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

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November 2019

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.

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 2017 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 biomass estimates for 2019, survey age compositions for 2017, fishery age compositions for 2018, and final catch for 2017 and 2018 and preliminary catch for 2019-2021 (see *Specified catch estimation* section).

Changes in the assessment methodology: The assessment methodology is the same as the 2017 assessment with updated input data.

Summary of Results

For the 2020 fishery, we recommend the maximum allowable ABC of **31,238** t. This ABC is a 9% increase from the 2019 ABC of 28,555 t. The increase is attributed to the model continuing to react to four (including 2019) consecutive survey biomass estimates larger than 1 million tons. This also resulted in a 13% higher ABC than the 2020 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 2018 catch compared to OFL. The official total catch for 2018 is 24,724 t which is less than the 2018 OFL of 34,762 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 2019 and 2021. The estimates of spawning biomass for 2019 was 205,292 t and 2021 is 194,795 t. Both estimates are above the current $B_{35\%}$ estimate of 111,943 t and, therefore, the stock is not currently overfished nor approaching an overfished condition. We have used the following risk table in this year's assessment:

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*	*Overall score (highest of the individual scores)*
Level 2: Substantially increased concerns	Level 2: Substantially increased concerns	Level 1: No apparent concern	Level 1: No apparent concern	Level 2: Substantially increased concerns

We have ranked the overall score for GOA Pacific ocean perch as level 2 because of the consistent underestimation by the assessment model of bottom trawl survey biomass since 2013. Bottom trawl survey estimates of POP biomass in the GOA indicate an unprecedented increase in abundance. While this risk table has been used to recommend reductions in ABC, in this case it indicates that an increase in ABC could be warranted due to the assessment model's consistent underestimation. However, we do not recommend an increase at this time due to the lack of guidelines on how to use this table to recommend increases in ABC. Further details for each of these risk table categories can be found in the *Harvest Recommendations* section.

Quantity	As estimated or specified *last* year for: 2019	2020	As estimated or recommended *this* year for: 2020	2021[1]
M (natural mortality)	0.066	0.066	0.065	0.065
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	496,922	481,608	544,569	524,883
Projected Female spawning biomass	176,934	172,345	201,518	194,795
$B_{100\%}$	293,621	293,621	319,837	319,837
$B_{40\%}$	117,448	117,448	127,935	127,935
$B_{35\%}$	102,767	102,767	111,943	111,943
F_{OFL}	0.113	0.113	0.108	0.108
$maxF_{ABC}$	0.094	0.094	0.090	0.090
F_{ABC}	0.094	0.094	0.090	0.090
OFL (t)	33,951	32,876	**37,092**	35,600
maxABC (t)	28,555	27,652	**31,238**	29,983
ABC (t)	28,555	27,652	**31,238**	29,983
Status	As determined *last* year for: 2017	2018	As determined *this* year for: 2018	2019
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 2020 and 2021 are derived using estimated catch of 23,768 for 2019, and projected catches of 29,061 t and 27,753 t for 2020 and 2021 based on realized catches from 2016-2018. This calculation is in response to management requests to obtain more accurate projections.

Area Apportionment

The following table shows the recommended apportionment for 2020 and 2021 from the random effects model.

Area Apportionment	Western	Central	Eastern	Total
	4.6%	75.8%	19.6%	100%
2020 Area ABC (t)	**1,437**	**23,678**	**6,123**	**31,238**
2021 Area ABC (t)	**1,379**	**22,727**	**5,877**	**29,983**

Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. The ratio of 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
2020 Area ABC (t)	**1,470**	**4,653**	**6,123**
2021 Area ABC (t)	**1,410**	**4,467**	**5,877**

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
2020 Area OFL (t)	**31,567**	**5,525**	**37,092**
2021 Area OFL (t)	**30,297**	**5,303**	**35,600**

Summaries for Plan Team

Species	Year	Biomass[1]	OFL	ABC	TAC	Catch[2]
Pacific ocean perch	2018	511,934	34,762	29,236	29,236	24,724
	2019	496,922	33,951	28,555	28,555	21,811
	2020	544,569	37,092	31,238		
	2021	524,883	35,600	29,983		

[1]Total biomass from the age-structured model

Stock	Area	2019 OFL	2019 ABC	2019 TAC	2019 Catch[2]	2020 OFL	2020 ABC	2021 OFL	2021 ABC
Pacific ocean perch	W		3,227	3,227	3,126		1,437		1,379
	C		19,646	19,646	15,397		23,678		22,727
	WYAK		3,296	3,296	3,288		1,470		1,410
	SEO	2,838	2,386	2,386	0	5,525	4,653	5,303	4,467
	W/C/WYK	31,113				31,567		30,297	
	Total	33,951	28,555	28,555	21,811	37,092	31,238	35,600	29,983

[2]Current as of October 7, 2019, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

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 goundfish 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)

In response to these three comments, we provide a risk table as recommended by the SSC (above in the *Summary of Results* section, and with more detail in the *Harvest Recommendations* section below). After completing this exercise, we do not recommend ABC be reduced below maximum permissible ABC.

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)

We made a presentation at the September PT meeting that provided preliminary investigations into these topics. Unfortunately, due to the government shutdown early in 2019 we were unable to schedule a CIE review for GOA rockfish. We are anticipating that this review will be conducted in the spring of 2020. Thus, while we have investigated a number of these topics suggested by the PT and SSC we do not make any recommended model changes this year, but rather will present and discuss these topics with the CIE panel. Any recommendations made by the CIE will be addressed in the full assessment in 2021.

"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)

We will be discussing the use of the acoustic survey data for POP in the 2020 CIE and will present the results of that review at the September 2020 PT meeting.

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. 2003a). 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 tended to undergo parturition earlier in the spawning season than younger fish. A more recent study suggest that larval quality is both a function of spawner age and parturition timing.

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. 2012a).

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. 2012a). 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	4.2

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
% Discard	6.5	4.8	7.6	9.5	3.8	7.2	14.8	4.7	5.7

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 decreased in 2019 compared to 2018, with the exception of Chinook salmon and herring whose increase was minor (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	1984-1999 (triennial), 2001-**2019** (biennial)
	Age Composition	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, **2017**
U.S. trawl fisheries	Catch	1961-**2019**
	Age Composition	1990,1998-2002, 2004, 2005, 2006, 2008, 2010, 2012, 2014, 2016, **2018**
	Length Composition	1963-1977, 1991-1997

Fishery

Catch

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.

Age and Size composition

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 2010-2019 (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. In the recent length composition data the mean length decreased slightly in 2017 and 2018, potentially indicating that some year classes that moved into the population.

Survey

Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the GOA in 1984, 1987, 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 1984 to 2019 surveys are provided in Table 9-9.

Comparison of Trawl Surveys in 1984-2019

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. The 1984 survey results should be treated with some caution, as a different survey design was used in the eastern GOA. In addition, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed here, and the estimates are believed to be the best available. Even so, the use of Japanese vessels in 1984 and 1987 does introduce an element of uncertainty as to the standardization of these two surveys and we do not use these surveys in the assessment model.

Biomass estimates of POP were relatively low in 1984 to 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.

Trawl Survey Age and Length Compositions

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1990-2017 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). 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.

Summer Acoustic-Trawl Survey

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 shelfbreak 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

This model is identical in all aspects to the model accepted in 2017 with the exception of new data, thus, there are no alternative models investigated.

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. 2003a). The von Bertlanffy parameters used for the 1960s and 1970s size to age transition matrix are:

L_∞ = 41.6 cm κ = 0.15 t_0 = -1.08

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

L_∞ = 41.3 cm κ = 0.18 t_0 = -0.50

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 = -0.05 b = 2.27

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_∞ = 920 g κ = 0.19 t_0 = -0.39 β = 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 2017 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 Box 1.

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	85
Average fishing mortality	μ_f	1
Fishing mortality deviations	ε_y^f	59
Fishery selectivity coefficients	s_a^f	6
Survey selectivity coefficients	s_a^t	2
Maturity-at-age coefficients	$\hat{m}_a$	2
Total		162

Uncertainty approach

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 2017 with updated data. 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 current assessment model is the same as 2017 we will evaluate the 2019 assessment based on differences in results compared to the 2017 assessment.

The 2019 model 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, the 2019 assessment model yields reasonable results and we use it to recommend the 2020 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 380,000 and 860,000 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 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 slightly smaller (2.01) than that estimated in 2017 (2.11). 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], Hanselman et al. 2006[1] [q=2.1], 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.

[1] Hanselman, D.H., S.K. Shotwell, J. Heifetz, and M. Wilkins. 2006. Catchability: Surveys, submarines and stock assessment. 2006 Western Groundfish Conference. Newport, OR. Presentation.

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 2017 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, and 2012 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 -0.27 (worse than the 2017 value of -0.22), 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 2017 (i.e., the 1977 – 2015 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 2019 estimates of these reference points are:

$B_{100\%}$	319,837
$B_{40\%}$	127,935
$B_{35\%}$	111,943
$F_{40\%}$	0.09
$F_{35\%}$	0.108

Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2020 is estimated at 201,518 t. This is above the $B_{40\%}$ value of 127,935 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 2020, yields the following ABC and OFL:

$F_{40\%}$	0.09
ABC	31,238
$F_{35\%}$	0.108
OFL	**37,092**

Projections and Status Determination

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 2019 numbers at age as estimated in the assessment (Table 9-18). This vector is then projected forward to the beginning of 2020 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2019. 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 2019 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.

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 2020, 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 2020 and 2021, *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 2016-2018 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 2014-2018 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 2019 or 2) above ½ of its MSY level in 2019 and above its MSY level in 2029 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 2021 or 2) above 1/2 of its MSY level in 2021 and expected to be above its MSY level in 2031 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.

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 (2018) is 24,724 t. This is less than the 2018 OFL of 34,762 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 2019:
a. If spawning biomass for 2019 is estimated to be below ½ B35%, the stock is below its MSST.
b. If spawning biomass for 2019 is estimated to be above B35% the stock is above its MSST.
c. If spawning biomass for 2019 is estimated to be above ½ B35% but below B35%, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 9-19). If the mean spawning biomass for 2029 is below B35%, 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 2021 is below 1/2 B35%, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2021 is above B35%, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2021 is above 1/2 B35% but below B35%, the determination depends on the mean spawning biomass for 2031. If the mean spawning biomass for 2031 is below B35%, 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.

Specified catch estimation

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. 2016-2018 for this year). For POP, the expansion factor for 2019 catch is 1.09.

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 (0.93), which was the average of the ratio of catch to ABC for the last three complete catch years (2016-2018). This yield ratio was multiplied by the projected ABCs for 2020 and 2021 from the assessment model to generate catches for those years.

Alternate Projection

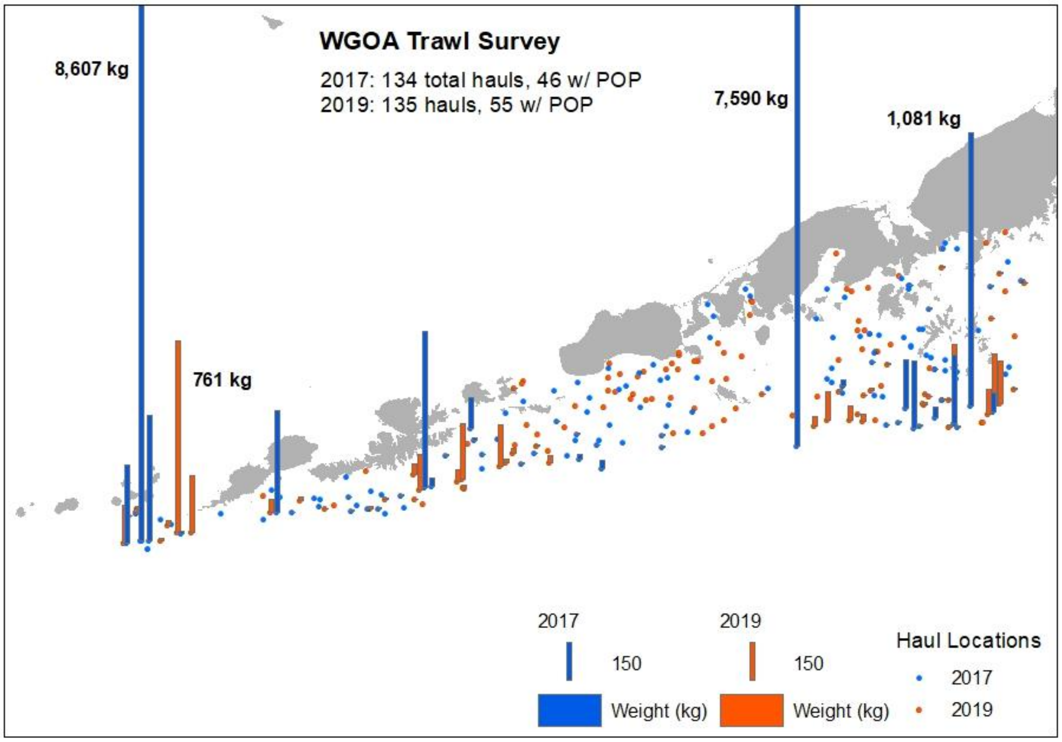
During the 2006 CIE review, it was suggested that projections should account for uncertainty in the entire assessment, not just recruitment from the endpoint of the assessment. We continue to present an alternative projection scenario using the uncertainty of the full assessment model, harvesting at 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 1979-2017 age-2 recruitments, and this projection predicts that the median spawning biomass will eventually tend toward these reference points while at harvesting at $F_{40\%}$.

Area Apportionment 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 **1,437** t for the Western area, **23,678** t for the Central area, and **6,123** 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 **1,470** t to the W. Yakutat area which would leave **4,653** t unharvested in the Southeast/Outside area.

Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.108), overfishing is set equal to 37,092 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 **31,567** t and **5,525** t in the SEO area.

Should the ABC be reduced below the maximum permissible ABC?

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

	Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Substantially increased concerns	Substantially increased assessment uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing an adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not consistent across all indicators
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., 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 the past two 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 (-0.22 in 2017 and -0.27 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). Since 2013, bottom trawl catches have been less variable and more uniform in distribution across the Gulf lending credibility to the recent increase in POP abundance observed by the bottom trawl survey. Because of the model's inability to estimate the recent increase in biomass suggested by the bottom trawl survey we rated the assessment-related concern as level 2, a substantially increased concern, due to additional uncertainty in the assessment model's performance.

Population dynamics considerations

As discussed in the *Assessment considerations* section above, the recent increase in POP biomass as estimated by either design-based or model-based methods is an unusual increase that has not been seen in the time series of biomass prior to 2013. 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. 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

POP are benthic continental slope (150-300m) dwellers as adults, with a pelagic then inshore benthic juvenile stage in the GOA (Love et al. 2002). Limited information on temperature, zooplankton, and condition of other marine species indicate less favorable foraging and growing conditions for the zooplanktivorous POP during 2019. Sea temperatures were at a record high for the entire GOA during the 2019 summer (Thoman and Welsh 2019). In waters above the continental shelf around Kodiak Island, temperatures were warmer through the water column during spring (6.8°C surface, 6.1°C bottom) and summer (13.3°C surface, 7.3°C bottom to 200m) (Rogers et al. 2019) and across the shelf during May (Danielson and Hopcroft 2019). The AFSC bottom trawl survey temperature profiles were similar to 2015 profiles with warmer anomalies (7.0°C) consistently observed across the entire survey area and penetrating to 200 m depths (Laman 2019a). Nearshore mean summer surface temperatures was second highest on record in northern southeast Alaska, 1997-2019 (Fergusson 2019). Summer and fall temperatures during 2019 indicate heat wave conditions similar to 2015-2016 in the GOA (Barbeaux 2019). It is reasonable to expect that the current heat wave 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).

The primary prey of the adult POP include calanoid copepods, euphausiids, myctophids, and miscellaneous prey in the GOA (Byerly 2001, Yang and Nelson 2000). 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). The biomass of copepods and euphausiids were slightly below the long-term mean around Kodiak Island, with Barnabus trough as a hotspot (Kimmel et al. 2019, Ressler 2019). In Icy Strait, northern southeast Alaska, the lipid content of all zooplankton taxa examined decreased, from 2018 to 2019 and were below average, except for euphausiids, indicating a decrease in the nutritional quality of the prey field utilized by larval and juvenile fish (Fergusson and Rogers 2019). However, bottom trawl CPUE of shrimp increased in the Kodiak, Chirikof, and Yakutat areas over the last few surveys, while they have remained fairly constant and low relative abundance in the eastern GOA (Palsson 2019). Body condition and reproductive success of other zooplanktivores were below average during the summer of 2019 and in marine heat wave years. For example, YOY pollock in the western GOA had lower than average body condition during the 2005 and 2015-16 marine heat wave years (Rogers et al. 2019). The body condition of 8 adult groundfish species captured near the sea floor in the AFSC bottom trawl surveys were below average except for adult Pacific cod (Laman 2019b). Little is known about the impacts of predators, such as fish and marine mammals, on POP. The 2019 foraging conditions were below average for the largely zooplanktivorous POP rockfish in the GOA. However, given that the indicators suggest a warming trend, larval fish abundance and condition appear to be below average, and euphausiid abundance is spotty and likely average in the GOA, due to the limited information on rockfish, we scored this category as level 1, normal concern.

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.

