | Aleutian Islands Subarea | | |
|---|---|---|---|---|
| **Year** | | **541** | **542** | **543** |
| **2000** | Retained (t) | 13,798 | 20,720 | 9,458 |
| | Discarded (t) | 163 | 1,484 | 742 |
| | ***Rate*** | ***1%*** | ***7%*** | ***7%*** |
| **2001** | Retained (t) | 7,632 | 28,678 | 19,333 |
| | Discarded (t) | 54 | 3,102 | 676 |
| | ***Rate*** | ***1%*** | ***10%*** | ***3%*** |
| **2002** | Retained (t) | 3,607 | 17,156 | 15,348 |
| | Discarded (t) | 213 | 4,827 | 2,085 |
| | ***Rate*** | ***6%*** | ***22%*** | ***12%*** |
| **2003** | Retained (t) | 5,626 | 22,566 | 14,877 |
| | Discarded (t) | 709 | 4,998 | 4,210 |
| | ***Rate*** | ***11%*** | ***18%*** | ***22%*** |
| **2004** | Retained (t) | 3,161 | 26,560 | 16,527 |
| | Discarded (t) | 520 | 3,610 | 3,027 |
| | ***Rate*** | ***14%*** | ***12%*** | ***15%*** |
| **2005** | Retained (t) | 3,356 | 33,598 | 18,852 |
| | Discarded (t) | 305 | 1,472 | 891 |
| | ***Rate*** | ***8%*** | ***4%*** | ***5%*** |
| **2006** | Retained (t) | 4,013 | 38,447 | 14,374 |
| | Discarded (t) | 232 | 1,389 | 263 |
| | ***Rate*** | ***5%*** | ***4%*** | ***2%*** |
| **2007** | Retained (t) | 19,752 | 25,475 | 8,847 |
| | Discarded (t) | 169 | 1,248 | 251 |
| | ***Rate*** | ***1%*** | ***5%*** | ***3%*** |
| **2008** | Retained (t) | 18,701 | 21,725 | 16,105 |
| | Discarded (t) | 18 | 745 | 395 |
| | ***Rate*** | ***0.1%*** | ***3%*** | ***2%*** |
| **2009** | Retained (t) | 25,734 | 28,349 | 15,578 |
| | Discarded (t) | 439 | 1,722 | 741 |
| | ***Rate*** | ***2%*** | ***6%*** | ***5%*** |
| **2010** | Retained (t) | 18,539 | 22,941 | 17,448 |
| | Discarded (t) | 386 | 2,120 | 1,184 |
| | ***Rate*** | ***2%*** | ***8%*** | ***6%*** |

### Fishery Length Frequencies

From 1977 to 1988, commercial catches were sampled for length and age structures by the NMFS foreign fisheries observer program. There was no JV allocation of Atka mackerel in 1989, when the fishery became fully domestic. Since the domestic observer program was not in full operation until 1990, there

was little opportunity to collect age and length data in 1989. Also, the 1980 and 1981 foreign observer samples were small, so these data were supplemented with length samples taken by R.O.K. fisheries personnel from their commercial landings. Data from the foreign fisheries are presented in Lowe and Fritz (1996).

Atka mackerel length distributions from the 2010 and 2011 fisheries by management area are shown in Figures 17.2 and 17.3, respectively. The modes at about 37-44 cm in the 2010 BSAI fishery length distributions represent the 2006 year class. The available 2011 fishery data are presented and should be considered preliminary. Preliminary data from the 2011 BSAI fisheries showed a smaller length distribution in the catches from area 542. This may be due to increased catches from Petrel Bank which have historically had smaller fish.

### Steller Sea Lions and Atka mackerel Fishery Interactions

Since 1979, the Atka mackerel fishery has occurred largely within areas designated in 1993 as Steller sea lion critical habitat (20 nm around rookeries and major haulouts). While total removals from critical habitat may be small in relation to estimates of total Atka mackerel biomass in the Aleutian region, fishery harvest rates in localized areas may have been high enough to affect prey availability of Steller sea lions (Section 12.2.2 of Lowe and Fritz 1997). The localized pattern of fishing for Atka mackerel apparently does not affect fishing success from one year to the next since local populations in the Aleutian Islands appear to be replenished by immigration and recruitment. However, this pattern could have created temporary reductions in the size and density of localized Atka mackerel populations which may have affected Steller sea lion foraging success during the time the fishery was operating and for a period of unknown duration after the fishery closed. As a consequence, the NPFMC passed regulations in 1998 and 2001 (described above) to disperse fishing effort temporally and spatially as well as reduce effort within Steller sea lion critical habitat.

NMFS is investigating the efficacy of trawl exclusion zones as a fishery-Steller sea lion management tool, and trying to determine the local movement rates of Atka mackerel through tagging studies. In August 1999, the AFSC conducted a pilot survey to explore the variance in survey catches of Atka mackerel and the feasibility of tagging as methods to determine small-scale changes in abundance and distribution. The tagging work was very successful and tagging surveys have been conducted near Seguam Pass (in area 541) in August 2000, 2001 and 2002 (McDermott *et al.* 2005). Results indicate that the 20 nm trawl exclusion zone around the rookeries on Seguam and Agligadak Islands is effective in minimizing disturbance to prey fields within them. The boundary of the 20 nm trawl exclusion zone at Seguam appears to occur at the approximate boundary of two naturally occurring assemblages. The movement rate between the two assemblages is small. Therefore, the results obtained here regarding the efficacy of the trawl exclusion zone may not generally apply to other, smaller zones to the west. The tagging work has been expanded and tagging was conducted inside and outside the 10 nm trawl exclusion zones in Tanaga Pass (in 2002), near Amchitka Island (in 2003) and off Kiska Island (in 2006). Movement rates at Tanaga pass and Kiska Island appear similar to those at Seguam with the trawl exclusion zones forming natural boundaries to local aggregations. Movement rates at Amchitka appear to be higher relative to Seguam (pers. comm. Elizabeth Logerwell and Susanne McDermott, AFSC). The boundaries at Amchitka bisect Atka mackerel habitat unlike Seguam and Tanaga.

## Data

### Fishery Data

Fishery data consist of total catch biomass from 1977 to 2010 and partial 2011 catch data (Table 17.1). Also, length measurements collected by observers and otoliths read by the AFSC Age and Growth Lab (Table 17.3) were used to create age-length keys to determine the age composition of the catch from

1977-2010 (Table 17.4). In previous assessments (prior to 2008), the catch-at-age in numbers was compiled using total annual BSAI catches and global (Aleutian-wide) year-specific age-length keys. The formulas used are described by Kimura (1989). As with the length frequencies, the age data for 1980-1981 and 1989 presented problems. The commercial catches in 1980 and 1981 were not sampled for age structures, and there were too few age structures collected in 1989 to construct a reasonable age-length key. Kimura and Ronholt (1988) used the 1980 survey age-length key to estimate the 1980 commercial catch age distribution, and these data were further used to estimate the 1981 commercial catch age distribution with a mixture model (Kimura and Chikuni 1987). However, this method did not provide satisfactory results for the 1989 catch data and that year has been excluded from the analyses (Lowe *et al*. 2007).

An alternative approach to compiling the catch-at-age data was adopted in the 2008 assessment in response to issues raised during the 2008 Center for Independent Experts (CIE) review of the Aleutian Islands Atka mackerel and pollock assessments. This method uses stratified catch by region (Table 17.2) and compiles (to the extent possible) region-specific age-length keys stratified by sex. This method also accounts for the relative weights of the catch taken within strata in different years. This approach was applied to catch-at-age data after 1989 (the period when consistent observer data were available) and follows the methods described by Kimura (1989) and modified by Dorn (1992; Table 17.4). Briefly, length-stratified age data are used to construct age-length keys for each stratum and sex. These keys are then applied to randomly sampled catch length frequency data. The stratum-specific age composition estimates are then weighted by the catch within each stratum to arrive at an overall age composition for each year. In summary, estimates of the proportion of catch-at-age are derived from the mean of the bootstrap sampling of the revised catch-at-age estimates. The bootstrap method also allows evaluation of sample-size scaling that better reflect inter-annual differences in sampling and observer coverage. Since body mass is applied in this estimation, stratum-weighted mean weights-at-age are available with the estimates of catch-at-age. The three strata for the Atka mackerel coincide with the three management areas (eastern, central, and western regions of the Aleutian Islands). This method was used to derive the age compositions for 1990-2010 (the period for which all the necessary information is readily available). Prior to 1990, the catch-age composition estimates remain the same as in previous assessments.

The most notable features of the estimated catch-at-age data (Table 17.4) are the strong 1975, 1977, 1999, 2000, and 2001 year classes, and large numbers of the 2006 year class which showed up in the 2009 and 2010 fisheries. The 1975 year class appeared strong as 3 and 4-year-olds in 1978 and 1979. It is unclear why this year class did not continue to show up strongly after age 4. The 1977 year class appeared strong through 1987, after entering the fishery as 3-year-olds in 1980. The 2002 fishery age data showed the first appearance in the fishery of the strong 1999 year class, and the 2003 and 2004 fishery data showed the first appearance of large numbers from the 2000 and 2001 year classes, respectively. The 2009 and 2010 fishery data are dominated by 3 and 4-year-olds, respectively of the 2006 year class, and continued to show the presence of the 2001 year class (Table 17.4).

Atka mackerel are a summer-fall spawning fish that do not appear to lay down an otolith annulus in the first year (Anderl *et al.*, 1996). For stock assessment purposes, one year is added to the number of otolith hyaline zones determined by the Alaska Fisheries Science Center Age and Growth Unit. All age data presented in this report have been corrected in this way.

### Survey Data

Atka mackerel are a difficult species to survey because: (1) they do not have a swim bladder, making them poor targets for hydroacoustic surveys; (2) they prefer hard, rough and rocky bottom which makes sampling with survey bottom trawl gear difficult; and (3) their schooling behavior and patchy distribution result in survey estimates with large variances. Despite these shortcomings, the U.S.-Japan cooperative trawl surveys conducted in 1980, 1983, 1986, and the 1991, 1994, 1997, 2000, 2002, 2004, 2006, and

2010 domestic trawl surveys, provide the only direct estimates of population biomass from throughout the Aleutian Islands region. Furthermore, the biomass estimates from the early U.S-Japan cooperative surveys are not directly comparable with the biomass estimates obtained from the U.S. trawl surveys because of differences in the net, fishing power of the vessels, and sampling design (Barbeaux *et al.* 2003).

Aleutian Islands trawl survey biomass estimates of Atka mackerel varied from 63,215 t in 1980 to 489,486 t in 1983, and 1,121,148 t in 1986 (Table 17.5). However, the high value for 1986 is not directly comparable to previous estimates. During the 1980 survey, no successful sampling occurred in shallow waters (<100 m) around Kiska and Amchitka Islands, and during the 1983 survey very few shallow water stations were successfully trawled. However, during the 1986 survey, several stations were successfully trawled in waters less than 100 m, and some produced extremely large catches of Atka mackerel. In 1986, the biomass estimate from this one depth interval alone totaled 1,011,991 t in the Central Aleutians (Table 17.5), or 90% of the total biomass of Atka mackerel in the Aleutian Islands. This was a 908,403 t increase over the 1983 biomass estimate for the same stratum-depth interval. The 1986 biomass estimate is associated with a large coefficient of variation (0.80). Due to differences in area and depth coverage of the surveys, it is not clear how this biomass estimate compares to earlier years.

The most recent Aleutian Islands biomass estimate from the 2010 Aleutian Islands bottom trawl survey is 844,571 t, up 16% relative to the 2006 survey estimate (no survey was conducted in 2008, Table 17.6). The breakdown of the Aleutian biomass estimates by area corresponds to the management sub-districts (541-Eastern, 542-Central, and 543-Western). The increase in biomass in the 2010 survey is largely a result of the increase in biomass found in the Western area (252,819 t in 2010 up from 100,693 t in 2006), despite a large decrease in the Central area. Relative to the 2006 survey, the 2010 biomass estimates are up 151% in the Western area, down 29% in the Central area, and up 13% in the Eastern area (Figure 17.4). The 95% confidence interval about the mean total 2010 Aleutian biomass estimate is **162,039-1,527,102 t**. The coefficient of variation (*CV*) of the 2010 mean Aleutian biomass is 40% (Table 17.6).

The distribution of biomass in the Western, Central, and Eastern Aleutians and the southern Bering Sea shifted between each of the surveys, and most dramatically in area 541 in the 2000 survey (Figure 17.4). The 2000 Eastern Aleutian area biomass estimate (900 t) was the lowest of all surveys, contributing only 0.2% of the total 2000 Aleutian biomass and represented a 98% decline relative to the 1997 survey. The extremely low 2000 biomass estimate for the Eastern area has not been reconciled, but there are several factors that may have had a significant impact on the distribution of Atka mackerel that were discussed in Lowe *et al.* (2001). We note that the distribution of Atka mackerel in the Eastern area is generally patchier, and up until the 2004 survey, the area-specific variances for the Eastern area have always been high relative to the Central and Western areas. Lowe *et al.* (2001) suggest that a combination of several factors coupled with the typically patchier distribution of Atka mackerel in area 541 may have impacted the distribution of the fish such that they were not available at the surveyed stations at the time of the 2000 survey.

The 2010 survey showed that the Eastern area contributed 47% of the total biomass which is nearly identical to the proportion detected in the 2006 survey, and represents the largest proportions in the time series (Table 17.6).

In 1994 for the first time since the initiation of the Aleutian triennial surveys, a significant concentration of biomass was detected in the southern Bering Sea area (66,603 t). This occurred again in 1997 (95,680 t), 2002 (59,883 t), and 2004 survey (267,556 t, Table 17.6). These biomass estimates are a result of large catches from a single haul encountered north of Akun Island in all four surveys. In addition, large catches of Atka mackerel in the 2004 survey were also encountered north of Unalaska Island, with a particularly large haul in the northwest corner of Unalaska Island. The 2004 southern Bering Sea strata biomass

estimate of 267,556 t is the largest biomass encountered in this area in the survey time series. The *CV* of the 2004 southern Bering Sea estimate is 43%, much lower than previous years as several hauls contributed to the 2004 estimate. The 2006 survey estimated only 12,284 t of biomass (*CV*=44%) from the southern Bering Sea area. Most recently, the 2010 survey estimated 102,755 t of biomass in the southern Bering Sea (*CV*=86%). As in past surveys, this biomass estimate is the result of a large catch from a single haul encountered north of Akun Island.

Areas with large catches of Atka mackerel during the 2004 survey included north of Akun Island and Unalaska Islands, Seguam Pass, Tanaga Pass, Kiska Island, Buldir Island, and Stalemate Bank (Figure 17.5). Similar to the 2004 survey, areas with large catches of Atka mackerel in the 2006 survey included Seguam Pass, Tanaga Pass, Kiska Island, and Stalemate Bank (Figure 17.**Error! Bookmark not defined.**). In the most recent 2010 survey, areas of large catches included north of Akun Island, northwest of the Islands of Four Mountains, Seguam Pass, Kiska Island, Buldir Island, and Stalemate Bank (Figure 17.**Error! Bookmark not defined.**). In the 2002, 2004, 2006, and 2010 surveys Atka mackerel were much less patchily distributed relative to previous surveys and were encountered in 55, 60, 51, and 57% of the hauls respectively, which are the highest rates of encounters in the survey time series.

The average bottom temperatures measured in the 2000 survey were the lowest of any of the Aleutian surveys, particularly in depths less than 200 m where 99% of the Atka mackerel are caught in the surveys (Figure 17.5). The average bottom temperatures measured in the 2002 survey were the second lowest of the Aleutian surveys, but significantly higher than the 2000 survey and very similar to the 1994 survey. The average bottom temperatures measured in the 2006 and 2010 surveys were slightly above the 2002 survey and very similar to the 1994 survey temperatures.

There is greater confidence in Atka mackerel biomass estimates from bottom trawl surveys of the groundfish community of the Aleutian Islands (AI) than the Gulf of Alaska (GOA). First, the coefficients of variation (*CV*) of the mean Atka mackerel biomass estimates have been considerably smaller from recent AI surveys compared to recent GOA surveys: 0.20, 0.17, and 0.28 from the 2002, 2004, 2006 AI surveys, respectively, compared with 1.00, 0.35, 0.50, and 0.46 from the 2001, 2003, 2005, and 2007 GOA surveys. However, it is noted that the most recent 2010 survey was associated with a *CV* of 40%, which is the highest *CV* in the domestic trawl survey time series. Second, while patchy in its distribution compared to other groundfish species, Atka mackerel have been much more consistently encountered in the AI than the GOA surveys, appearing 55%, 60, 51, and 57%% of the hauls in the 2002, 2004, 2006, and 2010 AI surveys, compared to 10%, 44%, 29%, and 20% of the hauls in the Shumagin area in the 2001, 2003, 2005, and 2007 GOA surveys, respectively. For these reasons we utilize bottom trawl surveys to assess the relative abundance of Atka mackerel in the Aleutian Islands, but do not consider the highly variable estimates of biomass from the GOA surveys useful for tracking abundance trends.

### *Survey Length Frequencies*

The 2000, 2002, 2004, and 2006 bottom trawl surveys and the fishery catch data revealed a strong east-west gradient in Atka mackerel size, with the smallest fish in the west and progressively larger fish to the east, (Figure 17.8 in Lowe *et al.* 2003, 2005, 2009). The 2010 survey length frequency distributions also show a strong east-west gradient in Atka mackerel size (Figure 17.7). The 2010 survey length frequency distributions from the Eastern area showed a mode of fish at 44 cm, larger than the Central and Western fish, and similar to the size distribution of fish sampled from the southern Bering Sea with a mode of 45 cm (Figure 17.6).

### *Survey Age Frequencies*

The 2004 survey age data is basically comprised of 3, 4, and 5-year olds of the 1999, 2000, and 2001 year classes, and is dominated by 3-year olds of the 2001 year class (Figure 17.7). The 2006 survey still

indicated large numbers from the 1999 year class and a very low number of fish from the 2002 year class. The fishery catch data also confirmed very low numbers of the 2002 year class. The 2006 survey and fishery saw an unusually high number of 2 year olds from the 2004 year class (Table 17.4). The 2007 fishery data confirmed a large number of 3 year olds from the 2004 year class. The most recent 2010 survey age composition is dominated by 3 and 4-year olds of the 2006 and 2007 year classes. The 2009 fishery data confirmed the strong presence of the 2006 year class in fishery catches. The mean ages of the 2004, 2006, and 2010 surveys are 4.2, 5.3, and 5.3 years, respectively.

### *Survey Abundance Indices*

A partial time series of relative indices from the 1980, 1983, 1986, and 1991 Aleutian Islands surveys had been used in the previous stock synthesis assessments (Lowe *et al.* 2001). The relative indices of abundance excluded biomass from the 1-100 m depth strata of the Southwest Aleutian Islands region (west of 180°) due to the lack of sampling in this stratum in some years. Because the excluded area and depth stratum have consistently been found to be locations of high Atka mackerel biomass in later surveys, it was determined that the indices did not provide useful additional information to the model. Analyses to determine the impact of omitting the relative time series showed that results without the relative index are more conservative (Lowe *et al*. 2002).

## Analytic approach

The 2002 BSAI Atka mackerel stock assessment introduced a new modeling approach implemented through the "Stock Assessment Toolbox" (an initiative by the NOAA Fisheries Office of Science and Technology) that evaluated favorably with previous assessments (Lowe *et al.* 2002). This approach used the Assessment Model for Alaska (AMAK)[1] from the Toolbox, which is similar to the stock synthesis application (Methot 1989, 1990; Fournier and Archibald 1982) used for Aleutian Islands Atka mackerel from 1991–2001, but allows for increased flexibility in specifying models with uncertainty in changes in fishery selectivity and other parameters such as natural mortality and survey catchability (Lowe *et al.* 2002). This approach (AMAK) has also been adopted for the Aleutian Islands pollock stock assessment (Barbeaux *et al.* 2004).

The Assessment Model for Alaska is developed using ADModel Builder language (Fournier 1998) and follows from the structure presented in Ianelli and Fournier (1998). ADMB is a C++ software language extension and automatic differentiation library that is now freely available. It allows for estimation of large numbers of parameters in non-linear models using automatic differentiation.

### Model structure

The AMAK models catch-at-age with the standard Baranov catch equation. The population dynamics follows numbers-at-age over the period of catch history (here 1977-2010) with natural and age-specific fishing mortality occurring throughout the 11-age-groups that are modeled (1-11+). Age 1recruitment in each year is estimated as deviations from a mean value expected from an underlying stock-recruitment curve. Deviations between the observations and the expected values are quantified with a specified error model and cast in terms of a penalized log-likelihood. The overall log-likelihood ($L$) is the weighted sum of the calculated log-likelihoods for each data component and model penalties. The component weights are inversely proportional to the specified (or in some cases, estimated) variances. Appendix Tables A-1 – A-3 provide a description of the variables used, and the basic equations describing the population

[1] AMAK. 2011. A statistical catch at age model for Alaska, version 2.0. NOAA version available on request to authors.

dynamics of Atka mackerel as they relate to the available data. The quasi[2] likelihood components and the distribution assumption of the error structure are given below:

| **Data component** | **Years of data** | **Likelihood form** | ***CV* or sample size (*N*)** |
|---|---|---|---|
| Catch biomass | 1977-2010 | Lognormal | *CV*=5% |
| Fishery catch age composition | 1977-2010 | Multinomial | Year specific *N*=25-234 |
| Survey biomass | 1991, 1994, 1997<br>2001, 2004, 2006, 2010 | Lognormal | Average *CV*=26% |
| Survey age composition | 1986, 1991, 1994, 1997<br>2001, 2004, 2006, 2010 | Multinomial | *N*=50 |
| Recruitment deviations | | Lognormal | |
| Stock recruitment curve | | Lognormal | |
| Selectivity smoothness (in age-coefficients, survey and fishery) | | Lognormal | |
| Selectivity change over time (fishery only) | | Lognormal | |
| Priors (where applicable) | | Lognormal | |

The age-composition components are heavily influenced by the sample size assumptions specified for the multinomial likelihood. Since sample variances of our catch-at-age estimates are available (Dorn 1992), "effective sample sizes" ( $\dot{N}_{i,j}$ ) can be derived as follows (where *i* indexes year, and *j* indexes age):

$$\dot{N}_{i,j} = \frac{p_{i,j}\left(1 - p_{i,j}\right)}{\mathrm{var}\left(p_{i,j}\right)}$$

where $p_{i,j}$ is the proportion of Atka mackerel in age group *j* in year *i* plus an added constant of 0.01 to provide some robustness. The variance of $p_{i,j}$ was obtained from the estimates of variance in catch-at-age. Thompson and Dorn (2003, p. 137) and Thompson (AFSC pers. comm.) note that the above is a random variable that has its own distribution. Thompson and Dorn (2003) show that the harmonic mean of this distribution is equal to the true sample size in the multinomial distribution. This property was used to obtain sample size estimates for the (post 1989) fishery numbers-at-age estimates (scaled to have a mean of 100; earlier years were set to constant values):

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| 25 | 25 | 25 | 25 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
| 47 | 35 | 10 | 10 | 66 | 59 | 117 | 16 | 82 | 219 | 234 | 104 |
| 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | | | |
| 136 | 133 | 133 | 89 | 117 | 89 | 144 | 150 | 150 | | | |

An ageing error conversion matrix is used in the assessment model to translate model population numbers at age to expected fishery catch at age. We estimated this matrix using an ageing error model fit to the observed percent agreement at ages 2 through 10. Mean percent agreement is close to 100% at age 2 and declines to 54% 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

[2] Quasi likelihood is used here because model penalties (not strictly relating to data) are included.

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. The probability that both readers agree and were off by more than two years was considered negligible.

### *Parameters estimated independently*

Natural Mortality

Natural mortality (*M*) is a difficult parameter to estimate reliably. One approach we took was to use the regression model of Hoenig (1983) which relates total mortality as a function of maximum age. His equation is:

$$\ln(Z) = 1.46 - 1.01(\ln(Tmax)).$$

Where *Z* is total instantaneous mortality (the sum of natural and fishing mortality, $Z=M+F$), and *Tmax* is the maximum age. The instantaneous total mortality rate can be considered an upper bound for the natural mortality rate if the fishing mortality rate is minimal. The catch-at-age data showed a 14-year-old fish in the 1990 fishery, and a 15-year-old in the 1994 fishery. Assuming a maximum age of 14 years and Hoenig's regression equation, *Z* was estimated to be 0.30 (Lowe 1992). Since fishing mortality was relatively low in 1990, natural mortality has been reasonably approximated by a value of 0.30 in past assessments.

An analysis was undertaken to explore alternative methods to estimate natural mortality for Atka mackerel (Lowe and Fritz, 1997). Several methods were employed based on correlations of *M* with life history parameters including growth parameters (Alverson and Carney 1975, Pauly 1980, Charnov 1993), longevity (Hoenig 1983), and reproductive potential (Roff 1986, Rikhter and Efanov 1976). Atka mackerel appear to be segregated by size along the Aleutian chain. Thus, natural mortality estimates based on growth parameters would be sensitive to any sampling biases that could result in under- or over-estimation of the von Bertalanffy growth parameters. Fishery data collections are more likely to be biased as the fishery can be more size selective and concentrates harvests in specific areas as opposed to the surveys. Natural mortality estimates derived from fishery data ranged from 0.05 to 1.13 with a mean of 0.53. Natural mortality estimates, excluding those based on fishery data, ranged from 0.12 to 0.74 with a mean value of 0.34. The current assumed value of 0.3 is consistent with these values. Also, a value of 0.3 is consistent with values of *M* derived by the methods of Hoenig (1983) and Rikhter and Efanov (1976) which do not rely on growth parameters (Lowe and Fritz, 1997).

The 2003 assessment explored the use of priors on *M*, resulting in drastically inflated biomass levels (Figure 17.11 in Lowe *et al.* 2003). Independent studies are being conducted outside the assessment which may provide further information to configure appropriate prior distributions for *M*. In the current assessment, a natural mortality value of 0.3 was used in the assessment model.

Length and Weight at Age

Atka mackerel exhibit large annual and geographic variability in length at age. Because survey data provide the most uniform sampling of the Aleutian Islands region, data from these surveys were used to evaluate variability in growth (Kimura and Ronholt 1988, Lowe *et al.* 1998). Kimura and Ronholt (1988) conducted an analysis of variance on length-at-age data from the 1980, 1983, and 1986 U.S.-Japan surveys, and the U.S.-U.S.S.R. surveys in 1982 and 1985, stratified by six areas. Results showed that length at age did not differ significantly by sex, and was smallest in the west and largest in the east. More recent analyses by Lowe *et al.* (1998) corroborated differential growth in three sub-areas of the Aleutian Islands and the Western Gulf of Alaska. Based on the work of Kimura and Ronholt (1988), and annual examination of length and age data by sex which has found no differences, growth parameters are presented for combined sexes. Parameters of the von Bertalanffy length-age equation and a weight-length

equation have been calculated for (1) the combined 1986, 1991, and 1994 survey data for the entire Aleutians region, and for the Eastern (541) and combined Central and Western (542 and 543) subareas, and (2) the combined 1990-96 fishery data for the same areas:

| Data source | $L_\infty$(cm) | $K$ | $t_0$ |
|---|---|---|---|
| **86, 91& 94 surveys** | | | |
| Areas combined | 41.4 | 0.439 | -0.13 |
| 541 | 42.1 | 0.652 | 0.70 |
| 542 & 543 | 40.3 | 0.425 | -0.38 |
| | | | |
| **1990-96 fishery** | | | |
| Areas combined | 41.3 | 0.670 | 0.79 |
| 541 | 44.1 | 0.518 | 0.35 |
| 542 & 543 | 40.7 | 0.562 | 0.37 |

Length-age equation: Length (cm) = $L_\infty\{1\text{-exp}[-K(\text{age-}t_0)]\}$

Both the survey and fishery data show a clear east to west size cline in length at age with the largest fish found in the eastern Aleutians.

