9. Assessment of the Pacific ocean perch stock in the Gulf of Alaska

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Executive Summary

Pacific ocean perch in the Gulf of Alaska are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in on-cycle (odd) years, we present a full stock assessment document with updated assessment and projection model results. Normally in alternate (even) yeas we present an executive summary, however, due to current work being undertaken on this assessment we present a full model this year in order to provide updates to the model in anticipation of additional model changes in next year's full assessment.

We use a statistical age-structured model as the primary assessment tool for Gulf of Alaska Pacific ocean perch which qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. For this year, we update the 2019 assessment model estimates with new data collected since the last full assessment.

Summary of Changes in Assessment Inputs

Changes in the input data: The input data were updated to include survey age compositions for 2019, final catch for 2019 and preliminary catch for 2020-2022. Further changes to input data included updating the data used to construct the ageing error matrix and the fishery age composition data was constructed by using an age-length key

Changes in the assessment methodology: The assessment methodology is the same as the 2019 assessment with updated input data. However, priors were changed in the current year's assessment for the bottom trawl survey catchability parameter (from 1 to 1.15) and natural mortality parameter (from 0.05 to 0.0614).

Summary of Results

For the 2021 fishery, we recommend the maximum allowable ABC of **36,177** t. This ABC is a 16% increase from the 2020 ABC of 31,238 t. The increase is attributed to the model continuing to react to four consecutive survey biomass estimates larger than 1 million tons as well as updating the priors for natural mortality and bottom trawl survey catchability. This also resulted in a 21% higher ABC than the 2021 ABC projected last year. The corresponding reference values for Pacific ocean perch are summarized in the following table, with the recommended ABC and OFL values in bold. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished. The test for determining whether a stock is overfished is based on the 2019 catch compared to OFL. The official total catch for 2019 is 25,470 t which is less than the 2019 OFL of 33,951 t; therefore, the stock is not being subjected to overfishing. The tests for evaluating whether a stock is overfished or approaching a condition of being overfished require examining model projections of spawning biomass relative to $B_{35\%}$ for 2020 and 2022. The estimates of spawning biomass for 2020 was 213,505 t and 2022 is 198,020 t. Both estimates are above the current $B_{35\%}$ estimate of 110,962 t and, therefore, the stock is not currently overfished nor approaching an overfished condition.

Quantity	As estimated or specified *last* year for: 2020	2021	As estimated or recommended *this* year for: 2021	2022[1]
M (natural mortality)	0.065	0.065	0.075	0.075
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	544,569	524,883	613,522	597,732
Projected Female spawning biomass	201,518	194,795	207,096	198,179
$B_{100\%}$	319,837	319,837	317,035	317,035
$B_{40\%}$	127,935	127,935	126,814	126,814
$B_{35\%}$	111,943	111,943	110,962	110,962
F_{OFL}	0.108	0.108	0.120	0.120
$maxF_{ABC}$	0.090	0.090	0.100	0.100
F_{ABC}	0.090	0.090	0.100	0.100
OFL (t)	37,092	35,600	42,977	41,110
maxABC (t)	31,238	29,983	**36,177**	34,602
ABC (t)	31,238	29,983	**36,177**	34,602
Status	As determined *last* year for: 2018	2019	As determined *this* year for: 2019	2020
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

[1]Projected ABCs and OFLs for 2021 and 2022 are derived using estimated catch of 24,235 for 2020, and projected catches of 32,989 t and 31,337 t for 2021 and 2022 based on realized catches from 2017-2019. This calculation is in response to management requests to obtain more accurate projections.

Area Apportionment

The following table shows the recommended apportionment for 2021 and 2022 from the random effects model.

Area Apportionment	Western	Central	Eastern	Total
	4.6%	75.8%	19.6%	100%
2021 Area ABC (t)	**1,643**	**27,429**	**7,105**	**36,177**
2022 Area ABC (t)	**1,572**	**26,234**	**6,796**	**34,602**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of Eastern Gulf biomass still obtainable in the W. Yakutat area (between 147° W and 140° W) is smaller than the 2017 assessment at 0.24, a decrease from 0.58. The random effects model was not applied for the WYAK and EYAK/SEO split and the weighting method of using upper 95% confidence of the ratio in biomass between these two areas used in previous assessments was continued. This results in the following apportionment of the Eastern Gulf area:

	W. Yakutat	E. Yakutat/Southeast	Total
2021 Area ABC (t)	**1,705**	**5,400**	**7,105**
2022 Area ABC (t)	**1,631**	**5,165**	**6,796**

In 2012, the Plan Team and SSC recommended combined OFLs for the Western, Central, and West Yakutat areas (W/C/WYK) because the original rationale of an overfished stock no longer applied. However, because of concerns over stock structure, the OFL for SEO remained separate to ensure this unharvested OFL was not utilized in another area. The Council adopted these recommendations. This results in the following apportionment for the W/C/WYK area:

	Western/Central/W. Yakutat	E. Yakutat/Southeast	Total
2021 Area OFL (t)	**41,493**	**1,484**	**42,977**
2022 Area OFL (t)	**39,691**	**1,419**	**41,110**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Pacific ocean perch	2019	496,922	33,951	28,555	28,555	25,470
	2020	544,569	37,092	31,238	31,238	24,235
	2021	613,522	42,977	36,177		
	2022	597,732	41,110	34,602		

[1]Total biomass from the age-structured model

		2020				2021		2022	
Stock	**Area**	**OFL**	**ABC**	**TAC**	**Catch[2]**	**OFL**	**ABC**	**OFL**	**ABC**
Pacific ocean perch	W		1,437	1,437	1,332		1,643		1,572
	C		23,678	23,678	18,879		27,429		26,234
	WYAK		1,470	1,470	1,466		1,705		1,631
	SEO	5,525	4,653	4,653	0	6,414	5,400	6,136	5,165
	W/C/WYK	31,567				45,003		43,048	
	Total	37,092	31,238	31,238	21,677	42,977	36,177	41,110	34,602

[2]Current as of October 10, 2020, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC requests that all authors fill out the risk table in 2019…" (SSC December 2018)

"…risk tables only need to be produced for groundfish assessments that are in 'full' year in the cycle." (SSC, June 2019)

"The SSC recommends the authors complete the risk table and note important concerns or issues associated with completing the table." (SSC, October 2019)

"The SSC requests the GPTs, as time allows, update the risk tables for the 2020 full assessments.

…..The SSC recommends dropping the overall risk scores in the tables.

…..The SSC requests that the table explanations be included in all the assessments which include a risk table for completeness.

….The SSC notes that the risk tables provide important information beyond ABC-setting which may be useful for both the AP and the Council and welcomes feedback to improve this tool going forward." (SSC December 2019)

As all these comments pertain to the risk table we combine them in our response. As requested, we provide a risk table in the *Harvest Recommendations* section that provides rationale for each level chosen and we drop the overall risk score. After completing this exercise, we do not recommend ABC be reduced below maximum permissible ABC.

Responses to SSC and Plan Team Comments Specific to this Assessment

"The Plan Team supports these future research topics, and additionally recommends:

1. *investigation of natural mortality, as the current estimate of 0.066 is higher than the expected value from the prior distribution (0.05) and may be constraining the model*
2. *re-evaluation of the age-plus group, as changes to the model and input data have occurred since this was previously evaluated*
3. *continued evaluation of methods for weighting for the compositional data as new models are developed and/or changes are made to input data."*

(Plan Team, November 2018)

"The SSC supports the author's and PT's suggestions to investigate the following topics in the next CIE review for GOA rockfish (scheduled for spring 2019):

- *incorporating hydroacoustic information into the assessment as the species are regularly found throughout the water column*
- *examining fishery-dependent information, e.g., how age samples are being collected*
- *examining catchability, which has been an ongoing issue for POP and other rockfish species, coupled with selectivity (a manuscript is currently in preparation to inform priors)*
- *examining the VAST model for POP, and possibly dusky and northern rockfish"*

(SSC, December 2018)

"The Team discussed the acoustic survey selectivity and recommends further exploration of using the raw acoustic survey lengths, the acoustic abundance weighted length compositions, or using the bottom trawl survey selectivity as a proxy." (September 2019)

The Team endorses the author considerations for the CIE review's terms of reference:

- *incorporating hydroacoustic information into the assessment as the species are regularly found throughout the water column,*

- *examining catchability, which has been an ongoing issue for POP and other rockfish species, coupled with selectivity (a manuscript is currently in preparation to inform priors)*
- *examining the VAST model for POP abundance and apportionment.*

(Plan Team, November 2019)

The SSC supports the GOA GPT recommendation to explore incorporating hydroacoustic information into the assessment, examining catchability and selectivity, and examining the VAST model for POP abundance and apportionment. The SSC agrees that the formation of an internal assessment review team prior to the CIE review would be beneficial. (SSC, December 2019)

We have combined these comments as they pertain to a group of analyses that were to be performed and presented to a CIE review. Unfortunately, due to the government shutdown caused by a lapse in appropriations early in 2019, we were unable to schedule a CIE review for GOA rockfish during 2019 and rescheduled to the spring of 2020. Due to the COVID-19 pandemic the CIE that was intended to be conducted in the spring of 2020 was cancelled and is currently scheduled for the spring of 2021. The recommendation by the SSC in the December 2019 meeting to form an internal review team prior to the CIE was also supported by the Advisory Panel and the Council in the December 2019 meeting. In response to this recommendation an internal review team was constructed to review the GOA Pacific ocean perch assessment. This team met regularly from March of 2020 to August of 2020 and plans to meet regularly again in 2021 prior to the CIE review. As a result of the internal review it was determined that presenting a full assessment this year that includes updates to data and parameter priors would be helpful as an intermediate step to additional model changes that may result from the CIE scheduled in 2021.

Introduction

Biology and distribution

Pacific ocean perch (*Sebastes alutus,* POP) has a wide distribution in the North Pacific from southern California around the Pacific rim to northern Honshu Is., Japan, including the Bering Sea. The species appears to be most abundant in northern British Columbia, the Gulf of Alaska (GOA), and the Aleutian Islands (Allen and Smith 1988). Adults are found primarily offshore on the outer continental shelf and the upper continental slope in depths of 150-420 m. Seasonal differences in depth distribution have been noted by many investigators. In the summer, adults inhabit shallower depths, especially those between 150 and 300 m. In the fall, the fish apparently migrate farther offshore to depths of ~300-420 m. They reside in these deeper depths until about May, when they return to their shallower summer distribution (Love et al. 2002). This seasonal pattern is probably related to summer feeding and winter spawning. Although small numbers of POP are dispersed throughout their preferred depth range on the continental shelf and slope, most of the population occurs in patchy, localized aggregations (Hanselman et al. 2001). POP are generally considered to be semi-demersal but there can at times be a significant pelagic component to their distribution. POP often move off-bottom during the day to feed, apparently following diel euphausiid migrations (Brodeur 2001). Commercial fishing data in the GOA since 1995 show that pelagic trawls fished off-bottom have accounted for as much as 31% of the annual harvest of this species.

There is much uncertainty about the life history of POP, although generally more is known than for other rockfish species (Kendall and Lenarz 1986). The species appears to be viviparous (the eggs develop internally and receive at least some nourishment from the mother), with internal fertilization and the release of live young. Insemination occurs in the fall, and sperm are retained within the female until fertilization takes place ~2 months later. The eggs hatch internally, and parturition (release of larvae) occurs in April-May. Information on early life history is very sparse, especially for the first year of life. POP larvae are thought to be pelagic and drift with the current, and oceanic conditions may sometimes cause advection to suboptimal areas (Ainley et al. 1993) resulting in high recruitment variability. However, larval studies of rockfish have been hindered by difficulties in species identification since many larval rockfish species share the same morphological characteristics (Kendall 2000). Genetic techniques using allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Li 2004) are capable of identifying larvae and juveniles to species, but are expensive and time-consuming. Post-larval and early young-of-the-year POP have been positively identified in offshore, surface waters of the GOA (Gharrett et al. 2002), which suggests this may be the preferred habitat of this life stage. Transformation to a demersal existence may take place within the first year (Carlson and Haight 1976). Small juveniles probably reside inshore in very rocky, high relief areas, and by age 3 begin to migrate to deeper offshore waters of the continental shelf (Carlson and Straty 1981). As they grow, they continue to migrate deeper, eventually reaching the continental slope where they attain adulthood. Adult and juvenile populations are believed to be spatially separated (Carlson and Straty 1981; Rooper et al. 2007).

POP are mostly planktivorous (Carlson and Haight 1976; Yang 1993; 1996; Yang and Nelson 2000; Yang 2003; Yang et al. 2006). In a sample of 600 juvenile perch stomachs, Carlson and Haight (1976) found that juveniles fed on an equal mix of calanoid copepods and euphausiids. Larger juveniles and adults fed primarily on euphausiids, and to a lesser degree, copepods, amphipods and mysids (Yang and Nelson 2000). In the Aleutian Islands, myctophids have increasingly comprised a substantial portion of the POP diet, which also compete for euphausiid prey (Yang 2003). POP and walleye pollock (*Theragra chalcogramma*) probably compete for the same euphausiid prey as euphausiids make up about 50% of the pollock diet (Yang and Nelson 2000). Consequently, the large removals of POP by foreign fishermen in the GOA in the 1960s may have allowed walleye pollock stocks to greatly expand in abundance.

Predators of adult POP are likely sablefish, Pacific halibut, and sperm whales (Major and Shippen 1970). Juveniles are consumed by seabirds (Ainley et al. 1993), other rockfish (Hobson et al. 2001), salmon, lingcod, and other large demersal fish.

POP is a slow growing species, with a low rate of natural mortality (estimated at 0.06), a relatively old age at 50% maturity (8.4 - 10.5 years for females in the GOA), and a very old maximum age of 98 years in Alaska (84 years maximum age in the GOA) (Hanselman et al. 2003). Age at 50% recruitment to the commercial fishery has been estimated to be between 7 and 8 years in the GOA. Despite their viviparous nature, they are relatively fecund with number of eggs/female in Alaska ranging from 10,000-300,000, depending upon size of the fish (Leaman 1991). Rockfish in general were found to be about half as fecund as warm water snappers with similar body shapes (Haldorson and Love 1991).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-compression could be deleterious to a population with highly episodic recruitment like rockfish (Longhurst 2002). Research on black rockfish (*Sebastes melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. de Bruin et al. (2004) examined POP (*S. alutus*) and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for POP or other rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. Spencer et al. (2007) showed that the effects of enhanced larval survival from older mothers decreased estimated F_{msy} (the fishing rate that produces maximum sustainable yield) by 3% to 9%, and larger decreases in stock productivity were associated at higher fishing mortality rates that produced reduced age compositions. Preliminary work at Oregon State University examined POP of adult size by extruding larvae from harvested fish near Kodiak, and found no relationship between spawner age and larval quality (Heppell et al. 2009). However, older spawners However, an updated analysis suggests that larval quality is both a function of spawner age and parturition timing, as older spawners tended to undergo parturition earlier in the spawning season than younger fish (Arnold et al. 2018).

Evidence of stock structure

A few studies have been conducted on the stock structure of POP. Based on allozyme variation, Seeb and Gunderson (1988) concluded that POP are genetically quite similar throughout their range, and genetic exchange may be the result of dispersion at early life stages. In contrast, analysis using mitochondrial DNA techniques indicates that genetically distinct populations of POP exist (Palof 2008). Palof et al. (2011) report that there is low, but significant genetic divergence (FST = 0.0123) and there is a significant isolation by distance pattern. They also suggest that there is a population break near the Yakutat area from conducting a principle component analysis. Withler et al. (2001) found distinct genetic populations on a small scale in British Columbia. Kamin et al. (2013) examined genetic stock structure of young of the year POP. The geographic genetic pattern they found was nearly identical to that observed in the adults by Palof et al. (2011).

In a study on localized depletion of Alaskan rockfish, Hanselman et al. (2007) showed that POP are sometimes highly depleted in areas 5,000-10,000 km^2 in size, but a similar amount of fish return in the following year. This result suggests that there is enough movement on an annual basis to prevent serial depletion and deleterious effects on stock structure.

In 2012, the POP assessment presented the completed stock structure template that summarized the body of knowledge on stock structure and spatial management (Hanselman et al. 2012).

Fishery

Historical Background

A POP trawl fishery by the U.S.S.R. and Japan began in the GOA in the early 1960s. This fishery developed rapidly, with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965, when a total of nearly 350,000 metric tons (t) was caught. This apparent overfishing resulted in a precipitous decline in catches in the late 1960s. Catches continued to decline in the 1970s, and by 1978 catches were only 8,000 t (Figure 9-1). Foreign fishing dominated the fishery from 1977 to 1984, and catches generally declined during this period. Most of the catch was taken by Japan (Carlson et al. 1986). Catches reached a minimum in 1985, after foreign trawling in the GOA was prohibited.

The domestic fishery first became important in 1985 and expanded each year until 1991 (Figure 9-1). Much of the expansion of the domestic fishery was apparently related to increasing annual quotas; quotas increased from 3,702 t in 1986 to 20,000 t in 1989. In the years 1991-95, overall catches of slope rockfish diminished as a result of the more restrictive management policies enacted during this period. The restrictions included: (1) establishment of the management subgroups, which limited harvest of the more desired species; (2) reduction of total allowable catch (TAC) to promote rebuilding of POP stocks; and (3) conservative in-season management practices in which fisheries were sometimes closed even though substantial unharvested TAC remained. These closures were necessary because, given the large fishing power of the rockfish trawl fleet, there was substantial risk of exceeding the TAC if the fishery were to remain open. Since 1996, catches of POP have increased again, as good recruitment and increasing biomass for this species have resulted in larger TAC's. In recent years, the TAC's for POP have usually been fully taken (or nearly so) in each management area except Southeast Outside. (The prohibition of trawling in Southeast Outside during these years has resulted in almost no catch of POP in this area). In 2013, approximately 21% of the TAC was taken in the Western GOA. NMFS did not open directed fishing for POP in this area because the catch potential from the expected effort (15 catcher/processors) for a one day fishery (shortest allowed) exceeded the available TAC. The 2014 fishery in this area didn't occur until October but nearly all of the TAC was harvested. Because of agreement among the fleet and the ability to collectively remain below TAC, we expect TAC to be fully taken in the future.

Detailed catch information for POP in the years since 1977 is listed in Table 9-1. The reader is cautioned that actual catches of POP in the commercial fishery are only shown for 1988-2019; for previous years, the catches listed are for the POP complex (a former management grouping consisting of POP and four other rockfish species), POP alone, or all *Sebastes* rockfish, depending upon the year (see Footnote in Table 9-1). POP make up the majority of catches from this complex. The acceptable biological catches and quotas in Table 9-1 are Gulf-wide values, but in actual practice the NPFMC has divided these into separate, annual apportionments for each of the three regulatory areas of the GOA.

Historically, bottom trawls have accounted for nearly all the commercial harvest of POP. In recent years, however, the portion of the POP catch taken by pelagic trawls has increased. The percentage of the POP Gulf-wide catch taken in pelagic trawls increased from an average of 7% during 1990-2005 to an average of 24% and up to 31% after 2006.

Before 1996, most of the POP trawl catch (>90%) was taken by large factory-trawlers that processed the fish at sea. A significant change occurred in 1996, however, when smaller shore-based trawlers began taking a sizeable portion of the catch in the Central area for delivery to processing plants in Kodiak. These vessels averaged about 50% of the catch in the Central Gulf area since 1998. By 2008, catcher vessels were taking 60% of the catch in the Central Gulf area and 35% in the West Yakutat area. Factory trawlers continue to take nearly all the catch in the Western Gulf area.

In 2007, the Central GOA Rockfish Program was implemented to enhance resource conservation and improve economic efficiency for harvesters and processors who participate in the Central GOA rockfish fishery. This rationalization program establishes cooperatives among trawl vessels and processors which receive exclusive harvest privileges for rockfish management groups. The primary rockfish management groups are northern rockfish, POP, and pelagic shelf rockfish.

Management measures/units

In 1991, the NPFMC divided the slope assemblage in the GOA into three management subgroups: POP, shortraker/rougheye rockfish, and all other species of slope rockfish. In 1993, a fourth management subgroup, northern rockfish, was also created. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups. These subgroups were established to protect POP, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC (acceptable biological catch) and TAC (total allowable catch), whereas prior to 1991, an ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the GOA (Western, Central, and Eastern) based on distribution of survey biomass.

Amendment 32, which took effect in 1994, established a rebuilding plan for POP. The amendment stated that "*stocks will be considered to be rebuilt when the total biomass of mature females is equal to or greater than* B_{MSY}" (Federal Register: April 15, 1994, http://alaskafisheries.noaa.gov/prules/noa_18103.pdf). Prior to Amendment 32, overfishing levels had been defined GOA-wide. Under Amendment 32, "*the overfishing level would be distributed among the eastern, central, and western areas in the same proportions as POP biomass occurs in those areas. This measure would avoid localized depletion of POP and would rebuild POP at equal rates in all regulatory areas of the GOA.*" This measure established management area OFLs for POP.

Amendment 41, which took effect in 2000, prohibited trawling in the Eastern area east of 140 degrees W. longitude. Since most slope rockfish, especially POP, are caught exclusively with trawl gear, this amendment could have concentrated fishing effort for slope rockfish in the Eastern area in the relatively small area between 140 degrees and 147 degrees W. longitude that remained open to trawling. To ensure that such a geographic over-concentration of harvest would not occur, since 1999 the NPFMC has divided the Eastern area into two smaller management areas: West Yakutat (area between 147 and 140 degrees W. longitude) and East Yakutat/Southeast Outside (area east of 140 degrees W. longitude). Separate ABC's and TAC's are now assigned to each of these smaller areas for POP, while separate OFLs have remained for the Western, Central, and Eastern GOA management areas.

In November, 2006, NMFS issued a final rule to implement Amendment 68 of the GOA groundfish Fishery Management Plan for 2007 through 2011. This action implemented the Central GOA Rockfish Program (formerly the Rockfish Pilot Program or RPP). The intention of this program is to enhance resource conservation and improve economic efficiency for harvesters and processors in the rockfish fishery. This should spread out the fishery in time and space, allowing for better prices for product and reducing the pressure of what was an approximately two week fishery in July. The authors will pay close attention to the benefits and consequences of this action.

Since the original establishment of separate OFLs by management areas for POP in the rebuilding plan (Amendment 32) in 1994, the spawning stock biomass has tripled. The rebuilding plan required that female spawning biomass be greater than B_{msy} and the stock is now 53% higher than B_{msy} (using $B_{40\%}$ as a proxy for B_{msy}). Management has prosecuted harvest accurately within major management areas using ABC apportionments. While evidence of stock structure exists in the GOA, it does appear to be along an isolation by distance cline, not sympatric groups (Palof et al. 2011; Kamin et al. 2013). Palof et al. (2011) also suggest that the Eastern GOA might be distinct genetically, but this area is already its own management unit, and has additional protection with the no trawl zone. Hanselman et al. (2007) showed that POP are reasonably resilient to serial localized depletions (areas replenish on an annual basis). The NPFMC stock structure template was completed for GOA POP in 2012 (Hanselman et al. 2012). Recommendations from this exercise were to continue to allocate ABCs by management area or smaller. However, the original rationale for area-specific OFLs from the rebuilding plan no longer exists because the overall population is above target levels and is less vulnerable to occasional overages. Therefore, in terms of rebuilding the stock, management area OFLs are no longer a necessity for the GOA POP stock.

Management measures since the break out of POP from slope rockfish are summarized in Table 9-2.

Bycatch and discards

Gulf-wide discard rates (% discarded, current as of October 23, 2019) for POP in the commercial fishery for 2000-2019 are listed as follows:

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Discard	11.3	8.6	7.3	15.1	8.2	5.7	7.8	3.7	4.1	6.8	4.1

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
% Discard	6.6	4.8	7.6	9.5	3.8	6.8	14.8	4.7	7.4	4.1

Total FMP groundfish catch estimates in the GOA rockfish targeted fisheries from 2013-2019 are shown in Table 9-3. For the GOA rockfish fishery during 2013-2019, the largest non-rockfish bycatch groups are arrowtooth flounder, Atka mackerel, walleye pollock, Pacific cod, and sablefish. Catch of POP in other GOA fisheries is mainly in arrowtooth flounder, walleye pollock-midwater, and rex sole targeted fishing (Table 9-4). Non-FMP species catch in the rockfish target fisheries is dominated by giant grenadier and miscellaneous fish (Table 9-5). The increase in POP discards in 2017 can likely be attributed to an extremely high bycatch of POP in the arrowtooth flounder directed fishery (Table 9-4). Hulson et al. (2014) compared bycatch for the combined rockfish fisheries in the Central GOA from before and during the Rockfish Program to determine the impacts of the Rockfish Program and found the bycatch of the majority of FMP groundfish species in the Central GOA was reduced following implementation of the Rockfish Program.

Prohibited species catch in the GOA rockfish fishery is generally low (Table 9-6). Catch of prohibited and non-target species generally decreased with implementation of the Central GOA Rockfish Program (Hulson et al. 2014). Catch of prohibited species generally increased modestly in 2020 compared to 2019, with the exception of golden king crab and halibut, where catches decreased (Table 9-6).

