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

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## Executive Summary

Pacific ocean perch in the Gulf of Alaska are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in on-cycle (odd) years, we present a full stock assessment document with updated assessment and projection model results.

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 2015 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 2017, survey age compositions for 2015, fishery age compositions for 2014 and 2016, and final catch for 2015 and 2016 and preliminary catch for 2017-2019 (see *Specified catch estimation* section). Two additional changes are recommended to the input data:

1. The fishery length composition data has been changed to 1 cm length bins and a plus length group of 45 cm
2. The 1984 and 1987 bottom trawl survey biomass and age composition have been removed from the time series

*Changes in the assessment methodology*: The assessment methodology has changed since the 2015 assessment and incorporates the following changes:

1. The bottom trawl survey biomass is fit with the log-normal distribution
2. An additional fishery selectivity time period is added (2007 – present) to coincide with the Central GOA rockfish program and the availability of older fish to the fishery

### Summary of Results

For the 2018 fishery, we recommend the maximum allowable ABC of **29,236** t from the recommended model. This ABC is a 22% increase from the 2017 ABC of 23,918 t. The increase is attributed to the 2017 survey biomass estimate which is the largest on record, and three consecutive survey biomass estimates larger than 1 million tons. This also resulted in a 25% higher ABC than the 2018 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 2016 catch compared to OFL. The official total catch for 2016 is 23,133 t which is less than the 2016 OFL of 28,431 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 2017 and 2019. The estimates of spawning biomass for 2017 was 156,563 t and 2019 is 177,539 t. Both estimates are above the current $B_{35\%}$ estimate of 102,767 t and, therefore, the stock is not currently overfished nor approaching an overfished condition.

| Quantity | As estimated or specified *last* year for: 2017 | 2018 | As estimated or recommended *this* year for: 2018 | 2019[1] |
|---|---|---|---|---|
| *M* (natural mortality) | 0.061 | 0.061 | 0.066 | 0.066 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 2+ ) biomass (t) | 445,672 | 437,123 | 511,934 | 497,600 |
| Projected Female spawning biomass | 156,563 | 156,444 | 180,150 | 177,539 |
| $B_{100\%}$ | 285,327 | 285,327 | 293,621 | 293,621 |
| $B_{40\%}$ | 114,131 | 114,131 | 117,448 | 117,448 |
| $B_{35\%}$ | 99,865 | 99,865 | 102,767 | 102,767 |
| $F_{OFL}$ | 0.119 | 0.119 | 0.113 | 0.113 |
| $maxF_{ABC}$ | 0.102 | 0.102 | 0.094 | 0.094 |
| $F_{ABC}$ | 0.102 | 0.102 | 0.094 | 0.094 |
| OFL (t) | 27,826 | 27,284 | **34,762** | 34,010 |
| maxABC (t) | 23,918 | 23,454 | **29,236** | 28,605 |
| ABC (t) | 23,918 | 23,454 | **29,236** | 28,605 |
| **Status** | As determined *last* year for: 2015 | 2016 | As determined *this* year for: 2016 | 2017 |
| 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 2018 and 2019 are derived using estimated catch of 21,813 for 2017, and projected catches of 26,045 t and 25,126 t for 2018 and 2019 based on realized catches from 2014-2016. This calculation is in response to management requests to obtain more accurate projections.

## Area Apportionment

The following table shows the recommended apportionment for 2018 and 2019 from the random effects model.

| Area Apportionment | Western | Central | Eastern | Total |
|---|---|---|---|---|
| | 11.3% | 68.8% | 19.9% | 100% |
| 2018 Area ABC (t) | **3,312** | **20,112** | **5,812** | **29,236** |
| 2019 Area ABC (t) | **3,240** | **19,678** | **5,687** | **28,605** |

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 2015 assessment at 0.58, a decrease from 0.61. 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 |
|---|---|---|---|
| 2018 Area ABC (t) | **3,371** | **2,441** | **5,812** |
| 2019 Area ABC (t) | **3,298** | **2,389** | **5,687** |

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 |
|---|---|---|---|
| 2018 Area OFL (t) | **31,860** | **2,902** | **34,762** |
| 2019 Area OFL (t) | **31,170** | **2,840** | **34,010** |

## Summaries for Plan Team

| Species | Year | Biomass[1] | OFL | ABC | TAC | Catch[2] |
|---|---|---|---|---|---|---|
| Pacific ocean perch | 2016 | 457,768 | 28,431 | 24,437 | 24,437 | 23,133 |
| | 2017 | 445,672 | 27,826 | 23,918 | 23,918 | 20,023 |
| | 2018 | 511,934 | 34,762 | 29,236 | | |
| | 2019 | 497,600 | 34,010 | 28,605 | | |

[1]Total biomass from the age-structured model

| Stock | Area | 2017 OFL | ABC | TAC | Catch[2] | 2018 OFL | ABC | 2019 OFL | ABC |
|---|---|---|---|---|---|---|---|---|---|
| Pacific ocean perch | W | | 2,679 | 2,679 | 2,566 | | 3,312 | | 3,240 |
| | C | | 16,671 | 16,671 | 14,701 | | 20,112 | | 19,678 |
| | WYAK | | 2,786 | 2,786 | 2,756 | | 3,371 | | 3,298 |
| | SEO | 2,073 | 1,782 | 1,782 | 0 | 2,902 | 2,441 | 2,840 | 2,389 |
| | W/C/WYK | 25,753 | | | | 31,860 | | 31,170 | |
| | Total | 27,826 | 23,918 | 23,918 | 20,023 | 34,762 | 29,236 | 34,010 | 28,605 |

[2]Current as of October 7, 2017, Source: NMFS Alaska Regional Office via the Alaska Fisheries Information Network (AKFIN).

## SSC and Plan Team Comments on Assessments in General

*Finally, an area apportionment approach using the RE model which specifies a common "process error" has been developed and should be considered.* (Plan Team, November 2015)

**A common "process error" was considered for this assessment. However, upon evaluating the data from the Western, Central, and Eastern data, including bottom trawl survey biomass and age and length compositions, it appears that the population dynamics (including recruitment and differences in abundance trends over time) among the three regions are different enough to warrant individual process error parameters. Thus, for apportionment we estimate separate process error parameters for each region.**

*The Team recommends that a workgroup or subset of authors investigate applying the geostatistical approach to selected stocks.* (Plan Team, November 2015)

*The SSC supports the GOA PT recommendation to form a study group to explore the criteria necessary for adopting the geostatistical generalized linear mixed model approach in assessments. If this study group is formed, the SSC requests that the group be expanded to include BSAI assessment authors and members from the AFSC survey program. Among the many questions this group could address, the SSC suggests including the following questions:*

> *1. Is the stratified random survey design used for the surveys correctly configured for application of the geostatistical approach?*
> *2. Should the geostatistical approach be applied to all species or a select suite of species that exhibit aggregated spatial distributions and rockfish-like life histories? If application of this approach is recommended for only a subset of managed species, what life history characteristics or biological criteria would qualify a species for this approach?*
> *3. What level of aggregation is necessary for application of the geostatistical approach?*
> *4. If the geostatistical approach is adopted should results also be used for area apportionments?*

(SSC, December 2015)

**We have grouped these two comments together as they deal with the same topic. A working group has been formed and is currently in the process of investigating the criteria for use of the geostatistical generalized linear mixed model (delta-GLMM) within assessments performed by the AFSC. Evaluation of the geostatistical delta generalized linear mixed model approach has focused on a range of species with different life histories and spatial distribution and addressed: 1) How do geostatistical delta-GLMM indices compare with design-based estimates?, 2) Are the scale or trend in geostatistical delta-GLMM indices sensitive to the level of spatial complexity specified?, 3) How does alternative specifications for temporal autocorrelation in intercepts and spatio-temporal random effects for encounter probability and positive catch rate components of the geostatistical delta-GLMM influence index estimates?, and 4) How do apportionment estimates from the geostatistical delta-GLMM compare with estimates from the current random effects model? Results from these initial evaluations were presented by C. Cunningham at the September 2017 PT meeting. Further investigations into the geostatistical delta-GLMM will continue with the intention of providing stock assessment authors with guidance on which trawl survey biomass index would be appropriate for their stock.**

*Many assessments are currently exploring ways to improve model performance by re-weighting historic survey data. The SSC encourages the authors and PTs to refer to the forthcoming CAPAM data-weighting workshop report.* (SSC, December 2015)

*The SSC recommends that the Gulf of Alaska Groundfish Plan Team (GOA GPT), BSAI GPT, and CPT encourage the continued use of multiple approaches to data weighting (not just the Francis (2011) method, but also including the harmonic mean and others).* (SSC, October 2016)

**We have grouped these two comments together as they deal with the same topic. At the 2017 September PT we presented a document investigating various methods investigating re-weighting**

**historical survey and fishery data, in particular, survey age compositions and fishery age and length compositions. We have decided to not implement any of these methods into the Pacific ocean perch assessment at this point in time to allow for the working group investigating the delta-GLMM geostatistical to provide guidance on which bottom trawl survey biomass index is appropriate for this assessment. This is because the delta-GLMM geostatistical estimator has the potential to significantly change the magnitude and uncertainty of the survey biomass estimates, which would subsequently have potential significant influence on any re-weighting method for compositional data.**

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

**We have followed the guidelines for naming alternative models investigated in this assessment and will continue to follow these guidelines in future assessments.**

*The SSC also recommends explicit consideration and documentation of ecosystem and stock assessment status for each stock, perhaps following the framework suggested below, during the December Council meeting to aid in identifying areas of concern.* (SSC October 2017)

**A newly proposed framework for considering ecosystem and socioeconomic factors has been submitted as an appendix in some assessments this year. This is an attempt to document these factors with respect to stock status and also provide indicators for continued monitoring to identify areas of concern. These reports are currently submitted as an appendix and in future years it is anticipated that they would be available for all stocks as the framework is adaptable for data-limited to data-rich stocks. We plan to evaluate and potentially incorporate this new ecosystem/socioeconomic report as an appendix when it becomes available for Gulf of Alaska Pacific ocean perch stock.**

## SSC and Plan Team Comments Specific to this Assessment

*"The Plan Team recommends evaluation of how the data weights given to the various fishery and survey age and length composition data affect the estimates of recruitment and age composition."* (Plan Team, September 2014)

*The Team recommends increasing the plus group for the length compositions to evaluate model performance.* (Plan Team, November 2015)

*In September (2014), the PT and SSC recommended evaluating data weighting for fishery and survey age and length compositions with respect to estimates of recruitment and age compositions. The authors note that this issue pertains to all GOA rockfish assessments and plan to do a more thorough evaluation of this issue for future assessments. The SSC agrees and would recommend a broader look at the issue across all GOA rockfish species, and to consider relevant recommendations from the 2015 CAPAM workshop on data weighting. Further, the SSC concurs with the PT recommendations for the next full POP assessment to investigate 1) increasing the plus group for length compositions to evaluate model performance, 2) using an alternate trawl survey index, 3) using alternative length bins, 4) including sample sizes for composition data, and 5) relating fishery selectivity to average depth fished.* (SSC, December 2015)

**We have grouped these comments as they pertain to similar topics. As stated above in the response to assessments in general, at the 2017 September PT we presented a document investigating various methods investigating re-weighting historical survey and fishery data, in particular, the input sample sizes used for survey age compositions and fishery age and length compositions. We have decided to not implement any of these methods into the Pacific ocean perch assessment at this point in time to allow for the working group investigating the delta-GLMM geostatistical to provide guidance on which bottom trawl survey biomass index is appropriate for this assessment (the implementation of which we also investigated and presented in September). This is because the delta-GLMM geostatistical estimator has the potential to significantly change the magnitude and uncertainty of the survey biomass estimates, which would subsequently have potential significant influence on any re-weighting method for compositional data. In the recommended assessment for this year we have changed the plus length group to 45 cm and length bins to 1 cm. We also investigated relating fishery selectivity to average depth fished in the September document, but significant improvements to the model did not result.**

*The Team recommends evaluating harvest rates in West Yakutat to compare with FABC rates.* (Plan Team, November 2015)

*The SSC concurs with the PT recommendation to evaluate harvest rates in WYAK for comparison to FABC rates.* (SSC, December 2015)

**We have addressed these comments by presenting the estimated exploitation rates in the *Area Apportionment of Harvest* section. In this analysis we estimated exploitation rates by dividing the catch in W. Yakutat by the bottom trawl survey biomass estimates (unadjusted and adjusted by model estimates of catchability). On average, the exploitation rates in W. Yakutat are less than $M$ and $F_{ABC}$, and are comparable to the exploitation rates in the Central GOA. Thus, we see no need to change the strategy currently employed to apportion ABC between the W. Yakutat and Southeast/Outside regions of the Eastern GOA.**

*The Team recommends 1 cm bin sizes using ≤16 cm as the starting bin and ≥45 cm as the plus length group.* (Plan Team, September 2017)

**This change has been reflected in the recommended assessment.**

*The Team concurs with the author and recommends bringing forward the Francis and Dirichlet-multinomial methods for consideration in the November assessment.* (Plan Team, September 2017)

**As stated in previous responses, we will investigate further changes to the age and length composition error structures when the delta-GLMM geostatistical index has been further developed.**

*The Team concurs with the author and recommends bringing forward the gamma selectivity method for* ***the November assessment.*** **(Plan Team, September 2017)**

**We present time-invariant gamma selectivity as an alternative model case considered in this year's assessment.**

*The Team recommends continuing use of the design-based estimates for bottom trawl survey biomass at this time.* (Plan Team, September 2017)

**We concur with the Team's recommendation and continue to use the design-based estimates for bottom trawl survey biomass in this assessment**

*The Team recommends bringing forward a model alternative in November that investigates dropping the 1984 and 1987 survey biomass estimates from the survey index but continuing to use the age compositions from these surveys.* (Plan Team, September 2017)

**We present two alternatives in this year's assessment as it pertains to the 1984 and 1987 bottom trawl surveys: (1) drop only the survey biomass but retain the age composition (as recommended by the Team), and (2) drop both the survey biomass and age composition. For this year's recommended model we remove both the biomass and age composition as in the second alternative.**

# 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 23% 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.

## 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 1988-2015; 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 1990-99 to an average of 10% and up to 23% after 2000.

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 25, 2017) for POP in the commercial fishery for 2000-2017 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 |
|---|---|---|---|---|---|---|---|
| % Discard | 6.5 | 4.8 | 7.6 | 9.5 | 3.8 | 7.5 | 13.4 |

Total FMP groundfish catch estimates in the GOA rockfish targeted fisheries from 2011-2017 are shown in Table 9-3. For the GOA rockfish fishery during 2011-2017, 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 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). The increase of prohibited species catch observed in 2017 compared to 2016 in the combined rockfish fisheries was for non-Chinook salmon, bairdi crab, and golden king crab (Table 9-6). Chinook salmon catch was lower than the average since 2011 in both 2016 and 2017.

# 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-**2017** (biennial) |
| | Age Composition | 1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, **2015** |
| U.S. trawl fisheries | Catch | 1961-**2017** |
| | Age Composition | 1990,1998-2002, 2004, 2005, 2006, 2008, 2010, 2012, **2014, 2016** |
| | Length Composition | 1963-1977, 1991-1997 |

## Fishery

*Catch*

Catches range from 2,500 t to 350,000 t from 1961 to 2017. 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 2008-2017 (the most recent 10 years). Table 9-8 summarizes age compositions for the fishery. Figures 9-2 and 9-3 show the distributions graphically for fishery age and length composition data fit by the assessment. The age compositions in all years of the fishery data show strong 1986 and 1987 year classes. These year classes were also strong in age compositions from the 1990-1999 trawl surveys. The 2004-2006 fishery data show the presence of strong 1994 and 1995 year classes. These two year classes are also the highest proportion of the 2003 survey age composition. Since 2008 the proportion of fish in the plus age group (25 years and older) of the fishery age composition has been increasing, from 0.016 in 2006 to 0.092 in 2016.

## 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 2017 surveys are provided in Table 9-9.

*Comparison of Trawl Surveys in 1984-2017*

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 1984-2017 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.

The biomass estimates for POP were generally more imprecise between 1996-2001 than after 2003 (Figure 9-4). Large catches of an aggregated species like POP in just a few individual hauls can greatly influence biomass estimates and may be a source of much variability. Anomalously large catches have especially affected the biomass estimates for POP in the 1999 and 2001 surveys. While there are still several large catches, the distribution of POP is becoming more spread out in the GOA (Figure 9-5). Previous research has focused on improving rockfish survey biomass estimates using alternate sampling designs (Quinn et al. 1999; Hanselman et al. 2001; Hanselman et al. 2003b). Research on the utility of hydroacoustics in gaining survey precision was completed in 2011 (Hanselman et al. 2012b; Spencer et al. 2012) which confirmed again that there are ways to improve the precision, but all of them require more sampling effort in high POP density strata. In addition, there is a study underway exploring the density of fish in untrawlable grounds that are currently assumed to have an equal density of fish compared to trawlable grounds.

Biomass estimates of POP were relatively low in 1984 to 1990, increased markedly in both 1993 and 1996, and became substantially higher in 1999 and 2001 with much uncertainty. Biomass estimates in 2003 have less sampling error with a total similar to the 1993 estimate indicating that the large estimates from 1996-2001 may have been a result of a few anomalous catches. However, the 2005-2011 estimates were similar to 1996-2001, but more precise. POP continue to be more uniformly distributed than in the past (Figure 9-5). In 2009, total biomass was similar to 2007, and is the fourth survey in a row with relatively high precision. The biomass estimate for 2013 was an all-time high and is one of the most precise of the survey time series. The 2013 survey design consisted of fewer stations than average, but the effect of this reduction in effort on POP survey catch was not apparent. The 2013 survey biomass increased in the Western, Central, and Easter Gulf. The Eastern gulf biomass was less precise than the Western and Central Gulf. Biomass decreased slightly in 2015 but is the second highest on record behind 2013. Specifically, the Western and Central areas decreased slightly but the Yakutat region biomass estimate was less than half of the 2013 estimate in 2015. Conversely, the Southeastern biomass estimate was more than double in 2015 than that of the 2013 estimate. The 2017 biomass estimate is the largest on record, with a CV of only 22%. The distribution of catches in the 2017 survey were comparable to 2013 and 2015 (Figure 9-5), but had an increase in larger hauls. This increase in biomass resulted in all areas of the Gulf, most notably in the Kodiak and Southeast regions Table 9-9. The average biomass from the trawl survey from 2013-2017 is nearly twice the average biomass from 1996-2011.

*Age Compositions*

Ages were determined from the break-and-burn method (Chilton and Beamish 1982). The survey age compositions from 1984-2015 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 13.7 years in 2015 (Table 9-10). The first four surveys identified a relatively strong 1976 year class and also showed a period of very weak year classes prior to 1976 (Figure 9-6). The weak year classes of the early 1970's may have delayed recovery of POP populations after they were depleted by the foreign fishery. The survey age data from 1990-1999 suggested that there was a period of large year classes from 1986-1989. In 1990-1993, the 1986 year class looked very strong. Beginning in 1996 and continuing in 1999 survey ages, the 1987 and 1988 year classes also became prominent. Rockfish are difficult to age, especially as they grow older, and perhaps some of the fish have been categorized into adjacent age classes between surveys. Alternately, these year classes were not available to the survey until much later than the 1986 year class. Recruitment of the stronger year classes from the late 1980s probably has accounted for much of the increase in the estimated biomass for POP in recent surveys as well as the increase in the plus age group observed in the survey and fishery age compositions. Indications from the 2009 to 2015 survey age compositions suggest that the 2006, 2008, and 2010 year classes may be particularly strong.

*Survey Size Compositions*

Gulf-wide population size compositions for POP are shown in Figure 9-7. The size composition for POP in 2001 was bimodal, which differed from the unimodal compositions in 1993, 1996, and 1999. The 2001 survey showed a large number of relatively small fish, ~32 cm fork length which may indicate recruitment in the early 1990s, together with another mode at ~38 cm. The 2009 and 2011 survey size composition data also indicate a strong 2006 year class, which would have been ~19 cm in 2009 and ~26 cm in 2011. 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.

# Analytic Approach

## 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

## Model Selection

In total, four changes were made to input data and model configuration in this year's assessment compared to the 2015 assessment. We present these changes in a step-wise manner, building upon each previous model change to arrive at the recommended model for this year's assessment. The following table provides the model case name and description of the changes made to the model.

| Model case | Description |
|---|---|
| 15.0 | 2015 model with data updated through 2017 (Model case M3 in 2015) |
| 15.0a | 15.0 with 1 cm length bins and a plus length group of 45 cm |
| 15.0b | 15.0a with 1984 and 1987 bottom trawl survey biomass removed |
| 15.0c | 15.0a with 1984 and 1987 bottom trawl survey biomass and age composition removed |
| 15.0d | 15.0c with log-normal distribution used to fit the bottom trawl survey biomass |
| 17.0 | 15.0d with dome-shaped fishery selectivity estimated for all years |
| 17.1 | 15.0d with additional dome-shaped selectivity time block starting in 2007 to coincide with the Central GOA rockfish program |

A brief description of each model case is provided below.

*15.0a – Length bins and plus length group*

In September, several alternatives of length bins ranging from 1 cm to 4 cm as well as an alternative plus length group of 45 cm were presented. The Team and SSC recommended that the 2017 assessment change the length bins to 1 cm and set the plus length group to 45 cm, which is reflected in model case 15.0a.

*15.0b and 15.0c – Removing the 1984 and 1987 bottom trawl survey data*

In 1984 and 1987 the bottom trawl survey was conducted through a cooperative survey between the U.S. and Japan and since 1990 has been survey conducted by the Alaska Fisheries Science Center Resource Assessment and Conservation Engineering (RACE) Division. Several differences between the 1980s surveys and the post 1990 surveys exist, including differences in the timing of sampling across the GOA and the duration of the tows, which have been standardized since the 1990s. Due to these differences several assessments in the GOA have removed this data from the time series (e.g., McGilliard et al. 2013). In this year's assessment we investigate two alternatives for removing the 1984 and 1987 bottom trawl survey data. The first alternative, model case 15.0b, removes only the 1984 and 1987 bottom trawl survey biomass but retains the age composition from these years. The second alternative, model case 15.0c, investigates the removal of both the bottom trawl survey biomass and age composition in 1984 and 1987.