The weight-length relationship determined from the same data sets are as follows:

weight (kg) = 9.08E-06 × length (cm) $^{3.0913}$ (86, 91 & 94 surveys; N = 1,052)
weight (kg) = 3.72E-05 × length (cm) $^{2.6949}$ (1990-1996 fisheries; N = 4,041).

The observed differences in the weight-length relationships from the survey and fishery data, particularly in the exponent of length, probably reflect the differences in the timing of sample collection. The survey data were all collected in summer, the spawning period of Atka mackerel when gonad weight would contribute the most to total weight. The fishery data were collected primarily in winter, when gonad weight would be a smaller percentage of total weight than in summer.

Year-specific weight-at-age estimates are used in the model to scale fishery and survey catch-at-age (and the modeled numbers-at-age) to total catch biomass and are intended to represent the average weight-at-age of the catch. Separate annual survey weights-at-age are complied for expanding modeled numbers into –age-selected- survey biomass levels (Table 17.7). Specifically, survey estimates of length-at-age were obtained using year-specific age-length keys. Weights-at-age were estimated by multiplying the length distribution at age from the age-length key, by the mean weight-at-length from each year-specific data set (De Robertis and Williams 2008). In addition, a single vector of weight-at-age values based on the 2004, 2006, and 2010 surveys is used to derive population biomass from the modeled numbers-at-age in order to allow for better estimation of current biomass (Table 17.7).

The fishery weight-at-age data presented in previous assessments (prior to 2008) were compiled based on unweighted, unstratified (Aleutian-wide) fishery catch-age samples to construct the year-specific age-length keys (see Table 17.8 in Lowe *et al*. 2007). Beginning with the 2008 assessment, the weights-at-age for the post 1989 fishery reflect stratum-weighted values based on the relative catches. The fishery weight-at-age data presented in Table 17.7 for 1990 to 2010, were compiled using the two-stage catch-estimation scheme described above in the Fishery Data section. Prior to 1990, the fishery weight-at-age estimates are as in previous assessments and given in Table 17.7.

Maturity at Age and Length

Female maturity at length and age were determined for Aleutian Islands Atka mackerel (McDermott and Lowe, 1997). The age at 50% maturity is 3.6 years. Length at 50% maturity differs by area as the length at age differs by Aleutian Islands sub-areas:

| | Length at 50% maturity (cm) |
|---|---|
| Eastern Aleutians (541) | 35.91 |
| Central Aleutians (542) | 33.55 |
| Western Aleutians (543) | 33.64 |

The maturity schedules are given in Table 17.8. Cooper and McDermott (2008) examined spatial and temporal variation in Atka mackerel female maturity at length and age. Maturity at length data varied significantly between different geographic areas and years, while maturity at age data failed to indicate differences and corroborated the age at 50% maturity determined by McDermott and Lowe (1997).

### *Parameters estimated conditionally*

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

Fishing Mortality

Fishing mortality is parameterized to be separable with a year component and an age (selectivity) component in all models. The selectivity relationship is modeled with a smoothed non-parametric relationship that can take on any shape (with penalties controlling the degree of change and curvature specified by the user; Table A-2). Selectivity is conditioned so that the mean value over all ages will be equal to one. To provide regularity in the age component, a moderate penalty was imposed on sharp shifts in selectivity between ages using the sum of squared second differences (log-scale). In addition, the age component parameters are assumed constant for ages 10 and older. Asymptotic growth is reached at about age 9 to 10 years. Thus, it seemed reasonable to assume that selectivity of fish older than age 10 would be the same. Prior to the 2008 assessment, selectivity had been allowed to vary annually with a low constraint as described in the 2002 assessment (Lowe *et al*. 2002). As suggested by the 2008 CIE reviewers, we adopted a new model configuration with blocks of years with constant selectivity which correspond approximately to the foreign fishery, the joint venture fishery, the domestic fishery prior to Steller sea lion regulations, and the domestic fishery post Steller sea lion regulations. This model configuration, with a refinement to the change-points in the fishery selectivity blocks implemented last year, is used in the current assessment.

Survey Selectivity and Catchability

For the bottom trawl survey, selectivity-at-age follows a parameterization similar to the fishery selectivity-at-age presented above (except with no allowance for time-varying selectivity). Here we specified that the average selectivity-at-age for the survey is equal to 1 over ages 4-10. This was done to standardize the ages over which selectivity most reasonably applies.

The 2003 assessment explored the use of a prior on survey catchability ($q$) through AMAK with mixed results that were difficult to interpret biologically (Lowe *et al.* 2003). In the 2004 assessment we presented a model (Model 4, Lowe *et al.* 2004), with a moderate prior on $q$ (mean = 1.0, $\sigma^2 = 0.2^2$) which was accepted and used as the basis for the ABC and OFL specifications since 2004. Our assumptions on survey catchability have not changed for the current assessment.

Recruitment

The Beverton-Holt form of stock recruitment relationship based on Francis (1992) was used (Table A-2). Values for the stock recruitment function parameters $\alpha$ and $\beta$ are calculated from the values of $R_0$ (the number of 0-year-olds in the absence of exploitation and recruitment variability) and the "steepness" of the stock-recruit relationship ($h$, Table A-2). The "steepness" parameter is the fraction of $R_0$ to be expected (in the absence of recruitment variability) when the mature biomass is reduced to 20% of its pristine level (Francis 1992). Past assessments have assumed a value of 0.8. A value of $h$ = 0.8 implies that at 20% of the unfished spawning stock size, an expected value of 80% of the unfished recruitment level will result. Model runs exploring other values of $h$ and the use of a prior on $h$ were explored in previous assessments (Lowe *et al.* 2002), but were found to have little or no bearing on the stock assessment results and were not carried forward for further evaluation at the time. As in past years, we assumed $h$ = 0.8 for all model runs since previous work showed that assessment results were insensitive to this assumption (and given the Tier 3 status does not affect future projections).

## Model Evaluation

In response to issues raised during the 2008 Center for Independent Experts (CIE) review of the Aleutian Islands Atka mackerel and pollock assessments, we changed a number of aspects of the input data and made refinements to the model configuration in the 2008 assessment. In summary, these changes focused on a more consistent approach to include survey data, the incorporation of a lower age+ bin (11+), calculated samples sizes for fishery catch-at-age data, revised compilation of catch- and weight-at-age data using a two-stage catch-estimation scheme based on stratified (by area) catch biomass and catch-at-age fishery samples, inclusion of an age-misclassification matrix, and incorporating blocks of years with constant selectivity. These changes were evaluated in a step-wise fashion and presented in Lowe *et al*. (2008).

The changes to the input data allowed for a more consistent approach and the change in the model configuration of fishery selectivity allowed for much greater parsimony with slight improvements to survey biomass fit at the cost of only a slight decrease in fishery age composition fits (Lowe *et al*. 2008). The revised model configuration assumed blocks of years with constant selectivity corresponding approximately to the foreign fishery, the joint venture fishery, the domestic fishery prior to Steller sea lion regulations, and the domestic fishery post Steller sea lion regulations. This model configuration was accepted by the SSC and used to set the 2009-2011 BSAI Atka mackerel ABCs and OFLs. In the current assessment we use the same model configuration. However we explored implementation of a random walk for a transition set of years in survey catchability as one approach to help resolve the poor residual pattern identified by the SSC in Dec. 2010. This model alternative is referred to as "Model 2."

Key results from the 2010 Model and the 2011 Model incorporating refinements to the change-points for the fishery selectivity blocks are given in Table 17.9.

## Model Results

The results discussed below are based on the 2011 Model with updated fishery catch- and weight-at-age values, 2010 fishery data, 2010 Aleutian Islands survey data, and 4 time periods each with constant selectivity as described above.

### Selectivity

For Atka mackerel, the estimated selectivity patterns are particularly important in describing their dynamics. Previous assessments have focused on the transitions between ages and time-varying selectivity (Lowe *et al.* 2002). The current assessment estimates selectivity at age schedules for 4 time periods in the fishery and a single selectivity pattern for the survey (Figures 17.8-17.11, Table 17.10). The

current 2011 selectivity estimate is similar to last year and is shifted to fish that have already reached maturity (Figure 17.9).

The fishery catches essentially consist of fish 3-11 years old, although a 15-year-old fish was found in the 1994 fishery. The fishery exhibits a slight dome-shaped selectivity pattern which is more pronounced prior to 1992 during the foreign and joint venture fisheries blocks (1977-1984 and 1985-1992, Figure 17.9). After 1992, fishery selectivity patterns are divided into 2 blocks of years (1993-1999, 2000-2011) each with constant selectivity. The patterns between these two blocks are fairly similar but do show slight differences at ages 3-7 and more notable differences at age 8 and older. Fish older than age 9 make up a very small percentage of the population each year, and the differences in the selectivity assumptions for the older ages are not likely to have a large impact. However, differences in selectivity for ages 3-8 can have a significant impact. The recent pattern for the years 2000-2011 reflects the large numbers of fish from the 1999, 2000, 2001, and 2006 year classes (Table 17.4). The age at 50% selectivity is estimated at about age 4 for both time periods. It is important to note the maturity-at-age vector (age at 50% maturity is 3.6 years). The estimated selectivity patterns since 1991 indicate the fishery is harvesting mature older fish relative to the foreign and joint venture fisheries.

Survey catches are mostly comprised of fish 3-9 years old. However, the 2010 survey showed significant numbers of 9-11 year olds of the 1999, 2000, and 2001 year classes. A 14-year old fish was found in the 1994 survey and a 15-year old fish was found in the 2000 survey. The current configuration estimates a smoothed nearly asymptotic pattern (Figure 17.10), which differs from previous year's estimates which exhibited a slightly dome-shaped selectivity pattern (Figure 17.13 in Lowe *et al*. 2009). The current estimated survey selectivity pattern is nearly identical to last year's estimate.

### Abundance Trend

The estimated time series of total numbers at age are given in Table 17.11. The estimated time series of total biomass (ages 1+) with approximate upper and lower 95% confidence limits are shown in Figure 17.11 and given in Table 17.12. A comparison of the spawning biomass trend from the current and previous assessments (Table 17.12) indicates consistent trends throughout the time series, i.e., biomass increased during the early 80s and again in the late 80s to early 90s. After the estimated peak spawning biomass in 1993, spawning biomass declined for nearly 10 years until 2001 (Figure 17.12). Thereafter, spawning biomass began a steep increase which continued to 2005.

### Recruitment Trend

The estimated time series of age 1 recruits indicates the strong 1977 and 1999 year class are the most notable in the current assessment, followed by the 1989 and 2001 year classes (Figure 17.13). The 1999 and 2001 year classes are estimated to be two of the four largest recent year classes in the time series (approximately 1.4 and 1.0 billion recruits, respectively) due to the persistent observations of these year classes in the 2010 fishery and in the 2010 survey. The current assessment estimates above average (greater than 20% of the mean) recruitment from the 1977, 1988, 1992, 1995, 1998, 1999, 2000, 2001, 2006 and 2007 year classes (Figure 17.13).

The average estimated recruitment from the time series 1978-2009 is 542 million fish and the median is 363 million fish (Table 17.13). The entire time series of recruitments (1977-2010) includes the 1976-2009 year classes. The Alaska Fisheries Science Center has recognized that an environmental "regime shift" affecting the long-term productive capacity of the groundfish stocks in the BSAI occurred during the period 1976-1977. Thus, the average recruitment value presented in the assessment is based on year classes spawned after 1976 (1977-2008 year classes). Projections of biomass are based on estimated recruitments from 1978-2009 using a stochastic projection model described below.

### Trend in Exploitation

The estimated time series of fishing mortalities on fully selected age groups and the catch-to-biomass (age 3+) ratios are given in Table 17.14 and shown in Figure 17.14.

### Model Fit

A summary of key results from the 2011 Model are presented in Table 17.9. The coefficient of variation or *CV* (reflecting uncertainty) about the 2011 biomass estimate is 19% and the *CV*s on the strength of the 1999 and 2001 year classes at age 1 are 18 and 22%, respectively (Table 17.9). Overall estimated recruitment variability for BSAI Atka mackerel is high (0.62). Sample size values were calculated for the fishery data and fixed at 50 for the bottom trawl survey data. The model estimated an average fishery effective sample size (*N*) of 129 and average survey effective *N* of 54, which compares well with the fixed value. The overall residual mean square error (RMSE) for the survey is estimated at 0.25 (Table 17.9). The RMSE is in line with estimates of sampling-error *CV*s for the survey which range from 14-40% and average 26% over the time series. The sampling-error variances should be considered as minimal estimates. Other sources of uncertainty (e.g., due to spatial variability and environmental conditions) can inflate the uncertainty associated with survey biomass estimates.

Figure 17.15 compares the observed and estimated survey biomass abundance values for the Bering Sea/Aleutian Islands and the two models that were evaluated this year. The large decrease in biomass indicated by the 1994 and 1997 surveys followed by the large increases in biomass from the 2000 and 2002 surveys appear to be consistent with recruitment patterns. However, the large increase observed in the 2004 survey fit poorly in both models. In the 2004 survey, an unusually high biomass (270,000 t) was estimated for the southern Bering Sea area. This value represented 30% of the entire 2004 BSAI survey biomass estimate. The 2006 survey indicates a downward trend which is consistent with the population age composition at the time. The most recent 2010 survey biomass estimate indicates a large increase that was not predicted by the assessment model. The 2010 survey biomass estimate for the southern Bering Sea was also unusually high (102,800 t) and represented a 735% increase over the 2006 southern Bering Sea estimate. We note that the model's predicted survey biomass trend is very conservative relative to the recent (2000, 2002, 2004, 2006, and 2010) observed bottom trawl survey biomass values (survey catchability is greater than 1).

The fits to the survey and fishery age compositions for Model 1 are depicted in Figures 17.16 and 17.17, respectively. The model fits the fishery age composition data well particularly after 1995, and the survey age composition data less so. This reflects the fact that the sample sizes for age and length composition data are higher for the fishery in some years than the survey. These figures also highlight the patterns in changing age compositions over time. Note that the older age groups in the fishery age data are largely absent until around 1985 when the 1977 year class appears. Recent fishery age composition fits may indicate the need for another change-point for the recent (2000-2010) selectivity block.

## Projections and harvest alternatives

### Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines "overfishing level" (OFL), the fishing mortality rate used to set OFL ($F_{OFL}$), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC ($max\ F_{ABC}$). The fishing mortality rate used to set ABC ($F_{ABC}$) may be less than this maximum permissible level, but not greater. The overfishing and maximum allowable ABC fishing mortality rates are given in terms of percentages of unfished female spawning biomass ($F_{SPR\%}$), on fully selected age groups. The associated long-term average female spawning biomass that would be expected under average estimated recruitment from 1978-2009 (542 million age 1 recruits) and *F* equal to $F_{40\%}$ and $F_{35\%}$ are denoted $B_{40\%}$ and $B_{35\%}$, respectively. The Tiers

require reference point estimates for biomass level determinations. We present the following reference points for BSAI Atka mackerel for Tier 3 of Amendment 56. For our analyses, we computed the following values from the 2011 Model results based on recruitment from post-1976 spawning events:

$B_{100\%}$ = 255,662 t female spawning biomass

$B_{40\%}$ = 102,265 t female spawning biomass

$B_{35\%}$ = 89,482 t female spawning biomass

### Specification of OFL and Maximum Permissible ABC

In the current assessment, the Model is configured with 4 time periods of constant selectivity. The last time period (2000-2010) reflects the domestic fishery after implementation of Steller sea lion protection measures. This selectivity pattern is shown in Figure 17.9 and used for projection purposes. The following rates are based on the 2000-2010 selectivity estimates:

| Full selection *F*s | |
|---|---|
| $F_{2011}$ | 0.221 |
| $F_{40\%}$ | 0.384 |
| $F_{35\%}$ | 0.469 |
| $F_{2011}/F_{40\%}$ | 0.504 |

For specification purposes to project the 2012 ABC, we assumed that the full TAC would be taken in 2011 (53,080 t). For projecting to 2013, an expected catch in 2012 is required. Typically this value is set to a recommended ABC, in this case the 2012 recommended ABC. However, recognizing that the Steller Sea Lion RPA's require TAC reductions, we assume the stock-wide catch based on a reduced overall BSAI-wide Atka mackerel catch for 2012. To arrive at such a reduction we assumed that only trace amounts of Atka mackerel (as bycatch in other fisheries) would be taken from Area 543 (Western Aleutian Islands) and about half of the allocation to Area 542 (Central Aleutian Islands) would be taken. We estimated that about 64% of the BSAI-wide ABC is likely to be taken. This percentage was applied to the maximum permissible 2012 ABC and that amount was assumed to be caught in order to estimate the 2013 ABC and OFL values.

It is important to note that for BSAI Atka mackerel, projected female spawning biomass calculations depend on the harvest strategy because spawning biomass is estimated at peak spawning (August). Thus, projections incorporate 7 months of the specified fishing mortality rate. For the 2011 Model, the projected year 2012 female spawning biomass ($SSB_{2012}$) is estimated to be 128,813 t under an assumed 2011 catch of 53,080 t and reduced 2012 catch reflecting the RPA adjustment to the 2012 ABC. The projected 2012 female spawning biomass estimate is above the $B_{40\%}$ value of 102,265 t, placing BSAI Atka mackerel in **Tier 3a**. The maximum permissible ABC and OFL values under **Tier 3a** are:

| Year | Catch | ABC | OFL | SSB |
|---|---|---|---|---|
| 2012 | 53,080 | 81,399 | 96,548 | 128,813 |
| 2013 | 52,095 | 67,067 | 78,260 | 103,848 |

Note that the 2012 and 2013 maximum permissible $F_{ABC} = F_{40\%} = 0.384$ and $F_{OFL}=F_{35\%} = 0.469$; also, catches in 2012 and 2013 are less than the recommended ABCs to reflect expected catch reductions under Steller sea lion RPAs.

## ABC Recommendation

Observations and characterizations of uncertainty in the Atka mackerel assessment are noted for ABC considerations.

1) Trawl survey estimates of Aleutian Islands biomass are highly variable; the 2000, 2002, and 2004 survey estimates showed 40, 50, and 15% increases respectively. The 2006 survey estimate of Aleutian Islands biomass decreased 18% relative to the 2004 survey. The planned 2008 survey was not conducted. The most recent 2010 survey increased 16% relative to the 2006 survey.
2) Under an $F_{40\%}$ harvest strategy and assuming SSL RPA catch reductions, 2012 female spawning biomass is projected to be above $B_{40\%}$ but drop below in 2014 to 2017 (Figure 17.18 and Table 17.15 Scenario 1).
3) The model's predicted survey biomass trend is very conservative relative to 2000, 2002, 2004, 2006 and 2010 observed bottom trawl survey biomass values.
4) The 2009 and 2010 fishery data are dominated by 3 and 4-year-olds, respectively, of the 2006 year class, and the 2010 data indicates a strong presence of the 2007 year class (Table 17.4).
5) The 2010 survey age composition is dominated by 3 and 4-year olds of the 2006 and 2007 year classes. The bottom trawl surveys have been a consistently good indicator of incoming year class strengths.
6) Currently we estimate the 1999 year class to be the largest in the time series (but with a moderate degree of uncertainty: $CV$=18%).

We believe the current model configuration provides an improved assessment of BSAI Atka mackerel relative to past model configurations. Given the current stock size, the appearance of three consecutive strong year classes which still persist in the population, an above average 2006 year class, and preliminary indications of an above average 2007 year class, the maximum permissible is precautionary and acceptable for Atka mackerel. We note that the maximum permissible reference fishing mortality rate ($F_{ABC}$) is higher than the natural mortality rate. This is due to the fact that estimated fishery selectivity-at-age is significantly older than the maturity-at-age. That is, the fishery targets the older mature portion of the population that had opportunities to spawn. Actual fishing mortality rates have been below $F_{ABC}$ . For perspective, a plot of relative harvest rate ($F_t/F_{35\%}$) versus relative female spawning biomass ($B_t/B_{35\%}$) is shown in Figure 17.19. For most of the time series (including the 2011 data point), the current assessment estimates that relative harvest rates have been below 1, and the relative spawning biomass rates have been greater than 1.0.

The probability of female spawning biomass dropping below $B_{20\%}$ in the next five years is very low (Figure 17.20).

**The 2012 yield associated with the maximum permissible $F_{40\%}$ fishing mortality rate of 0.384 is 81,399 t, which is our 2012 ABC recommendation for BSAI Atka mackerel.**

**The 2013 yield associated with the maximum permissible $F_{ABC}$ fishing mortality rate of 0.384 and assuming 2012 catch reductions, is 67,067 t, which is our 2013 ABC recommendation for BSAI Atka mackerel.**

The 2012 ABC recommendation down slightly from the Council's 2011 ABC but above the projections from last year's assessment for 2012 by 4%.

### Area Allocation of Harvests

Amendment 28 of the Bering Sea/Aleutian Islands Fishery Management Plan divided the Aleutian subarea into 3 districts at 177° E and 177° W longitude, providing the mechanism to apportion the Aleutian Atka mackerel TACs. The Council used a 4-survey (2000, 2002, 2004, and 2006) weighted average to apportion the 2010 ABC. The rationale for the weighting scheme was described in Lowe *et al.* (2001). Last year the 2010 survey provided updated information for the apportionment, and we dropped the 2000 survey and incorporated the 2010 survey distribution. In addition, the distribution of survey biomass used in the apportionment calculations was updated to include the southern Bering Sea area in area 541. This is consistent with the assessment and fishery management of area 541 for Atka mackerel. The data used to derive the percentages for the weighting scheme are given below:

| | 2002 | 2004 | 2006 | 2010 | 2011 Apportionment | Recommended 2012 & 2013 Apportionment |
|---|---|---|---|---|---|---|
| 541[1] | 30.26% | 44.20% | 48.91% | 52.57% | **47.27%** | **47.27%** |
| 542 | 38.94% | 23.27% | 37.51% | 20.74% | **28.09%** | **28.09%** |
| 543 | 30.80% | 32.52% | 13.58% | 26.69% | **24.64%** | **24.64%** |
| Weights | 8 | 12 | 18 | 27 | | |

[1]Includes eastern Aleutian Islands and southern Bering Sea areas.

The apportionments of the 2012 and 2013 recommended ABCs based on the most recent 4-survey weighted average are:

| | 2012 | 2013 |
|---|---|---|
| Eastern (541) | 38,477 | 31,703 |
| Central (542) | 22,865 | 18,839 |
| Western (543) | 20,057 | 16,525 |
| Total | 81,399 | 67,067 |

## Standard Harvest Scenarios and Projection Methodology

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3, of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2011 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2021 using a fixed value of natural mortality of 0.3, the recent schedule of selectivity estimated in the assessment (in this case the 2000-2010 selectivity), and the best available estimate of total (year-end) catch for 2011 (in this case assumed equal to the 2011 TAC of 53,080 t). In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning (August) and the maturity and population weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 500 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in a Supplemental Environmental Impact Statement 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 2012, 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.). *Note: We used this scenario to project the BSAI stock assuming catch reductions that may occur under SSL RPAs.*

*Scenario 2*: In all future years, $F$ is set equal to a constant fraction of *max* $F_{ABC}$, where this fraction is equal to the ratio of the $F_{ABC}$ value for 2012 recommended in the assessment to the *max* $F_{ABC}$ for 2012. (Rationale: When $F_{ABC}$ is set at a value below *max* $F_{ABC}$, it is often set at the value recommended in the stock assessment). *Note: We used this scenario to project the BSAI stock assuming catch reductions that may occur under SSL RPAs.*

*Scenario 3*: In all future years, $F$ is set equal to the 2006-2011 average $F$. (Rationale: For some stocks, TAC can be well below ABC, and recent average $F$ may provide a better indicator of $F_{TAC}$ than $F_{ABC}$.)

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

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

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (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 2011 or 2) above ½ of its MSY level in 2011 and above its MSY level in 2021 under this scenario, then the stock is not overfished.)

*Scenario 7*: In 2012 and 2013, $F$ is set equal to *max* $F_{ABC}$, and in all subsequent years, $F$ is set equal to $F_{OFL}$. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2024 under this scenario, then the stock is not approaching an overfished condition.)

### Status determination

The projections of female spawning biomass, fishing mortality rate, and catch corresponding to the seven standard harvest scenarios are shown in Table 17.15. Harvest scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest scenarios #6 and #7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2011:

a) If spawning biomass for 2011 is estimated to be below ½ $B_{35\%}$ , the stock is below its MSST.

b) If spawning biomass for 2011 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c) If spawning biomass for 2011 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest scenario #6 (Table 17.15). If the mean

spawning biomass for 2021 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

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

a) If the mean spawning biomass for 2014 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2014 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2014 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2024. If the mean spawning biomass for 2024 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

In the case of BSAI Atka mackerel, spawning biomass for 2011 is estimated to be above $B_{35\%}$. Therefore, the stock is above its MSST and is not overfished. Mean spawning biomass for 2014 under scenario 7 in Table 17.15 is above $B_{35\%}$ therefore, the stock is not approaching an overfished condition.

## Ecosystem Considerations

Steller sea lion food habits data (from analysis of scats) from the Aleutian Islands indicate that Atka mackerel is the most common prey item throughout the year (NMFS 1995, Sinclair and Zeppelin 2002). The prevalence of Atka mackerel and walleye pollock in sea lion scats reflected the distributions of each fish species in the Aleutian Islands region. The percentage occurrence of Atka mackerel was progressively greater in samples taken in the central and western Aleutian Islands, where most of the Atka mackerel biomass in the Aleutian Islands is located. Conversely, the percentage occurrence of pollock was greatest in the eastern Aleutian Islands.

Bottom contact fisheries could have direct negative impacts on Atka mackerel by destroying egg nests and/or removing the males that are guarding nests (Lauth *et al.* 2007b); however, this has not been examined quantitatively. Analyses of historic fishery CPUE revealed that the fishery may create temporary localized depletions of Atka mackerel, and historic fishery harvest rates in localized areas may have been high enough to affect prey availability of Steller sea lions (Section 12.2.2 of Lowe and Fritz 1997). The localized pattern of fishing for Atka mackerel could have created temporary reductions in the size and density of localized Atka mackerel populations which may have affected Steller sea lion foraging success during the time the fishery was operating and for a period of unknown duration after the fishery closed.

### Ecosystem effects on BSAI Atka mackerel

#### *Prey availability/abundance trends*

Figure 17.22 shows the food web of the Aleutian Islands summer survey region, based on trawl survey and food habits data, with an emphasis on the predators and prey of Atka mackerel (see the current Ecosystem Assessment's ecosystem modeling results section for a description of the methodology for constructing the food web).

Adult Atka mackerel in the Aleutians consume a variety of prey, but are primarily zooplanktivors, consuming mainly euphausiids and calanoid copepods (Yang 1996, Yang 2003). Food habits data from 1990-1994 indicates that Atka mackerel feed on calanoid copepods (40%) and euphausiids (25%) followed by squids (10%), juvenile pollock (6%), and finally a range of zooplankton including fish larvae, benthic amphipods, and gelatinous filter feeders (Fig. 17.25a). While Figure 17.23a shows an aggregate diet for the Aleutians management regions, Atka mackerel diet data also show a longitudinal gradient, with euphausiids dominating diets in the east and copepods and other zooplankton dominating in the

west. Greater piscivory, especially on myctophids, occurs in the island passes (Ortiz, 2007) Monitoring trends in Atka mackerel prey populations may, in the future, help elucidate Atka mackerel population trends. However, there is no long-term time series of zooplankton, squid, or small forage fish abundance information available.

Some preliminary results of sensitivity analysis suggest that Atka mackerel foraging in the Aleutian Islands may have a relatively strong competitive effect on walleye pollock distribution and abundance, as opposed to the Bering Sea where pollock may be more bottom-up (prey) controlled, or the Gulf of Alaska where pollock may be top-down (predator) controlled (Aydin *et al*. 2007). Since these sensitivity analyses treat the Aleutian Islands as a single "box model", it is possible that this is a mitigating or underlying factor for the geographical separation between Atka mackerel and pollock as a partitioning of foraging habitat.