Data

The following table summarizes the data used for this assessment (bold font denotes new data to this year's assessment):

Source	Data	Years
NMFS Groundfish survey	Survey biomass	1990-1999 (triennial), 2001-2019 (biennial)
	Age Composition	1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, **2019**
U.S. trawl fisheries	Catch	1961-**2020**
	Age Composition	1990,1998-2002, 2004, 2005, 2006, 2008, 2010, 2012, 2014, 2016, 2018
	Length Composition	1963-1977, 1991-1997

Fishery

Catches range from 2,500 t to 350,000 t from 1961 to 2019. Detailed catch information for POP is listed in Table 9-1 and shown graphically in Figure 9-1. This is the commercial catch history used in the assessment model. In response to Annual Catch Limits (ACLs) requirements, assessments now document all removals including catch that is not associated with a directed fishery. Estimates of all removals not associated with a directed fishery including research catches are available and are presented in Appendix 9-A. In summary, annual research removals have typically been less than 100 t and very little is taken in recreational or halibut fisheries. These levels likely do not pose a significant risk to the POP stock in the GOA.

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age composition of the commercial catch of POP. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Table 9-7 summarizes the length compositions from 2011-2020 (the most recent 10 years), Table 9-8 summarizes age compositions for the fishery, and Figures 9-2 and 9-3 show the distributions graphically for fishery age and length composition data fit by the assessment. The age compositions for the fishery prior to 2004 show strong 1986 and 1987 year classes. After 2004 the fishery age composition data show the presence of several relatively strong year classes including the 1993, 1994, and 1998 year classes. The 2018 fishery age composition data indicates that the 2008 year class may also be relatively strong. Each of these year classes, with the exception of the 1993 and 1994 year classes, have also been identified in the trawl survey age composition data.

Fishery length composition is available from the early 1960s to present (Figure 9-3 and Table 9-7). Due to the availability of age data from both the fishery and trawl survey we do not use the recent fishery length composition, but rather use the fishery length composition data shown in Figure 9-3. Fishery length composition data prior to the mid-1970s indicates that the mean length of POP was smaller than after the mid-1970s. We hypothesize that rather than year classes moving into the population in these years (and thus reducing the mean length) that there were differences in growth, thus, we use a difference size age transition matrix in these years (as described in the *Parameters Estimated Outside the Assessment Model* section below). In general, because of the selectivity of the fishery at older ages, there is not strong recruitment signal in the fishery length composition data.

Survey

Bottom trawl surveys were conducted on a triennial basis in the GOA in 1990, 1993, 1996, and a biennial survey schedule has been used since the 1999 survey. The surveys provide much information on POP, including an abundance index, age composition, and growth characteristics. The surveys are theoretically an estimate of absolute biomass, but we treat them as an index in the stock assessment. The surveys covered all areas of the GOA out to a depth of 500 m (in some surveys to 1,000 m), but the 2001 survey did not sample the eastern GOA. Summaries of biomass estimates from 1990 to 2019 surveys are provided in Table 9-9.

Regional and Gulf-wide biomass estimates (with corresponding coefficient of variation in total biomass) for POP are shown in Table 9-9. Gulf-wide biomass estimates for 1990-2019 and 95% confidence intervals are shown in Figure 9-4. Biomass estimates of POP were relatively low in 1990, increased markedly in both 1993 and 1996, and remained around the 1996 value in 1999 and 2001 (Table 9-9 and Figure 9-4). These surveys were characterized with relatively larger uncertainty with coefficients of variation (CV) greater than 20% (reaching a maximum in 1999 of 53%). Large catches of an aggregated species like POP in just a few individual hauls can greatly influence biomass estimates and are a source of much variability. Biomass estimates of POP decreased in 2003, then increased in 2005 and remained relatively stable until 2011, indicating that the biomass in 2003 may have been anomalously small. In 2013 biomass estimates increased markedly and have remained above one million tons since. The largest biomass estimate of the time series occurred in 2017, and has decreased in 2019. Since the 2003 survey biomass estimates of POP have been associated with relatively small uncertainty, with CVs below 20% in all but one year (2017, with a CV of 22%). This reduced uncertainty is because POP continue to be more uniformly distributed than in the past, as indicated by increasing proportion of tows that catch POP in the survey as well as declining uncertainty in the trawl survey biomass (Figure 9-5).

The 2019 biomass estimate is the third largest on record with a CV of only 14% (the smallest in the time series) and is 22% smaller than the 2017 biomass estimate. This decrease in biomass resulted in all areas of the Gulf, most notably in the Western Gulf (Table 9-9). The general distribution of catches in the 2019 survey were comparable to 2015 and 2017 in the Central and Eastern Gulf, although the large catches that occurred in 2015 and 2017 did not occur in 2019 (Figure 9-5). The most notable difference in POP catch distribution in 2019 compared to 2017 and 2015 is in the Western Gulf.

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1990-2019 surveys showed that although the fish ranged in age up to 84 years, most of the population was relatively young; mean survey age has increased from 9.2 years in 1990 to 15.6 years in 2017 (Table 9-10). The first four surveys identified relatively strong year classes in the mid-1980s (1984-1988) and also showed a period of very weak year classes during the 1970s to mid-19080s (Figure 9-6). The weak year classes through this period of time may have delayed recovery of POP populations after they were depleted by the foreign fishery. Since the 1999 survey the age compositions have indicated several stronger than average year classes. Starting with the 2003 and through the 2009 survey the age composition data indicated relatively strong year classes in 1998, 2000, and 2002. Since the 2009 survey the age composition data has distinguished relatively strong year classes in 2006, 2008, and 2010. The 2017 survey age composition indicates that the 2007 year class could also be relatively strong and the plus age group of 25 and older has increased to 0.15 (from an average of 0.04 prior to 2011). The 2019 survey age composition indicates the possible emergence of a strong 2016 year class. These relatively strong year classes since 1998 may be contributing to the increase in survey biomass observed since 2013.

Gulf-wide population size compositions for POP are shown in Figure 9-7. These size composition data identify several year classes that have moved through the population since 2001. The 2001 and 2009 survey length compositions indicated relatively strong year classes in 1998 and 2006 (which were ~17-21 cm in these surveys). The 2006 year class was again relatively strong in the 2011 data (which would have been ~24-28 cm) and both the 1998 and 2006 year classes were corroborated with the survey age composition data. The most recent length composition from the 2019 survey also indicates a mode at ~17-21 cm (age-3), which would be the 2016 year class. Survey size data are used in constructing the age-length transition matrix, but not used as data to be fitted in the stock assessment model.

Other times-series data

Acoustic-trawl (AT) surveys designed to evaluate walleye pollock abundance in the Gulf of Alaska have been conducted by the Alaska Fisheries Science Center (AFSC) in summer months (June – August) on odd years from 2013 to 2019 aboard the NOAA ship *Oscar Dyson* (Jones et al. 2014, Jones et al. 2017, Jones et al. 2019, Jones et al. in prep.). POP are routinely encountered during these surveys and abundance estimates for POP are available for the surveyed area. The surveys cover the Gulf of Alaska continental shelf and shelf break from depths of 50 to 1000 m, including associated bays and troughs, and extend from the continental shelf south of the Islands of Four Mountains in the Aleutian Islands eastward to Yakutat Bay. The surveys consist of widely-spaced (25 nmi) parallel transects along the shelf, and more closely spaced transects (1-15 nmi) in troughs, bays, and Shelikof Strait. Mid-water and bottom trawls are used to identify species and size of acoustic targets.

Surveys prior to 2019 used a single length distribution of POP caught in combined hauls to scale the acoustic data to abundance and biomass. Starting in 2019, the length distribution from the haul nearest to the acoustic signal was used for scaling. A generalized physoclist target strength (TS) to length (L) relationship ($TS = 20\text{Log}_{10}(L)-67.5$; Foote 1987) was used to scale acoustic signal to length. More specific computational details of the AT methods for abundance estimation can be found in Jones et al. 2019.

The summer Gulf AT survey data is not currently used in the assessment model, but biomass estimates are available since the 2013 survey. We will begin to report these estimates in the POP SAFE as current research is exploring the potential for including this information into the assessment model. Over 98% of the POP observed in 2019 were on transects that extend across the shelf and shelf-break, predominantly east of Kodiak Island (Figure 9-8). The AT biomass estimate for POP in 2019 is 140,688 t and is 18% lower than the 2017 estimate, which is consistent with the decrease seen in bottom trawl survey biomass estimates.

Analytic Approach

General Model Structure

We present results for POP based on an age-structured model using AD Model Builder software (Fournier et al. 2012). Prior to 2001, the stock assessment was based on an age-structured model using stock synthesis (Methot 1990). The assessment model used for POP is based on a generic rockfish model described in Courtney et al. (2007). The population dynamics, with parameter descriptions and notation are shown in Table 9-11. The formulae to estimate the observed data by the POP assessment is shown in Table 9-12. Finally, the likelihood and penalty functions used to optimize the POP assessment are shown in Table 9-13.

Since its initial adaptation in 2001, the models' attributes have been explored and changes have been made to the template to adapt to POP and other species. The following changes have been adopted within the POP assessment since the initial model in 2001:

- 2003: Size to age matrix added for the 1960s and 1970s to adjust for density-dependent growth, natural mortality and bottom trawl survey catchability estimated within model
- 2009: Fishery selectivity estimated for three time periods describing the transition from a foreign to domestic fishery, MCMC projections used with a pre-specified proportion of ABC for annual catch
- 2014: Maturity at age estimated conditionally with addition of new maturity data
- 2015: Extended ageing error matrix adopted to improve fit to plus age group and adjacent age classes
- 2017: Length bins for fishery length composition data set at 1cm, removed 1984 and 1987 trawl survey data, time block added to fishery selectivity starting in 2007 to coincide with the Central GOA rockfish program

Description of Alternative Models

The structure of this year's model is identical in all aspects to the model accepted in 2019. The changes we recommend in this year's model are to update ageing error input data, construct fishery age composition data in a more appropriate manner prior to model fitting, and updating natural mortality and bottom trawl survey catchability parameter priors with values from field studies and published literature. We recommend the following four changes in this year's model compared to the model accepted in 2019:

1. Update the reader-tester agreement data used to construct the ageing error matrix with new otolith readings, model 2017.1a
2. Construct the fishery age composition data with an age-length key, model 2017.1b
3. Change the prior on the bottom trawl survey catchability parameter from 1 to 1.15, model 2017.1c
4. Change the prior on the parameter for natural mortality from 0.05 to 0.0614, model 2017.1d

In model 2017.1a we update the reader and tester agreement data up through 2009 (as used in last year's assessment) with data through 2019. In model 2017.1b we construct an annual age-length key to estimate the fishery age compositions, which is common practice in several assessments at AFSC (e.g., Dorn et al. 2019, Spencer and Ianelli 2018). In the past, fishery age compositions have been computed using the age samples only; we feel this improves the information content within the fishery age composition by leveraging information contained within the length frequencies samples in addition to the age data. In model 2017.1c we update the prior for the bottom trawl survey catchability from 1 to 1.15, this is in response to recent field studies (Jones et al. in review) that have provided an estimate of bottom trawl survey catchability based on distributional differences for Pacific ocean perch between trawlable and untrawlable grounds. In response to recent Plan Team and SSC comments, we update the prior for the natural mortality in model 2017.1d from 0.05 to 0.0614 following the meta-analytical approach adopted by the NW Fishery Science Center (Hamel 2015, Then et al. 2015) of 5.40/maximum age, reported to three significant digits. For simplicity in tracking model changes over time, we name the current year's recommended model that integrates all of these changes 2020.1. In the results section below we present the results from the 2019 model with each change individually, as well as the results from the recommended model 2020.1.

Parameters Estimated Outside the Assessment Model

Growth of POP is estimated using length-stratified methods to estimate mean length and weight at age from the bottom trawl survey that are then modeled with the von Bertlanffy growth curve (Hulson et al. 2015). Two size to age transition models are employed in the POP assessment, the first for data from the 1960s and 1970s, the second for data after the 1980s. The additional size to age transition matrix is used to represent a lower density-dependent growth rate in the 1960s and 1970s (Hanselman et al. 2003). The von Bertlanffy parameters used for the 1960s and 1970s size to age transition matrix are:

$L_\infty = 41.6$ cm $\kappa = 0.15$ $t_0 = -1.08$

The von Bertlanffy parameters used for the post 1980s size to age transition matrix are:

$L_\infty = 41.1$ cm $\kappa = 0.18$ $t_0 = -0.49$

The size to age conversion matrices are constructed by adding normal error with a standard deviation equal to the bottom trawl survey data for the probability of different ages for each size class. This is estimated with a linear relationship between the standard deviation in length with age. The linear parameters used for the 1960s and 1970s size to age transition matrix are (*a*-intercept, *b*-slope):

$a = 0.42$ $b = 1.38$

The linear parameters used for the post 1980s size to age transition matrix are (*a*-intercept, *b*-slope):

$a = -0.01$ $b = 2.16$

Weight-at-age was estimated with weight at age data from the same data set as the length at age. The estimated growth parameters are shown below. A correction of $(W_\infty - W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

$W_\infty = 901$ g $\kappa = 0.20$ $t_0 = -0.37$ $\beta = 3.04$

Growth parameters are updated for each assessment with the addition of new age, length, and weight data from the trawl survey. The average percent change in spawning biomass estimated from the current assessment with 2019 growth parameters compared to using the updated growth information above was less than 0.5%.

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age based on percent agreement tests conducted at the AFSC Age and Growth lab. In 2015 an extended ageing error matrix was implemented into the POP assessment in order to improve the fit to the plus age group and adjacent age classes (Hulson et al. 2015). For a data plus age group of 25, the resulting model plus age group was 29 so that 99.9% of the fish greater than age 29 were within the 25 plus age group of the data.

Parameters Estimated Inside the Assessment Model

Natural mortality (*M*), catchability (*q*) and recruitment deviations (σ_r) are estimated with the use of prior distributions as penalties. The prior mean for *M* is based on a catch curve analysis to determine total mortality, *Z*. Estimates of *Z* could be considered as an upper bound for *M*. Estimates of *Z* for POP from Archibald et al. (1981) were from populations considered to be lightly exploited and thus are considered reasonable estimates of *M*, yielding a value of ~0.05. Natural mortality is a notoriously difficult parameter to estimate within the model so we assign a relatively precise prior CV of 10%. Catchability is a parameter that is somewhat unknown for rockfish, so while we assign it a prior mean of 1 (assuming all fish in the area swept are captured and there is no herding of fish from outside the area swept, and that there is no effect of untrawlable grounds), we assign it a less precise CV of 45%. This allows the parameter more freedom than that allowed to natural mortality. Recruitment deviation is the amount of variability that the model allows for recruitment estimates. Rockfish are thought to have highly variable recruitment, so we assign a high prior mean to this parameter of 1.7 with a CV of 20%.

Fishery selectivity is estimated within four time periods that coincide with the transition from a foreign to domestic fishery. These time periods are:

1) 1961-1976: This period represented the massive catches and overexploitation by the foreign fisheries which slowed considerably by 1976. We do not have age data from this period to examine, but we can assume the near pristine age-structure was much older than now, and that at the high rate of exploitation, all vulnerable age-classes were being harvested. For these reasons we chose to only consider asymptotic (logistic) selectivity.
2) 1977-1995: This period represents the change-over from the foreign fleet to a domestic fleet, but was still dominated by large factory trawlers, which generally would tow deeper and further from port.
3) 1996-2006: During this period we have noted the emergence of smaller catcher-boats, semi-pelagic trawling and fishing cooperatives. The length of the fishing season has also been recently greatly expanded.
4) 2007-Present: This period coincides with the start of the Rockfish Program in the Central Gulf, a fishing cooperative that has influenced the behavior and composition (catcher versus factory trawlers) of the fishery.

Fishery selectivity across these time periods transitions from an asymptotic selectivity from 1961-1976 into dome-shaped fishery selectivity after 1977. We fitted a logistic curve for the first block, an averaged logistic-gamma in the 2nd block, and a gamma function for the 3rd and 4th blocks. Bottom trawl survey selectivity is estimated to be asymptotic with the logistic curve.

Maturity-at-age is modeled with the logistic function conditionally within the assessment following the method presented in Hulson et al. (2011). Parameter estimates for maturity-at-age are obtained by fitting two datasets collected on female POP maturity from Lunsford (1999) and Conrath and Knoth (2013). Parameters for the logistic function describing maturity-at-age are estimated conditionally in the model so that uncertainty in model results (e.g., ABC) can be linked to uncertainty in maturity parameter estimates.

Other parameters estimated conditionally include, but are not limited to: mean recruitment, fishing mortality, and spawners per recruit levels. The numbers of estimated parameters for the recommended model are shown below. Other derived parameters are described in Tables 9-11 and 9-12.

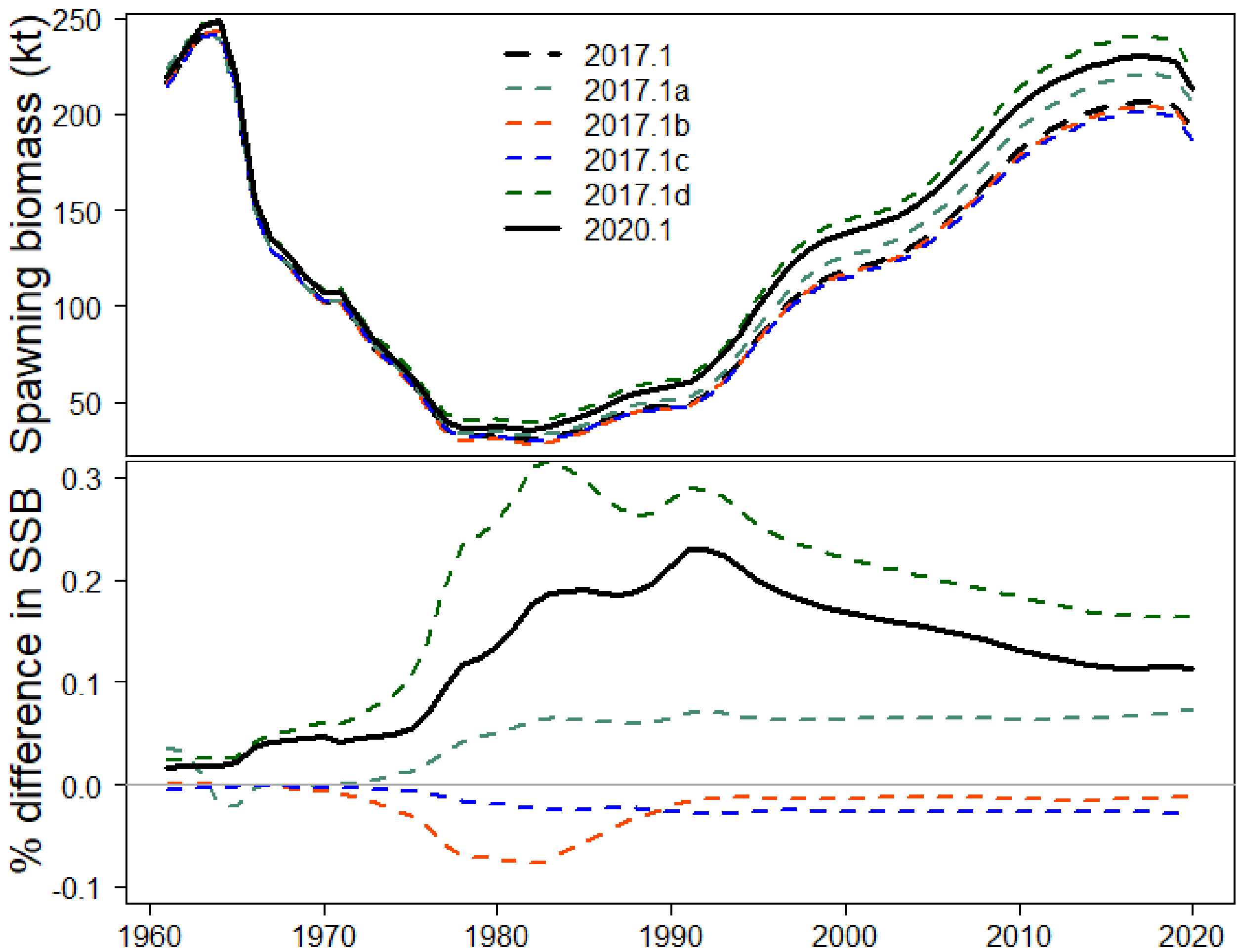
Parameter name	Symbol	Number
Natural mortality	M	1
Catchability	q	1
Log-mean-recruitment	μ_r	1
Recruitment variability	σ_r	1
Spawners-per-recruit levels	$F_{35\%}, F_{40\%}, F_{100\%}$	3
Recruitment deviations	ε_y^r	86
Average fishing mortality	μ_f	1
Fishing mortality deviations	ε_y^f	60
Fishery selectivity coefficients	s_a^f	6
Survey selectivity coefficients	s_a^t	2
Maturity-at-age coefficients	$\widehat{m}_a$	2
Total		164

Evaluation of model uncertainty is obtained through a Markov Chain Monte Carlo (MCMC) algorithm (Gelman et al. 1995). The chain length of the MCMC was 10,000,000 and was thinned to one iteration out of every 2,000. We omit the first 1,000,000 iterations to allow for a burn-in period. We use these MCMC methods to provide further evaluation of uncertainty in the results below including 95% credible intervals for some parameters (computed as the 5th and 95th percentiles of the MCMC samples).

Results

Model Evaluation

The model used in this assessment is the same as the model accepted in 2019 with updated data and parameter priors. When we present alternative model configurations, our usual criteria for choosing a superior model are: (1) the best overall fit to the data (in terms of negative log-likelihood), (2) biologically reasonable patterns of estimated recruitment, catchabilities, and selectivities, (3) a good visual fit to length and age compositions, and (4) parsimony. Because the changes for the current assessment involve updating data and parameter priors we do not perform the usual model comparison. However, the figure below shows the influence on model estimates of spawning biomass and the percent difference in spawning biomass (compared to model 2017.1) for each of model scenarios 2017.1 (last year's assessment model with updated data), 2017.1a-d (described above), and 2020.1 (which integrates all the changes made in scenarios 2017.1a-d).



The largest differences among model 2017.1 and scenarios 2017.1a-d are between 2017.1 and 2017.1a and 2017.1d. These differences are reflective of the updating of the ageing error matrix and its influence on recruitment estimates and the updating of the natural mortality parameter prior, which increases the model's estimate of natural mortality. When all the updates are integrated in model 2020.1 the model estimates an increase in spawning biomass in comparison to model scenario 2017.1.

Model 2020.1 generally results in reasonable fits to the data, estimates biologically plausible parameters, and produces consistent patterns in abundance compared to previous assessments. The assessment model continues to underestimate the trawl biomass since the 2013 survey, although, the retrospective pattern indicates that the model fit is continuing to improve to the trawl survey with additional assessments. Overall, model 2020.1 yields reasonable results and we use it to recommend the 2021 ABC and OFL.

Time Series Results

Key results have been summarized in Tables 9-14 to 9-18. Model predictions generally fit the data well (Figures 9-1, 9-2, 9-3, 9-4, and 9-6) and most parameter estimates and likelihood functions have remained similar to the last several years using this model (Table 9-14).

Definitions

Spawning biomass is the biomass estimate of mature females. Total biomass is the biomass estimate of all POP age two and greater. Recruitment is measured as the number of age two POP. Fishing mortality is the mortality at the age the fishery has fully selected the fish.

Biomass and exploitation trends

Estimated total biomass gradually increased from a low near 85,000 t in 1980 to over 596,000 t at the peak in 2015 (Figure 9-9). MCMC credible intervals indicate that the historic low is reasonably certain while recent increases are not quite as certain. These intervals also suggest that current biomass is likely between 418,000 and 969,000 t. Spawning biomass shows a similar trend (Figure 9-9). These estimates show a rapid increase since 1992, which coincides with an increase in uncertainty. The recent estimates of spawning biomass are nearly at historical levels prior to the 1970s. Age of 50% selection is 5 to 6 for the survey and between 7 and 9 years for the fishery (Figure 9-10). Fish are fully selected by both fishery and survey between 10 and 15. Current fishery selectivity is dome-shaped and with the addition of the recent time block after 2007 matches well with the ages caught by the fishery. Catchability is smaller (1.8) than that estimated in 2019 (2.01). The high catchability for POP is supported by several empirical studies using line transect densities counted from a submersible compared to trawl survey densities (Krieger 1993 [q=2.1], Krieger and Sigler 1996 [q=1.3], Jones et al. *In Review* [q=1.15]). Compared to the last full assessment, spawning biomass and age-6+ total biomass has increased in response to fitting the large trawl survey biomass estimates since 2013 (Table 9-15).