*15.0d – Applying the log-normal distribution to the bottom trawl survey biomass*

Since the inception of the POP assessment within ADMB in 2001 the bottom trawl survey biomass has been fit with the normal distribution. Commonly, index data like the bottom trawl survey are fit with the log-normal distribution in age-structured assessments like this one (Quinn and Deriso 1999). Further, a number of assessments at AFSC use the log-normal distribution to fit survey abundance data (e.g., Dorn et al. 2016). In model case 15.0d we replace the normal distribution with the log-normal distribution in the POP assessment to fit the bottom trawl survey biomass.

*17.1 and 17.2 – Fishery selectivity alternatives*

In September, several alternatives to time-dependent fishery selectivity were presented. The Team and SSC recommended that a time-invariant dome-shaped fishery selectivity be considered for the full assessment; this is model case 17.1.

With the addition of the 2014 and 2016 fishery age composition data in the 2017 full assessment we note that the plus age group from the fishery has increased since the mid 2000s, from an average of 0.01 from 1998 to 2006 to an average of 0.06 from 2008 to 2016 (to a maximum of 0.09 in 2016). Several changes in the POP population and in the fishery may help explain these observations. First, the population has grown dramatically since the early 1990's and the three most recent bottom trawl survey estimates indicate POP biomass in the GOA has increased substantially in recent years. The increase in the plus group is partly attributed to some of the strong recruitment in the late 1990s are now entering the plus age group. Second, the majority of POP in the GOA is harvested in the Central GOA. The implementation of the Rockfish Program in 2007 in this region has likely had significant effects on the behavior of the fleet: 1) the fishing season now extends from May-October instead of occurring only in July; 2) the Program was developed to help the shore-based fleet harvesting in this region improve economic efficiency; 3) and, with a cooperative-based approach the fleet can better specialize at catching certain portions of the stock in the fishery. These factors have likely changed how the fishery is prosecuted in the Central GOA and may have effects on selectivity or catchability that may have implications to this assessment. Considering nearly 70% of the POP population is in this region it is likely that fishing behavior in this region drives the overall responses in the GOA when estimating fishery selectivity within the POP assessment. Due to both the potential for changes to the age availability and selectivity of the fishery we investigate including a time block for fishery selectivity after 2007 in model case 17.2. In this model we estimate a dome-shaped fishery selectivity from 2007 to 2017 in addition to the selectivity time blocks estimated in previous assessments.

## 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 model 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:

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

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

$L_\infty = 41.3$ cm $\kappa = 0.18$ $t_0 = -0.48$

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):

$a = -0.06$ $b = 2.32$

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 $(W_\infty\text{-}W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

$W_\infty = 914$ g $\kappa = 0.19$ $t_0 = -0.36$ $\beta = 3.04$

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 ($\sigma_r$) are estimated with the use of prior distributions as penalties. The prior mean for *M* is based on 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 three 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-Present: 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.

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 block. 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 | $\mu_r$ | 1 |
| Recruitment variability | $\sigma_r$ | 1 |
| Spawners-per-recruit levels | $F_{35\%}, F_{40\%}, F_{100\%}$ | 3 |
| Recruitment deviations | $\varepsilon_y^r$ | 83 |
| Average fishing mortality | $\mu_f$ | 1 |
| Fishing mortality deviations | $\varepsilon_y^f$ | 57 |
| Fishery selectivity coefficients | $s_a^f$ | 4 |
| Survey selectivity coefficients | $s_a^t$ | 2 |
| Maturity-at-age coefficients | $\widehat{m}_a$ | 2 |
| Total | | 156 |

*Uncertainty approach*

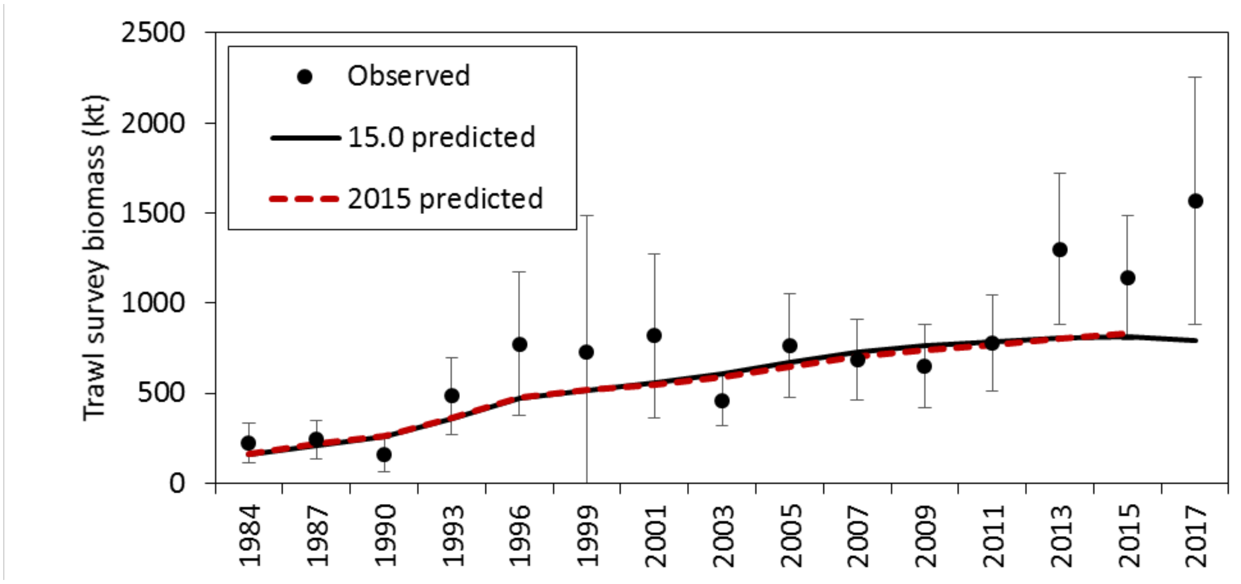
Evaluation of model uncertainty is obtained through a Markov Chain Monte Carlo (MCMC) algorithm (Gelman et al. 1995). The chain length of the MCMC was 10,000,000 and was thinned to one iteration out of every 2,000. We omit the first 1,000,000 iterations to allow for a burn-in period. We use these MCMC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

# Results

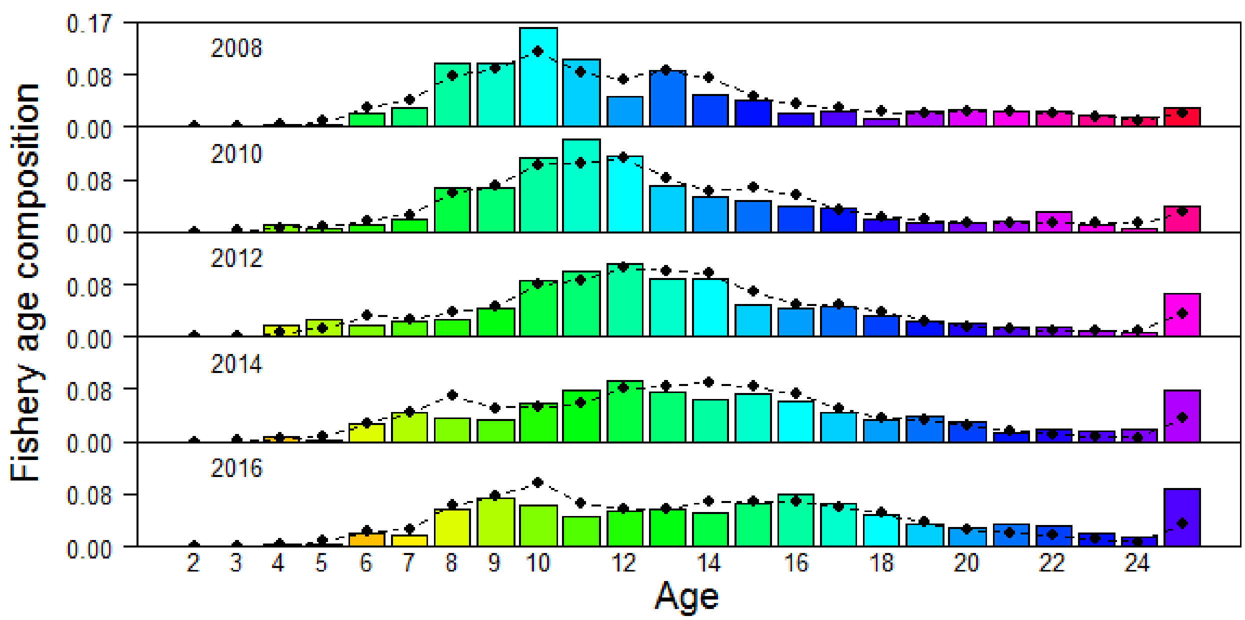
## Model Evaluation

In this year's assessment we recommend three changes to the input data: how the data is structured, which data is included, and how the data is estimated by the model. In addition, we recommend one change to the structure of the model, in particular, how time-dependent fishery selectivity is estimated. 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.

Upon updating the 2015 recommended model with data through 2017 two primary lack of fits to observed data were evident: (1) the fit to the last 3 years of bottom trawl survey, and (2) the fit to the plus age group of the fishery since the mid 2000s. The following figure compares the fit to the bottom trawl survey biomass from the 2015 assessment and the same model with data updated to 2017 (model case 15.0).



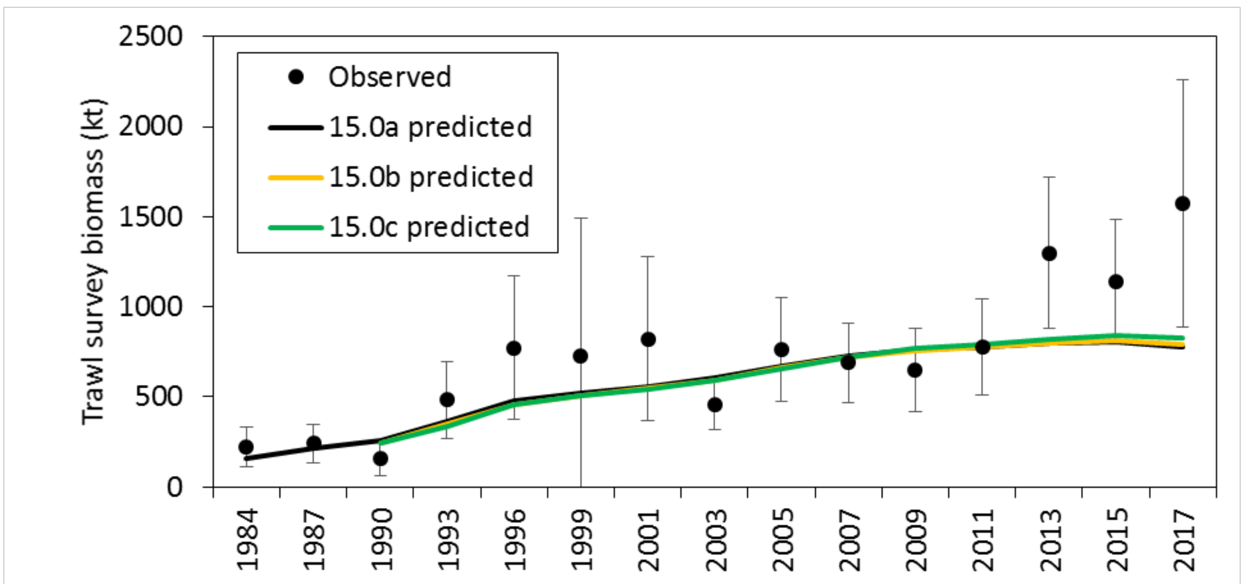

The model estimates of trawl survey biomass from model case 15.0 are very similar to the estimates from 2015, the estimates from both models fall outside the observed 2013 biomass confidence intervals and nearly fall outside the 2015 biomass confidence intervals. Model 15.0 additionally falls outside the observed 2017 confidence intervals and estimates a decrease in trawl survey biomass from 2015 to 2017. The following figure are the fits to the recent fishery age composition data (from 2008 to present) from model case 15.0.



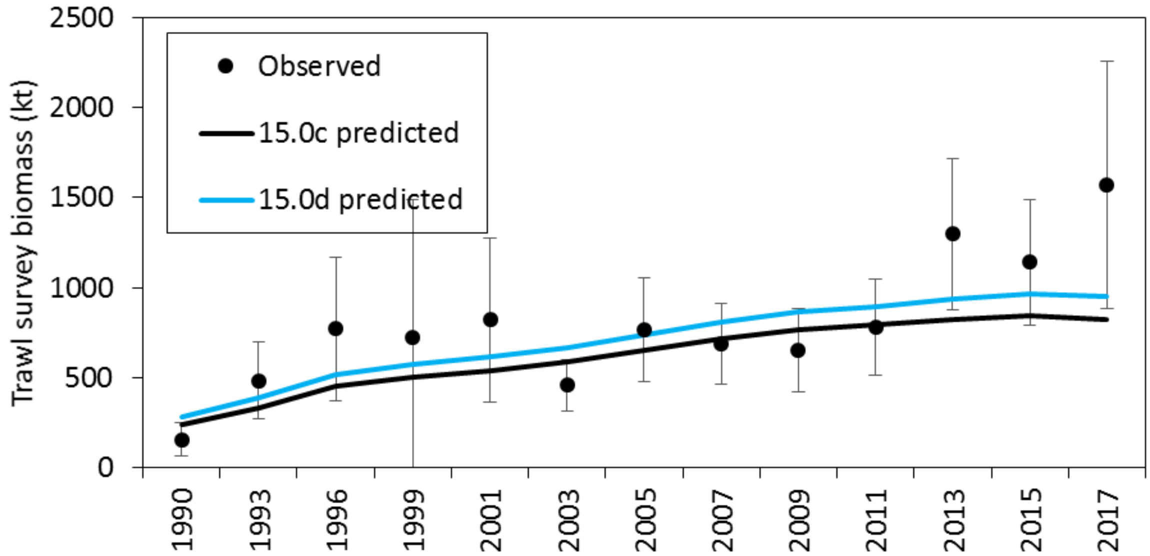

Since 2008 the plus age group in the fishery has been increasing, which the dome-shaped selectivity estimated from 1996 to present has not been able to fit since 2012. In addition to the normal criteria for model comparison and selection mentioned above we also investigate the fit from each model case to the recent bottom trawl survey biomass and fishery age compositions.

Changing the length bins to 1cm and the plus length group to 45 cm in model case 15.0a had little influence on model fit or model estimates compared to model case 15.0 (Table 9-14). The issues with the fit to the bottom trawl survey biomass and the fishery age composition mentioned above did not improve either, as noted from the small changes to the model fits in Table 9-14. We concur with the recommendation from the Team and SSC to change the length bins to 1 cm and the plus length group to 45 cm and recommend this change for the 2017 assessment; this change will also be reflected in all model cases presented hereon.

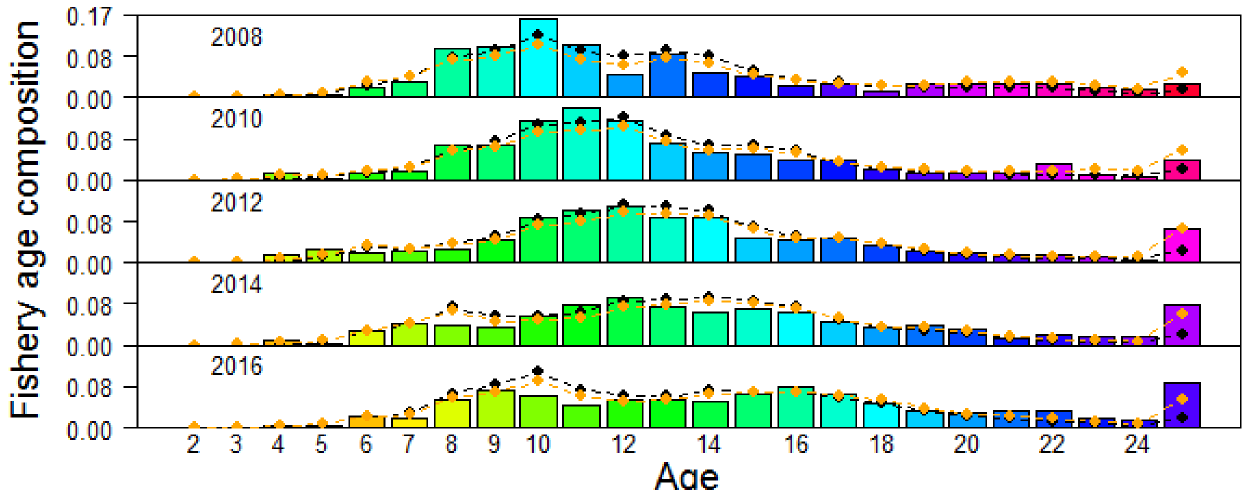
The fit to the bottom trawl survey biomass from model cases 15.0b and 15.0c were similar to the fit from model case 15.0a (see figure below), with a slight improvement in the fit resulting from model case 15.0c. Upon removing the 1984 and 1987 bottom trawl survey age composition data in addition to the biomass data in model case 15.0c not only did the negative log-likelihood of the bottom trawl survey biomass decrease compared to model case 15.0b, the recruitment deviations penalty also decreased considerably, indicating that there was an influence of these two years of data on recruitment estimates that is not reflected in the other data sources. Upon removing the 1984 and 1987 age composition data there remains 25 years of age composition between the observations from the bottom trawl survey and the fishery. In addition, it would be more consistent to remove both the bottom trawl survey biomass and age composition in 1984 and 1987 rather than remove only one data source. For these reasons we recommend removing both the 1984 and 1987 bottom trawl survey biomass and age composition from the POP assessment. The model changes made in case 15.0c will be reflected in all further model cases considered.




Fitting the bottom trawl survey biomass with the log-normal distribution for model case 15.0d resulted in an improved model fit to the biomass index (see figure below) compared to model case 15.0c. Across the time series, fitting the bottom trawl survey biomass with the log-normal distribution increased the model estimates and were within the confidence intervals of the observed biomass for the final three years of the time series. However, the fit to the plus age group in the fishery age composition was not improved (Table 9-14). Due to the improvement in fit to the bottom trawl survey biomass, and also because population index data are usually fit using the log-normal distribution, we recommend this change to in the 2017 assessment. This model change in case 15.0d will be reflected in all further model cases.




Estimating time-invariant dome-shaped selectivity for the fishery with the gamma function in model case 17.1 resulted in an increase in the negative log-likelihood for all the observed data fitted by the model compared to model case 15.0d (with the exception of fishery catch). Compared to model case 15.0d, model case 17.2, in which an additional dome-shaped selectivity time block was added after 2007, resulted in a decrease in the negative log-likelihood for the bottom trawl survey biomass and fishery age composition, the most notable decrease being for the fishery age composition. Compared to model case 17.1, the fit to the fishery plus age group was greatly improved with model case 17.2 (see figure below, estimates from 17.1 shown in black, and estimates from 17.2 shown in orange).




Model 17.2 utilizes the new information since 2017 effectively and fits the data better than the previous model. Fitting the bottom trawl survey biomass index with the log-normal distribution resulted in an improvement in the model fit and recent model biomass estimates are now within the confidence intervals of the observed biomass for the final three years of the time series. Additionally, adding a dome-shaped

selectivity time block after 2007 resulted in a decrease in the negative log-likelihood for the bottom trawl survey biomass and fishery age composition, which improved fit with the addition of only two parameters. Due to the improvement of fit to the bottom trawl survey biomass and the fishery age composition, with the addition of only 2 parameters, we recommend model case 17.2 to be used for the assessment of GOA POP in 2017 for recommending 2018 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 have remained similar to the last several years using this model.

*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 530,000 t at the peak in 2015 (Figure 9-8). 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 320,000 and 830,000 t. Spawning biomass shows a similar trend, but is not as smooth as the estimates of total biomass (Figure 9-8). This is likely due to large year classes crossing a steep maturity curve. Spawning biomass estimates show a rapid increase since 1992, which coincides with an increase in uncertainty. Age of 50% selection is 5 for the survey and between 7 and 9 years for the fishery (Figure 9-9). 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 larger (2.11) than that estimated in 2015 (1.95). 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]). Compared to the last full assessment (2015), spawning biomass and age-6+ total biomass has increased in response to fitting the large trawl survey biomass estimates since 2013 (Table 9-16).

Fully-selected fishing mortality shows that fishing mortality has decreased dramatically from historic rates and has leveled out in the last decade (Figure 9-10). 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 9-11). In addition, since 1999, POP SSB has been above $B_{40\%}$ and fishing mortality has been below $F_{40\%}$.

*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 9-12). Recruitment has increased since the early 1970s, with the 1986 year class and potentially the 2006 year classes being the highest in recent history. The 1990s and

[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.

2000s are starting to show some steady higher than average recruitments. The largest differences in estimated recruitment resulted in the more recent years compared to the previous assessment (Table 9-16 and Figures 9-12 and 9-13), which should not be unexpected given the increase in trawl survey biomass and the model's response through increasing recent recruitment estimates. The addition of new survey age data and the large 2013-2017 survey biomass suggests that the 2006 year class may be above average, as well as the 2008 and 2010 year classes (Figure 9-13). However, these recent recruitments are still highly uncertain as indicated by the MCMC credible intervals in Figure 9-12. 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 9-12).

*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 9-14) and credible intervals (Table 9-17 and 9-18). We also use these posterior distributions to show uncertainty around time series estimates of survey biomass (Figure 9-4), total and spawning biomass (Figure 9-8), fully selected fishing mortality (Figure 9-10) and recruitment (Figures 9-12).

Table 9-17 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 9-14). 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 9-15).

*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 -0.22, 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 9-16 (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 2015 (i.e., the 1977 – 2013 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 2017 estimates of these reference points are:

| | |
|---|---|
| $B_{100\%}$ | 293,621 |
| $B_{40\%}$ | 117,448 |
| $B_{35\%}$ | 102,767 |
| $F_{40\%}$ | 0.094 |
| $F_{35\%}$ | 0.113 |

*Specification of OFL and Maximum Permissible ABC*

Female spawning biomass for 2018 is estimated at 180,150 t. This is above the $B_{40\%}$ value of 117,448 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 2016, yields the following ABC and OFL:

| | |
|---|---|
| $F_{40\%}$ | 0.094 |
| ABC | 29,236 |
| $F_{35\%}$ | 0.113 |
| OFL | **34,762** |

*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 2017 numbers at age as estimated in the assessment. This vector is then projected forward to the beginning of 2018 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2017. 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 2017 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 2018, 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 2018 and 2019, $F$ is set equal to a constant fraction of *max* $F_{ABC}$, where this fraction is equal to the ratio of the realized catches in 2014-2016 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 2012-2016 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 2017 or 2) above ½ of its MSY level in 2017 and above its MSY level in 2027 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2018 and 2019, $F$ 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 2019 or 2) above 1/2 of its MSY level in 2019 and expected to be above its MSY level in 2029 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.***

## Status determination

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 2018, it does not provide the best estimate of OFL for 2019, because the mean 2018 catch under Scenario 6 is predicated on the 2018 catch being equal to the 2018 OFL, whereas the actual 2018 catch will likely be less than the 2018 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?