### *Predator population trends*

Atka mackerel are consumed by a variety of piscivores, including groundfish (e.g., Pacific cod, Pacific halibut, and arrowtooth flounder, Livingston *et al.* unpubl. manuscr.), marine mammals (e.g., northern fur seals and Steller sea lions, Kajimura 1984, NMFS 1995, Sinclair and Zeppelin 2002), skates, and seabirds (e.g., thick-billed murres, tufted puffins, and short-tailed shearwaters, Springer *et al.* 1999). Apportionment of Atka mackerel mortality between fishing, predation, and unexplained mortality, based on the consumption rates and food habits of predators averaged over 1990-1994 is shown in Figure 17.24. During these years, approximately 20% of the Atka mackerel exploitation rate (as calculated by stock assessment) was due to the fishery, 62% due to predation, and 18% "unexplained", where "unexplained" is the difference between the stock assessment total mortality and the sum of fisheries exploitation and quantified predation. This unexplained mortality may be due to data uncertainty, or Atka mackerel mortality due to disease, migration, senescence, etc.

Of the 62% of mortality due to predation, a little less than half (25% of total) is due to Pacific cod predation, and one quarter (15% of total) due to Steller sea lion predation, with the remainder spread across a range of predators (Figure 17.23b), based on Steller sea lion diets published by Merrick *et al.* (1997) and summer fish food habits data from the REEM food habits database.

If converted to tonnages, this translates to 100,000-120,000 t/year of Atka mackerel consumed by predatory fish (of which approximately 60,000 t is consumed by Pacific cod), and 40,000-80,000 t/year consumed by Steller sea lions during the early 1990s. Estimating the consumption of Atka mackerel by birds is more difficult to quantify due to data limitations: based on colony counts and residency times, predation by birds, primarily kittiwakes, fulmars, and puffins, on all forage and rockfish combined in the Aleutian Islands is at most 70,000 t/year (Hunt *et al.* 2000). However, colony specific diet studies, for example for Buldir Island, indicate that the vast majority of prey found in these birds is sandlance, myctophids, and other smaller forage fish, with Atka mackerel never specifically identified as prey items, and "unidentified greenlings" occurring infrequently (Dragoo *et al.* 2001). The food web model's estimate, based on foraging overlap between species, estimates the total Atka mackerel consumption by birds to be less than 2,000 t/year. While this might be an underestimate, it should be noted that most predation would occur on juveniles (<1year old) which is not counted in the stock assessment's total exploitation rates.

The abundance trends of Aleutian Islands Pacific cod has been quite variable, alternating between increases and decreases in recent surveys, and Aleutian Islands arrowtooth flounder has been increasing. Northern fur seals are showing declines, and Steller sea lions have shown some slight increases. The population trends of seabirds are mixed, some increases, some decreases, and others stable. Seabird population trends could potentially affect juvenile Atka mackerel mortality. Declining trends in predator

abundance could lead to possible decreases in Atka mackerel mortality, while increases in predator biomass could potentially increase the mortality.

### *Changes in habitat quality*

Climate

Interestingly, strong year classes of AI Atka mackerel have occurred in years of hypothesized climate regime shifts 1977, 1988, and 1999, as indicated by indices such as the Pacific Decadal Oscillation (Francis and Hare 1994, Hare and Mantua 2000, Boldt 2005). Bailey *et al.* (1995) noted that some fish species show strong recruitment at the beginning of climate regime shifts and suggested that it was due to a disruption of the community structure providing a temporary release from predation and competition. It is unclear if this is the mechanism that influences Atka mackerel year class strength in the Aleutian Islands. El Nino Southern Oscillation (ENSO) events are another source of climate forcing that influences the North Pacific. Hollowed *et al.* (2001) found that gadids in the GOA have a higher proportion of strong year classes in ENSO years. There was, however, no relationship between strong year classes of AI Atka mackerel and ENSO events (Hollowed *et al.* 2001).

Bottom temperature

Atka mackerel demonstrate schooling behavior and prefer hard, rough and rocky bottom substrate. Eggs are deposited in nests on rocky substrates between 15 and 144 m depth (Lauth *et al.* 2007b). The spawning period in Alaska occurs in late July to October (McDermott and Lowe 1997, Lauth *et al.* 2007b). During the incubation period egg nests are guarded by males, who will be on the nests until mid-January, given that females have been observed to spawn as late as October and given the length of the egg incubation period (McDermott and Lowe 1997, Lauth *et al.* 2007b, Lauth *et al.* 2007a). The distribution of Atka mackerel spawning and nesting sites are thought to be limited by water temperature (Gorbunova 1962). Temperatures below 3°C and above 15°C are lethal to eggs or unfavorable for embryonic development depending on the exposure time (Gorbunova 1962). Temperatures recorded at Alaskan nesting sites, 3.9 - 10.7 ºC, do not appear to be limiting, as they were within this range (Lauth *et al.* 2007b).

The 2000 Aleutian Islands summer bottom temperatures indicated that 2000 was the coldest year followed by summer bottom temperatures from the 2002 survey, which indicated the second coldest year (Figure 17.6). The 2004 AI summer bottom temperatures indicated that 2004 was an average year, while the 2006 and 2010 bottom temperatures were slightly below average. Bottom temperatures could possibly affect fish distribution, but there have been no directed studies, and there is no time series of data which demonstrates the effects on AI Atka mackerel.

## Atka mackerel fishery effects on the ecosystem

### *Atka mackerel fishery contribution to bycatch*

The levels of bycatch in the Atka mackerel fishery of prohibited species, forage fish, HAPC biota, marine mammals, birds, and other sensitive non-target species is relatively low except for the species which are noted in Table 17.16 and discussed below.

The Atka mackerel fishery has very low bycatch levels of some species of HAPC biota, e.g. seapens and whips. The bycatch of sponges and coral in the Atka mackerel fishery is highly variable. It is notable that in the last 3 years (2007-2009), the Atka mackerel fishery has taken on average about 52 and 25%, respectively of the total Aleutian Islands sponge and coral catches. It is unknown if the absolute levels of sponge and coral bycatch in the Atka mackerel fishery are of concern.

The bycatch of skates, which are considered a sensitive or vulnerable species based on life history parameters, is noted in Table 17.16. Skate bycatch in the Aleutian Islands Atka mackerel fishery is

variable and has averaged 158 t in the last 3 years (2007-2009). Over this same time period, the Atka mackerel fishery has taken an average of 13% of the total Aleutian Islands skate bycatch. It is unknown if the absolute levels of skate bycatch in the Atka mackerel fishery are of concern.

The bycatch of sculpin is notable and has averaged about 570 t from 2007 to 2009. This level of bycatch represents an average of 53% of the total Aleutian Islands sculpin bycatch. It is unknown if the absolute levels of sculpin bycatch in the Atka mackerel fishery are of concern.

### *Fishing gear effects on spawning and nesting habitat*

Bottom contact fisheries could have direct negative impacts on Atka mackerel by destroying egg nests and/or removing the males that are guarding nests (Lauth *et al.* 2007b); however, this has not been examined quantitatively. It was previously thought that all Atka mackerel migrated to shallow, nearshore areas for spawning and nesting sites. When nearshore bottom trawl exclusion zones near Steller sea lion rookeries were implemented this was hypothesized to eliminate much of the overlap between bottom trawl fisheries and Atka mackerel nesting areas (Fritz and Lowe 1998). Lauth *et al.* (2007b), however found that nesting sites in Alaska were "…widespread across the continental shelf and found over a much broader depth range…". The use of bottom contact fishing gear, such as bottom trawls, pot gear, and longline gear, utilized in July to January could, therefore, still potentially affect Atka mackerel nesting areas, despite trawl closures in nearshore areas around Steller sea lion rookeries.

Indirect effects of bottom contact fishing gear, such as effects on fish habitat, may also have implications for Atka mackerel. Living substrate that is susceptible to fishing gear includes sponges, seapens, sea anemones, ascidians, and bryozoans (Malecha *et al.* 2005). Of these, Atka mackerel sampled in the NMFS bottom trawl survey are primarily associated with emergent epifauna such as sponges and corals (Malecha *et al.* 2005, Stone 2006). Effects of fishing gear on these living substrates could, in turn, affect fish species that are associated with them.

### *Concentration of Atka mackerel catches in time and space*

Steller sea lion protection measures have spread out Atka mackerel harvests in time and space through the implementation of seasonal and area-specific TACs and harvest limits within sea lion critical habitat. However, this is still an issue of possible concern and research efforts continue to monitor and assess the availability of Atka mackerel biomass in areas of concern. Also, in some cases the sea lion protection measures have forced the fishery to concentrate in areas outside of critical habitat that had previously experienced lower levels of exploitation. The impact of the fishery in these areas outside of critical habitat is unknown.

### *Atka mackerel fishery effects on amount of large size Atka mackerel*

The numbers of large size Atka mackerel are largely impacted by highly variable year class strength rather than by the directed fishery. Year to year differences are attributed to natural fluctuations.

### *Atka mackerel fishery contribution to discards and offal production*

There is no time series of the offal production from the Atka mackerel fishery. The Atka mackerel fishery has contributed on average about 1,180 t of non-target discards in the Aleutian Islands from 2007 to 2009. Most of the Atka mackerel fishery discards of target species are comprised of small Atka mackerel. The average discards of Atka mackerel in the Atka mackerel fishery have been about 1,800 t over 2007-2009.

*Atka mackerel fishery effects on Atka mackerel age-at-maturity and fecundity*

The effects of the fishery on the age-at-maturity and fecundity of Atka mackerel are unknown. Studies were conducted to determine age-at-maturity (McDermott and Lowe 1997, Cooper and McDermott 2008) and fecundity (McDermott 2003, McDermott *et al*. 2007) of Atka mackerel. These are recent studies and there are no earlier studies for comparison on fish from an unexploited population. Further studies would be needed to determine if there have been changes over time and whether changes could be attributed to the fishery.

## Data gaps and research priorities

Regional and seasonal food habits data for Aleutian Islands is very limited. No time series of information is available on copepod and euphausiid abundance in the Aleutian Islands which would provide information on prey availability and abundance trends. Studies to determine the impacts of environmental indicators such as temperature regime on Atka mackerel are needed. Further studies to determine whether there have been any changes in life history parameters over time (e.g. fecundity, and weight- and length-at-age) would be informative. More information on Atka mackerel habitat preferences would be useful to improve our understanding of Essential Fish Habitat (EFH), and improve our assessment of the impacts to habitat due to fishing. Better habitat mapping of the Aleutian Islands would provide information for survey stratification and the extent of trawlable and untrawlable habitat.

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## Literature cited

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-178, 298 p.

Alverson, D.L., and M.J. Carney. 1975. A graphic review of the growth and decay of population cohorts. J. Cons. Int. Explor. Mer 36:133-143.

Anderl, D.M., A. Nishimura, and S.A. Lowe. 1996. Is the first annulus on the otolith of the Atka mackerel, *Pleurogrammus monopterygius*, missing? Fish. Bull. 94:163-169.

Bailey, K.M., J.F. Piatt, T.C. Royer, S.A. Macklin, R.K. Reed, M. Shima, R.C. Francis, A.B. Hollowed, D.A. Somerton, R.D. Brodeur, W.J. Ingraham, P.J. Anderson, and W.S. Wooster. 1995. ENSO events in the northern Gulf of Alaska, and effects on selected marine fisheries. Calif. Coop. Oceanic Fish. Invest. Rep. 36:78-96.

Barbeaux, S., J. Ianelli, and E. Brown. 2003. Aleutian Islands walleye pollock SAFE. Appendix to Eastern Bering Sea walleye pollock stock assessment *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Barbeaux, S., J. Ianelli, and E. Brown. 2004. Stock assessment of Aleutian Islands region pollock. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Boldt, J.L. (Ed). 2005. Ecosystem indicators for the North Pacific and their implications for stock assessment: Proceedings of first annual meeting of NOAA's Ecological Indicators research

program. AFSC Processed Rep.2005-04, Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

Canino, M.F, I.B. Spies, M.M. Hollowed, and J.L. Guthridge. *In press*. Mating behavior of Atka mackerel inferred from genetic analysis of egg masses in the wild and in captivity. Marine and Coastal Fisheries.

Canino, M.F., I.B. Spies, S.A. Lowe, and W.S. Grant. 2010. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science. 2:388–398.

Charnov, E.L. 1993. Life history invariants some explorations of symmetry in evolutionary ecology. Oxford University Press Inc., New York. 167p.

Cooper, D., and S. McDermott. 2008. Variation in Atka mackerel, *Pleurogrammus monopterygius*, spatial and temporal distribution by maturity stage. Pages 11-42 *in* S. F. McDermott, M. Canino, N. Hillgruber, D. W. Cooper, I. Spies, J. Guthridge, J. N. Ianelli, P. Woods. 2008. Atka mackerel *Pleurogrammus monopterygius* reproductive ecology in Alaska. North Pacific Research Board Final report, 163p.

DeRobertis, A. and K. Williams. 2008. Length –weight relationships in fisheries studies: the standard allometric model should be applied with caution. Trans. Amer. Fish. Soc. 137:707-719, 2008.

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

Dragoo, D.E., G.V. Byrd, and D.B. Irons. 2001. Breeding status, population trends, and diets of seabirds in Alaska, 2000. U.S. Fish and Wildl. Serv. Report AMNWR 01/07.

Fournier, D. 1998. An Introduction to AD model builder for use in nonlinear modeling and statistics. Otter Research Ltd. PO Box 2040, Sidney BC V8L3S3, Canada, 53p.

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

Francis, R.C., and S.R. Hare. 1994. Decadal scale regime shifts in the large marine ecosystems of the northeast Pacific: A case for historical science. Fish. Oceanogr. 3(1):279-291.

Francis, R.I.C.C. 1992. Use of risk analysis to assess fishery management strategies: a case study using orange roughy (*Hoplostethus atlanticus*) on the Chatham Rise, New Zealand. Can. J. Fish. Aquat. Sci. 49: 922-930.

Fritz, L.W. 1993. Trawl locations of walleye pollock and Atka mackerel fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska from 1977-1992. AFSC Processed Report 93-08, NMFS, 7600 Sand Point Way, NE, Seattle, WA 98115. 162 pp.

Fritz, L.W. and S.A. Lowe. 1998. Seasonal distributions of Atka mackerel (*Pleurogrammus monopterygius*) in commercially-fished areas of the Aleutian Islands and Gulf of Alaska. NOAA Tech. Memo. NMFS-AFSC-92. 29p.

Gorbunova, N.N. 1962. Razmnozhenie i razvite ryb semeistva terpugovykh (Hexagrammidae) (Spawning and development of greenlings (family Hexagrammidae)). Tr. Inst. Okeanol., Akad. Nauk SSSR 59:118-182. In Russian. (Trans. by Isr. Program Sci. Trans., 1970, p. 121-185 in T.S. Rass (editor), Greenlings: taxonomy, biology, interoceanic transplantation; available from the U.S. Dep. Commer., Natl. Tech. Inf. Serv., Springfield, VA., as TT 69-55097).

Guthridge, J. L. and N. Hillgruber. 2008. Embryonic development of Atka mackerel (*Pleurogrammus monopterygius*) and the effect of temperature. Pages 43-65 *in* S. F. McDermott, M. Canino, N. Hillgruber, D. W. Cooper, I. Spies, J. Guthridge, J. N. Ianelli, P. Woods. 2008. Atka mackerel *Pleurogrammus monopterygius* reproductive ecology in Alaska. North Pacific Research Board Final report, 163p.

Hare, S.R., and N.J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. Prog. Oceanogr. 47:103-145.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898-903.

Hollowed, A.B., S.R. Hare, and W.S. Wooster. 2001. Pacific Basin climate variability and patterns of Northeast Pacific marine fish production. Prog. Oceanogr. 49:257-282.

Hunt, G.L. Jr., H. Kato, and S.M. McKinnell [eds.] 2000. Predation by marine birds and mammals in the subarctic north Pacific Ocean. North Pacific Marine Science Organization (PICES) Scientific Report #25. 165 p.

Ianelli, J.N. and D.A. Fournier. 1998. Alternative age-structured analyses of the NRC simulated stock assessment data. In Restrepo, V.R. [ed.]. Analyses of simulated data sets in support of the NRC study on stock assessment methods. NOAA Tech. Memo. NMFS-F/SPO-30. 96 p.

Ianelli, J.N., S.A. Lowe, and M. Dorn. *In preparation*. Spatial management and assessment of Aleutian Islands Atka mackerel. Alaska Fisheries Science Center. 7600 Sand Point Way NE, Seattle WA 98115.

Kajimura, H. 1984. Opportunistic feeding of the northern fur seal *Callorhinus ursinus*, in the eastern north Pacific Ocean and eastern Bering Sea. NOAA Tech. Rept. NMFS SSRF-779. USDOC, NOAA, NMFS, 49 pp.

Kendall, A.W., and J.R. Dunn. 1985. Ichthyoplankton of the continental shelf near Kodiak Island, Alaska. U.S. Department of Commerce, NOAA Technical Report NMFS 20, 89 p.

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

Kimura D.K. and L.L. Ronholt. 1988. In R.G. Bakkala (editor), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1987, p. 143-171. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-139.

Kimura, D.K., and S. Chikuni. 1987. Mixtures of empirical distributions: an iterative application of the age-length key. Biometrics 43: 23-35.

Lauth, R. R., and E. Acuna. 2009. Results of the 2008 eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo., NMFS-AFSC-195, 229 p.

Lauth, R. R., J. Guthridge, D. Nichol, S. W. Mcentire, and N. Hillgruber. 2007a. Timing and duration of mating and brooding periods of Atka mackerel (*Pleurogrammus monopterygius*) in the North Pacific Ocean. Fish. Bull., U.S. 105:560-570. http://fishbull.noaa.gov/1054/lauth.pdf

Lauth, R. R., S. W. Mcentire, and H. H. Zenger, Jr. 2007b. Geographic distribution, depth range, and description of Atka mackerel *Pleurogrammus monopterygius* nesting habitat in Alaska. Alaska Fish. Res. Bull. 12:165-186. http://www.adfg.state.ak.us/pubs/afrb/vol12_n2/lautv12n2.pdf

Lee, J.U. 1985. Studies on the fishery biology of the Atka mackerel *Pleurogrammus monopterygius* (Pallas) in the north Pacific Ocean. Bull. Fish. Res. Dev. Agency, 34, pp.65-125.

Levada, T.P. 1979. Comparative morphological study of Atka mackerel. Pac. Sci. Res. Inst. Fish. Oceanogr. (TINRO), Vladivostok, U.S.S.R., Unpublished manuscript.

Livingston, P.A., M-S. Yang and G.M. Lang. Unpublished manuscript. Comparison of the role of walleye pollock in groundfish food webs of the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska. NMFS. Alaska Fisheries Science Center, 7600 Sand Point Way NE., Seattle, WA 98115.

Lowe, S. A. 1992. Atka Mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1993. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S.A., D.M. Van Doornik, and G.A. Winans. 1998. Geographic variation in genetic and growth patterns of Atka mackerel, *Pleurogrammus monopterygius* (Hexagrammidae), in the Aleutian archipelago. Fish. Bull. U.S. 96:502-515.

Lowe, S., J. Ianelli, H. Zenger, and R. Lauth. 2003. Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S., J. Ianelli, H. Zenger, K. Aydim, and R. Lauth. 2004. Stock assessment of Aleutian Islands Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S., J. Ianelli, H. Zenger, K. Aydim, and R. Lauth. 2005. Stock assessment of Aleutian Islands Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S., J. Ianelli, H. Zenger, and R. Reuter. 2002. Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S., J. Ianelli, M. Wilkins, K. Aydin, R. Lauth, and I. Spies. 2007. Stock assessment of Aleutian Islands Atka mackerel. *In* Stock Assessment and Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, Alaska, 99510.

Lowe, S., J. Ianelli, M. Wilkins, K. Aydin, R. Lauth, and I. Spies. 2008. Stock assessment of Aleutian Islands Atka mackerel. *In* Stock Assessment and Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, Alaska, 99510.

Lowe, S., J. Ianelli, M. Wilkins, K. Aydin, R. Lauth, and I. Spies. 2009. Stock assessment of Aleutian Islands Atka mackerel. *In* Stock Assessment and Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, Alaska, 99510.

Lowe, S.A. and L.W. Fritz. 1996. Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1997. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S.A. and L.W. Fritz. 1997. Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions as Projected for 1999. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Lowe, S.A., R.F. Reuter and H. Zenger. 2001. Atka mackerel. *In* Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. North Pacific Fisheries Management Council, P.O. Box 103136, Anchorage, AK.

Malecha, P.W., R.P. Stone, and J. Heifetz. 2005. Living substrate in Alaska: Distribution, abundance, and species associations. Pages 289-299 *in* P.W. Barnes and J.P. Thomas, editors. Benthic habitats and the effects of fishing. American Fisheries Society, Symposium 41, Bethesda, Maryland.

Martin, M. 2010. Aleutian Islands Survey Bottom Temperature Analysis. In S. Zador and S. Gaichas (Eds.) Ecosystem Considerations for 2011. Appendix C of the BSAI\GOA Stock Assessment and

Fishery Evaluation Reports. North Pacific Fishery Management Council, 605 W. 4th Ave., Suite 306, Anchorage, AK 99501.

Materese, A.C., D. M. Blood, S. J. Piquelle, J. L. Benson. 2003. Atlas of abundance and distribution patterns of ichthyoplankton from the Northeast Pacific Ocean and Bering Sea ecosystems based on research conducted by the Alaska Fisheries Science Center (1972-1996). U.S. Dep. Commer., NOAA Professional Paper, NMFS-1, 281 p.

McDermott, S. F. 2003. Improving abundance estimation of a patchily distributed fish, Atka mackerel (*Pleurogrammus monopterygius*). Dissertation, University of Washington, 150p .

McDermott, S.F., K.E. Pearson and D.R. Gunderson. 2007. Annual fecundity, batch fecundity, and oocyte atresia of Atka mackerel (Pleurogrammus monopterygius) in Alaskan waters. Fish Bull. 105:19-29.

McDermott, S. F., L. W. Fritz, and V. Haist. 2005. Estimating movement and abundance of Atka mackerel (*Pleurogrammus monopterygius*) with tag-release data. Fish. Oceanogr. 14, (Suppl 1), 113-.

McDermott, S.F. and S.A. Lowe. 1997. The reproductive cycle of Atka mackerel, *Pleurogrammus monopterygius*, in Alaska waters. Fish. Bull. U.S. 95:231-333.

Mel'nikov, I.V. and A. YA. Efimkin. 2003. The young of the northern Atka mackerel Pleurogrammus monopterygius in the epipelagic zone over deep-sea areas of the northern Pacific Ocean. J. Ichthyol. 43: 424-437.

Merrick, R.L., M.K. Chumbley, and G.V. Byrd. 1997. Diet diversity of Steller sea lions (*Eumetopias jubatus*) and their population decline in Alaska: a potential relationship. Can. J. Fish. Aquat. Sci. 54:1342-1348.

Methot, R.D. 1989. Synthetic estimates of historical abundance and mortality for northern anchovy. In E. Edwards and B. Megrey (eds.) Mathematical analysis of fish stock dynamics: reviews and current applications. Amer. Fish. Soc. Symposium 6:66-82.

Methot, R.D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. INPFC Bull. 50:259-277.

Nichol D.G., Somerton D.A. 2002. Diurnal vertical migration of the Atka mackerel *Pleurogrammus monopterygius* as shown by archival tags. Mar Ecol Prog Ser 239: 193-207.

NMFS. 1995. Status review of the Unites States Steller sea lion (*Eumetopias jubatus*) population. National Marine Mammal Laboratory, Alaska Fishery Science Center, National Marine Fisheries Service, 7600 Sand Point Way, NE, Seattle, WA 98115.

Ortiz, I. 2007. Ecosystem Dynamics of the Aleutian Islands. Ph.D. Thesis. University of Washington, Seattle.

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. 994p.

Rikhter, V.A., and V.N. Efanov. 1976. On one of the approaches to estimation of natural mortality of fish populations. ICNAF Res. Doc. 76/VI/8. Serial N. 3777. 13p.

Roff, D.A. 1986. The evolution of life history parameters in teleosts. Can. J. Fish. Aquat. Sci. 41:989-1000.

Rutenberg, E.P. 1962. Survey of the fishes family Hexagrammidae. Trudy Instituta Okeanologii Akademiya Nauk SSSR 59:3-100. In Russian. (Translated by the Israel Program for Scientific Translations, 1970. Pages 1-103 in T.S. Rass (editor), Greenlings: taxonomy, biology,

interoceanic transplantation; available from the U.S. Department of Commerce, National Technical Information Services, Springfield, Virginia, as TT 69-55097).

Sepez, J., C. Package, J. Isaacs, and K. Nixon. 2003. *NOAA Fisheries TEK Database: A Compilation of Written Source Material Documenting the Traditional Ecological Knowledge of Alaska Natives, With a Focus on Marine Resources.* Report prepared for National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle.

Sinclair E.H. and T.K. Zeppelin 2002. Seasonal and spatial differences in diet in the western stock of Steller sea lions (*Eumetopias jubatus*). Journal of Mammalogy 83(4).

Springer, A.M., J.F. Piatt, V.P. Shuntov, G.B. Van Vliet, V.L. Vladimirov, A.E. Kuzin, A.S. Perlov. 1999. Prog. in Oceanogr. 43(1999)443-487.

Stone, R.P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. Coral Reefs 25:229-238.

Thompson, G. G., and M. W. Dorn. 2003. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 127-222. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. NOAA Technical Memorandum, NMFS-AFSC-60, U.S. Department of Commerce, NOAA. p. 105.

Yang, M-S. 1999. The trophic role of Atka mackerel, *Pleurogrammus monopterygius*, in the Aleutian Islands area. Fishery Bulletin 97(4):1047-1057.

Yang, M-S. 2003. Food habits of the important groundfishes in the Aleutian Islands in 1994 and 1997. AFSC Processed Rep.2003-07, Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115. p. 233.

Zolotov, O.G. 1993. Notes on the reproductive biology of *Pleurogrammus monopterygius* in Kamchatkan waters. J. of Ichthy. 33(4), pp. 25-37.

