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

Sandra Lowe, James Ianelli, and Wayne Palsson

Executive Summary

Relative to the November 2014 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 2014 fishery age composition data were added.
3. The 2014 survey age composition data were added.
4. Total 2014 year end catch estimate was updated, and the projected total catch for 2015 was set equal to the 2015 TAC (54,500 t), based on the catch amounts occurring after Oct. 1 in recent years.
5. The estimated average selectivity for 2011-2015 was used for projections.
6. We assume that 80% of the BSAI-wide ABC is likely to be taken under the revised Steller Sea Lion Reasonable and Prudent Alternatives (SSL RPAs) implemented in 2015. This percentage was applied to the 2016 maximum permissible ABC, and that amount (72,240 t) was assumed to be caught in order to estimate the 2017 ABCs and OFL values. The 2017 catch is assumed equal to the 2017 maximum permissible ABC.

Summary of Changes in the Assessment Methodology

There were no changes to the assessment methodology.

Summary of Results

1. The addition of the 2014 fishery and survey age composition information impacted the estimated magnitude of the 2006-2007 year classes which both increased 15%, and the magnitude of the 2011 year class which increased 24%, relative to last year's assessment.
2. Estimated values of $B_{100\%}$, $B_{40\%}$, $B_{35\%}$ are 2% higher relative to last year's assessment.
3. Projected 2016 female spawning biomass (166,407 t) is essentially unchanged relative to last year's estimate of 2015 female spawning biomass (<1% decrease).
4. Projected 2016 female spawning biomass is above $B_{40\%}$ (135,654 t), thereby placing BSAI Atka mackerel in Tier 3a.
5. The projected 2016 yield at $maxF_{ABC} = F_{40\%} = 0.30$ is 90,340 t, which is 15% lower relative to last year's estimate for 2015.
6. The projected 2016 overfishing level at $F_{35\%}$ ($F = 0.35$) is 104,749 t, which is 16% lower than last year's estimate for 2015.

Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *recommended this* year for: 2016*	2017*
M (natural mortality rate)	0.30	0.30	0.30	0.30
Tier	3a	3a	3a	3a
Projected total (age 1+) biomass (t)	694,421	673,327	672,184	664,208
Projected Female spawning biomass				
Projected	167,136	146,682	166,407	147,496
$B_{100\%}$	333,237	333,237	339,135	339,135
$B_{40\%}$	133,295	133,295	135,654	135,654
$B_{35\%}$	116,633	116,633	118,697	118,697
F_{OFL}	0.489	0.489	0.35	0.35
$maxF_{ABC}$	0.403	0.403	0.30	0.30
F_{ABC}	0.403	0.403	0.30	0.30
OFL (t)	125,297	115,908[1]	104,749	99,490[1]
maxABC (t)	106,000	98,137[1]	90,340	85,840[1]
ABC (t)	106,000	98,137[1]	90,340	85,840[1]
Status	As determined *last* year for: 2013	2014	As determined *this* year for: 2014	2015
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on estimated total catch of 72,240 t in place of maximum permissible ABC for 2016, and 85,840 t equal to maximum permissible ABC for 2017.

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

Area apportionment of ABC

The apportionments of the 2016 and 2017 recommended ABCs based on the random effects model as requested by the SSC:

	2016 (t)	2017 (t)
Eastern (541+S.BSea)	30,832	29,296
Central (542)	27,216	25,860
Western (543)	32,292	30,684
Total	90,340	85,840

Responses to SSC and Plan Team Comments on Assessments in General

From the December 2014 SSC minutes: *The SSC requests that stock assessment authors use the following model naming conventions in SAFE chapters:*

- *Model 0: last years' model with no new data,*
- *Model 1: last years' model with updated data, and*
- *Model numbers higher than 1 are for proposed new models.*

Last year’s model with updated data is denoted Model 1 in the current assessment. However, we did not use the naming convention of Model 0 to refer to last year’s model with no new data, to avoid confusion.

Several references are made in this assessment to last year's model which was denoted Model 1 in last year's assessment, therefore it would be confusing (and incorrect) to reference Model 0 in last year's assessment. For clarity we refer to last year's Model 1 when referring to last year's model with no new data. Moving forward we will attempt to comply with the naming conventions.

The SSC also requests that stock assessment authors use the random effects model for area apportionment of ABCs. We provide (and recommend) the area apportionments of the 2016 and 2017 recommended ABCs based on the random effects model.

Responses to SSC and Plan Team Comments Specific to the Atka Mackerel Assessment

From their December 2014 minutes: *The SSC suggests that the high variability in survey abundance and trend estimates is the major source of uncertainty in the assessment, and should be featured prominently in "Data Gaps and Research Priorities".* The "Data Gaps and Research Priorities" section has been expanded to address concerns about the high variability in survey abundance and trend estimates.

The *SSC recommends the use of the random effects procedure for setting subarea ABC allocations in the future.* The random effects model was used to provide subarea ABC allocations for the 2016 and 2017 recommended ABCs. We also include the 4-survey average method used to obtain the 2015 allocations for comparison purposes.

From the November 2014 BSAI Plan Team minutes:
There were no Plan Team recommendations specific to the Atka mackerel assessment.

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 (AI), north along the eastern Bering Sea (EBS) shelf, and through the Gulf of Alaska (GOA) 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 GOA. 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).

In the eastern and central AI, 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 mm (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 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 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

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 AI 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 AI are inside fishery trawl exclusion zones which may serve as *de facto* marine reserves for protecting Atka mackerel (Cooper *et al*. 2010).

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. 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° C to 169 days at 1.6 °C, however, an incubation water temperature of 15 °C was lethal to developing embryos *in situ* (Guthridge and Hillgruber 2008). 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, Sinclair *et al*. 2013), 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.

Rand *et al*. (2010) analyzed Atka mackerel stomach data and determined that the east to west size cline in Atka mackerel sizes across the Aleutian Islands, was the result of food quality rather than food quantity or temperature, and may reflect local productivity. Atka mackerel near Amchitka Island (area 542) were eating more copepods and less euphausiids, whereas fish at Seguam pass (area 541) were eating more energy rich euphausiids and forage fish (Rand *et al*. 2010).

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 GOA and the AI (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, AI, and GOA. 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 GOA with samples from the eastern, central, and western AI 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 AI, Japan, and the GOA 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 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 GOA 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 AI or a self-perpetuating population in the GOA, 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. More recently, the strong 1999 and 2006 year classes documented in the AI showed up in the GOA. 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 Total Allowable Catches (TAC). Since 1994, the BSAI Atka mackerel TAC has been allocated to the three regions (541 Eastern Aleutians, 542 Central Aleutians, and 543 Western Aleutians).

Fishery

Catch History

Annual catches of Atka mackerel in the EBS and AI regions increased during the 1970s reaching an initial peak of over 24,000 t in 1978 (see BSAI SAFE Introduction 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), TAC, and Overfishing Levels (OFL) set by the North Pacific Fishery Management Council (NPFMC or 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 AI.

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 AI (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 0.5° 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 2014 and 2015 fishery operations are shown in Fig. 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 March 11, 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 AI subarea (based on the assessment for the 1993 fishery; Lowe 1992). In mid-1993, however, Amendment 28 to the 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 (Fig. 17.1). On August 11, 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 AI bottom trawl surveys. Table 17.2 gives the time series of BSAI Atka mackerel catches, corresponding ABC, OFL, 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 AI. 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 January 22, 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 August 8, 2000 through November 30, 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 were randomly assigned to one of two teams, which started fishing in either area 542 or 543. Vessels were not permitted to switch areas until the other team had 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, was closed to directed Atka mackerel fishing.

The 2010 NMFS Biological Opinion (BiOp) found that the fisheries for Alaska groundfish in the Bering Sea and AI and GOA, 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 BiOp found jeopardy and adverse modification of critical habitat, the agency was required to implement reasonable and prudent alternatives (RPAs) to the proposed actions (the fisheries). The 2010 BiOp included RPAs which required changes in groundfish fishery management in Management Sub-areas 543, 542, and 541 in the AI Management Area. NOAA Fisheries implemented the RPAs via an interim final rule before the start of the 2011 fishery in January.

Subsequently, the U.S. District Court ordered NMFS to prepare an Environmental Impact Statement (EIS) on the interim final rule. The NPFMC preferred alternative in the draft EIS for the final EIS differed from the interim final rule, and a reinitiation of consultation was requested for the proposed action under the preferred alternative. The NMFS Section 7 Consultation BiOp determined that the proposed action is not likely to jeopardize the continued existence of the western DPS of Steller sea lions and is not likely to destroy or adversely modify designated critical habitat (NMFS 2014a). The final EIS was issued May, 2014 (NMFS 2014b). The modifications to the RPAs went in to effect for the 2015 fishing year.

The RPAs from the 2010 BiOp and the 2014 Section 7 Consultation Biological Opinion specific to Atka mackerel are listed below.

RPAs from the 2010 Biological Opinion

In Area 543:

- 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.

In Area 542:

- 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 Area 543 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.

<u>In Bering Sea Subarea</u>:

- Close the Bering Sea subarea year round to directed fishing for Atka mackerel.
- Prohibit trawling for Atka mackerel from 0 to 20 nm around all Steller sea lion rookeries and haulouts and in the Bogoslof Foraging Area.

Revised RPAs from the 2014 Biological Opinion

The season dates for the AI Atka mackerel trawl fishery are modified relative to the action analyzed in the 2010 Biological Opinion. The season dates from the action in the 2010 BiOp, the interim final rule, and the 2014 BiOp are shown in the table below. The interim final rule changed the Atka mackerel trawl season dates to align the Atka mackerel seasons with the AI pollock and Pacific cod trawl fisheries and to temporally disperse catch. The Atka mackerel trawl fishery season dates are extended even further under the 2014 BiOp.

Atka mackerel trawl fishery season dates in 2010 Biological Opinion (BiOp), 2011–2014 Interim Final Rule, and the 2014 BiOp:

	A Season		B Season	
	Start	End	Start	End
Action in 2010 BiOp	20-Jan	15-Apr	1-Sep	1-Nov
Interim Final Rule	20-Jan	10-Jun	10-Jun	1-Nov
Action in 2014 BiOp	20-Jan	10-Jun	10-Jun	31-Dec

<u>In Area 543</u>:

- Modify the closure around Buldir Island from a 0 to 15 nm closure to trawl fishing for Atka mackerel to a 0 to 10 nm closure.
- Limit the Area 543 Atka mackerel TAC to less than or equal to 65 percent of the ABC.

The action analyzed in the 2010 BiOp did not include an Area 543-specific Atka mackerel harvest limit and prohibited directed fishing for Atka mackerel and Pacific cod.

<u>In Area 542</u>:

- Close Stellar sea lion CH to Atka mackerel fishing between 178°E and 180° longitude.
- Increase 0 to 10 nm closures to 0 to 20 nm closures year-round at five rookeries (Ayugadak Point, Amchitka/Column Rocks, Amchitka Island/East Cape, Semisopochnoi/Petrel, and Semisopochnoi/Pochnoi)
- Increase 0 to 3 nm closures to 0 to 20 nm at six haulouts (Unalga and Dinkum Rocks, Amatignak Island/Nitrof Point, Amchitka Island/Cape Ivakin, Hawadax Island (formerly Rat Island), Little Sitkin Island, and Segula Island).

The action analyzed in the 2010 BiOp included an Area 542-specific Atka mackerel harvest limit which set TAC for Area 542 to no more than 47 percent of the Area 542 ABC. The proposed action does not include an Area 542-specific Atka mackerel harvest limit.

<u>In Area 541</u>:

- Open a portion of CH in Area 541 from 12 to 20 nm southeast of Seguam Island.
- Beyond the 50 percent seasonal apportionments there would be no limit on the amount of the Atka mackerel TAC that could be harvested inside this open area of CH.

All of CH in Area 541 was closed to Atka mackerel fishing under the action analyzed in the 2010 BiOp. Fishing for Atka mackerel has been prohibited in Steller sea lion CH in Area 541 since 2001.

In Bering Sea Subarea:
Management of the Atka mackerel TAC in the AI Area 541 is combined with the Bering Sea subarea. In general, the harvest of Atka mackerel in the Bering Sea is incidental to harvest of other groundfish target species, and occurs in relatively small quantities in critical habitat areas closed to directed fishing for Atka mackerel

- Modify maximum retainable amount (MRA) regulations for Amendment 80 vessels and Western Alaska Community Development Quota (CDQ) entities operating in the Bering Sea subarea to revise the method for calculating the MRA.

The effect of the modifications in the Bering Sea subarea would provide for more of the combined Bering Sea/541 Atka mackerel TAC to be harvested in the Bering Sea subarea rather than the AI.

Amendment 78 to the BSAI Groundfish FMP closed a large portion of the AI subarea to nonpelagic trawling. The Amendment 78 closures to nonpelagic trawling include the AI Habitat Conservation Area (AIHCA), the AI Coral Habitat Protection Areas, and the Bowers Ridge Habitat Conservation Zone, located in the northern portion of Area 542 and 543. These closures were implemented on July 28, 2006. These closures are in addition to the Steller sea lion protection measures and, in combination, substantially limit the locations available for nonpelagic trawling in the AI subarea

Amendment 80 to the BSAI Groundfish FMP was adopted by the Council in June 2006 and implemented for the 2008 fishing year. This action allocated several BSAI non-pollock trawl groundfish species (including Atka mackerel) among trawl fishery sectors, facilitated the formation of harvesting cooperatives in the non-American Fisheries Act (non-AFA) trawl catcher/processor sector, and established a limited access privilege program (also referred to as a catch share program). BSAI Atka mackerel is one of the groundfish species directly affected by Amendment 80. Participation in the Atka mackerel fishery is now limited as a result of Amendment 80. In addition, the Alaska Seafood Cooperative (AKSC) formerly the Best Use Cooperative was 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. Discard data have been available for the groundfish fishery since 1990. Discards of Atka mackerel for 1990-1999 and 2000-2005 have been presented in previous assessments (Lowe *et al.* 2003 and Lowe *et al*. 2011, respectively).

Bering Sea/Aleutian Islands Atka mackerel discard data from 2006 to the present are given below:

Year	Fishery	Discarded (t)	Retained (t)	Total (t)	Discard Rate (%)
2006	Atka mackerel	1,793	57,815	59,608	3.0
	All others	1,252	1,035	2,287	
	All	3,045	58,850	61,895	
2007	Atka mackerel	1,730	55,563	57,293	3.0
	All others	324	1,130	1,454	
	All	2,054	56,693	58,747	
2008	Atka mackerel	1,091	54,024	55,114	2.0
	All others	158	2,810	2,968	
	All	1,249	56,834	58,082	
2009	Atka mackerel	2,620	67,271	69,891	3.7
	All others	326	2,590	2,916	
	All	2,946	69,861	72,807	
2010	Atka mackerel	3,880	63,191	67,071	5.8
	All others	95	1,480	1,575	
	All	3,975	64,671	68,646	
2011	Atka mackerel	1,191	47,377	48,568	2.5
	All others	575	2,667	3,242	
	All	1,766	50,044	51,810	
2012	Atka mackerel	929	44,097	45,026	2.1
	All others	415	2,384	2,799	
	All	1,344	46,481	47,825	
2013	Atka mackerel	448	19,387	19,835	2.3
	All others	254	3,092	3,346	
	All	702	22,479	23,181	
2014	Atka mackerel	113	28,053	28,166	0.4
	All others	274	2,511	2,785	
	All	387	30,564	30,951	

Discard rates have been 2-3% until 2009 when the discard rate increased to nearly 4%. The increases in 2009 and 2010 may have been due to large numbers of small fish from the 2006 and 2007 year classes. In 2011, Steller sea lion protection measures were implemented which resulted in closures of the Western and Central Aleutian sub-areas (543, 542) to the Atka mackerel fishery and a reduction in the Atka mackerel TAC in the Central Aleutian sub-area (542). The large decrease in the 2011 discard rate likely reflects regulatory changes to the operation of the Atka mackerel fishery. Most recently, the discard rate dropped significantly to less than 1% in 2014.

Until 1998, discard rates of Atka mackerel by all fisheries have generally been greatest in the western AI (543) and lowest in the east (541, Lowe *et al.* 2003). In the 2004 fishery, the discard rates decreased in both the central and western Aleutians (542 & 543) while the eastern rate increased (Lowe *et al*. 2011). Subsequently, the 2005 discard rates dropped significantly in all three areas, contributing to the large overall drop in the 2005 discard rate (Lowe *et al.* 2011). Discard rates have continued to decrease in eastern AI (541) since 2005, and the discard rates in the Central AI (542) have increased, reflecting a shift in effort of the Atka mackerel fishery. The 2011-2014 data from the Western AI (543) are minimal Atka mackerel catches from the rockfish fisheries; directed fishing for Atka mackerel in 543 is prohibited under Steller sea lion protection measures. The discard rates in the Eastern and Central AI dropped significantly in 2014 to less than 1%.

		Aleutian Islands Subarea		
Year		**541**	**542**	**543**
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	22,180	15,650
	Discarded (t)	18	746	395
	Rate	***0.1%***	***3%***	***2%***
2009	Retained (t)	25,734	28,415	15,512
	Discarded (t)	439	1,722	740
	Rate	***2%***	***6%***	***5%***
2010	Retained (t)	23,073	24,035	17,460
	Discarded (t)	384	2,354	1,190
	Rate	***2%***	***9%***	***6%***
2011	Retained (t)	39,214	9,828	0.3
	Discarded (t)	467	886	205
	Rate	***2%***	***8%***	***100%***
2012	Retained (t)	36,034	9,599	0.2
	Discarded (t)	308	723	195
	Rate	***1%***	***7%***	***100%***
2013	Retained (t)	15,481	416	1.3
	Discarded (t)	149	6,867	119
	Rate	***1%***	***6%***	***99%***
2014	Retained (t)	21,011	9,434	2
	Discarded (t)	42	86	240
	Rate	***0.2%***	***0.9%***	***99%***

Steller Sea Lions and Atka Mackerel Fishery Interactions

Since 1979, the Atka mackerel fishery has occurred largely within areas designated 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, past fishery harvest rates may have been high enough to affect prey availability of Steller sea lions in localized areas (Lowe and Fritz 1997). The localized pattern of fishing for Atka mackerel does not appear to affect fishing success from one year to the next because local populations in the Aleutian Islands are likely replenished by immigration and recruitment. However, temporary reductions in the size and density of localized Atka mackerel populations may have affected Steller sea lion foraging success during the time the fishery was operating in critical habitat, and this effect may have persisted for a period of unknown duration after the fishery was excluded from critical habitat. As a precautionary measure, 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 has ongoing tagging studies to determine the efficacy of trawl exclusion zones as a fishery-Steller sea lion management tool and to determine the local movement rates of Atka mackerel. Since 2000, the AFSC has released over 130,000 tagged fish and has recovered over 3,000 tagged fish. These studies are conducted to determine small scale changes in abundance and distribution of Atka mackerel around all of the major Steller sea lion rookeries along the Aleutian Island chain that are also targeted fishing areas for

Atka mackerel. Mark- recapture methods have been successful for this species because the variance estimates obtained are unaffected by species patchiness, and tagging and handling mortality are very low (less than 4% in previous studies). In addition, the fishing industry has aided in the tag recovery process, substantially reducing the expense of chartering survey vessels.

The tagging studies conducted near Seguam Pass (in area 541) in August 2000, 2001 and 2002 indicated that the 20 nm trawl exclusion zones around the rookeries on Seguam and Agligadak Islands are effective in minimizing disturbance to prey fields within them (McDermott *et al*. 2005). 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 in area 541 at Seguam regarding the efficacy of the trawl exclusion zone may not generally apply to other, smaller zones to the west. The tagging studies were expanded to management area 542, both 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 overlaying apparent natural boundaries to local aggregations. Movement rates at Amchitka were higher relative to Seguam. The boundaries at Amchitka bisect Atka mackerel habitat, unlike the boundaries at Seguam and Tanaga

After the release of the 2010 BiOp and implementation of the closure of area 543 to the Atka mackerel and Pacific cod fisheries, additional tagging studies were conducted with the primary objective of examining Atka mackerel populations near rookeries in all areas open to directed Atka mackerel fishing in the Aleutian Islands. Since 2006, NMFS has been working cooperatively with the North Pacific Fisheries Foundation (NPFF) to conduct field work. In May to June 2011 NMFS, in collaboration with NPFF, released 8,500 tagged fish in the Eastern Aleutian Islands subarea (Seguam pass, area 541) and 19,000 fish in the Central Aleutian Islands subarea (Tanaga pass and Petrel bank, area 542). In May and June 2014, an additional 20,000 fish were tagged and released in the Western Aleutian Islands (Buldir Island, Western Aleutian Island Seamounts, Aggatu Island, and Ingenstrem Rocks, area 543) as well as Seguam Pass in the Eastern Aleutian Islands Aleutian Islands (area 541). Tag recovery surveys were conducted by a chartered fishing vessel and augmented with recoveries from the fishery.

Additionally, during the 2012 tag recovery survey there was an opportunity to study the prey distribution of a Steller sea lion adult female that was tagged with a satellite-tracking tag in November 2011 by the AFSC National Marine Mammal Laboratory. A hydroacoustic transect was conducted, species composition data was collected from trawl hauls, and camera tows were conducted in the area where the sea lion was feeding (South Petrel Bank). This provided a unique opportunity to investigate possible prey species availability during the same time and in the same location where the tagged female sea lion was diving. The Steller sea lion appeared to be diving in an area with high prey diversity: 5 spatially close trawl hauls each a captured a different predominant prey species (including Pacific ocean perch, northern rockfish, walleye pollock, Pacific cod, and Atka mackerel (McDermott *et al*. 2014); http://www.afsc.noaa.gov/REFM/Stocks/fit/FITcruiserpts.htm.

These studies indicate that Atka mackerel exhibit very little large scale movement, with 98.5 % of tagged fish being recovered in the same study areas as they were released. The tagging model population and biomass estimates at the three study areas in the Eastern and Central Aleutian Islands showed large biomass estimates at Seguam Pass (541) and Petrel bank (542), both with approximately 190,000 t in the area open to fishing, and an estimated smaller biomass estimate (29,000 t) at Tanaga pass (542). In all three areas the local exploitation rate was below 10%, with 8% at Seguam pass, 4% at Petrel bank and 2% at Tanaga pass. These low exploitation rates indicated that there was little concern for localized depletion in the areas open to fishing in the Eastern and Central Aleutian Islands during 2011-2012 (McDermott *et al*. 2014). In 2015, several of the areas closed in 2010, including the Western Aleutians (area 543), were reopened to commercial fishing. Analysis of the local population biomass estimates from 2014 to 2015 in the Western Aleutian Islands is ongoing.

