17. Assessment of the Atka mackerel stock in the Gulf of Alaska

Sandra A. Lowe

November 2017

Executive Summary

Gulf of Alaska (GOA) Atka mackerel have been moved to a biennial stock assessment schedule to coincide with the availability of new survey data from the biennial trawl survey. A full assessment was presented in 2015, which included data from the 2015 GOA bottom trawl survey. On alternate (even) years we present an executive summary with updated catch, last year's key assessment parameters, any significant new information available in the interim, and projections for this year.

Gulf of Alaska Atka mackerel have been managed under Tier 6 specifications since 1996 due to the lack of reliable estimates of current biomass. In 2007, the assessment presented Tier 5 calculations of ABC and OFL based on 2007 survey biomass estimates, for consideration. However, the Plan Team and SSC agreed with the authors that reliable estimates of Atka mackerel biomass were not available and recommended continuing management under Tier 6. The 2016 executive summary presented Tier 6 recommendations and did not present Tier 5 calculations given the large variances associated with the 2015 survey biomass estimates, which was essentially based on one significant haul encountered in the western Gulf of Alaska off the Sanak Islands. The 2015 full assessment is available on the web (Lowe 2015, http://www.afsc.noaa.gov/refm/docs/2015/GOAatka.pdf). The Council set the Gulf-wide 2017 OFL, ABC, and TAC for Atka mackerel at 6,200 t, 4,700 t, and 3,000 t, respectively.

Relative to the November 2015 SAFE report and the 2016 executive summary (GOA Atka mackerel are assessed biennially), the following substantive changes have been made in the current draft of the Atka mackerel chapter:

Summary of Changes in Assessment Inputs

1. Catch data are updated through October 21, 2017.
2. Age data from the 2016 GOA fisheries are presented.
3. Biomass estimates from the 2017 GOA bottom trawl survey are presented.
4. Length frequency data from the 2017 GOA bottom trawl survey are presented.

Summary of Changes in the Assessment Methodology

There are no changes to the assessment methodology. Gulf of Alaska Atka mackerel have been managed under Tier 6 specifications since 1996 due to lack of reliable estimates of current biomass. In the 2007 assessment, Tier 5 calculations of ABC and OFL (based on 2007 survey biomass estimates) were presented for consideration. The Plan Team, SSC, and Council agreed with the authors that there is no reliable estimate of Atka mackerel biomass and recommended continuing management under Tier 6. This year, we again present Tier 6 recommendations, and do not present Tier 5 calculations of ABC and OFL given the large variance associated with the 2017 survey biomass estimates which are essentially based on one significant haul encountered in the Central Gulf of Alaska off Albatross Banks.

Summary of Results

Since 2006, the maximum permissible ABC has been 4,700 t under Tier 6 and the ABCs have been set at that level. The 2006-2008 TACs were set at 1,500 t to accommodate an increase in GOA Atka mackerel catches, and still allow for bycatch in other directed fisheries and minimize targeting. From 2008 to 2016, TACs have been set at 2,000 t to accommodate increases in GOA bycatch of Atka mackerel. In 2017 the TAC was raised to 3,000 t based on reports that the fleet was encountering more Atka mackerel on the fishing grounds. Given the patchy distribution of GOA Atka mackerel, which results in highly variable estimates of abundance and the variance associated with the 2017 survey biomass estimate (Gulf-wide *CV* of 62%), I continue to recommend that GOA Atka mackerel be managed under Tier 6. **I recommend a 2018 (and 2019) ABC for GOA Atka mackerel equal to the maximum permissible value of 4,700 t. The 2018 (and 2019) OFL is 6,200 t under Tier 6.**

Prudent management is still warranted and the rationale as given in the past for a TAC to provide for anticipated bycatch needs of other fisheries, principally for rockfish, Pacific cod, and pollock, and to only allow for minimal targeting should still be considered. The 2009-2016 TACs for GOA Atka mackerel were set at 2,000 t. The 2017 TAC was set at 3,000 t. It should be noted that the 2009 and 2010 catches exceeded the TAC in those years. However, since 2010 GOA Atka mackerel catches have been below TAC. The 2016 GOA Atka mackerel catch was 1,092 t, and as of October 21, 2017, the GOA Atka mackerel catch (1,023 t) is only 34% of the 3,000 t TAC.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2017	2018	**2018**	2019
Tier	6	6	**6**	6
OFL (t)	6,200	6,200	**6,200**	6,200
maxABC (t)	4,700	4,700	**4,700**	4,700
ABC (t)	4,700	4,700	**4,700**	4,700
Status	As determined *last* year for:		As determined *this* year for:	
	2015	2016	2016	2017
Overfishing	n/a	n/a	**n/a**	n/a

Responses to SSC and Plan Comments on Assessments in General

From the December 2016 SSC minutes: *In an effort improve record keeping as assessment authors formulate various stock status evaluation models, the Plan Team has recommended a systematic cataloging convention. Any new model that diverges substantial from the currently accepted model will be marked with the two-digit year and a "0" version designation (e.g., 16.0 for a model from 2016). Variants that incorporate major changes are then distinguished by incremental increases in the version integer (e.g., 16.1 then 16.2), and minor changes are identified by the addition of a letter designation (e.g., 16.1a).* ***The SSC recommends this method of model naming and notes that it should reduce confusion and simplify issues associated with tracking model development over time.***

Gulf of Alaska Atka mackerel are managed as a Tier 6 species and are not assessed with a model.

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

The SSC and Plan Team did not make any comments specific to the GOA Atka mackerel Assessment.

Introduction

Distribution

Atka mackerel (*Pleurogrammus monopterygius*) are distributed along the continental shelf in areas 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 (Rutenberg 1962). Moving eastward, they are distributed throughout the Komandorskiye and Aleutian Islands, north to the Pribilof Islands in the eastern Bering Sea, and eastward through the Gulf of Alaska (GOA) to southeast Alaska.

An Atka mackerel population existed in the GOA primarily in the Kodiak, Chirikof, and Shumagin areas, and supported a large foreign fishery through the early 1980s. By the mid-1980s, this fishery, and presumably the population, had all but disappeared. Evidence of low population levels was supported by Atka mackerel bycatch in other fisheries of less than 5 t from 1986 to 1988 (Table 17.1). The decline of the GOA Atka mackerel fishery suggests that the area may be the edge of the species' range. During periods of high recruitment in the Aleutian Islands (AI), it is thought that juvenile Atka mackerel may move into the GOA under favorable conditions (Ronholt 1989, Lowe *et al.* 2005). Recently, Atka mackerel have been detected by the summer trawl surveys primarily in the Shumagin (Western) area of the GOA.

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 AI and western GOA down to bottom depths of 144 m (Lauth *et al*. 2007b). Historical data from ichthyoplankton tows 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 (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).

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

Diets of commercially important groundfish species in the GOA during the summer of 1990 were analyzed by Yang (1993). Although Atka mackerel were not sampled as a predator species, it can be inferred that the major prey items of GOA Atka mackerel would likely be euphausiids and copepods as found in AI Atka mackerel (Yang, 1999). The abundance of Atka mackerel in the Gulf of Alaska is much lower compared to the AI. Atka mackerel only showed up as a minor component in the diet of arrowtooth flounder in the GOA (Yang, 1993). Adult Atka mackerel in the Aleutians 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).

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 GOA, and the Rat Islands in the AI. 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 (western AI) but not at Seguam Pass (eastern AI). 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 AI and GOA 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, declined and is very patchy in its distribution. Most recently, the strong 1998, 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

Gulf of Alaska Atka mackerel are managed as a Gulf-wide species and managed separately from the Bering Sea/Aleutian Islands. Considerations discussed above suggest that continued separate assessment and management of GOA Atka mackerel is prudent and precautionary.

Fishery

Catch History and Fishery Management

Prior to the mid-1980s, Atka mackerel were fished exclusively by foreign vessels, primarily from the Soviet Union. Landings were about 19,500 t in 1977 and 1978, then dropped to less than 5 t in 1986 (Table 17.1). Some joint venture operations participated in this fishery from 1983 to 1985. All landings since then have been taken by the domestic fishery.