# Tables

Table 17.1. Time series of Bering Sea/Aleutian Islands Atka mackerel catches (including discards and CDQ catches), corresponding Acceptable Biological Catches (ABC), and Total Allowable Catches (TAC) set by the North Pacific Fishery Management Council from 1978 to the present. Catches, ABCs, and TACs are in metric tons.

| Year | Catch | ABC | TAC |
|---|---|---|---|
| 1977 | 21,763 | a | a |
| 1978 | 24,249 | 24,800 | 24,800 |
| 1979 | 23,264 | 24,800 | 24,800 |
| 1980 | 20,488 | 24,800 | 24,800 |
| 1981 | 19,688 | 24,800 | 24,800 |
| 1982 | 19,874 | 24,800 | 24,800 |
| 1983 | 11,726 | 25,500 | 24,800 |
| 1984 | 36,055 | 25,500 | 35,000 |
| 1985 | 37,860 | 37,700 | 37,700 |
| 1986 | 31,990 | 30,800 | 30,800 |
| 1987 | 30,061 | 30,800 | 30,800 |
| 1988 | 22,084 | 21,000 | 21,000 |
| 1989 | 17,994 | 24,000 | 20,285 |
| 1990 | 22,206 | 24,000 | 21,000 |
| 1991 | 26,626 | 24,000 | 24,000 |
| 1992 | 48,532 | 43,000 | 43,000 |
| 1993 | 66,006 | 117,100 | 64,000 |
| 1994 | 65,360 | 122,500 | 68,000 |
| 1995 | 81,554 | 125,000 | 80,000 |
| 1996 | 103,942 | 116,000 | 106,157 |
| 1997 | 65,842 | 66,700 | 66,700 |
| 1998 | 57,097 | 64,300 | 64,300 |
| 1999 | 56,237 | 73,300 | 66,400 |
| 2000 | 47,230 | 70,800 | 70,800 |
| 2001 | 61,563 | 69,300 | 69,300 |
| 2002 | 45,288 | 49,000 | 49,000 |
| 2003 | 54,045 | 63,000 | 60,000 |
| 2004 | 60,562 | 66,700 | 63,000 |
| 2005 | 62,012 | 124,000 | 63,000 |
| 2006 | 61,894 | 110,200 | 63,000 |
| 2007 | 58,763 | 74,000 | 63,000 |
| 2008 | 58,090 | 60,700 | 60,700 |
| 2009 | 72,806 | 83,800 | 76,400 |
| 2010 | 68,619 | 74,000 | 74,000 |
| 2011[b] | 53,080 | 85,300 | 53,080 |

a) Atka mackerel was not a reported species group until 1978.
b) 2011 data as projected (64% of TAC expected due to western Aleutian closures and Central Aleutian Islands TAC being below ABC)

*Sources: compiled from NMFS Regional Office web site and various NPFMC reports.*

Table 17.2. Time series of Bering Sea/Aleutian Islands Atka mackerel catches (including discards and CDQ catches) by region, corresponding Acceptable Biological Catches (ABC), and Total Allowable Catches (TAC) set by the North Pacific Fishery Management Council from 1994 to the present. Apportioned catches prior to 1994 were assumed as the average apportionment for the years 1994-1998. Catches, ABCs, and TACs are in metric tons.

| Year | | Eastern (541) | Central (542) | Western (543) | Total | Year | | Eastern (541) | Central (542) | Western (543) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | Catch | 5,116 | 11,058 | 6,032 | 22,206 | 2001 | Catch | 8,424 | 32,829 | 20,309 | 61,563 |
| | ABC | | | | 24,000 | | ABC | 7,800 | 33,600 | 27,900 | 69,300 |
| | TAC | | | | 21,000 | | TAC | 7,800 | 33,600 | 27,900 | 69,300 |
| 1991 | Catch | 6,154 | 11,761 | 8,711 | 26,626 | 2002 | Catch | 4,920 | 22,291 | 18,077 | 45,288 |
| | ABC | | | | 24,000 | | ABC | 5,500 | 23,800 | 19,700 | 49,000 |
| | TAC | | | | 24,000 | | TAC | 5,500 | 23,800 | 19,700 | 49,000 |
| 1992 | Catch | 11,217 | 21,438 | 15,878 | 48,532 | 2003 | Catch | 10,725 | 25,435 | 17,885 | 54,045 |
| | ABC | | | | 43,000 | | ABC | 10,650 | 29,360 | 22,990 | 63,000 |
| | TAC | | | | 43,000 | | TAC | 10,650 | 29,360 | 19,990 | 60,000 |
| 1993 | Catch | 15,256 | 29,156 | 21,594 | 66,006 | 2004 | Catch | 10,838 | 30,169 | 19,554 | 60,562 |
| | ABC | | | | 117,100 | | ABC | 11,240 | 31,100 | 24,360 | 66,700 |
| | TAC | | | | 64,000 | | TAC | 11,240 | 31,100 | 20,660 | 63,000 |
| 1994 | Catch | 15,106 | 28,871 | 21,383 | 65,360 | 2005 | Catch | 7,200 | 35,069 | 19,743 | 62,012 |
| | ABC | 13,475 | 55,125 | 53,900 | 122,500 | | ABC | 24,550 | 52,830 | 46,620 | 124,000 |
| | TAC | 13,475 | 44,525 | 10,000 | 68,000 | | TAC | 7,500 | 35,500 | 20,000 | 63,000 |
| 1995 | Catch | 14,201 | 50,386 | 16,967 | 81,554 | 2006 | Catch | 7,421 | 39,836 | 14,637 | 61,894 |
| | ABC | 13,500 | 55,900 | 55,600 | 125,000 | | ABC | 21,780 | 46,860 | 41,360 | 110,200 |
| | TAC | 13,500 | 50,000 | 16,500 | 80,000 | | TAC | 7,500 | 40,000 | 15,500 | 63,000 |
| 1996 | Catch | 28,173 | 33,523 | 42,246 | 103,942 | 2007 | Catch | 22,943 | 26,723 | 9,097 | 58,763 |
| | ABC | 26,700 | 33,600 | 55,700 | 116,000 | | ABC | 23,800 | 29,600 | 20,600 | 74,000 |
| | TAC | 26,700 | 33,600 | 45,857 | 10,657 | | TAC | 23,800 | 29,600 | 9,600 | 63,000 |
| 1997 | Catch | 16,315 | 19,990 | 29,537 | 65,842 | 2008 | Catch | 19,118 | 22,329 | 16,643 | 58,090 |
| | ABC | 15,000 | 19,500 | 32,200 | 66,700 | | ABC | 19,500 | 24,300 | 16,900 | 60,700 |
| | TAC | 15,000 | 19,500 | 32,200 | 66,700 | | TAC | 19,500 | 24,300 | 16,900 | 60,700 |
| 1998 | Catch | 12,271 | 20,209 | 24,617 | 57,097 | 2009 | Catch | 26.417 | 30,070 | 16,319 | 72,806 |
| | ABC | 14,900 | 22,400 | 27,000 | 64,300 | | ABC | 27,000 | 33,500 | 23,300 | 83,800 |
| | TAC | 14,900 | 22,400 | 27,000 | 64,300 | | TAC | 27,000 | 32,500 | 16,900 | 76,400 |
| 1999 | Catch | 17,453 | 22,419 | 16,366 | 56,237 | 2010 | Catch | 23,608 | 26,389 | 18,650 | 68,647 |
| | ABC | 17,000 | 25,600 | 30,700 | 73,300 | | ABC | 23,800 | 29,600 | 20,600 | 74,000 |
| | TAC | 17,000 | 22,400 | 27,000 | 66,400 | | TAC | 23,800 | 29,600 | 20,600 | 74,000 |
| 2000 | Catch | 14,344 | 22,383 | 10,503 | 47,230 | 2011* | Catch | 41,298 | 11,560 | 222 | 53,080 |
| | ABC | 16,400 | 24,700 | 29,700 | 70,800 | | ABC | 40,300 | 24,000 | 21,000 | 85,300 |
| | TAC | 16,400 | 24,700 | 29,700 | 70,800 | | TAC | 40,300 | 11,280 | 1,500 | 53,080 |

* 2011 based on NMFS Regional Office Catch Accounting System apportionments (as of Nov 5th 2011) and projected to total.

Table 17.3. Numbers of Atka mackerel length-weight data, length frequency, and aged samples based on NMFS observer data 1990-2010.

| Year | Number of length-weight samples | Length frequency records | Number of aged samples |
|---|---|---|---|
| 1990 | 731 | 8,618 | 718 |
| 1991 | 356 | 7,423 | 349 |
| 1992 | 90 | 13,532 | 86 |
| 1993 | 58 | 12,476 | 58 |
| 1994 | 913 | 13,384 | 837 |
| 1995 | 1,054 | 19,653 | 972 |
| 1996 | 1,039 | 24,758 | 680 |
| 1997 | 126 | 13,412 | 123 |
| 1998 | 733 | 15,060 | 705 |
| 1999 | 1,633 | 12,349 | 1,444 |
| 2000 | 2,697 | 9,207 | 1,659 |
| 2001 | 3,332 | 11,600 | 935 |
| 2002 | 3,135 | 12,418 | 820 |
| 2003 | 4,083 | 13,740 | 1,008 |
| 2004 | 4,205 | 14,239 | 870 |
| 2005 | 4,494 | 13,142 | 1,024 |
| 2006 | 4,194 | 13,598 | 980 |
| 2007 | 2,100 | 11,841 | 884 |
| 2008 | 1,882 | 19,831 | 922 |
| 2009 | 2,374 | 15,207 | 971 |
| 2010 | 2,462 | 16,347 | 879 |

Table 17.4. Estimated catch-in-numbers at age (in millions) of Atka mackerel from the Aleutian Islands. These data were used to tune the age-structured analysis.

| **Age** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11+** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 6.83 | 31.52 | 20.06 | 15.11 | 1.22 | 0.39 | 0.20 | --- | --- | --- |
| 1978 | 2.70 | 60.16 | 15.57 | 9.22 | 3.75 | 0.59 | 0.34 | 0.11 | --- | --- |
| 1979 | 0.01 | 4.48 | 26.78 | 13.00 | 2.20 | 1.11 | --- | --- | --- | --- |
| 1980 | --- | 12.68 | 5.92 | 7.22 | 1.67 | 0.59 | 0.24 | 0.13 | --- | --- |
| 1981 | --- | 5.39 | 17.11 | 0.00 | 1.61 | 8.10 | --- | --- | --- | --- |
| 1982 | --- | 0.19 | 2.63 | 25.83 | 3.86 | 0.68 | --- | --- | --- | --- |
| 1983 | --- | 1.90 | 1.43 | 2.54 | 10.60 | 1.59 | --- | --- | --- | --- |
| 1984 | 0.09 | 0.98 | 7.30 | 7.07 | 10.79 | 21.78 | 2.21 | 0.96 | --- | --- |
| 1985 | 0.63 | 15.97 | 8.79 | 9.43 | 6.01 | 5.45 | 11.69 | 1.26 | 0.27 | --- |
| 1986 | 0.37 | 11.45 | 6.46 | 4.42 | 5.34 | 4.53 | 5.84 | 9.91 | 1.04 | 0.85 |
| 1987 | 0.56 | 10.44 | 7.60 | 4.58 | 1.89 | 2.37 | 2.19 | 1.71 | 6.78 | 0.75 |
| 1988 | 0.40 | 9.97 | 22.49 | 6.15 | 1.80 | 1.54 | 0.63 | 0.96 | 0.20 | 0.48 |
| 1989[a] | | | | | | | | | | |
| 1990 | 1.74 | 7.62 | 13.15 | 4.78 | 1.77 | 0.81 | 0.11 | 0.09 | 0.03 | 0.17 |
| 1991 | 0.00 | 4.15 | 6.49 | 7.78 | 5.71 | 3.94 | 1.04 | 0.18 | 0.35 | 0.22 |
| 1992 | 0.00 | 0.93 | 20.82 | 2.97 | 1.40 | 0.62 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993 | 0.00 | 13.55 | 18.33 | 38.88 | 12.16 | 6.76 | 4.17 | 0.61 | 0.59 | 0.00 |
| 1994 | 0.05 | 9.16 | 6.83 | 23.13 | 36.00 | 4.64 | 8.21 | 5.27 | 3.04 | 0.61 |
| 1995 | 0.13 | 20.65 | 33.67 | 9.81 | 18.78 | 33.09 | 4.01 | 5.84 | 7.90 | 2.98 |
| 1996 | 0.02 | 3.65 | 63.55 | 21.94 | 14.14 | 19.44 | 31.59 | 2.85 | 3.37 | 2.53 |
| 1997 | 0.00 | 17.11 | 4.66 | 66.28 | 3.72 | 1.56 | 0.67 | 3.56 | 0.36 | 0.00 |
| 1998 | 0.00 | 11.15 | 15.73 | 15.24 | 25.07 | 11.21 | 4.02 | 3.55 | 5.28 | 1.85 |
| 1999 | 1.17 | 1.08 | 38.31 | 8.85 | 7.09 | 9.93 | 5.24 | 1.80 | 1.49 | 1.79 |
| 2000 | 0.54 | 8.91 | 6.40 | 26.59 | 7.53 | 4.33 | 8.33 | 1.93 | 0.78 | 1.01 |
| 2001 | 1.87 | 20.59 | 13.57 | 8.68 | 27.20 | 8.16 | 4.60 | 3.86 | 0.78 | 0.50 |
| 2002 | 1.94 | 22.68 | 25.37 | 7.88 | 3.89 | 16.20 | 3.23 | 1.56 | 1.67 | 0.53 |
| 2003 | 0.78 | 19.96 | 49.54 | 20.63 | 5.95 | 3.27 | 7.02 | 0.78 | 0.49 | 0.85 |
| 2004 | 0.09 | 20.44 | 31.49 | 44.20 | 12.32 | 2.40 | 1.56 | 2.21 | 0.00 | 0.39 |
| 2005 | 1.43 | 3.96 | 35.31 | 27.23 | 28.97 | 9.68 | 1.54 | 0.25 | 0.85 | 0.00 |
| 2006 | 3.56 | 16.74 | 5.66 | 33.56 | 20.27 | 22.62 | 4.12 | 0.56 | 0.36 | 0.26 |
| 2007 | 2.25 | 19.63 | 11.63 | 5.39 | 19.94 | 15.90 | 12.46 | 2.69 | 0.77 | 0.08 |
| 2008 | 5.49 | 13.29 | 16.90 | 7.61 | 6.29 | 20.04 | 10.53 | 11.63 | 1.64 | 0.54 |
| 2009 | 4.69 | 31.92 | 15.73 | 20.00 | 8.81 | 8.56 | 16.59 | 8.24 | 8.71 | 1.79 |
| 2010 | 2.20 | 20.00 | 47.86 | 14.03 | 14.22 | 6.01 | 4.10 | 6.71 | 3.58 | 1.89 |

[a] Too few fish were sampled for age structures in 1989 to construct an age-length key.

Table 17.5. Atka mackerel estimated biomass in metric tons from the U.S.-Japan cooperative bottom trawl surveys, by subregion, depth interval, and survey year, with the corresponding Aleutian-wide coefficients of variation (*CV*).

| | | | Biomass | |
|---|---|---|---|---|
| Area | Depth (m) | 1980 | 1983 | 1986 |
| Aleutian | 1-100 | 193 | 239,502 | 1,013,678 |
| | 101-200 | 62,376 | 247,256 | 107,092 |
| | 201-300 | 646 | 2,565 | 368 |
| | 301-500 | 0 | 164 | 10 |
| | Total | 63,215 | 489,487 | 1,121,148 |
| | *CV* | 0.80 | 0.24 | 0.80 |
| Western | 1-100 | 193 | 49,115 | 1,675 |
| 543 | 101-200 | 692 | 124,806 | 40,675 |
| | 201-300 | | 1,559 | 111 |
| | 301-500 | 0 | 164 | 0 |
| | Total | 885 | 175,644 | 42,461 |
| Central | 1-100 | 0 | 103,588 | 1,011,991 |
| 542 | 101-200 | 58,666 | 1,488 | 20,582 |
| | 201-300 | 504 | 303 | 36 |
| | 301-500 | 0 | 0 | 10 |
| | Total | 59,170 | 105,379 | 1,032,619 |
| Eastern | 1-100 | | 86,800 | 11 |
| 541 | 101-200 | 3,018 | 120,962 | 45,835 |
| | 201-300 | 143 | 703 | 222 |
| | 301-500 | 0 | 0 | 0 |
| | Total | 3,161 | 208,465 | 46,068 |
| Southern | 1-100 | 6 | 0 | 429 |
| Bering Sea | 101-200 | 20,239 | 9 | 5 |
| | 201-300 | 2 | 0 | 1 |
| | 301-500 | | 0 | 0 |
| | Total | 20,247 | 9 | 435 |

Table 17.6. Aleutian Islands Atka mackerel survey biomass by bottom-depth category by region and subareas including area percentages (for each year) and coefficients of variation (*CV*) for 1991, 1994, 1997, 2000, 2002, 2004, 2006, and 2010.

| Area | Depth (m) | Biomass (t) 1991 | 1994 | 1997 | 2002 | 2004 | 2006 | 2010 |
|---|---|---|---|---|---|---|---|---|
| **Aleutian Islands** | 1-100 | 429,826 | 145,000 | 188,504 | 326,582 | 393,594 | 364,490 | 200,108 |
| | 101-200 | 293,554 | 455,452 | 177,663 | 393,055 | 488,534 | 326,136 | 643,793 |
| | 201-300 | 538 | 1,688 | 127 | 48,630 | 7,362 | 38,249 | 647 |
| | 301-500 | - | 22 | 20 | 221 | 288 | 61 | 22 |
| | Total | 723,918 | 602,161 | 366,314 | 768,488 | 889,778 | 728,935 | 844,571 |
| Area % of Total | | 100% | 100% | 100% | 100% | 100% | 100% | 100% |
| | *CV* | *15%* | *33%* | *29%* | *20%* | *17%* | *28%* | *40%* |
| **Western 543** | 1-100 | 168,968 | 93,847 | 90,824 | 51,921 | 140,669 | 64,429 | 56,621 |
| | 101-200 | 185,748 | 214,228 | 43,478 | 154,820 | 229,675 | 35,926 | 196,049 |
| | 201-300 | 304 | 1,656 | 63 | 48,367 | 6,033 | 318 | 132 |
| | 301-500 | - | 6 | - | 8 | 36 | 21 | 17 |
| | Total | 355,020 | 309,737 | 134,364 | 255,115 | 376,414 | 100,693 | 252,819 |
| Area % of Total | | 49.0% | 51.4% | 36.7% | 33.0% | 42.0% | 13.8% | 29.9% |
| | *CV* | 18% | 55% | 56% | 31% | 24% | 35% | 59% |
| **Central 542** | 1-100 | 187,194 | 50,513 | 70,458 | 122,502 | 198,501 | 192,832 | 101,463 |
| | 101-200 | 104,413 | 33,517 | 116,295 | 199,743 | 70,267 | 85,102 | 94,804 |
| | 201-300 | 71 | 13 | 53 | 169 | 358 | 103 | 209 |
| | 301-500 | - | 3 | 6 | 143 | 194 | - | - |
| | Total | 291,679 | 84,046 | 186,813 | 322,556 | 269,320 | 278,036 | 196,476 |
| Area % of Total | | 40.3% | 14.0% | 64.6% | 42.3% | 30.4% | 38.1% | 23.3% |
| | *CV* | 18% | 48% | 34% | 24% | 34% | 24% | 28% |
| **Eastern 541** | 1-100 | 73,663 | 641 | 27,222 | 152,159 | 54,424 | 107,230 | 42,025 |
| | 101-200 | 3,392 | 207,707 | 17,890 | 38,492 | 188,592 | 205,108 | 352,939 |
| | 201-300 | 163 | 19 | 11 | 94 | 971 | 37,829 | 306 |
| | 301-500 | - | 12 | 14 | 71 | 57 | 40 | 5 |
| | Total | 77,218 | 208,379 | 45,137 | 190,817 | 244,043 | 350,206 | 395,275 |
| Area % of Total | | 10.7% | 34.6% | 12.3% | 24.7% | 27.5% | 48.0% | 46.8% |
| | *CV* | 83% | 44% | 68% | 58% | 33% | 55% | 75% |
| **Bering Sea** | 1-100 | 47 | 66,562 | 95,672 | 59,682 | 124,896 | 10,284 | 97,543 |
| | 101-200 | 3 | 30 | 9 | 103 | 142,616 | 176 | 4,870 |
| | 201-300 | 11 | 3 | - | 98 | 39 | 1,842 | 323 |
| | 301-500 | - | 8 | - | - | 4 | 6 | 19 |
| | Total | 61 | 66,603 | 95,680 | 59,883 | 267,556 | 12,308 | 102,755 |
| | *CV* | 37% | 99% | 99% | 99% | 43% | 44% | 86% |

Table 17.7. Year-specific fishery and survey and the population weight-at-age (kg) values used to obtain expected survey and fishery catch biomass and population biomass. The population weight-at-age values are derived from the Aleutian trawl survey from the years 2004, 2006, and 2010. The 2011 fishery weight-at-age values are the average of the last ten years (2001-2010).

| | | Age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ |
| *Survey* | 1991 | 0.045 | 0.185 | 0.449 | 0.637 | 0.652 | 0.751 | 0.811 | 0.693 | 1.053 | 1.764 | 0.878 |
| | 1994 | 0.045 | 0.177 | 0.450 | 0.653 | 0.738 | 0.846 | 0.941 | 0.988 | 0.906 | 0.907 | 0.516 |
| | 1997 | 0.045 | 0.191 | 0.486 | 0.686 | 0.753 | 0.805 | 0.887 | 0.970 | 0.919 | 1.375 | 0.935 |
| | 2000 | 0.045 | 0.130 | 0.387 | 0.623 | 0.699 | 0.730 | 0.789 | 0.810 | 0.792 | 0.864 | 0.871 |
| | 2002 | 0.045 | 0.139 | 0.342 | 0.615 | 0.720 | 0.837 | 0.877 | 0.773 | 0.897 | 0.955 | 1.084 |
| | 2004 | 0.045 | 0.138 | 0.333 | 0.497 | 0.609 | 0.739 | 0.816 | 0.956 | 0.928 | 0.745 | 0.824 |
| | 2006 | 0.045 | 0.158 | 0.332 | 0.523 | 0.516 | 0.675 | 0.764 | 0.719 | 0.855 | 1.653 | 0.991 |
| | 2010 | 0.045 | 0.161 | 0.369 | 0.633 | 0.667 | 0.744 | 0.974 | 1.075 | 0.981 | 1.041 | 1.244 |
| *Avg 2004, 2006, 2010* | | 0.045 | 0.153 | 0.345 | 0.551 | 0.597 | 0.719 | 0.851 | 0.917 | 0.922 | 1.146 | 1.019 |
| *Fishery Foreign* | 1977 | 0.069 | 0.132 | 0.225 | 0.306 | 0.400 | 0.470 | 0.507 | 0.379 | 0.780 | 0.976 | 1.034 |
| | 1978 | 0.069 | 0.072 | 0.225 | 0.300 | 0.348 | 0.388 | 0.397 | 0.371 | 0.423 | 0.976 | 1.034 |
| | 1979 | 0.069 | 0.496 | 0.319 | 0.457 | 0.476 | 0.475 | 0.468 | 0.546 | 0.780 | 0.976 | 1.034 |
| | 1980 | 0.069 | 0.365 | 0.317 | 0.450 | 0.520 | 0.585 | 0.630 | 0.546 | 0.780 | 0.976 | 1.034 |
| | 1981 | 0.069 | 0.365 | 0.317 | 0.450 | 0.520 | 0.585 | 0.630 | 0.546 | 0.780 | 0.976 | 1.034 |
| | 1982 | 0.069 | 0.365 | 0.273 | 0.443 | 0.564 | 0.695 | 0.795 | 0.546 | 0.780 | 0.976 | 1.034 |
| | 1983 | 0.069 | 0.365 | 0.359 | 0.499 | 0.601 | 0.686 | 0.810 | 0.546 | 0.780 | 0.976 | 1.034 |
| | 1984 | 0.069 | 0.297 | 0.410 | 0.617 | 0.707 | 0.777 | 0.802 | 0.890 | 0.910 | 0.976 | 1.034 |
| | 1985 | 0.069 | 0.302 | 0.452 | 0.552 | 0.682 | 0.737 | 0.775 | 0.807 | 1.007 | 1.011 | 1.034 |
| | 1986 | 0.069 | 0.146 | 0.334 | 0.528 | 0.546 | 0.786 | 0.753 | 0.829 | 0.858 | 0.954 | 0.979 |
| | 1987 | 0.069 | 0.265 | 0.435 | 0.729 | 0.908 | 0.859 | 0.964 | 1.023 | 1.054 | 1.088 | 1.105 |
| | 1988 | 0.069 | 0.196 | 0.351 | 0.470 | 0.564 | 0.624 | 0.694 | 0.783 | 0.818 | 0.850 | 1.017 |
| *Domestic* | 1989 | 0.069 | 0.295 | 0.440 | 0.577 | 0.739 | 0.838 | 0.664 | 0.817 | 0.906 | 1.010 | 0.951 |
| | 1990 | 0.069 | 0.362 | 0.511 | 0.728 | 0.877 | 0.885 | 0.985 | 1.386 | 1.039 | 1.445 | 1.442 |
| | 1991 | 0.069 | 0.230 | 0.207 | 0.540 | 0.729 | 0.685 | 0.655 | 0.755 | 1.014 | 0.743 | 1.021 |
| | 1992 | 0.069 | 0.230 | 0.390 | 0.607 | 0.715 | 0.895 | 0.973 | 0.839 | 0.865 | 0.916 | 1.010 |
| | 1993 | 0.069 | 0.230 | 0.572 | 0.626 | 0.682 | 0.773 | 0.826 | 0.782 | 1.041 | 0.812 | 1.010 |
| | 1994 | 0.069 | 0.150 | 0.363 | 0.568 | 0.649 | 0.697 | 0.777 | 0.749 | 0.744 | 0.736 | 0.922 |
| | 1995 | 0.069 | 0.092 | 0.228 | 0.520 | 0.667 | 0.687 | 0.691 | 0.707 | 0.721 | 0.641 | 0.909 |
| | 1996 | 0.069 | 0.188 | 0.294 | 0.474 | 0.633 | 0.728 | 0.743 | 0.770 | 0.799 | 0.846 | 0.973 |
| | 1997 | 0.069 | 0.230 | 0.397 | 0.664 | 0.686 | 0.862 | 0.904 | 0.971 | 0.884 | 0.951 | 1.108 |
| | 1998 | 0.069 | 0.230 | 0.296 | 0.494 | 0.580 | 0.644 | 0.682 | 0.775 | 0.707 | 0.798 | 0.858 |
| | 1999 | 0.069 | 0.240 | 0.406 | 0.568 | 0.707 | 0.755 | 0.839 | 0.979 | 1.170 | 1.141 | 0.961 |
| | 2000 | 0.069 | 0.215 | 0.497 | 0.594 | 0.689 | 0.734 | 0.778 | 0.854 | 0.813 | 0.904 | 0.988 |
| | 2001 | 0.069 | 0.224 | 0.418 | 0.563 | 0.719 | 0.765 | 0.841 | 0.826 | 0.946 | 0.912 | 1.109 |
| | 2002 | 0.069 | 0.253 | 0.293 | 0.459 | 0.600 | 0.601 | 0.723 | 0.722 | 0.791 | 0.851 | 0.940 |
| | 2003 | 0.069 | 0.208 | 0.304 | 0.420 | 0.539 | 0.667 | 0.747 | 0.731 | 0.669 | 0.824 | 0.996 |
| | 2004 | 0.069 | 0.176 | 0.316 | 0.444 | 0.567 | 0.624 | 0.679 | 0.810 | 0.728 | 0.916 | 1.015 |
| | 2005 | 0.069 | 0.247 | 0.406 | 0.480 | 0.536 | 0.558 | 0.657 | 0.966 | 1.184 | 0.942 | 1.010 |
| | 2006 | 0.069 | 0.265 | 0.393 | 0.503 | 0.551 | 0.613 | 0.647 | 0.714 | 0.848 | 0.856 | 0.984 |
| | 2007 | 0.069 | 0.247 | 0.437 | 0.547 | 0.715 | 0.697 | 0.768 | 0.778 | 0.776 | 1.272 | 1.034 |
| | 2008 | 0.069 | 0.264 | 0.388 | 0.540 | 0.614 | 0.727 | 0.719 | 0.700 | 0.798 | 0.786 | 0.998 |
| | 2009 | 0.069 | 0.215 | 0.395 | 0.494 | 0.605 | 0.667 | 0.734 | 0.745 | 0.770 | 0.816 | 0.813 |
| | 2010 | 0.069 | 0.231 | 0.385 | 0.504 | 0.614 | 0.665 | 0.729 | 0.785 | 0.832 | 0.908 | 0.989 |
| | 2011 | 0.069 | 0.228 | 0.371 | 0.500 | 0.607 | 0.660 | 0.722 | 0.770 | 0.826 | 0.894 | 0.969 |

Table 17.8. Schedules of age and length specific maturity of Atka mackerel from McDermott and Lowe (1997) by Aleutian Islands subareas. Eastern - 541, Central - 542, and Western - 543.

