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

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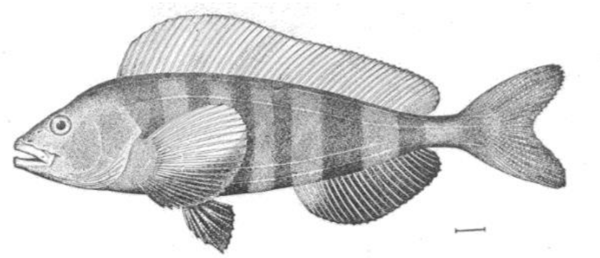

Executive Summary

Gulf of Alaska (GOA) Atka mackerel are on a biennial stock assessment schedule to coincide with the availability of new survey data from the biennial trawl survey. The previous full assessment was presented in 2019, which included data from the 2019 GOA bottom trawl survey. On alternate (even) years no assessment is due for GOA Atka mackerel because of its Tier 6 status. 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 2019 assessment presented Tier 6 recommendations and did not present Tier 5 calculations given the extreme drop in biomass indicated by the 2019 survey. The 2019 full assessment (Lowe 2019) is available at https://www.afsc.noaa.gov/REFM/Docs/2019/GOAatka.pdf. The Council set the Gulf-wide 2020 and 2021 OFL, ABC, and TAC for Atka mackerel at 6,200 t, 4,700 t, and 3,000 t, respectively.

Relative to the November 2019 SAFE report, the following substantive changes have been made in the current draft of the GOA Atka mackerel chapter:

Summary of Changes in Assessment Inputs

1. Catch data are updated through October 24, 2021.
2. Age data from the 2019 and 2020 GOA fisheries are presented.
3. Age data from the 2019 GOA bottom trawl survey are presented.
4. Biomass estimates from the 2021 GOA bottom trawl survey are presented.
5. Length frequency data from the 2021 GOA bottom trawl survey are presented.

Summary of Changes in the Assessment Methodology

There are no changes to the assessment methodology. Gulf of Alaska (GOA) Atka mackerel have been managed under Tier 6 specifications since 1996 due to lack of reliable estimates of current biomass. 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 1978-1995, and the maximum permissible ABC as 0.75 of the OFL.

This year, we again present Tier 6 recommendations, and do not present Tier 5 calculations of ABC and OFL given that the 2021 survey biomass estimates are essentially based on 1,459 fish caught in one haul off Unalaska Island in the Western Gulf of Alaska. A total of 1,507 Atka mackerel were caught in the 2021 survey, with a single haul capturing 98% of the Atka mackerel catch.

Summary of Results

Since 2006, the maximum permissible ABC has been 4,700 t under Tier 6 criteria, 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 to minimize targeting. From 2009 to 2016, TACs were 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 rockfish and Pacific cod fisheries were encountering more Atka mackerel on the fishing grounds. Given the patchy distribution of GOA Atka mackerel which results in highly variable estimates of abundance, the variance associated with the 2021 survey (Gulf-wide *CV* of 97%), and the unexplained extremely low 2019 survey biomass estimates (837 t), I continue to recommend that GOA Atka mackerel be managed under Tier 6. **I recommend a 2022 (and 2023) ABC for GOA Atka mackerel equal to the maximum permissible value of 4,700 t. The 2022 (and 2023) 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 and arrowtooth flounder, and an allowance for minimal targeting should still be considered. The 2020 GOA Atka mackerel catch was 608 t, and as of November 6, 2021, the GOA Atka mackerel catch (940 t) is only 31% of the 3,000 t TAC. Catches since 2006 have been above the 2019 GOA survey biomass estimate of 837 t, and have ranged from 1,000-1,400 t since 2011. It does not appear that the 2019 and 2021 survey biomass estimates are valid representations of GOA Atka mackerel abundance and population trends.

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2021	2022	**2022**	2023
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
	As determined *last* year for:		As determined *this* year for:	
Status	2017	2018	2018	2019
Overfishing	n/a	n/a	**n/a**	n/a

Responses to SSC and Plan Comments on Assessments in General

From the December 2019 and 2020 SSC minutes: The SSC recommends dropping the overall risk scores in the tables. *The overall risk score has been removed from the table.*

The SSC requests that the table explanations be included in all the assessments which include a risk table. *The risk table explanations are included.*

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 in 2019 or 2020.

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.

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 2020 and 2021 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) area in 2020 and 2021. Bycatch of Atka mackerel in the Shumagin and Chirikof (610, 620) areas significantly increased after 2018. 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). 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 2003-2014 levels of GOA Atka mackerel retained and discarded were discussed in Lowe (2015). The 2015 to 2020 levels of GOA Atka mackerel retained and discarded are given in Table 17.2.