*Is the stock being subjected to overfishing?* The official catch estimate for the most recent complete year (2016) is 23,128 t. This is less than the 2016 OFL of 28,431 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:

*Is the stock currently overfished?* This depends on the stock's estimated spawning biomass in 2017:
a. If spawning biomass for 2017 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2017 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2017 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 9-19). If the mean spawning biomass for 2027 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

*Is the stock approaching an overfished condition?* This is determined by referring to harvest Scenario #7:
a. If the mean spawning biomass for 2019 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2019 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2019 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2029. If the mean spawning biomass for 2029 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

Based on the above criteria and Table 9-19, the stock is not overfished and is not approaching an overfished condition.

*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. 2014-2016 for this year). For POP, the expansion factor for 2017 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 (0.92), which was the average of the ratio of catch to ABC for the last three complete catch years (2014-2016). This yield ratio was multiplied by the projected ABCs for 2018 and 2019 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 9-16). The $B_{35\%}$ and $B_{40\%}$ reference points and future recruitments are based on the 1979-2015 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*

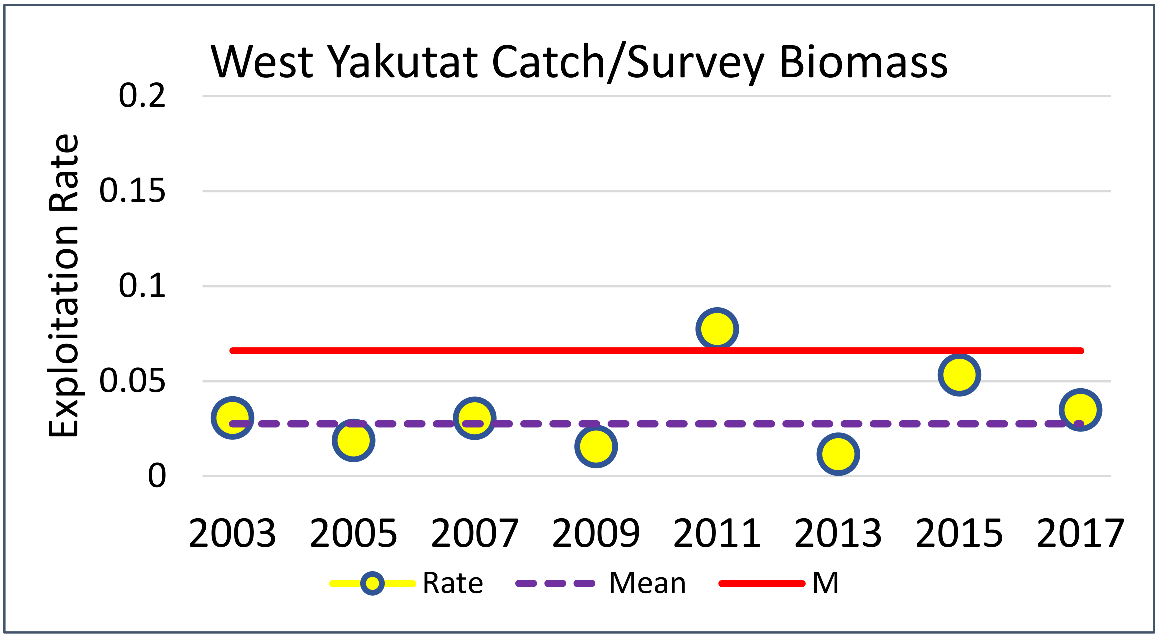
Apportionment of ABC and OFL among regulatory areas has been based on the random effects model developed by the survey averaging working group. The random effects model was fit to the survey biomass estimates (with associated variance) for the Western, Central, and Eastern GOA. The random effects model 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 9-17.

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 2017 compared to 2015. Using the random effects model estimates of survey biomass for the apportionment results in 11.3% for the Western area (up slightly from 11.2% in 2015), 68.8% for the Central area (down from 69.7% in 2015), and 19.9% for the Eastern area (up from 19.1% in 2015). Using the results of the random effects model results in recommended ABC's of **3,312** t for the Western area, **20,112** t for the Central area, and **5,812** t for the Eastern area.

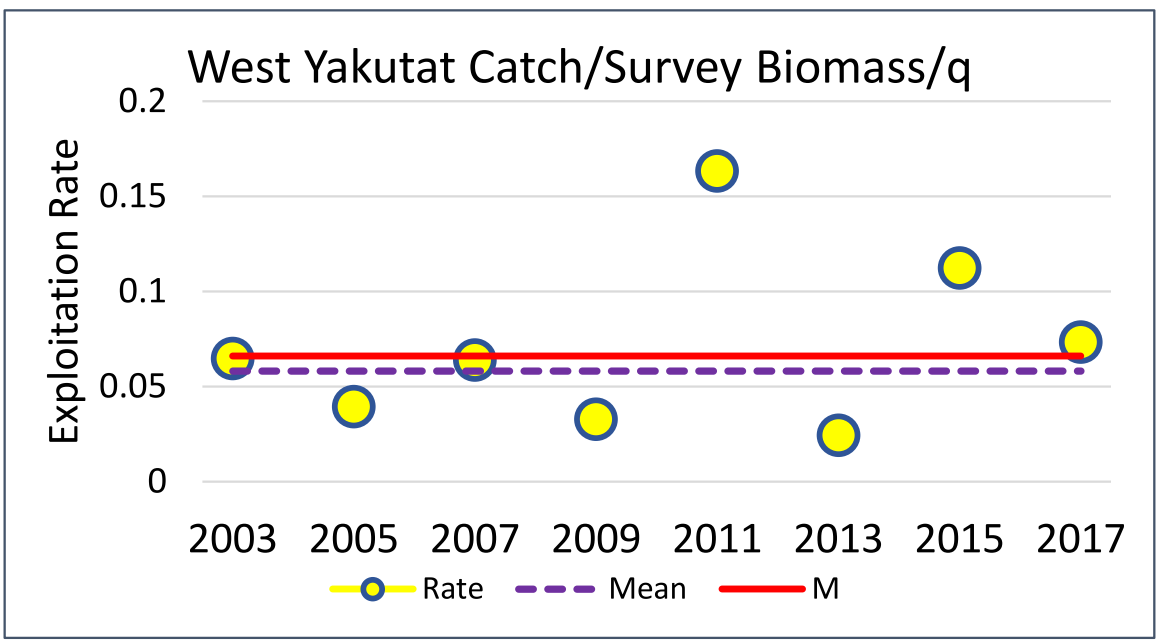
Amendment 41 prohibited trawling in the Eastern area east of 140° W longitude. In the past, the Plan Team has calculated an apportionment for the West Yakutat area that is still open to trawling (between 147°W and 140°W). We calculated this apportionment using the ratio of estimated biomass in the closed 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 2013, 2015, and 2017. We calculated the approximate upper 95% confidence interval using the variance of a weighted mean for the 2013-2017 weighed mean ratio. This resulted in a ratio of 0.58, down from 0.61 in 2015. This results in an ABC apportionment of **3,371** t to the W. Yakutat area which would leave **2,441** t unharvested in the Southeast/Outside area.

In November and December of 2015 the Team and SSC requested that the harvest rates in W. Yakutat be evaluated for comparison to $F_{ABC}$ rates. This is because the current method of apportionment between the W. Yakutat and Southeast/Outside areas, by design, may be putting more pressure on this smaller area than standard apportionment methods would. To address this concern we briefly examine the historical harvest rate under this method compared to the estimated biomass in that area.

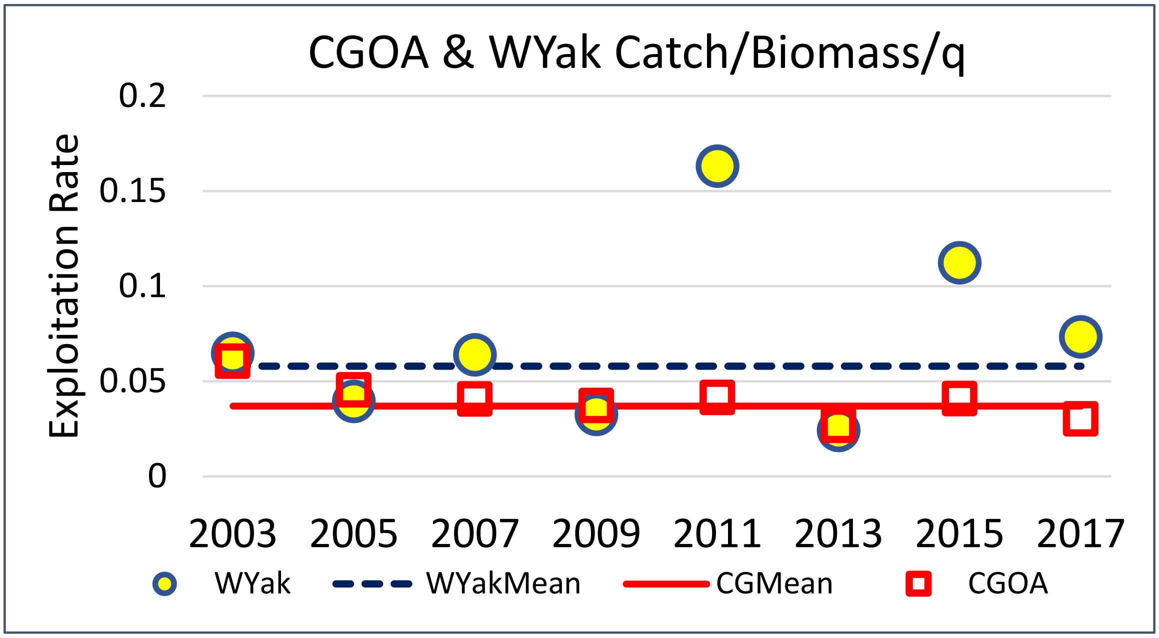
First we looked at exploitation rate by dividing the estimated survey biomass in W. Yakutat from 2003-2017 by the catch removed in those survey years (see figure below). Since natural mortality ($M$) is often used as a proxy for OFL/MSY, we plot the annual exploitation rates and the mean exploitation rate with natural mortality ($M$ =0.066). In this comparison, the annual exploitation rate only exceeds $M$ in 2011 and the mean is less than half of $M$.




The stock assessment model estimates that catchability is high (2.11) for the GOA trawl survey. When we account for the high catchability (see figure below), the exploitation rate exceeds *M* in 2011 and 2013 and is near *M* in several other years. However, the mean exploitation rate remains below *M*, but slightly above the Tier 5 ABC value of 0.75 *x M*. These values are all below the Tier 3 maximum $F_{ABC}$ of 0.094, but this value is challenging to directly compare to exploitation rate because of the dome-shaped selectivity of the fishery in the assessment model.



Finally, we can compare the exploitation rate of W. Yakutat to the exploitation rate of the neighboring management area (Central GOA). In this comparison, the two areas show similar exploitation rates six of the eight years, but were lower in the Central GOA 2011 and 2015 (see figure below).




In summary, it does appear that the rate of harvest is higher than the neighboring area. Additionally, even after taking in to account survey catchability, on average the exploitation rates do not show any cause for alarm. The several years of high rates in 2011 and 2015 could easily be explained by measurement error for a biomass estimate from such a small area (sampling variance estimates are not available for this area). Unless there are other socioeconomic factors to consider, we do not see a need to change this strategy at this time.

*Overfishing Definition*

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.113), overfishing is set equal to 34,762 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 **31,860** t and **2,902** t in the SEO area.

# 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. Recent 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 declined since 1984, although it is unclear whether this is a result of fishing or large year-classes of younger fish coming into the population.

*Fishery contribution to discards and offal production*: Fishery discard rates for the whole rockfish trawl fishery has declined from 35% in 1997 to 25% in 2004. Arrowtooth flounder comprised 22-46% of these discards. 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 (0.78 t), and sponges (2.98 t) 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 2016

Rockfish total catch in the Gulf of Alaska was 34 thousand t in 2016, up 17% from 2015 and above the 2007-2015 average of 25 thousand t (Table 1). Retained catch was 27.5 thousand t in 2016. Rockfish are an important component of the catch portfolio of GOA fisheries. Rockfish comprise roughly 10% of the retained catch and 3-4% of the ex-vessel value. Ex-vessel value in the GOA rockfish fisheries was $13.8 million up 11% from 2015 and above the 2007-2015 average of $10.4 million. While 2016 rockfish retained catch increased 12%, ex-vessel value only rose 2% as ex-vessel prices fell 9% (Table 1). The increase in 2016 ex-vessel value was the result of increased catch as ex-vessel price have remained relatively unchanged at $0.23 per pound. First-wholesale value was up 8% in 2016 to $37 million, which was above the 2007-2015 average of $31.1 million (Table 2).

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. Harvest levels of Pacific ocean perch are near the total allowable catch (TAC) and has been increasing in recent years with abundance. These increases largely account for the aggregate increase in rockfish catch and ex-vessel value as catch of other rockfish has remained fairly stable. The fisheries catch a diverse set of rockfish species and the other major species caught are northern and dusky (Table 1). Other rockfish caught 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 comprise roughly 12% of the retained catch and 5% of the ex-vessel value. 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 186 in 2007-2011 to 130 in 2016. 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 8% increase in 2016 first-wholesale value to $37 million was the result of increased catch and production (Table 2). The average price of rockfish products decreased 13% to $0.93 per pound with decreasing prices for each of the major rockfish species. 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 3). Exported H&G rockfish to China is re-processed (e.g., as fillets) and re-exported to domestic and international markets. Rockfish is also sold to Chinese consumers, as whole fish. The U.S. has accounted for approximately 15-20% of global rockfish production in recent years and 85-90% of global Pacific ocean perch production. Global production of rockfish has increased 9% from the 2007-2011 average to 283 thousand t in 2015 and global production of Pacific ocean perch has increased 52%. These increases in supply along with the strength of the dollar against currencies such as the Chinese Yuan may account for the downward trend in prices since 2015. Strong markets through 2017 may stabilize prices.

## 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 Pacific ocean perch across the GOA may enable improved assessment as well, given the closed area in the Eastern GOA and the recent increases in biomass in this area and the potential differences in population dynamics among the regions of the GOA. Incorporation of acoustics information that have been collected by the Mid-water Assessment and Conservation Engineering (MACE) group would also aid the assessment and would allow increased understanding of the changes to POP distribution in conjunction with the recent increases in biomass. Interaction with other species in the fishery, such as Walleye Pollock, should also be evaluated to determine the influence of POP population expansion. This research could potentially be done in a Management Strategy Evaluation (MSE) framework as well as Maximum Economic Yield (MEY) framework.

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# Tables

Table 9-1. Commercial catch[a] (t) of POP in the GOA, with Gulf-wide values of acceptable biological catch (ABC) and fishing quotas[b] (t), 1977-2017.

| | | Regulatory Area | | Gulf-wide | | 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[1] | 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. | 2,566 | 14,701 | 2,757 | 20,024 | 23,918 | 23,918 |

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 1991-2017 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; 1988-2017, POP.

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2017 total allowable catch.

Sources: Catch: 1977-84, Carlson et al. (1986); 1985-88, Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 S.W. 5th Avenue, Portland, OR 97201; 1989-2005, National Marine Fisheries Service, Alaska Region, P.O. Box 21668, Juneau, AK 99802. ABC and Quota: 1977-1986 Karinen and Wing (1987); 1987-1990, Heifetz et al. (2000); 1991-2017, NMFS AKRO BLEND/Catch Accounting System via AKFIN database.

* Catch as of 10/7/2017

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* | 20,024 | 23,918 | 23,918 | 27,826 | |

* Catch as of 10/7/2017

Table 9-3. FMP groundfish species caught in rockfish targeted fisheries in the GOA from 2011-2017. Conf. = Confidential because of less than three vessels or processors. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/25/2017.

| Species Group Name | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Average |
|---|---|---|---|---|---|---|---|---|
| POP | 13,120 | 13,953 | 11,555 | 15,283 | 17,566 | 20,402 | 16,339 | 15,460 |
| Northern Rockfish | 3,163 | 4,883 | 4,527 | 3,647 | 3,632 | 3,155 | 1,402 | 3,487 |
| Dusky Rockfish | 2,324 | 3,642 | 2,870 | 2,752 | 2,492 | 3,004 | 2,077 | 2,737 |
| Arrowtooth Flounder | 341 | 764 | 766 | 1,425 | 1,397 | 1,200 | 1,248 | 1,020 |
| Atka Mackerel | 1,404 | 1,173 | 1,162 | 446 | 988 | 595 | 483 | 893 |
| Walleye Pollock | 813 | 574 | 829 | 1,339 | 1,329 | 572 | 773 | 890 |
| Other Rockfish | 657 | 889 | 488 | 735 | 849 | 972 | 692 | 755 |
| Pacific Cod | 560 | 404 | 584 | 624 | 785 | 365 | 223 | 506 |
| Sablefish | 444 | 470 | 495 | 527 | 434 | 481 | 524 | 482 |
| Rougheye Rockfish | 287 | 219 | 274 | 359 | 225 | 351 | 283 | 285 |
| Shortraker Rockfish | 242 | 303 | 290 | 243 | 238 | 291 | 224 | 261 |
| Thornyhead Rockfish | 161 | 130 | 104 | 243 | 220 | 336 | 318 | 216 |
| Rex Sole | 51 | 72 | 89 | 84 | 116 | 140 | 100 | 93 |
| Demersal Shelf Rockfish | 27 | 111 | 135 | 38 | 39 | 40 | 40 | 62 |
| Deep Water Flatfish | 57 | 54 | 37 | 68 | 44 | 64 | 47 | 53 |
| Sculpin | 39 | 55 | 70 | 33 | 44 | 43 | 43 | 47 |
| Flathead Sole | 13 | 16 | 26 | 30 | 46 | 26 | 74 | 33 |
| Shallow Water Flatfish | 48 | 65 | 27 | 28 | 27 | 15 | 11 | 32 |
| Longnose Skate | 25 | 23 | 23 | 26 | 33 | 46 | 37 | 31 |
| Skate, Other | 15 | 20 | 18 | 45 | 21 | 18 | 21 | 23 |
| Shark | 5 | 5 | 93 | 2 | 6 | 12 | 24 | 21 |
| Squid | 12 | 15 | 10 | 19 | 24 | 12 | 20 | 16 |
| Big Skate | 8 | 13 | 2 | 4 | 7 | 5 | 2 | 6 |
| Octopus | 1 | 1 | 2 | 7 | 11 | 2 | 1 | 3 |

Table 9-4 . Catch (t) of GOA POP as bycatch in other fisheries from 2011-2017. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/25/2017.

| Target | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Average |
|---|---|---|---|---|---|---|---|---|
| Arrowtooth Flounder | 566 | 496 | 424 | 1400 | 593 | 1021 | 2972 | 1068 |
| Rex Sole - GOA | 291 | 94 | 714 | 423 | 227 | 50 | 101 | 271 |
| Pollock - midwater | 50 | 224 | 133 | 351 | 61 | 519 | 333 | 239 |
| Pacific Cod | 20 | 53 | 12 | 15 | 166 | 796 | 76 | 163 |
| Pollock - bottom | 124 | 70 | 294 | 179 | 115 | 163 | 130 | 153 |
| Shallow Water Flatfish - GOA | 2 | 3 | 20 | 11 | 2 | 139 | 48 | 32 |
| Atka Mackerel | 27 | - | 2 | - | - | 0 | 18 | 12 |
| Flathead Sole | 2 | 2 | 19 | 6 | - | 33 | 3 | 11 |
| Sablefish | 17 | 17 | 8 | 2 | 2 | 9 | 4 | 8 |
| Deep Water Flatfish - GOA | - | - | 1 | 1 | 1 | - | - | 1 |

Table 9-5. Non-FMP species bycatch estimates in tons for GOA rockfish targeted fisheries 2011 - 2017. Conf. = Confidential because of less than three vessels. Source: NMFS AKRO Blend/Catch Accounting System via AKFIN 10/25/2017.