Fully-selected fishing mortality shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 9-11). Goodman et al. (2002) suggested that stock assessment authors use a “management path” graph as a way to evaluate management and assessment performance over time. We chose to plot a phase plane plot of fishing mortality to F_{OFL} ($F_{35\%}$) and the estimated spawning biomass relative to unfished spawning biomass ($B_{100\%}$). Harvest control rules based on $F_{35\%}$ and $F_{40\%}$ and the tier 3b adjustment are provided for reference. The management path for POP has been above the $F_{35\%}$ adjusted limit for most of the historical time series (Figure 9-12). In addition, since 2004, POP SSB has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$ since 1983.

Recruitment

Recruitment (as measured by age 2 fish) for POP is highly variable and large recruitments comprise much of the biomass for future years (Figure 9-13). Recruitment has increased since the early 1970s, starting with the 1986 year class. Since the 1990s there have been several larger than average year classes, with the largest resulting in 2006. The largest differences in estimated recruitment between the current assessment and the 2019 assessment resulted at the end of the time series (Table 9-15 and Figures 9-13 and 9-14), which should not be unexpected given the influence of additional age composition data on recent recruitment estimates. The addition of new survey age data and the large 2013-2019 survey biomass suggests that the 2006-2009, 2010, 2012, and 2016 year classes may be above average (Figure 9-14). However, these recent recruitments are still highly uncertain as indicated by the MCMC credible intervals in Figure 9-13. POP do not seem to exhibit much of a stock-recruitment relationship because large recruitments have occurred during periods of high and low biomass (Figure 9-13).

Uncertainty results

From the MCMC chains described in *Uncertainty approach*, we summarize the posterior densities of key parameters for the recommended model using histograms (Figure 9-15) and credible intervals (Table 9-16 and 9-17). We also use these posterior distributions to show uncertainty around time series estimates of survey biomass (Figure 9-4), total and spawning biomass (Figure 9-9), fully selected fishing mortality (Figure 9-11) and recruitment (Figure 9-13).

Table 9-16 shows the maximum likelihood estimate (MLE) of key parameters with their corresponding standard deviation derived from the Hessian matrix. Also shown are the MCMC, mean, median, standard deviation and the corresponding Bayesian 95% credible intervals (BCI). The Hessian and MCMC standard deviations are similar for *q, M,* and $F_{40\%}$, but the MCMC standard deviations are larger for the estimates of female spawning biomass and ABC. These larger standard deviations indicate that these parameters are more uncertain than indicated by the Hessian approximation. The distributions of these parameters with the exception of natural mortality are slightly skewed with higher means than medians for current spawning biomass and ABC, indicating possibilities of higher biomass estimates (Figure 9-15). Uncertainty estimates in the time series of spawning biomass also result in a skewed distribution towards higher values, particularly at the end of the time series and into the 15 year projected times series (Figure 9-16).

Retrospective analysis

A within-model retrospective analysis of the recommended model was conducted for the last 10 years of the time-series by dropping data one year at a time. The revised Mohn's "rho" statistic (Hanselman et al. 2013) in female spawning biomass was -0.15 (better than the 2019 value of -0.27), indicating that the model increases the estimate of female spawning biomass in recent years as data is added to the assessment. The retrospective female spawning biomass and the relative difference in female spawning biomass from the model in the terminal year are shown in Figure 9-17 (with 95% credible intervals from MCMC). In general the relative difference in female spawning biomass early in the time series is low, in recent years the increases in spawning biomass have been up to 30% compared to the terminal year. This result is not unexpected as given the large trawl survey biomass estimates since 2013; the model is responding to this data by increasing the estimates of biomass in each subsequent year.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, POP in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$,,equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age-2 recruitments between 1979 and 2018 (i.e., the 1977 – 2016 year classes). Because of uncertainty in very recent recruitment estimates, we lag 2 years behind model estimates in our projection. Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2020 estimates of these reference points are:

$B_{100\%}$	317,035
$B_{40\%}$	126,814
$B_{35\%}$	110,962

$F_{40\%}$	0.10
$F_{35\%}$	0.12

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2021 is estimated at 207,096 t. This is above the $B_{40\%}$ value of 126,814 t. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2021, yields the following ABC and OFL:

$F_{40\%}$	0.10
ABC	36,177
$F_{35\%}$	0.12
OFL	**42,977**

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

For each scenario, the projections begin with the vector of 2020 numbers at age as estimated in the assessment (Table 9-18). This vector is then projected forward to the beginning of 2021 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2020. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch after 2020 is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1,000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

In response to GOA Plan Team minutes in 2010, we have established a consistent methodology for estimating current-year and future year catches in order to provide more accurate two-year projections of ABC and OFL to management. In the past, two standard approaches in rockfish models have been employed; assume the full TAC will be taken, or use a certain date prior to publication of assessments as a final estimate of catch for that year. Both methods have disadvantages. If the author assumes the full TAC is taken every year, but it rarely is, the ABC will consistently be underestimated. Conversely, if the author assumes that the catch taken by around October is the final catch, and substantial catch is taken thereafter, ABC will consistently be overestimated. Therefore, going forward in the GOA rockfish assessments, for current year catch, we are applying an expansion factor to the official catch on or near October 1 by the 3-year average of catch taken between October 1 and December 31 in the last three complete catch years (e.g. 2017-2019 for this year). For POP, the expansion factor for 2020 catch is 1.12.

For catch projections into the next two years, we are using the ratio of the last three official catches to the last three TACs multiplied against the future two years' ABCs (if TAC is normally the same as ABC). This method results in slightly higher ABCs in each of the future two years of the projection, based on both the lower catch in the first year out, and based on the amount of catch taken before spawning in the projection two years out. To estimate future catches, we updated the yield ratio (0.91), which was the average of the ratio of catch to ABC for the last three complete catch years (2017-2019). This yield ratio was multiplied by the projected ABCs for 2021 and 2022 from the assessment model to generate catches for those years.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2021, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)
>
> *Scenario 2*: In 2021 and 2022, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the realized catches in 2017-2019 to the ABC recommended in the assessment for each of those years. For the remainder of the future years, maximum permissible ABC is used. (Rationale: In many fisheries the ABC is routinely not fully utilized, so assuming an average ratio catch to ABC will yield more realistic projections.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2015-2019 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)
>
> *Scenario 5*: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above 1) above its MSY level in 2020 or 2) above ½ of its MSY level in 2020 and above its MSY level in 2030 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2020 and 2021, F is set equal to *max* F_{ABC}, and in all subsequent years F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is 1) above its MSY level in 2022 or 2) above 1/2 of its MSY level in 2022 and expected to be above its MSY level in 2032 under this scenario, then the stock is not approaching an overfished condition.)

Spawning biomass, fishing mortality, and yield are tabulated for the seven standard projection scenarios (Table 9-19). The difference for this assessment for projections is in Scenario 2 (Author's F); we use pre-specified catches to increase accuracy of short-term projections in fisheries (such as POP) where the catch is usually less than the ABC. This was suggested to help management with setting preliminary ABCs and OFLs for two year ahead specifications. The methodology for determining these pre-specified catches is described below in *Specified catch estimation.*

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2020, it does not provide the best estimate of OFL for 2021, because the mean 2020 catch under Scenario 6 is predicated on the 2020 catch being equal to the 2020 OFL, whereas the actual 2020 catch will likely be less than the 2020 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at the same estimated yield ratio as Scenario 2, except for all years instead of the next two. This projection propagates uncertainty throughout the entire assessment procedure based on MCMC. The projection shows wide credibility intervals on future spawning biomass (Figure 9-17). The $B_{35\%}$ and $B_{40\%}$ reference points and future recruitments are based on the 1979-2018 age-2 recruitments, and this projection predicts that the median spawning biomass will eventually tend toward these reference points while at harvesting at $F_{40\%}$.

Risk Table and ABC Recommendation

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 following template is used to complete the risk table:

	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., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) 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.

Assessment considerations

In recent assessments the GOA POP assessment model has resulted in a negative retrospective pattern, which is interpreted as the model continually increasing spawning biomass as new data are added (-0.27 in 2019 and -0.15 in the current assessment, Figure 9-17). While the assessment fits to composition data from the survey (age) and fishery (age and length) are generally adequate (Figures 9-2, 9-3, and 9-6), the retrospective pattern is driven by increases in the trawl survey biomass estimates since 2013. The assessment model has underestimated each survey biomass estimate since 2013, resulting in four consecutive years of negative residuals (Figure 9-4). It is for this reason that we set the assessment-related concern at level 2, a substantially increased concern.

Population dynamics considerations

As discussed in the *Assessment considerations* section above, the recent increase in POP biomass since 2011 is an unusual increase that has not been seen in the time series of biomass prior. In order to fit these large bottom trawl survey biomass estimates the assessment model has indicated several above average recruitment events in recent years (Figures 9-13 and 9-14), most notably in the mid-1980s, mid- and late-1990s, and since 2000. However, even with these above average recruitments the model is still not able to fit the increase in bottom trawl survey biomass satisfactorily. In comparison to many stocks in the North Pacific, this increase in biomass coinciding with warmer temperatures is atypical (with the exception of sablefish). This stock trend is unusual because both the stock trend and recruitment estimates have been increasing faster than seen recently, and as such, we rated the population-dynamics concern as level 2, a substantially increased concern.

Environmental/Ecosystem considerations

Pacific ocean perch are benthic, continental slope (150-300 m depths) dwellers as adults, with a pelagic then inshore benthic juvenile stage (age 1 to 3) in the Gulf of Alaska (GOA) (Carlson and Haight 1976, Love et al. 2002, Rooper and Bolt 2005, Rooper et al. 2007, NPFMC 2010). Spawning occurs during winter and early spring, larvae are released in highly variable ocean conditions and settle to the benthos within 3-6 months (Love et al. 2002). The fecundity is a function of the food available (which itself is an indirect function of temperature via oceanographic conditions) and temperature-dependent metabolic rates (Love et al. 2002). These factors also affect the rate of embryonic development and the date of parturition (Love et al. 2002). The limited information available on temperature, zooplankton, and conditions of other marine species indicate average foraging and growing conditions for the zooplanktivorous Pacific Ocean Perch during 2020. Heat wave conditions occurred during 2020 but were not as severe as 2019 during the summer and fall in the GOA (Watson 2020). Sea surface temperatures were about 1°C above normal in the western GOA and average in the eastern GOA during the 2020 summer (Alaska Center for Climate Assessment & Policy ACCAP, Thoman personal communication). Inside waters of the GOA were slightly more anomalously warm than offshore temperatures (ACCAP). Offshore of SewardKodiak, waters above the continental shelf at GAK1 along the Seward GAK line remained anomalously warm (0.5°C) at 200-250 m depth in 2020 but cooler than 2019 (Danielsen and Hopcroft 2020). Along the GOA slope, the AFSC Longline Survey Subsurface Temperature Index indicates above average temperatures at the surface and at depth (250 m) in 2020 relative to the 2005-2019 time series and cooler temperatures in 2020 relative to 2019 (Siwicke personal communication). In the inside waters, Prince William Sound has remained warm since 2014 (Campbell and McKinstryCampbell 2020). However, for the inside waters of the eastern GOA, the top 20 m temperatures of Icy Strait in northern southeast Alaska during summer were slightly below average (8.8°C) in 2020 relative to the 23 year time series (1997-2019) (Fergusson 2020). It is reasonable to expect that the recent heat wave during summer/fall of 2020 may impact age-0 rockfish in pelagic waters during a time when they are growing to a size that promotes over winter survival, however, it is unknown what this impact will be. Further, a recent study published on the U.S. West Coast suggests that the warming that occurred during 2014-2016 may have been beneficial for rockfish recruitment (Morgan et al. 2019). It is reasonable to expect that the current temperature condition would not adversely impact age-0 rockfish in pelagic waters during a time when they are growing to a size that promotes over winter survival.

The primary prey of the adult Pacific Ocean Perch include calanoid copepods, euphausiids, myctophids, and miscellaneous prey in the GOA (Byerly 2001, Yang 2000, Yang 2003). Warm conditions tend to be associated with zooplankton communities that are dominated by smaller and less lipid rich species in the GOA (Kimmel et al. 2019). There was limited information on zooplankton in 2020. In Icy Strait, northern southeast Alaska, the lipid content of all zooplankton taxa combined examined during 2020 was average for the time series (1997-2020) and similar to 2019. By taxa, lipid content was above average for the large calanoid copepods, average for hyperiid amphipods, but lower than average for euphausiids, small copepods and gastropods indicating average nutritional quality of the prey field utilized by larval and juvenile fish (Fergusson and Rogers 2020). In the western GOA, the mean biomass of large calanoids and euphausiids averaged over the top 100m south of Seward Alaska during May were about average in 2020 relative to the time series, 1998-2019 (Hopcroft and Coyle 2020). On the outer edge of the continental shelf in the central Gulf of Alaska, the breeding success as an indication for foraging success and nutrient-rich prey was above average for piscivorouspiscivorous sea birds on Middleton Island indicating good ocean conditions during 2020 (Hatch et al. 2020). Little is known about the impacts of predators, such as fish and marine mammals, on Pacific Ocean Perch. However, survival of larvae POP are thought more related to the abundance and timing of prey availability than predation, due to the lack of rockfish as a prey item (Love et al. 2002, Yang 2003). The 2020 foraging conditions were likely average, although data limited, for the largely zooplanktivorous Pacific Ocean Perch rockfish in the GOA. Given cooler conditions in 2020 than in 2019 and average densities and body condition of zooplankton with limited information on rockfish, we scored this category as level 1, as normal concern. There are some indicators showing positive and negative signals relevant to the stock but the pattern was not consistent across all indicators, and the actual effect is unknown.

Fishery performance

In general, fishery CPUE shows consistent patterns in abundance similar to the bottom trawl survey and there have been no recent changes to spatial distribution of catch, percent of TAC taken, or fishing duration. The exception to agreement between fishery CPUE and bottom trawl survey trends is in the Western GOA. In 2019 the Western GOA bottom trawl survey biomass decreased by nearly 80% (Figure 9-18), while the fishery CPUE increased in 2018 and 2019 compared to 2017. While there are differences between the trawl survey and fishery CPUE in the Western GOA, overall there are no indications of adverse signals or concerns about the fishery in terms of resource-use, performance, or behavior and thus we scored the fishery-performance concern as level 1, no apparent concern. We will continue to monitor the fishery performance as it pertains to the COVID-19 pandemic.

Summary and ABC recommendation

The following is a summary of the risk table:

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*
Level 2: Substantially increased concerns	Level 2: Substantially increased concerns	Level 1: No apparent concern	Level 1: No apparent concern

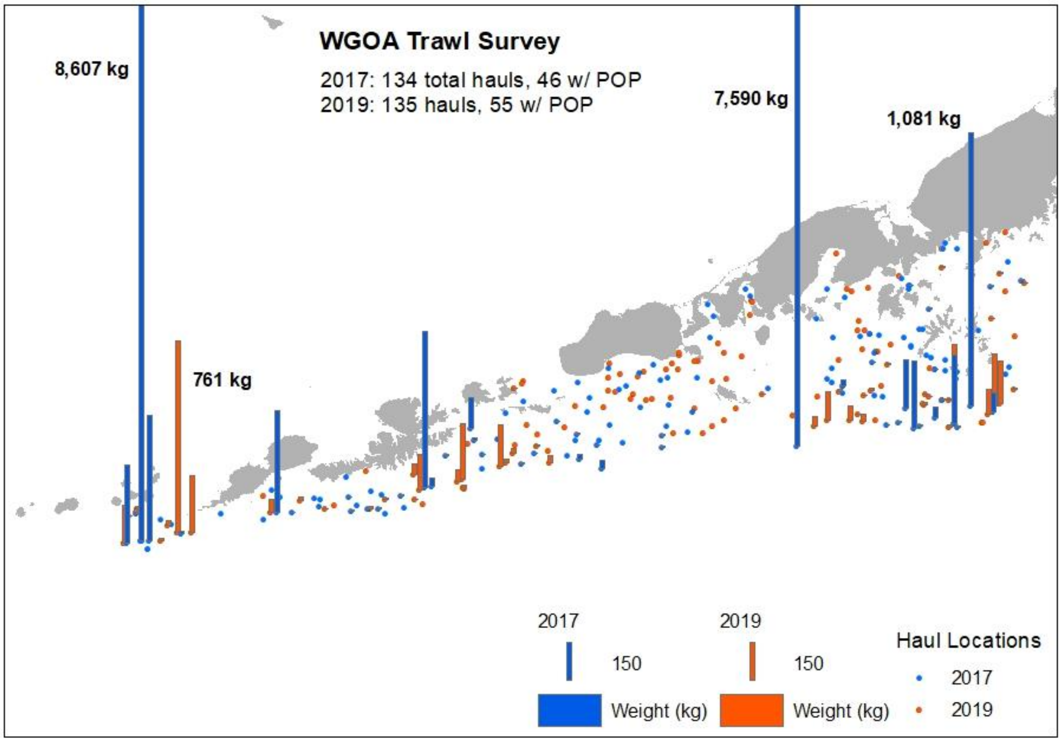
Bottom trawl survey estimates of POP biomass in the GOA indicate an unprecedented increase in abundance, which has not been properly explained by the population dynamics defined in the current assessment model. Even though we rate the population dynamics considerations at a level 2, we do not, however, recommend a reduction in ABC as the retrospective pattern in this assessment continues to indicate increasing population abundance.

Area Allocation of Harvests

Apportionment of ABC and OFL among regulatory areas has been based on the random effects model developed by the survey averaging working group. The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern GOA. The random effects model estimates a process error parameter (constraining the variability of the modeled estimates among years) and random effects parameters in each year modeled. The fit of the random effects model to survey biomass in each area is shown in Figure 9-18.

In general the random effects model fits the area-specific survey biomass reasonably well. The random effects model estimates increases in biomass in all regions in 2019 compared to 2017. Using the random effects model estimates of survey biomass for the apportionment results in 4.6% for the Western area (down from 11.2% in 2017), 75.8% for the Central area (up from 68.8% in 2017), and 19.6% for the Eastern area (down slightly from 19.9% in 2017).

The decrease in apportionment in the Western Gulf compared to previous years is large and is due to fewer large catches of POP in the bottom trawl survey in 2019 compared to 2017 (see map below). This results in both a smaller estimate of biomass and reduced uncertainty in the biomass estimate. There are no apparent errors or anomalies in these estimates. The number of hauls performed by the trawl survey in the Western Gulf were nearly identical between 2017 and 2019 and the number of hauls that capture POP increased in 2019 compared to 2017 (see text in map below) despite fewer large catches. Further, there were no significant changes in design or station placement of the survey in 2019 compared to previous years.



Using the results of the random effects model results in recommended ABC's of **1,643** t for the Western area, **27,429** t for the Central area, and **7,105** t for the Eastern area.

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. In the past, the Plan Team has calculated an apportionment for the West Yakutat area that is still open to trawling (between 147ºW and 140ºW). We calculated this apportionment using the ratio of estimated biomass in the closed area and open area. This calculation was based on the team's previous recommendation that we use the weighted average of the upper 95% confidence interval for the W. Yakutat. We computed this interval this year using the weighted average of the ratio for 2015, 2017, and 2019. We calculated the approximate upper 95% confidence interval using the variance of a weighted mean for the 2015-2019 weighed mean ratio. This resulted in a ratio of 0.24, down from 0.58 in 2017. This decrease is due to the large 2013 fraction of biomass in the W. Yakutat area moving out of the three year weighted average window; the 2019 fraction (0.19) is consistent with the 2015 (0.15) and 2017 (0.22) fractions. This results in an ABC apportionment of **1,705** t to the W. Yakutat area which would leave **5,400** t unharvested in the Southeast/Outside area.

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.12), overfishing is set equal to 42,977 t for POP. The overfishing level is apportioned by area for POP and historically used the apportionment described above for setting area specific OFLs. However, in 2012, area OFLs were combined for the Western, Central, and West Yakutat (W/C/WYK) areas, while East Yakutat/Southeast (SEO) was separated to allow for concerns over stock structure. This results in overfishing levels for W/C/WYK area of **45,003** t and **6,414** t in the SEO area.

Status Determination

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

1) Is the stock being subjected to overfishing? The official catch estimate for the most recent complete year (2019) is 25,470 t. This is less than the 2019 OFL of 33,951 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be overfished. Any stock that is expected to fall below its MSST in the next two years is defined to be approaching an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

2) Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2020:
a. If spawning biomass for 2020 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2020 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2020 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 9-19). If the mean spawning biomass for 2030 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

3) Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2022 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2022 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2022 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2032. If the mean spawning biomass for 2032 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 9-19, the stock is not overfished and is not approaching an overfished condition. The *F* that would have produced a catch for 2019 equal to the OFL of 2019 was 0.10.

Ecosystem Considerations

In general, a determination of ecosystem considerations for POP is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 9-20.

Ecosystem Effects on the Stock

Prey availability/abundance trends: Similar to many other rockfish species, stock condition of POP appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval POP may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval slope rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval slope rockfish (Gharrett et. al 2001). Some juvenile rockfish found in inshore habitat feed on shrimp, amphipods, and other crustaceans, as well as some mollusk and fish (Byerly 2001). Adult POP feed primarily on euphausiids. Little if anything is known about abundance trends of likely rockfish prey items. Euphausiids are also a major item in the diet of walleye pollock. Recent declines in the biomass of walleye pollock, could lead to a corollary change in the availability of euphausiids, which would then have a positive impact on POP abundance.

Predator population trends: POP are preyed upon by a variety of other fish at all life stages, and to some extent marine mammals during late juvenile and adult stages. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile slope rockfish, but information on these life stages and their predators is scarce.

Changes in physical environment: Stronger year classes corresponding to the period around 1977 have been reported for many species of groundfish in the GOA, including POP, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including slope rockfish. POP appeared to have strong 1986-88 year classes, and there may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could affect prey abundance and the survival of rockfish from the pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents. Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions. Carlson and Straty (1981), Pearcy et al (1989), and Love et al (1991) have noted associations of juvenile rockfish with biotic and abiotic structure. Research by Rooper and Boldt (2005) found juvenile POP abundance was positively correlated with sponge and coral.

The Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005) concluded that the effects of commercial fishing on the habitat of groundfish is minimal or temporary. The continuing upward trend in abundance of POP suggests that at current abundance and exploitation levels, habitat effects from fishing are not limiting this stock.

Effects of POP Fishery on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the GOA, bottom trawl fisheries for pollock, deepwater flatfish, and POP account for most of the observed bycatch of coral, while rockfish fisheries account for little of the bycatch of sea anemones or of sea whips and sea pens. The bottom trawl fisheries for POP and Pacific cod and the pot fishery for Pacific cod account for most of the observed bycatch of sponges (Table 9-5).

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The directed slope rockfish trawl fisheries used to begin in July, were concentrated in known areas of abundance, and typically lasted only a few weeks. The Rockfish Pilot project has spread the harvest throughout the year in the Central GOA. The recent annual exploitation rates on rockfish are thought to be quite low. Insemination is likely in the fall or winter, and parturition is likely mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery. There is momentum for extending the rockfish fishery over a longer period, which could have minor effects on reproductive output.

Fishery-specific effects on amount of large size target fish: The proportion of older fish has increased in the trawl survey and the estimated selectivity for the fishery in recent years in dome-shaped, thus, the fishery seems to be having negligible impact on the amount of older fish in the population.

Fishery contribution to discards and offal production: Fishery discard rates for the whole rockfish trawl fishery since 2000 are on average 33% and have ranged from 27% to 43%. Arrowtooth flounder comprised 7-44% of these discards since 2000, and have been less than 20% since 2008. Non-target discards are summarized in Table 9-5, with grenadiers (*Macrouridae sp.*) dominating the non-target discards.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Research is under way to examine whether the loss of older fish is detrimental to spawning potential.

Fishery-specific effects on EFH non-living substrate: Effects on non-living substrate are unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery is suspected to move around rocks and boulders on the bottom. Table 9-5 shows the estimated bycatch of living structure such as benthic urochordates, corals, sponges, sea pens, and sea anemones by the GOA rockfish fisheries. The average bycatch of corals/bryozoans and sponges by rockfish fisheries are a large proportion of the catch of those species taken by all Gulf-wide fisheries.

GOA Rockfish Economic Performance Report for 2019

Rockfish total catch in the Gulf of Alaska was virtually unchanged at 34 thousand t in 2019 relative to 2018 and retained catch decreased slightly to 30.8 thousand t (Table 9-21). Catch remains near the recent high in 2016 over the last decade. Rockfish are an important component of the catch portfolio of GOA fisheries. Ex-vessel value in the GOA rockfish fisheries in 2019 was $14.5 million down 2% from 2018. The change in ex-vessel value was combined effect of marginal decreases in catch and prices (Table 9-21). First-wholesale value was down 26% in 2019 to $33.7 million with a significant decrease in the first-wholesale price (Table 9-22).