In 1988, Atka mackerel were combined in the Other Species category due to low abundance and the absence of a directed fishery for the previous several years. However, beginning in 1990, Atka mackerel were targeted in the western GOA. From 1990-1993, catches of the Other Species category in the GOA were dominated by Atka mackerel, primarily from the Western GOA regulatory area. Atka mackerel were separated from the Other Species category and became a separate target category in the GOA in 1994, after approval of Amendment 31 to the Fishery Management Plan for the Groundfish Fishery of the GOA. Catches of Atka mackerel by GOA management areas since 1990 are shown below:

Gulf of Alaska (GOA) Catches (t) by Management Areas

Year	Western	Central	Eastern	Total
1990a	1,416	0	0	1,416
1991	3,249	9	0	3,258
1992	13,785	49	0	13,834
1993	4,867	2,143	0	7,010
1994	2,661	877	0	3,538
1995	329	370	2	701
1996	1,577	9	0	1,586
1997	321	8	2	331
1998	279	38	0	317
1999b	-	-	-	262
2000	-	-	-	170
2001	-	-	-	76
2002	-	-	-	85
2003	-	-	-	578
2004	-	-	-	819
2005	-	-	-	799
2006	-	-	-	876
2007	-	-	-	1,459
2008	-	-	-	2,109
2009	-	-	-	2,222
2010	-	-	-	2,417
2,011	-	-	-	1,615
2012	-	-	-	1,188
2013	-	-	-	1,277
2014	-	-	-	1,042
2015	-	-	-	1,175
2016	-	-	-	1,092
2017[c]	-	-	-	1,023

a/ Actual observed catch
b/ From 1999 to the present, TAC has been set GOA-wide; catches are not available by regulatory area from the NMFS Alaska Regional Office (AKRO) Catch Accounting System (CAS).
c/ 2017 data as of October 21, 2017 from NMFS AKRO CAS.

The 1990 catch of 1,416 t is a minimum estimate, since this was the tonnage actually observed by domestic observers. The Alaska Regional Office's estimate of catch for 1990 is underestimated, as GOA Atka mackerel catches were incorrectly being reported as landed in the AI. Total catches of Atka mackerel were small until 1992, when approximately 14,000 t were taken in the Shumagin area. In 1994, when Atka mackerel was taken out of the Other Species category and assigned a target species, the North Pacific Fishery Management Council (Council) assigned a Gulf-wide Atka mackerel ABC and TAC of 4,800 and 3,500 t, respectively (Table 17.1). For 1995 and 1996, the Council approved a Gulf-wide ABC and a total TAC of 3,240 t for GOA Atka mackerel (Table 17.1). For purposes of data collection and effort dispersion, 2,310 t was allocated to the Western or Shumagin subarea (Area 610), 925 t was allocated to the Central, or the combined Chirikof and Kodiak subareas (Areas 620 and 630), and 5 t was assigned to the Eastern GOA (Areas 640 and 650). The Western subarea (Area 610) was not opened to the directed Atka mackerel fishery in 1995 because the overfishing level for Pacific ocean perch (POP) was nearly reached; Atka mackerel fisheries have had significant bycatch of POP. In 1996, the fishery in the Western subarea was restricted to a 12-h opening on July 1, again due to concerns about the POP bycatch exceeding the POP TAC and approaching the overfishing level; about 1,600 t of Atka mackerel were caught. The 1996 Central POP catch exceeded the Central area POP overfishing level, thus there was no opening for the directed Atka mackerel fishery in that area. Since 1996 the Atka mackerel fishery has been managed as a bycatch-only fishery with Gulf-wide TACs of 1,000 t in 1997 and 600 t for the years 1998 to 2005.

The catch of GOA Atka mackerel jumped dramatically in 2003 to 578 t. Previous to this, catches were less than 100 t in 2001 and 2002 (Table 17.1). The 2004 Gulf-wide Atka mackerel catch of 819 t, exceeded the TAC (600 t) for Atka mackerel for the first time since this quota was implemented in 1998. The 2005 catch (799 t) also exceeded the 2005 Atka mackerel TAC. This increase of Atka mackerel in the GOA coincided with local sports fishermen reporting catches of Atka mackerel for the first time off Resurrection Bay and as far as Southeast Alaska in 2003. The 1999 year class has been documented as a very strong year class in the AI (Lowe *et al.* 2005). Twenty-seven Atka mackerel were sampled for otoliths by observers in the 2003 GOA fisheries. All 27 fish were aged and determined to be 4-year olds of the 1999 year class.

Figure 17.1 shows the 2016 and 2017 distributions of observed catches of Atka mackerel in the GOA summed by 20 km areas. Most of these catches occurred during July through October. Open circles represent observed catches greater than 1 t. Large catches were taken in the Chirikof (620) and Kodiak (630) areas in 2016. Under the Rockfish Program catcher processors who historically would move out of 610 after the POP fishery closed, are now remaining in the area and targeting northern and pelagic shelf rockfish. This is contributing to greater catches (much of it discarded) of Atka mackerel.

Description of the Directed Fishery

There has not been a directed fishery for Atka mackerel since 1996. A discussion of the directed fishery for the years 1990-1994 is given in Lowe and Fritz (2001).

Bycatch and Discards

The historical amount of Atka mackerel retained and discarded by target fishery and area in the GOA in 1994 and 1995 has been discussed in previous assessments (Lowe and Fritz 2001). The 2003-2011 levels of GOA Atka mackerel retained and discarded were discussed in Lowe (2015). The 2012 to 2016 levels of GOA Atka mackerel retained and discarded are given below:

Year	Fishery	Discarded (t)	Retained (t)	Total (t)
2012	Rockfish	488	684	1,172
	All others	13	2	15
	All	501	687	1,188
2013	Rockfish	403	759	1,162
	All others	27	88	115
	All	431	846	1,277
2014	Rockfish	47	399	446
	All others	29	566	596
	All	76	965	1,042
2015	Rockfish	141	847	988
	All others	186	53	239
	All	327	900	1,228
2016	Rockfish	58	537	595
	All others	78	419	497
	All	136	956	1,092

The 2003 through 2011 data indicated that most of the Atka mackerel bycatch in the GOA, which was coming out of the Shumagin and Chirikof areas, was taken in the rockfish fisheries (Lowe and Fritz 2001, Lowe 2015). There appears to have been some limited targeted fishing on Atka mackerel since 2003. In 2003 the flatfish and Pacific cod fisheries retained significant amounts of Atka mackerel. In 2007 the pollock and flatfish fisheries retained Atka mackerel. For the most part, there has been very little Atka mackerel retained by fisheries, other than rockfish, since 2003. The amount of Atka mackerel caught by the rockfish fisheries has declined since 2011, dropping significantly in 2014. However, catches of Atka mackerel nearly doubled in the 2015 rockfish fishery. Reports of the fleet encountering more Atka mackerel on the fishing grounds in 2016, led the Council to increase the 2017 TAC from 2,000 to 3,000 t. Catches of Atka mackerel in the rockfish fishery declined in 2016, but retained catches of Atka mackerel in the shallow water flatfish fishery increased. Total catches of Atka mackerel have not increased since 2012, and have remained at about 1,100-1,200 t.

Fishery and Steller Sea Lions

The western stock of Steller sea lions, which ranges from Cape Suckling (at 144°W) west through the AI and into Russia, is currently listed as endangered under the Endangered Species Act (ESA), and has been listed as threatened since 1990. From 1977 to 1984 and in 1990, up to 11% of the annual GOA Atka mackerel harvest was caught within 20 miles of all GOA sea lion rookeries and major haulouts, reflecting the offshore distribution of the fishery. In 1991-1993, however, the fishery moved closer to shore, and this percentage increased to 82-98%, almost all of which was caught between 10-20 nm of Steller sea lion rookeries on Ogchul and Adugak Islands (near Umnak Island), and Atkins and Chernabura Islands in the Shumagin Islands.

Leslie depletion estimates of local fishery harvest rates were computed to be much greater than estimated Gulf-wide harvest rates (Lowe and Fritz 1996; 1997). This raised concerns about how the fishery may have affected food availability, foraging success, and the potential for recovery of the Steller sea lion population. There has not been a directed GOA Atka mackerel fishery since 1996. Steller sea lion protection measures prohibit directed fishing for Atka mackerel in the GOA. The management of the Bering Sea/Aleutian Islands Atka mackerel fishery is detailed in Lowe *et al.* (2015).

Data

Fishery Data

Fishery length frequencies

Atka mackerel length distributions from the 1990-1994 directed fisheries are discussed in previous assessments (Lowe and Fritz 2001).