| Species Group Name | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|
| Benthic urochordata | Conf. | Conf. | Conf. | Conf. | 0.28 | 0.5 | 0.2 |
| Birds - Black-footed Albatross | - | Conf. | - | - | - | - | - |
| Birds - Northern Fulmar | Conf. | - | - | Conf. | - | - | Conf. |
| Bivalves | 0.01 | Conf. | Conf. | 0.01 | Conf. | Conf. | 0.01 |
| Brittle star unidentified | 0.01 | 0.03 | 0.02 | 0.05 | 0.05 | 0.03 | 0.6 |
| Capelin | - | - | 0.02 | - | - | Conf. | - |
| Corals Bryozoans | 0.26 | 0.36 | 0.18 | 1.92 | 0.7 | 0.85 | 0.47 |
| Corals Bryozoans - Red Tree Coral | 0.1 | Conf. | Conf. | Conf. | Conf. | - | - |
| Dark Rockfish | - | 55.38 | - | - | - | - | - |
| Eelpouts | Conf. | 0.3 | 0.04 | 0.13 | 0.01 | 0.02 | 0.81 |
| Eulachon | Conf. | Conf. | 0.07 | 0.02 | 0.03 | 0.04 | 0.13 |
| Giant Grenadier | 466.72 | 311.1 | 888.89 | 512.5 | 785.81 | 438.17 | 742.88 |
| Greenlings | 7.66 | 8.75 | 6.99 | 4.16 | 8.14 | 5.79 | 3.56 |
| Grenadier - Rattail Grenadier Unidentified | 88.88 | 72.89 | 27.87 | Conf. | 43.87 | 3.4 | Conf. |
| Gunnels | - | - | - | - | Conf. | - | - |
| Hermit crab unidentified | 0.02 | Conf. | 0.03 | 0.04 | 0.03 | 0.01 | 0.03 |
| Invertebrate unidentified | 0.35 | 3.85 | 0.18 | Conf. | 0.19 | 0.09 | 0.06 |
| Lanternfishes (myctophidae) | - | - | Conf. | - | 0.04 | 0.14 | 0 |
| Large Sculpins - Bigmouth Sculpin | - | 19.33 | - | - | - | - | - |
| Large Sculpins - Great Sculpin | - | 1.88 | - | - | - | - | - |
| Large Sculpins - Hemilepidotus Unidentified | - | Conf. | - | - | - | - | - |
| Large Sculpins - Red Irish Lord | - | Conf. | - | - | - | - | - |
| Large Sculpins - Yellow Irish Lord | - | 24.18 | - | - | - | - | - |
| Misc crabs | 0.05 | 0.04 | 0.05 | 0.08 | 0.16 | 0.35 | 0.57 |
| Misc crustaceans | Conf. | - | Conf. | Conf. | Conf. | 0.03 | 0.01 |
| Misc deep fish | - | - | Conf. | - | - | Conf. | Conf. |
| Misc fish | 129.52 | 151.71 | 159.64 | 124.6 | 143.5 | 101.66 | 110.06 |
| Misc inverts (worms etc) | Conf. | - | - | - | - | Conf. | - |
| Other Sculpins | - | 0.59 | - | - | - | - | - |
| Other osmerids | - | Conf. | 0.02 | Conf. | Conf. | 0.03 | Conf. |
| Pacific Hake | - | - | - | - | Conf. | 0.04 | Conf. |
| Pacific Sand lance | Conf. | - | - | - | - | - | - |
| Pandalid shrimp | 0.06 | 0.06 | 0.06 | 0.1 | 0.05 | 0.22 | 0.14 |
| Polychaete unidentified | - | - | Conf. | - | - | - | 0.02 |
| Scypho jellies | 0 | 0.16 | 0.39 | 5.13 | 1.63 | 8.05 | 0.54 |
| Sea anemone unidentified | 4.07 | 6.27 | 4.02 | 2.15 | 1.14 | 1.27 | 0.69 |
| Sea pens whips | 0.04 | - | 0.04 | 0.06 | Conf. | 0.02 | 0.03 |
| Sea star | 1.46 | 0.92 | 0.89 | 1.6 | 3.48 | 1.72 | 3 |
| Snails | 0.23 | 1.26 | 0.15 | 0.1 | 0.26 | 0.18 | 0.17 |
| Sponge unidentified | 3.95 | 1.37 | 1.27 | 1.81 | 5.45 | 2.88 | 3.17 |
| State-managed Rockfish | 18.49 | - | 66.71 | 50.39 | 47.47 | 13.34 | 24.19 |
| Stichaeidae | - | - | Conf. | Conf. | Conf. | - | Conf. |
| urchins dollars cucumbers | 0.44 | 0.3 | 0.28 | 0.21 | 0.99 | 0.34 | 0.4 |

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 10/25/2017.

| Species Group Name | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Average |
|---|---|---|---|---|---|---|---|---|
| Bairdi Crab | 0.03 | 0.09 | 0.07 | 0.19 | 0.05 | 0.00 | 0.74 | 0.17 |
| Blue King Crab | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Chinook Salmon | 1.01 | 1.56 | 2.32 | 1.25 | 1.91 | 0.38 | 0.17 | 1.23 |
| Golden K. Crab | 0.13 | 0.11 | 0.10 | 0.03 | 0.02 | 0.02 | 0.18 | 0.09 |
| Halibut | 108.02 | 109.22 | 112.95 | 123.46 | 157.09 | 120.42 | 99.30 | 118.64 |
| Herring | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.01 |
| Other Salmon | 0.21 | 0.31 | 2.02 | 0.56 | 0.34 | 0.22 | 0.56 | 0.60 |
| Opilio Crab | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Red King Crab | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Table 9-7. Fishery length frequency data for POP in the GOA from 2008-2017.

| Length (cm) | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 17 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 |
| 20 | 0.000 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 |
| 21 | 0.000 | 0.001 | 0.001 | 0.001 | 0.003 | 0.000 | 0.002 | 0.002 | 0.000 | 0.001 |
| 22 | 0.001 | 0.002 | 0.003 | 0.001 | 0.005 | 0.001 | 0.003 | 0.002 | 0.001 | 0.001 |
| 23 | 0.002 | 0.001 | 0.005 | 0.002 | 0.008 | 0.003 | 0.003 | 0.003 | 0.002 | 0.001 |
| 24 | 0.002 | 0.003 | 0.004 | 0.002 | 0.008 | 0.004 | 0.003 | 0.004 | 0.004 | 0.002 |
| 25 | 0.003 | 0.003 | 0.003 | 0.003 | 0.010 | 0.008 | 0.003 | 0.007 | 0.004 | 0.003 |
| 26 | 0.003 | 0.005 | 0.003 | 0.003 | 0.015 | 0.013 | 0.003 | 0.009 | 0.004 | 0.005 |
| 27 | 0.003 | 0.006 | 0.004 | 0.003 | 0.014 | 0.014 | 0.005 | 0.010 | 0.005 | 0.007 |
| 28 | 0.008 | 0.007 | 0.005 | 0.005 | 0.010 | 0.015 | 0.007 | 0.009 | 0.007 | 0.010 |
| 29 | 0.012 | 0.008 | 0.006 | 0.007 | 0.009 | 0.019 | 0.012 | 0.010 | 0.010 | 0.011 |
| 30 | 0.016 | 0.012 | 0.008 | 0.010 | 0.009 | 0.020 | 0.020 | 0.011 | 0.012 | 0.013 |
| 31 | 0.025 | 0.021 | 0.014 | 0.012 | 0.012 | 0.022 | 0.024 | 0.018 | 0.015 | 0.017 |
| 32 | 0.040 | 0.040 | 0.025 | 0.020 | 0.021 | 0.014 | 0.028 | 0.024 | 0.025 | 0.029 |
| 33 | 0.063 | 0.065 | 0.042 | 0.033 | 0.031 | 0.017 | 0.034 | 0.033 | 0.041 | 0.054 |
| 34 | 0.093 | 0.091 | 0.074 | 0.060 | 0.051 | 0.032 | 0.045 | 0.046 | 0.069 | 0.089 |
| 35 | 0.116 | 0.126 | 0.118 | 0.103 | 0.088 | 0.064 | 0.069 | 0.070 | 0.091 | 0.115 |
| 36 | 0.130 | 0.139 | 0.155 | 0.140 | 0.134 | 0.115 | 0.107 | 0.103 | 0.121 | 0.124 |
| 37 | 0.118 | 0.119 | 0.149 | 0.158 | 0.158 | 0.149 | 0.145 | 0.131 | 0.135 | 0.129 |
| 38 | 0.109 | 0.108 | 0.129 | 0.151 | 0.142 | 0.161 | 0.148 | 0.148 | 0.137 | 0.117 |
| 39 | 0.090 | 0.088 | 0.097 | 0.109 | 0.110 | 0.125 | 0.126 | 0.133 | 0.119 | 0.101 |
| 40 | 0.065 | 0.062 | 0.063 | 0.074 | 0.071 | 0.085 | 0.091 | 0.096 | 0.085 | 0.074 |
| 41 | 0.042 | 0.038 | 0.039 | 0.050 | 0.044 | 0.055 | 0.057 | 0.064 | 0.055 | 0.048 |
| 42 | 0.025 | 0.024 | 0.023 | 0.025 | 0.026 | 0.031 | 0.034 | 0.032 | 0.029 | 0.026 |
| 43 | 0.016 | 0.015 | 0.013 | 0.014 | 0.011 | 0.018 | 0.015 | 0.017 | 0.014 | 0.013 |
| 44 | 0.008 | 0.007 | 0.006 | 0.006 | 0.004 | 0.008 | 0.007 | 0.008 | 0.008 | 0.007 |
| ≥45 | 0.011 | 0.006 | 0.007 | 0.006 | 0.005 | 0.004 | 0.007 | 0.006 | 0.005 | 0.005 |
| Total | 8,154 | 9,948 | 11,174 | 9,800 | 12,881 | 10,761 | 14,462 | 15,813 | 19,982 | 16,218 |

Table 9-8. Fishery age compositions for GOA POP 1999-2012.

| Age | 1990 | 1998 | 1999 | 2000 | 2001 | 2002 | 2004 | 2005 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 0.002 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 |
| 4 | 0.016 | 0.000 | 0.000 | 0.005 | 0.004 | 0.003 | 0.002 | 0.001 | 0.001 | 0.005 | 0.013 | 0.018 | 0.009 | 0.004 |
| 5 | 0.042 | 0.000 | 0.003 | 0.015 | 0.002 | 0.014 | 0.007 | 0.012 | 0.003 | 0.005 | 0.005 | 0.026 | 0.003 | 0.002 |
| 6 | 0.048 | 0.000 | 0.016 | 0.037 | 0.017 | 0.016 | 0.051 | 0.021 | 0.045 | 0.021 | 0.013 | 0.020 | 0.030 | 0.022 |
| 7 | 0.071 | 0.002 | 0.024 | 0.026 | 0.040 | 0.035 | 0.040 | 0.085 | 0.089 | 0.031 | 0.019 | 0.023 | 0.046 | 0.018 |
| 8 | 0.054 | 0.008 | 0.029 | 0.056 | 0.029 | 0.097 | 0.049 | 0.085 | 0.114 | 0.102 | 0.070 | 0.028 | 0.039 | 0.059 |
| 9 | 0.069 | 0.045 | 0.043 | 0.064 | 0.058 | 0.078 | 0.166 | 0.103 | 0.108 | 0.103 | 0.071 | 0.046 | 0.036 | 0.078 |
| 10 | 0.106 | 0.148 | 0.051 | 0.057 | 0.060 | 0.108 | 0.177 | 0.142 | 0.084 | 0.161 | 0.120 | 0.092 | 0.061 | 0.065 |
| 11 | 0.057 | 0.166 | 0.178 | 0.054 | 0.060 | 0.105 | 0.067 | 0.114 | 0.106 | 0.108 | 0.149 | 0.105 | 0.082 | 0.047 |
| 12 | 0.083 | 0.203 | 0.191 | 0.132 | 0.063 | 0.051 | 0.075 | 0.074 | 0.087 | 0.048 | 0.122 | 0.116 | 0.096 | 0.057 |
| 13 | 0.057 | 0.121 | 0.130 | 0.127 | 0.131 | 0.070 | 0.069 | 0.047 | 0.061 | 0.090 | 0.074 | 0.093 | 0.080 | 0.059 |
| 14 | 0.109 | 0.113 | 0.088 | 0.110 | 0.146 | 0.108 | 0.036 | 0.044 | 0.037 | 0.051 | 0.057 | 0.093 | 0.067 | 0.053 |
| 15 | 0.042 | 0.057 | 0.120 | 0.104 | 0.084 | 0.086 | 0.036 | 0.021 | 0.035 | 0.043 | 0.051 | 0.051 | 0.076 | 0.069 |
| 16 | 0.016 | 0.031 | 0.061 | 0.060 | 0.092 | 0.065 | 0.049 | 0.032 | 0.026 | 0.023 | 0.041 | 0.045 | 0.065 | 0.083 |
| 17 | 0.028 | 0.033 | 0.021 | 0.052 | 0.061 | 0.054 | 0.050 | 0.050 | 0.027 | 0.026 | 0.040 | 0.049 | 0.048 | 0.068 |
| 18 | 0.009 | 0.014 | 0.019 | 0.031 | 0.071 | 0.038 | 0.041 | 0.041 | 0.035 | 0.011 | 0.021 | 0.033 | 0.036 | 0.051 |
| 19 | 0.012 | 0.014 | 0.003 | 0.025 | 0.040 | 0.035 | 0.030 | 0.032 | 0.038 | 0.026 | 0.014 | 0.025 | 0.041 | 0.035 |
| 20 | 0.010 | 0.002 | 0.003 | 0.008 | 0.015 | 0.011 | 0.021 | 0.026 | 0.027 | 0.028 | 0.014 | 0.021 | 0.032 | 0.029 |
| 21 | 0.012 | 0.004 | 0.000 | 0.010 | 0.012 | 0.003 | 0.009 | 0.028 | 0.025 | 0.026 | 0.016 | 0.015 | 0.015 | 0.036 |
| 22 | 0.003 | 0.004 | 0.008 | 0.011 | 0.002 | 0.005 | 0.007 | 0.011 | 0.010 | 0.026 | 0.032 | 0.016 | 0.021 | 0.034 |
| 23 | 0.005 | 0.012 | 0.003 | 0.004 | 0.006 | 0.003 | 0.005 | 0.008 | 0.015 | 0.020 | 0.011 | 0.011 | 0.016 | 0.020 |
| 24 | 0.009 | 0.002 | 0.000 | 0.001 | 0.000 | 0.003 | 0.006 | 0.007 | 0.010 | 0.015 | 0.006 | 0.006 | 0.020 | 0.014 |
| 25+ | 0.142 | 0.023 | 0.011 | 0.011 | 0.006 | 0.011 | 0.006 | 0.015 | 0.016 | 0.030 | 0.041 | 0.068 | 0.082 | 0.092 |
| Sample size | 578 | 513 | 376 | 734 | 521 | 370 | 802 | 727 | 734 | 609 | 631 | 1024 | 871 | 1201 |

Table 9-9. Biomass estimates (t) and Gulf-wide confidence intervals for POP in the GOA based on the 1984-2017 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% |

*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 0.003 | 0.019 | 0.005 | 0.006 | 0.006 | 0.006 | 0.016 | 0.001 | 0.003 | 0.005 | 0.001 | 0.000 | 0.006 |
| 3 | 0.002 | 0.101 | 0.043 | 0.018 | 0.016 | 0.020 | 0.057 | 0.034 | 0.020 | 0.087 | 0.030 | 0.022 | 0.027 |
| 4 | 0.058 | 0.092 | 0.155 | 0.021 | 0.036 | 0.045 | 0.053 | 0.050 | 0.018 | 0.045 | 0.046 | 0.012 | 0.008 |
| 5 | 0.029 | 0.066 | 0.124 | 0.044 | 0.043 | 0.052 | 0.071 | 0.077 | 0.044 | 0.049 | 0.124 | 0.067 | 0.061 |
| 6 | 0.079 | 0.091 | 0.117 | 0.088 | 0.063 | 0.026 | 0.040 | 0.073 | 0.041 | 0.025 | 0.042 | 0.058 | 0.024 |
| 7 | 0.151 | 0.146 | 0.089 | 0.125 | 0.038 | 0.041 | 0.054 | 0.119 | 0.056 | 0.096 | 0.036 | 0.064 | 0.078 |
| 8 | 0.399 | 0.056 | 0.065 | 0.129 | 0.088 | 0.059 | 0.107 | 0.070 | 0.089 | 0.065 | 0.024 | 0.055 | 0.053 |
| 9 | 0.050 | 0.061 | 0.054 | 0.166 | 0.145 | 0.095 | 0.115 | 0.087 | 0.125 | 0.106 | 0.071 | 0.057 | 0.107 |
| 10 | 0.026 | 0.087 | 0.055 | 0.092 | 0.185 | 0.054 | 0.057 | 0.092 | 0.094 | 0.047 | 0.073 | 0.042 | 0.048 |
| 11 | 0.010 | 0.096 | 0.036 | 0.045 | 0.110 | 0.114 | 0.053 | 0.063 | 0.063 | 0.053 | 0.105 | 0.066 | 0.036 |
| 12 | 0.016 | 0.018 | 0.024 | 0.052 | 0.080 | 0.144 | 0.044 | 0.035 | 0.064 | 0.079 | 0.073 | 0.064 | 0.027 |
| 13 | 0.015 | 0.011 | 0.028 | 0.038 | 0.034 | 0.086 | 0.036 | 0.027 | 0.050 | 0.035 | 0.065 | 0.067 | 0.052 |
| 14 | 0.019 | 0.011 | 0.072 | 0.025 | 0.036 | 0.067 | 0.057 | 0.031 | 0.030 | 0.039 | 0.047 | 0.059 | 0.033 |
| 15 | 0.005 | 0.009 | 0.017 | 0.026 | 0.028 | 0.046 | 0.048 | 0.039 | 0.026 | 0.047 | 0.037 | 0.053 | 0.058 |
| 16 | 0.003 | 0.011 | 0.011 | 0.011 | 0.006 | 0.040 | 0.042 | 0.022 | 0.013 | 0.013 | 0.024 | 0.029 | 0.049 |
| 17 | 0.008 | 0.013 | 0.005 | 0.036 | 0.013 | 0.023 | 0.032 | 0.027 | 0.018 | 0.006 | 0.015 | 0.030 | 0.044 |
| 18 | 0.004 | 0.007 | 0.008 | 0.007 | 0.009 | 0.013 | 0.029 | 0.036 | 0.039 | 0.015 | 0.024 | 0.037 | 0.034 |
| 19 | 0.002 | 0.005 | 0.004 | 0.003 | 0.014 | 0.003 | 0.016 | 0.024 | 0.028 | 0.005 | 0.024 | 0.029 | 0.014 |
| 20 | 0.000 | 0.005 | 0.006 | 0.002 | 0.013 | 0.012 | 0.015 | 0.021 | 0.043 | 0.012 | 0.023 | 0.024 | 0.036 |
| 21 | 0.003 | 0.004 | 0.004 | 0.002 | 0.003 | 0.007 | 0.010 | 0.013 | 0.024 | 0.032 | 0.018 | 0.018 | 0.036 |
| 22 | 0.003 | 0.003 | 0.002 | 0.004 | 0.004 | 0.008 | 0.005 | 0.018 | 0.022 | 0.062 | 0.009 | 0.011 | 0.024 |
| 23 | 0.002 | 0.002 | 0.002 | 0.002 | 0.003 | 0.012 | 0.006 | 0.004 | 0.016 | 0.013 | 0.018 | 0.016 | 0.013 |
| 24 | 0.003 | 0.002 | 0.006 | 0.004 | 0.000 | 0.004 | 0.007 | 0.008 | 0.018 | 0.022 | 0.019 | 0.016 | 0.014 |
| 25 | 0.110 | 0.083 | 0.070 | 0.054 | 0.027 | 0.025 | 0.031 | 0.030 | 0.055 | 0.043 | 0.053 | 0.104 | 0.117 |
| Sample size | 1428 | 1824 | 1754 | 1378 | 641 | 898 | 985 | 1009 | 1177 | 418 | 794 | 880 | 760 |

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<br>$\mu_r$ – average recruitment<br>$\varepsilon_y^r$ – 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<br>$M$ – natural mortality<br>$F_{a,y}$ – annual fishing mortality at age<br>$Z_{a,y}$ – 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 | $\delta^m$ – logistic slope parameter ($m$ denotes parameter for maturity)<br>$a_{50\%}^m$ – 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<br>$F_y$ – annual fishing mortality<br>$\mu_f$ – average fishing mortality<br>$\varepsilon^f_y$ – 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) | $\delta^f$ – logistic slope parameter (*f* denotes parameter for fishery)<br>$a^f_{50\%}$ – 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<br>$s^t_a$ – 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 | $\delta^t$ – logistic slope parameter (t denotes parameter for trawl survey)<br>$a^t_{50\%}$ – 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)<br>$k$ – 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)<br>$\sigma_{I,y}$ – annual survey sampling error |
| $L_{\hat{p}_a^f} = \lambda_{\hat{p}_a^f}\left(\sum_{Y} -n_{a,y}^f \sum_{A} (p_{a,y}^f + k) \ln(\hat{p}_{a,y}^f + k)\right)$ | Fishery age composition likelihood | $\lambda_{\hat{p}_a^f}$ – fishery age composition weight (1)<br>$n_{a,y}^f$ – fishery age composition input sample size (square root of sample size) |
| $L_{\hat{p}_l^f} = \lambda_{\hat{p}_l^f}\left(\sum_{Y} -n_{l,y}^f \sum_{A} (p_{l,y}^f + k) \ln(\hat{p}_{l,y}^f + k)\right)$ | Fishery length composition likelihood | $\lambda_{\hat{p}_a^f}$ – fishery length composition weight (1)<br>$n_{a,y}^f$ – fishery length composition input sample size (number of hauls standardized to maximum of 100) |
| $L_{\hat{p}_a^t} = \lambda_{\hat{p}_a^t}\left(\sum_{Y} -n_{a,y}^t \sum_{A} (p_{a,y}^t + k) \ln(\hat{p}_{a,y}^t + k)\right)$ | Bottom trawl survey age composition likelihood | $\lambda_{\hat{p}_a^t}$ – fishery age composition weight (1)<br>$n_{a,y}^t$ – fishery age composition input sample size (square root of sample size) |
| $L_m = \sum_{D}\sum_{A} Binom(n_{a,D}, \widehat{m}_a) + \lambda_m {}^{1}\!/\!\left(1 + e^{\delta^m a_{50\%}^m}\right)$ | Maturity likelihood | $D$ – Dataset<br>$n_{a,D}$ – number observed at age for maturity by dataset<br>$\lambda_m$ – maturity at age 0 penalty weight (1000) |
| $L_\theta = \frac{1}{2\sigma_\theta^2} \ln\left(\frac{\theta}{\theta_{prior}}\right)^2$ | Prior penalty, used for natural mortality ($M$), bottom trawl survey catchability ($q$), and recruitment variability ($\sigma_r$) | $\theta$ – parameter estimate<br>$\sigma_\theta^2$ – prior uncertainty<br>$\theta_{prior}$ – prior parameter estimate |
| $L_r = \lambda_r\left(\frac{1}{2\sigma_r^2}\sum_{Y} \varepsilon_y^r + Y \ln \sigma_r\right)$ | Recruitment deviation penalty | $\lambda_r$ – recruitment deviation penalty weight (1)<br>$\sigma_r$ – recruitment variability |
| $L_f = \lambda_f \sum_{Y} \varepsilon_y^f$ | Fishing mortality deviation penalty | $\lambda_f$ – fishing mortality deviation penalty weight (0.1) |