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. The rockfish fisheries retained about a 1,100 t of Atka mackerel bycatch in the Shumagin area in 2018, which is the highest level ever retained. Total catches of Atka mackerel have not increased since 2012, and have remained at about 1,200-1,400 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*. (2019).

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 2014 assessment, limited numbers of ages from the GOA fisheries have become available. A total of 186, 151, and 58 otoliths were collected from the GOA in 2018, 2019, and 2020 respectively. The GOA Atka mackerel fishery data is generally comprised of 3-6 year olds, and there is a lack of older ages. However, a large number of 7-year-olds appeared in the 2018 age composition; these fish are the 2011 year class, which were prevalent in the Aleutian Islands. The 2018 GOA data also show a large number of 3-year-olds similar to the 2018 BSAI fishery data (Figure 17.2, Lowe *et al*. 2019).

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 AFSC bottom trawl 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. Bottom trawl survey information is presented for 2009-2021 for consideration (Table 17.3).

The survey data from 2017 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 (Table 17.3, Figure 17.3), which was extrapolated over the largest (km^2) GOA stratum

The 2019 survey showed 87% of the GOA biomass in the Shumagin area based on a single haul of 8 fish caught off Davidson Bank. The 2019 GOA survey encountered the lowest numbers of Atka mackerel (46) since 1999 when the survey caught a total of 206 fish. The 2019 biomass estimates by area and the Gulf-wide biomass are the lowest in the survey time series (Table 17.3).

The most recent 2021 survey showed nearly 100% of the GOA biomass was in the Shumagin area based on a single haul taken off the Fox Islands (east of Unalaska Island) in the Western Gulf of Alaska (Figure 17.3). The Shumagin area and the Gulf of Alaska *CV*s were 97% (Table 17.3). A total of 1,507 Atka mackerel were caught in the 2021 survey, with a single haul responsible for 98% of the Atka mackerel catch.

Atka mackerel have been inconsistently caught in the GOA surveys, appearing in 14%, 11%, and 11% of the hauls in the Shumagin area in the 2017, 2019, and 202 GOA surveys, respectively (Table 17.3). Most of the GOA Atka mackerel has been distributed in the Shumagin area of the western GOA (Table 17.3). More 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 17.3). 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 Gulf wide in 6% of the hauls in the 2017 survey compared with 15% of the hauls in the 2015 survey. Atka mackerel were observed in 5% of the hauls in the 2019 survey, similar to 2017, and down to 3% in the most recent 2021 survey

These results demonstrate that the AFSC GOA bottom trawl survey, as it has been designed and used since 1984, does not assess GOA Atka mackerel well and that the resulting biomass estimates should not be considered consistent reliable indicators of absolute abundance or indices of trend.

Survey length frequencies

Length frequency distributions prior to 2017 were mainly between 40 and 50 cm and were discussed in 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 (Figure 17.4, Lowe 2019). The 2019 survey caught very few numbers of Atka mackerel (46 fish). The limited data show modes at 41-43 cm for males and 43 cm for females (Figure 17.4). The 2021 survey length frequency distribution is limited between 28 and 33 cm, with modes at 30-31 cm. These are very small fish and were nearly all sampled from 1 haul in the Shumagin area (east of Unalaska Island). The 2020 and 2021 Eastern Aleutian fishery length frequency distributions do not reflect large numbers of small fish, lengths range from about 33-45 cm (Lowe et al. 2021).

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, 2017, 2019). 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 (2011-2015) from the GOA trawl surveys are discussed in Lowe (2019).

Survey age information is available from the 2017 and 2019 summer bottom trawl survey. A total of 142, 41, and 68 otoliths were collected from the Western and Central Gulf of Alaska in 2017, 2019, and 2021, respectively. Over half of the Atka mackerel otoliths were collected each year in the Shumagin area. The 2017 data show 4, 5, and 6 year olds of the 2011-2013 year classes (Figure 17.5), which mirrors the 2017 GOA fishery age composition. So few fish were collected in the 2019 survey it is difficult to interpret the age data.

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:

Weight (kg) = 4.61E-05*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:

Weight (kg) = 1.55E-05 x 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 17.4. 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 (2018-2020) and surveys (2017 and 2019) show a limited distribution of ages.

Results

Harvest Recommendations

Amendment 56 reference points

As discussed above, bottom trawl survey information from the GOA surveys is presented for consideration, but is not recommended for Tier 5 harvest specifications. The 2019 survey estimated a GOA Atka mackerel biomass of 570 t from the Shumagin area. This represents 68% of the Gulf-wide Atka mackerel biomass estimate of 837 t, the lowest estimate in the time series. The Shumagin area biomass was essentially based on 8 fish caught off Davidson Bank. The survey data are not corroborated by the fishery data. Fishery catches of GOA Atka mackerel in 2019 were 1,254 t. The 2021 survey biomass in the GOA is estimated at 24,411 t, of which nearly 100% was caught in the Shumagin area. The 2021 Shumagin and GOA *CV*s are 97%.