Fishery age data

There is only very limited age data available from the historical fisheries that were actively targeting Atka mackerel, i.e., 1990 Davidson Bank fishery, the 1992 Umnak Island fishery, and the 1994 fishery which operated off Umnak Island, Davidson Bank and Shumagin Bank. These data are discussed in Lowe and Fritz (2001).

The very strong 1999 year class dominated the GOA Atka mackerel catch-age distributions in the mid to late 2000s. Fifty-three Atka mackerel otoliths from the 2007 GOA fisheries were aged and 38% were determined to be 8-year-olds of the 1999 year class. Forty-one percent of the 99 otoliths aged from the 2008 GOA fisheries were determined to be 9-year-olds of the 1999 year class (Lowe *et al*. 2009). It is interesting to note the appearance of 2-year-olds in the 2008 GOA catches from the 2006 year class. The 2006 year class has been determined to be above average in the AI (Lowe *et al*. 2011).

Since the 2015 assessment, ages from the 2014, 2015, and 2016 GOA fisheries have become available. A total of 238, 159 and 88 otoliths were collected from the GOA in 2014, 2015, and 2016, respectively. The data show large numbers of the 2011 year class which was prevalent in the Aleutian Islands. The 2014 and 2015 data continue to show the strong 2006 and 2007 year classes observed in the Aleutian Islands, these year classes are no longer observed in the 2016 data (Figure 17.2).

Survey Data

Bottom trawl surveys of the GOA groundfish community have been conducted triennially since 1984 and biennially since 1999 using an area-depth stratified and area-swept design. In 1999, the same GOA survey design was maintained, but effort allocation was shifted to provide more even coverage within depth strata. Atka mackerel are a very 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 the standard survey bottom trawl gear difficult; and (3) their schooling behavior and patchy distribution (particularly in the GOA), makes the species susceptible to large variances in catches which greatly affect area-swept estimates of biomass.

The general groundfish surveys of the GOA are particularly problematic for Atka mackerel given the characteristics described above. In 1996, a meaningful estimate of biomass could not be determined from the data due to extreme variances. Over 98% of the Atka mackerel caught in the 1996 survey were encountered in a single haul within a large stratum, which yielded a large stratum biomass with an extremely large confidence interval. Although estimates of abundance from earlier surveys have been presented in previous assessments, they were also compromised by the problem of large confidence intervals, although not to the same degree as observed in 1996.

The 2013 survey showed >90% of the GOA Atka mackerel biomass was in the Shumagin area of the western GOA, most of which was caught in two large hauls off Davidson Bank (Figure 17.3). The 2015 survey biomass estimate of GOA Atka mackerel is associated with a coefficient of variation (*CV*) of 62%, reflecting a variance of 323 million. Most of the 2015 GOA survey Atka mackerel biomass (79%) is distributed within the Shumagin area based on a single large haul caught off the Sanak Islands (Figure 17.3, Table 17.2). The most recent survey data from the 2017 survey showed that 63% of the GOA Atka mackerel biomass was in the Kodiak area of the Central GOA which is unusual for the GOA survey. The Kodiak biomass which is associated with a *CV* of 99%, is attributed to a single large haul taken off Albatross Banks (Figure 17.3) which was extrapolated over the largest (km^2) GOA stratum. Bottom trawl survey information is presented for 2009, 2011, 2013, 2015, and 2017 for consideration (Table 17.2).

Atka mackerel have been inconsistently caught in the GOA surveys, appearing in 24%, 24%, 16%, 26%, 14% of the hauls in the Shumagin area in the 2009, 2011, 2013, 2015, and 2017 GOA surveys, respectively (Table 17.2). Most of the GOA Atka mackerel biomass (99.6%, and 90%) in the 2009 and 2011 surveys, respectively, was distributed in the Shumagin area of the western GOA. This percentage dropped, to 69% and 79% of the GOA biomass distributed in the Shumagin area in the 2013 and 2015 surveys, respectively (Figure 17.3; Table 17.2). Most recently, the distribution of biomass shifted in the 2017 GOA survey. Twenty six percent of the biomass was distributed in the Shumagin area and the majority of the biomass (63%) was distributed in the Kodiak area (Table 17.2). This is an artificial result due to a single large haul extrapolated over the largest stratum in the Kodiak area and the entire GOA. Atka mackerel were only observed in 6% of the hauls in the 2017 survey compared with 15% of the hauls in the 2015 survey.

What can be concluded from this is that the general groundfish GOA bottom trawl survey, as it has been designed and used since 1984, does not assess GOA Atka mackerel well, and the resulting biomass estimates are not considered consistent reliable indicators of absolute abundance or indices of trend.

Survey length frequencies

Length frequency distributions from the 2007, 2009, and 2011 surveys fell mainly between 40 and 50 cm and were discussed in Lowe (2011). The 2013 and 2015 distributions also fall within this range, although the 2015 distribution is broader than in previous years, showing fewer large fish greater than 40 cm relative to the 2013 distribution (Figure 17.4 Lowe 2015). The 2017 length distribution is very different from previous years with lengths ranging only from 36 to 48 cm, and modes at 43 and 45 cm. It is interesting to note that the length frequency distributions of males and females differ slightly in the GOA surveys. The female length frequency distributions show a slightly greater proportion of large fish, while the male distributions show slightly greater proportions of small fish (Figure 17.4 in Lowe 2011, 2015, Figure 17.4). This has not been observed in the AI surveys; the male and female length frequency distributions are not differentiable and survey length frequency distributions are presented for combined sexes (Lowe *et al.* 2011).

Survey age data

Historical survey age data from the GOA trawl survey are only available from 1993 (Figure 10.11 in Lowe and Fritz 2001). The 1993 survey showed a mode of 5-year-olds from the 1988 year class which has also been documented as a strong year class in the AI (Lowe *et al.* 2005).

The 2011 assessment presented 2009 GOA survey age data. A total of 328 otoliths were collected from the Western and Central Gulf. The data showed the 1999 to 2001 year classes, which were exceptionally strong year classes in the AI (Lowe 2011). The 2013 GOA survey age data were presented in Lowe (2015). A total of 226 otoliths were collected and aged from the Shumagin (610) and Chirikof (620) areas. The strong 2006 year class and the 2007 year class were predominant in the 2013 survey age composition (Figure 17.5, Lowe 2015). Also, the 2011 year class was evident as 2-year olds in the 2013 GOA survey age composition. Large numbers of the 2011 year class were observed in the 2014 AI fishery and survey data (Lowe *et al*. 2015).

Survey age information is available from the 2015 summer bottom trawl survey. A total of 413 otoliths were collected from the Western and Central Gulf of Alaska. Over half (59%) of the Atka mackerel otoliths were collected in the Shumagin area. Similar to the 2015 GOA fishery data, the data are dominated by 4-year-olds of the 2011 year class, and the strong 2006 and 2007 year classes are still evident in the 2015 survey age composition (Figure 17.5).

Analytic Approach

Parameter Estimates

Natural mortality, age of recruitment, and maximum age

A natural mortality rate of 0.3 is assumed for GOA Atka mackerel based on analyses of natural mortality for AI Atka mackerel. The value of 0.3 was calculated with the method of Hoenig (1983), and is described in Lowe *et al*. (2009).

A qualitative look at the sparse GOA fishery age data shows recruitment patterns similar to the AI fishery. The age of first recruitment appears to be 2-3 years, and full recruitment at 4 years (Lowe and Fritz 2001). This pattern becomes somewhat obscured when a strong year class dominates the distributions.

The maximum age seen in the GOA fishery is 13 years (1990 fishery). This compares with a maximum age of 16 years for the AI.

Length and weight at age

Parameters of the von Bertalanffy length-age equation and a weight-length relationship were calculated from the combined 1990, 1992, and 1994 fishery data. Sexes were combined to provide an adequate sample size. The estimated von Bertalanffy growth parameters are:

L_∞ = 54.56 cm

K = 0.22

t_0 = -2.78 yr

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

The weight-length relationship was determined to be:

$$\text{Weight (kg)} = 4.61\text{E-}05 * \text{Length (cm)}^{2.698}$$

Growth parameters were also estimated from data collected during the 1993 GOA survey. As in the Aleutians, the survey tends to select for smaller fish-at-age than the fishery. The estimated von Bertalanffy parameters from the 1993 survey are:

L_∞ = 47.27 cm
K = 0.61
t_0 = 0.38 yr.