Table 9-14. Summary of results from 2017 compared with 2015 results

| **Likelihoods** | **2015** | **15.0** | **15.0a** | **15.0b** | **15.0c** | **15.0d** | **17.0** | **17.1** |
|---|---|---|---|---|---|---|---|---|
| Catch | 0.14 | 0.15 | 0.17 | 0.16 | 0.17 | 0.18 | 0.16 | 0.18 |
| Survey Biomass | 12.21 | 15.34 | 15.51 | 14.07 | 13.31 | 14.09 | 14.82 | 13.23 |
| Fishery Ages | 18.24 | 23.20 | 23.17 | 23.30 | 23.57 | 23.93 | 28.20 | 19.28 |
| Survey Ages | 32.03 | 33.69 | 33.55 | 33.37 | 18.74 | 18.72 | 18.93 | 19.55 |
| Fishery Sizes | 55.34 | 55.98 | 66.16 | 66.27 | 65.24 | 65.34 | 66.11 | 65.51 |
| Maturity | 103.52 | 103.52 | 103.52 | 103.52 | 103.52 | 103.52 | 103.52 | 103.52 |
| ***Data-Likelihood*** | 221.48 | 231.88 | 242.08 | 240.68 | 224.55 | 225.78 | 231.73 | 221.27 |
| **Penalties/Priors** | | | | | | | | |
| Recruitment Devs | 21.56 | 20.71 | 22.21 | 23.02 | 17.26 | 16.77 | 7.93 | 15.92 |
| F Regularity | 4.63 | 4.93 | 4.82 | 4.93 | 5.01 | 5.06 | 8.03 | 5.08 |
| $\sigma_r$ prior | 5.48 | 5.76 | 5.49 | 5.36 | 6.39 | 6.48 | 8.26 | 6.64 |
| $q$ prior | 1.12 | 0.92 | 1.02 | 0.89 | 1.07 | 1.46 | 0.35 | 1.39 |
| $M$ prior | 2.02 | 1.81 | 2.28 | 2.14 | 2.99 | 3.25 | 3.46 | 3.73 |
| ***Objective Fun Total*** | 256.29 | 266.01 | 277.92 | 277.01 | 257.27 | 258.79 | 259.76 | 254.04 |
| **Parameter Ests.** | | | | | | | | |
| Active parameters | 152 | 156 | 156 | 156 | 156 | 156 | 154 | 158 |
| Mohn’s rho | -0.17 | -0.21 | -0.22 | -0.21 | -0.18 | -0.22 | 0.20 | -0.22 |
| $q$ | 1.95 | 1.84 | 1.89 | 1.81 | 1.92 | 2.14 | 1.46 | 2.11 |
| $M$ | 0.061 | 0.060 | 0.062 | 0.062 | 0.064 | 0.065 | 0.065 | 0.066 |
| $\sigma_r$ | 0.88 | 0.86 | 0.88 | 0.88 | 0.83 | 0.83 | 0.75 | 0.82 |
| Mean Recruitment | 52.74 | 53.72 | 52.22 | 52.34 | 57.02 | 58.57 | 82.36 | 60.84 |
| $F_{40\%}$ | 0.102 | 0.095 | 0.096 | 0.096 | 0.097 | 0.098 | 0.109 | 0.094 |
| Total Biomass | 457,768 | 452,284 | 432,626 | 458,584 | 468,887 | 487,310 | 695,769 | 511,857 |
| $B_{CURRENT}$ | 157,080 | 163,584 | 155,579 | 166,056 | 166,967 | 171,981 | 250,893 | 180,014 |
| $B_{100\%}$ | 285,327 | 294,382 | 281,794 | 293,631 | 286,615 | 290,601 | 374,590 | 293,621 |
| $\mathbf{B_{40\%}}$ | 114,131 | 117,753 | 112,718 | 117,452 | 114,646 | 116,240 | 149,836 | 117,448 |
| ***maxABC*** | 24,437 | 23,599 | 22,870 | 24,231 | 25,799 | 26,953 | 37,210 | **29,235** |
| $F_{35\%}$ | 0.119 | 0.112 | 0.113 | 0.113 | 0.115 | 0.116 | 0.127 | 0.113 |
| $OFL_{F35\%}$ | 28,431 | 27,571 | 26,738 | 28,470 | 30,251 | 31,606 | 43,296 | **34,761** |

Table 9-15. Estimated numbers (thousands) in 2015, fishery selectivity, and survey selectivity of POP in the GOA. Also shown are schedules of age specific weight and female maturity.

| Age | Numbers in 2015 (1000's) | Maturity (%) | Weight (g) | Fishery selectivity (%) | Survey selectivity (%) |
|---|---|---|---|---|---|
| 2 | 61,032 | 0.7 | 44 | 0.0 | 8.6 |
| 3 | 57,573 | 1.3 | 98 | 0.5 | 14.8 |
| 4 | 54,169 | 2.5 | 167 | 2.4 | 24.2 |
| 5 | 67,234 | 4.7 | 244 | 6.5 | 37.0 |
| 6 | 38,200 | 8.8 | 322 | 13.2 | 52.0 |
| 7 | 81,154 | 15.8 | 398 | 22.2 | 66.6 |
| 8 | 32,558 | 26.9 | 470 | 33.1 | 78.6 |
| 9 | 88,664 | 41.8 | 534 | 45.1 | 87.1 |
| 10 | 57,934 | 58.4 | 592 | 57.1 | 92.6 |
| 11 | 89,127 | 73.3 | 642 | 68.6 | 95.8 |
| 12 | 28,707 | 84.3 | 685 | 78.8 | 97.7 |
| 13 | 33,577 | 91.3 | 723 | 87.1 | 98.7 |
| 14 | 18,096 | 95.3 | 754 | 93.5 | 99.3 |
| 15 | 40,075 | 97.6 | 781 | 97.7 | 99.6 |
| 16 | 23,715 | 98.7 | 804 | 99.8 | 99.8 |
| 17 | 38,034 | 99.3 | 822 | 100.0 | 99.9 |
| 18 | 22,426 | 99.7 | 838 | 98.4 | 99.9 |
| 19 | 31,936 | 99.8 | 851 | 95.4 | 100.0 |
| 20 | 13,436 | 99.9 | 862 | 91.3 | 100.0 |
| 21 | 9,625 | 100.0 | 871 | 86.2 | 100.0 |
| 22 | 14,442 | 100.0 | 879 | 80.5 | 100.0 |
| 23 | 11,819 | 100.0 | 885 | 74.5 | 100.0 |
| 24 | 4,603 | 100.0 | 890 | 68.2 | 100.0 |
| 25 | 5,156 | 100.0 | 894 | 62.0 | 100.0 |
| 26 | 4,146 | 100.0 | 898 | 55.9 | 100.0 |
| 27 | 3,749 | 100.0 | 901 | 50.0 | 100.0 |
| 28 | 2,804 | 100.0 | 903 | 44.5 | 100.0 |
| 29+ | 46,426 | 100.0 | 910 | 39.4 | 100.0 |

Table 9-16. 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 | 34,839 | 35,945 | 99,660 | 109,138 | 0.217 | 0.198 | 14,244 | 20,611 |
| 1978 | 29,188 | 31,339 | 82,686 | 94,528 | 0.097 | 0.085 | 77,505 | 18,511 |
| 1979 | 28,591 | 31,684 | 78,817 | 93,157 | 0.106 | 0.089 | 29,198 | 17,437 |
| 1980 | 27,562 | 31,636 | 74,112 | 91,057 | 0.147 | 0.119 | 23,413 | 17,048 |
| 1981 | 25,194 | 30,260 | 66,846 | 87,227 | 0.159 | 0.120 | 19,082 | 20,302 |
| 1982 | 22,888 | 28,808 | 75,765 | 87,989 | 0.072 | 0.061 | 45,155 | 33,330 |
| 1983 | 23,100 | 29,536 | 80,390 | 91,897 | 0.035 | 0.031 | 29,234 | 24,521 |
| 1984 | 25,079 | 31,620 | 86,245 | 97,425 | 0.032 | 0.028 | 31,333 | 21,077 |
| 1985 | 27,910 | 34,109 | 90,703 | 103,171 | 0.009 | 0.008 | 53,579 | 22,210 |
| 1986 | 32,106 | 37,723 | 103,221 | 112,879 | 0.021 | 0.019 | 86,788 | 28,856 |
| 1987 | 36,066 | 41,017 | 110,812 | 121,298 | 0.041 | 0.037 | 66,669 | 29,003 |
| 1988 | 39,094 | 43,517 | 116,222 | 127,593 | 0.074 | 0.067 | 121,897 | 29,766 |
| 1989 | 40,469 | 44,574 | 122,813 | 134,154 | 0.097 | 0.088 | 92,906 | 43,471 |
| 1990 | 40,749 | 44,771 | 135,100 | 146,238 | 0.097 | 0.090 | 76,304 | 68,759 |
| 1991 | 41,286 | 45,396 | 143,023 | 157,421 | 0.046 | 0.042 | 33,762 | 64,189 |
| 1992 | 45,609 | 49,979 | 172,212 | 188,079 | 0.038 | 0.035 | 43,218 | 100,467 |
| 1993 | 51,609 | 56,354 | 196,693 | 213,916 | 0.011 | 0.010 | 43,587 | 77,924 |
| 1994 | 60,934 | 66,156 | 222,274 | 239,805 | 0.008 | 0.008 | 48,607 | 62,239 |
| 1995 | 71,757 | 77,472 | 236,858 | 254,584 | 0.024 | 0.023 | 37,917 | 29,449 |
| 1996 | 81,651 | 87,768 | 247,307 | 264,932 | 0.034 | 0.032 | 88,776 | 36,424 |
| 1997 | 89,728 | 96,113 | 253,329 | 270,753 | 0.038 | 0.035 | 93,711 | 36,833 |
| 1998 | 95,719 | 102,206 | 257,976 | 275,326 | 0.035 | 0.032 | 55,331 | 41,445 |
| 1999 | 100,181 | 106,661 | 259,599 | 276,881 | 0.040 | 0.038 | 67,979 | 33,181 |
| 2000 | 102,609 | 109,043 | 271,283 | 289,395 | 0.038 | 0.035 | 137,833 | 75,759 |
| 2001 | 104,573 | 110,997 | 285,742 | 305,496 | 0.038 | 0.035 | 83,326 | 81,865 |
| 2002 | 106,407 | 112,920 | 290,951 | 311,281 | 0.040 | 0.038 | 122,753 | 48,084 |
| 2003 | 108,607 | 115,363 | 297,668 | 318,892 | 0.036 | 0.034 | 69,073 | 59,104 |
| 2004 | 112,270 | 119,452 | 322,808 | 348,192 | 0.036 | 0.033 | 97,002 | 123,905 |
| 2005 | 116,649 | 124,451 | 336,016 | 364,509 | 0.033 | 0.031 | 37,284 | 76,903 |
| 2006 | 122,123 | 130,795 | 359,219 | 393,479 | 0.038 | 0.035 | 63,633 | 115,609 |
| 2007 | 127,528 | 137,369 | 367,615 | 404,905 | 0.035 | 0.032 | 58,495 | 64,006 |
| 2008 | 133,826 | 144,955 | 382,212 | 425,855 | 0.033 | 0.029 | 170,831 | 96,163 |
| 2009 | 140,419 | 153,236 | 382,031 | 428,893 | 0.034 | 0.030 | 87,209 | 38,684 |
| 2010 | 146,233 | 160,980 | 385,250 | 436,654 | 0.040 | 0.036 | 121,603 | 64,109 |
| 2011 | 149,871 | 166,600 | 383,380 | 435,785 | 0.037 | 0.033 | 47,296 | 49,115 |
| 2012 | 153,001 | 171,627 | 410,234 | 463,173 | 0.036 | 0.032 | 67,471 | 137,402 |
| 2013 | 155,268 | 175,505 | 419,078 | 474,774 | 0.031 | 0.028 | 48,162 | 80,924 |
| 2014 | 158,513 | 180,005 | 437,813 | 497,888 | 0.040 | 0.035 | 53,343 | 112,968 |
| 2015 | 154,984 | 183,094 | 434,080 | 493,381 | 0.042 | 0.038 | 52,880 | 38,039 |
| 2016 | | 186,267 | | 500,668 | | 0.046 | | 87,506 |
| 2017 | | 180,163 | | 487,661 | | 0.045 | | 38,200 |

Table 9-17. Estimates of key parameters with Hessian estimates of standard deviation ($\sigma$), MCMC standard deviations ($\sigma$(MCMC)) and 95% Bayesian credible intervals (BCI) derived from MCMC simulations.

| Parameter | $\mu$ | $\mu$ (MCMC) | Median (MCMC) | $\sigma$ | $\sigma$(MCMC) | BCI-Lower | BCI-Upper |
|---|---|---|---|---|---|---|---|
| $q$ | 2.114 | 2.235 | 2.180 | 0.468 | 0.536 | 1.344 | 3.426 |
| $M$ | 0.066 | 0.068 | 0.068 | 0.006 | 0.006 | 0.056 | 0.082 |
| $F_{40\%}$ | 0.094 | 0.117 | 0.109 | 0.025 | 0.043 | 0.061 | 0.221 |
| *2018 SSB* | 180,010 | 184,336 | 178,422 | 42,577 | 46,585 | 111,382 | 292,672 |
| *2018 ABC* | 29,235 | 35,972 | 33,110 | 10,428 | 15,390 | 15,598 | 73,604 |

Table 9-18. 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 | 26,613 | 6,708 | 71,363 | 120,574 | 94,283 | 176,812 | 35,945 | 25,948 | 55,894 |
| 1978 | 43,717 | 11,389 | 95,858 | 106,716 | 79,783 | 164,227 | 31,339 | 21,207 | 52,050 |
| 1979 | 32,064 | 8,315 | 82,278 | 106,934 | 79,125 | 165,851 | 31,684 | 21,194 | 52,829 |
| 1980 | 27,491 | 7,253 | 67,655 | 106,928 | 78,403 | 167,097 | 31,636 | 20,911 | 53,130 |
| 1981 | 28,947 | 7,625 | 69,506 | 104,450 | 74,920 | 167,041 | 30,260 | 19,369 | 52,283 |
| 1982 | 37,561 | 11,436 | 87,232 | 102,726 | 71,456 | 166,174 | 28,808 | 17,647 | 51,225 |
| 1983 | 37,766 | 11,287 | 89,986 | 106,738 | 73,659 | 172,045 | 29,536 | 18,105 | 52,070 |
| 1984 | 38,802 | 11,054 | 91,553 | 113,886 | 79,271 | 180,780 | 31,620 | 19,873 | 54,419 |
| 1985 | 56,780 | 18,154 | 124,316 | 122,271 | 85,579 | 192,801 | 34,109 | 21,986 | 57,535 |
| 1986 | 89,977 | 36,373 | 181,777 | 135,283 | 95,944 | 209,976 | 37,723 | 25,024 | 61,735 |
| 1987 | 84,069 | 28,995 | 176,729 | 149,331 | 106,646 | 232,465 | 41,017 | 27,697 | 65,949 |
| 1988 | 131,210 | 62,627 | 246,137 | 165,607 | 118,104 | 256,367 | 43,517 | 29,449 | 69,738 |
| 1989 | 101,663 | 36,617 | 206,330 | 180,966 | 127,955 | 282,614 | 44,574 | 29,810 | 71,690 |
| 1990 | 81,049 | 28,518 | 164,683 | 195,144 | 135,377 | 308,511 | 44,771 | 29,113 | 73,099 |
| 1991 | 38,327 | 10,768 | 92,394 | 207,648 | 141,649 | 330,545 | 45,396 | 28,557 | 76,054 |
| 1992 | 47,436 | 16,929 | 97,781 | 225,875 | 154,133 | 357,959 | 49,978 | 31,285 | 83,330 |
| 1993 | 48,025 | 15,628 | 103,377 | 242,201 | 164,837 | 383,224 | 56,354 | 35,568 | 93,748 |
| 1994 | 54,060 | 18,560 | 111,883 | 261,203 | 179,926 | 409,888 | 66,156 | 42,662 | 108,067 |
| 1995 | 43,272 | 12,131 | 102,693 | 277,973 | 192,985 | 430,925 | 77,472 | 51,034 | 123,970 |
| 1996 | 98,826 | 41,086 | 194,671 | 290,769 | 202,395 | 449,356 | 87,768 | 58,285 | 139,623 |
| 1997 | 106,792 | 45,626 | 208,212 | 301,667 | 209,548 | 465,754 | 96,113 | 63,894 | 151,715 |
| 1998 | 62,736 | 17,996 | 144,376 | 311,015 | 215,044 | 479,448 | 102,206 | 67,968 | 160,789 |
| 1999 | 77,136 | 23,173 | 166,624 | 321,432 | 223,405 | 493,242 | 106,661 | 70,691 | 167,730 |
| 2000 | 161,681 | 83,408 | 317,602 | 334,121 | 230,956 | 513,491 | 109,043 | 71,723 | 171,466 |
| 2001 | 100,359 | 30,394 | 219,223 | 348,595 | 241,180 | 535,351 | 110,997 | 72,392 | 174,976 |
| 2002 | 150,847 | 70,037 | 298,251 | 366,222 | 252,310 | 563,098 | 112,920 | 73,359 | 177,764 |
| 2003 | 83,544 | 23,579 | 195,233 | 383,441 | 264,331 | 591,514 | 115,363 | 74,603 | 181,394 |
| 2004 | 125,604 | 51,438 | 255,947 | 403,537 | 277,224 | 623,152 | 119,452 | 77,524 | 187,859 |
| 2005 | 50,544 | 12,930 | 132,295 | 420,663 | 288,325 | 651,511 | 124,451 | 81,079 | 195,292 |
| 2006 | 83,769 | 27,627 | 192,191 | 436,898 | 297,986 | 675,620 | 130,795 | 85,146 | 205,158 |
| 2007 | 64,207 | 15,485 | 165,420 | 447,934 | 304,527 | 694,079 | 137,369 | 89,330 | 214,444 |
| 2008 | 179,576 | 81,206 | 381,343 | 462,000 | 312,803 | 715,881 | 144,955 | 93,875 | 226,701 |
| 2009 | 105,755 | 23,523 | 268,313 | 476,170 | 322,227 | 737,794 | 153,236 | 98,680 | 239,142 |
| 2010 | 147,563 | 46,227 | 338,370 | 491,966 | 334,728 | 764,400 | 160,980 | 103,382 | 251,569 |
| 2011 | 49,723 | 10,128 | 158,080 | 502,880 | 340,226 | 781,263 | 166,600 | 106,841 | 261,174 |
| 2012 | 114,436 | 26,844 | 302,083 | 515,498 | 347,120 | 802,690 | 171,627 | 110,351 | 270,463 |
| 2013 | 50,006 | 10,303 | 170,043 | 524,245 | 352,542 | 818,959 | 175,505 | 112,384 | 277,052 |
| 2014 | 82,053 | 14,711 | 303,409 | 532,774 | 358,975 | 831,908 | 180,005 | 115,637 | 285,811 |
| 2015 | 61,800 | 10,685 | 263,147 | 533,814 | 357,909 | 840,071 | 183,094 | 116,505 | 291,058 |
| 2016 | 61,484 | 10,983 | 313,539 | 531,045 | 355,001 | 840,992 | 186,267 | 117,695 | 297,151 |
| 2017 | 61,032 | 10,987 | 294,210 | 521,420 | 344,007 | 836,206 | 180,163 | 111,655 | 292,398 |
| 2018 | 79,337 | 14,953 | 287,988 | 511,860 | 334,212 | 831,093 | 180,010 | 111,382 | 292,672 |
| 2019 | 79,337 | 14,134 | 294,134 | 496,520 | 324,661 | 805,790 | 176,980 | 109,497 | 280,091 |

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. $B_{40\%}$ = 117,448 t, $B_{35\%}$ = 102,767 t, $F_{40\%}$ =0.094, and $F_{35\%}$ =0.113.

| Year | Maximum permissible F | Author's F* (prespecified catch) | Half maximum F | 5-year average F | No fishing | Overfished | Approaching overfished |
|---|---|---|---|---|---|---|---|
| | | | Spawning biomass (t) | | | | |
| 2017 | 180,165 | 180,165 | 180,165 | 180,165 | 180,165 | 180,165 | 180,165 |
| 2018 | 179,666 | 180,150 | 181,820 | 181,198 | 184,005 | 178,822 | 179,666 |
| 2019 | 175,633 | 177,539 | 184,002 | 181,550 | 192,819 | 172,441 | 175,633 |
| 2020 | 170,427 | 173,208 | 184,624 | 180,416 | 200,167 | 165,150 | 169,621 |
| 2021 | 164,427 | 166,986 | 183,919 | 178,079 | 206,098 | 157,358 | 161,412 |
| 2022 | 158,096 | 160,423 | 182,252 | 174,952 | 210,832 | 149,540 | 153,170 |
| 2023 | 151,904 | 153,998 | 180,048 | 171,491 | 214,694 | 142,150 | 145,370 |
| 2024 | 146,249 | 148,121 | 177,675 | 168,117 | 218,040 | 135,558 | 138,393 |
| 2025 | 141,434 | 143,098 | 175,515 | 165,184 | 221,222 | 130,022 | 132,507 |
| 2026 | 137,597 | 139,072 | 173,701 | 162,905 | 224,499 | 125,632 | 127,805 |
| 2027 | 134,669 | 135,975 | 172,890 | 161,284 | 227,953 | 122,288 | 124,176 |
| 2028 | 132,435 | 133,592 | 172,540 | 160,163 | 231,487 | 119,790 | 121,406 |
| 2029 | 130,717 | 131,741 | 172,107 | 159,412 | 235,041 | 117,954 | 119,322 |
| 2030 | 129,361 | 130,267 | 171,832 | 158,898 | 238,516 | 116,584 | 117,737 |
| | | | Fishing mortality | | | | |
| 2017 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 | 0.069 |
| 2018 | 0.094 | 0.084 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2019 | 0.094 | 0.083 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2020 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2021 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2022 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2023 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2024 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2025 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2026 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.113 | 0.113 |
| 2027 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.112 | 0.112 |
| 2028 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.111 | 0.111 |
| 2029 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.110 | 0.110 |
| 2030 | 0.094 | 0.094 | 0.047 | 0.061 | - | 0.109 | 0.109 |
| | | | Yield (t) | | | | |
| 2017 | 21,813 | 21,813 | 21,813 | 21,813 | 21,813 | 21,813 | 21,813 |
| 2018 | 29,236 | 29,236 | 14,884 | 19,072 | - | 34,762 | 29,236 |
| 2019 | 28,378 | 28,605 | 14,969 | 18,986 | - | 33,274 | 28,378 |
| 2020 | 27,377 | 27,832 | 14,942 | 18,765 | - | 31,676 | 32,550 |
| 2021 | 26,276 | 26,689 | 14,813 | 18,429 | - | 30,024 | 30,802 |
| 2022 | 25,138 | 25,505 | 14,606 | 18,011 | - | 28,393 | 29,076 |
| 2023 | 24,029 | 24,351 | 14,350 | 17,553 | - | 26,862 | 27,452 |
| 2024 | 23,020 | 23,300 | 14,083 | 17,102 | - | 25,509 | 26,013 |
| 2025 | 22,152 | 22,391 | 13,829 | 16,691 | - | 24,372 | 24,797 |
| 2026 | 21,433 | 21,635 | 13,602 | 16,334 | - | 23,450 | 23,806 |
| 2027 | 20,868 | 21,038 | 13,415 | 16,043 | - | 22,629 | 22,990 |
| 2028 | 20,457 | 20,600 | 13,280 | 15,831 | - | 21,885 | 22,233 |
| 2029 | 20,149 | 20,274 | 13,188 | 15,682 | - | 21,340 | 21,638 |
| 2030 | 19,920 | 20,034 | 13,138 | 15,592 | - | 20,979 | 21,225 |