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 2018

Rockfish total catch in the Gulf of Alaska in 2018 increased 8% to 34 thousand t and retained catch increased 17% to 31 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. Rockfish comprised roughly 8-13% of the GOA retained catch and 5-10% of the ex-vessel value between 2014-2018. Ex-vessel value in the GOA rockfish fisheries was $15 million up 23% from 2017. The change in ex-vessel value was combined effect of increased catch and prices which were up 5.6% to $0.24 (Table 9-21). First-wholesale value was up 16% in 2018 to $45.4 million with the increased production from catch (Table 9-22).

The most significant species in terms of market volume and value is Pacific ocean perch which accounts for upwards of 60% of the retained catch (Table 9-21). 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 change in the TAC largely accounts changes in Pacific ocean perch catch and ex-vessel value in 2017. The GOA rockfish fisheries catch a diverse set of rockfish species and the other major species caught are northern and dusky (Table 9-21). Typically, 75%-90% of the northern rockfish catch is harvested, in 2017 catches increased to 2.3 thousand t which was an increase from 2017 but below typical levels over the last decade. Catches of Dusky rockfish remained relatively stable increasing slightly to 2.8 thousand t in 2018. Other rockfish caught in the GOA include rougheye, shortraker, and thornyhead. In recent years, approximately 85% of the retained rockfish catch occurs in the Central Gulf, and 13% in the Western Gulf. In the Central Gulf, where the majority of rockfish are caught, rockfish comprised 16% of the retained catch and 12% 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 declined from an average of 179 in 2009-2013 to 112 in 2018. 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 23% increase in 2018 first-wholesale value to $45.4 million was the result of increased catch and production (Table 9-22). The average price of rockfish products decreased 6% to $1.15 per pound, which was primarily the result of decrease in the price of Pacific ocean perch which fell from $1.15 to $1.06 per pound. Approximately 70% of the rockfish produced are processed as headed and gutted (H&G) and the rest is mostly sold as whole fish. 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 60% of the Pacific ocean perch exported from the U.S. goes to China (Table 9-23). 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 11% from the 2009-2013 average to 263 thousand t to 2017 and global production of Pacific ocean perch has increased 26%. Global production of Atlantic redfish, a market competitor to Pacific ocean perch, has remained stable at roughly 50 thousand t. The U.S. dollar was relative stability in 2018 against other currencies, such as the Chinese Yuan, which mitigates its potential impact on market price. Export price data through June 2019 indicate a potential drop in the Pacific ocean perch price (Table 9-23). Tariffs between the U.S. and China and the associated uncertainty with trade policy has the potential to inhibit value growth in rockfish markets, both as a direct market for rockfish exports and because of China’s significance as a re-processor of rockfish products. Industry lacks immediate alternative reprocessing options to China. Export quantities of Pacific ocean perch increased in 2018 from the levels in 2014-2017 and the share of exports to China remained stable, however, export prices have continued to decline through June of 2019 (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.

Literature Cited

Ainley, D.G., Sydeman, W.J., Parrish, R.H., and Lenarz, W.H. 1993. Oceanic factors influencing distribution of young rockfish (Sebastes) in central California: A predator's perspective. CalCOFI Report 34: 133-139.

Allen, M .J., and G. B. Smith. 1988. Atlas and zoogeography of common fishes in the Bering Sea and northeastern Pacific. U.S. Dep. Commer., NOAA Tech. Rept. NMFS 66, 151 p.

Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-1979. Can. Tech. Rep. Fish. Aquat. Sci. 1048: iv +57 p.

Arnold, L.M/, W.D. Smith, P.D. Spencer, A.N. Evans, S.A. Heppell, and S.S. Heppell. 2018. The role of maternal age and contec-dependent maternal effects on the offspring provisioning of a long-lived marine teleost. R. Soc. Open sci. 5:170966.

Barbeaux S. 2019. Fall 2019 marine heatwave. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Berkeley, S. A., C. Chapman, and S. M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, Sebastes melanops. Ecology 85(5):1258-1264.

Bobko, S.J. and S.A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish (Sebastes melanops). Fisheries Bulletin 102:418-429.

Brodeur, R. D. 2001. Habitat-specific distribution of Pacific ocean perch (Sebastes alutus) in Pribilof Canyon, Bering Sea. Continent. Shelf Res., 21:207-224.

Byerly, Michael M. 2001. The ecology of age-1 Copper Rockfish (Sebastes caurinus) in vegetated habitats of Sitka sound, Alaska. M.S. thesis. University of Alaska, Fairbanks. Fisheries Division, 11120 Glacier Hwy, Juneau, AK 99801.

Carlson, H. R., and R. E. Haight. 1976. Juvenile life of Pacific ocean perch, *Sebastes alutus*, in coastal fiords of southeastern Alaska: their environment, growth, food habits, and schooling behavior. Trans. Am. Fish. Soc. 105:191-201.

Carlson, H. R., and R. R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.

Carlson, H.R., D.H. Ito, R.E. Haight, T.L. Rutecki, and J.F. Karinen. 1986. Pacific ocean perch. In R.L. Major (editor), Condition of groundfish resources of the Gulf of Alaska region as assessed in 1985, p. 155-209. U.S. Dept. Commer., NOAA Tech. Memo. NMFS F/NWC-106.

Chilton, D.E. and R.J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Can. Spec. Pub. Fish. Aquat. Sci. 60.

Conrath, C. L. and B. Knoth. 2013. Reproductive biology of Pacific ocean perch in the Gulf of Alaska. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 5: 21-27.

Courtney, D.L., J. N. Ianelli, D. Hanselman, and J. Heifetz. 2007. Extending statistical age-structured assessment approaches to Gulf of Alaska rockfish (Sebastes spp.). In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 429–449.

Danielson, S., and R. Hopcroft. 2019. Seward line May temperatures. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation

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

de Bruin, J., R. Gosden, C. Finch, and B. Leaman. 2004. Ovarian aging in two species of long-lived rockfish, sebastes aleutianus and S. alutus. Biol. Reprod. 71: 1036-1042.

Dorn, M. K. Aydin, B. Fissel, D. Jones, W. Palsson, K. Spalinger, and S. Stienessen. 2016. Assessment of the Walleye Pollock Stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Dougherty, A., A. Deary, and L. Rogers. 2019. Rapid larval assessment in the Gulf of Alaska. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Fergusson, E., and M. Rogers. 2019. Zooplankton nutritional quality trends in Icy Strait, Southeast Alaska. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Foote, K. G. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82:981-987.

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall, London. 526 pp.

Gharrett, A. J., A.K. Gray, and J. Heifetz. 2001. Identification of rockfish (*Sebastes* spp.) from restriction site analysis of the mitochondrial NM-3/ND-4 and 12S/16S rRNA gene regions. Fish. Bull. 99:49-62.

Gharrett, A. J., Z. Li, C. M. Kondzela, and A. W. Kendall. 2002. Final report: species of rockfish (*Sebastes* spp.) collected during ABL-OCC cruises in the Gulf of Alaska in 1998-2002. (Unpubl. manuscr. available from the NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801.)

Goodman, D., M. Mangel, G. Parkes, T.J. Quinn II, V. Restrepo, T. Smith, and K. Stokes. 2002. Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans. Draft report. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Haldorson, L, and M. Love. 1991. Maturity and fecundity in the rockfishes, Sebastes spp., a review. Mar. Fish. Rev. 53(2):25–31.

Hanselman, D.H., B. Clark, and M. Sigler. 2013. Report of the groundfish plan team retrospective investigations group, part II: the compilation. Presented at September 2013 Plan Team, 12 pp. http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/Retrospectives_2013_final3.pdf

Hanselman, D.H., S.K. Shotwell, P.J.F. Hulson, J. Heifetz, and J.N. Ianelli. 2012a. Assessment of the Pacific ocean perch stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501. pp. 563-592.

Hanselman, D.H., P.D. Spencer, D. McKelvey, and M. Martin. 2012b. Application of an acoustic-trawl survey design to improve rockfish biomass estimates. Fish. Bull. 110: 379-396.

Hanselman, D., P. Spencer, K. Shotwell,and R. Reuter. 2007. Localized depletion of three Alaska rockfish species. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 493 – 511.

Hanselman, D. H., J. Heifetz, J. Fujioka, and J. N. Ianelli. 2003a. Gulf of Alaska Pacific ocean perch. In Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska as projected for 2004. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D.M. Clausen. 2003b. Applications in adaptive cluster sampling of Gulf of Alaska rockfish. Fish. Bull. 101(3): 501-512.

Hanselman, D.H., T.J. Quinn II, C. Lunsford, J. Heifetz and D.M. Clausen. 2001. Spatial implications of adaptive cluster sampling on Gulf of Alaska rockfish. In Proceedings of the 17th Lowell-Wakefield Symposium: Spatial Processes and Management of Marine Populations, pp. 303-325. Univ. Alaska Sea Grant Program, Fairbanks, AK.

Heppell, S.S., S.A. Heppell, P. Spencer, W.D. Smith, and L. Arnold. 2009. Assessment of female reproductive effort and maternal effects in Pacific Ocean Perch *Sebastes alutus*: do big old females matter? Project 629 Final Report to the North Pacific Research Board.

Heifetz, J., D. M. Clausen, and J. N. Ianelli. 1994. Slope rockfish. In Stock assessment and fishery evaluation report for the 1995 Gulf of Alaska groundfish fishery, p. 5-1 - 5-24. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

Hobson, E.S., J.R. Chess, D.F. Howard. 2001. Interannual variation in predation on first-year Sebastes spp. by three northern California predators. Fish. Bull. 99: 292-302.

Hulson, P.-J.F., J. Hiefetz, D.H. Hanselman, S.K. Shotwell, and J.N. Ianelli. 2011. Assessment of the northern rockfish stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Hulson, P.-J.F., D.H. Hanselman, S.K. Shotwell, C.R. Lunsford, and J.N. Ianelli. 2014. Assessment of the Pacific ocean perch stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Hulson, P.-J.F., D.H. Hanselman, S.K. Shotwell, C.R. Lunsford, and J.N. Ianelli. 2015. Assessment of the Pacific ocean perch stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Jones, D. T., P. H. Ressler, S. C. Stienessen, A. L. McCarthy, and K. A. Simonsen. 2014. Results of the acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) in the Gulf of Alaska, June-August 2013 (DY2013-07). AFSC Processed Rep. 2014-06, 95 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Jones, D. T., S. Stienessen, and N. Lauffenburger. 2017. Results of the acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) in the Gulf of Alaska, June-August 2015 (DY2015-06). AFSC Processed Rep. 2017-03, 102 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Jones, D. T., N. E. Lauffenburger, K. Williams, and A. De Robertis. 2019. Results of the acoustic trawl survey of walleye pollock (*Gadus chalcogrammus*) in the Gulf of Alaska, June August 2017 (DY2017-06), AFSC Processed Rep. 2019- 08, 110 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE Seattle, WA 98115.

Jones, D.T., C.N. Rooper, C.D. Wilson, P. Spencer, D.H. Hanselman, and R.E. Wilborn. In Review. Estimates of Availability to Bottom Trawls for Select Rockfish Speices from Acoustic-Optic Surveys in the Gulf of Alaska.

Kamin, L. M., K. J. Palof, J. Heifetz, and A.J. Gharrett, A. J. 2013. Interannual and spatial variation in the population genetic composition of young-of-the-year Pacific ocean perch (Sebastes alutus) in the Gulf of Alaska. Fisheries Oceanography. doi: 10.1111/fog.12038.

Karinen, J. F., and B. L. Wing. 1987. Pacific ocean perch. In R. L. Major (editor), Condition of groundfish resources of the Gulf of Alaska region as assessed in 1986, p. 149-157. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-119.

Kendall, A. W., and W. H. Lenarz. 1986. Status of early life history studies of northeast Pacific rockfishes. Proc. Int. Rockfish Symp. Oct. 1986, Anchorage Alaska; p. 99-117.

Kendall, A.W., Jr. 2000. An historical review of Sebastes taxonomy and systematics. Mar. Fish. Rev. 62: 1-16.

Kimmel, D., C. Harpold, J. Lamb, M. Paquin, L. Rogers. 2019. Rapid zooplankton assessment in the western Gulf of Alaska. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Krieger, K.J., 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull. 91, 87-96.

Krieger, K.J., and M.F. Sigler. 1996. Catchability coefficient for rockfish estimated from trawl and submersible surveys. Fish. Bull. 94, 282-288.

Laman, N. 2019a. Gulf of Alaska survey bottom trawl temperature analysis. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Laman, N. 2019b. Gulf of Alaska groundfish condition. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Leaman, B. M. 1991. Reproductive styles and life history variables relative to exploitation and management of Sebastes stocks. Environmental Biology of Fishes 30: 253-271.

Leaman, B.M. and R.J. Beamish. 1984. Ecological and management implications of longevity in some Northeast Pacific groundfishes. Int. North Pac. Fish. Comm. Bull. 42:85-97.

Li, Z. 2004. Phylogenetic relationships and identification of juveniles of the genus Sebastes. University of Alaska-Fairbanks, School of Fisheries and Ocean Sciences. M.S. thesis.

Longhurst, A., 2002. Murphy's law revisited: longevity as a factor in recruitment to fish populations.. Fish. Res. 56:125-131.

Love, M.S., M.H. Carr, and L.J. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus Sebastes. Environmental Biology of Fishes 30:225-243.

Love M.S, M.M. Yoklavich, and L. Thorsteinson 2002. The Rockfishes of the Northeast Pacific. University of California Press, Los Angeles.

Lunsford, C. 1999. Distribution patterns and reproductive aspects of Pacific ocean perch (*Sebastes alutus*) in the Gulf of Alaska. M.S. thesis. University of Alaska Fairbanks, Juneau Center, School of Fisheries and Ocean Sciences.

Malecha, P. W., D. H. Hanselman, and J. Heifetz. 2007. Growth and mortality of rockfish (Scorpaenidae) from Alaskan waters. NOAA Tech. Memo. NMFS-AFSC-172. 61 p.

Major, R. L., and H. H. Shippen. 1970. Synopsis of biological data on Pacific ocean perch, *Sebastodes alutus*. FAO Fisheries Synopsis No. 79, NOAA Circular 347, 38 p.

McGilliard, C.R., W. Palsson, W. Stockhausen, and J. Ianelli. 2013. Assessment of the deepwater flatfish stock in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Methot, R.D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. INPFC Bull. 50: 259-289.

Morgan, C.A., B.R. Beckman, L.A. Weltkamp, and K.L. Fresh, 2019. Recent Ecosystem Disturbance in the Northern California Current. Fisheries 44(10):465-474.

National Marine Fisheries Service. 2005. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska. http://www.fakr.noaa.gov/habitat/seis/efheis.htm.

Palsson, W. 2019. Miscellaneous Species - Gulf of Alaska Bottom Trawl Survey. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Palof, K.J. 2008. Population genetic structure of Alaskan Pacific ocean perch (*Sebastes alutus*). M.S. thesis, University of Alaska Fairbanks, Fairbanks, Alaska. 65 pp.

Palof, K. J., J. Heifetz, and A. J. Gharrett. 2011. Geographic structure in Alaskan Pacific Ocean perch (*Sebastes alutus*) indicates limited life-time dispersal.Marine Biology 158:779–792.

Pearcy, W. G., D. L. Stein, M. A. Hixon, E. K. Pikitch, W. H. Barss, and R. M. Starr. 1989. Submersible observations of deep-reef fishes of Heceta Bank, Oregon. Fishery Bulletin 87:955-965.

Quinn II, T.J., D. Hanselman, D.M. Clausen, J. Heifetz, and C. Lunsford. 1999. Adaptive cluster sampling of rockfish populations. Proceedings of the American Statistical Association 1999 Joint Statistical Meetings, Biometrics Section, 11-20.

Quinn II, T.J., and Deriso, R.B. 1999. Quantitative fish dynamics. Oxford University Press, New York. 542 pp.

Ressler, P. 2019. Gulf of Alaska euphausiids “krill”. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Rogers, L., M. Wilson, and S. Porter. 2019. Abundance of YOY pollock and capelin in the Western Gulf of Alaska. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Rogers, L., M. Wilson, and D. Cooper. 2019. Body condition of age-0 pollock. In Zador, S., and Yasumiishi, E., 2019. Ecosystem Status Report 2019: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99501.

Rooper, C.N. and J.L. Boldt. 2005. Distribution of juvenile Pacific ocean perch *Sebastes alutus* in the Aleutian Islands in Relation to Benthic Habitat. Alaska Fishery Research Bulletin 11(2):102-112.

Rooper, C.N., J.L. Boldt, and M. Zimmerman. 2007. An assessment of juvenile Pacific ocean perch (*Sebastes alutus*) habitat use in a deepwater nursery. Estuar. Coast. Shelf. Sci. 75:371-380.

Schnute, J.T., R. Haigh, B.A. Krishka, and P. Starr. 2001. Pacific ocean perch assessment for the west coast of Canada in 2001. Canadian research document 2001/138. 90 pp.

Seeb, L. W. and D.R. Gunderson. 1988. Genetic variation and population structure of Pacific ocean perch (*Sebastes alutus*). Can. J. Fish. Aquat. Sci. 45:78-88.

Seeb, L. W., and A. W. Kendall, Jr. 1991. Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus Sebastes. Environmental Biology of Fishes 30:191-201.