The most significant species in terms of market volume and value is Pacific ocean perch which has accounted for upwards of 70% of the retained catch since 2017 (Table 9-22). Harvest levels of Pacific ocean perch are near the total allowable catch (TAC) and has been strong in recent years reflecting the underlying health of the stock. The GOA rockfish fisheries catch a diverse set of rockfish species and the other major species caught are northern and dusky (Table 9-22). Typically, 75%-90% of the northern rockfish TAC is harvested, and since 2017 this has dropped to roughly 60%. In 2019 retained catch of northern rockfish increased to 2.6, and retained catch of Dusky rockfish decreased to 2.2 thousand t in 2019. Other rockfish caught in the GOA include rougheye, shortraker, and thornyhead. In recent years, approximately 85% of the retained rockfish catch has occurred in the Central Gulf in recent years. In 2019 the Central Gulf's share fell to 81%, though this is within the range of the pre-2015 historical share. The Western Gulf's share of retained catch was 19%. In the Central Gulf, where the majority of rockfish are caught, rockfish comprised 15% of the retained catch and 13% of the ex-vessel value, which is up in part because of reduced catch and value in other fisheries, in particular Pacific cod. Catch in the GOA is distributed approximately evenly between catcher vessels and catcher processors, although there are a far greater number of catch vessels. The number of catcher vessels harvesting rockfish has increase from an average of 177 in 2010-2014 to 181 in 2019. Rockfish are primarily targeted using trawl gear.

The Central Gulf of Alaska rockfish fisheries are managed under a catch share program designed to reduce bycatch and discards and to improve quality and value. The Rockfish Program began in 2012 and followed a pilot program from 2007-2011. Quota is allocated to catcher vessel and catcher processor cooperatives. Catch shares have had the effect of spreading the production out over the year which enabled delivered product to be processed more strategically thereby increasing the quality of the product.

The majority of rockfish produced in the U.S. are exported, primarily to Asian markets. Pacific ocean perch is the only rockfish species with specific information in the U.S. trade data. Other species are aggregated into a non-specific category. Approximately 70% of the Pacific ocean perch exported from the U.S. went to China in 2019 (Table 9-23). This is an increase relative to recent years where approximately 60% of exports went to China. Exported H&G rockfish to China is re-processed (e.g., as fillets) and re-exported to domestic and international markets. Rockfish are also sold to Chinese consumers, as whole fish. The U.S. has accounted for just over 15% of global rockfish production in recent years and 85-90% of global Pacific ocean perch production. Global production of rockfish has increased 15% from the 2010-2014 average to 337 thousand t in 2017 and global production of Pacific ocean perch has increased 22%. Global production of Atlantic redfish, a market competitor to Pacific ocean perch, increased slightly to 52 thousand t but in recent years has remained relatively stable at roughly 50 thousand t. The U.S. dollar was relative stability in 2019 against other currencies, such as the Chinese Yuan, which mitigates its potential impact on market price. Because of China's significance as a re-processor of rockfish products, the tariffs between the U.S. and China have put downward pressure on rockfish prices which has inhibited value growth in rockfish markets. Industry lacks immediate alternative reprocessing options to China. Export quantities of Pacific ocean perch decreased in 2019 from 2018 and the share of exports to China increased despite declining export prices and increased production (Table 9-23).

Data Gaps and Research Priorities

There is little information on early life history of POP and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. In addition, modeling investigations into the potential relationships between recruitment or natural mortality and environmental indices should be conducted to enable the model to better describe the increase in biomass observed by the bottom trawl survey. Better estimation of recruitment and year class strength would improve assessment and management of the POP population. Studies to improve our understanding of POP density between trawlable and untrawlable grounds and other habitat associations would help in our determination of catchability parameters. Further investigations of spatial population dynamics of POP across the GOA may enable improved assessment as well, given the closed area in the Eastern GOA and the recent increases in biomass in this area and the potential differences in population dynamics among the regions of the GOA. Incorporation of acoustics information that have been collected by the Mid-water Assessment and Conservation Engineering (MACE) group would also aid the assessment and would allow increased understanding of the changes to POP distribution in conjunction with the recent increases in biomass. Interaction with other species in the fishery, such as Walleye Pollock, should also be evaluated to determine the influence of POP population expansion. This research could potentially be done in a Management Strategy Evaluation (MSE) framework as well as Maximum Economic Yield (MEY) framework.

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Tables

Table 9-1. Commercial catch[a] (t) of POP in the GOA, with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1977-2020 (*2020 catch as of 10/11/2020).

		Regulatory Area				Gulf-wide value	
Year	Fishery	Western	Central	Eastern	Total	ABC	Quota
1977	Foreign	6,282	6,166	10,993	23,441		
	U.S.	0	0	12	12		
	JV	-	-	-	-		
	Total	6,282	6,166	11,005	23,453	50,000	30,000
1978	Foreign	3,643	2,024	2,504	8,171		
	U.S.	0	0	5	5		
	JV	-	-	-	-		
	Total	3,643	2,024	2,509	8,176	50,000	25,000
1979	Foreign	944	2,371	6,434	9,749		
	U.S.	0	99	6	105		
	JV	1	31	35	67		
	Total	945	2,501	6,475	9,921	50,000	25,000
1980	Foreign	841	3,990	7,616	12,447		
	U.S.	0	2	2	4		
	JV	0	20	0	20		
	Total	841	4,012	7,618	12,471	50,000	25,000
1981	Foreign	1,233	4,268	6,675	12,176		
	U.S.	0	7	0	7		
	JV	1	0	0	1		
	Total	1,234	4,275	6,675	12,184	50,000	25,000
1982	Foreign	1,746	6,223	17	7,986		
	U.S.	0	2	0	2		
	JV	0	3	0	3		
	Total	1,746	6,228	17	7,991	50,000	11,475
1983	Foreign	671	4,726	18	5,415		
	U.S.	7	8	0	15		
	JV	1,934	41	0	1,975		
	Total	2,612	4,775	18	7,405	50,000	11,475
1984	Foreign	214	2,385	0	2,599		
	U.S.	116	0	3	119		
	JV	1,441	293	0	1,734		
	Total	1,771	2,678	3	4,452	50,000	11,475
1985	Foreign	6	2	0	8		
	U.S.	631	13	181	825		
	JV	211	43	0	254		
	Total	848	58	181	1,087	11,474	6,083
1986	Foreign	Tr	Tr	0	Tr		
	U.S.	642	394	1,908	2,944		
	JV	35	2	0	37		
	Total	677	396	1,908	2,981	10,500	3,702
1987	Foreign	0	0	0	0		
	U.S.	1,347	1,434	2,088	4,869		
	JV	108	4	0	112		
	Total	1,455	1,438	2,088	4,981	10,500	5,000
1988	Foreign	0	0	0	0		
	U.S.	2,586	6,467	4,718	13,771		
	JV	4	5	0	8		
	Total	2,590	6,471	4,718	13,779	16,800	16,800

Table 9-1. (continued)

		Regulatory Area				Gulf-wide value	
Year	Fishery	Western	Central	Eastern	Total	ABC	Quota
1989	U.S.	4,339	8,315	6,348	19,003	20,000	20,000
1990	U.S.	5,203	9,973	5,938	21,140	17,700	17,700
1991	U.S.	1,758	2,643	2,147	6,548	5,800	5,800
1992	U.S.	1,316	2,994	2,228	6,538	5,730	5,200
1993	U.S.	477	1,140	443	2,060	3,378	2,560
1994	U.S.	166	909	767	1,842	3,030	2,550
1995	U.S.	1,422	2,597	1,721	5,740	6,530	5,630
1996	U.S.	987	5,145	2,247	8,379	8,060	6,959
1997	U.S.	1,832	6,709	978	9,519	12,990	9,190
1998	U.S.	846	7,452	Conf.	8,908	12,820	10,776
1999	U.S.	1,935	7,911	627	10,473	13,120	12,590
2000	U.S.	1,160	8,379	Conf.	10,145	13,020	13,020
2001	U.S.	945	9,249	Conf.	10,817	13,510	13,510
2002	U.S.	2,723	8,262	Conf.	11,734	13,190	13,190
2003	U.S.	2,124	8,116	606	10,846	13,663	13,660
2004	U.S.	2,196	8,567	877	11,640	13,336	13,340
2005	U.S.	2,338	8,064	846	11,248	13,575	13,580
2006	U.S.	4,051	8,285	1,259	13,595	14,261	14,261
2007	U.S.	4,430	7,283	1,242	12,955	14,636	14,635
2008	U.S.	3,678	7,683	1,100	12,461	14,999	14,999
2009	U.S.	3,804	8,034	1,148	12,986	15,111	15,111
2010	U.S.	3,140	10,550	1,926	15,616	17,584	17,584
2011	U.S.	1,819	10,533	1,872	14,224	16,997	16,997
2012	U.S.	2,452	10,780	1,684	14,916	16,918	16,918
2013	U.S.	447	11,198	1,537	13,182	16,412	16,412
2014	U.S.	2,097	13,744	1,871	17,712	19,309	19,309
2015	U.S.	2,038	14,714	1,981	18,733	21,012	21,012
2016	U.S.	2,654	17,554	2,827	23,035	24,437	24,437
2017	U.S.	2,682	18,422	2,757	23,861	23,918	23,918
2018	U.S.	3,225	18,159	3,352	24,736	29,236	29,236
2019	U.S.	3,144	19,038	3,288	25,470	28,555	28,555
2020*	U.S.	1,332	18,879	1,466	21,677	31,238	31,238

Note: There were no foreign or joint venture catches after 1988. Catches prior to 1989 are landed catches only. Catches in 1989 and 1990 also include fish reported in weekly production reports as discarded by processors. Catches in 1991-2019 also include discarded fish, as determined through a "blend" of weekly production reports and information from the domestic observer program. Definitions of terms: JV = Joint venture; Tr = Trace catches;

[a]Catch defined as follows: 1977, all Sebastes rockfish for Japanese catch, and POP for catches of other nations; 1978, POP only; 1979-87, the 5 species comprising the POP complex; 1988-2019, POP.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2019 total allowable catch.

Sources: Catch: 1977-84, Carlson et al. (1986); 1985-88, Pacific Fishery Information Network (PacFIN); 1989-2019, National Marine Fisheries Service, Alaska Region. ABC and Quota: 1977-1986 Karinen and Wing (1987); 1987-1990, Heifetz et al. (2000); 1991-2019, NMFS AKRO BLEND/Catch Accounting System via AKFIN database.

Table 9-2. Management measures since the break out of POP from slope rockfish.

Year	Catch (t)	ABC	TAC	OFL	Management Measures
1988	1,621	16,800	16,800		The slope rockfish assemblage, including POP, was one of three management groups for *Sebastes* implemented by the North Pacific Management Council. Previously, *Sebastes* in Alaska were managed as "POP complex" or "other rockfish"
1989	19,003	20,000	20,000		
1990	21,140	17,700	17,700		
1991	6,548	5,800			Slope assemblage split into three management subgroups with separate ABCs and TACs: POP, shortraker/rougheye rockfish, and all other slope species
1992	6,538	5,730	5,200		
1993	2,060	3,378	2,560		
1994	1,842	3,030	2,550	3,940	Amendment 32 establishes rebuilding plan Assessment done with an age structured model using stock synthesis
1995	5,740	6,530	5,630	8,232	
1996	8,379	8,060	6,959	10,165	
1997	9,519	12,990	9,190	19,760	
1998	8,908	12,820	10,776	18,090	
1999	10,473	13,120	12,590	18,490	Eastern Gulf divided into West Yakutat and East Yakutat/Southeast Outside and separate ABCs and TACs assigned
2000	10,145	13,020	13,020	15,390	Amendment 41 became effective which prohibited trawling in the Eastern Gulf east of 140 degrees W.
2001	10,817	13,510	13,510	15,960	Assessment is now done using an age structured model constructed with AD Model Builder software
2002	11,734	13,190	13,190	15,670	
2003	10,846	13,663	13,660	16,240	
2004	11,640	13,336	13,340	15,840	
2005	11,248	13,575	13,575	16,266	
2006	13,595	14,261	14,261	16,927	
2007	12,955	14,636	14,636	17,158	Amendment 68 created the Central Gulf Rockfish Pilot Project
2008	12,461	14,999	14,999	17,807	
2009	12,986	15,111	15,111	17,940	
2010	15,616	17,584	17,584	20,243	
2011	14,224	16,997	16,997	19,566	
2012	14,916	16,918	16,918	19,498	
2013	13,182	16,412	16,412	18,919	Area OFL for W/C/WYK combined, SEO separate
2014	17,712	19,309	19,309	22,319	
2015	18,733	21,012	21,012	24,360	
2016	23,035	24,437	24,437	28,431	
2017	23,861	23,918	23,918	27,826	
2018	24,736	29,236	29,236	34,762	
2019	25,470	28,555	28,555	33,951	
2020*	21,677	31,238	31,238	37,092	

* Catch as of 10/11/2020

Table 9-3. FMP groundfish species caught in rockfish targeted fisheries in the GOA from 2014-2020. Conf. = Confidential because of less than three vessels or processors. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/19/2020.

Species Group Name	2014	2015	2016	2017	2018	2019	2020	Average
Pacific Ocean Perch	15,283	17,566	20,394	19,045	22,172	22,258	19,922	19,520
Northern Rockfish	3,647	3,632	3,155	1,601	2,152	2,313	2,307	2,687
Dusky Rockfish	2,752	2,493	3,008	2,193	2,695	2,153	2,056	2,479
Arrowtooth Flounder	1,426	1,397	1,197	1,416	761	732	834	1,109
Pollock	1,339	1,330	572	1,061	917	686	490	913
Other Rockfish	735	850	970	751	994	670	510	783
Atka Mackerel	446	988	595	543	1,140	824	602	734
Sablefish	527	440	484	590	708	801	602	593
Pacific Cod	647	785	364	253	401	322	126	414
Rougheye Rockfish	359	225	351	269	317	320	88	276
Thornyhead Rockfish	243	220	337	363	362	177	137	263
Shortraker Rockfish	243	238	294	257	269	269	225	256
Rex Sole	84	116	140	112	136	117	188	127
Flathead Sole	31	46	26	80	48	40	94	52
Deep Water Flatfish	68	44	64	64	66	39	19	52
Sculpin	33	44	41	42	65	53	30	44
Demersal Shelf Rockfish	38	40	42	41	58	57	12	41
Longnose Skate	26	33	46	42	46	28	23	35
Shallow Water Flatfish	30	27	14	12	57	34	22	28
Shark	2	6	12	39	48	62	20	27
Skate, Other	45	21	17	22	28	26	9	24
Squid	19	24	11	22	29	--	--	21
Big Skate	4	7	7	6	6	5	4	5
Octopus	7	11	2	1	3	9	1	5

Table 9-4. Catch (t) of GOA POP as bycatch in other fisheries from 2014-2020. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/19/2020.

Target	2014	2015	2016	2017	2018	2019	2020	Average
Arrowtooth Flounder	1,401	593	1,020	3,260	531	1,694	937	1,348
Pollock - midwater	347	61	521	1,090	862	594	193	524
Pollock - bottom	224	118	170	183	766	477	467	344
Rex Sole	423	227	50	101	353	354	78	226
Pacific Cod	13	161	698	77	0	20	0	138
Shallow Water Flatfish	11	3	139	79	9	43	79	52
Atka Mackerel	--	--	--	18	25	--	--	21
Sablefish	2	2	9	4	19	29	2	10
Flathead Sole	6	--	33	3	0	2	--	9
Deep Water Flatfish	1	1	--	--	--	--	--	1

Table 9-5. Non-FMP species bycatch estimates in tons for GOA rockfish targeted fisheries 2015 - 2020. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/19/2020.

Species Group Name	2015	2016	2017	2018	2019	2020
Benthic urochordata	0.28	0.5	0.2	0.07	0.4	0.12
Birds - Northern Fulmar	0	0	Conf.	Conf.	Conf.	0
Birds - Shearwaters	0	0	0	0	Conf.	0
Bivalves	Conf.	Conf.	0.01	Conf.	Conf.	0
Bristlemouths	0	0	0	0	0	Conf.
Brittle star unidentified	0.05	0.03	0.6	0.01	0.02	0.01
Capelin	Conf.	Conf.	0	0	0.16	Conf.
Corals Bryozoans - Corals Bryozoans Unidentified	0.7	0.84	0.47	1.36	0.88	0.17
Corals Bryozoans - Red Tree Coral	Conf.	0	0	0	0	0
Eelpouts	0.01	0.02	0.13	0.22	0	Conf.
Eulachon	0.03	0.04	0.13	0.13	0.27	0.1
Giant Grenadier	903.72	451.09	1048.43	1690.57	786.53	301.7
Greenlings	8.14	5.81	3.9	4.51	9.63	3.5
Grenadier - Rattail Grenadier Unidentified	47.4	5.45	12.34	5.33	4.01	1.69
Gunnels	Conf.	0	0	0	0	0
Hermit crab unidentified	0.03	0.01	0.03	0.01	Conf.	Conf.
Invertebrate unidentified	0.19	0.09	0.09	0.11	0.07	Conf.
Lanternfishes (myctophidae)	0.04	Conf.	0	Conf.	0.06	0.02
Misc crabs	0.16	0.35	1.1	0.38	0.14	0.09
Misc crustaceans	Conf.	0.03	0.01	Conf.	0.2	0.07
Misc deep fish	0	Conf.	Conf.	0	Conf.	0
Misc fish	143.5	101.47	114.69	109.98	519.97	84.96
Misc inverts (worms etc)	0	Conf.	0	0	0	Conf.
Other osmerids	Conf.	Conf.	Conf.	0	Conf.	0.98
Pacific Hake	Conf.	Conf.	Conf.	0.07	Conf.	Conf.
Pandalid shrimp	0.05	0.22	0.14	0.07	0.11	0.17
Polychaete unidentified	0	0	0.02	0	Conf.	0
Scypho jellies	1.65	8.13	0.54	0.92	8.44	3.03
Sea anemone unidentified	1.14	1.27	0.72	0.46	1.57	1.24
Sea pens whips	Conf.	0.02	0.03	0	0.03	0
Sea star	3.48	1.72	3.68	3.09	1.36	1.12
Snails	0.26	0.18	0.18	5.67	1.79	0.08
Sponge unidentified	5.45	2.88	3.21	13.67	5.88	0.52
Squid	0	0	0	0	10.87	31.61
State-managed Rockfish	47.47	13.34	24.48	52.88	46.46	53.11
Stichaeidae	Conf.	0	Conf.	0.51	0	Conf.
urchins dollars cucumbers	0.99	0.34	0.43	0.31	0.21	0.91

Table 9-6. Prohibited Species Catch (PSC) estimates reported in tons for halibut and herring, and thousands of animals for crab and salmon, by year, for the GOA rockfish fishery. Source: NMFS AKRO Blend/Catch Accounting System PSCNQ via AKFIN 10/19/2020.

Species Group Name	2015	2016	2017	2018	2019	2020	Average
Bairdi Crab	0.05	0.00	0.76	0.32	0.06	0.24	0.23
Blue King Crab	0	0	0	0	0	0	0
Chinook Salmon	1.91	0.38	0.52	0.34	0.41	0.63	0.78
Golden K. Crab	0.02	0.02	0.21	0.32	0.22	0.06	0.13
Halibut	157	124	125	100	115	89	120
Herring	0	0	0	0	0	0	0
Other Salmon	0.34	0.22	0.64	0.33	0.38	0.72	0.45
Opilio Crab	0	0	0	0	0	0	0
Red King Crab	0	0	0	0	0	0	0

Table 9-7. Fishery length frequency data for POP in the GOA from 2011-2020.

Length (cm)	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0
23	0	0.01	0	0	0	0	0	0	0	0
24	0	0.01	0	0	0	0	0	0	0	0
25	0	0.01	0.01	0	0.01	0	0	0	0	0
26	0	0.01	0.01	0	0.01	0	0	0	0	0
27	0	0.01	0.01	0.01	0.01	0	0.01	0.01	0	0
28	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
29	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0
30	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01
31	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01
32	0.02	0.02	0.01	0.03	0.02	0.02	0.03	0.03	0.03	0.02
33	0.03	0.03	0.02	0.03	0.03	0.04	0.05	0.06	0.05	0.04
34	0.06	0.05	0.03	0.04	0.05	0.07	0.09	0.09	0.08	0.07
35	0.10	0.09	0.06	0.07	0.07	0.09	0.11	0.11	0.12	0.10
36	0.14	0.13	0.12	0.11	0.10	0.12	0.12	0.13	0.14	0.13
37	0.16	0.16	0.15	0.15	0.13	0.14	0.13	0.13	0.13	0.13
38	0.15	0.14	0.16	0.15	0.15	0.14	0.12	0.11	0.13	0.12
39	0.11	0.11	0.13	0.13	0.14	0.12	0.11	0.10	0.10	0.12
40	0.08	0.07	0.09	0.09	0.10	0.09	0.08	0.07	0.08	0.10
41	0.05	0.04	0.06	0.06	0.07	0.06	0.05	0.05	0.05	0.07
42	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04
43	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02
44	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
≥45	0.01	0	0	0.01	0.01	0.01	0	0.01	0	0
Total	8,732	11,727	9,630	12,500	13,110	18,083	18,764	19,787	21,891	12,976

Table 9-8. Fishery age compositions for GOA POP 1990-2018.

Age	1990	1998	1999	2000	2001	2002	2004	2005	2006	2008	2010	2012	2014	2016	2018
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.02	0	0	0.01	0	0	0	0	0	0	0.01	0.02	0.01	0	0.01
5	0.04	0	0	0.01	0	0.01	0.01	0.01	0	0	0	0.03	0	0	0.01
6	0.05	0	0.02	0.04	0.02	0.02	0.05	0.02	0.04	0.02	0.01	0.02	0.03	0.02	0.03
7	0.07	0	0.02	0.03	0.04	0.04	0.04	0.09	0.09	0.03	0.02	0.02	0.05	0.02	0.01
8	0.05	0.01	0.03	0.06	0.03	0.1	0.05	0.09	0.11	0.1	0.07	0.03	0.04	0.06	0.06
9	0.07	0.04	0.04	0.06	0.06	0.08	0.17	0.1	0.11	0.1	0.07	0.05	0.04	0.08	0.06
10	0.11	0.15	0.05	0.06	0.06	0.11	0.18	0.14	0.08	0.16	0.12	0.09	0.06	0.06	0.13
11	0.06	0.17	0.18	0.05	0.06	0.11	0.07	0.11	0.11	0.11	0.15	0.11	0.08	0.05	0.11
12	0.08	0.2	0.19	0.13	0.06	0.05	0.07	0.07	0.09	0.05	0.12	0.12	0.1	0.06	0.05
13	0.06	0.12	0.13	0.13	0.13	0.07	0.07	0.05	0.06	0.09	0.07	0.09	0.08	0.06	0.05
14	0.11	0.11	0.09	0.11	0.15	0.11	0.04	0.04	0.04	0.05	0.06	0.09	0.07	0.05	0.04
15	0.04	0.06	0.12	0.1	0.08	0.09	0.04	0.02	0.04	0.04	0.05	0.05	0.08	0.07	0.03
16	0.02	0.03	0.06	0.06	0.09	0.06	0.05	0.03	0.03	0.02	0.04	0.04	0.07	0.08	0.04
17	0.03	0.03	0.02	0.05	0.06	0.05	0.05	0.05	0.03	0.03	0.04	0.05	0.05	0.07	0.05
18	0.01	0.01	0.02	0.03	0.07	0.04	0.04	0.04	0.04	0.01	0.02	0.03	0.04	0.05	0.06
19	0.01	0.01	0	0.02	0.04	0.04	0.03	0.03	0.04	0.03	0.01	0.03	0.04	0.03	0.05
20	0.01	0	0	0.01	0.02	0.01	0.02	0.03	0.03	0.03	0.01	0.02	0.03	0.03	0.04
21	0.01	0	0	0.01	0.01	0	0.01	0.03	0.02	0.03	0.02	0.01	0.01	0.04	0.03
22	0	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0.03	0.03	0.02	0.02	0.03	0.02
23	0.01	0.01	0	0	0.01	0	0	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.03
24	0.01	0	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02
25+	0.14	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.04	0.07	0.08	0.09	0.08
Sample size	578	513	376	734	521	370	802	727	734	609	631	1024	871	1201	1032

Table 9-9. Biomass estimates (t) and Gulf-wide confidence intervals for POP in the GOA based on the 1990-2019 trawl surveys.

	Western	Central		Eastern			
Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total	CV
1990	24,543	15,309	15,765	53,337	48,341	157,295	30%
1993	75,416	103,224	153,262	50,048	101,532	483,482	22%
1996	92,618	140,479	326,281	50,394	161,641	771,413	26%
1999	37,980	402,293	209,675	32,749	44,367	727,064	53%
2001*	275,211	39,819	358,126	44,397	102,514	820,066	27%
2003	72,851	116,278	166,795	27,762	73,737	457,422	16%
2005	250,912	75,433	300,153	77,682	62,239	766,418	19%
2007	158,100	77,002	301,712	52,569	98,798	688,180	17%
2009	31,739	209,756	247,737	97,188	63,029	649,449	18%
2011	99,406	197,357	340,881	68,339	72,687	778,670	17%
2013	157,457	291,763	594,675	179,862	74,686	1,298,443	16%
2015	130,364	280,345	482,849	93,661	153,188	1,140,407	16%
2017	194,627	367,439	663,955	97,629	246,709	1,570,359	22%
2019	43,057	266,614	667,596	88,937	145,942	1,212,145	14%

*The 2001 survey did not sample the eastern GOA (the Yakutat and Southeastern areas). Substitute estimates of biomass for the Yakutat and Southeastern areas were obtained by averaging the biomass estimates for POP in these areas in the 1993, 1996, and 1999 surveys, that portion of the variance was obtained by using a weighted average of the three prior surveys' variance.