*Projected ABCs and OFLs for 2018 and 2019 are derived using estimated catch of 21,813 for 2017, and projected catches of 26,045 t and 25,126 t for 2018 and 2019 based on realized catches from 2014-2016. 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; 2007-2011 average and 2012-2016.

| | Avg 07-11 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Total catch K mt | 23.6 | 27.4 | 24.9 | 28.8 | 29 | 34 |
| Retained catch K mt | 21.3 | 25.2 | 20.4 | 23.9 | 24.8 | 27.9 |
| Catcher Processors # | 12.4 | 16 | 13 | 9 | 8 | 12 |
| Catcher Vessels # | 186.2 | 205 | 172 | 173 | 139 | 130 |
| Catcher Vessel Share of Retained | 44% | 46% | 48% | 46% | 46% | 49% |
| Ex-vessel value M US$ | $8.2 | $16.3 | $11.8 | $11.9 | $12.4 | $13.8 |
| Ex-vessel price US$/lb | $0.175 | $0.294 | $0.262 | $0.225 | $0.227 | $0.225 |
| Central Gulf share of GOA rockfish catch | 64% | 73% | 83% | 84% | 84% | 87% |
| Pac. Ocn. Perch share of GOA rockfish catch | 59% | 56% | 52% | 59% | 65% | 66% |
| Northern rockfish share of GOA rockfish catch | 18% | 20% | 23% | 17% | 15% | 12% |
| Dusky rockfish share of GOA rockfish catch | 14% | 15% | 15% | 12% | 11% | 11% |

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; 2007-2011 average and 2012-2016.

| | Avg 07-11 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| First-wholesale production K mt | 11.4 | 13.0 | 12.3 | 14.2 | 14.5 | 18.1 |
| First-wholesale value M US$ | $28.1 | $42.8 | $28.2 | $34.1 | $34.3 | $37.0 |
| First-wholesale price/lb US$ | $1.12 | $1.50 | $1.04 | $1.09 | $1.07 | $0.93 |
| Pac. Ocn. perch share of value | 58% | 56% | 53% | 58% | 63% | 67% |
| Pac. Ocn. perch price/lb US$ | $1.07 | $1.47 | $0.94 | $0.98 | $0.96 | $0.83 |
| Northern rockfish share of value | 15% | 18% | 16% | 15% | 11% | 8% |
| Northern rockfish price/lb US$ | $1.01 | $1.35 | $0.86 | $1.04 | $0.98 | $0.89 |
| Dusky rockfish share of value | 11% | 14% | 12% | 11% | 11% | 8% |
| Dusky rockfish price/lb US$ | $0.96 | $1.48 | $0.93 | $1.07 | $1.20 | $0.86 |
| H&G share of value | 74% | 78% | 70% | 76% | 74% | 68% |

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; 2007-2011 average and 2012-2017.

| | 2007-2011 Average | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 (thru July) |
|---|---|---|---|---|---|---|---|
| Global production of rockfish K mt | 334.2 | 336.3 | 352.3 | 354.4 | 375.6 | - | - |
| Global production of Pac. Ocn. perch K mt | 67.1 | 81.6 | 92.7 | 100.4 | 103.6 | - | - |
| U.S. share of global Pac. Ocn. perch | 83.7% | 85.2% | 86.6% | 89.5% | 86.6% | - | - |
| U.S. Pac. Ocn. perch share of global rockfish | 10.7% | 13.6% | 15.0% | 16.7% | 16.0% | - | - |
| Export volume of Pac. Ocn. perch K mt | 10.0 | 13.0 | 20.1 | 23.8 | 22.7 | 25.6 | 9.3 |
| Export value of Pac. Ocn. perch M US$ | $16.7 | $36.9 | $66.4 | $79.6 | $77.7 | $84.6 | $30.5 |
| Export price/lb of Pac. Ocn. perch US$ | $0.76 | $1.29 | $1.50 | $1.52 | $1.55 | $1.50 | $1.49 |
| China's share of U.S. Pac. Ocn. perch export value | 60% | 67% | 42% | 65% | 52% | 67% | 60% |
| Exchange rate, Yuan/Dollar | 8.07 | 6.66 | 6.15 | 6.16 | 6.28 | 6.64 | - |

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

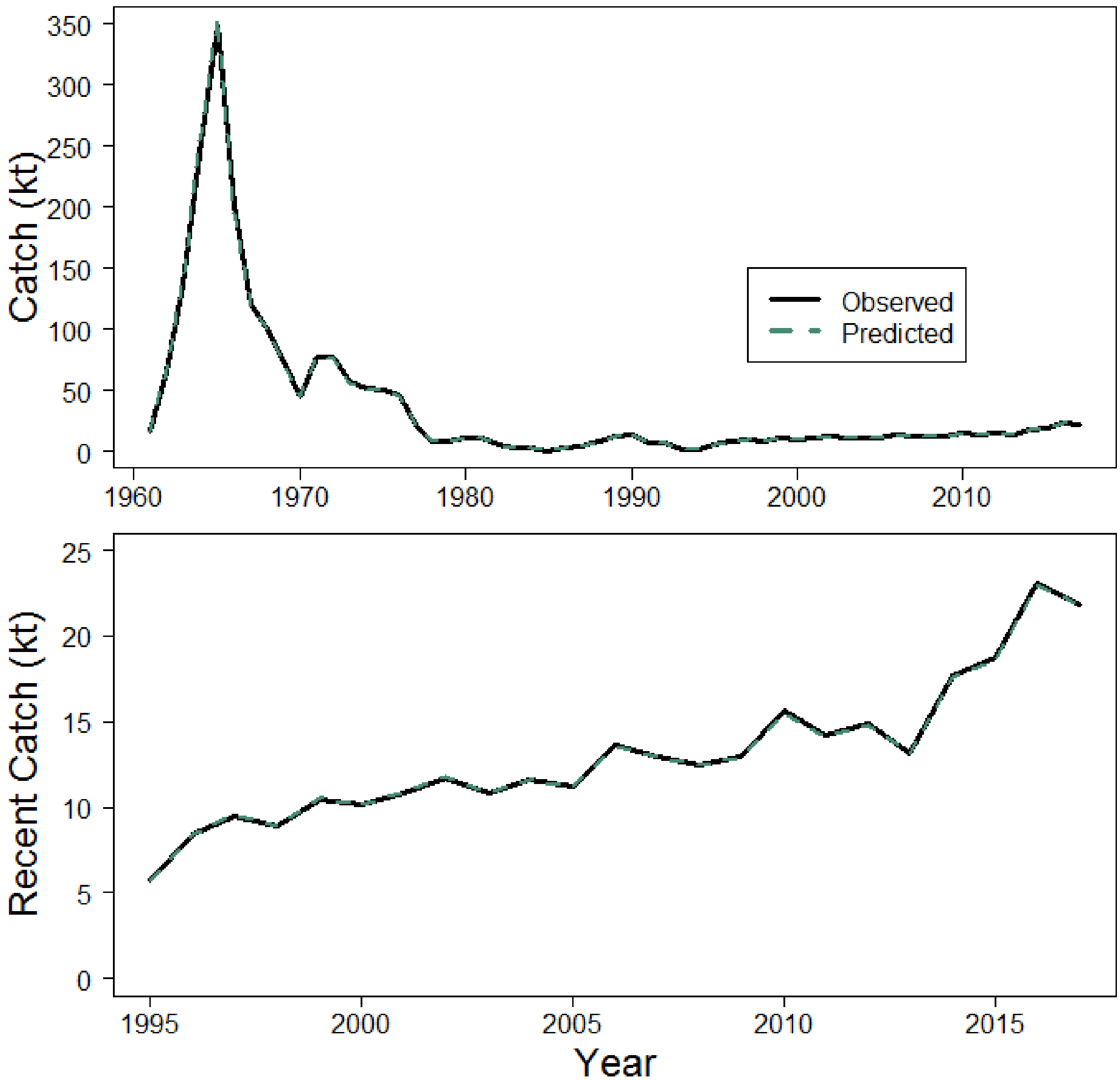


Figure 9-1. Estimated and observed long-term (top figure) and short-term (bottom figure) catch history for GOA POP.

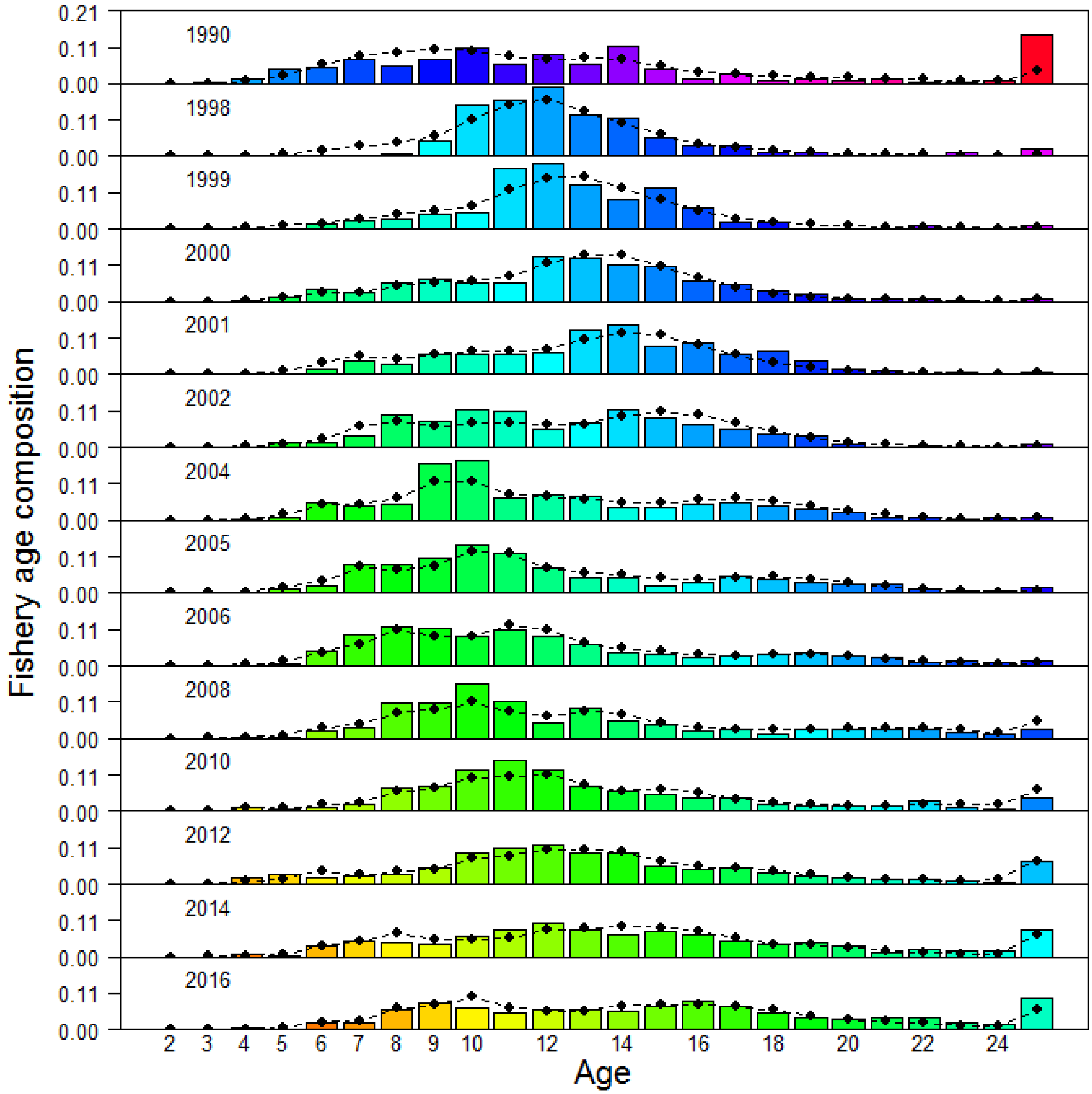


Figure 9-2. Fishery age compositions for GOA POP. Observed = bars, actual age composition predicted from author recommended model = line with circles. Colors follow cohorts.

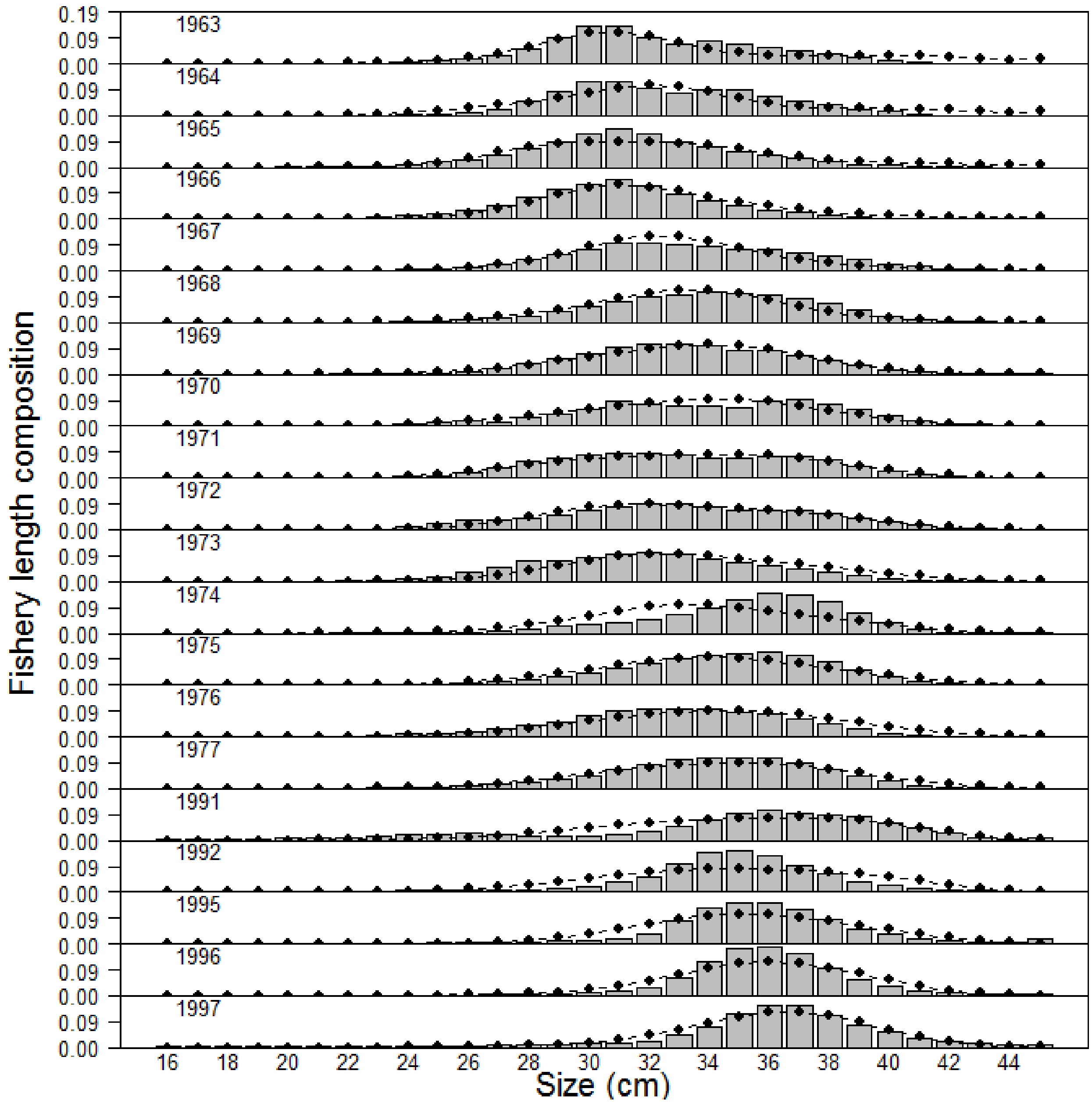


Figure 9-3. Fishery length (cm) compositions for GOA POP. Observed = bars, predicted from author recommended model = line with circles.

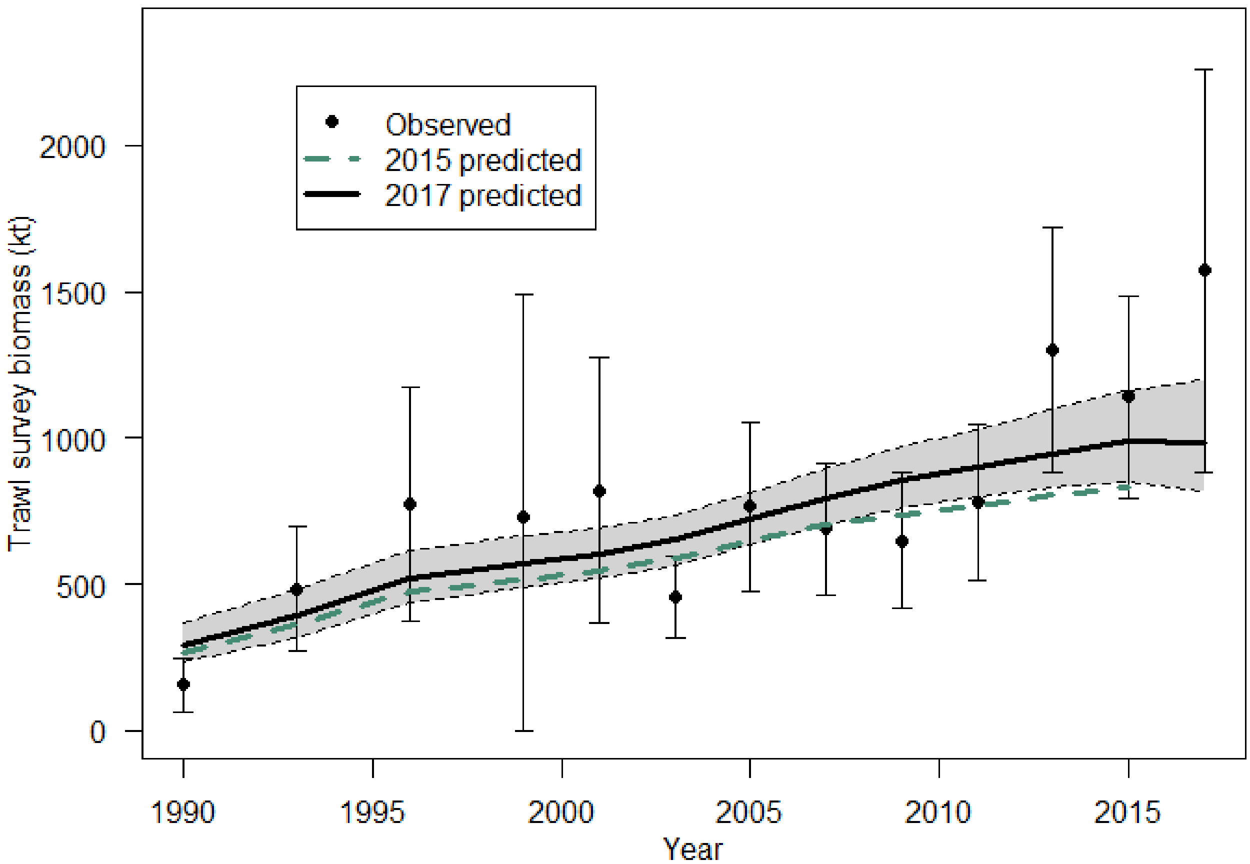


Figure 9-4. NMFS Groundfish Survey observed biomass estimates (open circles) with 95% sampling error confidence intervals for GOA POP. Predicted estimates from the recommended model (black line, with 95% confidence intervals shown in grey shaded region) compared with last year's model fit (green dotted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

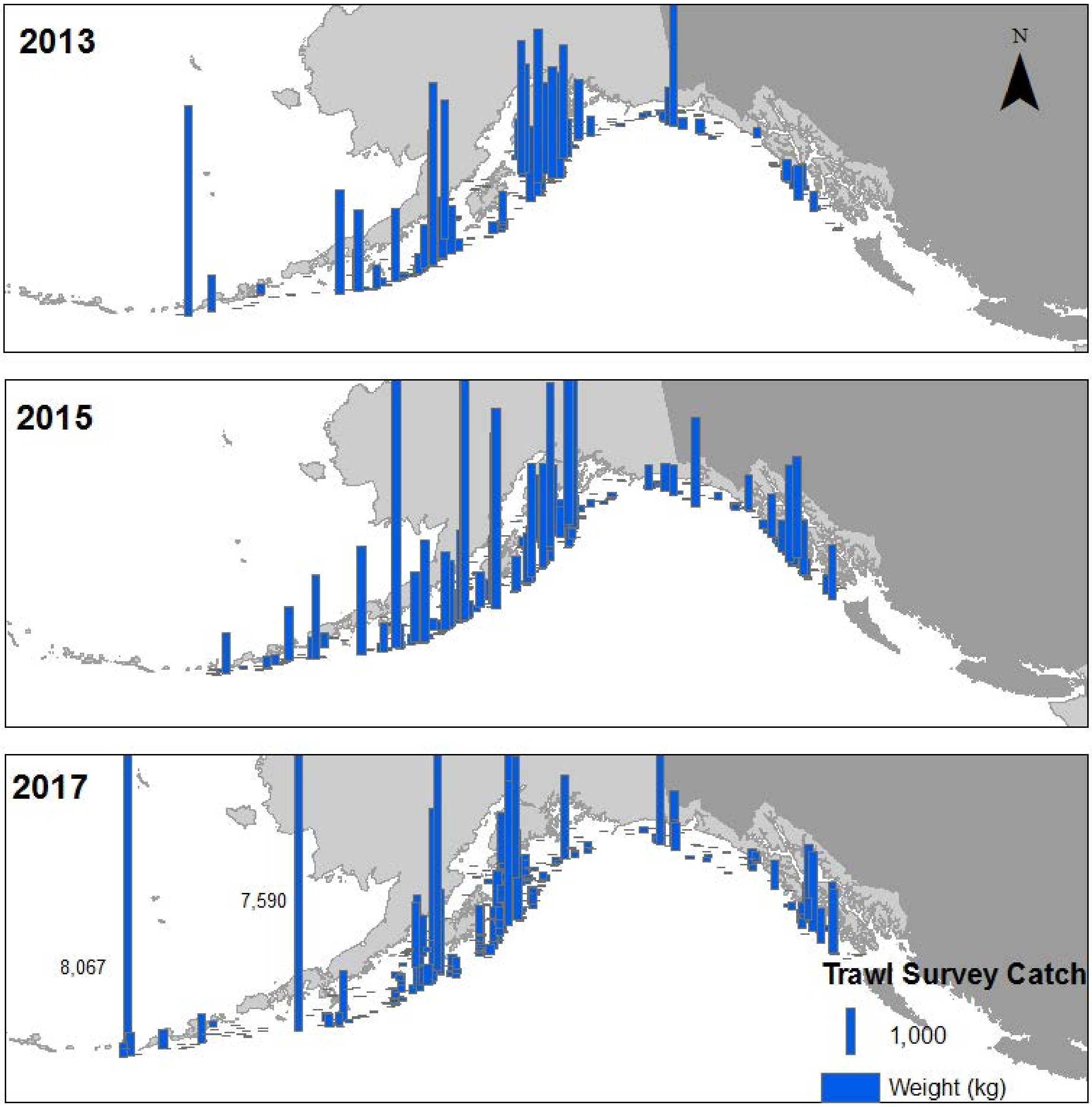


Figure 9-5. Distribution of GOA POP catches in the 2013-2017 GOA groundfish surveys.