Data

Fishery Data

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 2014 and preliminary 2015 fisheries by management area are shown in Figures 17.2 and 17.3, respectively. The modes at about 33-37 cm and 37-40 cm in the 2014 and 2015 fishery length distributions respectively, represent the 2011 year class which dominated the 2014 fishery catch. The available 2015 fishery data are presented and should be considered preliminary, but are similar to the 2014 distributions. A significant difference in 2015 is the presentation of data from fish sampled from area 543, which was previously closed to directed fishing for Atka mackerel. A bimodal distribution of fish is apparent in the 2015 distributions, and the modes at 28 and 31 cm may represent 2 year olds from the 2010 year class.

Fishery Age Data

Fishery data consist of total catch biomass from 1977 to 2014 and projected end of year 2015 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 1977-2014 (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 1990-2013 (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 and 2011 year classes which showed up in the 2009-2010 and 2014 fisheries, respectively. 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 exceptionally 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 2012 fishery data are dominated by 5 and 6-year-olds of the 2007 and 2006 year classes, respectively, and continue to show the presence of the 2001 year class. Significant numbers of 4 year olds of the 2009 year class were observed in the 2013 catch. Most recently, the 2011 year class dominated the 2014 fishery catch-at-age data, which also showed the continued presence of large numbers of the 2009 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; (3) their schooling behavior and patchy distribution result in survey estimates associated with large variances; and 4) Atka mackerel are thought to be very responsive to tide cycles. During extremes in the tidal cycle, Atka mackerel may not be accessible which could affect their availability to the survey. Despite these shortcomings, the U.S.-Japan cooperative trawl surveys conducted in 1980, 1983, 1986, and the 1991- 2014 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*. 2004).

Aleutian Islands trawl survey biomass estimates of Atka mackerel varied from 63,215 t in 1980 to 1,121,148 t in 1986 and 1,157,084 t in 2004 (Tables 17.5 and 17.6). 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. 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 2014 Aleutian Islands bottom trawl survey is 723,928 t, up 161% relative to the 2012 survey estimate (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 2014 survey is largely a result of the huge increase in biomass found in the Eastern Aleutian area (up 812%), but all areas showed large increases (Table 17.6). Relative to the 2012 survey, the 2014 biomass estimates are up 61% in the Western area, 88% in the Central area, and 789% in the combined Southern Bering Sea/Eastern area (Fig. 17.4). The 95% confidence interval about the mean total 2014 Bering Sea/Aleutian Islands biomass estimate is 120,479-1,338,622t. The coefficient of variation (*CV*) of the 2014 mean BSAI biomass is 24% (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, most dramatically in area 541 in the 2000 survey, and recently in the 2012 survey (Fig. 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 2012 Eastern Aleutian biomass estimate of 33,149 t was down 91% relative the 2010 survey, and represented 12% of the total 2012 Aleutian biomass. 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).

The area specific variances for area 541 have always been high relative to 542 and 543; the distribution of Atka mackerel in 541 is patchier with episodic large catches often resulting from trawl samples in the major passes. During 2012, large catches of Atka mackerel were not observed in area 541 as they were during 2006, 2010, and most recently in 2014. During the 2006, 2010, and 2014 surveys, the biomass from area 541 comprised 40 to 47% of the Aleutian Island biomass, but during 2012, only comprised 12% of the Atka mackerel biomass (Table 17.6).

This variation in survey biomass and low estimates for 2012 may be affected by colder than average temperatures in the region and their effects on fish behavior. Gear temperature near the bottom during the 2012 survey in area 541 was 0.25 °C colder than average for the 100 to 200 m depth stratum where 99% of the Atka mackerel are caught in the surveys, and both 2012 and 2000 were years with colder than average temperatures and low abundances of Atka mackerel (Fig. 17.5). Temperatures from the 2014 survey were some of the warmest in the time series over all depth strata (Fig. 17.5). Previous studies suggest that temperature affects the incubation period and potentially the occupation of nesting habitats by males (Lauth *et al*. 2007a). The effect of temperature on survey catchability and fish behavior should be examined more fully in the future to understand whether temperature affects the vertical or broad scale distribution of Atka mackerel to make them less available to the trawl during cold years.

Other factors could also affect survey catches. Sampling in area 541 includes passes with high currents that may affect towing success and catchability during daily tidal cycles and bi-weekly spring and neap tides. Atka mackerel are thought to be very responsive to tide cycles and current patterns, and the catchability of Atka mackerel may be influenced by currents. However, there were no changes in survey protocols during 2012 that affected trawling operations with respect to tidal cycles and tows at stations were attempted with some failures through different current strengths. Three stations were resampled at the end of the cruise in area 541 in 2012 without any effect on the catch per unit effort of Atka mackerel. There is no evidence to suggest that the survey vessels were not sampling properly in 2012. Appendix 1 in Lowe *et al*. (2001) examined the distribution of historical Atka mackerel survey data. Simulation results showed that it is very possible to underestimate the true biomass when the target organism has a very patchy distribution (E. Conners, Appendix 1 in Lowe *et al*. 2001).

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), 2004, (267,556 t), and in the 2010 survey (103,529 t, Table 17.6). These biomass estimates are a result of large catches from a single haul encountered north of Akun Island in all five 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. Most recently, the 2014 survey estimated only 1,443 t of biomass in the southern Bering Sea (*CV*=73%). Very little biomass was observed in the southern Bering Sea in 2012 and 2014, and no large hauls were encountered north of Akun Island similar to the 2006 and 2010 surveys (Fig. 17.6).

Areas with large catches of Atka mackerel in the 2010 survey included north of Akun Island, northwest of the Islands of Four Mountains, Seguam Pass, Kiska Island, Buldir Island, and Stalemate Bank (Fig. 17.6). In the 2012 survey there were no extremely large catches observed as in previous surveys, and moderate catches were only observed south of Amchitka Island, Kiska Island, and Stalemate Bank (Fig. 17.6) In the most recent 2014 survey, several large catches were observed at Seguam Pass, Atka Island, Tanaga Island, Kiska Island, and Stalemate Bank. In the 2002, 2004, 2006, and 2010 surveys Atka mackerel were much less patchily distributed relative to previous surveys and were encountered in 55, 58, 52, and 56% of the hauls respectively, which are the highest rates of encounters in the survey time series. Although no extremely large catches of Atka mackerel were encountered in the 2012 survey, low to moderate catches were observed in areas consistent with previous surveys, and the percent occurrence of Atka mackerel in the 2012 survey was 48%. In the most recent 2014 survey, Atka mackerel were encountered in 55% of the survey hauls, similar to surveys before 2012.

The average bottom temperatures measured in the 2000 and 2012 surveys 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 (Fig. 17.5). The average bottom temperatures measured in the 2014 survey were the second highest of the Aleutian surveys, significantly higher than the 2000 and 2012 surveys and very similar to the 1991 and 1997 surveys (Fig. 17.5).

Survey length frequencies

The bottom trawl surveys have consistently revealed a strong east-west gradient in Atka mackerel size, with the smallest fish in the west and progressively larger fish to the east along the Aleutian Islands chain. This was evident in the 2010 and 2012 surveys (Figure 17.7 in Lowe *et al.* 2011 and Lowe *et al*. 2012). The 2014 survey length frequency distributions also show a strong east-west gradient in Atka mackerel size (Fig. 17.7). The 2014 survey length frequency distributions from each area showed bimodal distributions. The Eastern Aleutians showed modes at 35 and 43-45 cm, larger than the Central and Western fish, both with modes at 24-25 and 37-38 cm. The smaller modes in the distributions represent 2 and 3-year olds of the 2012 and 2011 year classes.

Survey age data

The 2010 survey age composition was dominated by 3 and 4-year olds of the 2007 and 2006 year classes (Fig. 17.8 in Lowe *et al*. 2011). The 2009-2013 fishery data confirm the strong presence of the 2006 and 2007 year classes in fishery catches. The 2012 survey age composition is dominated by 3 and 5-year olds of the 2009 and 2007 year classes, respectively. The most recent 2014 survey age composition is dominated by 3 and 4-year olds of the 2011 and 2010 year classes, respectively; 7 and 8-year olds of the 2006 and 2007 year classes are still numerous (Fig. 17.8). The mean age in the 2014 survey age composition is 5.8 years. Table 17.7 gives estimated survey numbers at age of Atka mackerel from the Bering Sea/Aleutian Islands trawl surveys and numbers of Atka mackerel otoliths aged.

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 and have been omitted from the assessment since 2001. 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, Fournier 1998) 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).

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 1977-2015) with natural and age-specific fishing mortality occurring throughout the 11-age-groups that are modeled (1-11+). Age 1 recruitment in each year is estimated as deviations from a mean value expected from an underlying stock-recruitment curve. Deviations between the observations and the expected values are quantified with a specified error model and cast in terms of a penalized log-likelihood. 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. The model structure has not changed since the previous assessment. Appendix Tables A-1 – A-3 provide a description of the variables used, and the basic equations describing the population 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:

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[1] AMAK. 2015. A statistical catch at age model for Alaska, version 15.0. NOAA version available on request to authors.

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

Data component	**Years of data**	**Likelihood form**	***CV* or sample size (*N*)**
Catch biomass	1977-2015	Lognormal	*CV*=5%
Fishery catch age composition	1977-2014	Multinomial	Year specific *N*=25-233
Survey biomass	1991, 1994, 1997, 2000, 2002 2004, 2006, 2010, 2012, 2014	Lognormal	Average *CV*=25%
Survey age composition	1986, 1991, 1994, 1997, 2000 2002, 2004, 2006, 2010, 2012, 2014	Multinomial	*N*=50
Recruitment deviations		Lognormal	
Stock recruitment curve		Lognormal	
Selectivity smoothness (in age-coefficients, survey and fishery)		Lognormal	
Selectivity change over time (fishery and survey)		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	2002
47	35	10	10	65	59	116	16	82	218	233	103	135
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
132	132	88	116	88	143	149	128	83	100	100	100	

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 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 Outside the Assessment Model

The following parameters were estimated independently of other parameters outside of the assessment model: natural mortality (*M*), length and weight at age parameters, and maturity at age and length parameters. A description of these parameters and how they were estimated follows.

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. Hoenig's (1983) 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). Because 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 (Fig. 17.11 in Lowe *et al.* 2003). Based on the 2014 CIE review recommendations, we intend to explore alternative formulations of an age-dependent *M* selected outside the assessment model. Alternatives include the Lorenzen model (Lorenzen, 1996), and the *M*-at-age formulation suggested in the report of the Natural Mortality Workshop held in 2009 (Brodziak *et al.* 2011).

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. Studies by Lowe *et al.* (1998), Rand *et al*. (2010), and McDermott *et al*. (2014) corroborated differential growth in three sub-areas of the Aleutian Islands and the Western GOA, and the east to west differential size cline. 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_∞(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 compiled for expanding modeled numbers into –age-selected- survey biomass levels (Table 17.8). 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 2010, 2012, and 2014 surveys is used to derive population biomass from the modeled numbers-at-age in order to allow for better estimation of current biomass (Table 17.8).

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 17.8 for 1990 to 2015 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 17.8.

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 17.9. Cooper *et al*. (2010) 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 Inside the Assessment Model

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, survey selectivity, survey catchability, age 1 recruitment). A description of these parameters and how they were estimated follows.

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 over time, degree of declining selectivity at age (dome-shape, σ_d), and curvature as 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 (curvature) 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. A moderate penalty was imposed to allow the model limited flexibility on degree of declining selectivity at age. In the 2012 assessment we evaluated a range of alternative values for the prior penalty of the parameter determining the degree of dome-shape (σ_d) for fishery selectivity and assumed a value of 0.3 for σ_d for the recommended Model 2 which was accepted (Lowe *et al*. 2012). This assumption is carried forward in the current assessment.

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 corresponded 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 used in the 2008-2012 assessments. In the 2013 assessment, a method to allow fishery selectivity to vary without having to subjectively specify an arbitrary degree of penalty was implemented based on analysis developed and presented at the CAPAM workshop on selectivity (CAPAM 2013). The same method to constrain fishery selectivity variability as described in the 2013 assessment (Lowe *et al*. 2013), was used in this 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). In response to the December 2010 SSC minutes which noted a lack of model fit to survey biomass estimates after 1999, the 2011 assessment explored the implementation of a random walk for a transition set of years in survey catchability and time periods for survey selectivity, as one approach to help resolve the poor residual pattern identified (Lowe *et al*. 2011). Results were unsatisfactory and little improvement of model fit to survey biomass was noted. The random walk for catchability was not carried forward. Based on recommendations from the 2014 CIE review, we will explore options for implementing time-varying selectivity for the survey in the 2016 assessment. As in the past, we also 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 2002 assessment explored the estimation of M and survey catchability (q) simultaneously with various combinations of priors (Lowe *et al*. 2002). Preliminary results were unsatisfactory and difficult to interpret biologically. The 2003 assessment explored a range of priors on M or q, while the other parameter was fixed with mixed results that were also difficult to interpret and did not seem biologically reasonable (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.

The 2016 assessment will include a more comprehensive analysis of fishery and survey time-varying selectivity as requested by the SSC and in response to CIE recommendations.

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 α and β are calculated from the values of R_0 (the number of 0-year-olds in the absence of exploitation and recruitment variability) and the “steepness” 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). Prior to the 2012 assessment, the recruitment variance was fixed at a value 0.6. As in the 2014 assessment, we estimate this value.

Results

Model Evaluation

The current assessment uses the model configuration accepted and used for 2015 recommendations, and is carried forward here.

The 2014 CIE review noted the assessment appeared to reasonably capture the overall uncertainty and lacked any serious gaps or inconsistencies relative to the population dynamics. In 2014, results of Model 1 fell within the range of sensitivity runs explored in the assessment (Lowe *et al*. 2014).We thus select the same configuration for harvest recommendations based on the quality of fits to the age composition data and the general consistency between model uncertainty estimates and those achieved from the trawl survey. A summary of key results from the selected model is presented in Table 17.10. Results from the 2014 assessment are presented for comparison.

Model Fit

A summary of key results from Model 1 are presented in Table 17.10. The coefficient of variation or *CV* (reflecting uncertainty) about the 2015 biomass estimate is 24% and the *CV*s on the strength of the 2001 and 2006 year classes at age 1 are 17% (Table 17.10). Recruitment variability was moderate and estimated to be 0.47. 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 234 and average survey effective *N* of 99, which are higher than the input values but reasonable given the level of sampling that occurs in the fishery and survey. The overall residual mean square error (RMSE) for the survey is estimated at 0.24, which is in line with estimates of sampling-error *CV*s for the survey which range from 14-35% and average 25% over the time series (Table 17.6).

Figure 17.9 compares the observed and estimated survey biomass abundance values for the BSAI. The decreases in biomass indicated by the 1994 and 1997 surveys followed by the large increases in biomass from the 2000, 2002 and 2004 surveys appear to be consistent with recruitment patterns. However, the large increase observed in the 2004 survey was not fit as well by the model compared to the 2000, 2002, and 2006 surveys. In the 2004 survey, an unusually high biomass (268,000 t) was estimated for the southern Bering Sea area. This value represented 23% 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 2010 survey biomass estimate indicated 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 (103,500 t) and represented a 741% increase over the 2006 southern Bering Sea estimate. The 2012 survey is associated with the lowest variance in the time series but is poorly fit by the model (Fig. 17.9). However, the declining trend in biomass indicated by the 2012 survey is consistent with the population age composition. Population biomass would be expected to decline as the most recent strong year class (2006 year class) is aging and past peak cohort biomass. The large increase in survey biomass indicated by the most recent 2014 is also not fit well by the model. A moderate increase in the predicted survey biomass is estimated for 2014, consistent with continued strong presence of the 2006 and 2007 year classes and good recruitment from the 2009-2011 year classes. We note that the model's predicted survey biomass trend is very conservative relative to the recent (2004, 2010, and 2014) observed bottom trawl survey biomass values, but fits the other survey years quite well (survey catchability is approximately equal to 1).

The fits to the survey and fishery age compositions for Model 1 are depicted in Figures 17.10 and 17.11, respectively. The model fits the fishery age composition data well particularly after 1997, 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. It is interesting to note that the 2014 survey observed significantly fewer 3-year olds (2011 year class) than predicted, whereas the 2014 fishery catch was comprised of a larger proportion of 3-year olds than predicted. This is an unusual pattern for the fishery; large numbers of 3-year olds have not been observed in fishery catches since the appearance of the strong 1975 and 1977 year classes in 1978 and 1980, respectively.

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. Fits to the recent fishery age composition data in Lowe *et al*. (2012) indicated a need for greater flexibility in selectivity. The 2013 assessment allowed for more flexibility to estimate time-varying fishery selectivity, which improved fits to the fishery age compositions.

The results discussed below are based on the recommended Model 1 with updated 2014 fishery and survey catch- and weight-at-age values.

Time Series Results

Selectivity

For Atka mackerel, the estimated selectivity patterns are particularly important in describing their dynamics. Previous assessments focused on the transitions between ages and time-varying selectivity (Lowe *et al.* 2002, 2008, 2013). The current assessment allows for flexibility over time and age (Figures 17.12, 17.13, and 17.14; also Table 17.11). The current assessment's terminal year fishery selectivity estimate and the average selectivity for 2011-2015 (used for projections) differ from the terminal year in the 2014 assessment, showing higher selectivity for ages 3-4 (Figure 17.13). Fishery selectivity patterns are similar after age 4.

The fishery catches essentially consist of fish 3-11 years old, although15-year-old fish were found in the 2013 and 2014 fishery catches. The fishery exhibits a dome-shaped selectivity pattern which is more pronounced prior to 1992 during the foreign and joint venture fisheries (1977-1983 and 1984-1991, respectively (Fig.17.12). After 1991, fishery selectivity patterns are relatively consistent but do show 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 patterns since 2000 reflect the large numbers of fish from the 1999, 2000, 2001, 2006, and 2011 year classes (Table 17.4). The age at 50% selectivity is estimated at about ages 3-4 in 2008-2012 as the large year classes move through the population. A large shift has occurred recently with the large number of 3-year olds dominating the 2014 fishery age composition. The age at 50% selectivity decreased to about 2.5 years in the current assessment terminal year (Figure 17.13). It is important to note the maturity-at-age vector relative to the current selectivity patterns (age at 50% maturity is 3.6 years, Fig. 17.13).

Survey catches are mostly comprised of fish 3-9 years old. However, the 2014 survey still shows significant numbers of 13 and 14 year olds of the 2000 and 2001 year classes. A 17-year old fish was found in the 2012 survey and 3, 16-year old fish were caught in the 2014 survey. The 2014 survey also caught large numbers of 3 year olds of the 2011 year class. The current model configuration estimates a moderately dome-shape selectivity pattern (Fig. 17.14).

Abundance trend

The estimated time series of total numbers at age are given in Table 17.12. The estimated time series of total biomass (ages 1+) with approximate upper and lower 95% confidence limits are given in Table 17.13. A comparison of the spawning biomass trend from the current and previous assessments (Table 17.13 and Figure 17. 15) 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 (Fig. 17.15). Thereafter, spawning biomass began a steep increase which continued to 2005. The abundance trend has been declining since the most recent peak in 2005 which represented a build-up of biomass from the exceptionally strong 1999-2001 year classes. Estimates from the current assessment are slightly higher after 1990, and more so after 2003 which is attributed to higher estimates of recruitment levels, particularly for strong year classes after 2005.

Recruitment trend

The estimated time series of age 1 recruits indicates the strong 1999 year class as the most notable in the current assessment, followed by the 1977, 1988 and 2001 year classes (Figures 17.16 and 17.17). The

1999, 2000, and 2001 year classes are estimated to be three of the five largest recent year classes in the time series (approximately 2.2, 1.4, and 1.5 billion recruits, respectively) due to the persistent observations of these year classes in the fishery and survey catches. The current assessment estimates above average (greater than 20% of the mean) recruitment from the 1977, 1988, 1992, 1995, 1998, 1999, 2000, 2001, 2006 year classes (Fig 17.16).

The average estimated recruitment from the time series 1978-2014 is 695 million fish and the median is 514 million fish (Table 17.14). The entire time series of recruitments (1977-2015) includes the 1976-2014 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, and the 2015 estimate is only based on one year of data. Thus, the average recruitment value presented in the assessment is based on year classes spawned after 1976 through 2014 (1977-2013 year classes). Projections of biomass are based on estimated recruitments from 1978-2014 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 17.15 and shown in Figure 17.18.

Retrospective analysis

A retrospective analysis was conducted by regressively eliminating the most current year of information extending back to 2005. This allows judgment of the model performance as specified. For a stock with highly variable and uncertain survey information, the change and relative difference in spawning biomass is difficult to predict in subsequent years (Figure 17.19). The current model applied to a shortened time series often gives estimates that vary broadly from the full-data set model used for this assessment. In general, the pattern is consistent with the variability of survey observations in scaling the stock. Although the scale and uncertainty exhibited by the retrospective runs fall well within the confidence bands of the present model, patterns are still evident and require further investigation. The revised Mohn's rho statistic was estimated to be -0.048.

Projections and Harvest Recommendations

Results and recommendations in this section pertain to the authors' recommended baseline model (Model 1).

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 1978-2014 (695 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 **Model 1** results based on recruitment from post-1976 spawning events:

$B_{100\%}$ = 339,135 t female spawning biomass

$B_{40\%}$ = 135,654 t female spawning biomass

$B_{35\%}$ = 118,697 t female spawning biomass

Specification of OFL and Maximum Permissible ABC

In the current assessment, Model 1 is configured with time-varying selectivity. The average selectivity of the most recent 5-year period (2011-2015) is used for projection purposes. The following rates are based on the average of the 2011-2015 selectivity estimates:

Full selection Fs	2016
F_{2015}	0.16
$F_{40\%}$	0.30
$F_{35\%}$	0.35
$F_{2015}/F_{40\%}$	0.53

For specification purposes to project the 2016 ABC, we assumed a total 2015 year end catch of 54,500 t equal to the 2015 TAC, based on the amount of catch taken after Oct. 1 in recent years. For projecting to 2017, an expected catch in 2016 is required. Typically this value is set to a recommended ABC, in this case the 2016 recommended ABC. However, recognizing that the modified Steller sea lion RPAs implemented in 2015 require a TAC reduction in Area 543, we assume a stock-wide catch based on a reduced overall BSAI-wide Atka mackerel catch for 2016. Under the modified Steller sea lion RPAs, the Area 543 Atka mackerel TAC is set less than or equal to 65 percent of the Area 543 ABC. We estimated that about 80% of the BSAI-wide ABC is likely to be taken. This percentage was applied to the maximum permissible 2016 ABC and that amount was assumed to be caught in order to estimate the 2017 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. The projected 2016 female spawning biomass (SSB_{2016}) is estimated to be 166,407 t under an assumed 2015 catch of 54,500 t and reduced 2016 catch reflecting the RPA adjustment to the 2016 ABC.