| | INPFC Area | | | | |
|---|---|---|---|---|---|
| Length (cm) | 541 | 542 | 543 | Age | Proportion mature |
| 25 | 0 | 0 | 0 | 1 | 0 |
| 26 | 0 | 0 | 0 | 2 | 0.04 |
| 27 | 0 | 0.01 | 0.01 | 3 | 0.22 |
| 28 | 0 | 0.02 | 0.02 | 4 | 0.69 |
| 29 | 0.01 | 0.04 | 0.04 | 5 | 0.94 |
| 30 | 0.01 | 0.07 | 0.07 | 6 | 0.99 |
| 31 | 0.03 | 0.14 | 0.13 | 7 | 1 |
| 32 | 0.06 | 0.25 | 0.24 | 8 | 1 |
| 33 | 0.11 | 0.4 | 0.39 | 9 | 1 |
| 34 | 0.2 | 0.58 | 0.56 | 10 | 1 |
| 35 | 0.34 | 0.73 | 0.72 | | |
| 36 | 0.51 | 0.85 | 0.84 | | |
| 37 | 0.68 | 0.92 | 0.92 | | |
| 38 | 0.81 | 0.96 | 0.96 | | |
| 39 | 0.9 | 0.98 | 0.98 | | |
| 40 | 0.95 | 0.99 | 0.99 | | |
| 41 | 0.97 | 0.99 | 0.99 | | |
| 42 | 0.99 | 1 | 1 | | |
| 43 | 0.99 | 1 | 1 | | |
| 44 | 1 | 1 | 1 | | |
| 45 | 1 | 1 | 1 | | |
| 46 | 1 | 1 | 1 | | |
| 47 | 1 | 1 | 1 | | |
| 48 | 1 | 1 | 1 | | |
| 49 | 1 | 1 | 1 | | |
| 50 | 1 | 1 | 1 | | |

Table 17.9. Estimates of key results from AMAK for Bering Sea/Aleutian Islands Atka mackerel from last year's assessment (2010Model) and the current assessment (2011Model). The 2011Model results include 2010 fishery catch and age data. Coefficients of variation (*CV*) for some key reference values appearing directly below, are given in parentheses.

| Assessment Model | **2010Model** | **2011 Model** |
|---|---|---|
| *Model setup* | | |
| Survey catchability | 1.57 | 1.61 |
| Steepness | 0.80 | 0.80 |
| SigmaR | 0.6 | 0.6 |
| Natural mortality | 0.300 | 0.300 |
| Fishery Average Effective *N* | 124 | 129 |
| Survey Average Effective *N* | 51 | 54 |
| RMSE Survey | 0.235 | 0.250 |
| *-log Likelihoods* | | |
| Number of Parameters | 161 | 163 |
| Survey index | 4.84 | 5.66 |
| Catch biomass | 0.10 | 0.09 |
| Fishery age comp | 167.29 | 175.72 |
| Survey age comp | 46.73 | 47.10 |
| Sub total | 218.96 | 228.57 |
| *-log Penalties* | | |
| Recruitment | 16.417 | 16.342 |
| Selectivity constraint | 57.924 | 54.901 |
| Fishing mortality penalty | 0.001 | 0.001 |
| Prior | 4.133 | 4.634 |
| Total | 297.434 | 304.447 |
| *Fishing mortalities (full selection)* | | |
| *F* 2011 | 0.311 | 0.221 |
| *F* 2011/*F* 40% | 0.810 | 0.504 |
| *F* 40% | *0.384* | *0.384* |
| *F*35% | *0.468* | 0.469 |
| *Stock abundance* | | |
| Initial Biomass (t, 1977) | 345,860 | 355,167 |
| *CV* | (14%) | (14%) |
| Assessment year total biomass (t) | 596,750 | 546,127 |
| *CV* | (19%) | (19%) |
| 1999 year class (millions at age 1) | 1,425 | 1,370 |
| *CV* | (19%) | (18%) |
| 2001 year class (millions at age 1) | 1,051 | 1,028 |
| *CV* | (22%) | (22%) |
| Recruitment Variability | 0.639 | 0.622 |

Table 17.10. Estimates of Atka mackerel fishery (over time, 1977-2011) and survey selectivity at age. These are full-selection (maximum = 1.0) estimates.

| | **Age** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ |
| 1977 | 0.005 | 0.047 | 0.367 | 0.790 | 1.000 | 0.912 | 0.829 | 0.722 | 0.643 | 0.586 | 0.586 |
| 1978 | 0.005 | 0.047 | 0.367 | 0.790 | 1.000 | 0.912 | 0.829 | 0.722 | 0.643 | 0.586 | 0.586 |
| 1979 | 0.005 | 0.047 | 0.367 | 0.790 | 1.000 | 0.912 | 0.829 | 0.722 | 0.643 | 0.586 | 0.586 |
| 1980 | 0.005 | 0.047 | 0.367 | 0.790 | 1.000 | 0.912 | 0.829 | 0.722 | 0.643 | 0.586 | 0.586 |
| 1981 | 0.005 | 0.047 | 0.367 | 0.790 | 1.000 | 0.912 | 0.829 | 0.722 | 0.643 | 0.586 | 0.586 |
| 1982 | 0.005 | 0.047 | 0.367 | 0.790 | 1.000 | 0.912 | 0.829 | 0.722 | 0.643 | 0.586 | 0.586 |
| 1983 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1984 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1985 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1986 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1987 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1988 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1989 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1990 | 0.004 | 0.041 | 0.411 | 0.936 | 1.000 | 0.990 | 0.921 | 0.820 | 0.750 | 0.689 | 0.689 |
| 1991 | 0.002 | 0.019 | 0.136 | 0.523 | 0.796 | 0.908 | 0.966 | 1.000 | 0.962 | 0.926 | 0.926 |
| 1992 | 0.002 | 0.019 | 0.136 | 0.523 | 0.796 | 0.908 | 0.966 | 1.000 | 0.962 | 0.926 | 0.926 |
| 1993 | 0.002 | 0.019 | 0.136 | 0.523 | 0.796 | 0.908 | 0.966 | 1.000 | 0.962 | 0.926 | 0.926 |
| 1994 | 0.002 | 0.019 | 0.136 | 0.523 | 0.796 | 0.908 | 0.966 | 1.000 | 0.962 | 0.926 | 0.926 |
| 1995 | 0.002 | 0.019 | 0.136 | 0.523 | 0.796 | 0.908 | 0.966 | 1.000 | 0.962 | 0.926 | 0.926 |
| 1996 | 0.002 | 0.019 | 0.136 | 0.523 | 0.796 | 0.908 | 0.966 | 1.000 | 0.962 | 0.926 | 0.926 |
| 1997 | 0.002 | 0.019 | 0.136 | 0.523 | 0.796 | 0.908 | 0.966 | 1.000 | 0.962 | 0.926 | 0.926 |
| 1998 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 1999 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2000 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2001 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2002 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2003 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2004 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2005 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2006 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2007 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2008 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2009 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2010 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| 2011 | 0.001 | 0.021 | 0.208 | 0.543 | 0.699 | 0.820 | 1.000 | 0.998 | 0.906 | 0.799 | 0.799 |
| *Survey* | 0.033 | 0.168 | 0.531 | 0.806 | 0.838 | 0.885 | 0.980 | 1.000 | 0.951 | 0.922 | 0.922 |

Table 17.11. Estimated Atka mackerel numbers at age in millions, 1977-2011.

| | Age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ |
| 1977 | 228 | 379 | 223 | 71 | 48 | 23 | 19 | 17 | 14 | 12 | 66 |
| 1978 | 1,381 | 168 | 278 | 153 | 45 | 29 | 14 | 12 | 11 | 9 | 51 |
| 1979 | 341 | 1,022 | 123 | 190 | 95 | 27 | 17 | 9 | 8 | 7 | 39 |
| 1980 | 205 | 253 | 752 | 87 | 126 | 61 | 17 | 12 | 6 | 5 | 32 |
| 1981 | 225 | 152 | 186 | 538 | 60 | 85 | 42 | 12 | 8 | 4 | 26 |
| 1982 | 152 | 166 | 112 | 135 | 378 | 41 | 59 | 29 | 8 | 6 | 21 |
| 1983 | 216 | 113 | 123 | 81 | 95 | 263 | 29 | 42 | 21 | 6 | 19 |
| 1984 | 294 | 160 | 84 | 90 | 58 | 68 | 187 | 21 | 30 | 15 | 18 |
| 1985 | 410 | 218 | 118 | 59 | 59 | 38 | 44 | 124 | 14 | 20 | 22 |
| 1986 | 349 | 304 | 160 | 81 | 37 | 37 | 24 | 28 | 80 | 9 | 28 |
| 1987 | 526 | 258 | 223 | 110 | 51 | 23 | 23 | 15 | 18 | 52 | 24 |
| 1988 | 343 | 390 | 190 | 157 | 73 | 33 | 15 | 15 | 10 | 12 | 52 |
| 1989 | 1,332 | 254 | 287 | 134 | 104 | 48 | 22 | 10 | 10 | 7 | 44 |
| 1990 | 563 | 987 | 188 | 207 | 93 | 72 | 33 | 15 | 7 | 7 | 36 |
| 1991 | 281 | 417 | 729 | 136 | 145 | 65 | 50 | 23 | 11 | 5 | 30 |
| 1992 | 494 | 208 | 308 | 532 | 95 | 98 | 43 | 33 | 15 | 7 | 24 |
| 1993 | 888 | 366 | 154 | 224 | 367 | 63 | 64 | 28 | 22 | 10 | 20 |
| 1994 | 304 | 658 | 270 | 111 | 151 | 235 | 39 | 40 | 17 | 13 | 19 |
| 1995 | 325 | 225 | 485 | 194 | 73 | 94 | 142 | 24 | 24 | 10 | 19 |
| 1996 | 841 | 240 | 166 | 343 | 120 | 41 | 51 | 76 | 12 | 13 | 16 |
| 1997 | 146 | 622 | 176 | 115 | 200 | 62 | 20 | 24 | 36 | 6 | 14 |
| 1998 | 285 | 108 | 458 | 126 | 74 | 119 | 36 | 11 | 14 | 20 | 11 |
| 1999 | 665 | 211 | 79 | 316 | 78 | 43 | 67 | 19 | 6 | 7 | 18 |
| 2000 | 1,370 | 493 | 156 | 56 | 203 | 48 | 26 | 38 | 11 | 4 | 15 |
| 2001 | 906 | 1,014 | 363 | 109 | 36 | 127 | 29 | 15 | 22 | 6 | 11 |
| 2002 | 1,028 | 671 | 746 | 251 | 68 | 21 | 71 | 15 | 8 | 12 | 10 |
| 2003 | 226 | 761 | 495 | 526 | 163 | 42 | 13 | 41 | 9 | 5 | 13 |
| 2004 | 345 | 167 | 561 | 350 | 345 | 103 | 26 | 8 | 24 | 5 | 11 |
| 2005 | 527 | 255 | 123 | 399 | 232 | 221 | 65 | 16 | 5 | 15 | 10 |
| 2006 | 378 | 390 | 188 | 88 | 265 | 149 | 139 | 39 | 10 | 3 | 16 |
| 2007 | 950 | 280 | 288 | 133 | 58 | 169 | 93 | 83 | 23 | 6 | 12 |
| 2008 | 707 | 704 | 206 | 204 | 89 | 37 | 106 | 56 | 50 | 14 | 11 |
| 2009 | 338 | 523 | 519 | 146 | 133 | 56 | 23 | 62 | 33 | 30 | 16 |
| 2010 | 303 | 250 | 385 | 359 | 90 | 79 | 32 | 12 | 33 | 18 | 26 |
| 2011 | 349 | 224 | 184 | 269 | 227 | 55 | 46 | 18 | 7 | 19 | 26 |
| Average | 521 | 389 | 288 | 202 | 130 | 79 | 49 | 30 | 18 | 11 | 24 |

Table 17.12. Estimates of Atka mackerel biomass in metric tons with approximate lower and upper 95% confidence bounds for age 1+ biomass (labeled as LCI and UCI; computed for period 1977-2011). Also included are age 3+ and female spawning biomass in metric tons from the current assessment (1977-2012) compared to last year's (2010) assessment.

| | *Current assessment age 1+ biomass (t)* | | | *Age 3+ biomass (t)* | | *Female spawning biomass (t)* | |
|---|---|---|---|---|---|---|---|
| Year | Estimate | LCI | UCI | Current | 2010 | Current | 2010 |
| 1977 | 355,167 | 264,562 | 476,801 | 211,368 | 207,084 | 83,439 | 81,286 |
| 1978 | 411,872 | 302,261 | 561,231 | 214,178 | 208,888 | 85,204 | 82,219 |
| 1979 | 472,233 | 341,891 | 652,266 | 251,751 | 244,217 | 93,896 | 90,213 |
| 1980 | 543,513 | 391,862 | 753,853 | 440,041 | 427,308 | 111,424 | 107,100 |
| 1981 | 575,896 | 413,399 | 802,266 | 452,786 | 440,166 | 162,095 | 156,700 |
| 1982 | 513,572 | 367,781 | 717,157 | 429,887 | 419,272 | 169,111 | 163,980 |
| 1983 | 467,815 | 335,025 | 653,238 | 410,346 | 404,529 | 160,430 | 156,530 |
| 1984 | 440,622 | 318,536 | 609,501 | 412,914 | 409,682 | 143,281 | 140,840 |
| 1985 | 397,462 | 287,386 | 549,698 | 346,917 | 346,295 | 117,219 | 115,880 |
| 1986 | 369,568 | 269,919 | 506,006 | 293,895 | 295,698 | 97,002 | 96,789 |
| 1987 | 382,291 | 285,000 | 512,794 | 383,736 | 393,395 | 95,084 | 96,056 |
| 1988 | 397,019 | 307,296 | 512,939 | 298,194 | 310,026 | 96,818 | 99,754 |
| 1989 | 458,147 | 373,111 | 562,563 | 406,899 | 423,352 | 104,527 | 109,130 |
| 1990 | 555,428 | 472,481 | 652,936 | 515,190 | 532,675 | 120,521 | 125,500 |
| 1991 | 646,431 | 564,158 | 740,702 | 470,859 | 476,412 | 139,643 | 144,150 |
| 1992 | 693,762 | 612,328 | 786,026 | 711,807 | 709,584 | 184,016 | 185,790 |
| 1993 | 668,110 | 593,597 | 751,977 | 652,109 | 647,480 | 186,447 | 186,140 |
| 1994 | 648,198 | 576,804 | 728,427 | 523,630 | 519,579 | 166,253 | 164,850 |
| 1995 | 630,700 | 559,263 | 711,262 | 481,483 | 480,009 | 150,092 | 148,660 |
| 1996 | 577,850 | 506,461 | 659,302 | 450,722 | 451,182 | 136,493 | 135,840 |
| 1997 | 483,478 | 415,138 | 563,067 | 432,012 | 434,407 | 115,056 | 115,240 |
| 1998 | 474,242 | 403,630 | 557,207 | 385,889 | 393,841 | 108,895 | 109,180 |
| 1999 | 447,448 | 376,818 | 531,316 | 406,466 | 422,599 | 115,906 | 119,320 |
| 2000 | 463,083 | 390,081 | 549,746 | 365,143 | 382,709 | 102,103 | 107,400 |
| 2001 | 570,718 | 482,893 | 674,517 | 411,883 | 432,937 | 96,189 | 102,530 |
| 2002 | 705,308 | 595,168 | 835,830 | 475,374 | 499,470 | 121,100 | 129,140 |
| 2003 | 790,419 | 664,355 | 940,404 | 550,251 | 577,199 | 170,131 | 180,400 |
| 2004 | 776,564 | 645,984 | 933,540 | 650,092 | 678,833 | 199,390 | 210,790 |
| 2005 | 723,689 | 592,875 | 883,366 | 576,814 | 602,456 | 213,045 | 224,660 |
| 2006 | 638,209 | 512,184 | 795,243 | 499,987 | 524,304 | 185,491 | 196,170 |
| 2007 | 609,090 | 474,596 | 781,699 | 531,066 | 557,722 | 161,210 | 171,270 |
| 2008 | 617,908 | 464,389 | 822,179 | 449,569 | 471,961 | 146,694 | 155,990 |
| 2009 | 630,377 | 454,045 | 875,189 | 519,897 | 520,260 | 135,412 | 142,290 |
| 2010 | 608,636 | 417,585 | 887,096 | 535,291 | 532,415 | 146,139 | 145,910 |
| 2011 | 546,127 | 359,843 | 828,847 | 471,038 | 437,572 | 151,071 | 137,313 |
| 2012 | | | | 405,347 | | 128,800 | |

Table 17.13. Estimates of age-1 Atka mackerel recruitment (millions of recruits).

| | Age 1 Recruits | |
|---|---|---|
| Year | Current | 2010 assessment |
| 1977 | 228 | 222 |
| 1978 | 1,381 | 1,349 |
| 1979 | 341 | 336 |
| 1980 | 205 | 211 |
| 1981 | 225 | 237 |
| 1982 | 152 | 156 |
| 1983 | 216 | 221 |
| 1984 | 294 | 305 |
| 1985 | 410 | 434 |
| 1986 | 349 | 377 |
| 1987 | 526 | 535 |
| 1988 | 343 | 343 |
| 1989 | 1,332 | 1,289 |
| 1990 | 563 | 569 |
| 1991 | 281 | 280 |
| 1992 | 494 | 497 |
| 1993 | 888 | 899 |
| 1994 | 304 | 307 |
| 1995 | 325 | 327 |
| 1996 | 841 | 879 |
| 1997 | 146 | 162 |
| 1998 | 285 | 293 |
| 1999 | 665 | 693 |
| 2000 | 1,370 | 1,425 |
| 2001 | 906 | 938 |
| 2002 | 1,028 | 1,051 |
| 2003 | 226 | 229 |
| 2004 | 345 | 361 |
| 2005 | 527 | 545 |
| 2006 | 378 | 387 |
| 2007 | 950 | 871 |
| 2008 | 707 | 680 |
| 2009 | 338 | 288 |
| 2010 | 303 | Na |
| 2011 | 349 | Na |
| avg 78-09 | 542 | 546 |
| Med 78-09 | 363 | 382 |

Table 17.14. Estimates of full-selection fishing mortality rates and exploitation rates for Atka mackerel.

| Year | $F$[a] | Catch/Biomass Rate[b] |
|---|---|---|
| 1977 | 0.201 | 0.103 |
| 1978 | 0.226 | 0.113 |
| 1979 | 0.137 | 0.092 |
| 1980 | 0.094 | 0.047 |
| 1981 | 0.069 | 0.043 |
| 1982 | 0.064 | 0.046 |
| 1983 | 0.038 | 0.029 |
| 1984 | 0.123 | 0.087 |
| 1985 | 0.169 | 0.109 |
| 1986 | 0.176 | 0.109 |
| 1987 | 0.127 | 0.078 |
| 1988 | 0.116 | 0.074 |
| 1989 | 0.069 | 0.044 |
| 1990 | 0.060 | 0.043 |
| 1991 | 0.116 | 0.057 |
| 1992 | 0.137 | 0.068 |
| 1993 | 0.181 | 0.101 |
| 1994 | 0.222 | 0.125 |
| 1995 | 0.339 | 0.169 |
| 1996 | 0.457 | 0.231 |
| 1997 | 0.280 | 0.152 |
| 1998 | 0.339 | 0.148 |
| 1999 | 0.262 | 0.138 |
| 2000 | 0.250 | 0.129 |
| 2001 | 0.336 | 0.149 |
| 2002 | 0.242 | 0.095 |
| 2003 | 0.225 | 0.098 |
| 2004 | 0.205 | 0.093 |
| 2005 | 0.199 | 0.108 |
| 2006 | 0.216 | 0.124 |
| 2007 | 0.203 | 0.111 |
| 2008 | 0.236 | 0.129 |
| 2009 | 0.327 | 0.140 |
| 2010 | 0.289 | 0.128 |
| 2011 | 0.221 | 0.113 |

a Full-selection fishing mortality rates.
b Catch/biomass rate is the ratio of catch to beginning year age 3+ biomass.

Table 17.15. Projections of female spawning biomass in metric tons, full-selection fishing mortality rates (*F*) and catch in metric tons for Atka mackerel for the 7 scenarios. The values for $B_{100\%}$, $B_{40\%}$, and $B_{35\%}$ are 255,662 t, 102,265 t, and 89,482 t, respectively.

| | $B_{100\%}$ | $B_{40\%}$ | $B_{35\%}$ | $B_{2012}$ | $B_{2011}/B_{100\%}$ | | |
|---|---|---|---|---|---|---|---|
| | 255,662 | 102,265 | 89,482 | 128,813 | 0.504 | | |
| *Catch* | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
| 2011 | 53,080 | 53,080 | 53,080 | 53,080 | 53,080 | 53,080 | 53,080 |
| 2012 | 81,399 | 81,399 | 36,045 | 21,508 | 0 | 96,548 | 81,399 |
| 2013 | 67,067 | 67,067 | 34,390 | 21,438 | 0 | 71,515 | 67,067 |
| 2014 | 53,353 | 53,353 | 33,338 | 21,483 | 0 | 54,981 | 62,047 |
| 2015 | 52,391 | 52,391 | 33,654 | 22,070 | 0 | 55,560 | 58,213 |
| 2016 | 55,875 | 55,875 | 34,934 | 23,095 | 0 | 60,104 | 61,101 |
| 2017 | 58,787 | 58,787 | 36,543 | 24,319 | 0 | 63,310 | 63,642 |
| 2018 | 60,638 | 60,638 | 37,965 | 25,443 | 0 | 64,988 | 65,082 |
| 2019 | 61,852 | 61,852 | 39,012 | 26,297 | 0 | 66,047 | 66,072 |
| 2020 | 62,367 | 62,367 | 39,661 | 26,863 | 0 | 66,386 | 66,392 |
| 2021 | 62,902 | 62,902 | 40,147 | 27,280 | 0 | 66,846 | 66,847 |
| 2022 | 63,485 | 63,485 | 40,640 | 27,684 | 0 | 67,557 | 67,557 |
| 2023 | 63,385 | 63,385 | 40,811 | 27,875 | 0 | 67,298 | 67,298 |
| 2024 | 62,908 | 62,908 | 40,809 | 27,942 | 0 | 66,653 | 66,654 |
| *Fishing M* | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
| 2011 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 |
| 2012 | 0.384 | 0.384 | 0.157 | 0.092 | 0.000 | 0.469 | 0.384 |
| 2013 | 0.384 | 0.384 | 0.157 | 0.092 | 0.000 | 0.440 | 0.384 |
| 2014 | 0.342 | 0.342 | 0.157 | 0.092 | 0.000 | 0.383 | 0.407 |
| 2015 | 0.334 | 0.334 | 0.157 | 0.092 | 0.000 | 0.380 | 0.389 |
| 2016 | 0.340 | 0.340 | 0.157 | 0.092 | 0.000 | 0.392 | 0.396 |
| 2017 | 0.345 | 0.345 | 0.157 | 0.092 | 0.000 | 0.399 | 0.400 |
| 2018 | 0.348 | 0.348 | 0.157 | 0.092 | 0.000 | 0.403 | 0.403 |
| 2019 | 0.350 | 0.350 | 0.157 | 0.092 | 0.000 | 0.406 | 0.406 |
| 2020 | 0.351 | 0.351 | 0.157 | 0.092 | 0.000 | 0.407 | 0.407 |
| 2021 | 0.352 | 0.352 | 0.157 | 0.092 | 0.000 | 0.408 | 0.408 |
| 2022 | 0.353 | 0.353 | 0.157 | 0.092 | 0.000 | 0.409 | 0.409 |
| 2023 | 0.353 | 0.353 | 0.157 | 0.092 | 0.000 | 0.409 | 0.409 |
| 2024 | 0.352 | 0.352 | 0.157 | 0.092 | 0.000 | 0.407 | 0.407 |
| *Spawning biomass* | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
| 2011 | 151,071 | 151,071 | 151,071 | 151,071 | 151,071 | 151,071 | 151,071 |
| 2012 | 128,813 | 128,813 | 142,167 | 146,301 | 152,297 | 124,181 | 128,813 |
| 2013 | 103,848 | 103,848 | 132,772 | 142,763 | 158,178 | 96,177 | 103,848 |
| 2014 | 91,985 | 91,985 | 127,532 | 141,739 | 164,999 | 84,452 | 89,488 |
| 2015 | 92,967 | 92,967 | 130,441 | 147,398 | 176,572 | 85,783 | 87,905 |
| 2016 | 98,087 | 98,087 | 138,198 | 157,703 | 192,575 | 90,484 | 91,349 |
| 2017 | 101,878 | 101,878 | 144,762 | 166,325 | 205,938 | 93,607 | 93,920 |
| 2018 | 103,202 | 103,202 | 148,563 | 171,760 | 215,267 | 94,358 | 94,458 |
| 2019 | 104,506 | 104,506 | 152,227 | 176,959 | 224,222 | 95,229 | 95,262 |
| 2020 | 105,009 | 105,009 | 154,602 | 180,605 | 231,138 | 95,466 | 95,474 |
| 2021 | 105,737 | 105,737 | 156,930 | 184,055 | 237,559 | 96,025 | 96,026 |
| 2022 | 106,697 | 106,697 | 159,119 | 187,080 | 242,887 | 96,826 | 96,826 |
| 2023 | 106,444 | 106,444 | 159,783 | 188,394 | 246,064 | 96,463 | 96,463 |
| 2024 | 105,857 | 105,857 | 159,648 | 188,681 | 247,700 | 95,880 | 95,880 |

Table 17.16. Ecosystem effects.

| **Ecosystem effects on Atka mackerel** | | | |
|---|---|---|---|
| Indicator | Observation | Interpretation | Evaluation |
| *Prey availability or abundance trends* | | | |
| Zooplankton | Stomach contents, ichthyoplankton surveys | None | Unknown |
| *Predator population trends* | | | |
| Marine mammals | Fur seals declining, Steller sea lions increasing slightly | Possibly lower mortality on Atka mackerel | No concern |
| Birds | Stable, some increasing some decreasing | Affects young-of-year mortality | No concern |
| Fish (Pacific cod, arrowtooth flounder) | Arrowtooth abundance trends are increasing | Possible increased predation on Atka mackerel | No concern |
| *Changes in habitat quality* | | | |
| Temperature regime | 2006 AI summer bottom temperature slightly below average (excl. 2000) | Could possibly affect fish distribution | Unknown |
| ***The Atka mackerel* effects on ecosystem** | | | |
| Indicator | Observation | Interpretation | Evaluation |
| *Fishery contribution to bycatch* | | | |
| Prohibited species | Stable, heavily monitored | Likely to be a minor contribution to mortality | Unknown |
| Forage (including herring, Atka mackerel, cod, and pollock) | Stable, heavily monitored | Bycatch levels small relative to forage biomass | Unknown |
| HAPC biota (seapens/whips, corals, sponges, anemones) | Low bycatch levels of seapens/whips, sponge and coral catches are variable | Unknown | Possible concern for sponges and corals |
| Marine mammals and birds | Very minor direct-take | Likely to be very minor contribution to mortality | No concern |
| Sensitive non-target species | Skate catches are variable and have averaged 144 t from 2006-2008, which is about 13% of the AI skate catch over this time period | Data limited, need species-specific catch information | Possible Concern |
| Other non-target species | Sculpin catches are variable and have averaged about 500 t over the 2006-2008 time period | Unknown | Unknown |
| *Fishery concentration in space and time* | Steller sea lion protection measures spread out Atka mackerel catches in time and space. Fishery has expanded and concentrates in other areas outside of critical habitat | Mixed potential impact (fur seals vs Steller sea lions). Areas outside of critical habitat may be experiencing higher exploitation rates. | Possible concern |
| *Fishery effects on amount of large size target fish* | Depends on highly variable year-class strength | Natural fluctuation | Probably no concern |
| *Fishery contribution to discards and offal production* | Offal production—unknown<br>The Atka mackerel fishery contributes an average of 1,080 and 1,850 t of the total AI trawl non-target and Atka mackerel discards, respectively. | The Atka mackerel fishery is one of the few trawl fisheries operating in the AI. Numbers and rates should be interpreted in this context. | Unknown |
| *Fishery effects on age-at-maturity and fecundity* | Unknown | Unknown | Unknown |

## Figures

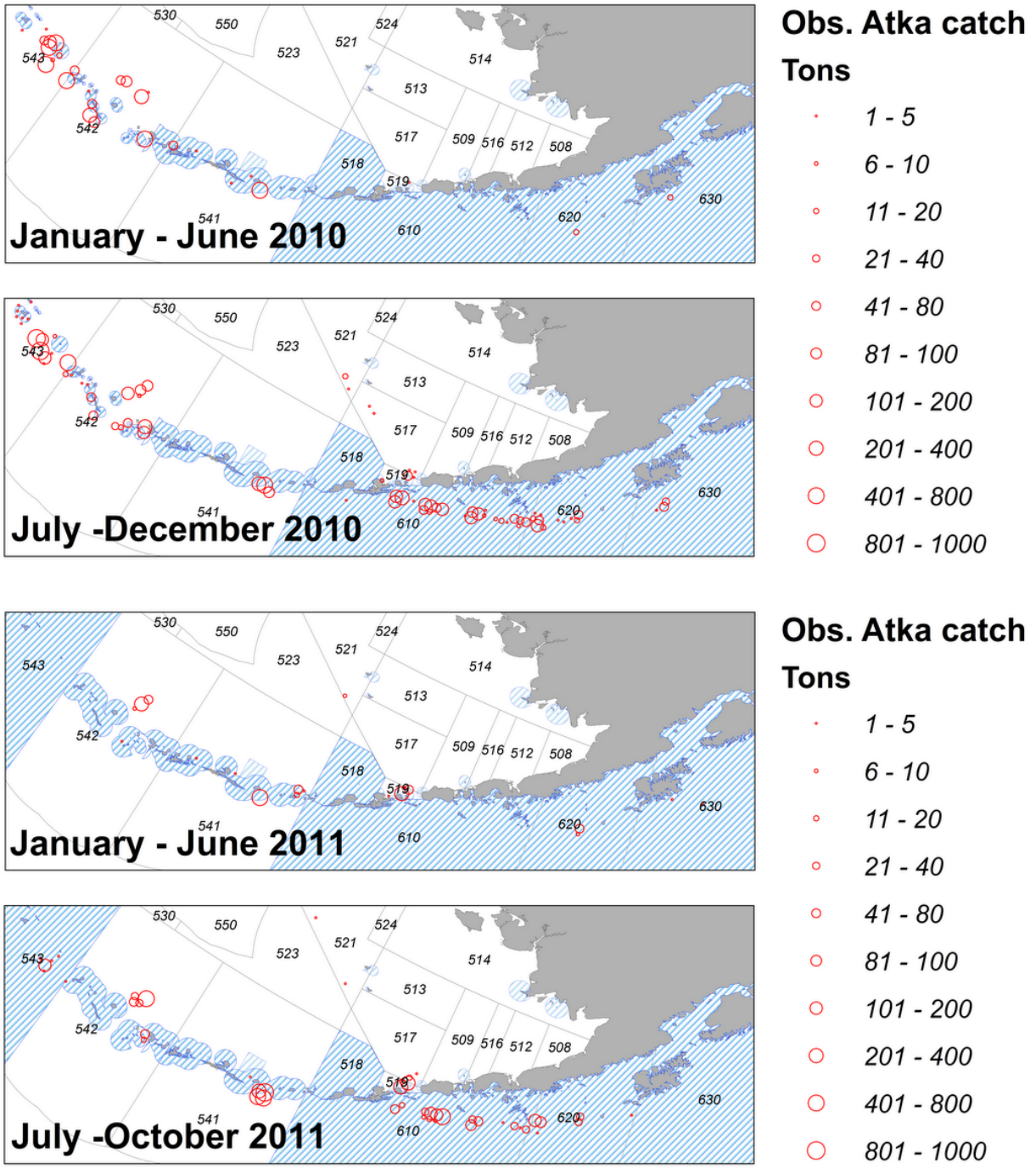



Figure 17.1. Observed catches of Atka mackerel summed for 20 km$^2$ cells for 2010 and 2011where observed catch per haul was greater than 1 t. Shaded areas represent areas closed to directed Atka mackerel fishing.