Spencer, P., Hanselman, D. and Dorn, M. 2007. The effect of maternal age of spawning on estimation of Fmsy for Alaska Pacific ocean perch. In: Heifetz, J., DiCosimo J., Gharrett, A.J., Love, M.S, O'Connell, V.M, and Stanley, R.D. (eds.). Biology, Assessment, and Management of North Pacific Rockfishes. Alaska Sea Grant, University of Alaska Fairbanks. pp 513 – 533.

Spencer, P., D.H. Hanselman, and D. McKelvey. 2012. Simulation modeling of a trawl-acoustic survey design for patchily distributed species. Fish. Res. 126: 289-299.

Withler, R.E., T.D. Beacham, A.D. Schulze, L.J. Richards, and K.M. Miller. 2001. Co-existing populations of Pacific ocean perch, *Sebastes alutus*, in Queen Charlotte Sound, British Columbia. Mar. Bio. 139: 1-12.

Yang, M-S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

Yang, M.S. 2003. Food habits of the important groundfishes of the Aleutian Islands in 1994 and 1997. National Marine Fisheries Service. AFSC Processed report 2003-07: 233 pp.

Yang, M.-S., and M.W. Nelson. 2000. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990, 1993, and 1996. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-112, 174 p.

Yang, M-S., K. Dodd, R. Hibpshman, and A. Whitehouse. 2006. Food habits of groundfishes in the Gulf of Alaska in 1999 and 2001. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-164, 199 p.

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), 1977-2019.

		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.	3,141	10,550	1,926	15,617	17,584	17,584
2011	U.S.	1,819	10,527	1,872	14,218	16,997	16,997
2012	U.S.	2,452	10,778	1,682	14,912	16,918	16,918
2013	U.S.	447	11,199	1,537	13,183	16,412	16,412
2014	U.S.	2,096	13,704	1,871	17,671	19,309	19,309
2015	U.S.	2,038	14,714	1,981	18,733	21,012	21,012
2016	U.S.	2,654	17,652	2,827	23,133	24,437	24,437
2017	U.S.	2,682	18,444	2,757	23,883	23,918	23,918
2018	U.S.	3,225	18,146	3,352	24,724	29,236	29,236
2019*	U.S.	3,126	15,397	3,288	21,811	28,555	28,555

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.

* Catch as of 10/7/2019

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	15,617	17,584	17,584	20,243	
2011	14,218	16,997	16,997	19,566	
2012	14,912	16,918	16,918	19,498	
2013	13,183	16,412	16,412	18,919	Area OFL for W/C/WYK combined, SEO separate
2014	17,671	19,309	19,309	22,319	
2015	18,733	21,012	21,012	24,360	
2016	23,128	24,437	24,437	28,431	
2017	23,883	23,918	23,918	27,826	
2018	24,724	29,236	29,236	34,762	
2019*	21,811	28,555	28,555	33,951	

* Catch as of 10/7/2019

Table 9-3. FMP groundfish species caught in rockfish targeted fisheries in the GOA from 2011-2019. Conf. = Confidential because of less than three vessels or processors. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/22/2019.

Species Group Name	2013	2014	2015	2016	2017	2018	2019	Average
Pacific Ocean Perch	11,555	15,283	17,566	20,402	19,077	22,165	19,888	17,991
Northern Rockfish	4,527	3,647	3,632	3,155	1,602	2,152	2,233	2,993
Dusky Rockfish	2,870	2,752	2,492	3,004	2,192	2,691	2,048	2,579
Arrowtooth Flounder	766	1,426	1,397	1,200	1,405	738	682	1,088
Pollock	829	1,339	1,330	572	1,057	906	494	932
Atka Mackerel	1,162	446	988	595	543	1,138	819	813
Other Rockfish	488	735	849	972	748	993	662	778
Sablefish	495	527	434	481	585	679	764	566
Pacific Cod	584	625	785	365	253	392	295	471
Rougheye Rockfish	274	359	225	351	269	317	289	298
Shortraker Rockfish	290	243	238	291	254	268	237	260
Thornyhead Rockfish	104	243	220	336	360	358	172	256
Rex Sole	89	84	116	140	112	133	113	112
Demersal Shelf Rockfish	135	38	39	40	40	57	56	58
Deep Water Flatfish	37	68	44	64	58	65	36	53
Sculpin	70	33	44	43	45	65	53	50
Flathead Sole	26	30	46	26	81	44	39	42
Shark	93	2	6	12	40	47	61	37
Longnose Skate	23	26	33	46	42	44	25	34
Skate, Other	18	45	21	18	22	27	26	26
Shallow Water Flatfish	27	28	27	15	11	19	33	23
Squid	10	19	24	12	22	29	--	19
Octopus	2	7	11	2	1	3	9	5
Big Skate	2	4	7	5	6	3	4	4

Table 9-4. Catch (t) of GOA POP as bycatch in other fisheries from 2013-2019. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/23/2019.

Target	2013	2014	2015	2016	2017	2018	2019	Average
Arrowtooth Flounder	424	1403	593	1021	3287	539	928	1171
Pollock - midwater	133	352	61	519	1115	902	351	490
Rex Sole	714	423	227	50	101	355	293	309
Pollock - bottom	294	179	115	163	151	696	293	270
Pacific Cod	12	15	167	797	77	3	4	153
Shallow Water Flatfish	20	11	2	139	50	14	46	40
Atka Mackerel	2	--	--	0	18	25	--	11
Flathead Sole	19	6	--	33	3	0	2	11
Sablefish	8	2	2	9	4	26	6	8
Deep Water Flatfish	1	1	1	--	--	--	--	1

Table 9-5. Non-FMP species bycatch estimates in tons for GOA rockfish targeted fisheries 2013 - 2019. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/23/2019.

Species Group Name	2013	2014	2015	2016	2017	2018	2019
Benthic urochordata	Conf.	Conf.	0.28	0.5	0.2	0.07	0.07
Birds - Northern Fulmar	0	Conf.	0	0	Conf.	0	0
Birds - Shearwaters	0	0	0	0	0	0	0
Bivalves	Conf.	0.01	Conf.	Conf.	0.01	0	0
Brittle star unidentified	0.02	0.05	0.05	0.03	0.6	0.01	0.02
Capelin	0.01	0	0	Conf.	0	0	Conf.
Corals Bryozoans - Corals Bryozoans Unidentified	0.18	1.92	0.7	0.85	0.47	1.57	0.76
Corals Bryozoans - Red Tree Coral	Conf.	Conf.	Conf.	0	0	0	0
Deep sea smelts (bathylagidae)	0	0	0	0	0	Conf.	0
Eelpouts	0.04	0.13	0.01	0.02	0.13	0.22	0
Eulachon	0.03	0.02	0.03	0.04	0.13	0.13	0.32
Giant Grenadier	889.29	512.88	786.39	426.49	1008.12	756.16	551
Greenlings	6.99	4.16	8.14	5.8	3.9	4.48	5.94
Grenadier - Rattail Grenadier Unidentified	29.6	5.45	45.42	5.45	12.26	22.08	8.45
Gunnels	0	0	Conf.	0	0	0	0
Hermit crab unidentified	0.03	0.04	0.03	0.01	0.03	0.01	Conf.
Invertebrate unidentified	0.18	Conf.	0.19	0.09	0.07	0.64	0.07
Lanternfishes (myctophidae)	Conf.	0	0.04	0.14	0	0	0.06
Misc crabs	0.05	0.08	0.16	0.35	1.14	0.72	0.16
Misc crustaceans	Conf.	Conf.	Conf.	0.03	0.01	0.13	0.21
Misc deep fish	Conf.	0	0	Conf.	Conf.	0	Conf.
Misc fish	159.66	124.62	143.54	101.74	114.64	139.25	101.1
Misc inverts (worms etc)	0	0	0	Conf.	0	0	0
Other osmerids	0.02	Conf.	Conf.	0.03	Conf.	0	Conf.
Pacific Hake	0	0	Conf.	0.04	Conf.	0.06	0
Pandalid shrimp	0.06	0.1	0.05	0.22	0.14	0.07	0.08
Polychaete unidentified	Conf.	0	0	0	0.02	0	0
Scypho jellies	0.39	5.13	1.63	8.07	0.54	0.97	7.37
Sea anemone unidentified	4.02	2.15	1.14	1.28	0.79	0.5	1.23
Sea pens whips	0.04	0.06	Conf.	0.02	0.03	0	0.02
Sea star	0.89	1.6	3.48	1.72	3.65	4.67	1.36
Snails	0.15	0.1	0.26	0.18	0.18	6.19	1.71
Sponge unidentified	1.28	1.81	5.45	2.88	3.2	14.63	5.82
Squid	0	0	0	0	0	0	10.28
State-managed Rockfish	66.76	50.39	47.47	13.36	24.48	50.24	43.4
Stichaeidae	Conf.	Conf.	Conf.	0	Conf.	0.64	0
urchins dollars cucumbers	0.28	0.21	0.99	0.34	0.43	0.29	0.19

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 10/23/2019.

Species Group Name	2013	2014	2015	2016	2017	2018	2019	Average
Bairdi Crab	0.07	0.19	0.05	0	0.76	0.2	0.06	0.19
Blue King Crab	0	0	0	0	0	0	0	0
Chinook Salmon	2.32	1.25	1.91	0.38	0.52	0.33	0.34	1.01
Golden K. Crab	0.1	0.03	0.02	0.02	0.21	0.32	0.22	0.13
Halibut	113	127	157	124	126	78	72	114
Herring	0	0	0	0	0.04	0.01	0.28	0.05
Other Salmon	2.02	0.56	0.34	0.22	0.64	0.31	0.24	0.62
Opilio Crab	0	0	0	0	0	0	0	0
Red King Crab	0	0	0	0	0	0	0	0

Table 9-7. Fishery length frequency data for POP in the GOA from 2010-2019.

Length (cm)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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	0.01	0	0	0	0	0	0	0
24	0	0	0.01	0	0	0	0	0	0	0
25	0	0	0.01	0.01	0	0.01	0	0	0	0
26	0	0	0.01	0.01	0	0.01	0	0	0	0
27	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0
28	0	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
29	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
30	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01
31	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01
32	0.02	0.02	0.02	0.01	0.03	0.02	0.03	0.03	0.03	0.03
33	0.04	0.03	0.03	0.02	0.03	0.03	0.04	0.05	0.06	0.05
34	0.07	0.06	0.05	0.03	0.04	0.05	0.07	0.09	0.09	0.08
35	0.12	0.1	0.09	0.06	0.07	0.07	0.09	0.11	0.11	0.12
36	0.16	0.14	0.13	0.12	0.11	0.1	0.12	0.12	0.13	0.14
37	0.15	0.16	0.16	0.15	0.15	0.13	0.14	0.12	0.12	0.13
38	0.13	0.15	0.14	0.16	0.15	0.15	0.14	0.12	0.11	0.12
39	0.1	0.11	0.11	0.12	0.13	0.13	0.12	0.11	0.1	0.1
40	0.06	0.07	0.07	0.09	0.09	0.1	0.09	0.08	0.07	0.08
41	0.04	0.05	0.04	0.06	0.06	0.06	0.06	0.05	0.04	0.05
42	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
43	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01
44	0.01	0.01	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01
≥45	0.01	0.01	0	0	0.01	0.01	0	0	0.01	0.01
Total	11,174	9,800	12,882	10,767	14,462	15,818	19,984	19,827	21,247	20,521

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 1984-2019 trawl surveys.

	Western	Central		Eastern			
Year	Shumagin	Chirikof	Kodiak	Yakutat	Southeast	Total	CV
1984	60,666	9,584	39,766	76,601	34,055	220,672	25%
1987	64,403	19,440	56,820	47,269	53,274	241,206	23%
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 for are based on "break and burn" reading of otoliths.

Age	1984	1987	1990	1993	1996	1999	2003	2005	2007	2009	2011	2013	2015	2017
2	0.003	0.019	0	0.01	0.01	0.01	0.02	0	0	0	0	0	0.01	0
3	0.002	0.101	0.04	0.02	0.02	0.02	0.06	0.03	0.02	0.09	0.03	0.02	0.03	0.01
4	0.058	0.092	0.15	0.02	0.04	0.05	0.05	0.05	0.02	0.04	0.05	0.01	0.01	0.02
5	0.029	0.066	0.12	0.04	0.04	0.05	0.07	0.08	0.04	0.05	0.12	0.07	0.06	0.03
6	0.079	0.091	0.12	0.09	0.06	0.03	0.04	0.07	0.04	0.03	0.04	0.06	0.02	0.01
7	0.151	0.146	0.09	0.13	0.04	0.04	0.05	0.12	0.06	0.1	0.04	0.06	0.08	0.03
8	0.399	0.056	0.06	0.13	0.09	0.06	0.11	0.07	0.09	0.07	0.02	0.06	0.05	0.03
9	0.050	0.061	0.05	0.17	0.14	0.09	0.12	0.09	0.12	0.11	0.07	0.06	0.11	0.08
10	0.026	0.087	0.05	0.09	0.19	0.05	0.06	0.09	0.09	0.05	0.07	0.04	0.05	0.07
11	0.010	0.096	0.04	0.04	0.11	0.11	0.05	0.06	0.06	0.05	0.1	0.07	0.04	0.05
12	0.016	0.018	0.02	0.05	0.08	0.14	0.04	0.03	0.06	0.08	0.07	0.06	0.03	0.05
13	0.015	0.011	0.03	0.04	0.03	0.09	0.04	0.03	0.05	0.03	0.07	0.07	0.05	0.04
14	0.019	0.011	0.07	0.02	0.04	0.07	0.06	0.03	0.03	0.04	0.05	0.06	0.03	0.04
15	0.005	0.009	0.02	0.03	0.03	0.05	0.05	0.04	0.03	0.05	0.04	0.05	0.06	0.04
16	0.003	0.011	0.01	0.01	0.01	0.04	0.04	0.02	0.01	0.01	0.02	0.03	0.05	0.05
17	0.008	0.013	0	0.04	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.03	0.04	0.06
18	0.004	0.007	0.01	0.01	0.01	0.01	0.03	0.04	0.04	0.01	0.02	0.04	0.03	0.05
19	0.002	0.005	0	0	0.01	0	0.02	0.02	0.03	0	0.02	0.03	0.01	0.04
20	0.000	0.005	0.01	0	0.01	0.01	0.01	0.02	0.04	0.01	0.02	0.02	0.04	0.03
21	0.003	0.004	0	0	0	0.01	0.01	0.01	0.02	0.03	0.02	0.02	0.04	0.04
22	0.003	0.003	0	0	0	0.01	0	0.02	0.02	0.06	0.01	0.01	0.02	0.03
23	0.002	0.002	0	0	0	0.01	0.01	0	0.02	0.01	0.02	0.02	0.01	0.01
24	0.003	0.002	0.01	0	0	0	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02
25	0.110	0.083	0.07	0.05	0.03	0.02	0.03	0.03	0.06	0.04	0.05	0.1	0.12	0.15
Sample size	1428	1824	1754	1378	641	898	985	1009	1177	418	794	880	760	1053

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
$\hat{m}_a = 1 \big/ \left(1 + e^{-\delta^m (a - a_{50\%}^m)}\right)$	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
$s^f_{a,t1} = 1 \Big/ \left(1 + e^{-\delta^f \left(a - a^f_{50\%}\right)}\right)$	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)
$s^t_a = 1 \Big/ \left(1 + e^{-\delta^t (a - a^t_{50\%})}\right)$	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
$L_{\hat{p}^f_a} = \lambda_{\hat{p}^f_a}\left(\sum_{Y} -n^f_{a,y} \sum_{A} (p^f_{a,y} + k) \ln(\hat{p}^f_{a,y} + k)\right)$	Fishery age composition likelihood	$\lambda_{\hat{p}^f_a}$ – fishery age composition weight (1) $n^f_{a,y}$ – fishery age composition input sample size (square root of sample size)
$L_{\hat{p}^f_l} = \lambda_{\hat{p}^f_l}\left(\sum_{Y} -n^f_{l,y} \sum_{A} (p^f_{l,y} + k) \ln(\hat{p}^f_{l,y} + k)\right)$	Fishery length composition likelihood	$\lambda_{\hat{p}^f_a}$ – fishery length composition weight (1) $n^f_{a,y}$ – fishery length composition input sample size (number of hauls standardized to maximum of 100)
$L_{\hat{p}^t_a} = \lambda_{\hat{p}^t_a}\left(\sum_{Y} -n^t_{a,y} \sum_{A} (p^t_{a,y} + k) \ln(\hat{p}^t_{a,y} + k)\right)$	Bottom trawl survey age composition likelihood	$\lambda_{\hat{p}^t_a}$ – fishery age composition weight (1) $n^t_{a,y}$ – fishery age composition input sample size (square root of sample size)
$L_m = \sum_{D} \sum_{A} Binom(n_{a,D}, \widehat{m}_a) + \lambda_m \, {}^{1}\!/\!\left(1 + e^{\delta^m a^m_{50\%}}\right)$	Maturity likelihood	D – Dataset $n_{a,D}$ – number observed at age for maturity by dataset λ_m – maturity at age 0 penalty weight (1000)
$L_\theta = \frac{1}{2\sigma^2_\theta} \ln\left(\frac{\theta}{\theta_{prior}}\right)^2$	Prior penalty, used for natural mortality (M), bottom trawl survey catchability (q), and recruitment variability (σ_r)	θ – parameter estimate σ^2_θ – prior uncertainty θ_{prior} – prior parameter estimate
$L_r = \lambda_r\left(\frac{1}{2\sigma^2_r} \sum_{Y} \varepsilon^r_y + Y \ln \sigma_r\right)$	Recruitment deviation penalty	λ_r – recruitment deviation penalty weight (1) σ_r – recruitment variability
$L_f = \lambda_f \sum_{Y} \varepsilon^f_y$	Fishing mortality deviation penalty	λ_f – fishing mortality deviation penalty weight (0.1)