The projected 2016 female spawning biomass estimate is above the $B_{40\%}$ value of 135,654 t, placing BSAI Atka mackerel in **Tier 3a**. The 2017 female spawning biomass estimate is also above $B_{40\%}$. The maximum permissible ABC and OFL values under **Tier 3a** are:

Year	Catch*	ABC	F_{ABC}	OFL	F_{OFL}	SSB	Tier
2016	72,272	90,340	0.30	104,749	0.35	166,407	3a
2017	85,840	85,840	0.30	99,490	0.35	147,496	3a

* Catch in 2016 is less than the recommended ABC to reflect expected catch reductions under Steller sea lion RPAs.

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 2015 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2028 using a fixed value of natural mortality of 0.3, the recent schedule of selectivity estimated in the assessment (in this case the average 2011-2015 selectivity), and the best available estimate of total (year-end) catch for 2015 (in this case assumed to be 54,500 t equal to TAC). In addition, the 2016 catch is reduced to accommodate Steller sea lion RPA TAC reductions for Scenarios 1 and 2. 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 2016 and 2017, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

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

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2016 recommended in the assessment to the *max* F_{ABC} for 2016. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment).

Scenario 3: In all future years, F is set equal to the 2011-2015 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

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

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

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as 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 2015 or 2) above ½ of its MSY level in 2015 and above its MSY level in 2025 under this scenario, then the stock is not overfished.)

Scenario 7: In 2016 and 2017, 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 2028 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 17.16. 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 2015:

a) If spawning biomass for 2015 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.

b) If spawning biomass for 2015 is estimated to be above $B_{35\%}$, the stock is above its MSST.

c) If spawning biomass for 2015 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 17.16). If the mean spawning biomass for 2025 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 2018 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.

b) If the mean spawning biomass for 2018 is above $B_{35\%}$, the stock is not approaching an overfished condition.

c) If the mean spawning biomass for 2018 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2028. If the mean spawning biomass for 2028 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 17.16, the BSAI Atka mackerel stock is not overfished and is not approaching overfishing.

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 2010 survey increased 25% relative to the 2006 survey, the 2012 survey decreased 70% relative to the 2010 survey, and the most recent 2014 survey increased 161% relative to the 2012 survey. It is noted that all areas in the Aleutian Islands showed increases in the 2014 survey.
2) The model's predicted survey biomass trend is very conservative relative to the 2004, 2010, and 2014 observed bottom trawl survey biomass values.
3) Under an $F_{40\%}$ harvest strategy and assuming SSL RPA catch reductions in 2016, female spawning biomass is projected to be above $B_{40\%}$ in 2016-2018, but drop below $B_{40\%}$ in 2019, thereafter, staying above $B_{40\%}$ through 2028 (Fig. 17.20 and Table 17.16 Scenarios 1 and 2). If SSL RPA catch reductions are in place beyond 2016, expected female spawning biomass levels would be higher than projected after 2016.
4) The 2014 fishery data are dominated by the 2011 year class, and show significant numbers of 5 year olds of the 2009 year class (Table 17.4).
5) The 2014 survey age composition is dominated by 3 and 4-year olds of the 2011 and 2010 year classes, and 7 and 8-year olds of the 2007 and 2006 year olds. The bottom trawl surveys have been a consistently good indicator of incoming year class strengths.

We believe the current accepted model configuration (Model 1) which was favorably reviewed by a CIE panel, provides an improved assessment of BSAI Atka mackerel relative to past model configurations. Given the current moderate stock size, an above average 2006 year class, and preliminary indications of good recruitment from the 2009, 2010, and 2011 year classes, the maximum permissible is acceptable for Atka mackerel. We note that the maximum permissible reference fishing mortality rate (F_{ABC}) which had previously been higher than the natural mortality rate, is equivalent to the natural mortality rate in the current assessment. This is due to the fact that previously estimated fishery selectivity-at-age was significantly older than the maturity-at-age. The recent fishery has targeted younger year classes, and the fishery selectivity-at-age is more in line with maturity-at-age. 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 17.21. For all of the time series (including the 2015 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 2016 yield associated with the Tier 3a maximum permissible F_{ABC} fishing mortality rate of 0.30 is 90,340 t, which is our 2016 ABC recommendation for BSAI Atka mackerel.

The 2017 yield associated with the Tier 3a maximum permissible F_{ABC} fishing mortality rate and assuming 2016 catch reductions, is 85,840 t, which is our 2017 ABC recommendation for BSAI Atka mackerel.

The 2016 ABC recommendation is 15% lower relative to the Council's 2015 ABC, and is 8% lower relative to the projections from last year's assessment for 2016. These decreases are consistent with the fishery and survey age composition data, and the increased selectivity of younger ages resulting in a lower $F_{40\%}$ reference fishing mortality rate.

Area Allocation of Harvests

Amendment 28 of the BSAI 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 (2006, 2010, 2012, and 2014) weighted average to apportion the 2015 ABC. The rationale for the weighting scheme was described in Lowe *et al.* (2001). The SSC requested that the Atka mackerel assessment use the random effects model for setting subarea ABC allocations (Dec. 2015 SSC minutes). Based on applying this method to each area separately (Fig. 17.22), and then summing to get the overall BSAI biomass, the percentage apportionments for the Aleutian Islands subareas are shown below, and are similar to the 4-survey weighted average used to apportion the 2015 ABC.

The method for computing apportionments by region for 2015 along with the alternative (recommended) method using the random effects model are shown below:

	Survey Year				2015	Recommended Random Effects
	2006	2010	2012	2014	Apportionment	Model
541[1]	48.90%	51.16%	12.34%	41.97%	36.31%	**34.13%**
542	37.52%	21.38%	39.41%	28.30%	31.23%	**30.13%**
543	13.58%	27.46%	48.25%	29.73%	31.45%	**35.75%**
Weights	8	12	18	27		

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

The apportionments of the 2016 and 2017 recommended ABCs based on the random effects model are:

	2016 (t)	2017 (t)
Eastern (541+S.BSea)	30,832	29,296
Central (542)	27,216	25,860
Western (543)	32,292	30,684
Total	90,340	85,840

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, Sinclair *et al*. 2013). 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 17.23 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. 17.24a). While Figure 17.24a 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 GOA 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, Sinclair *et al*. 2013), 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 17.25. 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 (Fig. 17.24b), 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 except in the Western Aleutians. 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.

During the 2012 NMFS Atka mackerel tag recovery survey, there was an opportunity to study the prey distribution of a Steller sea lion adult female that was tagged with a satellite-tracking tag in November 2011 by the AFSC National Marine Mammal Laboratory. A hydroacoustic transect was conducted, species composition data was collected from trawl hauls, and camera tows were conducted in the area where the sea lion was feeding (South Petrel Bank). This provided a unique opportunity to investigate possible prey species availability during the same time and in the same location where the tagged female sea lion was diving. The Steller sea lion appeared to be diving in an area with high prey diversity: 5 spatially close trawl hauls each a captured a different predominant prey species (including Pacific ocean perch, northern rockfish, walleye pollock, Pacific cod, and Atka mackerel (McDermott et al. 2014); http://www.afsc.noaa.gov/REFM/Stocks/fit/FITcruiserpts.htm).

Changes in habitat quality

Atka mackerel habitat associations

Another objective of the NMFS tagging studies (described in the Fishery section above), was to characterize Atka mackerel habitat by conducting underwater camera tows in each area where fish were recaptured. Underwater camera tows were used to explore habitat characteristics in areas of high Atka mackerel abundance. In camera tows from the Central and Eastern Aleutian Islands, Atka mackerel were associated almost exclusively with coarse-grained and rocky substrates. At Seguam and Petrel, greater than 60% of substrate identified during camera tows was rock (largely bedrock and boulders), while the remainder was largely gravel and cobble. At Tanaga, gravel and cobble composed 75% of all substrate. In all three study areas, fine-grained substrates (sand and mud) composed less than 1% of the substrate. At Seguam, nearly all substrate had between 26%-75% biocover (sponges and corals). Biocover at Tanaga and Petrel ranged from nearly bare to almost 100% (McDermott et al. 2014). Impacts to these habitats could potentially affect Atka mackerel, but at this time only associations to these habitat types have been established.

<u>Climate</u>

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 Niño 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). Average eddy kinetic energy (EKE, $cm^2\ s^{-2}$) from south of Amutka Pass in the Aleutian Islands was examined and found to be potentially informative (S. Lowe unpubl. data). Particularly strong eddies were observed in the fall of 1997/1998, 1999, 2004, and 2006/2007 suggesting increased volume, heat, salt, and nutrient fluxes. The 1999-2001 and the 2006 year classes were strong. The role of eddies may be the transport of larva which hatch in the fall, and or the increase in nutrients and favorable environment conditions. Further research is needed to determine the effects of climate on growth and year class strength, and the temporal and spatial scales over which these effects occur.

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 and 2012 Aleutian Islands summer bottom temperatures indicated that 2000 and 2012 was the coldest years followed by summer bottom temperatures from the 2002 survey, which indicated the second coldest year (Fig. 17.5). The 2004 AI summer bottom temperatures indicated that 2004 was an average year, while the 2006 and 2010 bottom temperatures were slightly below average. The average bottom temperatures measured in the 2014 survey were the second highest of the Aleutian surveys, significantly higher than the 2000 and 2012 surveys and very similar to the 1991 and 1997 surveys. 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 17.17 and discussed below.

The Atka mackerel fishery has very low bycatch levels of some species of Habitat Areas of Particular Concern (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 three years (2012-2014), the Atka mackerel fishery has taken on average about 15 and 14%, 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.

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. Most recently, RPAs from the 2010 BiOp closed the entire Western Aleutians (Area 543) to directed fishing for Atka mackerel, and several closures were implemented in critical habitat in the Central Aleutians (Area 542) and the TAC for Area 542 was reduced to no more than 47 percent of the Area 543 ABC. These measures were in place from 2011 to 2014. Revised RPAs were implemented in 2015. For the 2015 fishery, the Area 543 Atka mackerel TAC was set to less than or equal to 65 percent of the Area 543 ABC. In Area 542, there are expanded area closures and no requirement for a TAC reduction. Concentration of catches in time and space 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 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 *et al*. 2010) 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.

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 660 t of non-target discards in the Aleutian Islands from 2012 to 2014. 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 497 t over 2012-2014.

Data Gaps and Research Priorities

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.

The high variability in survey abundance and trend estimates is a major source of uncertainty in the assessment. Other approaches for analyzing the survey data such as spatial models, incorporating spatial covariates, especially those that are habitat related, into predictive estimates are research priorities. Changes in survey tow duration starting in 2002 may have resulted in a higher encounter rate for this species and may have resulted in an inconsistency in estimating the biomass over the complete time series. An evaluation of the survey data in terms of tow duration changes, survey design and the development of alternate estimation approaches possibly incorporating habitat information are 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.

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Tables

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

Year	Catch	ABC	TAC	OFL
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	435,000
1993	66,006	117,100	32,000	771,100
1994	65,360	122,500	68,000	484,000
1995	81,554	125,000	80,000	335,000
1996	103,942	116,000	106,157	164,000
1997	65,842	66,700	66,700	81,600
1998	57,097	64,300	64,300	134,000
1999	56,237	73,300	66,400	148,000
2000	47,230	70,800	70,800	119,000
2001	61,563	69,300	69,300	138,000
2002	45,288	49,000	49,000	82,300
2003	54,045	63,000	60,000	99,700
2004	60,562	66,700	63,000	78,500
2005	62,012	124,000	63,000	147,000
2006	61,894	110,000	63,000	130,000
2007	58,763	74,000	63,000	86,900
2008	58,090	60,700	60,700	71,400
2009	72,806	83,800	76,400	99,400
2010	68,619	74,000	74,000	88,200
2011	51,818	85,300	53,080	101,000
2012	47,826	81,400	50,763	96,500
2013	23,181	50,000	25,920	57,700
2014	30,947	64,131	32,322	74,492
2015	54,500[b]	106,000	54,000	125,297

a) Atka mackerel was not a reported species group until 1978.
b) 2015 projected total year catch (the 2015 catch is assumed equal to the 2015 TAC of 54,500 t, based on recent post Oct. 1 catches)

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 1995 to the present. Apportioned catches prior to 1995 are available in Lowe *et al*. (2013). Catches, ABCs, and TACs are in metric tons.

Year		Eastern (541)	Central (542)	Western (543)	Total	Year		Eastern (541)	Central (542)	Western (543)	Total
1995	Catch	14,199	50,387	16,966	81,552	2005	Catch	7,201	35,069	19,744	62,014
	ABC	13,500	55,900	55,600	125,000		ABC	24,550	52,830	46,620	124,000
	TAC	13,500	50,000	16,500	80,000		TAC	7,500	35,500	20,000	63,000
1996	Catch	28,173	33,524	42,246	103,943	2006	Catch	7,422	39,836	14,638	61,896
	ABC	26,700	33,600	55,700	116,000		ABC	21,780	46,860	41,360	110,200
	TAC	26,700	33,600	45,857	10,657		TAC	7,500	40,000	15,500	63,000
1997	Catch	16,318	19,990	29,537	65,845	2007	Catch	22,943	26,723	9,097	58,763
	ABC	15,000	19,500	32,200	66,700		ABC	23,800	29,600	20,600	74,000
	TAC	15,000	19,500	32,200	66,700		TAC	23,800	29,600	9,600	63,000
1998	Catch	11,597	20,029	24,248	55,874	2008	Catch	19,112	22,926	16,045	58,083
	ABC	14,900	22,400	27,000	64,300		ABC	19,500	24,300	16,900	60,700
	TAC	14,900	22,400	27,000	64,300		TAC	19,500	24,300	16,900	60,700
1999	Catch	16,245	21,596	15,082	52,923	2009	Catch	26,417	30,137	16,253	72,807
	ABC	17,000	25,600	30,700	73,300		ABC	27,000	33,500	23,300	83,800
	TAC	17,000	22,400	27,000	66,400		TAC	27,000	32,500	16,900	76,400
2000	Catch	13,152	20,575	8,713	42,440	2010	Catch	23,608	26,388	18,650	68,646
	ABC	16,400	24,700	29,700	70,800		ABC	23,800	29,600	20,600	74,000
	TAC	16,400	24,700	29,700	70,800		TAC	23,800	29,600	20,600	74,000
2001	Catch	7,905	30,365	18,264	56,534	2011	Catch	40,891	10,713	205	51,809
	ABC	7,800	33,600	27,900	69,300		ABC	40,300	24,000	21,000	85,300
	TAC	7,800	33,600	27,900	69,300		TAC	40,300	11,280	1,500	53,080
2002	Catch	4,606	20,699	16,737	42,042	2012	Catch	37,308	10,323	195	47,826
	ABC	5,500	23,800	19,700	49,000		ABC	38,500	22,900	20,000	81,400
	TAC	5,500	23,800	19,700	49,000		TAC	38,500	10,763	1,500	50,763
2003	Catch	10,725	25,435	17,885	54,045	2013	Catch	15,777	7,284	120	23,181
	ABC	10,650	29,360	22,990	63,000		ABC	16,900	16,000	17,100	50,000
	TAC	10,650	29,360	19,990	60,000		TAC	16,900	7,520	1,500	25,920
2004	Catch	10,840	30,169	19,555	60,564	2014	Catch	21,185	9,520	242	30,947
	ABC	11,240	31,100	24,360	66,700		ABC	21,652	20,574	21,905	64,131
	TAC	11,240	31,100	20,660	63,000		TAC	21,652	9,670	1,000	32,322
						2015*	Catch	27,000	17,000	10,500	54,500
							ABC	38,492	33,108	34,400	106,000
							TAC	27,000	17,000	10,500	54,500

*2015 projected total year catches by region assumed equal to the 2015 TACs, based on recent post Oct. 1 catches

Table 17.3. Numbers of Atka mackerel length-weight data, length frequency, and aged samples based on NMFS observer data 1990-2014.

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
2011	1,976	11,814	720
2012	1,495	13,794	1,012
2013	1,178	13,327	642
2014	1,301	14,210	1,061

Table 17.4. Estimated catch-in-numbers at age (in millions) of Atka mackerel from the BSAI region, 1977-2014. These data were used in fitting the age-structured model.

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	1.67	19.*00*	47.22	13.06	13.59	6.46	3.82	7.90	4.66	1.75
2011	1.05	3.02	17.61	22.41	6.68	4.89	1.16	2.73	4.44	4.82
2012	0.18	7.41	3.54	21.16	20.78	5.69	3.21	2.69	2.36	9.96
2013	1.56	7.42	19.99	4.59	14.75	11.71	2.52	1.32	0.85	3.44
2014	0.48	23.50	2.71	8.10	2.87	4.02	2.86	0.44	0.59	1.27

[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 543	1-100	193	49,115	1,675
	101-200	692	124,806	40,675
	201-300		1,559	111
	301-500	0	164	0
	Total	885	175,644	42,461
Central 542	1-100	0	103,588	1,011,991
	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 541	1-100		86,800	11
	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 Bering Sea	1-100	6	0	429
	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 of total (for each year) and coefficients of variation (*CV*) for 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012 and 2014.

Area	Depth (m)	1991	1994	1997	2000	2002	2004	2006	2010	2012	2014
		Biomass (t)									
Aleutian Islands + S. BS	1-100	429,873	211,562	284,176	160,940	394,092	518,232	374,774	304,909	130,616	286,064
	101-200	277,907	472,725	177,672	344,674	393,159	631,150	326,426	624,294	145,351	436,506
	201-300	520	1,691	130	8,636	48,723	7,410	40,091	1,008	886	716
	301-500	0	30	20	82	221	292	67	41	23	642
	Total	708,299	686,007	461,997	514,332	836,195	1,157,084	741,358	930,252	276,877	723,928
Regional area % of Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	CV	*14%*	*32%*	*31%*	*29%*	*20%*	*17%*	*28%*	*35%*	*18%*	*24%*
Western 543	1-100	168,968	93,847	90,824	120,257	50,481	140,669	64,429	59,449	62,247	115,359
	101-200	174,182	231,733	43,478	52,948	154,820	229,675	35,926	195,819	70,983	99,102
	201-300	276	1,656	66	7,910	48,362	6,033	318	134	350	172
	301-500	-	6	-	-	8	36	21	17	8	602
	Total	343,426	327,242	134,367	181,115	253,671	376,414	100,693	255,419	133,588	215,235
Regional area % of Total		48%	48%	29%	35%	30%	33%	14%	27%	48%	30%
	CV	*18%*	*57%*	*56%*	*56%*	*32%*	*24%*	*35%*	*58%*	*28%*	*29%*
Central 542	1-100	187,194	50,513	70,458	38,805	131,770	198,243	192,832	102,211	62,238	86,097
	101-200	100,329	33,255	116,295	290,766	199,743	70,267	85,215	96,457	46,861	118,612
	201-300	70.4	13	53.4	674.2	168.9	367.1	102.6	207	16.2	119.7
	301-500	0	2.9	5.7	9.3	142.5	194.1	0	0	15.1	39.8
	Total	287,594	83,784	186,813	330,255	331,824	269,071	278,150	198,874	109,130	204,868
Regional area % of Total		41%	12%	40%	64%	40%	23%	38%	21%	39%	28%
	CV	*17%*	*48%*	*36%*	*34%*	*24%*	*35%*	*24%*	*28%*	*27%*	*50%*
Eastern 541	1-100	73,663	641	27,222	25	152,159	54,424	107,230	44,981	6,029	84,252
	101-200	3,392	207,707	17,890	772	38,492	188,592	205,108	327,105	26,685	217,748
	201-300	162.8	18.6	10.6	48.4	94.2	970.5	37828.9	338.7	435.2	381.8
	301-500	0	12.3	14	73.1	71.3	57.2	40.1	4.9	0	0
	Total	77,218	208,379	45,137	919	190,817	244,043	350,206	372,429	33,149	302,383
Regional area % of Total		11%	30%	10%	0%	23%	21%	47%	40%	12%	42%
	CV	*83%*	*44%*	*68%*	*74%*	*58%*	*33%*	*55%*	*74%*	*46%*	*43%*
Bering Sea	1-100	47	66,562	95,672	1,853	59,682	124,896	10,284	98,268	103	356
	101-200	3	30	9	187	103	142,616	176	4,914	822	1,044
	201-300	11.4	3.1	0	3.5	97.7	39.3	1841.8	327.4	84.7	42.2
	301-500	0	8	0	0	0	3.8	6	18.7	0	0
	Total	61	66,603	95,680	2,044	59,883	267,556	12,308	103,529	1,010	1,443
Regional area % of Total		0%	10%	21%	0%	7%	23%	2%	11%	0%	0%
	CV	*37%*	*99%*	*99%*	*88%*	*99%*	*43%*	*44%*	*86%*	*77%*	*73%*

Table 17.7. Estimated survey numbers at age (in millions) of Atka mackerel from the Aleutian Islands trawl surveys and numbers of Atka mackerel otoliths aged (*n*).