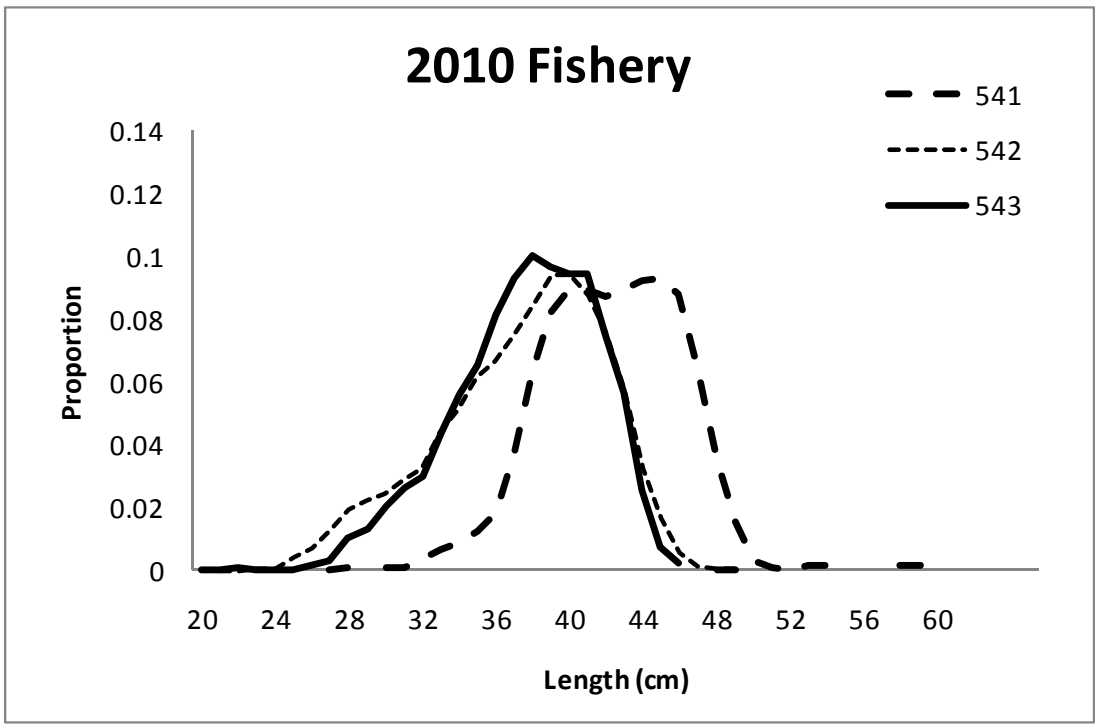



Figure 17.2. 2010 Atka mackerel fishery length-frequency data by area fished (see Figure 17.1). Numbers refer to management areas.

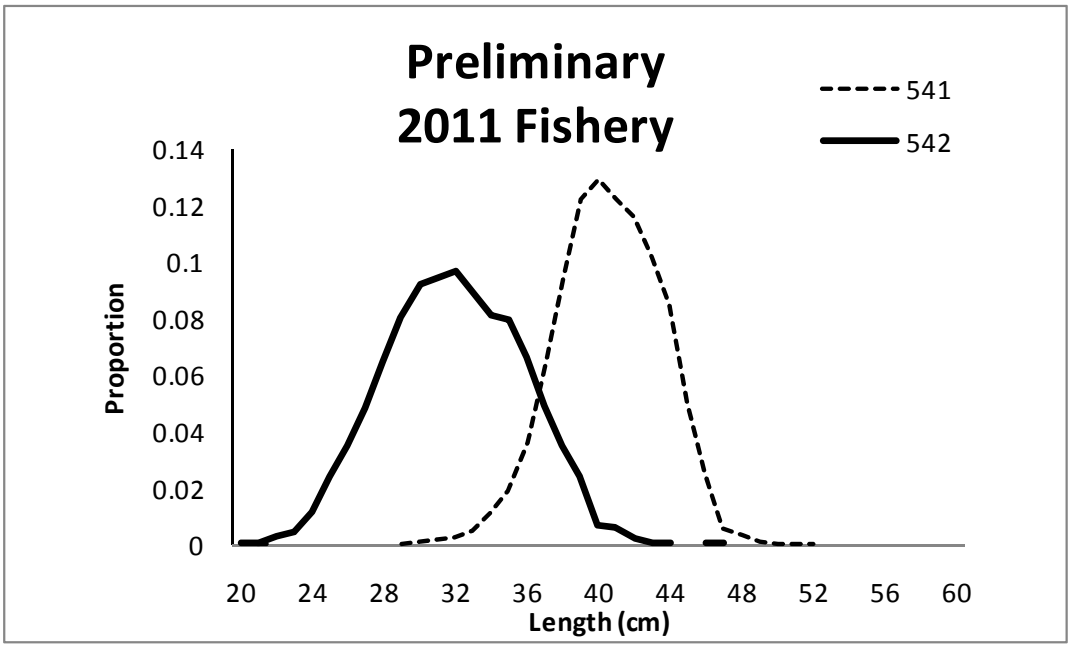



Figure 17.3. Preliminary 2011 Atka mackerel fishery length-frequency data by area fished (see Figure 17.1). Too few fish were measured in area 543 for presentation. Numbers refer to management areas.

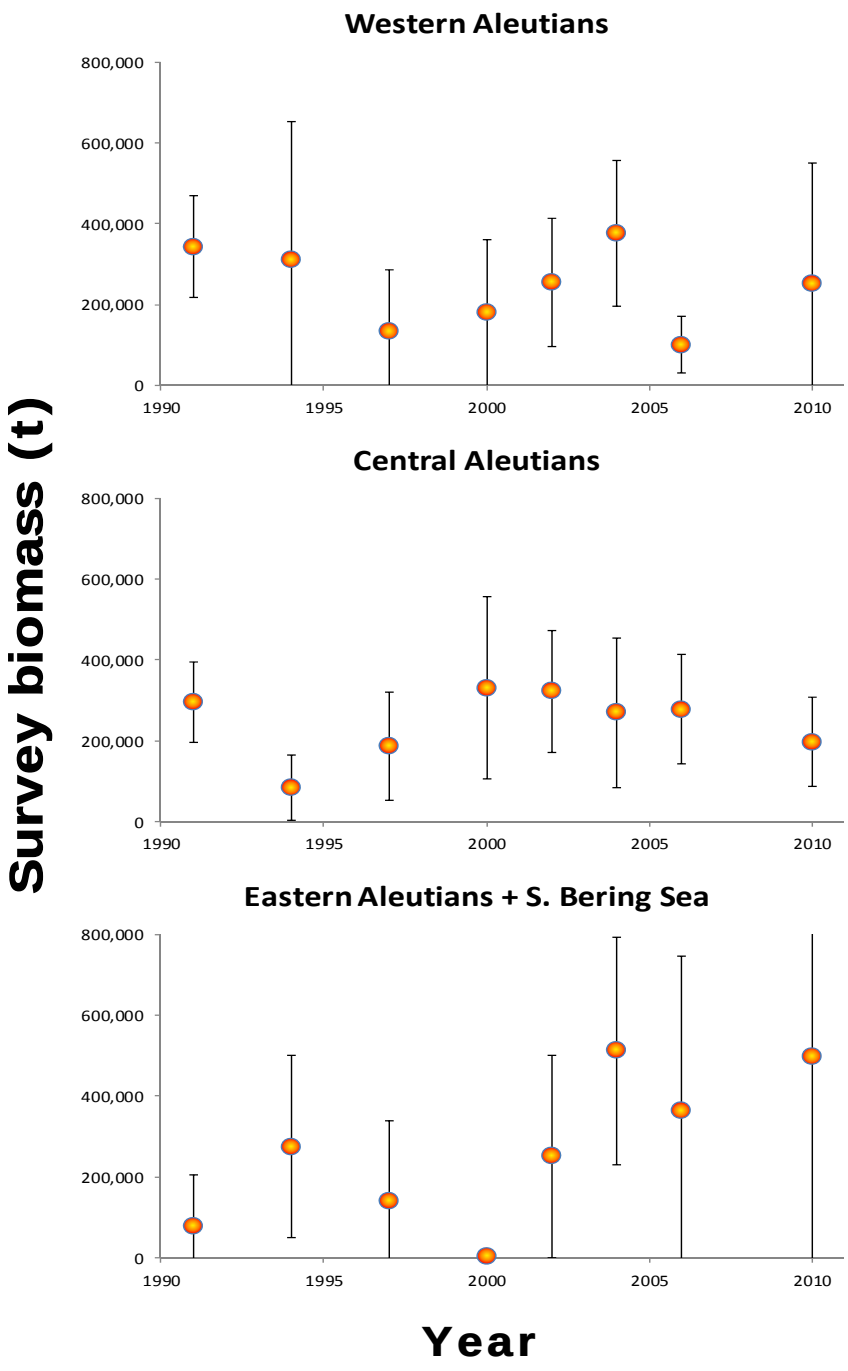



Figure 17.4. Atka mackerel Aleutian Islands survey biomass estimates by area and survey year. Bars represent 95% confidence intervals based on sampling error.

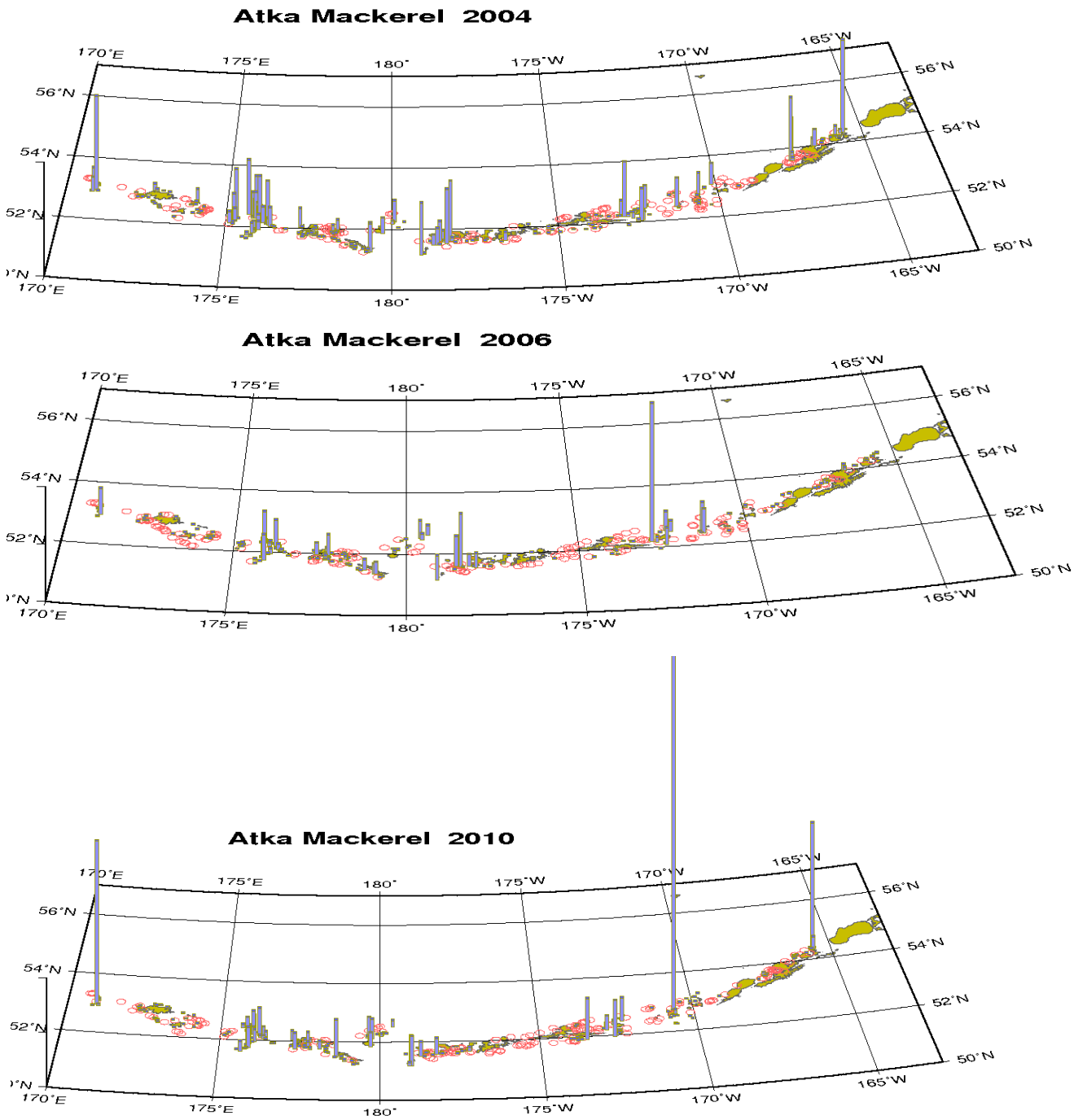



Figure 17.5. Bottom-trawl survey CPUE distributions of Atka mackerel catches during the summers of 2004, 2006, and 2010.

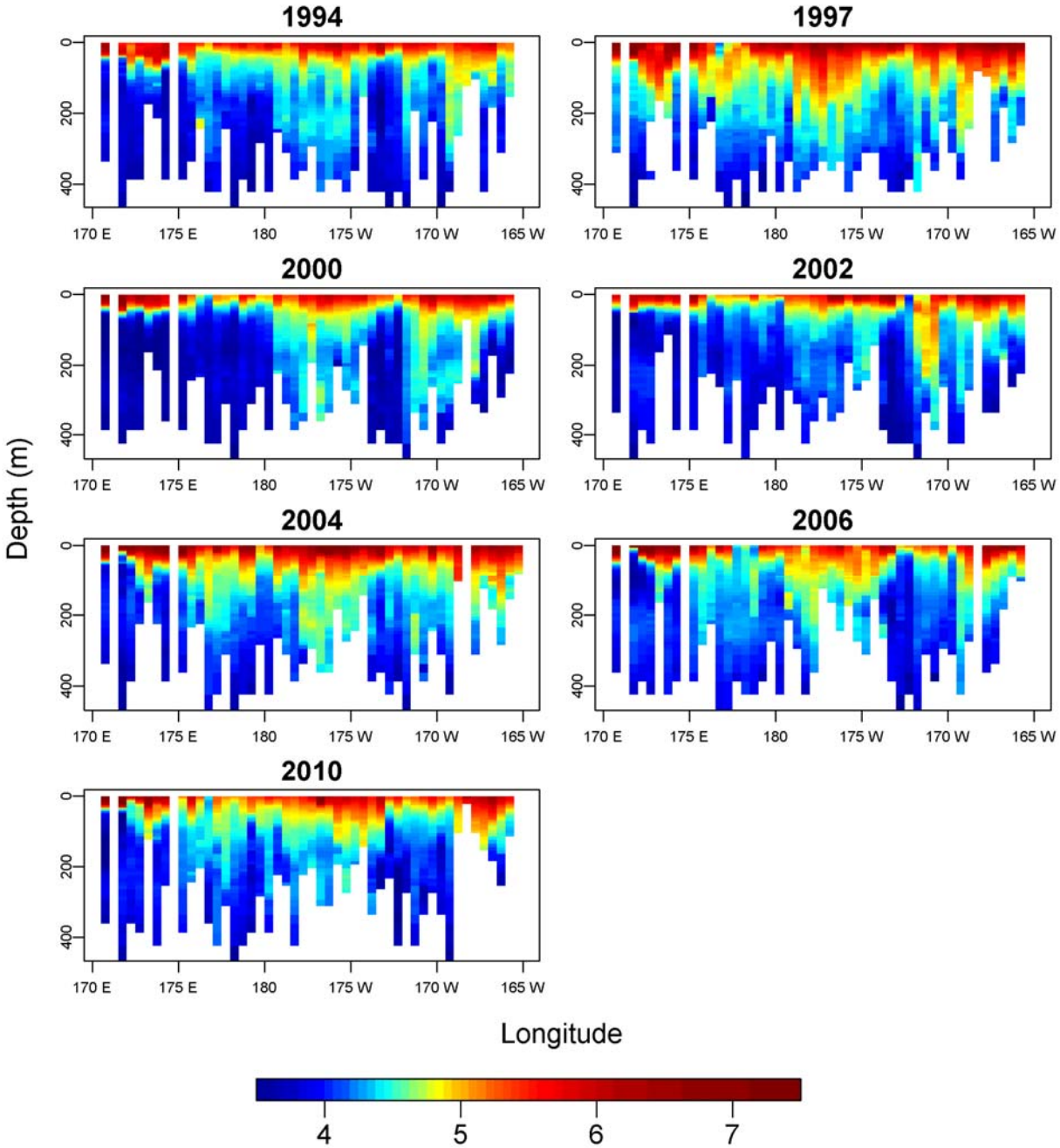



Figure 17.6. Date-adjusted water temperatures by depth interval and longitude based on Aleutian Islands summer bottom-trawl surveys since 1994 (Martin 2010). A full description of the estimation process is given in Martin (2010).

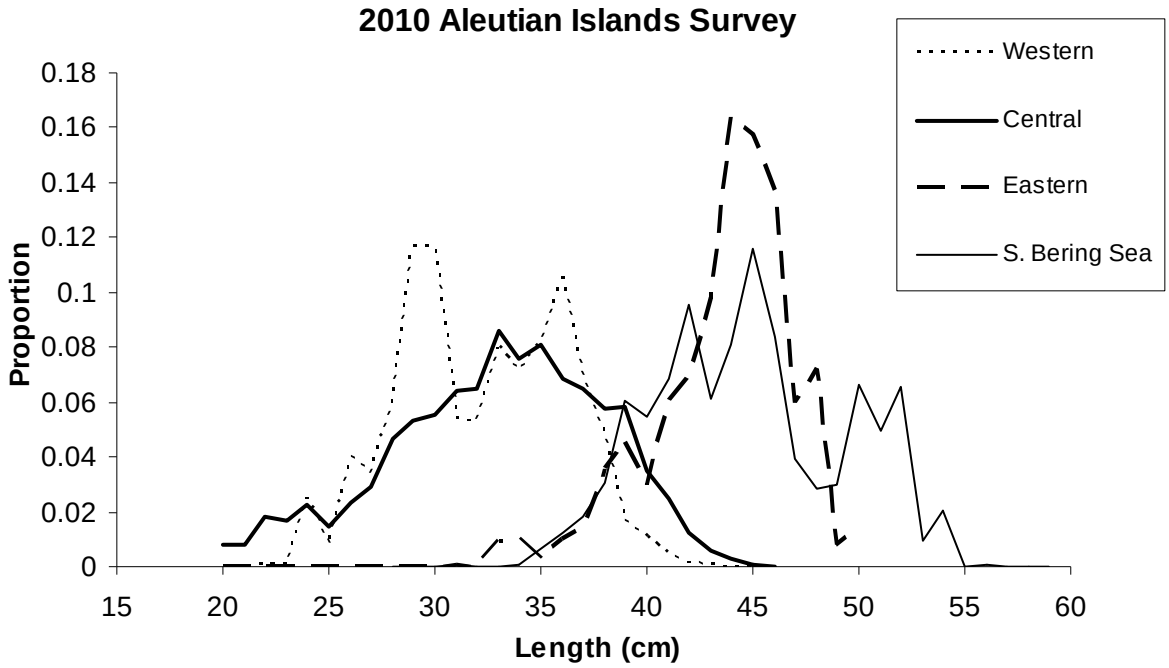



Figure 17.7. Atka mackerel bottom trawl survey length frequency data by subarea from the 2010 Aleutian Island survey.

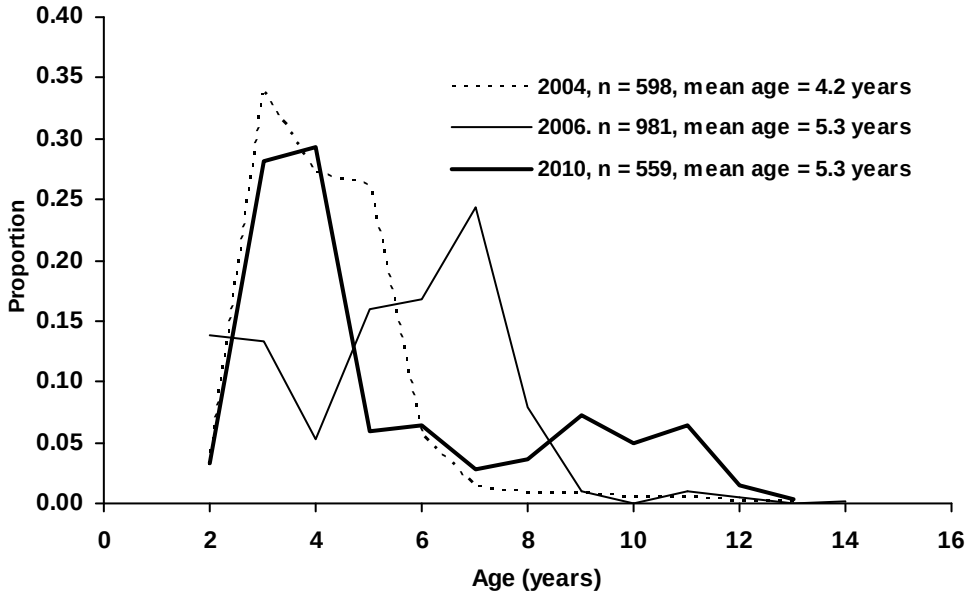



Figure 17.8. Atka mackerel age distributions from the Aleutian Islands region from the 2004, 2006, and 2010 bottom trawl surveys.

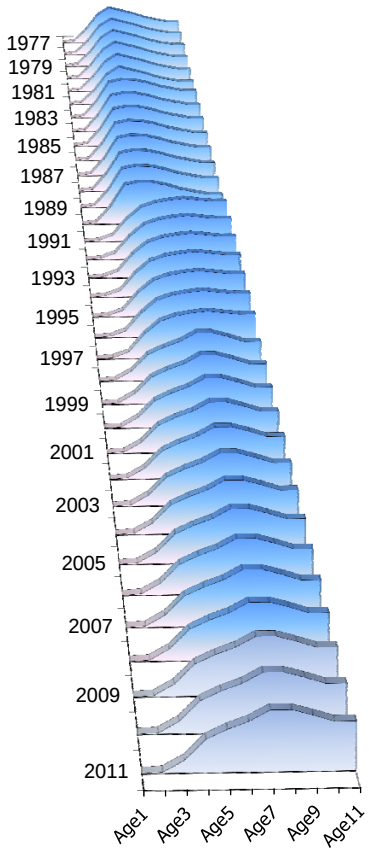



Figure 17.9. BSAI Atka mackerel assessment model configured to have 4 periods of distinct fishery selectivity patterns, 1977-2011.

Figure 17.10. Estimated fishery selectivity patterns from the terminal year in the current assessment and last year's assessment compared with the maturity-at-age estimates for BSAI Atka mackerel.

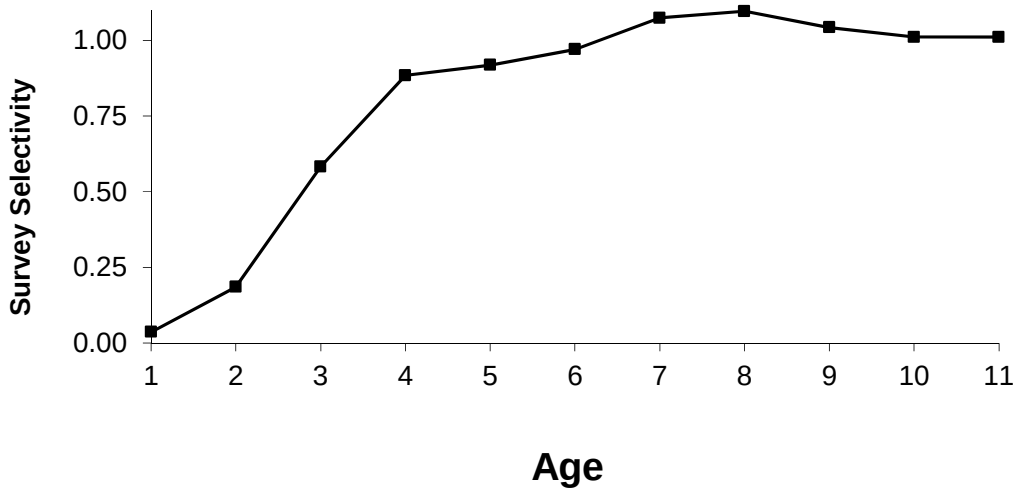



Figure 17.11. Estimated BSAI Atka mackerel survey selectivity-at-age.