The estimated weight-length relationship is:

$$\text{Weight (kg)} = 1.55\text{E-}05 \times \text{Length (cm)}^{2.979}$$

Maturity at length and age

Female maturity-at-length and age were determined for GOA Atka mackerel (McDermott and Lowe 1997). The maturity schedules are given in Table 17.3. The age at 50% maturity is 3.6 years and length at 50% maturity in the GOA is 38.2 cm. 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).

Selectivity at age

The small amount of age data for GOA Atka mackerel show similar selectivity patterns as seen in the AI survey and fishery data. The fishery data tend to show older fish than the survey samples. Recent age data from the GOA fisheries (2010-2016) and surveys (2009, 2011, 2013, 2015) show a limited distribution of ages, continued presence of the 2006 and 2007 year classes, and large numbers of the 2011 year class in the 2015 data.

Results

Harvest Recommendations

Amendment 56 reference points

As discussed above, bottom trawl survey information from the GOA surveys is presented for consideration. The 2017 survey estimated a GOA Atka mackerel biomass of 23,941 t for the Kodiak area with a *CV* of 99%. This represents 63% of the Gulf-wide Atka mackerel biomass estimate. Most of the Kodiak area biomass was caught in a single large haul off Albatross Banks. Given the extreme variance associated with the GOA survey biomass estimates, they do not provide reliable estimates for determination of OFL and maximum permissible ABC.

If there is no reliable estimate of current biomass, then Tier 6 of Amendment 56 of the GOA FMP defines the overfishing level (OFL) as the average catch from 1978-95, and the maximum permissible ABC as 0.75 of the OFL.

Specification of OFL and maximum permissible ABC

The average annual catch from 1978-95 is 6,200 t, which is the OFL as defined for Tier 6, and the maximum permissible ABC for GOA Atka mackerel is 4,700 t as defined for Tier 6.

The biomass estimates from the 2013, 2015, and 2017 surveys are highly variable with Gulf-wide *CV*s of 67, 62, and 66%, respectively. The biomass has been mostly observed in the Shumagin area (69%, and 79% of the Gulf-wide estimates in the 2013 and 2015 surveys, respectively), until the most recent 2017 GOA survey when 63% of the biomass was distributed in the Kodiak area compared to 26% in the Shumagin area. This is an artificial result of a single large haul from the Kodiak area extrapolated over the largest (km^2) GOA survey strata.

The 2015 and 2016 GOA fishery and 2015 survey catches are mainly comprised of the 2011 year class which has been documented in large numbers in the AI (Lowe *et al.* 2011, 2015). There does not appear to be an expanded population with a broad distribution of age classes, and speculation is that this is overflow from the AI population.

For the above reasons, we continue to recommend that GOA Atka mackerel be managed under **Tier 6, and recommend a 2018 (and 2019) ABC for GOA Atka mackerel equal to the maximum permissible value of 4,700 t. The 2018 (and 2019) OFL is 6,200 t under Tier 6.**

Prudent management is still warranted and the rationale as given in the past for a TAC to provide for anticipated bycatch needs of other fisheries, principally for Pacific cod, rockfish and pollock, and to only allow for minimal targeting should still be considered. The 2017 TAC for GOA Atka mackerel was increased from 2,000 t to 3,000 t. Total catches of GOA Atka mackerel have not increased since 2012, and have remained at about 1,100-1,200 t.

Status determination

Because the 2016 catch was below the 2016 OFL, GOA Atka mackerel are not being subject to overfishing. GOA Atka mackerel are in Tier 6, and it is not possible to make a status determination of whether the stock is *overfished* or *approaching* an overfished condition.

Ecosystem Considerations

Steller sea lion food habits data (from analysis of scats) from the AI 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 AI region. The percentage occurrence of Atka mackerel was progressively greater in samples taken in the central and western AI, where most of the Atka mackerel biomass in the AI is located. Conversely, the percentage occurrence of pollock was greatest in the eastern AI. Steller sea lion food habits data from the western GOA are relatively sparse, so it is not known how important Atka mackerel are to sea lions in this area. The close proximity of fishery locations to sea lion rookeries in the western Gulf suggests that Atka mackerel could be a prey item at least during the summer. Analyses of historic fishery CPUE revealed that the fishery may create temporary localized depletions of Atka mackerel and that these depletions may last for weeks after the vessels left the area. This supports the argument already made above in the ABC section for a conservative harvest policy for Atka mackerel in the GOA.

Ecosystem effects on GOA Atka mackerel

Prey availability/abundance trends

Atka mackerel are primarily zooplanktivores, consuming mainly euphausiids and calanoid copepods (Yang 1996, Yang and Nelson 2000, Yang 2003, Yang *et al.* 2006). Other zooplankton prey include larvaceans, gastropods, jellyfish, pteropods, amphipods, isopods, and shrimp (Yang and Nelson 2000, Yang 2003, Yang *et al.* 2006). Atka mackerel also consume fish, such as sculpins, juvenile Pacific halibut, eulachon, Pacific sand lance, juvenile Kamchatka flounder, juvenile pollock, and eelpouts, in small proportions relative to zooplankton (Yang and Nelson 2000, Yang *et al.* 2006, Aydin *et al.* 2007). The proportions of these various prey groups consumed by Atka mackerel vary with year and location (Yang and Nelson 2000). The diet of Atka mackerel in the GOA differs from their more diverse diet at the core of their range in AI, where they feed on copepods, polychaetes, deepwater mytophids, squids, and other invertebrates (Ortiz, 2007).

Monitoring trends in Atka mackerel prey populations may, in the future, help elucidate Atka mackerel population trends. There is no long-term time continuous time series of zooplankton biomass information available for the western GOA; however, there are six years (1998-2003) of zooplankton information along the Seward hydrographic line (extending offshore from the mouth of Resurrection Bay). This data shows that zooplankton composition and biomass varies with year, season, and the location of the front between the nearshore Alaska coastal current and the further offshore Alaska stream (Coyle and Pinchuk 2006). The time series of euphausiid biomass indicates that they were more abundant in 2002 and 2003, both inshore and offshore of the shelf-break front than in previous years (Coyle and Pinchuk 2006). The primary euphausiids species found offshore is *Euphausia pacifica*, whereas, inshore of the front, *Thysanoessa inermis* and *T. spinifera* are the dominant euphausiids species (Coyle and Pinchuk 2006). Both *E. pacifica* and *T. inermis* are consumed by GOA Atka mackerel (Yang 1999).

Continuous Plankton Recorders (CPRs) have been deployed in the North Pacific routinely since 2000. An index of Copepod Community Size is derived from the CPR data and calculated for three regions: the oceanic North-East Pacific, the Alaskan shelf SE of Cook Inlet, and the deep waters of the southern Bering Sea (Batten 2016). Ocean conditions in 2015 were warm across much of the North Pacific. The Copepod Community Size index saw negative anomalies for all three regions. The Alaska Shelf region had seen a bias towards smaller species since 2013 (Batten 2016). The negative anomalies for the Copepod Community Size Index are consistent with the warmer water favoring the smaller-bodied species which generally have a more southerly center to their distribution. It is interesting that on the shelf this switch to smaller species occurred in 2013 when the warmer temperatures first became apparent. The abundance of zooplankton organisms was generally higher than average so that biomass anomalies remained neutral despite smaller organisms. Prey size as indexed by mean Copepod Community Size may reflect changes in the nutritional quality of the organism to their predators. Changes in abundance or biomass, together with size, influences availability of prey to predators. Given that biomass anomalies remained neutral or positive, the reduced average size of the copepod community suggests that the biomass was packaged into numerous, but smaller, prey items. This may require more work by predators to obtain their nutritional needs (Batten 2016).

Predator population trends

Adult Atka mackerel are not currently a significant prey fish for other commercially important groundfish in the GOA. They are consumed occasionally by several piscivorous species in the western Gulf, such as arrowtooth flounder, Pacific halibut, and Pacific cod (Yang and Nelson 2000), at fork lengths ranging from 1-50cm, though primarily between 20-26cm fork length. The occasional nature of their consumption is probably due to their relative lack of abundance in the GOA rather than a lack of preference on the part of the predators; they are a critical food resource for piscivorous species in the western AI where they are a dominant groundfish species. Additional species which feed on Atka mackerel include Steller sea lions, Northern fur seals (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).