Table 9-10. Survey age composition (% frequency) data for POP in the GOA. Age compositions are based on "break and burn" reading of otoliths.

Age	1990	1993	1996	1999	2003	2005	2007	2009	2011	2013	2015	2017	2019
2	0	0.01	0.01	0.01	0.02	0	0	0	0	0	0.01	0	0.03
3	0.04	0.02	0.02	0.02	0.06	0.03	0.02	0.09	0.03	0.02	0.03	0.01	0.09
4	0.15	0.02	0.04	0.05	0.05	0.05	0.02	0.04	0.05	0.01	0.01	0.02	0.02
5	0.12	0.04	0.04	0.05	0.07	0.08	0.04	0.05	0.12	0.07	0.06	0.03	0.05
6	0.12	0.09	0.06	0.03	0.04	0.07	0.04	0.03	0.04	0.06	0.02	0.01	0.03
7	0.09	0.13	0.04	0.04	0.05	0.12	0.06	0.10	0.04	0.06	0.08	0.03	0.04
8	0.06	0.13	0.09	0.06	0.11	0.07	0.09	0.07	0.02	0.06	0.05	0.03	0.03
9	0.05	0.17	0.14	0.09	0.12	0.09	0.12	0.11	0.07	0.06	0.11	0.08	0.07
10	0.05	0.09	0.19	0.05	0.06	0.09	0.09	0.05	0.07	0.04	0.05	0.07	0.06
11	0.04	0.04	0.11	0.11	0.05	0.06	0.06	0.05	0.10	0.07	0.04	0.05	0.06
12	0.02	0.05	0.08	0.14	0.04	0.03	0.06	0.08	0.07	0.06	0.03	0.05	0.06
13	0.03	0.04	0.03	0.09	0.04	0.03	0.05	0.03	0.07	0.07	0.05	0.04	0.04
14	0.07	0.02	0.04	0.07	0.06	0.03	0.03	0.04	0.05	0.06	0.03	0.04	0.03
15	0.02	0.03	0.03	0.05	0.05	0.04	0.03	0.05	0.04	0.05	0.06	0.04	0.02
16	0.01	0.01	0.01	0.04	0.04	0.02	0.01	0.01	0.02	0.03	0.05	0.05	0.03
17	0	0.04	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.03	0.04	0.06	0.03
18	0.01	0.01	0.01	0.01	0.03	0.04	0.04	0.01	0.02	0.04	0.03	0.05	0.03
19	0	0	0.01	0	0.02	0.02	0.03	0.00	0.02	0.03	0.01	0.04	0.03
20	0.01	0	0.01	0.01	0.01	0.02	0.04	0.01	0.02	0.02	0.04	0.03	0.02
21	0	0	0	0.01	0.01	0.01	0.02	0.03	0.02	0.02	0.04	0.04	0.03
22	0	0	0	0.01	0	0.02	0.02	0.06	0.01	0.01	0.02	0.03	0.03
23	0	0	0	0.01	0.01	0	0.02	0.01	0.02	0.02	0.01	0.01	0.02
24	0.01	0	0	0	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02
25	0.07	0.05	0.03	0.02	0.03	0.03	0.06	0.04	0.05	0.10	0.12	0.15	0.12
Sample size	1,754	1,378	641	898	985	1,009	1,177	418	794	880	760	1,071	1,219

Table 9-11. Equations describing population dynamics of POP age-structured assessment model

Equation	Description	Parameters and notation
$N_{2,y} = e^{\mu_r + \varepsilon_y^r}$	Annual numbers at age of recruitment (age-2)	y – year μ_r – average recruitment ε_y^r – annual recruitment deviation
$N_{a,y} = N_{a-1,y-1} e^{-(M+F_{a-1,y-1})} = N_{a-1,y-1} e^{-Z_{a-1,y-1}}$	Annual numbers at age between recruitment age and plus age group	a – age M – natural mortality $F_{a,y}$ – annual fishing mortality at age $Z_{a,y}$ – annual total mortality at age
$N_{a^+,y} = N_{a^+-1,y-1} e^{-Z_{a^+-1,y-1}} + N_{a^+,y-1} e^{-Z_{a^+,y-1}}$	Annual numbers at age in plus age group	a^+ - plus age group (age-29 in model)
$SB_y = \sum_{a=2}^{a^+} w_a \hat{m}_a N_{a,y}$	Annual spawning biomass	$\hat{m}_a$ – maturity at age
$\hat{m}_a = 1 / \left(1 + e^{-\delta^m (a - a_{50\%}^m)}\right)$	Maturity at age	δ^m – logistic slope parameter (*m* denotes parameter for maturity) $a_{50\%}^m$ – logistic age at 50% parameter (*m* denotes parameter for maturity)

Table 9-12. Equations describing estimates of observed data fit by the POP age-structured assessment model.

Equation	Description	Parameters and notation
$\hat{C}_y = \sum_{a=2}^{a^+} w_a \frac{N_{a,y}F_{a,y}(1-e^{-Z_{a,y}})}{Z_{a,y}}$	Annual catch	w_a – weight at age
$F_{a,y} = s^f_{a,y}F_y = s^f_{a,y}e^{\mu_f+\varepsilon^f_y}$	Annual fishing mortality	$s^f_{a,y}$ – fishery selectivity by time period F_y – annual fishing mortality μ_f – average fishing mortality ε^f_y – annual fishing mortality deviation
$s^f_{a,t1} = {}^1\!/\!\left(1+e^{-\delta^f\left(a-a^f_{50\%}\right)}\right)$	Asymptotic fishery selectivity for 1961-1976 time period (logistic)	δ^f – logistic slope parameter (*f* denotes parameter for fishery) $a^f_{50\%}$ – logistic age at 50% parameter (*f* denotes parameter for fishery)
$\hat{I}_y = q\sum_{a=2}^{a^+} N_{a,y}s^t_a w_a$	Bottom trawl survey biomass index	q – bottom trawl survey catchability s^t_a – bottom trawl survey selectivity (*t* denotes selectivity for trawl survey)
$s^t_a = {}^1\!/\!\left(1+e^{-\delta^t(a-a^t_{50\%})}\right)$	Bottom trawl survey selectivity	δ^t – logistic slope parameter (t denotes parameter for trawl survey) $a^t_{50\%}$ – logistic age at 50% parameter (*t* denotes parameter for trawl survey)
$\hat{p}^t_{a,y} = T_{a\to a'}\frac{N_{a,y}s^t_a}{\sum_{a=2}^{a^+} N_{a,y}s^t_a}$	Bottom trawl survey age composition	$T_{a\to a'}$ – ageing error matrix
$\hat{p}^f_{a,y} = T_{a\to a'}\frac{\hat{C}_y}{\sum_{a=2}^{a^+}\hat{C}_y}$	Fishery age composition	
$\hat{p}^f_{l,y} = T_{a\to l,y}\frac{\hat{C}_y}{\sum_{a=2}^{a^+}\hat{C}_y}$	Fishery length composition	$T_{a\to l,y}$ – size to age transition matrix

Table 9-13. Equations describing the error structure of the POP age-structured assessment model.

Equation	Description	Parameters and notation
$L_{\hat{C}} = \lambda_{\hat{C}} \sum_{Y} \ln\left(\frac{C_y + k}{\hat{C}_y + k}\right)^2$	Catch likelihood	$\lambda_{\hat{C}}$ – catch likelihood weight (50) k – offset constant (0.00001)
$L_{\hat{I}} = \lambda_{\hat{I}} \sum_{Y} \frac{1}{2(\sigma_{I,y}/I_y)^2} \ln\left(\frac{I_y}{\hat{I}_y}\right)^2$	Bottom trawl survey biomass likelihood	$\lambda_{\hat{I}}$ – trawl survey biomass weight (1) $\sigma_{I,y}$ – annual survey sampling error
$L_{\hat{p}_a^f} = \lambda_{\hat{p}_a^f}\left(\sum_{Y} -n_{a,y}^f \sum_{A} (p_{a,y}^f + k) \ln(\hat{p}_{a,y}^f + k)\right)$	Fishery age composition likelihood	$\lambda_{\hat{p}_a^f}$ – fishery age composition weight (1) $n_{a,y}^f$ – fishery age composition input sample size (square root of sample size)
$L_{\hat{p}_l^f} = \lambda_{\hat{p}_l^f}\left(\sum_{Y} -n_{l,y}^f \sum_{A} (p_{l,y}^f + k) \ln(\hat{p}_{l,y}^f + k)\right)$	Fishery length composition likelihood	$\lambda_{\hat{p}_a^f}$ – fishery length composition weight (1) $n_{a,y}^f$ – fishery length composition input sample size (number of hauls standardized to maximum of 100)
$L_{\hat{p}_a^t} = \lambda_{\hat{p}_a^t}\left(\sum_{Y} -n_{a,y}^t \sum_{A} (p_{a,y}^t + k) \ln(\hat{p}_{a,y}^t + k)\right)$	Bottom trawl survey age composition likelihood	$\lambda_{\hat{p}_a^t}$ – fishery age composition weight (1) $n_{a,y}^t$ – fishery age composition input sample size (square root of sample size)
$L_m = \sum_{D}\sum_{A} Binom(n_{a,D}, \widehat{m}_a) + \lambda_m {}^{1}\!/\!\left(1 + e^{\delta^m a_{50\%}^m}\right)$	Maturity likelihood	D – Dataset $n_{a,D}$ – number observed at age for maturity by dataset λ_m – maturity at age 0 penalty weight (1000)
$L_\theta = \frac{1}{2\sigma_\theta^2} \ln\left(\frac{\theta}{\theta_{prior}}\right)^2$	Prior penalty, used for natural mortality (M), bottom trawl survey catchability (q), and recruitment variability (σ_r)	θ – parameter estimate σ_θ^2 – prior uncertainty θ_{prior} – prior parameter estimate
$L_r = \lambda_r\left(\frac{1}{2\sigma_r^2}\sum_{Y} \varepsilon_y^r + Y \ln \sigma_r\right)$	Recruitment deviation penalty	λ_r – recruitment deviation penalty weight (1) σ_r – recruitment variability
$L_f = \lambda_f \sum_{Y} \varepsilon_y^f$	Fishing mortality deviation penalty	λ_f – fishing mortality deviation penalty weight (0.1)

Table 9-14. Summary of results from 2020 compared with 2019 results

Likelihoods	**17.1 (2019)**	**20.1**
Catch	0.21	0.17
Survey Biomass	13.90	15.65
Fishery Ages	20.83	19.34
Survey Ages	22.34	25.65
Fishery Sizes	66.42	65.06
Maturity	103.52	103.52
Data-Likelihood	227.23	229.39
Penalties/Priors		
Recruitment Devs	16.26	10.56
F Regularity	5.43	5.92
σ_r prior	6.69	7.85
q prior	1.22	0.50
M prior	3.26	2.23
Objective Fun Total	260.09	256.45
Parameter Ests.		
Active parameters	162	164
Mohn's rho	-0.27	-0.15
q	2.01	1.80
M	0.065	0.076
σ_r	0.82	0.77
Mean Recruitment	62.09	84.07
$F_{40\%}$	0.09	0.10
Projected Total Biomass	544,569	613,522
$B_{CURRENT}$	201,518	207,096
$B_{100\%}$	319,837	317,035
$B_{40\%}$	127,935	126,814
maxABC	31,238	**36,177**
$F_{35\%}$	0.108	0.12
$OFL_{F35\%}$	37,092	**42,977**

Table 9-15. Estimated time series of female spawning biomass, 6+ biomass (age 6 and greater), catch/6 + biomass, and number of age two recruits for POP in the GOA. Estimates are shown for the current assessment and from the previous SAFE.

	Spawning biomass (t)		6+ Biomass (t)		Catch/6+ biomass		Age 2 recruits (1000's)	
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1977	36,256	40,061	109,908	124,086	0.196	0.174	20,935	37,131
1978	31,732	35,843	95,536	110,610	0.084	0.072	18,826	58,312
1979	32,170	36,619	94,402	110,393	0.088	0.075	17,761	44,463
1980	32,220	37,066	92,540	109,474	0.117	0.099	17,398	39,143
1981	30,941	36,255	88,952	107,187	0.119	0.098	20,753	40,614
1982	29,584	35,417	89,971	110,318	0.060	0.049	34,040	52,026
1983	30,414	36,779	94,157	116,263	0.030	0.024	25,129	53,390
1984	32,610	39,539	99,986	123,646	0.028	0.022	21,667	55,555
1985	35,225	42,759	106,070	131,133	0.008	0.006	22,902	80,342
1986	38,987	47,141	116,207	143,023	0.019	0.015	29,873	120,774
1987	42,447	51,235	125,127	153,814	0.036	0.029	30,163	112,743
1988	45,135	54,586	131,994	162,683	0.065	0.052	31,089	176,121
1989	46,407	56,600	139,337	173,213	0.085	0.068	45,580	138,034
1990	46,857	57,924	152,593	190,741	0.086	0.069	72,280	109,953
1991	47,786	59,896	164,993	207,052	0.040	0.032	67,449	54,357
1992	52,762	66,091	197,445	246,105	0.033	0.027	105,748	65,054
1993	59,632	74,354	224,895	278,750	0.009	0.007	81,735	66,738
1994	70,050	86,275	252,335	309,616	0.007	0.006	65,372	75,199
1995	82,083	99,781	268,385	326,211	0.021	0.018	31,195	61,039
1996	93,154	112,136	280,071	337,877	0.030	0.025	38,729	138,369
1997	102,278	122,223	287,160	344,702	0.033	0.028	39,165	151,075
1998	109,113	129,625	293,187	350,402	0.031	0.025	44,678	88,732
1999	114,256	134,973	295,965	352,169	0.036	0.030	35,709	109,736
2000	117,291	137,992	310,752	369,214	0.033	0.027	82,423	222,337
2001	119,911	140,535	329,882	391,194	0.033	0.028	90,564	138,211
2002	122,574	143,211	337,931	399,305	0.035	0.029	53,240	207,952
2003	125,886	146,719	347,970	410,347	0.031	0.026	65,058	113,829
2004	131,016	152,218	381,541	448,656	0.030	0.026	136,572	165,379
2005	137,226	158,925	401,015	469,645	0.028	0.024	84,404	67,722
2006	144,942	167,196	435,436	506,919	0.031	0.027	130,923	110,798
2007	153,035	175,850	450,015	521,048	0.029	0.025	70,302	84,172
2008	162,315	185,627	474,058	545,715	0.026	0.023	103,374	198,643
2009	172,309	195,869	478,657	547,383	0.027	0.024	40,939	145,129
2010	181,670	205,126	488,421	554,810	0.032	0.028	69,459	215,364
2011	188,674	211,665	488,659	551,694	0.029	0.026	52,204	70,905
2012	194,781	216,967	514,137	574,876	0.029	0.026	133,187	139,657
2013	199,444	220,585	527,685	587,001	0.025	0.022	89,983	51,312
2014	204,539	224,485	559,205	617,198	0.031	0.029	142,020	121,218
2015	208,180	226,878	556,392	610,830	0.033	0.031	41,239	83,036
2016	212,054	229,510	563,791	616,146	0.041	0.037	87,591	108,719
2017	214,103	230,379	548,331	595,937	0.043	0.040	31,272	73,482
2018	214,812	229,894	543,353	588,121	0.045	0.042	76,758	239,024
2019	205,292	227,341	529,266	570,619	0.045	0.045	51,040	119,324
2020		213,505		557,446		0.044		84,073

Table 9-16. Estimates of key parameters with Hessian estimates of standard deviation (σ), MCMC standard deviations (σ(MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations.

Parameter	μ	μ (MCMC)	Median (MCMC)	σ	σ(MCMC)	BCI-Lower	BCI-Upper
q	1.80	1.88	1.83	0.38	0.41	1.20	2.82
M	0.076	0.079	0.079	0.006	0.007	0.066	0.093
$F_{40\%}$	0.100	0.124	0.115	0.027	0.047	0.065	0.242
2020 SSB	207,010	213,320	208,064	46,957	47,994	132,805	320,443
2020 ABC	36,177	45,820	41,847	12,715	19,630	20,516	93,338

Table 9-17. Estimated time series of recruitment, female spawning biomass, and total biomass (2+) for POP in the GOA. Columns headed with 2.5% and 97.5% represent the lower and upper 95% credible intervals from the MCMC estimated posterior distribution.

	Recruits (age-2)			Total Biomass			Spawning Biomass		
Year	Mean	2.50%	97.50%	Mean	2.50%	97.50%	Mean	2.50%	97.50%
1977	37,131	10,814	96,380	139,557	103,015	221,223	40,061	27,521	67,431
1978	58,312	17,718	132,849	127,105	89,563	209,736	35,843	22,673	64,305
1979	44,463	12,982	109,833	128,997	90,019	212,690	36,619	22,969	65,586
1980	39,143	12,342	94,230	130,787	90,717	214,538	37,066	22,925	67,045
1981	40,614	12,359	95,023	130,187	88,985	215,955	36,255	21,894	66,161
1982	52,026	16,203	118,813	130,515	87,980	217,807	35,417	20,669	65,164
1983	53,390	16,096	125,995	136,747	92,583	227,052	36,779	21,629	66,548
1984	55,555	18,281	126,689	146,274	100,319	240,053	39,539	23,951	69,520
1985	80,342	27,704	177,287	157,455	109,400	254,107	42,759	26,755	73,427
1986	120,774	48,451	248,549	173,961	122,958	274,590	47,141	30,706	78,310
1987	112,743	40,586	236,391	192,052	136,894	299,777	51,235	34,086	83,135
1988	176,121	84,046	339,926	213,576	152,082	330,912	54,586	36,762	87,402
1989	138,034	54,183	282,041	234,856	166,164	365,983	56,600	37,946	90,447
1990	109,953	41,303	223,296	255,207	178,432	399,748	57,924	38,169	92,927
1991	54,357	16,403	127,571	273,300	188,338	430,825	59,896	38,816	96,914
1992	65,054	23,476	139,142	296,389	204,642	464,449	66,091	43,064	106,257
1993	66,738	24,320	144,824	316,680	219,728	493,677	74,354	49,056	118,597
1994	75,199	26,692	156,767	338,855	236,650	522,924	86,275	58,148	135,886
1995	61,039	19,824	144,987	357,909	251,978	547,511	99,780	68,049	154,717
1996	138,369	61,867	275,795	373,233	263,772	565,532	112,136	76,949	173,003
1997	151,075	65,863	302,880	387,261	273,741	586,327	122,223	84,101	187,561
1998	88,732	26,909	208,835	399,718	281,697	604,942	129,625	88,867	198,105
1999	109,736	37,609	241,155	413,519	292,495	624,651	134,973	92,601	205,539
2000	222,337	115,490	437,046	430,958	304,515	651,437	137,992	94,207	209,118
2001	138,211	44,311	302,387	450,430	319,295	681,805	140,535	96,054	212,510
2002	207,952	98,321	422,052	474,168	336,098	716,812	143,211	97,829	216,393
2003	113,829	34,092	263,822	497,124	351,769	749,435	146,719	100,044	221,619
2004	165,379	72,105	332,443	522,868	371,034	786,760	152,218	103,794	229,064
2005	67,722	19,043	178,987	544,235	386,501	819,809	158,925	108,666	238,083
2006	110,798	41,670	239,903	563,705	400,158	849,158	167,196	114,556	250,507
2007	84,172	25,051	211,101	576,546	409,185	866,829	175,850	120,497	264,314
2008	198,643	91,220	421,661	591,107	418,336	890,701	185,627	127,699	278,982
2009	145,129	46,410	331,424	605,337	430,093	912,827	195,869	134,721	294,363
2010	215,364	95,686	439,787	622,256	442,934	937,649	205,126	141,552	308,646
2011	70,905	17,624	193,217	633,599	451,254	953,942	211,665	145,691	318,396
2012	139,657	50,221	312,245	646,399	460,095	975,930	216,967	150,155	325,899
2013	51,312	13,127	151,492	653,747	464,832	987,209	220,584	152,545	331,124
2014	121,218	37,268	301,904	660,936	468,927	995,856	224,485	155,316	336,079
2015	83,036	20,718	237,985	659,858	466,602	995,704	226,878	156,704	340,121
2016	108,719	25,063	312,763	655,783	458,995	990,909	229,510	158,488	344,925
2017	73,482	16,940	264,175	644,375	448,236	977,229	230,379	156,975	349,679
2018	239,024	55,892	744,731	636,959	440,348	975,291	229,894	155,334	349,791
2019	119,324	23,832	439,368	629,149	429,278	971,121	227,341	151,620	347,965
2020	84,073	16,253	387,443	620,447	417,554	968,923	213,505	139,117	330,765
2021	109,759	22,334	382,760	613,260	406,663	969,213	207,010	132,805	320,443
2022	109,759	21,249	375,263	597,190	397,806	933,302	198,020	125,747	297,959

Table 9-18. Estimated numbers (thousands) in 2020, fishery selectivity (from the most recent time block), and survey selectivity of POP in the GOA. Also shown are schedules of age specific weight and female maturity.

Age	Numbers in 2020 (1000's)	Maturity (%)	Weight (g)	Fishery selectivity (%)	Survey selectivity (%)
2	84,073	0.7	44	0.1	9.7
3	110,602	1.3	98	1.0	15.3
4	205,240	2.5	167	3.7	23.5
5	58,345	4.7	243	9.0	34.2
6	79,556	8.8	321	16.9	46.8
7	55,725	15.8	396	26.9	59.8
8	74,157	26.9	466	38.3	71.6
9	28,431	41.8	530	50.3	81.0
10	69,644	58.4	586	62.0	87.8
11	31,649	73.3	636	72.8	92.4
12	85,668	84.3	678	82.0	95.4
13	51,287	91.3	715	89.5	97.2
14	62,250	95.3	746	95.0	98.3
15	23,376	97.6	772	98.5	99.0
16	27,283	98.7	794	100.0	99.4
17	14,809	99.3	812	99.8	99.7
18	32,198	99.7	828	98.1	99.8
19	19,787	99.8	840	95.0	99.9
20	32,349	99.9	851	91.0	99.9
21	19,261	100	860	86.1	100.0
22	27,758	100	867	80.7	100.0
23	12,265	100	873	75.0	100.0
24	8,875	100	878	69.1	100.0
25	13,530	100	882	63.2	100.0
26	11,119	100	885	57.4	100.0
27	4,418	100	888	51.8	100.0
28	4,928	100	890	46.5	100.0
29+	51,729	100	897	41.5	100.0

Table 9-19. Set of projections of spawning biomass and yield for POP in the GOA. This set of projections encompasses six harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see ***Projections and Harvest Alternatives***. All units in t. $B_{40\%}$ = 126,814 t, $B_{35\%}$ = 110,962 t, $F_{40\%}$ = 0.10, and $F_{35\%}$ = 0.12.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2020	213,530	213,530	213,530	213,530	213,530	213,530	213,530
2021	206,607	207,096	209,297	208,657	212,031	205,556	206,607
2022	196,331	198,179	206,488	204,032	217,233	192,478	196,331
2023	187,468	190,068	204,237	200,128	222,726	181,278	186,538
2024	180,465	182,821	203,044	197,451	228,976	172,342	177,035
2025	175,302	177,423	203,004	196,088	236,121	165,568	169,727
2026	171,382	173,277	203,640	195,552	243,752	160,281	163,943
2027	167,830	169,513	204,086	195,022	251,052	155,565	158,769
2028	164,104	165,590	203,762	193,947	257,383	150,870	153,658
2029	160,259	161,564	202,700	192,378	262,720	146,245	148,661
2030	156,522	157,665	201,763	190,559	267,265	141,899	143,986
2031	153,086	154,086	200,710	188,729	271,278	138,001	139,800
2032	150,015	150,890	199,279	186,996	274,887	134,620	136,157
2033	147,337	148,103	198,118	185,434	278,214	131,790	133,090
			Fishing mortality				
2020	0.064	0.064	0.064	0.064	0.064	0.064	0.064
2021	0.100	0.091	0.050	0.062	-	0.120	0.120
2022	0.100	0.090	0.050	0.062	-	0.120	0.120
2023	0.100	0.100	0.050	0.062	-	0.120	0.120
2024	0.100	0.100	0.050	0.062	-	0.120	0.120
2025	0.100	0.100	0.050	0.062	-	0.120	0.120
2026	0.100	0.100	0.050	0.062	-	0.120	0.120
2027	0.100	0.100	0.050	0.062	-	0.120	0.120
2028	0.100	0.100	0.050	0.062	-	0.120	0.120
2029	0.100	0.100	0.050	0.062	-	0.120	0.120
2030	0.100	0.100	0.050	0.062	-	0.120	0.120
2031	0.100	0.100	0.050	0.062	-	0.120	0.120
2032	0.100	0.100	0.050	0.062	-	0.119	0.119
2033	0.100	0.100	0.050	0.062	-	0.118	0.118
			Yield (t)				
2020	24,235	24,235	24,235	24,235	24,235	24,235	24,235
2021	36,177	36,177	18,442	22,712	-	42,977	36,177
2022	34,365	34,602	18,190	22,203	-	40,227	34,365
2023	32,826	33,279	17,990	21,776	-	37,912	39,005
2024	31,573	31,976	17,851	21,447	-	36,032	36,987
2025	30,558	30,911	17,762	21,197	-	34,512	35,337
2026	29,704	30,010	17,695	20,990	-	33,246	33,950
2027	28,965	29,228	17,635	20,806	-	32,164	32,760
2028	28,321	28,544	17,580	20,640	-	31,233	31,732
2029	27,734	27,923	17,514	20,474	-	30,406	30,821
2030	27,211	27,370	17,444	20,313	-	29,682	30,026
2031	26,738	26,870	17,363	20,151	-	29,002	29,308
2032	26,325	26,435	17,281	19,998	-	28,294	28,591
2033	25,952	26,045	17,195	19,850	-	27,624	27,893

*Projected ABCs and OFLs for 2021 and 2022 are derived using estimated catch of 24,235 for 2020, and projected catches of 32,989 t and 31,337 t for 2021 and 2022 based on realized catches from 2017-2019. This calculation is in response to management requests to obtain more accurate projections.