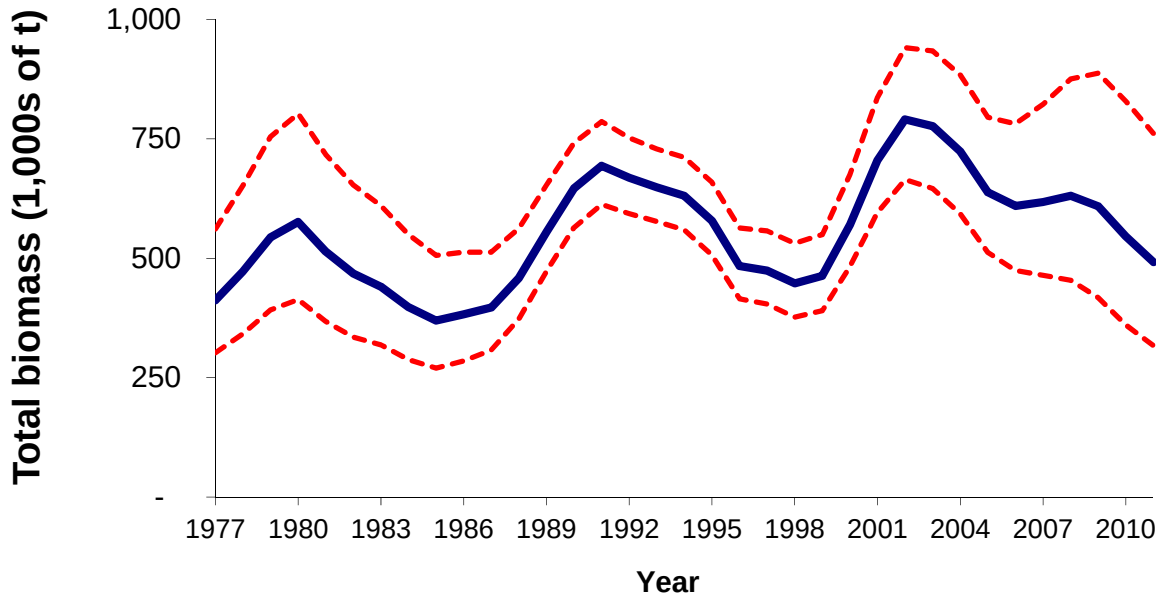



Figure 17.12. Time series of Aleutian Islands Atka mackerel total (age 1+) biomass estimates in thousands of metric tons, and approximate 95% confidence bounds.

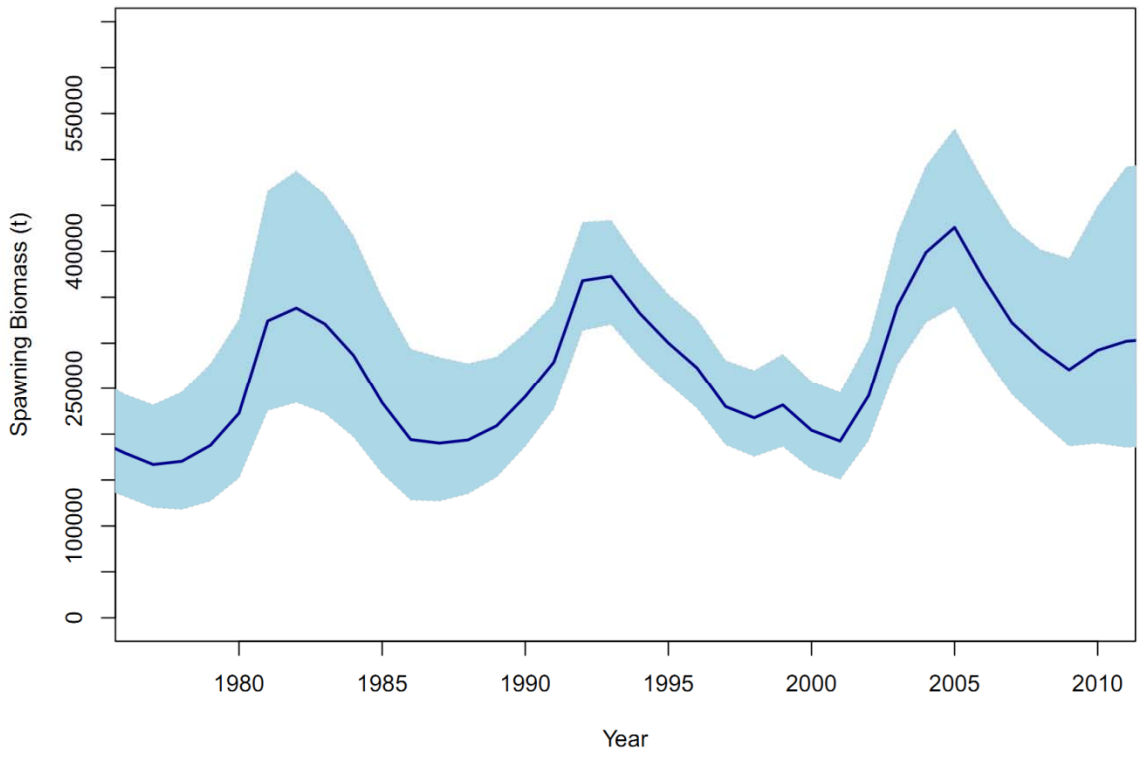



Figure 17.13. Estimated female spawning biomass from the current assessment with approximate 90% confidence intervals for BSAI Atka mackerel.

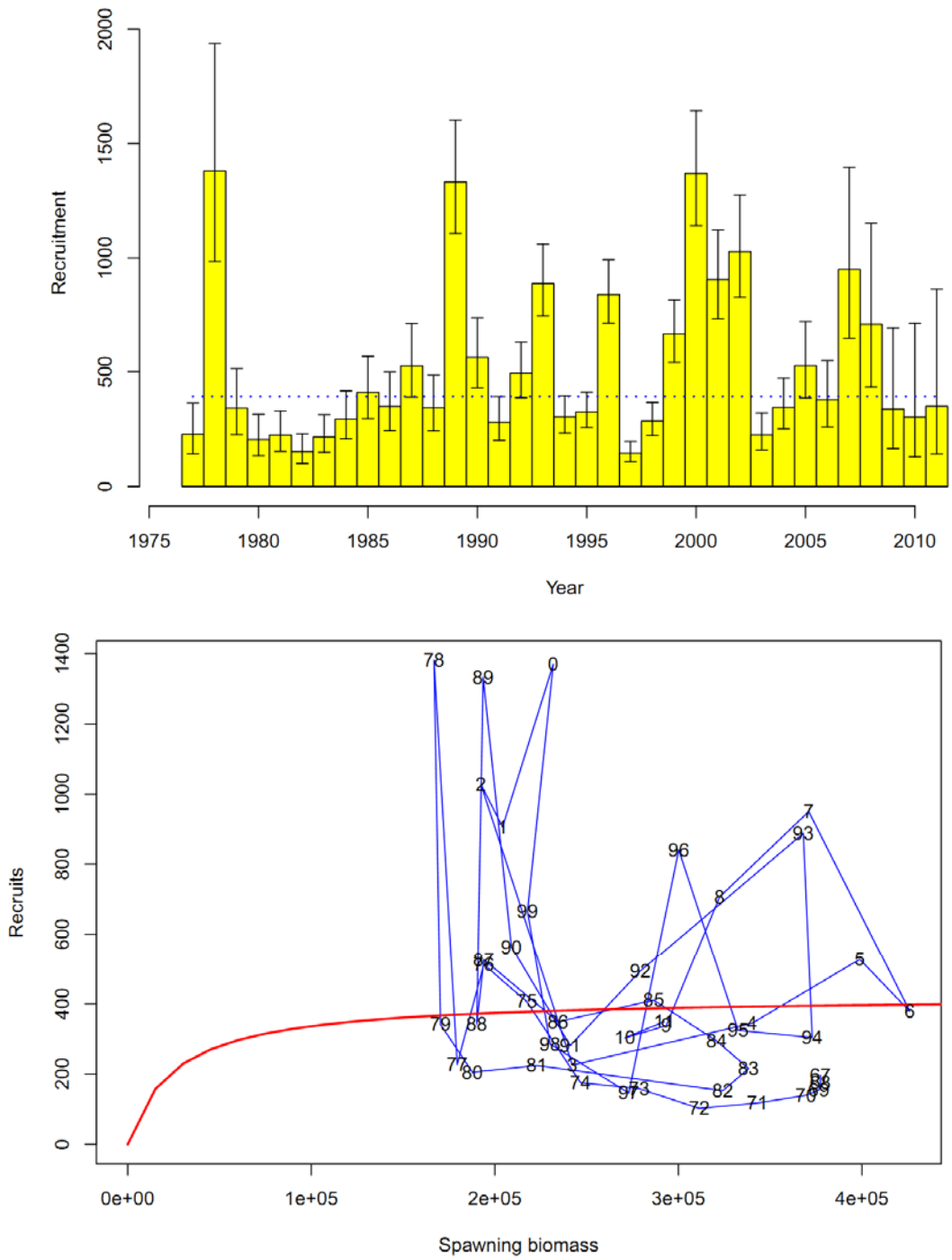



Figure 17.14. Age 1 recruitment of Atka mackerel as estimated from the current assessment, with error bars representing two standard errors (top panel) and the solid line indicating average recruitment (550 million) over 1978-2011, and estimated female spawning biomass levels in thousands of metric tons (lower panel). Solid line represents the underlying Beverton-Holt stock recruitment curve assumed in the model.

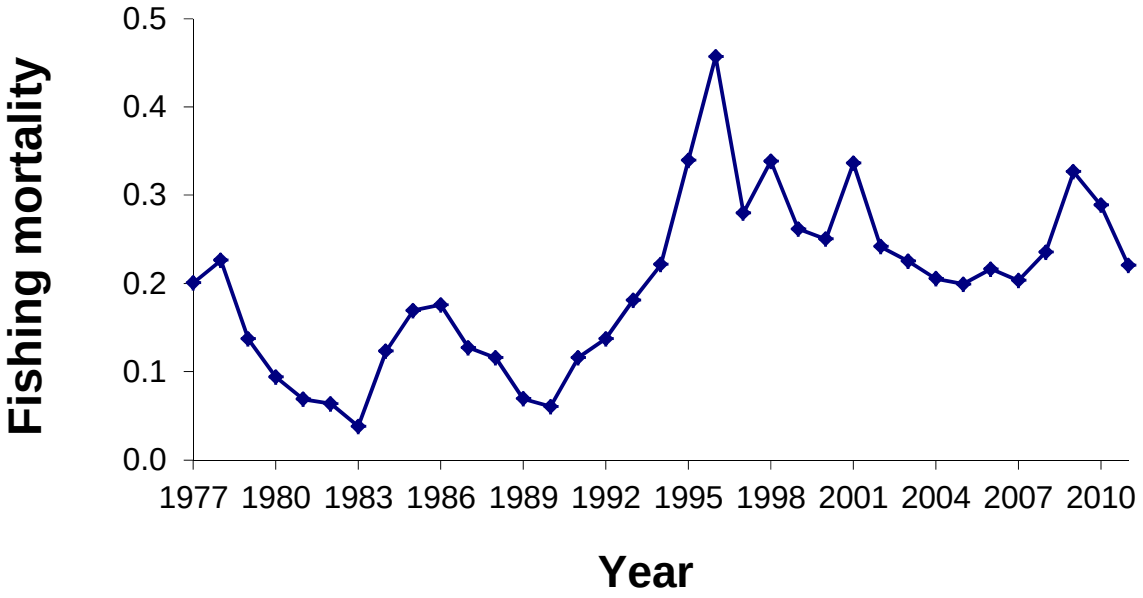



Figure 17.15. Estimated time series of full-selection fishing mortality rates of Atka mackerel, 1977-2011.

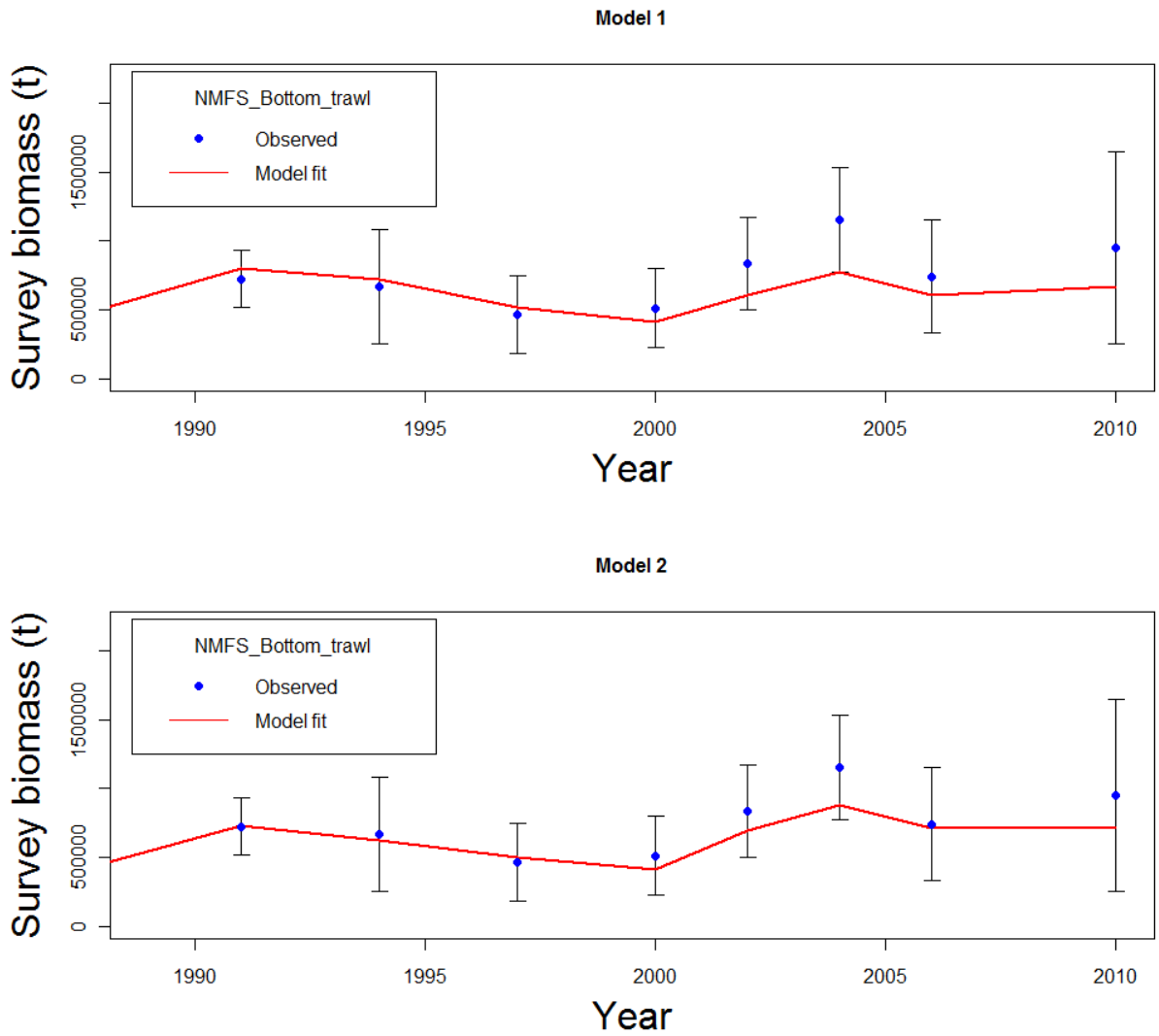



Figure 17.16. Observed and predicted survey biomass estimates in thousands of metric tons for Bering Sea/Aleutian Islands Atka mackerel. Error bars represent two standard errors (based on sampling) from the survey estimates. The upper panel is for Model 1 (selected), whereas Model 2 (lower panel) includes allowing a random walk in survey catchability in 1997 and 2000, 2002, then constant from 2004-2010 (with $\sigma$ =0.1 for penalty on catchability change).

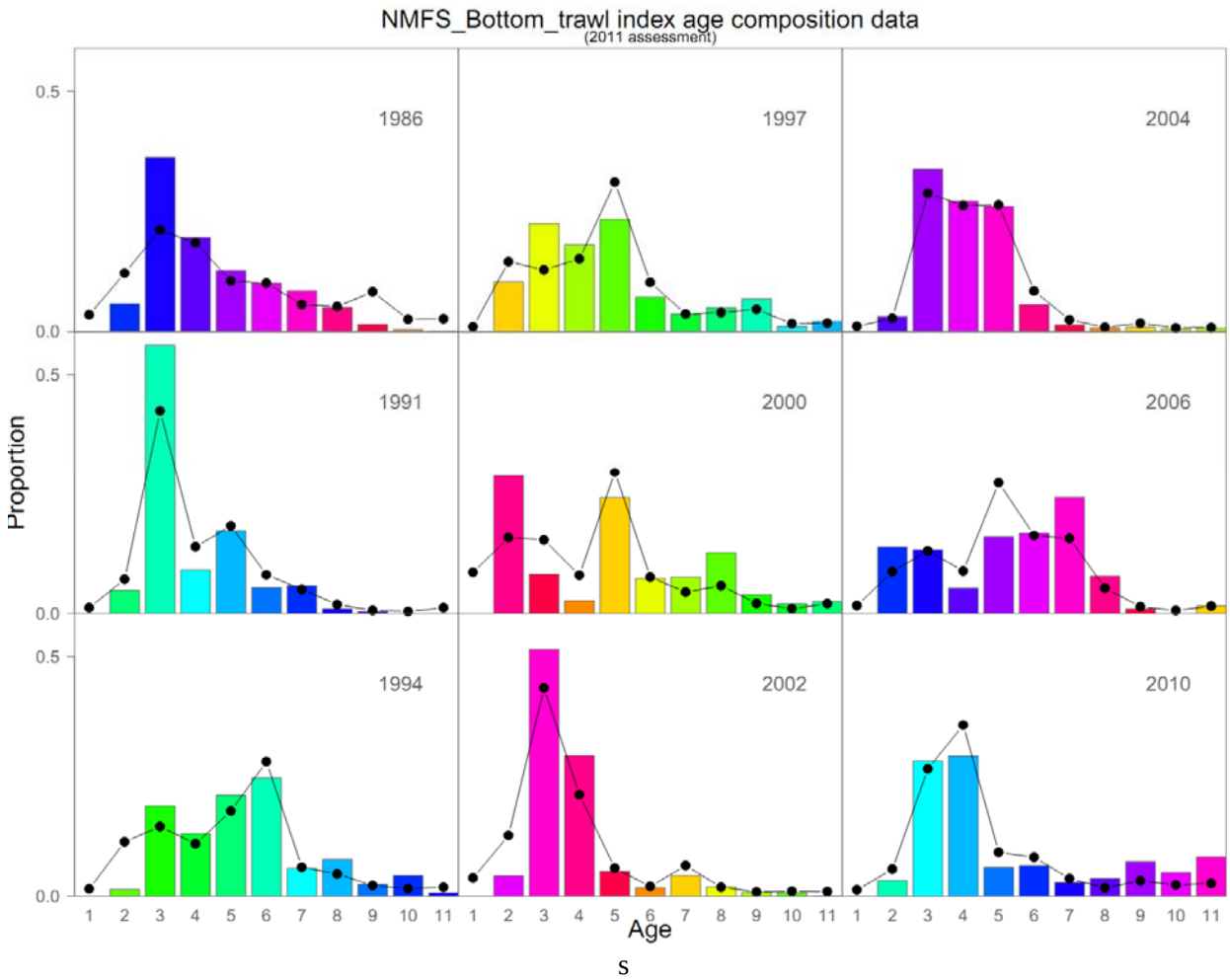



Figure 17.17. Observed and predicted **survey** proportions-at-age for BSAI Atka mackerel. Lines with "•" symbol are the model predictions and columns are the observed proportions at age (with colors corresponding to cohorts).

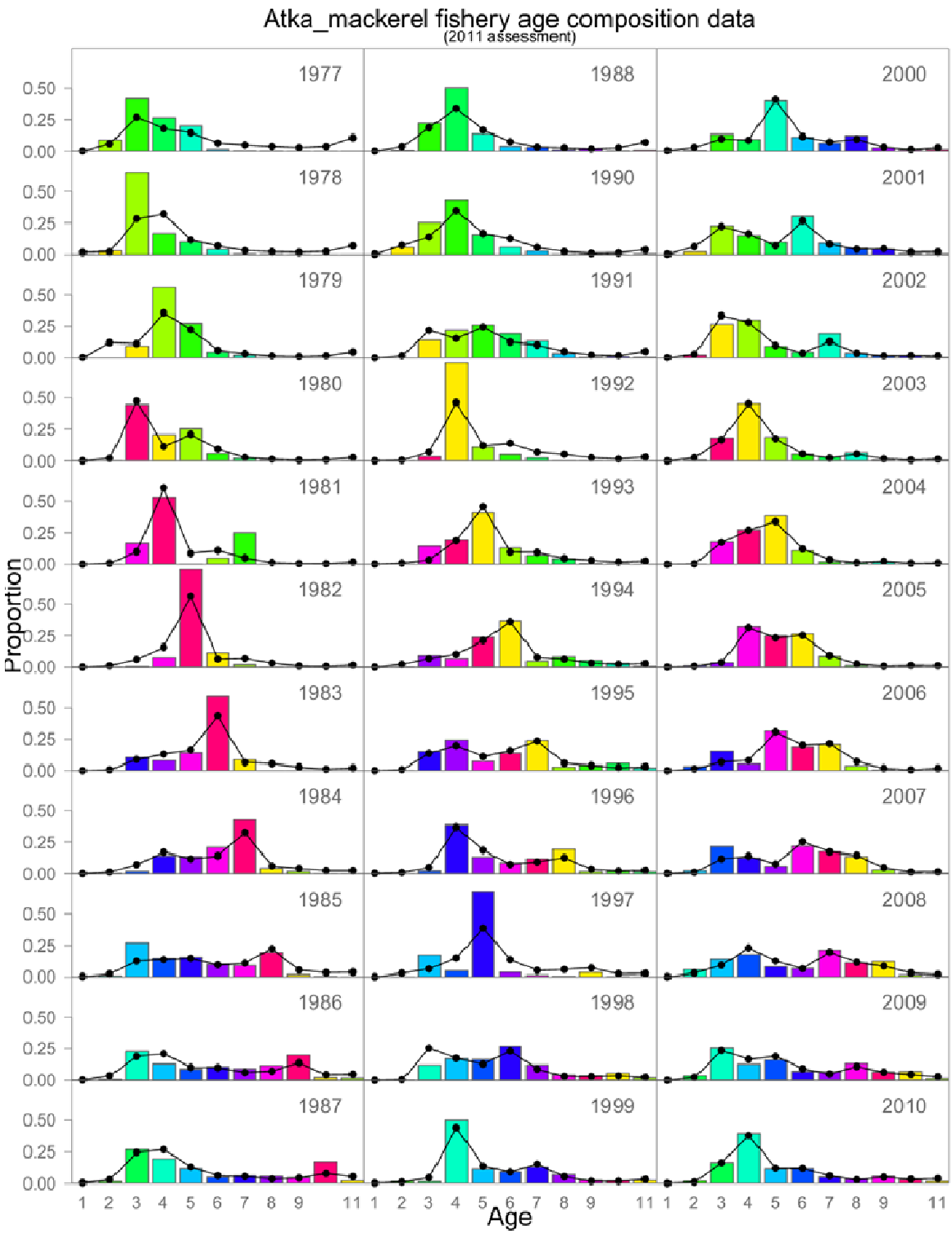
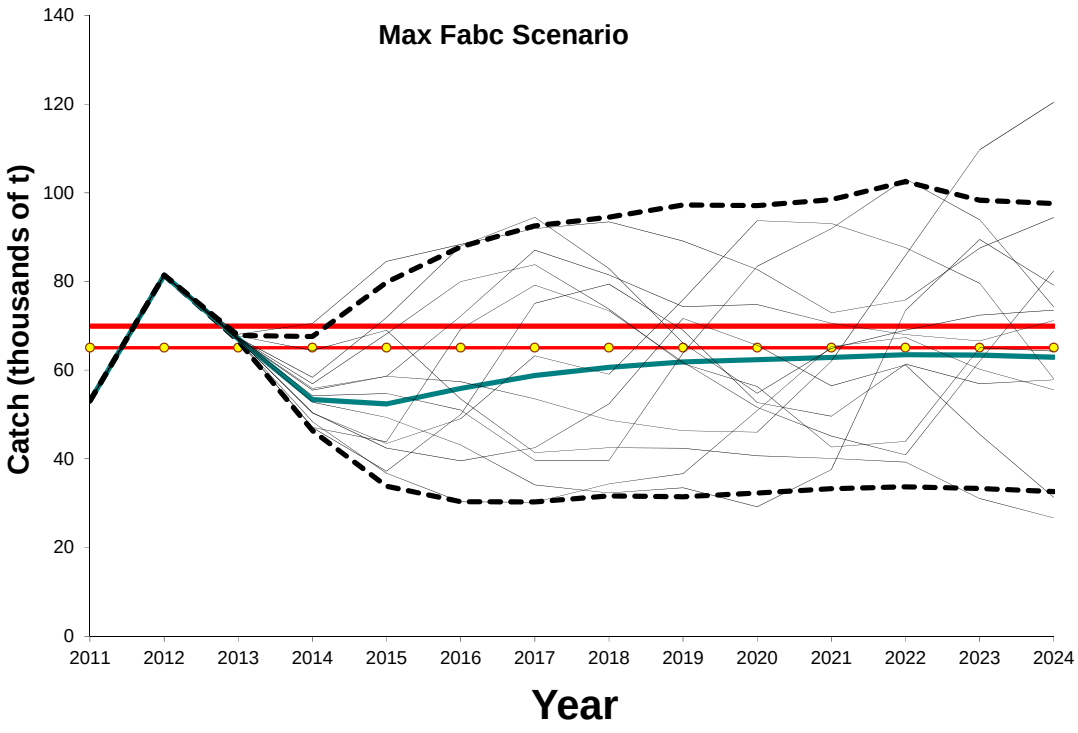



Figure 17.18. Observed and predicted Atka mackerel **fishery** proportions-at-age for BSAI Atka mackerel. Lines with "•" symbol are the model predictions and columns are the observed proportions at age (with colors corresponding to cohorts).



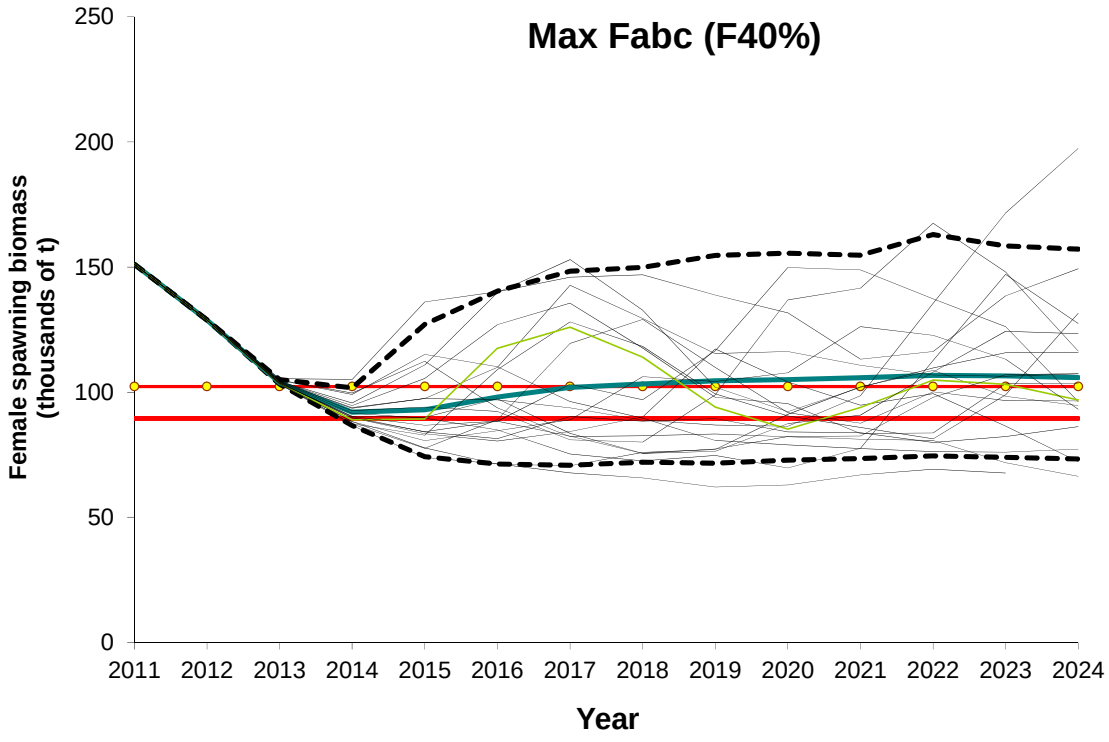




Figure 17.19. Projected catch in (top) and spawning biomass (bottom) in thousands of metric tons under maximum permissible Tier 3a harvest levels. The individual thin lines represent samples of simulated trajectories.