Age	*n*	2	3	4	5	6	7	8	9	10	11+
1986	712	157.53	985.94	532.35	344.94	274.32	230.87	135.80	40.74	10.86	2.72
1991	478	72.44	846.64	137.33	261.09	81.49	87.53	15.09	6.04	0.00	0.00
1994	745	12.37	166.06	114.83	185.49	217.29	51.23	68.01	22.08	37.98	6.18
1997	433	65.67	142.93	115.25	148.73	45.71	23.18	31.55	43.14	6.44	13.52
2000	831	269.32	76.68	25.25	226.30	68.26	71.07	118.76	37.41	18.70	23.38
2002	789	77.33	933.52	531.22	95.13	32.08	78.05	35.78	14.47	12.71	1.53
2004	598	66.94	726.25	584.22	560.93	120.42	29.00	16.47	19.23	10.67	15.32
2006	525	166.24	159.26	63.30	192.03	200.48	290.68	93.74	11.92	0.27	19.16
2010	560	45.18	386.11	400.88	82.19	86.99	39.26	50.56	98.85	67.84	112.04
2012	417	63.17	100.11	40.52	97.73	66.74	20.26	20.26	17.88	8.34	61.98
2014	478	109.92	155.54	150.30	130.30	87.45	172.27	149.99	44.11	22.87	63.07

Table 17.8. 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 average of years 2006, 2010, and 2012. The 2015 fishery weight-at-age values are the average of the last three years (2012-2014).

		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
	2012	0.045	0.161	0.360	0.517	0.627	0.705	0.762	0.820	0.863	0.809	0.949
	2014	0.045	0.162	0.465	0.524	0.662	0.709	0.856	0.951	0.920	0.808	1.017
Avg 2010,2012, 2014		0.045	0.161	0.398	0.558	0.652	0.720	0.864	0.949	0.921	0.886	1.070
Fishery	1977	0.069	0.132	0.225	0.306	0.400	0.470	0.507	0.379	0.780	0.976	1.072
Foreign	1978	0.069	0.072	0.225	0.300	0.348	0.388	0.397	0.371	0.423	0.976	1.072
	1979	0.069	0.496	0.319	0.457	0.476	0.475	0.468	0.546	0.780	0.976	1.072
	1980	0.069	0.365	0.317	0.450	0.520	0.585	0.630	0.546	0.780	0.976	1.072
	1981	0.069	0.365	0.317	0.450	0.520	0.585	0.630	0.546	0.780	0.976	1.072
	1982	0.069	0.365	0.273	0.443	0.564	0.695	0.795	0.546	0.780	0.976	1.072
	1983	0.069	0.365	0.359	0.499	0.601	0.686	0.810	0.546	0.780	0.976	1.072
	1984	0.069	0.297	0.410	0.617	0.707	0.777	0.802	0.890	0.910	0.976	1.072
	1985	0.069	0.302	0.452	0.552	0.682	0.737	0.775	0.807	1.007	1.011	1.072
	1986	0.069	0.146	0.334	0.528	0.546	0.786	0.753	0.829	0.858	0.954	1.052
	1987	0.069	0.265	0.435	0.729	0.908	0.859	0.964	1.023	1.054	1.088	1.098
	1988	0.069	0.196	0.351	0.470	0.564	0.624	0.694	0.783	0.818	0.850	1.064
Domestic	1989	0.069	0.295	0.440	0.577	0.739	0.838	0.664	0.817	0.906	1.010	1.065
	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	1.033
	2008	0.069	0.265	0.388	0.540	0.615	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	0.204	0.362	0.565	0.583	0.673	0.684	0.758	0.723	0.762	0.803
	2011	0.069	0.220	0.445	0.640	0.807	0.753	0.770	0.798	0.931	0.913	0.899
	2012	0.069	0.230	0.374	0.509	0.612	0.658	0.713	0.772	0.822	0.894	0.949
	2013	0.069	0.266	0.280	0.606	0.677	0.740	0.867	0.822	0.803	0.822	1.093
	2014	0.069	0.316	0.569	0.634	0.709	0.735	0.840	0.838	0.791	0.942	0.923
	2015	0.069	0.271	0.408	0.583	0.666	0.711	0.807	0.811	0.805	0.886	0.988

Table 17.9. 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 17.10. Estimates of key results from AMAK for Bering Sea/Aleutian Islands Atka mackerel from last year's assessment model with updated data (Model 1) and the selected sensitivity runs. Coefficients of variation (*CV*) for some key reference values appearing directly below, are given in parentheses. Note that likelihoods may not be strictly comparable between models due to different variance/weighting assumptions.

Assessment Model	**2014 Model 1**	**Current Assessment**
Model setup		
Survey catchability	1.04	1.05
Steepness	0.8	0.8
SigmaR	0.47	0.47
Natural mortality	0.3	0.3
Fishery Average Effective *N*	231	234
Survey Average Effective *N*	117	99
RMSE Survey	0.25	0.24
-log Likelihoods		
Number of Parameters	471	483
Survey index	5.75	6.54
Catch biomass	0	0
Fishery age comp	92.0	94.4
Survey age comp	36.8	45.2
Sub total	134.6	146.1
-log Penalties		
Recruitment	-3.4	-1.87
Selectivity constraint	74.7	79.5
Prior	0	0
Sub total	71.3	77.7
Total	205.8	223.8
Fishing mortalities (full selection)		
F_{2014}	0.12	0.08
$F_{2014}/F_{40\%}$	0.30	0.27
$F_{40\%}$	0.40	0.30
$F_{35\%}$	0.49	0.35
Stock abundance and recruitment		
Initial Biomass (t, 1977)	681,986	686,306
CV	23%	24%
Assessment year total biomass (t)	657,228	668,364
CV	22%	23%
2001 year class (millions at age 1)	1,489	1,546
CV	17%	17%
2006 year class (millions at age 1)	863	993
CV	18%	17%
Recruitment Variability	0.554	0.474

Table 17.11. Estimates of Atka mackerel fishery (over time, 1977-2015) and survey selectivity at age (normalized to have a maximum of 1.0).

	Age										
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1977	0.010	0.097	0.567	1.000	0.750	0.314	0.139	0.072	0.043	0.032	0.032
1978	0.009	0.118	0.972	1.000	0.904	0.493	0.226	0.110	0.062	0.044	0.044
1979	0.005	0.033	0.274	1.000	0.846	0.441	0.213	0.102	0.054	0.036	0.036
1980	0.005	0.039	0.266	0.844	1.000	0.622	0.395	0.185	0.082	0.047	0.047
1981	0.004	0.031	0.205	0.398	0.403	0.603	1.000	0.283	0.086	0.044	0.044
1982	0.004	0.021	0.093	0.335	1.000	0.898	0.449	0.192	0.087	0.052	0.052
1983	0.004	0.023	0.132	0.331	0.638	1.000	0.617	0.231	0.103	0.063	0.063
1984	0.004	0.025	0.122	0.384	0.686	1.000	0.928	0.426	0.187	0.102	0.102
1985	0.005	0.053	0.480	0.778	0.856	0.954	1.000	0.829	0.432	0.229	0.229
1986	0.005	0.041	0.303	0.486	0.559	0.652	0.844	1.000	0.768	0.363	0.363
1987	0.007	0.063	0.466	0.797	0.823	0.765	0.859	1.000	0.968	0.866	0.866
1988	0.004	0.037	0.347	1.000	0.633	0.418	0.379	0.347	0.310	0.248	0.248
1989	0.006	0.054	0.356	0.948	1.000	0.717	0.508	0.386	0.312	0.270	0.270
1990	0.004	0.043	0.450	1.000	0.787	0.512	0.374	0.278	0.218	0.184	0.184
1991	0.004	0.027	0.151	0.678	0.965	1.000	0.741	0.423	0.275	0.221	0.221
1992	0.004	0.027	0.164	0.718	1.000	0.830	0.624	0.444	0.328	0.270	0.270
1993	0.003	0.026	0.169	0.504	0.818	1.000	0.799	0.608	0.452	0.362	0.362
1994	0.003	0.022	0.164	0.483	0.920	1.000	0.922	0.974	0.759	0.487	0.487
1995	0.003	0.021	0.161	0.661	0.781	0.905	1.000	0.979	0.855	0.650	0.650
1996	0.002	0.013	0.090	0.458	0.600	0.794	0.975	1.000	0.558	0.370	0.370
1997	0.002	0.016	0.131	0.453	1.000	0.830	0.780	0.700	0.552	0.435	0.435
1998	0.002	0.016	0.116	0.522	0.845	0.891	1.000	0.922	0.723	0.528	0.528
1999	0.001	0.017	0.126	0.676	0.672	0.774	0.796	1.000	0.679	0.384	0.384
2000	0.001	0.013	0.266	0.639	0.789	0.800	0.837	1.000	0.539	0.277	0.277
2001	0.001	0.013	0.179	0.562	0.886	0.962	1.000	0.842	0.481	0.249	0.249
2002	0.001	0.013	0.112	0.381	0.564	0.768	1.000	0.677	0.383	0.222	0.222
2003	0.002	0.018	0.186	0.460	0.638	0.824	1.000	0.842	0.423	0.247	0.247
2004	0.004	0.040	0.302	0.788	1.000	0.954	0.959	0.855	0.543	0.312	0.312
2005	0.007	0.056	0.306	0.776	1.000	0.983	0.921	0.640	0.402	0.275	0.275
2006	0.009	0.097	0.640	0.745	0.962	1.000	0.966	0.598	0.382	0.273	0.273
2007	0.008	0.091	0.591	0.829	0.759	0.836	1.000	0.752	0.446	0.284	0.284
2008	0.007	0.072	0.488	0.707	0.694	0.848	1.000	0.887	0.695	0.320	0.320
2009	0.007	0.056	0.338	0.671	0.811	0.813	1.000	0.879	0.620	0.393	0.393
2010	0.006	0.053	0.309	0.844	0.982	1.000	0.937	0.843	0.659	0.358	0.358
2011	0.005	0.036	0.208	0.596	0.913	1.000	0.825	0.678	0.678	0.577	0.577
2012	0.004	0.031	0.189	0.429	0.821	1.000	0.888	0.698	0.673	0.697	0.697
2013	0.003	0.040	0.652	0.770	0.796	1.000	0.888	0.604	0.451	0.403	0.403
2014	0.003	0.040	0.652	0.770	0.796	1.000	0.888	0.604	0.451	0.403	0.403
2015	0.003	0.040	0.652	0.770	0.796	1.000	0.888	0.604	0.451	0.403	0.403
Ave2011-2015	0.003	0.038	0.471	0.667	0.824	1.000	0.876	0.638	0.541	0.497	0.497
Survey	0.011	0.141	0.599	0.828	0.772	0.775	1.000	0.977	0.696	0.537	0.537

Table 17.12. Estimated BSAI Atka mackerel begin-year numbers at age in millions, 1977-2015.

	Age										
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1977	331	445	310	128	113	71	63	51	40	30	106
1978	1,579	245	324	206	78	73	49	45	37	29	101
1979	480	1,168	178	206	130	50	50	35	33	27	95
1980	358	355	861	127	133	86	35	36	26	24	91
1981	444	265	262	621	86	89	60	25	26	19	85
1982	319	328	196	190	442	61	62	40	18	19	76
1983	413	236	243	144	138	306	43	45	29	13	71
1984	514	306	175	179	105	99	218	31	33	22	62
1985	601	381	226	128	127	72	65	145	22	24	61
1986	536	445	280	159	87	85	48	43	98	15	61
1987	692	397	328	200	111	60	58	32	28	66	54
1988	452	513	293	235	140	78	42	41	22	20	84
1989	1,619	335	378	210	158	98	55	30	29	16	75
1990	703	1,199	247	275	148	112	70	40	22	21	66
1991	373	521	886	179	194	105	80	51	29	16	64
1992	598	276	385	648	125	132	72	56	36	21	58
1993	1,136	443	204	280	448	84	90	50	40	26	57
1994	403	841	327	147	193	295	54	60	34	28	59
1995	424	298	621	236	101	124	187	35	38	22	59
1996	1,025	314	220	444	151	63	75	111	21	23	52
1997	207	759	232	158	278	90	35	39	57	12	49
1998	384	153	561	167	107	170	57	22	25	38	42
1999	1,055	284	113	405	110	66	103	33	13	16	52
2000	2,225	781	210	82	266	72	42	66	21	9	47
2001	1,379	1,648	577	149	55	173	47	27	42	14	40
2002	1,546	1,022	1,217	411	97	33	104	28	17	28	38
2003	346	1,145	755	881	282	64	21	63	18	12	46
2004	455	256	846	543	608	189	42	13	41	13	41
2005	617	337	189	610	375	412	129	29	9	29	39
2006	405	457	248	136	420	253	278	87	20	7	49
2007	993	300	335	172	93	282	169	187	61	14	40
2008	728	735	220	233	117	64	191	113	128	43	39
2009	237	539	540	153	157	79	42	124	74	86	58
2010	506	175	395	373	99	99	50	26	77	49	99
2011	259	374	129	277	238	61	61	31	16	51	103
2012	727	191	276	93	190	157	40	41	21	11	106
2013	524	538	141	199	64	124	99	26	27	14	77
2014	474	388	397	100	139	45	85	69	18	19	66
2015	507	351	287	279	69	97	31	59	49	13	61
Average	681	506	375	266	179	120	80	53	36	25	65

Table 17.13. 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 1977-2015). Also included are female spawning biomass in metric tons from the current recommended assessment model, Model 1 (1977-2015) compared to last year's (2014) assessment results.

	Current assessment age 1+ biomass (t)			Age 3+ biomass (t)		Female spawning biomass (t)	
Year	Estimate	LCI	UCI	Current	2014	Current	2014
1977	686,306	430,932	1,093,020	599,600	593,761	194,570	195,918
1978	711,359	440,142	1,149,700	601,180	598,061	187,100	189,565
1979	749,829	457,632	1,228,590	539,910	541,410	183,300	185,867
1980	841,725	514,428	1,377,260	768,400	744,694	195,290	195,253
1981	840,523	512,752	1,377,820	777,880	783,547	240,770	244,974
1982	790,383	480,873	1,299,110	723,080	712,679	252,140	250,169
1983	737,510	448,714	1,212,180	680,880	677,133	238,160	239,507
1984	715,103	438,245	1,166,870	642,680	641,628	223,200	225,315
1985	684,321	417,392	1,121,950	595,940	585,479	200,780	200,113
1986	665,993	406,461	1,091,240	570,160	560,323	182,380	182,730
1987	675,110	417,372	1,092,010	580,020	583,995	179,670	185,382
1988	700,752	441,430	1,112,410	597,760	587,278	189,190	188,732
1989	765,320	498,859	1,174,110	638,750	620,601	198,240	196,234
1990	862,067	583,651	1,273,290	637,120	623,772	212,120	210,342
1991	982,876	685,065	1,410,150	882,170	829,664	233,480	226,247
1992	993,110	699,500	1,409,960	921,770	894,637	277,890	272,842
1993	959,289	678,045	1,357,190	836,950	804,437	282,000	272,427
1994	926,177	653,761	1,312,110	772,360	744,253	250,710	244,682
1995	914,533	642,931	1,300,870	847,390	808,834	231,820	225,392
1996	840,252	578,970	1,219,450	743,630	719,624	218,400	212,854
1997	740,754	494,323	1,110,040	608,970	580,223	195,270	187,886
1998	722,334	481,491	1,083,650	680,400	651,830	181,630	178,579
1999	685,889	451,594	1,041,740	592,790	576,888	189,980	185,635
2000	757,727	506,969	1,132,520	532,010	500,536	175,910	167,116
2001	961,492	662,291	1,395,860	633,790	597,011	168,620	162,810
2002	1,232,930	866,362	1,754,580	998,810	926,235	220,210	211,301
2003	1,377,020	978,161	1,938,520	1,176,800	1,103,490	315,120	299,643
2004	1,376,640	979,141	1,935,500	1,315,000	1,214,159	376,620	352,769
2005	1,251,600	883,117	1,773,840	1,169,600	1,107,843	397,170	377,435
2006	1,122,530	782,453	1,610,420	1,030,700	951,380	365,480	338,829
2007	1,021,830	706,438	1,478,040	928,960	856,273	317,160	294,742
2008	961,148	663,535	1,392,250	809,870	752,935	277,780	260,525
2009	919,321	632,331	1,336,560	821,780	744,300	242,720	227,748
2010	839,363	566,008	1,244,740	788,430	699,693	233,410	212,093
2011	729,110	478,819	1,110,230	657,100	574,607	223,640	197,127
2012	677,146	439,510	1,043,270	613,690	529,370	198,120	168,315
2013	638,889	408,706	998,710	528,580	542,400	183,540	166,436
2014	665,052	427,093	1,035,590	581,180	573,648	177,910	176,036
2015	668,364	427,040	1,046,060	589,050		177,290	167,136
2016	636,454	394,063	1,027,940			164,076	

Table 17.14. Estimates of age-1 Atka mackerel recruitment (millions of recruits) and standard deviation (Std. dev.).

	Age 1 recruitment		
Year	Current	Std. dev	2014 assessment
1977	330.7	99.3	340
1978	1,578.5	399.0	1,620
1979	479.5	133.3	495
1980	357.9	104.9	369
1981	443.6	128.1	451
1982	319.0	94.7	321
1983	413.1	115.1	414
1984	514.4	136.5	513
1985	601.0	152.5	614
1986	536.3	140.3	540
1987	692.3	159.8	693
1988	452.3	106.1	452
1989	1,618.7	274.4	1,596
1990	702.8	138.3	708
1991	372.8	83.3	374
1992	597.8	112.9	593
1993	1,136.2	182.9	1,138
1994	402.9	84.9	402
1995	424.2	89.3	420
1996	1,025.4	180.8	1,020
1997	207.1	49.3	206
1998	383.7	85.1	377
1999	1,054.6	205.9	1,043
2000	2,224.5	375.0	2,174
2001	1,379.3	239.0	1,347
2002	1,545.8	259.7	1,489
2003	345.6	77.5	336
2004	454.9	95.1	436
2005	617.2	121.4	586
2006	404.9	82.5	373
2007	993.5	172.2	863
2008	727.8	140.5	633
2009	236.8	58.7	199
2010	505.9	117.1	527
2011	258.7	67.5	643
2012	726.6	190.3	585
2013	524.2	160.7	510
2014	473.5	202.6	515
2015	507.0	223.8	
Average 78-14	695.49		691.22
Median 78-14	514.35		527

Table 17.15. Estimates of full-selection fishing mortality rates and exploitation rates (Catch/Biomass) for BSAI Atka mackerel.

Year	*F*	Catch/Biomass Rate[b]
1977	0.190	0.036
1978	0.160	0.040
1979	0.138	0.043
1980	0.100	0.027
1981	0.102	0.025
1982	0.066	0.027
1983	0.041	0.017
1984	0.118	0.056
1985	0.111	0.064
1986	0.128	0.056
1987	0.067	0.052
1988	0.096	0.037
1989	0.051	0.028
1990	0.052	0.035
1991	0.082	0.030
1992	0.098	0.053
1993	0.144	0.079
1994	0.154	0.085
1995	0.226	0.096
1996	0.364	0.140
1997	0.192	0.108
1998	0.227	0.084
1999	0.176	0.095
2000	0.162	0.089
2001	0.220	0.097
2002	0.204	0.045
2003	0.154	0.046
2004	0.091	0.046
2005	0.093	0.053
2006	0.101	0.060
2007	0.106	0.063
2008	0.131	0.072
2009	0.202	0.089
2010	0.179	0.087
2011	0.129	0.079
2012	0.156	0.078
2013	0.071	0.044
2014	0.082	0.053
2015	0.163	0.093

[a] Catch/Biomass rate is the ratio of catch to beginning year age 3+ biomass.