Bycatch of Atka mackerel in the GOA fisheries has been relatively stable ranging from 600 t to 1,100 since 2015. Fishery catches in the Shumagin area have been 720, 702, and 401 t in 2019, 2020, and 2021 (as of 11/14/21), respectively. The TACs over this time period have been set at 3,000 t, thus the GOA Atka mackerel catch data are thought to represent true bycatch levels in other directed fisheries. Given the extreme variances associated with GOA survey biomass estimates and the recent lowest biomass estimate from the 2019 survey, the bottom trawl surveys 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 2017, 2019, 2021 surveys are highly variable with Gulf-wide *CV*s of 66, 27, and 97%, respectively. The biomass has been mostly observed in the Shumagin area The 2019 survey biomass estimate is the lowest in the time series and is not corroborated by GOA fishery data.

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 2022 (and 2023) ABC for GOA Atka mackerel equal to the maximum permissible value of 4,700 t. The 2022 (and 2023) 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 2021 TAC for GOA Atka mackerel was 3,000 t. Total catches of GOA Atka mackerel have remained at about 1,000-1,200 t since 2014.

Status determination

Because the 2020 catch was below the 2020 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.

Should the ABC be reduced below the maximum permissible ABC?

The SSC in its December 2018 minutes recommended that all assessment authors use the risk table when determining whether to recommend an ABC lower than the maximum permissible. The SSC also requested the addition of a fourth column on fishery performance, which has been included in the table below.

	Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Substantially increased concerns	Substantially increased assessment uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing an adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not consistent across all indicators
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e.,	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b)

			predators and prey of the stock)	different gear types
Level 4: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.

2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.

3. Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.

4. Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.

<u>Assessment considerations</u>: GOA Atka mackerel are managed under Tier 6 because we have no reliable estimates of biomass. There is no assessment model used to assess GOA Atka mackerel. The assessment uncertainty (no reliable estimate of biomass) is captured by the assessment by virtue of being in Tier 6. We rated the assessment-related concern as Level 1. We continue to have typical to moderately increased concerns about assessment-related uncertainty, particularly in regard to the survey data.

<u>Population dynamics considerations</u>: GOA Atka mackerel are managed under Tier 6 because we have no reliable estimates of biomass. There is no assessment model used to assess the population dynamics of GOA Atka mackerel. The uncertainty about population dynamics considerations is captured by the assessment by virtue of being in Tier 6. Stock and recent recruitment trends are unknown, therefore we cannot assign a concern level for Population Dynamics Considerations. The level of population dynamics-related concern is Unknown or UNK.

Environmental/Ecosystem considerations:

Environment: Ocean temperatures in 2021 at depths of spawning and nesting sites (14 – 144 m) were near the long-term mean and did not exceed the optimal range for egg survival and embryonic development (3°C to 15°C) (Watson 2021; AFSC Bottom Trawl Survey, Laman 2021; AFSC EcoFOCI survey, Rogers 2021; Seward Line Survey, Danielson 2021). However, western GOA started the year with warmer surface waters (satellite data; Watson 2021) and there was above average warmth (5.2°C) at 200m depth along the outer edge of the shelf during the summer (AFSC Longline Survey; Siwicke 2021). The general cooling trend since 2020 is predicted to continue in 2022, in alignment with predicted La Niña conditions and a negative phase of the Pacific Decadal Oscillation (PDO). Strong year classes of Aleutian Islands Atka mackerel have occurred in years of hypothesized climate regime shifts 1977, 1988, and 1999, as indicated by transitions to negative phases of the PDO. Assuming a similar relationship in the GOA, 2021 continues a transition into a negative PDO state, potentially associated with cooler ocean conditions and favorable conditions for Atka mackerel recruitment. Atka mackerel are primarily caught in the western GOA, with a preference for hard, rough, and rocky bottom substrate. The percent area disturbed by trawl fishing slightly increased in 2020 in the EGOA and continued a decreasing trend in the WGOA (divided at 147°W). The area disturbed remains low overall (0.2% and below 2%, respectively) and while intensive fishing in a region may have localized impacts, this is not cause for concern at the population level (Olson 2021).

Prey: GOA Atka mackerel are primarily zooplanktivores, and experienced a below-average to average prey based in 2021. The western GOA had lower spring biomass of large copepods and approximately average biomass of smaller copepods around the Semidi Islands, characteristic of previous warm, less productive years (e.g., 2019; Spring AFSC EcoFOCI survey, Kimmel et al. 2021). Planktivorous seabird reproductive success, an indicator of zooplankton availability and nutritional quality, was average in the Semidi Islands (Chowiet Island) and below average just north of Kodiak (E. Amatuli Island; Drummond 2021). Around the eastern edge of WGOA (Seward Line, Middleton Island) the biomass of large copepods was average to above-average (Seward Line Survey, Hopcroft 2021) and planktivorous seabirds had better reproductive success (Middleton Island, Hatch 2021), indicating improved forage conditions.