Table 9-20. Summary of ecosystem considerations for GOA POP.

Ecosystem effects on *GOA POP*

Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Primary contents of stomach	Important for all life stages, no time series	Unknown
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, ling cod, rockfish, arrowtooth)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment

***GOA POP* fishery effects on ecosystem**

Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several month starting 2007
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-targets rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies initiated in 2005 and ongoing

Table 9-21. GOA rockfish ex-vessel market data. Total and retained catch (thousand metric tons), number of vessels, catcher vessel share of retained catch, value (million US$), price (US$ per pound), Central Gulf's share of GOA rockfish retained catch, and Pacific ocean perch, northern rockfish, and dusk rockfish share of GOA rockfish retained catch; 2010-2014 average and 2015-2019.

	Avg 10-14	2015	2016	2017	2018	2019
Total catch K mt	25.96	29	33.9	31.8	34.2	34.2
Retained catch K mt	23.6	26.7	30.8	26.9	31.4	30.8
Catcher Processors #	13.2	8	12	11	9	9
Catcher Vessels #	176.6	171	233	208	189	181
Catcher Vessel Share of Retained	46%	46%	49%	42%	47%	48%
Ex-vessel value M US$	$11.3	$12.4	$13.9	$12.1	$14.8	$14.5
Ex-vessel price US$/lb	$0.224	$0.227	$0.225	$0.226	$0.239	$0.238
Central Gulf share of GOA rockfish catch	74%	84%	87%	84%	84%	81%
Pac. Ocn. Perch share of GOA rockfish catch	59%	65%	67%	73%	72%	74%
Northern rockfish share of GOA rockfish catch	18%	15%	12%	7%	8%	9%
Dusky rockfish share of GOA rockfish catch	13%	11%	11%	10%	10%	8%

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 9-22. GOA rockfish first-wholesale market data. Production (thousand metric tons), value (million US$), price (US$ per pound), Pacific ocean perch, northern rockfish and dusky rockfish share of GOA rockfish value and price (US$ per pound), and head-and-gut share of value; 2010-2014 average and 2015-2019.

	Avg 10-14	2015	2016	2017	2018	2019
First-wholesale production K mt	12.95	14.55	18.10	14.55	17.94	16.84
First-wholesale value M US$	$35.54	$34.20	$40.00	$39.20	$45.40	$33.70
First-wholesale price/lb US$	$1.245	$1.066	$1.002	$1.222	$1.148	$0.908
Pac. Ocn. perch share of value	59%	63%	62%	72%	71%	71%
Pac. Ocn. perch price/lb US$	$1.18	$0.96	$0.83	$1.15	$1.06	$0.83
Northern rockfish share of value	16%	11%	12%	5%	6%	7%
Northern rockfish price/lb US$	$1.14	$0.98	$1.38	$1.03	$1.03	$0.83
Dusky rockfish share of value	11%	11%	12%	8%	8%	8%
Dusky rockfish price/lb US$	$1.18	$1.20	$1.31	$1.02	$1.15	$0.88
H&G share of value	76%	74%	70%	79%	82%	77%

Source: NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 9-23. Rockfish U.S. trade and global market data. Global production of rockfish and Pacific Ocean perch (thousand metric tons), U.S. Pacific ocean perch shares of global production, export volume (thousand metric tons), value (million US$) and price (US$ per pound), China's share of Pacific Ocean perch export value and the Chinese Yaun/U.S. Dollar exchange rate; 2010-2014 average and 2015-2019..

	Avg 10-14	2015	2016	2017	2018	2019
Global production of rockfish K mt	285.6	301.4	313.1	317.4	336.6	-
Global production of Pac. Ocn. perch K mt	46.0	55.5	58.5	56.6	59.5	-
U.S. share of global Pac. Ocn. perch	85.8%	86.6%	88.5%	89.6%	94.4%	-
U.S. Pac. Ocn. perch share of global rockfish	13.8%	16.0%	16.5%	16.0%	16.7%	-
Export volume of Pac. Ocn. perch K mt	15.2	22.7	25.6	22.7	27.8	27.3
Export value of Pac. Ocn. perch M US$	$43.1	$77.7	$84.6	$76.1	$89.5	$82.3
Export price/lb of Pac. Ocn. perch US$	$1.29	$1.55	$1.50	$1.52	$1.46	$1.37
China's share of U.S. Pac. Ocn. perch export value	59%	52%	67%	55%	62%	71%
Exchange rate, Yuan/Dollar	6.38	6.23	6.64	6.76	6.62	6.91

Source: FAO Fisheries & Aquaculture Dept. Statistics http://www.fao.org/fishery/statistics/en. U.S. Department of Agriculture http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx.

Figures

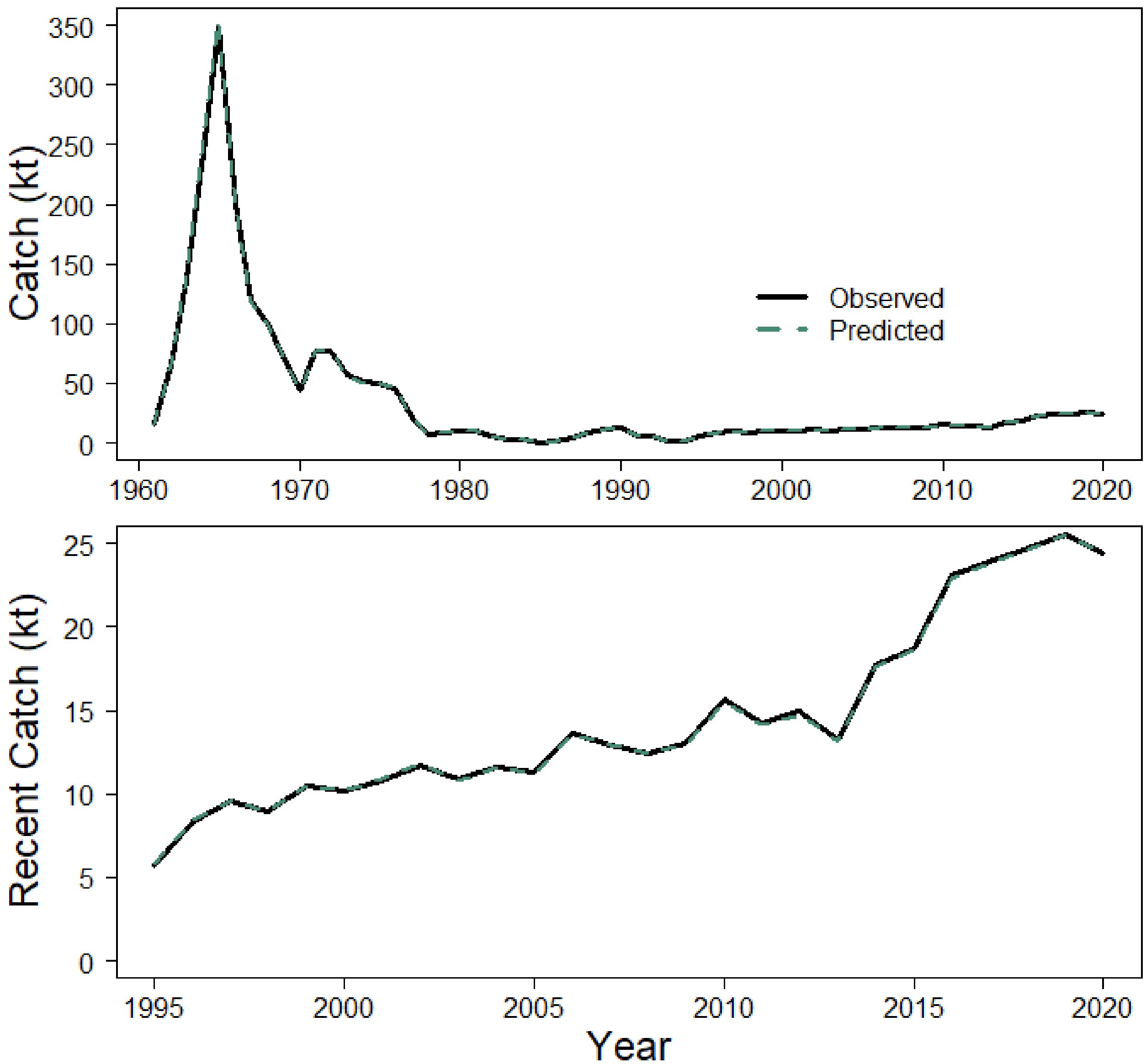

Figure 9-1. Estimated and observed long-term (top figure) and short-term (bottom figure) catch history for GOA POP.

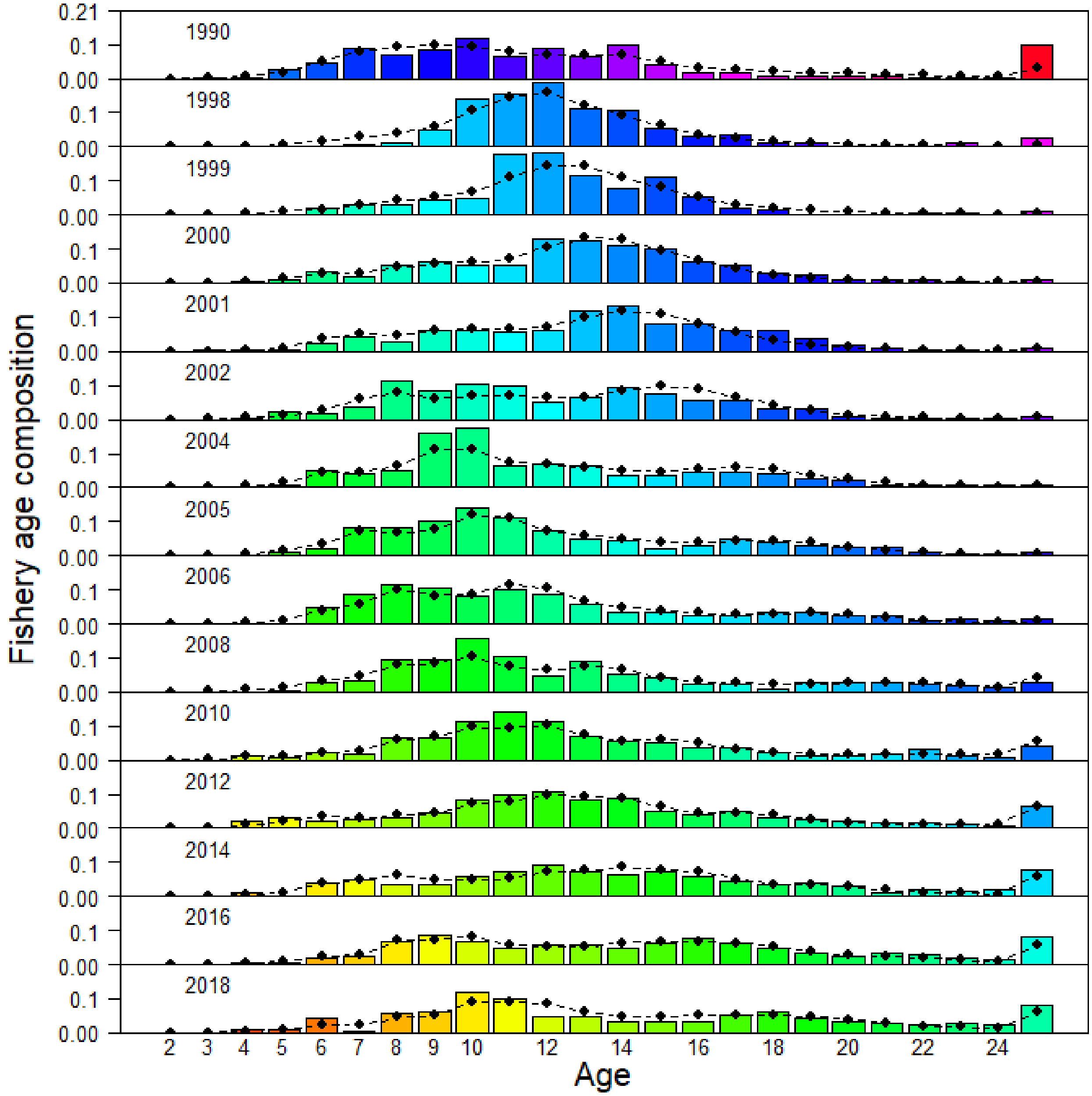

Figure 9-2. Fishery age compositions for GOA POP. Observed = bars, actual age composition predicted from author recommended model = line with circles. Colors follow cohorts.

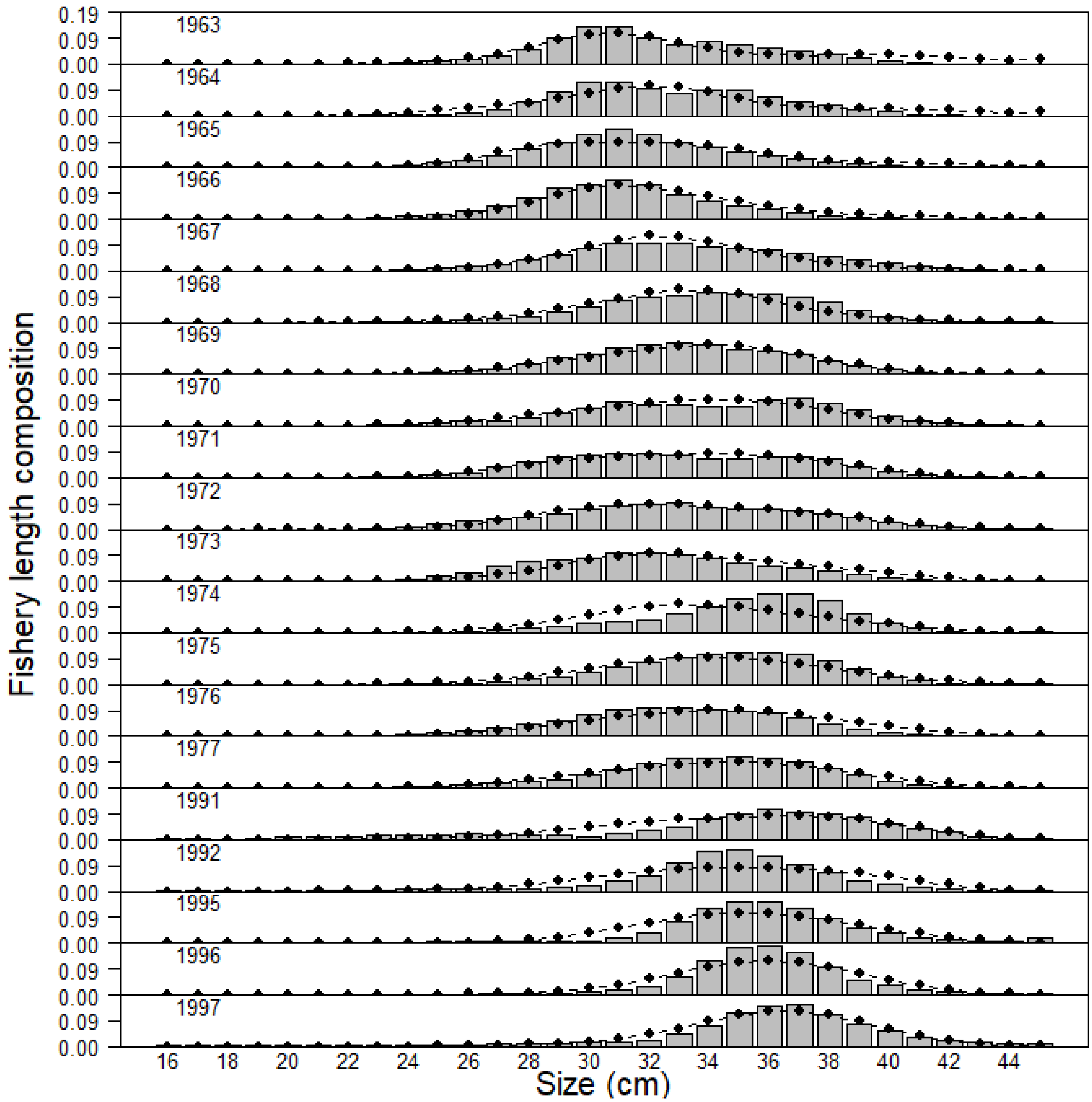

Figure 9-3. Fishery length (cm) compositions for GOA POP. Observed = bars, predicted from author recommended model = line with circles.

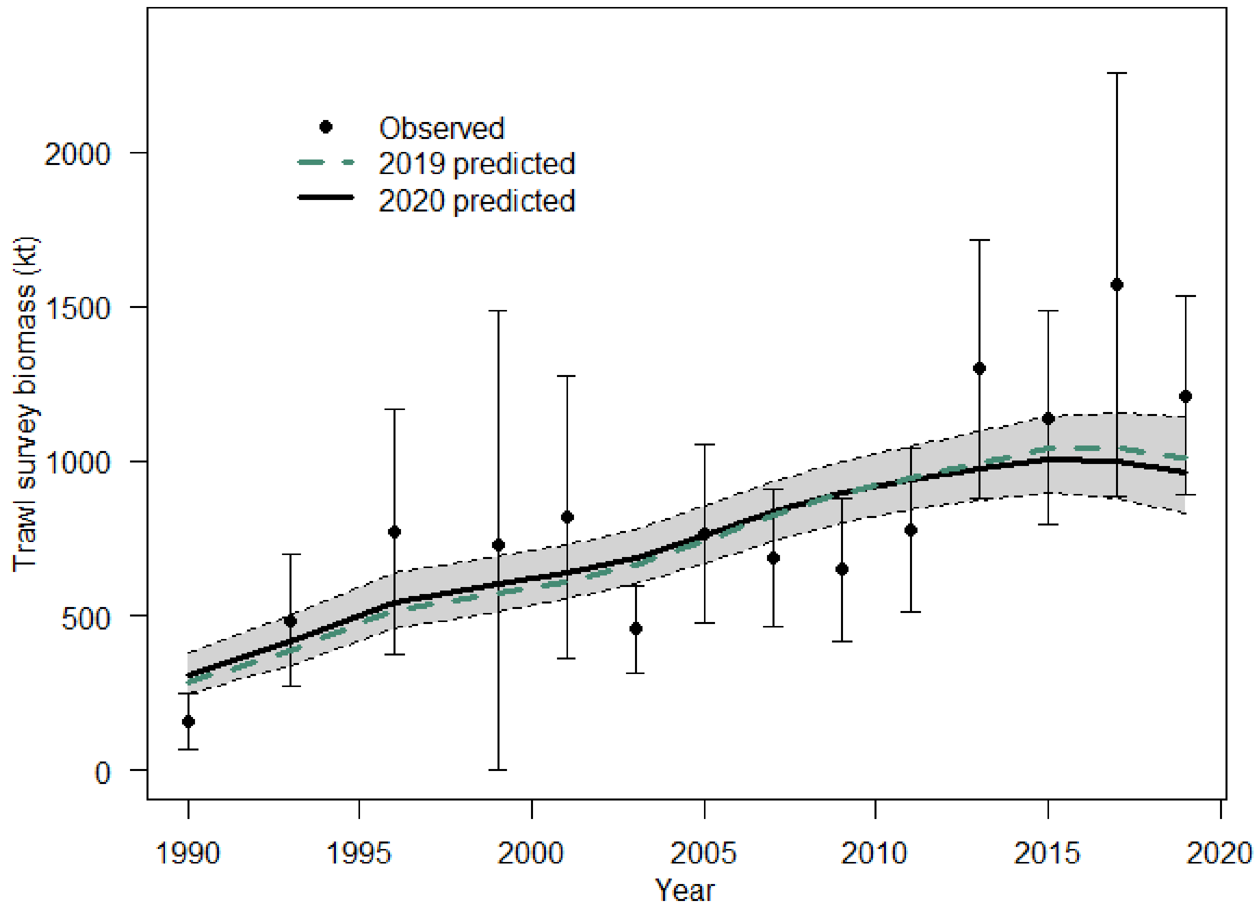

Figure 9-4. NMFS Groundfish Survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for GOA POP. Predicted estimates from the recommended model (black line, with 95% confidence intervals shown in grey shaded region) compared with last year's model fit (green dotted line).

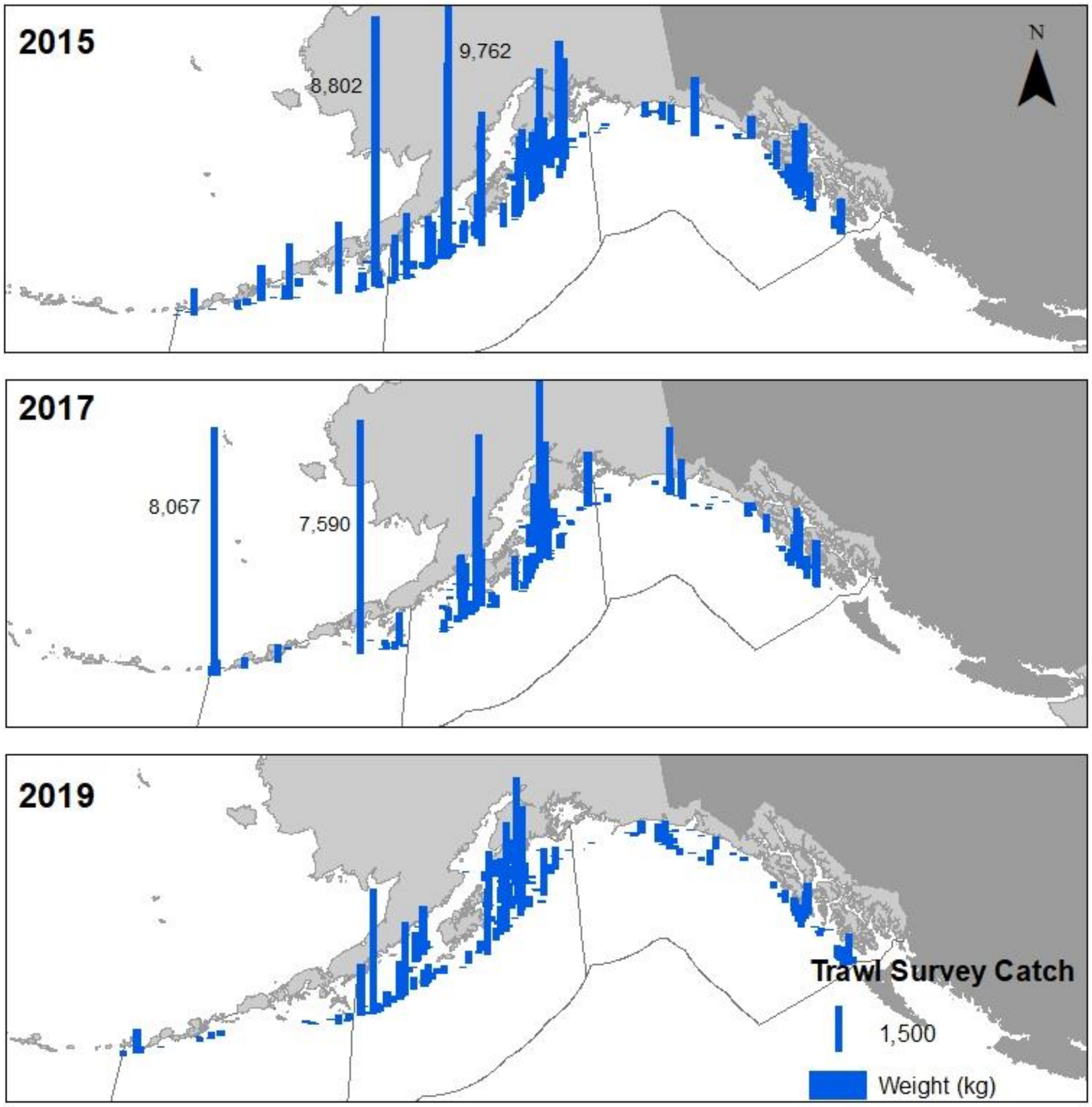

Figure 9-5. Distribution of GOA POP catches in the 2015-2019 GOA groundfish surveys.