Table 9-14. Summary of results from 2019 compared with 2017 results

Likelihoods	**17.1 (2017)**	**17.1 (2019)**
Catch	0.18	0.21
Survey Biomass	13.23	13.90
Fishery Ages	19.28	20.83
Survey Ages	19.55	22.34
Fishery Sizes	65.51	66.42
Maturity	103.52	103.52
Data-Likelihood	221.27	227.23
Penalties/Priors		
Recruitment Devs	15.92	16.26
F Regularity	5.08	5.43
σ_r prior	6.64	6.69
q prior	1.39	1.22
M prior	3.73	3.26
Objective Fun Total	254.04	260.09
Parameter Ests.		
Active parameters	158	162
Mohn's rho	-0.22	-0.27
q	2.11	2.01
M	0.066	0.065
σ_r	0.82	0.82
Mean Recruitment	60.84	62.09
$F_{40\%}$	0.094	0.09
Projected Total Biomass	511,934	544,469
$B_{CURRENT}$	180,014	201,518
$B_{100\%}$	293,621	319,837
$\mathbf{B_{40\%}}$	117,448	127,935
maxABC	29,236	**31,238**
$F_{35\%}$	0.113	0.108
$OFL_{F35\%}$	34,761	**37,092**

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	35,945	36,256	109,138	109,908	0.198	0.196	20,611	20,935
1978	31,339	31,732	94,528	95,536	0.085	0.084	18,511	18,826
1979	31,684	32,170	93,157	94,402	0.089	0.088	17,437	17,761
1980	31,636	32,220	91,057	92,540	0.119	0.117	17,048	17,398
1981	30,260	30,941	87,227	88,952	0.120	0.119	20,302	20,753
1982	28,808	29,584	87,989	89,971	0.061	0.060	33,330	34,040
1983	29,536	30,414	91,897	94,157	0.031	0.030	24,521	25,129
1984	31,620	32,610	97,425	99,986	0.028	0.028	21,077	21,667
1985	34,109	35,225	103,171	106,070	0.008	0.008	22,210	22,902
1986	37,723	38,987	112,879	116,207	0.019	0.019	28,856	29,873
1987	41,017	42,447	121,298	125,127	0.037	0.036	29,003	30,163
1988	43,517	45,135	127,593	131,994	0.067	0.065	29,766	31,089
1989	44,574	46,407	134,154	139,337	0.088	0.085	43,471	45,580
1990	44,771	46,857	146,238	152,593	0.090	0.086	68,759	72,280
1991	45,396	47,786	157,421	164,993	0.042	0.040	64,189	67,449
1992	49,979	52,762	188,079	197,445	0.035	0.033	100,467	105,748
1993	56,354	59,632	213,916	224,895	0.010	0.009	77,924	81,735
1994	66,156	70,050	239,805	252,335	0.008	0.007	62,239	65,372
1995	77,472	82,083	254,584	268,385	0.023	0.021	29,449	31,195
1996	87,768	93,154	264,932	280,071	0.032	0.030	36,424	38,729
1997	96,113	102,278	270,753	287,160	0.035	0.033	36,833	39,165
1998	102,206	109,113	275,326	293,187	0.032	0.031	41,445	44,678
1999	106,661	114,256	276,881	295,965	0.038	0.036	33,181	35,709
2000	109,043	117,291	289,395	310,752	0.035	0.033	75,759	82,423
2001	110,997	119,911	305,496	329,882	0.035	0.033	81,865	90,564
2002	112,920	122,574	311,281	337,931	0.038	0.035	48,084	53,240
2003	115,363	125,886	318,892	347,970	0.034	0.031	59,104	65,058
2004	119,452	131,016	348,192	381,541	0.033	0.030	123,905	136,572
2005	124,451	137,226	364,509	401,015	0.031	0.028	76,903	84,404
2006	130,795	144,942	393,479	435,436	0.035	0.031	115,609	130,923
2007	137,369	153,035	404,905	450,015	0.032	0.029	64,006	70,302
2008	144,955	162,315	425,855	474,058	0.029	0.026	96,163	103,374
2009	153,236	172,309	428,893	478,657	0.030	0.027	38,684	40,939
2010	160,980	181,670	436,654	488,421	0.036	0.032	64,109	69,459
2011	166,600	188,674	435,785	488,659	0.033	0.029	49,115	52,204
2012	171,627	194,781	463,173	514,137	0.032	0.029	137,402	133,187
2013	175,505	199,444	474,774	527,685	0.028	0.025	80,924	89,983
2014	180,005	204,539	497,888	559,205	0.035	0.031	112,968	142,020
2015	183,094	208,180	493,381	556,392	0.038	0.033	38,039	41,239
2016	186,267	212,054	500,668	563,791	0.046	0.041	87,506	87,591
2017	180,163	214,103	487,661	548,331	0.045	0.043	38,200	31,272
2018		214,812		543,353		0.045		76,758
2019		205,292		529,266		0.045		51,040

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	2.01	2.10	2.05	0.43	0.46	1.34	3.12
M	0.065	0.067	0.066	0.006	0.006	0.056	0.079
$F_{40\%}$	0.090	0.109	0.102	0.024	0.038	0.059	0.203
2020 SSB	201,500	206,642	201,302	45,449	46,914	129,217	312,721
2020 ABC	31,237	38,406	35,652	10,881	15,378	17,263	76,786

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	27,073	7,057	70,383	121,369	94,705	175,017	36,256	26,115	54,991
1978	44,432	11,869	97,701	107,771	80,631	162,403	31,732	21,457	51,026
1979	32,702	8,355	82,381	108,247	80,507	163,266	32,170	21,614	52,228
1980	28,128	7,588	65,409	108,506	80,035	164,843	32,220	21,510	52,750
1981	29,710	8,203	71,840	106,303	76,895	163,204	30,941	19,976	51,641
1982	38,706	11,493	85,944	104,876	74,435	163,638	29,584	18,395	50,561
1983	39,095	11,442	89,504	109,224	76,994	169,538	30,414	18,953	51,714
1984	40,336	11,208	96,054	116,760	83,120	179,456	32,610	20,956	54,320
1985	59,250	19,441	123,966	125,617	90,212	191,421	35,225	23,273	57,242
1986	94,122	37,663	187,326	139,244	101,360	209,561	38,987	26,524	61,397
1987	87,901	29,390	177,093	154,036	112,555	228,594	42,447	29,224	65,819
1988	137,441	67,530	258,621	171,277	125,135	252,272	45,135	31,365	69,105
1989	106,126	40,152	215,910	187,738	136,102	277,232	46,407	31,953	71,625
1990	84,730	29,247	168,919	203,152	145,131	303,473	46,857	31,491	73,557
1991	40,410	11,064	96,660	216,942	153,392	327,875	47,786	31,338	75,621
1992	50,201	17,237	104,651	236,535	166,744	356,699	52,762	34,634	82,947
1993	50,822	17,208	107,535	254,261	179,152	381,758	59,632	39,423	93,244
1994	57,996	20,353	120,383	274,723	194,320	408,776	70,050	47,162	107,138
1995	46,345	12,491	108,146	292,945	208,821	433,285	82,083	56,196	124,220
1996	106,998	46,716	207,037	307,372	219,194	453,130	93,154	64,169	140,039
1997	117,566	45,675	225,447	320,150	228,053	472,662	102,278	70,649	153,466
1998	69,124	20,372	154,795	331,498	235,718	488,790	109,113	75,046	163,082
1999	84,489	25,296	176,189	344,079	244,310	506,644	114,256	78,102	170,576
2000	177,332	91,673	336,713	359,379	254,651	529,891	117,291	79,724	175,427
2001	109,602	30,325	233,611	376,621	267,102	555,231	119,911	81,193	179,454
2002	169,983	81,445	326,955	397,625	281,554	586,163	122,574	82,864	184,230
2003	91,302	24,972	210,007	418,279	296,152	615,904	125,886	85,047	189,424
2004	134,414	57,295	267,133	441,933	312,840	650,954	131,016	88,216	197,491
2005	53,261	13,015	138,814	462,345	326,674	683,962	137,226	92,309	206,354
2006	90,375	30,618	191,936	481,699	340,030	710,668	144,942	97,964	217,978
2007	67,957	17,504	170,121	495,454	348,868	731,048	153,035	103,656	228,763
2008	173,331	75,974	358,475	511,353	361,038	756,699	162,315	110,640	241,883
2009	117,094	31,057	273,085	527,147	371,908	781,451	172,309	117,847	256,450
2010	184,720	75,310	377,992	545,565	385,307	809,491	181,670	124,082	270,976
2011	53,676	11,220	154,509	558,913	393,432	830,686	188,674	128,338	282,557
2012	114,063	34,799	262,039	573,813	403,654	852,811	194,781	132,336	291,656
2013	40,766	8,623	129,848	584,057	409,709	868,122	199,444	135,505	299,252
2014	100,118	23,396	265,248	594,359	417,243	886,612	204,539	138,761	307,615
2015	66,598	13,240	218,126	596,793	418,505	891,968	208,180	140,645	314,859
2016	67,430	11,741	243,405	595,291	415,685	890,541	212,054	142,547	321,321
2017	55,934	10,946	227,512	586,274	406,477	881,702	214,103	143,188	326,353
2018	62,698	10,951	299,756	574,048	394,955	874,958	214,812	141,821	328,826
2019	62,286	11,154	293,311	559,056	381,885	862,384	205,292	133,312	318,575
2020	83,850	14,826	290,556	544,569	366,656	849,974	201,518	129,217	312,721
2021	83,850	15,839	310,227	524,883	354,943	811,044	194,795	124,086	295,615

Table 9-18. Estimated numbers (thousands) in 2019, 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 2019 (1000's)	Maturity (%)	Weight (g)	Fishery selectivity (%)	Survey selectivity (%)
2	62,286	0.7	44	0.1	8.8
3	58,777	1.3	97	0.8	14.6
4	49,133	2.5	165	3.1	23.3
5	55,412	4.7	240	7.9	35
6	51,040	8.8	318	15.2	48.8
7	71,221	15.8	394	24.8	62.8
8	26,760	26.9	465	35.9	75
9	68,647	41.8	529	47.9	84.2
10	29,429	58.4	587	59.7	90.4
11	91,728	73.3	638	70.7	94.3
12	52,410	84.3	682	80.4	96.7
13	69,662	91.3	720	88.3	98.1
14	24,461	95.3	753	94.2	98.9
15	29,092	97.6	780	98	99.4
16	15,330	98.7	804	99.9	99.7
17	34,629	99.3	823	100	99.8
18	21,084	99.7	840	98.5	99.9
19	35,221	99.8	853	95.6	99.9
20	20,377	99.9	865	91.6	100
21	29,552	100	874	86.7	100
22	12,603	100	882	81.3	100
23	9,221	100	889	75.5	100
24	14,032	100	894	69.5	100
25	11,453	100	899	63.5	100
26	4,468	100	902	57.6	100
27	5,068	100	906	51.9	100
28	4,057	100	908	46.5	100
29+	51,208	100	915	41.4	100

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. $B_{40\%}$ = 127,935 t, $B_{35\%}$ = 111,943 t, $F_{40\%}$ =0.09, and $F_{35\%}$ =0.108.

Year	Maximum permissible F	Author's F* (prespecified catch)	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning biomass (t)				
2019	205,294	205,294	205,294	205,294	205,294	205,294	205,294
2020	201,180	201,518	203,537	202,610	205,927	200,265	201,180
2021	193,495	194,795	202,551	198,951	212,077	190,071	193,495
2022	185,327	187,184	200,495	194,403	217,059	179,734	184,489
2023	177,118	178,823	197,719	189,369	221,078	169,702	174,005
2024	169,191	170,741	194,501	184,162	224,310	160,281	164,140
2025	161,873	163,272	191,165	179,129	227,022	151,773	155,207
2026	155,532	156,787	188,094	174,680	229,611	144,499	147,538
2027	150,423	151,543	185,610	171,134	232,445	138,665	141,343
2028	146,544	147,542	183,755	168,559	235,674	134,216	136,569
2029	143,730	144,618	183,199	166,863	239,326	130,976	133,024
2030	141,679	142,469	183,093	165,788	243,214	128,668	130,417
2031	140,168	140,870	183,007	165,146	247,231	127,037	128,521
2032	139,017	139,639	182,538	164,762	251,225	125,854	127,108
			Fishing mortality				
2019	0.066	0.066	0.066	0.066	0.066	0.066	0.066
2020	0.090	0.084	0.045	0.063	-	0.108	0.108
2021	0.090	0.083	0.045	0.063	-	0.108	0.108
2022	0.090	0.090	0.045	0.063	-	0.108	0.108
2023	0.090	0.090	0.045	0.063	-	0.108	0.108
2024	0.090	0.090	0.045	0.063	-	0.108	0.108
2025	0.090	0.090	0.045	0.063	-	0.108	0.108
2026	0.090	0.090	0.045	0.063	-	0.108	0.108
2027	0.090	0.090	0.045	0.063	-	0.108	0.108
2028	0.090	0.090	0.045	0.063	-	0.108	0.108
2029	0.090	0.090	0.045	0.063	-	0.107	0.107
2030	0.090	0.090	0.045	0.063	-	0.105	0.105
2031	0.090	0.090	0.045	0.063	-	0.104	0.104
2032	0.090	0.090	0.045	0.063	-	0.103	0.103
			Yield (t)				
2019	23,768	23,768	23,768	23,768	23,768	23,768	23,768
2020	31,238	31,238	15,897	21,976	-	37,092	31,238
2021	29,833	29,983	15,721	21,436	-	34,944	29,833
2022	28,358	28,647	15,453	20,795	-	32,788	33,670
2023	26,879	27,140	15,120	20,093	-	30,702	31,485
2024	25,485	25,716	14,762	19,390	-	28,788	29,473
2025	24,237	24,440	14,411	18,733	-	27,112	27,705
2026	23,167	23,343	14,090	18,148	-	25,705	26,211
2027	22,302	22,453	13,820	17,664	-	24,585	25,013
2028	21,657	21,786	13,622	17,303	-	23,740	24,114
2029	21,195	21,304	13,487	17,047	-	22,932	23,346
2030	20,891	20,985	13,417	16,892	-	22,300	22,671
2031	20,678	20,763	13,394	16,810	-	21,881	22,198
2032	20,538	20,615	13,411	16,789	-	21,642	21,903

*Projected ABCs and OFLs for 2020 and 2021 are derived using estimated catch of 23,768 for 2019, and projected catches of 31,238 t and 29,983 t for 2020 and 2021 based on realized catches from 2016-2018. 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; 2009-2013 average and 2014-2018.

	Avg 2009-13	**2014**	**2015**	**2016**	**2017**	**2018**
Total catch (thousands of mt)	24.74	28.9	29	34	31.8	34.2
Retained catch (thousands of mt)	22.6	25.8	26.7	30.8	26.9	31.4
Catcher Processors #	14.4	9	8	12	11	9
Catcher Vessels #	179	173	139	130	126	112
Catcher Vessel Share of Retained	45%	46%	46%	49%	42%	47%
Ex-vessel value (millions of US$)	$10.0	$11.9	$12.4	$13.9	$12.1	$14.8
Ex-vessel price (US$/lb)	$0.207	$0.225	$0.227	$0.225	$0.226	$0.239
Central Gulf share of GOA rockfish catch	70%	84%	84%	87%	84%	84%
POP share of GOA rockfish catch	58%	59%	65%	67%	73%	72%
Northern rockfish share of GOA rockfish catch	19%	17%	15%	12%	7%	8%
Dusky rockfish share of GOA rockfish catch	14%	12%	11%	11%	10%	10%

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; 2009-2013 average and 2014-2018.

	Avg 2009-13	**2014**	**2015**	**2016**	**2017**	**2018**
First-wholesale production (thousands of mt)	12.24	14.23	14.55	18.10	14.55	17.94
First-wholesale value (millions of US$)	$33.18	$34.10	$34.20	$40.00	$39.20	$45.40
First-wholesale price/lb (US$)	$1.229	$1.087	$1.066	$1.002	$1.222	$1.148
POP share of value	58%	58%	63%	62%	72%	71%
POP price/lb (US$)	$1.17	$0.98	$0.96	$0.83	$1.15	$1.06
Northern rockfish share of value	17%	15%	11%	12%	5%	6%
Northern rockfish price/lb (US$)	$1.12	$1.04	$0.97	$1.38	$1.03	$1.02
Dusky rockfish share of value	12%	11%	11%	12%	8%	8%
Dusky rockfish price/lb (US$)	$1.11	$1.08	$1.19	$1.32	$1.04	$1.15
H&G share of value	75%	76%	74%	70%	79%	82%

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; 2009-2013 average and 2014-2019.