Competitors: Potential competitors of GOA Atka mackerel include large year classes of juvenile sablefish (2016, 2018) and a pink salmon which are returning in very high numbers this year (Murphy 2021, Shaul 2021).

Predators: GOA Atka mackerel are presumed to experience a continued reduced level of predation pressure in 2021, although, little is known about the impacts of predators, such as fish and marine mammals. They are consumed by several piscivorous species in the western Gulf, such as arrowtooth flounder, Pacific halibut, Pacific cod, and sablefish which, in aggregate are one standard deviation below long-term mean biomass, as sampled by the AFSC Bottom Trawl Survey (Whitehouse, 2021). Sablefish is the exception in that group, with an increasing abundance, however the large 2016 year class is maturing and moving off the shelf, potentially reducing their overlapping range (Goethell 2021). Additional species that feed on Atka mackerel but are either at reduced or stable population sizes, include Steller sea lions, Northern fur seals, and seabirds (e.g., thick-billed murres, tufted puffins, and short-tailed shearwaters).

We scored this category as Level 1 (normal concern) given moderate environmental conditions, below-average to average prey conditions, reduced predation pressure, limited information on competitors, and a lack of a mechanistic understanding for the direct and indirect effects of environmental change on the survival and productivity of Atka mackerel in the GOA.

Fishery performance: Steller sea lion regulations prohibit directed fisheries for GOA Atka mackerel. They are managed with TAC levels to provide for anticipated bycatch needs of other fisheries, principally for rockfish, Pacific cod, and pollock. The 2020 and 2021 GOA Atka mackerel catches were 608 t and 923 t, respectively, and as of October 24, 2021, the GOA Atka mackerel catches are well below the 3,000 t TAC. Fishery catches of GOA Atka mackerel have not shown any unusual trends in location, timing and catch levels. Catches since 2011 have been relatively consistent and ranged from 600-1,400. There are no apparent fishery/resource-use performance and/or behavior concerns therefore, I rated the fishery performance-related concern as Level 1.

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*
Level 1: Typical to moderately increased concerns	Level: UNK Stock and recruitment trends are unknown	Level 1: No apparent environmental/ ecosystem concerns	Level 1: No apparent fishery/resource-use performance and/or behavior concerns

The scores of level 1 suggests that setting the ABC below the maximum permissible is not warranted. Because GOA Atka mackerel are managed in Tier 6, we are not able to set a meaningful ABC based on stock abundance levels and trends which are unknown. Uncertainty for GOA Atka mackerel is accommodated through management with conservative TAC specifications.

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

<u>Climate and habitat quality</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 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). This has not been examined for GOA Atka mackerel.

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. 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.

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). 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).

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, deep-water myctophids, squids, and other invertebrates (Ortiz, 2007).

Zooplankton species composition and biomass vary with ocean temperature, season, and the location of the front between the nearshore Alaska coastal current and the further offshore Alaska stream (Coyle and Pinchuk 2006, Kimmel and Duffy-Anderson 2020, Arimitsu *et al.* 2021). 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). Matta et al. (2020) found growth of Atka mackerel corresponded negatively to years of higher pink salmon returns (generally odd years), indicating potential for competition around copepod prey.

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). 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 when their population sizes are large.

The overall biomass of major Atka mackerel groundfish predators in the GOA (arrowtooth flounder, Pacific cod, and halibut) has been relatively low. GOA arrowtooth estimated biomass increased from a low of 0.4 million t in 1970 to a high of 1.2 million tons in 2008. Arrowtooth biomass has been slowly declining since then. GOA Pacific cod biomass has shown a long decline from their peak in 1988 to 2007. Pacific cod biomass then increased to another peak in 2014, and has been greatly reduced since the 2014-2016 marine heatwave. Sablefish has been increasing in abundance since the 2014-2016 marine heatwave and is a groundfish predator, although the importance of Atka mackerel in their diet is not known. Piscivorous seabirds could also predate on juvenile Atka mackerel. While seabird population trends are note well known, some dramatically declined after the 2014-2016 marine heatwave (e.g., common murres, Suryan *et al.* 2021). Trends in the western Steller sea lion populations show modest increasing trend since a low in 2000 but are still much reduced relative to peaks prior to 1980. 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).

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.