Table 17.16. 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 339,135 t, 135,654 t, and 118,697 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2015	54,500	54,500	54,500	54,500	54,500	54,500	54,500
2016	72,272	72,272	21,634	26,896	0	104,749	90,340
2017	85,836	85,836	22,720	27,966	0	91,954	82,712
2018	84,556	84,556	25,008	30,584	0	85,232	92,868
2019	83,550	83,550	26,892	32,753	0	87,352	90,537
2020	85,484	85,484	28,528	34,648	0	90,776	92,041
2021	88,516	88,516	30,204	36,598	0	94,338	94,774
2022	91,071	91,071	31,525	38,129	0	97,167	97,307
2023	90,549	90,549	31,858	38,472	0	96,304	96,365
2024	90,152	90,152	32,055	38,672	0	95,601	95,644
2025	89,913	89,913	32,180	38,793	0	95,238	95,265
2026	89,105	89,105	32,101	38,673	0	94,381	94,391
2027	89,763	89,763	32,319	38,933	0	95,218	95,222
2028	90,011	90,011	32,461	39,094	0	95,542	95,543
Fishing M.	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2015	0.163	0.163	0.163	0.163	0.163	0.163	0.163
2016	0.234	0.234	0.066	0.083	0.000	0.353	0.299
2017	0.299	0.299	0.066	0.083	0.000	0.348	0.299
2018	0.293	0.293	0.066	0.083	0.000	0.317	0.333
2019	0.281	0.281	0.066	0.083	0.000	0.311	0.318
2020	0.279	0.279	0.066	0.083	0.000	0.312	0.315
2021	0.279	0.279	0.066	0.083	0.000	0.314	0.315
2022	0.280	0.280	0.066	0.083	0.000	0.316	0.317
2023	0.280	0.280	0.066	0.083	0.000	0.316	0.316
2024	0.280	0.280	0.066	0.083	0.000	0.315	0.315
2025	0.280	0.280	0.066	0.083	0.000	0.315	0.315
2026	0.280	0.280	0.066	0.083	0.000	0.314	0.314
2027	0.279	0.279	0.066	0.083	0.000	0.314	0.314
2028	0.279	0.279	0.066	0.083	0.000	0.314	0.314
Spawning biom.	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2015	177,285	177,285	177,285	177,285	177,285	177,285	177,285
2016	166,407	166,407	178,015	176,832	182,829	158,686	162,140
2017	147,496	147,496	181,123	177,932	194,505	133,987	141,490
2018	135,777	135,777	189,338	184,334	210,928	122,916	129,319
2019	134,986	134,986	204,241	197,603	233,523	123,339	126,742
2020	137,370	137,370	219,475	211,359	255,907	125,928	127,632
2021	138,751	138,751	231,035	221,666	273,692	127,168	128,020
2022	140,802	140,802	242,687	232,113	291,418	128,780	129,231
2023	141,768	141,768	251,209	239,654	305,000	129,354	129,595
2024	141,042	141,042	255,566	243,294	313,188	128,472	128,613
2025	140,578	140,578	258,547	245,755	319,033	128,015	128,096
2026	140,285	140,285	261,059	247,833	323,968	127,731	127,769
2027	140,196	140,196	262,609	249,095	327,193	127,681	127,698
2028	140,999	140,999	264,812	251,067	330,726	128,437	128,445

Table 17.17. 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 – Pribilof Island rookeries declining, Bogoslof breeding rookery increasing. Steller sea lions western stock increasing slightly	Mixed potential impact, possibly increased 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 stabilizing, possibly slight declining trend	Possible changes in predation on Atka mackerel	No concern
Changes in habitat quality			
Temperature regime	2014 AI summer bottom temperature was well above average (2nd highest in the time series, similar to 1991 and 1997 surveys)	Could possibly affect fish distribution	Unknown

***The Atka mackerel* effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Variable, 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
Fishery concentration in space and time	Steller sea lion protection measures spread out Atka mackerel catches in time and space. Western Aleutians (WAI) closed to directed Atka mackerel fishery (2011-2014); Atka mackerel TAC reduced in Central Aleutians (≤47% CAI ABC). WAI opened to directed fishing 2015; WAI TAC reduced to ≤65% WAI ABC. Fishery has become highly concentrated in 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 (environmental)	Probably no concern
Fishery contribution to discards and offal production	Offal production—unknown From 2012-2014, the Atka mackerel fishery contributed an average of 660 and 497 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

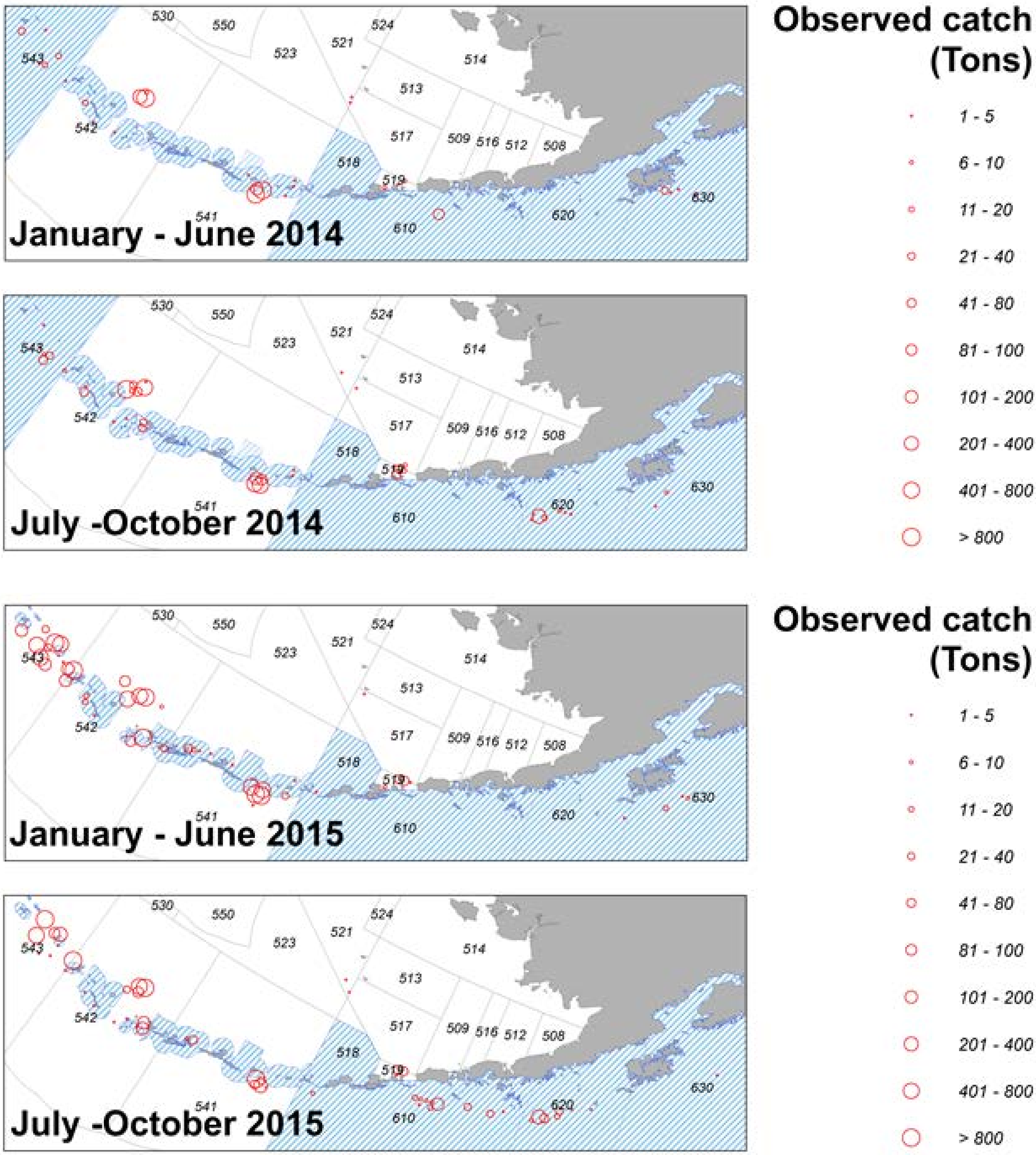


Figure 17.1. Observed catches of Atka mackerel summed for 20 km^2 cells for 2014 and 2015 where observed catch per haul was greater than 1 t. Shaded areas represent areas closed to directed Atka mackerel fishing.

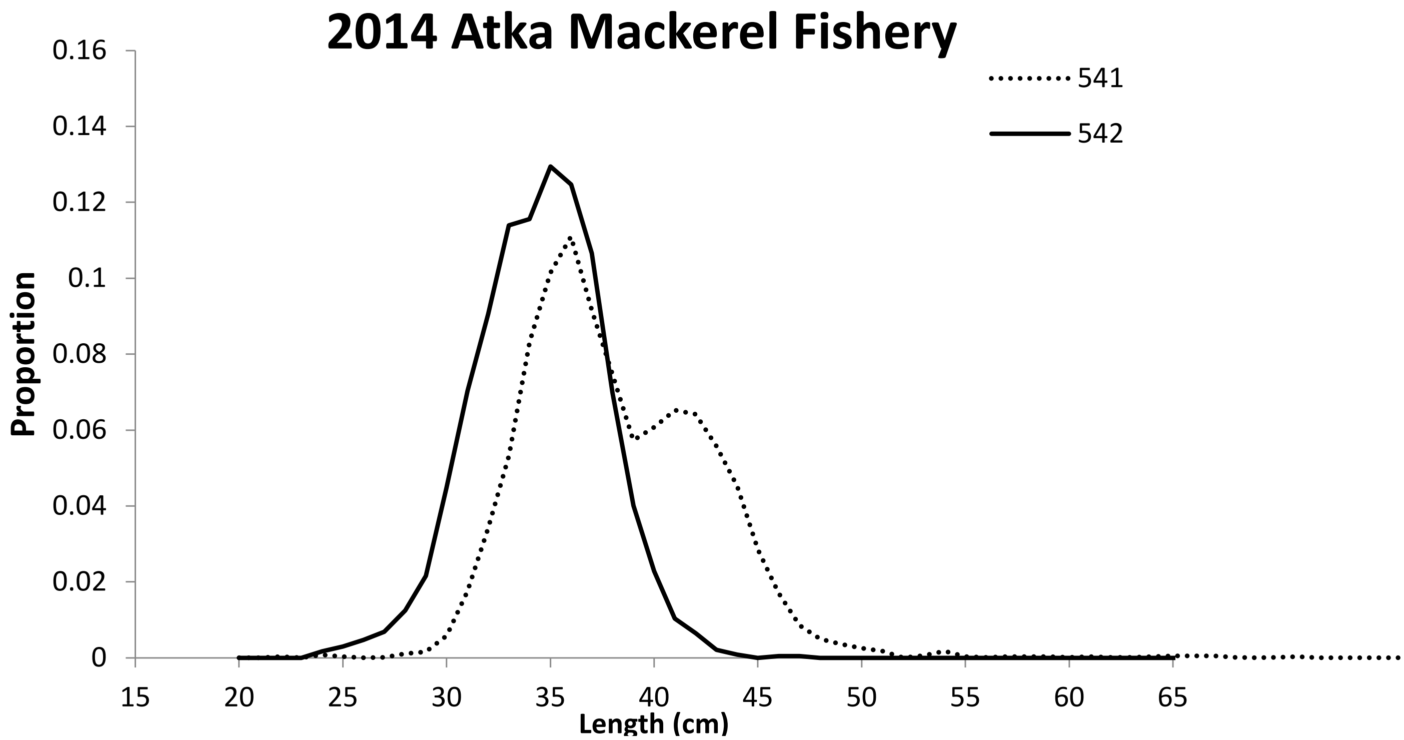


Figure 17.2. 2014 Atka mackerel fishery length-frequency data by area fished (see Figure 17.1). Numbers refer to management areas. Too few fish were measured in area 543 for presentation.

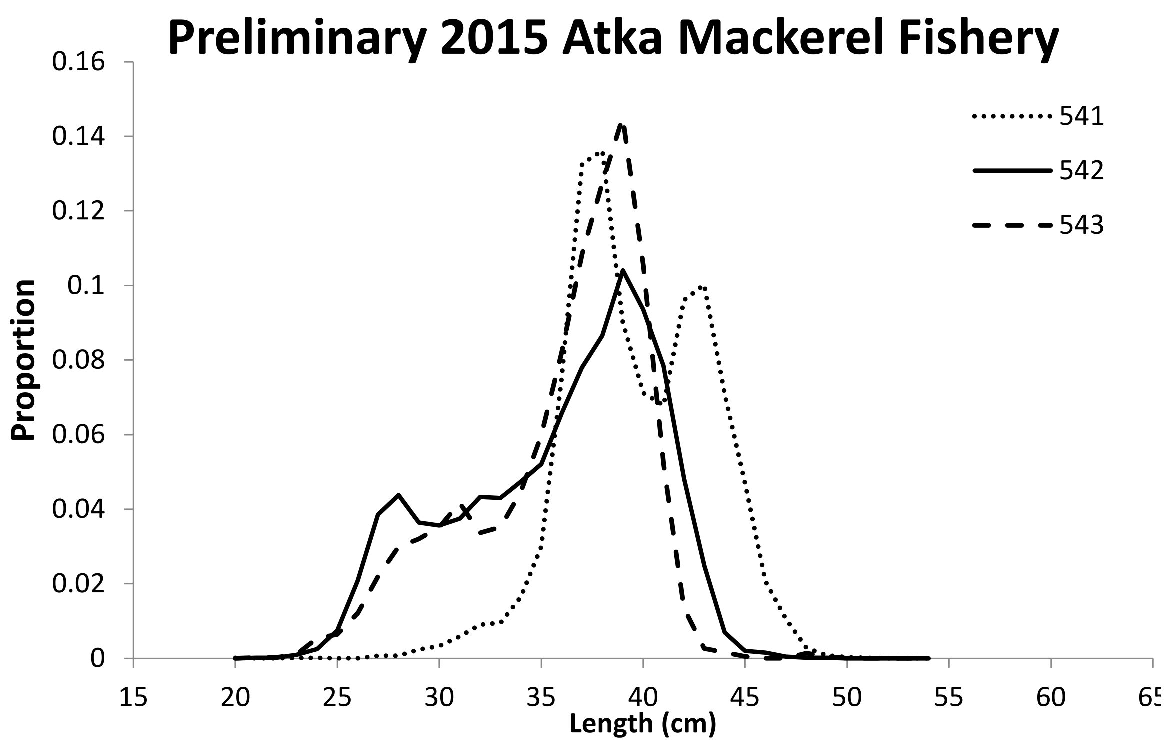


Figure 17.3. Preliminary 2015 Atka mackerel fishery length-frequency data by area fished (see Figure 17.1). Numbers refer to management areas.

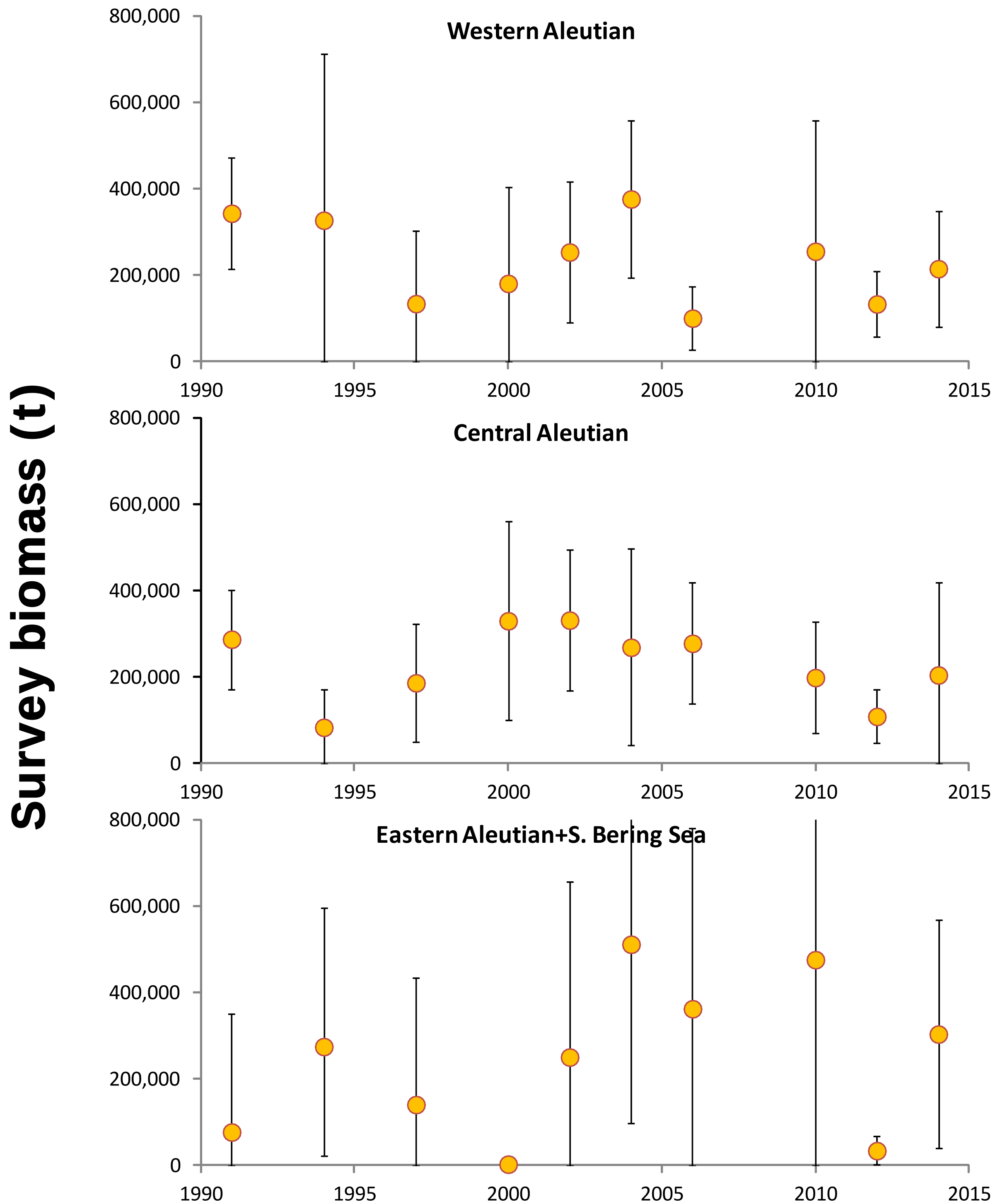


Figure 17.4. Atka mackerel Aleutian Islands survey biomass estimates by area and survey year. Bars represent 95% confidence intervals based on sampling error.

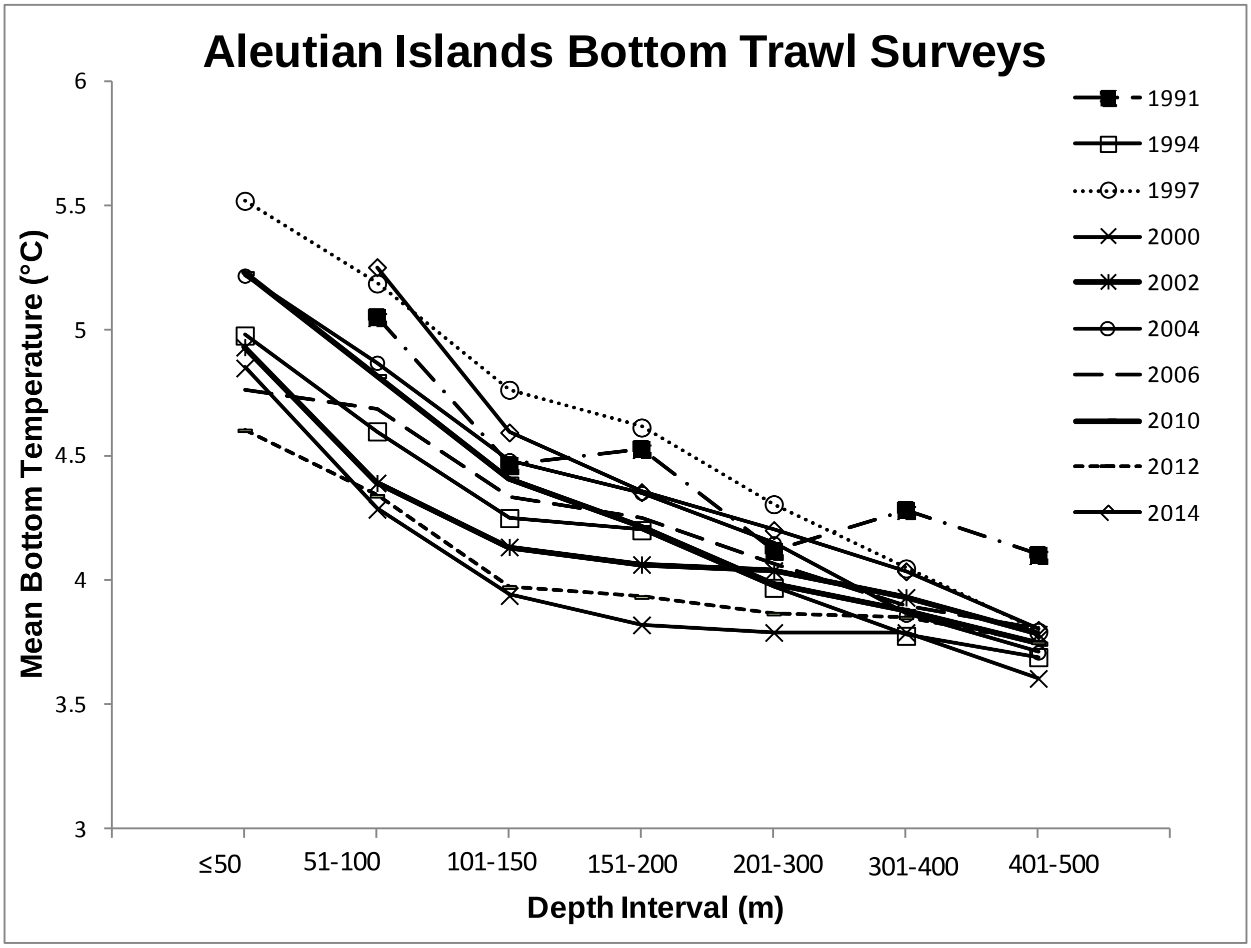


Figure 17.5. Average bottom temperatures by depth interval from Aleutian Islands summer bottom-trawl surveys, 1991 to 2014.