The overall biomass of major Atka mackerel groundfish predators in the GOA (arrowtooth flounder, Pacific cod, and halibut) has increased dramatically since the late 1970s. GOA arrowtooth biomass increased from a low of 0.4 million t in 1970 to a high of 2.1 million tons in 2009. Arrowtooth biomass has remained fairly stable since then (Spies *et al*. 2015). GOA Pacific cod biomass has shown a long decline from their peak in 1987 to 2007. Pacific cod biomass then increased from 2007 to 2016 (Barbeaux *et al*. 2016). The increase in groundfish predator biomass could potentially increase the mortality of Atka mackerel.

The population trends of seabirds in the GOA are mixed with some increasing, some decreasing, and others stable. At selected monitored sites in the central GOA, the majority of seabird populations did not show significant linear trends over time (Dragoo *et al.* 2006, Fitzgerald *et al.* 2006). There are a few populations that have increased over time, however, the majority of diving piscivorous seabird populations in 2003 that showed a significant population trend over time, showed a decreasing trend (Dragoo *et al.* 2006, Fitzgerald *et al.* 2006). Analysis of reproductive effort data (mean hatch date and reproductive success) indicate that 2015 was a poor reproductive year for many seabirds. The North Pacific experienced the second warm year after several sequential cold years. These oceanographic changes have influenced biological components of the ecosystem, which appears to have negative influences on seabird reproductive activity (Zador 2015). Black-legged kittiwakes had moderate reproductive success in 2016 at the Semidi Islands, in contrast to the complete failure in 2015 for kittiwakes as well as other seabird species (Zador and Yasumiishi 2016). Seabird population trends could potentially affect juvenile Atka mackerel mortality, but this has not been quantified in the GOA.

Trends in Steller sea lion populations are monitored at selected 'trend' sites in Alaska. Steller sea lion non-pup counts decreased sharply in both the central and eastern GOA through 1998 (Sinclair *et al.* 2006). In the eastern GOA, counts increased between 1998 and 2004, but were stable between 2004 and 2006. Since 1998 in the central GOA, counts continued to decline but at a slower rate (Sinclair *et al.* 2006). Recent modelled estimates of western GOA Steller sea lion non-pup counts are above the long term mean and continuing to increase, suggesting conditions are favorable for sea lions in the western GOA (Zador and Yasumiishi 2016). Atka mackerel comprise a small proportion of the Steller sea lion diet in the central GOA, but about 30% of the diet in the eastern AI/western GOA (Merrick *et al.* 1997). Overall, while Steller sea lions, Pacific cod, and arrowtooth flounder are all sources of significant mortality of Atka mackerel in the AI, predatory groundfish play a far larger numerical role than Steller sea lions in the GOA as even occasional predation events by these groundfish may add to a large degree of predator control due to the large and increasing size of their populations.

Changes in habitat quality

<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 GOA.
El Nino Southern Oscillation (ENSO) events are another source of climate forcing that influences the North Pacific. Hollowed *et al.* (2001) found that gadids in the GOA have a higher proportion of strong year classes in ENSO years. There was, however, no relationship between strong year classes of AI Atka mackerel and ENSO events (Hollowed *et al.* 2001). This has not been examined for GOA Atka mackerel. The state of the North Pacific atmosphere-ocean system during 2015-2016 featured the continuance of warm sea surface temperature anomalies that became prominent late in 2013. A strong El Niño developed during winter 2015-2016 (Zador and Yasumiishi 2016).

Average eddy kinetic energy (EKE, $cm^2 s^{-2}$) from south of Amutka Pass in the AI 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. A prominent eddy was located on the outer shelf south of the Kenai Peninsula during the summer of 2016 and probably contributed to enhanced cross-shelf exchanges in its immediate vicinity (Zador and Yasumiishi 2016). 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.

<u>Bottom temperature</u>

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 °C, do not appear to be limiting, as they were within this range (Lauth *et al.* 2007b).

Bottom temperatures, recorded in the GOA bottom trawl survey, were above normal in 1984, 1987, 2001, 2003, and 2005 for depths less than 150 m (Martin 2005). The 1990s were generally cooler than normal and 1999 was the coldest year (Martin 2005). This also coincided with the strongest year class of Atka mackerel in the GOA (1999 year class). One notable trend in the bottom temperatures of the GOA shows that there is a "general warming pattern in depths less than 50 m" (Martin 2005). The 2015 pattern of water temperatures were the warmest in the GOA surveys, and was similar to the pattern seen during the 2005 bottom trawl survey (Laman 2015). Overall GOA water temperatures in 2015 appear to be markedly warmer in the upper 200 m than during recent survey years. The 2015 temperature anomaly profiles are most similar to those from 2005 which was categorized as a weak ENSO year and is the second warmest survey year in the survey series. Recent phenomena of the resilient ridge of atmospheric high pressure that helped to establish the warm water "Blob" in the Northeast Pacific, are currently influencing water temperatures in the GOA survey area. It is unclear what effect these warm temperatures may have on Atka mackerel nesting sites that are within this depth range, or on adult fish distributions in response to water temperatures.

Atka Mackerel Fishery Effects on the Ecosystem

Atka mackerel fishery contribution to bycatch

There has not been a directed GOA Atka mackerel fishery since 1996; however, current trawl fisheries for pollock, cod, and rockfish do retain some levels of Atka mackerel. For a discussion of the contribution to discards and offal production or to bycatch of prohibited species, forage fish, HAPC biota, marine mammals, seabirds, sensitive species or non-target species from these fisheries, the reader should refer to the GOA pollock, Pacific cod, and rockfish assessments.

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 whips, sea anemones, ascidians, and bryozoans (Malecha *et al.* 2005, Malecha and Stone 2009). 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. The cumulative and long term effects from historic Atka mackerel fisheries are unknown.

Concentration of Atka mackerel catches in time and space

There is currently no directed Atka mackerel fishery in the GOA. However, from 1977 to 1984 and in 1990, up to 11% of the annual GOA Atka mackerel harvest was caught within 20 miles of all GOA sea lion rookeries and major haulouts, reflecting the offshore distribution of the fishery. In 1991-1993, the fishery moved closer to shore, and this percentage increased to 82-98%, almost all of which was caught between 10-20 nm of Steller sea lion rookeries on Ogchul and Adugak Islands (near Umnak Island), and Atkins and Chernabura Islands in the Shumagin Islands. Leslie depletion estimates of historic local fishery harvest rates were computed to be much greater than estimated Gulf-wide harvest rates (Lowe and Fritz 1996; 1997). This raised concerns about how the fishery may have affected food availability, foraging success, and the potential for recovery of the Steller sea lion population.

Atka mackerel fishery effects on amount of large size Atka mackerel
There is no directed fishery for Atka mackerel in the GOA. However, 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 historical 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

Atka mackerel fishery contribution to discards and offal production
There is no directed fishery for Atka mackerel, and therefore no contribution to discards and offal production.

Table 17.4 summarizes the ecosystem effects on GOA Atka mackerel and the fishery effects on the ecosystem

Data Gaps and Research Priorities

Regional and seasonal food habits data for GOA Atka mackerel is very limited. Studies to determine the impacts of environmental indicators such as temperature regime, on Atka mackerel are needed. 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 GOA would provide information for survey stratification and the extent of trawlable and untrawlable habitat.

Acknowledgments

We thank the AFSC survey personnel for the collection of data and providing the biomass estimates. We are especially grateful to all the fishery observers working with the Fishery Monitoring and Analysis (FMA) Division who collect vital data for the stock assessments. We also thank the staff of the AFSC Age and Growth Unit for the ageing of otoliths used to determine the age compositions in the assessment.

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Tables

Table 17.1 Gulf of Alaska Atka mackerel catches (including discards), and corresponding Acceptable Biological Catches (ABC), Total Allowable Catches (TAC), and Overfishing Levels (OFL) set by the North Pacific Fishery Management Council from 1977 to the present. Catches, ABCs, TACs, and OFLs are in t.