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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 17.1 cont. 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	1,093	4,700	2,000	6,200
2017	1,075	4,700	3,000	6,200
2018	1,438	4,700	3,000	6,200
2019	1,254	4,700	3,000	6,200
2020	608	4,700	3,000	6,200
2021[F]	923	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/ 2021 data as of October 24, 2021 from NMFS Alaska Regional Office Catch Accounting System (CAS)

Table 17.2 Discarded and retained catches of Atka mackerel from Gulf of Alaska rockfish directed fisheries, and all other directed fisheries, 2015-2020.

Year	Fishery	Discarded (t)	Retained (t)	Total (t)
2015	Rockfish	141	847	988
	All others	175	55	230
	All	316	902	1,228
2016	Rockfish	52	543	595
	All others	74	424	498
	All	126	967	1,093
2017	Rockfish	9	534	543
	All others	369	163	532
	All	378	697	1,075
2018	Rockfish	39	1,101	1,140
	All others	12	286	298
	All	51	1,387	1,438
2019	Rockfish	29	795	824
	All others	102	329	431
	All	131	1,124	1,255
2020	Rockfish	91	511	602
	All others	3	3	6
	All	94	514	608

Table 17.3. 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*
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%**
2019	Shumagin	123	14	11%	570	43,420	37%
	Chirikof	121	7	6%	125	2,479	40%
	Kodiak	176	6	3%	130	3,635	46%
	Yakutat	69	0	--	--	--	--
	Southeast	52	1	2%	12	149	100%
	Gulf of Alaska	**541**	**28**	**5%**	**837**	**49,683**	**27%**
2021	Shumagin	114	13	11%	24,354	555,169,346	97%
	Chirikof	115	4	3%	45	511	50%
	Kodiak	177	1	1%	12	143	100%
	Yakutat	70	0	0%	--	--	--
	Southeast	53	0	0%	--	--	--
	Gulf of Alaska	**529**	**18**	**3%**	**24,411**	**155,170,001**	**97%**

*Catch of Atka mackerel.