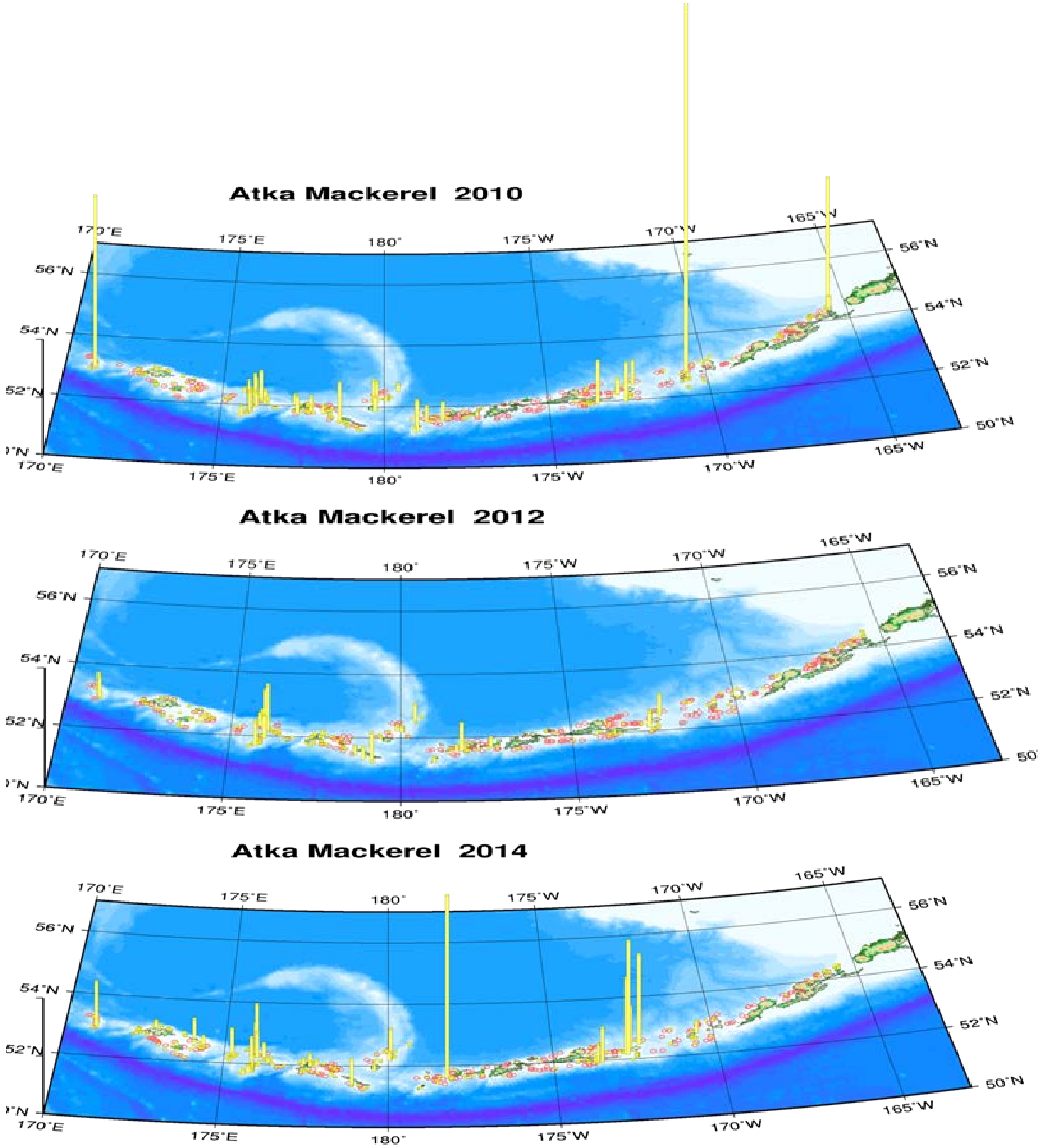
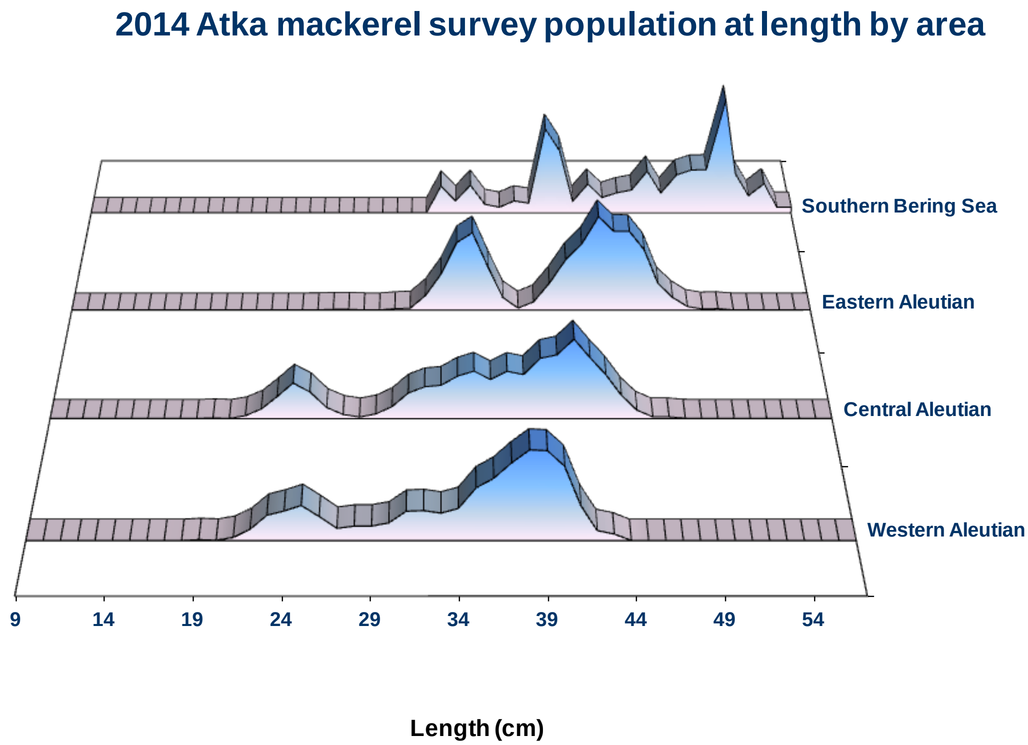


Figure 17.6. Bottom-trawl survey CPUE distributions of Atka mackerel catches during the summers of 2010, 2012, and 2014.



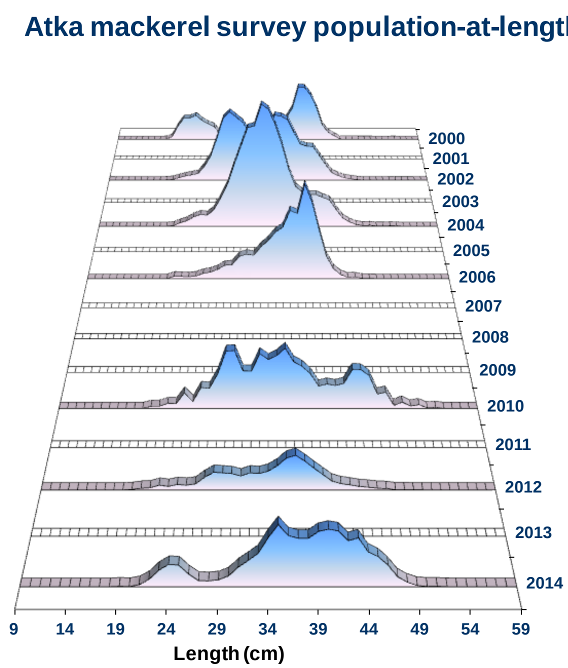


Figure 17.7. Atka mackerel bottom trawl survey length frequency data by subarea in 2014 (top) and for all areas, 2000-2014 (bottom). Vertical scale is proportion in top panel and estimated absolute numbers at age bottom panel.

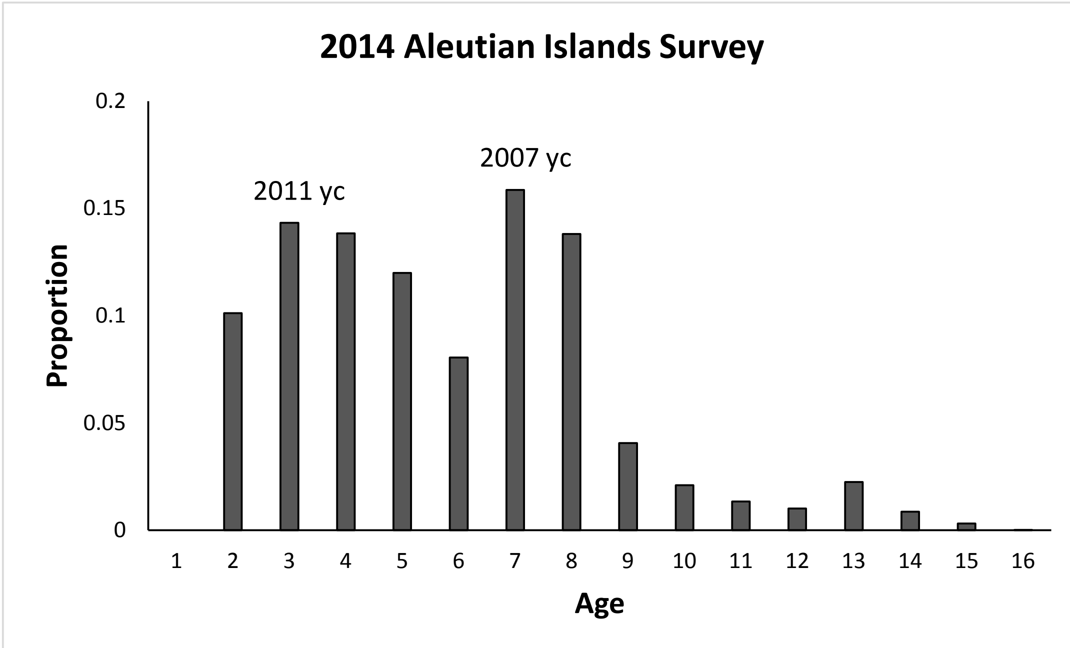


Figure 17.8. Atka mackerel age distribution from the Aleutian Islands 2014 bottom trawl survey. A total of 478 otoliths were aged; mean age from the 2014 survey is 5.8 years.

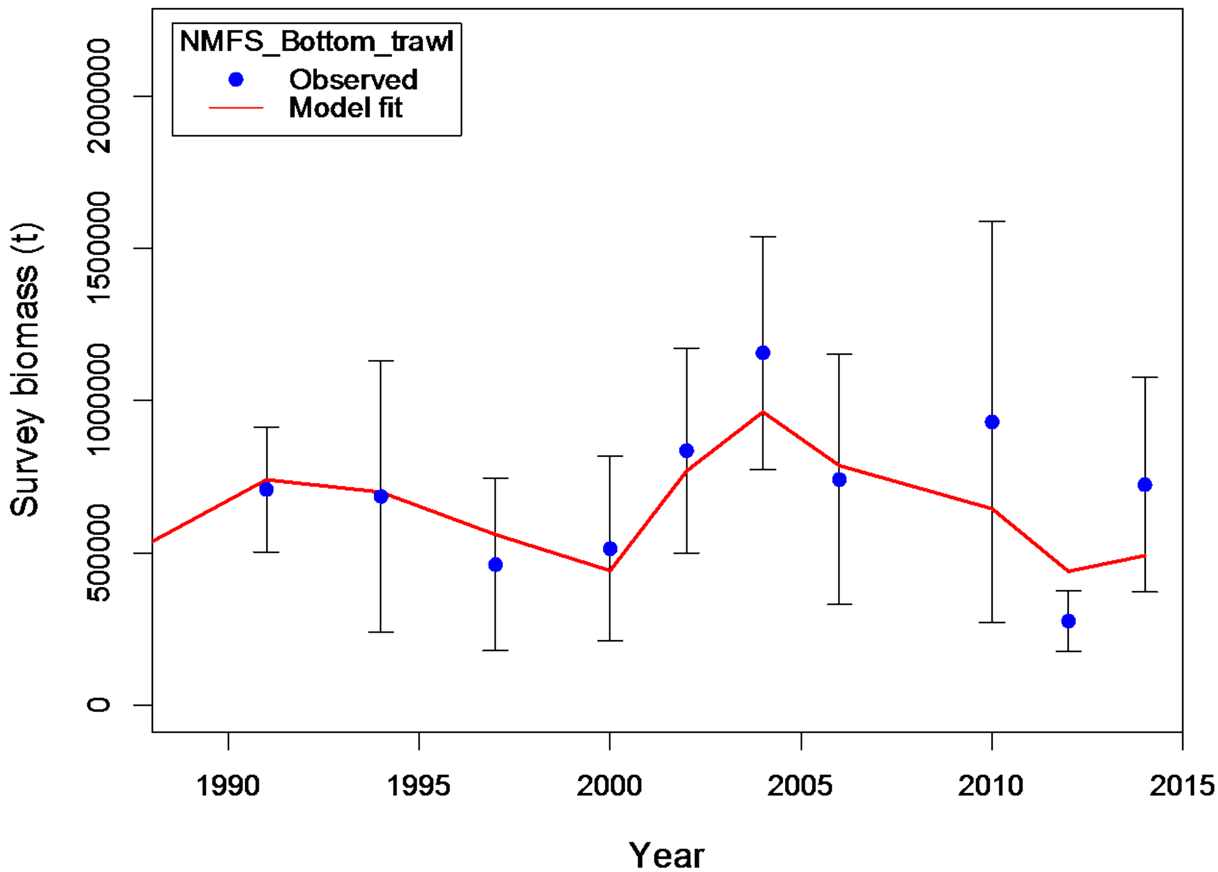


Figure 17.9. Observed (dots) and predicted (trend line) survey biomass estimates (t) for Bering Sea/Aleutian Islands Atka mackerel. Error bars represent two standard errors (based on sampling) from the survey estimates.

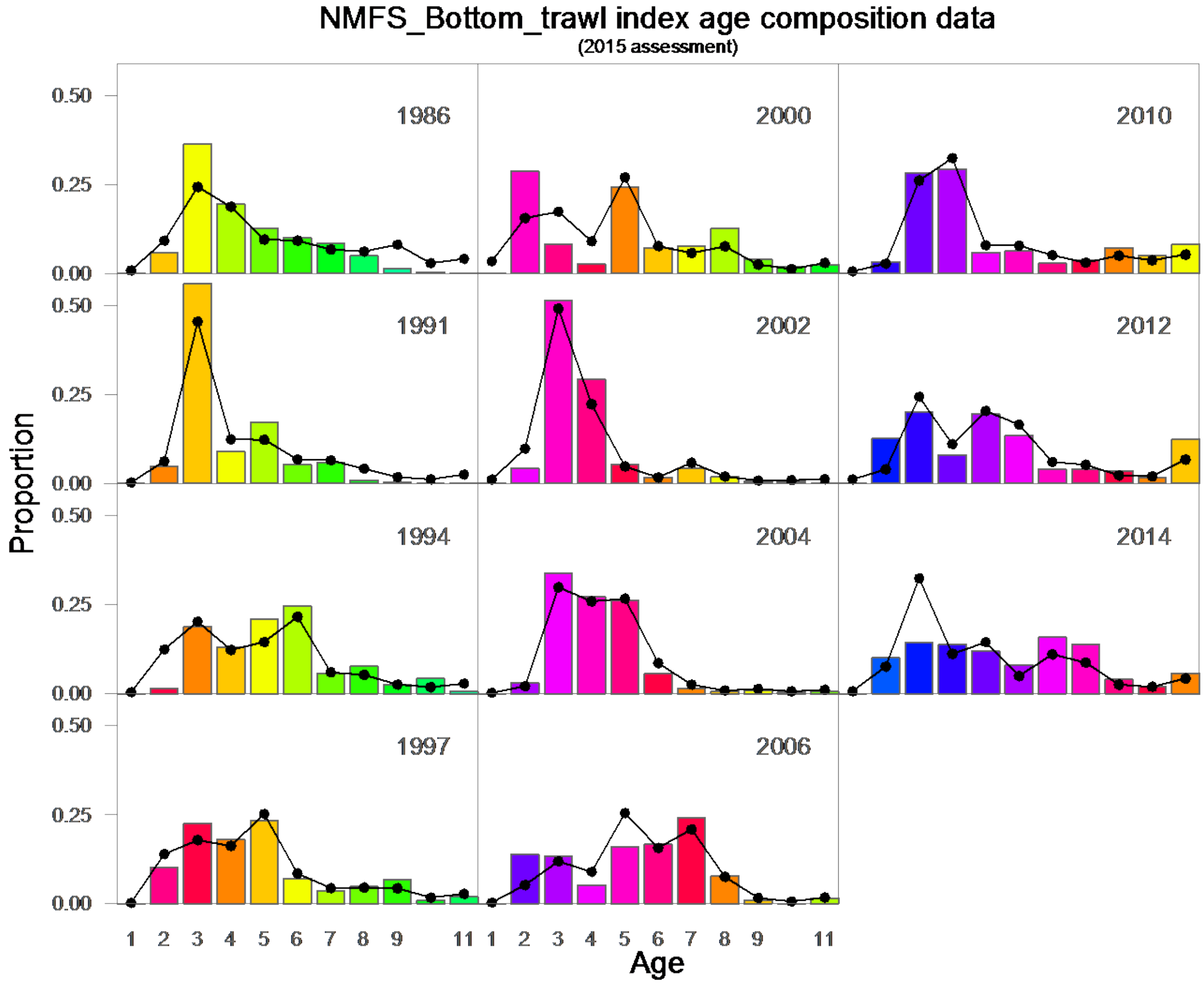


Figure 17.10. Observed and predicted **survey** proportions-at-age for BSAI Atka mackerel. Lines with "•" symbol are the model predictions and columns are the observed proportions at age.

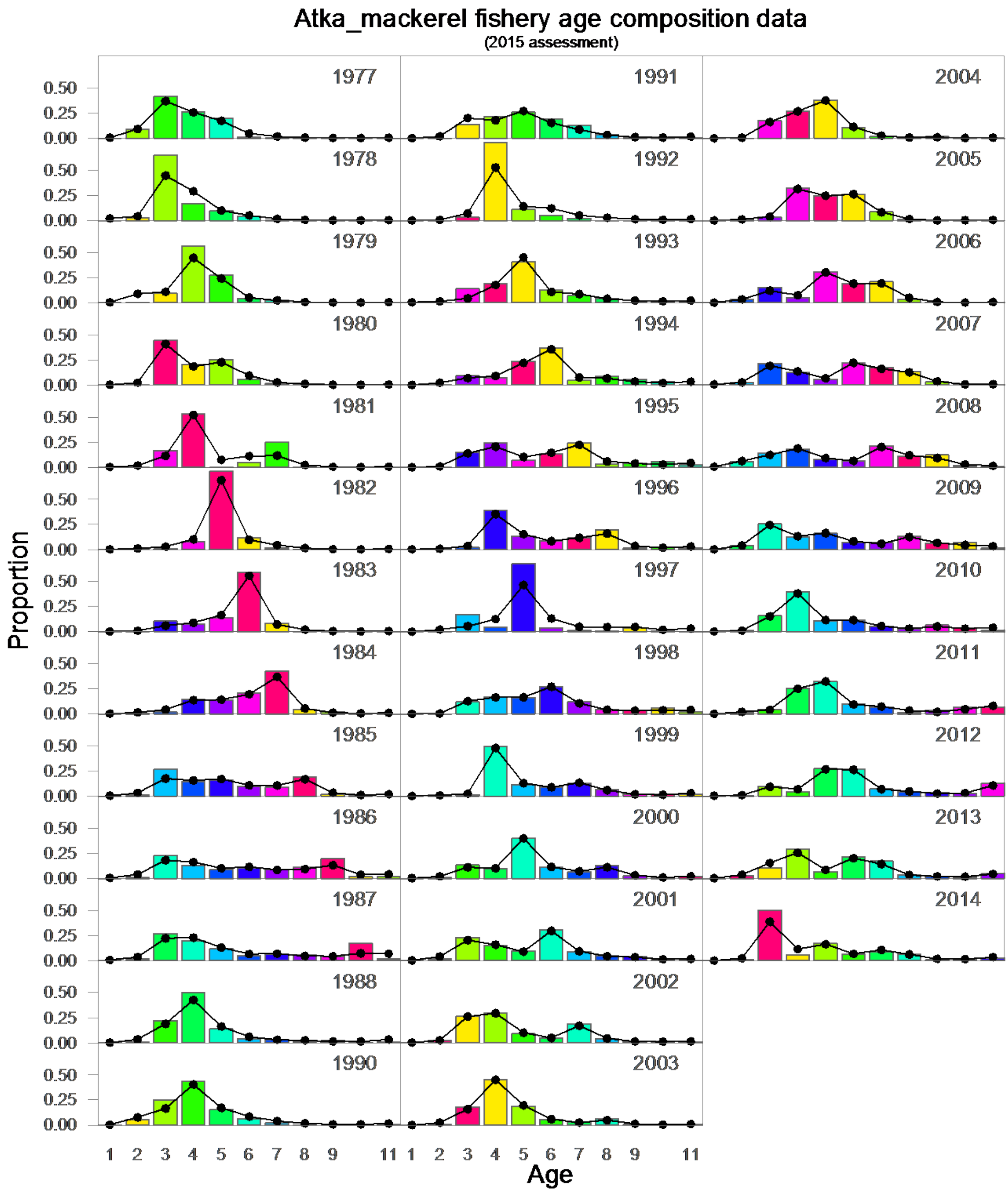


Figure 17.11. Observed and predicted Atka mackerel **fishery** proportions-at-age for BSAI Atka mackerel. Lines with "•" symbol are the model predictions and columns are the observed proportions at age (with colors corresponding to cohorts).

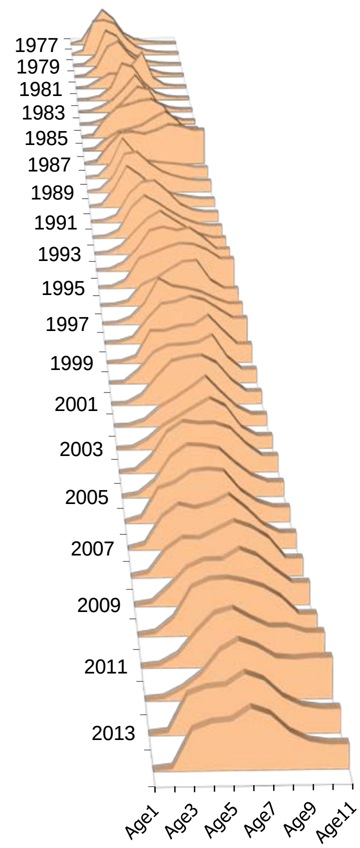


Figure 17.12. Fishery selectivity estimates over time for BSAI Atka mackerel.

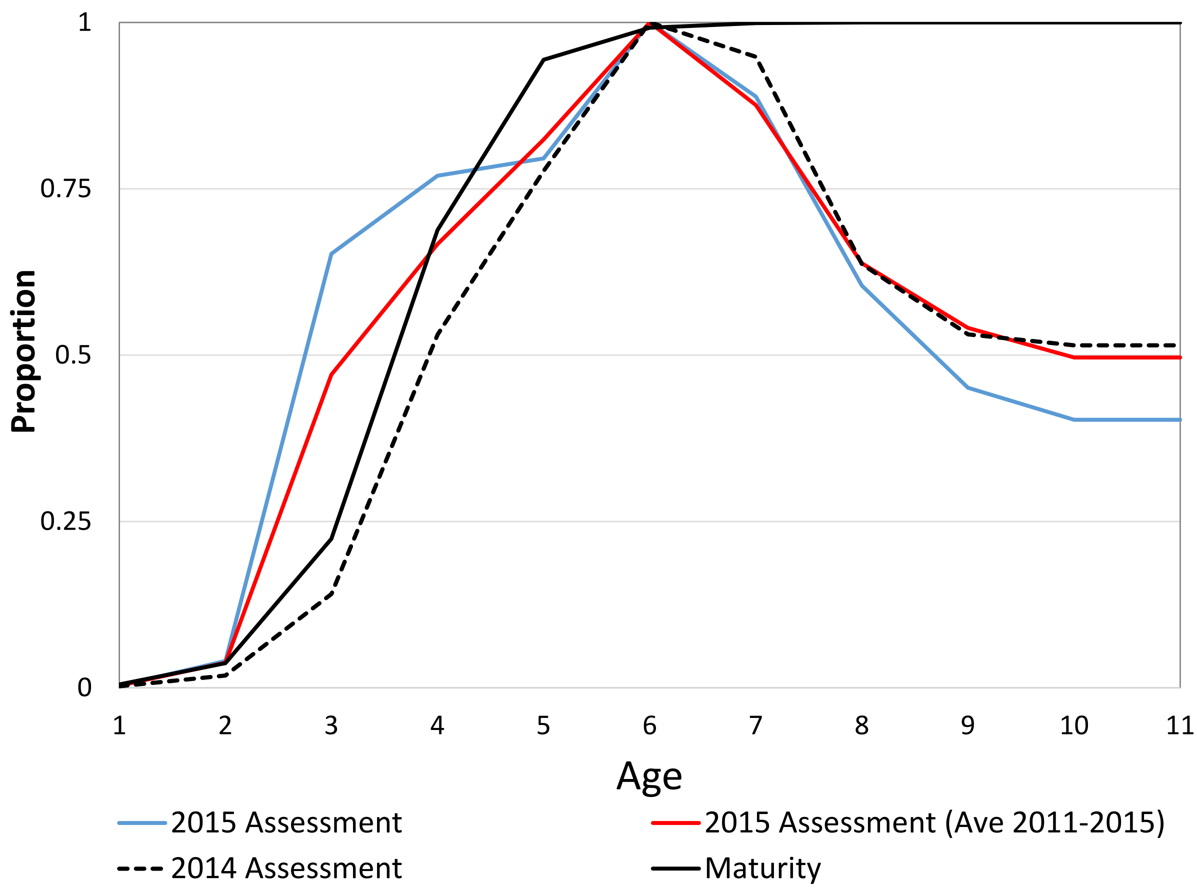


Figure 17.13. Estimated fishery selectivity patterns in the current assessment with a) the 2015 assessment terminal year, b) the 2015 assessment average selectivity for 2011-2015 (used for projections), and c) last year's assessment terminal year compared with the maturity-at-age estimates for BSAI Atka mackerel.