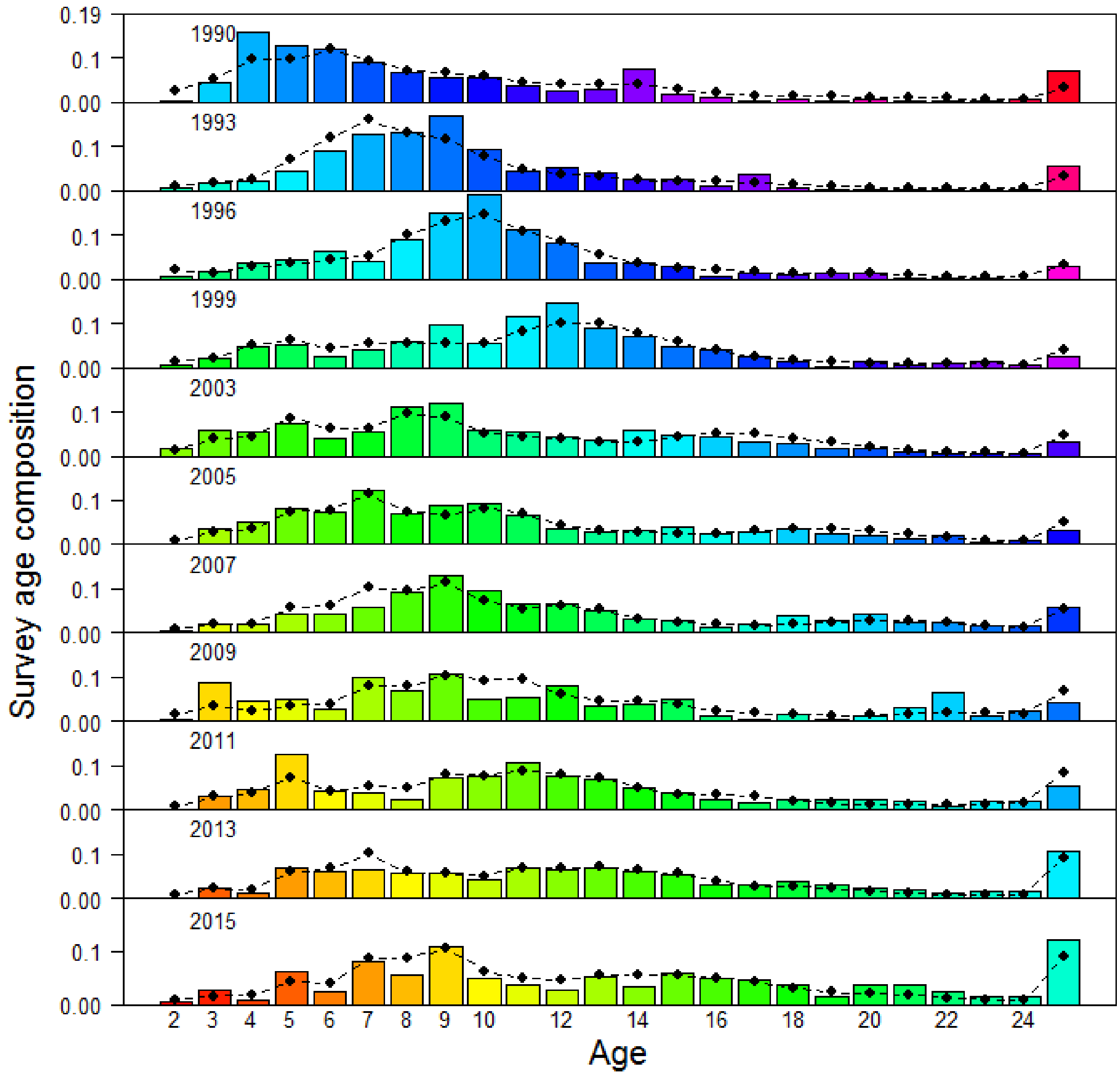


Figure 9-6. Groundfish survey age compositions for GOA POP. Observed = bars, actual age composition predicted from author recommended model = line with circles.

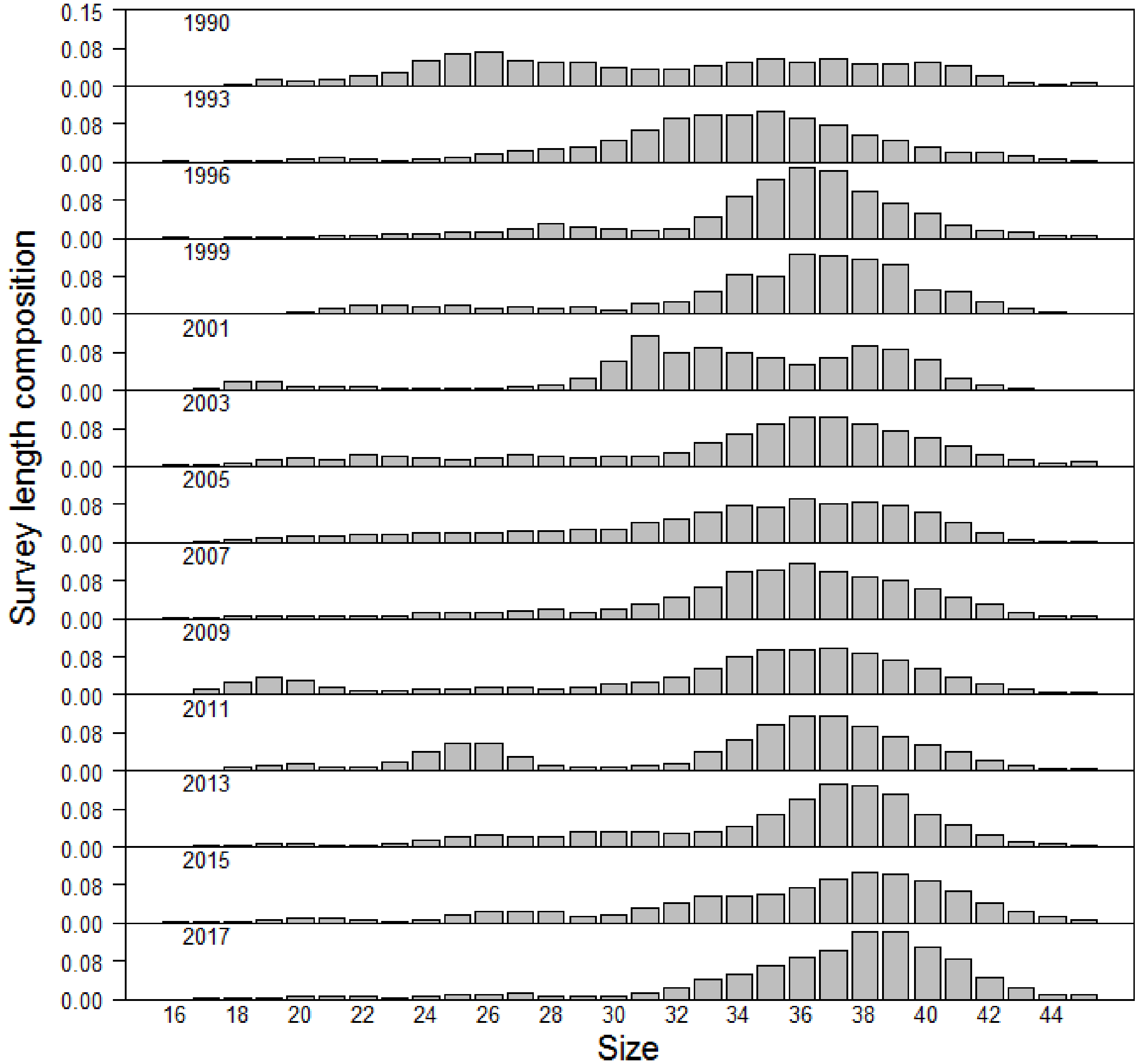


Figure 9-7. Groundfish survey length compositions for GOA POP. Observed = bars. Survey size not used in POP model because survey ages are available for these years.

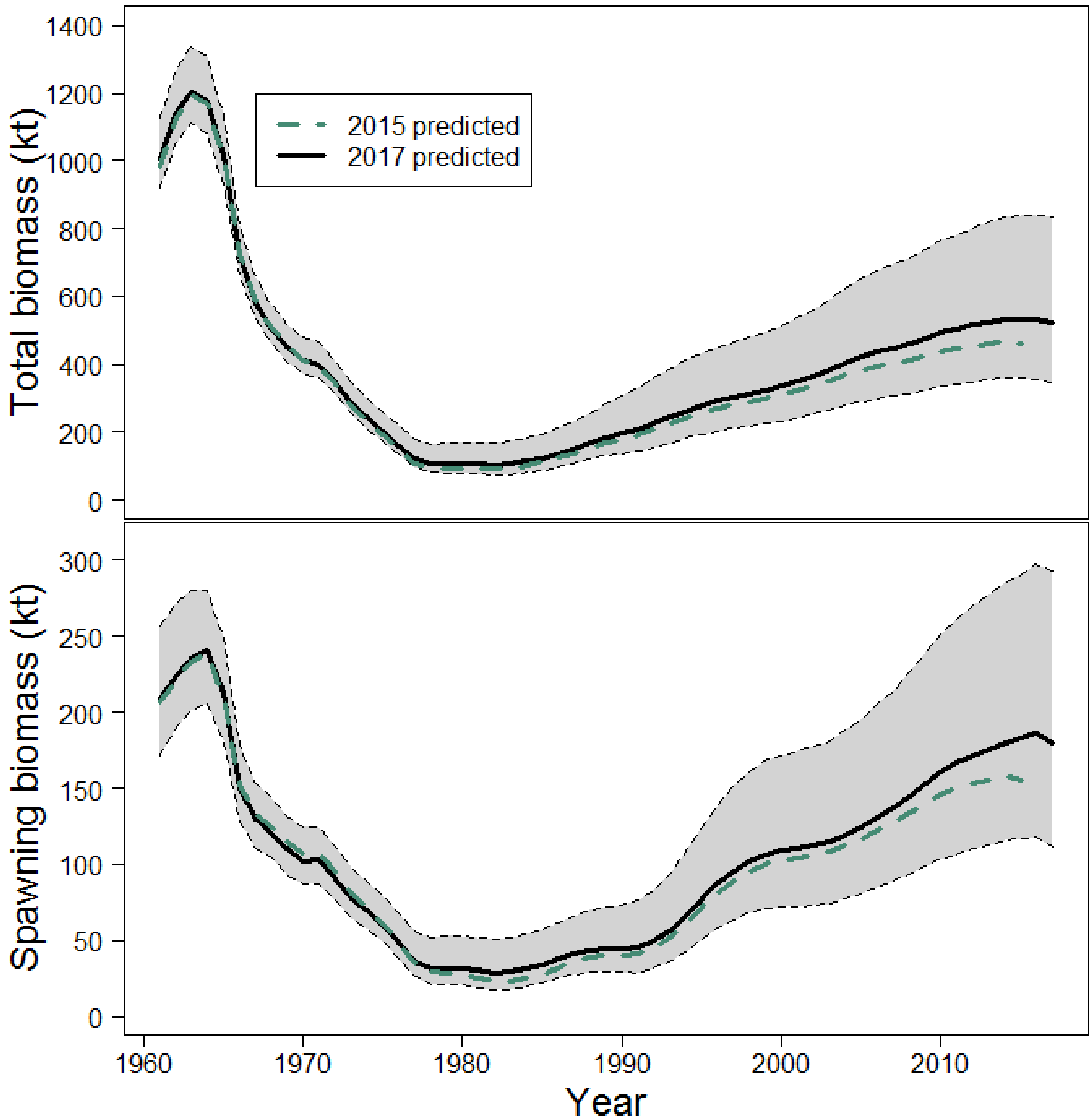


Figure 9-8. Model estimated total biomass (top panel, solid black line) and spawning biomass (bottom panel) with 95% credible intervals determined by MCMC (light grey region) for GOA POP. Last year's model estimates included for comparison (dashed line).

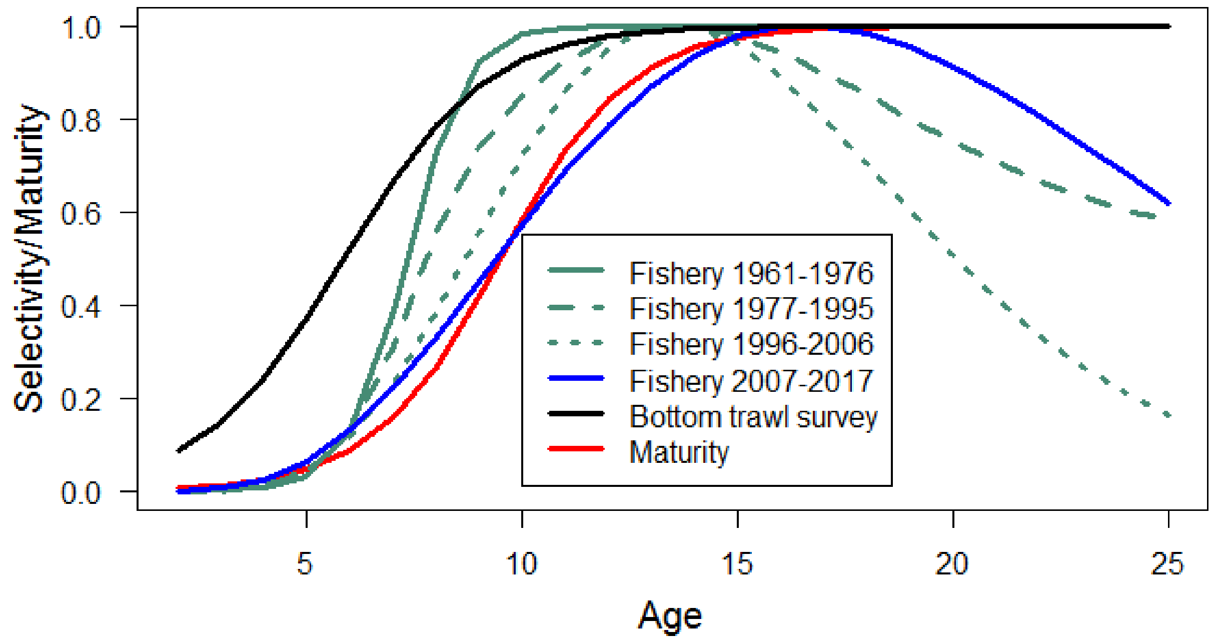


Figure 9-9. Estimated selectivities for the fishery for three periods and groundfish survey for GOA POP.

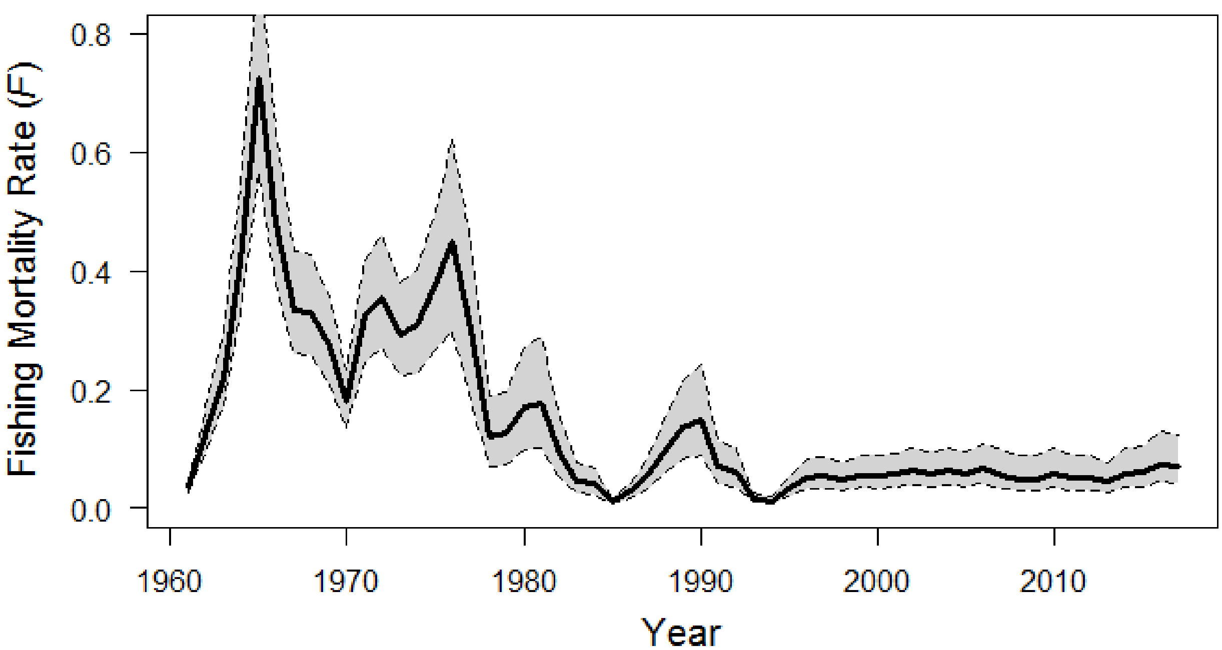


Figure 9-10. Estimated fully selected fishing mortality over time with 95% credible intervals determined by MCMC (light grey region) for GOA POP.

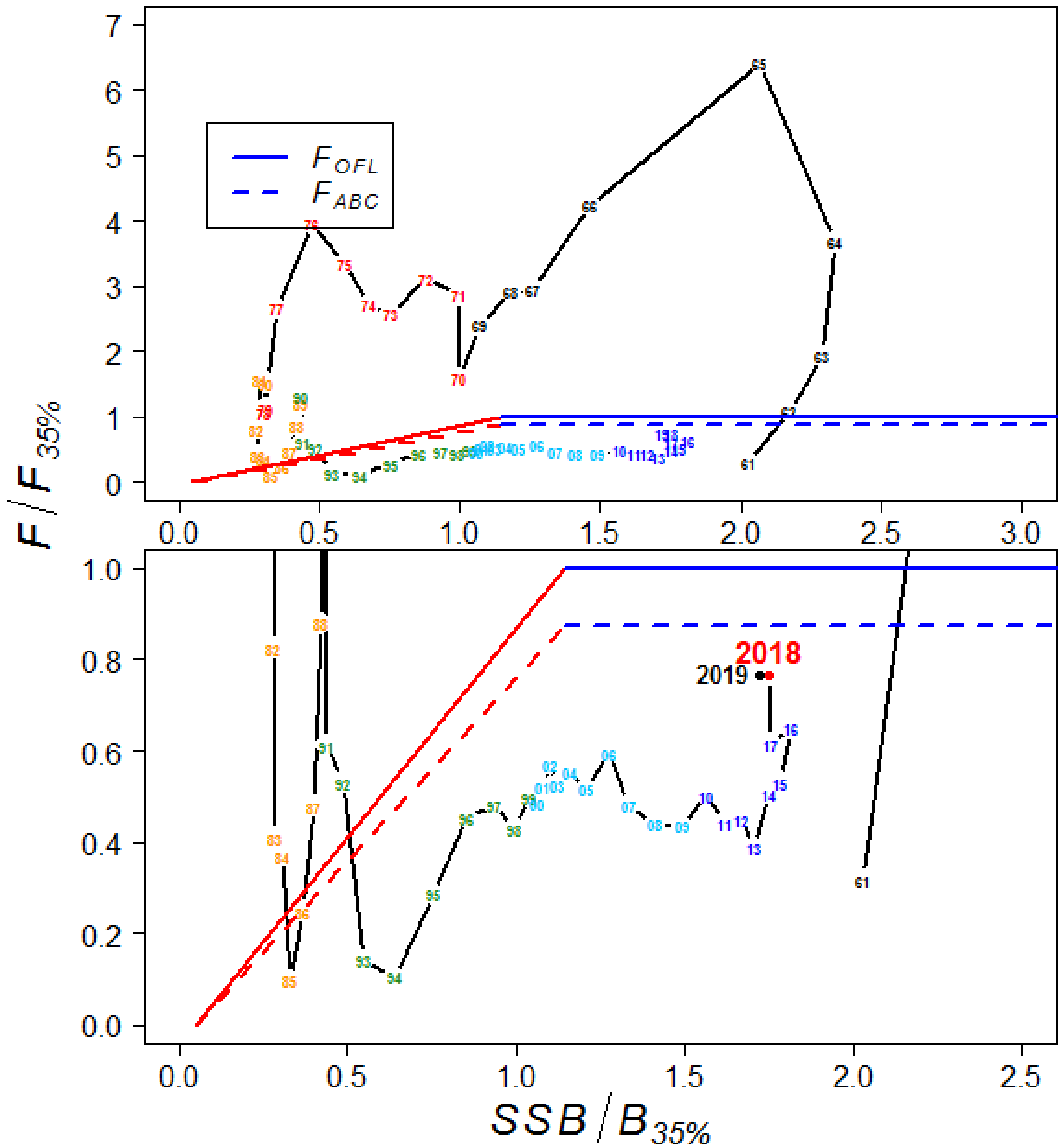


Figure 9-11. Time series of POP estimated spawning biomass relative to the target level B35% level and fishing mortality relative to F35% for author recommended model. Top shows whole time series. Bottom shows close up on more recent management path.