	Avg 2009-13	**2014**	**2015**	**2016**	**2017**	**2018**	**2019 (to June)**
Global production of rockfish (thousands of mt)	263.4	260.8	282.9	294.6	294.9	-	-
Global production of POP (thousands of mt)	41.8	53.0	55.5	58.5	56.6	-	-
U.S. share of global POP	84.4%	89.5%	86.6%	88.5%	89.6%	-	-
U.S. POP share of global rockfish	13.4%	18.2%	17.0%	17.6%	17.2%	-	-
Export volume of POP (thousands of mt)	12.5	23.8	22.7	25.6	22.7	27.8	4.1
Export value of POP (millions of US$)	$29.9	$79.6	$77.7	$84.6	$76.1	$89.5	$10.4
Export price/lb of POP (US$)	$1.08	$1.52	$1.55	$1.50	$1.52	$1.46	$1.14
China's share of U.S. POP export value	56%	65%	52%	67%	55%	62%	79%
Exchange rate, Yuan/Dollar	6.51	6.14	6.23	6.64	6.76	6.62	6.74

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

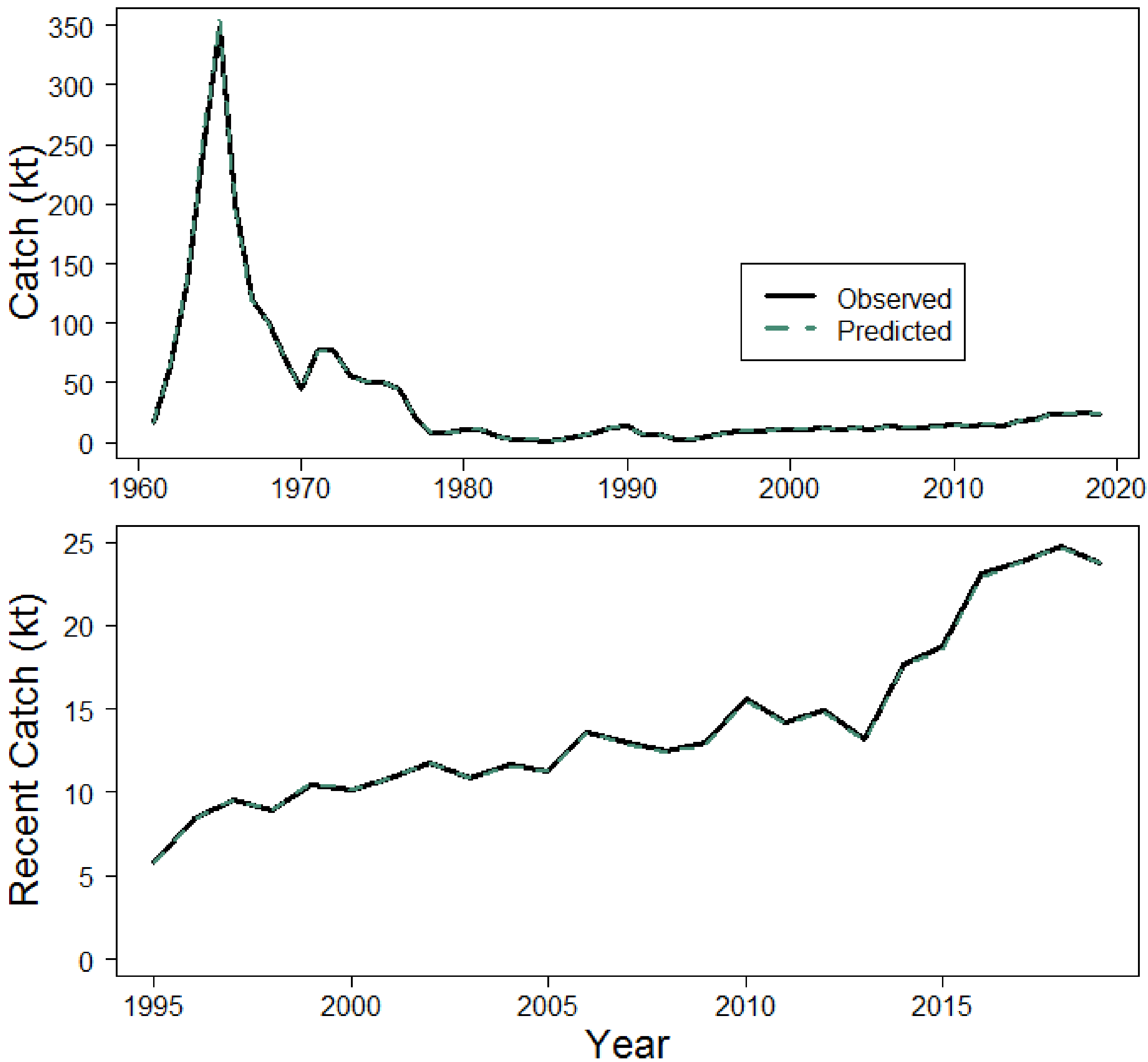


Figure 9-1. Estimated and observed long-term (top figure) and short-term (bottom figure) catch history for GOA POP.

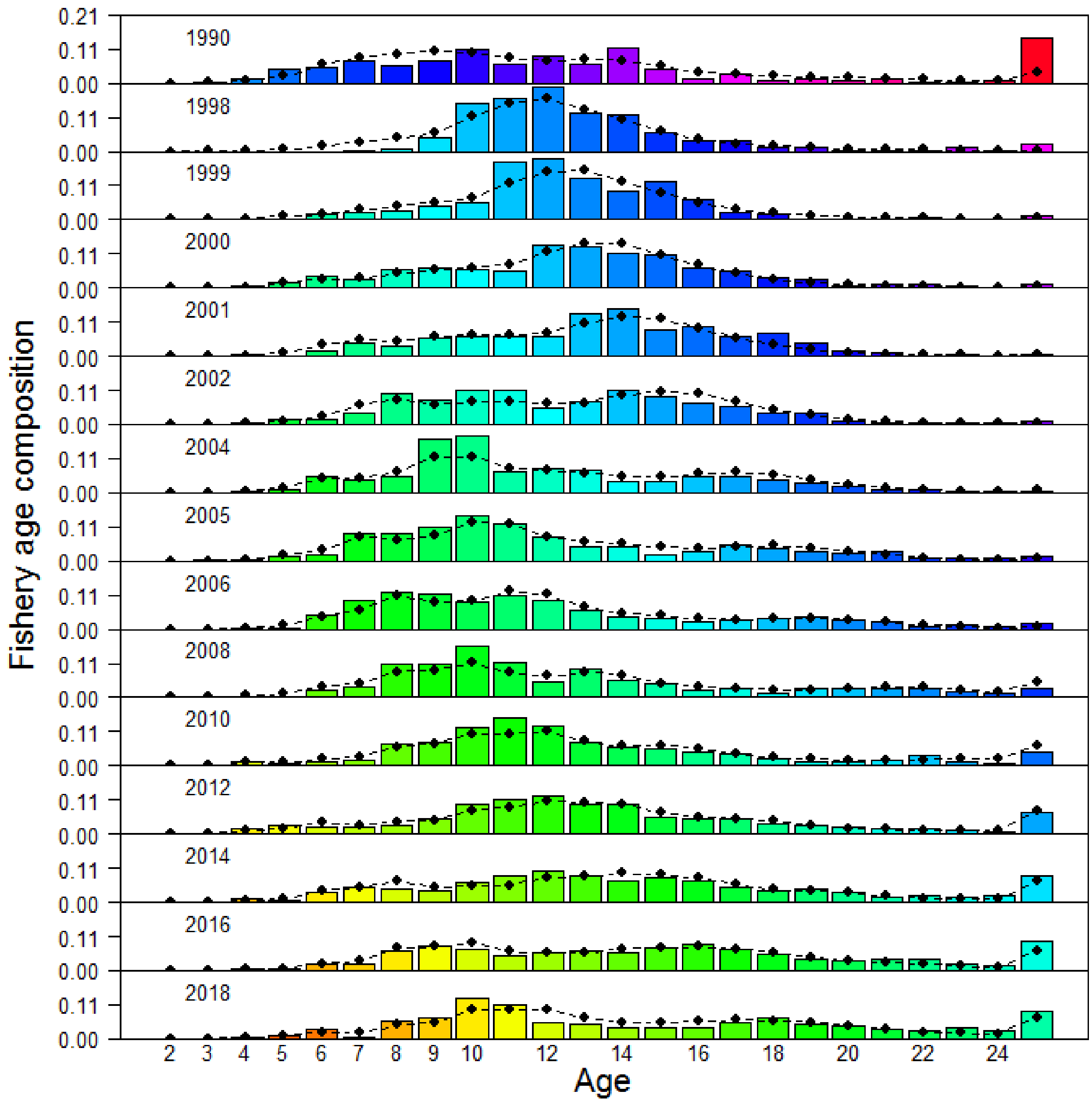


Figure 9-2. Fishery age compositions for GOA POP. Observed = bars, actual age composition predicted from author recommended model = line with circles. Colors follow cohorts.

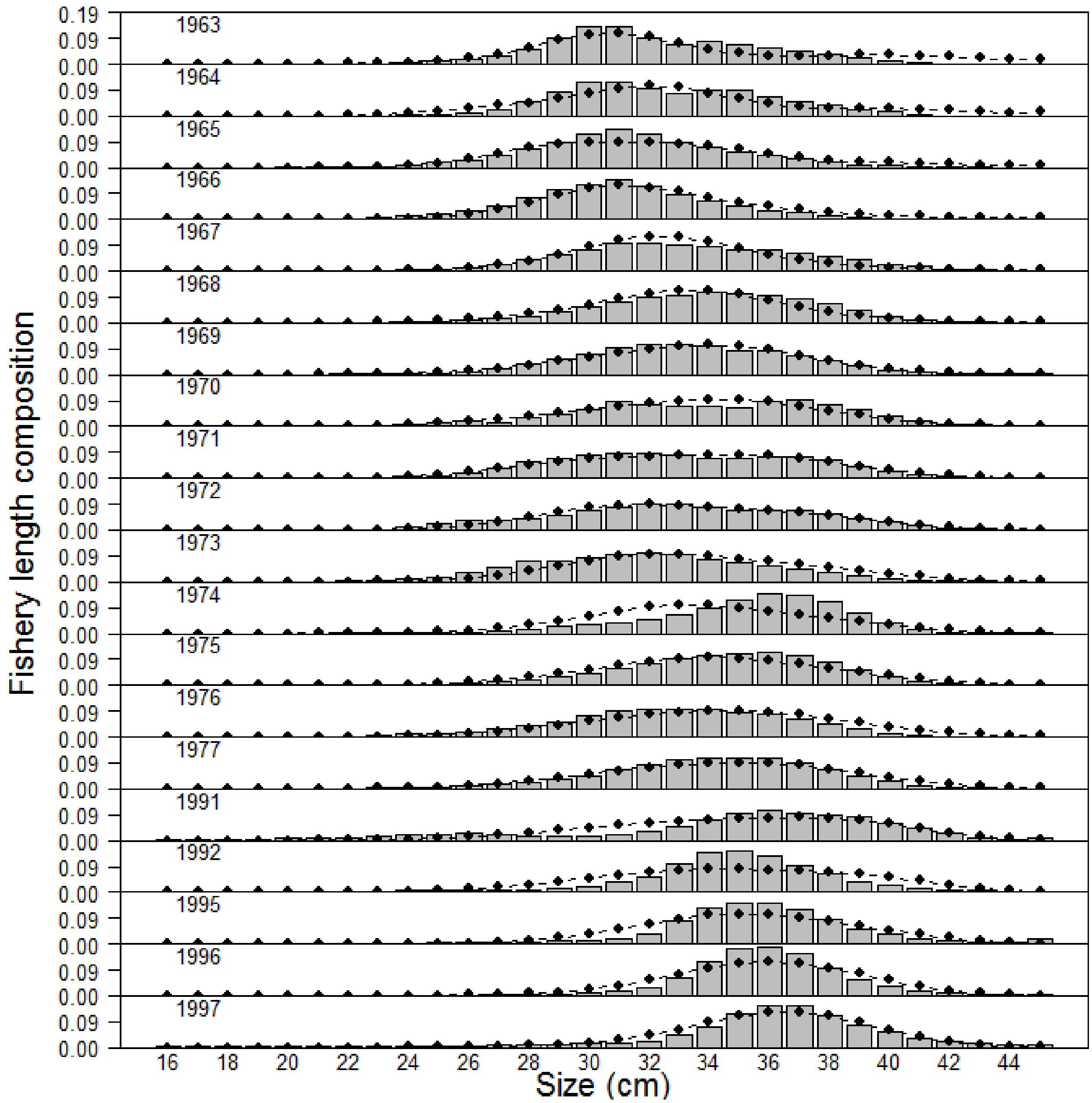


Figure 9-3. Fishery length (cm) compositions for GOA POP. Observed = bars, predicted from author recommended model = line with circles.

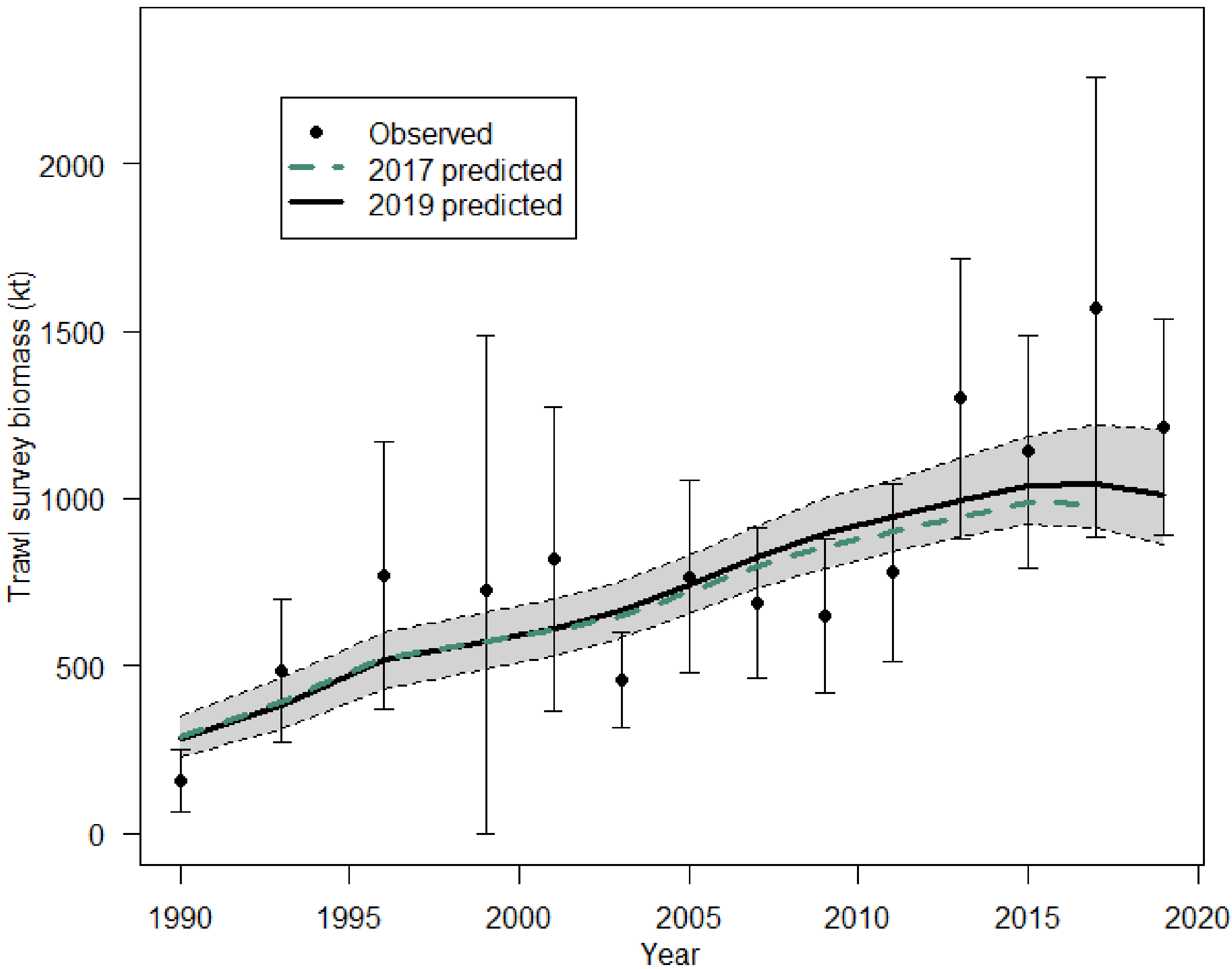


Figure 9-4. NMFS Groundfish Survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for GOA POP. Predicted estimates from the recommended model (black line, with 95% confidence intervals shown in grey shaded region) compared with last year's model fit (green dotted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