Table 17.4. 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		

Figures

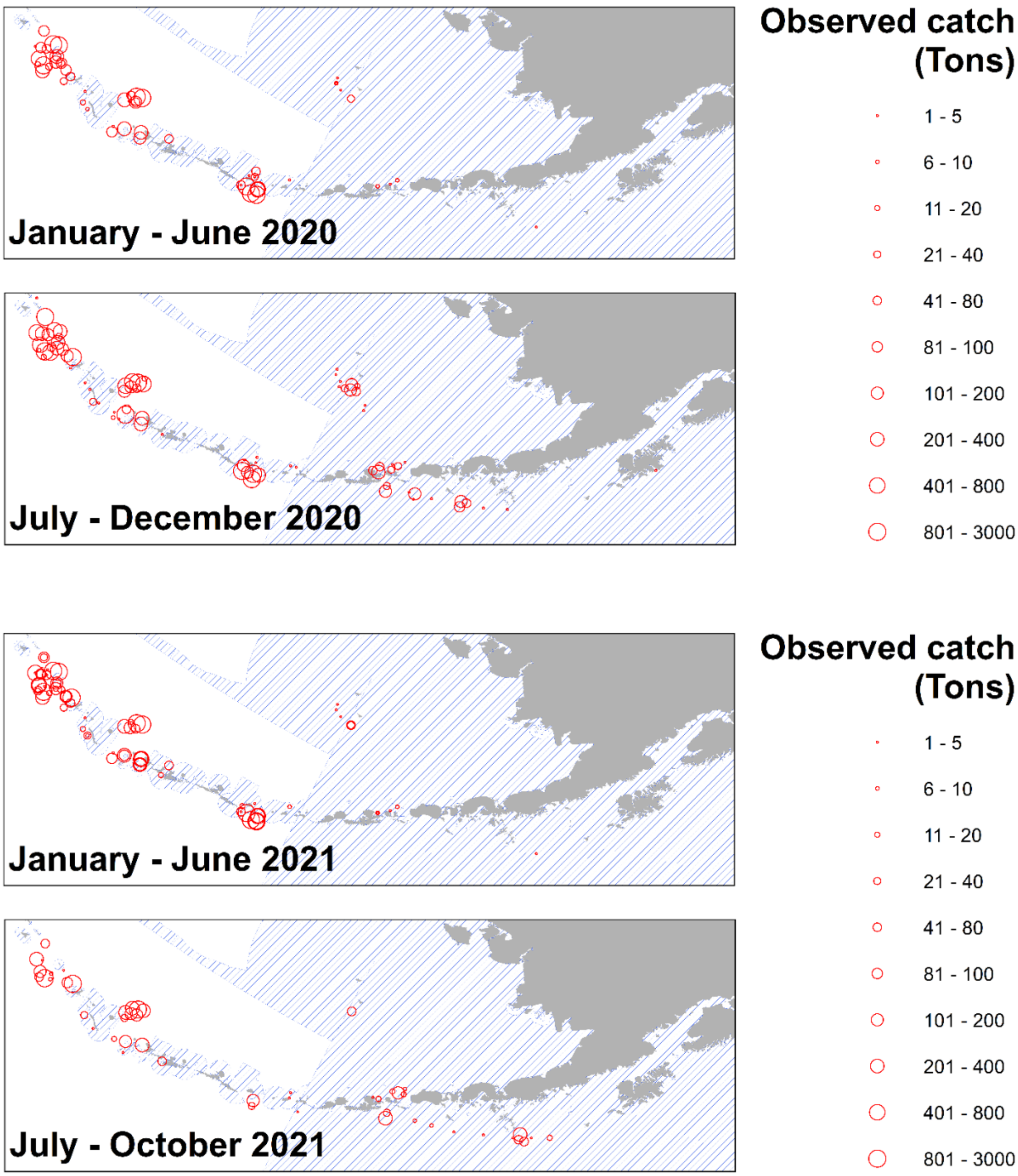

Figure 17.1. Observed catches of Atka mackerel in the 2018 and 2019 fisheries, summed by 20 km^2 cells. Open circles represent catches greater than 1 t; closed circles represent catches less than 1 t. Hashed circular areas represent no trawl zones.

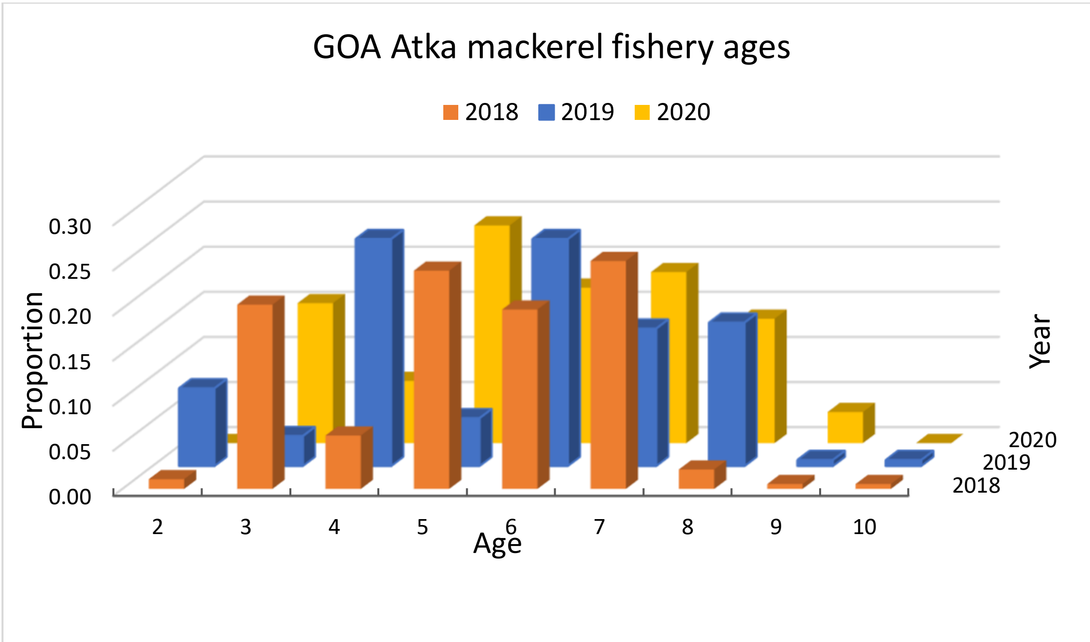

Figure 17.2. Age frequency distribution of Atka mackerel from the 2018-2020 Gulf of Alaska fisheries. A total of 186, 151, and 58 otoliths were collected and aged from the GOA in 2018, 2019, and 2020, respectively.