Year	Catch	ABC	TAC	OFL
1977	19,455		22,000[d]	
1978	19,588		24,800[d]	
1979	10,949		26,800[d]	
1980	13,166		28,700[d]	
1981	18,727		28,700[d]	
1982	6,760		28,700[d]	
1983	12,260		28,700[d]	
1984	1,153		28,700[d]	
1985	1,848		5,000[d]	
1986	4	4,700	4,678[d]	
1987	1	0	240[e]	
1988[a]				
1989[a]				
1990	1,416[b]			
1991	3,258[b]			
1992	13,834[b]			
1993	5,146[b]			
1994[c]	3,538	4,800	3,500	19,040
1995	701	3,240	3,240	11,700
1996	1,580	3,240	3,240	9,800
1997	331	1,000	1,000	6,200
1998	317	600	600	6,200
1999	262	600	600	6,200

a/ Atka mackerel were added to the Other Species category in 1988; catches of Atka mackerel were included in the Other Species category.
b/ Catches of Atka mackerel was reported separately for 1990-1993.
c/ Atka mackerel were assigned a target species in 1994.
d/ Reported as OY (Optimum Yield).
e/ Reported as TQ (Target Quota).
f/ 2017 data as of October 21, 2017 from NMFS Alaska Regional Office Catch Accounting System (CAS)

Table 17.1cont. Gulf of Alaska Atka mackerel catches (including discards), and corresponding Acceptable Biological Catches (ABC), Total Allowable Catches (TAC), and Overfishing Levels (OFL) set by the North Pacific Fishery Management Council from 1977 to the present. Catches, ABCs, TACs, and OFLs are in t.

Year	Catch	ABC	TAC	OFL
2000	170	600	600	6,200
2001	76	600	600	6,200
2002	85	600	600	6,200
2003	583	600	600	6,200
2004	819	600	600	6,200
2005	799	600	600	6,200
2006	876	4,700	1,500	6,200
2007	1,459	4,700	1,500	6,200
2008	2,109	4,700	1,500	6,200
2009	2,223	4,700	2,000	6,200
2010	2,405	4,700	2,000	6,200
2011	1,615	4,700	2,000	6,200
2012	1,188	4,700	2,000	6,200
2013	1,277	4,700	2,000	6,200
2014	1,042	4,700	2,000	6,200
2015	1,228	4,700	2,000	6,200
2016	1,092	4,700	2,000	6,200
2017[f]	1,023	4,700	3,000	6,200

a/ Atka mackerel were added to the Other Species category in 1988; catches of Atka mackerel were included in the Other Species category.
b/ Catches of Atka mackerel was reported separately for 1990-1993.
c/ Atka mackerel were assigned a target species in 1994.
d/ Reported as OY (Optimum Yield).
e/ Reported as TQ (Target Quota).
f/ 2017 data as of October 21, 2017 from NMFS Alaska Regional Office Catch Accounting System (CAS)

Table 17.2. Gulf of Alaska Atka mackerel mean biomass estimates (biomass, t), variance, and coefficient of variation (*CV*), by area from the 2009, 2011, 2013, 2015, and 2017 Gulf of Alaska bottom trawl surveys. Number of hauls conducted in each area, and number and percentage (%) of hauls with Atka mackerel catch are also given.

	Year	Haul count	Hauls with catch*	% hauls with catch*	Biomass	Biomass variance	*CV*
2009	Shumagin	196	48	24%	135,089	12,748,474,113	84%
	Chirikof	190	14	7%	224	6,987	37%
	Kodiak	280	21	8%	294	5,497	25%
	Yakutat	83	1	1%	16	266	100%
	Southeast	74	0	--	--	--	--
	Gulf of Alaska	823	84	10%	135,623	12,748,486,855	83%
2011	Shumagin	163	39	24%	87,888	2,891,008,491	61%
	Chirikof	155	37	24%	8,676	34,850,679	68%
	Kodiak	228	9	4%	670	151,812	58%
	Yakutat	68	0	--	--	--	--
	Southeast	56	0	--	--	--	--
	Gulf of Alaska	670	85	13%	97,234	2,926,010,982	56%
2013	Shumagin	136	22	16%	72,249	4,584,424,199	94%
	Chirikof	126	23	18%	26,554	345,077,199	70%
	Kodiak	187	26	14%	6,293	26,407,221	82%
	Yakutat	61	6	10%	297	15,090	41%
	Southeast	38	1	3%	18	344	100%
	Gulf of Alaska	548	78	14%	105,411	4,955,924,053	67%
2015	Shumagin	189	50	26%	22,737	317,625,776	78%
	Chirikof	179	32	18%	4,368	5,346,209	53%
	Kodiak	256	29	11%	1,676	242,746	29%
	Yakutat	80	4	5%	36	208	40%
	Southeast	68	0	--	--	--	--
	Gulf of Alaska	772	115	15%	28,816	323,213,939	62%
2017	Shumagin	125	17	14	9,991	39,657,110	63%
	Chirikof	118	11	9	3,771	11,202,683	89%
	Kodiak	178	3	2	23,941	563,449,615	99%
	Yakutat	70	0	--	--	--	--
	Southeast	45	0	--	--	--	--
	Gulf of Alaska	536	31	6	37,703	614,309,409	66%

*Catch of Atka mackerel.

Table 17.3. Schedules of age and length specific maturity from McDermott and Lowe (1997).

Length (cm)	Proportion mature	Age	Proportion mature
20	0	1	0
21	0	2	0.04
22	0	3	0.22
23	0	4	0.69
24	0	5	0.94
25	0	6	0.99
26	0	7	1
27	0	8	1
28	0	9	1
29	0	10	1
30	0		
31	0.01		
32	0.01		
33	0.02		
34	0.05		
35	0.09		
36	0.17		
37	0.29		
38	0.46		
39	0.63		
40	0.78		
41	0.88		
42	0.93		
43	0.97		
44	0.98		
45	0.99		
46	1		
47	1		
48	1		
49	1		
50	1		

Table 17.4. Ecosystem Considerations.

Ecosystem effects on GOA Atka mackerel

Indicator	*Observation*	*Interpretation*	*Evaluation*
Prey availability or abundance trends			
Zooplankton	Data limited, indication of higher euphausiid abundance 2002-2003, Copepod Community Size index has declined, negative anomalies since 2012, bias towards smaller species	Trends could affect nutritional quality of prey, influence availability of prey	Unknown
Forage fish	Data limited, increase of capelin and sandlance 2007-2013 (cold years), low trends for both forage fish, sandlance at long term low	Current low trends suggest lower availability to forage fish predators	No concern
Predator population trends			
Groundfish predators	Increased biomass groundfish predators since late 1970s	Possibly higher mortality on Atka mackerel	Possible concern
Marine mammals	Modeled estimates of WGOA SSL non-oup counts above long term mean and increasing	Very minor increase in Atka mackerel mortality	No concern
Seabirds	Complete reproductive failure in 2015	Seabird population trends could affect juvenile Atka mackerel mortality	Possible concern
Changes in habitat quality			
Climate	Shifts in 1977, 1989, 1999, warmest SST anomalies 2015-2016, warm water “Blob” in NE Pacific	Regime shifts may provide temporary release from competition and predation, warm temperatures may affect embryonic development at nesting sites, may affect distribution of adult fish	Possible concern
Bottom temperature	Warming at depths <50m, 2015 survey warmest in series, similar to 2005	May affect embryonic development at nesting sites, may affect distribution of adult fish	Unknown
Fishing gear effects on habitat	Mixed trends in effort	May affect spawning and nesting habitat	Possible concern

Table 17.4. cont. Ecosystem Considerations

GOA Atka mackerel fishery effects on ecosystem

Indicator	*Observation*	*Interpretation*	*Evaluation*
Fishery contribution to bycatch	No directed fishery	No effect on ecosystem	No concern
Fishery concentration in space and time	No directed fishery	No effect on ecosystem	No concern
Fishery effects on amount of large size target fish	No directed fishery	No effect on ecosystem	No concern
Fishery effects on age-at maturity and fecundity	No directed fishery	No effect on ecosystem	No concern
Fishery contribution to discards and offal production	No directed fishery	No effect on ecosystem	No concern