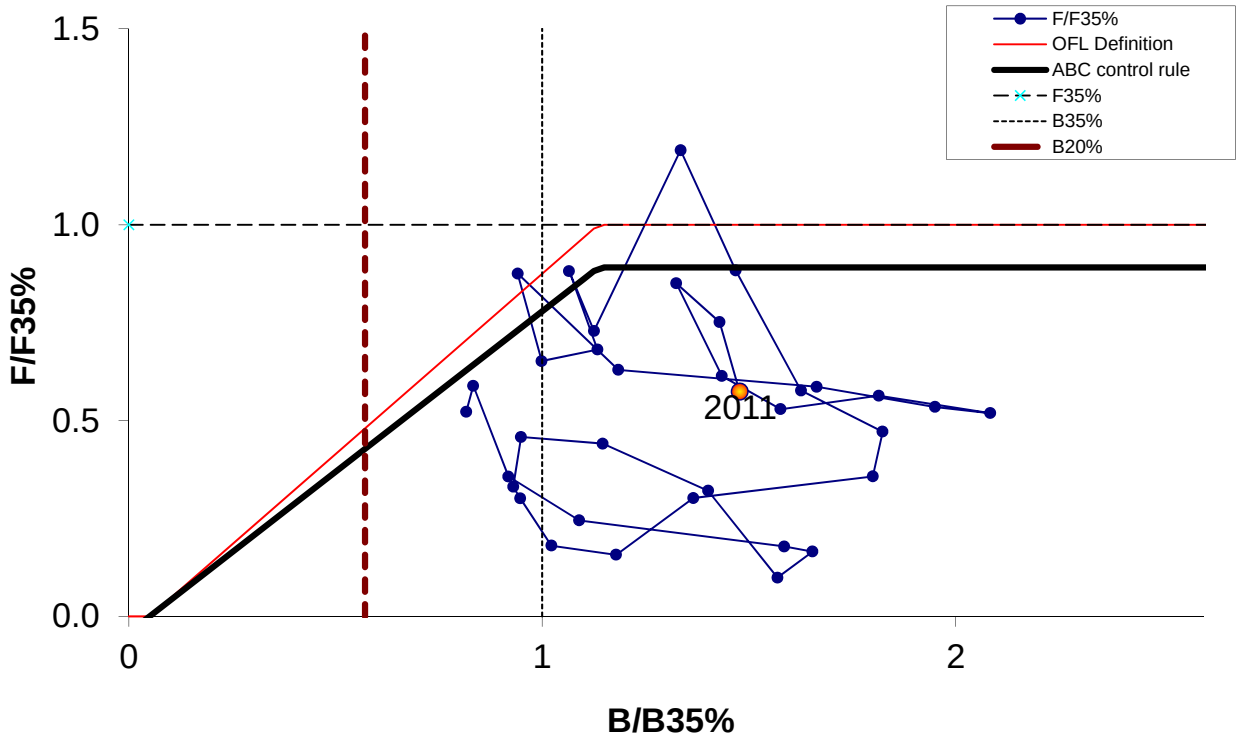



Figure 17.20. Aleutian Islands Atka mackerel spawning biomass relative to $B_{35\%}$ and fishing mortality relative to $F_{OFL}$ (1977-2011). The ratio of fishing mortality to $F_{OFL}$ is calculated using the estimated selectivity pattern in that year. Estimates of spawning biomass and $B_{35\%}$ are based on current estimates of 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.

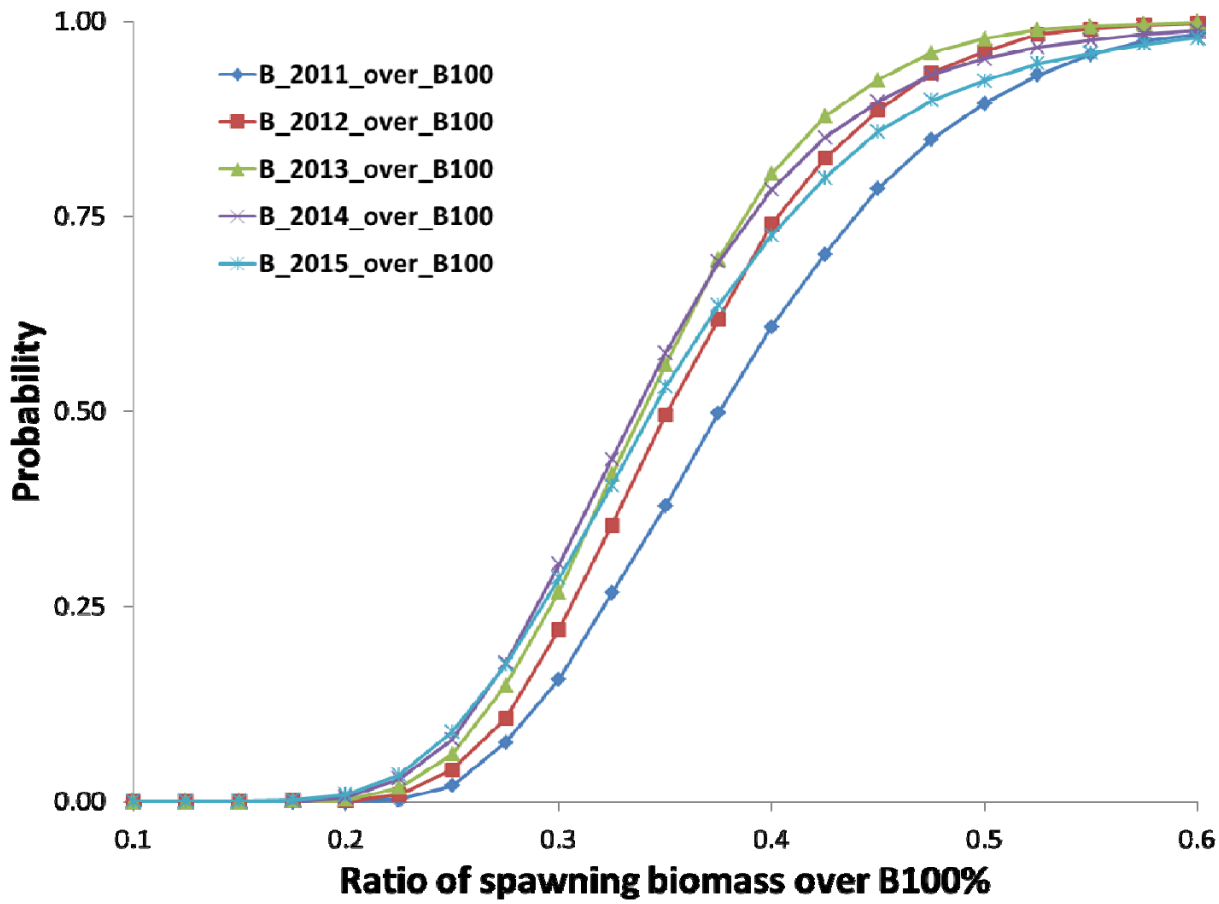



Figure 17.21. Posterior density projections of spawning biomass (relative to $B_{100\%}$) for Aleutian Islands Atka mackerel for the next 5 years under a strict $F_{50\%}$ harvest rate (similar to the fishing mortality rates incurred over the history of Atka mackerel). For the model as configured, this suggest that there is a very low probability that the stock is below $B_{20\%}$ (0.2 on horizontal scale). The joint posterior density was approximated by 1,000,000 MCMC simulations, storing every 200th sample to obtain these marginal cumulative probability estimates.

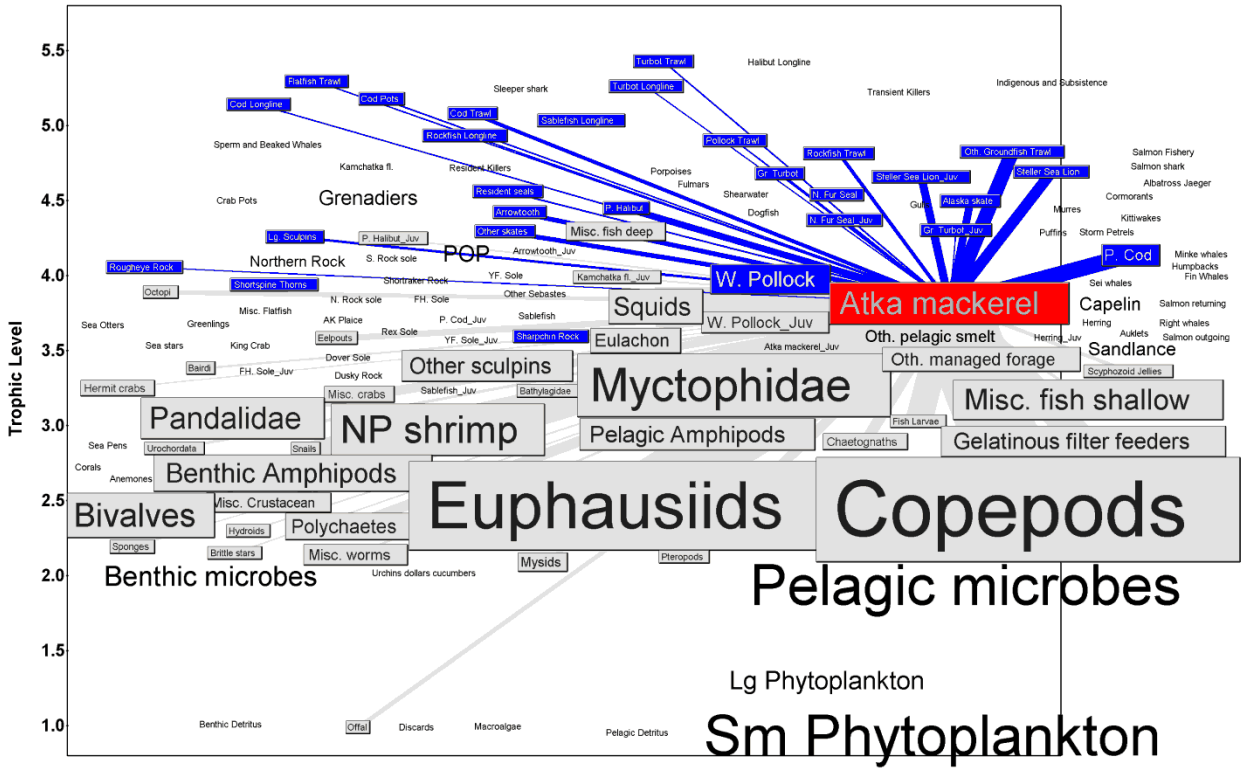
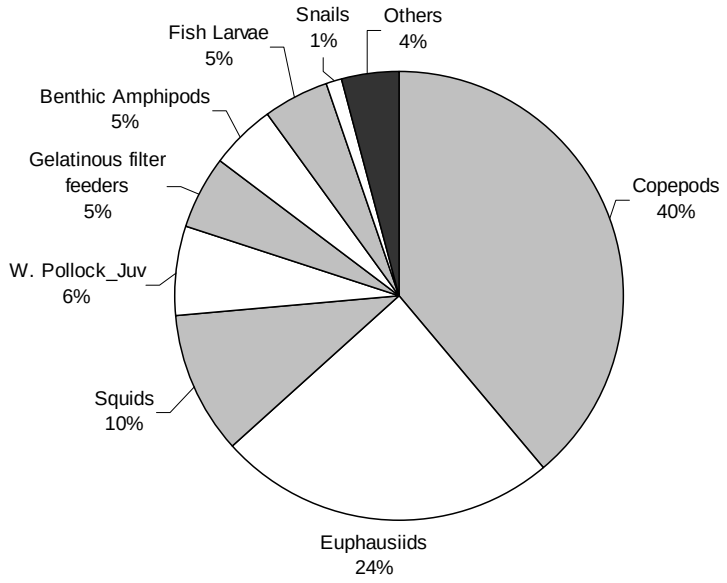
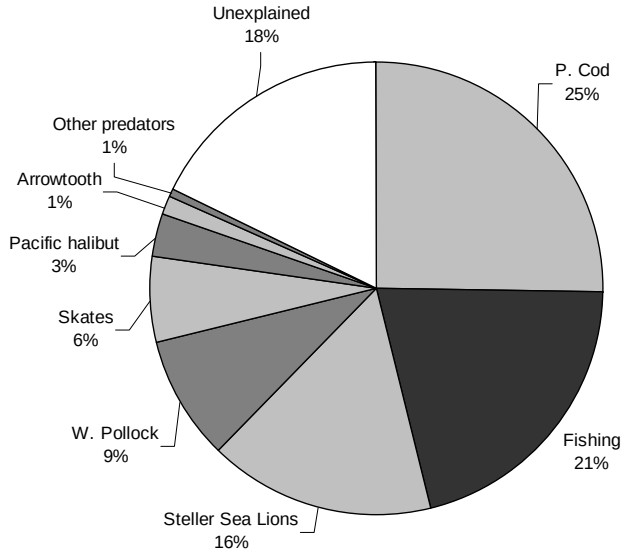



Figure 17.22. The food web of the Aleutian Islands survey region, 1990-1994, emphasizing the position of age 1+ Atka mackerel. Outlined species represent predators of Atka mackerel (dark boxed with light text) and prey of Atka mackerel (light boxes with dark text). Box and text size are proportional to each species' standing stock biomass, while line widths are proportional to the consumption between boxes (t/year). Trophic levels of individual species may be staggered up to +/-0.5 of a trophic level for visibility.




(A)




(B)

Figure 17.23. (A) Diet of age 1+ Atka mackerel, 1990-1994, by percentage wet weight in diet weighted by age-specific consumption rates. (B) Percentage mortality of Atka mackerel by mortality source, 1990-1994. "Unexplained" mortality is the difference between the stock assessment total exploitation rate averaged for 1990-1994, and the predation and fishing mortality, which are calculated independently of the assessment using predator diets, consumption rates, and fisheries catch.

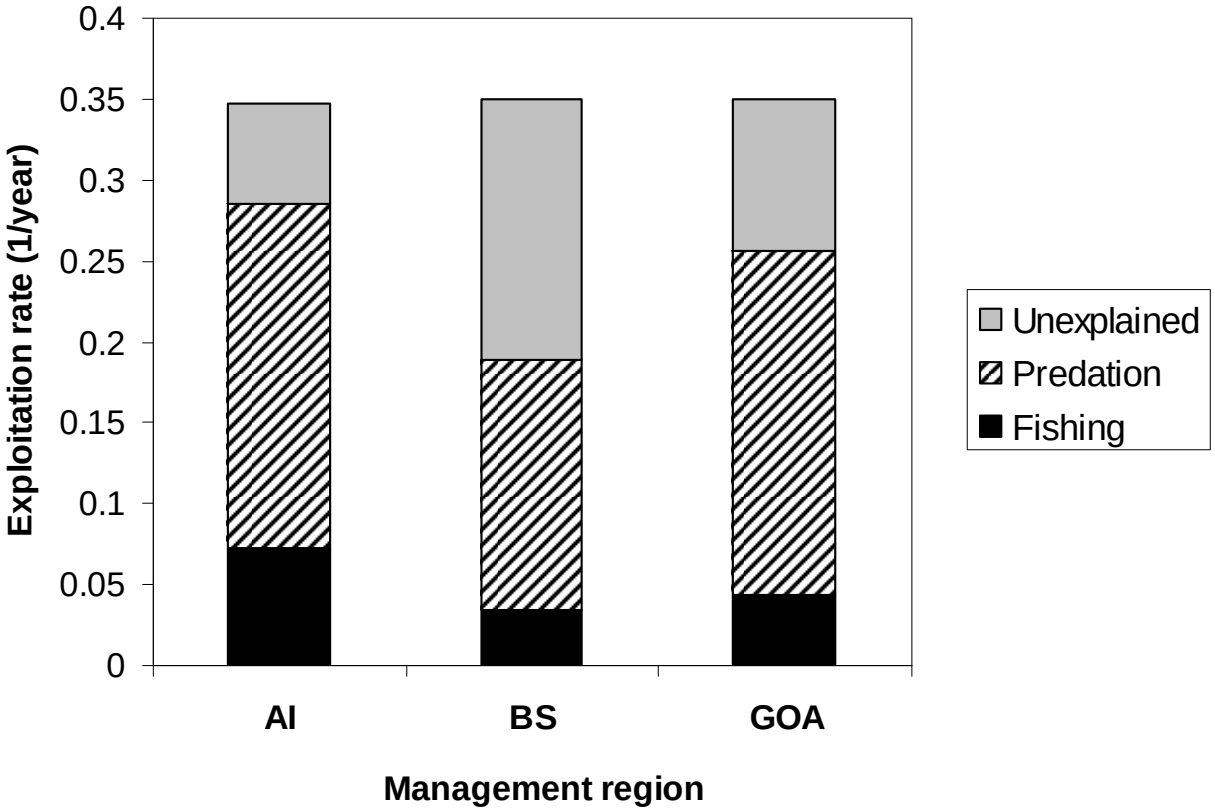



Figure 17.24. Total exploitation rate of age 1+ Atka mackerel, 1990-1994, proportioned into exploitation by fishing (black), predation (striped) and "unexplained" mortality (grey). "Unexplained" mortality is the difference between the stock assessment total exploitation rate averaged for 1990-1994, and the predation and fishing mortality, which are calculated independently of the assessment using predator diets, consumption rates, and fisheries catch.

Appendix 17.A

Table A-1. Variable descriptions and model specification.

| General Definitions | Symbol/Value | Use in Catch at Age Model |
|---|---|---|
| Year index: $i$ = {1977, …., 2011} | $i$ | |
| Age index: $j$ = {1, 2, 3, …, $A$} | $j$ | |
| Mean weight by age $j$ | $W_j$ | |
| Maximum age beyond which selectivity is constant | $Maxage$ | Selectivity parameterization |
| Instantaneous Natural Mortality | $M$ | Fixed $M$=0.30, constant over all ages |
| Proportion females mature at age $j$ | $p_j$ | Definition of spawning biomass |
| Sample size for proportion at age $j$ in year $i$ | $T_i$ | Scales multinomial assumption about estimates of proportion at age |
| Survey catchability coefficient | $q^s$ | Prior distribution = lognormal(1.0 , $\sigma_q^2$) |
| Stock-recruitment parameters | $R_0$ | Unfished equilibrium recruitment |
| | $h$ | Stock-recruitment steepness |
| | $\sigma_R^2$ | Recruitment variance |
| **Estimated parameters** | | |
| | $\phi_i(35),\ R_0,\ h,\ \varepsilon_i(45), \sigma_R^2,\ \mu^f,\ \mu^s,\ M,\ \eta_j^s(10),\ \eta_j^f(10),\ F_{50\%}, F_{40\%}, F_{30\%}, q^s$ | |

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

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

| Description | Symbol/Constraints | Key Equation(s) |
|---|---|---|
| Survey abundance index ($s$) by year | $Y_i^s$ | $\hat{Y}_i^s = q_i^s \sum_{j=1}^{A} s_j^s W_{ij} e^{Z_{i,j}\frac{7}{12}} N_{ij}$ |
| Catch-at-age by year | $C_{ij}$ | $\hat{C}_{ij} = N_{ij} \frac{F_{ij}}{Z_{ij}} \left(1 - e^{-Z_{ij}}\right)$ |
| Catch biomass | $\hat{C}_i^B$ | $\hat{C}_i^B = \sum_j W_{ij} \hat{C}_{ij}$ |
| Initial numbers at age | $j = 1$ | $N_{1977,1} = e^{\mu_R + \varepsilon_{1977}}$ |
| | $1 < j < A$ | $N_{1977,j} = e^{\mu_R + \varepsilon_{1978-j}} \prod_{j=1}^{j} e^{-M}$ |
| Maximum age | $j = A$ | $N_{1977,A} = N_{1977,A-1}\left(1 - e^{-M}\right)^{-1}$ |
| Subsequent years ($i > 1977$) | $j = 1$ | $N_{i,1} = e^{\mu_R + \varepsilon_i}$ |
| | $1 < j < A$ | $N_{i,j} = N_{i-1,j-1} e^{-Z_{i-1,j-1}}$ |
| | $j = A$ | $N_{i,15^+} = N_{i-1,14}\, e^{-Z_{i-1,14}} + N_{i-1,15}\, e^{-Z_{i-1,15}}$ |
| Year effect, $i$ = 1967, …, 2009 | $\varepsilon_i, \sum_{i=1967}^{2011} \varepsilon_i = 0$ | $N_{i,1} = e^{\mu_R + \varepsilon_i}$ |
| Index catchability<br>Mean effect | $\mu^s, \mu^f$ | $q_i^s = e^{\mu^s}$ |
| Age effect | $\eta_j^s, \sum_{j=1}^{A} \eta_j^s = 0$ | $s_j^s = e^{\eta_j^s}$ $j \le$ maxage |
| | | $s_j^s = e^{\eta_{\text{maxage}}^s}$ $j >$ maxage |
| Instantaneous fishing mortality | | $F_{ij} = e^{\mu_f + \eta_j^f + \phi_i}$ |
| mean fishing effect | $\mu_f$ | |
| Annual effect of fishing in year $i$ | $\phi_i, \sum_{i=1977}^{2011} \phi_i = 0$ | |
| Age effect of fishing (regularized) in year time variation allowed | $\eta_{ij}^f, \sum_{j=1}^{A} \eta_{ij} = 0$ | $s_{ij}^f = e^{\eta_j^f}$, $j \le$ maxage<br>$s_{ij}^f = e^{\eta_{\text{maxage}}^f}$ $j >$ maxage |
| In years where selectivity is constant over time | $\eta_{i,j}^f = \eta_{i-1,j}^f$ | $i \ne$ change year |
| Natural Mortality | $M$ | |
| Total mortality | | $Z_{ij} = F_{ij} + M$ |
| Recruitment<br>Beverton-Holt form | $\tilde{R}_i$ | $\tilde{R}_i = \frac{\alpha B_i}{\beta + B_i}$,<br>$\alpha = \frac{4hR_0}{5h-1}$ and $\beta = \frac{B_0(1-h)}{5h-1}$ where<br>$B_0 = \tilde{R}_0 \varphi$<br>$\varphi = \frac{e^{-AM} W_A p_A}{1 - e^{-M}} + \sum_{j=1}^{A} e^{-M(j-1)} W_j p_j$ |

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

| Likelihood /penalty component | | Description / notes |
|---|---|---|
| Abundance indices | $L_1 = \lambda_1 \sum_i \ln\left( Y_i^s \big/ \hat{Y}_i^s \right)^2 \frac{1}{2\sigma_i^2}$ | Survey abundance |
| Prior on smoothness for selectivities | $L_2 = \sum_l \lambda_2^l \sum_{j=1}^{A} \left( \eta_{j+2}^l + \eta_j^l - 2\eta_{j+1}^l \right)^2$ | Smoothness (second differencing), Note: $l=\{s,$ or $f\}$ for survey and fishery selectivity |
| Prior on recruitment regularity | $L_3 = \lambda_3 \sum_{i=1967}^{2010} \varepsilon_i^2$ | Influences estimates where data are lacking (e.g., if no signal of recruitment strength is available, then the recruitment estimate will converge to median value). |
| Catch biomass likelihood | $L_4 = \lambda_4 \sum_{i=1977}^{2010} \ln\left( C_i^B \big/ \hat{C}_i^B \right)^2$ | Fit to survey |
| Proportion at age likelihood | $L_5 = -\sum_{l,i,j} T_{ij}^l P_{ij}^l \ln\left( \hat{P}_{ij}^l \cdot P_{ij}^l \right)$ | $l=\{s, f\}$ for survey and fishery age composition observations |
| Fishing mortality regularity | $L_6 = \lambda_6 \sum_{i=1978}^{2010} \phi_i^2$ | (relaxed in final phases of estimation) |
| Priors | $L_7 = \left[ \lambda_7 \frac{\ln\left( M/\hat{M} \right)^2}{2\sigma_M^2} + \lambda_8 \frac{\ln\left( q/\hat{q} \right)^2}{2\sigma_q^2} \right]$ | Prior on natural mortality, and survey catchability (reference case assumption that these are precisely known at 0.3 and 1.0, respectively). |
| Overall objective function to be minimized | $\dot{L} = \sum_{i=1}^{7} L_i$ | |

Appendix 17B. Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total 2010 removals that do not occur during directed groundfish fishing activities. These include removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but do not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System (CAS) estimates. Estimates for Atka mackerel from this dataset are shown along with trawl survey removals from 1977-2009 in Table 17B-1. Removals from activities other than directed fishing totaled 140 t in 2010. This is approximately 0.2% of the 2010 ABC of 74,000 t and represents a very low risk to the stock. If these removals were accounted for in the stock assessment model, the recommended ABCs for 2012 and 2013 would likely change very little.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011). There are no reported catches >0.5 t of BSAI Atka mackerel from this dataset.

**References**

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

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

Table 17B-1. Total removals of BSAI Atka mackerel (t) from activities not related to directed fishing, since 1977. “Trawl” refers to a combination of the NMFS echo-integration; small-mesh; large-mesh; and Aleutian Islands bottom trawl surveys; and occasional short-term research projects involving trawl gear. “Longline” refers to either the NMFS or IPHC longline survey. “Other” refers to recreational, personal use, and subsistence harvest.

| | | | Longline | | | |
|---|---|---|---|---|---|---|
| Year | Source | Trawl | NMFS | IPHC | Other | Total |
| 1977 | AFSC | 0 | | | | 0 |
| 1978 | AFSC | 0 | | | | 0 |
| 1979 | AFSC | 0 | | | | 0 |
| 1980 | AFSC | 48 | | | | 48 |
| 1981 | AFSC | 0 | | | | 0 |
| 1982 | AFSC | 1 | | | | 1 |
| 1983 | AFSC | 151 | | | | 151 |
| 1984 | AFSC | 0 | | | | 0 |
| 1985 | AFSC | 0 | | | | 0 |
| 1986 | AFSC | 130 | | | | 130 |
| 1987 | AFSC | 0 | | | | 0 |
| 1988 | AFSC | 0 | | | | 0 |
| 1989 | AFSC | 0 | | | | 0 |
| 1990 | AFSC | 0 | | | | 0 |
| 1991 | AFSC | 77 | | | | 77 |
| 1992 | AFSC | 0 | | | | 0 |
| 1993 | AFSC | 0 | | | | 0 |
| 1994 | AFSC | 147 | | | | 147 |
| 1995 | AFSC | 0 | | | | 0 |
| 1996 | AFSC | 0 | | | | 0 |
| 1997 | AFSC | 85 | | | | 85 |
| 1998 | AFSC | 0 | | | | 0 |
| 1999 | AFSC | 0 | | | | 0 |
| 2000 | AFSC | 105 | | | | 105 |
| 2001 | AFSC | 0 | | | | 0 |
| 2002 | AFSC | 171 | | | | 171 |
| 2003 | AFSC | 0 | | | | 0 |
| 2004 | AFSC | 240 | | | | 240 |
| 2005 | AFSC | 0 | | | | 0 |
| 2006 | AFSC | 99 | | | | 99 |
| 2007 | AFSC | 0 | | | | 0 |
| 2008 | AFSC | 0 | | | | 0 |
| 2009 | AFSC | 0 | | | | 0 |
| 2010 | AKRO | 140 | 0 | 0 | 0 | 140 |

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