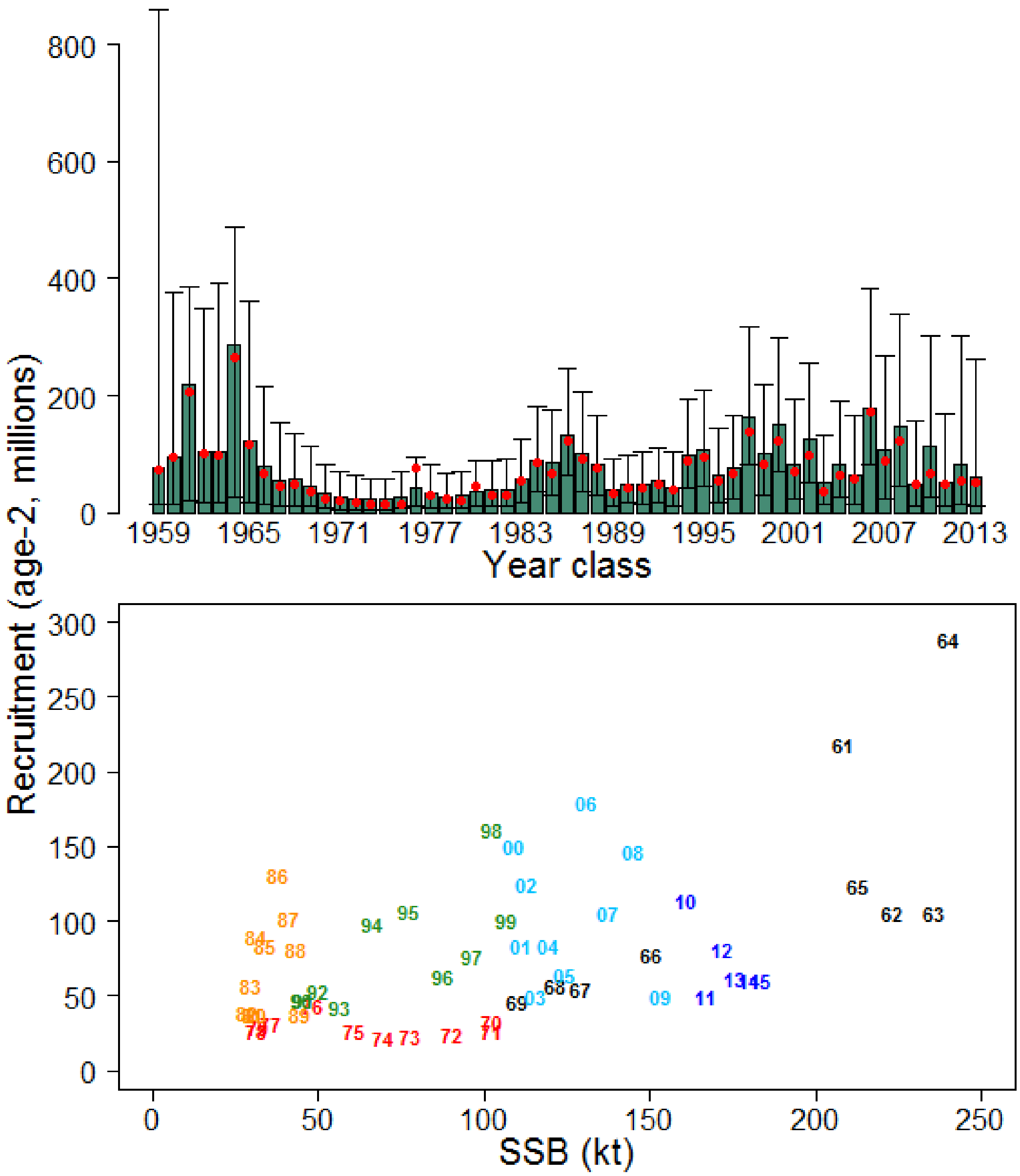


Figure 9-12. Estimated recruitment of GOA POP (age 2) by year class with 95% credible intervals derived from MCMC (top). Estimated recruits per spawning stock biomass (bottom). Red circles in top graph are last year’s estimates for comparison.

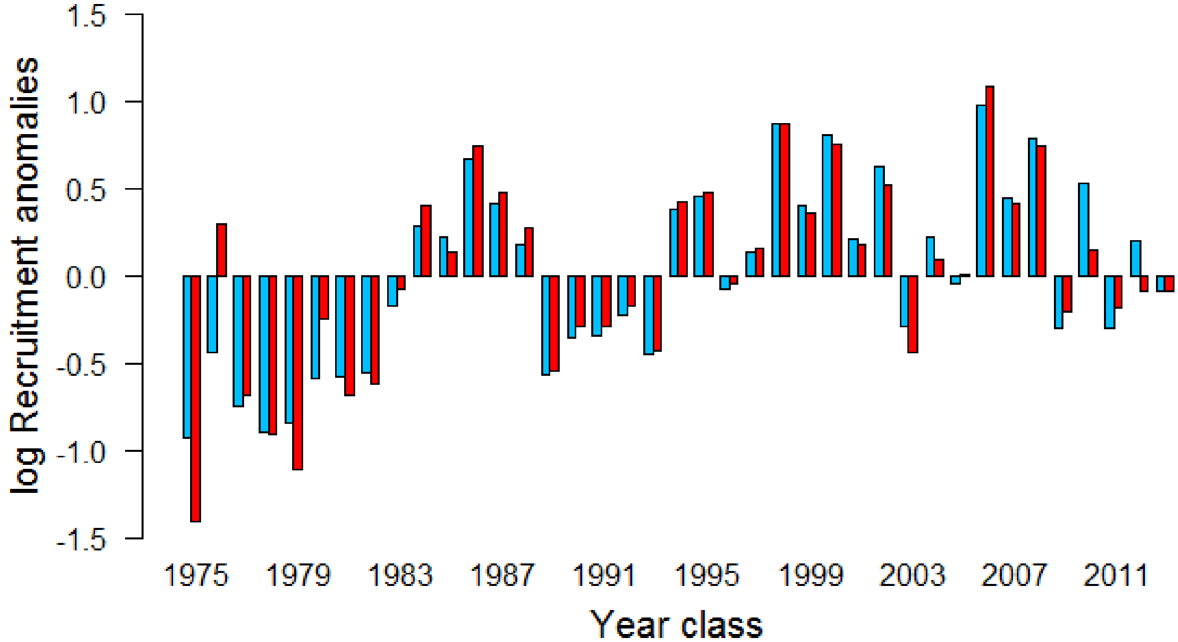


Figure 9-13. Recruitment deviations from average on the log-scale comparing last cycle's model (red) to current year recommended model (blue) for GOA POP.

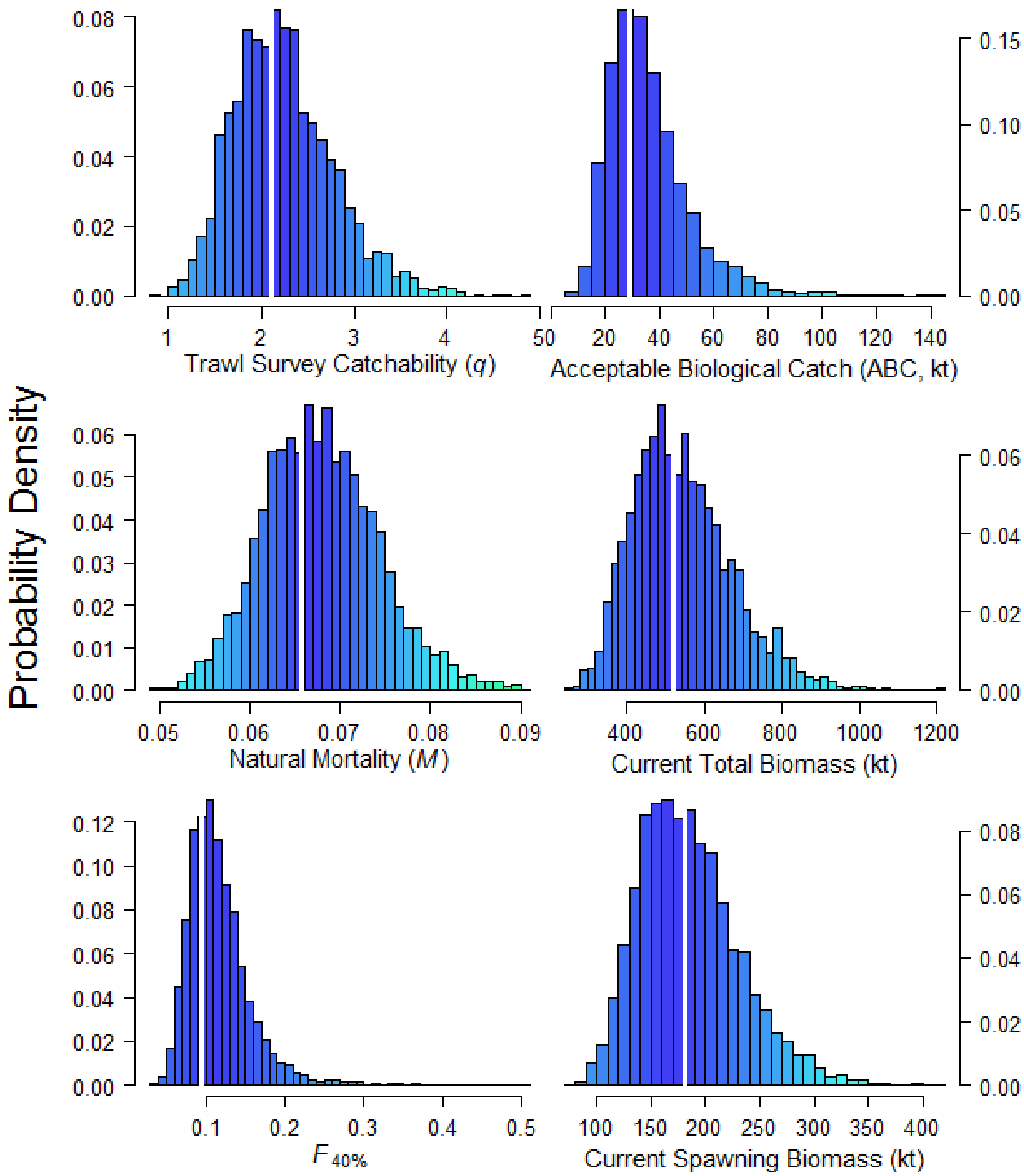


Figure 9-14. Histograms of estimated posterior distributions of key parameters derived from MCMC for GOA POP. The vertical white lines are the recommended model estimates.

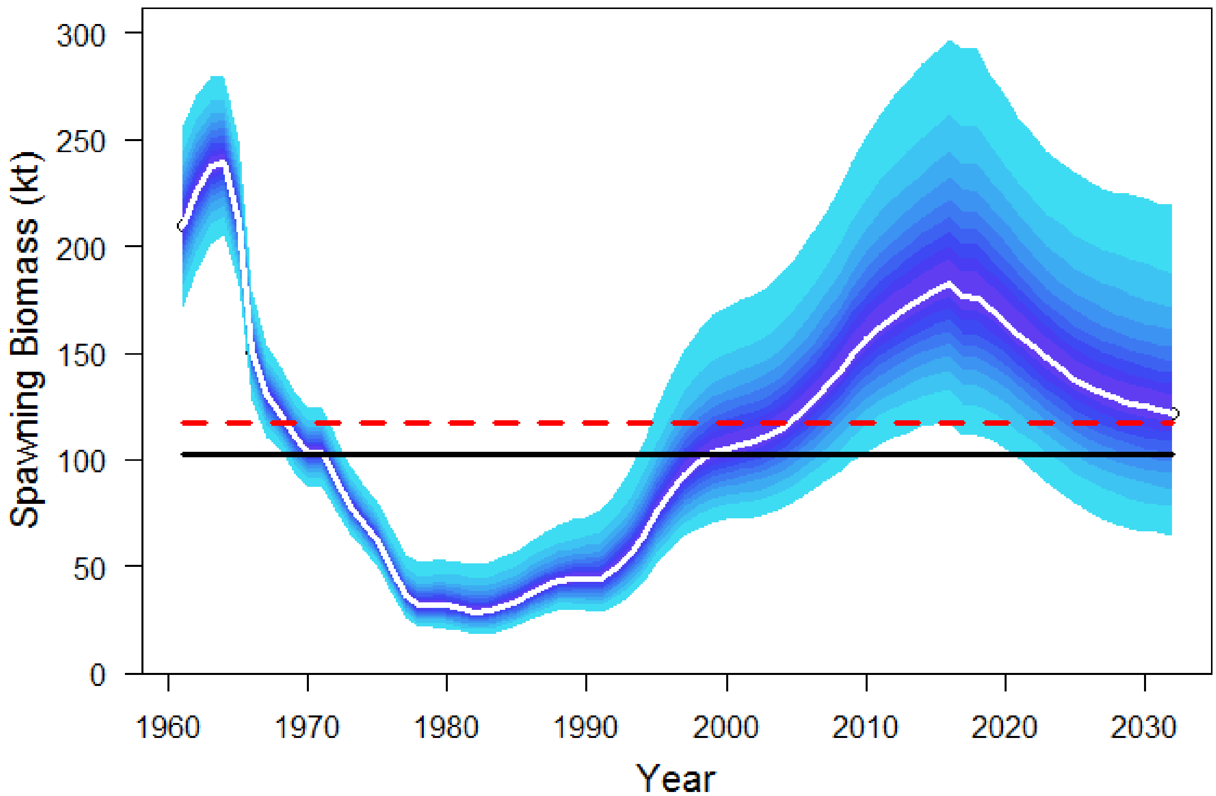


Figure 9-15. Bayesian credible intervals for entire spawning stock biomass series including projections through 2030. Red dashed line is $B_{40\%}$ and black solid line is $B_{35\%}$ based on recruitments from 1979-2013. The white line is the median of MCMC simulations. Each shade is 5% of the posterior distribution.

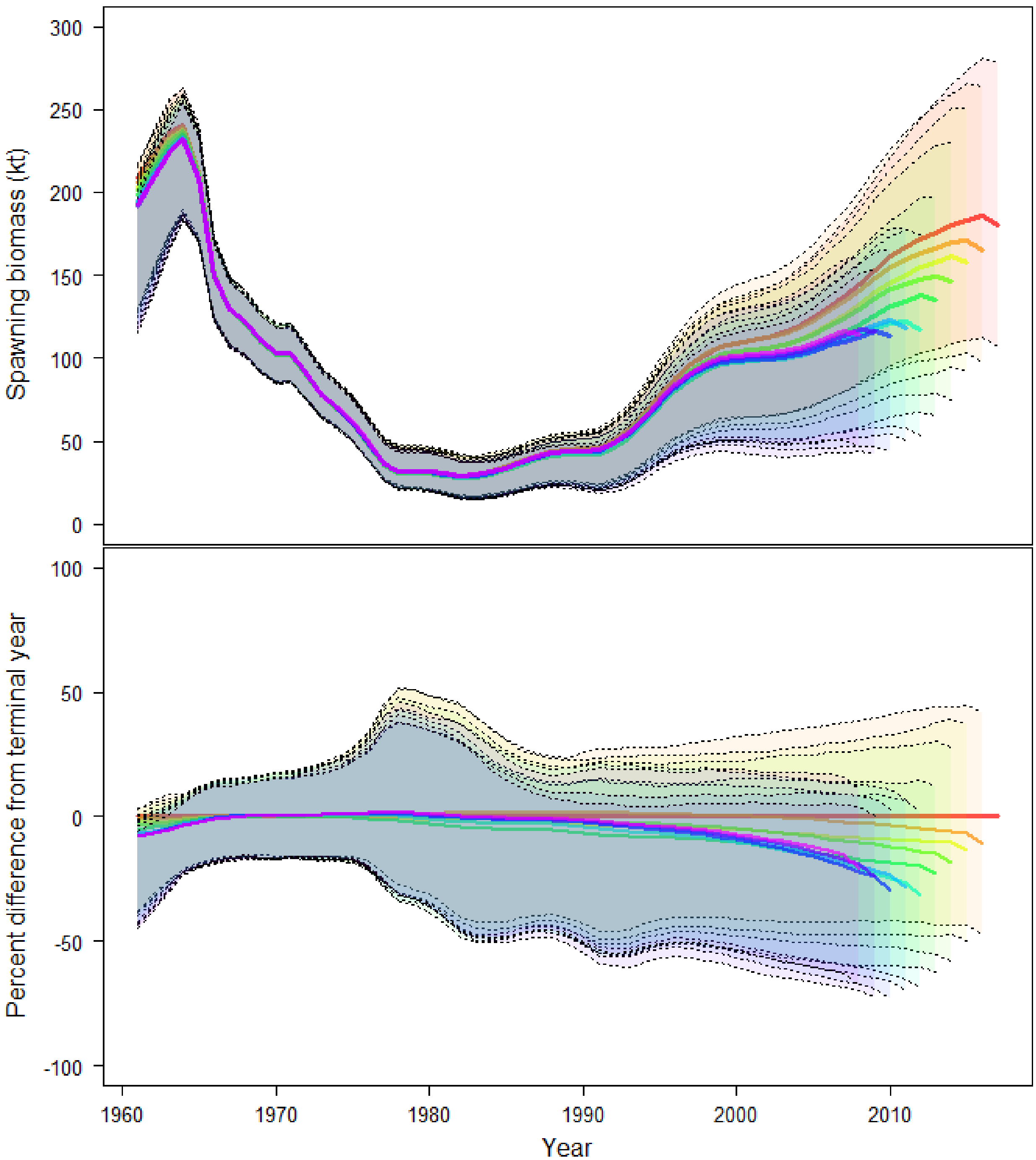


Figure 9-16. Retrospective peels of estimated female spawning biomass for the past 10 years from the recommended model with 95% credible intervals derived from MCMC (top), and the percent difference in female spawning biomass from the recommended model in the terminal year with 95% credible intervals from MCMC.

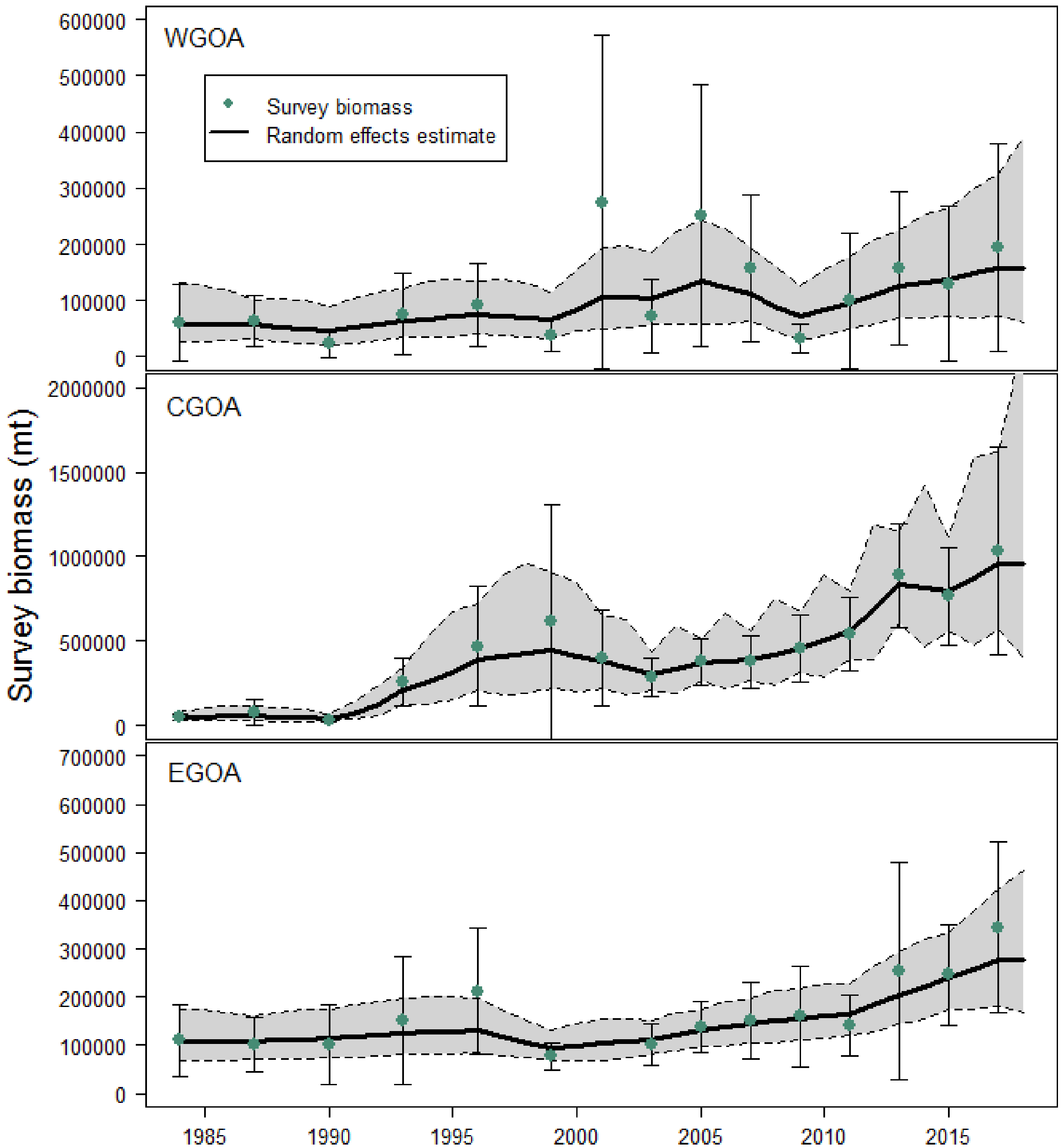


Figure 9-17. Random effects model fit (black line with 95% confidence intervals in light grey region) to regional bottom trawl survey biomass (green points with 95% sampling error confidence intervals).

# 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 | | 83 | 4 | 87 |
| 2014 | | 3 | 2 | 5 |
| 2015 | | 124 | <1 | 125 |
| 2016 | | <1 | <1 | 1 |