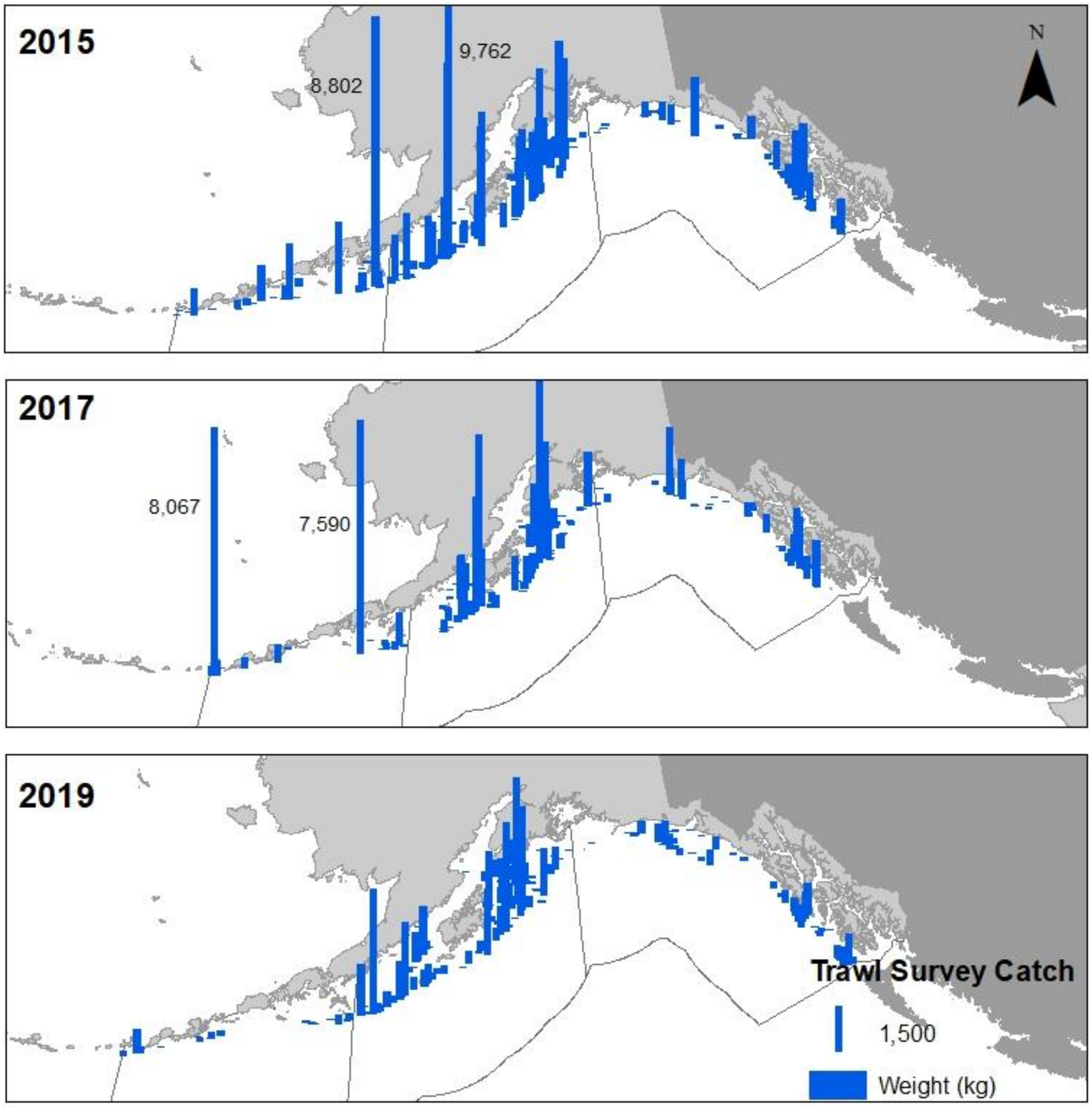


Figure 9-5. Distribution of GOA POP catches in the 2015-2019 GOA groundfish surveys.

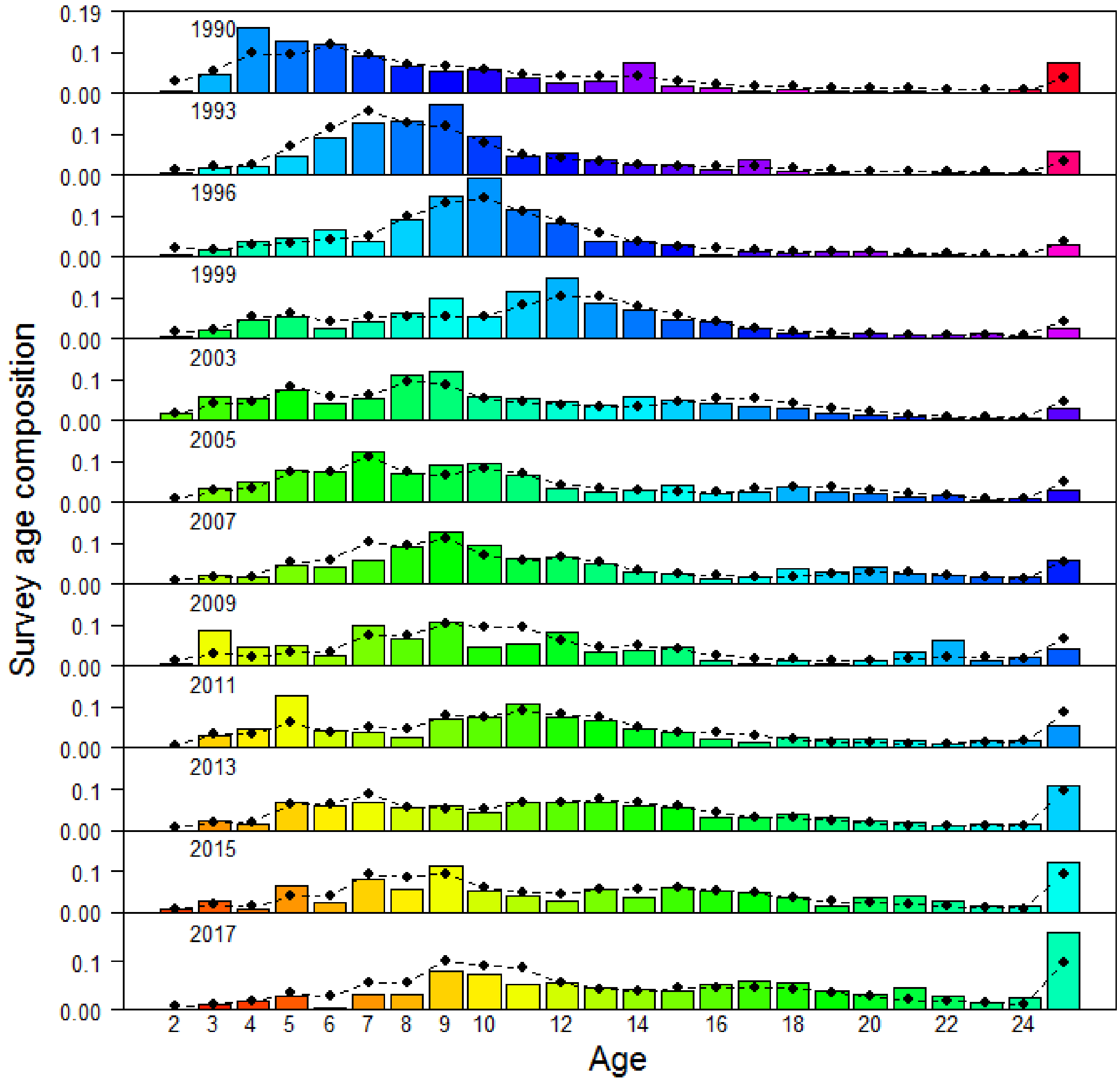


Figure 9-6. Groundfish survey age compositions for GOA POP. Observed = bars, actual age composition predicted from author recommended model = line with circles.

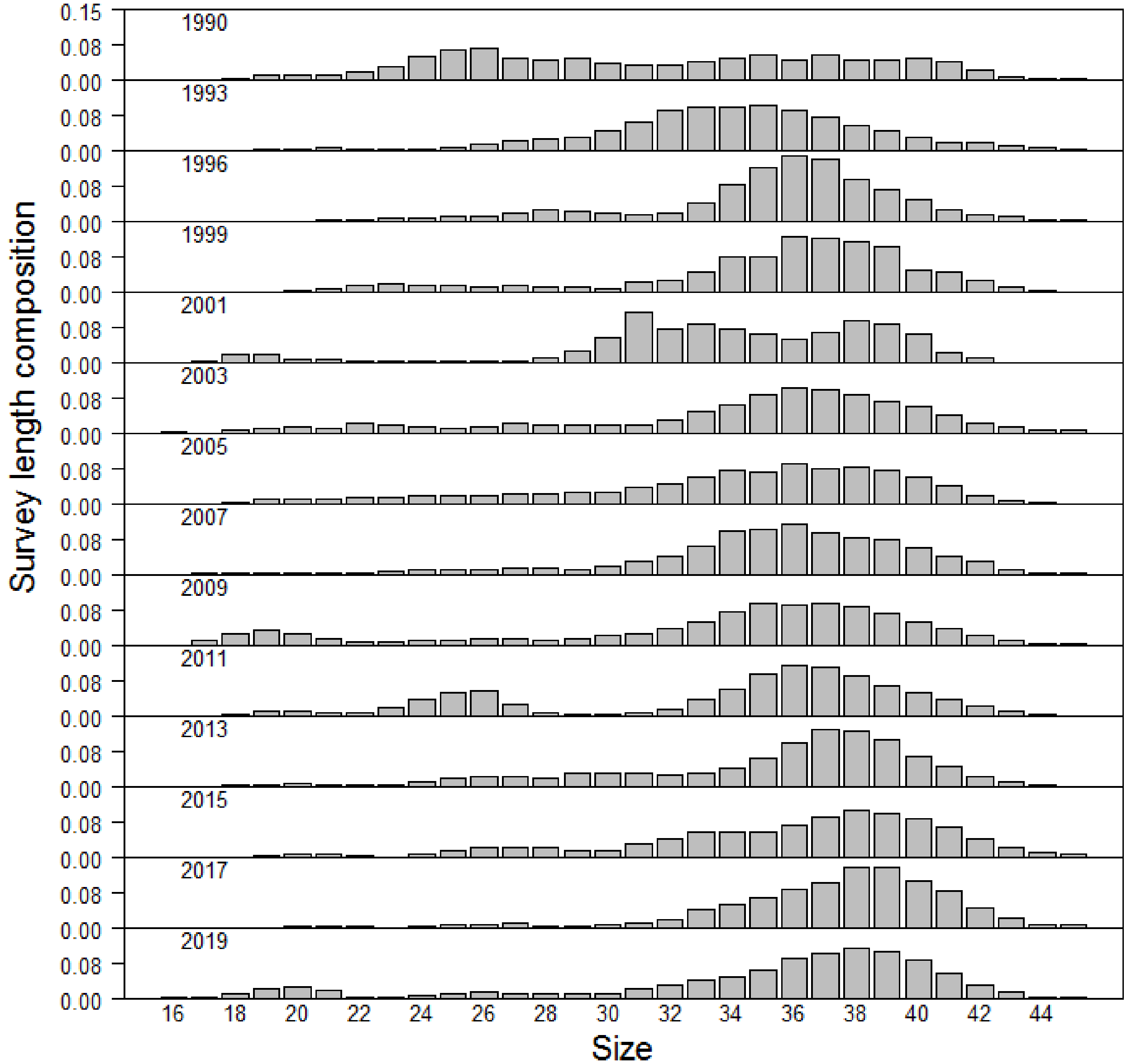


Figure 9-7. Groundfish survey length compositions for GOA POP. Observed = bars. Survey size not used in POP model because survey ages are available for these years.

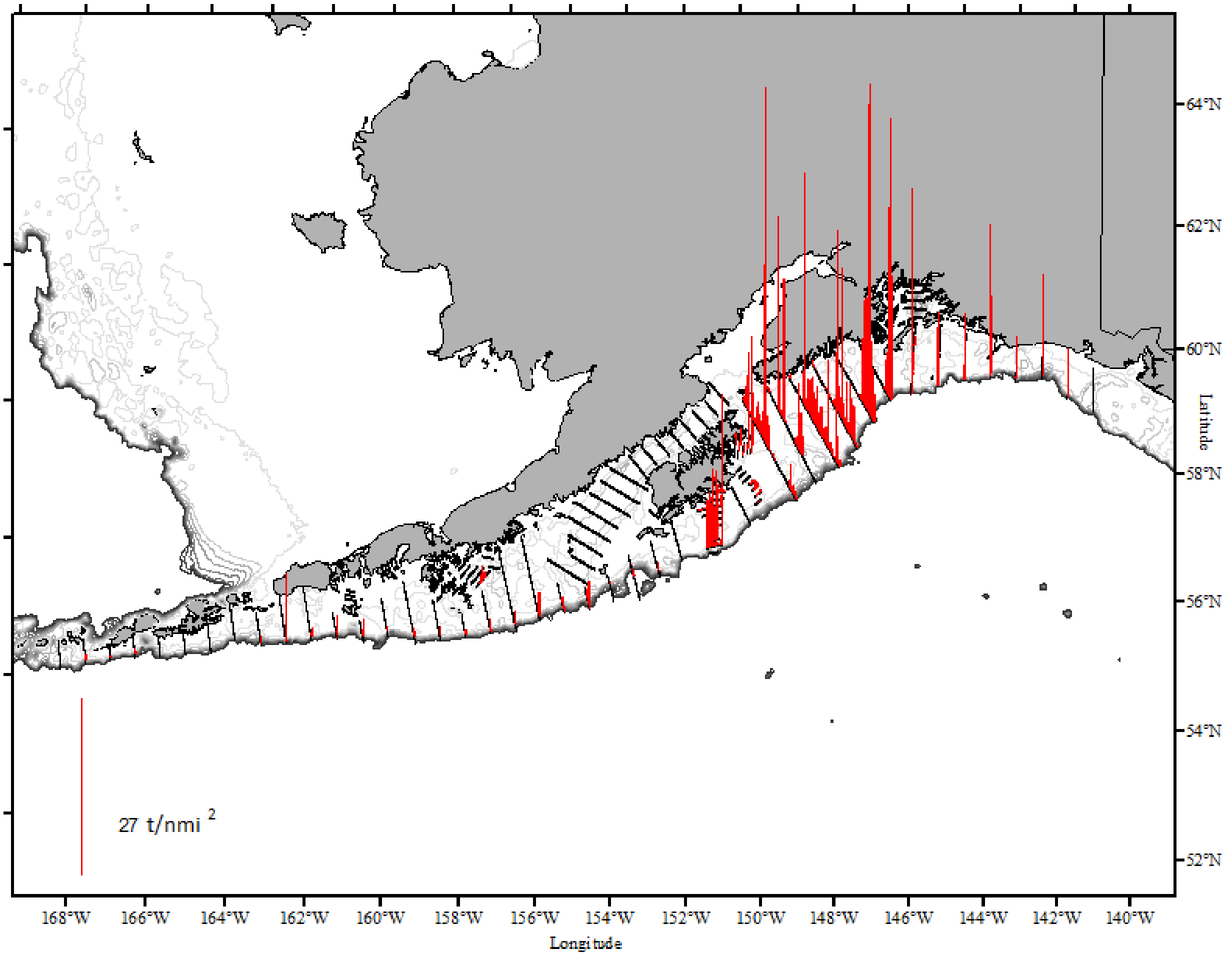


Figure 9-8. Density (t/nmi2) of POP observed during the 2019 GOA acoustic-trawl survey.

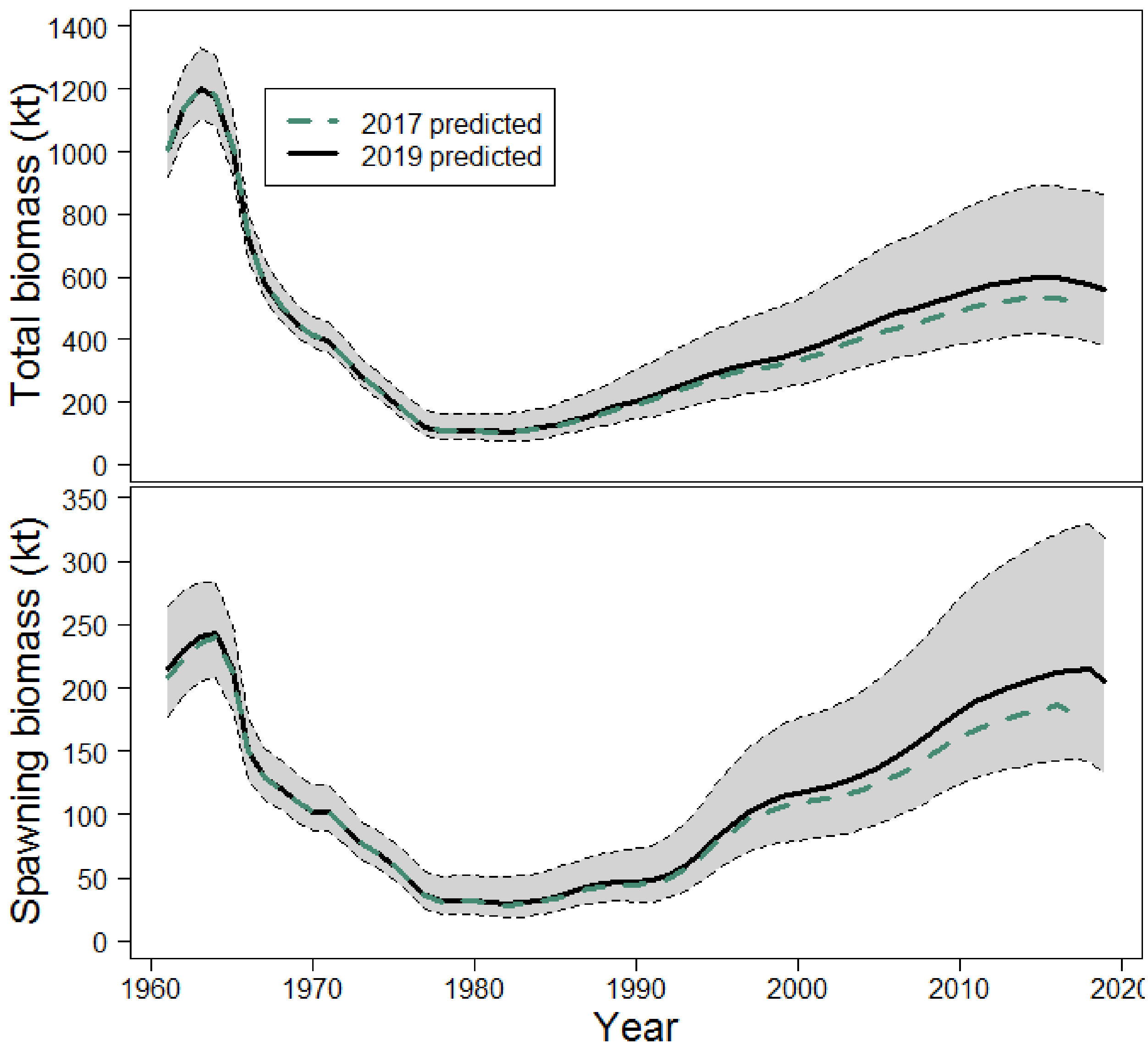


Figure 9-9. Model estimated total biomass (top panel, solid black line) and spawning biomass (bottom panel) with 95% credible intervals determined by MCMC (light grey region) for GOA POP. Last year's model estimates included for comparison (dashed line).