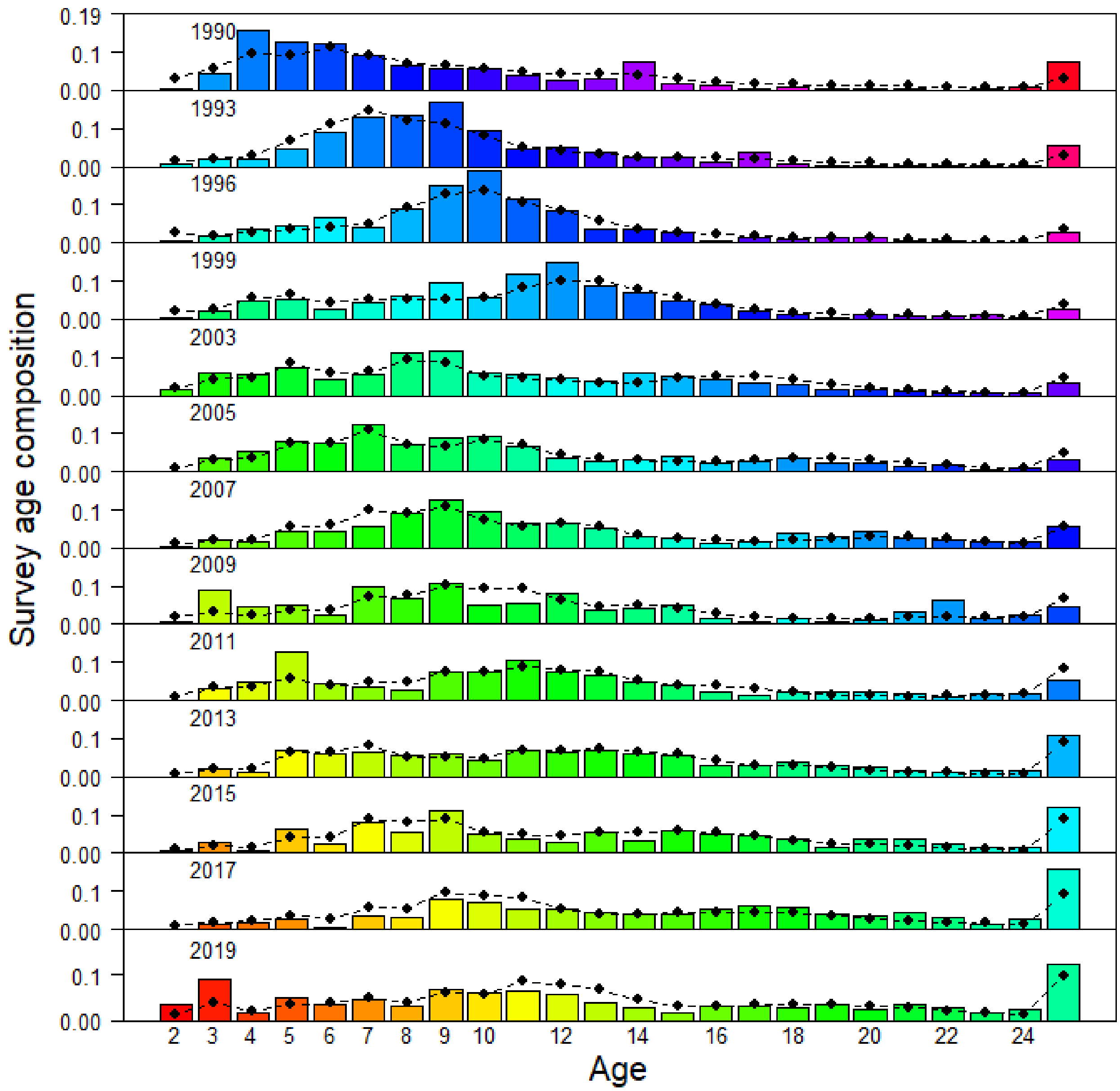

Figure 9-6. Groundfish survey age compositions for GOA POP. Observed = bars, actual age composition predicted from author recommended model = line with circles.

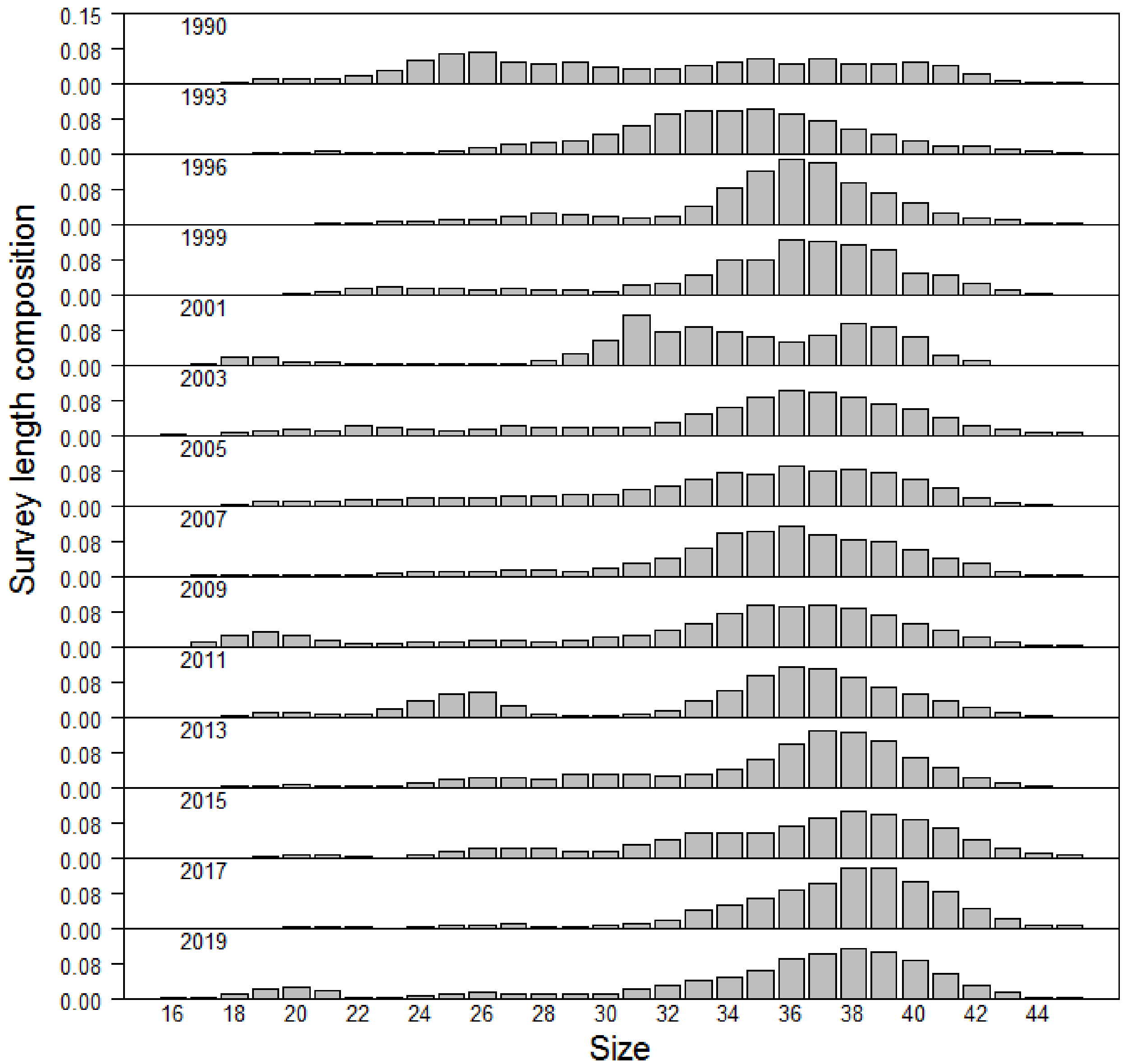

Figure 9-7. Groundfish survey length compositions for GOA POP. Observed = bars. Survey size not used in POP model because survey ages are available for these years.

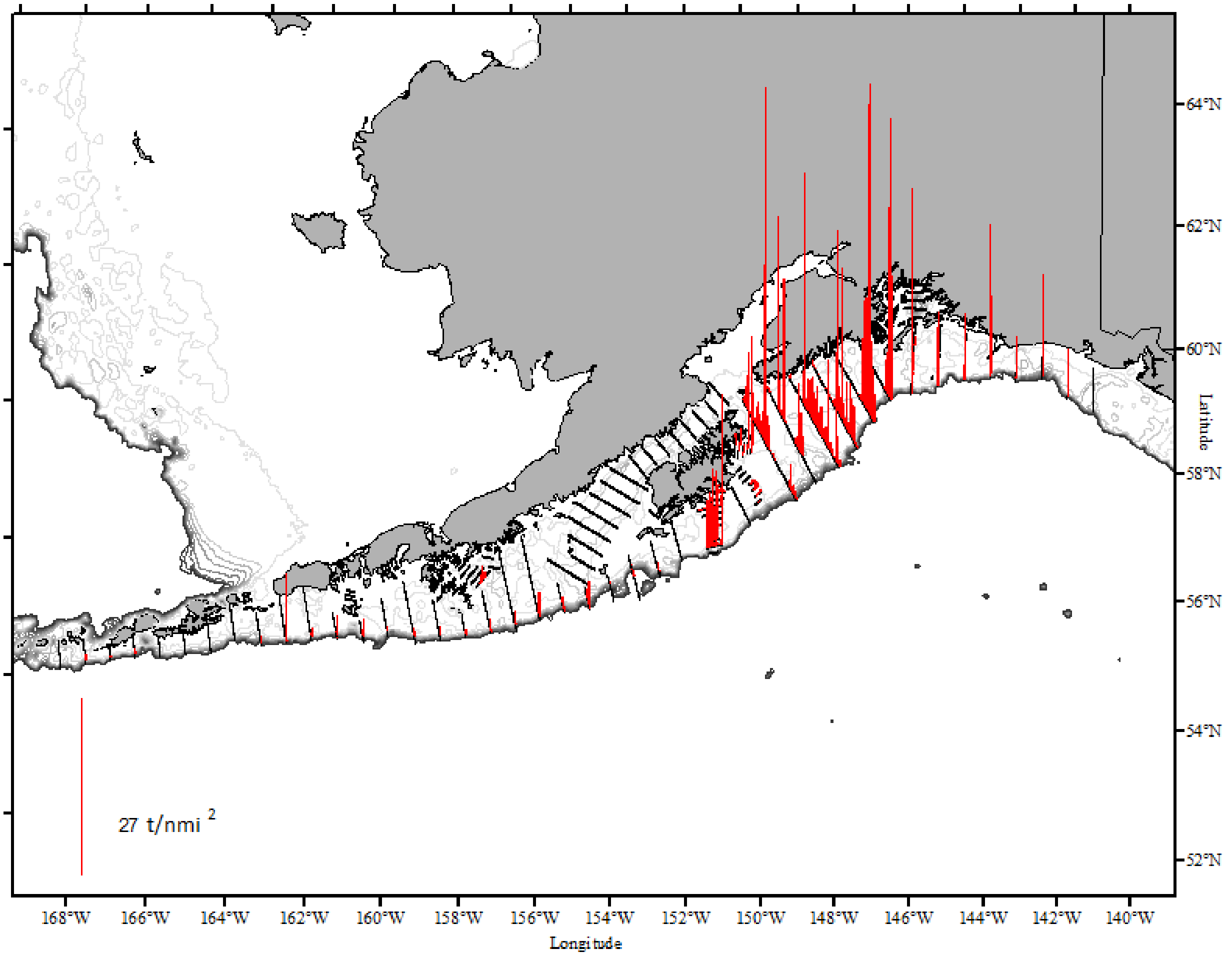

Figure 9-8. Density (t/nmi^2) of POP observed during the 2019 GOA acoustic-trawl survey.

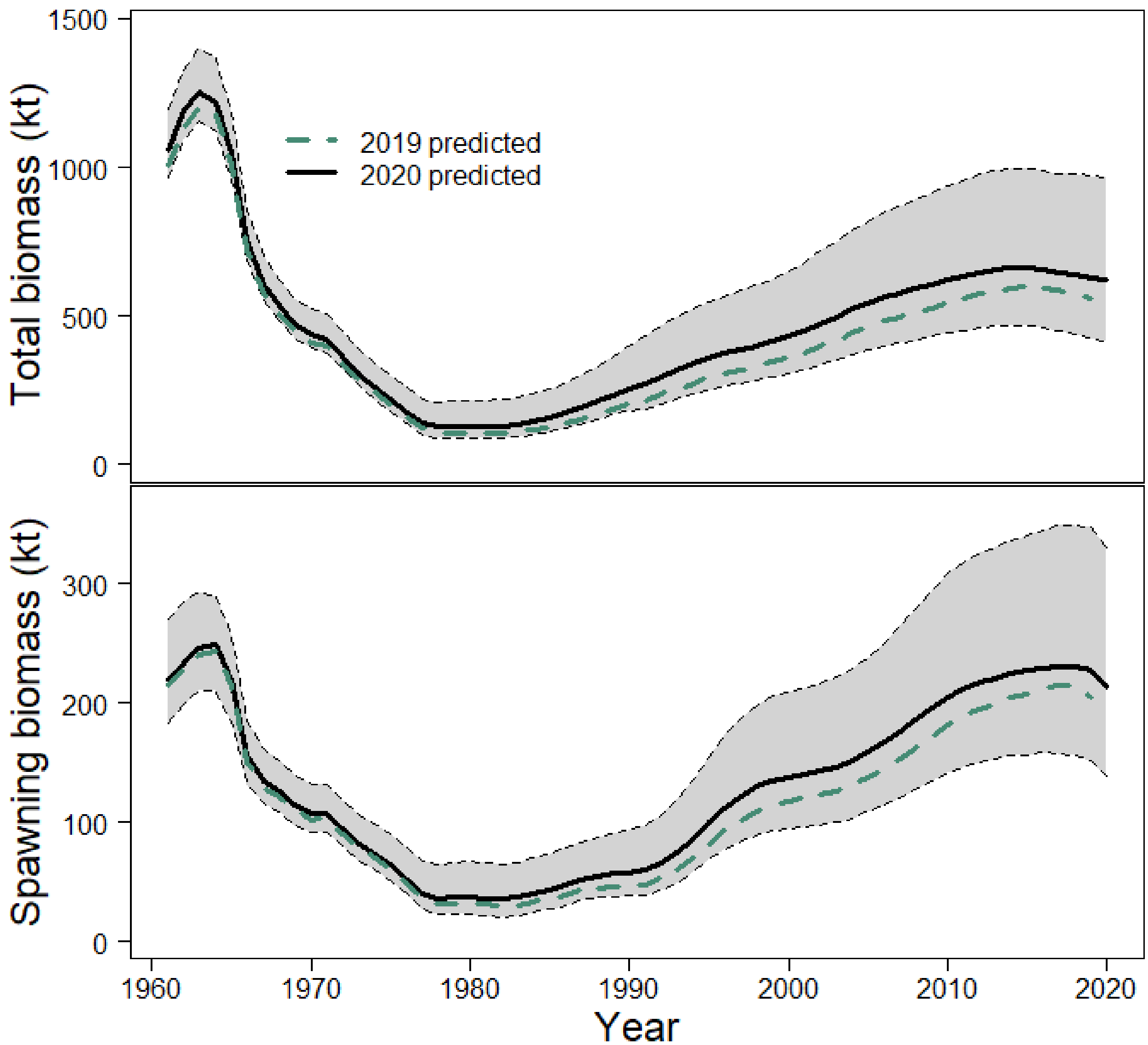

Figure 9-9. Model estimated total biomass (top panel, solid black line) and spawning biomass (bottom panel) with 95% credible intervals determined by MCMC (light grey region) for GOA POP. Last year's model estimates included for comparison (dashed line).

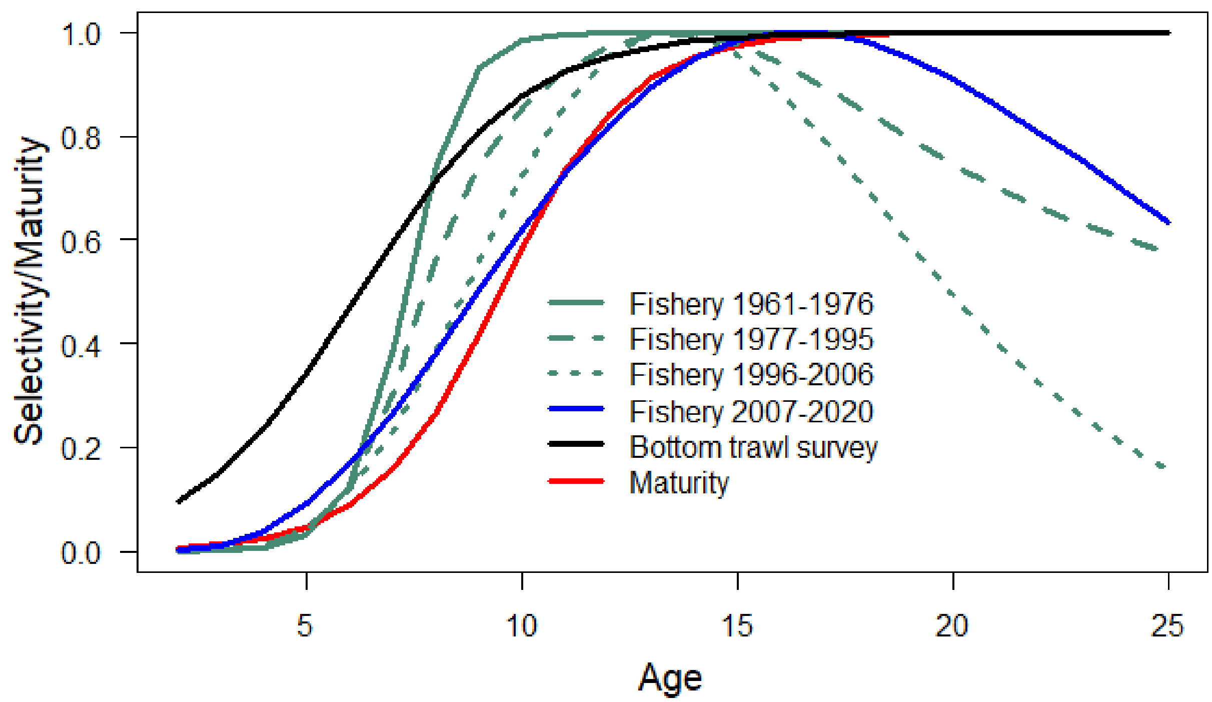

Figure 9-10. Estimated selectivities for the fishery and groundfish survey with maturity for GOA POP.

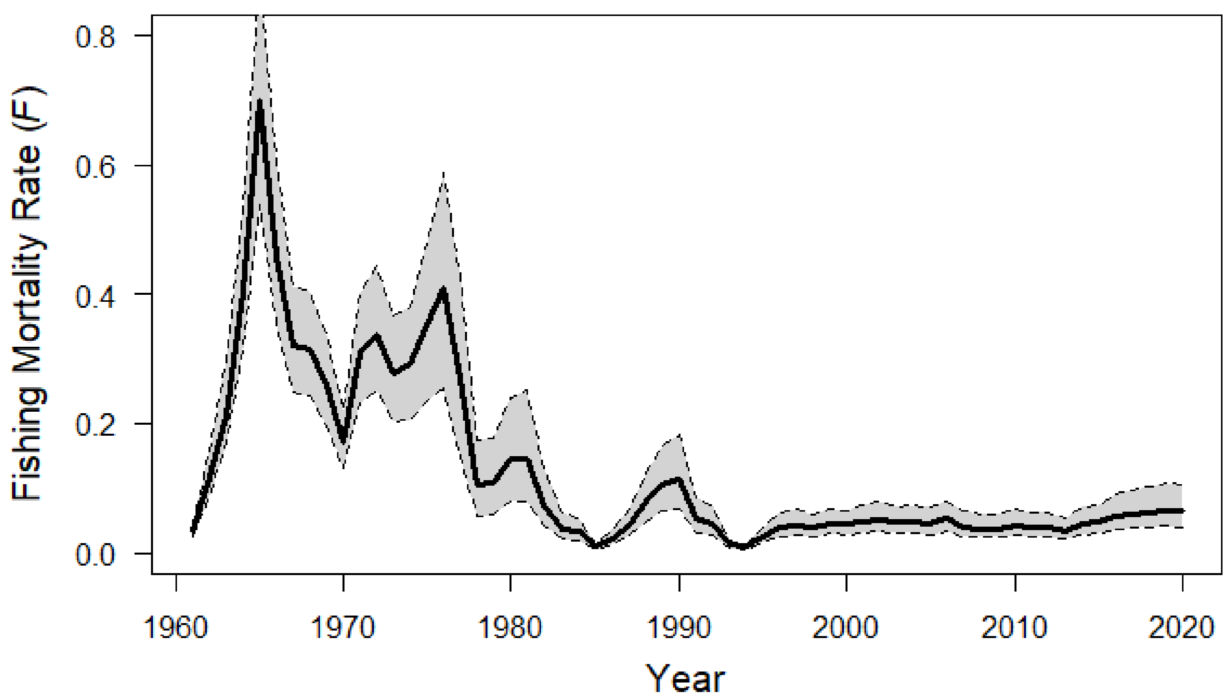

Figure 9-11. Estimated fully selected fishing mortality over time with 95% credible intervals determined by MCMC (light grey region) for GOA POP.

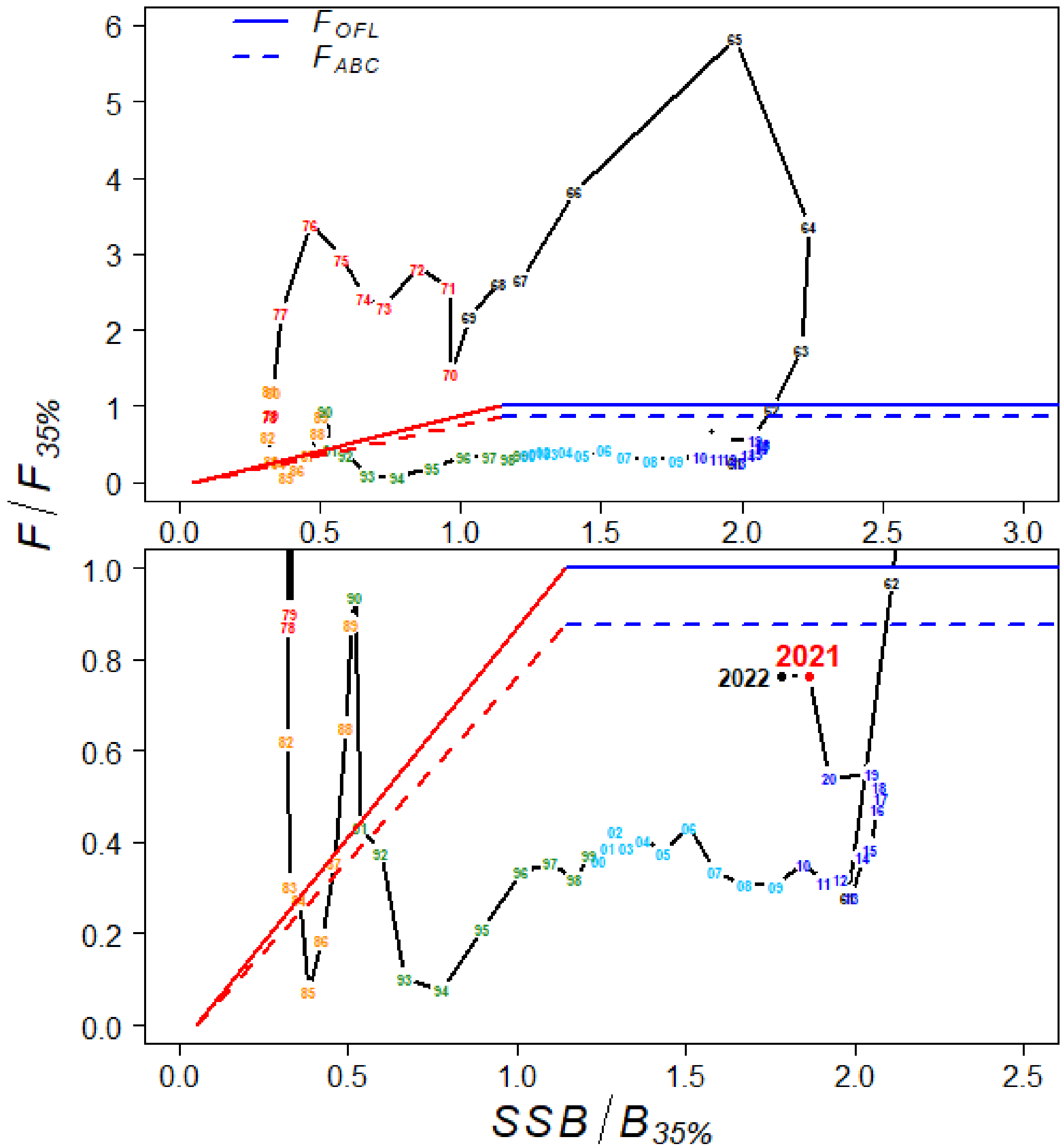

Figure 9-12. Time series of POP estimated spawning biomass relative to the target level B35% level and fishing mortality relative to F35% for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.