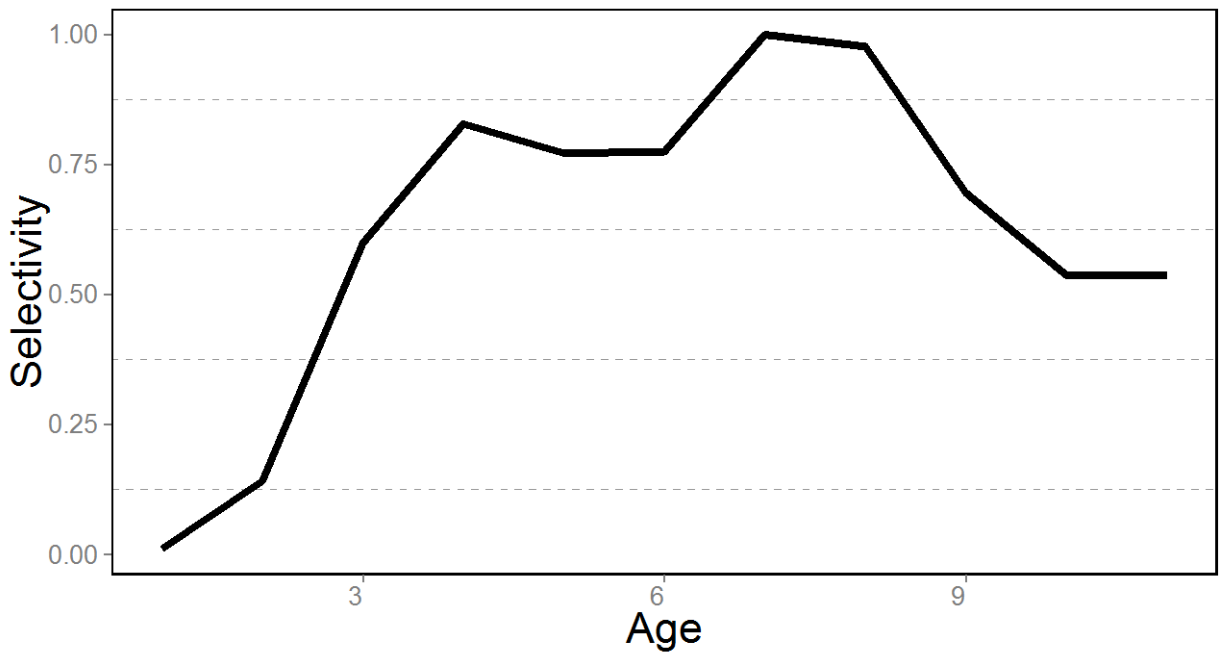


Figure 17.14. Estimated BSAI Atka mackerel survey selectivity-at-age from the current recommended model configuration (Model 1). Selectivity estimates have been normalized to a maximum value of 1.0 for presentation.

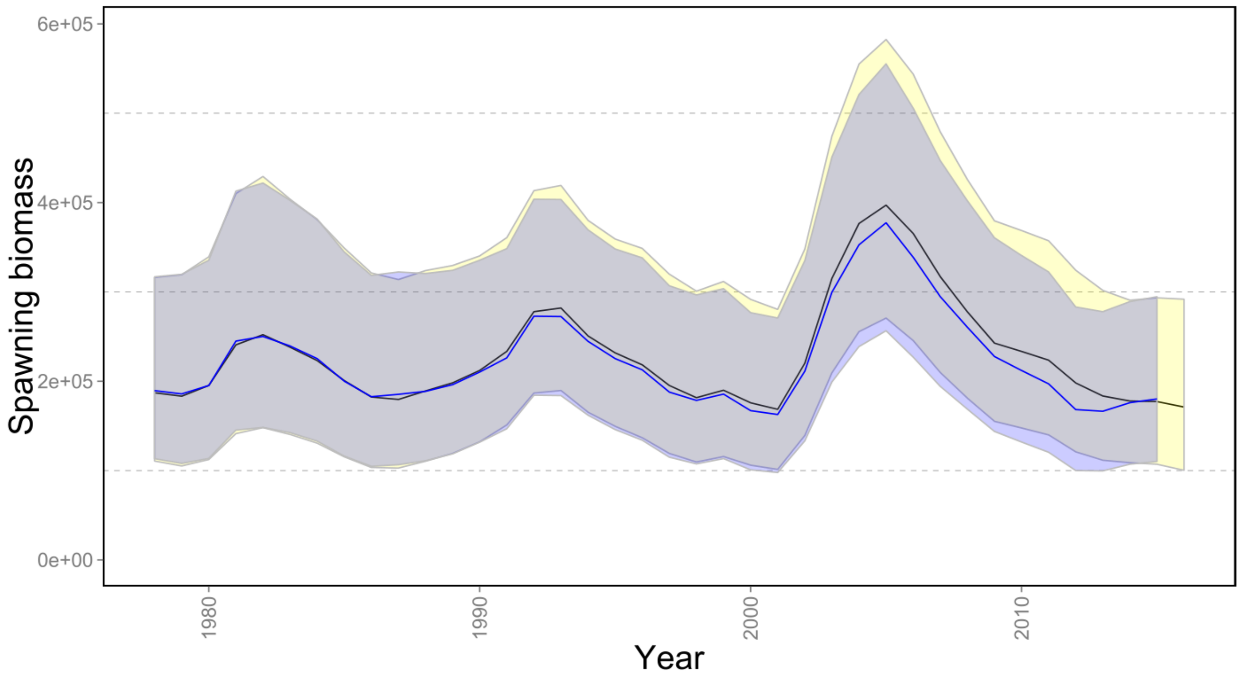


Figure 17.15. Time series of estimated Aleutian Islands Atka mackerel spawning biomass with approximate 95% confidence bounds compared to last year's (2014 assessment) selected model.

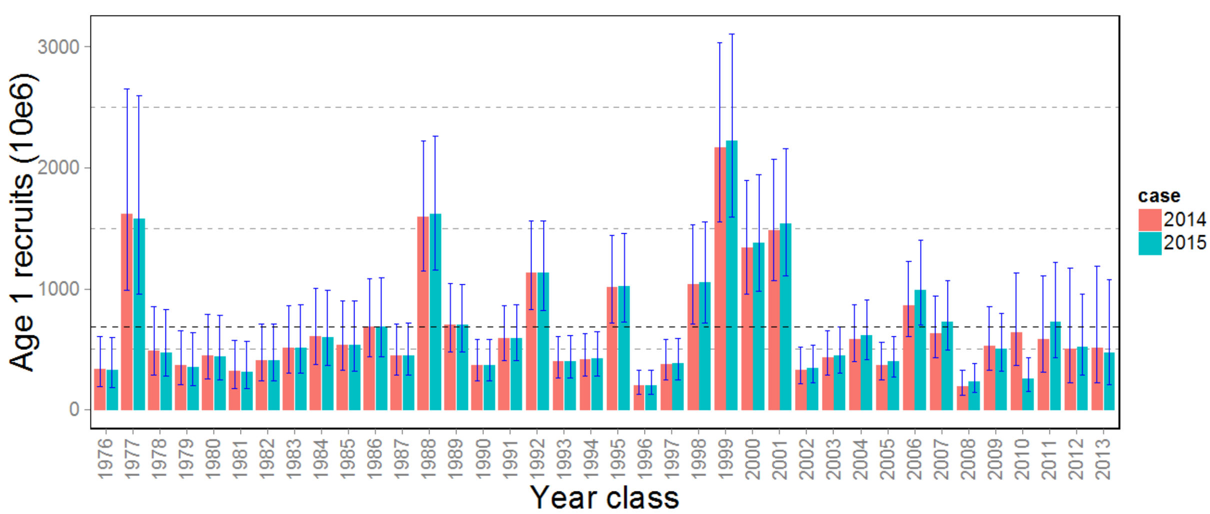


Figure 17.16. Age 1 recruitment from the current assessment (2015) with the dashed line indicating average recruitment (695 million) over 1978-2014, and age 1 recruitment as estimated from the 2014 assessment.

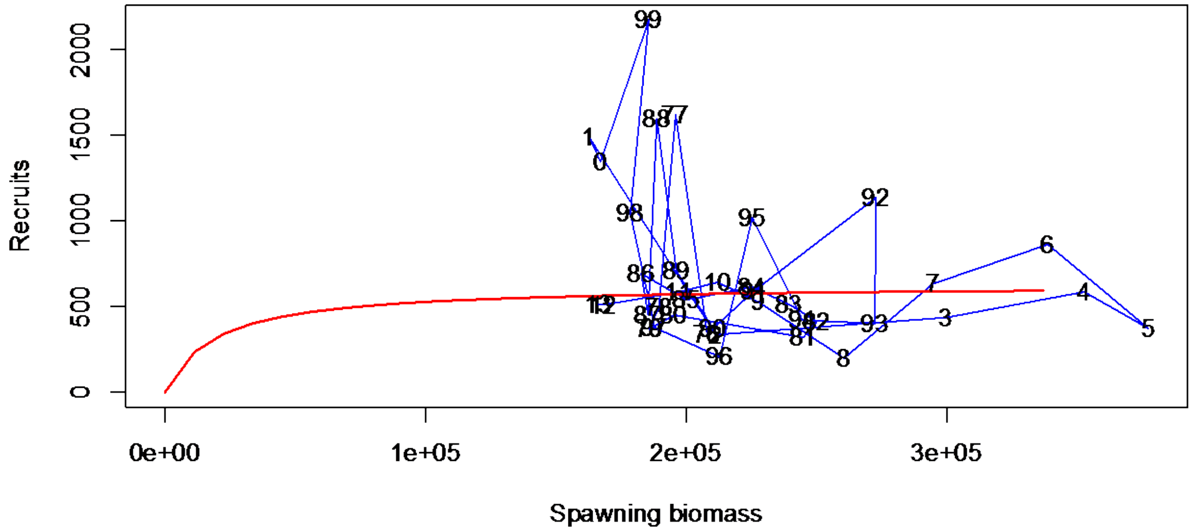


Figure 17.17. Estimated age 1 recruits (millions) versus female spawning biomass (t) for BSAI Atka mackerel. Solid line indicates Beverton-Holt stock recruitment curve (with steepness fixed at 0.6).

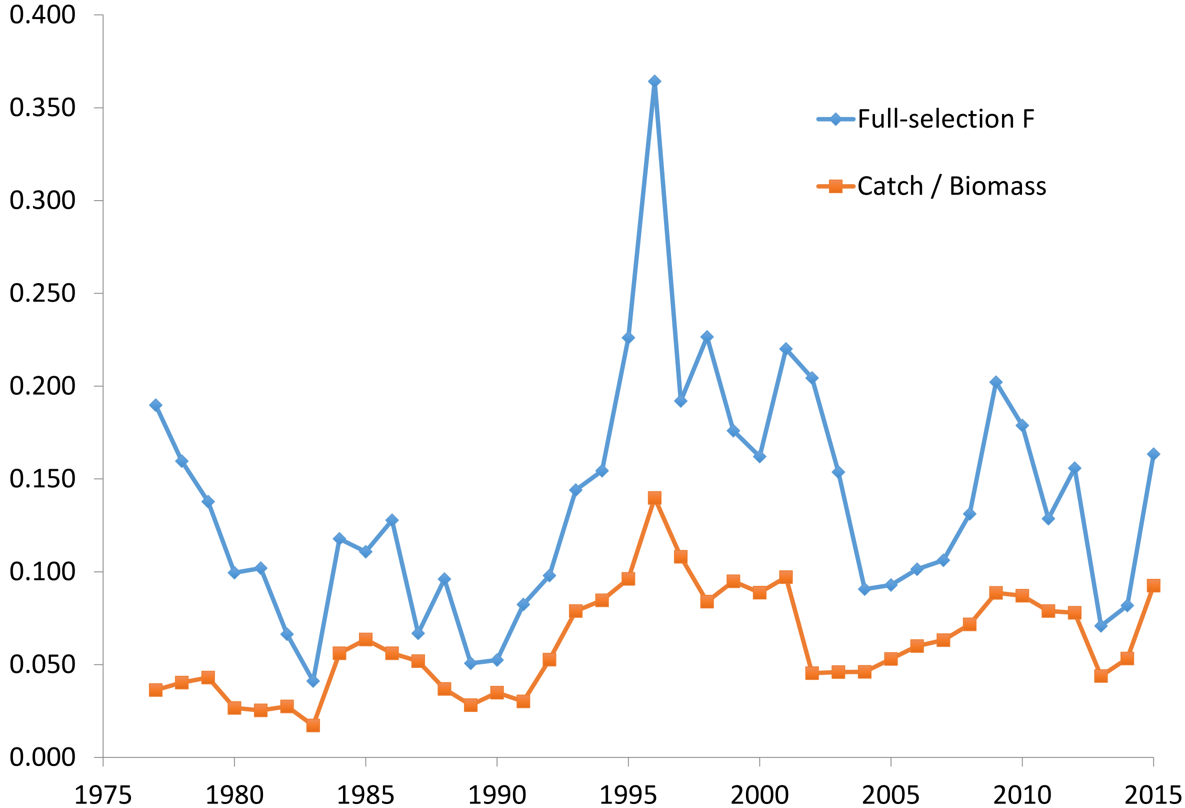


Figure 17.18. Estimated time series of Model 1 full-selection fishing mortality and catch/biomass exploitation rates of Atka mackerel, 1977-2015. Catch/biomass rates are the ratios of catch to beginning year age 3+ biomass.

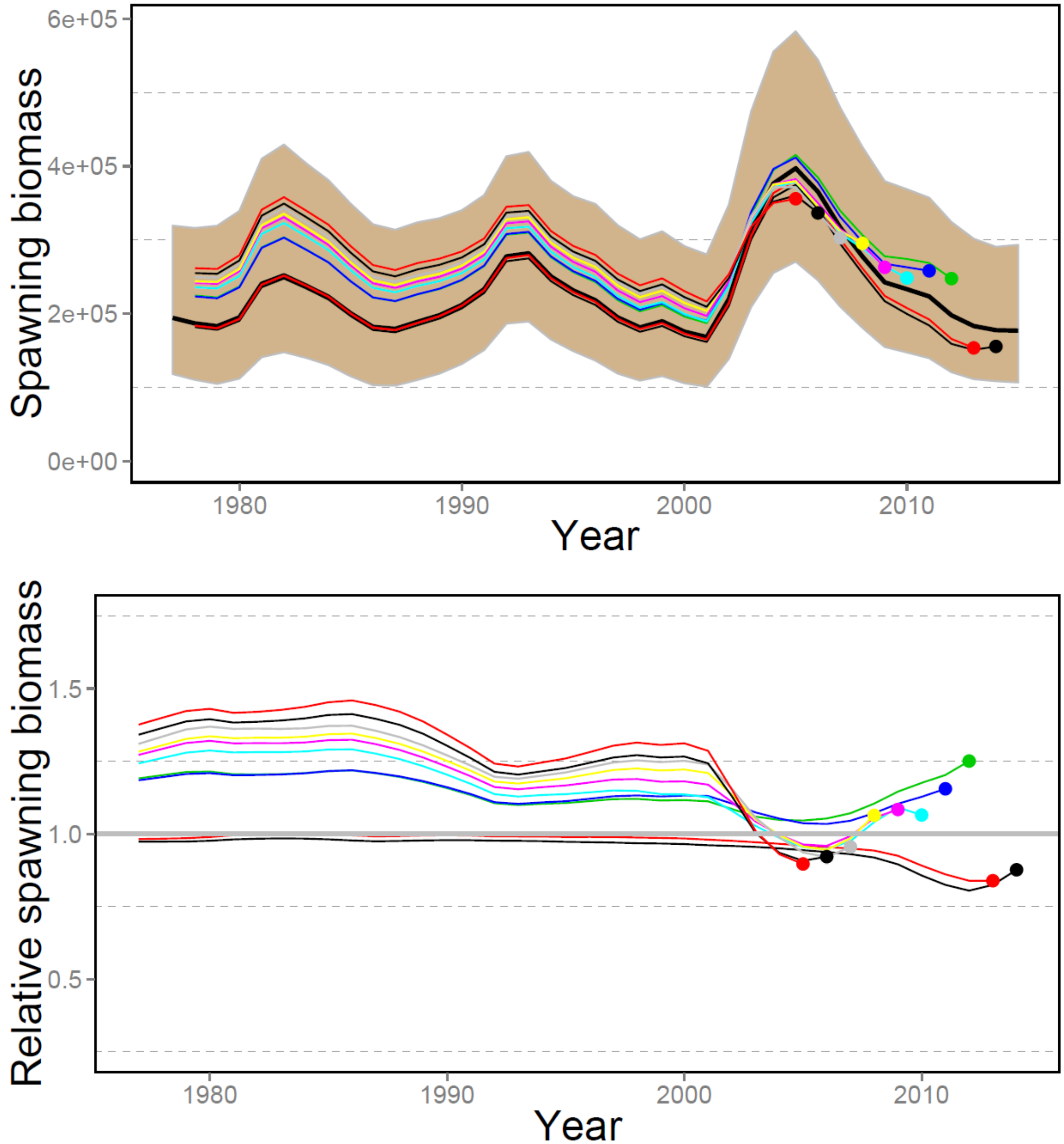
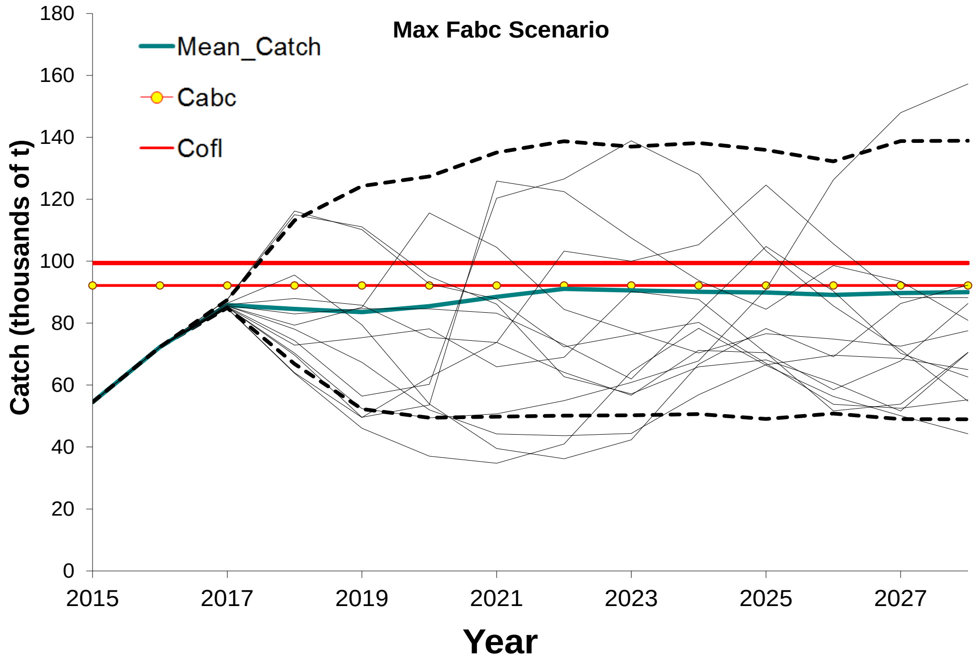


Figure 17.19. Retrospective plots showing the spawning biomass over time (top) and the relative difference (bottom) over 10 different "peels".



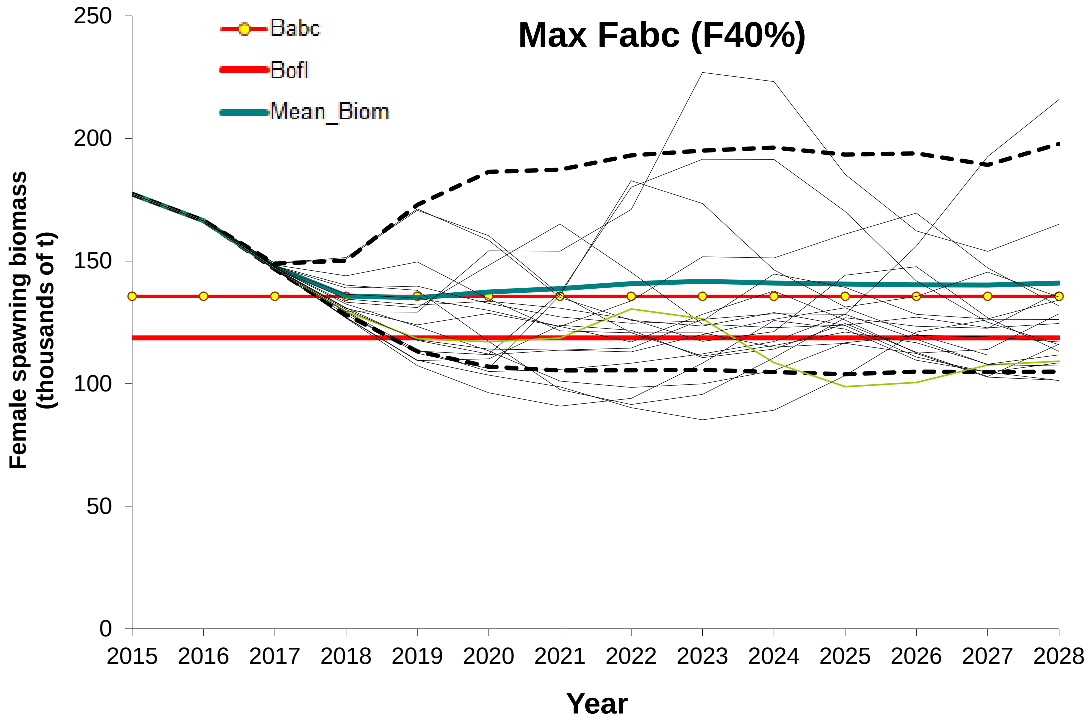


Figure 17.20. Projected Atka mackerel catch (assuming TAC taken in 2015 and reduced 2016 catch; top) and spawning biomass (bottom) in thousands of metric tons under maximum permissible Tier 3a harvest specification. The individual thin lines represent samples of simulated trajectories.