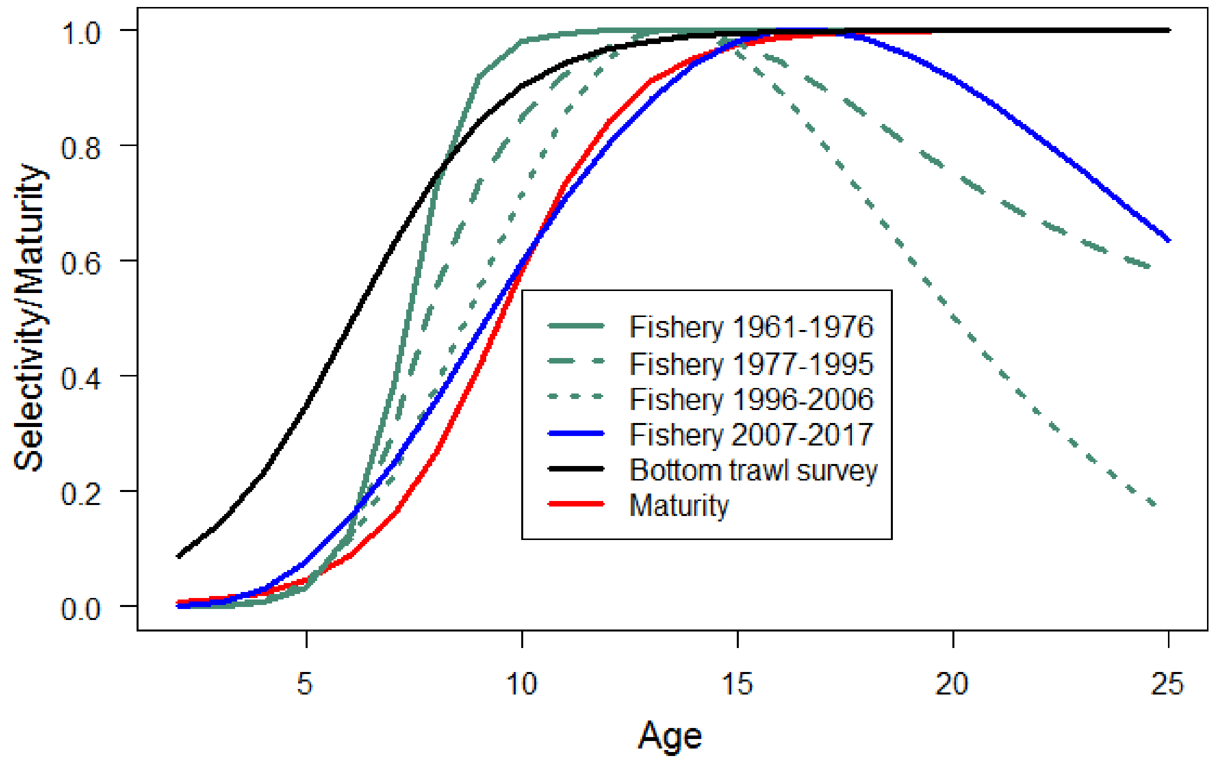


Figure 9-10. Estimated selectivities for the fishery and groundfish survey with maturity for GOA POP.

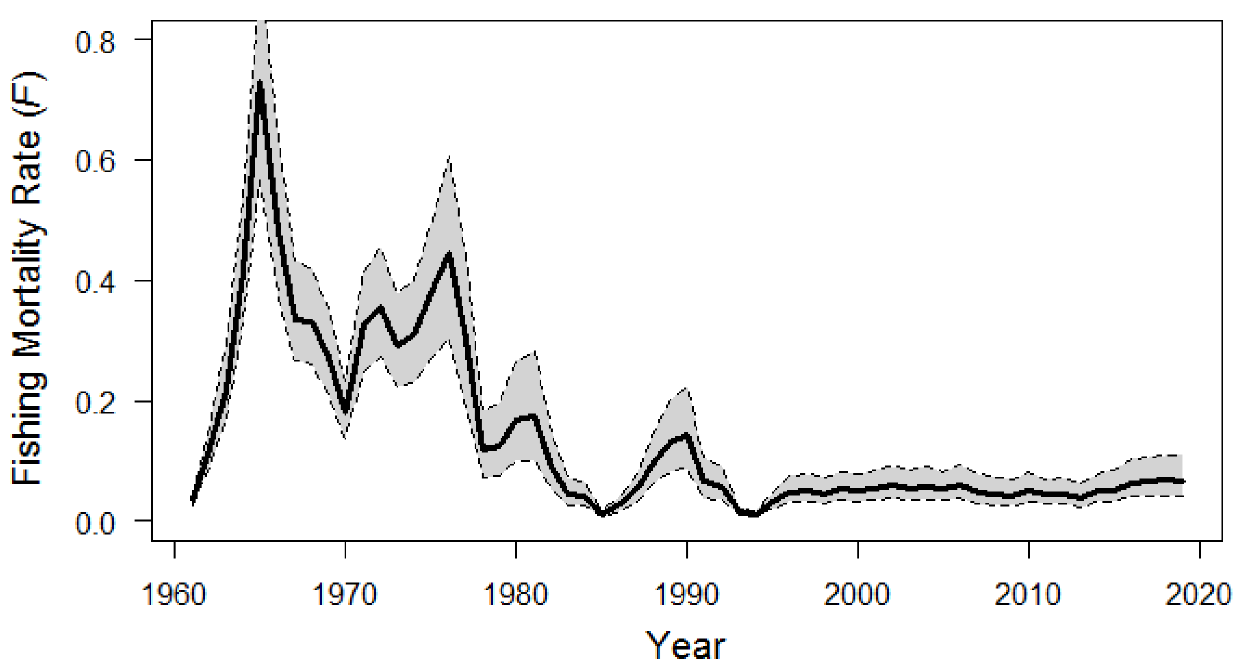


Figure 9-11. Estimated fully selected fishing mortality over time with 95% credible intervals determined by MCMC (light grey region) for GOA POP.

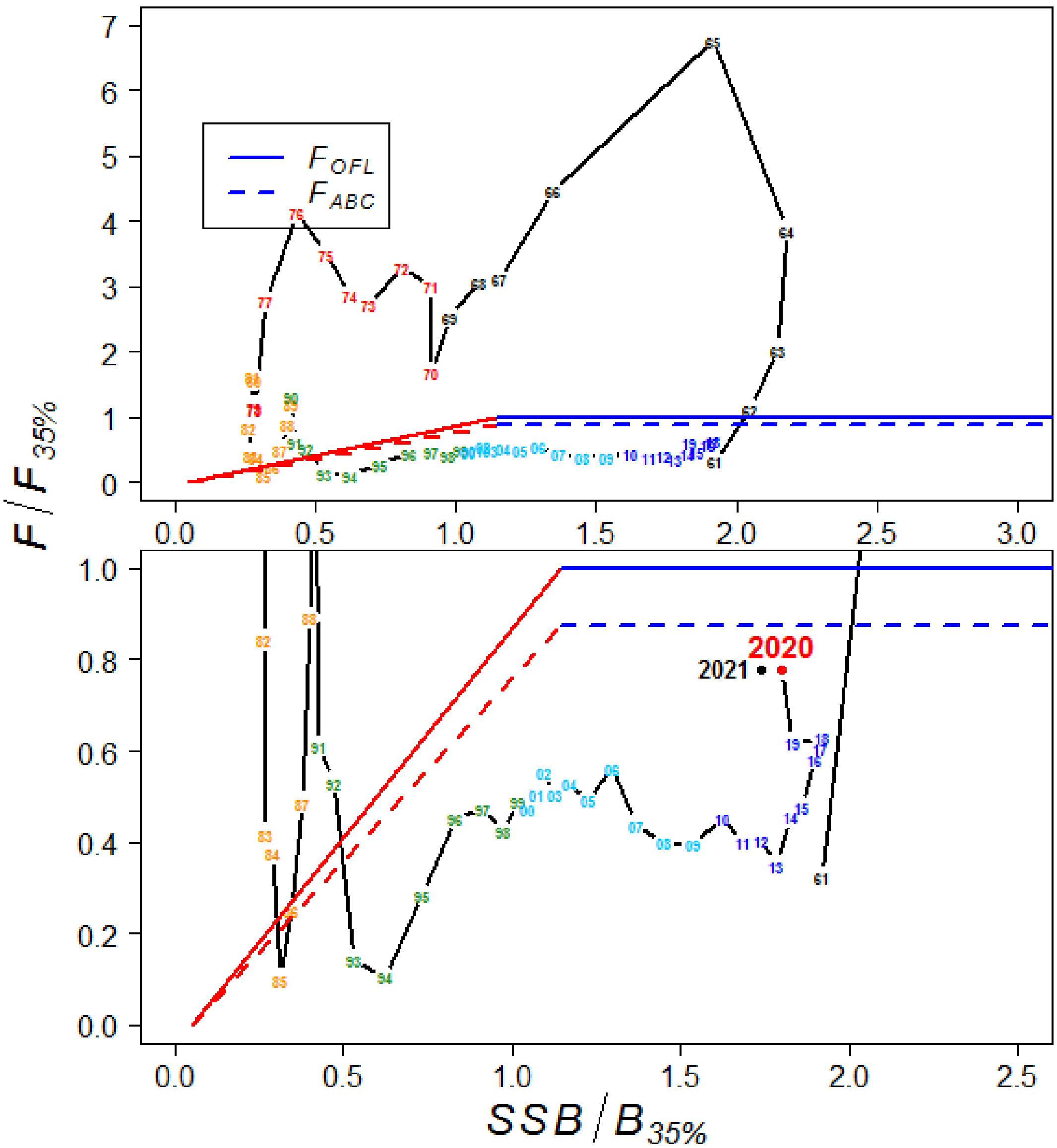


Figure 9-12. Time series of POP estimated spawning biomass relative to the target level B35% level and fishing mortality relative to F35% for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.

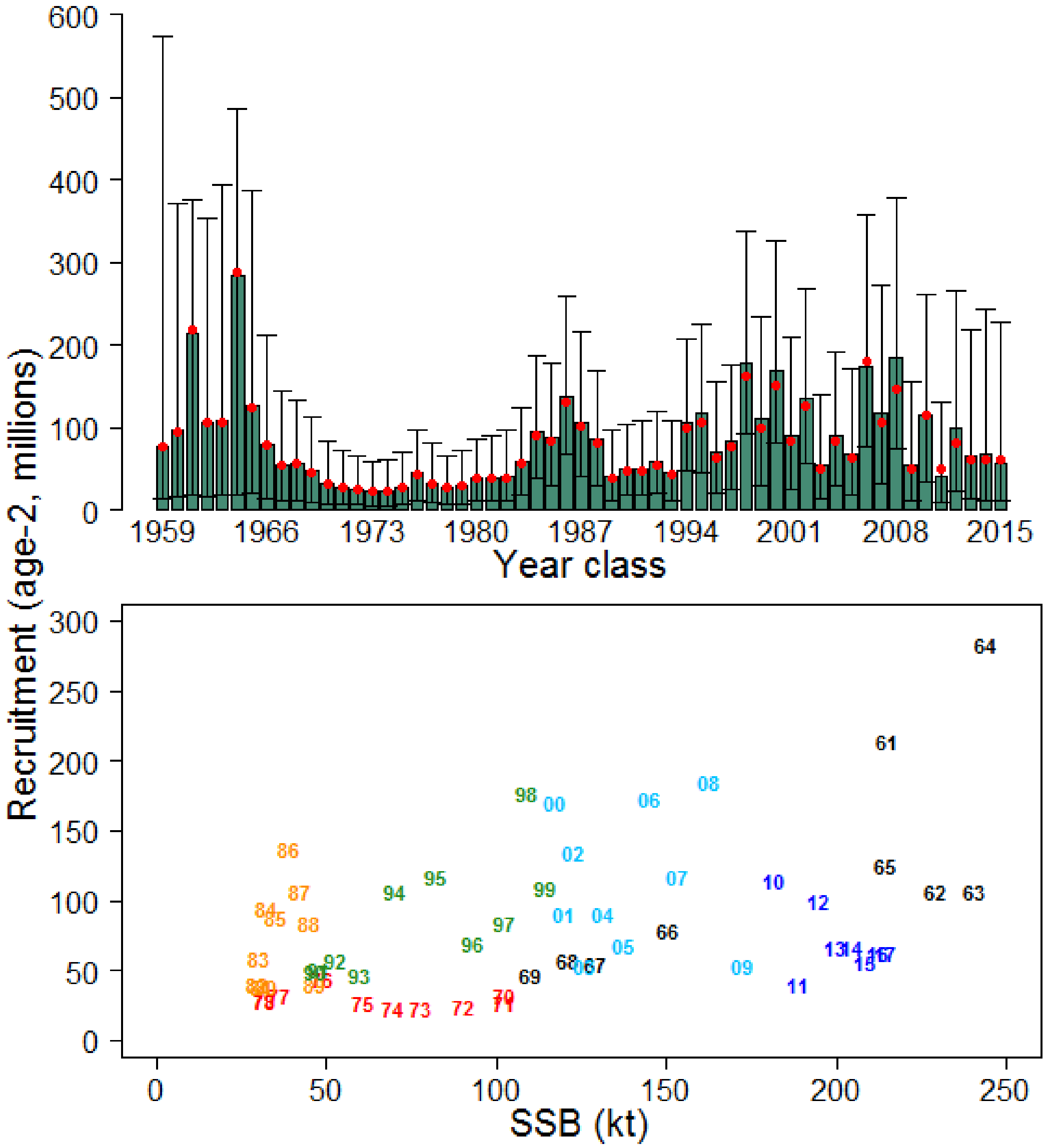


Figure 9-13. Estimated recruitment of GOA POP (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimated recruits per spawning stock biomass (bottom). Red circles in top graph are last year's estimates for comparison.