Figures

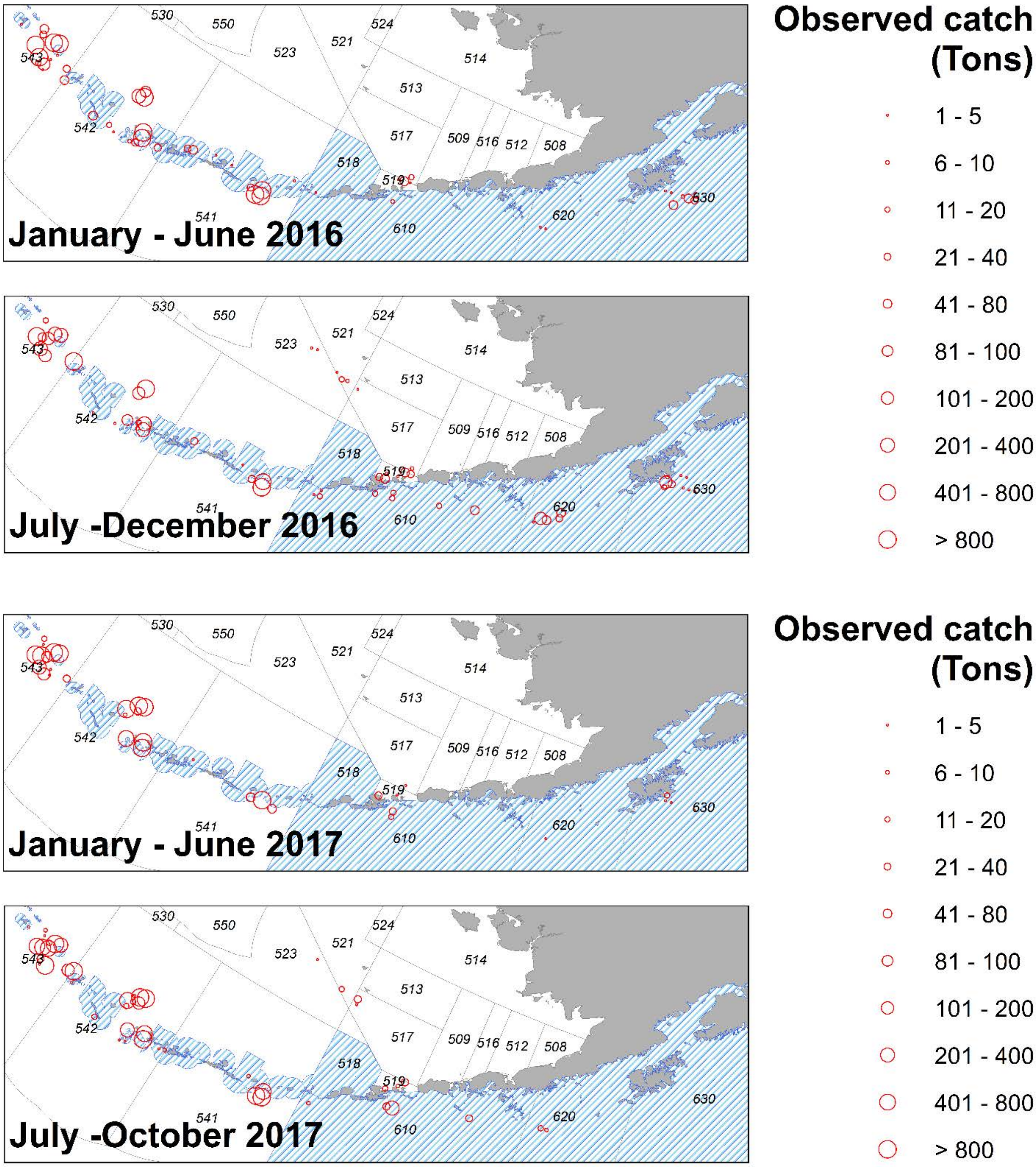

Figure 17.1. Observed catches of Atka mackerel in the 2016 and 2017 fisheries, summed by 20 km^2 cells. Open circles represent catches greater than 1 t; closed circles represent catches less than 1 t. Hashed circular areas represent no trawl zones.

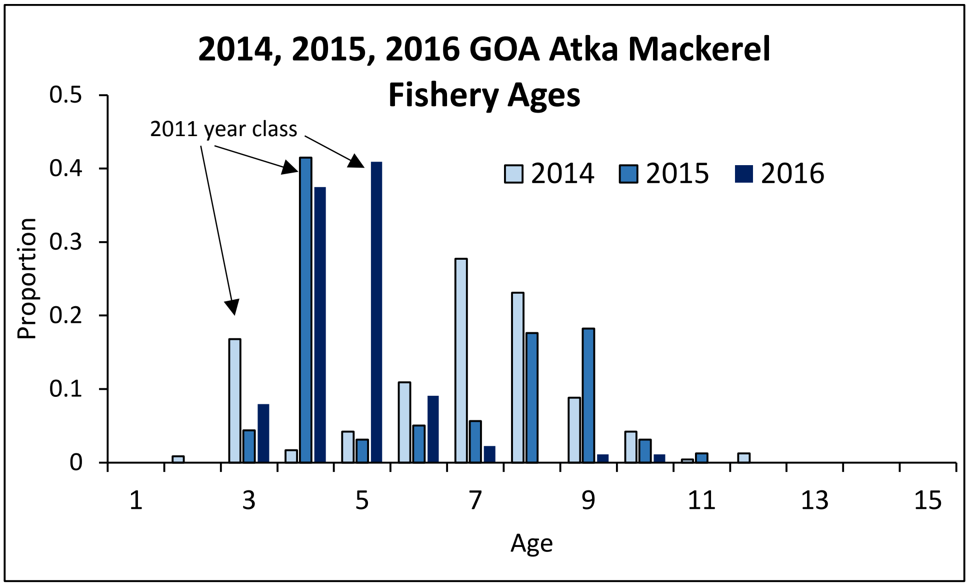

Figure 17.2. Age frequency distribution of Atka mackerel from the 2014, 2015, and 2016 Gulf of Alaska fisheries. A total of 238, 159, and 88 otoliths were collected and aged from the GOA in 2014, 2015, and 2016, respectively.