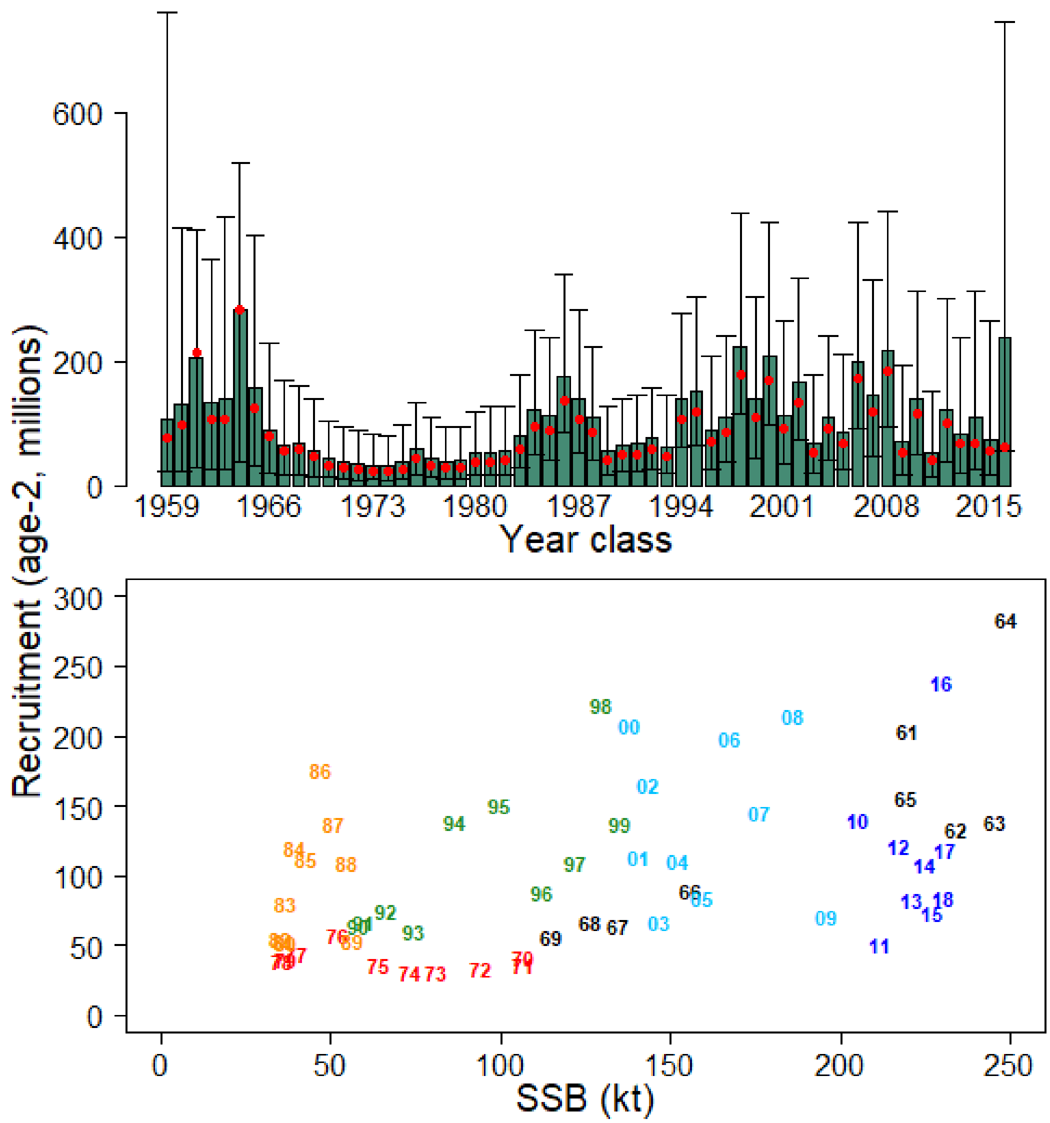

Figure 9-13. Estimated recruitment of GOA POP (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimated recruits per spawning stock biomass (bottom). Red circles in top graph are last year's estimates for comparison.

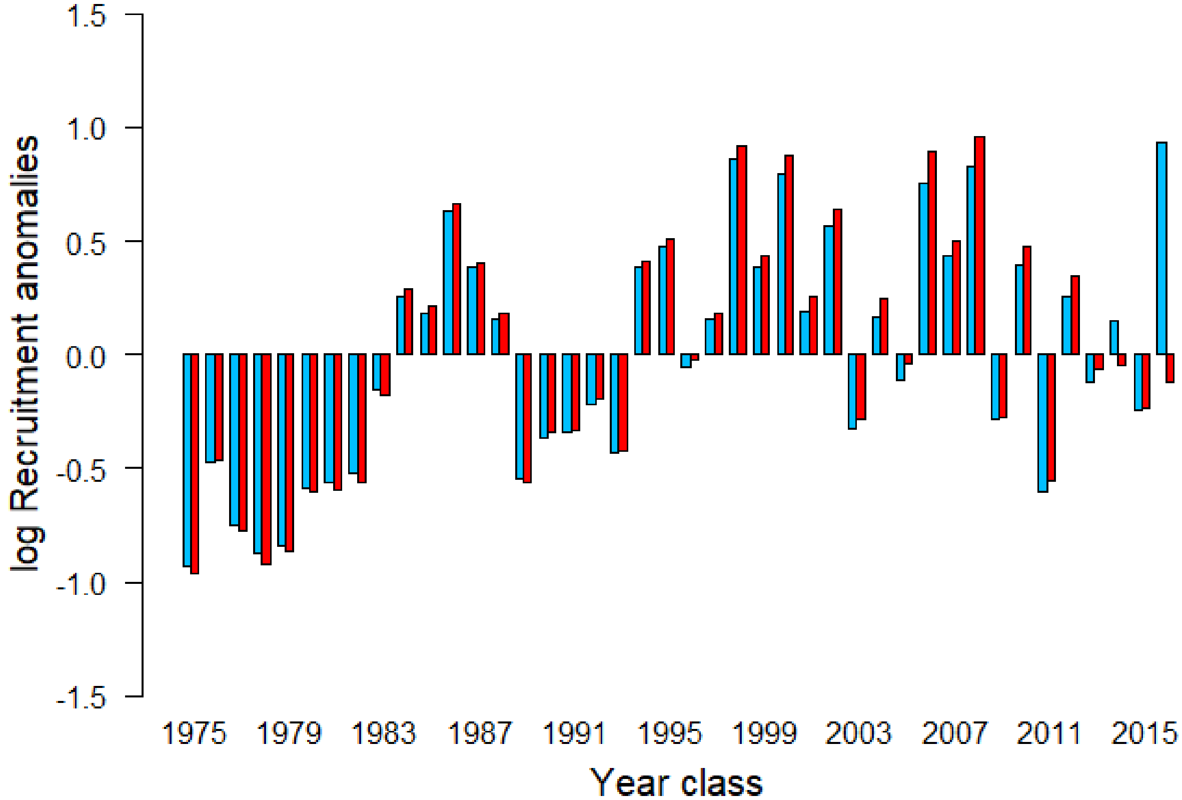

Figure 9-14. Recruitment deviations from average on the log-scale comparing last cycle's model (red) to current year recommended model (blue) for GOA POP.

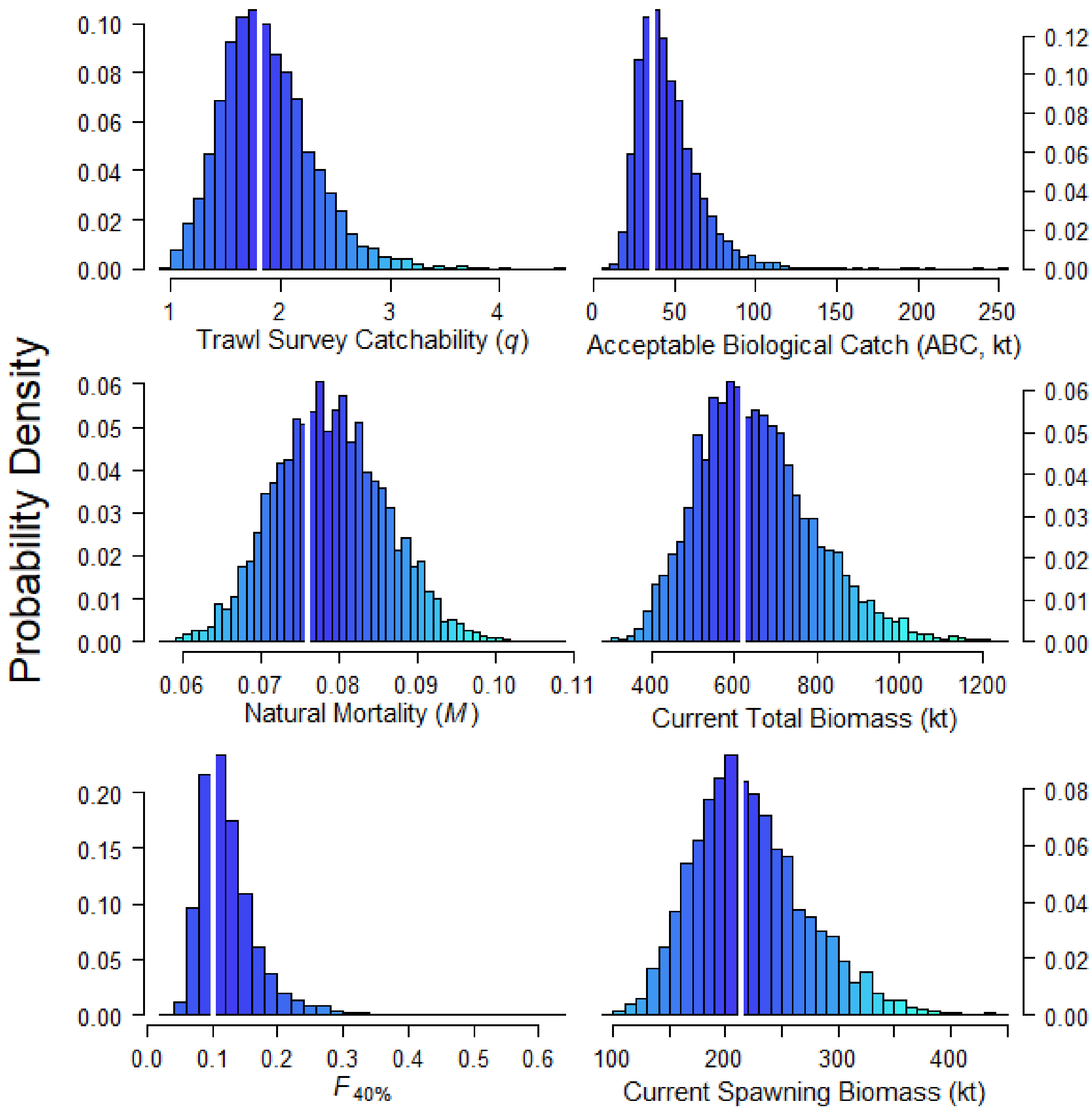

Figure 9-15. Histograms of estimated posterior distributions of key parameters derived from MCMC for GOA POP. The vertical white lines are the recommended model estimates.

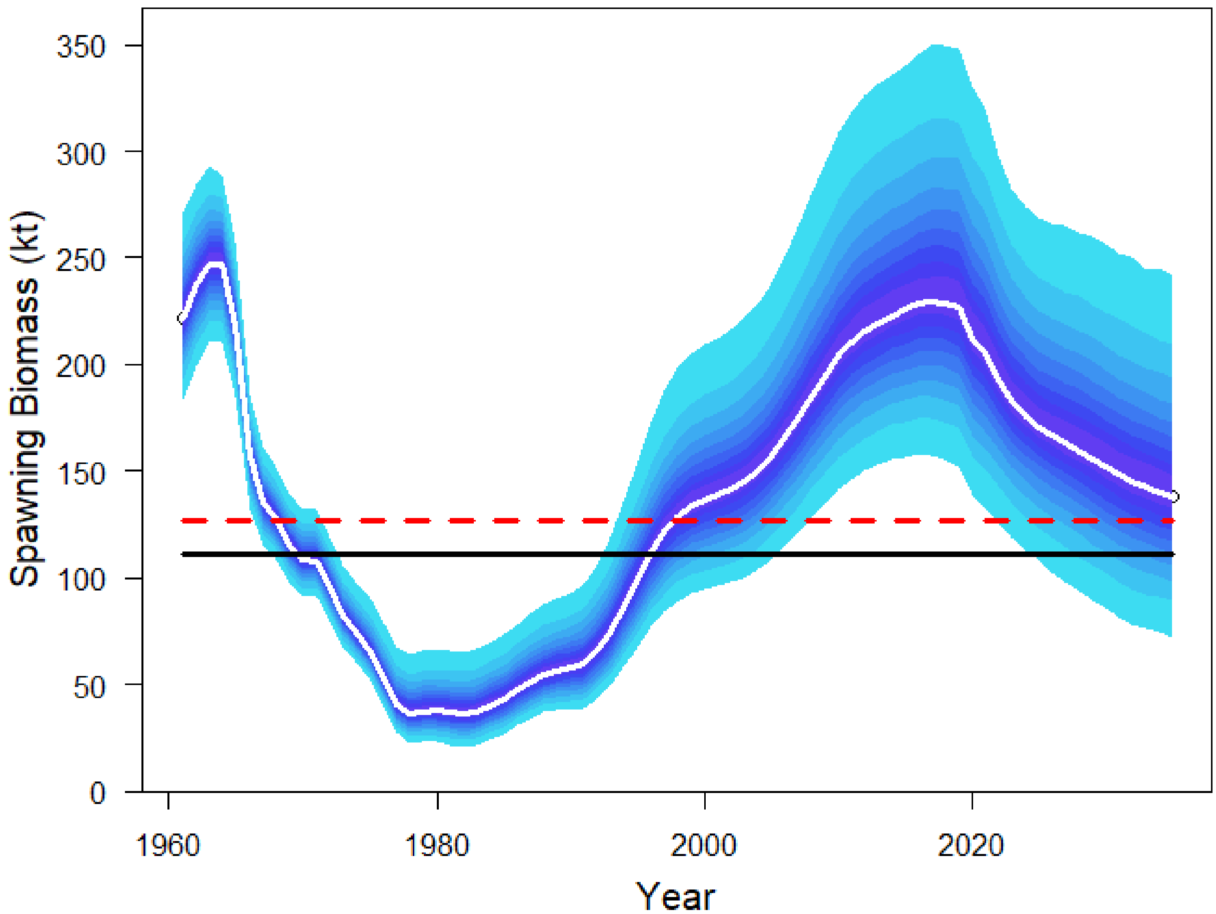

Figure 9-16. Bayesian credible intervals for entire spawning stock biomass series including projections through 2030. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2015. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

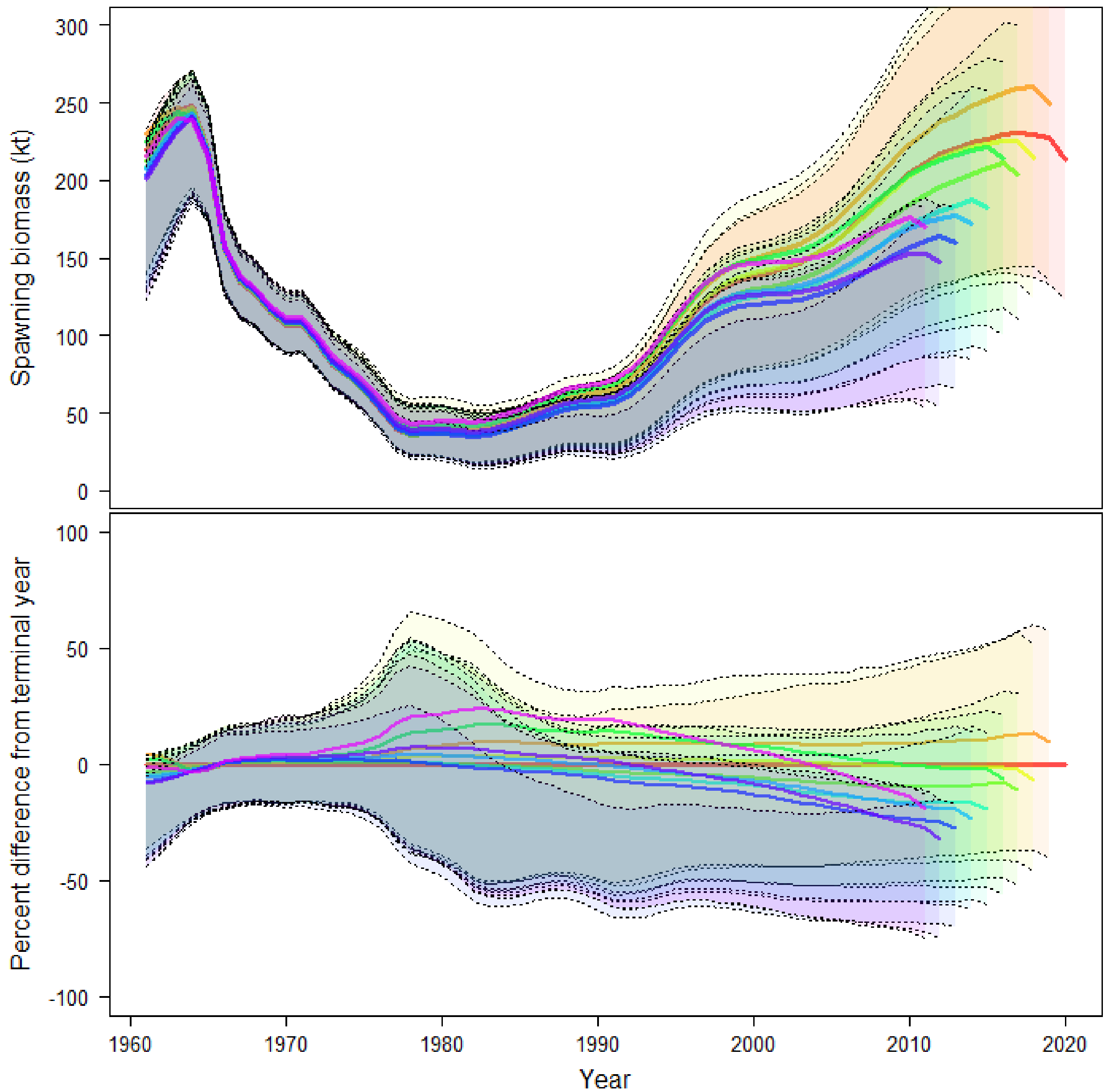

Figure 9-17. Retrospective peels of estimated female spawning biomass for the past 10 years from the recommended model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the recommended model in the terminal year with 95% credible intervals from MCMC.

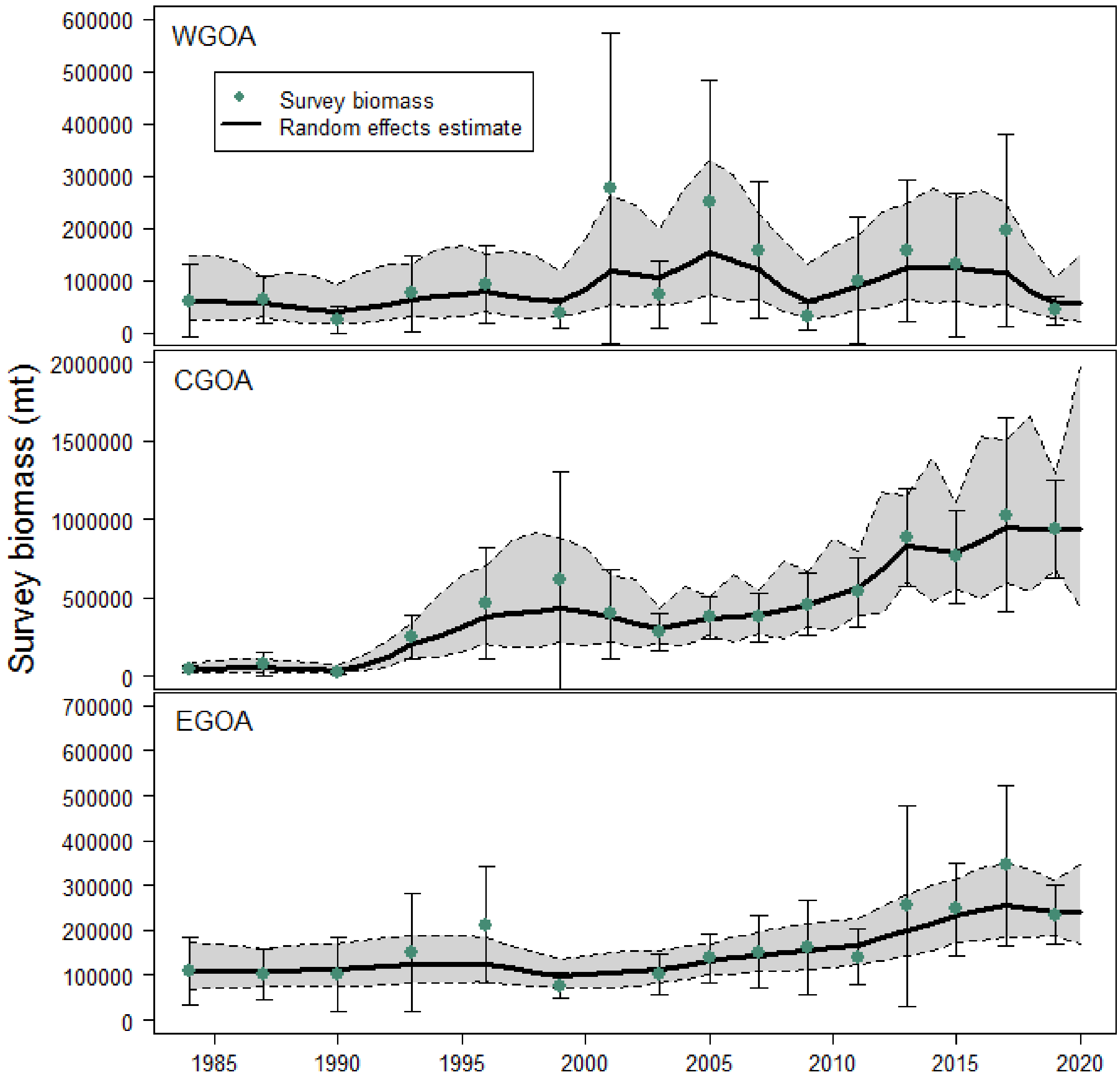

Figure 9-18. Random effects model fit (black line with 95% confidence intervals in light grey region) to regional bottom trawl survey biomass (green points with 95% sampling error confidence intervals).

Appendix 9A.—Supplemental catch data

In order to comply with the Annual Catch Limit (ACL) requirements, non-commercial removals and estimates total removals that do not occur during directed groundfish fishing activities are presented. This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does 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 estimates. For GOA POP, removals are minimal relative to the fishery catch and compared to the research removals for many other species. The majority of removals are taken by the Alaska Fisheries Science Center's biennial bottom trawl survey which is the primary research survey used for assessing the population status of POP in the GOA. Other research conducted using trawl gear catch minimal amounts of POP. No reported recreational or subsistence catch of POP occurs in the GOA. Total removals from activities other than directed fishery are such that they represent a very low risk to the POP stock. The increase in removals in odd years (e.g., 2013 and 2015) are due to the biennial cycle of the bottom trawl survey in the GOA. However, since 2000 removals have been less than 150 t, and do not pose significant risk to the stock.

Table 9A-1. Total removals of GOA POP (t) from activities not related to directed fishing, since 1977. Trawl survey sources are a combination of the NMFS echo-integration, small-mesh, and GOA bottom trawl surveys, and occasional short-term research projects. Other is recreational, personal use, and subsistence harvest.

Year	Source	Trawl	Other	Total
1977	**Assessment of POP in the GOA (Hanselman et al. 2010)**	13		13
1978		6		6
1979		12		12
1980		13		13
1981		57		57
1982		15		15
1983		2		2
1984		77		77
1985		35		35
1986		14		14
1987		69		69
1988		0		0
1989		1		1
1990		26		26
1991		0		0
1992		0		0
1993		59		59
1994		0		0
1995		0		0
1996		81		81
1997		1		1
1998		305		305
1999		330		330
2000		0		0
2001		43		43
2002		60		60
2003		43		43
2004		0		0
2005		84		84
2006		0		0
2007		93		93
2008		0		0
2009		69		69
2010	**AKRO**	<1	3	3
2011		64	<1	64
2012		<1	<1	1
2013		87	<1	87
2014		4	<1	5
2015		124	<1	125
2016		<1	<1	1
2017		96	3	99
2018		<1	<1	1
2019		<1	87	87