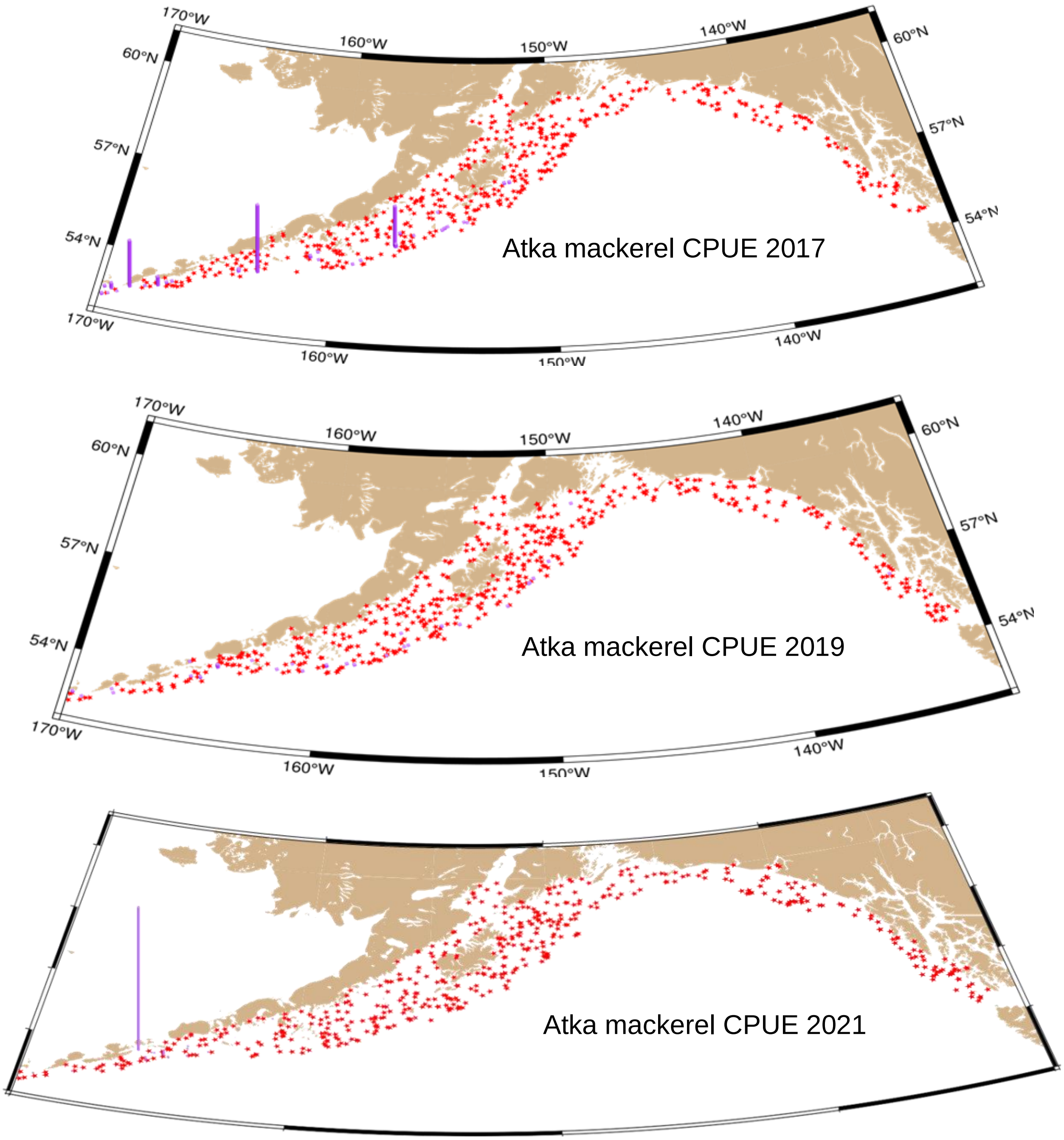

Figure 17.3. Atka mackerel bottom trawl survey CPUE by station for 2017, 2019, and 2021. Stars represent tows where Atka mackerel were absent, height of bars is proportional to CPUE by weight.