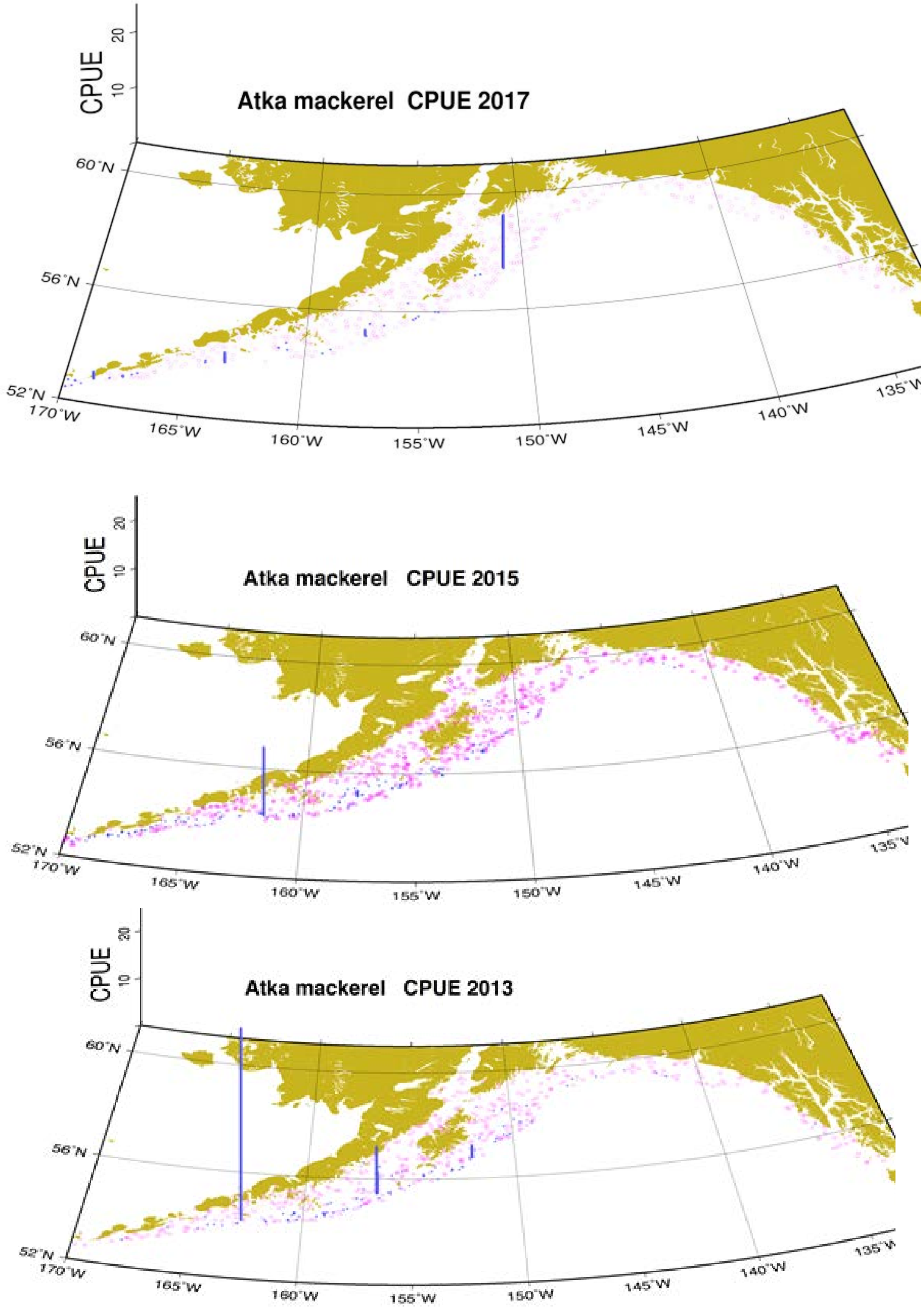

Figure 17.3. Atka mackerel bottom trawl survey CPUE by station, 2013, 2015, and 2017. Circles represent tows where Atka mackerel were absent, height of bars is proportional to CPUE by weight.

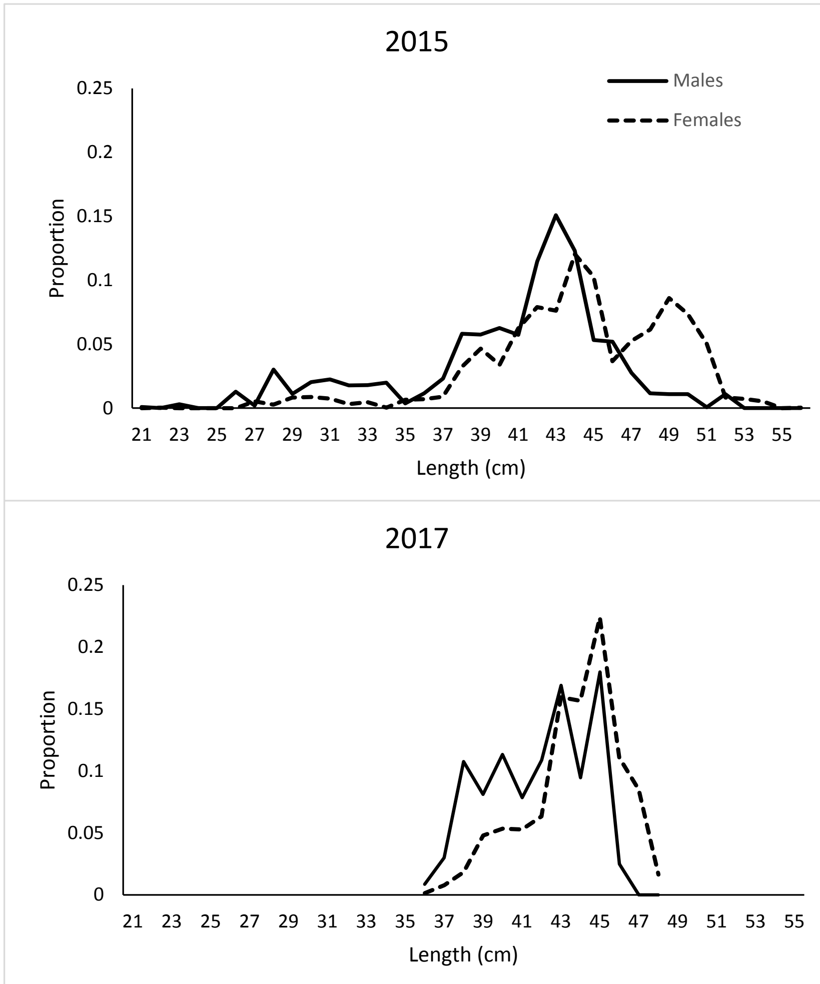

Figure 17.4. Atka mackerel length frequency distributions from the 2015 and 2017 Gulf of Alaska bottom trawl surveys.

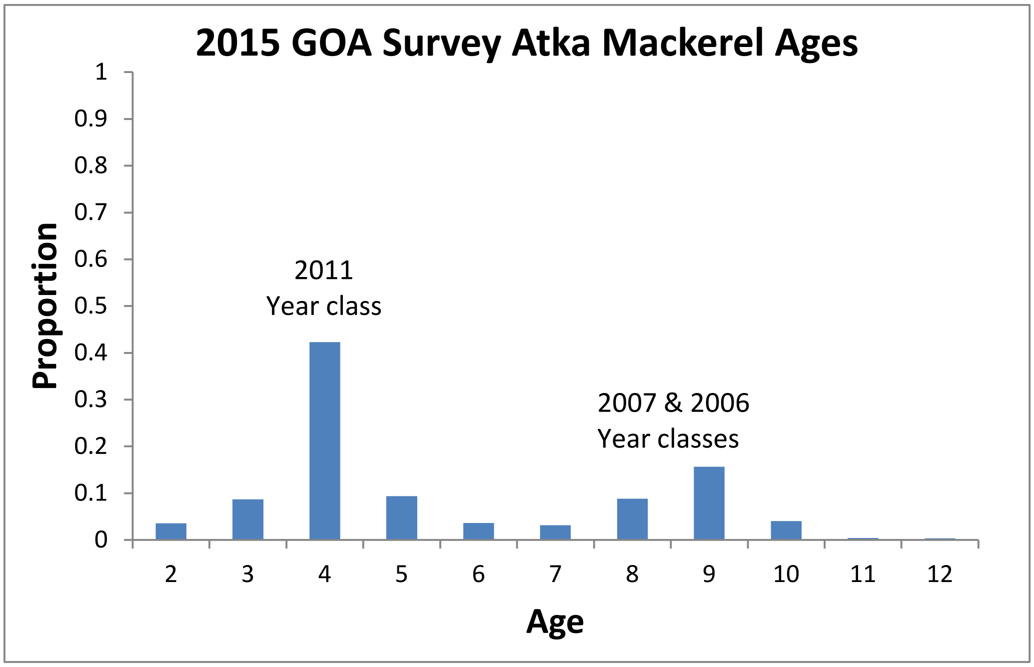

Figure 17.5 Age frequency distribution of Atka mackerel from the 2015 Gulf of Alaska bottom trawl survey. A total of 413 otoliths were collected and aged from the Shumagin (610) and Chirikof (620), and Kodiak (630) areas.

Appendix 17A.—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 1977-2015 in Table 17A-1. Removals from activities other than directed fishing since 2000 have been less than 15 t, with 6 t and 4 t caught in the 2013 and 2015 NMFS bottom trawl surveys, respectively (Table 17A-1). These catches represent a negligible risk to the stock.

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 of GOA Atka mackerel from this dataset.

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Table 17A-1. Total removals of GOA 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 GOA 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	3				3
1979	AFSC	0				0
1980	AFSC	4				4
1981	AFSC	35				35
1982	AFSC	27				27
1983	AFSC	0				0
1984	AFSC	7				7
1985	AFSC	66				66
1986	AFSC	0				0
1987	AFSC	6				6
1988	AFSC	0				0
1989	AFSC	0				0
1990	AFSC	3				3
1991	AFSC	0				0
1992	AFSC	0				0
1993	AFSC	2				2
1994	AFSC	0				0
1995	AFSC	0				0
1996	AFSC	15				15
1997	AFSC	0				0
1998	AFSC	0				0
1999	AFSC	0				0

Table 17A-1. continued

Year	Source	Trawl	Longline NMFS	Longline IPHC	Other	Total
2000	AFSC	0				0
2001	AFSC	13				13
2002	AFSC	0				0
2003	AFSC	6				6
2004	AFSC	0				0
2005	AFSC	9				9
2006	AFSC	0				0
2007	AFSC	6				6
2008	AFSC	0				0
2009	AFSC	10				10
2010	AFSC	0				0
2011	AFSC	6				6
2012	AFSC	0				0
2013	AFSC	6				6
2014	AFSC	0				0
2015	AFSC	4				4
2016	AFSC	0				0