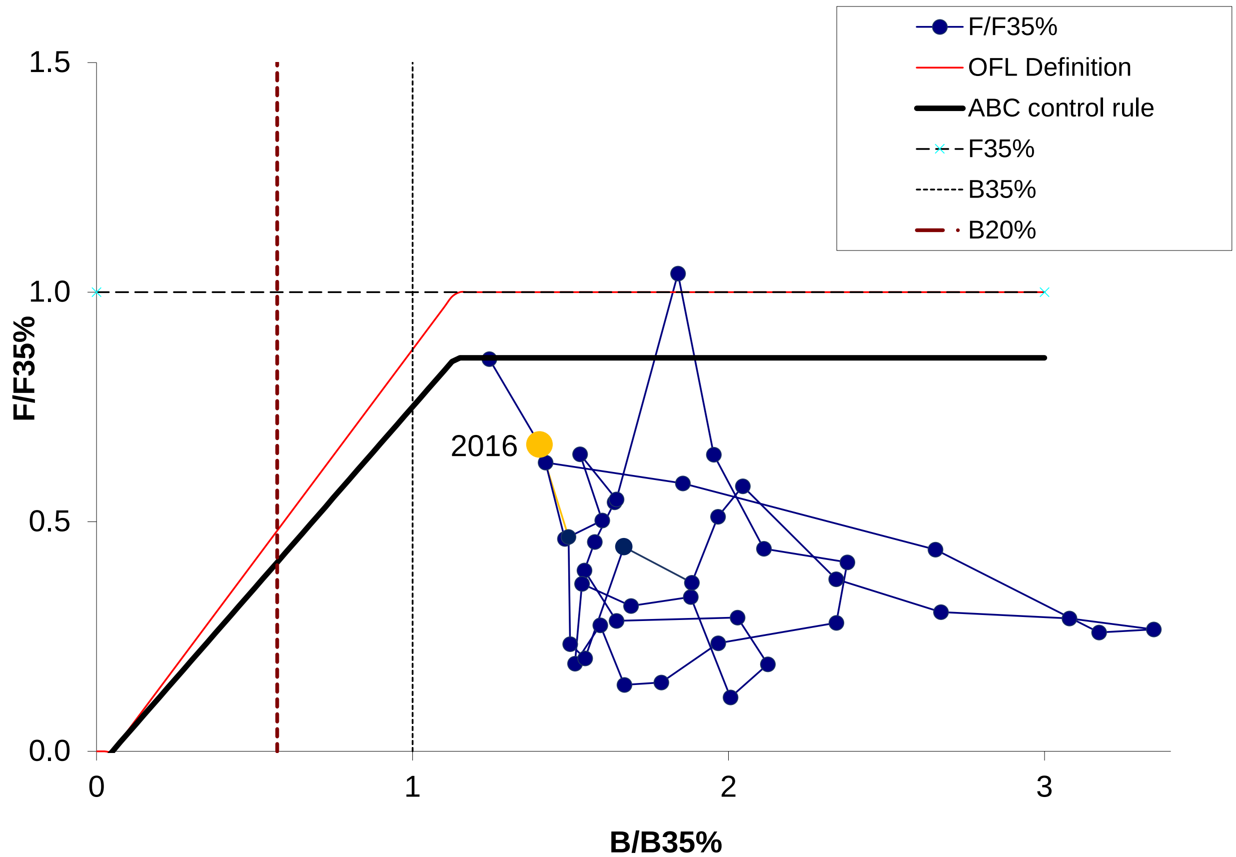


Figure 17.21. Aleutian Islands Atka mackerel spawning biomass relative to $B_{35\%}$ and fishing mortality relative to F_{OFL} (1977-2017). The ratio of fishing mortality to F_{OFL} is calculated using the estimated selectivity pattern in that year. Estimates of spawning biomass and $B_{35\%}$ are based 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.

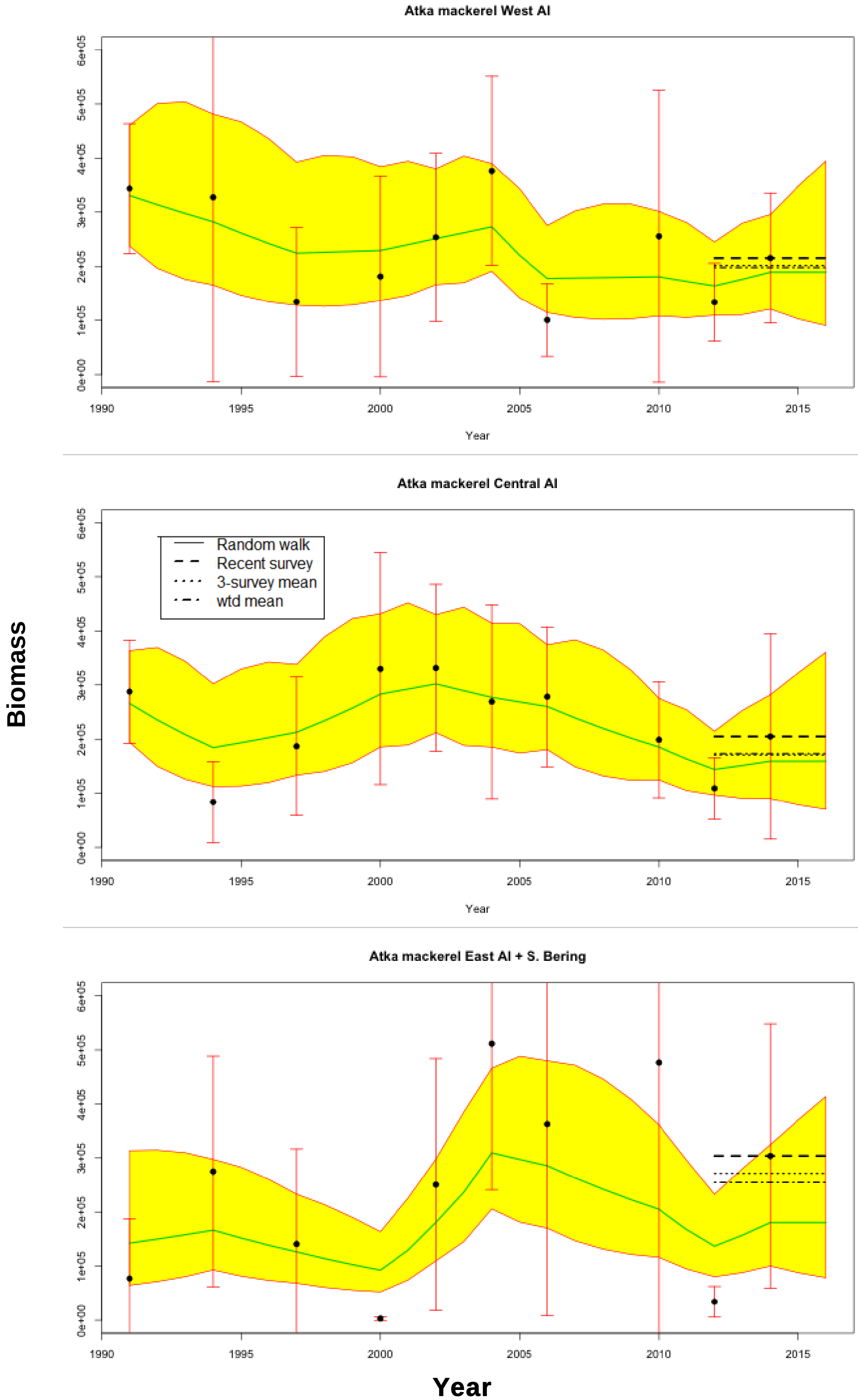


Figure 17.22. Atka mackerel bottom trawl survey biomass by subarea 1991-2014 with random effects model fitting for area apportionment purposes. Dashed lines represent alternative methods for averaging surveys.

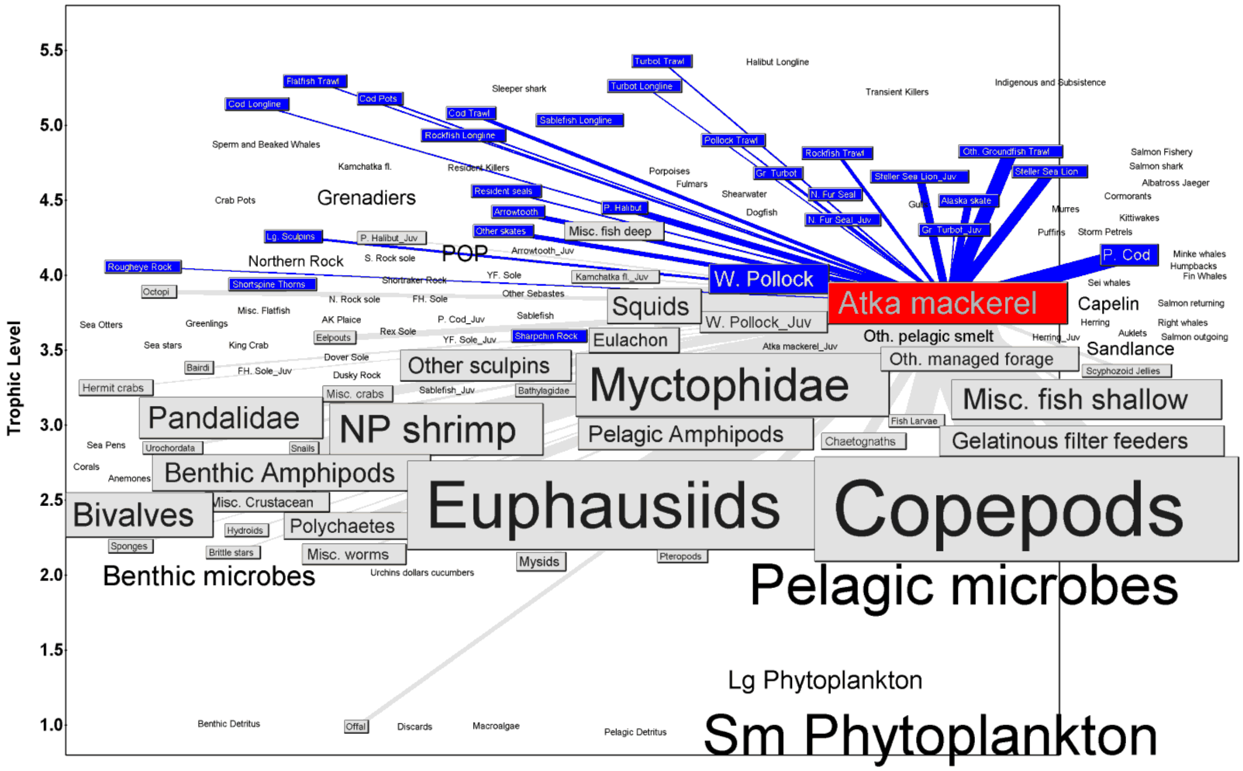
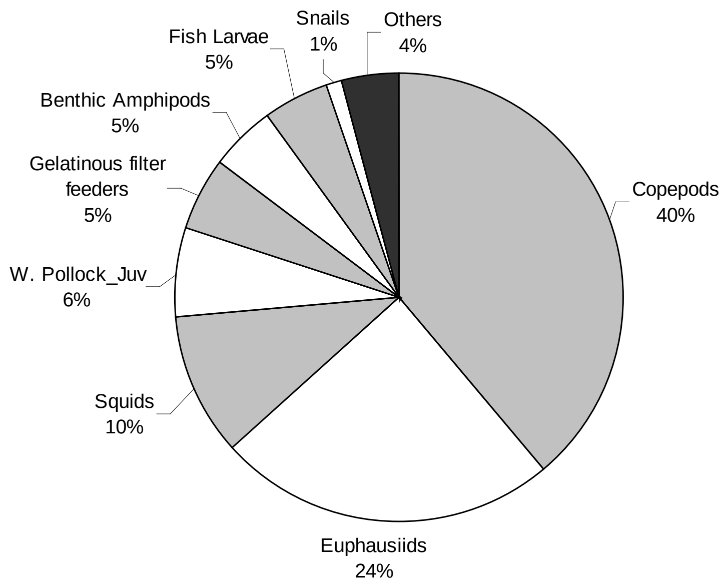
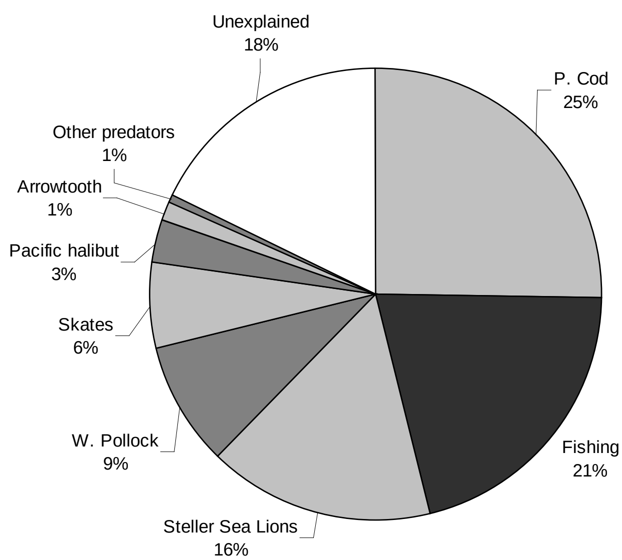


Figure 17.23. The food web of the Aleutian Islands survey region, 1990-1994, emphasizing the position of age 1+ Atka mackerel. Outlined species represent predators of Atka mackerel (dark boxed with light text) and prey of Atka mackerel (light boxes with dark text). Box and text size are proportional 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 17.24. (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.

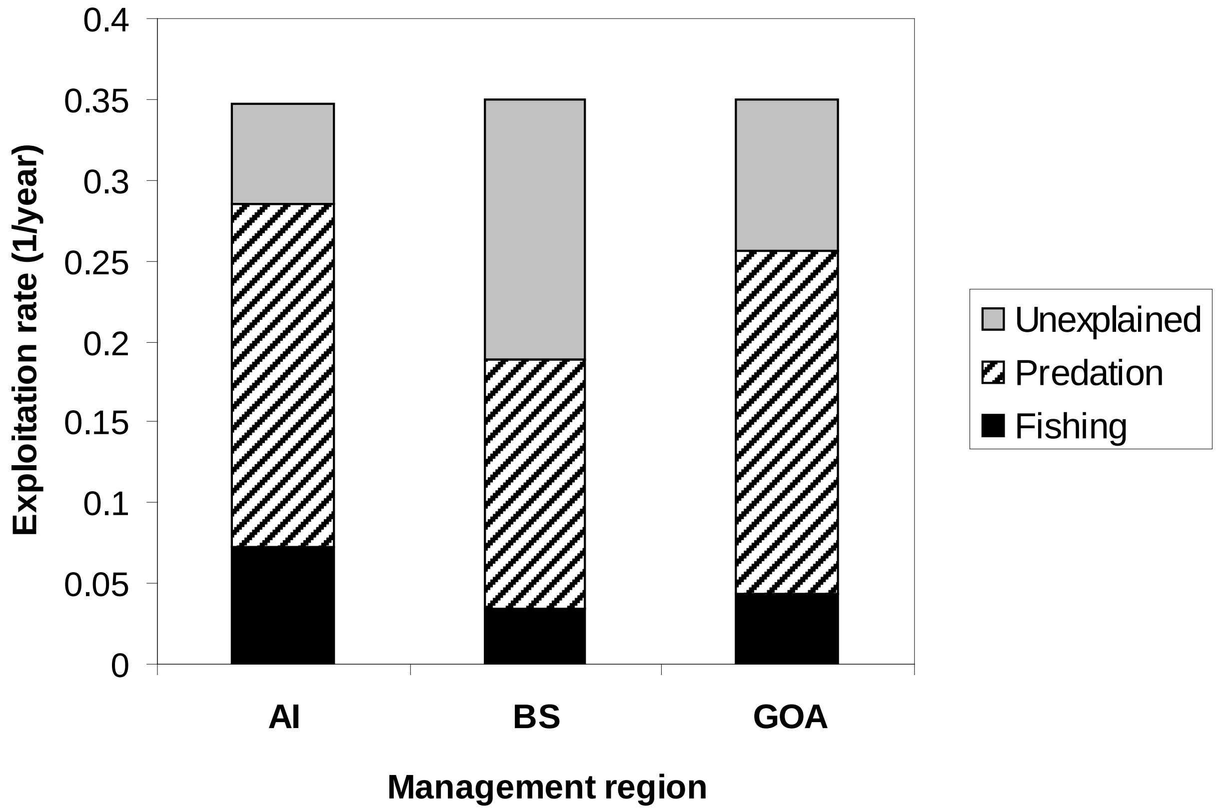


Figure 17.25. Total exploitation rate of age 1+ Atka mackerel, 1990-1994, proportioned into exploitation by fishing (black), predation (striped) and “unexplained” mortality (grey). “Unexplained” mortality is the difference between the stock assessment total exploitation rate averaged for 1990-1994, and the predation and fishing mortality, which are calculated independently of the assessment using predator diets, consumption rates, and fisheries catch.

Appendix 17A

Table A-1. Variable descriptions and model specification.

General Definitions	Symbol/Value	Use in Catch at Age Model
Year index: i = {1977, …., 2015}	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
	σ_d^2	Dome-shape penalty variance term
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 , σ_q^2)
Stock-recruitment parameters	R_0	Unfished equilibrium recruitment
	h	Stock-recruitment steepness
	σ_R^2	Recruitment variance
Estimated parameters		
$\phi_i(37),\ R_0,\ \varepsilon_i(47),\ \sigma_R^2,\ \mu^f,\ \mu^s,\ M,\ \eta_j^s(10),\ \eta_j^f(10),\ F_{50\%},\ F_{40\%},\ F_{30\%},\ q^s$		

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	$j = 1$	$N_{1977,1} = e^{\mu_R + \varepsilon_{1977}}$
	A $1 < j < A$	$N_{1977,j} = e^{\mu_R + \varepsilon_{1978-j}} \prod_{j=1}^{j} e^{-M}$
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, …, 2015	$\varepsilon_i, \sum_{i=1967}^{2015} \varepsilon_i = 0$	$N_{i,1} = e^{\mu_R + \varepsilon_i}$
Index catchability Mean effect	μ^s, μ^f	$q_i^s = e^{\mu^s}$
Age effect	$\eta_j^s, \sum_{j=1}^{A} \eta_j^s = 0$	$s_j^s = e^{\eta_j^s}$ $j \le$ 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	μ_f	
Annual effect of fishing in year i	$\phi_i, \sum_{i=1977}^{2015} \phi_i = 0$	
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 $s_{ij}^f = e^{\eta_{\text{maxage}}^f}$ $j >$ maxage
In years where selectivity is constant over time	$\eta_{i,j}^f = \eta_{i-1,j}^f$	$i \ne$ change year
Natural Mortality	M	
Total mortality		$Z_{ij} = F_{ij} + M$
Recruitment Beverton-Holt form	$\tilde{R}_i$	$\tilde{R}_i = \frac{\alpha B_i}{\beta + B_i}$, $\alpha = \frac{4hR_0}{5h-1}$ and $\beta = \frac{B_0(1-h)}{5h-1}$ where $B_0 = \tilde{R}_0 \varphi$ $\varphi = \frac{e^{-AM} W_A p_A}{1 - e^{-M}} + \sum_{j=1}^{A} e^{-M(j-1)} W_j p_j$

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	$L_1 = \lambda_1 \sum_i \ln\left(Y_i^s / \hat{Y}_i^s\right)^2 \frac{1}{2\sigma_i^2}$	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 extent of dome-shape for fishery selectivity	$L_3 = \sum_l \lambda_3^l \sum_{j=5}^{A}\left(I_j d_j\right)^2$ $d_j = \left(\ln\left(s_j^f\right) - \ln\left(s_{j-1}^f\right)\right)$ $I_j = \begin{cases} 1 \text{ if } d_j > 0 \\ 0 \text{ if } d_j \le 0 \end{cases}$	Allows model some flexibility on degree of declining selectivity at age
Prior on recruitment regularity	$L_4 = \lambda_4 \sum_{i=1967}^{2015} \varepsilon_i^2 +$ $0.5 \sum_{t=1977}^{2015}\left(\ln R_t - \ln \hat{R}_t\right) / \sigma_R^2$	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	$L_5 = \lambda_5 \sum_{i=1977}^{2015} \ln\left(C_i^B / \hat{C}_i^B\right)^2$	Fit to survey
Proportion at age likelihood	$L_6 = -\sum_{l,i,j} T_{ij}^l P_{ij}^l \ln\left(\hat{P}_{ij}^l \cdot P_{ij}^l\right)$	*l={s, f}* for survey and fishery age composition observations
Fishing mortality regularity	$L_. = \lambda_6 \sum_{i=1978}^{2015} \phi_i^2$	(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 *M is* precisely known at 0.3).
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 available 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 1977-2014 in Table 17B-1. Removals from activities other than directed fishing totaled 140 t in 2010, 1,529 t in 2011, 62 t in 2012, <1 t in 2013, and 111 t in 2014. This is approximately 0.2, 2.0, <0.1, <0.1, and 0.2% of the 2010, 2011, 2012, 2013, and 2014 ABCs respectively, and represent a very low risk to the stock. These removals were not incorporated in the stocks assessment. If these removals were accounted for in the stock assessment model, the recommended ABCs for 2016 and 2017 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	AFSC	140				140
2011	AFSC	1,529				1,529
2012	AFSC	62				62
2013	AFSC					
2014	AFSC	111				111