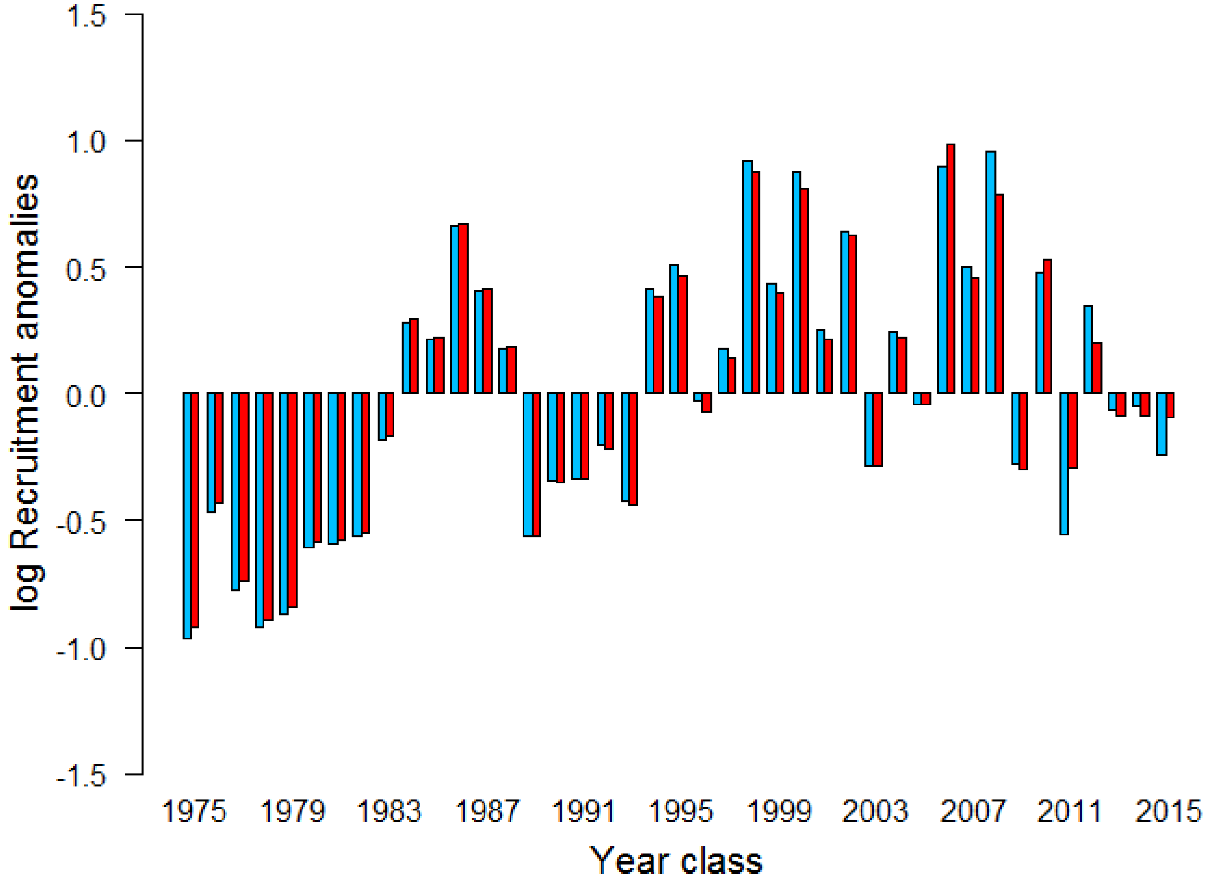


Figure 9-14. Recruitment deviations from average on the log-scale comparing last cycle's model (red) to current year recommended model (blue) for GOA POP.

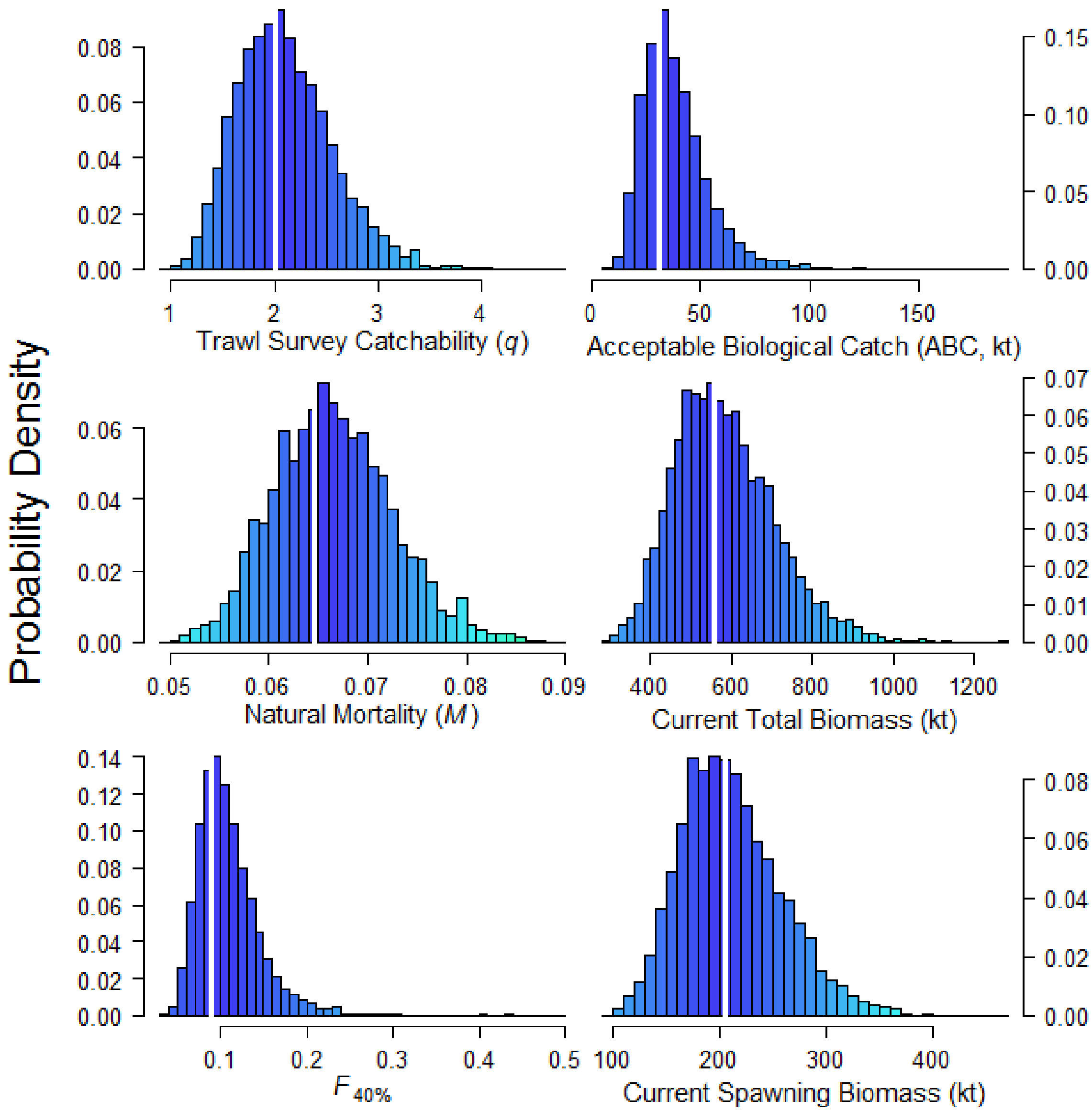


Figure 9-15. Histograms of estimated posterior distributions of key parameters derived from MCMC for GOA POP. The vertical white lines are the recommended model estimates.

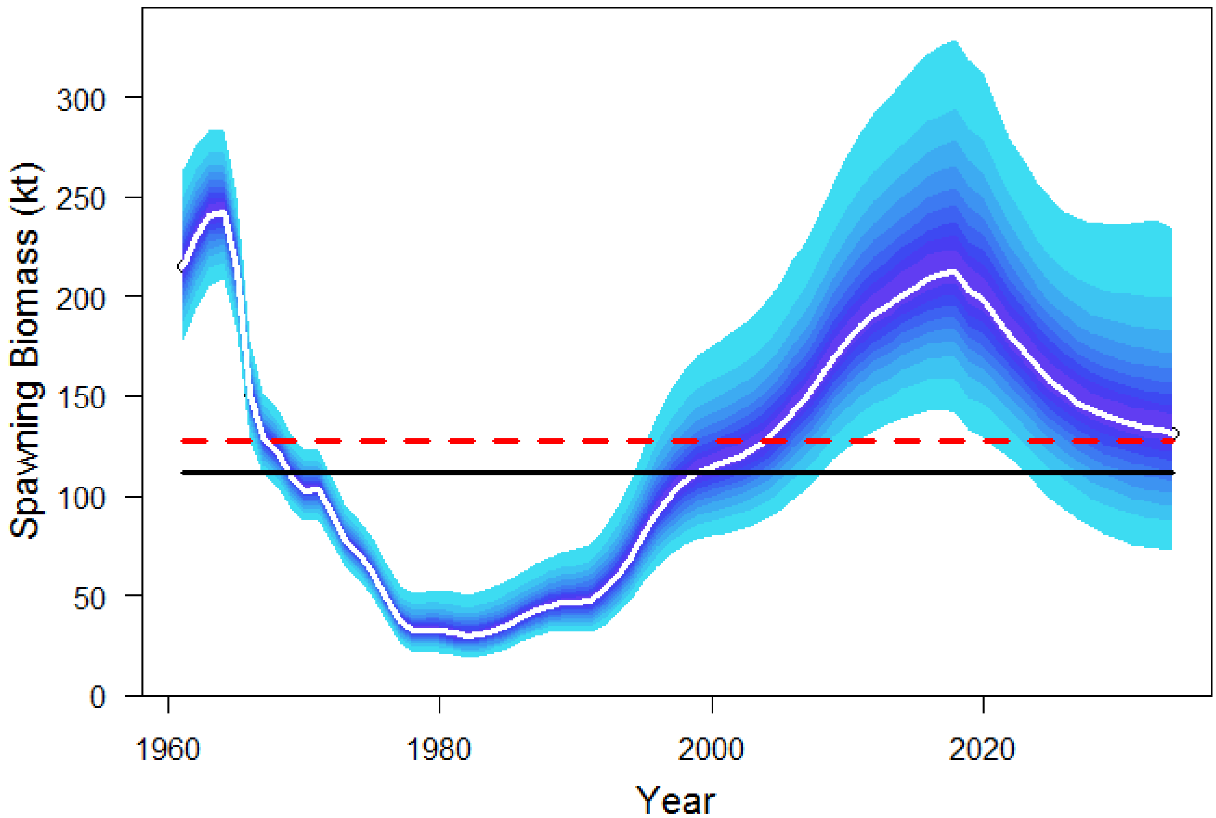


Figure 9-16. Bayesian credible intervals for entire spawning stock biomass series including projections through 2030. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2015. The white line is the median of MCMC simulations. Each shade is 5% of the posterior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

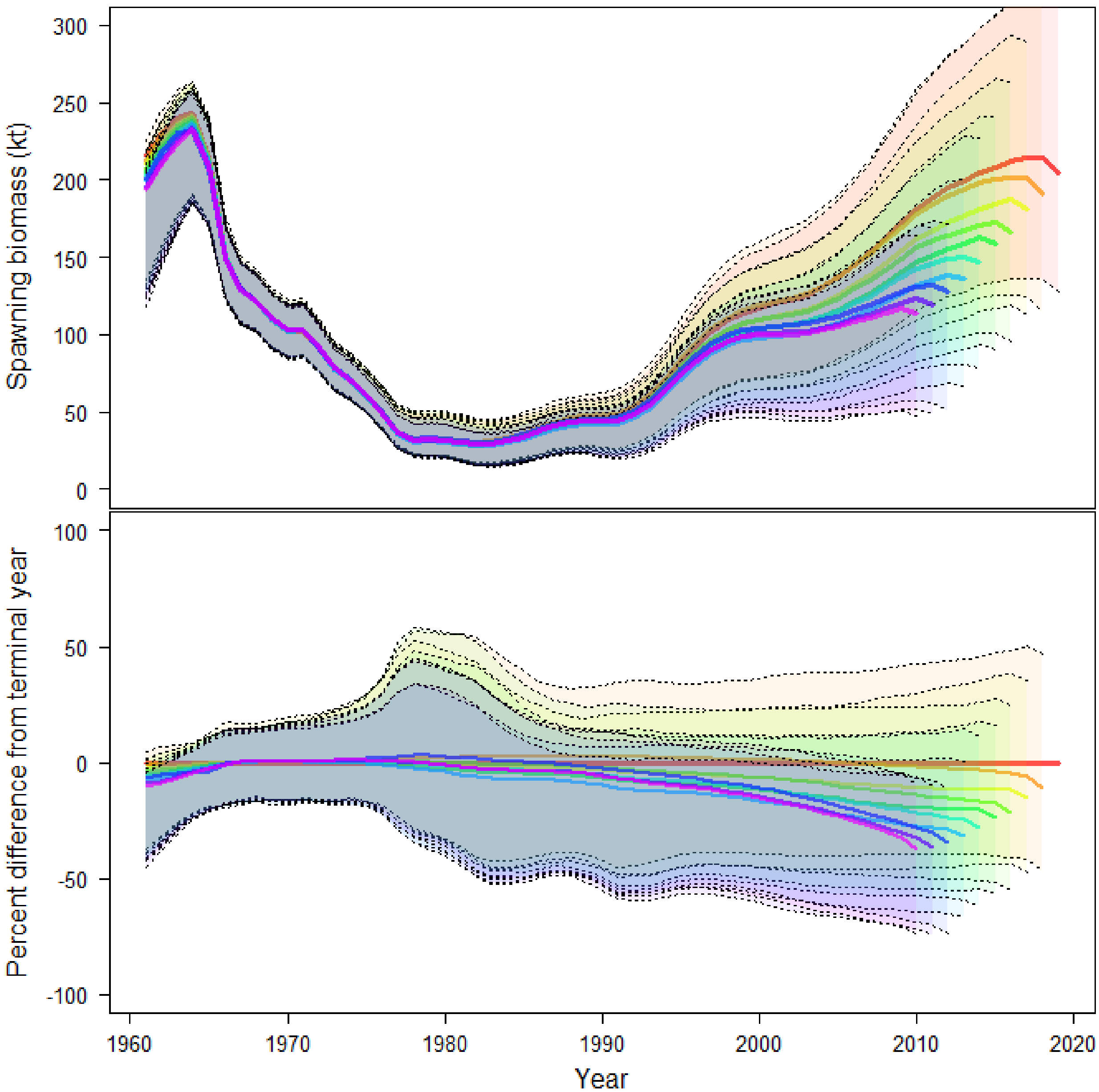


Figure 9-17. Retrospective peels of estimated female spawning biomass for the past 10 years from the recommended model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the recommended model in the terminal year with 95% credible intervals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

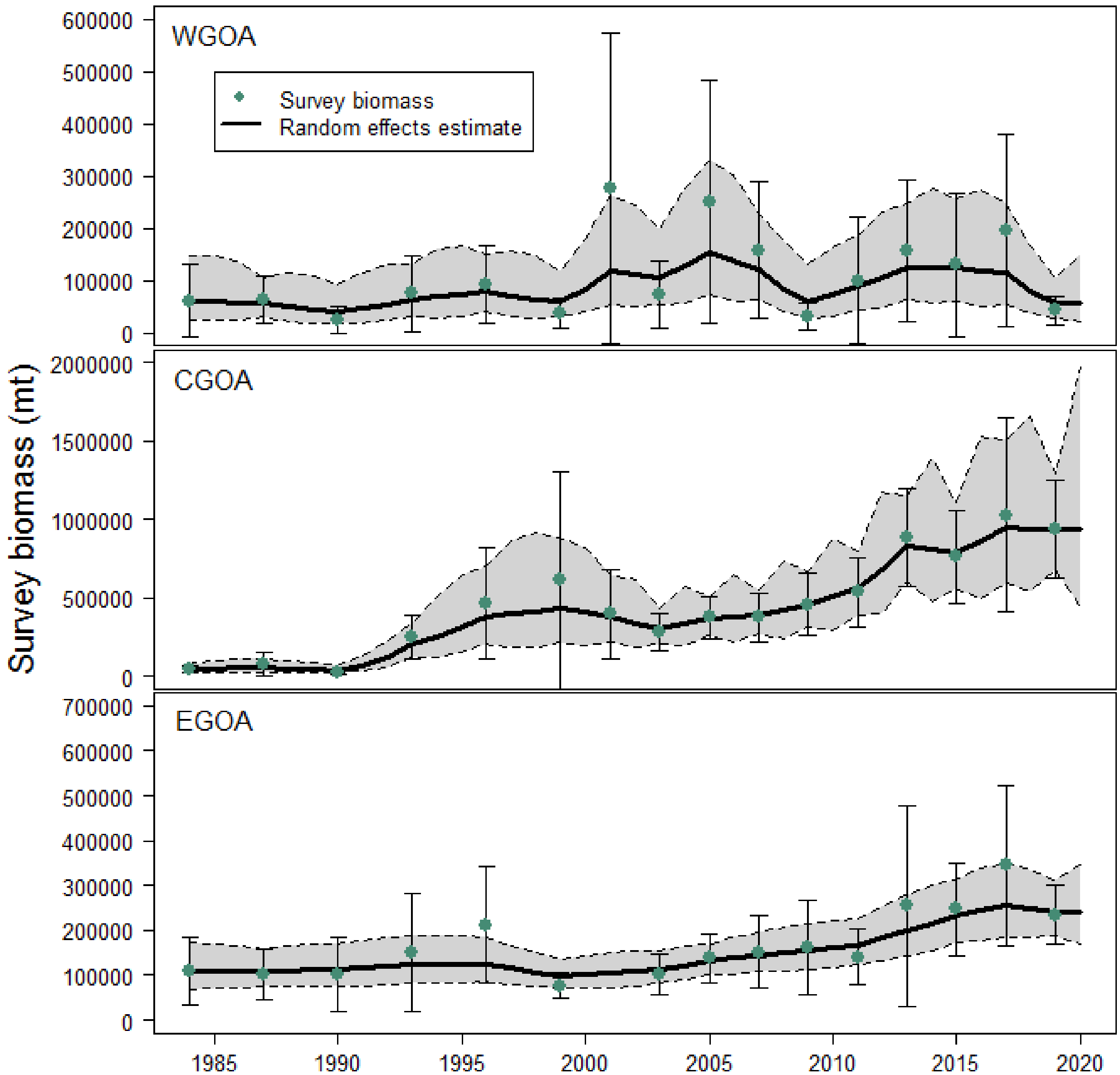


Figure 9-18. Random effects model fit (black line with 95% confidence intervals in light grey region) to regional bottom trawl survey biomass (green points with 95% sampling error confidence intervals).

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		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	**Assessment of POP in the GOA (Hanselman et al. 2010)**	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		<1	3	3
2011	**AKRO**	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