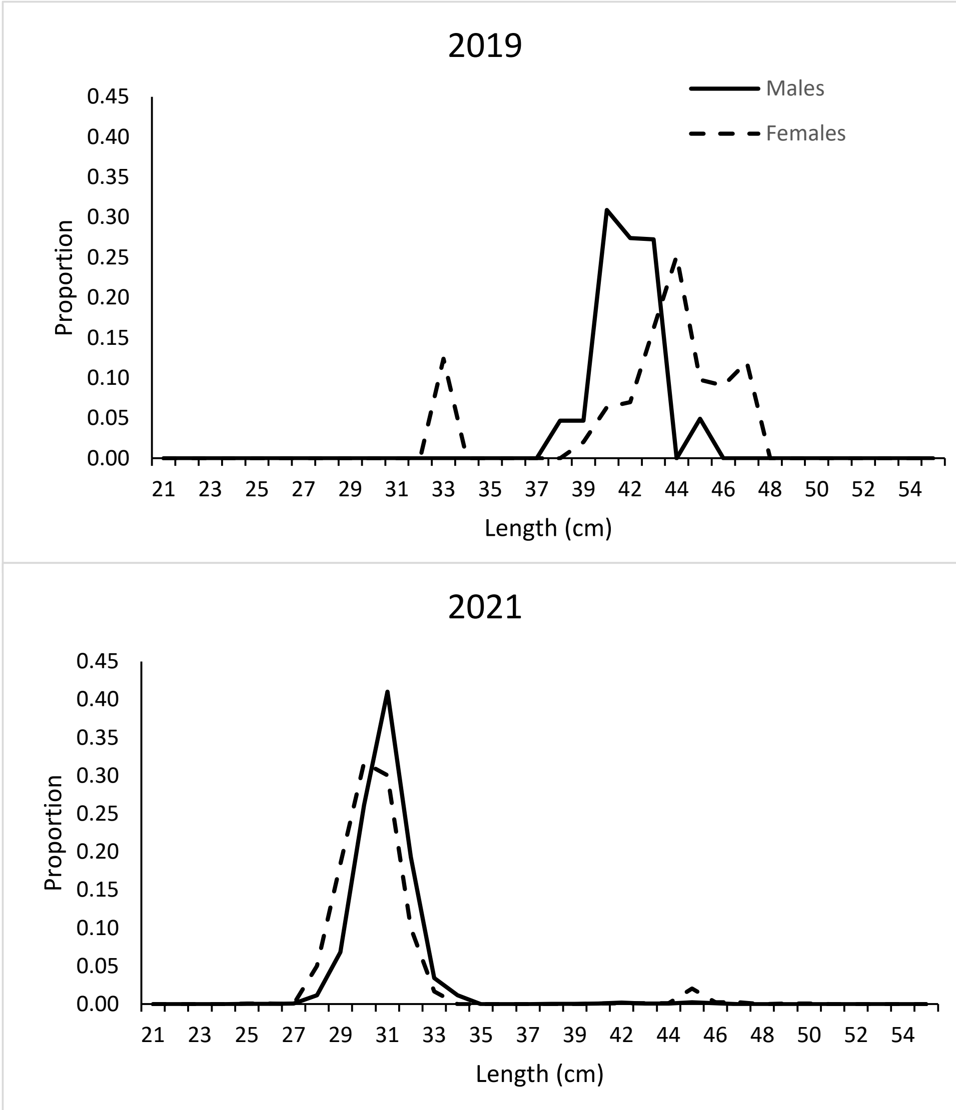

Figure 17.4. Atka mackerel population length frequency distributions from the 2019 and 2021 Gulf of Alaska bottom trawl surveys. The 2019 survey caught very few Atka mackerel throughout the Gulf of Alaska, compared to the 2021 survey which also caught few Atka mackerel, but almost all were taken in the Shumagin area.

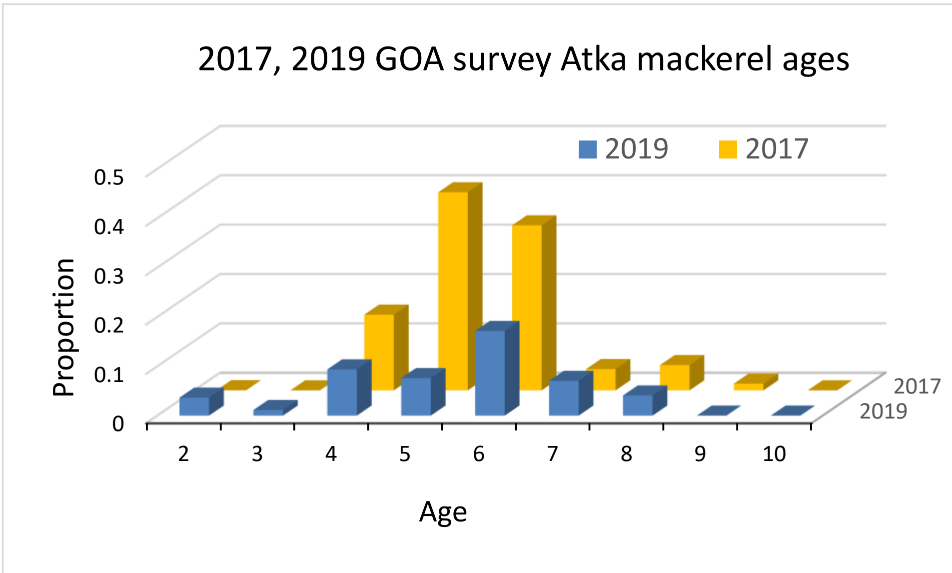

Figure 17.5 Age frequency distributions of Atka mackerel from the 2017 and 2019 Gulf of Alaska bottom trawl surveys. A total of 142 and 41 otoliths were collected and aged from the 2017 and 2019 surveys, respectively.

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 1977-2020 in Table 17A-1. Removals from activities other than directed fishing since 2000 have been less than 15 t, with 6 t, 4 t, and 2 t caught in the 2013, 2015, and 2017 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

			Longline			
Year	Source	Trawl	NMFS	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
2017	AFSC	2				2
2018	AFSC	0				0
2019	AFSC	0				0
2020*	--	--				--

*No AFSC bottom trawl surveys were conducted in 2020.